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Nevada
Environmental
Restoration
Project

Completion Report for Well Cluster ER-20-5

March 1997

Environmental Restoration
Division

U.S. Department of Energ
Nevada Operations Offic

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COMPLETION REPORT FOR
WELL CLUSTER ER-20-5

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List of Acronyms and Abbreviations

AIN	Annulus Investigation
AWS	Atlas Wireline Services
bbl	Barrel(s)
bgs	Below ground surface
BHA	Bottom-hole assembly
BHI	Baker Hughes INTEQ
BN	Bechtel Nevada
BOP	Blow-out prevention system
BWS	Barbour Well Surveying
$CaCl_2$	Calcium chloride
cm	Centimeter(s)
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
FMP	Fluid Management Plan
ft	Foot (feet)
ft/hr	Foot (feet) per hour
gal	Gallon(s)
GEG	Geophysical Engineering Group of the Joint Test Organization
gpm	Gallon(s) per minute
HES	Haliburton Engineering Services
in.	Inch(es)
IT	IT Corporation
kg	Kilogram(s)
km	Kilometer(s)
L	Liter(s)
LAF	Lava flow aquifer
lb	Pound(s)
LCM	Lost circulation material
Lpm	Liter(s) per minute
m	Meter(s)
m^3	Cubic meter(s)

List of Acronyms and Abbreviations *(Continued)*

m/hr	Meter(s) per hour
MPa	MegaPascal(s)
NTS	Nevada Test Site
od	Outside diameter
pCi/L	PicoCurie(s) per liter
psi	Pound(s) per square inch
REECo	Reynolds Electrical & Engineering Co., Inc.
RSN	Raytheon Services Nevada
RVC	Records of Verbal Communication
TCU	Tuff confining unit
TD	Total depth
UGTA	Underground Test Area
USGS	U.S. Geological Survey
WP	Working Point

1.0 Introduction

1.1 Project Description

The Well Cluster ER-20-5 drilling and completion project was conducted for the U.S. Department of Energy, Nevada Operations Office (DOE/NV), in support of the Nevada Environmental Restoration Project at the Nevada Test Site (NTS) in Nye County, Nevada. This project is part of the U.S. Department of Energy's (DOE's) Underground Test Area (UGTA) subproject at the NTS. Its primary tasks include collecting geological, geophysical, hydrological, and water chemistry data from new and existing wells to define groundwater quality in addition to pathways and rates of groundwater migration. A program of drilling wells near the sites of selected underground nuclear tests (near-field drilling) was implemented as part of the UGTA subproject to obtain site-specific data about the nature and extent of migration of radionuclides that might have been produced by an underground nuclear explosion. Well Cluster ER-20-5 is the first UGTA near-field drilling project initiated at the NTS.

The well cluster is located on Pahute Mesa in Area 20 in the northwestern corner of the NTS (Figure 1-1) near the location of the underground nuclear test (event), code-named TYBO, conducted in Emplacement Hole U-20y (Figure 1-2). A group of technical experts on NTS geology and the weapons testing program (comprising DOE, Lawrence Livermore, Los Alamos, and contractor personnel) selected TYBO for the near-field program primarily because of the test's yield, its hydrogeologic setting, the time elapsed since its detonation, and its relatively shallow depth of burial. The well cluster is thought to be hydraulically downgradient from TYBO, and drilling was designed to intersect an aquifer exposed to the TYBO explosion products. In addition, a deeper hole drilled at this location would penetrate a lower aquifer and provide additional data in this portion of Pahute Mesa.

As each hole in the cluster was drilled, data about water production, radionuclides, and geology were analyzed so that the completion could be designed to maximize data collection. Subsequent holes could then be planned to accomplish the remaining project goals. Well Cluster ER-20-5 consists of three holes drilled on the same pad (Figure 1-3). Well ER-20-5#1 (at a depth of 860.5 meters {m} {2,823 feet [ft]}) was completed in a welded ash-flow tuff aquifer, approximately two cavity radii southwest of the edge of TYBO collapse chimney.
Well ER-20-5#3 penetrated a lava-flow aquifer; and Well ER-20-5#2 was abandoned because of drilling problems.

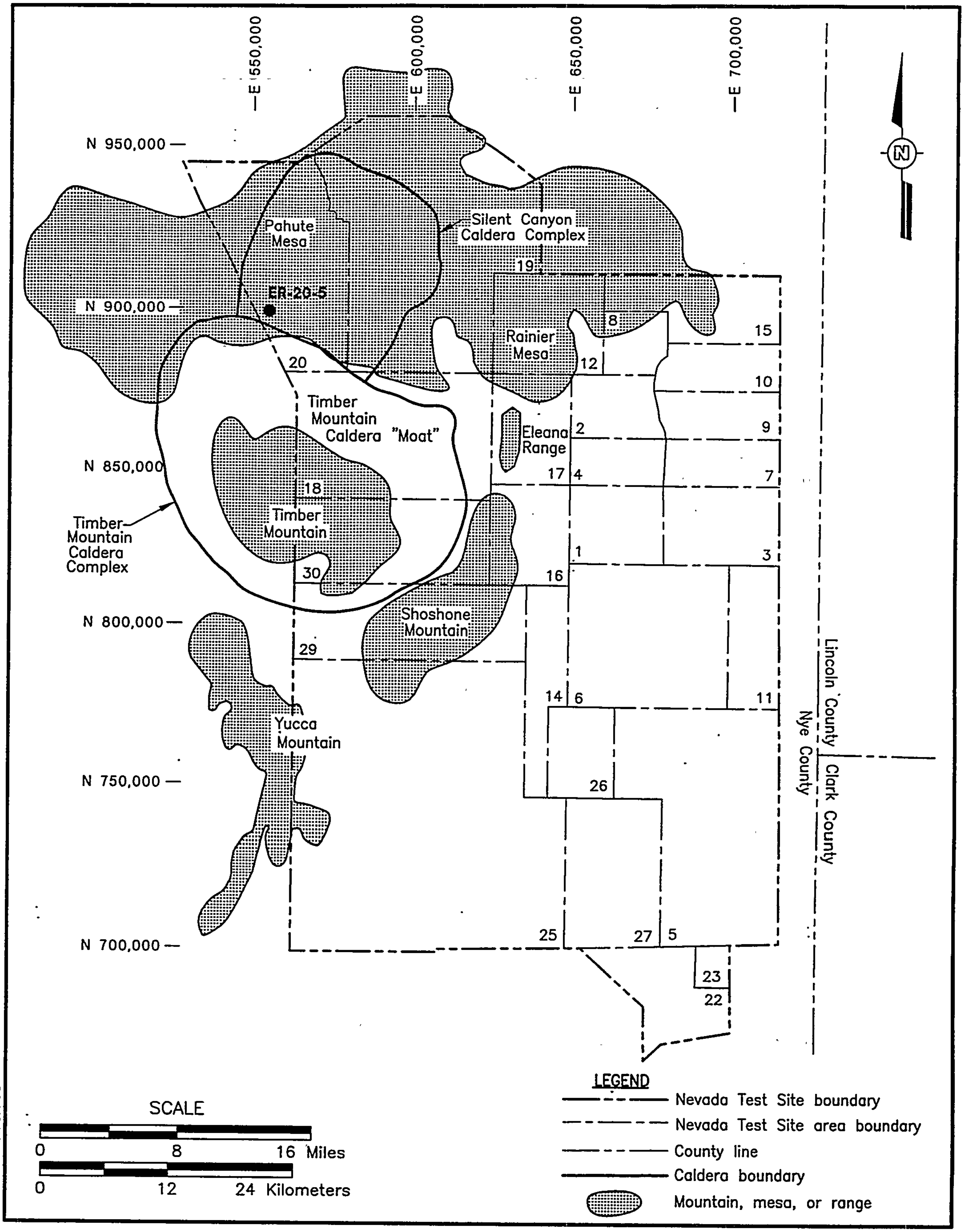


Figure 1-1
Location of Well Cluster ER-20-5

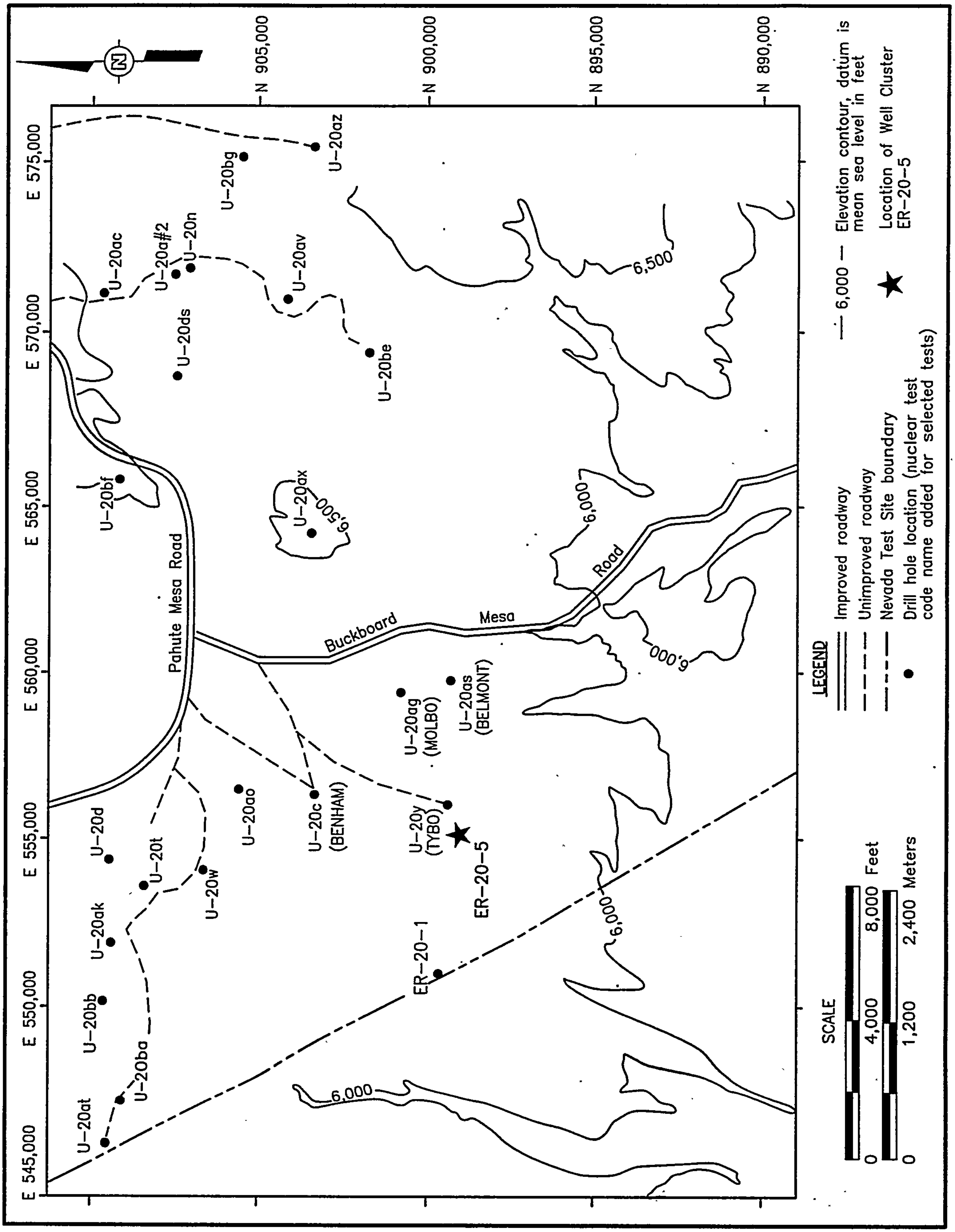


Figure 1-2
Area Map for Well Cluster ER-20-5,
Area 20, Nevada Test Site

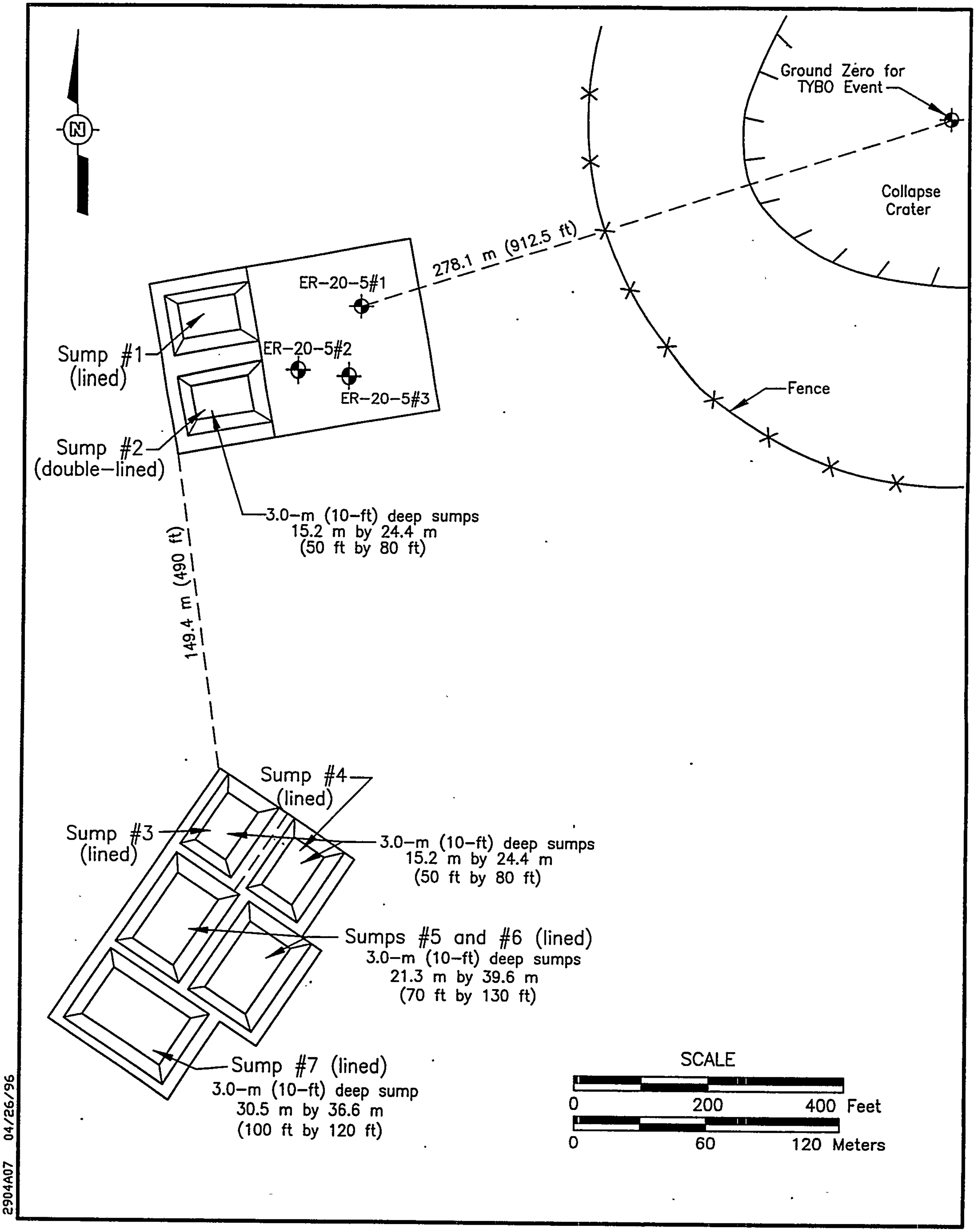


Figure 1-3
Final Drill-Site Configuration for Well Cluster ER-20-5

The Nevada State Planar Coordinates and elevation of each well collar are provided in Table 1-1 along with additional site summary and survey information.

Table 1-1
Well Cluster ER-20-5 Site Summary

Hole Designation		ER-20-5#1	ER-20-5#2 (abandoned)	ER-20-5#3
Site Coordinates[a]	Central Nevada State Planar (feet)	N899,133.6 E555,173.9	N899,037.7 E555,095.9	N899,031.1 E555,169.7
	Universal Transverse Mercator (Zone 11) (meters)	N4,119,208.3 E546,385.9	N4,119,178.9 E546,362.2	N4,119,177.0 E546,384.7
Surface Elevation[b]		1,902.5 m (6,241.8 ft)	1,902.6 m (6,242.2 ft)	1,902.5 m 6,241.9 ft
Drilled Depth		860.5 m (2,823 ft)	819.6 m (2,689 ft)	1,308.8 m (4,294 ft)
Fluid-Level Depth (Open Borehole)		626.4 m (2,055 ft) (11/03/95)	Not measured	627.6 m (2,060 ft) (02/07/96)
Fluid-Level Elevation (Open Borehole)		1,276.2 m (4,187 ft)	Not applicable	1,276.5 m[c] (4,188 ft)

[a]1927 North American Datum. Measurement made by Bechtel Nevada Survey.
[b]1929 North American Vertical Datum. Measurement made by Bechtel Nevada Survey.
[c]Elevation calculated using data from drill-hole deviation survey (see Section 5.3).

IT Corporation (IT) was the principal environmental contractor for the project. The drilling contractor was Welch & Howell Drilling. Engineering, inspection, geotechnical services, and field support were provided by Bechtel Nevada (BN, formerly Raytheon Services Nevada [RSN] and Reynolds Engineering & Electrical Co., Inc. [REECo]). The roles and responsibilities of these and other contractors involved in the project are described in Contract DE-RP-08-95NV.11808 and in drilling programs prepared for the second and third holes of the cluster (RSN, 1995a, 1995b). See the *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-5* report (IT, 1995) for a description of the project plans and goals. A Fluid Management Plan (FMP) was developed in addition to the UGTA FMP (DOE, 1994) to address the special conditions expected during drilling of a well that could produce radioactive investigation-derived waste (IT, 1995).

This document presents construction data and summarizes the scientific data gathered during the drilling and well-installation phases for all three holes drilled at Well Cluster ER-20-5. Some of this information is preliminary and unprocessed, but was released so that drilling, geotechnical, well design, and completion data could be rapidly disseminated. Additional information about water levels, aquifer testing, and groundwater sampling will be reported after any of this work is performed. Any additional geologic and/or geophysical investigations conducted for this project will be described in one or more analysis and interpretation reports. The lithologic and stratigraphic logs, however, are provided in final form.

1.2 Hydrologic Effects of Nuclear Tests

1.2.1 Phenomenology

Underground nuclear explosions cause physical changes in the near field as a result of cavity growth, ground shock, and chimney formation. Temporary increases in temperature and fluid pressure and, in some cases, the groundwater level, have been observed. More permanent changes expected in the near-field include enhanced fracture permeability, increased porosity due to bulking of broken material in the cavity/chimney region, and the creation of a potentially permeable vertical conduit between aquifers through the chimney material.

1.2.2 TYBO

The TYBO underground nuclear test was conducted in Emplacement Hole U-20y in 1975. The reported depth of burial (which corresponds to the location of the Working Point [WP] or explosion point) of the TYBO device was 765 m (2,510 ft), which was approximately 135 m (443 ft) below the static water level in Emplacement Hole U-20y. The TYBO WP was located in zeolitic, nonwelded tuff near the bottom of the welded portion of the Topopah Spring Tuff, the principal aquifer penetrated by Emplacement Hole U-20y. The explosion cavity around the WP (now collapsed) is projected to have been approximately 200 m (656 ft) in diameter (IT, 1995). The collapse chimney, estimated to be approximately cylindrical, extends to the ground surface above the WP and is believed to be the primary vertical conduit for any migration of radionuclides from the TYBO cavity. The Topopah Spring welded-tuff aquifer is believed to be the primary conduit for any lateral migration of waterborne radionuclides from the TYBO cavity.

Tritium, a nonreactive but mobile byproduct, was expected to be the primary radionuclide encountered at Well Cluster ER-20-5. It was thought that some volatile or nonreactive radionuclides might also be found, but at much lower activities than tritium.

The collars of Wells ER-20-5#1, #2, and #3 are located 278, 310, and 290 m (912, 1,017, and 951 ft) southwest, respectively, of the TYBO surface ground zero (Figure 1-3).

1.2.3 Other Nearby Tests

Three other underground nuclear tests were conducted 1.3 to 1.4 kilometers (km) (4,364 to 4,580 ft) from the Well Cluster ER-20-5 site: BENHAM (U-20c; 1968), MOLBO (U-20ag; 1982), and BELMONT (U-20as; 1986) (Figure 1-2). These sites are inferred to be up-gradient from the well cluster. Based on the reported yield ranges of these events and the time elapsed since they were conducted, it was considered a slight possibility that tritium from BENHAM could have traveled to the vicinity of Well Cluster ER-20-5 via a deeper aquifer, a lava embedded within the Calico Hills Tuff (IT, 1995). This deeper unit was penetrated by Well ER-20-5#3.

Additional information on the phenomenology and expected radionuclides of these nuclear tests is given in the Well Cluster ER-20-5 drilling and completion criteria report (IT, 1995).

1.3 Objectives

The primary purpose of constructing Well Cluster ER-20-5 was to obtain data that characterize the distribution of radionuclides in the rock and groundwater adjacent to and hydraulically down-gradient from the TYBO nuclear test. Individual objectives, as discussed in the drilling and completion criteria report (IT, 1995), included the following:

- Obtain groundwater samples for analysis of near-event groundwater chemistry.
- Obtain geologic and hydrologic data to aid in evaluating parameters that affect radionuclide transport.
- Obtain access to one discrete completion zone in each well to conduct long-term monitoring of groundwater chemistry downgradient of the TYBO test.
- Obtain hydrogeologic information to further identify and characterize the nature and influence of the postulated groundwater potentiometric trough that trends roughly north-south along the western boundary of NTS Area 20.
- Confirm the presence and nature of the upper zeolitized portion of the Calico Hills Formation which serves as an aquitard and, thus, could restrict the vertical movement of groundwater in this area.

1.4 Project Summary

The conductor holes for the three wells in Well Cluster ER-20-5 were drilled and cased to 3.4 m (11 ft) before the Welch & Howell rig was set up on location to drill the first hole. An exclusion zone, which served as part of the primary contamination control system, was established before drilling of Well ER-20-5#1 began on October 15, 1995. The details of the drilling and completion operations for each hole are given in Sections 3.0, 4.0, and 5.0 of this report.

Composite drill cuttings were collected during drilling of ER-20-5#1 every 3 m (10 ft) from the surface to the total depth (TD). The collection interval was 6 m (20 ft) in most of the upper part of the section in Wells ER-20-5#2 and #3, reverting to 3-m (10-ft) intervals below 610 m (2,000 ft) in both holes. Sidewall samples were collected in the lower portion of Well ER-20-5#3. Geophysical logging was conducted to aid in construction of the wells, to help verify the geology, and to help characterize the hydrology of the units. The logging program for the cluster was designed for coverage of the entire stratigraphic section without excessive overlap from hole to hole.

1.4.1 Well ER-20-5#1

Well ER-20-5#1 was drilled to the depth of 63.1 m (207 ft) using a 12¼-inch (in.) hammer bit and mud, then reamed to a diameter of 0.61 m (24 in.). When the 20-in. surface casing could not be set apparently due to borehole deviation, the hole was enlarged to 0.66 m (26 in.). The surface casing was finally set at the depth of 62.2 m (204.1 ft) and its annulus cemented to the surface. A 17½-in. bit was used to drill through the cement remaining in the casing, then a blow-out prevention system (BOP) was constructed at the collar before drilling continued. Well ER-20-5#1 was then rotary-drilled using air-foam with conventional circulation and a 12¼-in. bit to the TD of 860.5 m (2,823 ft) in approximately six days. Tritium was encountered at the depth of approximately 681.2 m (2,235 ft), approximately 54.9 m (180 ft) below the static water level.

The target aquifer, the welded Topopah Spring Tuff, was encountered between 659.6 and 789.4 m (2,164 to 2,590 ft). The static, open-hole water level prior to installation of the pump and access strings was measured at 626.4 m (2,055 ft) on November 3, 1995. An hour of circulating after TD was reached served as precompletion development.

The monitoring well constructed in Well ER-20-5#1 consists of 5½-in. main string and a 2⅞-in. access string. The 5½-in. stainless-steel main string was landed off at 793.4 m (2,603.0 ft). This bull-nosed string has one slotted interval consisting of alternating slotted and blank joints, from 701.4 to 784.2 m (2,301.3 to 2,572.9 ft). The Moyno® pump is set within the 5½-in. casing on a 2⅞-in stainless-steel pump string with No-Turn Tools®, which, properly set, will prevent counter-rotation of the stator and allow easy removal of the pump if desired. The pump rotor was installed in the stator on a ⅞-in. coated drive-rod string. A slotted 2⅞-in. fiberglass access string was installed adjacent to the 5½-in. string, landed off at 723.5 m (2,373.7 ft).

The bottom of the hole is plugged with fill to 824.5 m (2,705 ft), and a bottom plug of cement was placed to 809.2 m (2,655 ft). The slotted interval is gravel-packed from 694.3 to 809.2 m (2,278 to 2,655 ft) with sand placed at 685.5 to 694.3 m (2,249 to 2,278 ft). The borehole annulus was cemented from 206.7 to 685.5 m (678 to 2,249 ft). Then, to advance the cementing operation through a wash-out zone, gravel was placed at 200.3 to 206.7 m (657 to 678 ft), with sand above, at 198.4 to 200.3 m (651 to 657 ft); the remainder of the hole was filled with alternating stages of cement and gravel.

IT personnel measured the fluid level in the access string at 626.1 m (2,054 ft) on November 17, 1995, and ran a pumping test on December 23, 1995. The Moyno® pump was operated for an hour on February 14, 1995, and found to.be working properly.

1.4.2 Well ER-20-5#2

Immediately after Well ER-20-5#1 was completed, the drill rig was repositioned and rigged up on Well ER-20-5#2. Commencing on November 17, 1995, the hole was drilled to the depth of 106.1 m (348 ft) with a 24-in. button bit and mud, then a 16-in. surface casing was set at 105.4 m (345.8 ft) and its annulus cemented to the surface. The cement was drilled out, and the rig was secured for the Thanksgiving holiday. When operations resumed, the hole was rotary-drilled to 819.6 m (2,689 ft) with a 12¼-in. button bit and air-foam using conventional circulation in approximately five days. Tritium was encountered at the depth of approximately 675.4 m (2,216 ft), approximately 4.9 m (16 ft) after the onset of water production.

After a short shut-down for minor rig repairs, the hole began to fill around the bit, and the bit became stuck at 808.6 m (2,653 ft). Efforts to free the bit and pipe lasted for most of two days before a fishing service was brought on site. By means of string shots and jarring over a period of seven days, fishing operations recovered drill pipe down to 552.6 m (1,813 ft). The DOE Field Manager made the decision to abandon the hole, and a plug of cement and gravel was pumped on top of the unrecovered pipe and bottom-hole assembly (BHA) to the depth of

500.8 m (1,643 ft) on December 8, 1995. The upper part of the borehole was used for disposal of cuttings from Well ER-20-5#3 surface hole, which filled the hole to a depth of approximately 19.8 m (65 ft). The remainder of the hole was cemented to the surface on February 13, 1996. The hole reached TD in the lower nonwelded portion of the Topopah Spring Tuff. No completion was attempted in Well ER-20-5#2.

1.4.3 Well ER-20-5#3

Work began on Well ER-20-5#3 immediately after the BHA was cemented in Well ER-20-5#2. Rotary drilling from under the conductor casing began on December 12, 1995, with a 26-in. bit and mud to the depth of 252.1 m (827 ft). A 20-in. surface casing was set at 250.9 m (823.2 ft) and its annulus cemented to the surface on December 19, 1995. Rotary drilling with air-foam in conventional circulation (used for the remainder of the hole) began with a 17½-in. bit on December 22, 1995, and reached the depth of 269.1 m (883 ft) before operations were shut down for the Christmas holiday. Drilling resumed on December 26, 1995, but the next day, at the depth of 319.1 m (1,047 ft), a drill collar failed and the BHA had to be recovered by a fishing service. Drilling continued with the 17½-in. bit to the depth of 955.5 m (3,135 ft), reached on January 8, 1996. A string of 13⅜-in. intermediate casing was set at 950.0 m (3,116.8 ft), but severe difficulties were experienced in cementing it in with a multiple-stage cementing tool. In addition, operations were halted for a total of nine days for an operational review. Efforts to cement the intermediate casing resumed on January 22, 1996, and drilling resumed on February 2, 1996, after cementing and rig repairs. The remainder of the hole was drilled with a 12¼-in. bit, and the TD of 1,308.8 m (4,294 ft) was reached on February 5, 1996. Tritium was first encountered in the returns at the depth of 685.8 m (2,250 ft).

The hole penetrated a lava-flow aquifer between the depths of 988.2 and 1,113.1 m (3,242 to 3,652 ft) and reached TD in zeolitic, nonwelded Calico Hills tuff. The static, open-hole water level prior to installation of the pump and access strings was measured at approximately 627.6 m (2,059 ft) on February 8, 1996. Three hours of circulating after TD was reached served as precompletion development.

The monitoring well constructed in Well ER-20-5#3 consists of 5½-in. main string and a 2⅞-in. access string. The 5½-in. stainless-steel main string was landed off at 1,192.9 m (3,913.7 ft). This bull-nosed string has one screened interval consisting of alternating screened and blank joints, from 1,045.6 to 1,183.2 m (3,430.4 to 3,881.9 ft). The Moyno® pump is set within the 5½-in. casing on a 2⅞-in stainless-steel pump string with No-Turn Tools®. The pump rotor was installed in the stator on a ⅞-in coated drive rod string. The slotted 2⅞-in. fiberglass access string planned for installation in the well was dropped in the hole and not recovered. A total of 108 joints (968.0 m [3,175.8 ft]) of fiberglass tubing remain in the hole. The open upper end of the tubing is estimated to be at 256 m (840 ft) below the surface.

The bottom of the hole is plugged with unwashed gravel to 1,229.6 m (4,034 ft) and with cement to 1,205.2 m (3,954 ft). The screened interval is gravel-packed from 1,034.2 to 1,205.2 m (3,393 to 3,954 ft) with sand placed at 1,020.5 to 1,034.2 m (3,348 to 3,393 ft). The remaining borehole annulus was cemented to 625.4 m (2,052 ft) with the upper part of the hole left open in case it is possible to reenter the dropped fiberglass tubing.

1.5 Project Manager

Inquiries regarding Well Cluster ER-20-5 should be directed to the UGTA Project Manager at:

Environmental Restoration Division
DOE/Nevada Operations Office
Post Office Box 98518
Las Vegas, Nevada 89193-8518

2.0 Geology and Hydrogeology of Well Cluster ER-20-5

Well Cluster ER-20-5 is located within the Silent Canyon caldera complex (Figure 1-1), one of several calderas and caldera complexes within the southwestern Nevada volcanic field. The Silent Canyon caldera complex has been filled and covered by volcanic rocks up to five kilometers thick, consisting mainly of rhyolitic lavas and ash-flow tuffs with interbedded nonwelded and bedded tuffs (Ferguson et al., 1994). These rocks are cut by north- to north-northeast-trending, mostly down-to-the-west, high-angle normal faults related to Basin and Range extension (Byers et al., 1976). Regional groundwater flow is generally to the south and southwest within aquifers formed by the fractured lava and welded ash-flow tuff units. Zeolitic nonwelded and bedded tuffs act as regional and local confining units (Blankennagel and Weir, 1973). For a more detailed discussion of the regional geology and hydrology of Well Cluster ER-20-5, see the drilling and completion criteria report (IT, 1995).

None of the three holes in the cluster provided data on the entire geologic section penetrated at the site because of their differing total depths, lack of cuttings samples due to intermittent or poor fluid returns in some intervals, or limited geophysical log coverage (see descriptions of data obtained from each hole in Sections 3.2, 4.2, and 5.2). However, careful examination of the data indicated that the geology encountered in all three holes was very similar. Thus, one set of composite stratigraphic and lithologic logs was prepared for this site. These detailed logs were prepared by BN geologists through examination of the drill cuttings, sidewall core samples, and geophysical logs from the holes, and they are provided in Appendix C. A general discussion of the geology of Well Cluster ER-20-5 is given below.

Because Well Cluster ER-20-5 is located very close to the TYBO event site, the rocks penetrated at the well cluster were, as predicted prior to drilling, very similar to the rocks penetrated at Emplacement Hole U-20y (Figure 2-1). Unsaturated rocks were penetrated from the surface to approximately 626.4 m (2,055 ft) and consisted mainly of vitric to devitrified and minor zeolitic bedded tuff, ash-flow tuff, and lava of the Timber Mountain and Paintbrush Groups. Saturated rocks penetrated below the static water level consist mainly of devitrified welded ash-flow tuff, vitric to devitrified and zeolitic lava, and zeolitic, nonwelded and bedded tuffs of the Paintbrush Group and Volcanics of Area 20.

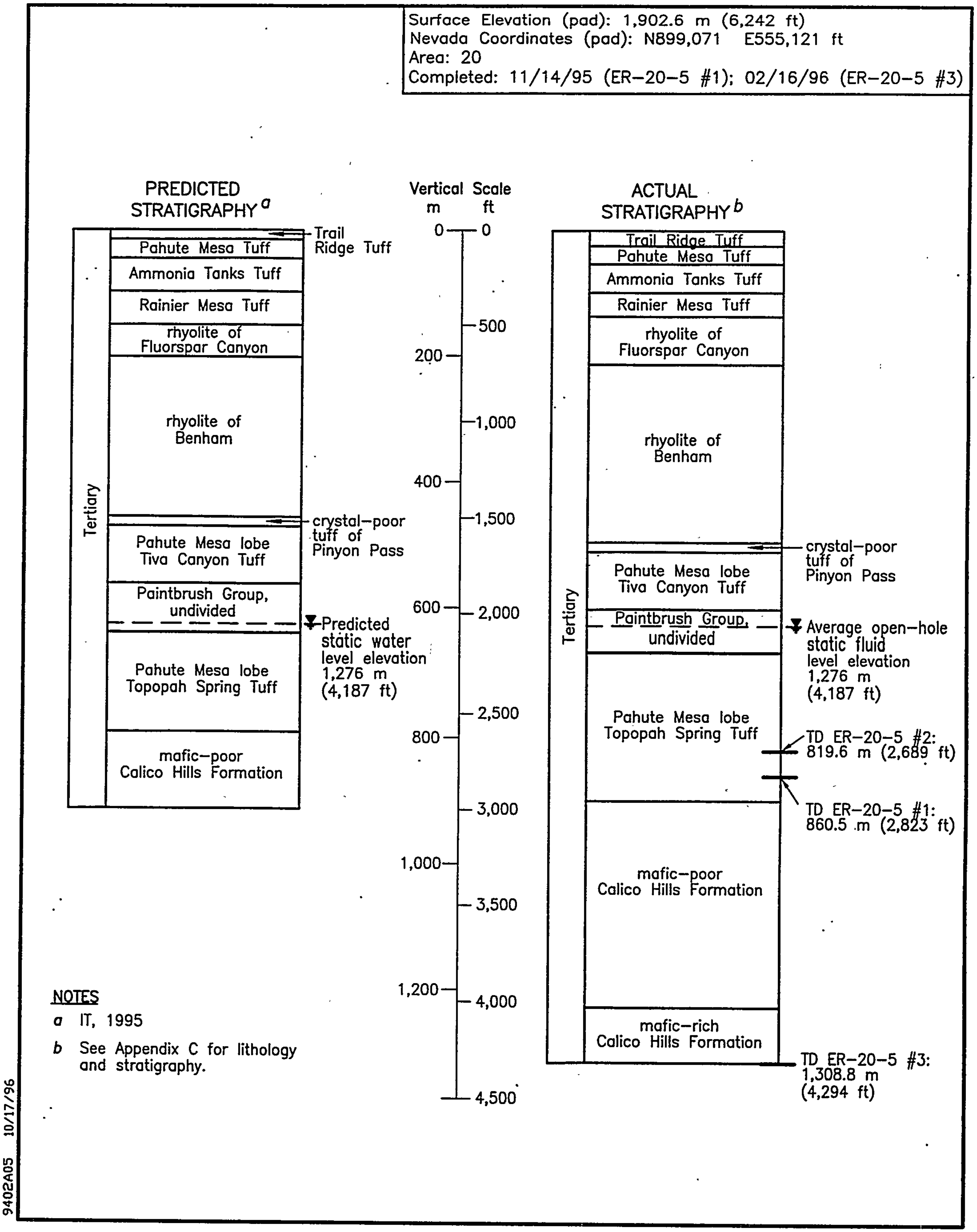


Figure 2-1
Predicted and Actual (Composite) Stratigraphy at Well Cluster ER-20-5

The rock units penetrated at Well Cluster ER-20-5 generally dip less than five degrees to the east. Most of the natural fractures, which are present mainly in the welded tuff and lava flow units, trend northeast-southwest (Price, 1996).

The welded portion of the Topopah Spring Tuff, which was logged from 659.6 to 789.7 m (2,164 to 2,591 ft), was penetrated at both Well Cluster ER-20-5 and Emplacement Hole U-20y (Figure 2-2). This unit is a welded-tuff aquifer consisting of 130.1 m (427 ft) of fractured, moderately welded ash-flow tuff. Directly overlying this welded unit are 58.2 m (191 ft) of zeolitic bedded tuffs of the Paintbrush Group. Below this welded unit are 189.3 m (621 ft) of zeolitic nonwelded tuffs of the lower portion of the Topopah Spring Tuff and the underlying Calico Hills Formation. Both of these zeolitic tuffs are believed to act as confining units. The TYBO working point was located in zeolitic, nonwelded Topopah Spring Tuff 765 m (2,510 ft) below the ground surface; however, the explosion cavity extended into the overlying welded Topopah Spring Tuff.

Another aquifer consisting of fractured vitric to devitrified rhyolitic lava was penetrated in Well ER-20-5#3 from 988.2 to 1,113.1 m (3,242 to 3,652 ft). This lava-flow aquifer was also penetrated at Emplacement Hole U-20c, the site of the BENHAM underground nuclear test, 1,330 m (4,364 ft) north-northeast of Well Cluster ER-20-5 (Figure 2-2). This aquifer is present within the Calico Hills Formation at both locations, bounded above and below by intervals of zeolitic, nonwelded Calico Hills tuff which are believed to act as tuff confining units. Although the BENHAM WP was located 1,402 m (4,600 ft) below the ground surface, below this lava flow, it is believed that the explosion cavity extended upward into the lava. Well ER-20-5#3 was drilled to intercept this lava-flow aquifer.

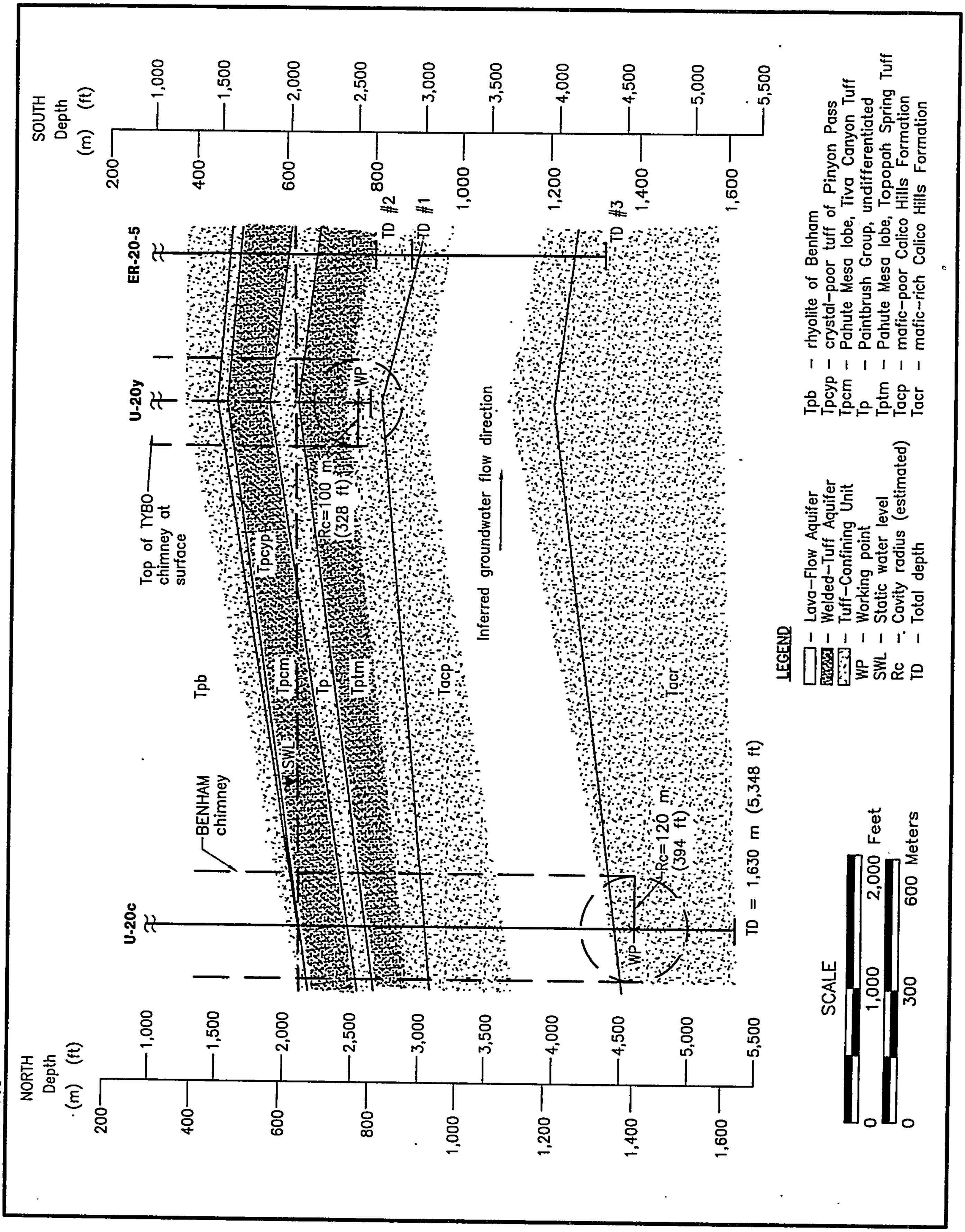


Figure 2-2
Hydrogeologic Cross-Section Through U-20c, U-20y, and Well Cluster ER-20-5 (North-South)

3.0 Well ER-20-5#1

3.1 Drilling Summary

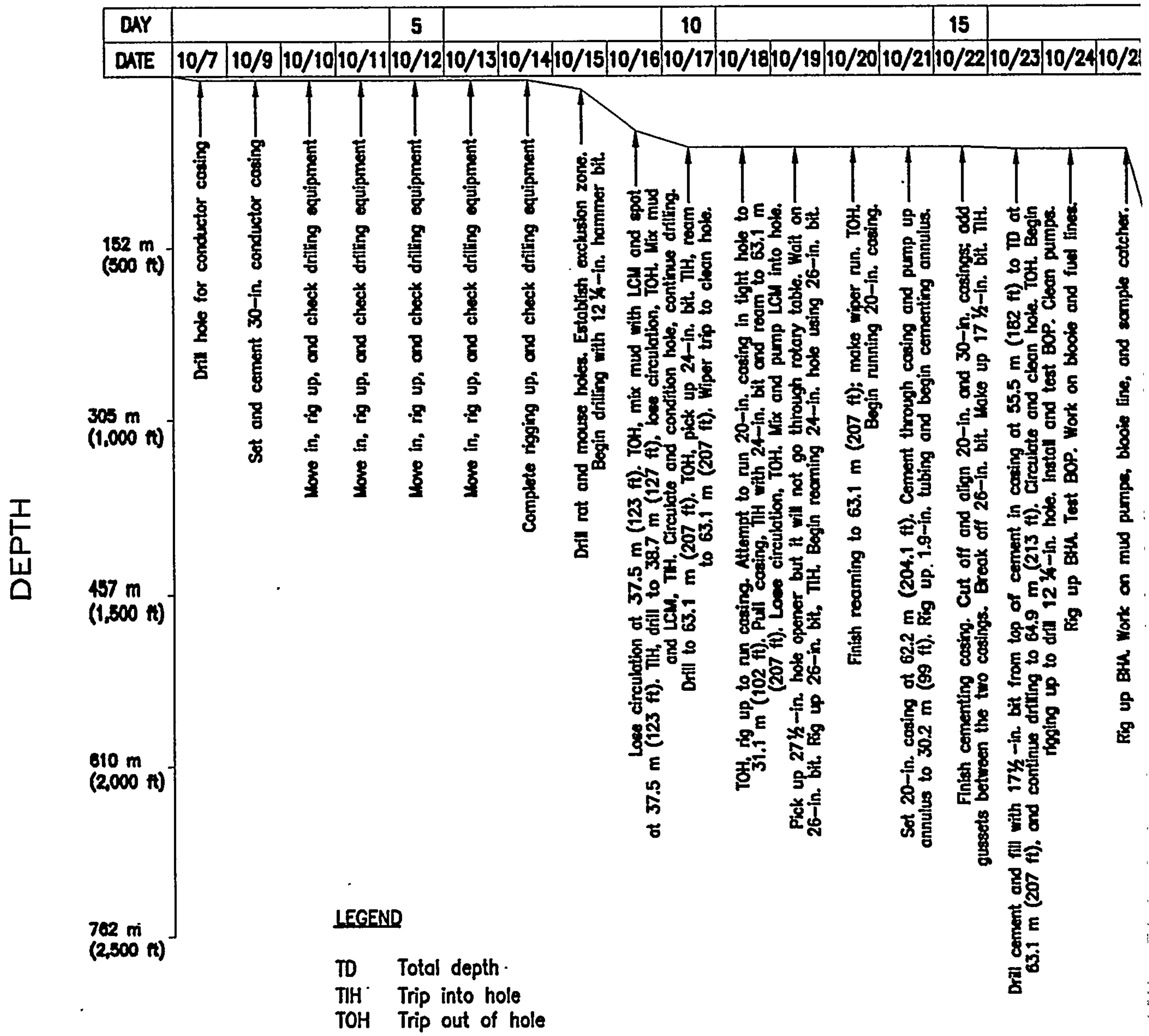
The drilling requirements for Well ER-20-5#1 were outlined in Contract DE-RP-08-95NV11808, and changes to these criteria were documented in RSN Records of Verbal Communication (Appendix A-1). No RSN drilling program was prepared for this hole. This summary was compiled from the RSN daily rig reports, field notes prepared by the IT Field Representatives, and the BN Well ER-20-5#1 hole history (BN, 1996a) where complete details of drilling activities can be found.

The drill site had previously been prepared with two lined sumps (one of these double-lined) on the pad and two additional lined sumps and an infiltration basin located approximately 150 m (490 ft) south of the pad. (Three additional lined sumps were built in the infiltration basin during drilling of Well ER-20-5#3 [see Paragraph 5.1.3 and Figure 1-3].) The conductor holes were drilled with a bucket rig to 3.4 m (11 ft), and conductor casing set for all three holes before the Welch & Howell rig was set up on location. Welch & Howell Rig #10 was used for this project; the rig consisted of a Pyramid mast and substructure with a 176,904-kilogram (390,000-pound) static hook load rating. The exclusion zone was established on October 15, 1995, before drilling of Well ER-20-5#1 began.

See Figure 3-1 for a graphical presentation of the drilling and completion history for Well ER-20-5#1, and see Table 3-1 for abridged drill hole statistics. A graphical depiction of drilling parameters, including penetration rate, revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-2. Details of the composition of drill fluid, additives, and cements used are provided in Appendix A-4.

3.1.1 Drilling History

After the mouse and rat holes were completed, Well ER-20-5#1 was drilled to the depth of 63.1 m (207 ft) using a 12¼-in. hammer bit and mud, then reamed to 0.61 m (24 in.). When circulation was lost at the depth of 37.5 m (123 ft), lost circulation material (LCM) (consisting of cedar fiber) was spotted in the hole, and additional LCM was used later (as necessary) during reaming. The 20-in. surface casing could not be set, possibly because the hole had deviated, so the hole was enlarged to 0.66 m (26 in.) and the surface casing was finally set at the depth of 62.2 m (204.1 ft). The casing was cemented by pumping cement down the casing and pressurizing it with water to 2.75 megaPascals (MPa)



Well ER-20-5 #1 Summary

Hole spudded	10/15/95
Surface hole completed and cased	10/22/95
Begin drilling 12 ¼-in. hole	10/27/95
Begin recording tritium in returns	10/30/95
Reach total drilled depth of 860.5 m (2,823 ft)	11/02/95
Complete well	11/14/95

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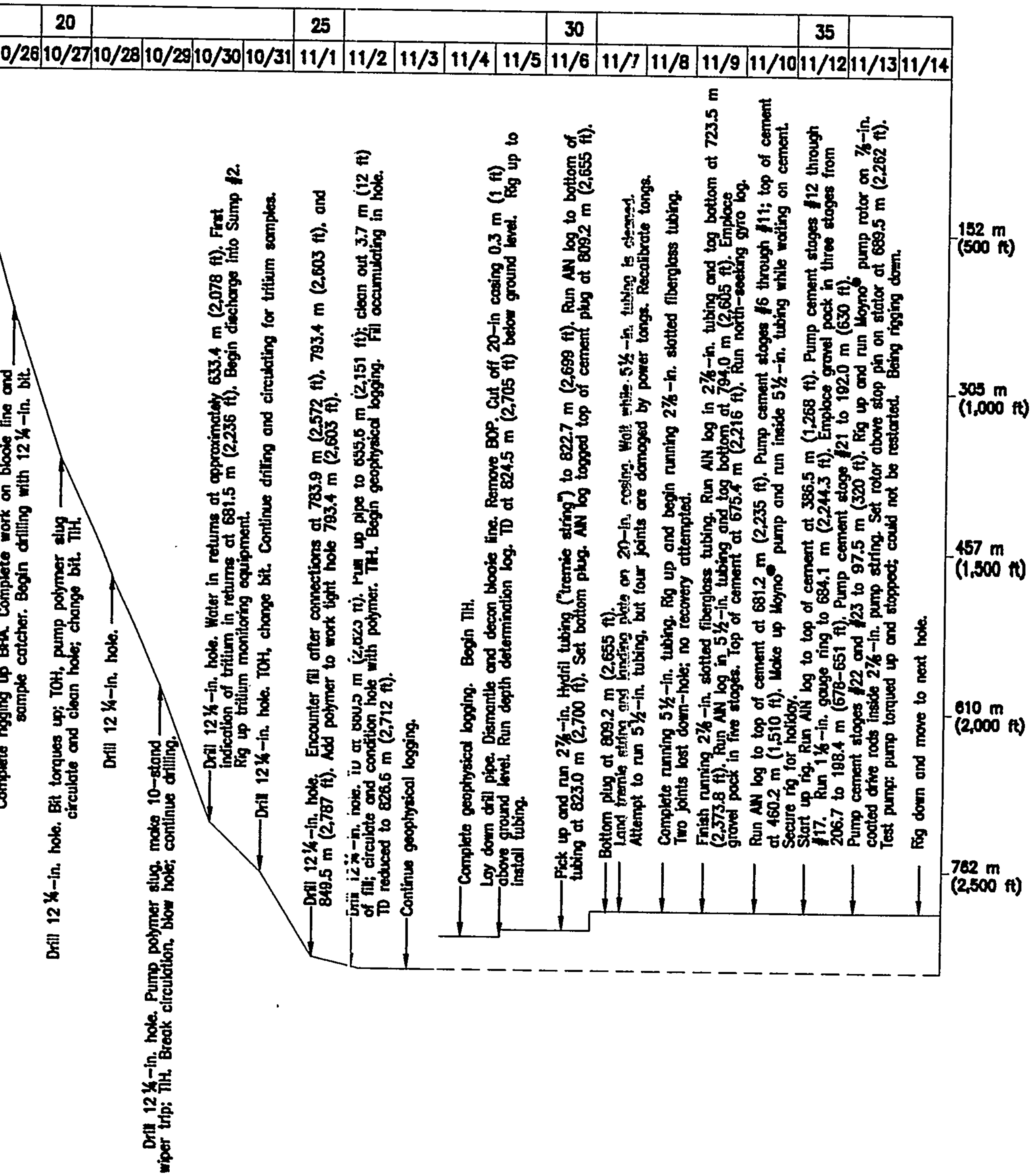

FIGURE 3-1
WELL ER-20-5#1
DRILLING AND COMPLETION HISTORY

Table 3-1
Abridged Drill Hole Statistics for Well ER-20-5#1

LOCATION DATA: Coordinates: Central Nevada State Planar: N899,133.6, E555,173.9 feet (ft)
Universal Transverse Mercator: N4,119,208.3, E546,385.9 meters (m)

Ground Elevation: 1,902.5 m (6,241.8 ft)

DRILLING DATA:

Spud Date:	10/15/95
Total Depth (TD):	860.5 m (2,823 ft)
Date TD Reached:	11/02/95
Date Well Completed:	11/14/95
Hole Diameter:	91.4 centimeters (cm) (36 inches [in.]) from surface to 3.4 m (11 ft); 66.0 cm (26 in.) to 63.1 m (207 ft); 44.5 cm (17½ in.) to 64.9 m (213 ft); 31.1 cm (12¼ in.) to 860.5 m (2,823 ft).
Drilling Techniques:	Dry auger-drilling with bucket rig to 3.4 m (11 ft). Rotary drilling with dry air using a 12¼-in. hammer bit and conventional circulation to 11.3 m (37 ft). Rotary drilling with mud (and lost circulation material as needed) to 63.1 m (207 ft). Reaming with 24-in. bit to 63.1 m (207 ft). Reaming with 26-in. bit to 63.1 m (207 ft). Rotary drilling with 17½-in. mill-tooth bit through cement in casing at 55.5 to 64.9 m (182 to 213 ft) with conventional circulation and mud. Rotary drilling with 12¼-in. button bit to TD at 860.5 m (2,823 ft) using air-foam with conventional circulation.

CASING DATA: 76.2-cm (30-in.) conductor casing from surface to 3.4 m (11 ft). 50.8-cm (20-in.) surface casing set at 62.2 m (204.1 ft). No intermediate casing.

WELL COMPLETION DATA:

The pump string is installed within slotted 14.0-cm (5½-in.) outside diameter (od) stainless-steel casing landed off 793.4 m (2,603.0 ft). A Moyno® pump stator was installed at the bottom of 7.3-cm (2⅞-in.) od stainless-steel tubing, with No-Turn Tools® above and below the stator. The stop pin below the pump stator is located at the depth of 689.8 m (2,263.1 ft). The pump rotor was installed in the stator on the end of a 2.2-cm (⅞-in.) od-coated, drive-rod string. A slotted access string consisting of 7.3-cm (2⅞-in.) od fiberglass tubing was landed off at 723.5 m (2,373.7 ft).

	Pump String	Access String
Total Depth:	793.4 m (2,603.0 ft)	723.5 m (2,373.7 ft)
Depth of Slotted Section:	701.4-784.2 m (2,301.3-2,572.9 ft)	705.6 to 723.5 m (2,315.0-2,373.7 ft)
Depth of Sand Pack:	685.5-694.3 m (2,249-2,278 ft)	Same as for pump string
Depth of Gravel Pack:	694.3-809.2 m (2,278-2,655 ft)	Same as for pump string
Depth of Moyno® Pump:	683.1-689.8 m (2,241.2-2,263.1 ft)	Not applicable
Fluid Depth[a]:	626.4 m (2,055 ft)	

DRILLING CONTRACTOR: Welch & Howell Drilling

GEOPHYSICAL LOGS BY: Atlas Wireline Services, Baker Hughes INTEQ, Barbour Well Surveying, Desert Research Institute, Geophysical Engineering Group of the Joint Test Organization

SURVEYING CONTRACTOR: Bechtel Nevada

[a]Fluid level in the open borehole as of November 3, 1995.

(400 pounds per square inch [psi]). The cement was displaced up the annulus to the depth of 30.2 m (99 ft), and cement was left inside the casing to a depth of 55.5 m (182 ft). The remaining open annular volume was cemented to ground level through 1.9-in. tubing.

A 17½-in. mill-tooth bit was used to drill through the cement and approximately 1.8 m (6 ft) beyond, to 64.9 m (213 ft). Approximately three days were then spent rigging up the BHA, constructing and testing the blow-out prevention system, preparing the cuttings sampling system, and working on the fuel lines and mud pumps.

Drilling continued on October 26, 1995, using a rotary assembly with a 12¼-in. button bit and air-foam. The drillers made a trip at the depth of 327.7 m (1,075 ft) when the bit torqued up. A slug of polymer drilling fluid was pumped down-hole, and the hole was cleaned prior to tripping out. Drilling continued with few problems though the drillers pumped another polymer slug and made a short wiper trip at 548.0 m (1,798 ft). No fill was encountered after this trip.

The first observation of water in the returns was reported at the depth of 633.4 m (2,078 ft) on October 30, 1995. The presence of tritium was noted at the depth of 681.2 m (2,235 ft) the same day. The drillers tripped out for a bit change on October 31, 1995, after drilling to 747.1 m (2,451 ft). The drilling rate, which had reached as high as 19.8 m (65 ft) per hour after a drilling break at 604.7 m (1,984 ft), was kept to an average of about 6 m (20 ft) per hour to allow for timely analysis of fluid samples for tritium concentrations. The TD of 860.5 m (2,823 ft) was reached on November 2, 1995, after drilling approximately 46 m (150 ft) below the target aquifer.

The gyro survey run in the well indicates that at the depth of 789.4 m (2,590 ft), the borehole is 18.2 m (59.7 ft) west-southwest of the well collar with an average inclination of 1.8 degrees.

3.1.2 Drilling Problems

Few drilling problems were encountered during operations at Well ER-20-5#1, and those were caused mainly by hole sloughing and lost circulation. The following paragraphs summarize the primary difficulties encountered during drilling of Well ER-20-5#1:

- The lost circulation at 36.6 to 61.0 m (120 to 200 ft) was attributed to joints and/or fractures within welded portions of the Thirsty Canyon Tuff or to pumiceous bedded tuffs between the welded zones.

- The 20-in. surface casing could not be set in the original 24-in. hole, apparently due to a slight dogleg in the upper part of the hole. This problem was solved by enlarging the hole to 66 centimeters (cm) (26 in.) to the casing point at 63.1 m (207 ft).

- Borehole sloughing (fill encountered at connections) was noted below the depth of approximately 792 m (2,600 ft). Accumulation of fill at the bottom of the hole during logging decreased the TD by 51.2 m (168 ft). Based on examination of the drill cuttings and the caliper log, the source of most of the fill material is believed to be bedded Ammonia Tanks Tuffs, penetrated between 67.7 and 95.7 m (222 to 314 ft). Bedded tuffs of the rhyolite of Fluorspar Canyon, penetrated between 139.6 and 214.0 m (458 to 702 ft), may also have contributed, based on the caliper log.

3.1.3 Fluid Management

A mix of gel (mud) and polymer was used to drill Well ER-20-5#1 to the depth of 64.9 m (213 ft) with applications of cedar-fiber LCM as needed. The remainder of the hole was drilled using air-foam with applications of polymer as needed to condition the hole. Separate, lined sumps were used to hold clean and contaminated discharge fluids.

The drilling effluent was monitored in accordance with the methods prescribed in the *Fluid Management Plan for the Underground Test Area Operable Unit* (DOE, 1994) and the *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-5* (IT, 1995). The results of analyses on samples of drilling fluid indicate that all fluids routed to the infiltration area are within the fluid quality objectives established in the FMP for radiochemical parameters.

Appendix B of this report contains the *Well ER-20-5#1 Fluid Management Status Report*. The fluid disposition form lists final volumes and data for drilling and completing the well and for initial well development. The final volumes of fluids imported to and produced at Well ER-20-5#1 were calculated from water-truck delivery tickets and measurements of fluids in the sumps. The solids produced were calculated using the diameter of the borehole and the depth drilled, with added volume attributed to rock bulking factors.

3.2 Geologic Data Collection

3.2.1 Collection of Drill Cuttings

Triplicate sets of composite drill cuttings were collected continuously from Well ER-20-5#1 at 3.1-m (10-ft) intervals as drilling progressed from the surface to the TD of the well at 860.5 m (2,823 ft). Samples were not obtained from 21 intervals. Eleven intervals were missed due to lack of fluid returns to the surface and the others were missed due to various technical difficulties. Hole sloughing degraded the quality of the cuttings, particularly below the depth of 807.7 m (2,650 ft). All samples are stored under secure conditions at the U.S. Geological Survey (USGS) Geologic Data Center and Core Library in Mercury, Nevada. One set of samples was sealed with custody tape at the rig site as an archive sample; one set was left unsealed in the original sample containers; and the third set was washed and stored as per standard Core Library procedures.

3.2.2 Geophysical Logging Data

Geophysical logs were run after drilling to characterize the lithology, structure, and hydrogeologic properties of the rocks. In addition, logs were run to check borehole conditions, determine fluid levels and other hydrologic data, identify radionuclides, and monitor the completion process. All geophysical logs run in Well ER-20-5#1 during drilling and completion are listed in Table 3-2. The logs are available from BN in Mercury, Nevada, and copies are on file at the IT office in Las Vegas, Nevada.

Overall, the quality of the geophysical data was acceptable, although hole rugosity degraded certain logs (i.e., density). Also, accumulating fill due to hole sloughing precluded log coverage below the depth of about 811 m (2,660 ft). Preliminary geophysical data from the caliper, compensated density, compensated neutron, spectral gamma ray, and differential temperature logs are presented as a composite log in Appendix D.

3.3 Hydrology of Well ER-20-5#1

3.3.1 Preliminary Water Level and Water Production Information

Groundwater was first detected by visual evaluation of the drilling effluent at approximately 633.4 m (2,078 ft). The fluid level in the open borehole (measured during geophysical logging and before installation of the tubing in the well) consistently stabilized at a depth of approximately 626.4 m (2,055 ft) and an elevation of 1,276.2 m (4,187 ft). The depth to water at Well Cluster ER-20-5 had been projected to be approximately 623 m (2,043 ft) at an elevation of approximately 1,276 m (4,187 ft) (IT, 1995). The difference in the expected and measured water depths lies in the 3.6-m (11.8-ft) difference between the projected ground elevation and the as-built elevation of the well-cluster pad.

Significant production of water from Well ER-20-5#1 began at the depth of approximately 657.8 m (2,158 ft), soon after drilling into the welded Topopah Spring Tuff. The welded portion

Table 3-2
Well ER-20-5#1 Geophysical Log Summary

Geophysical Logs	Log Purpose	Logging Service	Date Logged	Run Number	Top of Logged Interval (bgs)[a] meters (feet)	Bottom of Logged Interval (bgs) meters (feet)
Annulus Investigation Log	Omnidirectional density (check for cement and/or fluid location)	GEG[b]	11/06/95 11/06/95 11/09/95 11/09/95 11/10/95 11/12/95 11/12/95	AIN-1 AIN-2 AIN-3 AIN-4 AIN-5 AIN-6 AIN-7	762.0 (2,500) 762.0 (2,500) 548.6 (1,800) 548.6 (1,800) 335.3 (1,100) 152.4 (500) 61.0 (200)	824.2 (2,704) 816.6 (2,679) 723.3 (2,373) 794.3 (2,606) (722.4 2,370) (411.5 1,350) 213.4 (700)
3-arm Caliper/Dual Laterolog/ Gamma Ray	Determine drill hole conditions/ lithology/stratigraphic correlation	AWS[c]	11/02/95	CA3-1/ DLL-1/GR-2	626.4 (2,055)	833.3 (2,734)
3-arm Caliper/Gamma Ray/Digital Acoustic Compensated	Determine drill hole conditions/ stratigraphic correlation/fracture identification	AWS	11/03/95	CA3-2/ GR-4/DAC-1	626.4 (2,055)	824.2 (2,704)
Chemical Log	Determine pH, electrical conductivity, and temperature of fluid	GEG DRI[d]	11/02/95 11/04/95	CHEM-1 CHEM-2	655.3 (2,150) 626.4 (2,055)	856.5 (2,810) 824.4 (2,706)
Directional Gyroscope	Borehole deviation	BHI[e]	11/09/95	DRG-1	0 (0)	789.4 (2,590)
Downhole Video	Borehole examination for fractures and lithology	BWS[f]	11/03/95	TV-1	0(0)	701.0 (2,300)
Gamma Ray/4-arm Caliper	Stratigraphic correlation/ determine hole conditions, cement volumes	AWS	11/02/95	GR-1/CA4-1	0.6 (2)	835.2 (2,740)
Gamma Ray/Borehole Televiewer	Stratigraphic correlation/ borehole examination for fractures and lithology	AWS	11/03/95	GR-3/BHTV-1	626.4 (2,055)	826.0 (2,710)
Gamma Ray/Compensated Neutron/ Compensated Densilog	Stratigraphic correlation/water content/ lithologic determination	AWS	11/03/95	GR-5/ CN-1/CDL-1	62.2 (204)	826.0 (2,710)
Spectral Gamma Ray	Stratigraphic correlation, mineralogy, natural radiation, identify explosion products	AWS	11/03/95	SGR-1	0.6 (2)	814.4 (2,672)
Temperature	Groundwater temperature and fluid flow	AWS	11/03/95	TL-1	552.6 (1,813)	827.5 (2,715)
Thermal Flow (Electrical Conductivity, Temperature)	Determine rate/direction of groundwater flow within the borehole	DRI	11/04/95	HPFLOW-1	710.2 (2,330)	777.2 (2,550)
Total Magnetic Intensity	Stratigraphic correlation, lithologic information	GEG	11/04/95	MPP-1	64.0 (210)	824.2 (2,704)

Source: BN Logging Section
[a] Below ground surface
[b] Geophysical Engineering Group of the Joint Test Organization
[c] Atlas Wireline Services
[d] Desert Research Institute
[e] Baker Hughes INTEQ
[f] Barbour Well Surveying

of the Topopah Spring Tuff was expected to be the main source of water production at Well Cluster ER-20-5, and water production steadily increased to approximately 454 liters per minute (Lpm) (120 gallons per minute [gpm]) as the unit was penetrated. However, water production continued to increase (to a maximum of approximately 568 Lpm (150 gpm) as the hole penetrated the underlying zeolitic, nonwelded tuffs of the lower portion of the Topopah Spring Tuff, which had been expected to act as a tuff confining unit. Two possible explanations were posed for this situation: (a) a water-producing fracture (or fractures) was encountered in the zeolitic, nonwelded tuffs; or more likely, (b) continued drilling and circulating served to develop the welded Topopah Spring Tuff aquifer. It is also possible (with air-foam drilling) that more efficient water-production conditions existed at some distance above the bit and thus more fluid was produced after the welded-tuff aquifer was fully penetrated.

3.3.2 Preliminary Thermal Flow Log Data

Thermal flow meter data, along with temperature, electrical conductivity, and pH measurements can characterize borehole fluid variability, which may indicate inflow and outflow zones. Personnel of the Desert Research Institute made flow meter measurements at three locations in the borehole (710.2 m [2,330 ft], 743.7 m [2,440 ft], and 777.2 m [2,550 ft]), but were unable to achieve a seal with the packer at the bottom of the hole. Preliminary analysis of the data indicated downward flow of one liter per minute or less at all three locations.

3.3.3 Radionuclides Encountered

Tritium was encountered in the fluid returns when the hole had reached the depth of 681.2 m (2,235 ft), approximately 54.9 m (180 ft) below the static water level. Tritium activities averaged less than about 15 million picoCuries per liter (pCi/L) from 681.2 to 729.1 m (2,235 to 2,392 ft), ranging from 774,000 to 17,500,000 pCi/L, and then jumped to an average of approximately 40 to 60 million pCi/L for the interval 729.1 to 840.3 m (2,392 to 2,757 ft). From 840.3 m (2,757 ft) to the last sample measured at 858.6 m (2,817 ft), the tritium levels averaged approximately 64 to 75 million pCi/L. A maximum of 78.5 million pCi/L was recorded at 851.3 m (2,793 ft). See Appendix B for a listing of tritium and water-production data. See Section 6.0 for a graphic comparison of tritium and water-production data for all three holes in the cluster.

3.3.4 Noble Gas Experiment

Air used for drilling was tagged with krypton starting at the depth of approximately 610 m (2,000 ft), just before groundwater was encountered. The presence of the krypton may allow monitoring of well development and may provide a means of measuring groundwater flow between the individual wells in the cluster.

3.4 Precompletion and Open-Hole Development

The only precompletion development attempted in Well ER-20-5#1 was circulation and conditioning of the borehole for about one hour after TD was reached, prior to geophysical logging.

3.5 Completion

The objective of well completion is to hydraulically isolate one or more water-producing zones in order to collect potentiometric and water-chemistry data from specific zones. Completion activities at Well ER-20-5#1 began immediately after logging was concluded and a bottom plug had been set on November 6, 1995, and were concluded on November 14, 1995. Figures 3-2 and 3-3 are schematics of the final well-completion design for Well ER-20-5#1, and Figure 3-4 shows a plan view and profile of the wellhead configuration. Data for this section were obtained from the RSN daily rig reports and tubing records for Well ER-20-5#1.

3.5.1 Proposed Completion Design

The original criteria plan for Well Cluster ER-20-5 called for the construction of one completion zone in each hole of the cluster with the first hole to be the deepest. Well ER-20-5#1 was to be completed in the welded portion of the Topopah Spring Tuff, which was expected to be the primary aquifer, located between two zeolitic, nonwelded tuff confining units (IT, 1995). The completion design was to be basically the same for all three holes (though the completion depths would be different in each hole), consisting of a screened completion string with a retrievable pump and an adjacent screened access string for taking samples and water-level measurements. The pair of strings was to be permanently installed to access a discrete interval.

3.5.2 As-Built Completion Design

The as-built completion design provides access to the portion of the borehole in which intermediate water production and tritium levels were measured. The slotted casing contains a pump stator positioned on a separate string with No-Turn Tools® which are expected to prevent counter-rotation of the stator and allow easy removal of the pump if desired. The pump rotor was installed on a drive-rod string. A separate slotted string was installed adjacent to the pump string for monitoring water levels. The string compositions are listed on Table 3-3 and tubing materials are listed in Appendix A-3.

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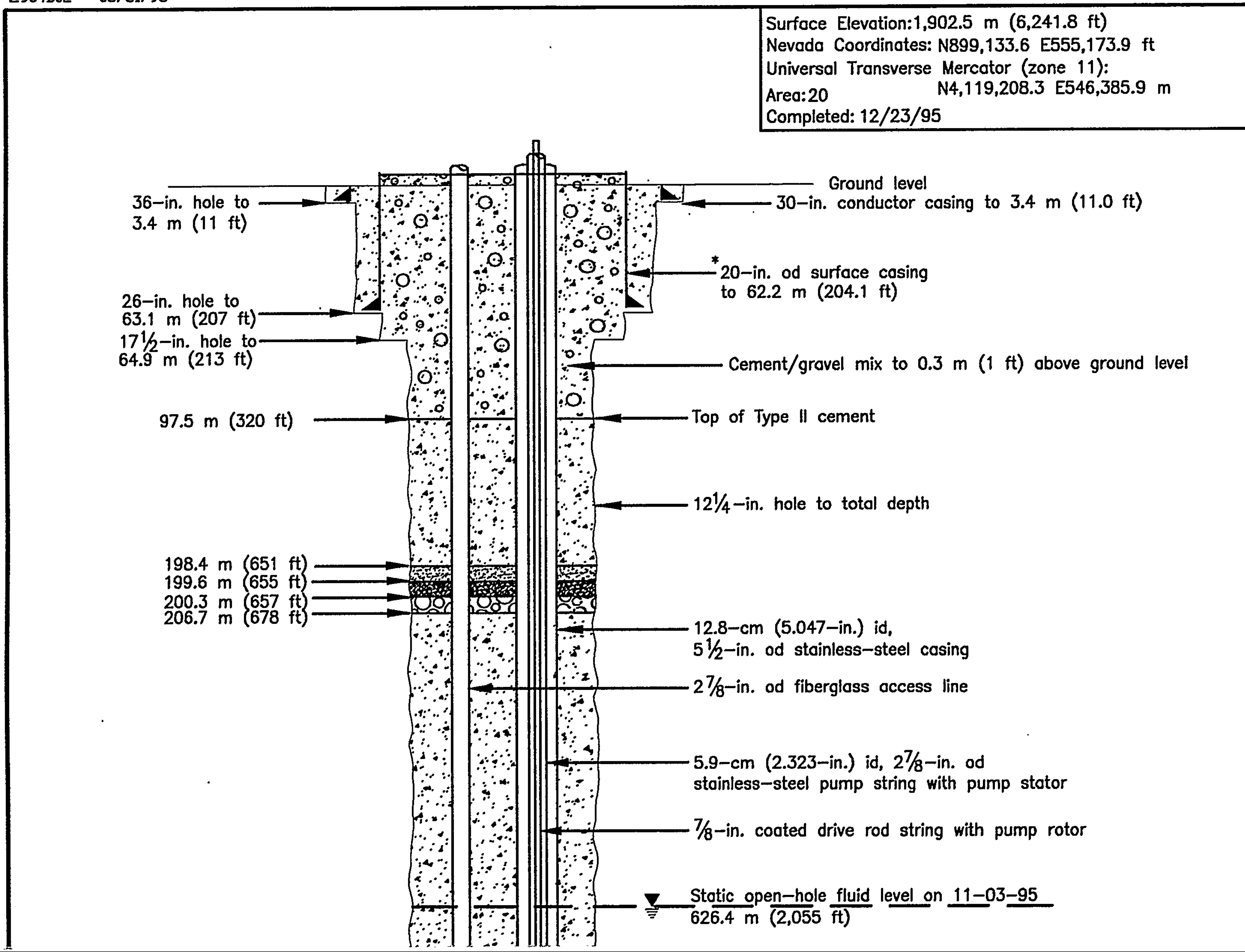
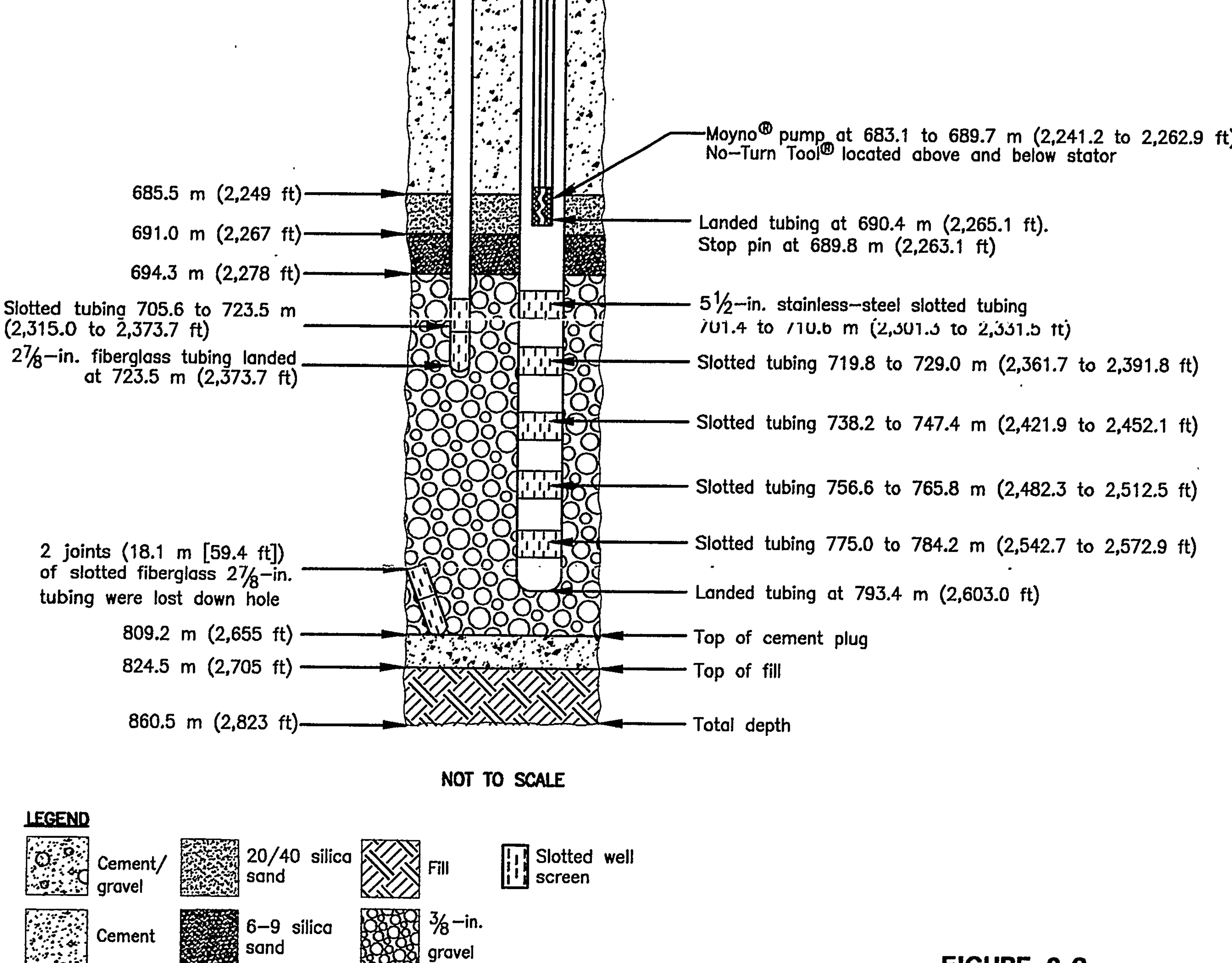




*Additional details regarding tubing type, grade, diameter, etc. are provided in Appendix A–3.
See Figure 3–3 for details of completion configuration.

FIGURE 3-2
AS-BUILT SCHEMATIC OF WELL ER-20-5#1

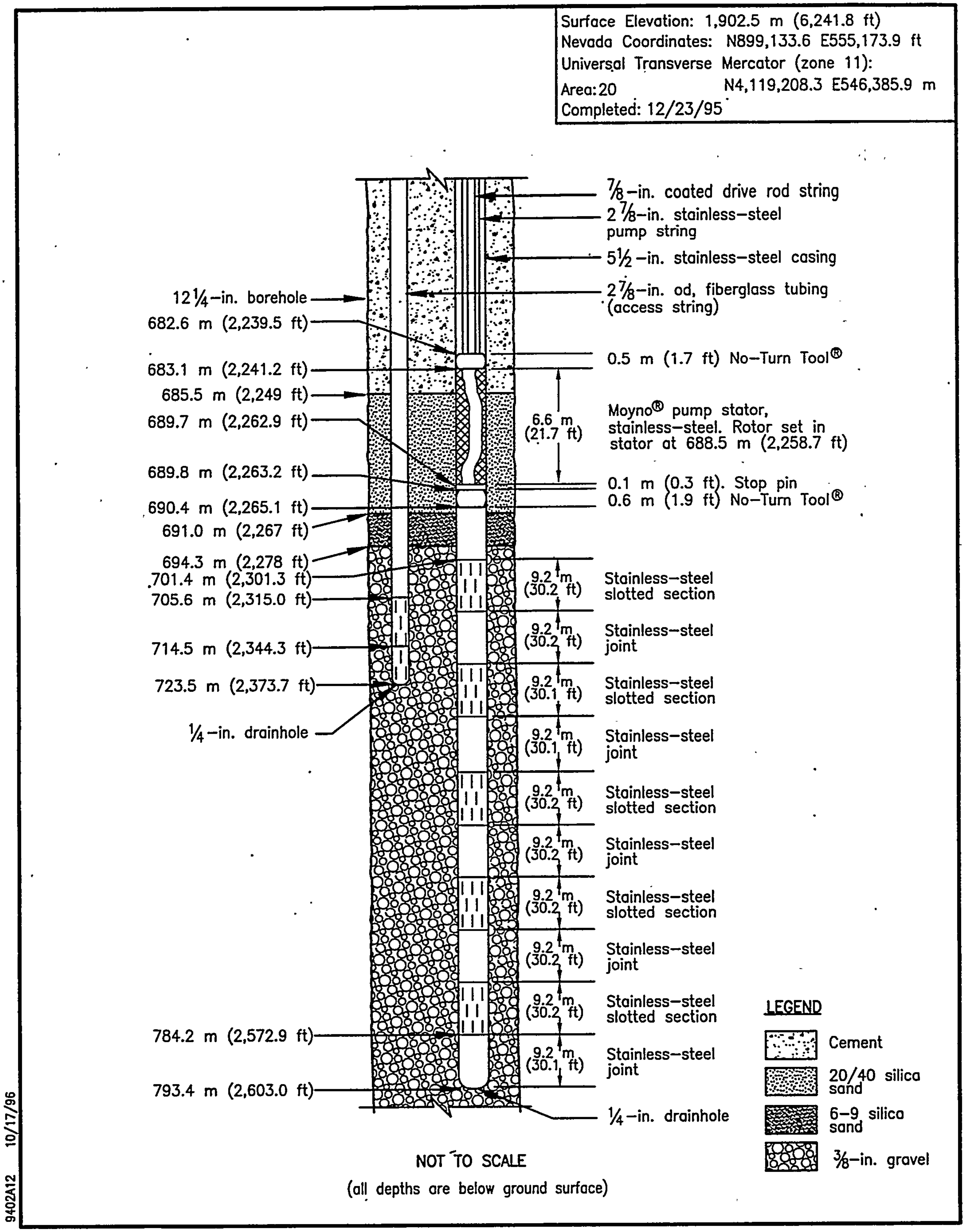
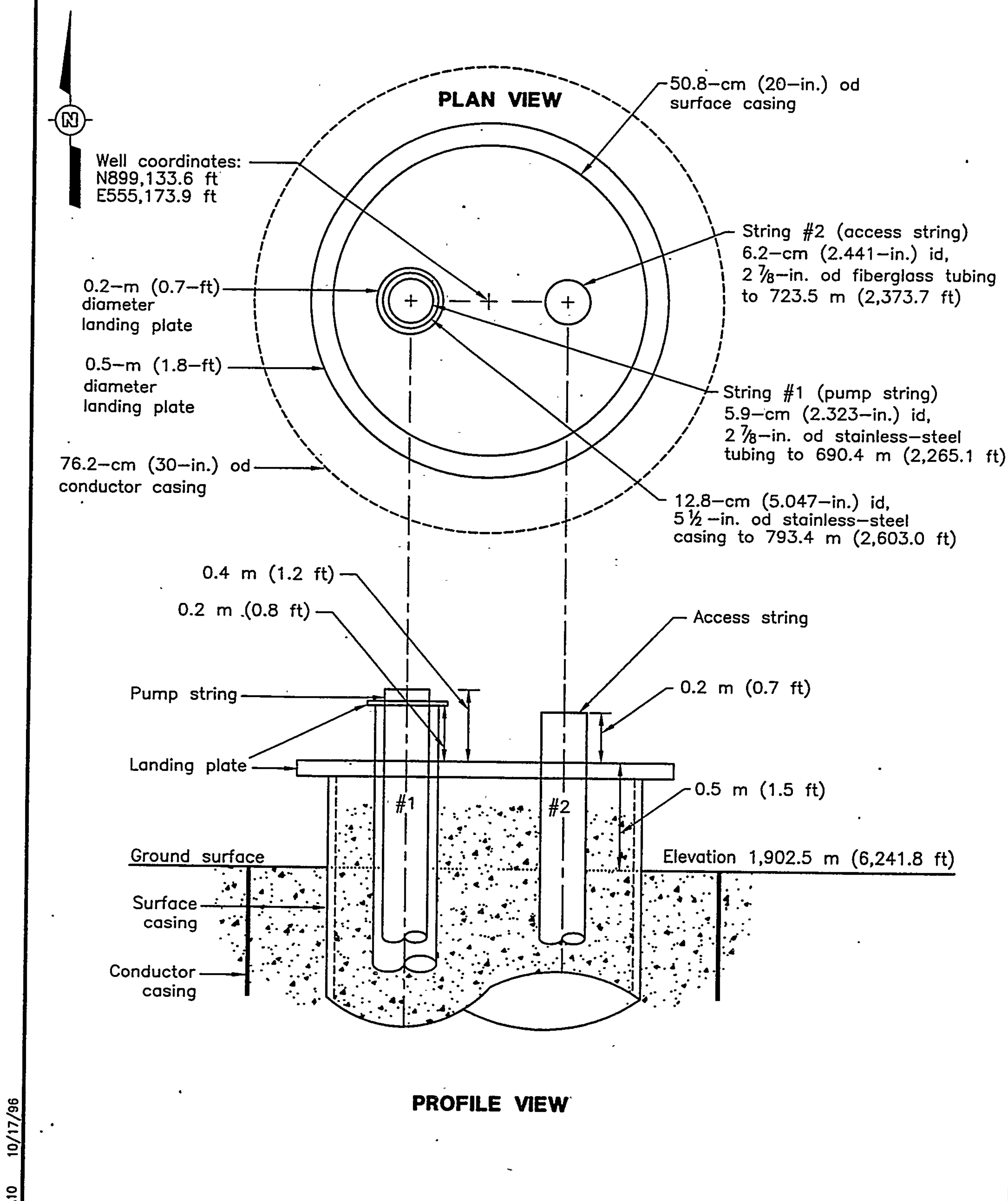


Figure 3-3
Detail of Well ER-20-5#1 Completion Configuration



See Appendix A–3 for casing and tubing data.

Figure 3-4
Well ER-20-5#1 Wellhead Diagram

Table 3-3
Well ER-20-5#1 Construction Summary

<table>
<tr><th>Completion String</th><th colspan="2">Configuration</th><th>Cement</th><th>Sand/Gravel</th></tr>
<tr><td rowspan="11">5½-inch Stainless-steel</td><td rowspan="11">Ground surface to
793.4 m
(2,603.0 ft)</td><td>Blank
0 to 701.4 m
(2,301.3 ft)</td><td rowspan="15">Type II
plus 2% $CaCl_2$

97.5 to 198.4 m
(320-651 ft)

and

206.7 to 685.5 m
(678-2,249 ft)

and

809.2 to 824.5 m
(2,655-2,705 ft)</td><td rowspan="15">20/40 Sand

198.4 to 199.6 m
(651 to 655 ft)
and
685.5 to 691.0 m
(2,249 to 2,267 ft)

6-9 Sand

199.6 to 200.3 m
(655 to 657 ft)
and
691.0 to 694.3 m
(2,267 to 2,278 ft)

3/8-inch Gravel

200.3 to 206.7
(657 to 678 ft)
and
694.3 to 809.2 m
(2,278 to 2,655 ft)</td></tr>
<tr><td>Slotted
701.4 to 710.6 m
(2,301.3 to 2,331.5 ft)</td></tr>
<tr><td>Blank
710.6 to 719.8 m
(2,331.5 to 2,361.7 ft)</td></tr>
<tr><td>Slotted
719.8 to 729.0 m
(2,361.7 to 2,391.8 ft)</td></tr>
<tr><td>Blank
729.0 to 738.2 m
(2,391.8 to 2,421.9 ft)</td></tr>
<tr><td>Slotted
738.2 to 747.4 m
(2,421.9 to 2,452.1 ft)</td></tr>
<tr><td>Blank
747.7 to 756.6 m
(2,452.1 to 2,482.3 ft)</td></tr>
<tr><td>Slotted
756.6 to 765.8 m
(2,482.3-2,512.5 ft)</td></tr>
<tr><td>Blank
765.8 to 775.0 m
(2,512.5-2,542.7 ft)</td></tr>
<tr><td>Slotted
775.0 to 784.2 m
(2,542.7to 2,572.9 ft)</td></tr>
<tr><td>Blank and
bull-nosed
774.2 to 793.4 m
(2,572.9-2,603.0 ft)</td></tr>
<tr><td rowspan="2">2⅞-inch Stainless-steel tubing</td><td rowspan="2">Ground surface to
690.4 m (2,265.1 ft)

inside 5½-inch casing</td><td>Moyno® pump stator
683.1 to 689.8 m
(2,241.2 to 2,263.1 ft)</td></tr>
<tr><td>No-Turn Tools

682.6 to 683.1
(2,239.5 to 2,241.2 ft)
and
689.8 to 690.4 m
(2,263.1 to 2,265.1 ft)</td></tr>
<tr><td>⅞-inch Coated drive rods</td><td>Ground surface to
689.5 m (2,262.0 ft)</td><td>Moyno® pump rotor
set in stator</td></tr>
<tr><td>2⅞-inch Fiberglass
Smith Fiberglass Products, Inc.</td><td>Ground surface to
723.5 m (2,373.7 ft)</td><td>Blank
Ground Surface to
705.6 m (2,315.0 ft)

Slotted
705.6 to 723.5 m
(2,315.0 to 2,373.7 ft)</td></tr>
</table>

The casing for the pump string is 5½-in. stainless-steel for its entire length. The bottom 9.2-m (30.1-ft) joint is bull-nosed with a 0.64-cm (0.25-in.) drain-hole to serve as a fluid drain in the event of excessive drawdown. The first joint above the bull-nose is blank, followed by alternating slotted and blank joints. A total of five 9.2-m (30.1-ft) long slotted joints are located between 701.4 and 784.2 m (2,301.3 to 2,572.9 ft). The lowest four slotted sections have 60 rows of sawed slots 0.20 cm (0.078 in.) wide and 5.08 cm (2.0 in.) long on staggered 15.2-cm (6-in.) centers. The uppermost slotted joint has 112 rows of saw-cut slots 0.20 cm (0.078 in.) wide and 5.08 cm (2.0 in.) long with 24 slots per row.

The Moyno® pump stator was installed on 2⅞-in. stainless-steel tubing within the 5½-in. casing at 683.1 to 689.8 m (2,241.2 to 2,263.1 ft) with No-Turn Tools located above and below the stator. The 2⅞-in. stainless-steel string is unslotted, but open on the bottom (via the pump stator section). The pump rotor was installed in the stator on a string of 7.6 m (25 ft) long, ⅞-in. coated drive rods equipped with spin-through rod guides. The number of guides per rod was determined by computer analysis of side-loading, based on borehole deviation data (Schwichtenberg, 1996).

A 2⅞-in fiberglass tubing string was installed in Well ER-20-5#1 adjacent to the 5½-in. casing string to serve as an access string. The fiberglass tubing was landed off at 723.5 m (2,373.7 ft). The first two joints (lowest 17.9 m [58.7 ft]) of this tube are slotted, and the end of the tube is stainless-steel and bull-nosed with a 0.64-cm (0.25-in.) drain-hole. Each slotted joint has 16 rows of saw-cut slots 6.35 cm (2.5 in.) long by 0.32 cm (0.125 in.) wide on staggered 15.2-cm (6-in.) centers.

3.5.3 Rationale for Differences Between Actual and Proposed Well Design

The as-built design for Well ER-20-5#1 was developed after water production and tritium data called into question the original concept of the TYBO near-field hydrology (see Section 3.3.1). Only one distinct water production zone was recognized based on drilling data. Because each of the holes in the cluster was planned to have only one completion interval, technical personnel chose to gravel-pack the middle of the producing zone. Thus the gravel-pack extends from the welded Topopah Spring Tuff into the underlying zeolitic, nonwelded Topopah Spring Tuff, though the slotted interval is confined to the welded tuff section. The completion strings installed in Well ER-20-5#1 are very similar to the proposed design (IT, 1995).

3.5.4 Completion Method

Well construction materials were inspected in accordance with relevant procedures before delivery to the drill site. Standard UGTA decontamination procedures were employed to prevent the introduction of contaminants into the well. However, as some time had passed since an inspection, the tubing was reexamined at the site. Some joints of the 5½-in. casing had become dirty and/or had an unacceptable thread-protection compound on them and were rejected. All tubing installed in the well was recleaned as per standard UGTA practice. Caliper logs were used to calculate the volumes of cement needed during well construction. The completion was conducted in two stages: the first included the emplacement of the tubing, cement, sand, and gravel in the completion interval, November 6-13, 1995, and the second entailed cementing the upper part of the borehole (in three shifts between November 28 and December 4, 1995).

A "tremie" line consisting of 2⅞-in. Hydril® tubing was tripped into the hole and used for emplacement of the cement, gravel, and sand in the first stage of the completion process. The Photon Annulus Investigation (AIN) log was used to monitor the rise in cement and the placement of sand and gravel as well as to verify tubing depths. The bottom of the hole is plugged with fill to 824.5 m (2,705 ft). The hole was cemented from the top of fill to the depth of 809.2 m (2,655 ft) using Type II cement plus 2-percent calcium chloride ($CaCl_2$). The pump string was landed at 793.4 m (2,603.0 ft), and the fiberglass access string was landed at 723.5 m (2,373.7 ft) (two joints of fiberglass tubing were lost downhole and not recovered). The slotted interval was packed with ⅜-in. gravel from 694.3 to 809.2 m (2,278 to 2,655 ft). The sand pack above the gravel consists of 6/9 Colorado sand placed at 691.0 to 694.3 m (2,267 to 2,278 ft) and 20-40 silica sand placed at 685.5 to 691.0 m (2,249 to 2,267 ft). The borehole annulus was then cemented to 460.2 m (1,510 ft). The pump stator was installed inside the 5½-in. casing while waiting on cement, and then cementing continued. To advance the cementing operation through a wash-out zone, gravel was placed at 200.3 to 206.7 m (657 to 678 ft) with sand above at 198.4 to 200.3 m (651 to 657 ft); then cement was emplaced to 97.5 m (320 ft). At that point, the pump rotor was installed in the stator, and the operation was rigged down to move to the next hole.

In the second stage of the completion, the remainder of the hole was filled with cement mixed with ⅜-in. aggregate, a layer of ¼-in. by ⅜-in. gravel, then more cement was mixed with ⅜-in. gravel. Cement rise was monitored with a tag line.

The pump failed to operate properly when it was tested immediately after installation. On December 20, 1995, the standard-size rotor was removed and replaced with a double-undersize rotor. This pump assembly also failed when it was tested and, when it was pulled on January 5, 1996, was found to be scarred, indicating that it had extended past the stop pin. A single, undersize rotor was installed on a shorter drive rod. When the pump was tested on February 14, 1996, it was found to function properly; the well produced fluid at a rate of approximately 64 Lpm (17 gpm) during this test.

3.6 Actual Versus Planned Costs and Scheduling

The BN cost model for the ER-20-5 well cluster was originally developed on a per-hole basis for generic 914.4-m (3,000-ft) deep holes. In this model, drilling, logging and completion for a 914.4-m (3,000-ft) deep hole was projected to require 20 days to accomplish. Actual time spent (after rigging up) on drilling and completion of Well ER-20-5#1, with a TD of 860.5 m (2,823), was 30 days. Extra days were spent in trying to set the surface casing and reaming.

The cost analysis for Well ER-20-5#1 can be divided into charges by the drilling contractor (including drilling equipment and fluids) and charges by the support contractors (including radiation technicians, inspection services, geophysical logging, cementing services, and completion materials). The total planned cost of Well ER-20-5#1 was $1,062,143. The actual cost of Well ER-20-5#1 through completion totaled $1,433,685, or approximately 35.0 percent more than the planned cost. Table 3-4 provides a list of the planned and actual costs. Figure 3-5 is a comparison of planned and actual costs by day for drilling and completing Well ER-20-5#1.

Table 3-4
Well ER-20-5#1 Actual Versus Planned Costs

Activity	Planned Cost[a]	Actual Cost	Percent Difference Actual Versus Planned
Drilling contractor	$339,600	$463,100[b]	36.4
Support contractors	$722,543	$970,585[c]	-34.3
Total	$1,062,143	$1,433,685	35.0

[a]Based on BN model for 914.4-m (3,000-ft) hole.
[b]Source: DOE/ERD, 1995
[c]Source: BN Drilling, 1996

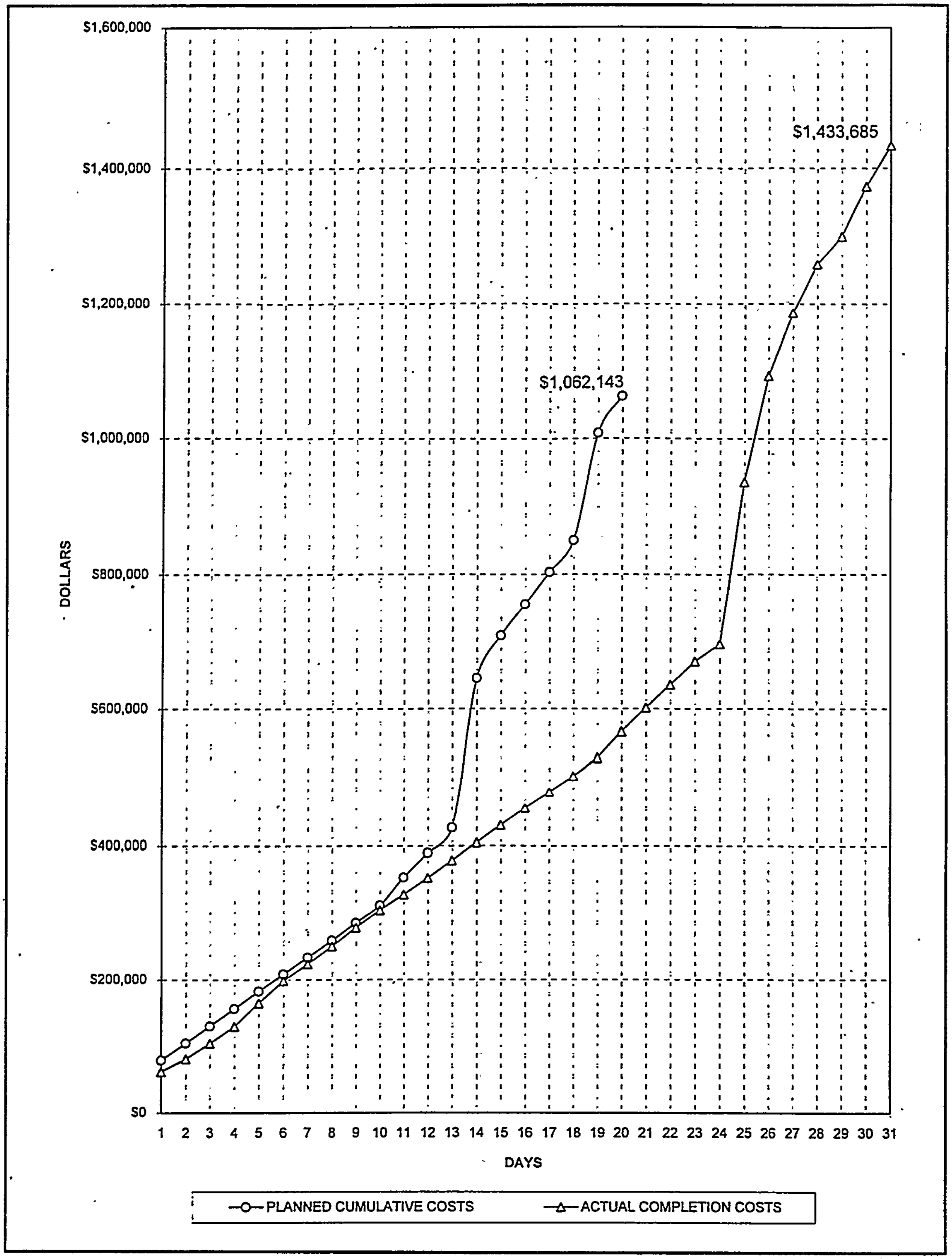


Figure 3-5
Actual Versus Planned Costs for Drilling and Completion of Well ER-20-5#1

3.7 Summary and Lessons Learned

3.7.1 Summary

Drilling commenced at Well ER-20-5#1 on October 15, 1995, and concluded on November 2, 1995, when the TD of 860.5 m (2,823 ft) was reached. The completion string was installed, gravel-packed, and the hole was cemented to 97.5 m (320 ft) on November 6-13, 1995, and the cement job was finished in three shifts between November 28 and December 4, 1995. Crews worked on a seven-day-per-week, 8-hour-per-day schedule to rig up on the location, and then worked a 24-hour-per-day schedule for most of the rest of the operation. Thirty-one working days were expended on drilling, logging, and completion activities.

The only difficulties encountered in drilling Well ER-20-5#1 were the result of lost circulation in the upper part of the hole and sloughing of wall material from above the depth of about 213 m (700 ft). Applications of LCM aided the first problem, though gravel had to be used in cementing this interval to reduce loss of cement. The second problem resulted in a decrease in the accessible depth of the hole by 51.2 m (168 ft) due to accumulation of fill.

Composite drill cuttings were collected every 3 m (10 ft) from the surface to the TD. No sidewall samples were taken. Geophysical logging was conducted after drilling was finished to aid in construction of the well, to help verify the geology, and to help characterize the hydrology of the units penetrated.

One slotted, stainless-steel pump string and one slotted, fiberglass access string were successfully installed in the well with the gravel-packed interval at 694.3 to 809.2 m (2,278 to 2,655 ft). The position of the gravel pack in the completion interval allows access to a water-producing zone that encompasses the Topopah Spring welded tuff and the underlying zeolitic nonwelded Topopah Spring Tuff.

The objectives of the TYBO near-field drilling project were furthered by the drilling and completion of Well ER-20-5#1: geologic, hydrogeologic, and water-quality data were collected which will aid in evaluating radionuclide transport and in understanding the character of the groundwater system in the area, and the well was successfully completed in a discrete water-producing zone. However, data from the subsequent holes in the cluster must be evaluated to determine the overall success of the project (see Section 6.0).

The total planned cost for Well ER-20-5#1 was $1,062,143. The actual cost of the well was $1,433,685, or 35.0 percent more than the planned cost.

3.7.2 Lessons Learned

This section describes lessons learned during the drilling and construction of Well ER-20-5#1. Lessons learned from the project as a whole are addressed in Section 6.0.

Drilling

A high penetration rate below the water table made it very difficult to collect and analyze fluid samples quickly enough to permit timely recognition of radionuclides. It was found that keeping the penetration rate below the water table no greater than about 6 meters per hour (m/hr) (20 feet per hour [ft/hr]) improved sample turnaround time. Rapid penetration rates also resulted in the contamination of drill cuttings by material from uphole, making timely recognition of lithologic contacts very difficult.

It was found that time lost tripping to change bits under contaminated conditions could be saved by changing to a new bit just above the predicted static water level before radionuclides in the groundwater are encountered.

Logging

Evaluation of the caliper log should have suggested the need for longer pad arms on the density tool. The density data are invalid over large intervals because of poor contact with the borehole.

Completion

Because standard pipe dope cannot be used in an environmental monitoring well, special food-grade greases were located and used.

Some thread problems were encountered with the 5½-in. stainless-steel casing due to unfamiliarity with the tongs used to handle the casing.

Two joints of 2⅞-in. fiberglass tubing were lost downhole when the elevator subs malfunctioned. In addition, the drill crew may not have fully understood how to handle fiberglass. A better method of handling the fiberglass tubing is needed. The suggestion was made to use a casing subcontractor on future holes.

Confusion over cleaning and inspection of casing caused delays in installing the 5½-in. casing string. Also, it was found that it was not possible to clean tubing as efficiently at the drill site as at the Area 1 facility. The procedures for cleaning, inspection, and delivery of tubing should be reviewed.

The Moyno® pump rotor was changed out twice before it was discovered that the insertion string was too long. Drive-rod stretch factors used to determine string lengths should be double-checked.

It was elected to reduce cementing time and material (and thus cost) by using gravel in eroded intervals more than about 60 m (200 ft) above the static water level. It was suggested to investigate the cost of using an outside cementing contractor to eliminate problems with crew availability.

Planning

It was decided to use the drilling contract as the on-site document to guide drilling of Well ER-20-5#1. However, it was found that the responsibilities of the various organizations and some technical issues (cementing and completion programs) were not covered in the contract in adequate detail: Formal drilling programs were, thus, prepared for subsequent holes in the cluster.

All changes to the project plan were documented in Records of Verbal Communication (RVCs). However, it was found that a quicker turnaround on the sign-off of RVCs was needed and a point of contact for all RVCs was selected.

Last-minute changes in the program that affected equipment and crews resulted in operational difficulties. Any changes should be committed to early and communicated to those affected by the changes.

Operational

Because of problems with equipment orders, it was suggested that an inventory of drilling equipment be made, and the possibility of segregating UGTA equipment was explored. All procurements must be followed through, and all materials and equipment arriving at the NTS must be inspected for damage and compliance with requirements.

4.0 Well ER-20-5#2

4.1 Drilling Summary

The drilling requirements for Well ER-20-5#2 were outlined in Contract DE-RP-08-95NV11808 and RSN Drilling Program D-011-001 (RSN, 1995a); any changes to the program were documented in RSN Records of Verbal Communication (Appendix A-1). This summary was compiled from the RSN daily rig reports and field notes prepared by the IT Field Representative. Complete details of drilling activities can be found in the BN Well ER-20-5#2 hole history (BN, 1996b). See Section 3.1 of this report for information on site preparations and drilling of the surface hole for Well ER-20-5#2. A graphical depiction of drilling parameters, including penetration rate, revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-2. Details of the composition of drill fluids, additives, and cements used are provided in Appendix A-4. Figure 4-1 is a chart of the drilling history for Well ER-20-5#2. A summary of the drilling statistics for Well ER-20-5#2 is given in Table 4-1.

4.1.1 Drilling History

Immediately after completion of Well ER-20-5#1, the drill rig was moved over to Well ER-20-5#2, and three shifts were spent rigging up on the new location. Commencing November 17, 1995, the cement in the conductor casing of Well ER-20-5#2 was drilled out and a new hole was drilled to the depth of 13.4 m (44 ft) with a 24-in. mill-tooth bit. After the mouse and rat holes were drilled with a 12¼-in. air hammer, drilling of the main hole continued with the 24-in. bit. Drilling was conducted with mud in conventional circulation, and cedar-fiber LCM was added as necessary when circulation was temporarily lost.

Upon reaching the depth of 106.1 m (348 ft) on November 19, 1995, a casing point was picked in the welded Rainier Mesa Tuff by the DOE Field Manager. A 16-in. surface casing was set at the depth of 105.4 m (345.8 ft). The casing was cemented by pumping cement down the casing and displacing it with a wiper plug and water to a pressure of 2.75 MPa (400 psi). The cement was forced up the annulus, and cement was left inside the casing at a depth of 91.4 m (300 ft). The remaining, open annular volume was cemented to ground level from the surface.

A 12¼-in. button bit was used to drill through the cement in the casing to the depth of 104.2 m (342 ft). To avoid leaving an open hole over the impending holiday break, drilling was stopped, and drillers spent the next seven shifts cleaning the hole, cleaning out the mud pits, installing

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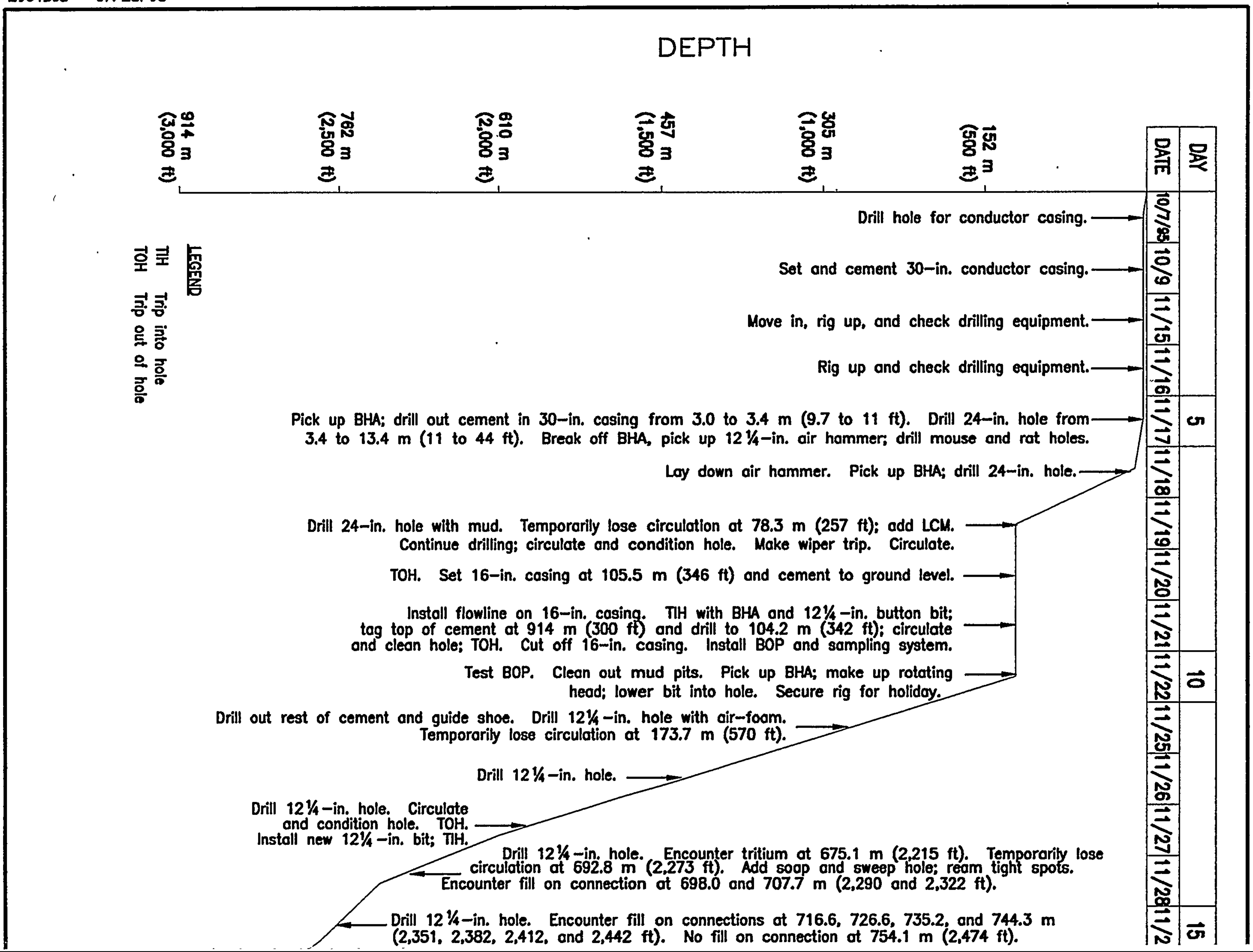
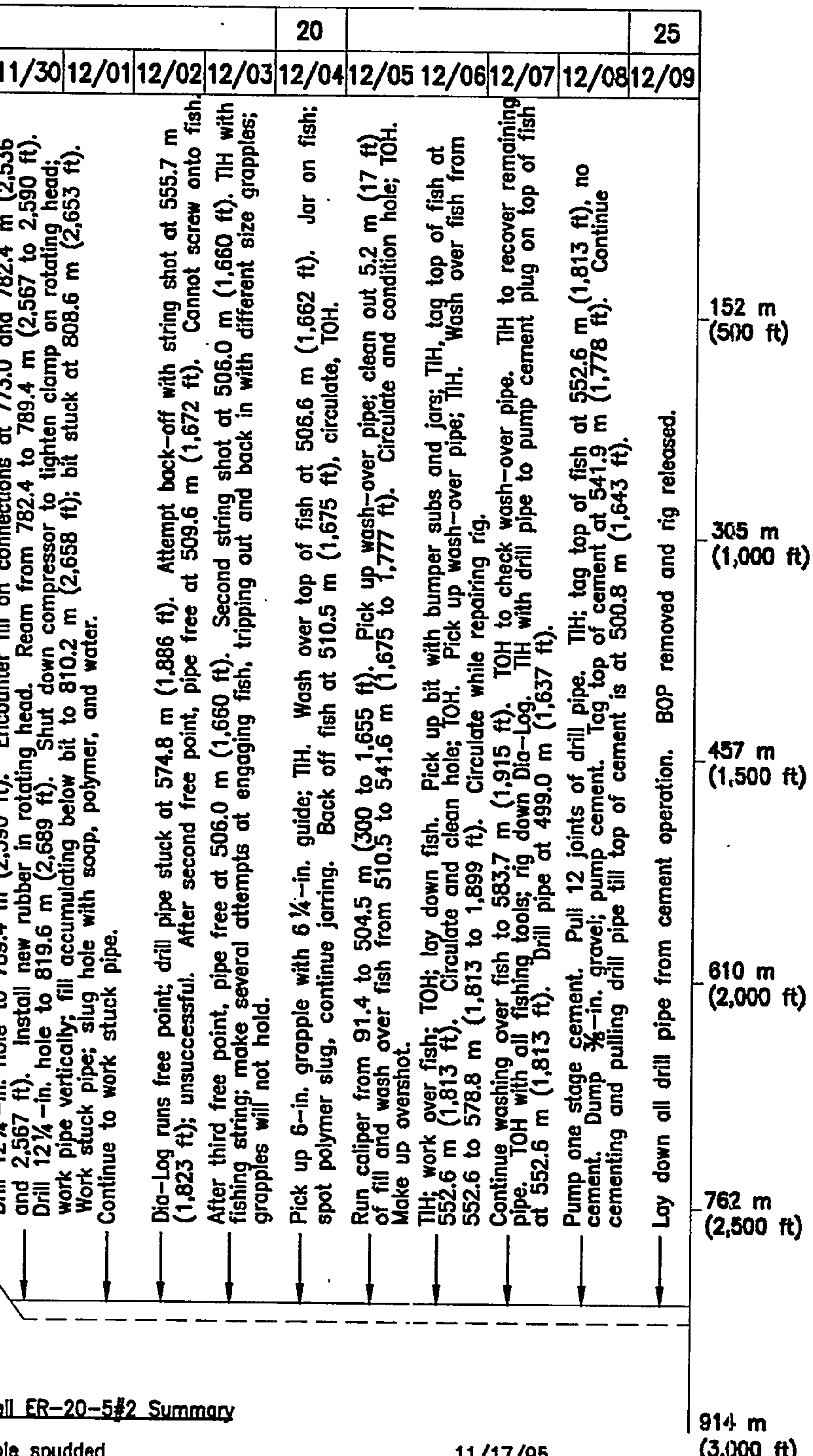




ell ER-20-5#2 Summary

ole spudded	11/17/95
urface hole completed and cased	11/20/95
egin drilling 12¼-in. hole	11/25/95
egin recording tritium in returns	11/28/95
each total drilled depth of 814.6 m (2,689 ft)	11/30/95
ole cemented	02/13/96

FIGURE 4-1
WELL ER-20-5#2
DRILLING HISTORY

Table 4-1
Abridged Drill Hole Statistics for Well ER-20-5#2

LOCATION DATA: Coordinates: Central Nevada State Planar: N899,037.7, E555,095.9 feet (ft)
Universal Transverse Mercator: N4,119,178.9, E546,362.2 meters (m)

Ground Elevation: 1,902.6 m (6,242.2 ft)

DRILLING DATA:

Spud Date:	11/17/95
Total Depth (TD):	819.6 m (2,689 ft)
Date TD Reached:	11/30/95
Date Well Completed:	Not completed
Hole Diameter:	91.4 centimeters (cm) (36 inches [in.]) from surface to 3.4 m (11 ft); 61.0 cm (24 in.) to 106.1 m (348 ft); 31.1 cm (12¼ in.) to 819.6 m (2,689 ft).
Drilling Techniques:	Dry auger drilling with bucket rig to 3.4 m (11 ft). Rotary drilling with mud (and lost circulation material as needed) using 24-in. bit and conventional circulation to 106.1 m (348 ft). Rotary drilling with 12¼-in. button bit through cement in casing at 91.4 m (300 ft) to 104.2 m (342 ft) with conventional circulation and mud. Rotary drilling with 12¼-in. button bit to TD at 819.6 m (2,689 ft) with air-foam and conventional circulation, reaming tight spots as necessary. Bit stuck at 808.6 m (2,653 ft) due to severe hole sloughing after brief shutdown to tighten clamp on rotating head. Fishing operations recover 552.6 m (1,813 ft) of drill pipe. Leave bottom hole assembly, drill pipe, and one joint of wash-over pipe in hole. Top of fish at 552.6 m (1,813 ft). Bottom of hole and fish cemented in to 500.8 m (1,643 ft). Hole filled with uncontaminated cuttings to 19.8 m (65 ft). Top of hole cemented to ground level.

CASING DATA: 76.2-cm (30-in.) conductor casing from surface to 3.4 m (11 ft). 40.6-cm (16-in.). Surface casing set at 105.4 m (345.8 ft). No intermediate casing.

WELL COMPLETION DATA:

No completion strings installed.

Fluid Depth: Not measured

DRILLING CONTRACTOR: Welch & Howell Drilling Company

GEOPHYSICAL LOGS BY: Dia-Log, Geophysical Engineering Group of the Joint Test Organization

SURVEYING CONTRACTOR: Bechtel Nevada and testing the BOP system, and installing the cuttings sampling system. The BHA was lowered into the hole before the rig was secured for the holiday on November 22, 1995.

When operations resumed on November 25, 1995, the remaining cement and guide shoe were drilled out of the 16-in. casing. The next five days were spent drilling with a rotary assembly and a 12¼-in. bit with air-foam in conventional circulation. To avoid additional trips below the water table, a trip was made to change the bit at 601.4 m (1,973 ft). The rate of penetration averaged approximately 6 to 12 m (20 to 40 ft) per hour (with a few zones of slower drilling), but was slowed to 3 to 4.5 m (10 to 15 ft) per hour below the water table to allow for timely analysis of fluids for tritium activity. Water production from Well ER-20-5#2 began at the depth of approximately 670 m (2,200 ft) on November 28, 1995. The presence of tritium was first logged at the depth of 675.4 m (2,216 ft).

Problems with lost circulation, sloughing, and tight spots began at approximately 670 m (2,200 ft), and the hole was conditioned with polymer and soap as necessary. Up to 7.3 m (24 ft) of fill was encountered when making connections between 698.0 and 782.4 m (2,290 to 2,567 ft), and tight spots had to be reamed in this interval.

The compressor was shut down for 15 minutes at the drilled depth of 819.6 m (2,689 ft) on November 30, 1995, to tighten the clamp on the rotating head (the repair was necessary to prevent continued exposure of the drill crew to tritiated groundwater). While the driller was working the drill pipe vertically, fill began to accumulate around the bit, and the BHA became stuck with the bit at 808.6 m (2,653 ft). Drillers worked the stuck pipe by jarring and slugging the hole with soap, polymer, and water until the fishing service company (Dia-Log) arrived on site on December 2, 1995. Fishing efforts included three string shots and jarring using various size grapples. Some drill pipe was recovered after several runs with wash-over pipe to remove fill around the fish. On December 7, 1995, fishing operations were terminated, leaving a fish consisting of the BHA (62.9 m [206.3 ft]), drill pipe (193.2 m [633.7 ft]), and a joint of wash-over pipe in the borehole with the top of the fish at 552.6 m (1,813 ft). A plug of cement and gravel was pumped on top of the fish (some of which dropped down around the fish) and cementing continued till the top of cement was at 500.8 m (1,643 ft) on December 8, 1995. Well ER-20-5#2 was then considered abandoned. Figure 4-2 shows the final configuration of the borehole, and Table 4-2 lists the equipment left in the borehole.

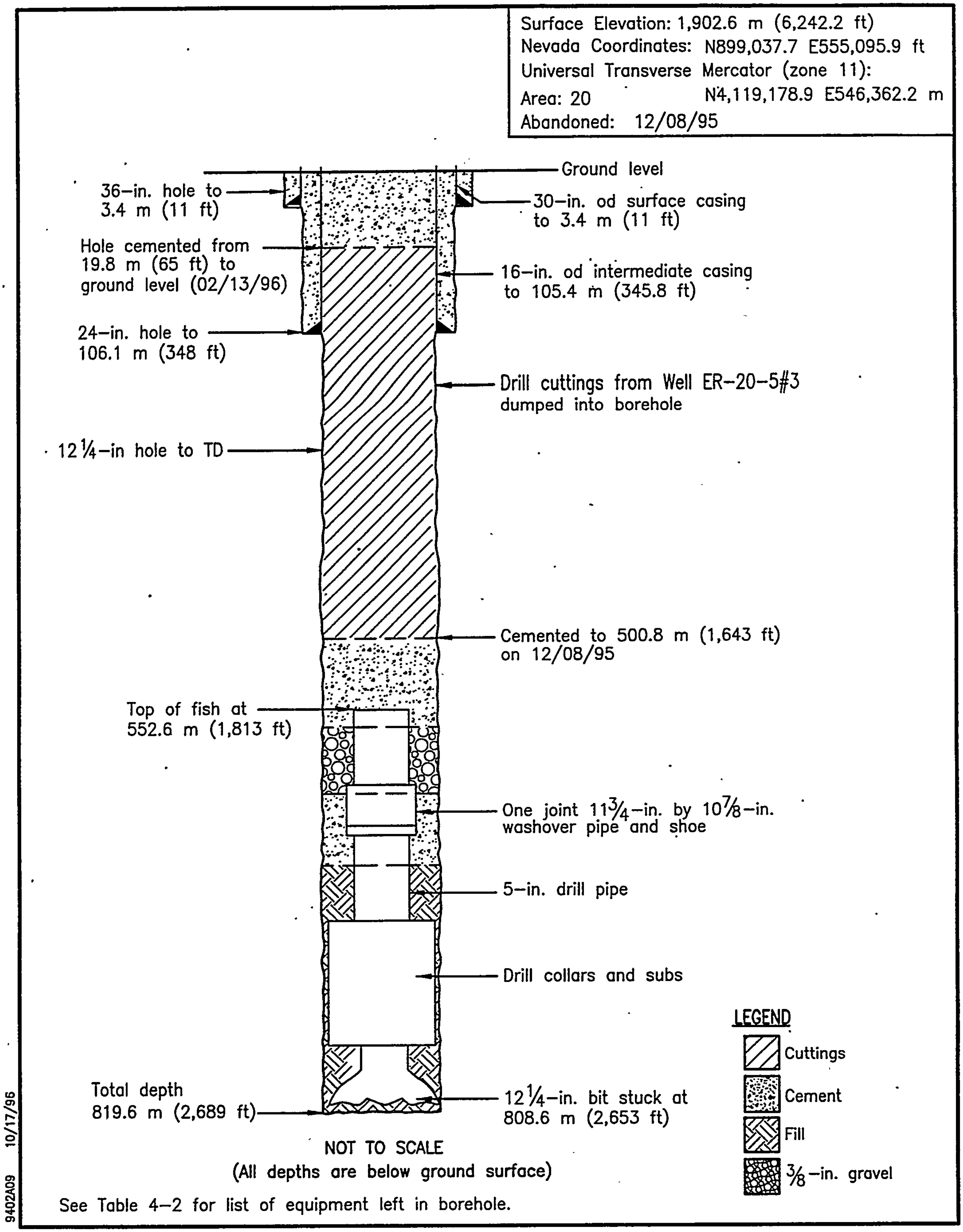


Figure 4-2
As-Built Schematic of Well ER-20-5#2

Table 4-2
Equipment Left in the Well ER-20-5#2 Borehole

Components Left Downhole		Length meters (feet)
Fishing Assembly	Washover pipe and shoe	9.88 (32.42)
Drill Pipe	4½-inch drill pipe	87.93 (288.47)
	Cross-over sub	0.54 (1.78)
Bottom-Hole Assembly	8-inch drill collars (5)	44.86 (147.18)
	String stabilizer	1.42 (4.65)
	8-inch drill collar (1)	7.73 (25.35)
	String stabilizer	1.40 (4.60)
	Shock sub	4.60 (15.08)
	Bit sub	0.80 (2.63)
	Roller reamer	1.78 (5.83)
	12¼-inch bit	0.30 (1.00)
TOTAL		161.24 (529.99)

Uncontaminated drill cuttings from Well ER-20-5#3 were dumped into Well ER-20-5#2 so that the borehole was filled with cuttings to the depth of approximately 19.8 m (65 ft). The remaining hole was cemented to the ground level on February 13, 1996. Figure 4-3 shows a plan view and profile of the wellhead.

4.1.2 Drilling Problems

No drilling problems were encountered until the hole reached the depth of approximately 670 m (2,200 ft), where sloughing rock fragments up to 2.5 cm (1 in.) in size were recovered while sweeping the hole. While drilling from approximately 670 to 753 m (2,200 to 2,470 ft) problems with surging circulation and rough drilling were noted in addition to borehole sloughing and lost circulation mentioned previously. Most of the fill material in the drill cuttings consists of bedded tuffs of the rhyolite of Fluorspar Canyon, penetrated between 139.6 and 214.0 m (458 to 702 ft), and the caliper log indicates erosion from the Fluorspar Canyon interval. In addition, fragments of devitrified lava of the rhyolite of Benham (penetrated between 214.0 and 495.3 m [702 to 1,625 ft]) were also found in lesser quantities.

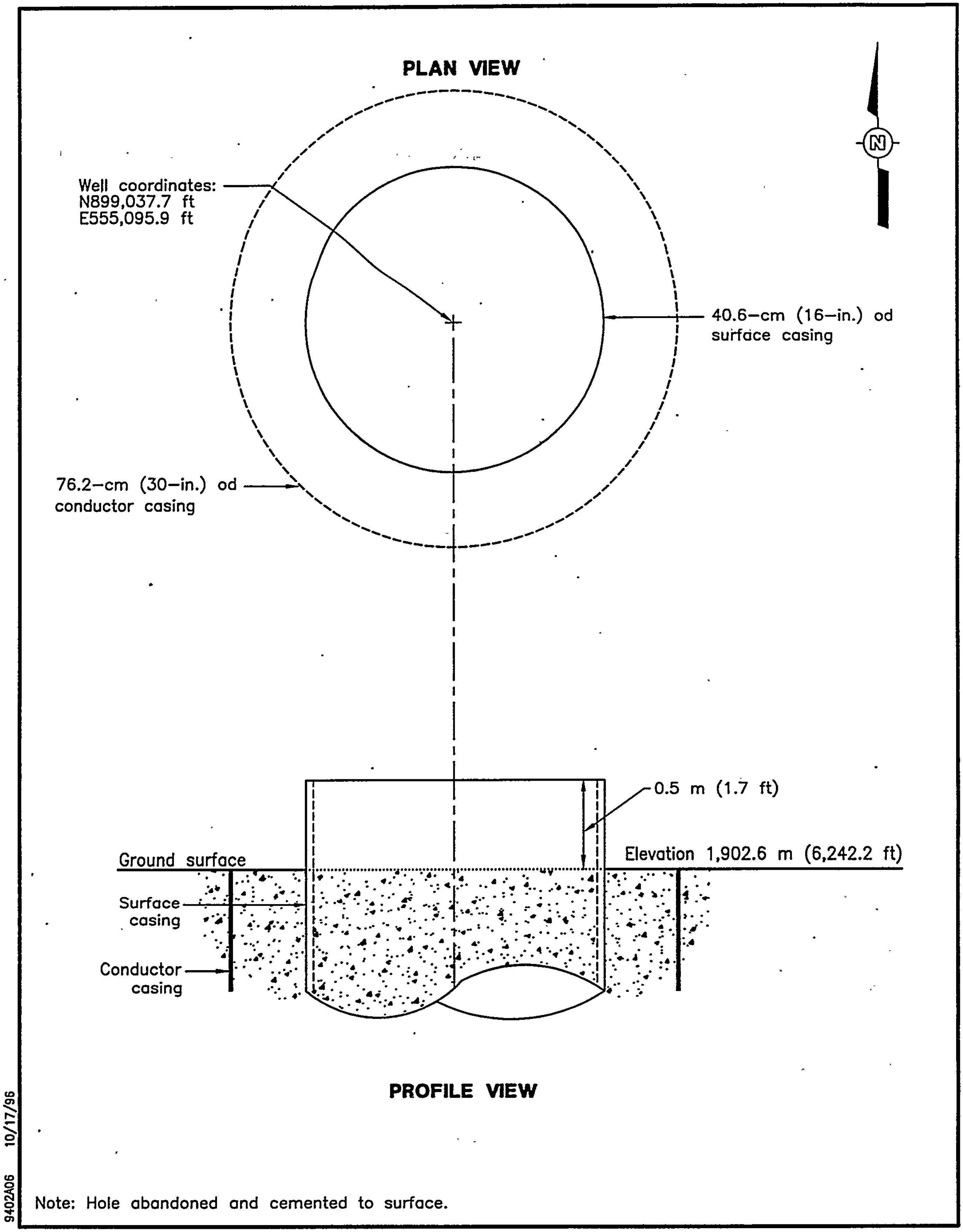


Figure 4-3
Well ER-20-5#2 Wellhead Diagram

4.1.3 Fluid Management

A mix of gel (mud) and polymer was used to drill Well ER-20-5#2 to the depth of 106.1 m (348 ft) with applications of cedar-fiber LCM as needed. The remainder of the hole was drilled using air-foam with applications of polymer as needed to condition the hole. The resulting clean and contaminated fluids were stored in separate, lined sumps. Fluids were transferred from the upper to the lower sumps during drilling (see Figure 1-3).

The drilling effluent was monitored in accordance with the methods prescribed in the *Fluid Management Plan for the Underground Test Area Operable Unit* (DOE, 1994) and the *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-5* (IT, 1995). The results of analyses on samples of drilling fluid collected indicate that all fluids routed to the infiltration area are within the fluid quality objectives established in the FMP for radiochemical parameters.

Appendix B of this report contains the Well ER-20-5#2 *Fluid Management Status Report*. The fluid disposition form lists final volumes and data for drilling the well. The final volumes of fluids imported to and produced at Well ER-20-5#2 were calculated from water truck delivery tickets and measurements of fluids in the sumps. The solids produced were calculated using the diameter of the borehole and the depth drilled with added volume attributed to rock bulking factors.

4.2 Geologic Data Collection

4.2.1 Collection of Drill Cuttings

Triplicate sets of composite drill cuttings were collected continuously from Well ER-20-5#2 at 3.1-m (10-ft) intervals as drilling progressed from the surface to 106.7 m (350 ft), at 6.1-m (20-ft) intervals from 106.7 to 609.6 m (350 to 2,000 ft), and again at 3.1-m (10-ft) intervals from 609.6 m (2,000 ft) to the TD at 819.6 m (2,689 ft). Samples were not obtained from eight intervals due to lack of fluid returns to the surface. Hole sloughing degraded the quality of the cuttings, particularly below the depth of 807.7 m (2,650 ft). All samples are stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One set of samples was sealed with custody tape at the rig site as an archive sample; one set was left unsealed in the original sample containers; and the third set was washed in accordance with standard USGS Core Library procedures.

4.2.2 Geophysical Logging Data

The only geophysical logs run in Well ER-20-5#2 were a caliper log and three free-point logs. The caliper log was run in the remaining open hole during fishing operations. The free-point logs were run during fishing operations to locate fill surrounding the drill pipe and were used to determine the placement of string shots. All geophysical logs run in Well ER-20-5#2 are listed in Table 4-3. The logs are available from BN in Mercury, Nevada, and copies are on file at IT in Las Vegas, Nevada.

Table 4-3
Well ER-20-5#2 Geophysical Log Summary

Geophysical Logs	Log Purpose	Date Logged	Run Number	Top of Logged Interval (bgs)[a] meters (feet)	Bottom of Logged Interval (bgs) meters (feet)
6-arm Caliper[b]	Determine drill hole conditions	12/05/95	CA6-1	91.4 (300)	504.4 (1,655)
Free-Point (Pipe)[c]	Locate fill in annulus around drill pipe	12/02/95 12/02/95 12/03/95	FPP-1 FPP-2 FPP-3	Not applicable	Not applicable

[a]Below ground surface
[b]Run by the Geophysical Engineering Group of the Joint Test Organization
[c]Run by Dia-Log Corp.

4.3 Hydrology

4.3.1 Water Production Information

Groundwater production began at the depth of approximately 670 m (2,200 ft) at approximately 38 Lpm (10 gpm).. This rate remained fairly steady to the depth of about 728.5 m (2,390 ft) and then increased to approximately 227 Lpm (60 gpm). From that point water production steadily increased with depth to a maximum of approximately 833 Lpm (220 gpm) at the depth of 769.6 m (2,525 ft) and continued at that rate to the TD. The fluid level was not measured in the borehole before the hole was abandoned.

4.3.2 Radionuclides Encountered

Tritium was first encountered in the fluid returns when the borehole had been drilled to 675.4 m (2,216 ft), approximately 48.8 m (160 ft) below the projected static water level. Tritium activity rapidly increased to approximately 76 million pCi/L at the depth of 699.2 m (2,294 ft) and then decreased to approximately 31.5 million pCi/L at 712.9 m (2,339 ft). Tritium activity in the fluid returns then rose again, peaking at levels of 103, 116, and 111 million pCi/L at the depths of

747.7, 775.4, and 808.0 m (2,453, 2,544, and 2,651 ft), respectively. See Appendix B for a listing of tritium and water-production data. See Section 6.0 for a graphic comparison of tritium and water-production data for all three wells in the cluster.

4.3.3 Noble Gas Experiment

Air used for drilling was tagged with a neon-xenon tracer starting at the drilled depth of 630 m (2,067 ft).

4.4 Precompletion and Open-Hole Development

No precompletion or open-hole development was conducted at Well ER-20-5#2.

4.5 Completion

No completion strings were installed at Well ER-20-5#2.

4.6 Actual Versus Planned Costs and Scheduling

The BN cost model for the ER-20-5 well cluster was originally developed on a per-hole basis for generic 914.4-m (3,000-ft) deep holes. In this model, drilling, logging and completion for a 914.4-m (3,000-ft) deep hole was projected to require 20 days to accomplish. Actual time spent (after rigging up) on drilling and fishing in Well-ER-20-5#2, with a drilled depth of 819.6 m (2,689 ft), was 22 days. Seven days were spent fishing to try to recover the lost BHA and no completion string was installed.

The cost analysis for Well-ER-20-5#2 can be divided into charges by the drilling contractor (including drilling equipment, fluids, and the fishing subcontractors) and charges by the support contractors (including radiation technicians, inspection services, geophysical logging, and cementing services). The total planned cost of Well ER-20-5#2, including completion, was $1,062,143. The actual cost of Well ER-20-5#2, including fishing and cementing, totaled $765,131, or approximately 28.0 percent less than the planned cost. Table 4-4 lists the planned and actual costs. Figure 4-4 is a comparison of planned and actual costs by day for drilling Well ER-20-5#2.

Table 4-4
Well ER-20-5#2 Actual Versus Planned Costs

Activity	Planned Cost[a]	Actual Cost	Percent Difference Actual Versus Planned
Drilling contractor	$339,600	$462,352[b]	36.1
Support contractors	$722,543	$302,779[c]	-58.1
Total	$1,062,143	$765,131	-28.0

[a]Based on BN model for a 914.4-m (3,000-ft) hole
[b]Source: DOE/ERD
[c]BN Drilling

4.7 Summary and Lessons Learned

4.7.1 Summary

Drilling operations commenced at Well ER-20-5#2 on November 17, 1995. Drilling stopped when the BHA became stuck at the depth of 814.6 m (2,689 ft) on November 30, 1995, but fishing to recover the lost BHA continued through December 7, 1995. The hole was abandoned after partial cementing on December 8, 1995. No completion string was installed. Crews worked a seven-day-per-week, 24-hour-per-day schedule for most of the operation. Twenty-one working days were expended on drilling, fishing, and cementing activities.

Problems with lost circulation, sloughing, and tight spots began at approximately 670 m (2,200 ft). The hole was conditioned with polymer and soap when tight spots were encountered. The severe borehole sloughing that caused the loss of the hole was unanticipated because the same geologic section had been drilled in Well ER-20-5#1 with fewer problems.

Some of the drill pipe was recovered, but the BHA, some drill pipe, and a joint of wash-over pipe were left in the hole with the top of the 256.0-m (840-ft) long fish at 552.6 m (1,813 ft). A plug of cement and gravel was pumped on top of the fish and cementing continued till the top of cement was at 500.8 m (1,643 ft) on December 8, 1995. The borehole was filled with uncontaminated drill cuttings from Well ER-20-5#3 to the depth of approximately 19.8 m (65 ft), and the remaining hole was cemented to the ground level on February 13, 1996.

Composite drill cuttings were collected at 3.1- or 6.1-m (10- or 20-ft) intervals from the surface to the TD. No sidewall samples were taken. Geophysical logging was limited to a caliper log and several free-point logs to locate fill around the fish.

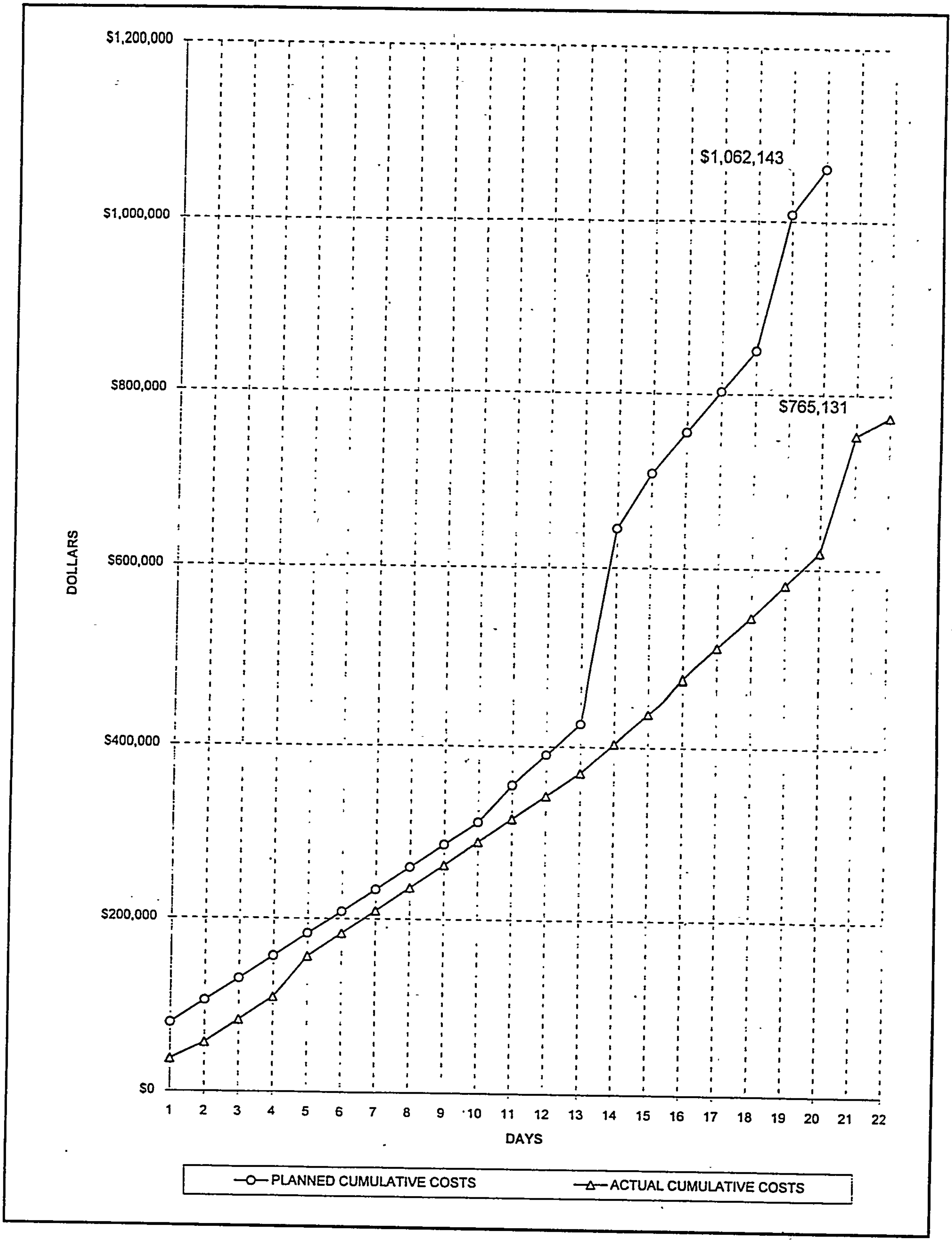


Figure 4-4
Actual Versus Planned Costs for Drilling of Well ER-20-5#2

The total planned cost for Well-ER-20-5#2 was $1,062,143. The actual cost of the well was $765,131, or 28.0 percent less than the planned cost.

The objectives of the TYBO near-field drilling project were furthered only through the collection of geologic, water-production, and tritium data during drilling.

4.7.2 Lessons Learned

Setting of the surface casing to at least the bottom of the bedded tuff of the rhyolite of Fluorspar Canyon (approximately 213 m [700 ft]) based on the caliper log from Well ER-20-5#1 might have prevented excessive sloughing of up-hole material in Well ER-20-5#2.

Any equipment that conducts contaminated fluids (such as the rotating head that required repair during drilling below the water table) should be kept in top working order to avoid delays while working under contaminated conditions.

5.0 Well ER-20-5#3

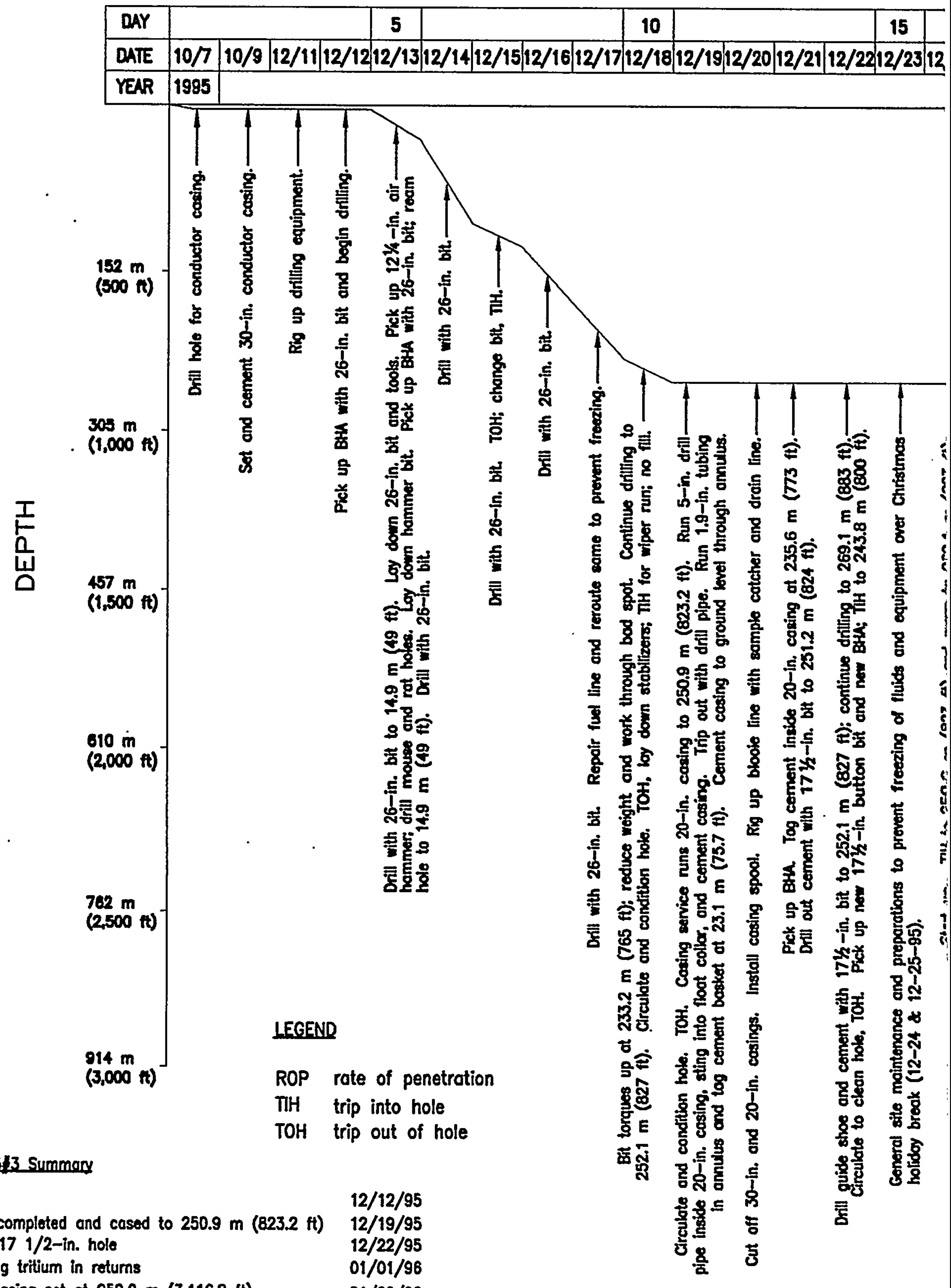
5.1 Drilling Summary

The drilling requirements for Well ER-20-5#3 were outlined in Contract #95NV11808 and RSN Drilling Program D-012-001.96 (RSN, 1995b); any changes to the program were documented in RSN and BN Records of Verbal Communication (Appendix A-1). This summary was compiled from the RSN and BN daily rig reports and from field notes prepared by the IT Field Representative. Complete details of drilling activities can be found in the BN Well ER-20-5#3 Hole History (BN, 1996c). See Section 3.1 of this report for information about site preparations and drilling of the surface hole for Well ER-20-5#3. A graphic depiction of drilling parameters, including penetration rate, revolutions per minute, pump pressure, and weight on the bit is presented in Appendix A-2. Details of the composition of drill fluids, additives, and cements are provided in Appendix A-4. See Figure 5-1 for a graphical presentation of the drilling and completion history and Table 5-1 for abridged drill hole statistics.

5.1.1 Drilling History

Welch & Howell rigged up to drill Well ER-20-5#3 on December 11-12, 1995, immediately after cementing the lower part of Well ER-20-5#2. Commencing on December 12, 1995, the cement in the conductor casing was drilled out, and new hole was drilled to the depth of 14.9 m (49 ft) with a 26-in. bit. The drillers rigged up and drilled the rat and mouse holes with a 12¼-in. air hammer on December 13, 1995. The crew then picked up the BHA with the 26-in. bit and continued drilling the main hole using mud and conventional circulation. Circulation was temporarily lost several times, and LCM (consisting of cottonseed hulls) was mixed with the drilling mud. Rotary drilling with the 26-in. bit continued through December 18, 1995, to the first casing point in a lava flow of the Rhyolite of Benham, at the depth of 252.1 m (827 ft).

A casing subcontractor arrived on site on December 19, 1995, and set the 20-in. surface casing at 250.9 m (823.2 ft). Then 5-in. drill pipe was run in and stung into the casing float collar. Water was pumped down the drill pipe (to make sure it was clear) followed by cement; the cement was then forced up the annulus of the casing under water pressure. Cement filled the casing to 235.6 m (773 ft). The cement job was completed by running a tremie line (1.9-in. tubing) in the annulus and pumping cement through the tubing from the cement basket at 23.1 m (75.7 ft) to the surface.



Well ER-20-5#3 Summary

Hole spudded	12/12/95
Surface hole completed and cased to 250.9 m (823.2 ft)	12/19/95
Begin drilling 17 1/2-in. hole	12/22/95
Begin recording tritium in returns	01/01/96
Intermediate casing set at 950.0 m (3,116.8 ft)	01/09/96
Drilling hiatus	01/10/96 – 01/21/96
Begin drilling 12 1/4-in. hole	01/30/96
Reach total drilled depth of 1,308.8 m (4,294 ft)	02/05/96
Well completed	02/16/96

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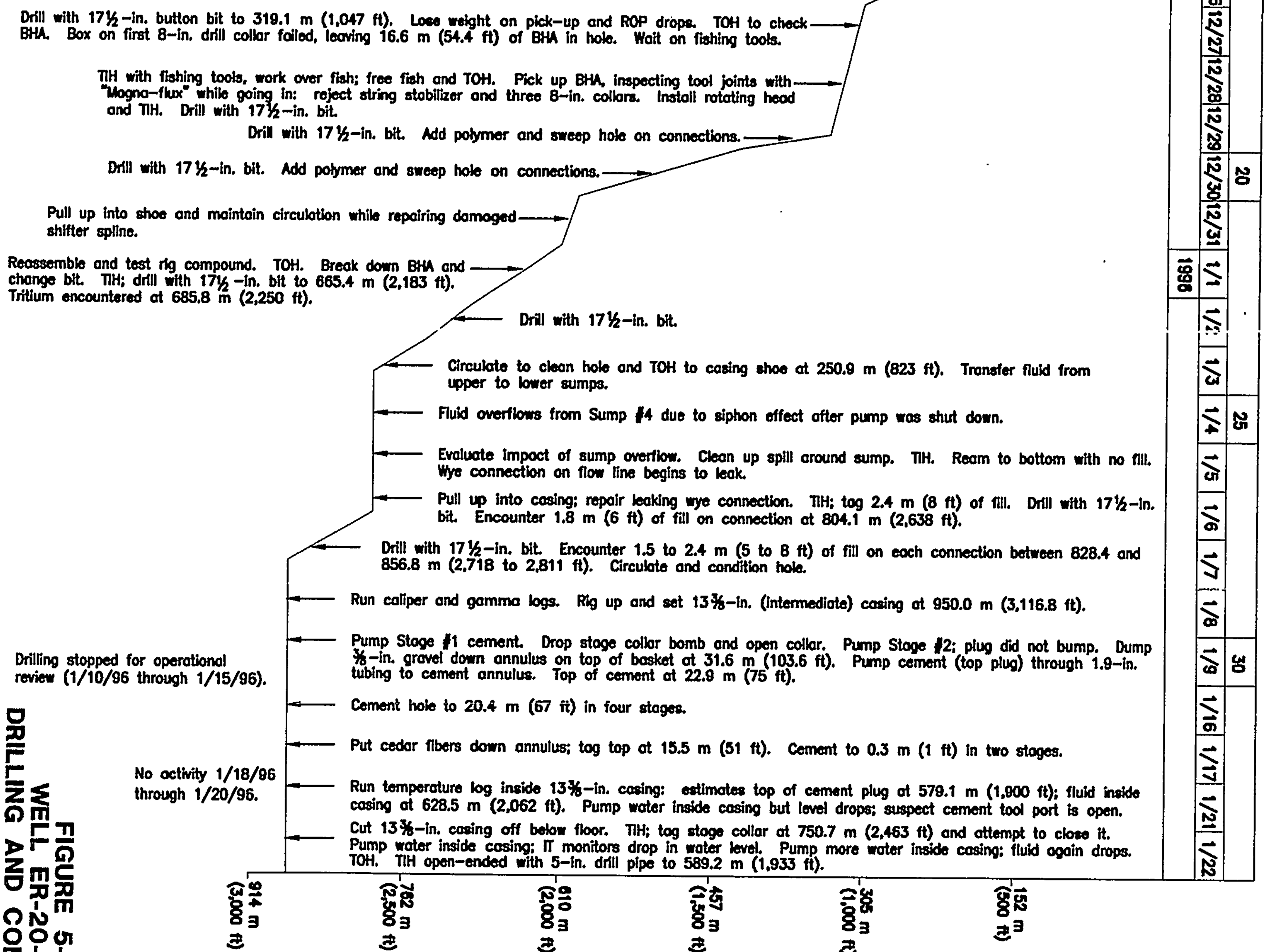

FIGURE 5-1
WELL ER-20-5#3
DRILLING AND COMPLETION HISTORY
SHEET 1 OF 2

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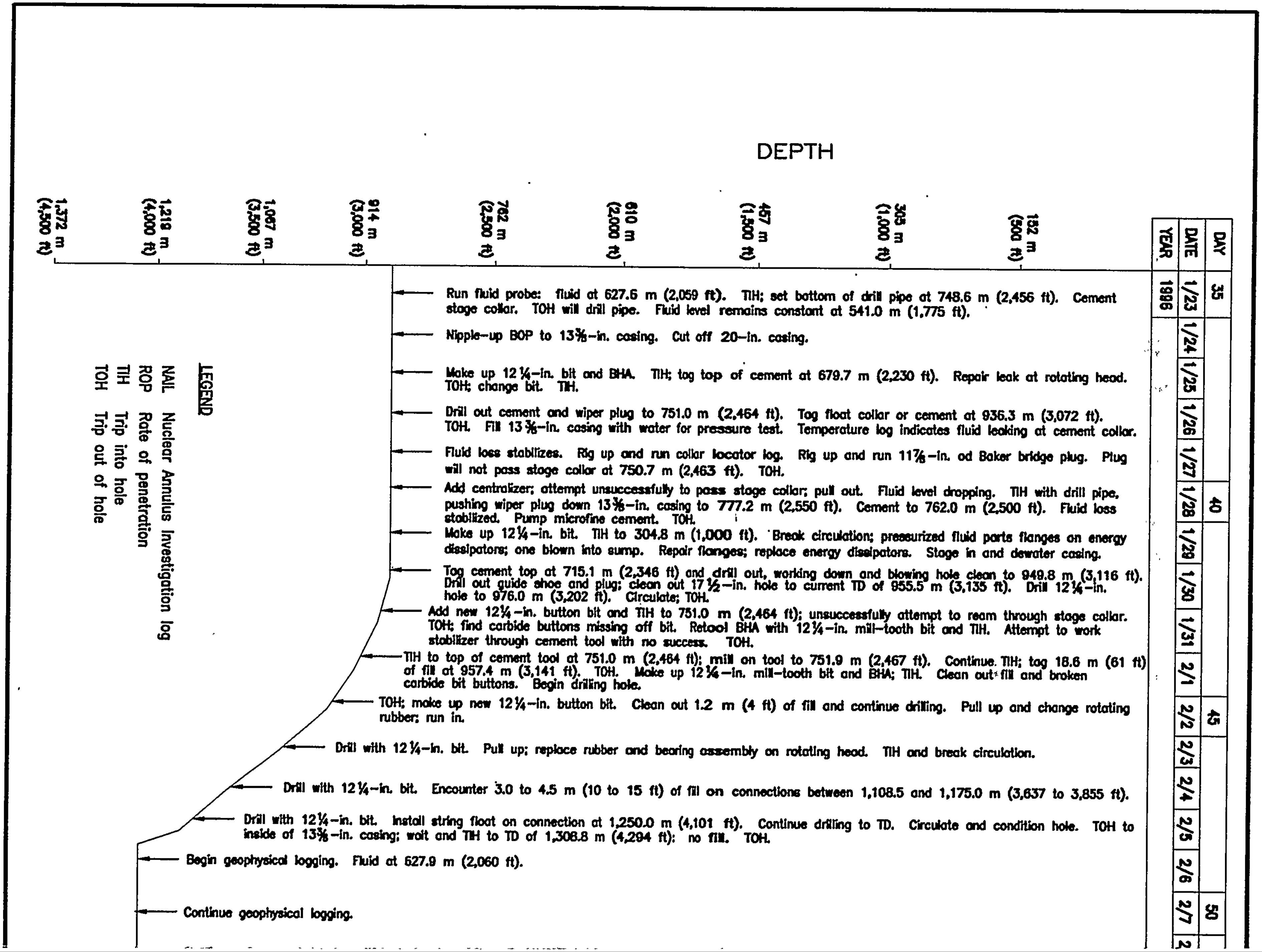

in hole. Run 25-shot core gun; one barrel lost.

2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/16
			55				

- Rig up and run rotary sidewall coring tool. Two attempts to run thermal flow log; tool shorts and packer will not inflate. Attempt to run magnetic log but tool does not read correctly. Run heat-pulse flow meter log.
- Nipple down rotating head and BOP. Cut-off 13⅜-in. casing 0.5 m (1.5 ft) above ground level. TIH; lay down pipe and drill collars. Casing service picks up and runs 2⅞-in. Hydril tubing (tremie line).
- Run NAIL log; top of fluid at 628.5 m (2,062 ft); TD at 1,307.6 m (4,290 ft). Place unwashed gravel to 1,229.3 m (4,033 ft). Pump cement. Run NAIL log; top of cement at 1,205.2 m (3,954 ft). Pick up and run 5½-in. stainless-steel casing.
- Land 5½-in. stainless-steel casing at 1,192.9 m (3,913.7 ft). Run 2⅞-in. fiberglass tubing. Tubing hangs up and parts at connection while trying to work string; drops 1.2 m (4 ft). Screw onto tubing and work bad joints out of hole; replace. Lower again to 955.5 m (3,135 ft) where it sticks again. Tubing pulls through elevators and 108 joints are lost down hole. Obtain background log using NAIL tool. Fluid at 627.9 m (2,060 ft).
- Gravel-pack hole using ⅜-in. gravel to 1,034.2 m (3,393 ft), 6-9 sand to 1,029.6 m (3,378 ft), and 20-40 sand to 1,020.5 m (3,348 ft). Cement hole to 1,014.4 m (3,328 ft).
- Run north-seeking gyro survey. Obtain background log. Try to flush tubing with water: no success. TOH; find bottom nine joints plugged with cement. Remove plugged sections and TIH with tremie line to 1,022.2 m (3,288 ft). Pump cement to 934.2 m (3,065 ft).
- Continue cementing to 579.1 m (1,900 ft). Pull remaining tremie line. Pick up and assemble No-Turn Tools® and Moyno® pump. Run stator in 5½-in. string on 2⅞-in. stainless steel tubing and land bottom of pump assembly at 1,038.3 m (3,406.5 ft).
- Run rotor in hole on ⅞-in. coated drive rods. Land bottom of rotor at 1,035.9 m (3,398.5 ft). Hook up hydraulic unit and flow line; start pumping at 1009 hr. Take water sample. Release rig. Continue pumping till 1900 hr.

152 m (500 ft)
305 m (1,000 ft)
457 m (1,500 ft)
610 m (2,000 ft)
762 m (2,500 ft)
914 m (3,000 ft)
1,067 m (3,500 ft)
1,219 m (4,000 ft)
1,372 m (4,500 ft)

FIGURE 5-1
WELL ER-20-5#3
DRILLING AND COMPLETION HISTORY
SHEET 2 OF 2

Table 5-1
Abridged Drill Hole Statistics for Well ER-20-5#3

LOCATION DATA:	Coordinates:	Central Nevada State Planar: N899,031.1, E555,169.7 feet (ft) Universal Transverse Mercator: N4,119,177.0, E546,384.7 meters (m)
	Ground Elevation:	1,902.5 m (6,241.9 ft)
DRILLING DATA:		
	Spud Date:	12/13/95
	Total Depth (TD):	1,308.8 m (4,294 ft)
	Date TD Reached:	02/05/96
	Date Well Completed:	02/16/96
	Hole Diameter:	91.4 centimeters (cm) (36 inches [in.]) from surface to 3.4 m (11 ft); 66.0 cm (26 in.) to 252.1 m (827 ft); 44.5 cm (17½ in.) to 955.5 m (3,135 ft); 31.1 cm (12¼ in.) to 1,308.8 m (4,294 ft).
	Drilling Techniques:	Dry auger drilling with bucket rig to 3.4 m (11 ft). Rotary drilling with mud (and lost-circulation material as needed) using a 26-in. bit and conventional-circulation to 252.1 m (827 ft). Rotary drilling with a 17½-in. button bit and mud to 269.1 m (883 ft). Rotary drilling with a 17½-in. bit and air-foam (and polymer as needed) in conventional circulation to 955.5 m (3,135 ft). Rotary drilling with a 12¼-in. button bit and air-foam in conventional circulation to TD.
CASING DATA:		30-in. conductor casing from surface to 3.4 m (11 ft); 20-in. surface casing to 250.9 m (823.2 ft); 13⅜-in. intermediate casing to 950.0 m (3,116.8 ft).
WELL COMPLETION DATA:		The pump string is installed within 14.0-cm (5½-in.) outside diameter (od) stainless-steel casing landed off at 1,192.9 m (3,913.7 ft). A Moyno® pump stator was installed at the bottom of 7.3-cm (2⅞-in.) od stainless-steel tubing, with No-Turn Tools® above and below the stator. The stop pin below the pump stator is located at the depth of 1,037.8 m (3,404.7 ft). The pump rotor was installed in the stator on the end of a 2.2-cm (⅞-in.) od coated drive-rod string. The slotted, 7.3-cm (2⅞-in.) od fiberglass access string planned for installation in the well was dropped in the hole and not recovered. 108 joints (968.0 m [3,175.8 ft]) of fiberglass tubing remain in the hole. The open end of the tubing is estimated to be at 256 m (840 ft) below the ground surface.
		Pump String
	Total Depth:	1,192.9 m (3,913.7 ft)
	Depth of Screened Section:	1,045.6 to 1,183.2 m (3,430.4 to 3,881.9 ft). (8 joints of casing in this interval are slotted, with internal wire screens)
	Depth of Sand Pack:	1,020.5 to 1,034.2 m (3,348 to 3,393 ft)
	Depth of Gravel Pack:	1,034.2 to 1,205.2 m (3,393 to 3,954 ft)
	Depth of Moyno® Pump:	1,031.1 to 1,037.7 m (3,382.8 to 3,404.5 ft)
	Fluid Depth[a]:	627.9 m (2,060 ft)
DRILLING CONTRACTOR:		Welch & Howell Drilling
GEOPHYSICAL LOGS BY:		Atlas Wireline Services, Baker Hughes INTEQ, Desert Research Institute, Geophysical Engineering Group, Haliburton Engineering Services
SURVEYING CONTRACTOR:		Bechtel Nevada

[a]Fluid level in the open borehole as of February 7, 1996.

The drillers spent December 20-21, 1995, preparing to drill from under the casing. They drilled out the cement remaining inside the casing with a 17½-in. bit and then stopped to set up two more compressors on location in preparation for air-foam drilling. Drilling resumed on December 22, 1995, to 269.1 m (883 ft), then was stopped to prepare for the upcoming holiday hiatus. Drillers circulated to clean the hole then tripped out, picked up a new 17½-in. button bit and tripped back in to just above the casing shoe. They spent the rest of the day and December 23, 1995, performing general site maintenance and preparing the site to prevent freezing of fluids and equipment over the holiday.

Activities resumed at Well ER-20-5#3 on the day shift, December 26, 1995. Using air-foam in conventional circulation, the drillers reamed with the 17½-in. button bit to 269.1 m (883 ft), then continued drilling new hole. On December 27, 1995, the box on the first 8-in. drill collar failed at 319.1 m (1,047 ft), leaving 16.6 m (54.4 ft) of the BHA in the hole. The operation waited on fishing tools for 16 hours, but then the BHA was recovered and drilling resumed in 8 hours. As the BHA was reassembled and lowered into the hole, the joints were inspected for cracks by the Magna-flux process. The replacement string stabilizer and three 8-in. collars were rejected and replaced as a result of this inspection.

Drilling with the 17½-in. bit resumed on the afternoon of December 28, 1995, and continued for the next three days with few problems. When the bit torqued up occasionally, drillers added polymer and made wiper trips. The penetration rate averaged 1.8 to 3.7 m (6 to 12 ft) per hour in the welded tuff, but increased to as much as 18.3 m (60 ft) per hour in bedded tuffs. On December 31, 1995, at the depth of 602.9 m (1,978 ft), the drillers pulled up into the casing shoe to repair a damaged reverse shifter spline. This repair and testing of the rig compound drive afterward took approximately 24 hours, and then the drillers took the opportunity before encountering tritium to trip out and change bits. Tritium was encountered in the returns at the depth of 685.8 m (2,250 ft) on January 1, 1996.

Rotary drilling continued with the 17½-in. bit at approximately 6.1 to 9.1 m (20 to 30 ft) per hour in the nonwelded tuffs (but slowing in the welded tuffs), to the depth of 783.6 m (2,571 ft) on January 3, 1996. Drilling was then stopped so that fluid could be transferred from the upper sumps (Sumps #1 and #2) to the lower sumps (Sumps #3 and #4) and to wait for installation of liner in a new sump (#5). Drilling did not resume until January 6, 1996, because one of the sumps overflowed during fluid transfer (see Section 5.1.3) and because of trouble with a fluid leak at the wye connection on the flow line. By that time 2.4 m (8 ft) of fill had accumulated, and drilling continued with 1.5 to 2.4 m (5 to 8 ft) of fill on each connection between 828.4 and 856.8 m (2,718 to 2,811 ft). On January 8, 1996, drilling was stopped at 955.5 m (3,135 ft), to set casing in the upper nonwelded tuff of the Calico Hills Formation and for geophysical logging. An apparent deviation of the hole made it impossible to run the 4-arm caliper/gamma tool past ledges in the borehole, but when centralizers were added, the caliper tool was run successfully; and a gamma log was run separately. After logging was completed the casing subcontractor rigged up to run the intermediate casing.

The 13⅜-in. casing, set at 950.0 m (3,116.8 ft), had been made up with a multiple stage cementing tool, including a float shoe, a float collar, a stage collar, and four cement baskets. Water and cement were pumped for the lower plug and the first-stage (wiper) plug run to displace the cement. Cement was pumped through the multiple stage cementing tool after the "opening cone" was dropped to open the stage collar, but water used to displace the cement showed no resistance so it was assumed that the water and cement escaped to the formation. To complete the first-stage cement job, ⅜-in. gravel was dumped down the annulus onto the cement basket at 31.6 m (103.6 ft), and the annulus was cemented to 22.9 m (75 ft) through a 1.9-in. tremie line.

Activities at Well Cluster ER-20-5 were halted from January 10, 1996 through January 20, 1996, to resolve operational issues. A total of two shifts were spent on January 16 and 17, 1996, cementing the rest of the annulus outside of the intermediate casing (cedar fibers were put down the hole during cementing to reduce loss of cement near the cement basket at 31.6 m [103.6 ft]).

When activities resumed on the day shift, January 21, 1996, efforts were made to close the stage collar of the DV tool, but the casing would not hold water pumped into it as a test of the cement job. The next day, the stage collar was cemented through drill pipe set at 751.3 m (2,465 ft); and after this the water level in the casing remained stable.

January 24, 1996, was spent on preparations for drilling from under the intermediate casing, and the next day the crew made up a 12¼-in. bit and BHA, tripped in, and tagged the top of cement at 679.7 m (2,230 ft). They repaired a leak at the rotating head and then tripped out to change bits and install a float above the bit. The drillers worked through the cement plugs and the wiper plug inside the casing and tagged the float collar (or cement) at 936.3 m (3,072 ft). Water was pumped for a pressure test, but it was determined after monitoring fluid drop and running a temperature log that the fluid was leaking at the stage collar. Baker Hughes INTEQ attempted to run a bridge plug, but the plug would not pass through the stage collar at 750.7 m (2,463 ft). A wiper plug was finally pushed down the casing to 777.2 m (2,550 ft), and the casing was cemented above the plug using a microfine cement that was expected to flow more readily through the cement ports. Evaluation of the cement bond log indicates that the annulus of the intermediate casing is cemented from the bottom of the casing up to the depth of 664.8 m (2,181 ft).

Energy dissipators had been installed at the end of the flow line to disperse the force of the fluid and cuttings discharged into the sump, and thus prevent damage to the sump liner and lofting of contaminated fluid and foam by wind. During preparations to resume drilling on January 29, 1996, the drillers attempted to unload a large volume of fluid from the hole. The high fluid pressure parted the flanges on the energy dissipators and blew a dissipator into Sump #2. On January 30, 1996, after repairs were made, drillers tripped in with a 12¼-in. bit and began drilling out cement, guide shoes, and plugs inside the casing.

Drilling continued to the depth of 976.0 m (3,202 ft) with decreasing tritium concentrations in the return fluids below the casing (discharge was diverted to the noncontaminated sump [#1]). The drillers made a trip to change bits. The new 12¼-in. bit would not pass the stage collar, and after tripping out, carbide buttons were found missing off the bit. Milling with 12¼-in. mill-tooth bit was not successful, so after a short wait on the proper equipment, a taper mill was used to mill on the tool. Drillers then tripped in with the 12¼-in. mill-tooth bit, cleaned the hole, and recovered broken carbide buttons. A new 12¼-in. button bit was then made up, and drilling resumed on February 2, 1996.

Tritium activity increased again, and discharge was switched back to Sump #2 on February 3, 1996, when the depth was approximately 1,052.5 m (3,453 ft). Drilling continued at a rate of approximately 6.1 to 12.2 m (20 to 40 ft) per hour to the TD of 1,308.8 m (4,294 ft) on February 5, 1996. Geophysical logging was conducted February 6-9, 1996.

The gyro survey run in the well indicates that at the depth of 1,193.0 m (3,914 ft) the borehole is 121.7 m (399.3 ft) northwest of the well collar. At the bottom of the well, the borehole inclination is 13.18 degrees. See Sections 5.7.2 and 6.3 for discussions of the implications of severe borehole deviation.

5.1.2 Drilling Problems

Drilling progress at Well ER-20-5#3 was impacted by a variety of factors, including activities associated with shut-down for a holiday and coping with cold weather. The primary delays were due to equipment repairs and difficulties in cementing the intermediate casing. Activities were also halted midway through drilling for an operational review. The following paragraphs summarize the primary difficulties encountered during drilling of Well ER-20-5#3.

- Borehole sloughing caused only minor difficulties during drilling. Drillers encountered a small amount of fill on several connections between 783.6 and 856.8 m (2,571 to 2,811 ft). Fill was also encountered on connections between 1,108.6 and 1,175.0 m (3,637 to 3,855 ft). Examination of the caliper log and cuttings indicates that the source of the fill was near the bit location.

- Loss of fluid returns to the surface occurred at 3.4 to 5.2 m (11 to 17 ft) where the main hole communicated to the mouse hole. Lack of returns was also reported at 22.6 m (74 ft) and 112.2 to 113.7 m (368 to 373 ft). Thereafter, the LCM mixed in the drill fluid minimized fluid loss.

- A delay in drilling of approximately 24 hours (waiting on fishing tools, fishing, and checking replacement equipment) was caused by the failure of an 8-in. drill collar. Also several shifts were spent repairing various other rig and flow line components.

- The attempt was made to use the Weatherford Gemoco® multiple stage cementing system to cement the intermediate casing. Several days were spent alternately trying to seal the casing and test it for leakage. Some cement was probably lost to the formation. Reaming through the stage collar also proved difficult, and drilling through the cone that was dropped to open the stage collar released lead shot into the hole. Afterward a Baker bridge plug would not pass through the casing, possibly because the stage collar had been damaged during efforts to cement the casing. Examination of the Acoustic Televiewer indicates that the upper stage collar was parted.

- Difficulties in running some of the geophysical logging tools indicated that the hole was deviated from the vertical and this was verified when the gyro survey showed that near the TD the borehole is 121.7 m (399.3 ft) northwest of the collar coordinates. The gyro data show that the hole is steeply inclined near the TD, but there are no severe doglegs and the deviation caused no problems in setting casing or the completion string. However, hydrologic interpretations will have to take into account the fact that the elevation of the screened interval at 1,045.6 to 1,183.2 m (3,430.4 to 3,881.9 ft) is approximately 7.6 to 11.0 m (25 to 36 ft) higher than indicated by the drilled depth of the hole.

5.1.3 Fluid Management

A mix of mud (gel) and polymer with cottonseed hull LCM was used to drill Well ER-20-5#3 to the depth of 269.1 m (883 ft). The remainder of the hole was drilled using air-foam with applications of polymer as needed to condition the hole. The clean and contaminated discharge fluids were held in separate, lined sumps.

It was noted after drilling of the first two holes in this cluster that this site did not have enough lined storage capacity. The decision was made to convert the infiltration basin on the lower sump pad into additional lined sumps, and three new lined sumps were constructed during drilling of Well ER-20-5#3 (Figure 1-3). The liner in Sump #5 was installed and inspected by January 5, 1996, and the liner in Sump #6 was installed and inspected by January 12, 1996, before drilling resumed after the intermediate casing was set. Sump #7 was completed by January 30, 1996. Sumps #5 and #6 were used for fluid storage during drilling of Well ER-20-5#3. Sump #7 will be available for use during hydrologic testing.

During transfer of tritiated effluent from the upper to the lower sumps on January 4, 1996, approximately 9,464 liters (L) (2,500 gal) of fluid overflowed the lower sumps and spilled onto the access road and nearby desert area. An area of approximately 74.3 m^2 (800 ft^2) was affected by the spill. Analysis of this fluid indicated maximum tritium levels of approximately 66 million to 84 million pCi/L. Results of the investigation of this incident can be found in the DOE "Operating Experience Weekly Summary" for January 12-18, 1996 (DOE, 1996).

The drilling effluent was monitored in accordance with methods prescribed in the *Fluid Management Plan for the Underground Test Area Operable Unit* (DOE, 1994) and the *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-5* (IT, 1995). The results of analyses on samples of drilling fluid collected indicate that all fluids routed to the infiltration area and desert are within the fluid quality objectives established in the FMP for radiochemical parameters. However, a fluid sample taken from the flow line on January 31, 1996, indicated elevated lead levels. Further investigation indicated that the likely source of the lead was the opening cone or "bomb" used to open and close the port collars in the cementing tool.

Appendix B of this report contains the *Well ER-20-5#3 Fluid Management Status Report*. The fluid disposition form lists final volumes and data for drilling and completing the well. The final volumes of fluids imported to and produced at Well ER-20-5#3 were calculated from water-truck delivery tickets and measurement of fluids in the sumps. The solids produced were calculated using the diameter of the borehole and depth drilled, with added volume attributed to rock bulking factors.

5.2 Geologic Data Collection

5.2.1 Collection of Drill Cuttings

Triplicate sets of composite drill cuttings were collected continuously from Well ER-20-5#3 at 6.1-m (20-ft) intervals to 610 m (2,000 ft) and then at 3-m (10-ft) intervals to the TD at 1,308.8 m (4,294 ft). Samples were not obtained from 25 intervals including six missed due to lack of fluid returns in the upper part of the hole. All samples are stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One set of samples was sealed with custody tape at the rig site as an archive sample; one set was left unsealed in the original sample containers; and the third set was washed as per standard USGS Core Library procedures.

5.2.2 Sidewall Core Samples

After drilling was completed, sidewall core samples were collected to verify the stratigraphy and lithology penetrated in the interval 990.6 to 1,304.5 m (3,250 to 4,280 ft) and to obtain material for rock properties tests and analysis of matrix water. Percussion gun sidewall core samples were collected by Atlas Wireline Services who ran a 25-shot core gun and recovered 14 cores on February 8, 1996. Haliburton Engineering Services ran a rotary sidewall tool on February 9, 1996, and recovered ten samples out of twenty attempted. The sample depths were selected by the IT Field Representative. All attempted sample depths and the results of coring are listed in Table 5-2.

5.2.3 Geophysical Data

Geophysical logs were run after drilling to characterize the lithology, structure, and hydrogeologic properties of the rocks below the depth of the intermediate casing (geophysical data had been obtained for the upper part of the stratigraphic section at this location in Well ER-20-5#1). In addition, logs were run in Well ER-20-5#3 to check borehole conditions, determine fluid levels and other hydrologic data, identify radionuclides, and monitor the completion process. All geophysical logs run in Well ER-20-5#3 during drilling and completion are listed in Table 5-3. The logs are available from BN in Mercury, Nevada, and copies are on file at the IT office in Las Vegas, Nevada.

Overall, the quality of the geophysical data is acceptable. Preliminary geophysical data from the caliper, gamma ray, spectral gamma ray, resistivity, conductivity, epithermal neutron, temperature, and acoustic logs are presented as a composite in Appendix D.

5.3 Hydrology of Well ER-20-5#3

Production of water from Well ER-20-5#3 began at the depth of approximately 694.9 m (2,280 ft), soon after drilling into welded Topopah Spring Tuff. As noted at the previous two wells in the cluster, water production steadily increased as the Topopah Spring Tuff was penetrated to a maximum of about 946 Lpm (250 gpm) at the bottom of the welded tuff unit. Production continued to increase slightly and then reached a maximum of approximately 1,287 Lpm (340 gpm) even as the hole penetrated the underlying nonwelded Topopah Spring Tuff, a tuff confining unit. Water production decreased to almost nothing after the intermediate casing was set at 950.0 m (3,116.8 ft), and then abruptly increased to a maximum of approximately 1,790 Lpm (473 gpm) within the lava flow in the Calico Hills Formation at the

Table 5-2
Sidewall Samples Collected from Well ER-20-5#3
(Page 1 of 2)

Core Depth meters (feet)	Tool Used	Recovery centimeters (inches)	Stratigraphic Unit[a]	Hydrogeologic Unit[b]
963.2 (3,160)	PG[c]	2.5 (1.0)	Tacp[d]	TCU[e]
973.8 (3,195)	PG	1.9 (0.75)	Tacp	TCU
973.8 (3,195)	PG	1.9 (0.75)	Tacp	TCU
990.6 (3,250)	PG	0	--	--
990.6 (3,250)	PG	0	--	--
990.6 (3,250)	R[f]	0	--	--
990.6 (3,250)	R	2.5 (1.0)	Tacp	LFA[g]
1,005.8 (3,300)	PG	0	--	--
1,005.8 (3,300)	PG	3.8 (1.5)	Tacp	LFA
1,033.3 (3,390)	PG	0	--	--
1,033.3 (3,390)	R	5.1 (2.0)	Tacp	LFA
1,040.6 (3,414)	PG	trace	Tacp	LFA
1,040.6 (3,414)	R	3.2 (1.25)	Tacp	LFA
1,048.5 (3,440)	PG	trace	Tacp	LFA
1,048.7 (3,440.5)	R	5.1 (2.0)	Tacp	LFA
1,053.4 (3,456)	PG	0	--	--
1,053.4 (3,456)	R	1.3 (0.5)	Tacp	LFA
1,066.8 (3,500)	R	3.2 (1.25)	Tacp	LFA
1,079.0 (3,540)	R	0	--	--
1,080.2 (3,544)	PG	0	--	--
1,080.2 (3,544)	R	0	--	--
1,085.1 (3,560)	PG	0 (lost barrel)	--	--
1,085.1 (3,560)	R	0	--	--
1,085.1 (3,560)	R	5.1 (2.0)	Tacp	LFA
1,102.8 (3,618)	R	0	--	--
1,103.4 (3,620)	R	0	--	--
1,104.0 (3,622)	R	0	--	--
1,112.5 (3,650)	R	2.9 (1.13)	Tacp	LFA

Table 5-2
Sidewall Samples Collected from Well ER-20-5 #3
(Page 2 of 2)

Core Depth meters (feet)	Tool Used	Recovery centimeters (inches)	Stratigraphic Unit[a]	Hydrogeologic Unit[b]
1,143.0 (3,750)	PG	0	--	--
1,143.0 (3,750)	R	3.8 (1.5)	Tacp	LFA
1,152.1 (3,780)	PG	0	--	--
1,152.1 (3,780)	R	0	--	--
1,152.8 (3,782)	R	0	--	--
1,153.4 (3,784)	R	0	--	--
1,185.7 (3,890)	R	5.1 (2.0)	Tacp	LFA
1,204.0 (3,950)	PG	3.2 (1.25)	Tacp	TCU
1,219.2 (4,000)	PG	4.4 (1.75)	Tacp	TCU
1,237.5 (4,060)	PG	0	--	--
1,243.6 (4.080)	PG	4.4 (1.75)	Tacp	TCU
1,275.6 (4,185)	PG	4.4 (1.75)	Tacr[h]	TCU
1,283.2 (4,210)	PG	2.9 (1.13)	Tacr	TCU
1,299.7 (4,264)	PG	trace	Tacr	TCU
1,304.5 (4,280)	PG	4.4 (1.75)	Tacr	TCU
1,304.5 (4,280)	PG	3.8 (1.5)	Tacr	TCU

[a] Stratigraphic nomenclature from Ferguson et al. (1994)
[b] Modified from Winograd and Thordarson (1975) and Laczniak et al. (1996)
[c] Percussion Gun Sidewall Core Tool operated by Atlas Wireline Services
[d] Mafic-poor Calico Hills Formation
[e] Tuff confining unit
[f] Rotary Sidewall Core Tool operated by Haliburton Engineering Services
[g] Lava flow aquifer
[h] Mafic-rich Calico Hills Formation

drilled depth of 1,063.8 m (3,490 ft). Water production varied as the lava flow was penetrated and then decreased to approximately 454 Lpm (120 gpm) after the next lower tuff confining unit was penetrated (Figure 2-2). Production of water again increased at the depth of 1,231.4 m (4,040 ft). See Figure 5-2 for a graphic presentation of water production and tritium activity for Well ER-20-5#3. See Appendix B for a listing of water-production and tritium data. A comparison of water-production and tritium data for all three holes in the cluster is presented in Section 6.1.

Table 5-3
Well ER-20-5#3 Geophysical Log Summary

Geophysical Logs	Log Purpose	Logging Service	Date Logged	Run Number	Top of Logged Interval (bgs)[a] meters (feet)	Bottom of Logged Interval (bgs) meters (feet)
Annulus Investigation Log	Omnidirectional density (check for cement and/or fluid location)	GEG[b]	02/11/96 02/12/96 02/13/96	AIN-1 AIN-4[c] AIN-5	609.6 (2,000) 914.4 (3,000) 929.6 (3,050)	1,236.9 (4,058) 1,194.2 (3,918) 1,036.3 (3,400)
Caliper Log	Determine hole condition	GEG	01/08/96	CA6-1	234.1 (768)	955.2 (3,134)
Cement Bond Log	Check cement bond	AWS[d]	02/07/96	CBL-1	610.8 (2,004)	971.1 (3,186)
Chemical Log	Determine pH, electrical conductivity, and temperature of fluid. (Note: pH tool not working.)	DRI[e]	02/06/96	CHEM-1	672.1 (2,205)	1,308.5 (4,293)
Directional Gyroscope	Borehole deviation	BHI[f]	02/13/96	DRG-1	7.6 (25)	1,193.0 (3,914)
Gamma Ray	Stratigraphic correlation	GEG	01/08/96	GR-1	234.7 (770)	953.4 (3,128)
Gamma Ray/Borehole Televiewer	Stratigraphic correlation/ borehole examination for fractures and lithology	AWS	02/07/96	GR-3/BHTV-1	740.7 (2,430)	1,306.7 (4,287)
Gamma Ray/4-arm Caliper	Stratigraphic correlation/ determine hole conditions, cement volumes	AWS	02/08/96	GR-5/CA4-2	950.1 (3,117)	1,307.0 (4,288)
Gamma Ray/Digital Full-wave Acoustic	Stratigraphic correlation	AWS	02/07/96	GR-7/DAC-1	627.6 (2,059)	1,303.6 (4,277)
Gamma Ray/Dual Laterolog/4-arm Caliper	Stratigraphic correlation/ lithology/hole conditions	AWS	02/06/96	GR-2/ DLL-1/CA4-4	950.1 (3,117)	1,301.8 (4,271)
Gamma Ray/Epithermal Neutron/ Compensated Density	Stratigraphic correlation/water content/lithologic determination	AWS	02/08/96	GR-4/ ENP-1/CDL-1	627.6 (2,059)	1,306.7 (4,287)
Percussion Gun Sidewall/Gamma Ray	Obtain samples/stratigraphic correlation	AWS	02/08/96	SGUN-1/ GR-6	963.2 (3,160)	1,304.5 (4,280)
Heat Pulse Flow Meter (electrical conductivity, temperature)	Determine rate/direction of groundwater flow within the borehole	GEG	02/09/96	HPFLOW-1	640.1 (2,100)	1,270.4 (4,168)
Temperature (High Resolution)	Groundwater temperature	GEG	01/21/96 01/26/96 02/06/96	HRT-1 HRT-2 HRT-3	0.6 (2.0) 61.0 (200) 609.6 (2,000)	751.9 (2,468) 933.0 (3,061) 1,308.8 (4,294)
Mechanical Coring Tool	Obtain samples	HES[g]	02/08/96	MCT-1	990.6 (3,250)	1,185.7 (3,890)
Spectralog	Identify natural radionuclides and explosion products (Tracer-scan equivalent)	AWS	02/07/96	SL-1	613.3 (2,012)	1,293.3 (4,243)
Differential Temperature	Groundwater temperature	GEG	02/08/96	TLDLT-5	594.4 (1,950)	1,308.2 (4,292)

Source: BN Logging Section
[a] Below ground surface
[b] Geophysical Engineering Group of the Joint Test Organization
[c] AIN runs 2 and 3 were not presented.
[d] Atlas Wireline Services
[e] Desert Research Institute
[f] Baker Hughes INTEQ
[g] Haliburton Engineering Services

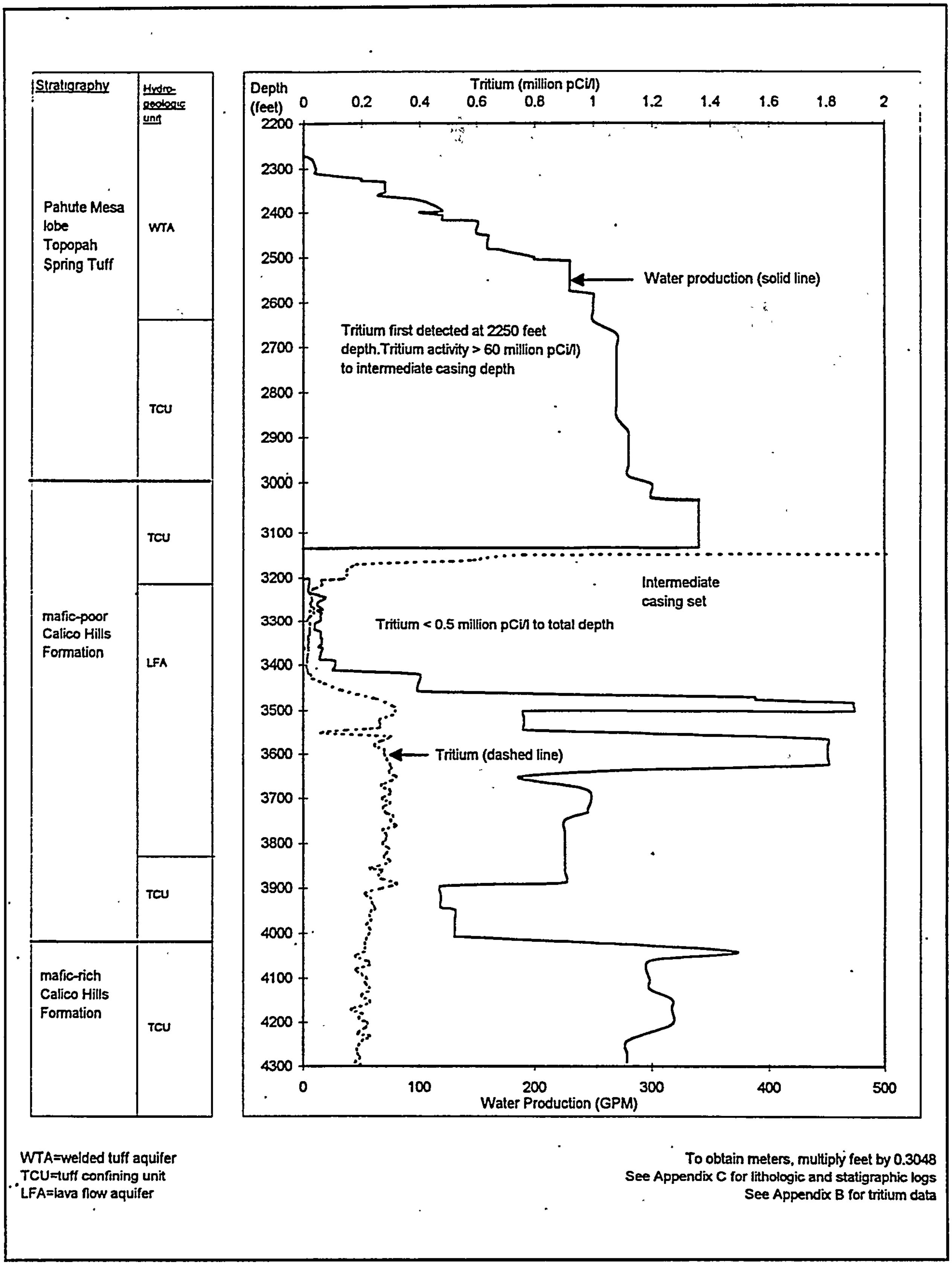

Figure 5-2
Tritium Activity and Water Production Versus Depth for Well ER-20-5#3

The fluid level in the open borehole (measured during geophysical logging and before installation of the tubing in the well) consistently stabilized at a depth of approximately 627.9 m (2,060 ft) and an elevation of 1,276.5 m (4,188 ft). This elevation was determined using the borehole deviation survey data which indicate that at the borehole depth of 627.9 m (2,060 ft), the true vertical depth is approximately 626.1 m (2,054 ft), very similar to that measured in Well ER-20-5#1.

5.3.1 Radionuclides Encountered

Tritium was first encountered in the fluid returns when the borehole had been drilled to 685.8 m (2,250 ft), approximately 57.6 m (189 ft) below the projected static water level. Tritium activity rose to over 100 million pCi/L when the hole reached the drilled depth of 724.5 m (2,377 ft) in the welded Topopah Spring Tuff. Tritium activity continued at about 100 million pCi/L until the hole had penetrated most of the underlying tuff confining unit, when the activities began to decrease. After the intermediate casing was set at 950.0 m (3,116.8 ft), the tritium level dropped to less than 10,000 pCi/L. However, when water production increased during penetration of the lava-flow aquifer within the Calico Hills Formation, tritium levels also rose again to a maximum of approximately 318,000 pCi/L at the depth of 1,066.8 m (3,500 ft). It will not be known until testing of this lower lava-flow aquifer if the tritium levels recorded during drilling can be attributed to the lava flow or if there was leakage from the welded-tuff aquifer above, which was cased off. If the tritium is present in the lava flow aquifer, this might suggest transport through the lava flow of contamination from the BENHAM event located approximately 1.3 km north of Well Cluster ER-20-5. Another possible interpretation for the presence of tritium in the lower lava-flow aquifer is communication of the lava flow with the welded Topopah Spring Tuff through fractures in the intervening tuff confining unit.

5.3.2 Flow Log Data

Desert Research Institute personnel ran a thermal flow log, but succeeded in recording data at only one station before failure of the packers forced cancellation of the survey. Preliminary evaluation of the data at the depth of 754.4 m (2,475 ft) indicated no flow. Personnel of the Geophysical Engineering Group ran a heat-pulse flowmeter log at thirteen stations between 640.1 and 1,270.4 m (2,100-4,168 ft). The results of both of these surveys were considered to be inconclusive with regard to flow direction.

5.3.3 Noble Gas Experiment

Air used for drilling was tagged with krypton starting at the drilled depth of approximately 610 m (2,000 ft), just before groundwater was encountered. The presence of the tracer gas may aid in monitoring of well development.

5.4 Precompletion and Open-Hole Development

Precompletion development was conducted in Well ER-20-5#3 by circulating and conditioning the borehole for three hours after TD was reached and before geophysical logging.

5.5 Completion

Completion activities at Well ER-20-5#3 began immediately after logging was concluded and a bottom plug set on February 11, 1996. Completion activities were concluded on February 16, 1996. Figure 5-3 is a schematic of the final well-completion design for Well ER-20-5#3, and Figure 5-4 shows a plan view and profile of the well-head configuration. Data for this section were obtained from the BN daily rig reports and tubing records for Well ER-20-5#3.

5.5.1 Proposed Completion Design

The original plan for Well Cluster ER-20-5 called for the construction of one completion zone in each hole of the cluster with the first hole drilled the deepest to access the lower welded ash-flow tuff of the Topopah Spring Tuff. The next two holes were to be completed in shallower transmissive zones in the Topopah Spring Tuff and undifferentiated Paintbrush Group tuffs (IT, 1995). However, after abandonment of Well ER-20-5#2, it was decided to drill a deep hole to investigate the lower lava-flow aquifer. The completion design was to be basically the same for all three holes (though the completion depths would be different in each hole), consisting of a screened completion string with a retrievable pump, and an adjacent screened access string for taking samples and water-level measurements. The pairs of completion strings were to be permanently installed to access a discrete interval in each well.

5.5.2 As-Built Completion Design

The as-built completion design of Well ER-20-5#3 provides access to the lower lava-flow aquifer within the mafic-poor Calico Hills Formation. The slotted casing contains a pump stator positioned on a separate string with No-Turn Tools® to prevent counter-rotation of the stator and allow easy removal of the pump if desired. The pump rotor was also installed. The slotted fiberglass access string was dropped in the hole and not recovered. The string compositions are listed on Table 5-4 and tubing materials are listed in Appendix A-3.

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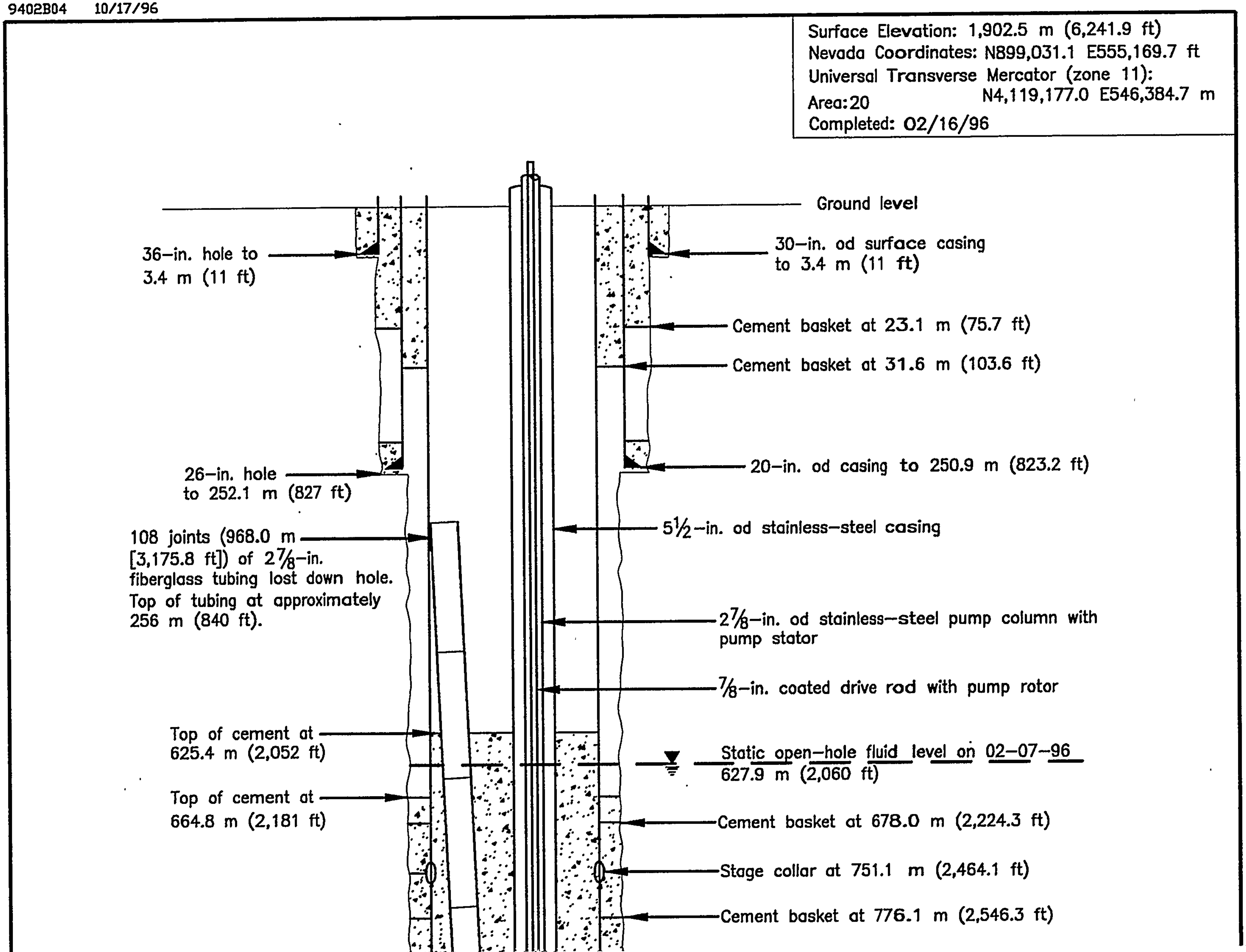

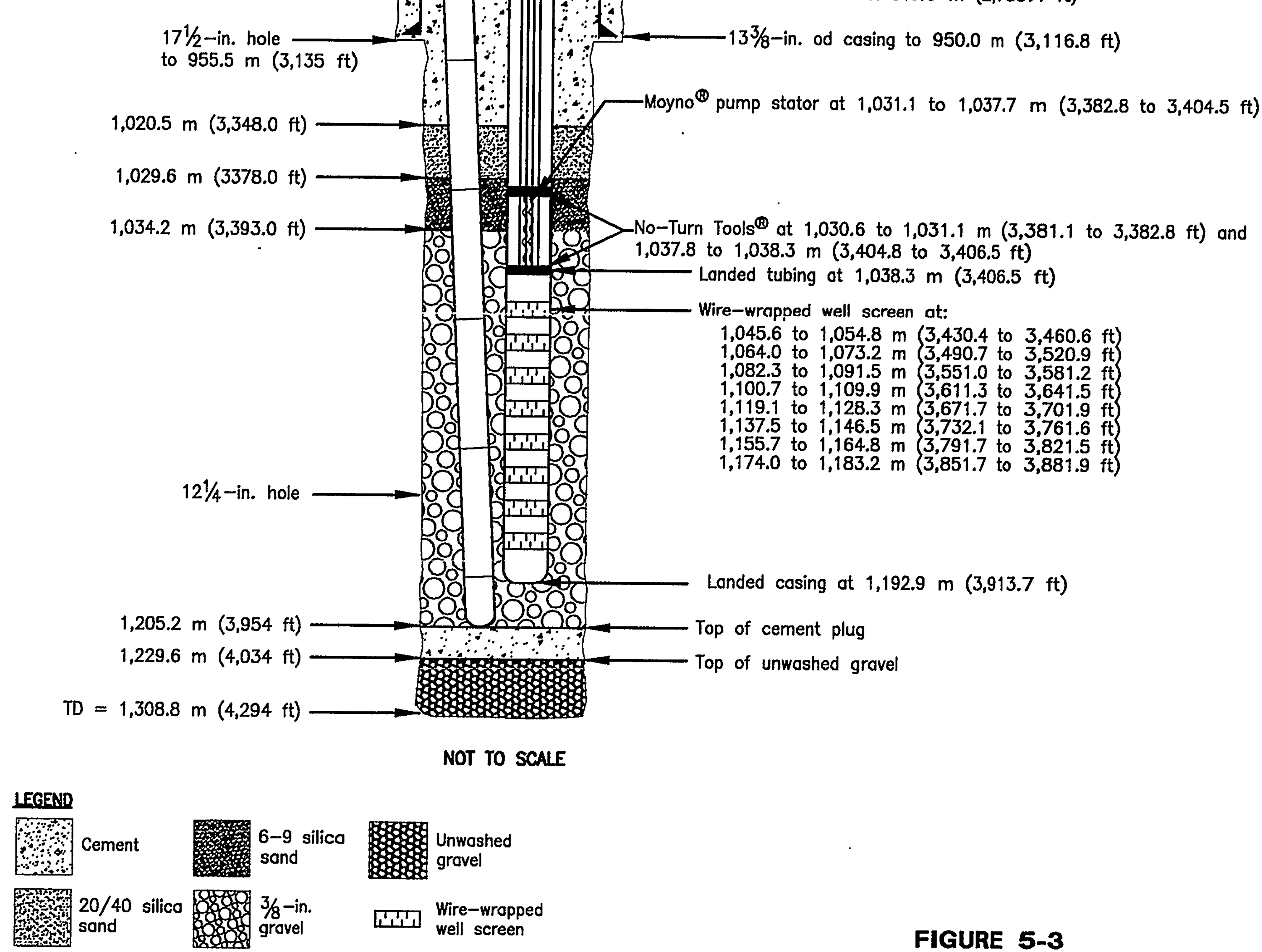

FIGURE 5-3
AS-BUILT SCHEMATIC OF WELL ER-20-5#3

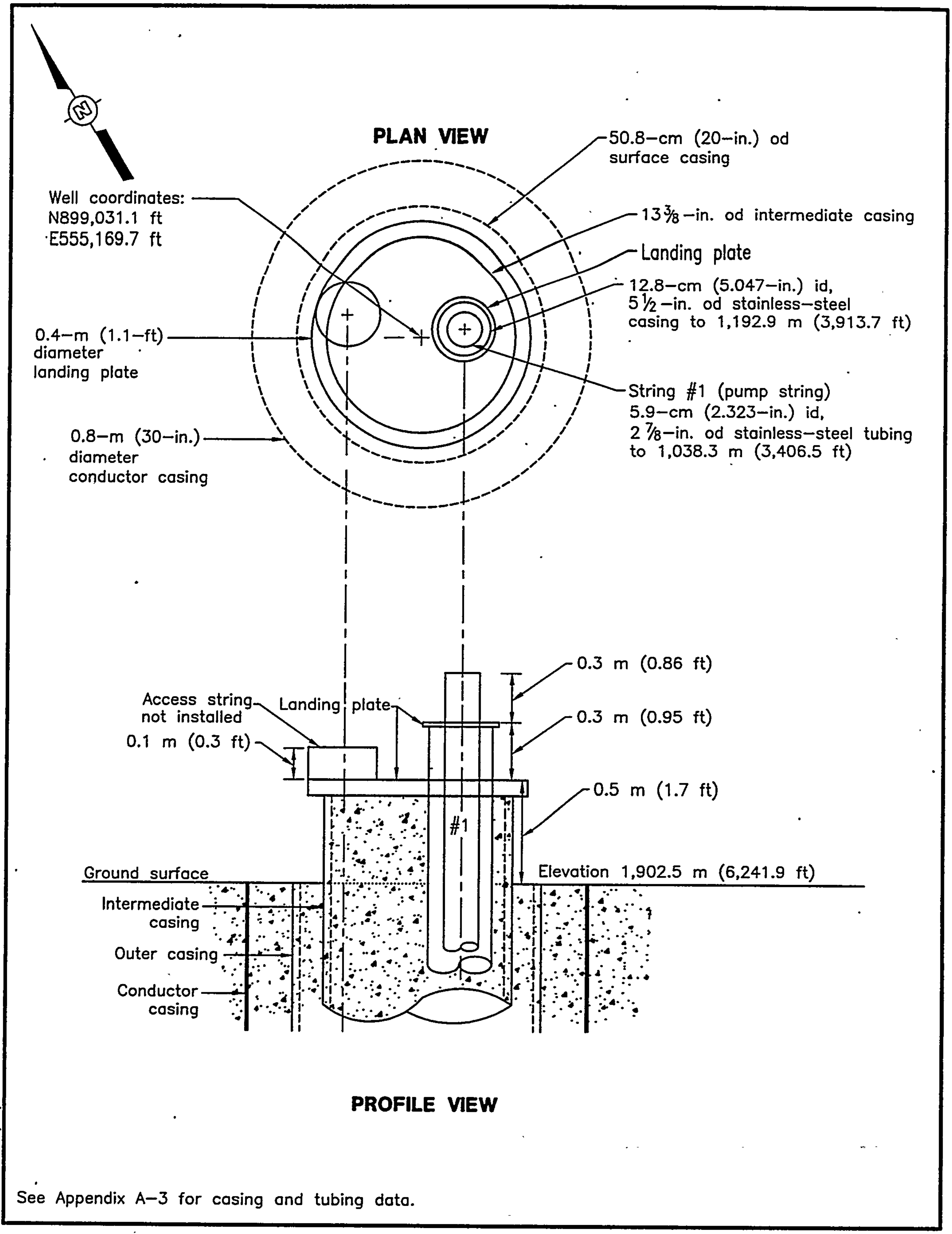

Figure 5-4
Well ER-20-5#3 Wellhead Diagram

Table 5-4
Well ER-20-5#3 Completion String Construction Materials Summary

<table>
<tr><th>Completion String</th><th colspan="2">Configuration</th><th>Cement</th><th>Sand/Gravel</th></tr>
<tr><td rowspan="17">5½-inch Stainless-steel casing</td><td rowspan="17">Ground surface to 1,192.9 m (3,913.7 ft)</td><td>Blank
0 to 1,045.6 m
(0 to 3,430.4 ft)</td><td rowspan="21">Type II
plus 2% $CaCl_2$

625.4 to 1,020.5 m
(2,052-3,348 ft)

and

1,205.2 to 1,229.6 m
(3,954-4,034 ft)</td><td rowspan="21">20/40 Sand

1,020.5 to 1,029.6 m
(3,348 to 3,378 ft)

6-9 Sand

1,029.6 to 1,034.2 m
(3,378 to 3,393 ft)

3/8-inch Gravel

1,034.2 to 1,205.2 m
(3,393 to 3,954 ft)

Unwashed Gravel

1,229.6 to 1,308.8 m
(4,034 to 4,294 ft)</td></tr>
<tr><td>Slotted/Screened
1,045.6 to 1,054.8 m
(3,430.4 to 3,460.6 ft)</td></tr>
<tr><td>Blank
1,054.8 to 1,064.0
(3,460.6 to 3,490.7 ft)</td></tr>
<tr><td>Slotted/Screened
1,064.0 to 1,073.2 m
(3,490.7 to 3,520.9 ft)</td></tr>
<tr><td>Blank
1,073.2 to 1,082.3 m
(3,520.9 to 3,551.0 ft)</td></tr>
<tr><td>Slotted/Screened
1,082.3 to 1,091.5 m
(3,551.0 to 3,581.2 ft)</td></tr>
<tr><td>Blank
1,091.5 to 1,100.7 m
(3,581.2 to 3,611.3 ft)</td></tr>
<tr><td>Slotted/Screened
1,100.7 to 1,109.9 m
(3,611.3 to 3,641.5 ft)</td></tr>
<tr><td>Blank
1,109.9 to 1,119.1 m
(3,641.5 to 3,671.7 ft)</td></tr>
<tr><td>Slotted/Screened
1,119.1 to 1,128.3 m
(3,671.7 to 3,701.9 ft)</td></tr>
<tr><td>Blank
1,128.3 to 1,137.5 m
(3,701.9 to 3,732.1 ft)</td></tr>
<tr><td>Slotted/Screened
1,137.5 to 1,146.5 m
(3,732.1 to 3,761.6 ft)</td></tr>
<tr><td>Blank
1,146.5 to 1,155.7 m
(3,761.6 to 3,791.7 ft)</td></tr>
<tr><td>Slotted/Screened
1,155.7 to 1,164.8 m
(3,791.7 to 3,821.5 ft)</td></tr>
<tr><td>Blank
1,164.8 to 1,174.0 m
(3,821.5 to 3,851.7 ft)</td></tr>
<tr><td>Slotted/Screened
1,174.0 to 1,183.2 m
(3,851.7 to 3,881.9 ft)</td></tr>
<tr><td>Blank and bull-nosed
1,183.2 to 1,192.9 m
(3,881.9 to 3,913.7 ft)</td></tr>
<tr><td rowspan="2">2⅞-inch Stainless-steel tubing</td><td rowspan="2">Ground surface to 1,038.3 m (3,406.5 ft) inside 5½-inch casing</td><td>Moyno® pump stator
1,031.1 to 1,037.7 m
(3,382.8 to 3,404.5 ft)</td></tr>
<tr><td>No-Turn Tools

1,037.8 to 1,038.3 m
(3,404.8 to 3,406.5 ft)
and
1,030.6 to 1,031.1 m
(3,381.1 to 3,382.8 ft)</td></tr>
<tr><td>⅞-inch coated drive rods</td><td>Ground surface to 1,035.9 m (3,398.5 ft) inside 2⅞-inch tubing</td><td>Moyno® pump rotor set in stator</td></tr>
<tr><td>2⅞-inch Fiberglass tubing</td><td>Approximately 256 to 1,205.2 m (840-3,954 ft)</td><td>Dropped in hole</td></tr>
</table>

The casing for the pump string is 5½-in. stainless-steel for its entire length. The bottom 0.6-m (2.0-ft) joint is bull-nosed and blank with a 0.64-cm (0.25-in.) hole to serve as a sediment trap, followed by alternating blank and slotted joints. A total of eight 9.0- to 9.2-m (29.5- to 30.2-ft) long slotted joints are located between 1,045.6 and 1,183.2 m (3,430.4 to 3,881.9 ft). The terminal 0.76 m (2.5 ft) of each slotted joint is blank (for strength at the connection), and the middle 7.6 m (25 ft) is perforated with 160 1.27-cm (½-in.) diameter holes per foot. Stainless-steel screen consisting of wire wrapped around wire ribs with 0.20-cm (0.078-in.) openings between wraps was installed within each slotted joint.

The Moyno® pump stator was installed on 2⅞-in. stainless-steel tubing within the 5½-in. casing at 1,031.1 to 1,037.7 m (3,382.8 to 3,404.5 ft) with No-Turn Tools® located above and below the stator. The 2⅞-in. stainless-steel string is unslotted, but open on the bottom (via the pump stator section). The pump rotor was installed in the stator on a ⅞-in. drive-rod string equipped with spin-through guide rods. The number of guides per rod was established by computer analysis of side-loading, based on borehole deviation data.

5.5.3 Rationale for Differences Between Actual and Proposed Well Design

Well ER-20-5#3 was completed in the lower lava-flow aquifer as planned after drilling Wells ER-20-5#1 and #2. The final design for Well ER-20-5#3 was determined after evaluation of the tritium activity and water production data. The gravel pack extends through the interval in which the highest water production and tritium activities were measured below the intermediate casing and spans the lower portion of the lava-flow aquifer and the upper part of the underlying tuff confining unit. The completion strings planned for this well are very similar to the proposed design, but the loss of the 2⅞-in. fiberglass access string precludes water-level measurements in the hole while pumping. However, samples can be obtained from the pump string, and it can serve as a pumping well for the cluster. The access line may still be useful if proposed attempts to reconnect the line are successful.

5.5.4 Completion Method

Well construction materials were inspected in accordance with relevant procedures before delivery to the drill site. Standard UGTA decontamination procedures were employed to prevent the introduction of contaminants into the well. Caliper logs were used to calculate the volumes of cement, sand, and gravel needed during well construction. A tremie line consisting of 2⅞-in. Hydril® tubing was used for placing all gravel, sand, and cement; emplacement of these materials was monitored using the AIN log. All casing and tubing strings were run by a casing installation subcontractor.

Unwashed gravel was placed in the bottom of the hole to the depth of 1,229.6 m (4,034 ft), followed by a plug of Type II cement plus 2-percent $CaCl_2$ to the depth of 1,205.2 m (3,954 ft). The 5½-in. casing was landed at 1,192.9 m (3,913.7 ft). As the 2⅞-in. fiberglass access tube was being lowered into the hole, it stopped and then parted as personnel tried to work it free. The string dropped, but was recovered and the damaged joints replaced. The tube became stuck again while being lowered, and as personnel tried to work it up, it pulled through the elevators and 108 joints (968.0 m [3,175.8 ft]) were lost down the hole. No attempt was made to recover this string. The open upper end of the tubing is estimated to be at 256 m (840 ft).

The slotted interval was packed with ⅜-in. gravel from 1,034.2 to 1,205.2 m (3,393 to 3,954 ft); 6-9 Colorado sand was placed at 1,029.6 to 1,034.2 m (3,378 to 3,393 ft); and 20/40 silica sand was placed at 1,020.5 to 1,029.6 m (3,348 to 3,378 ft). The borehole annulus was cemented to 1,014.4 m (3,328 ft), and then Baker Hughes INTEQ arrived on site and conducted the gyro survey inside the 5½-in. casing. Cementing continued with Type II cement plus 2-percent $CaCl_2$ to 579.1 m (1,900 ft), but the cement fell back to 625.4 m (2,052 ft). At that point, the tremie line was removed, and the pump stator was installed inside the 5½-in. string, followed by the rotor. The pump was successfully tested and allowed to run for several hours.

5.6 Actual Versus Planned Costs and Scheduling

The BN cost model for the ER-20-5 well cluster was originally developed on a per-hole basis for generic 914.4-m (3,000-ft) deep holes. A separate cost plan was developed for Well ER-20-5#3 which was planned to be approximately 1,402 m (4,600 ft) deep. In this model, drilling, logging and completion were projected to require 33 days to accomplish. Actual time spent on Well ER-20-5#3, with a TD of 1,308.8 m (4,294 ft), was 65 days. However, 9 of those days were charged at a lower rig rate during a shut-down for an operations review. Additional rig time was spent in trying to cement the intermediate casing string.

The cost analysis for Well ER-20-5#3 can be divided into charges by the drilling contractor (including drilling equipment, fluids, and the casing and fishing subcontractors) and charges by the support contractors (including radiation technicians, inspection services, geophysical logging, cementing services, and completion materials). The total planned cost of Well ER-20-5#3 was $1,460,035. The actual cost of the well was $2,581,304, or approximately 76.8 percent more than the planned cost. Table 5-5 lists the planned and actual costs. Figure 5-5 is a comparison of planned and actual costs by day for drilling Well ER-20-5#3 (costs charged during the operational review are lumped on one day).

Table 5-5
Well ER-20-5#3 Actual Versus Planned Costs

Activity	Planned Cost[a]	Actual Cost	Percent Difference Actual Versus Planned
Drilling contractor	$519,600	$ 977,242[b]	88.1
Support contractor	$940,435	$1,604,062[c]	70.6
Total	$1,460,035	$2,581,304	76.8

[a]Based on BN model for a 1,402-m (4,600-ft) hole
[b]Source: DOE/ERD
[c]Source: BN Drilling

5.7 Summary and Lessons Learned

5.7.1 Summary

Drilling commenced at Well ER-20-5#3 on December 12, 1995, and concluded on February 5, 1996, when the TD of 1,308.8 m (4,294 ft) was reached. After geophysical logging, the completion string was installed and gravel-packed, and the hole was cemented to 625.4 m (2,052 ft) on February 10-16, 1996. Crews worked seven-day-per-week, 24-hour-per-day schedules for most of the operation. Operations were halted for a total of nine days for an operational review. A total of 59 working days was expended on drilling, logging, and completion activities.

The main problems encountered in drilling Well ER-20-5#3 were related to equipment repairs and difficulties in cementing the intermediate casing. Borehole sloughing caused only minor difficulties.

Composite drill cuttings were collected every 6 m (20 ft) from the surface to 610 m (2,000 ft) and then every 3 m (10 ft) to TD. Both percussion gun and rotary sidewall samples were taken in the interval 990.6 to 1,304.5 m (3,250 to 4,280 ft). Geophysical logging was conducted after drilling was finished to aid in construction of the well to help verify the geology and to help characterize the hydrology of the units.

One stainless-steel pump string was successfully installed inside 5½-in. stainless-steel screened casing, and the pump was successfully tested. The slotted fiberglass access line was dropped in the hole and not recovered. The position of the gravel pack in the completion interval allows access to a water-producing zone within the lower lava-flow aquifer within the Calico Hills Formation. However, due to the borehole deviation, the elevation of the completion interval is approximately 7.6 to 11.0 m (25 to 36 ft) higher than indicated by the drill-hole depth.

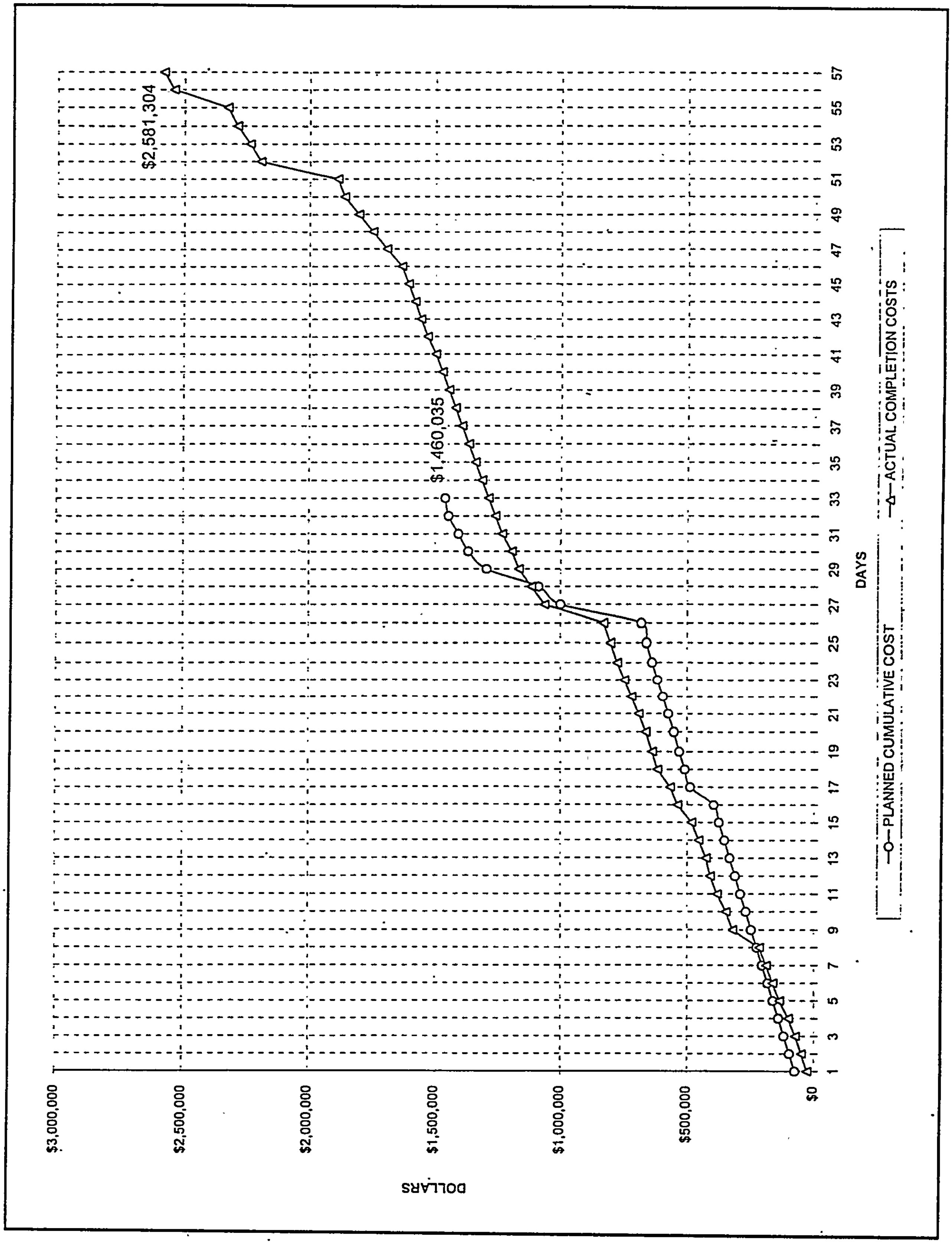

Figure 5-5
Actual Versus Planned Costs for Drilling and Completion of Well ER-20-5#3

The total planned cost for Well ER-20-5#3 was $1,460,035. The actual cost of the well was $2,581,304, or 76.8 percent more than the planned cost.

5.7.2 Lessons Learned

This section describes lessons learned during the drilling and completion of Well ER-20-5#3. Lessons learned from the project as a whole are addressed in Section 6.0.

Drilling

Steps should be taken during drilling to prevent excessive borehole deviation, because it can be a potentially serious problem in a near-field drilling project. In this case, the deviation created an inconvenience which will have to be addressed every time any analysis is done using borehole depths for interpretation of hydrologic or geologic data. In addition, the following factors should be considered:

- The long-term effects of operating a pump set at an angle are not yet known.
- The drift of the borehole away from the study area may decrease the effectiveness of the hydrologic testing planned for this site.
- If the borehole had drifted toward the TYBO explosion cavity, there would have been the potential for encountering unexpectedly high radiation levels. Higher radiation levels might have caused personnel health and safety concerns, may have impacted fluid management procedures, and may have caused more severe contamination of hardware.

Isolating the main sloughing zones in the upper part of the hole (based on experience in Wells ER-20-5#1 and #2) by setting the surface casing deeper greatly improved borehole stability.

A better understanding of the multistage cementing system employed to set the intermediate casing is required if this method is to be used in future wells.

When the drillers tried to unload too much water while staging into the hole, high fluid pressure in the system blew an energy dissipator off the flow line into the contaminated sump. This was a potentially dangerous situation (due to the unpredictable discharge of energy); it exposed personnel unnecessarily to contaminated fluids while retrieving the equipment; and it resulted in unnecessary contamination of hardware.

Completion

Better methods for handling fiberglass tubing must be developed if fiberglass remains the material of choice for completing wells.

Field calculation of the stretch of the drive rods was based on stretch coefficients measured in other wells and resulted in correct placement of the pump rotor. Work should be done to verify these field calculations and develop a standard calculation for other installations.

The use of a subcontract casing crew to install completion tubulars for Well ER-20-5#3 greatly increased the safety, speed, and efficiency of the operation compared to construction of Well ER-20-5#1. This practice should be considered for future operations.

Fluid Management

Care should be taken in designing sump and fluid transfer systems so that unexpected actions such as siphoning are prevented. In addition, the frequent inspections of sump areas should be made, especially before and after fluid transfers.

A full disclosure of the materials in down-hole systems should be required. The lead components of the multistage cementing tool led to elevated lead levels in the fluid discharge. Lead components should generally be avoided to reduce the amount of solid hazardous wastes and should not be used in environmental wells.

6.0 Summary, Recommendations, and Lessons Learned from Well Cluster ER-20-5

6.1 Summary

Operations commenced at Well Cluster ER-20-5 with the drilling of the conductor holes for all three wells on the same pad on October 7, 1995; the conductor casings were set on October 9, 1995. Drilling and completion of Well ER-20-5#1 began on October 15, followed by drilling and abandonment of Well ER-20-5#2, and drilling and completion of Well ER-20-5#3. Drilling and completion activities at the well cluster were concluded on February 16, 1996.

Crews worked on a seven-day-per-week, 24-hours-per-day schedule, and 110 working days were expended on well-drilling, logging, and completion activities. Activities were suspended for five days due to holidays, and a nine-day hiatus occurred during drilling of Well ER-20-5#3 for an operational review.

Drilling of Well ER-20-5#1 to the TD of 860.5 m (2,823 ft) took place from October 15, 1995, to November 2, 1995. A string of 20-in. surface casing was set at 62.2 m (204.1 ft) in the 26-in. diameter hole, and a 12¼-in. hole was drilled from the bottom of the casing to TD. Borehole sloughing in the lower part of the hole resulted in a decrease in the accessible depth of the hole by 51.2 m (168 ft) due to accumulation of fill. This borehole instability also precluded open-hole development (except circulating) and hydrologic testing. Completion activities took place on November 6-13, 1995. One slotted, stainless-steel pump string and one slotted, fiberglass access string were installed in the well as planned in the lower part of the welded Topopah Spring Tuff, approximately 178 m (584 ft) from the edge of the TYBO collapse chimney.

Drilling of Well ER-20-5#2 commenced on November 17, 1995, and was halted due to catastrophic borehole sloughing at the depth of 819.6 m (2,689 ft) on November 30, 1995. Seven days were spent fishing to retrieve the lost BHA, but the operation was abandoned on December 7, 1995, leaving the BHA and some drill pipe in the hole. The hole was partially cemented and then used for disposal of uncontaminated drill cuttings from Well ER-20-5#3. The remainder of the borehole was cemented to the surface on February 13, 1996. No completion strings were installed in the borehole.

Drilling of Well ER-20-5#3 to the TD of 1,308.8 m (4,294 ft) took place from December 12, 1995 to February 5, 1996. A 20-in. surface casing was set at 250.9 m (823.2 ft) in the 26-in. diameter hole, and a 17½-in. diameter hole was drilled from the bottom of the casing to 955.5 m (3,135 ft). A 13⅜-in. intermediate casing string was cemented in the hole to seal off the welded Topopah Spring Tuff aquifer, and a 12¼-in. hole was drilled from the bottom of the casing to TD. The primary difficulty encountered in drilling was in cementing the intermediate casing using a multi-stage cementing system. Completion activities took place on February 10-16, 1996. One slotted, stainless-steel pump string was successfully installed in the well. The slotted, fiberglass access string was dropped in the hole and not recovered. The gravel-pack was placed in the lower lava-flow aquifer within the Calico Hills Formation, which has the potential to be carrying radionuclides from the BENHAM event, located approximately 1.3 km from the ER-20-5 well cluster, or it may be connected through fractures to the welded-tuff aquifer.

Composite drill cuttings were collected every 3 m (10 ft) in Well ER-20-5#1 from surface to TD. The sampling interval was 6 m (20 ft) in most of the upper part of the section in Wells ER-20-5#2 and #3, reverting to 3-m (10-ft) intervals below 610 m (2,000 ft) in both holes. A few intervals were missed due to intermittent or poor fluid returns in the upper parts of the holes, and many of the samples below the depth of approximately 807.7 m (2,650 ft) in Wells ER-20-5#1 and #2 were degraded due to borehole sloughing. Twenty-four sidewall samples were collected at 19 locations within the Calico Hills Formation at Well ER-20-5#3. The sidewall samples and cuttings for all three holes are archived at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

Geophysical logging was conducted in Wells ER-20-5#1 and #3 to aid in construction of the wells, to help verify the geology, and to help characterize the hydrology of the units. Geophysical logs for the holes are on file at BN in Mercury, Nevada, and at the IT office in Las Vegas, Nevada. Because of fill in the bottom of Well ER-20-5#1, loss of Well ER-20-5#2 before logging, and casing off of the upper part of the Well ER-20-5#3, a full suite of geophysical logs was not obtained through some intervals of the stratigraphic section except through casing. However, careful examination of the data indicated that the geology in all three holes is very similar, and composite stratigraphic and lithologic logs were prepared for the site using the cuttings, sidewall samples, and well-log data.

The elevation of the static, open-hole water level in Wells ER-20-5#1 and #3 is approximately 1,276 m (4,187 ft), as predicted prior to drilling. The measured depth to water in the two holes differs, however, because of the severe deviation of Well ER-20-5#3. Water production in the three holes during drilling ranged from less than 380 Lpm (100 gpm) to 950 Lpm (250 gpm) within the welded Topopah Spring Tuff aquifer. Water production in the welded-tuff aquifer in all three holes was somewhat less than expected.

In the lower lava-flow aquifer penetrated in Well ER-20-5#3, water production was as high as 1,790 Lpm (473 gpm) but varied apparently due to changes in drilling parameters.

Tritium was encountered in all three holes soon after penetrating the water table. Tritium activity remained lowest in Well ER-20-5#1 (less than approximately 80 million pCi/L). Tritium levels in the welded Topopah Spring Tuff in Wells ER-20-5#2 and #3 were similar, peaking at approximately 116 million pCi/L and then dropping off (in Well ER-20-5#3) in the underlying nonwelded Topopah Spring Tuff. After the welded-tuff aquifer was sealed off by the intermediate casing, tritium levels decreased dramatically but then began to rise with increasing water production within the lower lava-flow aquifer to a maximum of approximately 318,000 pCi/L (see Figure 5-3). See Figure 6-1 for a comparison of water production and tritium activity for all three wells. See Figure 6-2 for the drill site configuration showing deviations of Wells ER-20-5#1 and ER-20-5#3. Figure 6-3 illustrates the two completions constructed in Well Cluster ER-20-5 relative to the TYBO explosion cavity and chimney.

The original estimate for Well Cluster ER-20-5 projected that drilling and completion would require 73 days to accomplish. The actual time spent on drilling, logging, and completion activities for all three holes was 110 days. The planned cost for three wells was $3,584,321. The actual cost of the well construction project was $4,780,120, or approximately 33.4 percent more than the planned cost. Table 6-1 provides a comparison of the actual and planned costs.

Because of the loss of Well ER-20-5#2 and the decision not to drill a fourth hole at this site, planned completions in the less transmissive zone above the welded Topopah Spring Tuff and in the underlying Calico Hills tuff confining unit were not constructed. Lack of geologic and hydrologic data from the tuff confining unit will make interpretation of the presence of tritium in the underlying lava-flow aquifer (Well ER-20-5#3) more difficult. However, the overall objectives of characterizing the radionuclides adjacent to TYBO and obtaining hydrologic data for this site will probably be achieved if hydrologic testing is conducted.

If the access tube in Well ER-20-5#3 is not successfully reentered, it is not known how the presence of the broken tube will affect future hydrologic tests conducted at this site. The severe deviation of Well ER-20-5#3 will have to be taken into consideration when analyzing any water-level or regional geologic data because the elevation of the screened interval (1,045.6 to 1,183.2 m [3,430.4 to 3,881.9 ft]) is approximately 7.6 to 11.0 m (25 to 36 ft) higher than indicated by the drilled depth of the hole. In addition, the lateral migration of the borehole placed the completion zone approximately 91 m (300 ft) northwest of the collar location, a significant distance from the other well in this cluster.

6.2 Recommendations for Additional Data Interpretation

The planned sampling and hydrologic testing must be conducted at Well Cluster ER-20-5 to accomplish the remaining objectives of this near-field drilling project. In addition, long-term

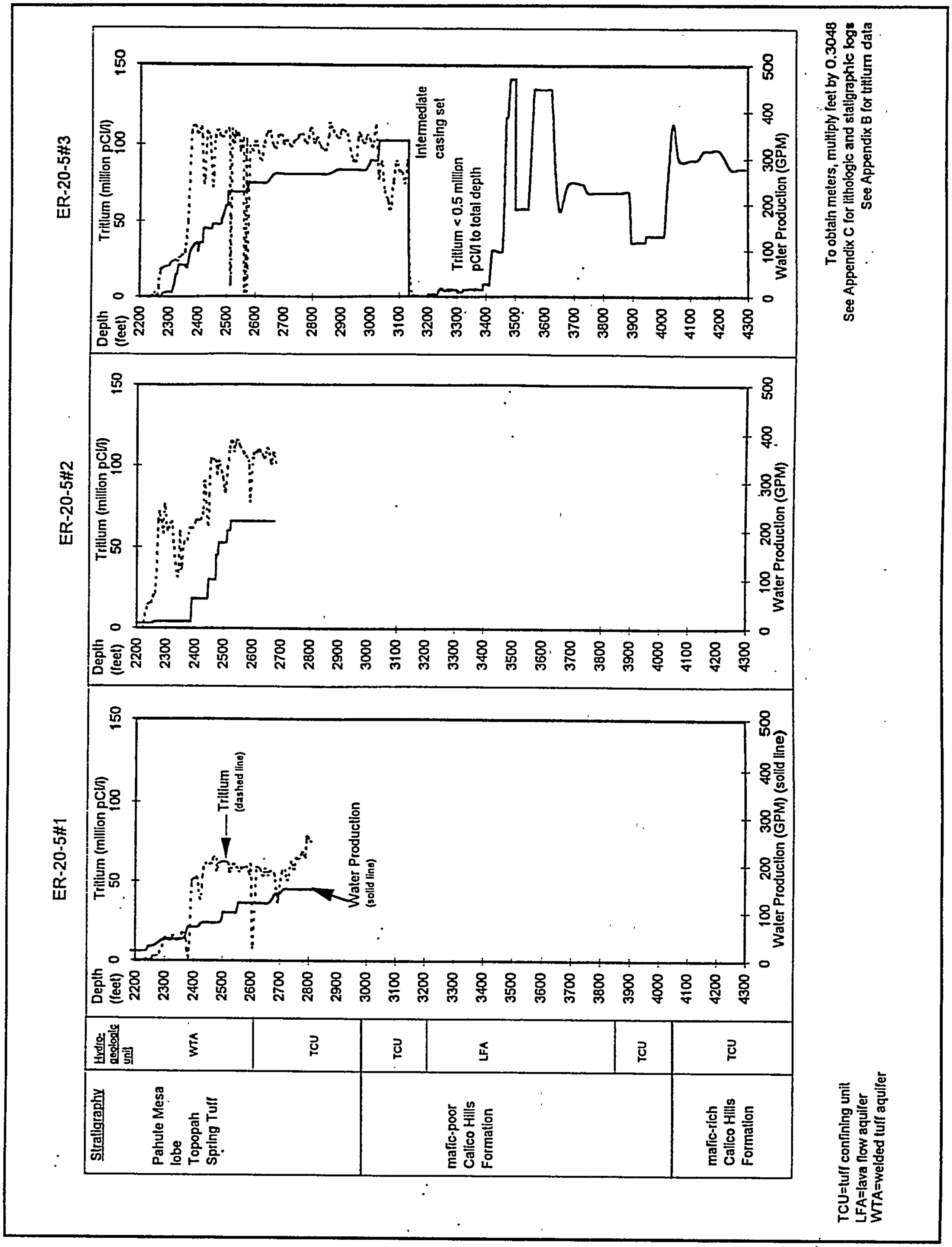

Figure 6-1
Tritium Activity and Water Production Versus Depth for Well Cluster ER-20-5

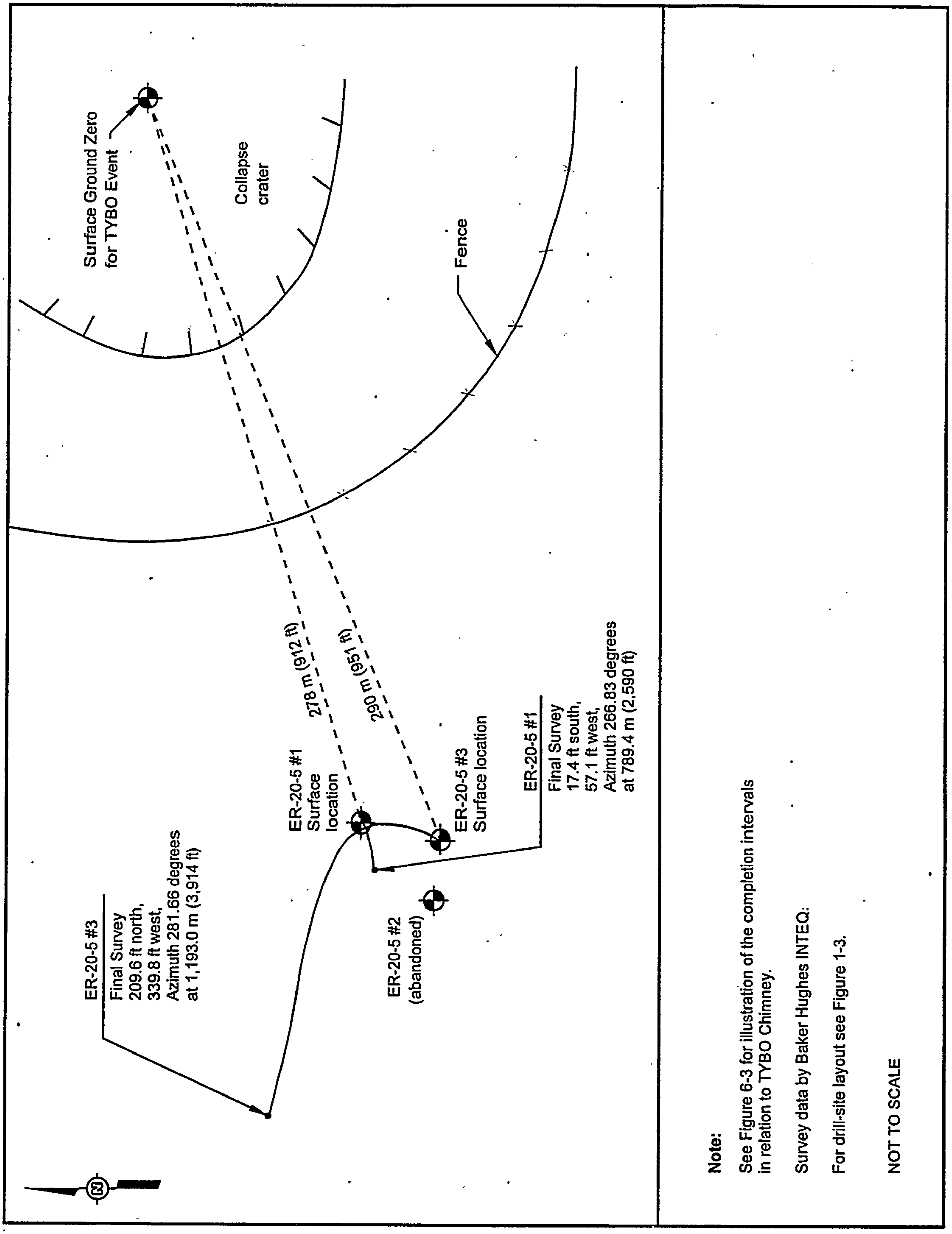

Figure 6-2
Well Cluster ER-20-5 Drill Site Configuration Showing Deviations of Wells ER-20-5#1 and ER-20-5#3

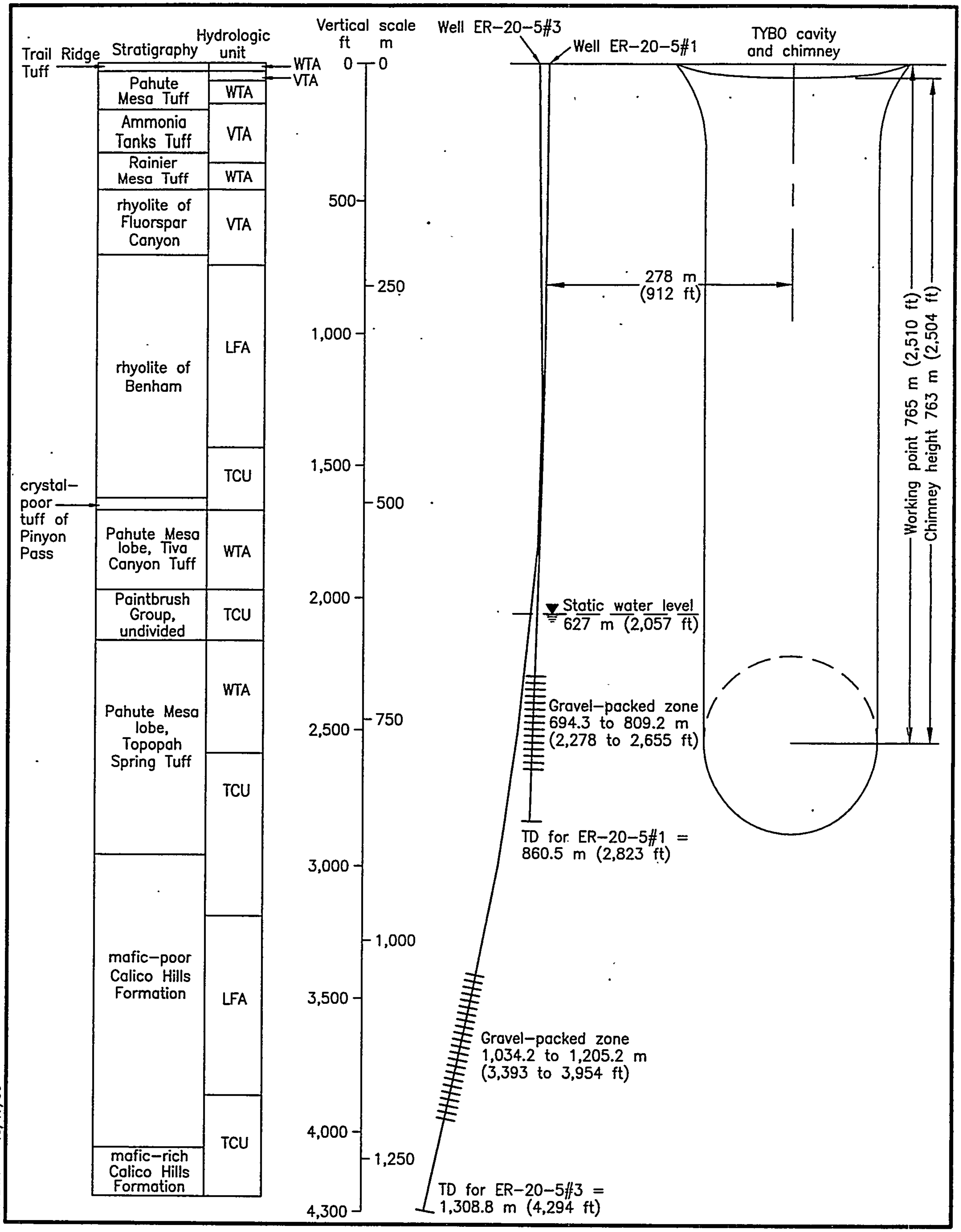

Figure 6-3
Southwest-Northeast Diagramatic Section Through TYBO, ER-20-5#1, and ER-20-5#3 Showing Completion Zones

Table 6-1
Well Cluster ER-20-5 Actual Versus Planned Costs

Activity	Cluster Well ER-20-5	Planned Cost	Actual Cost	Percent Difference Actual Versus Planned
Drilling contractor	#1	$339,600	$463,100	36.4
	#2	$339,600	$462,352	36.1
	#3	$519,600	$977,242	88.1
Subtotal		*$1,198,800*	*$1,902,694*[a]	*58.7*
Support contractor	#1	$722,543	$970,585	34.3
	#2	$722,543	$302,779	-58.1
	#3	$940,435	$1,604,062	70.6
Subtotal		*$2,385,521*	*$2,877,426*[b]	*-20.6*
Total		**$3,584,321**	**$4,780,120**	**33.4**

[a]Source: DOE/ERD
[b]Source: BN Drilling

groundwater monitoring of the wells (whose completion intervals lie approximately 1.8 to .7 cavity radii from the edge of the TYBO chimney) will further the goals of the UGTA near-field drilling program. The effort should be made to reenter the 2⅞-in. fiberglass access line dropped in Well ER-20-5#3 (all indications are that the line is open). The line would then be useable for water-level measurements.

The following paragraphs describe additional work needed to further interpret the geologic, hydrologic, and geophysical data gathered during drilling and completion of Wells ER-20-5#1, #2, and #3.

Identification of Other Radionuclides

Samples of drilling effluent and spectral gamma logs should be analyzed to determine what radionuclides (if any) in addition to tritium are present in the groundwater at the TYBO site.

Noble Gas Tracer Study

Krypton and a neon-xenon mix added to the drilling air may provide an additional means to determine the status of well development and provide a way to track groundwater movements between the wells. Sampling and analysis required for this study should be pursued during well development.

Matrix Permeability Studies
Tests on sidewall samples planned by scientists at Los Alamos and Lawrence Livermore National Laboratories should be pursued to provide data about how radionuclides might migrate through or be attenuated by the rock matrix (in addition to migration through fractures).

Hydrologic Characterization of Western Area 20
Geologic and hydrogeologic data from Well Cluster ER-20-5 should be analyzed to further identify and characterize the postulated potentiometric trough that trends roughly north-south along the western boundary of Area 20. This analysis might also more precisely define groundwater flow directions and velocities.

6.3 Lessons Learned

Lessons learned during construction of each well are addressed in the appropriate section of this report. This section describes lessons learned during the Well Cluster ER-20-5 operation which may be unique to near-field drilling projects.

Drilling
It was found that keeping the penetration rate to no greater than about 6 m/hr (20 ft/hr) below the water table improved the collection and timely analysis of fluid samples for tritium contamination and improved the quality of the drill cuttings used for geologic interpretation. However, maintaining a lower rate of penetration increases the total water produced during drilling, which could necessitate building supplemental sump volume to handle water produced during development and testing. Also, lower penetration rates increase the time to reach TD and, therefore, increase the cost of the project. Thus, evaluation of several trade-offs affect the decision to limit penetration rates during drilling.

Borehole deviation was not specified as a concern in advance of drilling at Well Cluster ER-20-5. However, severe borehole deviation can be a potentially serious problem in a near-field drilling project and should be kept to a minimum. The following are some possible difficulties that could be encountered as a result of severe borehole deviation:

- If the hole drifts toward the cavity, the chance of encountering higher than anticipated concentrations of radionuclides increases.
- Deviation of closely spaced holes could significantly impact hydrologic testing.

- In this case, the difference between the drilled and actual depths will have to be addressed every time any analysis is done using borehole depths for interpretation of hydrologic or geologic data.

It was found that using flanges instead of victaulic fittings at flow-line connections would provide a stronger coupling to withstand high-pressure surges.

The need for additional sump volume was recognized early in the Well Cluster ER-20-5 project, but drilling delays were experienced during construction of the new sumps. Planning of lined storage capacity should allow for a reserve capacity to accommodate unexpectedly high or prolonged water production.

Completion
Difficulties with the installation of Moyno® pumps appeared to be primarily a result of the underestimated stretch of the drive rod string used to insert the rotor into the stator. Efforts are underway to determine correct stretch factors and installation procedures for pump rotors.

Better methods for handling fiberglass tubing must be developed if fiberglass remains the material of choice for completing wells.

The use of a subcontract casing crew to install casing and completion tubulars should be considered for future operations to improve safety, speed, and efficiency of the operation.

Planning
Given the lead time necessary for some types of training (i.e., Hazardous-Site Worker and RadWorker II) training requirements should be planned in advance for all personnel who might be needed at the site.

Drilling, cementing, and completion plans frequently were not available for review prior to initiating work. Time for preparation and adequate review of operations documents should be built into work schedules.

It was found that better communication between scientific personnel in the office and field personnel who are implementing and documenting completion construction is required. Sometimes office personnel (hydrologists) were not informed of changes to completion designs made in the field.

Better use of available geologic expertise might have prevented confusion in determining casing point locations.

7.0 References

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Appendix A
Drilling Data

A-1 Well Cluster ER-20-5 List of Records of Verbal Communication

A-2 Well Cluster ER-20-5 Drilling Parameter Logs

A-3 Well Cluster ER-20-5 Casing and Tubing Data

A-4 Well Cluster ER-20-5 Drilling Fluids and Cement Composition

Appendix A-1

Well Cluster ER-20-5
List of Records of Verbal Communication

A-1
List of Raytheon Services Nevada and Bechtel Nevada Corporation Records of Verbal Communication for Well Cluster ER-20-5 Drilling and Completion
(Page 1 of 2)

RVC#	Date	Subject
RVC-0420	07/03/95	Equipment for Energy Dissipators at UGTA Operable Unit Well ER-20-5
RVC-0431	10/04/95	Water Test of Double-lined Sump at UGTA Well ER-20-5
RVC-0432	10/05/95	Conductor Casing for Three Wells at UGTA Well ER-20-5
RVC-0433	10/06/95	Surface Casing at UGTA Well ER-20-5#1
RVC-0434	10/24/95	Satellite Accumulation Area at UGTA Well ER-20-5
RVC-0435	10/30/95	Tubular Support for UGTA Well ER-20-5#1
RVC-0436	10/31/95	Additional Portable Toilet & Cleaning: ER-20-5
RVC-0437	10/31/95	Shipment of Contaminated Samples from UGTA Wells
RVC-0439	10/31/95	Pumps Required at UGTA Well ER-20-5
RVC-0440	10/31/95	Stemming Materials for UGTA Wells ER-20-5#1 and #2
RVC-0440A	11/01/95	Stemming Materials for UGTA Well ER-20-5
RVC-0441	11/02/95	Slips for UGTA Fiberglass Tubing use
RVC-0442	11/02/95	Completion of UGTA Well ER-20-5#1
RVC-0443	11/05/95	Completion Casing, Tubing & Stemming Depths: ER-20-5#1
RVC-0444	11/06/95	Change in Fiberglass Tubing Setting at UGTA ER-20-5#1
RVC-0445	11/08/95	Setting the No-Turn Tools®
RVC-0446	11/15/95	16-in. Outside Diameter Casing and Tools for UGTA Well ER-20-5#2
RVC-0447	11/16/95	2⅞-in. Elevators Modification to Fit 2⅞-in. Fiberglass Tubing
RVC-0448	11/21/95	Aluminum Tripods for IT Corp.
RVC-0449	11/21/95	Shipment of UGTA Tubulars for Perforations/Screens
RVC-0450	11/21/95	REECo Cementing Services: UGTA Support Work
RVC-0451	11/27/95	Shipment of Tubulars for Repairs/Modifications
RVC-0452	11/27/95	Tubulars/Equipment to be Transported to ER-20-5
RVC-0453	11/28/95	Road Maintenance for UGTA Wellsite ER-20-5
RVC-0454	11/28/95	Second Set of 2⅞-in. Slip Dies for Star Fiberglass Tubing
RVC-0455	12/04/95	Cleaning of Tubulars for UGTA WELL ER-20-5#3
RVC-0456	12/05/95	Additional Sump Construction/Lining at UGTA Well ER-20-5
RVC-0457	12/11/95	Transportation & Cleaning of 20-in. Outside Diameter Casing from YMP
RVC-0458	12/12/95	Overtime Authorization for Infiltration Basin Sumps: ER-20-5
RVC-0459	01/08/96	ER-20-5#3 Casing and Cementing Programs

A-1
List of Raytheon Services Nevada and Bechtel Nevada Corporation Records of Verbal Communication for Well Cluster ER-20-5 Drilling and Completion
(Page 2 of 2)

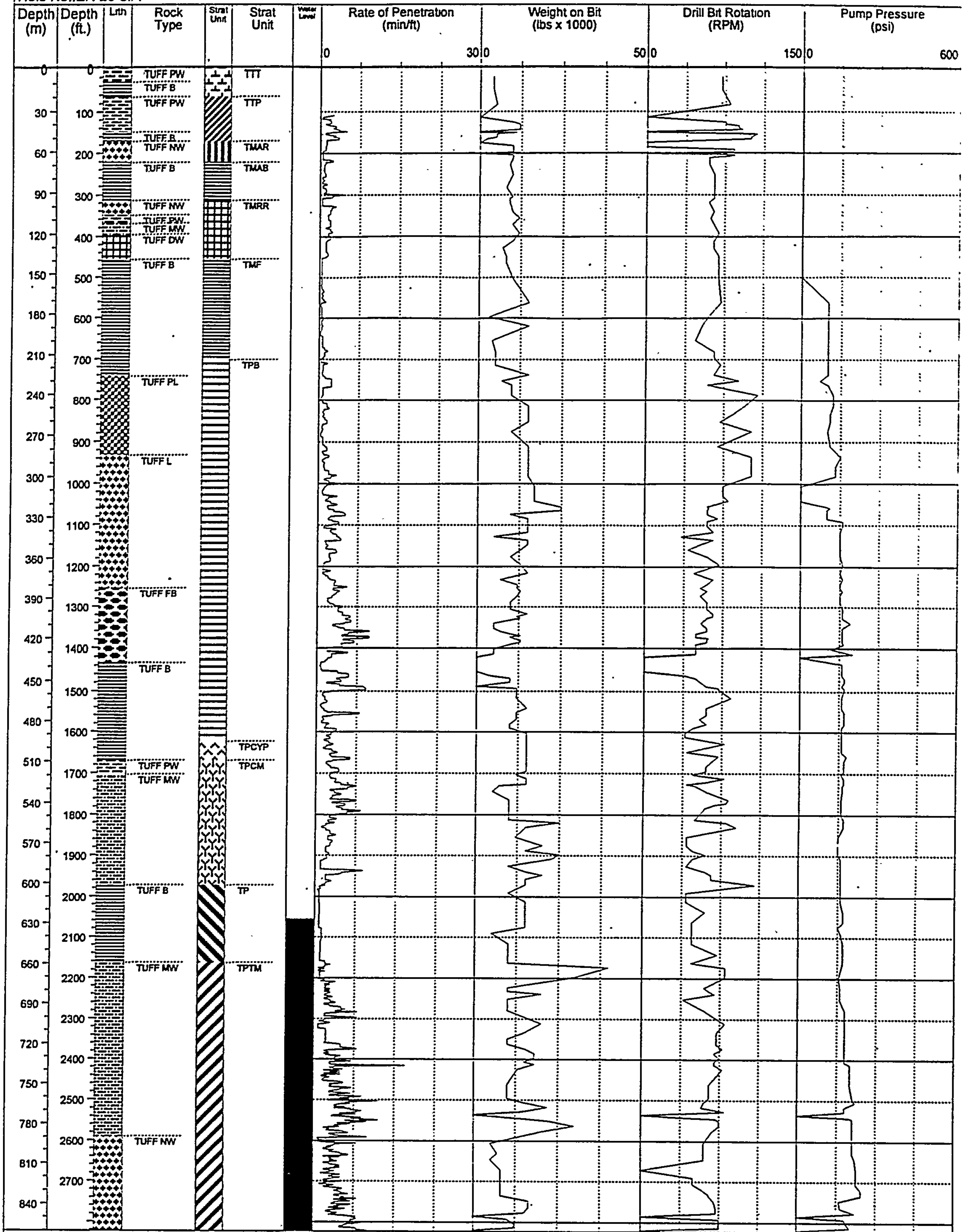
RVC#	Date	Subject
RVC-0460	01/08/96	Documentation of Approval for Cementing Equipment: ER-20-5#3
RVC-0461	01/18/96	Tritium Monitoring/Analyzing at UGTA Well ER-20-5
RVC-D:001:96	01/25/96	Overtime Authorization for Construction of Sump #7
RVC-D:002:96	01/25/96	Borrow Dirt for Berm Construction at Sump #7: ER-20-5
RVC-D:003:96	02/10/96	Completion of ER-20-5#3
RVC-D:004:96	02/10/96	Casing Transport and Cleaning

Appendix A-2

Well Cluster ER-20-5 Drilling Parameter Logs

Drilling Parameters

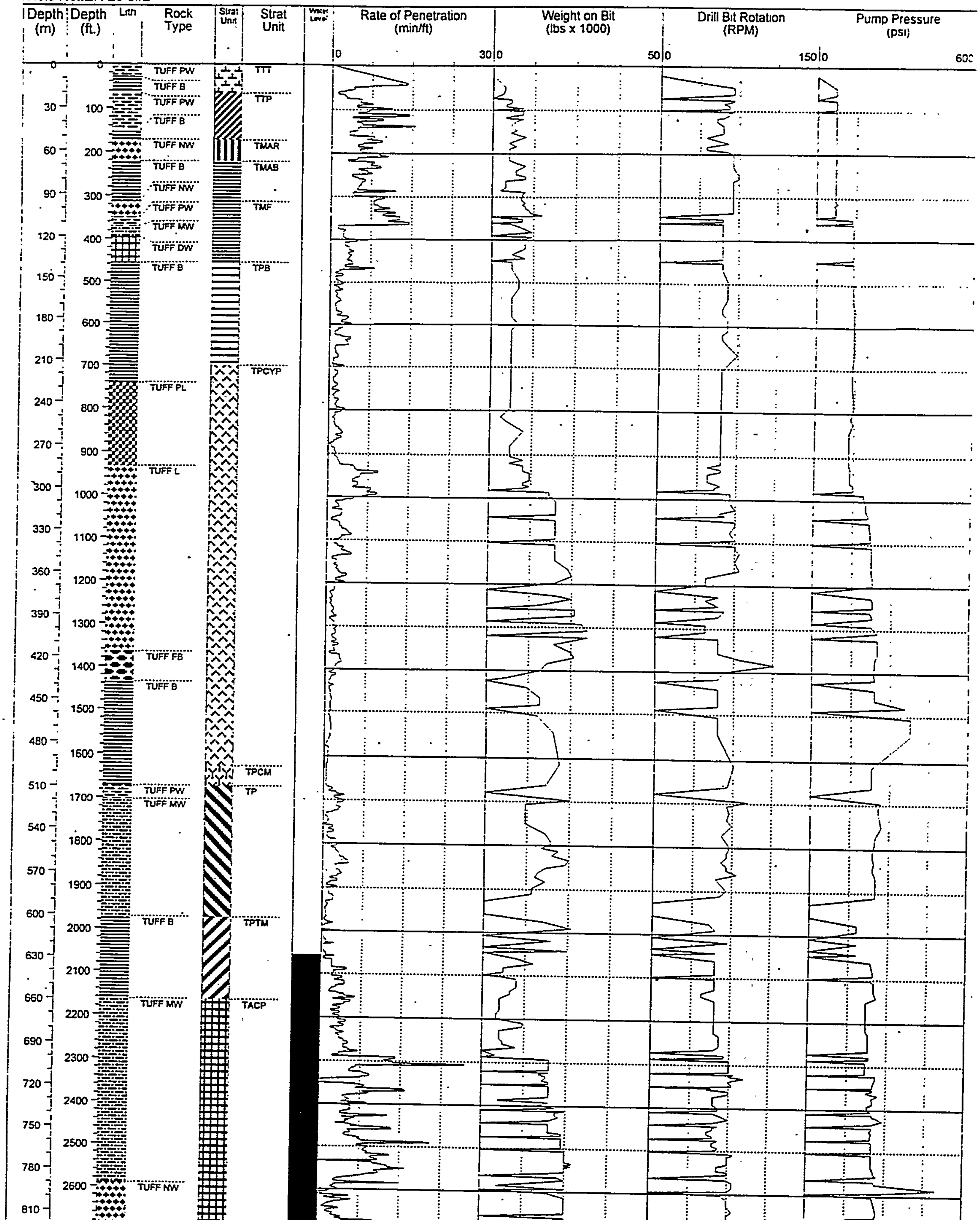
Hole No.:ER-20-5#1



See Appendix C for additional lithologic and stratigraphic data

Drilling Parameters

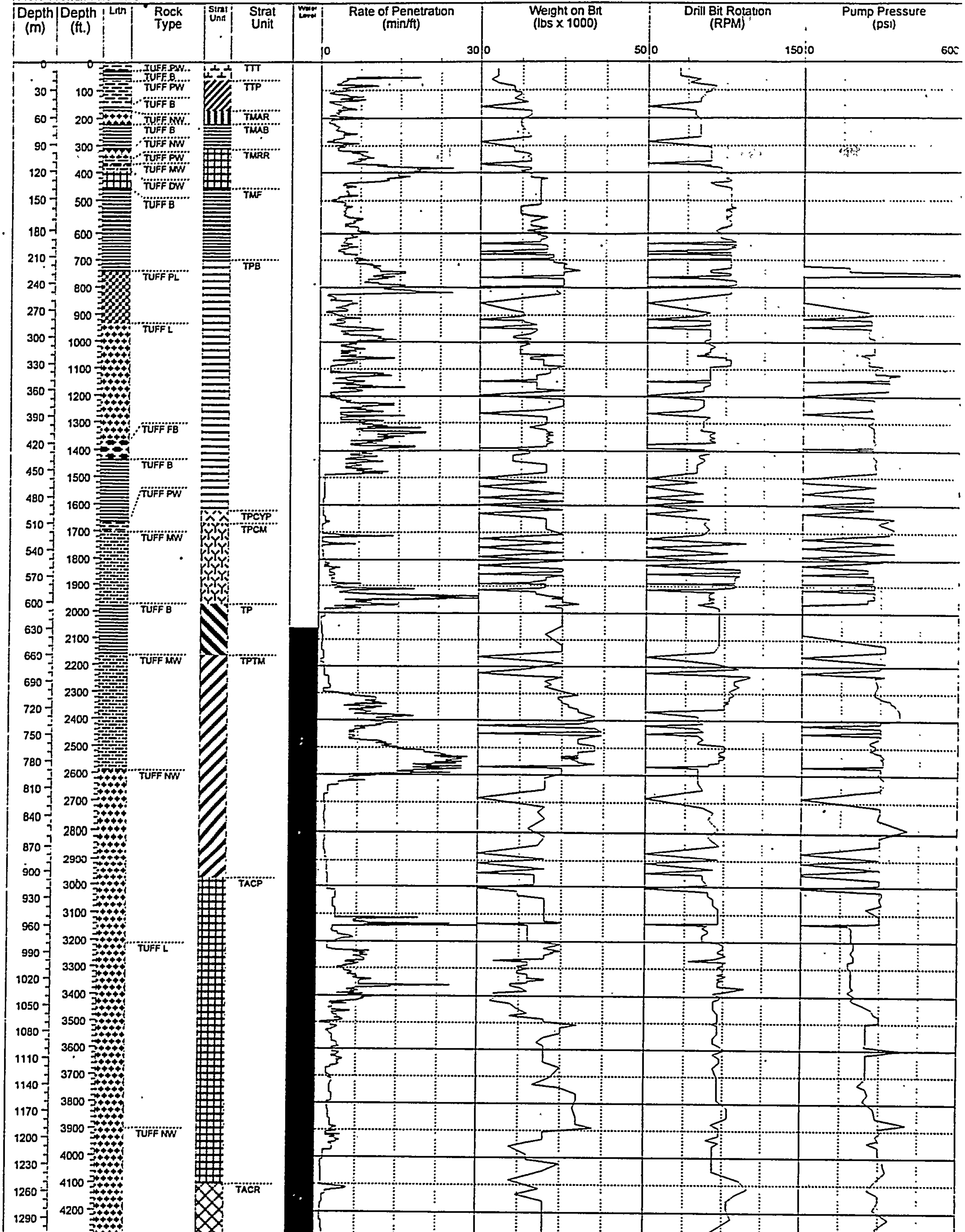
Hole No.:ER-20-5#2



See Appendix C for additional lithologic and stratigraphic data

Drilling Parameters

Hole No.:ER-20-5#3



See Appendix C for additional lithologic and stratigraphic data

Appendix A-3

Well Cluster ER-20-5
Casing and Tubing Data

Table A 3-1
Casing and Tubing Data for Well ER-20-5#1

Casing and Tubing	Depth Interval meters (feet)	Type	Grade	Outside Diameter (inches)	Inside Diameter centimeters (inches)	Wall centimeters (inches)	Weight per foot (pound/foot)
Conductor Casing	0 to 3.4 (0 to 11.0)	Carbon steel	K-55	30	74.30 (29.25)	0.95 (0.375)	98.93
Surface Casing	0 to 62.2 (0 to 204.1)	Carbon steel	J-55	20	48.26 (19.0)	1.27 (0.5)	94.0
5½-inch Casing	0 to 793.4 (0 to 2,603.0)	Stainless steel	T304L	5½	12.82 (5.047)	0.58 (0.227)	14.6
Pump String	0 to 690.4 (0 to 2,265.1)	Stainless steel	T304	2⅞	5.0 (2.323)	0.70 (0.276)	7.66
Drive Rod String (pump rotor on end of string)	0 to 688.5 m (0 to 2,258.7 ft)	Solid carbon-steel rod	Grade D Coated with 3M Skotchkote SC-135	⅞	Not applicable	Not applicable	2.20
Access String	0 to 785.1 (0 to 2,373.7)	Fiberglass	Smith Fiberglass Products	2⅞	6.17 (2.43)	0.58 (0.23)	2.14

Table A 3-2
Casing and Tubing Data for Well ER-20-5#2

Casing	Depth Interval meters (feet)	Type	Grade	Outside Diameter (inches)	Inside Diameter centimeters (inches)	Wall centimeters (inches)	Weight per foot (pound/foot)
Conductor Casing	0 to 3.4 (0 to 11.0)	Carbon steel	K-55	30	74.3 (29.25)	0.95 (0.375)	98.93
Surface Casing	0 to 105.4 (0 to 345.8)	Carbon steel	J-55	16	38.7 (15.25)	0.95 (0.375)	65.0

Table A 3-3
Casing and Tubing Data for Well ER-20-5#3

Casing and Tubing	Depth Interval meters (feet)	Type	Grade	Outside Diameter (inches)	Inside Diameter centimeters (inches)	Wall centimeters (inches)	Weight per foot (pound/foot)
Conductor Casing	0 to 3.4 (0 to 11.0)	Carbon steel	K-55	30	74.30 (29.25)	0.95 (0.375)	98.93
Surface Casing	0 to 250.9 (0 to 823.2)	Carbon steel	J-55	20	48.26 (19.0)	1.27 (0.5)	94.0
Intermediate Casing	0 to 950.0 (0 to 3,116.8)	Carbon steel	K-55	13⅜	32.04 (12.61)	0.97 (0.38)	54.5
5½-inch Casing	0 to 1,192.9 (0 to 3,913.7)	Stainless steel	T304L	5½	12.82 (5.05)	0.58 (0.227)	14.6
Pump String	0 to 1,038.3 (0 to 3,406.5)	Stainless steel	T304	2⅞	5.90 (2.323)	0.70 (0.276)	7.66
Drive Rod String (pump rotor on end of string)	0 to 1,035.9 (0 to 3,398.5)	Solid carbon-steel rod	Grade D Coated with 3M Scotchkote SC-135	⅞	Not applicable	Not applicable	2.20
Access String	977.0 m (3,205.4 ft) dropped down-hole	Fiberglass	Star Fiberglass Systems	2⅞	5.99 (2.36)	0.58 (0.23)	2.14

Appendix A-4

Well Cluster ER-20-5
Drilling Fluids and Cement Composition

Table A 4-1
Well ER-20-5#1 Drilling Fluids

Viscosifier (Mud)	Viscosifier/ Polymer/LCM[a] (Typical[b])	Viscosifier/LCM (Typical[b])	Air-Foam (Typical[c])	Air-foam/Polymer (Typical[d])
Quik-Gel® [e]	1,928 kg[f] (4,250 lb[g]) Quik-Gel® 0.019 m^3 [h] (5 gal [i]) EZ-Mud Plus® [e] Maxi-Seal® [j] 18 kg (40 lb) Cedar Fiber	907 kg (2,000 lb) Quik-Gel® 363 kg (800 lb) Cedar Fiber	0.011 to 0.015 m^3 (3-4 gal) Quik-Foam® [e] per 7.9 m^3 (50 bbl[k]) water	0.019 m^3 (5 gal) Quik-Foam® and 0.006 m^3 (1.5 gal) EZ-Mud Plus® per 7.9 m^3 (50 bbl) water

[a]Lost circulation material
[b]Various proportions of viscosifier (gel), polymer, and LCM were used in drilling the first 64.9 m (213 ft) of the hole.
[c]Air-foam, made up with various proportions of Quik-Foam®, was used as the drilling fluid from 64.9 m (213 ft) to TD.
[d]Various proportions of polymer were added to suit conditions during air-foam drilling.
[e]Quik-Gel®, EZ-Mud Plus®, and Quik-Foam® are products of Baroid Drilling Fluids, Inc.
[f]Kilograms
[g]Pounds
[h]Cubic meters
[i]Gallons
[j]Maxi-Seal is a product of Agri-Empressa
[k]Barrels

Notes: 1. All water used to mix drilling fluids for Well ER-20-5#1 came from Water Well 20.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 20 to 40 milligrams per liter.

Table A 4-2
Well ER-20-5#1 Cement Composition

Cement Composition	Conductor Casing	Surface Casing	Bottom Plug	Completion
Type II	Top 1.2 m[a] (4 ft[b])	In annulus: 0 to 63.1 m (0 to 207 ft)	Not used	Not used
Type II plus 2% $CaCl_2$ [c]	Lower 1.8 m (6 ft)	Not used	809.2 to 823.6 m (2,603.0 to 2,702 ft)	97.5 to 198.4 m (320 to 651 ft) 206.7 to 685.5 m (678 to 2,249 ft) 809.2 to 824.5 m (2,265 to 2,705 ft)
Type II plus 4% bentonite	Not used	In annulus: 30.2 to 63.1 m (99 to 207 ft)	Not used	Not used

[a]Meters
[b]Feet
[c]Calcium chloride

Table A 4-3
Well ER-20-5#2 Drilling Fluids

Mud (Typical[a])	Air-Foam (Typical[b])	Air-foam/Polymer (Typical[c])
1,928 kg[d] (4,250 lb[e]) Quik-Gel® [f] 0.019 m^3 [g] (5 gal [h]) EZ-Mud Plus® [f] 18 kg (40 lb) Cedar Fiber	0.011 to 0.015 m^3 (3-4 gal) Quik-Foam® [f] per 7.9 m^3 (50 bbl[i]) water	0.011 to 0.015 m^3 (3-4 gal) Quik-Foam® and 0.006 m^3 (2 gal) EZ-Mud Plus® per 7.9 m^3 (50 bbl) water

[a] Various proportions of viscosifier (gel), polymer, and LCM were used in drilling the first 106.1 m (348 ft) of hole.
[b] Air-foam, made with various proportions of Quik-Foam®, was used as the drilling fluid from 106.1 m (348 ft) to TD.
[c] Various proportions of polymer were added to suit conditions during air-foam drilling.
[d] Kilograms
[e] Pounds
[f] Quik-Gel®, EZ-Mud Plus®, and Quik-Foam® are products of Baroid Drilling Fluids, Inc.
[g] Cubic meters
[h] Gallons
[i] Barrels

Notes: 1. All water used to mix drilling fluids for Well ER-20-5#2 came from Water Well 20.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 20 to 40 milligrams per liter.

Table A 4-4
Well ER-20-5#2 Cement Composition

Cement Composition	Conductor Casing	Surface Casing	Borehole Backfill
Type II	Top 0.9 m[a] (3 ft[b])	Not used	Not used
Type II plus 2% $CaCl_2$[c]	Lower 2.1 m (7 ft)	In annulus: 0 to 106.1 m (0 to 348 ft)	8.5 m^3 (300 ft^3) on top of fish at 552.6 m (1,813 ft) and on top of gravel to 541.9 m (1,778 ft) and 19.8 m (65 ft) to surface
Type II plus 3% $CaCl_2$	Not used	Not used	7.1 m^3 (250 ft^3) 500.8 to 541.9 m (1,643-1,778 ft)
⅜-inch gravel	Not used	Not used	907 kg[c] (2,000 lb[d]) on top of fish at 552.6 m (1,813 ft)

[a] Meters
[b] Feet
[c] Calcium chloride
[d] Pounds

Table A 4-5
Well ER-20-5#3 Drilling Fluids

Mud[a]	Mud/LCM[b] (Typical[c])	Air-Foam (Typical[d])	Air-Foam/Polymer (Typical[e])
Quik-Gel®[f] 907 kg (2,000 lb)	Quik-Gel® 907 kg[g] (2,000 lb[h]) Cottonseed Hulls	0.019 to 0.030 m^3[i] (5-8 gal[j]) Quik-Foam®[f] per 7.9 m^3 (50 bbl[h]) water	0.019 m^3 (5 gal) Quik-Foam® and 0.006 m^3 (1.5 gal) EZ-Mud Plus®[f] per 7.9 m^3 (50 bbl[k]) water

[a] Mud used to drill from 3.4 to 22.6 m (11-74 ft)
[b] Lost circulation material
[c] Various proportions of viscosifier and LCM were used in drilling from 22.6 to 252.1 m (74-827 ft).
[d] Air-foam, made with various proportions of Quik-Foam®, was used as the drilling fluid from 252.1 m (827 ft) to TD.
[e] Various proportions of polymer were added to suit conditions during air-foam drilling.
[f] Quik-Gel®, EZ-Mud Plus®, and Quik-Foam® are products of Baroid Drilling Fluids, Inc.
[g] Kilograms
[h] Pounds
[i] Cubic meters
[j] Gallons
[k] Barrels

Notes: 1. All water used to mix drilling fluids for Well ER-20-5#3 came from Water Well 20.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 20 to 40 milligrams per liter.

Table A 4-6
Well ER-20-5#3 Cement Composition

Cement Composition	Conductor Casing	Surface Casing	Intermediate Casing	Bottom Plug	Completion
3/8-inch gravel	Not used	Not used	In annulus: Approximately 227 kg[a] (500 lb[b]) on top of cement basket at 31.6 m[c] (103.6 ft[d])	Not used	Not used
Cedar fiber	Not used	Not used	In annulus: 15.5 to 20.4 m (51 to 67 ft)	Not used	Not used
Type II	Top 0.9 m (3 ft)	Not used	In annulus: 13.7 to 15.5 m) (45 to 51 ft)	Not used	Not used
Type II plus 2% $CaCl_2$[e]	Lower 2.1 m (7 ft)	In annulus: 0 to 252.1 m (0 to 827 ft)	In annulus: On top of gravel to 22.9 m (75 ft) and 0.3 to 13.7 m (1 to 45 ft) and approximately 751.1 to 955.5 m (2,464.1 to 3,135 ft)[f]	1,205.2 to 1,229.6 m (3,954 to 4,034 ft)	625.4 to 1,020.5 m (2,052 to 3,348 ft)
Type II plus 4% bentonite	Not used	Not used	In annulus: approximately 751.1 to 955.5 m (2,464.1 to 3,135 ft)[f]	Not used	Not used
Haliburton Services Micro Matrix Cement	Not used	Not used	In annulus: approximately 751.1 to 955.5 m (2,464.1 to 3,135 ft)[f]	Not used	Not used

[a] Kilograms
[b] Pounds
[c] Meters
[d] Feet
[e] Calcium chloride
[f] Numerous efforts were made to cement the intermediate casing through the upper cement port on the multiple stage cementing tool, located at 751.1 m (2,464.1 ft). Some cement was lost to the formation. It is not possible to determine exactly which cements were emplaced at which location within this interval.

Appendix B

Well Cluster ER-20-5 Fluid Management Status Reports and Tritium Data

ER FLUID DISPOSITION STATUS REPORTING FORM

Site Identification: ER-20-5-#1
Site Location: NTS, Area 20
Site Coordinates: N899133.6, E555173.9
Well Classification: Near Field
IT Project No: 764029.04.02.01.00

Report Date: 7/31/96
DOE/NV Acting Sub-Project Manager: B. Bangerter
IT Project Manager: J. Eberlin
IT Site Representative: Jeff Wurtz
IT Waste Coordinator: Terre Maize

Well Construction Activity	Activity Duration		#Ops.Days (A)	Well Depth (m)	Sump #1 (m^3) (lined/north)		Sump #2 (m^3) (lined/south)		Infiltration (m^3) to Ground Surface
	From	To			Solids (B)	Liquid	Solids	Liquid	Liquids
Stage I: Vadose-Zone Drilling	10/16/95	10/30/95	9	628	95	276	NA	NA	NA
Stage II: Saturated-Zone Drilling	10/30/95	10/30/95	4	861	6	27	20	608	NA
Stage III: Initial Well Development	12/23/95	12/23/95	1	NA	NA	NA	NA	18	NA
Stage IV: Final Development									
Stage V: Aquifer Testing									
Cumulative Production Totals to Date: 11/02/95			14	861	101	303	20	626	NA

(A) Operational days refer to the number of days that the drill rig was in operation during at least part of one shift.
(B) Solids volume estimates include calculated added volume attributed to rock bulking factors.

NA = Not Applicable; m = meters; m^3 = cubic meters; AIP = Analysis in Process

Tritium Curie Inventory as of 2/7/96: Sump #1 (lined) = 0.03, Sump #2 (double-lined) = 0.14, Sump #3 (lined) = 82, Sump #4 (lined) = 113, Sump #5 (lined) = 171, Sump #6 (lined) = 19.
Total Device Capacities (m^3): Sump #1 = 1700, Sump #2 = 1700, Sump #3 = 1700, Sump #4 = 1700, Sump #5 & #6 = 3860 each, Sump #7 = 4800.
Remaining Device Capacity (m^3)(Approximate) as of 02/07/96: Sump #1 = 638, Sump #2 = 1194, Sump #3 = 442, Sump #4 = 3, Sump #5 =997, Sump #6 = 546, Sump #7 = 4800.

IT Authorizing Signature/Date John Eberlin 8/5/96

ER FLUID DISPOSITION STATUS REPORTING FORM

Site Identification: ER-20-5-#2
Site Location: NTS, Area 20
Site Coordinates: N899037.7, E555095.9
Well Classification: Near Field
IT Project No: 764029.04.02.01.00

Report Date: 7/31/96
DOE/NV Acting Sub-Project Manager: B. Bangerter
IT Project Manager: J. Eberlin
IT Site Representative: Jeff Wurtz
IT Waste Coordinator: Terre Maize

Well Construction Activity	Activity Duration		#OpsDays (A)	Well Depth (m)	Sump #1 (m^3) (lined/north)		Sump #2 (m^3) (lined/south)		Sump #3 (m^3) (lined/west)		Infiltratio (m^3) to Ground Surface
	From	To			Solids (B)	Liquid	Solids	Liquid	Solids	Liquid	Liquids
Stage I: Vadose-Zone Drilling	11/18/95	11/28/95	11	628	108	305	NA	NA	NA	NA	254
Stage II: Saturated-Zone Drilling	11/28/95	11/30/95	2	809	6	12	16	290	148	1616	NA
Stage III: Initial Well Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stage IV: Final Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stage V: Aquifer Testing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Production Totals to Date: 12/07/95			13	809	215*	366[1]	36*	290*	762[2]	1616[3]	254

(A) Operational days refer to the number of days that the drill rig was in operation during at least part of one shift.
(B) Solids volume estimates include calculated added volume attributed to rock bulking factors.

NA = Not Applicable; m = meters; m^3 = cubic meters; AIP = Analysis In Process

*These totals also include the volumes from Well ER-20-5 #1.
[1]Fluids total represents volume less 254 m^3 released to ground surface. [2]Volume represents transferred fluids from Sump #2 generated from Wells ER-20-5 #1 & #2.
[3]Volume represents transferred fluids from Sump #2 to Sump #4

Well plugged and abandoned.

Tritium Curie Inventory: Sump #1 (lined) = 0.03 , Sump #2 (double-lined) = 0.14, Sump #3 (lined) = 82, Sump #4 (lined) = 113.
Total Device Capacities (m^3): Sump #1 through Sump #4 = 1700 each. Sump #5 and #6 = 3860 each.
Remaining Device Capacity (m^3) (Approximate) as of 02/07/96: Sump #1 = 1119, Sump #2 = 1374, Sump #3 = 934, Sump #4 = 84.

IT Authorizing Signature/Date: John Eberlin 8/5/96

ER FLUID DISPOSITION STATUS REPORTING FORM

Site Identification: ER-20-5-#3
Site Location: NTS, Area 20
Site Coordinates: N889031.1, E555169.7
Well Classification: Near Field
IT Project No: 764029.04.01.01.00

Report Date: 7/31/96
DOE/NV Acting Sub-Project Manager: B. Bangerter
IT Project Manager: J. Eberlin
IT Site Representative: Jeff Wurtz
IT Waste Coordinator: Terre Maize

Well Construction Activity	Activity Duration		#OpsDays (A)	Well Depth (m)	Sump #1 (m^3) (lined/north)		Sump #2 (m^3) (lined/south)		Sump #3 (m^3) (lined/west)		Sumps #4-#6 (m^3) (lined/east)		Infiltration (m^3) to Ground Surface
	From	To			Solids (B)	Liquid	Solids	Liquid	Solids	Liquid	Solids	Liquid	Liquids
Stage I: Vadose-Zone Drilling	12/13/95	01/01/96	15	628	188	460	NA	NA	NA	NA	NA	NA	NA
Stage II: Saturated-Zone Drilling	01/01/96	02/05/96	18	1309	8	9	109	762	202	81	2865	3249	NA
Stage III: Initial Well Development	02/15/96	02/15/96	1	1309	NA	NA	NA	30	NA	NA	NA	NA	NA
Stage IV: Final Development													
Stage V: Aquifer Testing													
Cumulative Production Totals to Date: 02/06/96			34	1309	312*	835*	145*	792*	1258*	1697*	2865[4]	3249[4]	NA

(A) Operational days refer to the number of days that the drill rig was in operation during at least part of one shift.
(B) Solids volume estimates include calculated added volume attributed to rock bulking factors.

NA = Not Applicable; m = meters; m^3 = cubic meters; AIP = Analysis In Process

*These totals also include the volumes from Well ER-20-5 #2.

[4]Fluid volumes resulting from ER-20-5 #3 saturated drilling only.

Tritium Curie Inventory as of 2/7/96: Sump #1 (lined) = 0.03, Sump #2 (double-lined) = 0.14, Sump #3 (lined) = 82, Sump #4 (lined) = 113, Sump #5 (lined) = 171, Sump #6 (lined) = 19.
Total Device Capacities (m^3): Sump #1 through Sump #4 = 1700 each. Sump #5 & #6 = 3860 each.
Remaining Device Capacity (m^3) (Approximate) as of 02/07/96: Sump #1 = 553, Sump #2 = 793,, Sump #3 = 442, Sump #4 = 3, Sump #5 = 995, Sump #6 =661.

IT Authorizing Signature/Date: John Eberlin 8/5/96

UGTA Analytical Fluid Sample Results, ER-20-5

Site	Sample No.	Sample Date	Gross Alpha	Error	Gross Beta	Error	Tritium	Error	Arsenic	Q	Barium	Q	Cadmium	Q	Chromium	Q	Lead	Q	Selenium	Q	Silver	Q	Mercury	Q
			pCi/L	(±)	pCi/L	(±)	pCi/L	(±)	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
ER-20-5#1	GCP00340	10/26/95					-236	156																
ER-20-5#1	GCP00341	10/26/95	34.1	7.0	17.2	5.6																	0.45	
ER-20-5#1	GCP00341 - Totals								165		1200		7.8		448		544		7.9		6.0	U		
ER-20-5#1	GCP00342	10/28/95	-0.32	0.60	-0.18	0.80																	0.10	U
ER-20-5#1	GCP00342 - Totals								3.1	U	2.4	B	2.3	U	3.7	U	2.2	B	2.6	U	6.0	U		
ER-20-5#1	GCP00343	10/29/95	52.2	9.9	42	5.5	-117	147															0.22	
ER-20-5#1	GCP00343 - Totals								31.0	U	186	B	3.0	U	27.0	U	119		30.8	B	5.0	U	0.24	
ER-20-5#1	GCP00343 - Dissolved								31.0	U	94.6	B	3.0	U	27.0	U	73.0		26.0	U	5.0	U		
ER-20-5#1	GCP00344	10/30/95	24.5	5.8	14.4	5.3																	0.30	
ER-20-5#1	GCP00344 - Totals								121		167	B	2.3	U	31.5		66.0		2.6	U	6.0	U		
ER-20-5#1	GCP00345	10/30/95	186	26	110	13																	0.58	
ER-20-5#1	GCP00345 - Totals								441		519	B	3.0	U	27.0	U	161		30.3	B	5.0	U	0.45	
ER-20-5#1	GCP00345 - Dissolved								385		546	B	3.0	U	27.0	U	169		26.0	U	5.0	U		
ER-20-5#1	GCP00346	10/30/95					753000	75300																
ER-20-5#1	GCP00347	11/8/95	141	26	31.0	5.8	52500	5250																
ER-20-5#2	GCP00348	11/19/95	-0.14	0.53	0.004	0.26																	0.10	U
ER-20-5#2	GCP00348 - Totals								3.1	U	2.9	B	0.30	U	2.7	U	1.4	B	2.6	U	0.50	U		
ER-20-5#1	GCP00349	11/21/95	23.7	260																				
ER-20-5#2	GCP00350	11/25/96	12.5	4.0	5.74	1.50																	0.19	B
ER-20-5#2	GCP00350 - Totals								132		410		9.6		1360		182		20.4		6.0	U		
ER-20-5#2	GCP00351	11/25/96	28.9	5.7	4.45	1.19																	4.6	
ER-20-5#2	GCP00351 - Totals								179		1120		18.9		757		721		26.0		8.6	B		
ER-20-5#2	GCP00352	11/28/95	19.2	5.1	13.7	3.1																	1.2	
ER-20-5#2	GCP00352 - Totals								1340		876		5.0	U	239		333		5.0	U	10.0	U	0.20	U
	GCP00352 - Dissolved								17.1		59.6	B	5.0	U	20.0	U	27.7		5.0	U	10.0	U		
ER-20-5#2	GCP00353	11/28/95	90.4	12.2	6.58	1.19																	0.17	B
ER-20-5#2	GCP00353 - Totals								6.8	B	17.8	B	2.3	U	8.1	B	5.8		2.6	U	6.0	U		
ER-20-5#2	GCP00354	11/29/95	3.08	2.70	4.39	1.61	303000	30300															0.18	B
ER-20-5#2	GCP00354 - Totals								3.1	U	10.2	B	2.3	U	116		2.8	B	4.7	B	6.0	U	0.15	B
ER-20-5#2	GCP00354 - Dissolved								3.1	U	2.4	B	2.3	U	121		3.6		3.4	B	6.0	U		
ER-20-5#2	GCP00355	11/29/95					28100	2820																

UGTA Analytical Fluid Sample Results, ER-20-5

Site	Sample No.	Sample Date	Gross Alpha	Error	Gross Beta	Error	Tritium	Error	Arsenic	Q	Barium	Q	Cadmium	Q	Chromium	Q	Lead	Q	Selenium	Q	Silver	Q	Mercury	Q
			pCi/L	(±)	pCi/L	(±)	pCi/L	(±)	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
ER-20-5#2	GCP00356 - Totals	11/29/95															1.8	B						
ER-20-5#3	GCP00357	12/26/95	150	24	99.6	12.1																	6.3	
ER-20-5#3	GCP00357 - Totals								247		1440		12.5		904		1080		4.5	U	0.80	U		
ER-20-5#3	GCP00358	12/22/95	-0.44	0.52	0.63	1.10																	1.5	
ER-20-5#3	GCP00358 - Totals								59.1		264		3.2	B	467		246		22.2		0.80	U		
ER-20-5#3	GCP00359	12/30/95					141	182																
ER-20-5#3	GCP00360	1/2/96	8.66	1.50	6.13	0.83																	0.68	
																							0.11	B
ER-20-5#3	GCP00360 - Totals								348		406		3.5	B	235		103		8.9		0.80	U		
ER-20-5#3	GCP00360 - Dissolved								8.6	B	46.4	B	3.4	B	5.1	B	13.4		6.2		0.80	U		
ER-20-5#3	GCP00361	1/2/96	-1.53	1.14	2.09	0.58																	0.13	B
																							0.13	B
ER-20-5#3	GCP00361 - Totals								4.6	U	10.0	B	4.6	B	51.3		1.7	U	5.9		0.80	U		
ER-20-5#3	GCP00361 - Dissolved								4.6	U	7.3	B	1.5	B	51.6		9.3		9.2		0.80	U		
ER-20-5#3	GCP00362	1/2/96					2E+07	2E+06																
ER-20-5#3	GCP00363	1/2/96	67.4	12.0	43.4	5.6																	0.21	
ER-20-5#3	GCP00363 - Totals								14.1		63.4	B	1.3	B	36.2		17.0		4.5	U	0.80	U		
ER-20-5#3	GCP00364	1/5/96	59.2	7.1	37.1	3.9	7E+07	7E+06															0.10	U
ER-20-5#3	GCP00364 - Totals								12.2		59.5	B	5.0		6.8		15.4		6.0		0.80	U		
ER-20-5#3	GCP00365	1/31/96	3.3	7.5	11.7	5.3																	0.10	U
																							0.10	U
ER-20-5#3	GCP00365 - Totals								9.4	B	113	B	0.70		80.0		1310		4.5	U	0.80	U		
ER-20-5#3	GCP00365 - Dissolved								4.6	U	87.1	B	0.70	U	70.3		204		4.5	U	0.80	U		

Key:
Error = 2 Sigma Error
pCi/L = Picocuries per Liter
µg/L = Micrograms per Liter
Q = Laboratory Qualifier
U = Not detected
B = Detected above instrument detection limit, but below reporting limit

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)
2158	657.7	#N/A	20	2493	759.9	61.82	#N/A	2770	844.3	#N/A	150
2168	660.7	#N/A	20	2502	762.5	#N/A	100	2780	847.3	68.68	#N/A
2180	664.5	#N/A	20	2503	762.9	62.15	#N/A	2786	849.2	#N/A	150
2198	670.0	0.00	#N/A	2510	765.0	62.50	#N/A	2787	849.5	#N/A	150
2217	675.8	#N/A	20	2511	765.3	#N/A	100	2789	850.1	65.43	#N/A
2227	678.8	0.00	#N/A	2520	768.1	60.89	#N/A	2794	851.6	78.51	#N/A
2231	680.0	#N/A	20	2525	769.5	#N/A	100	2800	853.4	#N/A	150
2234	680.9	#N/A	20	2525	769.6	55.50	#N/A	2806	855.3	75.55	#N/A
2236	681.5	0.77	#N/A	2531	771.5	#N/A	100	2812	857.1	#N/A	150
2246	684.5	#N/A	30	2539	773.9	60.83	#N/A	2817	858.6	#N/A	150
2255	687.3	1.10	#N/A	2542	774.7	#N/A	100	2818	858.9	75.59	#N/A
2258	688.4	#N/A	30	2544	775.3	#N/A	100				
2261	689.2	2.90	#N/A	2547	776.4	#N/A	100				
2271	692.2	2.73	#N/A	2556	779.1	#N/A	120				
2281	695.2	4.80	#N/A	2557	779.4	56.04	#N/A				
2291	698.3	8.78	#N/A	2565	781.8	58.13	#N/A				
2300	701.0	#N/A	45	2570	783.3	#N/A	120				
2301	701.3	14.30	#N/A	2574	784.6	58.37	#N/A				
2311	704.4	13.40	#N/A	2583	787.3	59.28	#N/A				
2321	707.4	13.10	#N/A	2586	788.3	#N/A	120				
2324	708.2	#N/A	45	2595	791.0	54.09	#N/A				
2330	710.2	15.60	#N/A	2600	792.5	60.65	#N/A				
2340	713.2	12.90	#N/A	2605	794.0	8.17	#N/A				
2345	714.6	#N/A	45	2620	798.6	58.63	#N/A				
2350	716.3	13.20	#N/A	2629	801.3	#N/A	120				
2357	718.3	#N/A	45	2633	802.5	57.19	#N/A				
2360	719.3	17.28	#N/A	2635	803.1	#N/A	120				
2369	722.0	#N/A	50	2641	805.0	53.17	#N/A				
2370	722.4	17.48	#N/A	2649	807.4	57.94	#N/A				
2380	725.5	#N/A	70	2659	810.5	53.75	#N/A				
2383	726.3	2.14	#N/A	2661	811.1	#N/A	120				
2391	728.7	#N/A	70	2667	812.9	56.40	#N/A				
2393	729.4	49.72	#N/A	2682	817.5	54.03	#N/A				
2401	731.8	51.19	#N/A	2684	818.1	#N/A	140				
2403	732.4	#N/A	70	2692	820.5	36.88	#N/A				
2410	734.6	#N/A	70	2698	822.4	#N/A	140				
2411	734.9	52.63	#N/A	2698	822.4	42.32	#N/A				
2413	735.5	51.64	#N/A	2708	825.4	55.93	#N/A				
2416	736.2	#N/A	70	2715	827.5	#N/A	150				
2423	738.5	38.31	#N/A	2718	828.4	56.72	#N/A				
2433	741.6	57.69	#N/A	2728	831.5	50.82	#N/A				
2434	741.9	#N/A	80	2730	832.1	#N/A	150				
2443	744.6	61.41	#N/A	2733	833.0	#N/A	150				
2460	749.8	60.77	#N/A	2738	834.5	#N/A	150				
2470	752.9	65.16	#N/A	2740	835.2	62.44	#N/A				
2480	755.9	64.11	#N/A	2750	838.2	57.69	#N/A				
2480	755.9	56.61	#N/A	2758	840.6	64.84	#N/A				
2487	758.0	61.01	#N/A	2760	841.2	#N/A	150				
2490	759.0	#N/A	80	2765	842.8	64.38	#N/A				

Static water level = 626.4 meters (2,055 feet)
pCi/L = picocuries per liter times 10E6
#N/A = no measurement taken

Total depth = 860.5 meters (2,823 feet)
GPM = gallons per minute

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meter	Tritium (pCi/L)*	Water (GPM)
2205	672.1	#N/A	10	2352	716.9	#N/A	14	2498	761.4	#N/A	175
2206	672.4	0.00	#N/A	2353	717.2	36.27	#N/A	2501	762.3	#N/A	175
2214	674.8	#N/A	10	2355	717.8	#N/A	14	2503	762.9	84.90	#N/A
2216	675.4	0.02	#N/A	2357	718.4	#N/A	14	2505	763.5	#N/A	175
2221	677.0	0.54	#N/A	2361	719.6	52.50	#N/A	2506	763.8	83.50	#N/A
2223	677.6	#N/A	10	2364	720.5	#N/A	14	2507	764.1	#N/A	175
2226	678.5	7.88	#N/A	2371	722.7	#N/A	14	2510	765.0	#N/A	175
2231	680.0	#N/A	10	2373	723.3	54.37	#N/A	2513	766.0	98.30	#N/A
2236	681.5	#N/A	10	2377	724.5	#N/A	14	2513	766.0	#N/A	200
2239	682.4	14.85	#N/A	2382	726.0	#N/A	14	2516	766.9	#N/A	200
2242	683.4	#N/A	10	2383	726.3	61.87	#N/A	2518	767.5	#N/A	200
2248	685.2	#N/A	10	2386	727.3	#N/A	14	2520	768.1	111.00	#N/A
2249	685.5	16.00	#N/A	2388	727.9	#N/A	60	2521	768.4	#N/A	200
2254	687.0	#N/A	10	2391	728.8	61.62	#N/A	2525	769.6	115.00	#N/A
2256	687.6	20.26	#N/A	2397	730.6	#N/A	60	2525	769.6	#N/A	220
2260	688.8	#N/A	14	2401	731.8	#N/A	60	2526	769.9	#N/A	220
2263	689.8	21.65	#N/A	2405	733.0	66.37	#N/A	2529	770.8	#N/A	220
2271	692.2	#N/A	14	2410	734.6	#N/A	60	2531	771.4	115.00	#N/A
2273	692.8	#N/A	14	2412	735.2	#N/A	60	2531	771.4	#N/A	220
2274	693.1	66.58	#N/A	2413	735.5	#N/A	60	2534	772.4	#N/A	220
2276	693.7	71.80	#N/A	2416	736.4	66.38	#N/A	2535	772.7	109.00	#N/A
2280	694.9	66.38	#N/A	2419	737.3	#N/A	60	2536	773.0	#N/A	220
2283	695.9	#N/A	14	2423	738.5	#N/A	60	2537	773.3	#N/A	220
2284	696.2	#N/A	14	2427	739.7	70.23	#N/A	2538	773.6	113.00	#N/A
2285	696.5	65.78	#N/A	2432	741.3	#N/A	60	2540	774.0	#N/A	220
2290	698.0	#N/A	14	2434	741.9	90.56	#N/A	2543	775.1	#N/A	220
2291	698.3	59.01	#N/A	2438	743.1	#N/A	60	2545	775.7	116.00	#N/A
2292	698.6	#N/A	14	2442	744.3	#N/A	60	2546	775.9	#N/A	220
2294	699.2	#N/A	14	2443	744.6	#N/A	60	2548	776.7	#N/A	220
2295	699.5	76.42	#N/A	2446	745.5	63.33	#N/A	2550	777.3	#N/A	220
2302	701.6	#N/A	14	2448	746.2	#N/A	100	2551	777.5	114.00	#N/A
2304	702.3	60.88	#N/A	2452	747.4	#N/A	100	2556	779.1	112.00	#N/A
2307	703.2	#N/A	14	2454	748.0	103.92	#N/A	2561	780.6	#N/A	220
2314	705.3	#N/A	14	2459	749.5	#N/A	100	2567	782.4	#N/A	220
2315	705.6	64.58	#N/A	2463	750.7	#N/A	100	2568	782.7	#N/A	220
2317	706.2	#N/A	14	2467	751.9	#N/A	100	2569	783.0	108.00	#N/A
2320	707.1	65.72	#N/A	2471	753.2	103.00	#N/A	2576	785.2	106.00	#N/A
2320	707.1	#N/A	14	2472	753.5	#N/A	100	2578	785.8	#N/A	220
2322	707.7	#N/A	14	2474	754.1	#N/A	150	2586	788.2	103.00	#N/A
2325	708.7	53.89	#N/A	2476	754.7	#N/A	150	2588	788.8	100.00	#N/A
2325	708.7	#N/A	14	2477	755.0	94.70	#N/A	2592	790.0	77.84	#N/A
2329	709.9	#N/A	14	2479	755.6	#N/A	150	2594	790.5	#N/A	220
2334	711.4	#N/A	14	2481	756.2	103.00	#N/A	2595	790.8	#N/A	220
2339	712.9	#N/A	14	2484	757.1	#N/A	175	2598	791.9	#N/A	220
2340	713.2	31.53	#N/A	2487	758.0	#N/A	175	2602	793.1	107.00	#N/A
2343	714.1	#N/A	14	2490	759.0	#N/A	175	2608	795.0	#N/A	220
2348	715.7	#N/A	14	2491	759.3	96.80	#N/A	2612	796.1	108.00	#N/A
2349	716.0	59.86	#N/A	2494	760.2	#N/A	175	2620	798.7	#N/A	220
2351	716.6	#N/A	14	2497	761.1	92.10	#N/A	2622	799.2	110.00	#N/A

Static water level not measured
pCi/L* = picocuries per liter X 10E6
#N/A = no measurement taken

Table derived from IT field data
Total depth = 819.6 meters (2,689 feet)
GPM = gallons per minute

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)								
2632	802.2	107.00	#N/A								
2636	803.5	#N/A	220								
2642	805.3	105.00	#N/A								
2647	806.8	#N/A	220								
2652	808.3	111.00	#N/A								
2655	809.2	#N/A	220								
2659	810.5	#N/A	220								
2663	811.7	#N/A	220								
2665	812.3	101.00	#N/A								
2673	814.7	108.00	#N/A								
2674	815.0	#N/A	220								
2677	815.9	#N/A	220								
2681	817.2	102.00	#N/A								
2690	819.9	1.18	#N/A								

Static water level not measured
pCi/L* = picocuries per liter X 10E6
#N/A = no measurement taken

Table derived from IT field data
Total depth = 819.6 meters (2,689 feet)
GPM = gallons per minute

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)
2201	670.9	0.00	#N/A	2436	742.5	#N/A	150	2581	786.7	98.35	#N/A
2201	670.9	#N/A	0	2442	744.3	104.35	#N/A	2588	788.9	#N/A	250
2211	673.9	0.00	#N/A	2447	745.8	#N/A	150	2591	789.7	95.73	#N/A
2215	675.1	#N/A	0	2452	747.4	72.59	#N/A	2592	790.0	#N/A	250
2221	677.0	0.00	#N/A	2452	747.4	#N/A	160	2601	792.8	101.40	#N/A
2231	680.0	0.00	#N/A	2459	749.5	104.10	#N/A	2603	793.3	#N/A	250
2233	680.6	#N/A	0	2460	749.8	#N/A	160	2611	795.8	95.00	#N/A
2237	681.7	#N/A	0	2469	752.6	108.50	#N/A	2618	798.1	#N/A	250
2241	683.1	0.00	#N/A	2476	754.7	105.90	#N/A	2621	798.9	89.75	#N/A
2244	684.0	#N/A	0	2480	755.9	#N/A	160	2631	801.9	100.59	#N/A
2251	686.1	2.60	#N/A	2482	756.5	#N/A	170	2640	804.6	#N/A	250
2261	689.2	1.03	#N/A	2486	757.7	104.30	#N/A	2641	805.0	106.80	#N/A
2264	689.9	#N/A	0	2488	758.3	#N/A	180	2651	808.0	107.79	#N/A
2270	691.9	#N/A	0	2498	761.4	#N/A	200	2661	811.1	99.53	#N/A
2271	692.2	17.00	#N/A	2503	762.9	#N/A	200	2668	813.2	#N/A	270
2281	695.2	19.55	#N/A	2506	763.8	#N/A	230	2671	814.1	97.17	#N/A
2281	695.2	#N/A	8	2509	764.7	108.80	#N/A	2681	817.2	104.69	#N/A
2291	698.3	19.94	#N/A	2511	765.4	#N/A	230	2693	820.8	105.27	#N/A
2301	701.3	21.07	#N/A	2513	766.0	#N/A	230	2701	823.3	100.03	#N/A
2303	702.0	#N/A	11	2514	766.3	7.47	#N/A	2701	823.3	#N/A	270
2310	704.1	#N/A	10	2519	767.8	108.60	#N/A	2711	826.3	102.06	#N/A
2311	704.4	23.14	#N/A	2519	767.8	#N/A	230	2726	830.9	98.39	#N/A
2318	706.5	#N/A	30	2523	769.0	#N/A	230	2732	832.7	#N/A	270
2321	707.4	24.90	#N/A	2525	769.6	100.35	#N/A	2735	833.6	#N/A	270
2324	708.2	#N/A	50	2528	770.5	#N/A	230	2736	833.9	101.64	#N/A
2329	709.9	#N/A	50	2530	771.3	#N/A	230	2746	837.0	103.47	#N/A
2330	710.2	23.83	#N/A	2531	771.4	107.60	#N/A	2756	840.0	105.46	#N/A
2332	710.8	#N/A	70	2533	772.1	#N/A	230	2766	843.1	105.93	#N/A
2336	712.0	25.86	#N/A	2535	772.7	104.79	#N/A	2776	846.2	#N/A	270
2337	712.3	#N/A	70	2535	772.8	#N/A	230	2779	847.0	100.38	#N/A
2345	714.6	#N/A	70	2538	773.7	#N/A	230	2794	851.6	109.64	#N/A
2346	715.1	27.81	#N/A	2539	773.9	106.49	#N/A	2800	853.5	#N/A	270
2355	717.8	#N/A	70	2540	774.2	#N/A	230	2806	855.3	101.09	#N/A
2356	718.1	30.32	#N/A	2542	774.7	#N/A	230	2816	858.3	104.00	#N/A
2364	720.4	#N/A	65	2543	775.1	105.43	#N/A	2826	861.4	99.12	#N/A
2366	721.2	49.96	#N/A	2547	776.3	96.03	#N/A	2826	861.4	#N/A	270
2373	723.3	#N/A	100	2547	776.3	#N/A	230	2846	867.5	96.37	#N/A
2378	724.8	107.42	#N/A	2551	777.5	98.20	#N/A	2855	870.2	#N/A	270
2386	727.3	111.24	#N/A	2552	777.8	#N/A	230	2856	870.5	105.15	#N/A
2392	729.1	111.16	#N/A	2557	779.2	#N/A	230	2861	872.0	113.27	#N/A
2397	730.6	#N/A	120	2558	779.7	102.80	#N/A	2871	875.1	108.42	#N/A
2400	731.5	#N/A	100	2562	780.9	3.10	#N/A	2881	878.1	105.59	#N/A
2401	731.8	106.45	#N/A	2563	781.2	#N/A	230	2888	880.3	#N/A	280
2407	733.7	#N/A	120	2565	781.8	10.49	#N/A	2891	881.2	103.60	#N/A
2412	735.2	110.23	#N/A	2568	782.7	#N/A	230	2901	884.2	108.70	#N/A
2417	736.7	#N/A	120	2569	783.0	102.80	#N/A	2901	884.2	#N/A	280
2420	737.6	#N/A	150	2571	783.6	0.04	#N/A	2911	887.3	107.80	#N/A
2422	738.2	74.66	#N/A	2571	783.6	#N/A	230	2919	889.7	#N/A	280
2432	741.3	107.42	#N/A	2579	786.1	#N/A	250	2921	890.3	106.00	#N/A

Static water level = 627.6 meters (2,059 feet)
pCi/L* = picocuries per liter X 10E6
#N/A = no measurement taken

Table derived from IT field data
Total depth = 1,308.8 meters (4,294 feet)
GPM = gallons per minute

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)
2931	893.4	97.32	#N/A	3189	972.1	#N/A	0	3352	1021.7	#N/A	16
2941	896.4	90.30	#N/A	3193	973.2	0.15	#N/A	3354	1022.3	#N/A	16
2949	898.9	#N/A	280	3202	976.0	#N/A	0	3356	1022.9	0.02	#N/A
2951	899.5	89.60	#N/A	3203	976.1	#N/A	5	3359	1023.8	#N/A	14
2951	899.5	#N/A	280	3203	976.3	0.14	#N/A	3361	1024.4	0.02	#N/A
2961	902.5	106.60	#N/A	3206	977.2	0.06	#N/A	3361	1024.4	#N/A	14
2962	902.8	#N/A	280	3216	980.2	0.07	#N/A	3363	1024.9	#N/A	17
2971	905.6	102.60	#N/A	3219	981.2	#N/A	5	3363	1025.0	0.01	#N/A
2981	908.6	100.40	#N/A	3226	983.3	0.03	#N/A	3363	1025.0	#N/A	17
2986	910.1	#N/A	280	3233	985.4	#N/A	5	3367	1026.3	0.02	#N/A
2991	911:7	105.40	#N/A	3236	986.3	0.02	#N/A	3376	1029.0	0.02	#N/A
3001	914.7	102.30	#N/A	3239	987.2	#N/A	14	3378	1029.6	#N/A	15
3003	915.3	#N/A	300	3241	987.9	#N/A	14	3384	1031.4	0.01	#N/A
3011	917.8	98.33	#N/A	3244	988.8	0.03	#N/A	3388	1032.7	#N/A	15
3012	918.1	#N/A	300	3245	989.1	#N/A	19	3391	1033.6	#N/A	27
3021	920.8	111.00	#N/A	3250	990.6	0.03	#N/A	3392	1033.9	0.01	#N/A
3027	922.6	#N/A	300	3255	992.1	0.03	#N/A	3404	1037.5	0.01	#N/A
3031	923.8	78.24	#N/A	3258	993.0	#N/A	12	3406	1038.1	#N/A	27
3032	924.2	#N/A	340	3262	994.3	0.03	#N/A	3411	1039.7	0.02	#N/A
3035	925.1	#N/A	340	3269	996.4	0.04	#N/A	3412	1040.0	#N/A	26
3041	926.9	89.18	#N/A	3271	997.0	#N/A	17	3417	1041.5	0.02	#N/A
3051	929.9	69.51	#N/A	3273	997.6	#N/A	12	3421	1042.7	#N/A	100
3055	931.2	#N/A	340	3275	998.2	0.02	#N/A	3422	1043.0	0.03	#N/A
3061	933.0	64.20	#N/A	3279	999.4	0.04	#N/A	3429	1045.2	0.03	#N/A
3071	936.0	57.56	#N/A	3279	999.4	#N/A	16	3435	1047.0	#N/A	100
3076	937.4	#N/A	340	3283	1000.7	#N/A	15	3439	1048.2	0.07	#N/A
3081	939.1	76.73	#N/A	3287	1001.9	0.03	#N/A	3454	1052.8	0.13	#N/A
3083	939.7	#N/A	340	3288	1002.2	#N/A	15	3457	1053.7	#N/A	100
3091	942.1	89.36	#N/A	3290	1002.8	#N/A	15	3464	1055.8	0.18	#N/A
3101	945.2	83.26	#N/A	3297	1004.9	0.01	#N/A	3471	1058.0	#N/A	388
3111	948.2	81.78	#N/A	3298	1005.2	#N/A	15	3474	1058.9	0.25	#N/A
3121	951.3	74.71	#N/A	3306	1007.7	0.02	#N/A	3477	1059.8	#N/A	388
3123	951.9	#N/A	340	3306	1007.7	#N/A	10	3483	1061.6	#N/A	473
3127	953.2	#N/A	340	3314	1010.1	#N/A	10	3489	1063.4	#N/A	473
3131	954.3	88.82	#N/A	3316	1010.7	0.02	#N/A	3491	1064.1	0.31	#N/A
3132	954.7	#N/A	340	3319	1011.6	#N/A	10	3501	1067.1	0.32	#N/A
3134	955.1	#N/A	340	3324	1013.2	0.02	#N/A	3502	1067.4	#N/A	473
3135	955.5	#N/A	0	3324	1013.2	#N/A	15	3502	1067.4	#N/A	191
3139	956.8	9.09	#N/A	3329	1014.7	#N/A	15	3511	1070.2	0.31	#N/A
3141	957.4	#N/A	0	3331	1015.3	0.02	#N/A	3516	1071.7	#N/A	191
3149	959.8	0.76	#N/A	3332	1015.6	#N/A	15	3521	1073.2	0.26	#N/A
3153	961.0	#N/A	0	3336	1016.8	0.02	#N/A	3524	1074.1	#N/A	191
3161	963.5	0.58	#N/A	3338	1017.4	#N/A	15	3531	1076.2	0.26	#N/A
3162	963.8	#N/A	0	3341	1018.3	#N/A	16	3535	1077.5	#N/A	191
3169	965.9	0.19	#N/A	3343	1018.9	0.02	#N/A	3541	1079.3	0.26	#N/A
3170	966.2	#N/A	0	3344	1019.3	#N/A	16	3546	1080.8	#N/A	191
3174	967.4	0.17	#N/A	3345	1019.6	0.02	#N/A	3551	1082.3	0.06	#N/A
3184	970.5	0.15	#N/A	3350	1021.1	0.02	#N/A	3561	1085.4	0.30	#N/A
3184	970.6	#N/A	0	3350	1021.1	#N/A	16	3566	1086.9	#N/A	451

Static water level = 627.6 meters (2,059 feet)
pCi/L* = picocuries per liter X 10E6
#N/A = no measurement taken

Table derived from IT field data
Total depth = 1,308.8 meters (4,294 feet)
GPM = gallons per minute

Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)	Depth (feet)	Depth (meters)	Tritium (pCi/L)*	Water (GPM)
3571	1088.4	0.27	#N/A	3896	1187.4	#N/A	119	4231	1289.6	0.23	#N/A
3581	1091.5	0.25	#N/A	3901	1189.0	0.27	#N/A	4241	1292.7	0.21	#N/A
3581	1091.5	#N/A	451	3911	1192.1	0.21	#N/A	4242	1292.8	#N/A	279
3590	1094.2	#N/A	451	3914	1193.0	#N/A	119	4251	1295.7	0.19	#N/A
3591	1094.5	0.28	#N/A	3921	1195.1	0.23	#N/A	4261	1298.8	0.19	#N/A
3601	1097.6	0.28	#N/A	3924	1196.0	#N/A	119	4270	1301.5	#N/A	279
3609	1100.0	#N/A	451	3931	1198.2	0.23	#N/A	4271	1301.8	0.19	#N/A
3611	1100.6	0.29	#N/A	3941	1201.2	0.24	#N/A	4281	1304.8	0.20	#N/A
3624	1104.6	#N/A	451	3943	1201.8	#N/A	119	4291	1307.9	0.18	#N/A
3631	1106.7	0.30	#N/A	3947	1203.0	0.25	#N/A	4292	1308.1	#N/A	279
3638	1108.9	#N/A	264	3948	1203.4	#N/A	131	4295	1309.1	0.20	#N/A
3641	1109.8	0.30	#N/A	3951	1204.3	0.23	#N/A				
3651	1112.8	0.32	#N/A	3961	1207.3	0.23	#N/A				
3653	1113.4	#N/A	186	3971	1210.4	0.23	#N/A				
3661	1115.9	0.30	#N/A	3971	1210.4	#N/A	131				
3671	1118.9	0.27	#N/A	3981	1213.4	0.22	#N/A				
3681	1122.0	0.30	#N/A	3991	1216.5	0.23	#N/A				
3681	1122.0	#N/A	245	4001	1219.5	0.23	#N/A				
3691	1125.0	0.30	#N/A	4005	1220.7	#N/A	131				
3701	1128.1	0.27	#N/A	4007	1221.3	#N/A	131				
3711	1131.1	0.30	#N/A	4011	1222.6	0.22	#N/A				
3721	1134.2	0.27	#N/A	4021	1225.6	0.21	#N/A				
3727	1136.1	#N/A	245	4031	1228.6	0.21	#N/A				
3731	1137.2	0.28	#N/A	4038	1230.8	#N/A	368				
3732	1137.6	#N/A	245	4041	1231.7	0.21	#N/A				
3741	1140.3	0.31	#N/A	4051	1234.7	0.18	#N/A				
3750	1142.9	#N/A	226	4061	1237.8	0.22	#N/A				
3751	1143.3	0.30	#N/A	4061	1237.8	#N/A	298				
3761	1146.4	0.32	#N/A	4071	1240.8	0.23	#N/A				
3764	1147.3	0.32	#N/A	4081	1243.9	0.18	#N/A				
3771	1149.4	0.27	#N/A	4091	1246.9	0.20	#N/A				
3779	1151.9	#N/A	226	4101	1250.0	0.22	#N/A				
3781	1152.4	0.28	#N/A	4105	1251.1	#N/A	298				
3791	1155.5	0.28	#N/A	4111	1253.0	0.21	#N/A				
3797	1157.2	#N/A	226	4121	1256.1	0.23	#N/A				
3801	1158.5	0.27	#N/A	4124	1257.0	#N/A	298				
3811	1161.6	0.29	#N/A	4131	1259.1	0.22	#N/A				
3821	1164.6	0.29	#N/A	4141	1262.2	0.20	#N/A				
3831	1167.7	0.28	#N/A	4148	1264.2	#N/A	317				
3839	1170.1	#N/A	226	4153	1265.8	0.23	#N/A				
3841	1170.7	0.30	#N/A	4163	1268.9	0.20	#N/A				
3851	1173.8	0.26	#N/A	4170	1271.1	#N/A	317				
3857	1175.6	0.23	#N/A	4171	1271.3	0.17	#N/A				
3861	1176.8	0.27	#N/A	4181	1274.4	0.20	#N/A				
3866	1178.5	#N/A	226	4191	1277.4	0.19	#N/A				
3871	1179.9	0.26	#N/A	4201	1280.5	0.22	#N/A				
3881	1182.9	0.27	#N/A	4204	1281.5	#N/A	317				
3888	1185.0	#N/A	226	4211	1283.5	0.22	#N/A				
3891	1186.0	0.32	#N/A	4226	1288.1	0.19	#N/A				

Static water level = 627.6 meters (2,059 feet)
pCi/L* = picocuries per liter X 10E6
#N/A = no measurement taken

Table derived from IT field data
Total depth = 1,308.8 meters (4,294 feet)
GPM = gallons per minute

Appendix C

Well Cluster ER-20-5
Stratigraphic and Lithologic Logs

Composite Stratigraphic Log of Well Cluster ER-20-5

(Compiled by Lance B. Prothro, Bechtel Nevada, 11 April 1996)

The lithologies encountered in Wells ER-20-5 #1, #2, and #3 were found to be very similar. Thus, this log combines the stratigraphic data obtained from the three drill holes into a single composite stratigraphic log for the Well Cluster ER-20-5 site. Due to significant deviation of the lower portion of the ER-20-5#3 borehole, true vertical depths and thicknesses are provided in parentheses for intervals below 659.6 meters (2164 feet). Stratigraphic nomenclature is from Ferguson et al., 1994.

Depth					Thickness	
Meters	Feet	Lithology	Stratigraphic Unit	Symbol	Meters	Feet
0 - 20.1	0 - 66	**Ash-Flow Tuff and underlying Bedded Tuff**: Partially welded; vitric to devitrified, peralkaline.	Trail Ridge Tuff, Thirsty Canyon Group	Ttt	20.1	66
20.1 - 52.4	66 - 172	**Ash-Flow Tuff and underlying Bedded Tuff**: Partially welded; vitric to devitrified, peralkaline.	Pahute Mesa Tuff, Thirsty Canyon Group	Ttp	32.3	106
52.4 - 67.7	172 - 222	**Ash-Flow Tuff**: Nonwelded; vitric.	mafic-poor Ammonia Tanks Tuff, Timber Mountain Group	Tmap	15.3	50
67.7 - 95.7	222 - 314	**Bedded Tuff:** Vitric.	bedded Ammonia Tanks Tuff, Timber Mountain Group	Tmab	28.0	92
95.7 - 139.6	314 - 458	**Ash-Flow Tuff**: Nonwelded to densely welded; vitric to devitrified.	mafic-rich Rainier Mesa Tuff, Timber Mountain Group	Tmrr	43.9	144

Composite Stratigraphic Log of Well Cluster ER-20-5 (cont.)

Depth					Thickness	
Meters	Feet	Lithology	Stratigraphic Unit	Symbol	Meters	Feet
139.6 - 214.0	458 - 702	**Bedded Tuff**: Vitric.	rhyolite of Fluorspar Canyon, Timber Mountain Group	Tmf	74.4	244
214.0 - 495.3	702 - 1625	**Lava, basal Flow Breccia, and overlying and underlying Bedded Tuff**: Vitric to devitrified; pumiceous, perlitic, and zeolitic in part.	rhyolite of Benham, Paintbrush Group	Tpb	281.3	923
495.3 - 509.3	1625 - 1671	**Bedded Tuff**: Zeolitic.	crystal-poor tuff of Pinyon Pass, Paintbrush Group	Tpcyp	14.0	46
509.3 - 601.4	1671 - 1973	**Ash-Flow Tuff**: Partially to moderately welded; devitrified.	Pahute Mesa lobe of the Tiva Canyon Tuff, Paintbrush Group	Tpcm	92.1	302
601.4 - 659.6	1973 - 2164	**Bedded Tuff**: Zeolitic.	Paintbrush Group, undivided	Tp	58.2	191
659.6 - 906.8 (659.6 - 902.2)	2164 - 2975 (2164 - 2960)	**Ash-Flow Tuff:** Nonwelded and moderately welded; zeolitic and devitrified.	Pahute Mesa lobe of the Topopah Spring Tuff, Paintbrush Group	Tptm	247.2 (242.6)	811 (796)

Composite Stratigraphic Log of Well Cluster ER-20-5 (cont.)

Depth					Thickness	
Meters	Feet	Lithology	Stratigraphic Unit	Symbol	Meters	Feet
906.8 - 1250.9 (902.2 - 1238.1)	2975 - 4104 (2960 - 4062)	**Lava and overlying and underlying Nonwelded Tuff**: Devitrified, vitrophyric, and zeolitic; pumiceous and silicified in part.	mafic-poor Calico Hills Formation, Volcanics of Area 20	Tacp	344.1 (335.9)	1129 (1102)
1250.9 - 1308.8 (1238.1 - 1294.2) TD	4104 - 4294 (4062 - 4246) TD	**Nonwelded Tuff:** Zeolitic.	mafic-rich Calico Hills Formation, Volcanics of Area 20	Tacr	> 57.9 (> 56.1)	> 190 (> 184)

Composite Lithologic Log of Well Cluster ER-20-5

(Compiled by Lance B. Prothro, Bechtel Nevada, 11 April 1996)

The lithologies encountered in Wells ER-20-5 #1, #2, and #3 were found to be very similar. Thus, this log combines the geologic data obtained from the three drill holes into a single composite lithologic log for the Well Cluster ER-20-5 site. The log was compiled using the following information: 1) geophysical logs from ER-20-5 #1 from the surface to approximately 823.0 m (2700 ft); 2) washed drill cuttings samples at 3.0 and 6.1 m (10 and 20 ft) intervals from ER-20-5 #2 from 3.0 - 658.4 m (10 - 2160 ft); and 3) washed drill cuttings samples at 3.0 m (10 ft) intervals, percussion gun core samples, and geophysical logs from ER-20-5 #3 from 658.4 to 1308.8 m (2160 to 4294 ft). Additional information utilized in the construction of the log included unpublished petrographic; lithologic, and stratigraphic information from R.G. Warren (Los Alamos National Laboratory) and various geologic information from IT Corp. Report *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-5, February 1995.* Stratigraphic nomenclature is from Ferguson et al., 1994.

The lithologic descriptions follow Bechtel Nevada Department Procedure NTS-GEO-003. Stratigraphic and lithologic divisions are tied to geophysical logs whenever possible. Due to significant deviation of the ER-20-5 #3 borehole, true vertical depths below 789.7 m (2591 ft) are provided in italics.

Depth Interval meters/(feet)	Lithology	Stratigraphy
0 - 9.1 m (0 - 30 ft)	**Partially Welded Ash-Flow Tuff**: Grayish-brown; devitrified; rare dark-gray pumice; minor feldspar phenocrysts; minor mafic minerals of olivine and much less clinopyroxene; rare moderate-brown (5 YR 3/4) lithic fragments up to 1 mm in diameter.	Trail Ridge Tuff
9.1 - 20.1 m (30 - 66 ft)	**Bedded Tuff**: Drill cuttings samples consist mostly of very-pale-orange, light-gray, and white vitric pumice fragments. Pumice fragments contain very rare feldspar phenocrysts and olivine. Interval probably consists of bedded, pumice-rich ash-fall deposits.	Trail Ridge Tuff
20.1 - 45.7 m (66 - 150 ft)	**Partially Welded Ash-Flow Tuff**: Brownish-black to grayish-black, becoming moderate-brown below 36.6 m (120 ft); devitrified, weakly scoriaceous in part; rare grayish-black pumice; minor feldspar phenocrysts; rare mafic minerals of olivine and much less clinopyroxene.	Pahute Mesa Tuff

Depth Interval meters/(feet)	Lithology	Stratigraphy
45.7 - 52.4 m (150 - 172 ft)	**Bedded Tuff**: Drill cuttings samples are a mixture of various pumice and tuffaceous rock fragments; loose crystals of feldspar, olivine, and much less clinopyroxene; and abundant cottonseed hull fibers (i.e. lost circulation material). Lithology partly inferred from geophysical logs.	Pahute Mesa Tuff
52.4 - 67.7 m (172 - 222 ft)	**Nonwelded Tuff**: Moderate-brown (5YR 4/4); vitric; minor to common white and light-brown (5YR 5/6) to dark-yellowish-orange pumice; minor felsic phenocrysts of feldspar and lesser quartz; minor mafic minerals of biotite (including conspicuously large "booklets" up to 3 mm in size) and clinopyroxene.	mafic-poor Ammonia Tanks Tuff
67.7 - 95.7 m (222 - 314 ft)	**Bedded Tuff:** Drill cuttings samples are a mixture of pumice and various tuffaceous rock fragments; loose crystals of quartz and feldspar, and abundant cottonseed hull fibers (i.e. lost circulation material). However, the pumice fragments dominate the samples and are white, vitric, and contain rare quartz and feldspar phenocrysts, biotite, clinopyroxene, and a trace of sphene.	bedded Ammonia Tanks Tuff

Depth Interval meters/(feet)	Lithology	Stratigraphy
95.7 - 106.7 m (314 - 350 ft)	**Nonwelded Ash-Flow Tuff**: Lithology not well represented in drill cuttings samples due to poor circulation of drilling fluid. Geology inferred from geophysical logs.	mafic-rich Rainier Mesa Tuff
106.7 - 112.8 m (350 - 370 ft)	**Partially Welded Ash-Flow Tuff**: Grayish-red (5Y 4/2); partially devitrified; minor to common mostly white pumice; common felsic phenocrysts of feldspar and quartz; minor biotite, trace of clinopyroxene; rare dusky-red lithic fragments up to 2 mm in diameter. Drill cuttings samples contain abundant fragments of cement and large (>2 cm) pieces of black rubber from cement plug.	mafic-rich Rainier Mesa Tuff
112.8 - 120.7 m (370 - 396 ft)	**Moderately Welded Ash-Flow Tuff:** Grayish-red (5R 4/2); devitrified; minor grayish-pink pumice; common felsic phenocrysts of quartz and feldspar; minor biotite; rare dusky-red lithic fragments up to 2 mm in diameter. Drill cuttings samples contain abundant fragments of cement and large (>2 cm) pieces of black rubber from cement plug.	mafic-rich Rainier Mesa Tuff

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
120.7 - 139.6 m (396 - 458 ft)	**Densely Welded Ash-Flow Tuff:** Grayish-red (10R 4/2) to dark-gray, mottled in part; vitric to devitrified, vitrophyric and weakly perlitic in part; common felsic phenocrysts of feldspar and quartz; common biotite.	mafic-rich Rainier Mesa Tuff
139.6 - 214.0 m (458 - 702 ft)	**Bedded Tuff:** Drill cuttings samples are a mixture of mostly pumice and tuffaceous rock fragments. Pumice is vitric and ranges in color from grayish-orange and light-brown (5YR 6/4) to white. Feldspar and quartz crystals occur as phenocrysts in the pumice fragments and as loose crystals. Biotite, present mainly as rare small flakes in the pumice, was the only mafic mineral observed.	rhyolite of Fluorspar Canyon
214.0 - 226.2 m (702 - 742 ft)	**Bedded Tuff:** Drill cuttings samples are very similar to those from the interval above. Stratigraphy and lithology based on geophysical logs.	rhyolite of Benham
226.2 - 284.4 m (742 - 933 ft)	**Pumiceous Lava:** Pale-yellowish-brown, becoming black in part below approximately 265.2 m (870 ft); vitric, frothy, perlitic in part below approximately 265.2 m (870 ft); rare feldspar phenocrysts; common biotite; minor conspicuous sphene; rare fragments of white, translucent chalcedony occur in samples throughout interval.	rhyolite of Benham

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
284.4 - 382.2 m (933 - 1254 ft)	**Lava:** Light-gray to grayish-red (10R 4/2), mottled; devitrified; rare feldspar phenocrysts; common biotite; trace of hornblende; trace of sphene.	rhyolite of Benham
382.2 - 416.4 m (1254 - 1366 ft)	**Lava:** Grayish-black and light-brown (5YR 5/6), mottled; devitrified (light-brown) to vitric and perlitic (grayish-black); rare feldspar phenocrysts; common biotite; minor conspicuous sphene.	rhyolite of Benham
416.4 - 437.4 m (1366 - 1435 ft)	**Flow Breccia:** Grayish-orange, pale- to dark-yellowish-brown, and pale-reddish-brown, mottled; devitrified; silicified in part; rare feldspar phenocrysts, common biotite; minor conspicuous sphene.	rhyolite of Benham
437.4 - 495.3 m (1435 - 1625 ft)	**Bedded Tuff:** Pale-reddish-brown, grayish-yellow, and very-pale-orange; zeolitic; minor mostly grayish-yellow pumice; minor feldspar phenocrysts; common biotite; rare to minor moderate-brown lithic fragments up to 4 mm in diameter; rare sphene.	rhyolite of Benham

Depth Interval meters/(feet)	Lithology	Stratigraphy
495.3 - 509.3 m (1625 - 1671 ft)	**Bedded Tuff**: Pale-yellowish-brown; zeolitic; minor to common very-pale-orange pumice; rare feldspar phenocrysts; rare biotite; rare dusky-brown lithic fragments up to 2 mm in diameter.	crystal-poor tuff of Pinyon Pass
509.3 - 519.4 m (1671 - 1704 ft)	**Partially Welded Ash-Flow Tuff**: Light-brownish-gray; devitrified with moderate vapor-phase mineralization; minor light-gray pumice; rare feldspar phenocrysts; rare biotite; rare moderate-brown (5YR 3/4) lithic fragments up to 1 mm in diameter; rare sphene.	Pahute Mesa lobe Tiva Canyon Tuff
519.4 - 601.4 m (1704 - 1973 ft)	**Moderately Welded Ash-Flow Tuff**: Moderate-brown (5YR 3/4) to approximately 527.3 m (1730 ft), grayish-red (10R 4/2) from approximately 527.3 - 579.1 m (1730 - 1900 ft), and mottled grayish-brown and light-brown (5YR 5/6) below approximately 579.1 m (1900 ft); devitrified; rare mostly light-gray pumice; rare feldspar phenocrysts; rare biotite; minor sphene.	Pahute Mesa lobe Tiva Canyon Tuff

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
601.4 - 659.6 m (1973 - 2164 ft)	**Bedded Tuff**: Yellowish-gray (5Y 8/4) moderate-reddish-brown and dark-yellowish-orange; zeolitic; minor to common pumice; rare to minor feldspar phenocrysts; rare to minor biotite; rare to common lithic fragments up to 1 cm in diameter. Conspicuous chalcedony- and manganese oxide-filled fractures up to 1 mm in width observed in fragments of drill cuttings samples at approximately 637.0 m (2090 ft).	Paintbrush Group, undivided
659.6 - 789.7 m (2164 - 2591 ft)	**Moderately Welded Ash-Flow Tuff**: Grayish-red (10R 4/2) to approximately 717.8 m (2355 ft), moderate-brown (5 YR 3/4) from 717.8 to 748.3 m (2355 - 2455 ft), and light-brown (5YR 5/6) and mottled below 748.3 m (2455 ft); devitrified; becoming partially zeolitic below approximately 748.3 m (2455 ft); rare flattened pumice; minor felsic phenocrysts of feldspar and a trace of quartz; minor mafic minerals of biotite, with conspicuous clinopyroxene below approximately 763.5 m (2505 ft).	Pahute Mesa lobe Topopah Spring Tuff

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
789.7 - 906.8 m (2591 - 2975 ft) *789.7 - 902.2 m* *(2591 - 2960 ft)*	**Nonwelded Ash-Flow Tuff:** Pale-brown to approximately 830.6 m (2725 ft) *826.9 m (2713 ft)*, moderate-reddish-brown below; zeolitic; common grayish-yellow and very-pale-orange pumice; rare felsic phenocrysts of feldspar and a trace of quartz; minor biotite; rare dark-reddish-brown lithic fragments up to 2 mm in diameter.	Pahute Mesa lobe Topopah Spring Tuff
906.8 - 979.0 m (2975 - 3212 ft) *902.2 - 972.6 m* *(2960 - 3191 ft)*	**Nonwelded Tuff:** Yellowish-gray (5Y 7/2) to dusky-yellow; zeolitic, silicified in part; very rare felsic phenocrysts of feldspar and quartz; rare biotite.	mafic-poor Calico Hills Formation
979.0 - 988.2 m (3212 - 3242 ft) *972.6 - 981.8 m* *(3191 - 3221 ft)*	**Lava:** Yellowish-gray (5Y 7/2); zeolitic; pumiceous; very rare felsic phenocrysts of feldspar and quartz; rare biotite; rare manganese oxide-filled fractures less than 0.5 mm in width.	mafic-poor Calico Hills Formation

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
988.2 - 1067.4 m (3242 - 3502 ft) *981.8 - 1059.2 m (3221 - 3475 ft)*	**Lava:** Moderate-yellowish-brown to approximately 999.7 m (3280 ft) *993.0 m (3258 ft),* pale-reddish-brown to grayish-red (10R 4/2) from approximately 999.7 to 1039.4 m (3280 - 3410 ft) *993.0 - 1031.7 m (3258 - 3385 ft),* and mostly medium-light-gray below approximately 1039.4 m (3410 ft) *1031.7 (3385 ft)*; mostly devitrified to partially zeolitic, vitrophyric and silicified in part; rare felsic phenocrysts of feldspar and quartz; rare biotite; flow-banded in part; common chalcedony- and manganese oxide-filled fractures less than 1 mm in width.	mafic-poor Calico Hills Formation
1067.4 - 1113.1 m (3502 - 3652 ft) *1059.2 - 1104.0 m (3475 - 3622 ft)*	**Lava:** Light brownish-gray and grayish-black to approximately 1082.0 m (3550 ft) *1073.5 m (3522 ft),* mostly grayish-black below; partially devitrified (light-brownish-gray fragments) and vitrophyric (grayish-black fragments) to approximately 1082.0 m (3550 ft) *1073.5 m (3522 ft),* mostly vitrophyric below; rare feldspar phenocrysts; rare biotite.	mafic-poor Calico Hills Formation
1113.1 - 1189.3 m (3652 - 3902 ft) *1104.0 - 1178.1 m (3622 - 3865 ft)*	**Lava:** Pale-yellowish-brown and yellowish-gray (5Y 7/2), mottled; zeolitic; pumiceous; rare felsic phenocrysts of feldspar and quartz; rare biotite.	mafic-poor Calico Hills Formation

Composite Lithologic Log of Well Cluster ER-20-5 (cont.)

Depth Interval meters/(feet)	Lithology	Stratigraphy
1189.3 - 1250.9 (3902 - 4104 ft) *1178.1 - 1238.1 m* *(3865 - 4062 ft)*	**Nonwelded Tuff**: Grayish-orange to moderate-yellowish-brown; zeolitic; minor pumice; rare felsic phenocrysts of feldspar and quartz; rare biotite; rare moderate-reddish-brown lithic fragments up to 2 mm in diameter.	mafic-poor Calico Hills Formation
1250.9 - 1308.8 m (4104 - 4294 ft) TD *1238.1 - 1294.2 m* *(4062 - 4246 ft)* *TD*	**Nonwelded Tuff**: Moderate-orange-pink to moderate-reddish-brown; zeolitic; minor pumice; minor felsic phenocrysts of feldspar and quartz; minor biotite; rare moderate-reddish-brown lithic fragments up to 3 mm in diameter.	mafic-rich Calico Hills Formation

Appendix D

Well Cluster ER-20-5 Geophysical Logs

Appendix D contains geophysical logs run at Wells ER-20-5#1 and ER-20-5#3. Table D-1, Geophysical Log Summary, summarizes the logs presented. See Table 3-2 for more information on logs run in Well ER-20-5#1, and Table 5-3 for more information on logs run in Well ER-20-5#3.

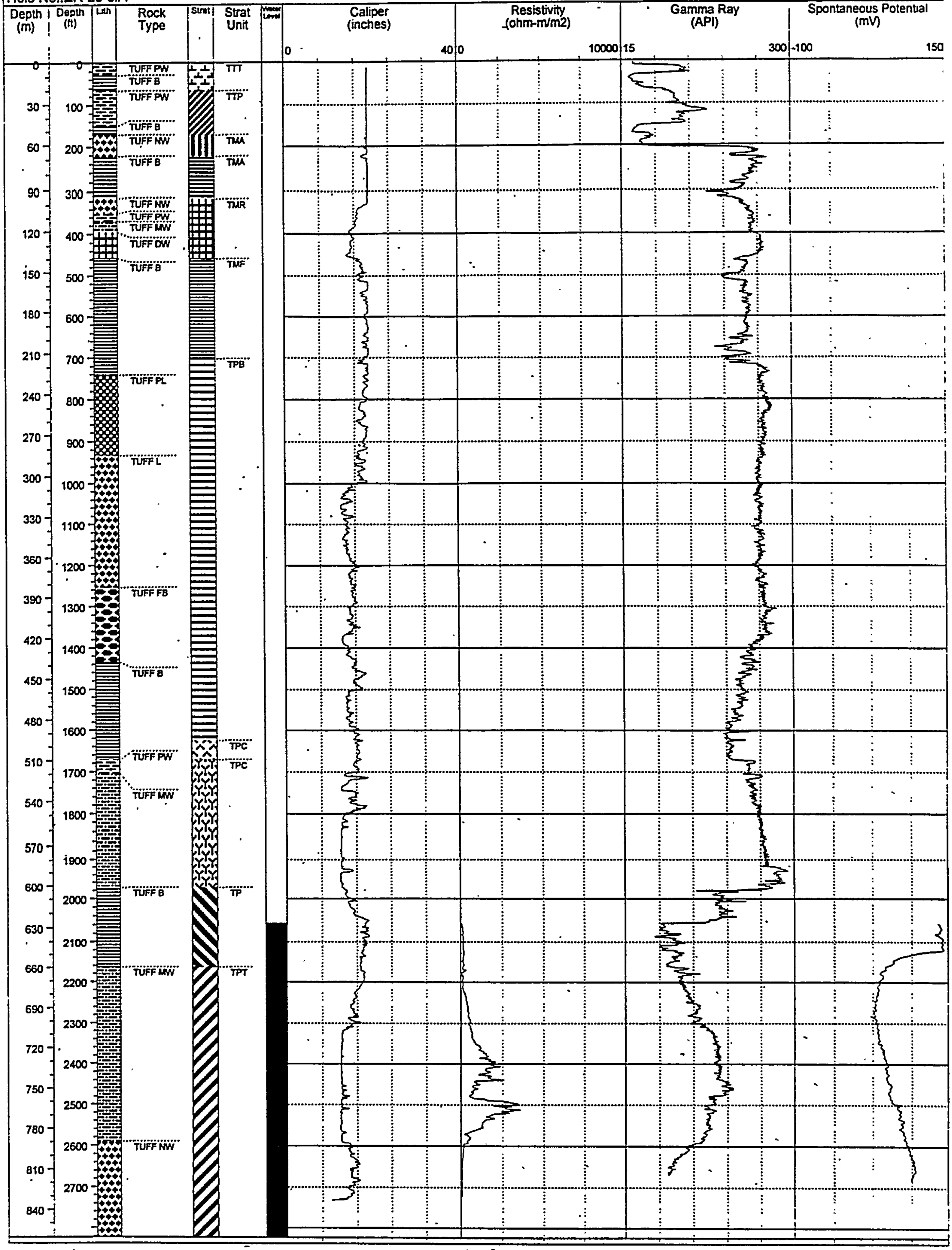
Table D-1
Geophysical Log Summary for Well ER-20-5#1

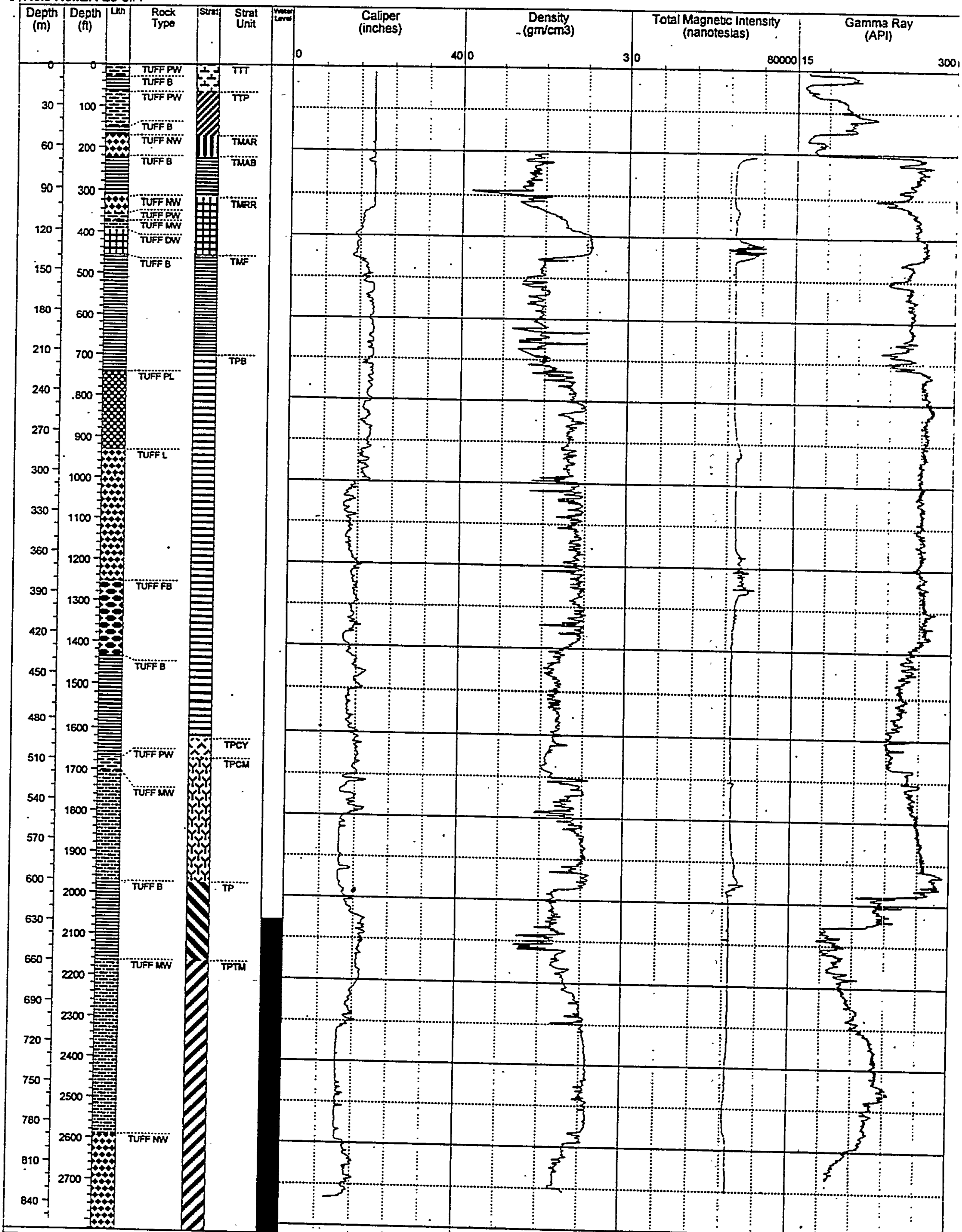
Log Type	Log Interval meters (feet)	Run #	Run Date
Caliper	0.6 to 835.2 (2 to 2,740)	CA4-1	11/02/95
Compensated Density	62.2 to 826.0 (204 to 2,710)	CDL-1	11/03/95
Digital Acoustic Log	626.4 to 833.3 (2,055 to 2,734)	DAC-1	11/03/95
Dual Laterolog (Self Potential and Resistivity)	626.4 to 833.3 (2,055 to 2,734)	DLL-1	11/02/95
Chemical Log (Electrical Conductivity)	626.4 to 824.4 (2,055 to 2,706)	CHEM-2	11/04/95
Compensated Neutron	626.4 to 820.2 (2,055 to 2,691)	CN-1	11/03/95
Gamma Ray	0.6 to 835.2 (2 to 2,740)	GR-1	11/02/96
Spectralog	0.6 to 814.4 (2 to 2,672)	SGR-1	11/03/95
Temperature	552.6 to 827.5 (1,813 to 2,715)	TL-1	11/03/95
Total Magnetic Intensity	64.0 to 824.2 (210 to 2,704)	MPP-1	11/04/95

Table D-2
Geophysical Log Summary for Well ER-20-5#3

Log Type	Log Interval meters (feet)	Run #	Run Date
Caliper	234.1 to 955.2 (768 to 3,134)	CA6-1	01/08/96
Caliper	950.1 to 1,307.0 (3,117 to 4,288)	CA4-2	02/08/96
Chemical Log (Electrical Conductivity and Temperature)	672.1 to 1,308.5 (2,205 to 4,293)	CHEM-1	02/06/96
Compensated Density	627.6 to 1,306.7 (2,059 to 4,287)	CDL-1	02/08/96
Epithermal Neutron Porosity	627.6 to 1,306.7 (2,059 to 4,287)	ENP-1	02/08/96
Digital Acoustic	627.6 to 1,303.6 (2,059 to 4,277)	DAC-1	02/07/96
Spectralog	613.3 to 1,293.3 (2,012 to 4,242)	SL-1	02/07/96
Dual Laterolog (Resistivity and Self Potential)	950.1 to 1,301.8 (3,117 to 4,271)	DLL-1	03/22/94
Gamma Ray	234.7 to 1,301.8 (770 to 4,271)	GR-1 and 2	02/06/96
Temperature	609.6 to 1,308.8 (2,000 to 4,294)	HRT-3	02/08/96

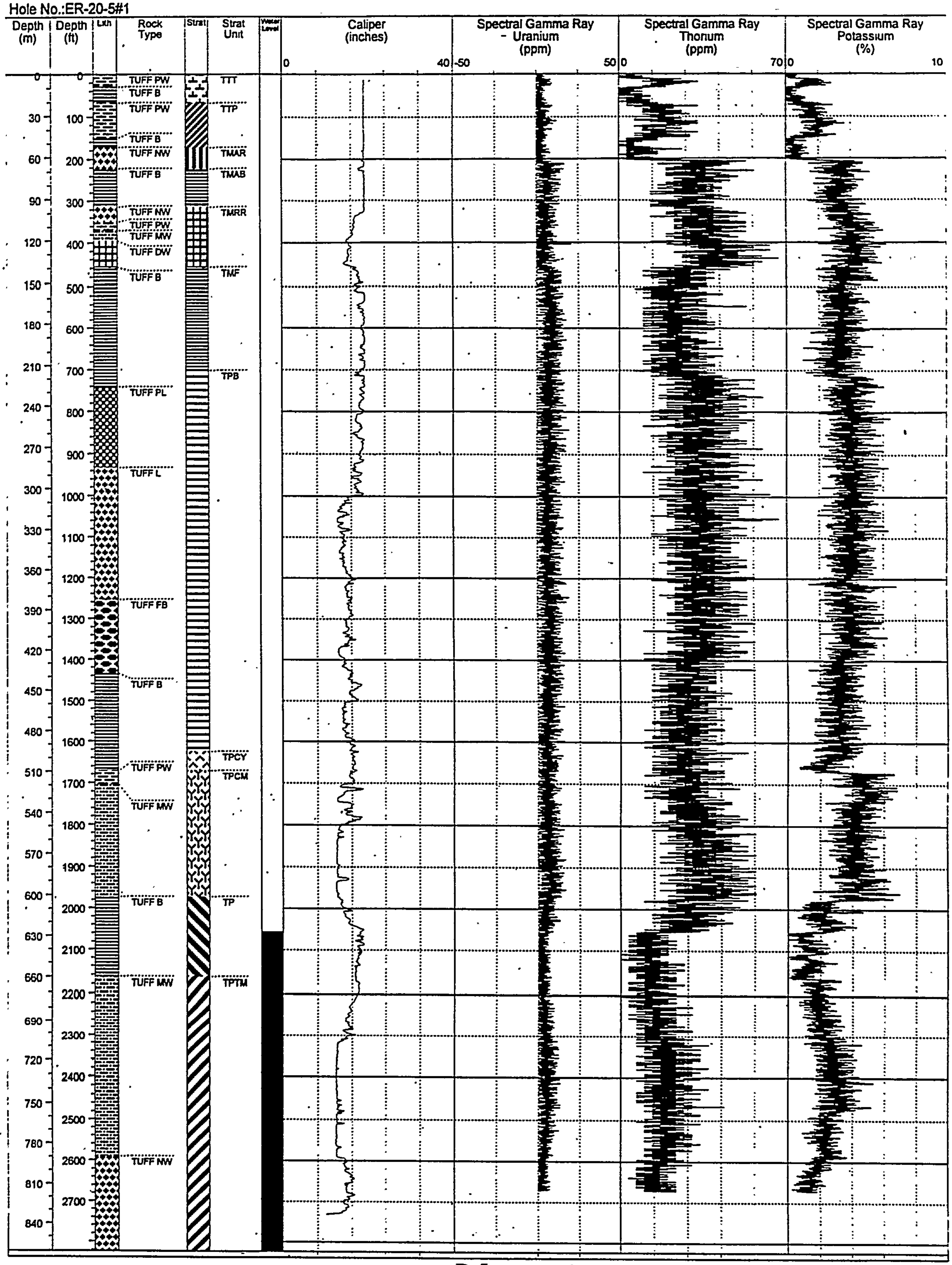
Geophysical Logs
Hole No.:ER-20-5#1

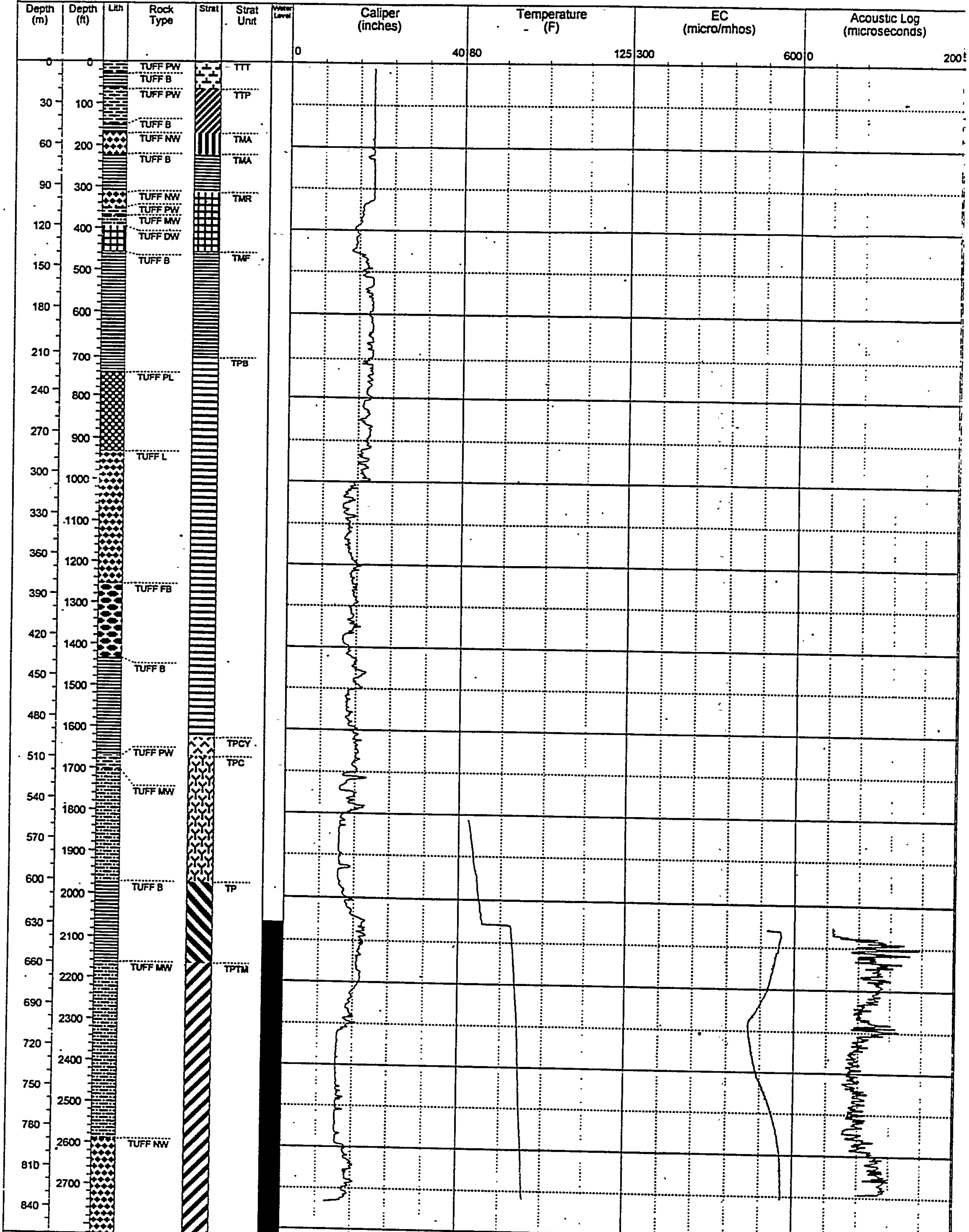



Depth (m)
Depth (ft)
Lith
Rock Type
Strat
Strat Unit
Water Level
Caliper (inches)
0
40
Density (gm/cm3)
0
3
Total Magnetic Intensity (nanoteslas)
0
80000
Gamma Ray (API)
15
300
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
540
570
600
630
660
690
720
750
780
810
840
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
TUFF PW
TUFF B
TUFF PW
TUFF B
TUFF NW
TUFF B
TUFF NW
TUFF PW
TUFF MW
TUFF DW
TUFF B
TUFF PL
TUFF L
TUFF FB
TUFF B
TUFF PW
TUFF MW
TUFF B
TUFF MW
TUFF NW
TTT
TTP
TMAR
TMAB
TMRR
TMF
TPB
TPCY
TPCM
TP
TPTM

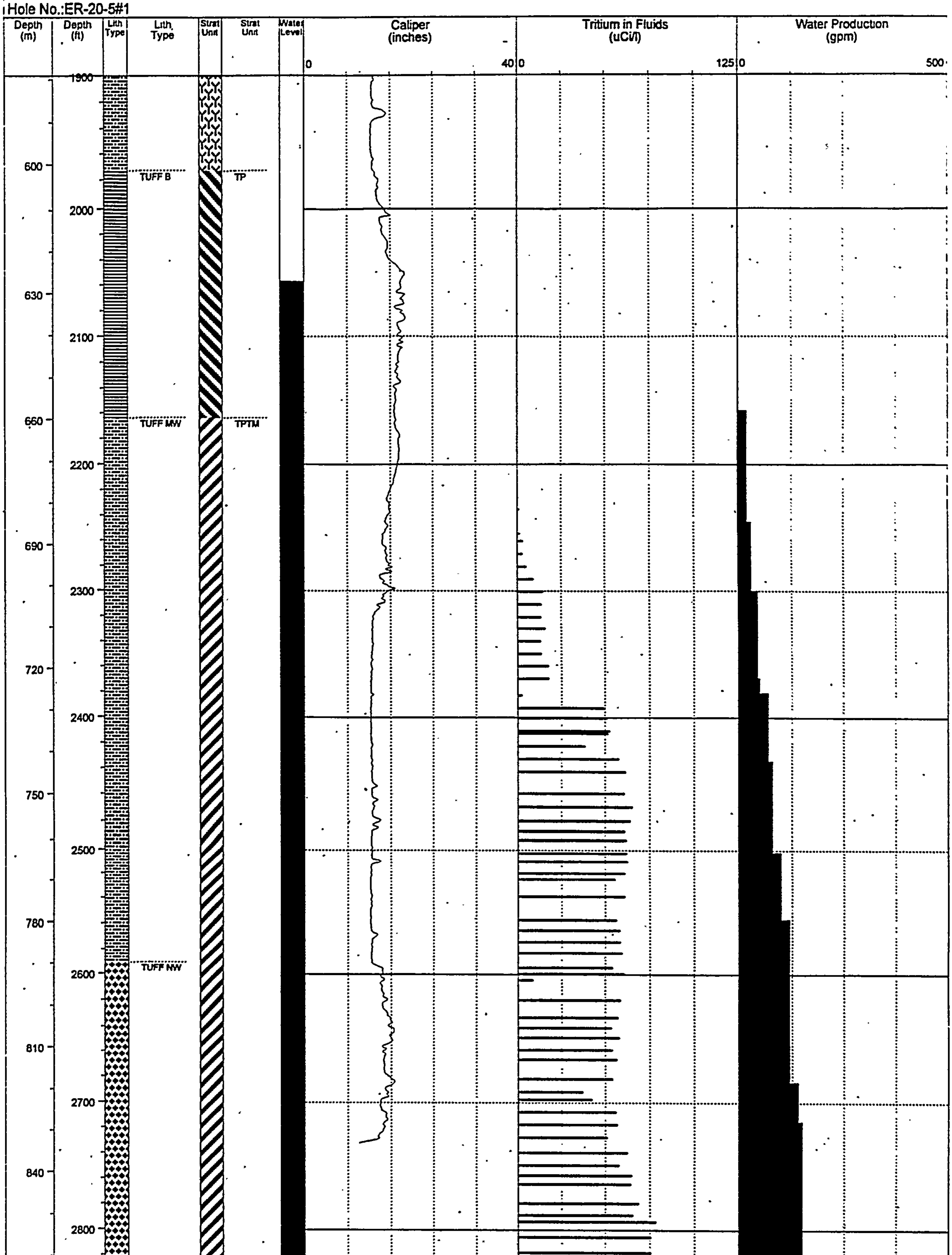
Geophysical Logs

Hole No.:ER-20-5#1




Depth (m)
Depth (ft)
Lith
Rock Type
Strat
Strat Unit
Water Level
Caliper (inches)
Temperature (F)
EC (micro/mhos)
Acoustic Log (microseconds)
TUFF PW
TUFF B
TUFF NW
TUFF MW
TUFF DW
TUFF PL
TUFF L
TUFF FB
TTT
TTP
TMA
TMR
TMF
TPB
TPCY
TPC
TP
TPTM

Geophysical Logs
Hole No.:ER-20-5#1



Geophysical Logs

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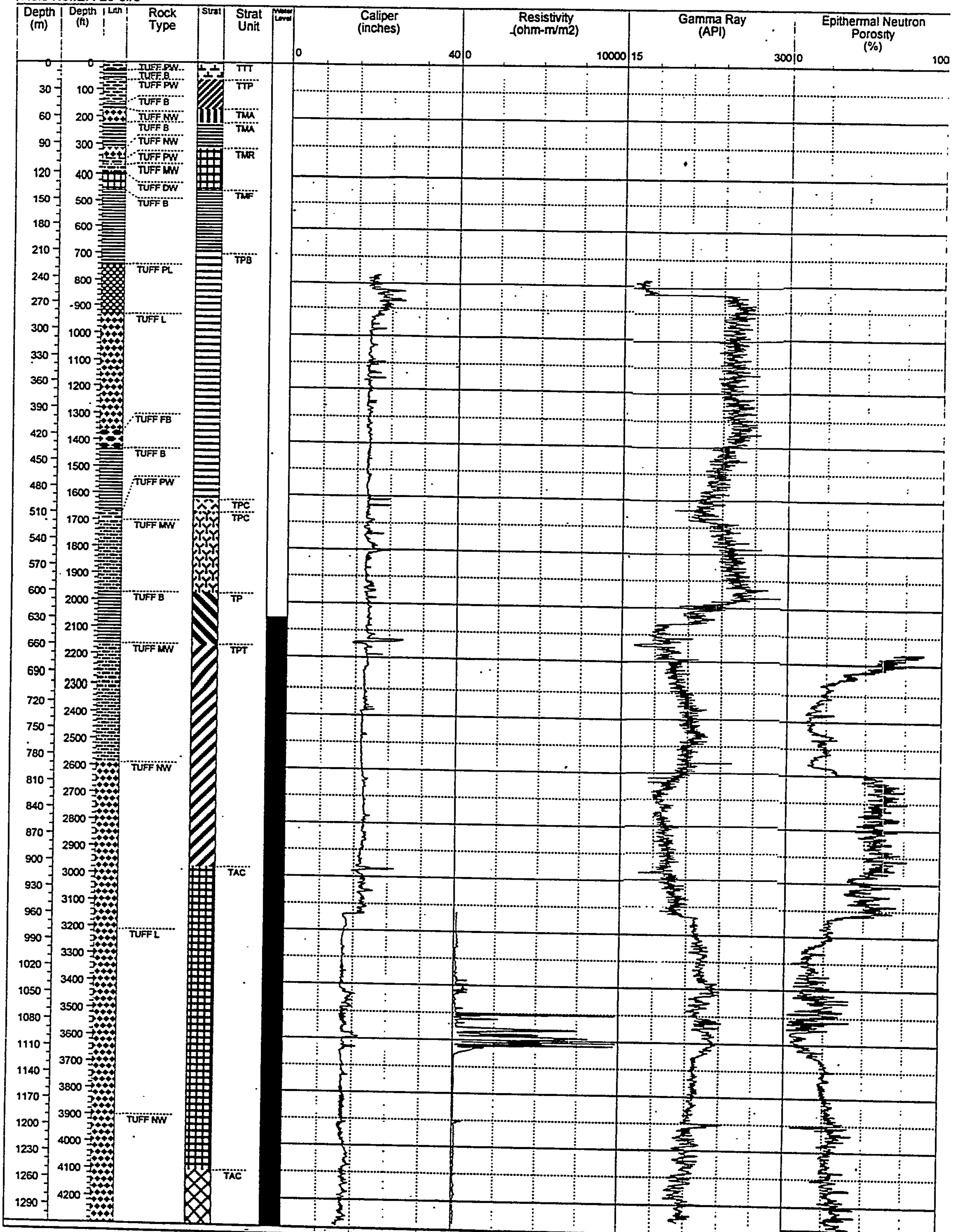

Geophysical Logs

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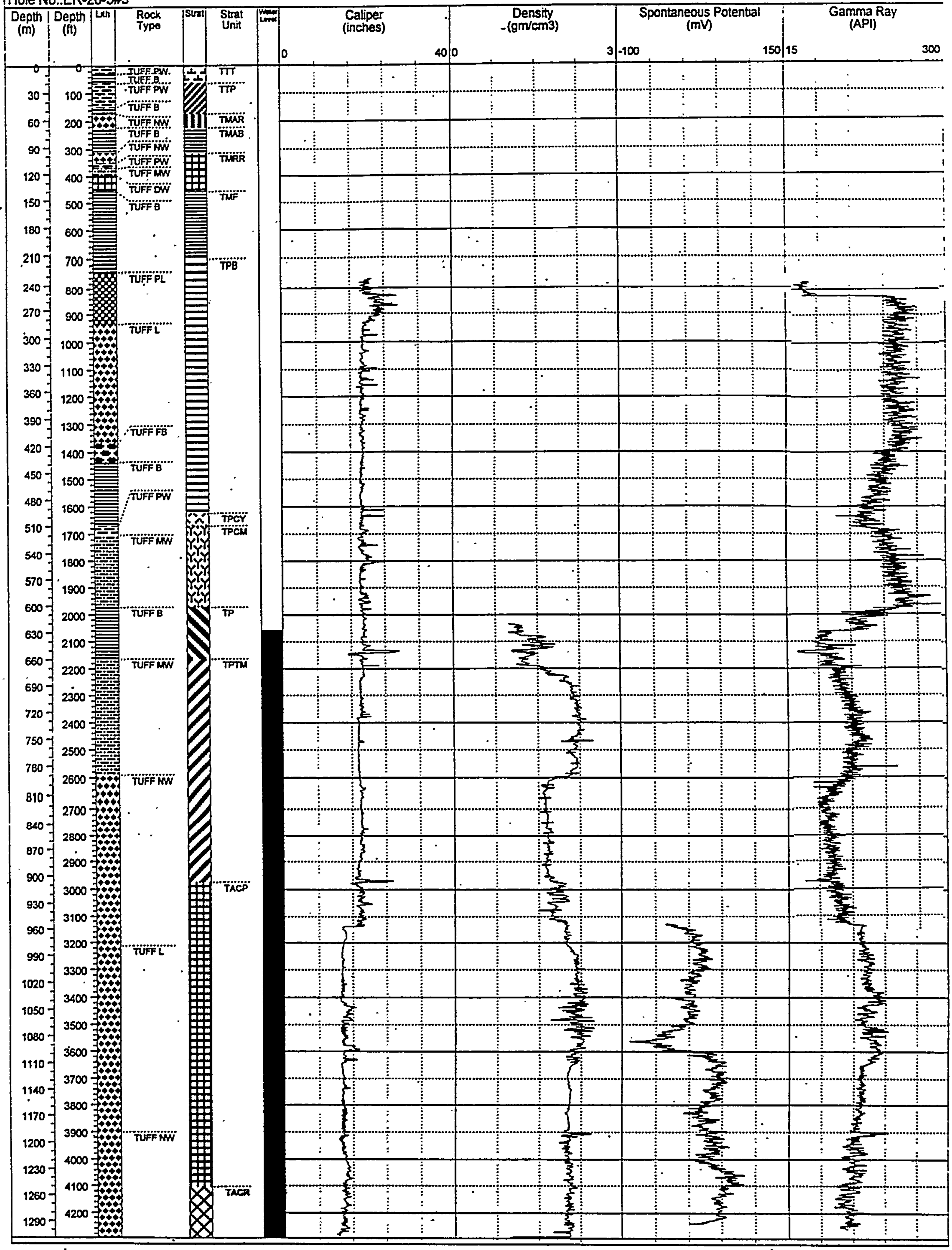

Geophysical Logs

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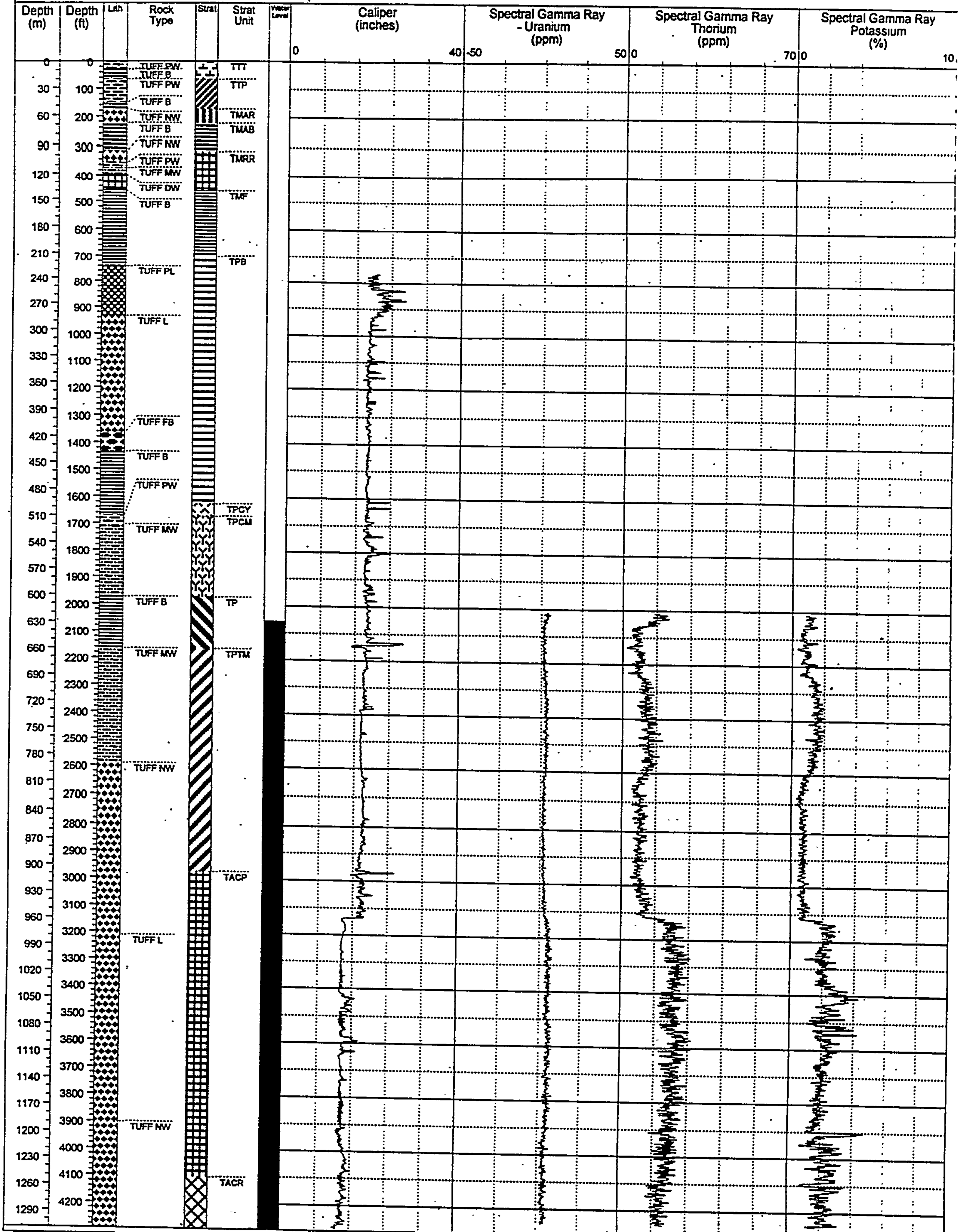
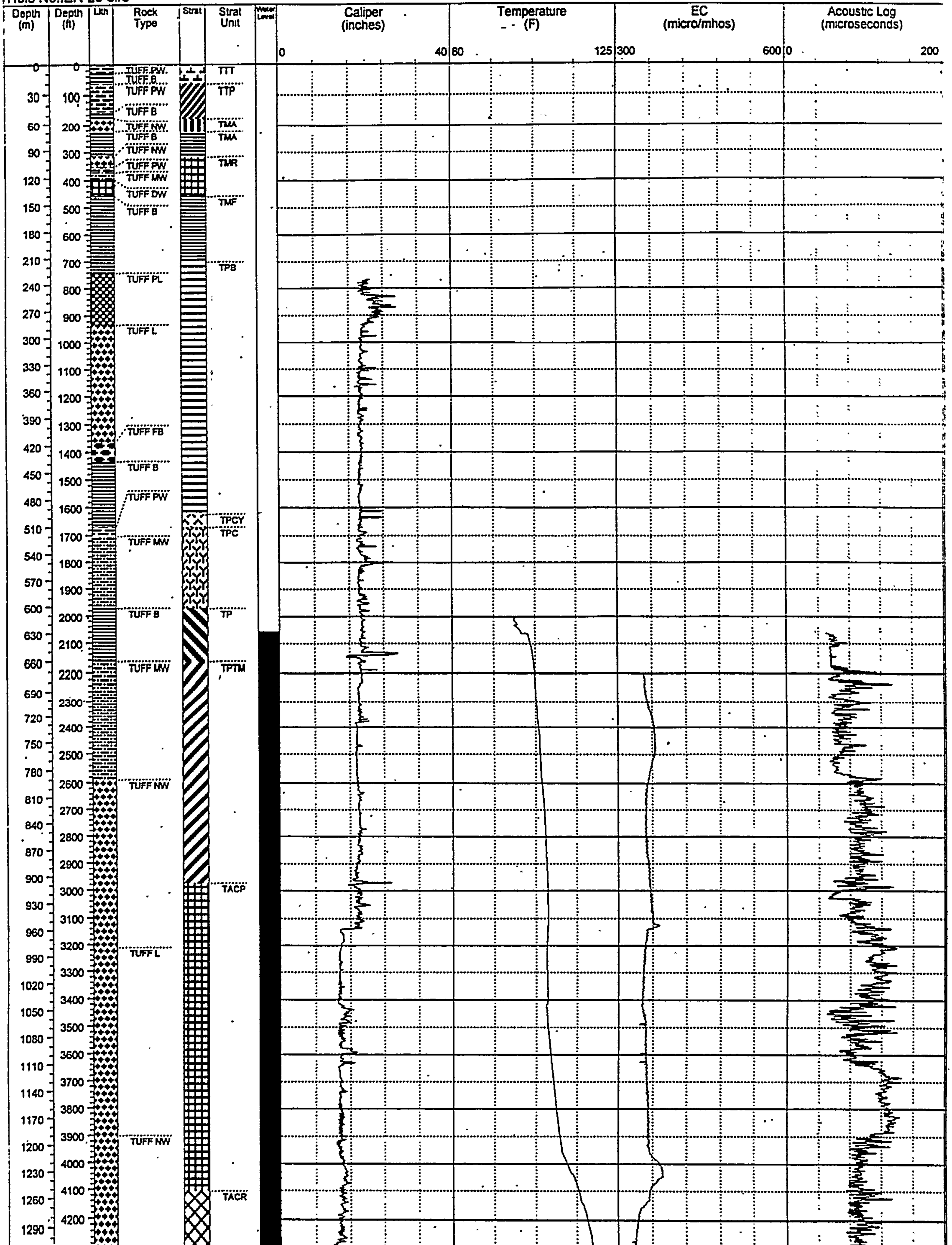


Geophysical Logs
Hole No.:ER-20-5#3



Geophysical Logs
Hole No.:ER-20-5#3