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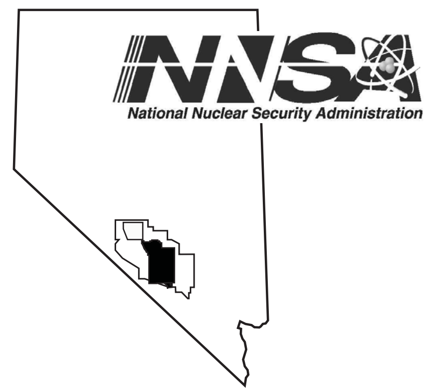

Completion Report for Wells ER-20-8 and ER-20-8#2

Corrective Action Units 101 and 102: Central and Western Pahute Mesa

February 2011

Environmental Restoration Project

U.S. Department of Energy
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Completion Report for Wells ER-20-8 and ER-20-8#2

Corrective Action Units 101 and 102: Central and Western Pahute Mesa

Prepared for:
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Las Vegas, Nevada

Prepared by:
Underground Test Area and Boreholes Programs and Operations
National Security Technologies, LLC
Las Vegas, NV

February 2011

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DOE/NV--1440

Completion Report for Wells ER-20-8 and ER-20-8#2

Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada

Approved by: ______________________ Date: 3/3/2011

for Wilhelm R. Wilborn
Federal Sub-Project Director
Underground Test Area Project

Approved by: ______________________ Date: 3/3/2011

for Robert F. Boehlecke
Federal Project Director
Environmental Restoration Project

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Abstract

Wells ER-20-8 and ER-20-8#2 were drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office in support of the Nevada Environmental Restoration Project at the Nevada National Security Site (formerly Nevada Test Site), Nye County, Nevada. The holes were drilled in July and August 2009, as part of the Pahute Mesa Phase II drilling program. The primary purpose of these wells was to provide detailed hydrogeologic information in the Tertiary volcanic section that will help address uncertainties within the Pahute Mesa–Oasis Valley hydrostratigraphic framework model. They may also be used as long-term monitoring wells. The original plan was to drill one well, with completion zones in each of three aquifers originally predicted at this location. However, a fourth aquifer located below the first aquifer was unexpectedly encountered and contained low levels of tritium. The upper two aquifers were isolated behind casing before drilling into the lower aquifers in Well ER-20-8. Well ER-20-8#2 was then drilled on the same pad and did not penetrate the lower two aquifers; completions were installed in the upper two aquifers.

The first borehole, Well ER-20-8, was drilled in July and August 2009. The main 52.1-centimeter hole was drilled to a depth of 499.3 meters and cased with 40.6-centimeter casing set at 491.9 meters. The hole diameter was then decreased to 37.5 centimeters and the well was deepened to 719.9 meters. The borehole was then cased with 27.3-centimeter casing set at 716.3 meters. The borehole diameter was then decreased to 25.1 centimeters, and drilled to a total depth of 1,049.1 meters. Three piezometer strings were installed in Well ER-20-8. A string of carbon-steel 4.1-centimeter tubing with one slotted interval was inserted outside the 27.3-centimeter casing within the 37.5-centimeter borehole for access to the Benham and Scrugham Peak aquifers. The other two piezometer strings are both 7.3-centimeter stainless-steel tubing hung on 6.0-centimeter carbon-steel tubing via crossover subs. The upper of these two strings was landed at 886.7 meters, for monitoring the Tiva Canyon aquifer, and the lower string was landed at 1,006.5 meters, for monitoring the Topopah Spring aquifer. The completion casing string, set at the depth of 1,019.1 meters, consists of 14.0-centimeter stainless-steel casing hanging from 14.0-centimeter carbon-steel casing. The stainless-steel casing has two slotted intervals open to the Tiva Canyon and Topopah Spring aquifers. A bridge plug was installed at 915.9 m (3,005 ft) between the two slotted intervals in the 5½-in. completion string to isolate the two lower aquifers from each other.

Data collected during and shortly after construction of Well ER-20-8 include composite drill cuttings samples collected every 3.0 meters, sidewall core samples from 27 depth intervals,

various geophysical logs, water quality (primarily tritium) measurements, and water level measurements. Well ER-20-8 penetrated 1,049.1 meters of Tertiary volcanic rock, including one partially and one fully saturated lava-flow aquifer, and two saturated welded-tuff aquifers.

Fluid levels were measured in the piezometer strings of Well ER-20-8 on September 8, 2009. The water levels were as follows: 508.3 meters for the Benham and Scrugham Peak aquifers, measured in the 4.1-centimeter piezometer string; 508.0 meters for the underlying Tiva Canyon aquifer, measured in the upper 7.3-centimeter monitoring string; and 508.1 meters for the lower-most aquifer, the Topopah Spring aquifer, measured in the lower 7.3-centimeter piezometer string. Preliminary measurements by a commercial laboratory indicated 1,300 picocuries per liter of tritium in a water sample from approximately 650.7 meters depth in the Scrugham Peak aquifer.

The second borehole, Well ER-20-8#2, was drilled 15.8 meters west of Well ER-20-8 in August 2009. The main 44.5-centimeter hole was drilled to a depth of 495.6 meters and was cased with 34.0-centimeter casing set at 488.3 meters. The hole diameter was then decreased to 31.1 centimeters, and the well was drilled to a total depth of 712.6 meters. The completion string, set at the depth of 701.0 meters, consists of 19.4-centimeter stainless-steel casing hanging from 19.4-centimeter internally epoxy-coated carbon-steel casing. This casing string has one continuous slotted interval open to the Benham and Scrugham Peak aquifers. A piezometer string was installed adjacent to the completion string. This string was set at a depth of 681.0 meters and consists of 7.3-centimeter stainless-steel tubing hanging from 6.0-centimeter internally epoxy-coated carbon-steel tubing. The 7.3-centimeter piezometer string has one continuous slotted interval also open to the Benham and Scrugham Peak aquifers.

Data collected during and shortly after construction of Well ER-20-8#2 include composite drill cuttings samples collected every 3.0 meters, several geophysical logs, water quality (primarily tritium) measurements, and water level measurements. Well ER-20-8#2 penetrated 712.6 meters of Tertiary volcanic rock, including one partially and one fully saturated lava-flow aquifer.

The fluid level was measured at a depth of 508.4 meters inside the 19.4-centimeter completion casing of Well ER-20-8#2 on September 8, 2009. No tritium above the background level resolution of the field instruments was detected in this hole.

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List of Acronyms and Abbreviations

BA	Benham aquifer
BN	Bechtel Nevada
CAIP	Corrective Action Investigation Plan
CAU	Corrective Action Unit
CBIL	Circumferential Borehole Imaging Log
CHZCM	Calico Hills zeolitic composite unit
cm	centimeter(s)
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
FAWP	field activity work package
FFACO	Federal Facility Agreement and Consent Order
FMP	Fluid Management Plan
ft	foot (feet)
gpm	gallons per minute
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
ID	inside diameter
in.	inch(es)
kg	kilogram(s)
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
Lpm	liters per minute
m	meter(s)
m^3	cubic meters
Ma	million years ago
NAD	North American Datum
NAIL	Nuclear Annulus Investigation Log
NARA	National Archives and Records Administration
N-I	Navarro-Intera, LLC
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
NTMMSZ	northern Timber Mountain moat structural zone

List of Acronyms and Abbreviations (continued)

OD	outside diameter
PM–OV	Pahute Mesa–Oasis Valley
pCi/L	picocuries per liter
RCT	radiological control technician
SCCC	Silent Canyon caldera complex
SNJV	Stoller-Navarro Joint Venture
SPA	Scrugham Peak aquifer
TD	total depth
TCA	Tiva Canyon aquifer
TMCC	Timber Mountain caldera complex
TSA	Topopah Spring aquifer
TWG	Technical Working Group
UGT	underground nuclear test
UGTA	Underground Test Area
UDI	United Drilling, Inc.
UPCU	upper Paintbrush confining unit
USGS	U.S. Geological Survey
yd^3	cubic yards

1.0 Introduction

1.1 Project Description

Well ER-20-8 and supplemental Well ER-20-8#2 were drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Restoration Project at the Nevada National Security Site (NNSS; formerly Nevada Test Site), Nye County, Nevada. These boreholes together constitute the second well drilled as part of the Phase II hydrogeologic investigation well-drilling program in the Central and Western Pahute Mesa area of Nye County, Nevada.

The Pahute Mesa Phase II drilling program is part of the Corrective Action Investigation Plan (CAIP) for the Central and Western Pahute Mesa Corrective Action Units (CAUs) 101 and 102, respectively (NNSA/NSO, 2009a). The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended February 2008).

The Central and Western Pahute Mesa CAUs and the associated well drilling program are part of the NNSA/NSO Environmental Restoration Project's Underground Test Area (UGTA) Sub-Project at the NNSS. Two of the goals of the UGTA Sub-Project are to evaluate the nature and extent of contamination in groundwater due to underground nuclear testing and to establish a long-term groundwater monitoring network. As part of the UGTA Sub-Project, scientists are developing computer models to predict groundwater flow and contaminant migration within and near the NNSS. To build and test these models, it is necessary to collect geologic, geophysical, and hydrologic data from new and existing wells to define groundwater quality, migration pathways, and migration rates. Data from these wells will allow for more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may be used as long-term monitoring wells.

The Well ER-20-8 site is located near the northwest boundary of the NNSS (Figure 1-1), between the Silent Canyon and Timber Mountain caldera complexes, in an area known as the Bench. The primary purpose of drilling at this location was to obtain detailed hydrogeologic information in the Tertiary volcanic section that will help address uncertainties within the Pahute Mesa–Oasis Valley (PM–OV) hydrostratigraphic framework model (HFM) (Bechtel Nevada [BN], 2002) and subsequent flow and transport modeling.

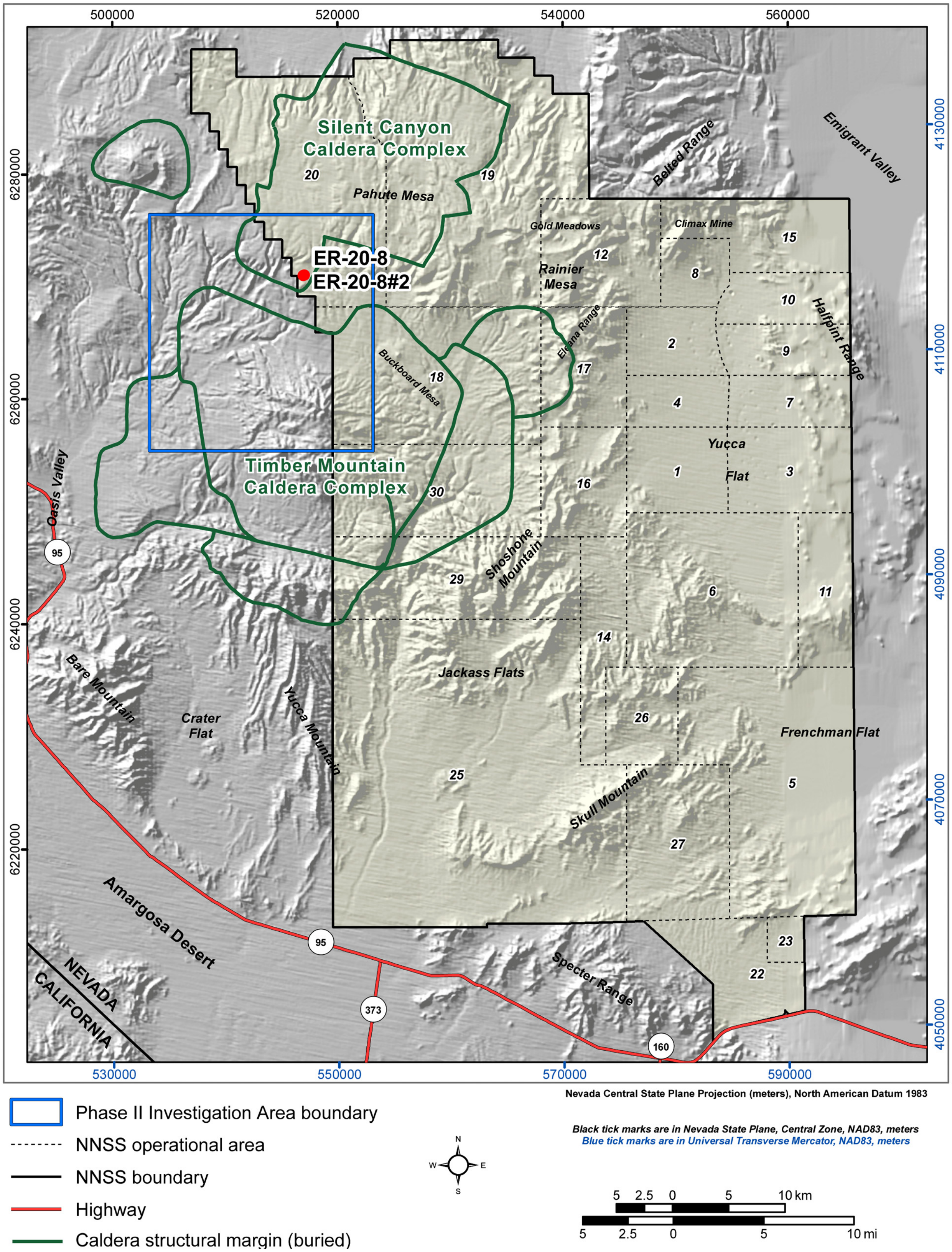

Figure 1-1
Reference Map Showing the Location of the Well ER-20-8 Site

1.2 Project Organization

The construction of Well ER-20-8 was intended to help fulfill the goals of the UGTA Sub-Project. Several advisory groups function within the sub-project, whose responsibilities include ensuring that the sub-project goals are properly planned and achieved. The roles of these groups as regards successful construction of the wells at the ER-20-8 site are described in this section.

The UGTA Technical Working Group (TWG) is a committee of scientists and engineers from NNSA/NSO, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), the Nevada Division of Environmental Protection, the Desert Research Institute (DRI), the U.S. Geological Survey (USGS), Stoller-Navarro Joint Venture (SNJV; environmental contractor at the time, now Navarro-Intera, LLC [N-I]), and National Security Technologies, LLC (NSTec; NNSS management and operating contractor). The TWG has responsibility for providing technical advice and recommendations to the UGTA Sub-Project Manager to promote the effective closure of CAUs on the NNSS and ensure the continuing protection of the public health. The TWG's Pahute Mesa CAU Guidance Team and the TWG CAIP subcommittee assisted NNSA/NSO in developing the CAIP for the Pahute Mesa CAUs. The TWG's Well ER-20-8 drilling advisory team, which included the NNSA/NSO UGTA Sub-Project Manager, the SNJV field manager, the NSTec UGTA manager/drilling engineer, a hydrologist, a geologist, and a radio-chemist, provided technical advice during drilling, design, and construction of the well, to ensure that Well ER-20-8 was constructed to meet scientific objectives identified in the CAIP and the drilling criteria. See *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a) for descriptions of the general plan and goals of the Pahute Mesa Phase II drilling initiative project, as well as specific goals for each well.

SNJV was the principal environmental contractor for the project, and SNJV personnel collected geologic and hydrologic data during drilling (SNJV's name was changed to Navarro-Intera, LLC in July 2010; all subsequent references to the activities of this entity in this report will be N-I). Site supervision, engineering, construction, inspection, and geologic support were provided by NSTec. The drilling company was United Drilling, Inc. (UDI), a subcontractor to NSTec. The roles and responsibilities of these and other contractors involved in the project are described in NSTec subcontract number 107553 and in field activity work packages (FAWP) numbers D-004-001.09, D-007-001.09, and D-008-001.09 (NSTec, 2009a; 2009b; 2009c).

General guidelines for managing fluids used and generated during drilling, completion, and testing of UGTA wells are provided in the UGTA Fluid Management Plan (FMP) (NNSA/NSO, 2009b). Estimates of expected production of fluid and drill cuttings for the Pahute Mesa holes are given in Appendix O of the drilling and completion criteria document for the drilling project (SNJV, 2009a), along with sampling requirements and contingency plans for management of any hazardous waste produced. All activities were conducted according to specific FAWPs (e.g., NSTec, 2009a; 2009b; 2009c; SNJV, 2009b) and the UGTA Project Health and Safety Plan, Revision 2 (NSTec, 2008).

This report presents construction data and summarizes scientific data gathered during the drilling of Wells ER-20-8 and ER-20-8#2. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. Well data reports prepared by N-I contain additional information on fluid management, waste management, and environmental compliance for the project (N-I, 2010a; 2010b). Hydrogeologic information for this area is presented in the data documentation package for the PM–OV HFM prepared by BN (2002). Documentation for Phase I flow and transport modeling, which guided this Phase II data collection activity, can be found in SNJV (2006; 2007; 2009c). Pre-drilling geologic information for this area (including any changes in the geologic interpretation since completion of the PM–OV HFM [BN, 2002]) is compiled in the Phase II drilling criteria document (SNJV, 2009a). Information on well development, aquifer testing, and groundwater analytical sampling (which are outside the scope of this report) are typically compiled and disseminated separately.

1.3 Location and Significant Nearby Features

The Well ER-20-8 site is located in NNSS Area 20 at an elevation of about 1,782.5 meters (m) (5,848 feet [ft]), approximately 1,219 m (4,000 ft) south of the topographic edge of Pahute Mesa. The drill site is about 2,073 m (6,800 ft) northeast of UGTA Well ER-EC-6 and about 1,905 m (6,250 ft) southeast of UGTA Well ER-EC-11. The locations of these features in relation to the well site are shown in Figure 1-2. Additional information about Wells ER-20-8 and ER-20-8#2 is provided in Table 1-1.

The Well ER-20-8 site is located in an area known as the Bench, a structural region defined as the area between the northern Timber Mountain moat structural zone (NTMMSZ) and the Timber Mountain caldera complex (TMCC) (Figure 1-3). The surface topography in the vicinity is relatively flat with gentle rolling hills. The well site is located on top of one of these low hills. Drainage at the Well ER-20-8 site is to the northeast.

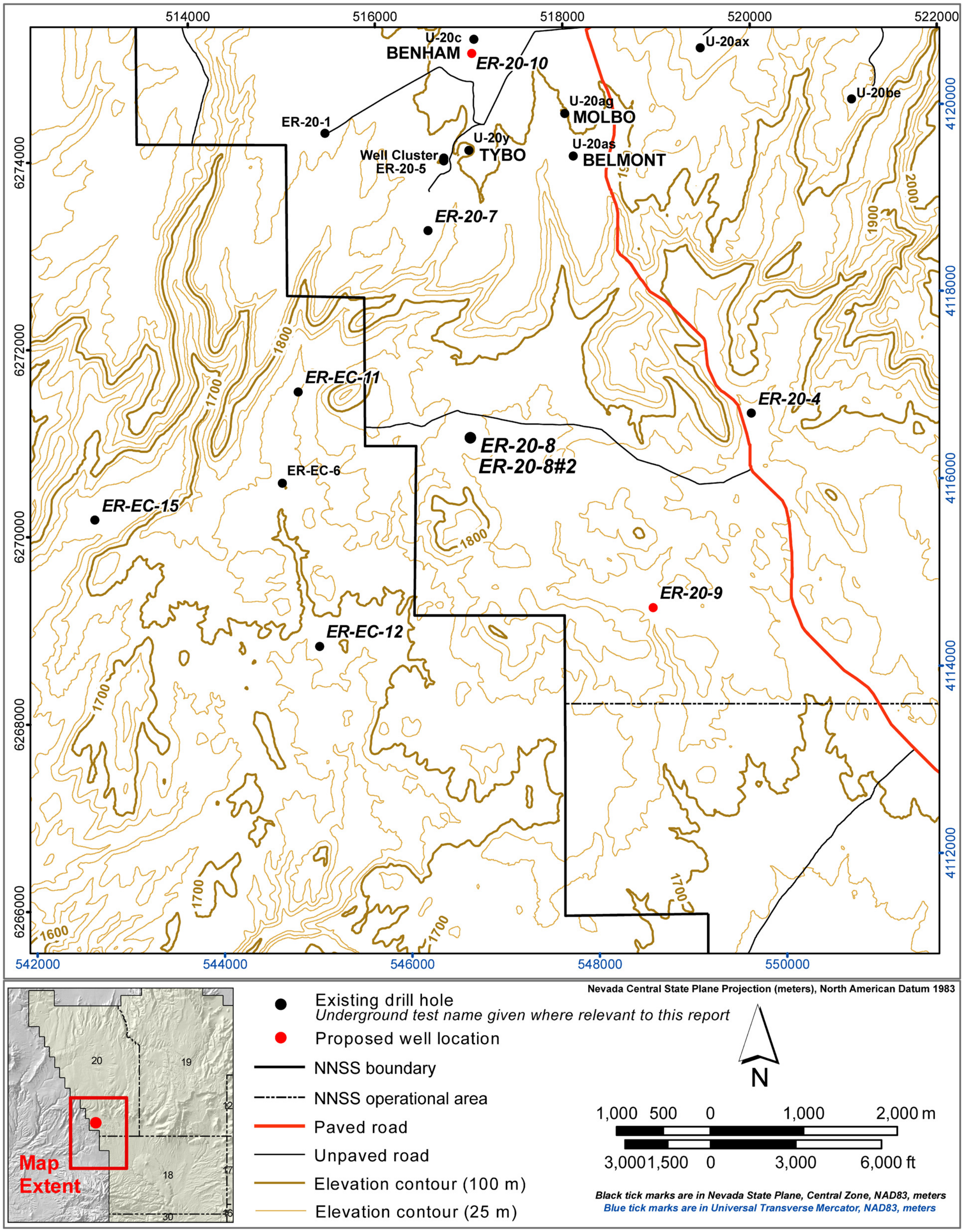

Figure 1-2
Topographic Map of the Well ER-20-8 Site Area Showing the Locations of Roads and Nearby Drill Holes

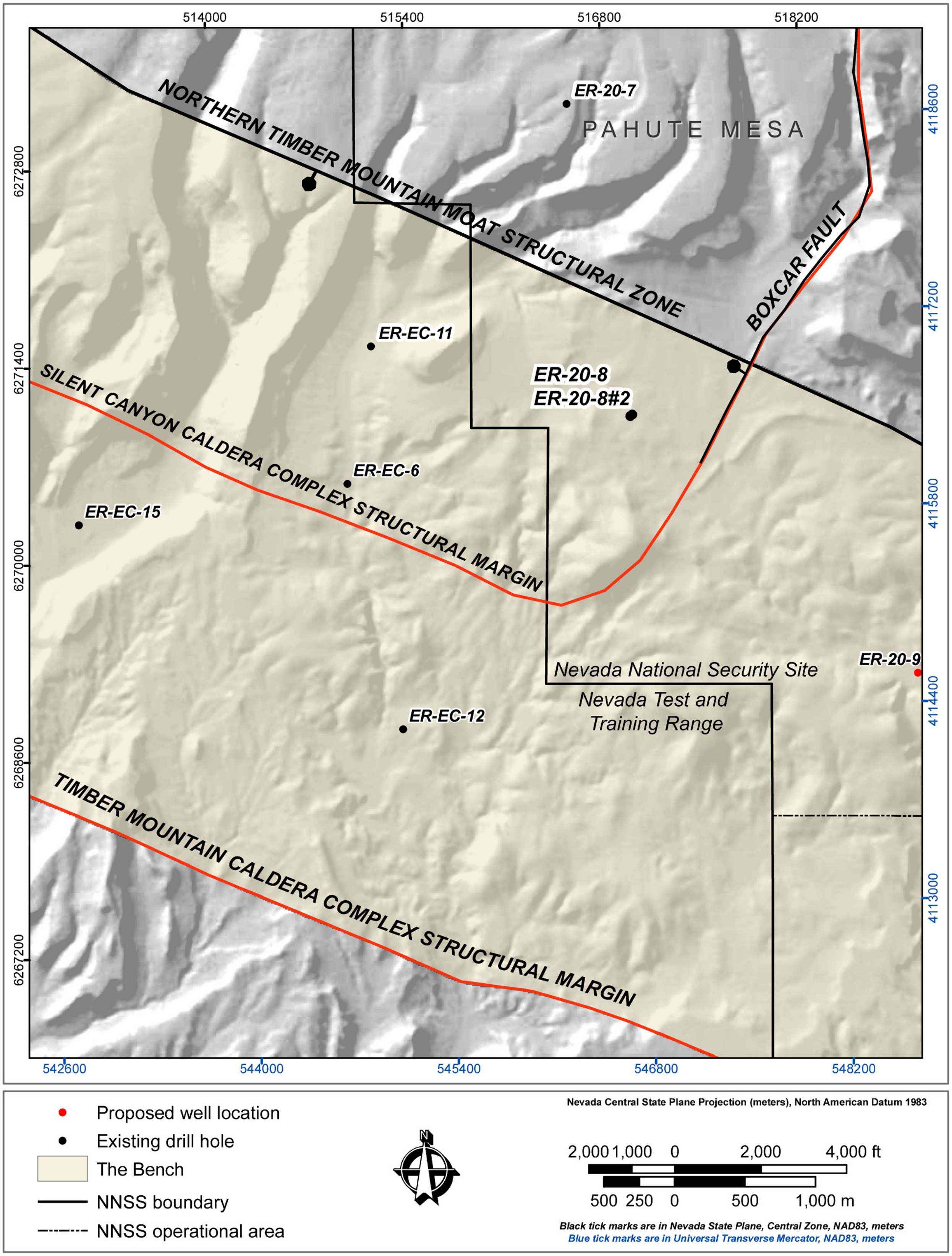

Figure 1-3
Orthophoto of the Well ER-20-8 Site Area, Showing Location of the Bench

Table 1-1
Site Data Summary for Wells ER-20-8 and ER-20-8#2

Well Designation		Well ER-20-8	Well ER-20-8#2
Site Coordinates [a]	Nevada State Plane (Central Zone) (NAD 83) meters	N 6,271,065.3 E 517,027.5	N 6,271,058.3 E 517,013.9
	Nevada State Plane (Central Zone) (NAD 83) feet	N 20,574,320.2 E 1,696,281.0	N 20,574,297.3 E 1,696,236.3
	Nevada State Plane (Central Zone) (NAD 27) feet	N 889,318.1 E 556,125.2	N 889,295.2 E 556,080.6
	Universal Transverse Mercator (Zone 11) (NAD 83) meters	N 4,116,415.5 E 546,606.1	N 4,116,408.4 E 546,592.5
Surface Elevation [a, b]		1,782.6 m (5,848.3 ft)	1,782.7 m (5,848.8 ft)
Drilled Depth		1,049.1 m (3,442 ft)	712.6 m (2,338 ft)
Preliminary Fluid-Level Depth [c]		**BA/SPA:** 508.3 m (1,667.5 ft) **TCA:** 508.0 m (1,666.7 ft) **TSA:** 508.1 m (1,666.9 ft)	**BA/SPA:** 508.4 m (1,668.1 ft)
Fluid-Level Elevation		1,274.4 m (4,181 ft)	1,274.4 m (4,181 ft)
Surface Geology		Rhyolitic lava (rhyolite of Tannenbaum Hill)	

a Measurements made by NSTec Survey. NAD = North American Datum (National Archives and Records Administration [NARA], 1989; U.S. Coast and Geodetic Survey, 1927).

b Measurement made by NSTec Survey. Elevation at top of construction pad. National Geodetic Vertical Datum, 1929 (NARA, 1973). Elevations are relative to mean sea level.

c Measurements made by N-I on September 8, 2009.
BA = Benham aquifer; SPA = Scrugham Peak aquifer; TCA = Tiva Canyon aquifer; TSA = Topopah Spring aquifer

The underground nuclear tests (UGTs) closest to the Well ER-20-8 site are TYBO (U-20y), BELMONT (U-20as), MOLBO (U-20ag), and BENHAM (U-20c) (Figure 1-2). Three of the tests were conducted below the water table, and BELMONT was conducted approximately 9 m (29 ft) above the water table. The UGT closest to the Well ER-20-8 site is TYBO, located approximately 3,078 m (10,100 ft) to the north. Table 1-2 provides additional information regarding these nearby tests.

1.4 Objectives

The primary purpose for drilling at the Well ER-20-8 site was to obtain detailed hydrogeologic information from the shallow- to intermediate-depth Tertiary volcanic section in the area known as the Bench, between the NTMMSZ and the TMCC (NNSA/NSO, 2009a). These wells are expected to produce data that will improve modeling of flow and transport within CAUs 101 and 102. The Well ER-20-8 site may be a favorable location for a long-term monitoring well.

The objectives for Well ER-20-8, as described in Appendix C of the drilling and completion criteria document for the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells (SNJV, 2009a), are listed below, along with well-specific activities necessary to accomplish the objectives:

1. Characterize the hydrogeology of southwestern Pahute Mesa to reduce uncertainties within the southern Pahute Mesa area of the PM–OV HFM. In particular, data from the well are expected to aid in accomplishing the following specific goals:

   – Provide detailed hydrogeologic information for the shallow- to intermediate-depth Tertiary volcanic section. The aquifers of interest are the Benham aquifer (BA), the Tiva Canyon aquifer (TCA), and the Topopah Spring aquifer (TSA).

   – Refine the location of structural features such as the NTMMSZ and the Boxcar fault, and infer what effect they may have on groundwater flow.

   – Provide detailed geology and configuration of aquifer units in the upper portion of the saturated section where contaminant transport is most likely.

2. Investigate radionuclide migration down-gradient from the TYBO and BENHAM UGTs.

3. Obtain hydraulic properties such as detailed fracture data and hydrologic information for the BA, TCA, and TSA, to improve subsequent flow and transport modeling for the area between the former test areas at Pahute Mesa and the TMCC.

Table 1-2
Information for Underground Nuclear Tests Relevant to the Well ER-20-8 Site

Emplacement Hole Name	Test Name [a]	Test Date [a]	Surface Elevation [b] meters (feet)	Working Point		Regional Water Level		Announced Yield [a] (kilotons)	Working Point Formation [c, d]	Working Point HSU [c, e]
				Depth [b] meters (feet)	Elevation meters (feet)	Depth [b] meters (feet)	Elevation meters (feet)			
U-20y	TYBO	5/14/1975	1,907 (6,257)	765 (2,510)	1,142 (3,747)	630 (2,067)	1,277 (4,190)	200–1,000	Tpt	TSA
U-20as	BELMONT	10/16/1986	1,898 (6,227)	605 (1,985)	1,293 (4,242)	614 (2,014)	1,284 (4,213)	20–150	Tpb(b)	UPCU
U-20ag	MOLBO	2/12/1982	1,900 (6,234)	638 (2,093)	1,262 (4,141)	619 (2,031)	1,281 (4,203)	20–150	Tpb	BA
U-20c	BENHAM	12/19/1968	1,914 (6,281)	1,402 (4,600)	512 (1,681)	639 (2,096)	1,275 (4,185)	1,150	Th	CHZCM

a U.S. Department of Energy, Nevada Operations Office (DOE/NV), 2000a
b DOE/NV, 1999
c BN, 2002

d Stratigraphic nomenclature:
Tpt = Topopah Spring Tuff
Tpb(b) = rhyolite of Benham, bedded
Tpb = rhyolite of Benham
Th = Calico Hills Formation

e Hydrostratigraphic nomenclature:
TSA = Topopah Spring aquifer
UPCU = upper Paintbrush confining unit
BA = Benham aquifer
CHZCM = Calico Hills zeolitic composite unit

The following activities are necessary to accomplish these goals:

- Collect drill cuttings and other geologic samples for geologic evaluation and for detailed mineralogic analysis. The mineralogic data will help define the vertical distribution of reactive minerals such as clays, zeolites, and iron oxides in the Tertiary volcanic section.
- Obtain geophysical log data from the borehole, including image logs for fracture identification and other logs for lithologic and stratigraphic identification and interpretation of rock properties.
- Collect aqueous geochemistry samples for analysis to determine whether tritium and other radionuclides have migrated to the well location. These analyses will also make it possible to better define possible groundwater flow paths based on water chemistry.
- Obtain detailed water-level data to determine the regional water level and investigate potential local groundwater flow down-gradient from the TYBO and BENHAM UGTs.

Additional data that will help characterize the hydrology in southwestern Pahute Mesa will be obtained during later hydraulic testing at these wells. Specific criteria for these later tests will be provided elsewhere (e.g., FAWPs and well development and testing plans), but, ultimately, the ER-20-8 wells are expected to provide data for determination of horizontal and vertical conductivity and hydraulic properties of saturated hydrostratigraphic units (HSUs) penetrated.

The completed wells will accommodate single-well hydraulic testing for the two deeper aquifers, and cross-well testing of the upper lava-flow aquifers. These wells could be potential observation wells for future multiple-well aquifer tests.

1.5 Project Summary

This section summarizes construction operations for Wells ER-20-8 and ER-20-8#2; the details are provided in Sections 2.0 through 5.0 of this report.

Wells ER-20-8 and ER-20-8#2 were drilled on the same pad approximately 15.8 m (52 ft) apart (Figure 1-4). The original plan called for drilling one well, with completion zones in each of the three aquifers originally predicted at this site. However, a fourth aquifer, the Scrugham Peak aquifer (SPA), was encountered unexpectedly below the BA (and separated from the BA by the upper Paintbrush confining unit). In addition, low levels of tritium were encountered in a localized zone within the SPA, so the NNSA/NSO and the Pahute Mesa CAU Guidance Team

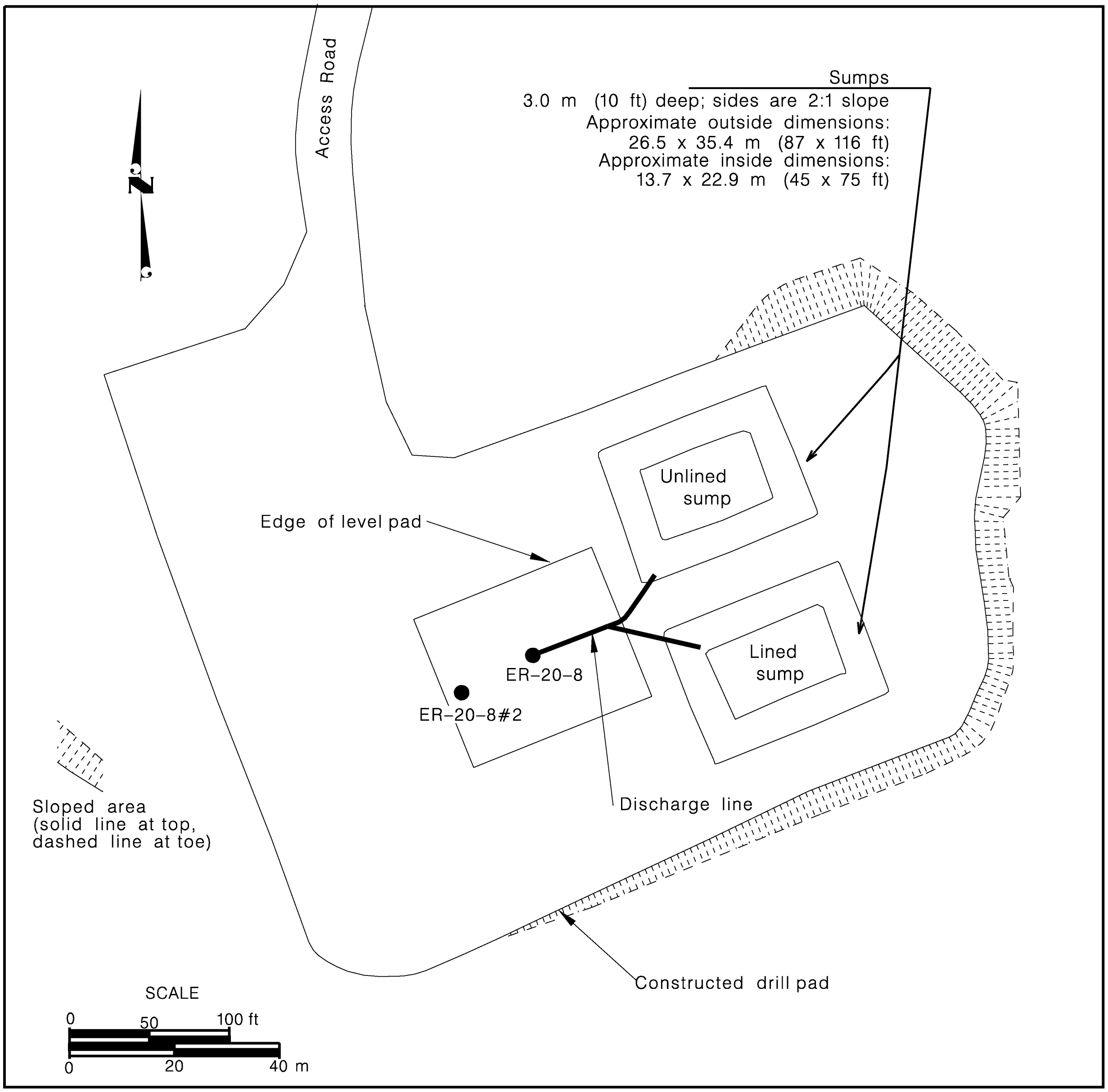

Figure 1-4
Drill Site Configuration for Wells ER-20-8 and ER-20-8#2

decided to isolate the BA and SPA behind casing before the well was drilled deeper to prevent potential contamination of the lower aquifers (TCA and TSA).

Well ER-20-8 was then drilled to a total depth (TD) of 1,049.1 m (3,442 ft), and completion zones were established in the TCA and TSA. A piezometer string provides for limited access to the upper lava-flow aquifers, the BA and SPA. Well ER-20-8#2 was drilled to a TD of 712.6 m (2,338 ft). It did not penetrate the TCA or the TSA and was completed in the BA and SPA.

For both holes, composite drill cuttings were collected every 3.0 m (10 ft) after the start of drilling of the main holes to TD. At Well ER-20-8, 27 sidewall core samples were collected at various depths. Open-hole geophysical logging was conducted in Well ER-20-8 to help verify the geology and characterize the hydrologic properties of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition. The only geophysical logging conducted in Well ER-20-8#2 were chemistry and flow logs, and logs for monitoring well completion and stemming, because the same geologic section was well characterized in nearby Well ER-20-8.

1.5.1 Well ER-20-8

A 106.7-centimeter (cm) (42.0-inch [in.]) diameter surface conductor hole was constructed by drilling to a depth of 33.2 m (109 ft) and installing a string of 30-in. conductor casing to the depth of 31.5 m (103.4 ft). Drilling of the main hole with a 20½-in. tri-cone bit, using air-foam in conventional circulation began on July 12, 2009. The 52.1-cm (20.5-in.) diameter surface hole was drilled to a depth of 499.3 m (1,638 ft), and 16-in. surface casing was set at 491.9 m (1,614.0 ft). The top of the BA was reached at 468.5 m (1,537 ft). The hole diameter was decreased to 37.5 cm (14.75 in.) at the depth of 499.3 m (1,638 ft), and the well was drilled to the depth of 719.9 m (2,362 ft). The top of the SPA was reached at 549.9 m (1,804 ft). Tritium in the amount of 1,300 picocuries per liter (pCi/L) (about 1/15 of the Safe Drinking Water Act limit of 20,000 pCi/L]) was encountered in the SPA at a depth of approximately 650.7 m (2,135 ft), which is approximately 142.6 m (468 ft) below the static water level. A string of 10¾-in. casing was set at the depth of 716.3 m (2,350.0 ft) to isolate the BA and SPA. The borehole diameter was again reduced in size, to 25.1 cm (9.875 in.) for drilling to the TD of 1,049.1 m (3,442 ft), reached on August 8, 2009. The top of the TCA was reached at 766.0 m (2,513 ft) and the top of the TSA was reached at 961.6 m (3,155 ft). The open-hole water level prior to installation of the completion string was measured at 507.5 m (1,665 ft) on August 9, 2009, during geophysical logging. About a month later, a water level of 508.1 m (1,667 ft) was measured by N-I.

The well has three piezometer strings and one completion casing string. A string of 1.6-in. carbon-steel tubing was installed between the borehole wall and the 10¾-in. casing. This string has one slotted interval at the depth of 636.6 to 645.9 m (2,088.5 to 2,119.1 ft) for water level measurements in the BA and SPA. Two 2⅞-in. tubing strings were also inserted into the borehole. Both of these strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs. The upper tubing string is slotted from 761.5 to 886.4 m (2,498.2 to 2,908.1 ft) for monitoring within the TCA. The lower tubing string is slotted from 957.3 to 1,006.1 m (3,140.9 to 3,301.0 ft) for monitoring within the TSA.

The well was completed with a string of 5½-in. stainless-steel casing, which hangs from 5½-in. carbon-steel casing via a crossover sub. The carbon-steel casing is positioned in the unsaturated zone to a point approximately 24.4 m (80 ft) above the water table. The 5½-in. stainless-steel casing has two slotted intervals, one at 757.8 to 887.7 m (2,486.1 to 2,912.4 ft) and the other at 953.1 to 1,005.4 m (3,126.9 to 3,298.4 ft), allowing access to the TCA and TSA, respectively. These two zones are separated by layers of cement. A bridge plug was installed at 915.9 m (3,005 ft) between the two slotted intervals in the 5½-in. completion string to isolate the two lower aquifers from each other.

1.5.2 Well ER-20-8#2

A 106.7-cm (42.0-in.) diameter surface conductor hole was constructed by drilling to a depth of 25.5 m (83.5 ft) and installing a string of 20-in. conductor casing to the depth of 24.9 m (81.7 ft). Drilling of the main hole with a 17½-in. tri-cone bit, using air-foam in conventional circulation, began on August 22, 2009. The 44.5-cm (17.5-in.) diameter surface hole was drilled to a depth of 495.6 m (1,626 ft), and 13⅜-in. surface casing was set at 488.3 m (1,602.2 ft). The top of the BA was reached at 468.5 m (1,537 ft). The hole diameter was decreased to 31.1 cm (12.25 in.) at the depth of 495.6 m (1,626 ft), and the well was drilled to the TD of 712.6 m (2,338 ft), which was reached on August 30, 2009. The top of the SPA was reached at 549.9 m (1,804 ft). The open-hole water level prior to installation of the completion string was measured at 508.7 m (1,669 ft) on August 30, 2009, during geophysical logging. Several days later, the water level was measured at 508.4 m (1,668 ft) by N-I.

The well has one piezometer string and one completion casing string. A string of 2⅞-in. stainless-steel tubing with one slotted interval was installed adjacent to the completion casing. The 2⅞-in. tubing hangs from a string of 2⅜-in. carbon-steel tubing connected via a crossover sub. The slotted interval is at the depth of 506.9 to 680.7 m (1,663.1 to 2,233.4 ft) for water level measurements in the BA and SPA.

A string of 7⅝-in. epoxy-coated carbon-steel casing, connected to 7⅝-in. stainless-steel casing via a crossover sub, was installed in Well ER-20-8#2. The carbon-steel casing is located within the unsaturated zone to a point approximately 7.9 m (26 ft) above the water table. The completion casing has one slotted interval at 512.2 to 689.8 m (1,680.4 to 2,263.2 ft), allowing access to the BA and SPA.

1.6 Contact Information

Inquiries concerning Wells ER-20-8 and ER-20-8#2 should be directed to the UGTA Federal Project Director at:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Environmental Restoration Project
P. O. Box 98518
Las Vegas, Nevada 89193-8518

2.0 Well ER-20-8

This section contains detailed descriptions of the drilling process and fluid management issues, geologic data collection, and completion information for Well ER-20-8. See Section 3.0 for detailed information about the construction of Well ER-20-8#2.

2.1 Well-Specific Objectives

The scientific objectives for Well ER-20-8 are listed in Section 1.4.

2.2 Drilling Summary

This section contains detailed descriptions of the drilling process and fluid management issues.

2.2.1 Introduction

The general drilling requirements for all the 2009 Pahute Mesa Phase II wells were provided in *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a). Specific requirements for Well ER-20-8 were outlined in FAWPs number D-004-001.09 and D-007-001.09 (NSTec, 2009a; 2009b). The layout of the drill site is shown in Figure 1-4. A summary of drilling statistics for the well is given in Table 2-1. Figure 2-1 is a chart of the drilling and completion history for Well ER-20-8. The following information was compiled primarily from NSTec daily drilling reports.

2.2.2 Drilling History

Field operations at Well ER-20-8 began on June 15, 2009, when an NSTec crew set up the Mobile Drill B-59 hollow-stem auger drill rig and completed drilling a 20.3-cm (8-in.) diameter pilot hole to the depth of 18.3 m (60 ft). Grab samples of drill cuttings were collected at 1.5-m (5-ft) intervals. Starting on June 17, 2009, NSTec drillers used the Auger II drill rig to drill a 106.7-cm (42-in.) conductor hole to the depth of 33.2 m (109 ft). A string of 30-in. conductor casing was set at the depth 31.5 m (103.4 ft). The conductor casing was cemented in place on June 25, 2009, using 20.3 cubic meters (m^3) (26.5 cubic yards [yd^3]) of Redi-Mix Formula 400 (see cement composition in Appendix A-3). The cement was pumped into the annulus between the casing and the formation to the depth of 32.0 m (105 ft).

Table 2-1
Abridged Drill Hole Statistics for Well ER-20-8

LOCATION DATA:

Coordinates:	Nevada State Plane (Central Zone)	(NAD 27):	N 889,318.1 ft	E 556,125.2 ft
	Nevada State Plane (Central Zone)	(NAD 83):	N 6,271,065.3 m	E 517,027.5 m
	Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,116,415.5 m	E 546,606.1 m

Surface Elevation [a]: 1,782.6 m (5,848.3 ft)

DRILLING DATA:

Spud Date: 07/12/2009 (main hole drilling with Wilson Mogul 42B rig)

Total Depth (TD): 1,049.1 m (3,442 ft)

Date TD Reached: 08/08/2009

Date Well Completed: 08/15/2009 (date completion string was cemented in place)

Hole Diameter: 106.7 cm (42 in.) from surface to 33.2 m (109 ft); 52.1 cm (20.5 in.) from 33.2 to 499.3 m (109 to 1,638 ft); 37.5 cm (14.75 in.) from 499.3 to 719.9 m (1,638 to 2,362 ft); 25.1 cm (9.875 in.) from 719.9 m (2,362 ft) to TD of 1,049.1 m (3,442 ft).

Drilling Techniques: Drill 20.3-cm (8-in.) pilot hole with hollow-stem auger rig to 18.3 m (60 ft), then drill 106.7-cm (42-in.) hole from surface to 33.2 m (109 ft) with dry-hole auger. Center-punch with 20½-in. button bit mounted below a 26-in. hole-opener to 34.1 m (112 ft); rotary drill with 20½-in. tricone bit, using air-foam in direct circulation from 34.1 to 499.3 m (112 to 1,638 ft); rotary drill with 14¾-in. tricone bit to 719.9 m (2,362 ft); rotary drill with 9⅞-in. tricone bit to TD of 1,049.1 m (3,442 ft).

CASING DATA: 30-in. conductor casing to 31.5 m (103.4 ft); 16-in. surface casing, 0 to 491.9 m (1,614.0 ft); 10¾-in. intermediate casing, 0 to 716.3 m (2,350.0 ft).

WELL COMPLETION DATA [b]:

A string of 5½-in. stainless-steel casing hangs from 5½-in. carbon-steel casing via a crossover sub. The carbon-steel casing is positioned in the unsaturated zone to a point approximately 24.4 m (80 ft) above the water table. The 5½-in. casing (ID of 12.82 cm [5.047 in.]) has two slotted intervals, and was landed at 1,019.1 m (3,343.6 ft). A string of carbon-steel 1.6-in. tubing (ID of 3.505 cm [1.38 in.]) with one slotted interval was inserted outside the 10¾-in. casing in the annulus of the hole, and set at the depth of 645.9 m (2,119.1 ft) for use as a piezometer within the BA and SPA. Two 2⅞-in. piezometers were also installed. Both stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing (ID of 5.067 cm [1.995 in.]), connected via crossover subs. The upper piezometer was landed at 886.7 m (2,909.2 ft) for monitoring within the TCA, and the lower piezometer was landed at 1,006.5 m (3,302.2 ft) for monitoring within the TSA. A bridge plug was set at 915.9 m (3,005 ft)

Depth of Slotted Sections:	5½-casing:	757.8 to 887.7 m	(2,486.1 to 2,912.4 ft)
		953.1 to 1,005.4 m	(3,126.9 to 3,298.4 ft)
	1.6-in. piezometer:	636.6 to 645.9 m	(2,088.5 to 2,119.1 ft)
	Upper 2⅞-in. piezometer:	761.5 to 886.4 m	(2,498.2 to 2,908.1 ft)
	Lower 2⅞-in. piezometer:	957.3 to 1,006.1 m	(3,140.9 to 3,301.0 ft)

Depth of Sand Packs: 743.7 to 753.2 m (2,440 to 2,471 ft) 935.7 to 943.4 m (3,070 to 3,095 ft)

Depth of Gravel Packs: 753.2 to 896.1 m (2,471 to 2,940 ft) 943.4 to 1,048.5 m (3,095 to 3,440 ft)

Depth of Pump: Not installed at time of completion

Water Depth [c]: Fluid-level depths measured on September 8, 2009: 508.3 m (1,667.5 ft) for the BA and SPA measured in 1.6-in. piezometer string; 508.0 m (1,666.7 ft) for the TCA, measured in the upper 2⅞-in. piezometer string; and 508.1 m (1,666.9 ft) for the TSA measured in the lower 2⅞-in. piezometer string.

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Baker Atlas, DRI, Colog

SURVEYING CONTRACTOR: National Security Technologies, LLC

a Elevation of ground level at wellhead, relative to mean sea level. National Geodetic Vertical Datum, 1929 (NARA, 1973).

b ID = inside diameter. See Section 2.6 of this report for more detailed data on completion intervals. See Table A-2-1 for more details about the casing and tubing materials.

c Fluid level tags by Navarro Nevada Environmental Services. BA = Benham aquifer; SPA = Scrugham Peak aquifer; TCA = Tiva Canyon aquifer; TSA = Topopah Spring aquifer

WELL ER–20–8 SUMMARY

Activity	Date
Begin drilling for conductor hole:	06/15/2009
Conductor hole completed and 30–in. casing set at 31.5 m (103.4 ft):	06/25/2009
Begin drilling 20 1/2–in. surface hole:	07/12/2009
Set 16–in. surface casing at 491.9 m (1,614.0 ft):	07/23/2009
Land 10 3/4–in. casing at 716.3 m (2,350.0 ft):	08/04/2009
Begin drilling 9 7/8–in. hole:	08/05/2009
Reach total drilled depth of 1,049.1 m (3,442 ft):	08/08/2009
Well completed:	08/15/2009

LEGEND

BHA	bottom hole assembly
CA–6	six–arm caliper
CN	compensated neutron
CBIL	Circumferential borehole imaging log
DLL	dual laterolog
DRI	Desert Research Institute
ft	foot (feet)
GR	gamma ray
HDIL	high density induction log
HO	hole opener
in.	inch(es)
m	meter(s)
NAIL	nuclear annulus investigation log
SGR	spectral gamma ray
SLM	steel line measurement
SP	spontaneous potential
SWC	sidewall core
SWL	static water level
TD	total depth
TFM	thermal flow meter
TIH	trip into hole
TL	temperature log
TOH	trip out of hole
UDI	United Drilling Inc.
XMAC	cross–multipole array acoustilog
ZDL	Z–densilog

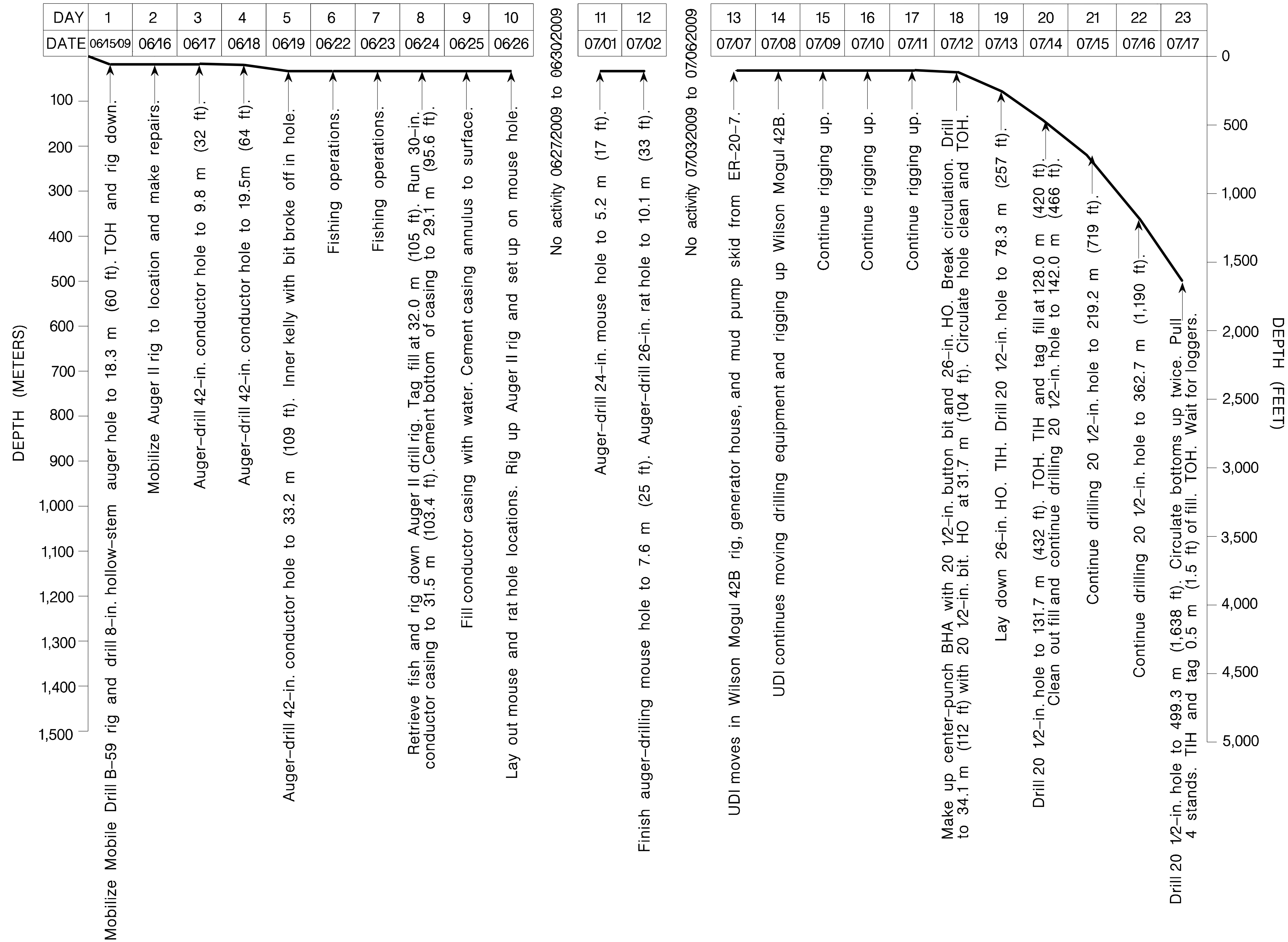

FIGURE 2–1

WELL ER–20–8
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 2

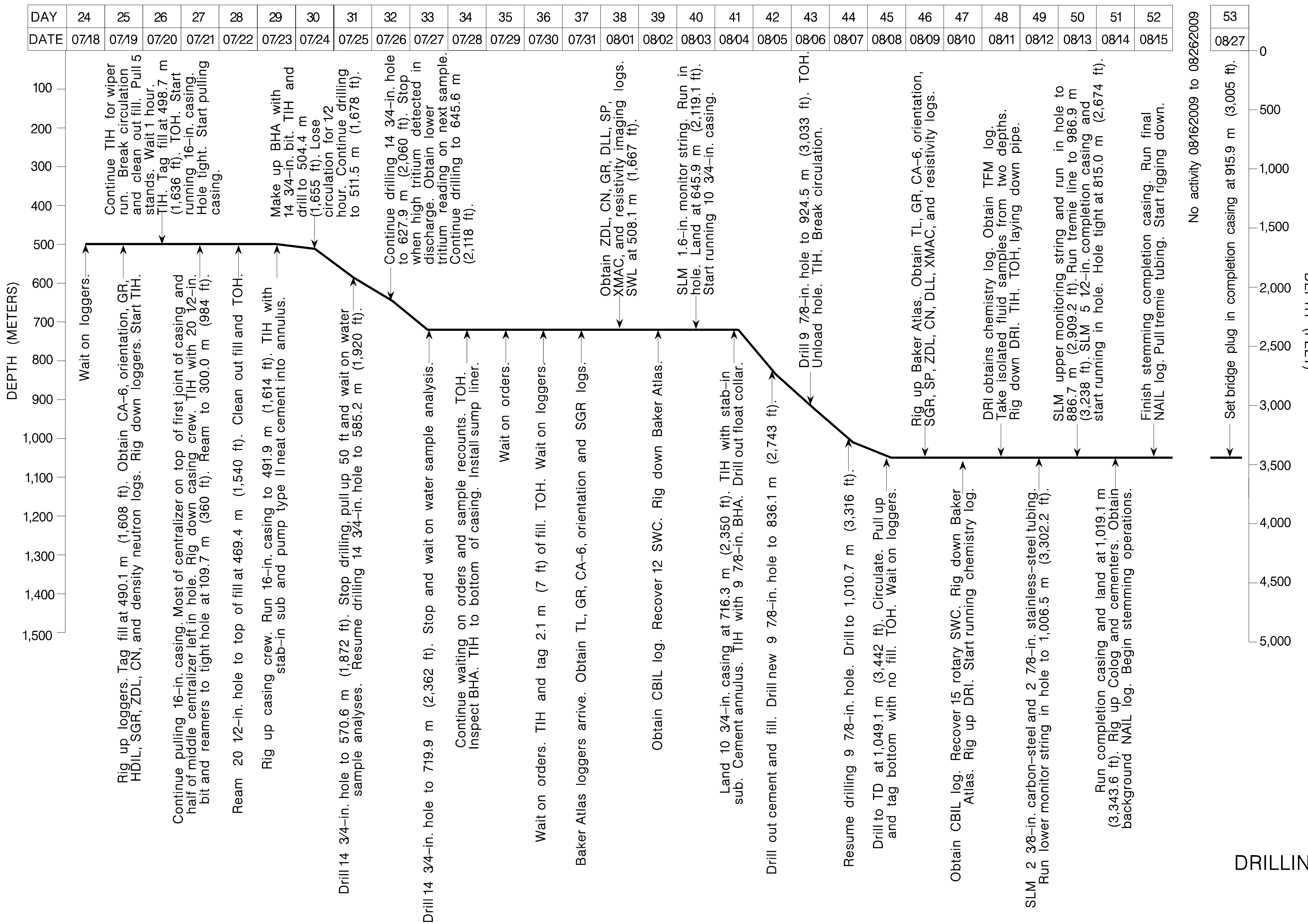

FIGURE 2-1

WELL ER-20-8
DRILLING AND COMPLETION HISTORY

SHEET 2 OF 2

The UDI crews arrived on July 7, 2009, and began rigging up the Wilson Mogul 42B drill rig. They finished rigging up on July 12, 2009, and began drilling from the top of cement inside the 30-in. casing. The drill crew worked through the cement at the bottom of the 30-in. casing with a center-punch assembly consisting of a 20½-in. button bit mounted 2.4 m (8.0 ft) below a 26-in. hole opener. The drilling fluid was an air/water/soap mix in conventional circulation. The hole-opener was removed when the hole reached the depth of 34.1 m (112 ft). Drilling of the surface hole with a 20½-in. rotary tricone bit and air-foam began on July 13, 2009.

On July 14, 2009, at 0215 hours, a radiological control technician (RCT) notified the site supervisor of a tritium reading of 459,868 pCi/L from a fluid sample taken at 0110 hours at the depth of 84.1 m (276 ft). Drilling and circulation were stopped. An RCT re-ran the fluid sample from 0110 hours and also ran a fluid sample from 0210 hours, taken at the depth of 89.6 m (294 ft). The first sample was re-measured as 422.6 pCi/L and the second sample measured 12,490 pCi/L. The RCT determined the original high reading was false, and the project manager authorized drilling to resume.

At several connections between 92.4 and 262.1 m (303 and 860 ft) depth, up to 3.7 m (12 ft) of fill was encountered. On July 16, 2009, at 0800 hours, circulation was lost for 30 minutes at the depth of approximately 253.0 m (830 ft). The 20½-in. surface hole was drilled to a depth of 499.3 m (1,638 ft), at which point drilling was suspended for geophysical logging and installation of the surface casing.

Geophysical logging began and ended on July 19, 2009. The Baker Atlas logging crew completed the required geophysical logs, then rigged down and departed the location. The UDI drillers tripped back in to the hole and tagged fill at a depth of 489.8 m (1,607 ft), indicating a total accumulation of 9.4 m (31 ft) during logging. An hour after they finished cleaning out the fill and conditioning the hole, 0.6 m (2 ft) of fill had accumulated.

On July 20, 2009, after the hole was cleaned out, the casing subcontractor began installing a string of 16-in. casing. The hole became tight at 268.2 m (880 ft), and casing operations had to be stopped in order to ream and straighten the hole. The casing crew rigged down and departed the site on July 21, 2009. After UDI reamed the hole and cleaned out the fill, casing operations resumed on July 23, 2009. The 16-in. casing was landed on July 23, 2009, at a depth of 491.9 m (1,614.0 ft), and the bottom of the casing was cemented with 7.8 m^3 (10.2 yd^3) of Type II neat cement. The top of cement in the annulus is estimated to be at the depth of 446.2 m (1,464 ft), based on geophysical log data.

After the installation of the casing, on July 24, 2009, the drill crew lowered a bottom-hole assembly with a 14¾-in. bit into the hole to drill out the cement and clean out the hole, with air-foam as the drilling fluid. They tagged the top of cement at 489.5 m (1,606 ft) inside the 16-in. casing. They drilled cement from 489.5 to 492.6 m (1,606 to 1,616 ft) and fill from 492.6 to 499.3 m (1,616 to 1,638 ft). Returns were lost at 503.8 m (1,653 ft). The hole was advanced to 504.4 m (1,655 ft) with no returns, then drilling was stopped to wait for circulation. Circulation was regained 30 minutes later, and returns showed soap diluted with formation water. A sample was obtained for analysis and the results showed a concentration of 1,585 pCi/L tritium.

Field analyses of water samples made July 25–27, 2009, indicated that several samples contained tritium, but after these samples were re-run, they had lower counts. Samples with high levels were re-run, and most repeat results showed much lower tritium levels that were well below the Safe Drinking Water Act limit of 20,000 pCi/L. For example, tritium in sample ER-20-8-071709-16 was initially measured at 39,070.7 pCi/L; when the sample was re-measured, the tritium level was 2,075.0 pCi/L. The erroneous high readings are believed to be due to chemoluminescence. This problem, which produces erroneous positive and high values, is not uncommon in onsite field analyses. However, three samples remained above 20,000 pCi/L after being re-run several times. See Section 2.2.4 for more information about these samples.

Connections made at 663.2, 690.7, and 700.1 m (2,176, 2,266, and 2,297 ft) had 1.8 to 3.7 m (6 to 12 ft) of fill. Polymer was added to the drilling fluid mix formula after this third connection with fill.

On July 27, 2009, when the hole was at 719.9 m (2,362 ft), drilling operations were suspended so that issues related to tritium level measurements could be resolved. During this break, N-I measured the fluid level at 508.1 m (1,667 ft) and an NSTec crew installed a liner in sump #2. Examination of drill cuttings collected to date showed a formation change at 688.2 m (2,258 ft), indicating that the borehole had penetrated through two aquifer units (BA and SPA) into an underlying confining unit.

The Well ER-20-8 drilling advisory team evaluated options for completing the well, based on data obtained to date. In order to prevent potential contamination of the target aquifer units expected to underlie the confining unit, the team decided to case off the upper aquifers before drilling deeper. Drilling was suspended so that geophysical logs could be run and a string of intermediate casing installed. The top of fill was tagged at the depth of 717.8 m (2,355 ft).

Geophysical logging and sidewall sampling operations began on July 31, 2009. Baker Atlas recorded a water-level depth at 508.1 m (1,667 ft). During logging, a TD of 717.5 m (2,354 ft) was recorded, indicating a total accumulation of 2.4 m (8 ft) of fill. Logging operations were completed on August 2, 2008.

After logging was completed, a 4.1-cm (1.6-in.) piezometer string with one slotted interval was landed on August 3, 2009, at a depth of 645.9 m (2,119.1 ft). This string, which is positioned in the annular space between the surface and intermediate casings, was not gravel-packed or cemented, and will permit monitoring within the upper aquifers (BA and SPA). Immediately after the piezometer was installed, the casing subcontractor installed the intermediate casing. This 10¾-in. casing was landed on August 4, 2009, at a depth of 716.3 m (2,350 ft). The bottom of the casing was cemented with 5.0 m^3 (6.5 yd^3) of Type II neat cement. The top of cement in the annulus is estimated to be at the depth of 655.3 m (2,150 ft), based on geophysical log data.

After the installation of the intermediate casing, the drill crew lowered a bottom-hole assembly with a 9⅞-in. bit into the hole to drill out the cement and clean out the hole. They drilled out the float collar from 702.3 to 702.9 m (2,304 to 2,306 ft), and on August 5, 2009, tagged the top of cement at 702.9 m (2,306 ft) inside the 10¾-in. casing. The crew drilled cement from 702.9 to 717.5 m (2,306 to 2,354 ft) and cleaned out fill from 717.5 to 719.9 m (2,354 to 2,362 ft). Discharge from the well was then diverted to the lined sump.

Drilling with air-foam and a 9⅞-in. bit commenced on August 5, 2009. As before, chemo-luminescence caused several erroneously high tritium level readings. However, re-analysis yielded much lower values (within the minimum detectable concentration range of the field equipment). As water production increased, the amount of polymer in the drilling fluid mix was increased.

Drilling with the 9⅞-in. bit continued to 924.5 m (3,033 ft). At this point, drilling operations were suspended to prepare for geophysical logging. The drillers pulled the drill pipe up a short distance and returned to the bottom of the borehole, with no fill encountered. The drill crew began to remove the drill pipe for logging, but stopped before this was complete when the drilling advisory team decided to continue drilling below the TCA and into the Topopah Spring Tuff. Drilling resumed, but on August 7, 2009, the bit became stuck after the connection at 944.0 m (3,097 ft). Circulation was lost for about 30 minutes, after the pipe was freed. Circulation was lost again for about 90 minutes, after making a connection at 982.1 m (3,222 ft). Approximately 0.6 m (2 ft) of fill accumulated during the connection at 1,039.7 m (3,411 ft). At the TD of 1,049.1 m (3,442 ft) reached on August 8, 2009, the borehole had penetrated through the Topopah Spring Tuff and entered the underlying confining unit.

Geophysical logging and sidewall sampling operations were conducted by Baker Atlas crews on August 9–10, 2009. Baker Atlas recorded the water level as 507.5 m (1,665 ft). After completion of sidewall sampling, the Baker Atlas crew conducted a depth check with a sinker bar and tagged fill at 1,048.5 m (3,440 ft). They then pulled their equipment out of the hole in preparation for logging and water sampling by DRI personnel. DRI operations were completed on August 11, 2009.

On August 12, 2009, the drill crew installed two 2⅞-in. piezometer strings, each with one slotted interval. The lower piezometer was set at 1,006.5 m (3,302.2 ft), and the upper at 886.7 m (2,909.2 ft). See Section 2.6 for completion details.

Insertion of the 5½-in. stainless-steel completion casing began on August 13, 2009, and the string, which has two slotted intervals, was landed on August 14, 2009, at a depth of 1,019.1 m (3,343.6 ft). During insertion of the casing, it became stuck at 815.0 m (2,674 ft) and the project manager was called to discuss options for the continued insertion of the string. Several hours later, UDI was able to free the casing and casing operations were completed. The production casing and the two piezometer strings were sand- and gravel-packed and cemented (see Section 2.6 for details). Stemming operations were completed on August 15, 2009, and the drillers started demobilizing the rig and drilling equipment. Crews worked one shift per day after that, until mobilization to Well ER-20-8#2 was completed on August 22, 2009. A bridge plug that isolates the two lower aquifers from each other was installed at 915.9 m (3,005 ft) by Baker Atlas on August 27, 2009.

The inclination of the borehole was determined from Directional Survey logs run by Baker Atlas during each logging operation (July 19, July 31, and August 9, 2009). Three gentle changes in borehole orientation are visible on the Directional Survey plots, at approximately 189.0, 646.2, and 844.3 m (620, 2,120, and 2,770 ft). These changes generally correspond to formation changes or changes in drilling parameters. The average borehole inclination is 0.5 to 1.2 degrees, with the greatest deviation of 2.3 degrees at 310.9 m (1,020 ft). The bottom of the borehole is 5.32 m (17.46 ft) east-southeast of the wellhead.

A graphical depiction of drilling parameters, including penetration rate, rotary revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-1. See Appendix A-2 for a listing of tubing and casing materials. Drilling fluids and cements used in Well ER-20-8 are listed in Appendix A-3.

2.2.3 Drilling Problems

On June 19, 2009, during drilling of the 106.7-cm (42-in.) conductor hole with the Mobil Auger II rig, the inner kelly with the bit broke off at the rope socket. Fishing operations were conducted on June 22–24, 2009. During drilling of the main hole, circulation was temporarily lost at several depth intervals. The tight hole at 268.2 m (880 ft) caused a two-day delay in installation of the surface casing. The casing crew had to rig down and depart the site during reaming, then rig up and install the casing after the hole was straightened. Issues related to tritium measurements were the cause of most other delays.

2.2.4 Fluid Management

The drilling effluent was monitored during drilling according to the methods prescribed in the UGTA Project FMP (NNSA/NSO, 2009b) and the associated state-approved, well-specific, fluid management strategy letter (SNJV, 2009d). The air-foam/polymer drilling fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation) and then discharged into a sump. Water used to prepare drilling fluids came from Area 20 Water Well (U-20WW). Lithium bromide was added to the drilling fluid as a tracer to provide a means of estimating groundwater production. The rate of water production was estimated from the dilution of the tracer in the drilling fluid returns.

Radionuclides exceeding fluid quality objectives were not expected at Well ER-20-8, based on Phase I flow and transport modeling (SNJV, 2006; 2007; 2009c). To manage the anticipated water production, two unlined sumps (sump #1 and sump #2) were constructed prior to drilling. However, after low levels of tritium were encountered, sump #2 was lined to prepare for the possibility of encountering higher levels (Figure 1-4).

Samples of drilling effluent were collected hourly as necessary by N-I and analyzed on site by RCTs for the presence of tritium. Starting at a depth of 719.9 m (2,362 ft), samples were collected every half hour. Samples were once again collected hourly, starting with the sample from 819.0 m (2,687 ft).

As detailed in the N-I data report (N-I, 2010a) and summarized in Appendix B of this report, the onsite monitoring results for the drilling fluid indicated that tritium levels were generally below drinking water standards, as measured by field instruments. False high tritium levels were measured on several samples, which was attributed to chemoluminescence, a common problem in field analyses (see Section 2.2.2). However, three samples remained above 20,000 pCi/L after being re-run several times. Sample ER-20-8-072509-13, collected while drilling at the depth of 558.1 m (1,831 ft), was run and then re-run two times. The initial reading was 24,669.0 pCi/L and the final reading was 20,939.7 pCi/L. Sample ER-20-8-072609-8, from the depth of 604.1 m (1,982 ft), was run and then re-run three times. The initial reading was 41,690.3 pCi/L and the final reading was 34,262.8 pCi/L. Sample ER-20-8-072609-10, from the depth of 613.0 m (2,011 ft), was run and then re-run three times. The initial reading was 94,140.6 pCi/L and the final reading was 97,182.0 pCi/L.

A measurement of 1,300 pCi/L of tritium by a commercial laboratory was recorded for a fluid sample collected during drilling from about the depth of 650.7 m (2,135 ft). Three samples of drilling effluent from the depths of 691.9, 699.2, and 719.9 m (2,270, 2,294, and 2,362 ft) analyzed by LLNL all showed less than 2,000 pCi/L (LLNL, 2009a). These data are from drilling effluent samples and may not be representative of the groundwater; thus, they should be considered preliminary values. Valid groundwater data will not be available until the well is developed and properly sampled.

No lead monitoring was performed. Lead monitoring is not initiated until discharge fluids exceed the UGTA fluid management criteria for tritium (200,000 pCi/L), as specified in the Well ER-20-8 fluid management strategy letter (SNJV, 2009d) approved by the Nevada Division of Environmental Protection. N-I personnel checked all down-hole equipment for lead prior to use in the borehole, and none was found.

All fluid quality objectives were met, as shown on the fluid management reporting form (Appendix B). The form in Table B-1 lists volumes of solids (drill cuttings) and fluids produced during well-construction operations (vadose-zone drilling and saturated-zone drilling; well development and aquifer testing are not addressed in this report). The volume of solids produced was calculated using the diameter of the borehole (from caliper logs) and the depth drilled, and includes added volume attributed to a rock bulking factor. The volumes of fluids listed on the report are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps. The fluid management sample was collected from the unlined sump #1 after drilling of Well ER-20-8#2 was completed (Table B-2), and serves as the fluid management sample for both wells.

2.3 Geologic Data Collection

This section describes the sources of geologic data obtained from Well ER-20-8 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology along the predicted groundwater flow path through the Bench area was one of the primary objectives of Well ER-20-8, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the drilling project.

Geologic data collected at Well ER-20-8 consist of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in the N-I FAWP (SNJV, 2009b).

2.3.1 Drill Cuttings

Composite drill cuttings were collected at 3.0-m (10-ft) intervals as drilling progressed. Twelve samples were collected by NSTec during construction of the conductor hole, between the depths of 1.5 and 18.3 m (5 and 60 ft). Below that depth, N-I personnel collected triplicate samples, each consisting of approximately 550 cubic centimeters of material, from 319 intervals from 33.5 to 1,048.5 m (110 to 3,440 ft). Samples are missing from 14 intervals, including 10 from the mafic-poor Calico Hills Formation, encountered below the depth of 999.7 m (3,280 ft). Missed intervals are attributed to poor returns and loss of circulation.

The samples are stored under environmentally controlled, secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample, one set was left unsealed in the original sample containers, and the third set was washed and stored according to standard USGS Core Library procedures. The washed set was used by NSTec geologists to construct the detailed lithologic log presented in Appendix C. The N-I field representative collected an additional set of reference drill cuttings samples from each of the cuttings intervals. This set was examined at the drill site for use in preparing field lithologic descriptions, and remains in the custody of N-I.

2.3.2 Sidewall Core Samples

Sidewall core samples were collected at selected depths in Well ER-20-8 to verify the stratigraphy and lithology and for special analytical tests. Sample locations were selected by NSTec geologists and the N-I field representative on the basis of field lithologic logs, geophysical logs, and quality/quantity of drill cuttings, with consideration of borehole conditions determined from caliper logs. Baker Atlas used a rotary sidewall coring tool to collect samples between the depths of 499.9 and 1,008.9 m (1,640 and 3,310 ft). A total of 32 sample depths were attempted, with 27 cores recovered. Table 2-2 summarizes the results of sidewall coring operations at Well ER-20-8.

2.3.3 Sample Analyses

Seven sidewall cores and fifteen sample splits of drill cuttings from various depths in Well ER-20-8 were submitted to Comprehensive Volcanic Petrographics, LLC, for petrographic analysis. Splits of the seven sidewall cores and fifteen samples of drill cuttings from the same depths were submitted to the Hydrology, Geochemistry, and Geology Group of the Earth and Environmental Sciences Division at LANL for mineralogic (x-ray diffraction) and chemical (x-ray fluorescence) analyses. The samples were selected after initial geologic evaluation of the cuttings and core samples and geophysical logs.

Five samples from outcrops near the Well ER-20-8 site were collected to aid in the understanding of stratigraphic relationships of the Paintbrush Group lavas encountered in the well. Petrographic, mineralogic, and chemical analyses were made on these samples by the entities listed above. See Section 4.2.2 for additional discussion of the purpose of these samples.

The primary purpose of these analytical data is to confirm stratigraphic identification and to characterize mineral alteration. In addition, the data provide detailed information on mineralogic composition for transport modeling, and will aid in evaluation of geophysical log signatures. The results of the petrographic analyses are reported in Warren (2010), and the results of the mineralogic and chemical analyses are reported in WoldeGabriel et al. (2009). Table 2-3 lists all samples analyzed.

2.3.4 Geophysical Log Data

Geophysical logs were run in the borehole to further characterize the lithology, structure, and hydrologic properties of the rocks encountered, and to evaluate borehole conditions. Geophysical logging was conducted in three stages during drilling: prior to installation of the 16-in. surface casing at 491.9 m (1,614.0 ft), prior to installation of the 10¾-in. intermediate casing at 716.3 m (2,350.0 ft), and after the TD was reached at 1,049.1 m (3,442 ft). The overall quality of the geophysical log data collected was very good. A complete listing of the logs, dates run, depths, and service companies is provided in Table 2-4. Note that a gamma ray log is typically included with each logging run for depth control.

Table 2-2
Sidewall Samples from Well ER-20-8

Core Depth [a]		Recovery [b] centimeters (inches)	Formation	Lithology
meters	feet			
499.9	1,640	3.05 (1.20)	rhyolite of Benham	Flow breccia
504.4	1,655	3.05 (1.20)	rhyolite of Benham	Pumiceous lava
551.7	1,810	Wash out	rhyolite of Scrugham Peak	Pumiceous lava
552.6	1,813	3.81 (1.50)	rhyolite of Scrugham Peak	Pumiceous lava
568.8	1,866	4.06 (1.60)	rhyolite of Scrugham Peak	Rhyolitic lava and flow breccia
600.5	1,970	4.06 (1.60)	rhyolite of Scrugham Peak	Vitrophyric lava
603.5	1,980	2.79 (1.10)	rhyolite of Scrugham Peak	Vitrophyric lava
615.1	2,018	4.19 (1.65)	rhyolite of Scrugham Peak	Vitrophyric lava
626.7	2,056	3.05 (1.20)	rhyolite of Scrugham Peak	Rhyolitic lava
637.0	2,090	3.18 (1.25)	rhyolite of Scrugham Peak	Rhyolitic lava
646.8	2,122	3.81 (1.50)	rhyolite of Scrugham Peak	Rhyolitic lava
654.7	2,148	2.79 (1.10)	rhyolite of Scrugham Peak	Vitrophyric lava
688.8	2,260	Wash out	Paintbrush Group, undivided	Bedded tuff
690.1	2,264	Wash out	Paintbrush Group, undivided	Bedded tuff
690.2	2,264.5	Wash out	Paintbrush Group, undivided	Bedded tuff
693.1	2,274	3.43 (1.35)	Paintbrush Group, undivided	Bedded tuff
737.6	2,420	1.27 (0.50)	Paintbrush Group, undivided	Bedded tuff
743.7	2,440	1.27 (0.50)	Paintbrush Group, undivided	Bedded tuff
762.0	2,500	3.81 (1.50)	tuff of Pinyon Pass	Nonwelded tuff
883.9	2,900	3.43 (1.35)	Tiva Canyon Tuff	Ash-flow tuff, nonwelded
957.1	3,140	4.06 (1.60)	Paintbrush Group, undivided	Bedded tuff
961.3	3,154	3.81 (1.50)	Paintbrush Group, undivided	Bedded tuff
967.7	3,175	3.81 (1.50)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
974.8	3,198	3.56 (1.40)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
979.9	3,215	4.06 (1.60)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
986.0	3,235	3.94 (1.55)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
987.4	3,239.5	Wash out	Topopah Spring Tuff	Ash-flow tuff, moderately welded
987.6	3,240	1.91 (0.75)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
987.9	3,241	3.81 (1.50)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
989.1	3,245	3.18 (1.25)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
997.9	3,274	4.45 (1.75)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,008.9	3,310	4.45 (1.75)	mafic-poor Calico Hills Formation	Bedded Tuff

All samples obtained by Baker Atlas using the rotary sidewall coring tool: core diameter = 25.4 millimeters (1 in.)

a All depths are drilled depths.

b Shaded rows indicate samples attempted but not recovered.

Table 2-3
Rock Samples from Well ER-20-8 and Vicinity Selected for Petrographic, Mineralogic, and Chemical Analysis [a]

Depth [b, c]		Sample Identifier [d]
meters	feet	
231.6	760	ER20/8-760D
259.1	850	ER20/8-850D
286.5	940	ER20/8-940D
353.6	1,160	ER20/8-1,160D
384.0	1,260	ER20/8-1,260D
438.9	1,440	ER20/8-1,440D
466.3	1,530	ER20/8-1,530D
493.8	1,620	ER20/8-1,620D
548.6	1,800	ER20/8-1,800D
576.1	1,890	ER20/8-1,890D
600.5	1,970	ER20/8-1,970RS
654.7	2,148	ER20/8-2,148RS
737.6	2,420	ER20/8-2,420D
762.0	2,500	ER20/8-2,500RS

Depth [b, c]		Sample Identifier [d]
meters	feet	
780.3	2,560	ER20/8-2,560D
841.2	2,760	ER20/8-2,760D
923.5	3,030	ER20/8-3,030D
957.1	3,140	ER20/8-3,140RS
967.7	3,175	ER20/8-3,175RS
986.0	3,235	ER20/8-3,235RS
997.9	3,274	ER20/8-3,274RS
1,048.5	3,440	ER20/8-3,440D
N/A [e]	N/A	LP20A1
N/A	N/A	LP20A2
N/A	N/A	LP20A3
N/A	N/A	LP20A4
N/A	N/A	SP20A5

a Mineralogic analysis by x-ray diffraction; chemical analysis by x-ray fluorescence.

b All depths are drilled depths.

c Depths for petrographic, mineralogic, and chemical analyses represent base of 3.0-m (10-ft) sample interval for drill cuttings samples.

d "D" in sample identifier indicates drill cuttings sample. "RS" indicates rotary sidewall core sample. "LP" indicates outcrop sample (see Section 4.2.2).

e N/A = not applicable

Table 2-4
Well ER-20-8 Geophysical Log Summary

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
Differential Temperature / Gamma Ray	Saturated zone: groundwater temperature / stratigraphic and depth correlation	BA	8/1/2009 8/9/2009	TL-1 / GR-5 TL-2 / GR-13	718.4 (2,357) 1,048.8 (3,441)	432.8 (1,420) 446.2 (1,464)
* 6-Arm Caliper / Aligned Borehole Profile / Gamma Ray	Borehole conditions, cement volume calculation / lithologic and stratigraphic correlation	BA	7/19/2009 7/31/2009 8/9/2009	CA6-1 / ORIT-1 / GR-1 CA6-2 / ORIT-2 / GR-4 CA6-3 / ORIT-7 / GR-14	487.7 (1,600) 714.8 (2,345) 1,045.2 (3,429)	0 (0) 491.9 (1,614) 701.0 (2,300)
* Gamma Ray / * Digital Spectralog	Stratigraphy, mineralogy, and natural and man-made radiation determination	BA	7/19/2009 7/31/2009 8/9/2009	GR-2 / SGR-1 GR-4 / SGR-2 GR-14 / SGR-3	479.8 (1,574) 709.6 (2,328) 1,040.0 (3,412)	6.7 (22) 411.5 (1,350) 685.8 (2,250)
* High Definition Induction / * Gamma Ray	Lithologic determination; saturation of formations; stratigraphic and depth correlation	BA	7/19/2009	HDIL-1 / GR-2	484.9 (1,591)	31.7 (104)
* Compensated Z-Densilog / * Compensated Neutron / Gamma Ray / Caliper	Stratigraphic and lithologic determination / identification of welding, alteration, rock porosity, and water content	BA	7/19/2009 8/1/2009 8/9/2009	ZDL-1 / CN-1 / GR-3 / CAL-1 ZDL-2 / CN-2 / GR-6 / CAL-2 ZDL-3 / CN-3 / GR-15 / CAL-3	489.2 (1,605) 717.5 (2,354) 1,047.6 (3,437)	31.7 (104) 472.4 (1,550) 596.2 (1,956)
Circumferential Borehole Imaging / Gamma Ray	Structural analysis, including fracture characterization. Recognition of lithologic features	BA	8/1/2009 8/10/2009	CBIL-1 / ORIT-6 / GR-11 CBIL-2 / ORIT-10 / GR-19	716.6 (2,351) 1,047.9 (3,438)	508.1 (1,667) 716.3 (2,350)
* X-Multipole Array Acoustilog / Gamma Ray	Primary matrix porosity	BA	8/1/2009 8/9/2009	XMAC-1 / ORIT-3 / GR-8 XMAC-2 / ORIT-8 / GR-17	712.0 (2,336) 1,043.0 (3,422)	508.1 (1,667) 701.0 (2,300)
Resistivity Imaging / Gamma Ray	Saturated zone: lithologic characterization, bedding dip, fracture and void analysis.	BA	8/1/2009 8/1/2009 8/10/2009	STAR-1 / ORIT-4 / GR-9 STAR-2 / ORIT-5 / GR-10 STAR-3 / ORIT-9 / GR-18	716.6 (2,351) 716.6 (2,351) 1,047.3 (3,436)	508.1 (1,667) 508.1 (1,667) 719.3 (2,360)
* Dual Laterolog / Gamma Ray	Lithologic determinations, identification of alteration, recognition of welding; distinguishing low versus high porosity	BA	8/1/2009 8/9/2009	DLL-1 / GR-7 DLL-2 / GR-16 / SP-1 (merged)	713.8 (2,342) 1,044.5 (3,427)	508.1 (1,667) 716.3 (2,350)
Rotary Sidewall Coring Tool / Gamma Ray	Geologic samples	BA	8/2/2009 8/10/2009	RCOR-1 / GR-12 RCOR-2 / GR-20	693.1 (2,274) 1,008.9 (3,310)	499.9 (1,640) 737.6 (2,420)

Table 2-4
Well ER-20-8 Geophysical Log Summary (continued)

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
* Chemistry / * Temperature Log	Groundwater chemistry and temperature	DRI	8/10/2009	Chem-1 / TL-3	1,045.5 (3,430)	507.5 (1,665)
* Heat Pulse Flow Log	Groundwater flow rate and direction	DRI	8/11/2009	HPFlow-1	1,043.9 (3,425)	780.3 (2,560)

a Logs presented in geophysical log summary, Appendix D, are indicated by *.

b BA = Baker Atlas DRI = Desert Research Institute.

c Drilled depth.

The logs are available from NSTec in Mercury, Nevada, and copies are on file at the office of N-I in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada. Plots of selected geophysical log data are provided in Appendix D.

2.4 Hydrology of Well ER-20-8

This section discusses pre-development water-level information, water production, flow meter and chemistry log data, and groundwater characterization samples for Well ER-20-8.

2.4.1 Water-Level Information

Prior to drilling, the water level at Well ER-20-8 was estimated to be within the BA at a depth of 502.9 m (1,650 ft) below ground surface. During geophysical logging operations on August 1, 2009, after the borehole had penetrated the BA and SPA but not the TCA or TSA, a fluid level depth of 508.1 m (1,667 ft) or 1,274.4 m (4,181 ft) elevation was measured. After the borehole reached TD (August 8, 2009), fluid level depths were measured during logging by Baker Atlas, DRI, and Colog. Measured fluid depths ranged from 507.5 to 508.7 m (1,665 to 1,669 ft), and averaged 508.1 m (1,667 ft), which is the same as measured on August 1, 2009. Approximately one month later, on September 8, 2009, water levels were measured by N-I in the three piezometer strings. In the upper piezometer string (accessing the BA and SPA), the water level was 508.3 m (1,667.5 ft). In the intermediate piezometer string (accessing the TCA), the water level was 508.0 m (1,666.7). In the lower piezometer string (accessing the TSA), the water level was 508.1 m (1,666.9 ft). An average of these three measurements gives 508.1 m (1,667.0 ft) as a fluid depth.

2.4.2 Water Production

Water production was estimated during drilling of Well ER-20-8 on the basis of dilution of a lithium bromide tracer, as measured at the rig site by N-I field personnel. The first observation of water in returns was reported on July 24, 2009, at the depth of approximately 504.1 m (1,654 ft). A negligible amount of water was produced while drilling the BA; however, the estimated water production ranged from 94.6 to 1,552.0 liters per minute (Lpm) (25 to 410 gallons per minute [gpm]) while drilling the SPA. Estimated water production while drilling through the TCA ranged from 37.9 to 1,324.9 Lpm (10 to 350 gpm). During drilling in the TSA, water production was estimated at 946.4 to 1,324.9 Lpm (250 to 350 gpm).

Estimated water production rates during drilling are presented graphically in Appendix A-1. More accurate water production information will be available after hydraulic testing is conducted following completion and development of the well.

2.4.3 Flow Meter and Chemistry Log Data

Flow meter data, along with temperature, electrical conductivity, and pH measurements, are typically used to characterize borehole fluid variability in UGTA wells, and may indicate inflow and outflow zones. DRI personnel ran their suite of logs shortly after TD was reached (see plots of log data in Appendix D, page D-6). The chemistry log measured temperature, electrical conductivity, and pH in the interval 487.7 to 1,049.1 m (1,600 to 3,442 ft) on August 10, 2009. However, after running the chemistry log, DRI reported that the pH portion of the logging tool failed and that the pH data recorded were not accurate.

DRI personnel measured the fluid flow rate and direction using their Heat Pulse Flow log at 11 depths between 780.3 and 1,043.9 m (2,560 and 3,425 ft) within the TCA and TSA, on August 11, 2009. The DRI flow log indicated that water from the lower portion of the borehole has an upward flow. A fracture zone with water flowing into the borehole was noted between 972.3 and 987.6 m (3,190 and 3,240 ft), and water appeared to be flowing out of a fracture zone between 832.1 and 847.3 m (2,730 and 2,780 ft) with a flow rate of approximately 20.8 Lpm (5.5 gpm). An upward flow was measured at 780.3 m (2,560 ft), and water is thought to enter fractures noted between approximately 762.0 m (2,500 ft) and the bottom of the surface casing at 716.3 m (2,350 ft). From approximately 819.9 to 832.1 m (2,690 to 2,730 ft), water flows downward at a rate of approximately 22.7 Lpm (6.0 gpm) into the same outflow fracture zone between 832.1 and 847.3 m (2,730 and 2,780 ft).

2.4.4 Groundwater Samples

Following geophysical logging on August 11, 2009, DRI personnel collected depth-discrete groundwater characterization samples within the open borehole at the depths of 823.0 and 963.2 m (2,700 and 3,160 ft). The purpose of these samples was to provide a framework of initial groundwater chemistry based on a select number of analytical parameters. These samples were analyzed for metals, organic and inorganic constituents, tritium, gross alpha and beta, and plutonium. Man-made radionuclides were not detected in these samples (N-I, 2010a).

N-I personnel collected three 500-milliliter (0.5-quart) fluid samples from the fluid discharge line on July 27, 2009, during drilling at the depths of 691.9, 699.2, and 719.9 m (2,270, 2,294, and 2,362 ft). See Section 2.2.4 for more information about these samples.

All of these samples were collected prior to completion and final development of the well. The analytical results should be used with care because water quality measurements may be affected by constituents of the drilling fluids, and thus not accurately reflect natural groundwater quality.

The results of groundwater analyses are typically reported in data reports prepared by the analyzing laboratories and in UGTA project reports (e.g., the water chemistry database and the transport data document).

2.5 Precompletion and Open-Hole Development

Initial well development conducted in Well ER-20-8 consisted of using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole, prior to the final logging operation, after the TD was reached.

2.6 Well Completion

Well completion refers to the installation in a borehole of one or more strings of tubing or casing that is slotted or screened at one or more locations along their length. The completion process also typically includes emplacement of backfill materials around the string(s), with coarse fill such as gravel adjacent to the open intervals and impervious materials such as cement placed between or above the open intervals to isolate them. The string(s) serves as a conduit for inserting a pump in the well, for inserting devices for measuring fluid level, and for sampling, so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole.

The proposed design for Well ER-20-8 was presented in the criteria document (SNJV, 2009a) and in the NSTec FAWP (NSTec, 2009b). The completion plans are summarized here in Section 2.6.1.1, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 2.6.1.2. The rationale for differences between the planned and actual design is discussed in Section 2.6.1.3, and the completion methods are presented in Section 2.6.2. Figure 2-2 is a schematic diagram of the well completion design. Figure 2-3 shows a plan view and profile of the final wellhead surface completion. Table 2-6 is a construction summary for the completion strings.

2.6.1 Well Completion Design

The following sections describe the well completion design and methods. The final completion design differs from the proposed design, as described in the following sections.

2.6.1.1 Proposed Completion Design

The original completion design (presented in SNJV, 2009a) was based on the assumption that the Well ER-20-8 site would consist of a single well with three isolated completion zones, one in each target aquifer (i.e., the BA, TCA, and TSA). It was predicted that the water table would be

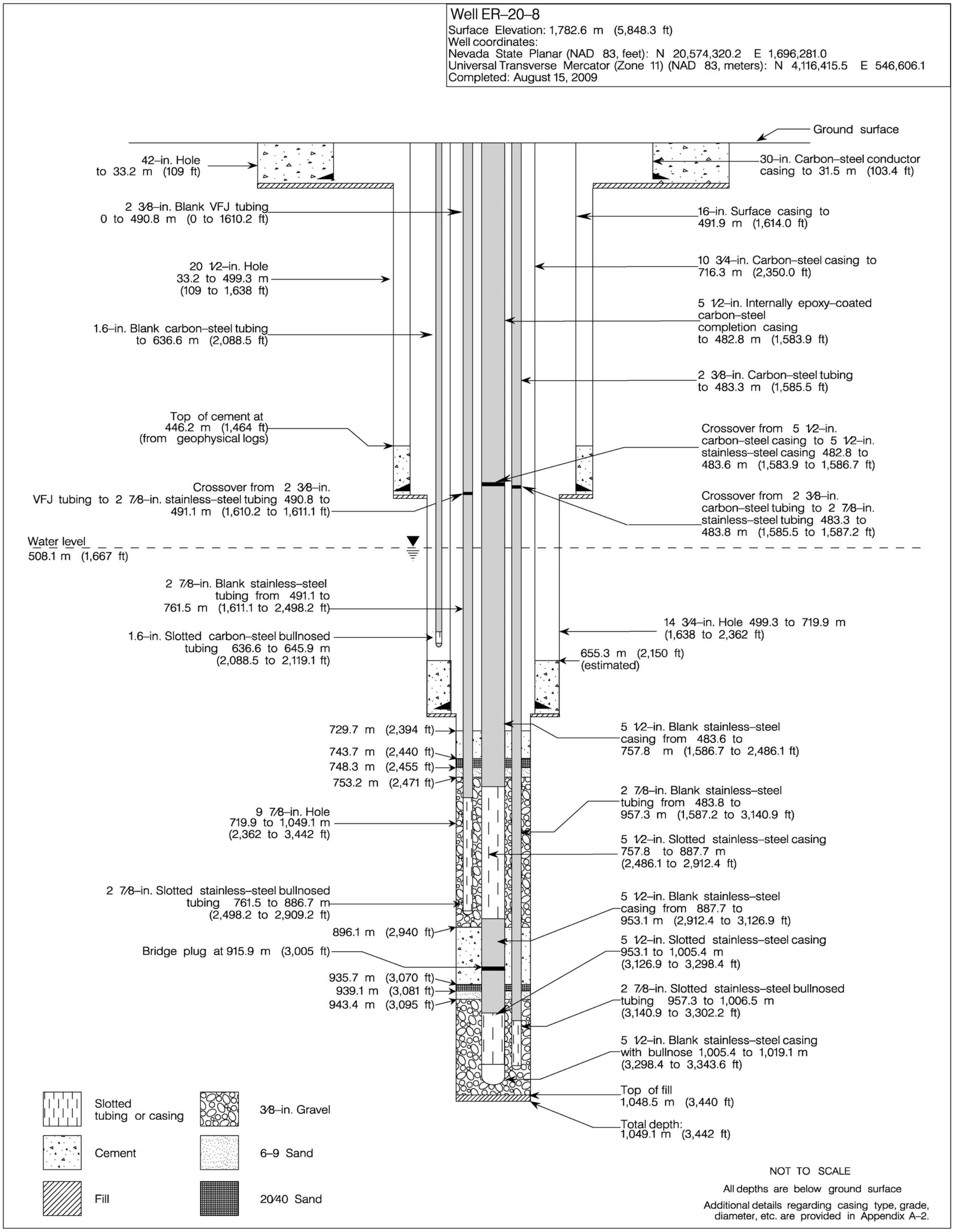

Figure 2-2
As-Built Completion Schematic for Well ER-20-8

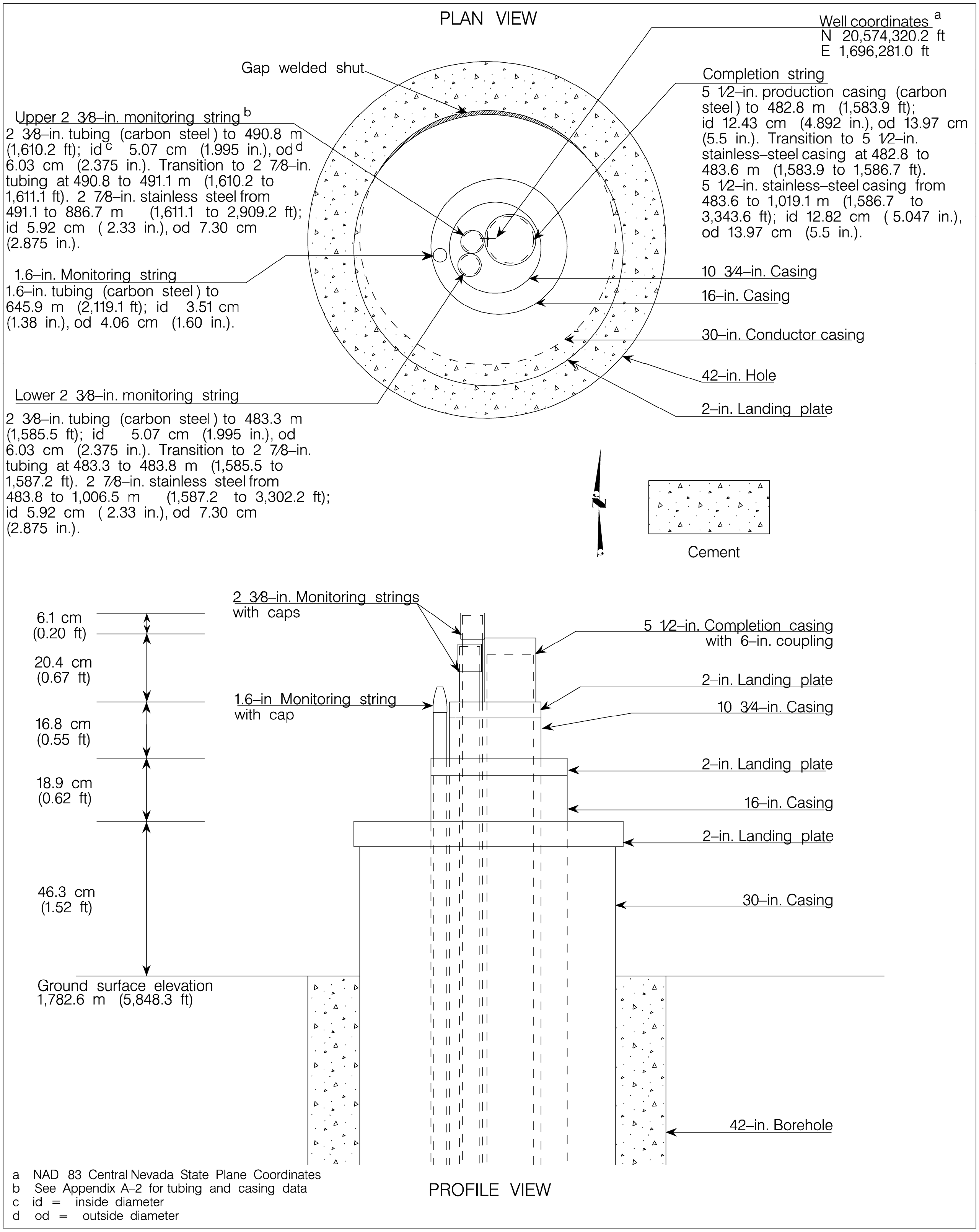

Figure 2-3
Wellhead Diagram for Well ER-20-8

Table 2-5
Well ER-20-8 Completion String Construction Summary

Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
1.6-in. carbon-steel tubing (BA and SPA access) [a]	0 to 645.9 (0 to 2,119.1)	Blank 0 to 636.6 (0 to 2,088.5)	None	None
		Slotted bullnose [b] 636.6 to 645.9 (2,088.5 to 2,119.1)		
2⅜-in. carbon-steel tubing with crossover sub	0 to 491.1 (0 to 1,611.1)	Blank	None	None
2⅞-in. stainless-steel tubing (TCA access) [a]	491.1 to 886.7 (1,611.1 to 2,909.2)	Blank 491.1 to 761.5 (1,611.1 to 2,498.2)	Type II neat cement 729.7 to 743.7 (2,394 to 2,440)	20/40 sand 743.7 to 748.3 (2,440 to 2,455) 6–9 sand 748.3 to 753.2 (2,455 to 2,471) ⅜-in. washed gravel 753.2 to 896.1 (2,471 to 2,940)
		Slotted and bullnosed [c] 761.5 to 886.7 (2,498.2 to 2,909.2)	None	
2⅜-in. carbon-steel tubing with crossover sub	0 to 483.8 (0 to 1,587.2)	Blank	None	None
2⅞-in. stainless-steel tubing (TSA access) [a]	483.8 to 1,006.5 (1,587.2 to 3,302.2)	Blank 483.8 to 957.3 (1,587.2 to 3,140.9)	Type II neat cement 896.1 to 935.7 (2,940 to 3,070)	None
		Slotted and bullnosed [c] 957.3 to 1,006.5 (3,140.9 to 3,302.2)	None	20/40 sand 935.7 to 939.1 (3,070 to 3,081) 6–9 sand 939.1 to 943.4 (3,081 to 3,095) ⅜-in. washed gravel 943.4 to 1,048.5 (3,095 to 3,440)

Table 2-5
Well ER-20-8 Completion String Construction Summary, continued

Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
5½-in. carbon-steel, internally epoxy-coated production casing and crossover sub with stainless-steel double pin	0 to 483.6 (0 to 1,586.7)	Blank	None	None
5½-in. stainless-steel production casing	483.6 to 1,019.1 (1,586.7 to 3,343.6)	Blank 483.6 to 757.8 (1,586.7 to 2,486.1)	Type II neat cement 729.7 to 743.7 (2,394 to 2,440)	20/40 sand 743.7 to 748.3 (2,440 to 2,455) 6–9 sand 748.3 to 753.2 (2,455 to 2,471) ⅜-in. washed gravel 753.2 to 896.1 (2,471 to 2,940)
		10 consecutive slotted joints [d] 757.8 to 887.7 (2,486.1 to 2,912.4)	None	
		Blank 887.7 to 953.1 (2,912.4 to 3,126.9)	Type II neat cement 896.1 to 935.7 (2,940 to 3,070)	None
		4 consecutive slotted joints [d] 953.1 to 1,005.4 (3,126.9 to 3,298.4)	None	20/40 sand 935.7 to 939.1 (3,070 to 3,081) 6–9 sand 939.1 to 943.4 (3,081 to 3,095) ⅜-in. washed gravel 943.4 to 1,048.5 (3,095 to 3,440)
		Blank and bullnosed 1,005.4 to 1,019.1 (3,298.4 to 3,343.6)		
Bridge plug set at 915.9 m (3,005 ft)				

a BA = Benham aquifer; SPA = Scrugham Peak aquifer; TCA = Tiva Canyon aquifer; TSA = Topopah Spring aquifer.

b Slots are 0.318 cm (0.125 in.) wide (torch-cut) and 30.5 cm (12.0 in.) long, arranged in 3 rows, on staggered 61.0-cm (24.0-in.) centers.

c Slots are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long, arranged in 8 rows, on staggered 10.2-cm (4.0-in.) centers.

d Slots are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long, arranged in 18 rows, on staggered 15.2-cm (6.0-in.) centers.

near the top of the BA and that the well would reach TD just below the TSA within the Calico Hills zeolitic composite unit (CHZCM). The primary goal of the proposed completion design was to provide groundwater production data from the BA, TCA, and TSA, and to provide access to groundwater for monitoring and sampling. The 16-in. casing was intended to extend to the depth of approximately 496.8 m (1,630 ft) to isolate the near-surface units from the underlying BA, TCA, and TSA.

The well was planned to be completed with a single string of 7⅝-in. production casing extending through the three target aquifers. This casing string was to be slotted and gravel-packed throughout the slotted sections in the target aquifers. Since three saturated aquifers were expected, two cement isolation intervals were planned to separate the three aquifers. The completion string was to consist of epoxy-coated carbon-steel to within 6.1 m (20 ft) above the water table and stainless-steel casing below the water table.

Three piezometer tubes were to be positioned inside the 14¾-in. open hole, between the borehole wall and the well-completion string to monitor water levels during testing and for collecting water samples directly from the developed intervals for the BA, TCA, and TSA. The bottom portions of the tubing strings were to be slotted and positioned within the gravel-packed intervals at approximately the same depths as the slotted intervals in the completion string. The tubing strings were to be separated by the same cement isolation intervals as in the completion string.

2.6.1.2 As-Built Completion Design

The final Well ER-20-8 completion design was determined by the UGTA Well ER-20-8 drilling advisory team after the temporary TD of 499.3 m (1,638 ft) was reached. The team designed the completion on the basis of onsite evaluation of data such as lithology, water production, drilling data, and data from various geophysical logs.

The upper lava-flow aquifers, the BA and SPA, were isolated from the two lower aquifers, the TCA and TSA, by the 10¾-in. intermediate casing before drilling proceeded through the TCA and TSA. The following is a description of the main completion of the TCA and TSA.

The main completion string consists of a string of 5½-in. stainless-steel casing suspended from 5½-in. carbon-steel casing, and was set at the depth of 1,019.1 m (3,343.6 ft). The 5½-in. epoxy-coated carbon-steel casing and crossover sub extend from the surface to the depth of 483.6 m (1,586.7 ft), which is 24.4 m (80 ft) above the water table. The stainless-steel 5½-in. casing is slotted in the intervals 757.8 to 887.7 m (2,486.1 to 2,912.4 ft) and 953.1 to 1,005.4 m

(3,126.9 to 3,298.4 ft), which are open to the TCA and TSA, respectively. The upper slotted section consists of ten consecutive slotted joints and the lower slotted section consists of four consecutive slotted joints. The two slotted sections are separated by 65.4 m (214.5 ft) of blank casing. The completion string was terminated with 13.1 m (42.9 ft) of blank stainless-steel casing with a 0.73-m (2.4-ft) long stainless-steel bullnose to function as a sediment sump. The machine-cut openings in each slotted casing joint are 0.159 cm (0.0625 in.) wide and 5.08 cm (2.0 in.) long. The slots are arranged in rows of 18, with rows staggered 20 degrees on 15.2-cm (6.0-in.) centers. The two slotted sections of the casing string are gravel-packed. A cement isolation interval separates the two deepest aquifers.

Three piezometer strings were installed in Well ER-20-8. A string of carbon-steel 1.6-in. tubing with one slotted interval was inserted in the annulus between the 16-in. and 10¾-in. casing strings, within the 37.5-cm (14.75-in.) hole. This string was set at the depth of 645.9 m (2,119.1 ft) for use as a monitoring string within the BA and SPA, and is isolated from the lower formations by the intermediate (10¾-in.) casing. The string is slotted and bullnosed from 636.6 to 645.9 m (2,088.5 to 2,119.1 ft). The slots in the 1.6-in. tubing are 0.318 cm (0.125 in.) wide (torch-cut) and 30.5 cm (12.0 in.) long. The slots in each joint are arranged in rows of three, with rows staggered 120 degrees on 61.0-cm (24.0-in.) centers.

Two 2⅞-in. piezometer strings were also inserted into the borehole. Both stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs. The upper piezometer was landed at 886.7 m (2,909.2 ft) for monitoring within the TCA. It is bullnosed and slotted in the interval 761.5 to 886.7 m (2,498.2 to 2,909.2 ft). The lower tubing string was landed at 1,006.5 m (3,302.2 ft) for monitoring within the TSA. It is bullnosed and slotted from 957.3 to 1,006.5 m (3,140.9 to 3,302.2 ft). The machine-cut openings in each slotted joint of both 2⅞-in. tubing strings are 0.159 cm (0.0625 in.) wide and 5.08 cm (2.0 in.) long. The slots in each joint are arranged in rows of eight, with rows staggered 45 degrees on 10.2-cm (4.0-in.) centers. The slotted sections of the 2⅞-in. tubing strings were gravel packed and separated by cement.

On August 27, 2009, a bridge plug was installed at 915.9 m (3,005 ft) between the two slotted intervals in the 5½-in. completion string to isolate the two lower aquifers from each other.

2.6.1.3 Rationale for Differences between Actual and Proposed Well Design

The proposed well completion design for Well ER-20-8 (SNJV, 2009a; NSTec, 2009b) was based on the expectation that no man-made radionuclides would be encountered in the well

(SNJV, 2007; 2007; 2009c). Only one well was planned to be drilled, which would have three isolated completion zones, one each in the BA, the TCA, and the TSA. The SPA (unexpectedly encountered below the BA) contained low levels of tritium, and state regulations required that it be isolated from the lower two aquifers to avoid cross-contamination. This was achieved by casing off the BA and SPA, and a piezometer string was installed to monitor water levels in that isolated interval. The main completion string and two additional piezometers were installed to provide access to the TCA and the TSA. Because the BA and SPA were cased off to prevent contamination of the lower aquifers, another well, ER-20-8#2, was drilled nearby specifically for access to those two aquifers (see Section 3.0). Therefore, adjustments to the original completion plan were made, as described above.

2.6.2 Well Completion Method

The upper piezometer string was placed in the annular space between the surface casing and the intermediate casing before the intermediate casing was installed, prior to deepening the hole from 719.9 m (2,362 ft) to the final TD. The main completion casing and two deeper piezometer strings were installed after the final geophysical logging had been conducted.

The UDI crew installed the two deeper piezometer strings described above on August 12–13, 2009, then inserted a 2⅜-in. Hydril® tremie line for use during emplacement of stemming material (the tremie line was pulled up as stemming progressed). The casing crew began running the main completion string on August 13, 2009. A tight spot was encountered at 815.0 to 877.8 m (2,674 to 2,880 ft), but the crew was able to work past it and landed the string as planned, at 1,019.1 m (3,343.6 ft), on August 14, 2009. Colog ran a Nuclear Annulus Investigation Log (NAIL) in the 5½-in. completion string to monitor placement of stemming materials. A layer of ⅜-in. washed gravel 105.2 m (345 ft) thick was emplaced around the lower completion zone. Next, a section of sand was placed above the gravel to prevent cement from infiltrating the gravel pack. A 4.3-m (14-ft) layer of 6-9 coarse silica sand and a 3.4-m (11-ft) layer of 20-40 fine silica sand were placed above the gravel that surrounds the lower completion zone, and a 39.6-m (130-ft) section of neat Type II cement was placed on the sand layers. The upper gravel layer, which is 143.0 m (469 ft) thick, was placed on the cement layer, and surrounds the upper completion zone. A 4.9-m (16-ft) layer of 6-9 coarse silica sand and a 4.6-m (15-ft) layer of 20-40 fine silica sand were placed above this upper gravel layer, then a 14.0-m (46-ft) section of neat Type II cement was placed on these sand layers to seal the completion zones (Figure 2-2; Table 2-6).

The UDI drill rig was rigged down after the final cementing and stemming operations in preparation for moving the rig to ER-20-8#2. Hydrologic testing is planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion. A bridge plug was installed on August 27, 2009, between the two slotted intervals in the 5½-in. completion string at 915.9 m (3,005 ft) to isolate the two lower aquifers from each other.

All well construction materials used for the completion were inspected according to relevant procedures, as listed in SNJV (2009a). Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

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3.0 Well ER-20-8#2

This section contains detailed descriptions of the drilling process and fluid management issues, geologic data collection, and completion information for Well ER-20-8#2. See Section 2.0 for detailed information about the construction of Well ER-20-8.

3.1 Well-Specific Objectives

The scientific objectives for the Well ER-20-8 site are listed in Section 1.4.

3.2 Drilling Summary

This section contains detailed descriptions of the drilling process and fluid management.

3.2.1 Introduction

The general drilling requirements for all the 2009 Pahute Mesa Phase II wells were provided in *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a). Well ER-20-8#2 is considered the necessary extension of Well ER-20-8 and it allows access to the BA and SPA, which were cased off in Well ER-20-8 (see discussion in Subsections 2.2.2 and 2.6). Specific requirements for Well ER-20-8#2 were outlined in FAWP number D-008-001.09 (NSTec, 2009c). The layout of the drill site is shown in Figure 1-4. A summary of drilling statistics for the well is given in Table 3-1. Figure 3-1 is a chart of the drilling and completion history for Well ER-20-8#2. The following information was compiled primarily from NSTec daily drilling reports.

3.2.2 Drilling History

Field operations at Well ER-20-8#2 began on August 17, 2009, when an NSTec crew set up the Auger II drill rig and began drilling a 106.7-cm (42-in.) conductor hole. By the next day, the conductor hole was drilled to 25.5 m (83.5 ft), and a string of 20-in. conductor casing was set at the depth 24.9 m (81.7 ft). The conductor casing was cemented in place on August 19, 2009, using 26.8 m^3 (35.0 yd^3) of Redi-Mix Formula 400 (see cement composition in Appendix A-3). The cement was pumped into the annulus between the casing and the formation, with a rise inside the casing to the depth of 22.6 m (74 ft).

Table 3-1
Abridged Drill Hole Statistics for Well ER-20-8#2

LOCATION DATA:

Coordinates:

Nevada State Plane (Central Zone)	(NAD 27):	N 889,295.2 ft E 556,080.6 ft
Nevada State Plane (Central Zone)	(NAD 83):	N 6,271,058.3 m E 517,013.9 m
Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,116,408.4 m E 546,592.5 m

Surface Elevation [a]: 1,782.7 m (5,848.8 ft)

DRILLING DATA:

Spud Date: 08/22/2009 (main hole drilling with Wilson Mogul 42B rig)

Total Depth (TD): 712.6 m (2,338 ft)

Date TD Reached: 08/30/2009

Date Well Completed: 09/02/2009 (date completion string was stemmed)

Hole Diameter: 106.7 cm (42 in.) from surface to 25.5 m (83.5 ft); 44.5 cm (17.5 in.) from 25.5 to 495.6 m (83.5 to 1,626 ft); 31.1 cm (12.25 in.) from 495.6 m (1,626 ft) to TD of 712.6 m (2,338 ft).

Drilling Techniques: Dry-hole auger 106.7 cm (42 in.) hole from surface to 25.5 m (83.5 ft); rotary drill with 17½ in. tricone bit, using air-foam in direct circulation from 25.5 to 495.6 m (83.5 to 1,626 ft); rotary drill with 12¼-in. tricone bit to TD of 712.6 m (2,338 ft).

CASING DATA: 20-in. conductor casing to 24.9 m (81.7 ft); 13⅜-in. surface casing to 488.3 m (1,602.2 ft); 7⅝-in. casing to 701.0 m (2,300.0 ft).

WELL COMPLETION DATA:

A string of 7⅝-in. epoxy-coated carbon-steel casing, connected to 7⅝-in. stainless-steel casing via a crossover sub, was installed in Well ER-20-8#2. The carbon-steel casing is located within the unsaturated zone to a point approximately 7.9 m (26 ft) above the water table. The 7⅝-in. outside-diameter stainless-steel casing has an inside diameter of 17.78 cm (7.001 in.). The 7⅝-in. outside-diameter carbon-steel casing has an inside diameter 17.70 cm (6.969 in.). The completion casing was landed at 701.1 m (2,300 ft). A string of 2⅞-in. stainless-steel tubing with one slotted interval was installed adjacent to the completion casing. The 2⅞-in. tubing hangs from a string of 2⅜-in. carbon-steel tubing, and was landed at 681.0 m (2,234.3 ft). Detailed data for the completion interval are provided in Section 3.6 of this report.

Depth of Slotted Section:
7⅝-in. casing: 512.2 to 689.8 m (1,680.4 to 2,263.2 ft)
2⅞-in. tubing: 506.9 to 680.7 m (1,663.1 to 2,233.4 ft)

Depth of Gravel Pack: 494.7 to 712.6 m (1,623.0 to 2,338.0 ft)

Depth of Pump: Not installed at the time of completion

Water Depth [b]: Fluid-level depth of 508.4 m (1,668.1 ft) for the BA and SPA, measured inside the 7⅝-in. completion casing on September 8, 2009, six days after stemming operations were completed.

DRILLING CONTRACTOR: United Drilling, Inc.

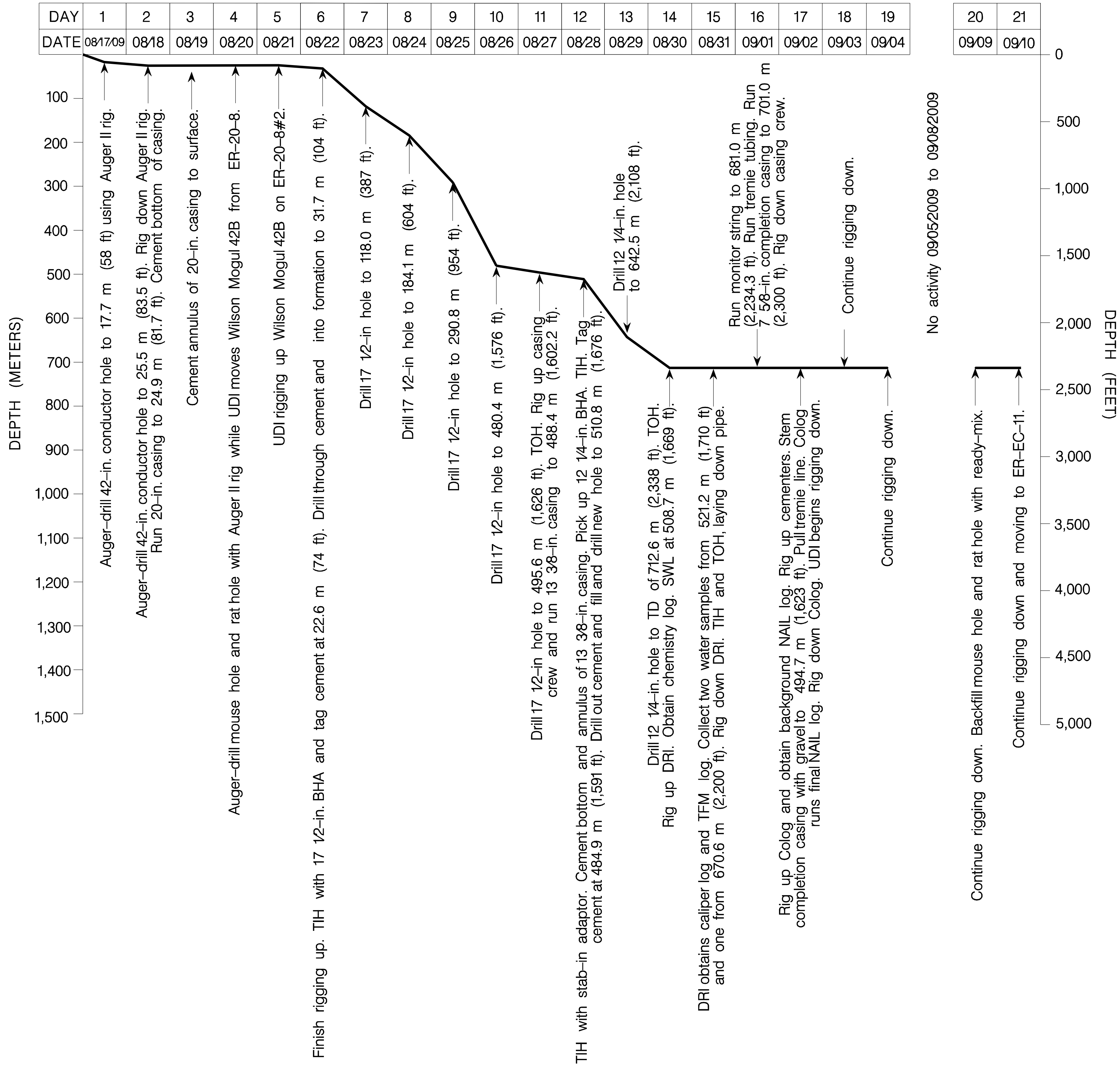
GEOPHYSICAL LOGS BY: Desert Research Institute

SURVEYING CONTRACTOR: National Security Technologies, LLC

a Elevation of ground level at wellhead, relative to mean sea level. National Geodetic Vertical Datum, 1929 (NARA, 1973).
b Fluid level tag by Navarro Nevada Environmental Services.

WELL ER-20-8#2 SUMMARY

Activity	Date
Begin drilling for conductor hole:	08/17/2009
Conductor hole completed and 20-in. casing set at 24.9 m (81.7 ft):	08/19/2009
Begin drilling 17 1/2-in. hole:	08/22/2009
Set 13 3/8-in. casing at 488.4 m (1,602.2 ft):	08/27/2009
Begin drilling 12 1/4-in. hole:	08/28/2009
Reach total drilled depth of 712.6 m (2,338 ft):	08/30/2009
Well completed:	09/02/2009



LEGEND

BHA	bottom hole assembly
DRI	Desert Research Institute
ft	foot (feet)
in.	inch(es)
m	meter(s)
NAIL	nuclear annulus investigation log
SWL	static water level
TD	total depth
TFM	thermal flow meter
TIH	trip into hole
TOH	trip out of hole
UDI	United Drilling Inc.

FIGURE 3-1

WELL ER-20-8#2
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 1

The UDI crews began rigging up to drill with the Wilson Mogul 42B drill rig on August 21, 2009. They finished rigging up on August 22, 2009, and began drilling from the top of cement inside the 20-in. casing at 22.6 m (74 ft), using a bottom-hole assembly with a 17½-in. rotary bit. The drilling fluid was an air/water/soap mix in conventional circulation. The 44.5-cm (17.5-in.) surface hole was drilled as planned to the casing point within the rhyolite of Benham. This point was reached on August 27, 2009, at the depth of 495.6 m (1,626 ft), which is approximately 13.1 m (43 ft) above the expected water table depth. After the drillers cleaned and conditioned the borehole, they tagged 0.3 m (1 ft) of fill at the bottom of the hole.

On August 27, 2009, the casing subcontractor installed a string of 13⅜-in. casing, which was set at the depth of 488.3 m (1,602.2 ft). The bottom of the casing was cemented with 5.7 m^3 (7.4 yd^3) of Type II neat cement on August 28, 2009. The top of cement inside the casing was tagged by the drillers with the 12¼-in. bottom-hole assembly at the depth of 484.9 m (1,591 ft). The top of the cement in the annulus is estimated to be at the depth of 432.2 m (1,418 ft). The crew drilled out cement and the shoe from 484.9 to 488.3 m (1,591 to 1,602 ft) and cleaned out fill to 495.6 m (1,626 ft).

Drilling of the 31.1-cm (12.25-in.) production hole began on August 28, 2009. Circulation was temporarily lost in a suspected fracture zone near the depth of 499.9 m (1,640 ft) but was recovered at 502.9 m (1,650 ft) after the fluid injection rate was increased. N-I reported water production starting at the depth of 512.4 m (1,681 ft) the next day, and they began collecting fluid samples for tritium analysis every 30 minutes. On August 30, 2009, the TD of the hole was reached at 712.6 m (2,338 ft), after the full thickness of the target aquifer (SPA) had been penetrated. The drillers circulated fluid in the hole and then tagged 0.3 m (1 ft) of fill.

The only geophysical logging conducted in Well ER-20-8#2 was done by DRI personnel on August 30–31, 2009. They also collected water samples and measured the water level at the depth of 508.1 m (1,667 ft).

On September 1, 2009, the drill crew inserted the 2⅞-in. piezometer string and landed it at the depth 681.0 m (2,234.3 ft). The casing subcontractor installed 7⅝-in. completion casing and landed it at the depth of 701.0 m (2,300.0 ft). The completion casing and piezometer string were gravel packed (see completion details in Section 3.6). Stemming operations were completed on September 2, 2009, and the drillers started rigging down. There was no activity at the rig site September 4–8, 2009, and demobilization of the rig and drilling equipment began on

September 9, 2009. The crews worked one shift per day after that until demobilization was completed on September 12, 2009.

A graphical depiction of drilling parameters, including penetration rate, rotary revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-1. See Appendix A-2 for a listing of tubing and casing materials. Drilling fluids and cements used in Well ER-20-8#2 are listed in Appendix A-3.

3.2.3 Drilling Problems

Drilling proceeded smoothly and as planned, with only minor difficulties in a zone of lost circulation.

3.2.4 Fluid Management

During drilling, the drilling effluent was monitored according to the methods prescribed in the UGTA Project FMP (NNSA/NSO, 2009b) and the associated state-approved, well-specific, fluid management strategy letter (SNJV, 2009d), which was updated to include both boreholes at the Well ER-20-8 site. The air-foam/polymer drilling fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation) and then discharged into a sump. Water used to prepare drilling fluids came from Area 20 Water Well (U-20WW). Lithium bromide was added to the drilling fluid as a tracer to provide a means of estimating groundwater production. The rate of water production was estimated from the dilution of the tracer in the drilling fluid returns.

Radionuclides exceeding fluid quality objectives were not expected at Well ER-20-8#2, based on Phase I flow and transport modeling (SNJV, 2006; 2007; 2009c) and fluid analyses from Well ER-20-8. To manage the anticipated water production, the two sumps (sump #1 and sump #2) constructed prior to drilling Well ER-20-8 were used (Figure 1-4). A liner had been installed in sump #2 during drilling of Well ER-20-8.

Samples of drilling effluent were collected hourly as necessary by N-I and analyzed on site by RCTs for the presence of tritium. Starting at a depth of 497.1 m (1,631 ft), samples were collected every half hour. Samples were once again collected hourly, starting with the sample from 663.5 m (2,177 ft). As detailed in the N-I data report (N-I, 2010b) and summarized in Appendix B of this report, the onsite monitoring results for the drilling indicated that tritium levels measured in the drilling fluid were below drinking water standards, as measured by field instruments. No tritium above the minimum detection limit of the field instruments was detected. However, among 13 composite samples of drilling fluid analyzed by LLNL (see Table 3-3 in Section 3.4.4), the highest tritium level, approximately 1,500 pCi/L, was measured in the sample from the depth of approximately 712.6 m (2,338 ft) (LLNL, 2010b; N-I, 2010b).

No lead monitoring was performed. Lead monitoring is not initiated until discharge fluids exceed the UGTA fluid management criteria for tritium (200,000 pCi/L), as specified in the Well ER-20-8 fluid management strategy letter (SNJV, 2009d) approved by the Nevada Division of Environmental Protection. N-I personnel checked all down-hole equipment for lead prior to use in the borehole, and none was found.

All fluid quality objectives were met, as shown on the fluid management reporting form (Appendix B). The form in Table B-3 lists volumes of solids (drill cuttings) and fluids produced during well-construction operations (vadose-zone drilling and saturated-zone drilling; well development and aquifer testing are not addressed in this report). The volume of solids produced was calculated using the diameter of the borehole (from caliper logs) and the depth drilled, and includes added volume attributed to a rock bulking factor. The volumes of fluids listed on the report are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps. The fluid management sample was collected from the unlined sump #1 after drilling of Well ER-20-8#2 was completed (Table B-2), and serves as the fluid management sample for both wells.

3.3 Geologic Data Collection

This section describes the sources of geologic data obtained from Well ER-20-8#2 and the methods of data collection. A complete set of geologic data, including sidewall samples and geophysical logs, was obtained at nearby Well ER-20-8 (see Section 2.3). Thus, only drill cuttings, a flow log, a water chemistry log, and a caliper log were obtained at Well ER-20-8#2. Data collection, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in the N-I FAWP (SNJV, 2009b).

3.3.1 Drill Cuttings

Composite drill cuttings were collected at 3-m (10-ft) intervals as drilling progressed. N-I personnel collected triplicate samples, each consisting of approximately 550 cubic centimeters of material, from 225 intervals from 27.4 m (90 ft) to TD. These samples are stored under environmentally controlled, secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample, one set was left unsealed in the original sample containers, and the third set was washed and stored according to standard USGS Core Library procedures. The washed set was examined by NSTec geologists to verify that the geology of Well ER-20-8#2 is not significantly different from the geology of nearby Well ER-20-8 (see Section 4.0). Formation tops in the two holes differed from each other by less than 3.0 m (10 ft). N-I field representatives collected an additional set of reference drill cuttings samples from each of the cuttings intervals. This set was examined at the drill site for use in preparing field lithologic descriptions and remains in the custody of N-I.

No drill cuttings samples were selected for further analysis, as petrographic, mineralogical, and chemical analyses were conducted on a full set of samples from nearby Well ER-20-8 (see Section 2.3.3).

3.3.2 Geophysical Log Data

As mentioned above, the full suite of geophysical logs was not run in Well ER-20-8#2 due to its proximity to Well ER-20-8, where a full suite of logs was run (see Table 2-4 and Appendix D). However, DRI ran a caliper log, a flow log, and a water chemistry log in the borehole to further characterize the hydrologic properties of the BA and SPA after the TD was reached at 712.6 m (2,338 ft). The overall quality of this data is considered to be good. A complete listing of the logs, dates run, depths, and the service company is provided in Table 3-2. The logs are available from DRI in Las Vegas, Nevada, and from NSTec in Mercury, Nevada. Copies are on file at the office of N-I in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

3.4 Hydrology of Well ER-20-8#2

This section discusses pre-development water level information, water production, flow meter and chemistry log data, and groundwater characterization samples for Well ER-20-8#2.

3.4.1 Water-Level Information

Prior to drilling, the water level at Well ER-20-8#2 was estimated to be 508.1 m (1,667 ft) below ground surface and within the BA. During logging operations on August 31, 2009, one day after the borehole reached TD, a fluid level depth of 508.1 m (1,667 ft) (elevation of 1,274.7 m [4,182 ft]) was measured by DRI. On September 8, 2009, a water level of 508.4 m (1,668.1 ft) was measured by N-I in the completion casing (the BA and SPA).

Table 3-2
Well ER-20-8#2 Geophysical Log Summary

Geophysical Log Type [a]	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval [b] meters (feet)	Top of Logged Interval [b] meters (feet)
3-Arm Caliper	Borehole conditions, cement volume calculation	08/31/2009	CAL-1	712.3 (2,337)	481.6 (1,580)
* Chemistry / * Temperature Log	Groundwater chemistry and temperature	08/30/2009	Chem-1 / TL-1	712.9 (2,339)	508.7 (1,669)
* Heat Pulse Flow Log	Groundwater flow rate and direction	08/31/2009	HPFlow-1	699.5 (2,295)	521.2 (1,710)

Note: All logs were run by Desert Research Institute.
a Logs presented in geophysical log summary, Appendix D, are indicated by *.
b Drilled depth

3.4.2 Water Production

Water production was estimated during drilling of Well ER-20-8#2 on the basis of dilution of a lithium-bromide tracer, as measured by N-I field personnel. The first observation of water in returns was reported on August 29, 2009, at the depth of approximately 512.4 m (1,681 ft). A negligible amount of water was produced while drilling the BA. Estimated water production ranged from 189.3 to 1,324.9 Lpm (50 to 350 gpm) while drilling the SPA. Estimated water production rates during drilling are presented graphically in Appendix A-1. More accurate water production information will be available after hydraulic testing is conducted following completion and development of the well.

3.4.3 Flow Meter and Chemistry Log Data

Flow meter data, along with temperature, electrical conductivity, and pH measurements, are typically used to characterize borehole fluid variability in UGTA wells, and may indicate inflow and outflow zones. DRI personnel ran their chemistry log to obtain temperature, electrical conductivity, and pH measurements in the interval 508.7 to 712.9 m (1,669 to 2,339 ft). DRI personnel measured the fluid flow rate and direction (Heat Pulse Flow log) at seven depths between 521.2 and 699.5 m (1,710 and 2,295 ft) within the SPA, on August 31, 2009 (data plots provided in Appendix D, page D-7).

The flow log indicated that water from the lower portion of the borehole has an upward flow of approximately 2.3 Lpm (0.6 gpm), and water from the upper portion of the borehole has a downward flow of approximately 3.4 Lpm (0.9 gpm). Two prominent zones of flow occur in relatively narrow intervals that correspond to inflection points on the electrical conductivity and pH logs: an interval of inflow near the depth of 625.4 m (2,052) and an interval of outflow at 652.3 m (2,140 ft). Both zones occur within the same rhyolitic lava flow of the rhyolite of Scrugham Peak and may be related to the contacts between the stoney lava interior and the vitrophyric intervals above and below it. The mechanism controlling these flow zones is currently poorly understood.

3.4.4 Groundwater Samples

Following logging on August 31, 2009, DRI personnel collected a total of six depth-discrete groundwater characterization samples within the open borehole at two depths, 521.2 and 670.6 m (1,710 and 2,200 ft). The purpose of these samples was to provide a framework of initial groundwater chemistry based on a select number of analytical parameters. These samples were analyzed for metals, organic and inorganic constituents, tritium, gross alpha and beta, and plutonium. All tritium values were less than 1,000 pCi/L (N-I, 2010b).

N-I personnel collected 13 composite water samples from the fluid discharge line on August 29–30, 2009, for analysis by LLNL. These samples were analyzed for tritium and anions. All values for tritium were 1,500 pCi/L or less (N-I, 2010b). See Table 3-3 for a list of samples.

All of these samples were collected prior to completion and final development of the well. The analytical results should be used with care because water quality measurements may be affected by constituents of the drilling fluids, and thus not accurately reflect natural groundwater quality. The results of groundwater analyses are typically reported in data reports prepared by the analyzing laboratories and in UGTA project reports (e.g., the water chemistry database and the transport data document).

3.5 Precompletion and Open-Hole Development

Initial well development conducted in Well ER-20-8#2 consisted of using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole, prior to the logging operation, after the TD was reached.

3.6 Well Completion

Well completion refers to the installation in a borehole of one or more strings of tubing or casing that is slotted or screened at one or more locations along their length. The completion process

Table 3-3
Composite Fluid Samples Collected During Drilling of Well ER-20-8#2

Sample Number	Depth Interval meters (feet)
ER-20-8-2-082909-1	518.2–533.4 (1,700–1,750)
ER-20-8-2-082909-2	533.4–548.6 (1,750–1,800)
ER-20-8-2-082909-3	548.6–563.9 (1,800–1,850)
ER-20-8-2-082909-4	563.9–579.1 (1,850–1,900)
ER-20-8-2-082909-5	579.1–594.4 (1,900–1,950)
ER-20-8-2-082909-6	594.4–609.6 (1,950–2,000)
ER-20-8-2-082909-7	609.6–624.8 (2,000–2,050)
ER-20-8-2-082909-8	624.8–640.1 (2,050–2,100)
ER-20-8-2-083009-1	640.1–655.3 (2,100–2,150)
ER-20-8-2-083009-2	655.3–670.6 (2,150–2,200)
ER-20-8-2-083009-3	670.6–685.8 (2,200–2,250)
ER-20-8-2-083009-4	685.8–701.0 (2,250–2,300)
ER-20-8-2-083009-5	701.0–712.6 (2,300–2,338)

Source: N-I, 2010b

also typically includes emplacement of backfill materials around the string(s), with coarse fill such as gravel adjacent to the open intervals and impervious materials such as cement placed between or above the open intervals to isolate them. The string(s) serves as a conduit for inserting a pump in the well, for inserting devices for measuring fluid level, and for sampling, so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole.

The proposed design for Well ER-20-8#2 was presented in the NSTec FAWP (NSTec, 2009c). The completion plans are summarized here in Section 3.6.1.1, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 3.6.1.2. The rationale for differences between the planned and actual design is discussed in Section 3.6.1.3, and the completion methods are presented in Section 3.6.2. Figure 3-2 is a schematic diagram of the well completion design. Figure 3-3 shows a plan view and profile of the final wellhead surface completion. Table 3-4 is a construction summary for the completion strings.

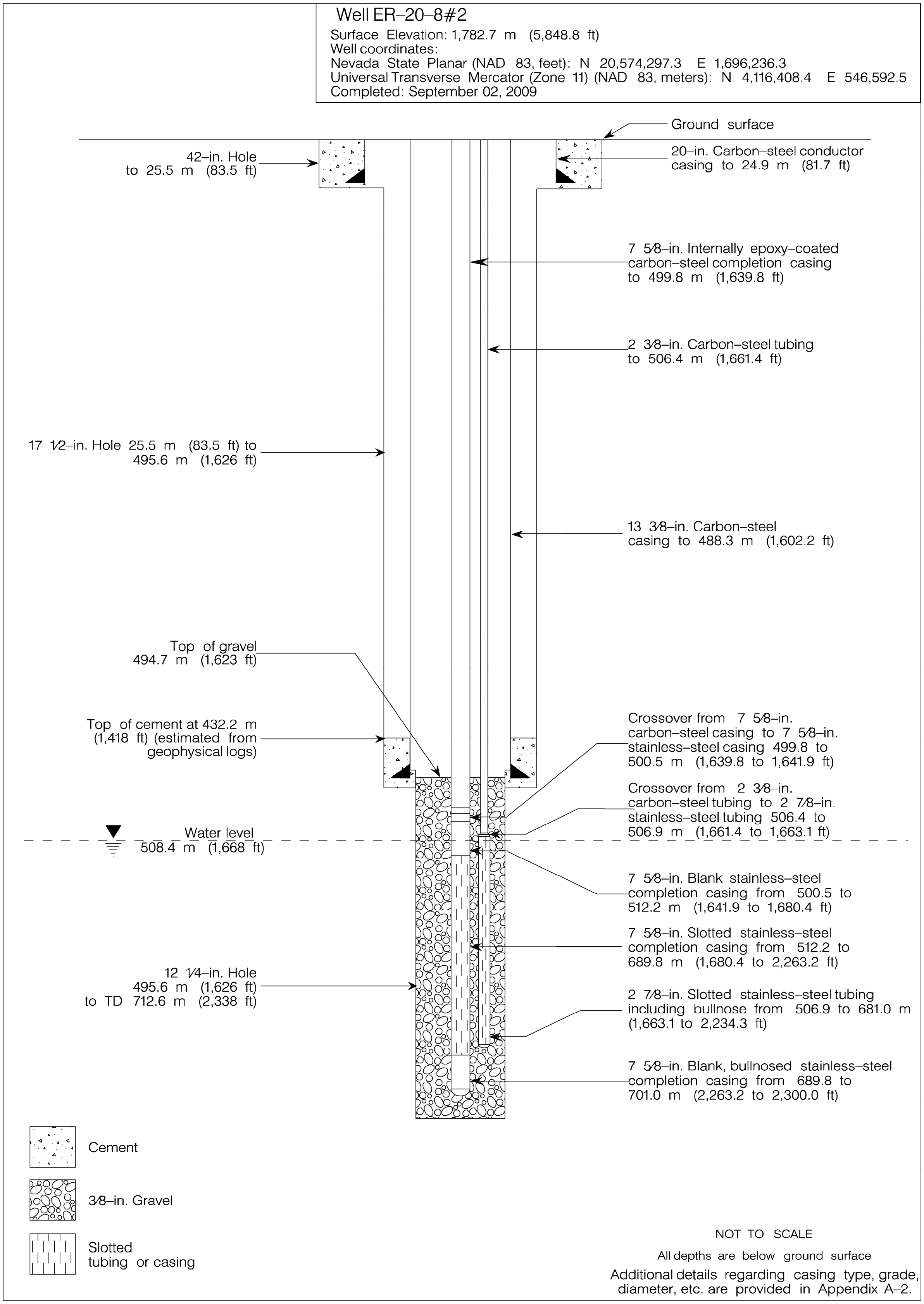


Figure 3-2
As-Built Completion Schematic for Well ER-20-8#2

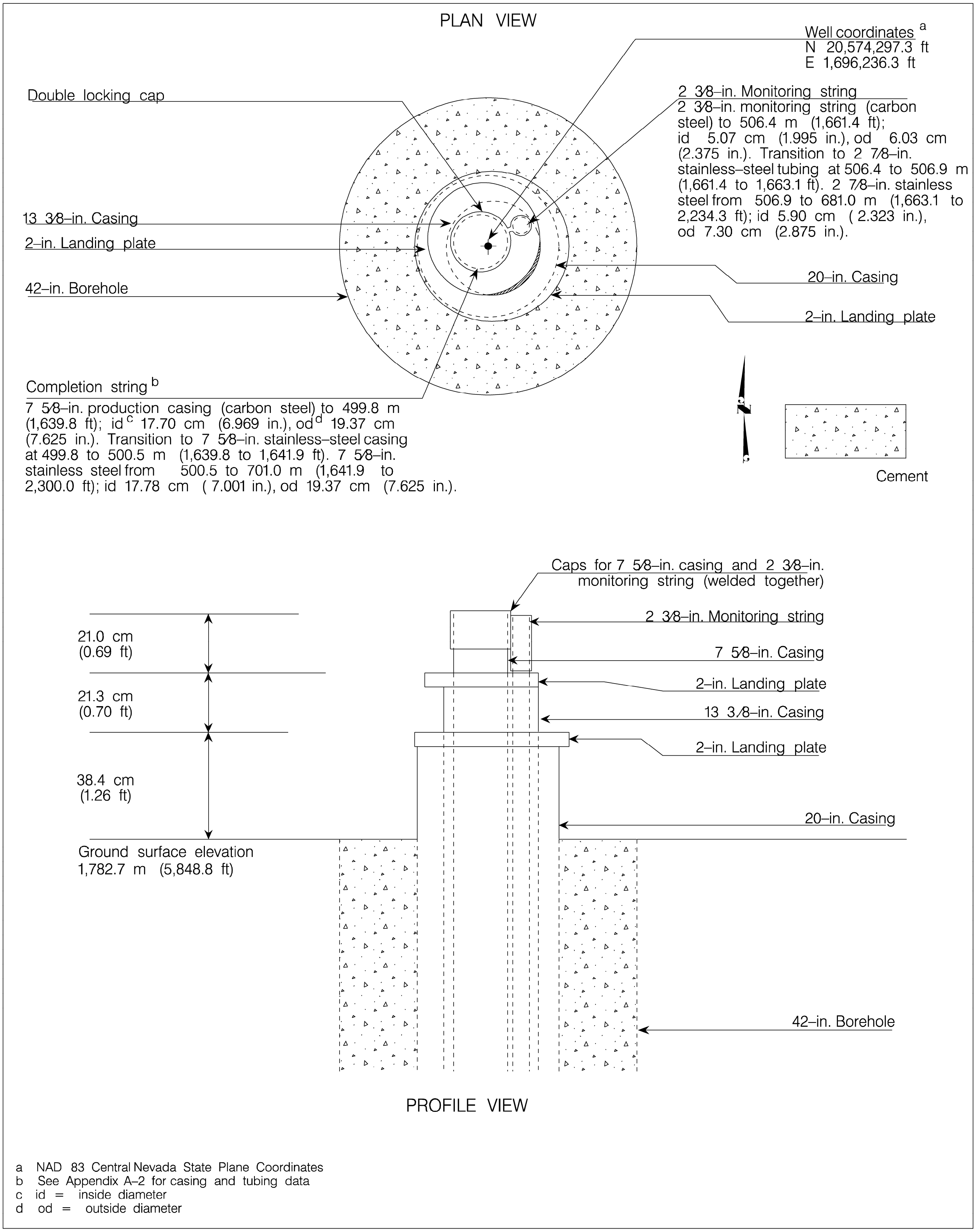


Figure 3-3
Wellhead Diagram for Well ER-20-8#2

Table 3-4
Well ER-20-8#2 Completion String Construction Summary

Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
2⅜-in. carbon-steel tubing with crossover sub	0 to 506.9 (0 to 1,663.1)	Blank	None	None
2⅞-in. stainless-steel tubing (BA and SPA access) [b]	506.9 to 681.0 (1,663.1 to 2,234.3)	Slotted and bullnosed [a]		⅜-in. trona gravel 494.7 to 712.6 (1,623.0 to 2,338.0)
7⅝-in. epoxy-coated carbon-steel production casing with crossover sub	0 to 500.5 (0 to 1,641.9)	Blank		
7⅝-in. stainless-steel production casing	500.5 to 701.0 (1,641.9 to 2,300.0)	Blank 500.5 to 512.2 (1,641.9 to 1,680.4)		
		15 consecutive slotted joints [c] 512.2 to 689.8 (1,680.4 to 2,263.2)		
		Blank and bullnosed 689.8 to 701.0 (2,263.2 to 2,300.0)		

a Slots are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long, arranged in 8 rows, on staggered 15.2-cm (6.0-in.) centers.

b BA = Benham aquifer; SPA = Scrugham Peak aquifer

c Slots are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long, arranged in 18 rows, on staggered 15.2-cm (6.0-in.) centers.

3.6.1 Well Completion Design

The following sections describe the well completion design and methods. The final completion design was generally the same as the proposed design, as described in the following sections.

3.6.1.1 Proposed Completion Design

The original proposed well completion design (presented in SNJV, 2009a) for Well ER-20-8 was based on the expectation that there would be no man-made radionuclides, only one well would be drilled, and it would have three isolated completion zones (see Section 2.6.1.1). However, the SPA contained low levels of tritium and state regulations required that it be isolated from the other two lower aquifers to avoid cross-contamination. Because the BA and SPA had to be isolated from the underlying TCA and TSA in Well ER-20-8, a second well, ER-20-8#2, was drilled nearby specifically to access the BA and SPA.

The primary goal of the proposed completion design for Well ER-20-8#2 was to provide groundwater production data from the BA and SPA and to provide access to groundwater for monitoring and sampling. It was predicted that the water table would be near the top of the BA and that the well would reach TD just below the SPA within the upper Paintbrush confining unit (UPCU). On this basis, Well ER-20-8#2 was planned to be completed with a single string of 7⅝-in. casing extending through the BA and SPA. A 2⅞-in. piezometer string was to be placed within the annulus between the 13⅜-in. casing and the 7⅝-in. completion casing to monitor the BA and SPA.

3.6.1.2 As-Built Completion Design

The design of the Well ER-20-8#2 completion was determined through consultation with members of the UGTA Well ER-20-8 drilling advisory team on the basis of the hydrogeology encountered at Well ER-20-8. Well-specific data from Well ER-20-8#2, such as lithology, water production, and drilling data were evaluated to confirm expectations and fine-tune the completion design.

The main completion string consists of a section of 7⅝-in. stainless-steel casing suspended from 7⅝-in. internally epoxy-coated carbon-steel casing connected via a crossover sub, and was set at the depth of 701.0 m (2,300.0 ft). The 7⅝-in. carbon-steel casing and crossover sub extend from the surface to the depth of 500.5 m (1,641.9 ft), which is about 7.9 m (26 ft) above the water table. The stainless-steel 7⅝-in. casing is slotted in the interval from 512.2 to 689.8 m (1,680.4 to 2,263.2 ft) within the BA and SPA. The slotted section consists of 15 consecutive slotted joints and was terminated with 10.5 m (34.4 ft) of blank stainless-steel casing and a 0.7-m (2.4-ft) stainless-steel bullnose to function as a sediment sump. The openings in each slotted casing joint are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long. The slots are arranged in rows of 18, with rows staggered 20 degrees on 15.2-cm (6.0-in.) centers. The slotted interval is isolated from all formations above the gravel pack by the 13⅜-in. casing. The completion string was gravel-packed from 494.7 to 712.6 m (1,623.0 to 2,338.0 ft).

The piezometer string consists of a section of 2⅞-in. stainless-steel tubing suspended from 2⅜-in. carbon-steel tubing connected via a crossover sub, and was set at the depth of 681.0 m (2,234.3 ft). The 2⅜-in. carbon-steel tubing extends from the surface to the depth of 506.9 m

(1,663.1 ft), which is 1.5 m (5 ft) above the water table. The stainless-steel 2⅞-in. tubing is slotted in the interval from 506.9 to 681.0 m (1,663.1 to 2,234.3 ft) within the BA and SPA. The slotted section consists of 30 consecutive slotted joints and was terminated with a 0.25 m (0.83 ft) stainless-steel bullnose. The openings in each slotted casing joint are 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long. The slots are arranged in rows of eight, with rows staggered 45 degrees on 15.2-cm (6.0-in.) centers. The slotted portion of the piezometer string lies within the same gravel pack as the slotted section of the 7⅞-in. production casing.

3.6.1.3 Rationale for Differences between Actual and Proposed Well Design

The drilling conditions and hydrogeology for this site were defined by Well ER-20-8, located 15.8 m (52 ft) to the northeast. Consequently, minimal adjustment had to be made and Well ER-20-8#2 was constructed generally as planned.

The original planned depth of the piezometer string was 688.8 m (2,260 ft). However, because two of the slotted 2⅞-in. stainless-steel joints were found to be damaged and no replacement joints were available, the position of the slotted portion of the string was shifted upward. Because of this shift, the crossover between the 2⅜-in. carbon-steel tubing and the 2⅞-in. stainless-steel is closer to the water table than planned, and the bottom of the slotted section is higher than planned.

3.6.2 Well Completion Method

On September 1, 2009, UDI inserted the 2⅞-in. piezometer string, landing it at 681.0 m (2,234.3 ft). As noted above, this is approximately 7.8 m (25.7 ft) higher than planned because two unusable joints were found. UDI next installed the 2⅜-in. Hydril® tremie line, which would be used to emplace the stemming material. The casing subcontractor installed the production casing, which was landed, as planned, at 701.0 m (2,300.0 ft). The inside of the casing was scraped to remove metal burrs that had been noted adjacent to some of the cut slots, prior to insertion. Colog ran a NAIL tool in the 7⅝-in. completion string to monitor placement of stemming materials. A layer of ⅜-in. trona gravel 217.9 m (715 ft) thick was emplaced around the completion zone, from the bottom of the borehole to the depth 494.7 m (1,623.0 ft) (Figure 3-2). No sand or cement was used in the completion.

The UDI drill rig was released after the production casing was installed and stemming operations were complete. Hydrologic testing is planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion.

All well construction materials used for the completion were inspected according to relevant procedures, as listed in SNJV (2009a). Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

4.0 Geology and Hydrogeology

4.1 Introduction

This section describes the geology and hydrogeology of the Well ER-20-8 site. The basis for the discussions here is the geologic characterization of Well ER-20-8 presented as a detailed lithologic log in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling parameters. Petrographic, mineralogic, and chemical analyses on select lithologic samples from Well ER-20-8 were incorporated into the detailed lithologic log. Information on fractures was obtained from the interpretation of borehole image logs.

A separate detailed lithologic log was not prepared for Well ER-20-8#2 because the well penetrated the same geologic section (the upper part) as nearby Well ER-20-8. However, geologists examined the drill cuttings samples from Well ER-20-8#2 to verify that there are no differences between the wells. Formation tops, as determined from cuttings samples from the two wells, differed by less than 3.0 m (10 ft).

4.2 Geology

This section is divided into three discussions relating to the geology of the Well ER-20-8 site. Section 4.2.1 briefly describes the geologic setting of the Pahute Mesa and Bench areas and the Well ER-20-8 site. The stratigraphic and lithologic units penetrated at the wells are discussed in detail in Section 4.2.2. Because of the significant influence some alteration products have on the hydraulic properties of certain rocks, alteration of the rocks encountered at the well is discussed separately in Section 4.2.3. Detailed descriptions of the stratigraphy, lithology, and alteration of the rocks encountered are provided in the detailed lithologic log presented in Appendix C. Tables 4-1 and 4-2 provide the definitions of stratigraphic units and HSUs used in various figures in this report. See Figure 4-1 for a surface geologic map of the area surrounding the Well ER-20-8 site.

4.2.1 Geologic Setting

Wells ER-20-8 and ER-20-8#2 are located within a geologically complex area that is mainly the result of volcano-tectonic processes associated with nearby calderas that formed approximately 9 to 14 million years ago (Ma) (Sawyer et al., 1994). The wells were drilled just below the southern rim of Pahute Mesa, a high volcanic plateau composed of lava and tuff of generally rhyolitic composition. The volcanic rocks that compose Pahute Mesa bury the Silent Canyon

Table 4-1
Key to Stratigraphic Units and Symbols Used in this Report

Stratigraphic Unit	Map Symbol
Colluvium	QTc
Thirsty Canyon Group, undivided	Tt
Beatty Wash Formation	Tfb
Ammonia Tanks Tuff	Tma
rhyolite of Tannenbaum Hill	Tmat
debris-flow breccia	Tmatx
Rainier Mesa Tuff	Tmr
rhyolite of Fluorspar Canyon	Tmrf
Paintbrush Group, undivided	Tp
rhyolite of Benham	Tpb
rhyolite of Scrugham Peak	Tps
tuff of Pinyon Pass	Tpcy
Tiva Canyon Tuff Pahute Mesa lobe of the Tiva Canyon Tuff	Tpc Tpcm
rhyolite of Delirium Canyon	Tpd
Topopah Spring Tuff Pahute Mesa lobe of the Topopah Spring Tuff	Tpt Tptm
Calico Hills Formation mafic-poor Calico Hills Formation	Th Thp
Crater Flat Group	Tc
rhyolite of Inlet	Tci
rhyolite of Kearsarge	Tcpk
rhyolite of EC-1	Tcpe
Bullfrog Tuff	Tcb
Grouse Canyon Tuff	Tbg
Volcanics of Oak Spring Butte	To

Table 4-2
Key to Hydrostratigraphic Units and Symbols Used in this Report

Hydrostratigraphic Unit	Symbol
Thirsty Canyon volcanic aquifer	TCVA
Tannenbaum Hill lava-flow aquifer	THLFA
Tannenbaum Hill composite unit	THCM
Timber Mountain aquifer	TMA
Fluorspar Canyon confining unit	FCCU
Paintbrush vitric-tuff aquifer	PVTA
Benham aquifer	BA
upper Paintbrush confining unit	UPCU
Scrugham Peak aquifer	SPA
middle Paintbrush confining unit	MPCU
Tiva Canyon aquifer	TCA
lower Paintbrush confining unit	LPCU
Topopah Spring aquifer	TSA
Calico Hills zeolitic composite unit	CHZCM
Calico Hills confining unit	CHCU
Inlet aquifer	IA
Crater Flat composite unit	CFCM
Crater Flat confining unit	CFCU
Bullfrog confining unit	BFCU
Belted Range aquifer	BRA
Pre-Belted Range composite unit	PBRCM

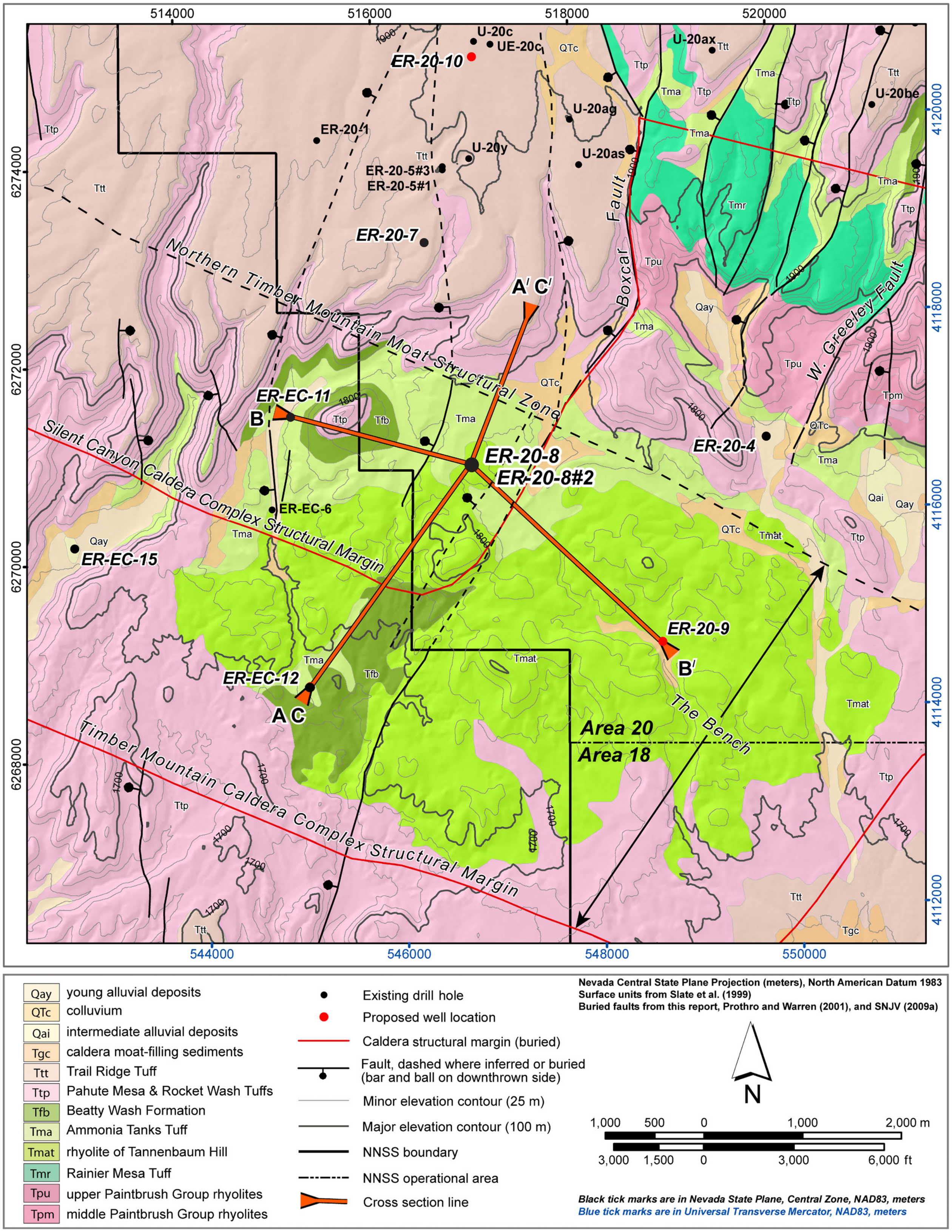


Figure 4-1
Surface Geologic Map of the Well ER-20-8 Area

caldera complex (SCCC), which consists of two overlapping calderas—the Grouse Canyon caldera and the younger Area 20 caldera (Sawyer and Sargent, 1989). These calderas were formed by voluminous eruptions of ash-flow tuffs of generally rhyolitic composition, between approximately 13 and 14 Ma (Sawyer et al., 1994). The wells are located within the boundaries of the Area 20 caldera, but their TDs are well above the volcanic rocks associated with the formation of the Area 20 caldera.

The wells also lie approximately 4,250 m (14,000 ft) northeast of the northern structural margin of the TMCC. This caldera complex formed as a result of the eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff, 11.6 and 11.45 Ma, respectively. The youngest volcanic units in the area are a series of ash-flow tuffs erupted from the Black Mountain caldera, located approximately 13 kilometers (8 miles) northwest of the wells. These tuffs include the 9.4-Ma Rocket Wash and Pahute Mesa tuffs and the 9.3-Ma Trial Ridge Tuff.

The well site is constructed on the rhyolite of Tannenbaum Hill (Slate et al., 1999), which consists of rhyolitic lava extruded onto a structural bench during the time period between the caldera-forming eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff. This structural bench, designated the Northwestern Timber Mountain Bench by Warren et al. (2000) but referred to as simply the Bench in this and other Phase II documents (SNJV, 2009a; NNSA/NSO, 2010a), is bounded on the north by the NTMMSZ and on the south by the buried northern structural margin of the TMCC (Figure 4-1). The NTMMSZ is a north-northwest trending buried structural zone first recognized geophysically (Mankinen et al., 1999; Grauch et al., 1999) and subsequently confirmed by data from PM–OV Phase I drilling (DOE/NV, 2000b). The NTMMSZ is a down-on-the-southwest fault (or fault zone) that displaces rock units as young as the Rainier Mesa Tuff by more than 300 m (1,000 ft). The NTMMSZ appears to be related to the formation of the TMCC, with major movement occurring between the eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff (DOE/NV, 2000b).

Numerous normal faults have been mapped at the surface on Pahute Mesa (Slate et al., 1999). These faults generally strike in a northerly direction and dip to the west. Three normal faults are known to occur in the immediate vicinity of the Well ER-20-8 site. A small fault is located approximately 457 m (1,500 ft) to the northwest, another small fault is located approximately 274 m (900 ft) to the southeast, and the inferred southwestern extension of the Boxcar fault is located about 610 m (2,000 ft) to the southeast at the surface (Byers and Cummings, 1967). These three faults strike northeast and are characterized as high-angle, down-on-the-west normal faults.

4.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Wells ER-20-8 and ER-20-8#2 are illustrated in Figure 4-2, and a preliminary interpretation of the distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figures 4-3 and 4-4. The determination of the volcanic stratigraphic and lithologic units penetrated by Wells ER-20-8 and ER-20-8#2 was aided by examination of, and correlation with, nearby Well ER-20-7. (Well ER-20-7 is located on Pahute Mesa approximately 2,286 m [7,500 ft] to the north of the Well ER-20-8 site, and was the first hole drilled in the 2009 Phase II drilling campaign [NNSA/NSO, 2010a]) Geologic information from Well ER-EC-6 (DOE/NV, 2000b) and from surface exposures along the Boxcar fault was also consulted.

It should be noted throughout the following discussions that the cross sections in Figures 4-3 and 4-4 do not necessarily reflect detailed bedding dip patterns described from the borehole image logs. Bedding dip patterns from boreholes in complex volcanic environments like the Bench can be difficult to interpret and to extrapolate beyond the near-wellbore region because they represent the cumulative dip of complex structural and depositional processes, some of which may be local in origin (e.g., draping over paleo-topography). Bedding dip patterns acquired from all the Phase II wells, as well as from previous Phase I wells, however, will be reevaluated together with other geologic data during model construction, after completion of Phase II data acquisition, and according to the schedule in the current version of the UGTA life cycle baseline.

Drilling at the Well ER-20-8 site began in lava of the rhyolite of Tannenbaum Hill of the Timber Mountain Group, which forms the ground surface in the vicinity of the well site (Slate et al., 1999; Figure 4-1). The rhyolite of Tannenbaum Hill was encountered from the surface to the depth of 334.7 m (1,098 ft). The upper two-thirds of the unit at the Well ER-20-8 site consists of vitric and devitrified rhyolitic lava overlying a basal flow breccia. Perlitic structures and spherulites, common features of rhyolitic lava, were observed throughout the lava and flow breccia. The lava and flow breccia overlie an enigmatic interval tentatively identified as nonwelded to moderately welded ash-flow tuff. The interval has characteristics of both ash-flow tuff and lava, and may represent a transition from pyroclastic to more viscous effusive eruptions. The lowermost 46.9 m (154 ft) of the rhyolite of Tannenbaum Hill consists of zeolitic bedded tuff. The stratigraphic assignment of the rhyolite of Tannenbaum Hill is based on outcrop (Byers and Cummings, 1967; Slate et al., 1999), lava-flow lithology, stratigraphic position above the Rainier Mesa Tuff (see discussion below), and mineralogic assemblage, including the presence of quartz phenocrysts, rare to minor biotite, and the presence of sphene. The rhyolite of

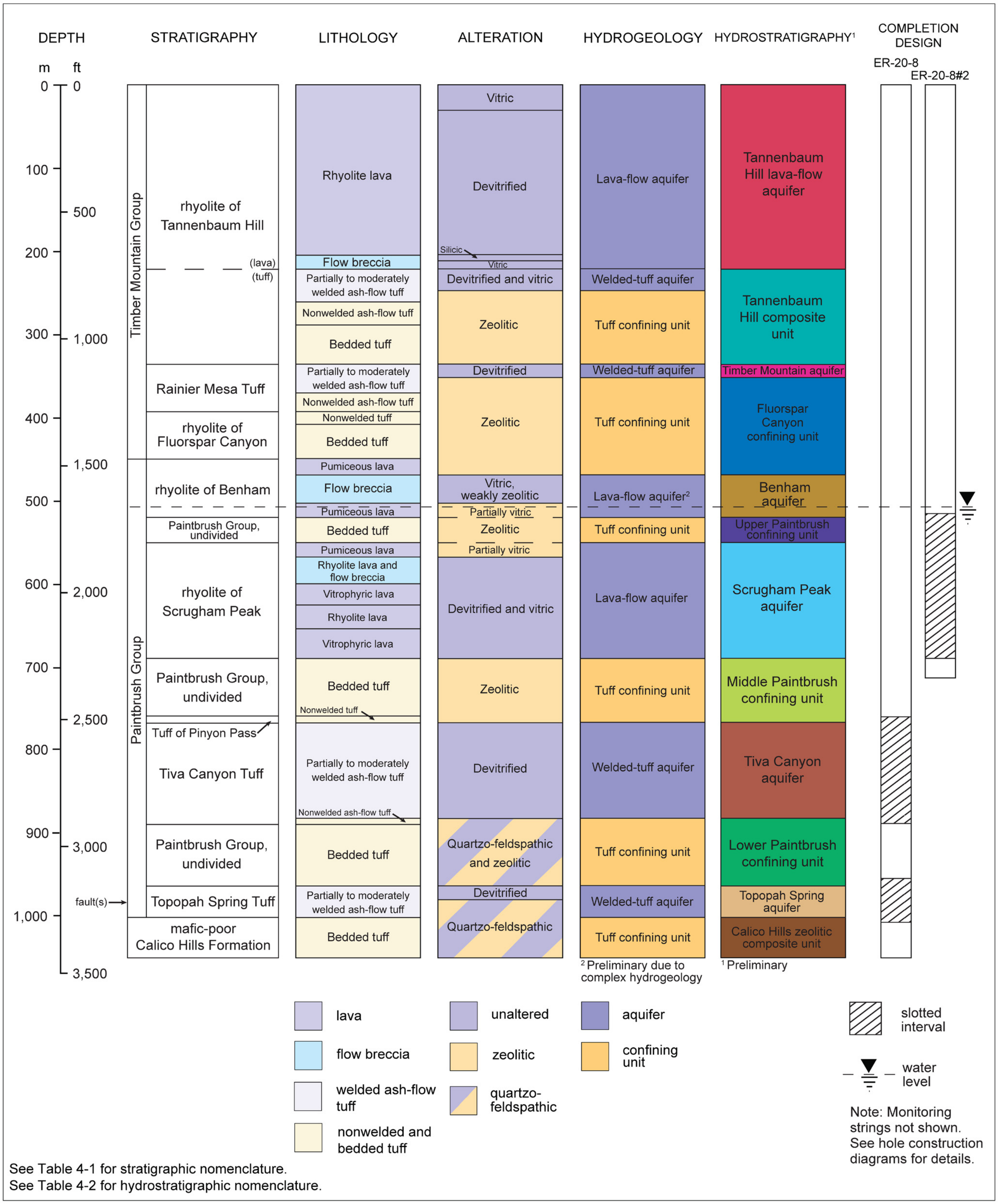


Figure 4-2
Graphical Presentation Showing Stratigraphy, Lithology, Alteration, and Hydrogeologic Units for Well ER-20-8

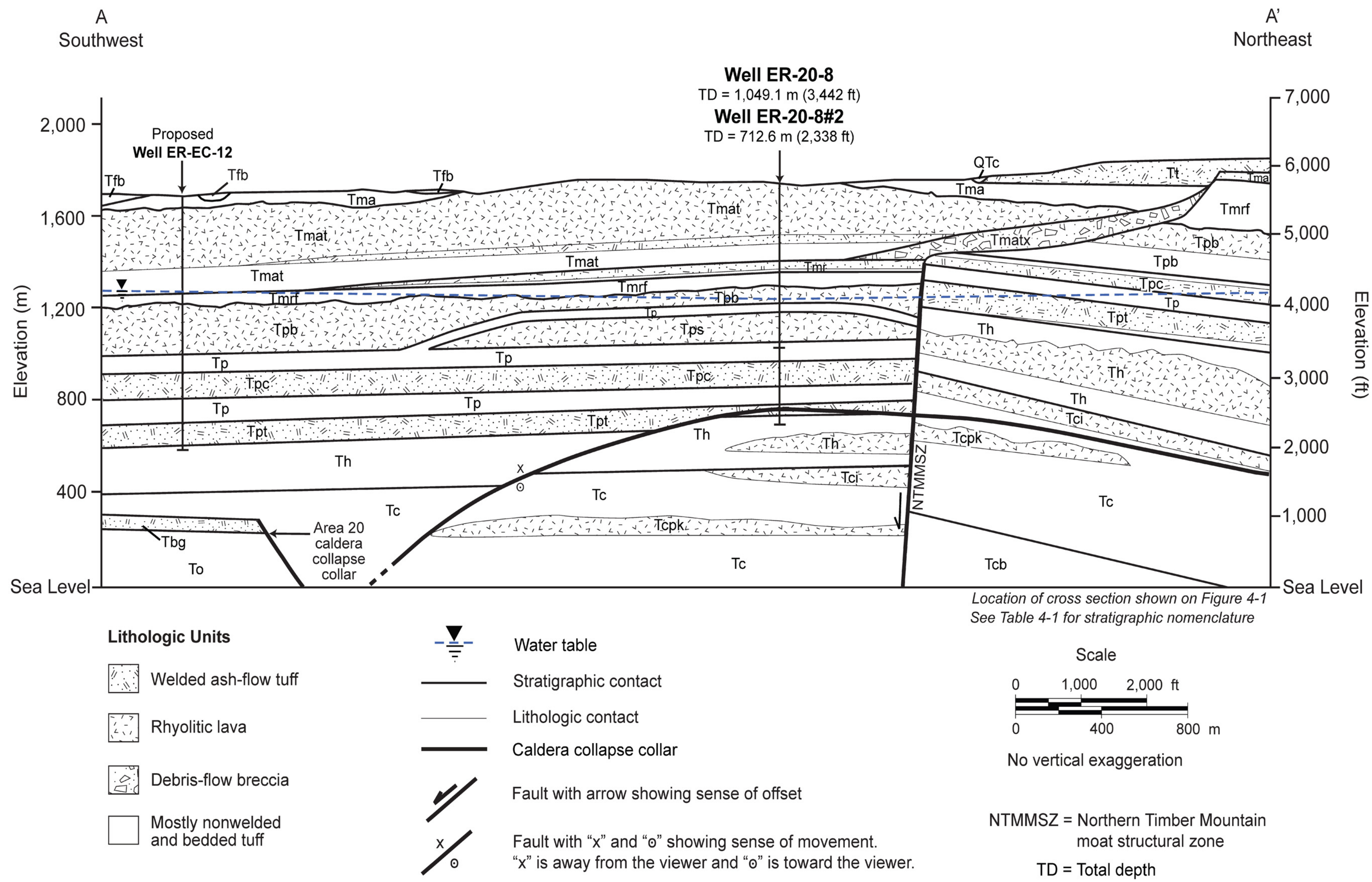


Figure 4-3
Southwest–Northeast Geologic Cross Section A–A' through Wells ER-20-8 and ER-20-8#2

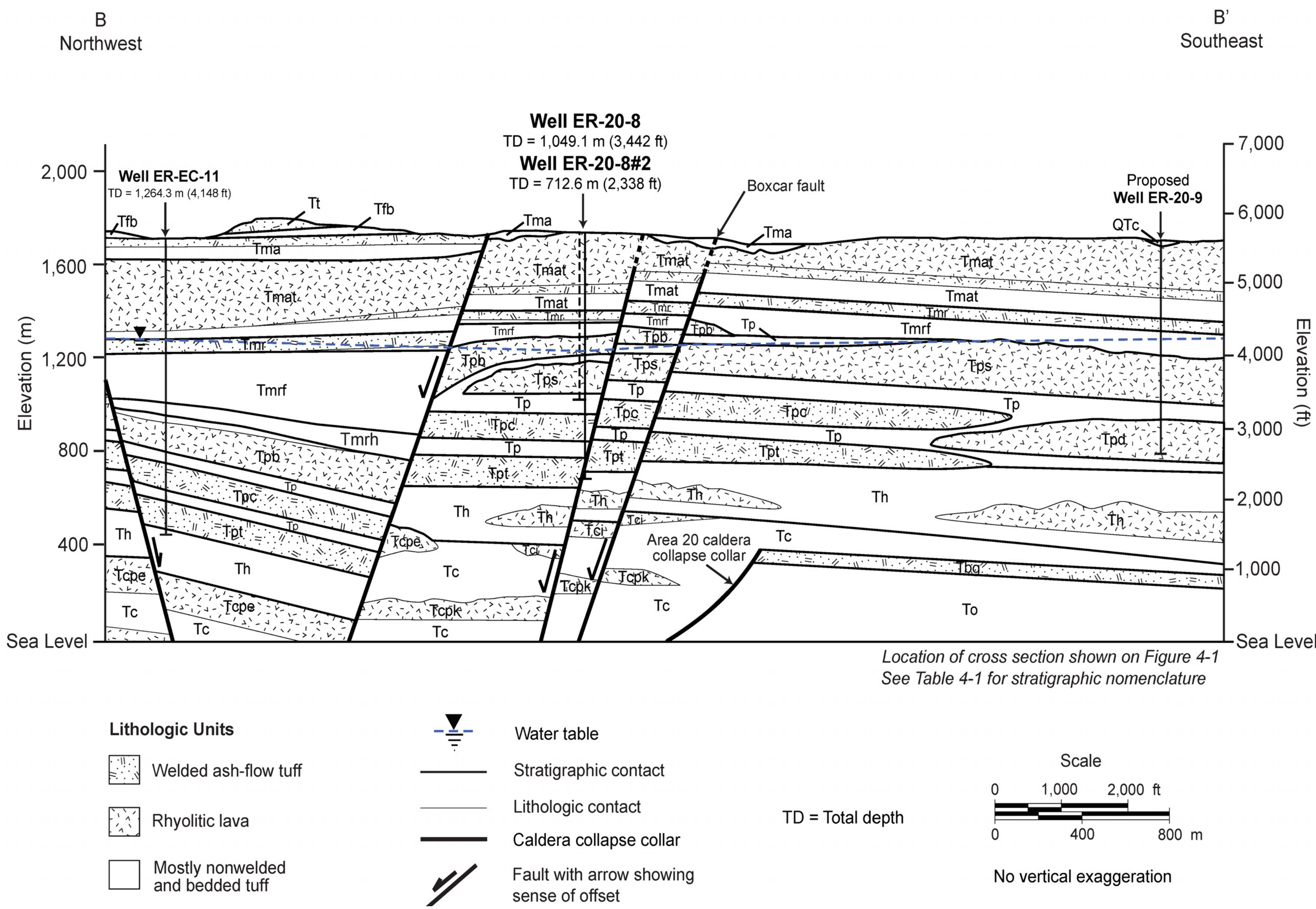


Figure 4-4
Northwest–Southeast Geologic Cross Section B–B’ through Wells ER-20-8 and ER-20-8#2

Tannenbaum Hill was deposited onto the Bench during a time period between the caldera-forming eruptions of the Rainier Mesa and Ammonia Tanks Tuffs.

Below the rhyolite of Tannenbaum Hill, Wells ER-20-8 and ER-20-8#2 penetrated 55.5 m (182 ft) of nonwelded to moderately welded ash-flow tuff assigned to the Rainier Mesa Tuff, which is also a formation of the Timber Mountain Group. The assignment of Rainier Mesa Tuff is based on the interval's stratigraphic position between the sphene-rich rhyolite of Tannenbaum Hill and the quartz-deficient units of the Paintbrush Group (see discussion below), ash-flow tuff lithology, and mineralogic assemblage, which includes quartz phenocrysts and the absence of sphene. Detailed petrographic analyses indicate that the mafic-poor member of the Rainier Mesa Tuff was encountered. The relatively thin occurrence of the Rainier Mesa Tuff in Wells ER-20-8 and ER-20-8#2 indicates that the unit is an extra-caldera out-flow sheet, and that the well location lies outside of the Rainier Mesa caldera (i.e., TMCC).

Below the Rainier Mesa Tuff, Wells ER-20-8 and ER-20-8#2 penetrated 59.4 m (195 ft) of quartz-bearing, zeolitic nonwelded and bedded tuffs. The upper 17.1 m (56 ft) of the interval is lithic-rich, and may represent a cobble-rich deposit that is observed in outcrop at the base of the Rainier Mesa Tuff in the area. The presence of quartz phenocrysts and the stratigraphic position of the interval directly beneath the Rainier Mesa Tuff indicate that these rocks are also part of the Timber Mountain Group. An excellent correlation between Wells ER-20-8 and ER-20-8#2 and nearby Wells ER-20-5#1 and ER-20-7, using the thorium curves presented in the spectral gamma ray logs, indicates that the interval is the rhyolite of Fluorspar Canyon, the basal formation of the Timber Mountain Group in the area.

The next major stratigraphic interval in Wells ER-20-8 and ER-20-8#2 is the Paintbrush Group, consisting of a sequence of rhyolitic lava and tuff characterized by the almost complete absence of quartz phenocrysts (Slate et al., 1999). In Wells ER-20-8 and ER-20-8#2, lava and bedded tuff compose the upper portion of the Paintbrush Group and welded ash-flow tuff and bedded tuff compose the lower portion. The Paintbrush Group was erupted from calderas and related vents that are approximately spatially coincident with the TMCC, between 12.7 and 12.8 Ma (Sawyer et al., 1994). The first (youngest) Paintbrush Group unit encountered in the wells below the Timber Mountain Group is the rhyolite of Benham. Wells ER-20-8 and ER-20-8#2 encountered 70.4 m (231 ft) of rhyolitic lava flow of the rhyolite of Benham, consisting of pumiceous lava and flow breccia. The rhyolite of Benham was identified on the basis of its lava-flow lithology, its stratigraphic position at the top of the Paintbrush Group section, and its mineralogic assemblage, which includes minor biotite, conspicuous sphene, and very rare quartz phenocrysts. Lithic and pumice fragments (i.e., pyroclasts) were noticeably absent from the lava-flow interval. Lava of the rhyolite of Benham occurs throughout the area. It is exposed at the surface along the up-thrown side of the Boxcar fault approximately 2,743.2 m (9,000 ft) northeast of the well site (map unit Trpq in Byers and Cummings, 1967) and is present in all wells drilled in the area west of the Boxcar fault (Prothro and Warren, 2001; DOE/NV, 2000b; DOE/NV, 2000c; NNSA/NSO, 2010a; 2010b). The relatively thin occurrence of the rhyolite of Benham lava in Wells ER-20-8 and ER-20-8#2, compared to other holes to the north and west, suggests that the two wells encountered the unit near its southeastern limit.

A 29.9-m (98-ft) interval of zeolitic bedded tuff was penetrated below the rhyolite of Benham. The lower portion of the interval is clearly pyroclastic in origin, but the upper portion, although visibly bedded, has characteristics of both tuff and lava and likely represents a transition from pyroclastic eruptions to extrusion of lava. The absence of quartz phenocrysts throughout the interval and its stratigraphic position between lava flows of the Paintbrush Group (see discussion below) indicate that the rocks within the interval belong to the Paintbrush Group. Analysis of borehole image logs from Well ER-20-8 indicates the bedded tuff within the interval dips approximately 17 degrees to the southwest (Prothro, 2010).

Below the Paintbrush Group bedded tuffs, the wells encountered the rhyolite of Scrugham Peak at a depth of 549.9 m (1,804 ft). This Paintbrush Group formation consists of 138.4 m (454 ft) of rhyolitic lava, vitrophyre, flow breccia, and pumiceous lava. Features common in rhyolitic lava flows, such as flow banding, perlitic structures, and spherulites, were observed within the interval. The rhyolite of Scrugham Peak in Wells ER-20-8 and ER-20-8#2, though very similar to the rhyolite of Benham, was initially recognized by correlation of drill cuttings with well documented outcrops near the Boxcar fault (Byers and Cummings, 1967). The identification was confirmed by petrographic analysis of five samples collected from outcrops on the up-thrown side of the Boxcar fault approximately 2,400 m (8,000 ft) northeast of the well site (Warren, 2010). The rhyolite of Scrugham Peak is exposed along the south face of Pahute Mesa east of the Boxcar fault (Trpb in Byers and Cummings, 1967); however, it is absent in holes to the north and west of the well site, indicating that Wells ER-20-8 and ER-20-8#2 encountered the unit near its western limit.

Below the rhyolite of Scrugham Peak, the wells penetrated 77.7 m (255 ft) of zeolitic bedded and nonwelded tuff. The stratigraphic position and absence of quartz phenocrysts indicate that these tuffs also belong to the Paintbrush Group. The lower 7.9 m (26 ft) of the interval is assigned more precisely to the tuff of Pinyon Pass based on correlation with other holes in the area.

Analysis of borehole image logs from the well indicates the bedded tuffs dip 27 degrees to the south (Prothro, 2010).

Below the tuff of Pinyon Pass, Well ER-20-8 encountered ash-flow tuff of the Tiva Canyon Tuff, in the interval from 766.0 to 888.5 m (2,513 to 2,915 ft). A very thin, partially welded zone was encountered at the top of the Tiva Canyon Tuff, and below this, the well penetrated 112.8 m (370 ft) of moderately to densely welded ash-flow tuff. The lower 7.6 m (25 ft) of the Tiva Canyon Tuff is nonwelded. Lithophysae and bedding-parallel cooling joints were observed in the borehole image logs within the moderately to densely welded portions of the unit (Prothro, 2010). Borehole image logs also indicate that higher-angle fractures occur in the upper and lower portions of the welded Tiva Canyon Tuff. The Tiva Canyon Tuff was identified by the relatively thick ash-flow tuff lithology, stratigraphic position between the rhyolite of Scrugham Peak and the underlying Topopah Spring Tuff (see discussion below) and its mineralogic assemblage, which includes sphene and biotite but no quartz phenocrysts. The Tiva Canyon Tuff was erupted 12.7 Ma from the Claim Canyon caldera located south of the well site between Timber Mountain and Yucca Mountain (Sawyer et. al., 1994). Although the northern portion of the Claim Canyon caldera, including its northern margin, was obliterated by the formation of the younger TMCC, the relatively thin occurrence of the unit in Well ER-20-8 clearly indicates that the northern margin of the Claim Canyon caldera is south of the well.

Beneath the Tiva Canyon Tuff, 73.1 m (240 ft) of zeolitic bedded tuff was penetrated in Well ER-20-8. Borehole image logs indicate that the interval is anomalously fractured compared to other intervals of bedded tuff in the well. The position of these bedded tuffs between two Paintbrush Group ash-flow tuffs, the Tiva Canyon Tuff and the Topopah Spring Tuff (see discussion below), would seem to indicate that they also belong to the Paintbrush Group. However, petrographic analysis of a sample from the lower portion of the interval suggests that the lower portion may include other stratigraphic units coeval with the Paintbrush Group or possibly even units older than the Paintbrush Group (i.e., mafic-poor Calico Hills Formation) that represent landslide debris (Warren, 2010). Analysis of borehole image logs from the well indicates the bedded tuffs dip 23 degrees to the south (Prothro, 2010).

The Topopah Spring Tuff was encountered at the base of the Paintbrush Group at 961.6 m (3,155 ft). This unit consists of 33.5 m (110 ft) of moderately welded ash-flow tuff with 4.6 m (15 ft) of partially welded ash-flow tuff at the top of the unit. The Topopah Spring Tuff is devitrified at the top, becoming strongly quartzo-feldspathic with substantial argillization below 978.4 m (3,210 ft). Borehole image logs show that fractures within the Topopah Spring Tuff occur within three distinct clusters (Prothro, 2010). One cluster occurs within the partially welded zone at the top of the formation. The other two occur within moderately welded ash-flow tuff from 972.0 to 975.1 m (3,189 to 3,199 ft) and 984.5 to 990.6 m (3,230 to 3,250 ft), and coincide with conspicuous borehole enlargements and a zone of water flow into the borehole as interpreted by DRI scientists from the thermal flow log from Well ER-20-8 (see Section 2.4.3).

The Topopah Spring Tuff was identified by its ash-flow tuff lithology, the absence of quartz phenocrysts, and its stratigraphic position at the base of the Paintbrush Group section. The Topopah Spring Tuff in Well ER-20-8 is 88.4 to 110.6 m (290 to 363 ft) thinner than in other holes in the area such as Wells ER-EC-6 (DOE/NV, 2000b), ER-20-7 (NNSA/NSO, 2010a), ER-EC-11 (NNSA/NSO, 2010b), and ER-20-5#3 (DOE/NV, 1997). The proximity of these wells to Well ER-20-8 suggests that the thinning is not related to depositional processes (i.e., stratigraphic thinning) but instead to faulting (i.e., structural thinning). This means that the Well ER-20-8 borehole intercepted a fault that effectively cuts out approximately 91.4 m (300 ft) of Topopah Spring Tuff in the well. Detailed analyses of data from the well, including detailed correlation with nearby wells, indicate that the fault is within the Topopah Spring Tuff and not at the top or base of the unit. The location of the fault likely coincides with one of the two fracture clusters observed on the borehole image log from 938.8 to 941.8 m (3,080 to 3,090 ft) and 972.0 to 975.1 m (3,189 to 3,199 ft). The Topopah Spring Tuff was erupted 12.8 Ma from a caldera whose location is unknown but likely lies buried beneath the TMCC (Sawyer et al., 1994). The relatively thin occurrence of the Topopah Spring Tuff in holes in the area of Wells ER-20-8 and ER-20-8#2 is consistent with a caldera source south of the wells.

Well ER-20-8 reached TD at 1,049.1 m (3,442 ft) within the mafic-poor Calico Hills Formation, which consists of quartzo-feldspathic bedded tuff. The mafic-poor Calico Hills Formation is recognized by its stratigraphic position below the Topopah Spring Tuff, the presence of quartz phenocrysts, and the generally rare occurrence of felsic phenocrysts and biotite.

4.2.3 Alteration

The volcanic rocks penetrated at Wells ER-20-8 and ER-20-8#2 are generally unaltered above 246.0 m (807 ft). Unaltered rocks include nonwelded and bedded tuffs and lavas that have retained their original vitric (i.e., glassy) character. The welded portions of the ash-flow tuffs are mostly devitrified as a result of recrystallization of the original glass matrix to microcrystalline quartz and feldspar during cooling and degassing as the welding process proceeded. The rhyolitic lava is mostly devitrified, but some is vitric. Below 246.0 m (807 ft), the original glass matrix of the nonwelded and bedded tuffs and rhyolitic lava has been altered mainly to zeolite, with some silicification. Quartzo-feldspathic alteration was seen below 880.9 m (2,890 ft), beginning at the base of the Tiva Canyon Tuff.

4.3 Predicted and Actual Geology

The geology encountered at Wells ER-20-8 and ER-20-8#2 was generally as predicted prior to drilling (Figure 4-5). However, the section encountered in the wells includes two additional units, the Rainier Mesa Tuff and rhyolite of Scrugham Peak, which were known to occur in the vicinity but not predicted to extend into the Well ER-20-8 site. Although it is extensive on Pahute Mesa, the absence of Rainier Mesa Tuff in nearby Well ER-EC-6 (DOE/NV, 2000b) suggested prior to drilling that the unit was not present in this portion of the Bench. However, Wells ER-20-8 and ER-20-8#2 encountered 55.5 m (182 ft) of Rainier Mesa Tuff below the rhyolite of Tannenbaum Hill.

It was predicted prior to drilling that Well ER-20-8 would encounter a rather thick interval of rhyolitic lava flow of the rhyolite of Benham, similar to that encountered in other holes west and north of the well, where it ranges from 163.7 to 211.2 m (537 to 693 ft) thick. However, after penetrating only 70.4 m (231 ft) of pumiceous lava and flow breccia of the rhyolite of Benham, the well penetrated 29.9 m (98 ft) of bedded tuff before encountering another rhyolitic lava flow(s). This lower flow(s) is 138.4 m (454 ft) thick and assigned to the rhyolite of Scrugham Peak. The rhyolite of Scrugham Peak is exposed extensively along the south face of Pahute Mesa east of the Boxcar fault. However, the rhyolite of Scrugham Peak was not encountered in nearby Well ER-EC-6, located 2,072.6 m (6,800 ft) west-southwest of the Well ER-20-8 site, nor in any of the holes north of the well on Pahute Mesa. This suggests that Wells ER-20-8 and ER-20-8#2 drilled into the western flank of the rhyolite of Scrugham Peak and that the rhyolite of Benham thins over the constructional high created by the rhyolite of Scrugham Peak and overlying bedded tuffs.

Below the rhyolite of Scrugham Peak, Well ER-20-8 penetrated a stratigraphic sequence very similar to that predicted prior to drilling, except for the structural thinning of the Topopah Spring Tuff. The fault responsible for the thinning of the Topopah Spring Tuff is likely a west-dipping, down-on-the-west normal fault. This interpretation is based on the observation that most of the mapped surface faults in the area are west-dipping normal faults (Byers and Cummings, 1967) and that the fault likely corresponds to one of the two prominent west-dipping fracture clusters observed within the Topopah Spring Tuff in the borehole (Prothro, 2010). Assuming a 75-degree westward dip, the fault would project to the surface approximately 274 m (900 ft)

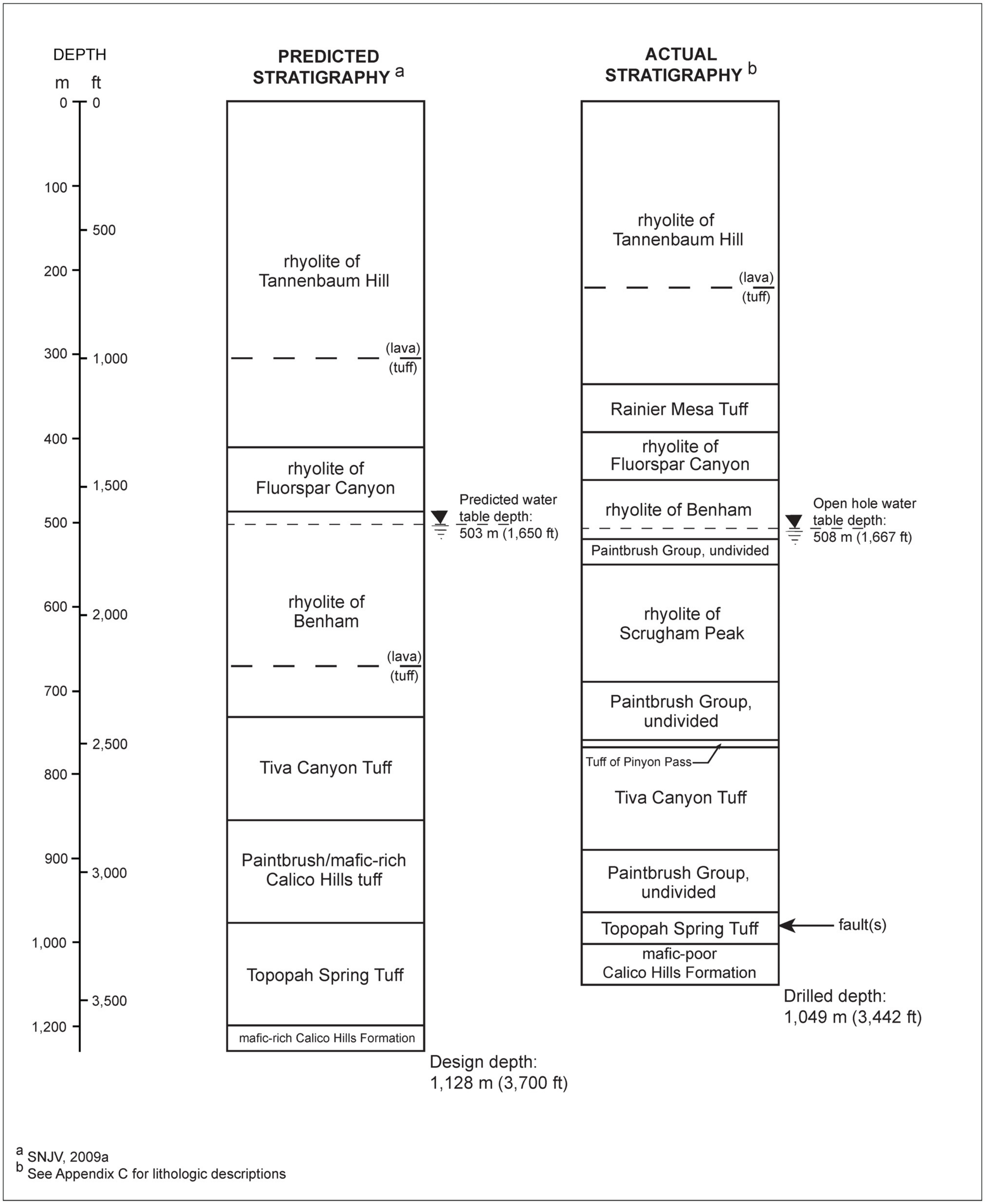


Figure 4-5
Predicted and Actual Stratigraphy at Well ER-20-8

southeast of the well site. Although no fault is mapped at the surface where the fault projects, many faults in the area are inferred, indicating that faults are poorly exposed and difficult to map in this area. Although the southwestward extension of the Boxcar fault is only about 610 m (2,000 ft) southeast of Well ER-20-8, it is unlikely that the Boxcar fault is responsible for the thinning of the Topopah Spring Tuff in the well because it would require a dip of less than 60 degrees, which is much shallower than the measured dips of faults in the area (Byers and Cummings, 1967).

4.4 Hydrogeology

The saturated portion of Well ER-20-8 consists of an alternating sequence of welded-tuff aquifers, lava-flow aquifers, and tuff confining units. Welded ash-flow tuffs of the Tiva Canyon Tuff and Topopah Spring Tuff form two distinct welded-tuff aquifers in the well, while the zeolitic bedded and nonwelded tuffs that occur between the two welded-tuff aquifers and below the welded Topopah Spring Tuff form tuff confining units. An interpretation of the possible distribution of the HSUs in the vicinity of Well ER-20-8 site is shown in cross section in Figure 4-6.

Prior to drilling, it was predicted that the water table would be encountered at a depth of 502.9 m (1,650 ft) and within lava-flow aquifer of the rhyolite of Benham. The actual water table depth (measured for each of the isolated aquifers) on September 8, 2009, was 508.1 m (1,667 ft) and was within lava-flow aquifer of the rhyolite of Benham. However, only the lower 11.6 m (38 ft) of the BA is saturated.

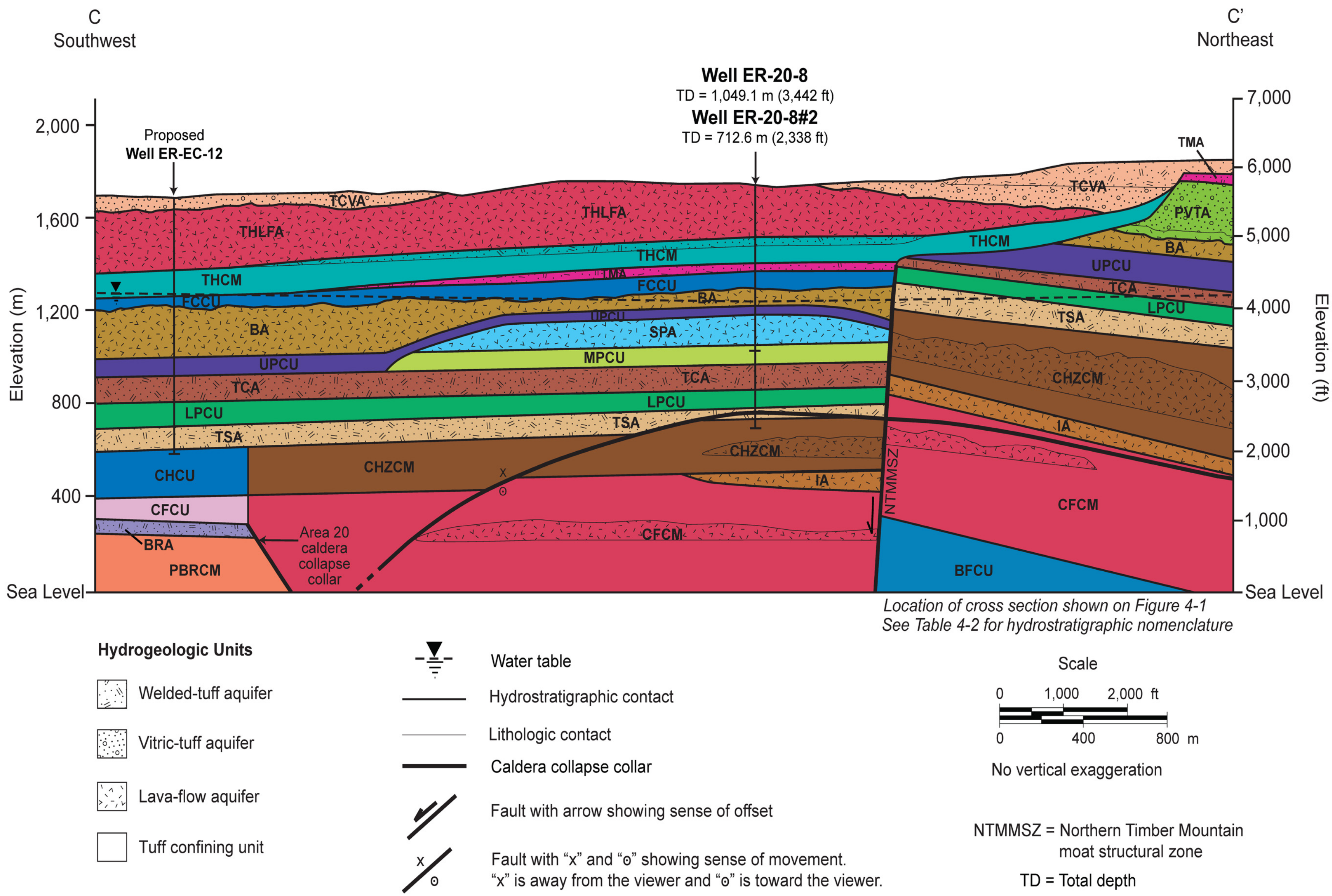


Figure 4-6
Southwest–Northeast Hydrostratigraphic Cross Section C–C’ through Wells ER-20-8 and ER-20-8#2

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5.0 Planned and Actual Costs and Scheduling

This section provides brief discussions of the planned and actual schedule and cost for constructing Wells ER-20-8 and ER-20-8#2.

5.1 Well ER-20-8

The original NSTec-approved baseline task plan cost estimate for drilling and completing Well ER-20-8 was based on drilling to a planned TD of 1,127.8 m (3,700 ft) and installing one production casing string and up to three piezometer strings. Construction of Well ER-20-8 was expected to take 31 days.

It took 34 days to construct Well ER-20-8, starting with drilling of the 52.1-cm (20.5-in.) surface hole. This includes two days spent reaming the hole to straighten it to permit installation of the 16-in. casing, and four days spent evaluating options for completing the well after low levels of tritium were encountered in the SPA. The installation of 10¾-in. casing after drilling through the SPA was not part of the original plan for this well. This activity took an additional five days, including an additional geophysical logging call-out. The final TD of the borehole, at 1,049.1 m (3,442 ft) is 78.6 m (258 ft) less than the original planned TD. The final geophysical logging and well completion took three days less than planned. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 5-1.

The cost analysis for Well ER-20-8 begins with the mobilization of the UDI drill rig to the site, where the conductor hole had already been constructed. The total construction cost for Well ER-20-8 includes all drilling costs: charges by the drilling subcontractor, charges by other support subcontractors (including compressor services, drilling fluids, casing services, down-hole tools, and geophysical logging), and charges by NSTec for mobilization and demobilization of equipment, cementing services, RCT services, inspection services, site supervision, and geotechnical consultation. The cost of building the access roads, drill pad, sumps, and conductor hole is not included, nor is the cost of well-site support by N-I personnel.

The total planned cost for constructing Well ER-20-8 was $4,891,955. The actual cost was $4,113,780, or 15.6 percent less than the planned cost. Figure 5-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-20-8.

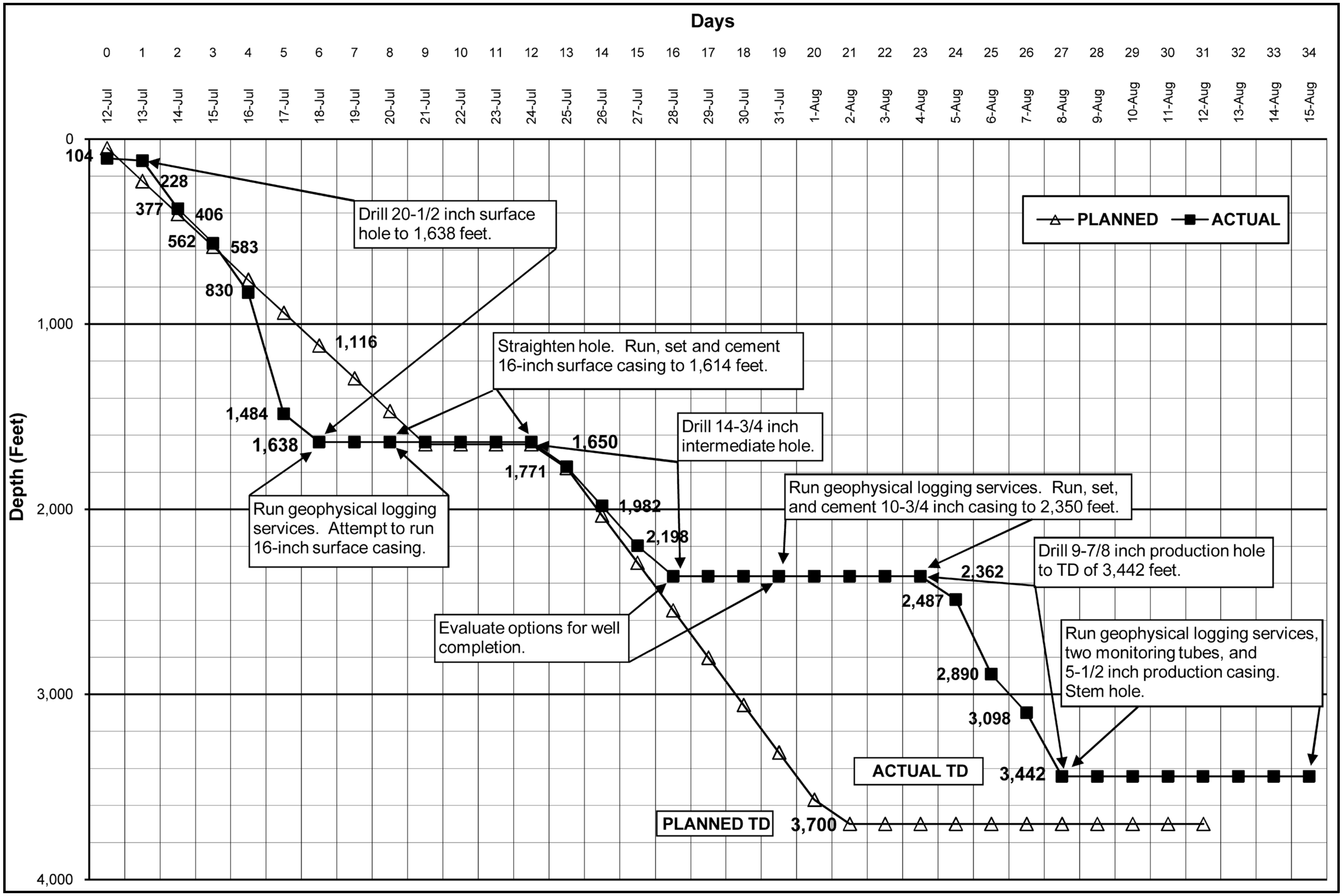

Figure 5-1
Planned versus Actual Construction Progress for Well ER-20-8

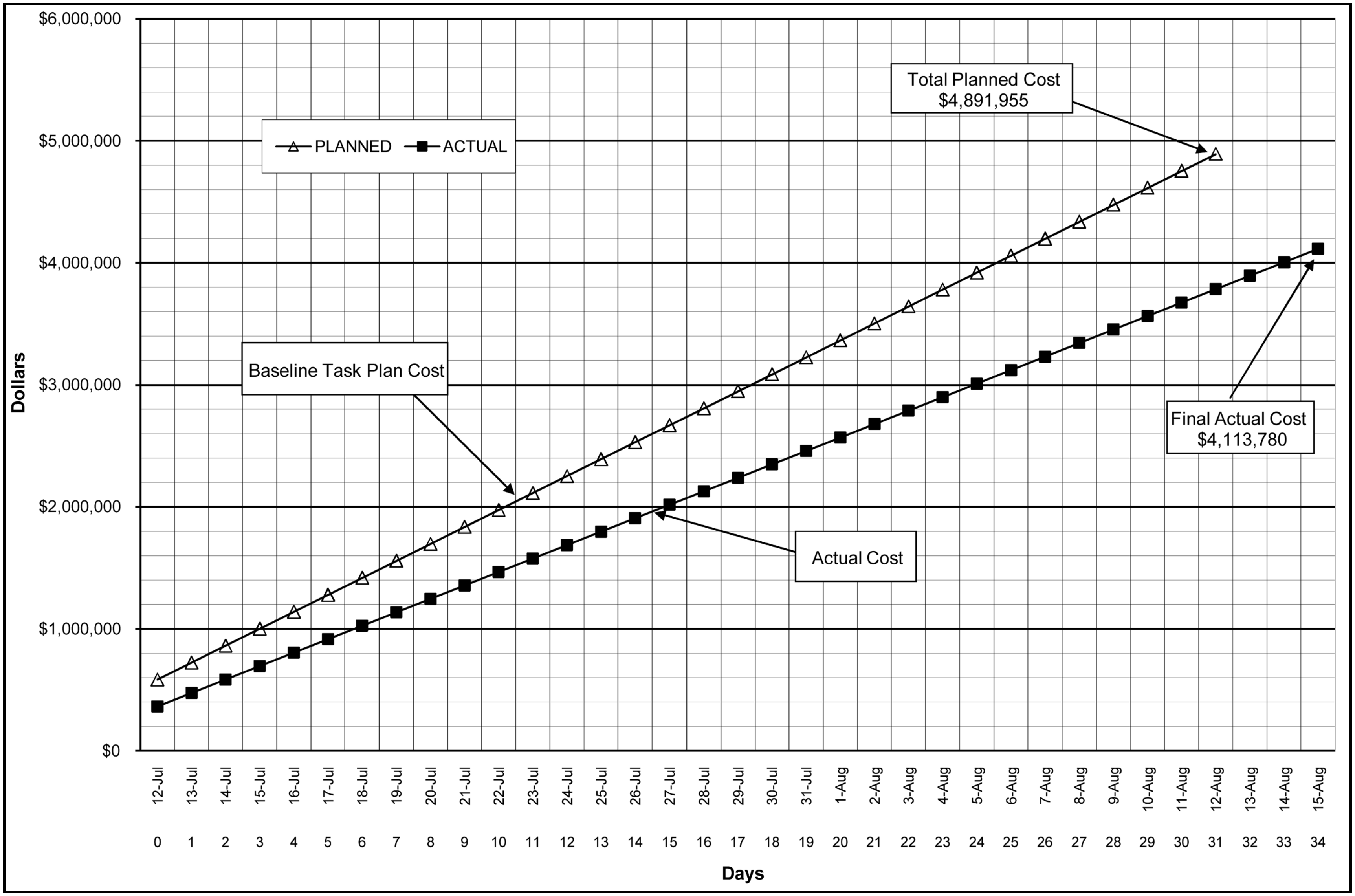

Figure 5-2
Planned versus Actual Cost for Constructing Well ER-20-8

5.2 Well ER-20-8#2

The original NSTec-approved baseline task plan cost estimate for drilling and completing Well ER-20-8#2 was based on drilling to a planned TD of 731.5 m (2,400 ft) and installing one production casing string and one piezometer string. Construction of Well ER-20-8#2 was expected to take 14 days.

It took 11 days to construct Well ER-20-8#2, starting with drilling of the 44.5-cm (17.5-in.) surface hole. It took one day less than expected to install the 13⅜-in. surface casing, and two days less than expected to install the final completion. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 5-3.

The cost analysis for Well ER-20-8#2 begins with the mobilization of the UDI drill rig from Well ER-20-8 across the drill pad to the Well ER-20-8#2 site, where the conductor hole had already been constructed. The total construction cost for Well ER-20-8#2 includes all drilling costs: charges by the drilling subcontractor, charges by other support subcontractors (including compressor services, drilling fluids, casing services, down-hole tools, and geophysical logging), and charges by NSTec for mobilization and demobilization of equipment, cementing services, RCT services, inspection services, site supervision, and geotechnical consultation. The cost of building the access roads, drill pad, sumps, and conductor hole is not included, nor is the cost of well-site support by N-I personnel.

The total planned cost for constructing Well ER-20-8#2 was $1,545,200. The actual cost was $987,425, or 36.1 percent less than the planned cost. Figure 5-4 presents a comparison of the planned and actual costs, by day, for construction of Well ER-20-8#2.

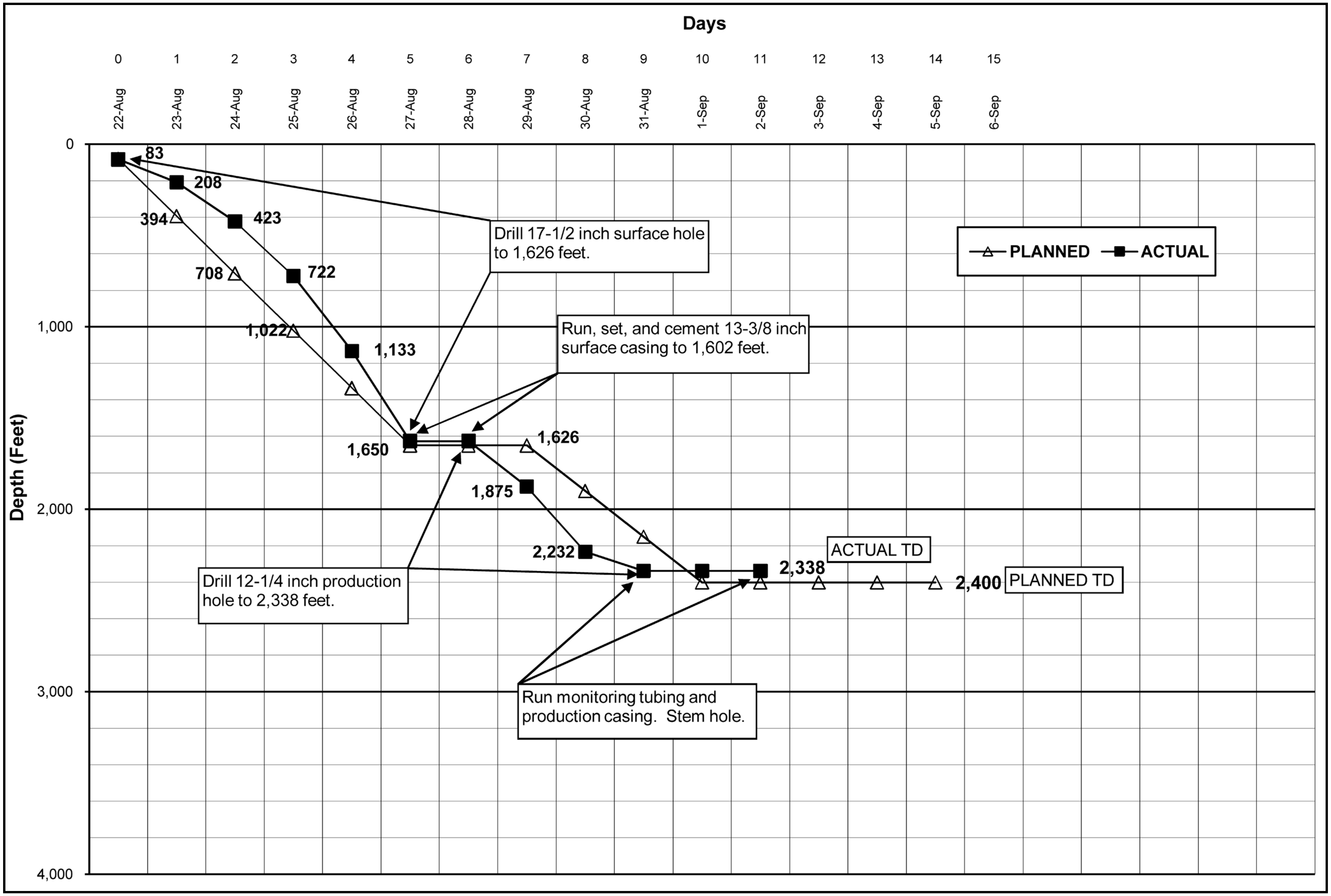

Figure 5-3
Planned versus Actual Construction Progress for Well ER-20-8#2

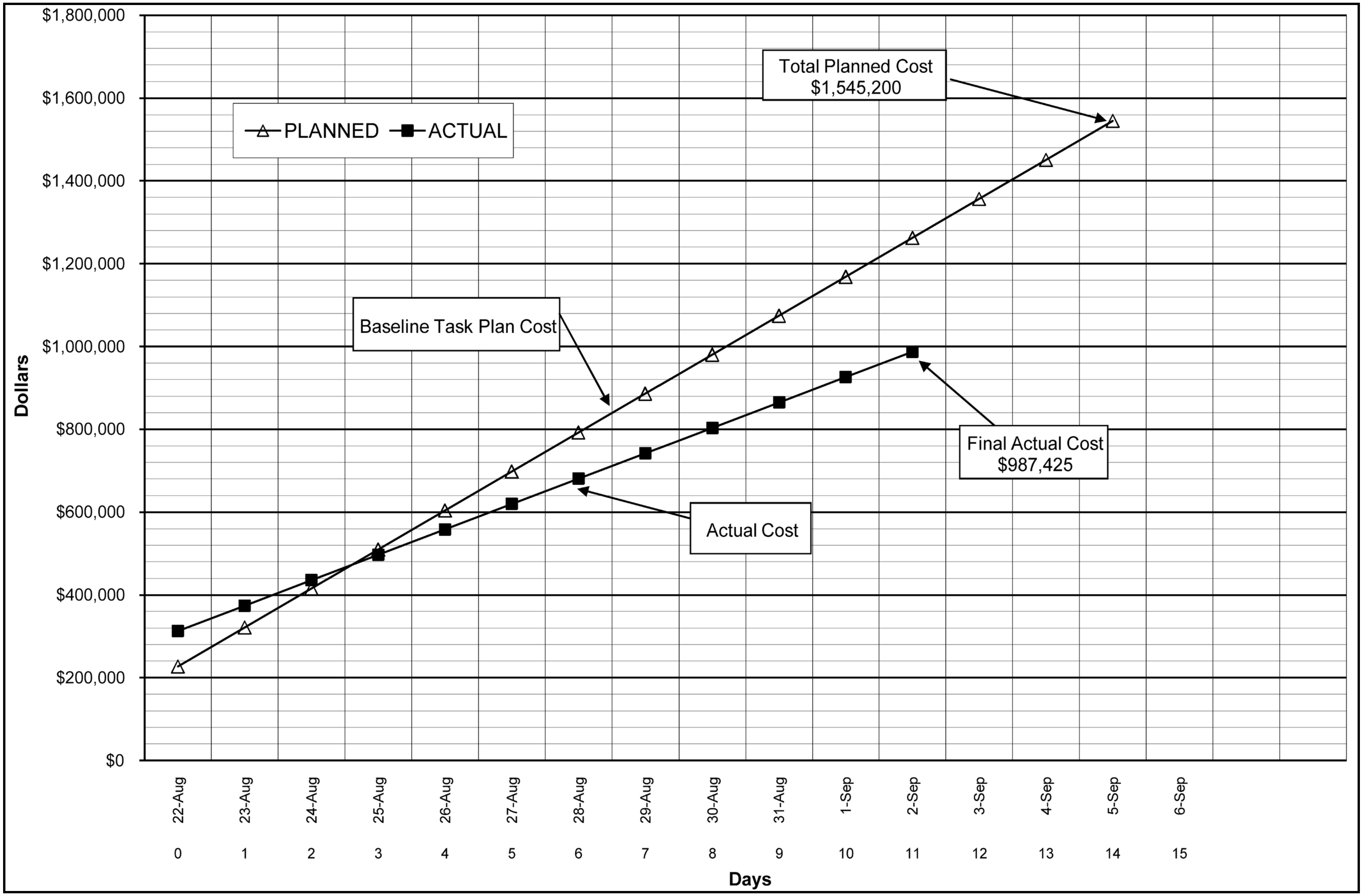

Figure 5-4
Planned versus Actual Cost for Constructing Well ER-20-8#2

6.0 Summary, Recommendations, and Lessons Learned

6.1 Summary

Construction summaries for the wells drilled at the Well ER-20-8 site are presented in this section.

6.1.1 Well ER-20-8

Main hole drilling at Well ER-20-8 commenced on July 12, 2009, and concluded on August 8, 2009, at a total drilled depth of 1,049.1 m (3,442 ft). The borehole was completed within the TCA and TSA. Few problems were encountered during drilling, though circulation was temporarily lost in several depth intervals. The tight hole at 268.2 m (880 ft) caused a two-day delay in casing operations because the hole had to be reamed and the casing crew had to rig down and depart the site. Issues related to tritium occurrences in the fluid discharge were the cause of most delays.

The completion string consists of 5½-in. stainless-steel casing suspended from 5½-in. carbon-steel casing. The carbon-steel casing extends to a depth that is 24.4 m (80 ft) above the water table. The 5½-in. casing is slotted in the intervals 757.8 to 887.7 m (2,486.1 to 2,912.4 ft) and 953.1 to 1,005.4 m (3,126.9 to 3,298.4 ft), providing access to the TCA and TSA, respectively, for monitoring and sampling. The top slotted section consists of ten consecutive stainless-steel slotted joints, and the bottom slotted section consists of four consecutive stainless-steel slotted joints. Both slotted intervals are gravel-packed and separated by cement. The upper BA and SPA aquifers are cased off from the lower TCA and TSA aquifers.

The well has three piezometer strings: two strings each access one of the target aquifers, and one string accesses both the BA and SPA. A string of 1.6-in. carbon-steel tubing was installed between the borehole wall and the 10¾-in. casing. This string has one slotted interval at the depth of 636.6 to 645.9 m (2,088.5 to 2,119.1 ft) for monitoring within the BA and SPA. Two 2⅞-in. tubing strings were inserted into the borehole. Both stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs. The upper tubing string is slotted from 761.5 to 886.4 m (2,498.2 to 2,908.1 ft) for monitoring within the TCA. The lower tubing string is slotted from 957.3 to 1,006.1 m (3,140.9 to 3,301.0 ft) for monitoring within the TSA.

Data collected during and shortly after construction of Well ER-20-8 include composite drill cuttings samples collected every 3.0 m (10 ft) from 33.5 to 1,048.5 m (110 to 3,440 ft). In addition, 27 sidewall core samples were collected in the interval 499.9 to 1,008.9 m (1,640 to 3,310 ft). Open-hole geophysical logging was conducted before each string of casing was run (i.e., the 16-in., 10¾-in., and 5½-in. casing strings). Some of these logs were used to aid in construction of the well, while others helped to verify the geology and determine the hydrologic characteristics of the rocks.

6.1.2 Well ER-20-8#2

Main hole drilling at Well ER-20-8#2 commenced on August 22, 2009, and concluded on August 30, 2009, at a total drilled depth of 712.6 m (2,338 ft). No problems were encountered during drilling. The borehole was completed within the BA and SPA and did not reach the depth of the TCA or TSA.

The completion string consists of 7⅝-in. epoxy-coated carbon-steel casing, connected to 7⅝-in. stainless-steel casing via a crossover sub. The carbon-steel casing is located within the unsaturated zone to a point approximately 7.9 m (26 ft) above the water table. The completion casing has one slotted interval from 512.2 to 689.8 m (1,680.4 to 2,263.2 ft), providing access to the BA and SPA for monitoring and sampling. The slotted section consists of 15 consecutive stainless-steel slotted joints. The completion casing was gravel packed from 494.7 to 712.6 m (1,623.0 to 2,338.0 ft).

The well has one piezometer string that accesses the BA and SPA. It consists of a string of 2⅞-in. stainless-steel tubing with one slotted interval, and it was installed adjacent to the completion casing. The 2⅞-in. tubing hangs from a string of 2⅜-in. carbon-steel tubing connected via a crossover sub. The slotted interval is at the depth of 506.9 to 680.7 m (1,663.1 to 2,233.4 ft) for monitoring within the BA and SPA.

Data collected during and shortly after construction of Well ER-20-8#2 include composite drill cuttings samples collected every 3.0 m (10 ft) from 27.4 m (90 ft) to TD. A caliper log, flow log, and water chemistry log were conducted before the completion string was run. These logs helped to determine the hydrologic characteristics of the aquifer penetrated.

6.1.3 Geology and Hydrology

Both wells were collared in the rhyolite of Tannenbaum Hill and penetrated Tertiary volcanic rocks through their entire depth. These rocks consist largely of rhyolitic lavas, bedded and nonwelded to moderately welded ash-flow tuffs, and zeolitic nonwelded tuffs. Water levels were measured in both wells on September 8, 2009. These pre-development water levels for all four aquifers in Well ER-20-8 and for the BA and SPA in Well ER-20-8#2 ranged from 508.0 to 508.4 m (1,666.7 to 1,668.1 ft). The average of these values is 508.1 m (1,667.1 ft), which equates to an approximate elevation of 1,274.4 m (4,181 ft).

Tritium was the only radionuclide encountered in both Well ER-20-8 and Well ER-20-8#2. Tritium levels in the drilling effluent at Well ER-20-8 were generally below drinking water standards (as measured by field instruments) while drilling. Preliminary laboratory measurements on drilling effluent samples taken during drilling in the upper two aquifers average 1,300 pCi/L. No tritium above the minimum detection levels of the field instruments was detected in the lower two aquifers, the TCA and the TSA. Other chemical constituents analyzed for but not detected include metals, organic and inorganic constituents, gross alpha and beta, and plutonium.

Tritium levels in the drilling fluid at Well ER-20-8#2 were at or below the minimum detection levels (as measured by field instruments) while drilling. Laboratory analyses for tritium on drilling effluent averaged less than 1,500 pCi/L for the upper two aquifers.

Data for samples of drilling effluent may not be representative of the groundwater. Valid groundwater data will not be available until the well is developed and properly sampled.

6.2 Recommendations

All the geologic and hydrologic data and interpretations from Wells ER-20-8 and ER-20-8#2 should be integrated into the PM–OV Phase II HFM. This will allow for more precise characterization of groundwater flow direction and velocity in the Pahute Mesa area.

The water level in Wells ER-20-8 and ER-20-8#2 should be monitored during the drilling and testing of nearby wells. Groundwater chemistry, particularly with respect to radionuclides, should be monitored on a routine basis to learn more about the nature and extent of the contaminants from the TYBO and BENHAM UGTs, which are located up-gradient from Wells ER-20-8 and ER-20-8#2. It is important that all completion zones in this well pair be tested and that all zones be monitored during pumping tests. Depth-discrete sampling and monitoring for tritium could prove to be very informative regarding contaminant transport through the BA and SPA.

Real-time tritium monitoring in the field, particularly for low levels, was problematic. The chemoluminescence problem caused several delays while waiting for additional analyses.

Alternative methods of obtaining "quick turn-around" field analytical data were evaluated briefly by a small working group, which produced no final recommendations, but this problem should be investigated further.

6.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA Sub-Project continues to improve as experience is gained with each new well. Sometimes difficult drilling conditions are encountered and challenges are confronted. Several new lessons were learned during the construction of Wells ER-20-8 and ER-20-8#2, the second well site in the 2009 Pahute Mesa Phase II drilling initiative, which built upon those learned during drilling of Well ER-20-7, the first well in this series (NNSA/NSO, 2010a).

- The CAU guidance teams and hole-specific drilling advisory teams formed by the UGTA TWG continued to provide timely assistance and guidance for addressing "surprises" and assessing their impacts on the overall program.
- Care should be taken in selecting geophysical logs, because the quality of some types of logs (e.g., circumferential borehole imaging log [CBIL]) is degraded in large-diameter boreholes. In an email to the drilling advisory team, Drellack (2010) recommended a maximum hole size for the CBIL log of 37.5 cm (14.75 ft) in future UGTA wells.
- Sections of the 7⅝-in. casing used in Well ER-20-8#2 were found to have burrs on the inside because some of the slots were not completely cut. Also, some of the threads on the 2⅞-in. tubing planned for use as a piezometer in Well ER-20-8#2 were damaged and no replacements were available. A more thorough inspection of tubing and casing should be conducted before items are delivered to the well site. This might prevent time lost at the rig correcting defects and could preclude having to redesign completion strings because enough tubing is not available to install the string as designed.

7.0 References

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Appendix A
Drilling Data

A-1 Drilling Parameter Logs for Wells ER-20-8 and ER-20-8#2

A-2 Tubing and Casing Data for Wells ER-20-8 and ER-20-8#2

A-3 Drilling Fluids and Cement Composition for Wells ER-20-8 and ER-20-8#2

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Appendix A-1

Drilling Parameter Logs for Wells ER-20-8 and ER-20-8#2

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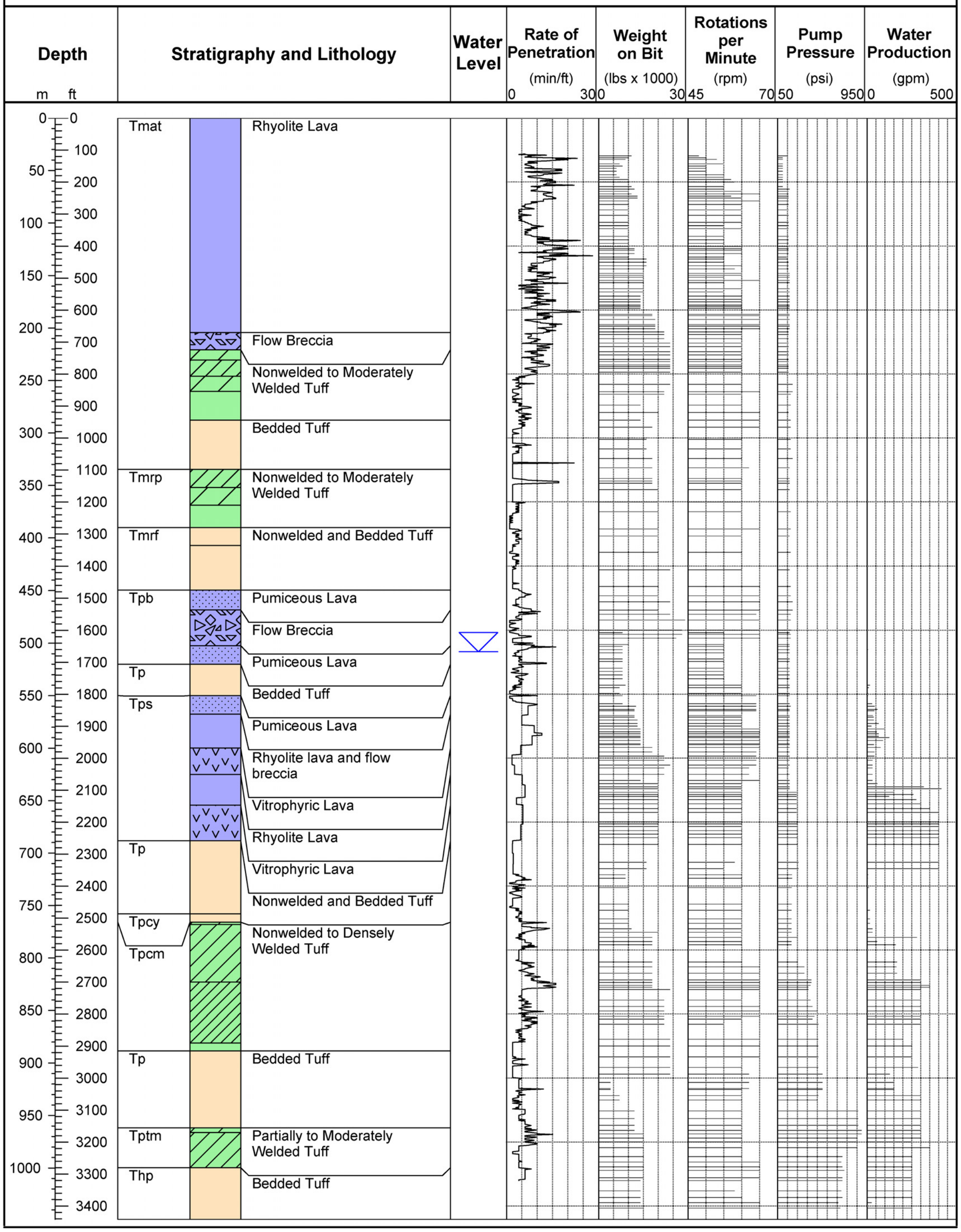
Well ER-20-8

Logging Company: Baker Atlas
Drilled Depth: 1,049.1 m (3,442 ft)
Date TD Reached: August 8, 2009
Drill Method: Rotary/Air foam

Surface Elevation: 1,782.6 m (5,848.3 ft)
Coordinates (UTM [NAD 83]): N 4,116,415.5 m
E 546,606.1 m
Water Level: 508.1 m (1,667 ft) on September 8, 2009

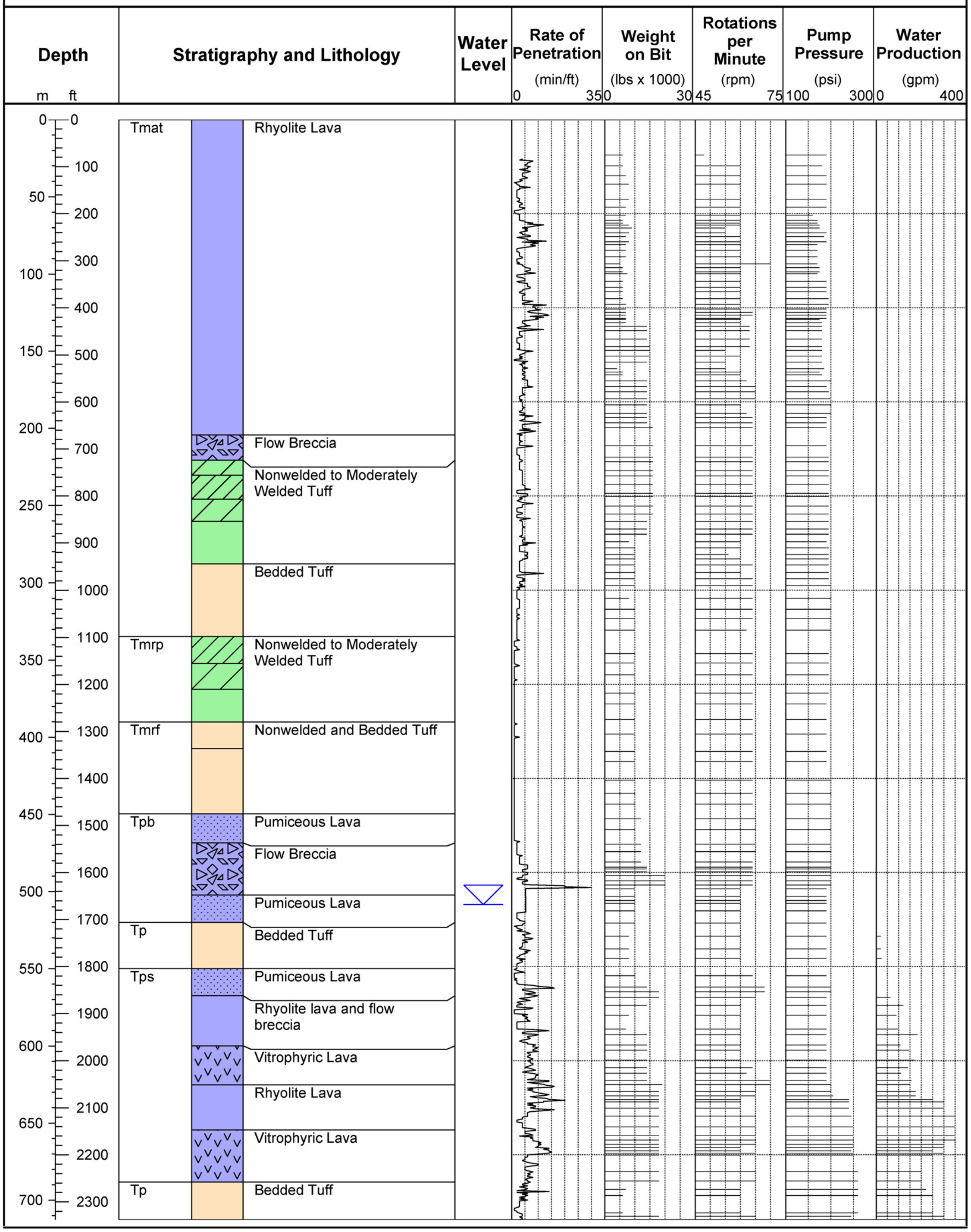


See legend for lithology symbols on Page D-2.

Well ER-20-8#2

Logging Company: Baker Atlas
Drilled Depth: 712.6 m (2,338 ft)
Date TD Reached: August 30, 2009
Drill Method: Rotary/Air foam

Surface Elevation: 1,782.7 m (5,848.8 ft)
Coordinates (UTM [NAD 83]): N 4,116,408.4 m
E 546,592.5 m
Water Level: 508.4 m (1,668 ft) on September 8, 2009



See legend for lithology symbols on Page D-2.

Appendix A-2
Tubing and Casing Data for Wells ER-20-8 and ER-20-8#2

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Table A-2-1
Tubing and Casing Data for Well ER-20-8

Casing and Tubing	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** (pounds)
Conductor	0 to 31.5 (0 to 103.4)	Carbon Steel	B	76.2 (30)	73.7 (29)	1.270 (0.500)	158.0
Surface	0 to 195.2 (0 to 640.4)	Carbon Steel	K55	40.6 (16)	38.74 (15.250)	0.953 (0.375)	65.0
	195.2 to 491.9 (640.4 to 1,614.0)	Carbon Steel	K55	40.6 (16)	38.13 (15.010)	1.257 (0.495)	84.0
Intermediate	0 to 716.3 (0 to 2,350.0)	Carbon Steel	K55	27.31 (10.75)	25.53 (10.05)	0.889 (0.350)	40.5
Completion (internal epoxy coating)	0 to 483.6 (0 to 1,586.7)	Carbon-Steel Casing with Stainless-Steel Crossover	L80	13.97 (5.500)	12.43 (4.892)	0.772 (0.304)	17.0
Completion	483.6 to 1,019.1 (1,586.7 to 3,343.6)	Stainless Steel	L304	13.97 (5.500)	12.82 (5.047)	0.577 (0.227)	14.6
Piezometer String	0 to 645.9 (0 to 2,119.1)	Carbon Steel	N80>	4.06 (1.60)	3.51 (1.38)	0.279 (0.110)	2.4
Upper Piezometer String	0 to 491.1 (0 to 1,611.1)	Carbon-Steel Tubing with Stainless-Steel Crossover	J55	6.03 (2.375)	5.07 (1.995)	0.483 (0.190)	4.6
	491.1 to 886.7 (1,611.1 to 2,909.2)	Stainless Steel	SS L304	7.30 (2.875)	5.92 (2.33)	0.693 (0.273)	7.66
Lower Piezometer String	0 to 483.8 (0 to 1,587.2)	Carbon-Steel Casing with Stainless-Steel Crossover	N80>	6.03 (2.375)	5.07 (1.995)	0.483 (0.190)	4.6
	483.8 to 1,006.5 (1,587.2 to 3,302.2)	Stainless Steel	SS L304	7.30 (2.875)	5.92 (2.33)	0.693 (0.273)	7.66

Table A-2-2
Tubing and Casing Data for Well ER-20-8#2

Casing and Tubing	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** (pounds)
Conductor	0 to 3.8 (0 to 12.4)	Carbon Steel	B	50.8 (20)	48.57 (19.124)	1.113 (0.438)	94.0
	3.8 to 24.9 (12.4 to 81.7)	Carbon Steel	B	50.8 (20)	48.26 (19.00)	1.270 (0.500)	106.5
Surface	0 to 214.5 (0 to 703.6)	Carbon Steel	K55	33.97 (13.375)	31.79 (12.515)	1.092 (0.430)	61.0
	214.5 to 488.4 (703.6 to 1,602.2)	Carbon Steel	K55	33.97 (13.375)	31.53 (12.415)	1.219 (0.480)	68.0
Completion (with crossover)	0 to 500.5 (0 to 1,641.9)	Epoxy-coated Carbon Steel	N80	19.37 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4
Completion	500.5 to 701.0 (1,641.9 to 2,300.0)	Stainless Steel	SSTP304	19.37 (7.625)	17.783 (7.001)	0.792 (0.312)	25.8
Piezometer String (with crossover)	0 to 506.9 (0 to 1,663.1)	Carbon Steel	N80>	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Piezometer String	506.9 to 681.0 (1,663.1 to 2,234.3)	Stainless Steel	SSL304	7.303 (2.875)	5.900 (2.323)	0.701 (0.276)	7.66

Appendix A-3

Drilling Fluids and Cement Composition for Wells ER-20-8 and ER-20-8#2

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Table A-3-1
Drilling Fluids Used in Well ER-20-8

Typical Air-Foam/Polymer Mix
18.9 to 113.6 liters (5 to 30 gallons) Geofoam® [a]
0 to 3.8 liters (0 to 1 gallon) LP701® [a]
per
7,949 liters (50 barrels) water

a Geofoam® foaming agent and LP701® polymer additive are products of Geo Drilling Fluids, Inc.

NOTES:

1. All water used to mix drilling fluids for Well ER-20-8 came from Area 20 Water Well (U-20WW).

2. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids to make up a final concentration of approximately 20 to 30 parts per million LiBr. The concentration was increased in zones of higher water production to make up a solution of 50 to 60 parts per million LiBr.

Table A-3-2
Well ER-20-8 Cement Composition

Cement Composition	30-inch Conductor Casing	16-inch Surface Casing	10¾-inch Intermediate Casing	5½-inch Completion Casing
Redi-Mix Formula 400: 998 kilograms (2,200 pounds) sand, 326 kilograms (719 pounds) Portland cement, and 232 liters (61 gallons) water per cubic yard	0 to 32.0 m [a] (0 to 105 ft) [b]	none	none	none
Type II neat	none	446.2 to 492.6 m (1,464 to 1,616 ft)	655.3 to 717.5 m (2,150 to 2,354 ft)	729.7 to 743.7 m (2,394 to 2,440 ft) 896.1 to 935.7 m (2,940 to 3,070 ft)

a meter(s)
b foot (feet)

Table A-3-3
Drilling Fluids Used in Well ER-20-8#2

Typical Air-Foam/Polymer Mix
37.9 to 56.8 liters (10 to 15 gallons) Geofoam® [a] per 7,949 liters (50 barrels) water

a Geofoam® foaming agent is a product of Geo Drilling Fluids, Inc.

NOTES:
1. All water used to mix drilling fluids for Well ER-20-8#2 came from Area 20 Water Well (U-20WW).

2. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids to make up a final concentration of approximately 20 to 30 parts per million LiBr. The concentration was increased in zones of higher water production to make up a solution of 50 to 60 parts per million LiBr.

Table A-3-4
Well ER-20-8#2 Cement Composition

Cement Composition	20-inch Conductor Casing	13⅜-inch Surface Casing	7⅝-inch Completion Casing
Redi-Mix Formula 400: 998 kilograms (2,200 pounds) sand, 326 kilograms (719 pounds) Portland cement, and 232 liters (61 gallons) water per cubic yard	0 to 25.5 m [a] (0 to 83.5 ft) [b]	none	none
Type II neat	none	432.2 to 495.6 m (1,418 to 1,626 ft)	none

a meter(s)
b foot (feet)

Appendix B

Fluid Management Data for Wells ER-20-8 and ER-20-8#2

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Table B-1
Well ER-20-8 Fluid Disposition Reporting Form

FLUID DISPOSITION REPORTING FORM

Site Identification: ER-20-8
Site Location: NTS Area 20
Site Coordinates: N: 4,116,218.33 m E: 546,686.35 m
(UTM, NAD 27, Zone 11)
Well Classification: ER Hydrogeologic Investigation Well
Project No: RU09-600

Report Date: February 2010
NNSA/NSO Federal Sub-Project Director: Bill Wilborn
SNJV Project Manager: Sam Marutzky
SNJV Site Representative: Michael Pitterle
SNJV Environmental Specialist: Mark Heser

Well Construction Activity	Activity Duration		#Ops. Days[a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Volume of Infiltration Area (m^3)[c]	Other[d] (m^3)	Fluid Quality Objectives Met?
	From	To				Solids[b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	7/12/2009	7/24/2009	8	508.1	480	161	369	-	-	-	N/A	Yes
Phase I: Saturated-Zone Drilling	7/24/2009	8/08/2009	7	1,049.2	239	33	972	25	490	3,864	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			13	1,049.2	719	194	1,341	25	490	3,864	N/A	Yes

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift. Includes reaming the borehole from 360 to 1,638 ft bgs from 7/21/2009 through 7/22/2009.
[b] Solids volume estimates include calculated added volume attributed to rock bulking factor (150%).
[c] Ground surface discharge. While drilling in the saturated zone from 8/06/2009 through 8/08/2009 there was a regular transfer of fluid from Sump #2 to Sump #1, which then discharged to the surface infiltration area.
[d] Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site.
NA = Not Applicable; m = meters; m^3 = cubic meters

Total Facility Capacities: Sump #1 = 1,547 m^3 Sump #2 = 1,547 m^3

Infiltration Area (assuming negligible infiltration) = N/A m^3

Remaining Facility Capacity (approximate) as of 08/15/2009: Sump #1 = 376 m^3 (24%) Sump #2 = 1,093 m^3 (71%)

Current Average Tritium = 790 pCi/L
Sump #1 FMP sample collected on 9/01/2009 after completing Well ER-20-8 #2

NNES Authorizing Signature/Date: [signature] 3-9-10

LV\2-25-10\forms\form_158

Table B-2
Analytical Results for Fluid Management Samples from the Well ER-20-8 Site

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act* Metals (mg/L)							
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
20-8-2-090109-1	09/01/2009	Sample from Sump #1	Total	0.01	0.1 U	0.001	0.021	0.04	0.005	0.01	0.0002 U
			Dissolved	0.006	0.1 U	0.00078	0.01	0.0081	0.0032	0.01	0.0002 U
20-8-2-090109-2	09/01/2009	Duplicate Sample from Sump #1	Total	0.0088	0.1 U	0.00099	0.016	0.04	0.0037	0.01	0.0002 U
			Dissolved	0.0062	0.1 U	0.00045	0.01 U	0.0021	0.005	0.01	0.0002 U
			Detection Limit	0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002

Sample Number	Date Collected	Comment		Radiological Indicator Parameters (pCi/L)		
				Tritium	Gross Alpha	Gross Beta
20-8-2-090109-1	09/01/2009	Sample from Sump #1	Result	790	4.2	12.9
			Error	240	1.6	2.9
			MDC	320	1.6	2.7
20-8-2-090109-2	09/01/2009	Duplicate Sample from Sump #1	Result	280 U	5.2	14.4
			Error	240	1.8	3.1
			MDC	390	1.8	2.8

Data provided by Navarro-Intera, LLC (N-I, 2010a; 2010b)

Samples were taken following completion of Well ER-20-8#2. They serve as fluid management samples for both Wells ER-20-8 and ER-20-8#2. Sump #1 is the unlined sump located on the Well ER-20-8 drill pad.

Analyses for metals and radionuclides (filtered prior to analysis) performed by Paragon Analytics, Inc.

Notes: U = Compound was analyzed for but not detected ("Non-Detect").
mg/L = milligrams per liter   pCi/L = picocuries per liter

Analytical methods: All metals except mercury: Environmental Protection Agency (EPA) Procedure SW-846 6010
Mercury: EPA Procedure SW-846 7470
Tritium: EPA 906.0
Gross alpha and gross beta: EPA 900.0

Table B-3
Well ER-20-8#2 Fluid Disposition Reporting Form

FLUID DISPOSITION REPORTING FORM

Site Identification: ER-20-8 #2
Site Location: NTS Area 20
Site Coordinates: N: 4,116,211.30 m E: 546,672.68 m
(UTM, NAD 27, Zone 11)
Well Classification: ER Hydrogeologic Investigation Well
Project No: RU09-601

Report Date: February 2010
NNSA/NSO Federal Sub-Project Director: Bill Wilborn
SNJV Project Manager: Sam Marutzky
SNJV Site Representative: Michael Pitterle
SNJV Environmental Specialist: Mark Heser

Well Construction Activity	Activity Duration		#Ops. Days[a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Volume of Infiltration Area (m^3)[c]	Other[d] (m^3)	Fluid Quality Objectives Met?
	From	To				Solids[b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	8/22/2009	8/27/2009	6	508.1	420	117	229	-	-	-	N/A	Yes
Phase I: Saturated-Zone Drilling	8/28/2009	8/30/2009	3	712.8	175	23	171	-	-	1,194	N/A	Yes
Phase II: Initial Well Development	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Aquifer Testing	11/28/2009	12/18/2009	15	712.8	N/A	-	555	-	-	6,571	N/A	Yes
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			24	712.8	595	140	955	-	-	7,765	N/A	Yes

[a] **Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift. Phase II Aquifer testing included six days of Step Drawdown testing from 11/28/2009 through 12/03/2009, and nine days of Constant Rate Pumping from 12/10/2009 through 12/18/2009.**
[b] **Solids volume estimates include calculated added volume attributed to rock bulking factor (150%).**
[c] **Ground surface discharge. During Phase II Aquifer testing, the remaining drilling fluid in Sump #2 of 228 m^3 was pumped into Sump #1 on 11/30/2009 after fluids began to flow from Sump #1 to the infiltration area.**
[d] **Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site.**
NA = Not Applicable; m = meters; m^3 = cubic meters

Total Facility Capacities: Sump #1 = 1,547 m^3 Sump #2 = 1,547 m^3

Infiltration Area (assuming negligible infiltration) = N/A m^3

Remaining Facility Capacity (approximate) as of 12/18/2009: Sump #1 = 130 m^3 (8%) Sump #2 = 79 m^3 (5%)
Note: On 11/30/2009 NSTec began filling Sump #2 with water from NTS Water Well #8 for construction purposes.

Current Average Tritium = 880 pCi/L.
FMP sample collected from discharge line on 12/18/2009 at the completion of the constant rate pump test.

NNES Authorizing Signature/Date: [signature] 3-9-10

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Appendix C
Detailed Lithologic Log for Well ER-20-8

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Table C-1
Detailed Lithologic Log for Well ER-20-8

Logged by Jennifer Mercadante, Lance Prothro, and Sigmund Drellack, NSTec, September 2009
Updated to incorporate analytical data, March 2010

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
0–18.3 (0–60)	18.3 (60)	AC	None	**Rhyolitic Lava:** Pale yellowish brown (10YR 6/2) to olive gray (5Y 4/1); vitric; perlitic and weakly spherulitic; minor felsic phenocrysts of quartz and feldspar; minor biotite; some are copper-colored; sphene is present.	rhyolite of Tannenbaum Hill (Tmat)
18.3–33.5 (60–110)	15.2 (50)	N/A	None	**Rhyolitic Lava:** Interval of missing cuttings. Lithology based on surface exposures and over- and underlying sample data.	
33.5–61.0 (110–200)	27.5 (90)	DA	None	**Rhyolitic Lava:** Very dusky red (10R 2/2) spherulitic lava, devitrified; pale yellowish brown (10YR 6/2) and dark yellowish brown (10YR 4/2) lava, devitrified to partially silicic; rare light olive gray (5Y 6/1) perlitic lava, vitric; rare to minor felsic phenocrysts of quartz and feldspar; rare biotite. Interval gradually loses perlites and spherulites towards the base. The cuttings from 33.5 to 36.6 m (110 to 120 ft) include abundant cement fragments.	
61.0–175.3 (200–575)	114.3 (375)	DA	None	**Rhyolitic Lava:** Mottled, brownish gray (5YR 4/1) and medium light gray (N6) to 91.4 m (300 ft), becoming mostly medium gray (N5) to base of interval; devitrified; minor felsic phenocrysts of feldspar and quartz; rare bronze biotite; some spherulites. Appears less dense from 82.3 to 97.5 m (270 to 320 ft).	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
175.3–204.2 (575–670)	28.9 (95)	DA	None	**Rhyolitic Lava:** Moderate brown (5YR 4/4); mostly devitrified and silicic, but vitric and perlitic from approximately 176.8 to 182.9 m (580 to 600 ft) and vitrophyric from 192.0 to 198.1 m (630 to 650 ft); rare to minor felsic phenocrysts of feldspar and quartz; rare bronze and black biotite; sphene is present.	rhyolite of Tannenbaum Hill (Tmat)
204.2–210.3 (670–690)	6.1 (20)	DA	None	**Flow Breccia:** Pale yellowish brown (10YR 6/2) matrix with moderate reddish orange (10R 6/6) to moderate reddish brown (10R 4/6) clasts; mostly silicic, lesser devitrified; rare to minor felsic phenocrysts of quartz and feldspar; rare biotite; sphene is present.	
210.3–220.7 (690–724)	10.4 (34)	DA	None	**Flow Breccia:** Dark yellowish brown (10YR 4/2) and black (N1); mostly vitric, lesser devitrified and silicic; strongly perlitic; rare to minor felsic phenocrysts of feldspar and quartz; minor black biotite, trace hornblende; sphene is present.	
220.7–230.4 (724–756)	9.7 (32)	DA	231.6 (760) [d]	**Partially Welded Ash-Flow Tuff:** Pale brown (5YR 5/2); devitrified, texture of pumice reminiscent of vapor-phase mineralization; minor pumice is moderate brown (5YR 4/4) to light brown (5YR 5/6); minor felsic phenocrysts of quartz and feldspar; minor bronze biotite, trace hornblende; minor lithic fragments, dominantly 0.25 to 1 mm in diameter with thin white halo around fragments.	
230.4–246.0 (756–807)	15.6 (51)	DA	None	**Moderately Welded Ash-Flow Tuff:** Moderate reddish brown (10R 4/6) with black (N1) perlitic inclusions; vitric; minor white and white/gray/black pumice; minor felsic phenocrysts including quartz and feldspar; rare biotite; rare lithic fragments; sphene present. Vitrophyric below 239.3 m (785 ft) with conspicuous perlitic black glass (free) and inclusions showing perlitic texture.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
246.0–260.3 (807–854)	14.3 (47)	DA	259.1 (850)	**Partially Welded Ash-Flow Tuff:** Moderate reddish brown (10R 4/6); zeolitic, texture of pumice reminiscent of vapor-phase mineralization; minor pumice; common felsic phenocrysts including quartz and feldspar; minor biotite; minor lithic fragments; sphene is present.	rhyolite of Tannenbaum Hill (Tmat)
260.3–287.7 (854–944)	27.4 (90)	DA	286.5 (940)	**Nonwelded Ash-Flow Tuff:** Light brown (5YR 6/4); zeolitic with corroded pumice having the appearance of vapor phase mineralization; minor pumice, most are moderate yellow (5Y 7/6); minor felsic phenocrysts of quartz and feldspar; minor biotite; minor lithic fragments; manganese oxide stains.	
287.7–309.4 (944–1,015)	21.7 (71)	DA	None	**Bedded Tuff:** Grayish orange (10YR 7/4); zeolitic; minor pumice is moderate yellow (5Y 7/6); minor to common felsic phenocrysts of quartz (including dipyramidal quartz) and feldspar; minor biotite; minor lithic fragments; sphene is present; manganese oxide stains.	
309.4–332.2 (1,015–1,090)	22.8 (75)	DA	None	**Bedded Tuff:** Grayish yellow (5Y 8/4) to yellowish gray (5Y 7/2); zeolitic, top of interval is silicified in part; minor pumice; minor felsic phenocrysts of quartz and feldspar; minor biotite; common to abundant, mostly dark-colored, volcanic lithic fragments; apparent increase in lithic fragments at top of interval; free lithic fragments are conspicuous and about 3 mm in diameter, but up to 10 mm in diameter; sphene is present; manganese oxide stains. The lithic-rich nature of this interval may indicate that it is a debris-flow.	
332.2–334.7 (1,090–1,098)	2.5 (8)	DB4	None	**Reworked Tuff:** Moderate reddish brown (10R 4/6); zeolitic to weakly argillic; rare to minor pumice; minor felsic phenocrysts of quartz and feldspar; minor biotite; common to abundant lithic fragments, most <0.5 mm; cuttings have dessication cracks.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
334.7–352.0 (1,098–1,155)	17.3 (57)	DA	None	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2); mostly devitrified, vapor-phase mineralization of pumice; rare pumice; common felsic phenocrysts including quartz and feldspar; minor biotite, rare clinopyroxene; trace to rare lithic fragments.	mafic-poor Rainier Mesa Tuff (Tmrp)
352.0–368.8 (1,155–1,210)	16.8 (55)	DA	353.6 (1,160)	**Partially Welded Ash-Flow Tuff:** Grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4); zeolitic, texture of pumice reminiscent of vapor-phase mineralization; minor pumice; rare to minor felsic phenocrysts of quartz (including dipryamidal quartz) and feldspar; minor biotite; rare to minor lithic fragments; yellowish-orange remnant glass shards.	
368.8–390.1 (1,210–1,280)	21.3 (70)	DA	384.0 (1,260)	**Nonwelded Ash-Flow Tuff:** Pale brown (5YR 5/2); zeolitic, texture of pumice reminiscent of vapor-phase mineralization; minor pumice; minor felsic phenocrysts including quartz and feldspar; rare to minor biotite; rare to minor lithic fragments; conspicuous yellowish-orange glass shards.	
390.1–407.2 (1,280–1,336)	17.1 (56)	DA	None	**Nonwelded Tuff:** Very pale orange (10YR 8/2) to grayish orange (10YR 7/4); zeolitic; minor pumice; common felsic phenocrysts of quartz (including dipryamidal quartz) and feldspar; minor biotite; conspicuously lithic-rich with common to abundant dark-colored lithic fragments, about 6 mm in diameter on average, mostly free fragments; manganese oxide stains. The lithic-rich nature of this unit may indicate that it is a debris-flow.	rhyolite of Fluorspar Canyon (Tmrf)
407.2–449.6 (1,336–1,475)	42.4 (139)	DA	438.9 (1,440)	**Bedded Tuff:** Moderate reddish brown (10R 4/6) and moderate reddish orange (10R 6/6); zeolitic; common white pumice; rare felsic phenocrysts including quartz and feldspar; rare biotite; rare to minor lithic fragments.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
449.6–468.5 (1,475–1,537)	18.9 (62)	DA	466.3 (1,530)	**Pumiceous Lava:** Pale greenish yellow (10Y 8/2); zeolitic; rare to minor feldspar phenocrysts; minor biotite, trace hornblende; sphene is present; manganese oxide stains.	rhyolite of Benham (Tpb)
468.5–502.3 (1,537–1,648)	33.8 (111)	DA RSWC	493.8 (1,620)	**Flow Breccia:** Pale olive (10Y 6/2) and brownish gray (5YR 4/1); vitric, weakly zeolitic, minor silicification; rare feldspar phenocrysts; rare to minor biotite; perlitic. Also: Olive gray (5Y 4/1), dusky yellow (5Y 6/4), grayish brown (5YR 3/2), and yellowish gray (5Y 7/2); devitrified, weakly zeolitic, minor silicification in part; rare to minor feldspar phenocrysts; minor biotite; spherulitic; sphene is present. Cement fragments in cuttings from 499.9 m (1,640 ft) to bottom of interval.	
502.3–520.0 (1,648–1,706)	17.7 (58)	DA DB4 RSWC	None	**Pumiceous Lava:** Grayish yellow (5Y 8/4); mostly zeolitic, partially vitric; rare to minor feldspar phenocrysts; minor to common biotite; evidence of silica-healed fractures; manganese oxide stains; sphene is present, mostly as casts; partially altered sphene and pseudomorphs after sphene also present. Below 515.1 m (1,690 ft), pumiceous lava is moderate yellowish brown (10YR 5/4) and light olive gray (5Y 5/2); vitric, partially zeolitic; rare to minor feldspar; rare biotite; finely striped, fibrous texture in parts. Grades into basal flow breccia from 519.4 to 520.0 m (1,704 to 1,706 ft) (observed in borehole image log). Lower contact dips 24 degrees southwest. Cement fragments in cuttings from top of interval to 506.0 m (1,660 ft).	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
520.0–549.9 (1,706–1,804)	29.9 (98)	DA	548.6 (1,800)	**Bedded Tuff:** Light brown (5YR 6/4) and yellowish gray (5Y 7/2); mostly zeolitic, partly vitric, weak silicification at the bottom of the interval; common to abundant pumice is corroded and crystalized (yellow); rare to minor feldspar phenocrysts; rare to minor biotite; minor lithic fragments; sphene casts. Reworked bed from 549.2 to 550.5 m (1,802 to 1,806 ft) with virtually no pumice, abundant sub-millimeter, sub-rounded lithic fragments; appears more dense than the bedded tuff above it. Average bedding dip is 17 degrees southwest. Lower contact dips 14 degrees southwest (based on borehole image log). Cement fragments in cuttings from 527.3 to 530.4 m (1,730 to 1,740 ft).	Paintbrush Group, undivided (Tp)
549.9–567.5 (1,804–1,862)	17.6 (58)	DA RSWC	None	**Pumiceous Lava:** Pale greenish yellow (10Y 8/2); zeolitic above 557.8 m (1,830 ft), zeolitic, vitric, and weakly silicic below 557.8 m (1,830 ft), becoming vitric and perlitic at base of interval (light olive gray [5Y 5/2] and dark greenish gray [5GY 4/1]); minor feldspar phenocrysts; common biotite; conspicuous manganese oxide stains, commonly coating phenocrysts and lithic fragments; sphene is present; vuggy porosity associated with chalcedony-like silicification. From 554.7 to 560.8 m (1,820 to 1,840 ft), there are conspicuous moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4) tuffaceous fragments, which may represent alteration along the contact between this interval and the overlying bedded tuff. Lower contact dips 63 degrees west (based on borehole image log).	rhyolite of Scrugham Peak (Tps)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
567.5–599.8 (1,862–1,968)	32.3 (106)	DA RSWC	576.1 (1,890)	**Rhyolitic Lava and Flow Breccia:** Dusky yellow (5Y 6/4) and grayish orange (10YR 7/4) mottled with medium light gray (N6) above 582.2 m (1,910 ft), moderate brown (5YR 4/4), moderate yellowish brown (10YR 5/4), dark gray (N3) with olive gray (5Y 4/1) and dark yellowish brown (10YR 2/2) tints below 582.2 m (1,910 ft); mostly zeolitic, lesser vitric to 582.2 m (1,910 ft), becoming devitrified, silicic, and vitric below 582.2 m (1,910 ft); conspicuously spherulitic above 582.2 m (1,910 ft), perlitic and spherulitic below 582.2 m (1,910 ft); minor feldspar phenocrysts; minor to common biotite; sphene is present. Highly variable interval. The variability is likely the result of large-scale flow layering as observed on the STAR tool. Flow layering dips 66 degrees south-southeast.	rhyolite of Scrugham Peak (Tps)
599.8–625.1 (1,968–2,051)	25.3 (83)	DA RSWC	600.5 (1,970)	**Vitrophyric Lava:** Olive gray (5Y 4/1) and black (N1) to 609.6 m (2,000 ft), olive gray, black, and moderate brown (5YR 4/4) from 609.6 m (2,000 ft) to base of interval; vitric (olive gray and black) and devitrified to partially silicic (moderate brown); lower 3.0 to 6.1 m (10 to 20 ft) of interval becomes mostly devitrified; minor feldspar phenocrysts; minor biotite; vitric portion is perlitic; devitrified to partially silicic portion is weakly spherulitic; sphene is present. Lower contact dips 39 degrees northwest (based on borehole image log).	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
625.1–654.4 (2,051–2,147)	29.3 (96)	DA RSWC	None	**Rhyolitic Lava:** Medium gray (N5) and medium light gray (N6) becoming mottled with grayish red (10R 4/2) at 643.1 m (2,110 ft); devitrified, partially vitric in the upper 6.1 m (20 ft); rare to minor feldspar phenocrysts; minor mostly black biotite; sphene is present. May be flow breccia below 643.1 m (2,110 ft). The lower contact dips 12 degrees east-southeast. Bedding-like features near the base of the interval dip approximately 30 degrees southeast (based on borehole image log).	rhyolite of Scrugham Peak (Tps)
654.4–688.2 (2,147–2,258)	33.8 (111)	DA RSWC	654.7 (2,148)	**Vitrophyric Lava:** Black (N1) and very dusky red (10R 2/2), becoming mostly dark reddish brown (10R 3/4) below 676.7 m (2,220 ft); vitric, but becoming less vitric and more devitrified below 676.7 m (2,220 ft) (dark reddish brown portion); rare to minor feldspar phenocrysts; minor biotite; weakly perlitic; sphene is present. The lower contact dips 43 degrees south (based on borehole image log).	
688.2–758.0 (2,258–2,487)	69.8 (229)	DA RSWC	737.6 (2,420)	**Bedded Tuff:** Dominantly light brown (5YR 6/4), lesser moderate yellowish brown (10YR 5/4) to grayish orange (10YR 7/4) to about 743.7 m (2,440 ft), becoming more grayish orange (10YR 7/4) and grayish yellow (5Y 8/4) to moderate yellow (5Y 7/6) to the bottom of the interval; zeolitic; minor to common pumice, which is corroded and crystallized in the upper portion of the interval (688.2 to 746.8 m [2,258 to 2,450 ft]); minor feldspar phenocrysts; common biotite; common lithic fragments; sphene present in the upper portion (688.2 to 746.8 m [2,258 to 2,450 ft]). Fault at 735.5 m (2,413 ft) dips 42 degrees north-northwest (based on borehole image log). Bedding dips approximately 27 degrees south (based on borehole image log). Cement fragments in cuttings from 719.3 m (2,360 ft) to bottom of interval.	Paintbrush Group, undivided (Tp)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
758.0–766.0 (2,487–2,513)	8.0 (26)	DB4 RSWC	762.0 (2,500)	**Nonwelded Tuff:** Pale yellowish brown (10YR 6/2) (dry color); zeolitic; common pumice; minor feldspar phenocrysts; rare mafic minerals of biotite and magnetite; rare lithic fragments. Description is of the RSWC from 762.0 m (2,500 ft). Possibly argillized in the basal 0.6 m (2 ft). The lower contact dips 21 degrees south (based on borehole image log).	tuff of Pinyon Pass (Tpcy)
766.0–768.1 (2,513–2,520)	2.1 (7)	DB4	None	**Partially Welded Ash-Flow Tuff:** Brownish gray (5YR 4/1); devitrified, vapor-phase mineralization; rare to minor pumice; minor feldspar phenocrysts; minor biotite; rare lithic fragments; sphene is present.	Pahute Mesa lobe of Tiva Canyon Tuff (Tpcm)
768.1–772.7 (2,520–2,535)	4.6 (15)	DA	None	**Moderately Welded Ash-Flow Tuff:** Moderate brown (5YR 4/4); devitrified, vapor-phase mineralization observed in some pumice fragments; rare to minor pumice; minor feldspar phenocrysts; minor biotite; rare lithic fragments; manganese-oxide-filled hairline fractures present in cuttings from 774.2 to 777.2 m (2,540 to 2,550 ft).	
772.7–880.9 (2,535–2,890)	108.2 (355)	DA	780.3 (2,560) 841.2 (2,760)	**Moderately Welded Ash-Flow Tuff:** Moderate brown (5YR 4/4), grayish red (10R 4/2), pale brown (5YR 5/2), dark yellowish brown (10YR 4/2) mottled with grayish brown (5YR 3/2), and moderate brown (5YR 3/4); devitrified; rare to minor pumice; rare to minor feldspar phenocrysts, some altered; rare to minor biotite, some bronze; trace to rare lithic fragments; minerals become less visible with depth; sphene is present. Cuttings from 838.2 to 841.2 m (2,750 to 2,760 ft) are weakly spherulitic. Possible increase in welding from 823.0 to 880.9 m (2,700 to 2,890 ft). Possible vitrophyre from 877.8 to 880.9 m (2,880 to 2,890 ft). Lithophysal zones from 790.7 to 823.3 m (2,594 to 2,701 ft) and 845.8 to 851.9 m (2,775 to 2,795 ft) (based on borehole image log).	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
880.9–888.5 (2,890–2,915)	7.6 (25)	DA RSWC	None	**Nonwelded Ash-Flow Tuff:** Light brown (5YR 5/6) and moderate brown (5YR 4/4); zeolitic and weakly quartzo-feldspathic; rare pumice; rare feldspar phenocrysts; rare unrecognizable mafic minerals; rare lithic fragments; sphene is present. RSWC from 883.9 m (2,900 ft) has manganese-oxide-filled fractures; manganese oxide staining on RSWC and cuttings.	Pahute Mesa lobe of Tiva Canyon Tuff (Tpcm)
888.5–961.6 (2,915–3,155)	73.1 (240)	DA RSWC	923.5 (3,030) 957.1 (3,140)	**Bedded Tuff:** Mostly grayish orange (10YR 7/4), also moderate yellow (5Y 7/6), dark yellowish orange (10YR 6/6), and light brown (5YR 6/4) and (5YR 5/6); quartzo-feldspathic and zeolitic; rare to minor pumice; rare feldspar phenocrysts increasing to minor below 914.1 m (3,000 ft) (petrographic analyses indicate rare quartz phenocrysts in samples at 923.5 and 957.1 m [3,030 and 3,140 ft]); trace to rare biotite increases to rare to minor below 914.4 m (3,000 ft); lithic-rich interval from 902.2 to 914.1 m (2,960 to 3,000 ft) (devitrified lava, purplish red, most 1 to 3 mm in size), mostly free fragments, rare to common lithic fragments in matrix, most tiny; sphene casts and crystals. RSWC from 961.3 m (3,154 ft) is the argillic base of the unit. Bedding dips 23 degrees south (based on borehole image log).	Paintbrush Group, undivided (Tp)
961.6–966.2 (3,155–3,170)	4.6 (15)	DB4	None	**Partially Welded Ash-Flow Tuff:** Medium light gray (N6); devitrified, may be quartzo-feldspathic; minor pumice; minor feldspar phenocrysts; minor to common biotite; trace to rare lithic fragments.	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
966.2–999.7 (3,170–3,280)	33.5 (110)	DA RSWC	967.7 (3,175) 986.0 (3,235) 997.9 (3,274)	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2), moderate brown (5YR 4/4), and pale brown (5YR 5/2); mostly devitrified, weakly quartzo-feldspathic above 978.4 m (3,210 ft), becoming strongly quartzo-feldspathic, including substantial argillization to 999.7 m (3,280 ft), which is mainly observed in pumice fragments; rare to minor pumice, argillic pumice below 978.4 m (3,210 ft) is yellowish gray (5Y 7/2) and light olive brown (5Y 5/6); minor feldspar phenocrysts, some partially altered above 978.4 m (3,210 ft), common pseudomorphs after feldspars below 978.4 m (3,210 ft) (petrographic analyses indicate rare, but increasing abundance of quartz phenocrysts with depth); minor biotite; minor lithic fragments. Partially welded near the base of the interval. Pumice and feldspars are soapy/waxy when scratched. Fracture surface on RSWC from 974.8 m (3,198 ft), has soft white residue. Two clusters of west-dipping fractures were noted on borehole image log, at 972.0–975.1 m (3,189–3,199 ft) and at 984.5–990.6 m (3,230–3,250 ft)	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)
999.7–1,049.1 (3,280–3,442) Total depth	49.4 (162)	DA RSWC	1,048.5 (3,440)	**Bedded Tuff:** Moderate reddish brown (10R 4/6); quartzo-feldspathic; common to abundant pumice; most are less than 1 to 2 mm in size, and amount of pumice over 5 mm increases towards the bottom of the hole; rare felsic phenocrysts of quartz and feldspar; rare biotite; rare lithic fragments. RSWC from 1,008.9 m (3,310 ft) is a breccia.	mafic-poor Calico Hills Formation (Thp)

NOTES:

a **AC =** auger cuttings; **DA** = drill cuttings that represent lithologic character of interval; **DB4** = cuttings that are intimate mixtures of units; generally less than 50% of drill cuttings represent lithologic character of interval; **RSWC =** rotary sidewall core. See Table 2-2 in this report for more information about sidewall samples.

NOTES, continued:

b Depth of lithologic samples selected for laboratory analyses. Laboratory analyses include petrography (from polished thin sections), mineralogy (x-ray diffraction), and chemistry (x-ray fluorescence). See Table 2-3 in this report for a complete list of laboratory analyses.

c Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs. Colors describe wet sample color unless otherwise noted.

Abundances for felsic phenocrysts, pumice fragments, and lithic fragments: **trace** = only one or two individuals observed; **rare** = $\leq$ 1%; **minor** = 5%; **common** = 10%; **abundant** = 15%; **very abundant** $\geq$ 20%.

Abundances for mafic minerals: **trace** = only one or two individuals observed; **rare** = $\leq$ 0.05%; **minor** = 0.2%; **common** = 0.5%; **abundant** = 1%; **very abundant** = $\geq$ 2%.

d Sample is representative of the indicated interval rather than the interval corresponding with the depth due to drilling lag time.

Appendix D

Geophysical Logs Run in Wells ER-20-8 and ER-20-8#2

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Appendix D contains plots of selected geophysical logs run in Well ER-20-8. Table D-1 summarizes the logs presented. See Table 2-4 for more information.

Table D-1
Wells ER-20-8 and ER-20-8#2 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Well ER-20-8				
Caliper	CA6-1 CA6-2 CA6-3	7/19/2009 7/31/2009 8/9/2009	0–487.7 491.9–714.8 701.0–1,045.2	0–1,600 1,614–2,345 2,300–3,429
X-Multipole Array Acoustilog (sonic)	XMAC-1 XMAC-2	8/1/2009 8/9/2009	508.1–712.0 701.0–1,043.0	1,667–2,336 2,300–3,422
Gamma Ray	GR-2 GR-4 GR-14	7/19/2009 7/31/2009 8/9/2009	6.7–479.8 411.5–709.6 685.8–1,040.0	22–1,574 1,350–2,328 2,250–3,412
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2 SGR-3	7/19/2009 7/31/2009 8/9/2009	6.7–479.8 411.5–709.6 685.8–1,040.0	22–1,574 1,350–2,328 2,250–3,412
High Definition Induction and Dual Laterolog (resistivity)	HDIL-1 DLL-1 DLL-2	7/19/2009 8/1/2009 8/9/2009	31.7–484.9 508.1–713.8 716.3–1,044.5	104–1,591 1,667–2,342 2,350–3,427
Density	ZDL-1 ZDL-2 ZDL-3	7/19/2009 8/1/2009 8/9/2009	31.7–489.2 472.4–717.5 596.2–1,047.6	104–1,605 1,550–2,354 1,956–3,437
Compensated Neutron	CN-2 CN-3	8/1/2009 8/9/2009	472.4–717.5 596.2–1,047.6	1,550–2,354 1,956–3,437
Chemistry (pH and conductivity) Temperature	Chem-1 TL-3	8/10/2009	507.5–1,045.5	1,665–3,430
Heat Pulse Flow Log	HPFlow-1	8/11/2009	780.3–1,043.9	2,560–3,425
Well ER-20-8#2				
Chemistry (pH and conductivity) Temperature	Chem-1 TL-1	8/30/2009	508.7–712.9	1,669–2,339
Heat Pulse Flow Log	HPFlow-1	8/31/2009	521.2–699.5	1,710–2,295

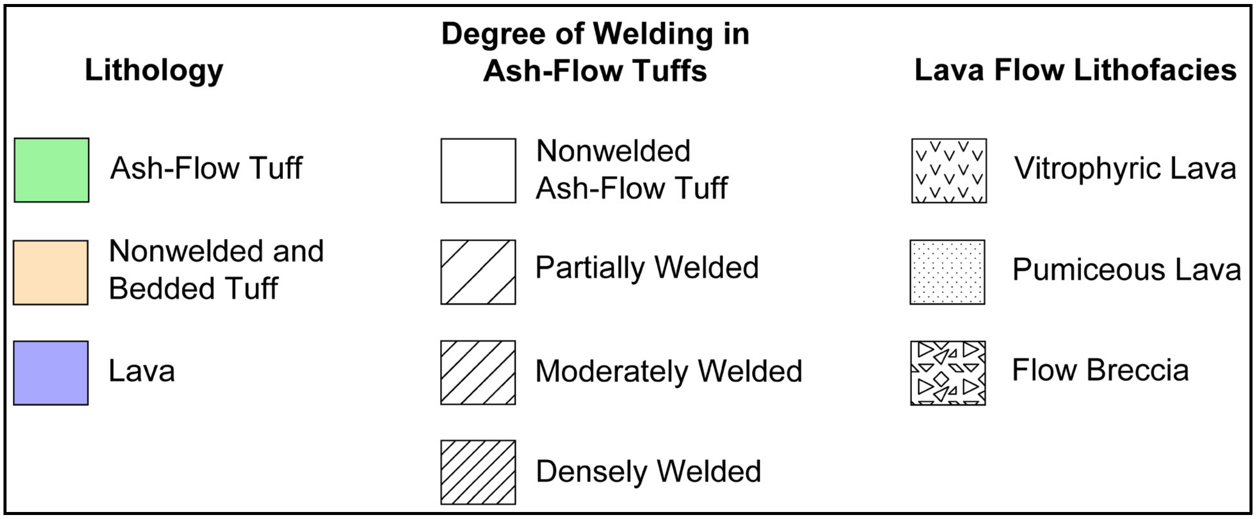
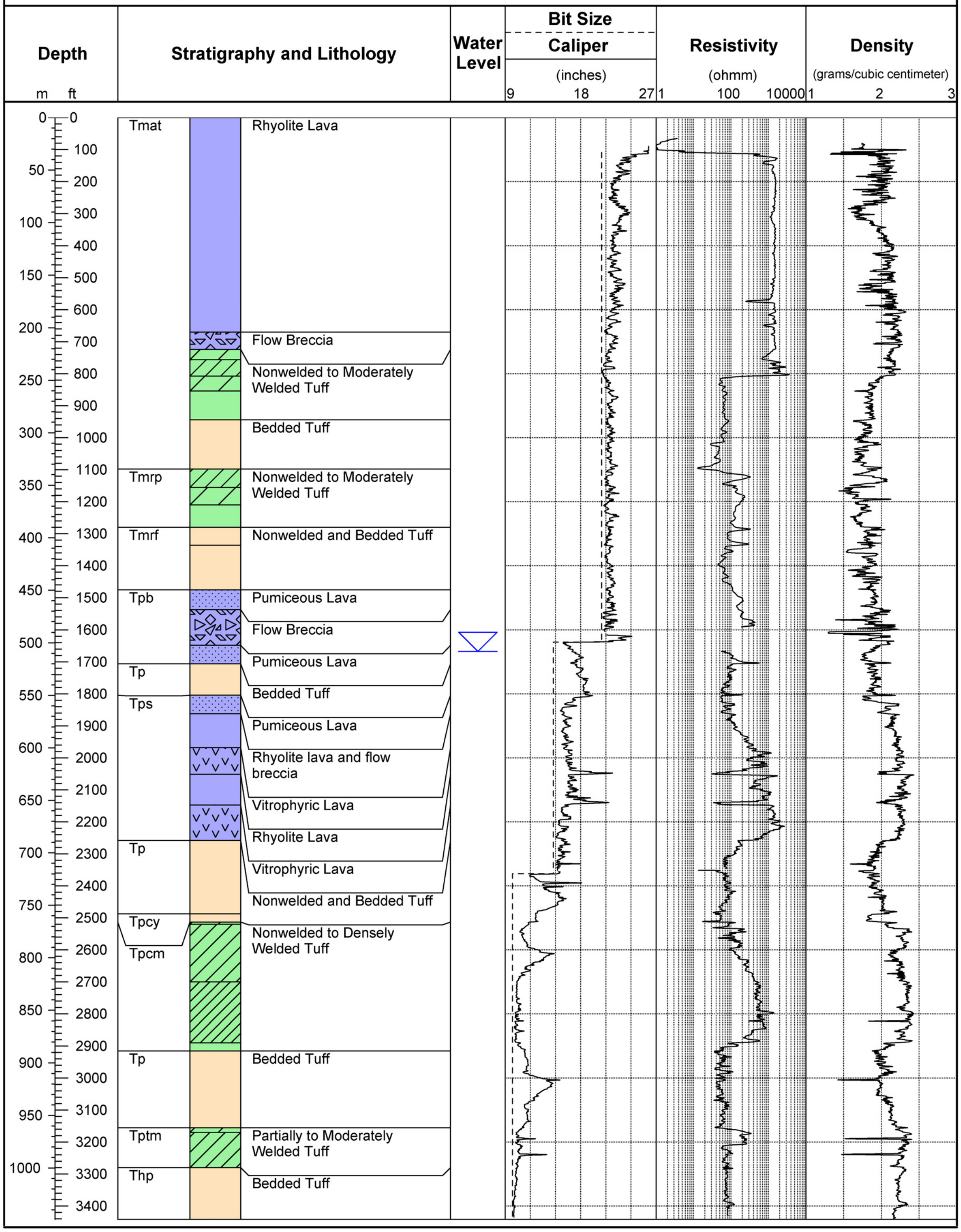


Figure D-1
Legend for Lithology Symbols Used on Log Plots

Well ER-20-8

Logging Company: Baker Atlas
Date Logged: July 19 and 31 and August 1 and 9, 2009
Drilled Depth: 1,049.1 m (3,442 ft)
Date TD Reached: August 8, 2009
Drill Method: Rotary/Air foam

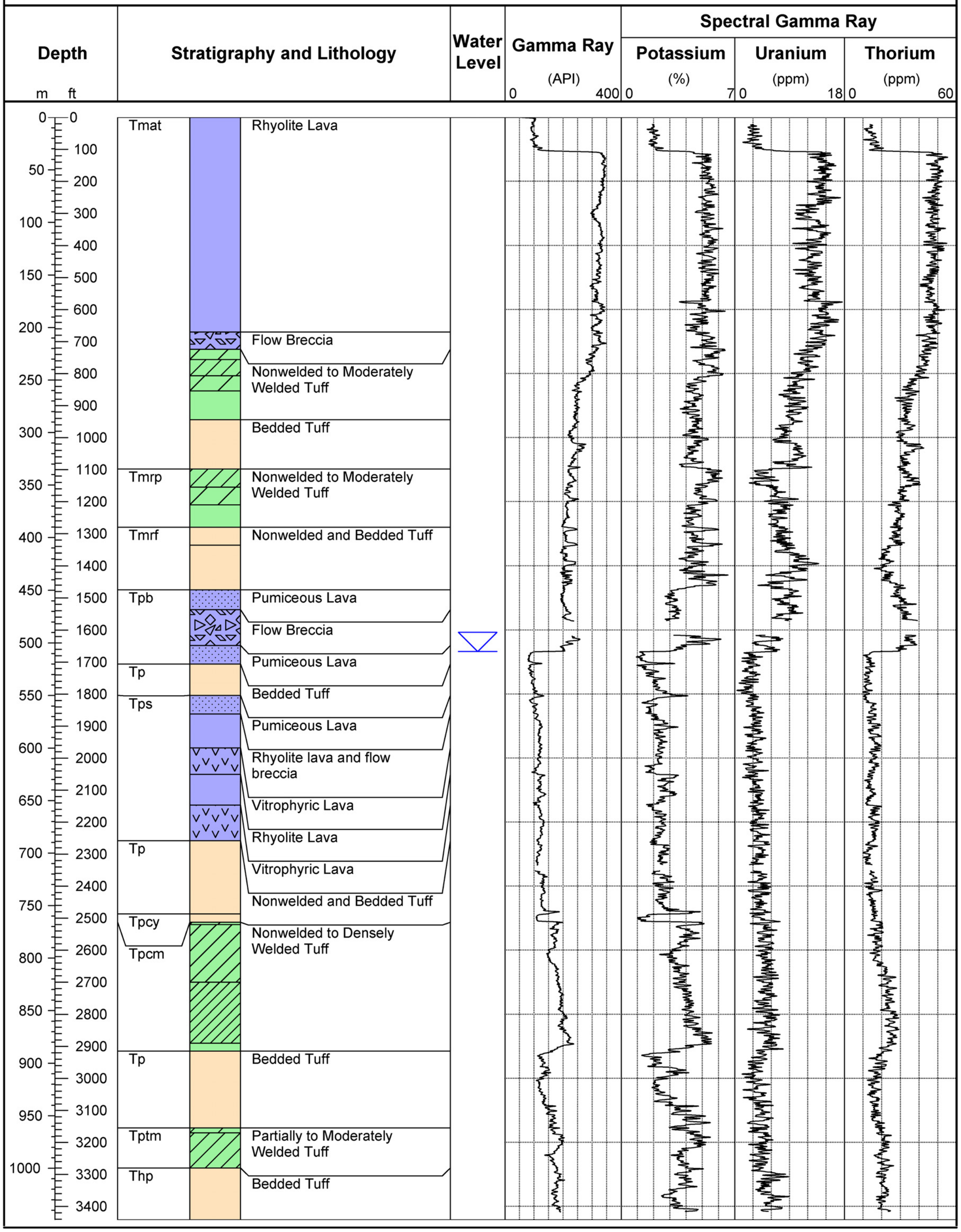
Surface Elevation: 1,782.6 m (5,848.3 ft)
Coordinates (UTM [NAD 83]): N 4,116,415.5 m
E 546,606.1 m
Water Level: 508.1 m (1,667 ft) on September 8, 2009



Well ER-20-8

Logging Company: Baker Atlas
Date Logged: July 19 and 31 and August 9, 2009
Drilled Depth: 1,049.1 m (3,442 ft)
Date TD Reached: August 8, 2009
Drill Method: Rotary/Air foam

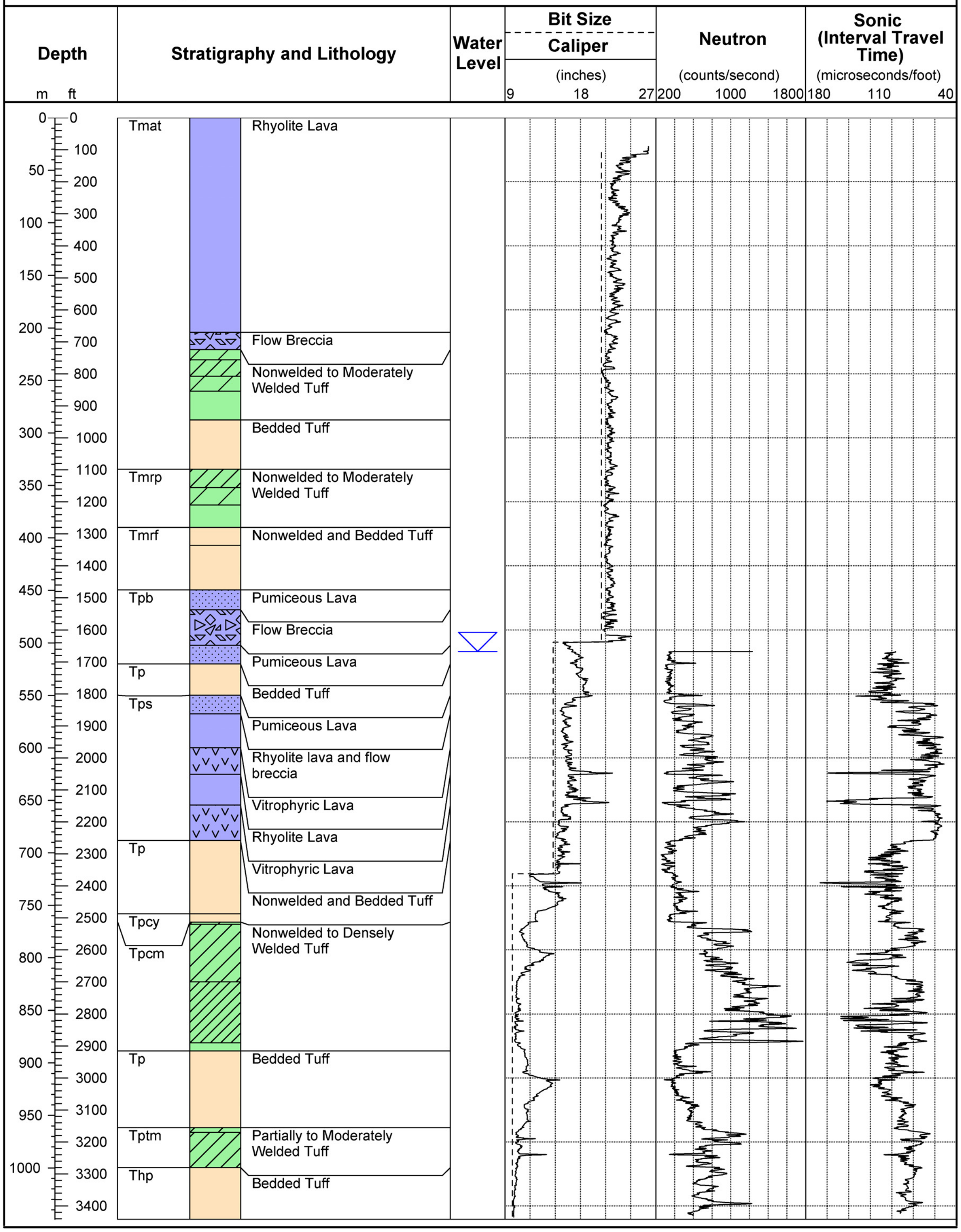
Surface Elevation: 1,782.6 m (5,848.3 ft)
Coordinates (UTM [NAD 83]): N 4,116,415.5 m
E 546,606.1 m
Water Level: 508.1 m (1,667 ft) on September 8, 2009



Well ER-20-8

Logging Company: Baker Atlas
Date Logged: July 19 and 31 and August 1 and 9, 2009
Drilled Depth: 1,049.1m (3,442 ft)
Date TD Reached: August 8, 2009
Drill Method: Rotary/Air foam

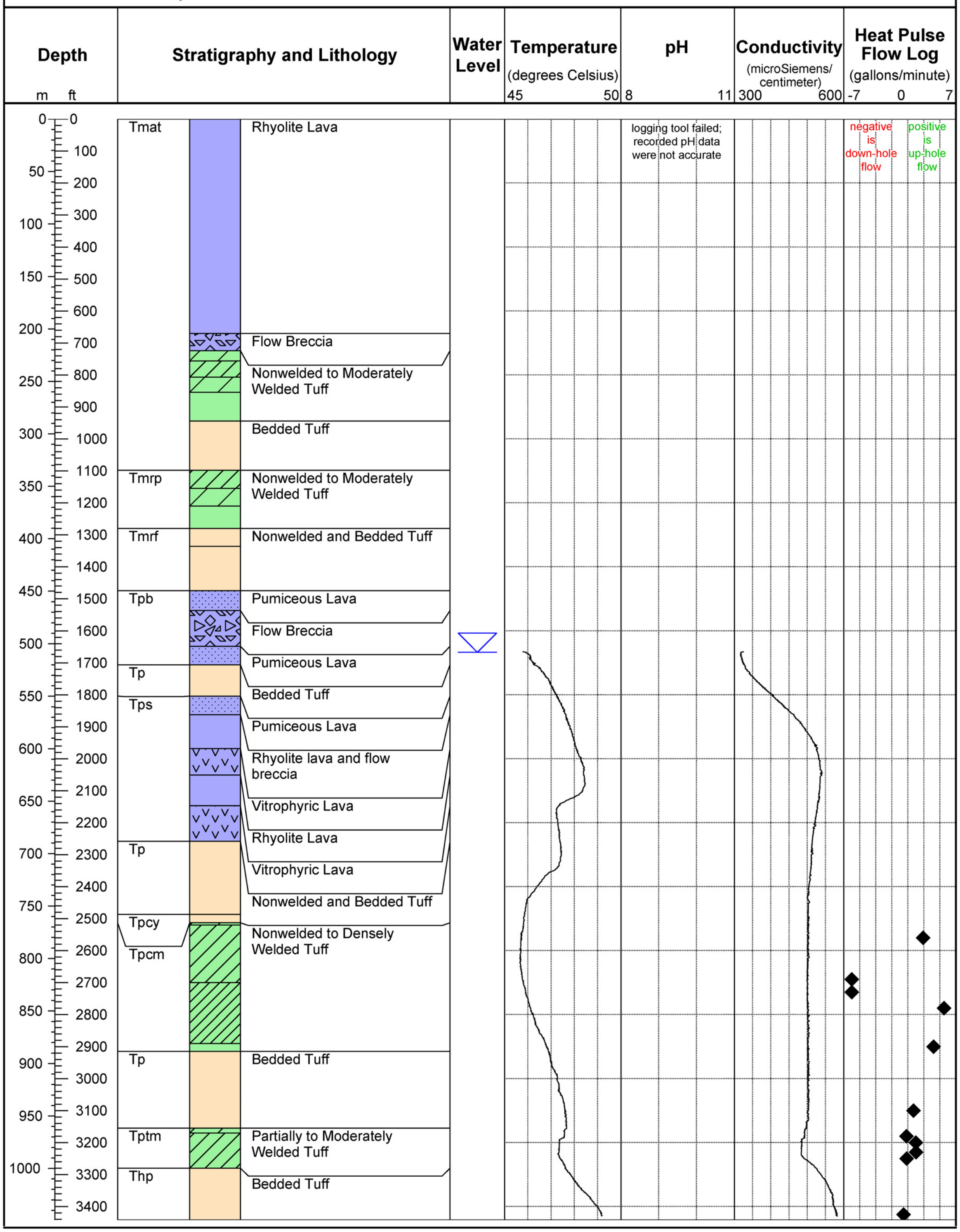
Surface Elevation: 1,782.6 m (5,848.3 ft)
Coordinates (UTM [NAD 83]): N 4,116,415.5 m
E 546,606.1 m
Water Level: 508.1 m (1,667 ft) on September 8, 2009



Well ER-20-8

Logging Company: Desert Research Institute
Date Logged: August 10 and 11, 2009
Drilled Depth: 1,049.1 m (3,442 ft)
Date TD Reached: August 8, 2009
Drill Method: Rotary/Air foam

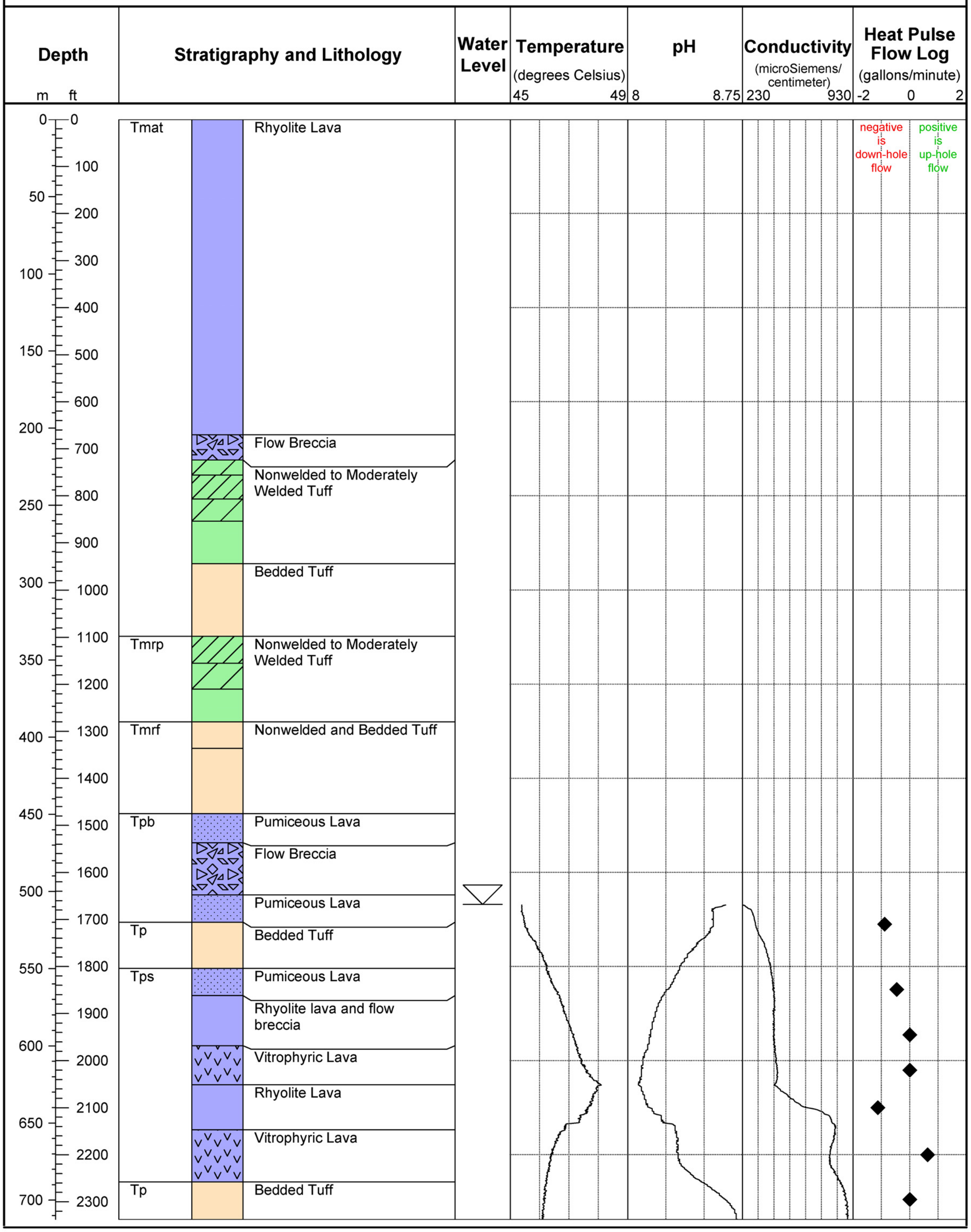
Surface Elevation: 1,782.6 m (5,848.3 ft)
Coordinates (UTM [NAD 83]): N 4,116,415.5 m
E 546,606.1 m
Water Level: 508.1 m (1,667 ft) on September 8, 2009



Well ER-20-8#2

Logging Company: Desert Research Institute
Date Logged: August 30 and 31, 2009
Drilled Depth: 712.6 m (2,338 ft)
Date TD Reached: August 30, 2009
Drill Method: Rotary/Air foam

Surface Elevation: 1,782.7 m (5,848.8 ft)
Coordinates (UTM [NAD 83]): N 4,116,408.4 m
E 546,592.5 m
Water Level: 508.4 m (1,668 ft) on September 8, 2009



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