DOE/NV--1446

Nevada
Environmental
Restoration
Project

Completion Report for Well ER-EC-12

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

April 2011

Environmental Restoration Project

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

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Completion Report for Well ER-EC-12

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, Nevada

April 2011

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DOE/NV--1446

Completion Report for Well ER-EC-12

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

Approved by: ______________________ Date: 5/2/2011
Bill R. Wilborn
Federal Sub-Project Director
Underground Test Area Project

Approved by: ______________________ Date: 5/2/11
Robert F. Boehlecke
Federal Project Director
Environmental Restoration Project

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Abstract

Well ER-EC-12 was 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 known as the Nevada Test Site), Nye County, Nevada. The well was drilled in June and July 2010 as part of the Pahute Mesa Phase II drilling program. The primary purpose of the well was to provide detailed hydrogeologic information in the Tertiary volcanic section in the area between Pahute Mesa and the Timber Mountain caldera complex that will help address uncertainties within the Pahute Mesa–Oasis Valley hydrostratigraphic model. In particular, the well was intended to help define the structural position and hydraulic parameters for volcanic aquifers potentially down-gradient from historic underground nuclear tests on Pahute Mesa. It may also be used as a long-term monitoring well.

The main 52.1-centimeter (cm) hole was drilled to a depth of 429.5 meters (m) and cased with 40.6-cm casing to 385.8 m. The hole diameter was then decreased to 37.5 cm, and the well was drilled to a total depth of 1,240.2 m. The completion casing string, set to the depth of 1,140.6 m, consists of 16.8-cm stainless-steel casing hanging from 19.4-cm carbon-steel casing. The 16.8-cm stainless-steel casing has two slotted intervals open to the Tiva Canyon aquifer and the Topopah Spring aquifer. Three piezometer strings were also installed in Well ER-EC-12 in the annulus between the completion string and the borehole wall. All three strings are composed of 7.3-cm stainless steel tubing hung on 6.0-cm carbon-steel tubing via crossover subs. The shallow string was landed at 817.2 m, for monitoring the Tiva Canyon aquifer. The intermediate string was landed at 1,134.6 m, for monitoring the Topopah Spring aquifer. The deep string was landed at 1,194.5 m, for monitoring the Crater Flat confining unit, the deepest unit encountered in the well.

Data collected during and shortly after hole construction include composite drill cuttings samples collected every 3.0 m, sidewall core samples from 26 depth intervals, various geophysical logs, water quality (primarily tritium) measurements, and water level measurements. The well penetrated 1,240.2 m of Tertiary volcanic rock, including two saturated welded-tuff aquifers.

The water levels measured in the three piezometer strings on August 5, 2010, were as follows: 415.4 m for the Tiva Canyon aquifer, measured in the shallow 7.3-cm piezometer string; 415.8 m for the underlying Topopah Spring aquifer, measured in the intermediate 7.3-cm piezometer string; and 413.6 m for the Crater Flat confining unit, measured in the deep 7.3-cm piezometer string. No tritium above the detection limit of the field instruments was detected in this hole

during drilling. Measurements by a commercial laboratory indicated that tritium levels for discrete water samples collected at 832.1 and 1,182.6 m depth are below the minimum detectable concentration.

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List of Acronyms and Abbreviations

BA	Benham aquifer
BN	Bechtel Nevada
CAIP	Corrective Action Investigation Plan
CAU	Corrective Action Unit
CFCU	Crater Flat confining 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)
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
id	inside diameter
in.	inch(es)
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	meter(s)
m^3	cubic meters
Ma	million years ago
MDC	minimum detectable concentration
NAD	North American Datum
NAIL	Nuclear Annular Investigation Log
NARA	National Archives and Records Administration
N-I	Navarro-Intera, LLC
NNES	Navarro Nevada Environmental Services, 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
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
od	outside diameter
pCi/L	picocuries per liter
PM–OV	Pahute Mesa–Oasis Valley
psi	pounds per square inch
SCCC	Silent Canyon caldera complex
SNJV	Stoller-Navarro Joint Venture
TCA	Tiva Canyon aquifer
TD	total depth
TMCC	Timber Mountain caldera complex
TSA	Topopah Spring aquifer
TWG	Technical Working Group
UDI	United Drilling, Incorporated
UGT	underground nuclear test
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
yd^3	cubic yards

1.0 Introduction

1.1 Project Description

Well ER-EC-12 was constructed 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 known as the Nevada Test Site [NTS]), Nye County, Nevada. Well ER-EC-12 was the fifth well drilled as part of the Underground Test Area (UGTA) Sub-Project Phase II hydrogeologic investigation well-drilling program in the southwestern Pahute Mesa area. It was the first well of the second drilling campaign of the Phase II drilling program, and was constructed in the summer of 2010.

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 (NNSA/NSO, 2009a). The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended March 2010).

The Central and Western Pahute Mesa CAUs and the associated well drilling program are part of the NNSA/NSO Environmental Restoration Project's 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.

Well ER-EC-12 is located on the Nevada Test and Training Range (NTTR), approximately 1,074.4 meters (m) (3,525 feet [ft]) west of the northwest boundary of the NNSS, between the Silent Canyon and Timber Mountain caldera complexes (Figure 1-1), in an area known as the Bench (Figure 1-2). 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 Bench area of the Pahute Mesa–Oasis Valley (PM–OV) hydrostratigraphic framework

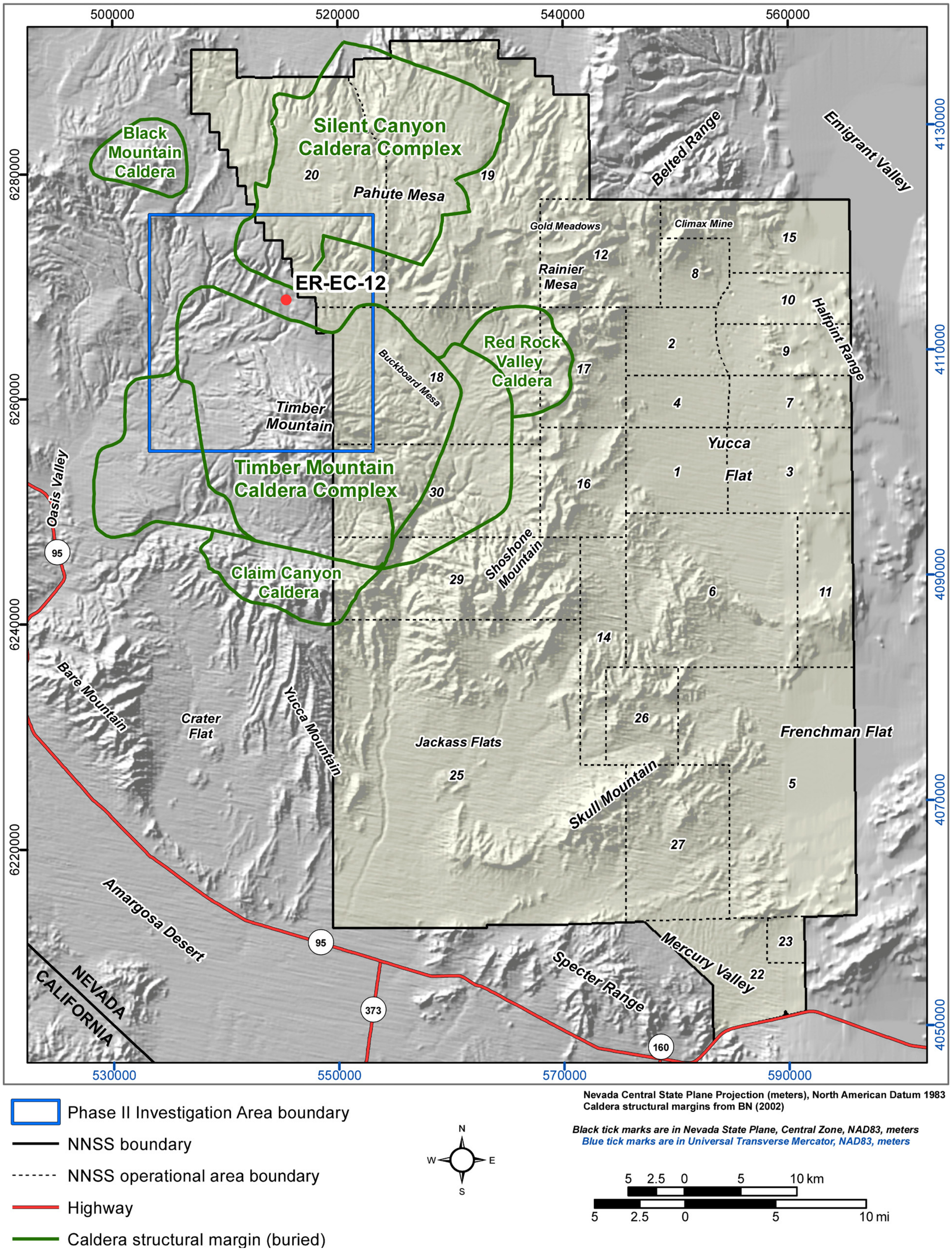


Figure 1-1
Reference Map Showing the Location of Well ER-EC-12

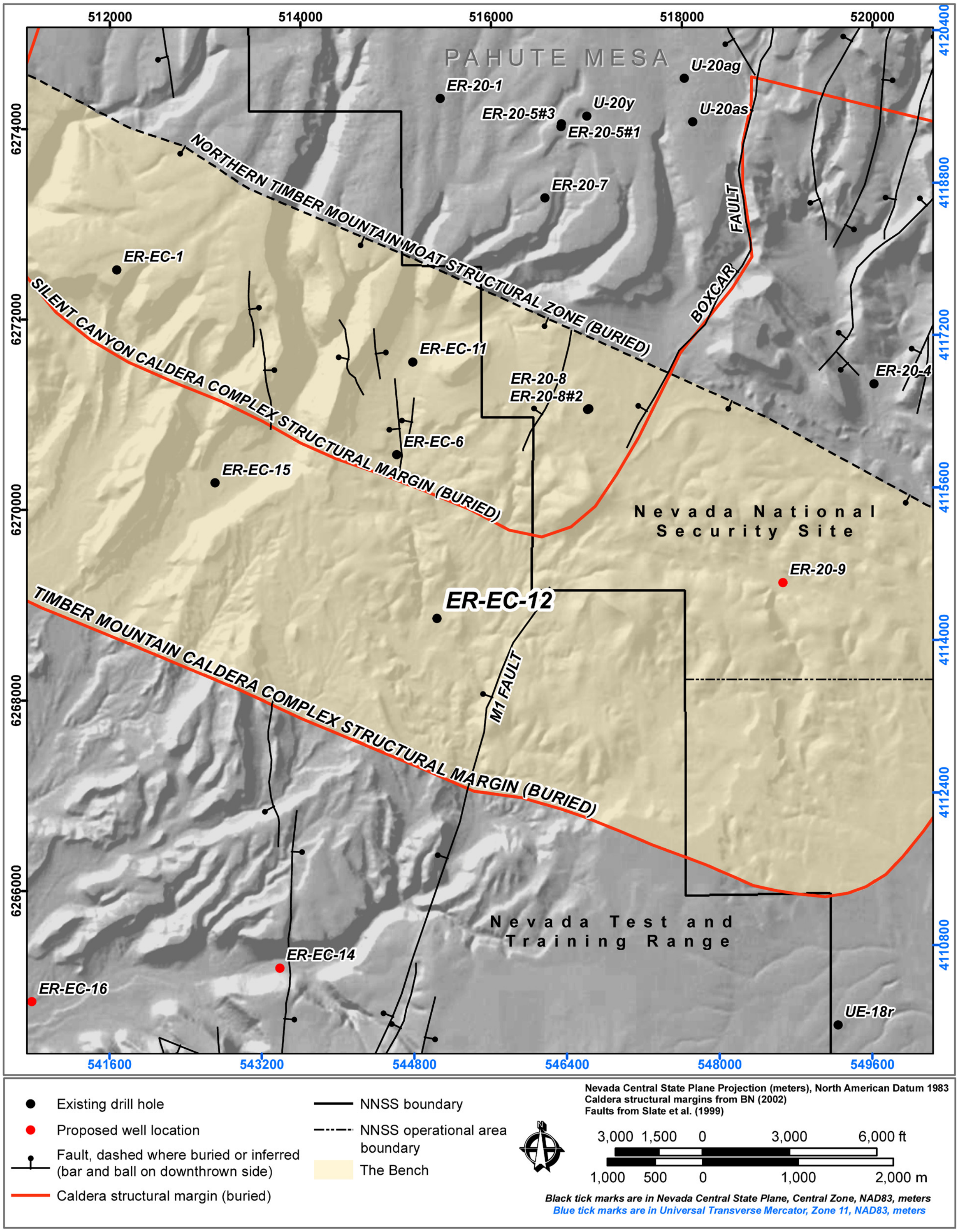


Figure 1-2
Shaded Relief Map of the Well ER-EC-12 Area Showing the Location of the Bench

model (HFM) (Bechtel Nevada [BN], 2002) and subsequent flow and transport modeling (Stoller-Navarro Joint Venture [SNJV], 2009a).

More specifically, the primary purpose of this well was to provide information that will refine the understanding of the hydrogeology in the Bench area between Pahute Mesa and the Timber Mountain caldera complex (TMCC) (Figure 1-1). In particular, the well was intended to help define the structural position and hydraulic parameters for the Benham aquifer (BA), the Tiva Canyon aquifer (TCA), the Topopah Spring aquifer (TSA), and nearby faults and caldera structures. A secondary purpose of this well was to further investigate migration of radionuclides from former testing areas on Pahute Mesa (SNJV, 2009a). Radionuclides have been detected at UGTA wells located to the north (up-gradient) of Well ER-EC-12, in a contaminant plume thought to originate from the TYBO and BENHAM underground nuclear tests (UGTs) (SNJV, 2009b). Consequently, Well ER-EC-12 may be a favorable location for a long-term monitoring well.

1.2 Project Organization

The construction of Well ER-EC-12 was intended to help fulfill the goals of the UGTA Sub-Project. Several 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 regarding successful construction of Well ER-EC-12 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), Navarro Nevada Environmental Services, LLC (NNES; environmental contractor), 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-EC-12 drilling advisory team, which included the NNSA/NSO UGTA Sub-Project Manager, the NNES 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 assure that Well ER-EC-12 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.

NNES was the principal environmental contractor for the project, and NNES personnel collected geologic and hydrologic data during drilling. (NNES's name was changed to Navarro-Intera, LLC (N-I), effective July 14, 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, Incorporated (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 (FAWPs) number D-003-001.10 and D-006-001.10 (NSTec, 2010a and 2010b).

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, 2010a; 2010b; NNES, 2010a) 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 Well ER-EC-12. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. A well data report prepared by N-I contains additional information on fluid management, waste management, and environmental compliance for the project (N-I, 2011). 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, and 2009b). 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) and the addendum to the criteria document (NNES, 2010b). 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

Well ER-EC-12 is located on the Nevada Test and Training Range at an elevation of 1,686.2 m (5,532.0 ft). It is located south of Pahute Mesa, approximately 1,768 m (5,800 ft) south of Well ER-EC-6; 2,713 m (8,900 ft) southwest of Wells ER-20-8 and ER-20-8#2; 2,713 m (8,900 ft) south of Well ER-EC-11; and 2,713 m (8,900 ft) southeast of Well ER-EC-15. The locations of these wells in relation to Well ER-EC-12 are shown in Figure 1-3. Additional information about Well ER-EC-12 is provided in Table 1-1.

Well ER-EC-12 is located in an area known as the Bench, which is a structural domain defined as the area between the northern Timber Mountain moat structural zone (NTMMSZ) and the structural margin of the TMCC (Figure 1-2). Well ER-EC-12 is located on volcanic terrain on the southern section of the Bench, between the buried Silent Canyon caldera complex (SCCC) structural margin and the TMCC structural margin. The surface topography in the vicinity consists of gentle rolling hills. The surface topography at the wellhead is relatively flat, with drainage to the south (Figure 1-3).

The closest UGTs to Well ER-EC-12 are TYBO (U-20y) and BELMONT (U-20as) (Figure 1-3). Well ER-EC-12 was sited approximately 5,578 m (18,300 ft) south-southwest of the TYBO test location and approximately 5,883 m (19,300 ft) southwest of the BELMONT test location. The TYBO test was conducted below the water table, and BELMONT was conducted approximately 9 m (29 ft) above the water table (U.S. Department of Energy, Nevada Operations Office [DOE/NV], 2000a). See Table 1-2 for information pertaining to nearby tests.

1.4 Objectives

The primary purpose for drilling Well ER-EC-12 was to obtain detailed hydrogeologic information from the shallow- to intermediate-depth Tertiary volcanic section in order to refine the understanding of the hydrogeology in the Bench area, between the NTMMSZ and the TMCC (NNSA/NSO, 2009a; NNES, 2010b). In particular, the well was intended to help define the structural position and hydraulic parameters for the BA, TCA, and TSA. The well was also expected to provide information regarding the nature and hydrologic character of the M1 fault (Figure 1-2) and the collapse collar of the TMCC (see Section 4.0 for more information about these geologic features).

A secondary purpose of this well was to further investigate migration of radionuclides from former testing areas on Pahute Mesa. Radionuclides have been detected at UGTA

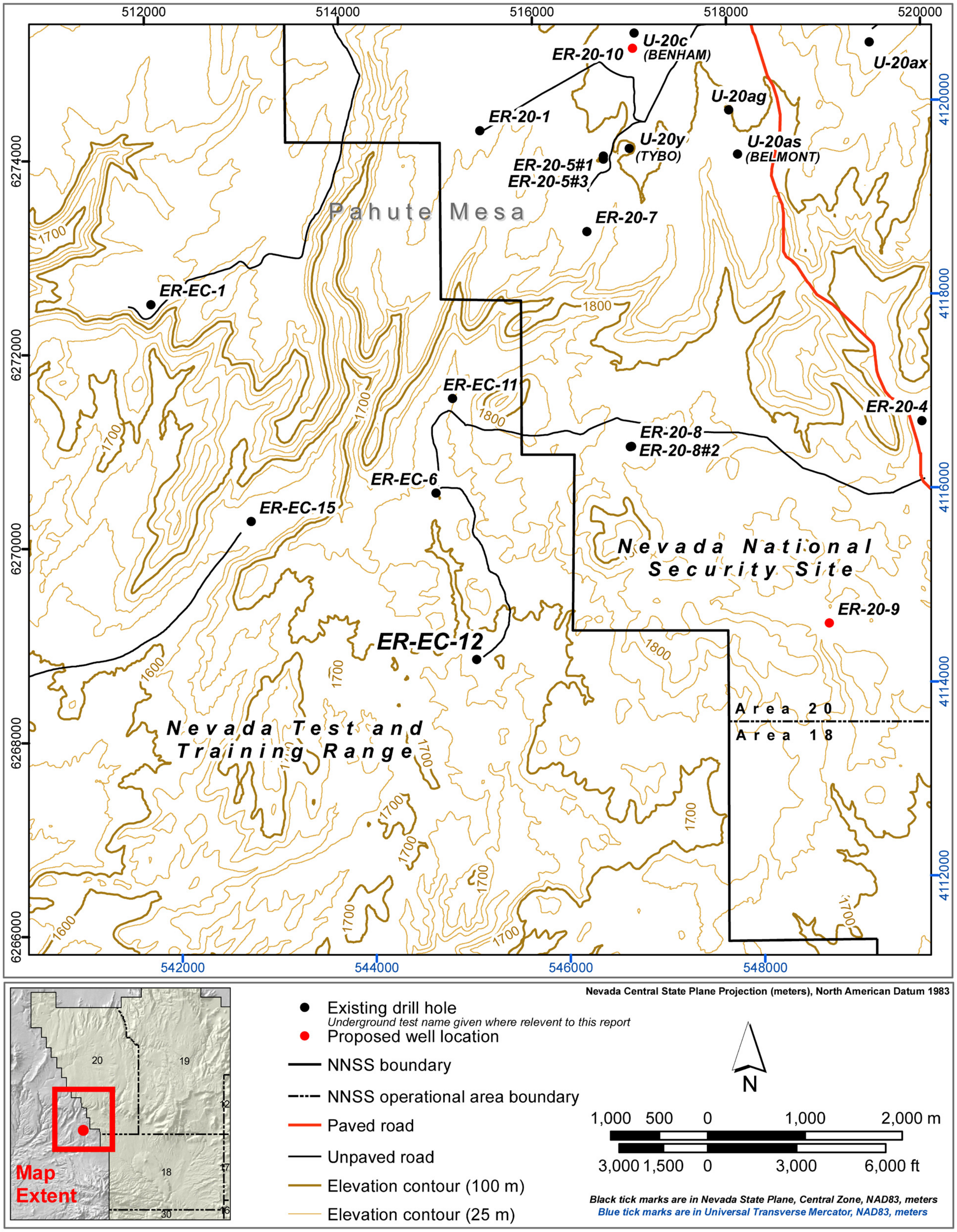


Figure 1-3
Topographic Map of the Well ER-EC-12 Area, Showing the Locations of Roads and Nearby Drill Holes

Table 1-1
Site Data Summary for Well ER-EC-12

Site Coordinates [a]	**Nevada State Plane (Central Zone) (NAD 27)** N 882,101.1 ft E 550,891.2 ft **Nevada State Plane (Central Zone) (NAD 83)** N 6,268,865.6 m E 515,432.1 m **UTM (Zone 11) (NAD 83)** N 4,114,210.7 m E 545,018.9 m **UTM (Zone 11) (NAD 27)** N 4,114,013.6 m E 545,099.1 m **Geographic (NAD 83)** (degrees, minutes, seconds) Latitude: 37˚ 10' 23.7" Longitude: 116˚ 29' 34.4" **Township and Range** Northeast 1/4 of Northwest 1/4 of Section 10, Township 9 South, Range 49 East
Surface Elevation [a, b]	1,686.2 m (5,532.0 ft)
Drilled Depth	1,240.2 m (4,069 ft)
Fluid-Level Depth [c]	415.4 m (1,363.0 ft)
Fluid-Level Elevation	1,270.7 m (4,169 ft)
Surface Geology	Nonwelded ash-flow tuff (Ammonia Tanks Tuff)

a Measurements made by NSTec Survey using NAD 27 Nevada State Plane coordinates in feet. All other coordinates listed were calculated from NAD 27 feet using Corpscon (U.S. Army Corps of Engineers, 2004). NAD = North American Datum (National Archives and Records Administration [NARA], 1989; U.S. Coast and Geodetic Survey, 1927). UTM = Universal Transverse Mercator.

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

c Measured in the shallow piezometer string by N-I on August 5, 2010.

Table 1-2
Information for Underground Nuclear Tests Relevant to Well ER-EC-12

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	05/14/1975	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	02/12/1982	1,900 (6,234)	638 (2,093)	1,262 (4,141)	619 (2,031)	1,281 (4,203)	20–150	Tbp	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 DOE/NV (2000a)
b NNSA/NSO (2009a)
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 HSU = hydrostratigraphic unit
Hydrostratigraphic nomenclature:
- **TSA** = Topopah Spring aquifer
- **UPCU** = upper Paintbrush confining unit
- **BA** = Benham aquifer
- **CHZCM** = Calico Hills zeolitic composite unit

Wells ER-20-5, ER-20-7, ER-20-8/ER-20-8#2, and ER-EC-11 (DOE/NV, 1997; NNSA/NSO, 2010a; 2011a; 2010b). The leading edge of this contaminant plume (thought to originate from the TYBO and BENHAM UGTs [DOE/NV, 1997]) may be located just north (up-gradient) of Well ER-EC-6 (Figure 1-3), where no radionuclides were detected. Well ER-EC-12, located south-southeast of Well ER-EC-6, is expected to produce data that will improve modeling of groundwater flow and contaminant transport within CAUs 101 and 102, and may be a favorable location for a long-term monitoring well.

The objectives for Well ER-EC-12, as described in Appendix D of the drilling and completion criteria document for the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells and its addendum (SNJV, 2009a; NNES, 2010b), 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 BA, TCA, and the TSA.

   – Refine the location of structural features such as the collapse collar of the TMCC and the M1 fault (the possible southern extension of 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 former testing areas in southwestern Pahute Mesa.
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.

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 UGTs conducted in southwestern Pahute Mesa.

Additional data that will help characterize the hydrology of the Bench area and southwestern Pahute Mesa will be obtained during later hydraulic testing at this well. Specific criteria for these later tests will be provided elsewhere (e.g., FAWPs and the well development and testing plan), but, ultimately, Well ER-EC-12 is expected to provide data for determination of horizontal and vertical conductivity and hydraulic properties of saturated hydrostratigraphic units (HSUs) penetrated.

The completed well will accommodate single-well hydraulic testing and could be a potential observation well (and possibly a pumping well) for future multiple-well aquifer tests.

1.5 Project Summary

This section summarizes construction operations for Well ER-EC-12; the details are provided in Sections 2.0 through 7.0 of this report.

A 106.7-centimeter (cm) (42-inch [in.]) diameter surface conductor hole was constructed by drilling to a depth of 16.0 m (52.5 ft), and installing a string of 30-in. conductor casing to the depth of 15.7 m (51.5 ft). Drilling of the main hole with a 20½-in. tricone bit, using an air-foam drilling fluid in conventional circulation, began on June 25, 2010. The 52.1-cm (20.5-in.) diameter surface hole was drilled to a depth of 429.5 m (1,409 ft) and 16-in. surface casing was set at 385.8 m (1,265.9 ft). The hole diameter was decreased to 37.5 cm (14.75 in.) at the depth of 429.5 m (1,409 ft) and the well was drilled to a total depth (TD) of 1,240.2 m (4,069 ft), reached on July 9, 2010. The top of the TCA was encountered at 578.5 m (1,898 ft). The top of the TSA was reached at 944.9 m (3,100 ft). The last open-hole fluid-level depth measured prior to installation of the completion string was 416.4 m (1,366 ft) on July 14, 2010, during geophysical logging. On August 5, 2010, about two weeks after the well was completed, a fluid level of 415.4 m (1,363.0 ft) was measured in the shallow piezometer string (in the TCA). No tritium above the minimum detection level of the field instruments was detected in this hole during drilling.

Three piezometer strings were installed in Well ER-EC-12. Each string is composed of 2⅞-in. stainless-steel tubing that hangs on 2⅜-in. carbon-steel tubing via a crossover sub. The shallow string was landed at 817.2 m (2,681.2 ft), the intermediate string was landed at 1,134.6 m (3,722.3 ft), and the deep string was landed at 1,194.5 m (3,918.8 ft). The shallow piezometer string is slotted from 584.8 to 817.2 m (1,918.6 to 2,681.2 ft) for monitoring within the TCA. The intermediate piezometer string is slotted from 987.5 to 1,134.6 m (3,239.9 to 3,722.3 ft) for monitoring within the TSA. The deep piezometer string is slotted from 1,181.6 to 1,194.5 m (3,876.7 to 3,918.8 ft) for monitoring within the Crater Flat confining unit (CFCU), the deepest unit encountered in the borehole. The three completion zones are gravel-packed and separated by layers of cement.

The completion casing string, set to the depth of 1,140.6 m (3,742 ft), consists of 6⅝-in. stainless-steel casing hanging from 7⅝-in. internally epoxy-coated carbon-steel casing via a crossover sub. The carbon-steel casing is positioned in the unsaturated zone at a point approximately 3.4 m (11 ft) above the water table. The 6⅝-in. stainless-steel casing has two slotted intervals, one at 588.5 to 817.2 m (1,930.8 to 2,681.1 ft) and the other at 993.4 to 1,133.5 m (3,259.1 to 3,718.7 ft), allowing access to the TCA and TSA, respectively. These two zones are gravel-packed and separated by an interval of cement within the annulus outside the completion casing. A bridge plug was set at 861.1 m (2,825 ft) inside the completion casing to isolate the two aquifers.

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 15.8 m (52 ft) to TD, and 26 sidewall core samples were recovered at various depths between 332.2 and 1,193.3 m (1,090 and 3,915 ft). Open-hole geophysical logging of the well was conducted 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 well was drilled entirely within Tertiary volcanic rocks.

1.6 Contact Information

Inquiries concerning Well ER-EC-12 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
Post Office Box 98518
Las Vegas, Nevada 89193-8518

2.0 Drilling Summary

2.1 Introduction

This section contains detailed descriptions of the drilling process and fluid management issues. The general drilling requirements for all the Pahute Mesa Phase II wells were provided in *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a) and its addendum (NNES, 2010b). Specific requirements for Well ER-EC-12 were outlined in FAWP numbers D-003-001.10 and D-006-001.10 (NSTec, 2010a and 2010b). The layout of the drill site is shown in Figure 2-1. Figure 2-2 is a chart of the drilling and completion history for Well ER-EC-12. A summary of drilling statistics for the well is given in Table 2-1. The following information was compiled primarily from NSTec daily drilling reports.

2.2 Drilling History

Field operations at Well ER-EC-12 began on March 23, 2010, when an NSTec crew set up the Mobile Drill B-59 hollow-stem auger drill rig and drilled a 20.3-cm (8-in.) diameter pilot hole to refusal at the depth of 14.6 m (48 ft). Starting on March 24, 2010, NSTec drillers used the Auger II drill rig to drill a 106.7-cm (42-in.) diameter conductor hole to the depth of 16.0 m (52.5 ft). A string of 30-in. conductor casing was set at the depth of 15.7 m (51.5 ft). The conductor casing was cemented in place on April 5, 2010, using 9.2 cubic meters (m^3) (12.1 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 seal the annulus from the depth of 16.0 m (52.5 ft) to ground level.

The UDI crews arrived on June 17, 2010, and began rigging up the Wilson Mogul 42B drill rig. They finished rigging up on June 24, 2010, and began drilling from the top of cement inside the 30-in. casing at 13.4 m (44 ft) on June 25, 2010. 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. tricone bit mounted 5.2 m (17 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 21.0 m (69 ft).

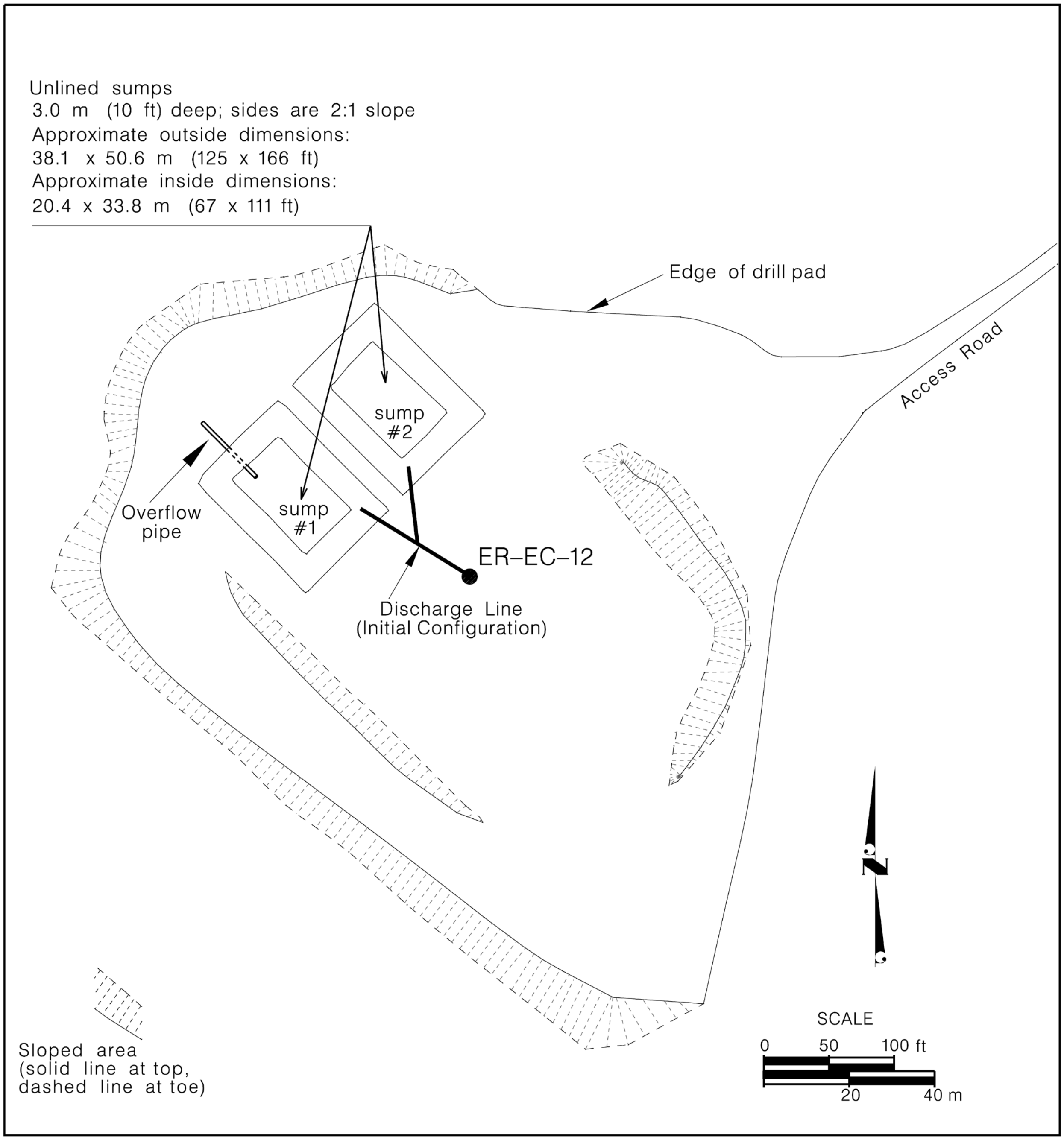
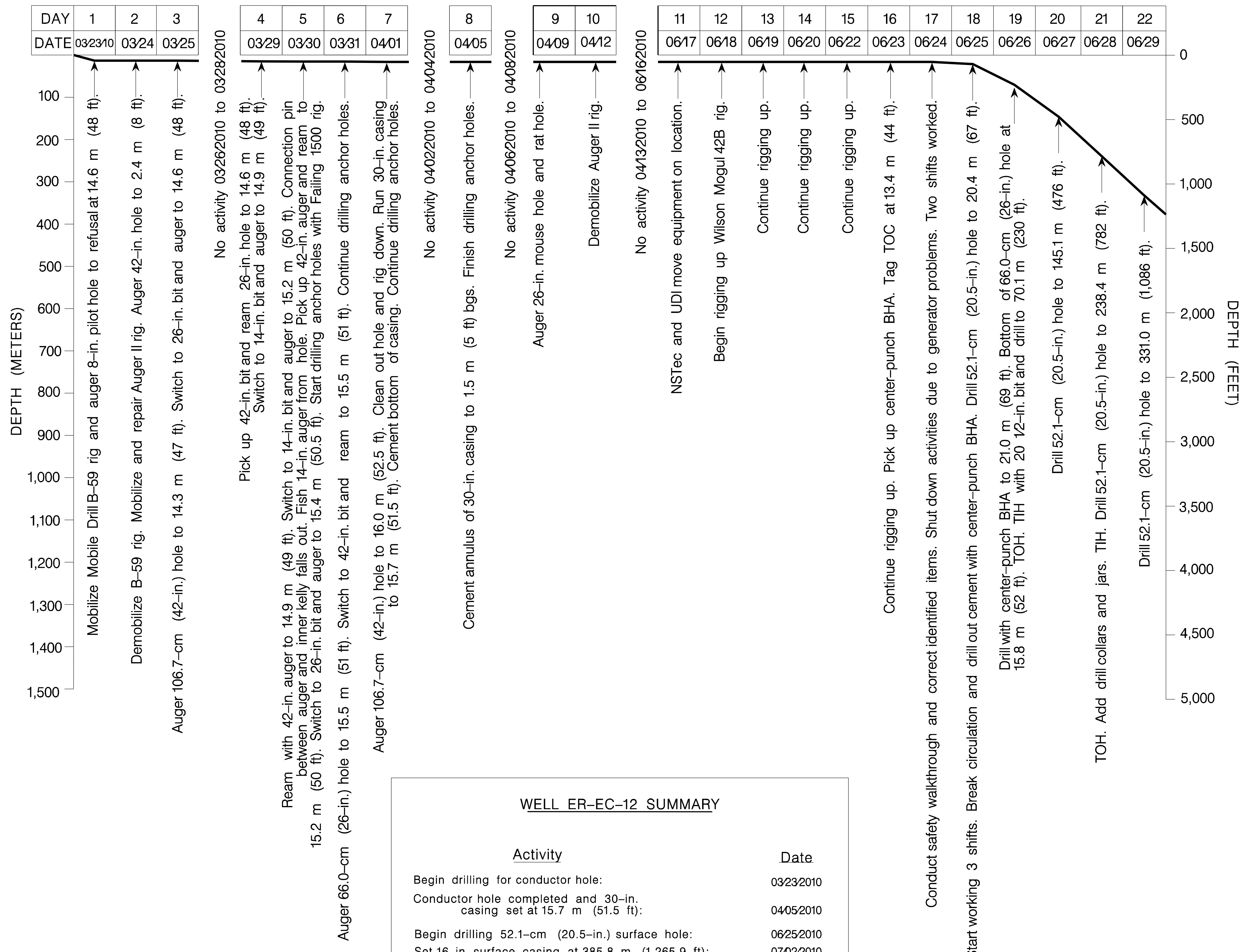


Figure 2-1
Drill Site Configuration for Well ER-EC-12

LEGEND

BA	Baker Atlas
bgs	below ground surface
BHA	bottom hole assembly
cm	centimeter(s)
CT	chemistry /temperature
DPS	deep piezometer string
DRI	Desert Research Institute
ft	foot (feet)
ft^3	cubic feet
in.	inch(es)
IPS	intermediate piezometer string
m	meter(s)
m^3	cubic meters
NAIL	nuclear annular investigation log
N–I	Navarro – Intera, LLC
NSTec	National Security Technologies, LLC
P–SWC	percussion sidewall core
RIH	run in hole
R–SWC	rotary sidewall core
SLM	steel line measurement
SPS	shallow piezometer string
TD	total depth
TFL	thermal flow log
TIH	trip into hole
TOC	top of cement
TOF	top of fluid
TOH	trip out of hole
UDI	United Drilling Inc.
WOC	wait on cement



WELL ER–EC–12 SUMMARY

Activity	Date
Begin drilling for conductor hole:	03/23/2010
Conductor hole completed and 30–in. casing set at 15.7 m (51.5 ft):	04/05/2010
Begin drilling 52.1–cm (20.5–in.) surface hole:	06/25/2010
Set 16–in. surface casing at 385.8 m (1,265.9 ft):	07/02/2010
Begin drilling 37.5–cm (14.75–in.) hole:	07/03/2010
Reach total drilled depth of 1,240.2 m (4,069.0 ft):	07/09/2010
Well completed:	07/21/2010

FIGURE 2–2

WELL ER–EC–12
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 2

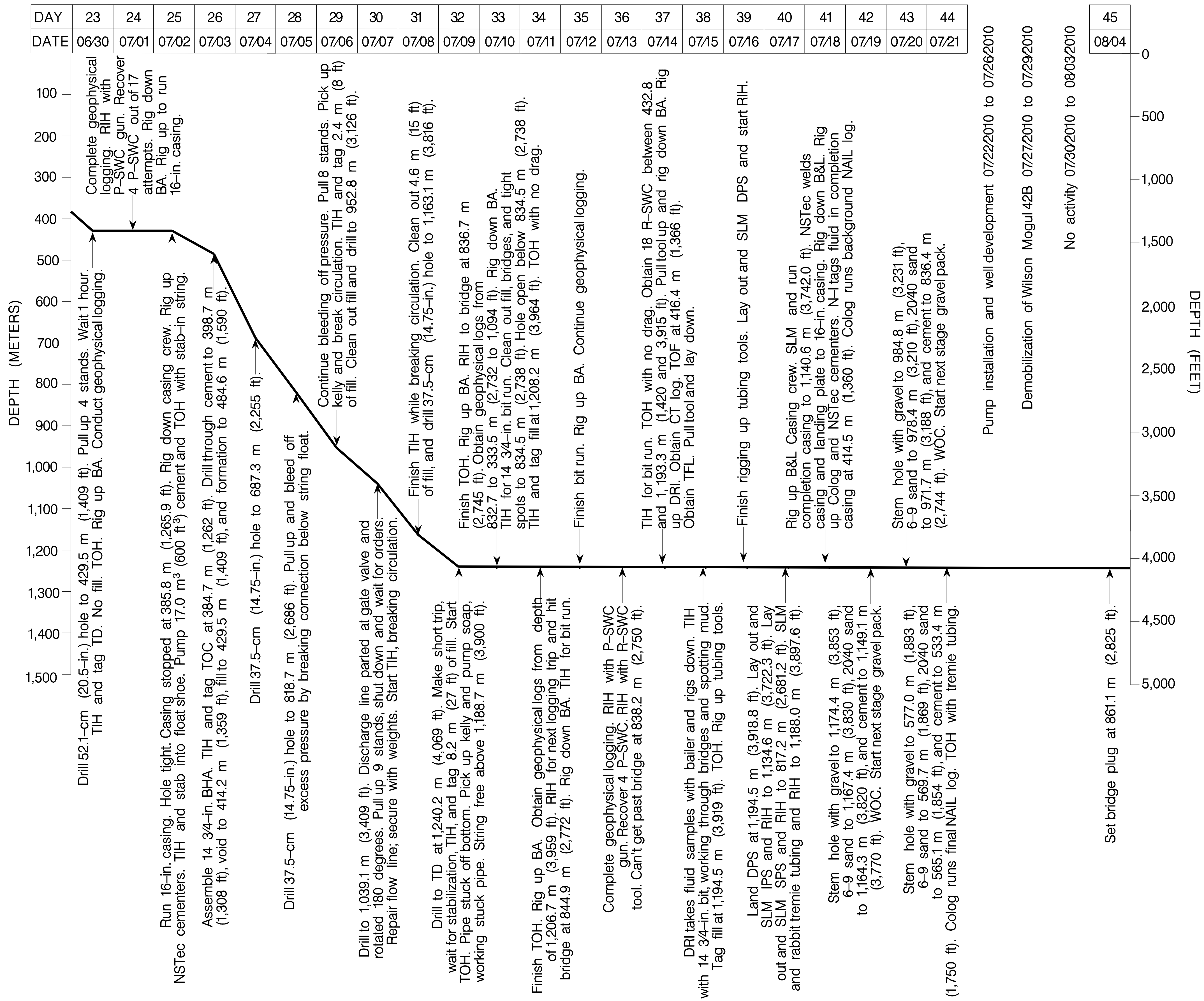


FIGURE 2-2

WELL ER-EC-12
DRILLING AND COMPLETION HISTORY

SHEET 2 OF 2

Table 2-1
Abridged Drill Hole Statistics for Well ER-EC-12

LOCATION DATA:

Coordinates:

Nevada State Plane (Central Zone)	(NAD 27):	N 882,101.1 ft	E 550,891.2 ft
Nevada State Plane (Central Zone)	(NAD 83):	N 6,268,865.6 m	E 515,432.1 m
Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,114,210.7 m	E 545,018.9 m
Universal Transverse Mercator (Zone 11)	(NAD 27):	N 4,114,013.6 m	E 545,099.1 m

Surface Elevation [a]: 1,686.2 m (5,532.0 ft)

DRILLING DATA:

Spud Date: 06/25/2010 (main hole drilling with Wilson Mogul 42B rig)

Total Depth (TD): 1,240.2 m (4,069 ft)

Date TD Reached: 07/09/2010

Date Well Completed: 07/21/2010 (date completion string was cemented in place)

Hole Diameter: 106.7 cm (42 in.) from surface to 16.0 m (52.5 ft); 52.1 cm (20.5 in.) from 16.0 to 429.5 m (52.5 to 1,409 ft); 37.5 cm (14.75 in.) from 429.5 m (1,409 ft) to TD of 1,240.2 m (4,069 ft).

Drilling Techniques: Drill 20.3-cm (8-in.) pilot hole with hollow-stem auger rig to 14.6 m (48 ft), then drill 106.7-cm (42-in.) hole from surface to 16.0 m (52.5 ft) with dry-hole auger. Center-punch with 20½-in. tricone bit mounted below a 26-in. hole opener to 21.0 m (69 ft); rotary drill with 20½-in. tricone bit, using air-foam in direct circulation from 16.0 to 429.5 m (52.5 to 1,409 ft); rotary drill with 14¾-in. tricone bit, using air-foam and polymer in direct circulation to the TD of 1,240.2 m (4,069 ft).

CASING DATA: 30-in. conductor casing to 0 to 15.7 m (0 to 51.5 ft); 16-in. surface casing 0 to 385.8 m (0 to 1,265.9 ft); 7⅝-in. casing to 411.6 m (1,350.4 ft); cross-over sub at 411.6 to 412.1 m (1,350.4 to 1,352.0 ft); 6⅝-in. casing 412.1 to 1,140.6 m (1,352.0 to 3,742.0 ft).

WELL COMPLETION DATA [b]:

A string of 6⅝-in. stainless-steel casing hangs from 7⅝-in. epoxy-coated carbon-steel casing via a crossover sub. The carbon-steel casing terminates within the unsaturated zone approximately 3.4 m (11 ft) above the water table. The 7⅝-in. outside diameter casing has an inside diameter (id) of 17.701 cm (6.969 in.). The 6⅝-in. casing has an id of 15.504 cm (6.104 in.) and was landed at 1,140.6 m (3,742.0 ft). Three 2⅞-in. piezometer strings (id of 5.994 cm [2.36 in.]) were also installed. The three 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 shallow piezometer string was landed at 817.2 m (2,681.2 ft), the intermediate piezometer string was landed at 1,134.6 m (3,722.3 ft), and the deep piezometer string was landed at 1,194.5 m (3,918.8 ft). A bridge plug was set at 861.1 m (2,825 ft).

Depth of Slotted Sections:	6⅝-in. completion casing:	588.5 to 817.2 m (1,930.8 to 2,681.1 ft) 993.4 to 1,133.5 m (3,259.1 to 3,718.7 ft)
	Shallow 2⅞-in. piezometer string (TCA):	584.8 to 817.2 m (1,918.6 to 2,681.2 ft)
	Intermediate 2⅞-in. piezometer string (TSA):	987.5 to 1,134.6 m (3,239.9 to 3,722.3 ft)
	Deep 2⅞-in. piezometer string (CFCU):	1,181.6 to 1,194.5 m (3,876.7 to 3,918.8 ft)

Depth of Sand Packs:	565.1 to 577.0 m (1,854 to 1,893 ft)	971.7 to 984.8 m (3,188 to 3,231 ft)	1,164.3 to 1,174.4 m (3,820 to 3,853 ft)
Depth of Gravel Packs:	577.0 to 836.4 m (1,893 to 2,744 ft)	984.8 to 1,149.1 m (3,231 to 3,770 ft)	1,174.4 to 1,194.5 m (3,853 to 3,919 ft)

Depth of Pump: Not installed at time of completion

Water Depth [c]: Fluid-level depths measured on August 5, 2010: 415.4 m (1,363.0 ft) in the shallow 2⅞-in. piezometer string; 415.8 m (1,364.3 ft) in the intermediate 2⅞-in. piezometer string; and 413.6 m (1,356.9 ft) in the deep 2⅞-in. piezometer string.

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Baker Atlas, Desert Research Institute, Colog

SURVEYING CONTRACTOR: National Security Technologies, LLC

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

b See Section 7.0 of this report for more detailed data on completion intervals. See Table A-2-1 for more details about the casing and tubing materials. TCA = Tiva Canyon aquifer; TSA = Topopah Spring aquifer; CFCU = Crater Flat confining unit.

c Fluid level tags by Navarro-Intera.

Drilling of the surface hole with a 20½-in. rotary tricone bit and air-foam began June 26, 2010. The drilling fluid was an air/water/soap mix in conventional circulation. Drilling continued uneventfully with no fill reported after pipe connections. Drilling was stopped on June 28, 2010, to make up a new bottom hole assembly. When the crew ran the drill pipe back into the hole, they tagged 0.3 m (1 ft) of fill at the bottom. The 52.1-cm (20.5-in.) hole was drilled to a depth of 429.5 m (1,409 ft), at which point drilling was suspended to allow for the analysis of tritium and lithium bromide tracer samples.

The tritium analysis indicated 1,597 picocuries per liter (pCi/L) of tritium, which is below the minimum detection level (or minimum detectable concentration [MDC]) of the field instruments, at the depth of 429.5 m (1,409 ft). The tracer analysis gave an estimated water-production rate of 11.4 to 15.1 liters per minute (3 to 4 gallons per minute) from the depth of approximately 420.6 m (1,380 ft); this was the first observation of groundwater in the fluid returns.

UDI then circulated the borehole, waited an hour, and then checked for fill. No fill was encountered and the crew removed the drill pipe from the hole in preparation for geophysical logging and the installation of surface casing.

Geophysical logging and sidewall sampling began on June 30, 2010, and proceeded smoothly. However, the first attempt to collect percussion sidewall cores was unsuccessful due to problems with the tool. The problem was quickly corrected and when the tool was lowered back into the borehole to resume coring, it tagged fill at a depth of 426.1 m (1,398 ft), indicating a total accumulation of 3.4 m (11 ft) of fill during logging. After the remainder of the cores were collected, Baker Atlas rigged down and departed the location on July 1, 2010.

After logging operations were complete, the casing subcontractor began installing a string of 16-in. casing. Resistance due to a "tight hole" was encountered at 26.5 m (87 ft) and the casing could not get past 29.6 m (97 ft). Casing operations were stopped in order to remove all the centralizers from the casing. The crew then worked the casing through the tight spot until the casing was again obstructed due to tight hole conditions at 385.8 m (1,265.9 ft) on July 2, 2010. The casing was set at that depth, which is 40.3 m (132.1 ft) above its intended depth of 426.1 m (1,398 ft). The bottom of the casing was cemented with 17.0 m^3 (22.2 yd^3) of Type II neat cement on July 2, 2010. The top of cement in the annulus is estimated to be at the depth of 301.8 m (990 ft), based on geophysical log data.

After installation of the casing, on July 3, 2010, the drill crew lowered a bottom-hole assembly with a 14¾-in. bit into the hole. They tagged the top of cement at 384.7 m (1,262 ft) inside the 16-in. casing. They drilled cement from 384.7 to 398.7 m (1,262 to 1,308 ft) and contacted a "void" at 398.7 m (1,308 ft). They lowered the string through the "void" from 398.7 to 414.2 m (1,308 to 1,359 ft) and cleaned out fill from 414.2 to 419.7 m (1,359 to 1,377 ft). Circulation was lost and took 30 minutes to regain. The drillers then cleaned out fill from 419.7 to 429.5 m (1,377 to 1,409 ft) and circulated fluid to clean the hole.

Drilling with the 14¾-in. bit through formation commenced on July 3, 2010. The drilling fluid was an air/water/soap mix with a polymer additive in conventional circulation. Connections made at 637.9, 647.4, 656.5, and 704.4 m (2,093, 2,124, 2,154, and 2,311 ft) each had 1.5 m (5 ft) of fill. Connections made at 704.4 and 713.8 m (2,311 and 2,342 ft) had 1.2 m (4 ft) of fill.

On July 5, 2010, after making a connection at 818.7 (2,686 ft) and adding a string float between joints 58 and 57, the pressure rapidly increased to 1,200 pounds per square inch (psi). Despite attempts to decrease the air pressure below the string float using the soap pump, the pressure increased to 1,400 psi. The drillers turned off the pump, pulled up to the string float, and broke the connection below it to bleed off the pressure from the string. The drillers then installed another string float between joints 48 and 49. They broke circulation, tagged fill at 816.3 m (2,678 ft), cleaned out the fill, and then resumed drilling.

On July 7, 2010, N-I notified NSTec that there was a hole at the end of the flow line. UDI continued drilling while waiting for the welder to arrive, but suspended drilling operations when the welder arrived to patch the hole in the flow line. UDI then attempted to regain circulation after the line was repaired. During initial hole unloading at a depth of 1,039.1 m (3,409 ft), the pressure surge from the fluid being discharged stressed the flow line assembly. During this surge, the cast iron body of the 10-in. gate valve on the flow line parted just behind the downstream flange connecting it to the 16-in. portion of the flow line and turned it 180 degrees. The line impacted the cuttings collection area; however, no injuries resulted from the incident. Operations were shut down and the project manager was called for further instructions.

The incident was investigated according to NSTec procedures (NSTec Incident Report Case #2010-116). A remedial action was taken that required that the flow line be redesigned to strengthen it and fasten it to the ground more securely, thus reducing the likelihood that a high-pressure surge could cause it to come loose. The fork in the flow line and gate valves used to re-direct discharge to the two sumps (Figure 2-1) were removed and the 16-in. flow line section directed to sump #2 was removed and used for the new flow line into sump #1. Four 152.4-cm (60-in.) weights (5,443.1 kilograms [12,000 pounds] each), stacked two high and secured with tie-downs, were placed on both sides of the flow line. After the line was secured, UDI began running the drill pipe back into the hole and cleaned out 4.6 m (15 ft) of fill. Drilling of the 37.5-cm (14.75-in.) hole resumed on July 8, 2010.

Drilling continued, but under conditions with intermittent circulation and high volume and high pressure during discharge. While circulating fluid at 1,240.2 m (4,069 ft) below ground surface on July 9, 2010, a hole developed in the 10¾-in. section of the flow line near the 16-in. surface casing (wellhead). Drilling operations were immediately shut down and the project manager was notified. At this time, based on drill cuttings data, site geologists believed the borehole had entered the Topopah Spring Tuff, which was the deepest target aquifer. However, based on the estimated amount of time it would take to repair the flow line and then drill the estimated 61.0 to 91.4 m (200 to 300 ft) to reach the base of the current geologic unit, it was decided to terminate the hole at the current depth of 1,240.2 m (4,069 ft). The drillers pulled up a few stands of drill pipe, to 1,066.8 m (3,500 ft), and waited for the hole to stabilize. They ran the pipe back in and tagged fill at 1,232.0 m (4,042 ft), then removed the drill string from the borehole in preparation for logging operations.

Geophysical logging and sidewall sampling operations were conducted by Baker Atlas crews on July 10–14, 2010. During running the Digital Spectralog and Compensated Z-Densilog, bridges (fill material that blocks the borehole) were encountered at 836.7 m (2,745 ft) and 844.9 m (2,772 ft). The logging crew also had to work through a bridge at 835.8 m (2,742 ft) while running the R_t Explorer log. During the percussion core run, a bridge was encountered at 835.8 m (2,742 ft). The logging crew worked the tool through the bridge and continued running the tool in to a depth of 1,199.7 m (3,936 ft), then started taking cores at the prescribed depths as they pulled the tool up. They encountered a tight spot at 845.8 m (2,775 ft) and could not work below that point, but continued collecting samples through the upper part of the hole. After completing percussion gun sampling, the logging crew ran the rotary core tool, but could not work past a bridge at 835.2 m (2,740 ft), and pulled out. The UDI crew ran the drilling assembly into the hole and spent several hours working through the tight spots between 838.2 m and 850.4 m (2,750 and 2,790 ft) to open the hole. After the hole was cleaned out, Baker Atlas completed all required rotary core sampling with only minor problems with tight spots. They tagged fill at the depth of 1,196.0 m (3,924 ft).

After completing rotary sidewall coring operations, the Baker Atlas crew rigged down and preparations were made for logging and water sampling by DRI personnel. DRI operations were completed on July 15, 2010, though they also encountered some problems due to tight hole conditions.

To increase the chances of successfully running the piezometer and completion strings through the problem sloughing zone between 823.0 and 853.4 m (2,700 and 2,800 ft), it was decided to place a slug of bentonite/polymer mud to stabilize the borehole. On July 15, 2010, UDI ran the 14¾-in. bit into the hole to place the mud, and encountered bridges at 835.8 and 841.2 m (2,742 and 2,760 ft). They were able to work through the bridges and tagged fill at 1,194.5 m (3,919 ft). They pulled 9.1 m (30 ft) off bottom and placed mud up to the depth of 896.1 m (2,940 ft).

On July 16 and 17, 2010, the drill crew installed three 2⅞-in. piezometer strings, each with one slotted interval. Fill was tagged at 1,194.5 m (3,919 ft) prior to running the deep string. The deep piezometer string was set at 1,194.5 m (3,918.8 ft), the intermediate piezometer string was set at 1,134.6 m (3,722.3 ft), and the shallow piezometer string was set at 817.2 m (2,681.2 ft). See Section 7.0 for completion details.

On July 18, 2010, the casing subcontractor installed the 6⅝-in. completion casing string. This string has two slotted intervals, and it was landed at a depth of 1,140.6 m (3,742.0 ft). The completion casing and the three piezometer strings were sand- and gravel-packed and cemented (see Section 7.0 for details). Stemming operations were completed on July 21, 2010.

Since mud was placed in the borehole and well development and testing were not scheduled for as much as a year, it was decided to clean out as much mud as possible from the well using a submersible pump. After stemming operations were completed, UDI attempted to run the pump in the hole on July 22, 2010. The pump could not be advanced past the depth of 442.0 m (1,450 ft) due to excessive resistance, despite several attempts to work through it. They then removed the pump string from the hole and ran a string of 3½-in. Hydril tubing into the hole. No obstructions were encountered, so it was decided that a smaller diameter pump was needed. On July 24, 2010, the pump string with the smaller diameter pump was landed at 530.7 m (1,741 ft), with the pump intake at approximately 516.0 m (1,693 ft). Pumping took place until July 26, 2010, and then the pump was removed.

The drillers started demobilizing the rig and drilling equipment on July 26, 2010, and crews worked one shift per day after that, until demobilization to the Well ER-20-4 site was completed on August 5, 2010. A bridge plug that isolates the two slotted intervals in the completion casing string was installed at 861.1 m (2,825 ft) by Baker Atlas on August 4, 2010.

The inclination of the borehole was determined from borehole orientation logs run by Baker Atlas during each logging operation (June 30 and July 11, 2010). Most of the changes in borehole orientation visible on the borehole directional survey plots are relatively gentle and generally correspond to formation changes or changes in drilling parameters. However, at a depth of about 610 m (2,000 ft), the borehole path makes a dramatic reversal from a generally southeasterly direction to a northwesterly direction. This depth roughly corresponds to the top of the welded Tiva Canyon Tuff. The average borehole inclination is 1.7 degrees, with the greatest deviations of 3.4 degrees at 172.2 and 217.9 m (565 and 715 ft) and 3.3 degrees at 1,193.3 m (3,915 ft). The borehole drifted approximately 9.4 m (31 ft) to the southwest on a bearing of 36.6 degrees. At the lowest logged depth of 1,206.7 m (3,959 ft), the true vertical depth is calculated to be 1,206.1 m (3,956.9 ft), a difference of 0.6 m (2.1 ft).

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-EC-12 are listed in Appendix A-3.

2.3 Drilling Problems

Tight hole conditions at 26.5 m (87 ft) caused a minor delay in installation of the surface casing. The sloughing zone between 823.0 and 853.4 m (2,700 and 2,800 ft) and the bridges it created caused several problems and delays during logging operations. Examination of drill cuttings samples and the caliper log indicate that the interval where sloughing occurred is an altered bedded tuff of the Paintbrush Group.

The sudden flow-line separation was a major operational issue that caused a day’s delay during the investigation and subsequent re-engineering of the flow line. Another flow-line problem spurred the decision to terminate drilling hole at the current hole depth.

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 (NNES, 2010c). 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 Water Well 8 (WW-8), located in the northeast portion of the NNSS in Area 18. A concentrated lithium bromide solution 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-EC-12 based on Phase I flow and transport modeling (SNJV, 2006, 2007, and 2009b). To manage the anticipated water production, two unlined sumps (sump #1 and sump #2) were constructed prior to drilling (Figure 2-1).

Samples of drilling effluent were collected hourly as necessary by N-I and analyzed onsite by radiological control technicians for the presence of tritium. As detailed in the N-I data report (N-I, 2011) and summarized in Appendix B of this report, the onsite monitoring results for the drilling fluid indicated that tritium levels were generally below the MDC, and well 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. After the samples were re-run, the tritium levels were found to be below the MDC.

No lead monitoring of discharge fluids 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-EC-12 fluid management strategy letter (NNES, 2010c) approved by the Nevada Division of Environmental Protection. N-I personnel checked all down-hole equipment for lead prior to use in the borehole. The lead analyses were below 2 micrograms per liter (2 parts per billion).

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 form are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps.

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3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-EC-12 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-EC-12, 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-EC-12 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 (NNES, 2010a).

3.2 Drill Cuttings

NSTec geologists collected 3 samples during construction of the conductor hole, at the depths of 6.1, 12.2, and 14.6 m (20, 40, and 48 ft). During drilling of the main hole, N-I personnel collected composite drill cuttings at 3.0-m (10-ft) intervals. Triplicate samples, each consisting of approximately 550 cubic centimeters of material, were collected from 400 intervals from 15.8 to 1,240.2 m (52 to 4,069 ft). Samples are missing from two intervals, 1,124.7 to 1,127.8 m (3,690 to 3,700 ft) and 1,231.4 to 1,234.4 m (4,040 to 4,050 ft), due to intermittent and temporary poor drilling fluid returns.

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 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.

3.3 Sidewall Core Samples

Sidewall core samples were collected at selected depths in Well ER-EC-12 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 the quality and quantity of drill cuttings, with consideration of borehole conditions determined from caliper logs. Baker Atlas used a percussion-gun sidewall coring tool to collect samples between the depths of 332.2 and 1,179.6 m (1,090 and 3,870 ft). A total of 42 sample depths were attempted, with 8 cores recovered. Baker Atlas also used a rotary sidewall coring tool to obtain sidewall samples between the depths of 432.8 and 1,193.3 m (1,420 and 3,915 ft). A total of 30 samples depths were attempted, with 18 cores recovered. Table 3-1 summarizes the results of sidewall coring operations at Well ER-EC-12.

3.4 Sample Analysis

Nine sidewall cores and 19 samples of drill cuttings from various depths in Well ER-EC-12 were submitted to Comprehensive Volcanic Petrographics, LLC, for petrographic analysis. A split of the same sidewall cores, excluding one from 432.8 m (1,420 ft), and 19 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. The primary purpose of the 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 (2011), and the results of the mineralogic and chemical analyses are reported in WoldeGabriel et al. (2010). Table 3-2 lists all samples analyzed.

3.5 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 two stages during drilling: prior to installation of the 16-in. casing at 385.8 m (1,265.9 ft) and after the TD was reached at 1,240.2 m (4,069 ft). The overall quality of the geophysical log data collected was very good.

Table 3-1
Sidewall Samples from Well ER-EC-12

Core Depth [a]		Tool Used [b]	Recovery [c] centimeters (inches)	Formation	Lithology
meters	feet				
332.2	1,090	SWC	E	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
338.3	1,110	SWC	L	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
342.9	1,125	SWC	E	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
353.6	1,160	SWC	E	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
356.6	1,170	SWC	E	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
370.6	1,216	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
374.9	1,230	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
379.2	1,244	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
385.3	1,264	SWC	1.91 (0.75)	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
391.7	1,285	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, nonwelded
394.7	1,295	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, nonwelded
405.4	1,330	SWC	3.18 (1.25)	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
408.4	1,340	SWC	E	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
413.3	1,356	SWC	1.27 (0.50)	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
416.7	1,367	SWC	M	rhyolite of Tannenbaum Hill	Ash-flow tuff, partially welded
421.8	1,384	SWC	3.81 (1.50)	rhyolite of Tannenbaum Hill	Nonwelded tuff
423.4	1,389	SWC	M	rhyolite of Tannenbaum Hill	Nonwelded tuff
432.8	1,420	RS	3.68 (1.45)	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide mesobreccia, tuffaceous sandstone and gravel, and reworked tuff
449.9	1,476	SWC	4.45 (1.75)	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide mesobreccia, tuffaceous sandstone and gravel, and reworked tuff
480.4	1,576	SWC	E	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
520.6	1,708	RS	W	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
520.6	1,708	RS [d]	3.68 (1.45)	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
521.2	1,710	SWC	E	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
521.2	1,710	RS	W	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
547.4	1,796	SWC	3.18 (1.25)	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia

Table 3-1
Sidewall Samples from Well ER-EC-12 (continued)

Core Depth [a]		Tool Used [b]	Recovery [c] centimeters (inches)	Formation	Lithology
meters	feet				
573.0	1,880	SWC	M	landslide deposits related to the rhyolite of Tannenbaum Hill	Landslide megabreccia
591.3	1,940	RS	3.18 (1.25)	Tiva Canyon Tuff	Ash-flow tuff, moderately welded
755.9	2,480	RS	4.06 (1.60)	Tiva Canyon Tuff	Ash-flow tuff, moderately welded
771.1	2,530	RS	2.67 (1.05)	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
809.5	2,656	SWC	M	Tiva Canyon Tuff	Ash-flow tuff, partially welded to nonwelded
819.3	2,688	SWC	E	Tiva Canyon Tuff	Ash-flow tuff, partially welded to nonwelded
819.3	2,688	SWC [d]	M	Tiva Canyon Tuff	Ash-flow tuff, partially welded to nonwelded
819.3	2,688	RS	W	Tiva Canyon Tuff	Ash-flow tuff, partially welded to nonwelded
819.3	2,688	RS [d]	3.43 (1.35)	Tiva Canyon Tuff	Ash-flow tuff, partially welded to nonwelded
845.8	2,775	RS	W	Paintbrush Group, undivided	Bedded tuff
845.8	2,775	RS [d]	3.05 (1.20)	Paintbrush Group, undivided	Bedded tuff
861.1	2,825	SWC	3.51 (1.38)	Paintbrush Group, undivided	Bedded tuff
874.8	2,870	SWC	E	Paintbrush Group, undivided	Bedded tuff
874.8	2,870	SWC [d]	M	Paintbrush Group, undivided	Bedded tuff
893.7	2,932	SWC	E	Paintbrush Group, undivided	Bedded tuff
893.7	2,932	SWC [d]	M	Paintbrush Group, undivided	Bedded tuff
910.7	2,988	SWC	1.27 (0.50)	Paintbrush Group, undivided	Bedded tuff
927.2	3,042	SWC	E	Paintbrush Group, undivided	Bedded tuff
938.8	3,080	SWC	E	Paintbrush Group, undivided	Bedded tuff
947.3	3,108	SWC	M	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
947.3	3,108	SWC [d]	M	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
966.2	3,170	SWC	E	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
990.6	3,250	SWC	M	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
991.8	3,254	RS	3.43 (1.35)	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded

Table 3-1
Sidewall Samples from Well ER-EC-12 (continued)

Core Depth [a]		Tool Used [b]	Recovery [c] centimeters (inches)	Formation	Lithology
meters	feet				
991.8	3,254	RS [d]	W	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
993.6	3,260	SWC	E	Topopah Spring Tuff	Ash-flow tuff, nonwelded to partially welded
1,018.0	3,340	RS	3.43 (1.35)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,030.2	3,380	RS [d]	3.05 (1.20)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,030.2	3,380	RS	W	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,082.0	3,550	RS	3.05 (1.20)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,121.4	3,679	RS [f]	W	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,121.4	3,679	RS [e]	2.54 (1.00)	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,121.7	3,680	RS	W	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,121.7	3,680	RS [d]	W	Topopah Spring Tuff	Ash-flow tuff, moderately welded
1,135.1	3,724	RS [f]	3.30 (1.30)	mafic-poor Calico Hills Formation	Nonwelded tuff
1,135.1	3,724	SWC	E	mafic-poor Calico Hills Formation	Nonwelded tuff
1,135.1	3,724	RS	W	mafic-poor Calico Hills Formation	Nonwelded tuff
1,135.1	3,724	RS [d]	W	mafic-poor Calico Hills Formation	Nonwelded tuff
1,135.3	3,724	RS [e]	1.27 (0.50)	mafic-poor Calico Hills Formation	Nonwelded tuff
1,150.3	3,774	SWC	E	mafic-poor Calico Hills Formation	Nonwelded tuff
1,150.3	3,774	RS	3.81 (1.50)	mafic-poor Calico Hills Formation	Nonwelded tuff
1,150.3	3,774	RS [d]	W	mafic-poor Calico Hills Formation	Nonwelded tuff
1,167.4	3,830	SWC	E	mafic-poor Calico Hills Formation	Nonwelded tuff
1,167.4	3,830	RS	2.79 (1.10)	mafic-poor Calico Hills Formation	Nonwelded tuff
1,179.6	3,870	SWC	E	mafic-rich Calico Hills Formation	Bedded tuff
1,179.6	3,870	RS	3.30 (1.30)	mafic-rich Calico Hills Formation	Bedded tuff
1,193.3	3,915	RS	3.175 (1.25)	rhyolite of Jorum	Nonwelded tuff

a All depths are drilled depths.

b SWC = percussion-gun sidewall coring tool; core diameter: 17.3 millimeters (0.68 inch)
RS = rotary sidewall coring tool; core diameter: 25.4 millimeters (1 inch)

c Shaded rows indicate samples attempted but not recovered. E = empty barrel; L = lost barrel; M = misfire; W = washout.

d Second attempt

e Third attempt

f Fourth attempt

Table 3-2
Rock Samples from Well ER-EC-12 Selected for Petrographic, Mineralogic, and Chemical Analysis [a]

Depth [b, c]		Sample Identifier [d]
meters	feet	
42.7	140	EREC/12–140D
70.1	230	EREC/12–230D
106.7	350	EREC/12–350D
350.5	1,150	EREC/12–1,150D
390.1	1,280	EREC/12–1,280D
426.7	1,400	EREC/12–1,400D
432.8	1,420	EREC/12–1,420RS
475.5	1,560	EREC/12–1,560D
493.8	1,620	EREC/12–1,620D
520.6	1,708	EREC/12–1,708RS
570.0	1,870	EREC/12–1,870D
606.6	1,990	EREC/12–1,990D
701.0	2,300	EREC/12–2,300D
755.9	2,480.1	EREC/12–2,480RS
804.7	2,640	EREC/12–2,640D
838.2 [e]	2,750 [e]	EREC/12–2,750D
845.8	2,775	EREC/12–2,775RS
856.5	2,810	EREC/12–2,810D
935.7	3,070	EREC/12–3,070D
966.2	3,170	EREC/12–3,170D
1,018.0	3,340	EREC/12–3,340RS
1,030.2	3,380	EREC/12–3,380RS
1,091.2	3,580	EREC/12–3,580D
1,109.5	3,640	EREC/12–3,640D
1,150.3	3,774	EREC/12–3,774RS
1,167.4	3,830.1	EREC/12–3,830RS
1,179.6	3,870.1	EREC/12–3,870RS
1,222.2	4,010	EREC/12–4,010D

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.
e Sample was taken from drill cuttings recovered at the depth of 1,069.8 m (3,510 ft), but represents material sloughed from the borehole wall at the depth of 838.2 m (2,750 ft). Warren (2011) calls this sample 3,510DB(1.

A complete listing of the logs, dates run, depths, and service companies is provided in Table 3-3. Note that a gamma ray log is typically included with each logging run for depth control. Electronic and paper versions of the logs are stored at NSTec offices 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.

Table 3-3
Well ER-EC-12 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 [d]	Saturated zone: groundwater temperature, stratigraphic and depth correlation	BA	7/11/2010	TL-1 / GR-6	1,208.5 (3,965)	304.8 (1,000)
Aligned Borehole Profile (i.e., oriented * 6-arm caliper) / Gamma Ray	Borehole conditions, cement volume calculation, lithologic features, borehole orientation, stratigraphic and depth correlation	BA	6/30/2010 7/10/2010 7/11/2010	CA6-1 / ORIT-1 / GR-1 CA6-2 / ORIT-2 / GR-5 CA6-3 / ORIT-3 / GR-7	425.8 (1,397) 829.4 (2,721) 1,206.7 (3,959)	15.2 (50) 330.1 (1,083) 301.8 (990)
* Gamma Ray / * Digital Spectralog	Stratigraphy, mineralogy, and natural and man-made radiation determination	BA	6/30/2010 7/11/2010	SGR-1 / GR-1 SGR-2 / GR-7	418.2 (1,372) 1,198.8 (3,933)	2.7 (9) 301.8 (990)
* High Definition Induction / Gamma Ray	Lithologic determination; saturation of formations; stratigraphic and depth correlation	BA	7/1/2010	HDIL-1 / GR-2 / SP-1	425.2 (1,395)	15.7 (51.5)
* Compensated Z-Densilog / * Compensated Neutron / Gamma Ray / Caliper	Stratigraphic and lithologic determination, identification of welding, alteration, rock porosity, and water content	BA	7/1/2010 7/12/2010	ZDL-1 / CN-1 / GR-3 / CAL-1 ZDL-2 / CN-2 / GR-10 / CAL-2	425.8 (1,397) 1,203.4 (3,948)	3.0 (10) 266.7 (875)
Circumferential Borehole Imaging / Gamma Ray	Structural analysis, including fracture characterization. Recognition of lithologic features	BA	7/12/2010	CBIL-1 / ORIT-5 / GR-11	1,202.1 (3,944)	417.0 (1,368)
* X-Multipole Array Acoustilog / Gamma Ray	Primary matrix porosity	BA	7/12/2010	XMAC-1 / ORIT-4 / GR-9	1,198.5 (3,932)	420.3 (1,379)
Resistivity Imaging / Gamma Ray	Saturated zone: lithologic characterization, bedding dip, fracture and void analysis.	BA	7/13/2010	STAR-1 / ORIT-6 / GR-12	1,200.3 (3,938)	417.0 (1,368)
* R_t Explorer / Gamma Ray	Lithologic determinations, identification of alteration, recognition of welding; distinguishing low versus high porosity	BA	7/13/2010	RTEX-1 / GR-13 / CA6-4	1,193.6 (3,916)	416.4 (1,366)
Percussion Gun Sidewall Tool / Gamma Ray	Geologic samples	BA	7/1/2010 7/13/2010	SWC-1 / GR-4 SWC-2 / GR-14	423.4 (1,389) 1,179.6 (3,870)	332.2 (1,090) 449.9 (1,476)

Table 3-3
Well ER-EC-12 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)
Dual Laterolog / Gamma Ray	Lithologic determinations, identification of alteration, recognition of welding; distinguishing low versus high porosity	BA	7/11/2010	DLL-1 / GR-8 / SP-2	1,203.2 (3,947.5)	420.3 (1,379)
Rotary Sidewall Coring Tool / Gamma Ray	Geologic samples	BA	7/14/2010	RCOR-1 / GR-15	1,193.3 (3,915)	432.8 (1,420)
* Chemistry / * Temperature Log	Groundwater chemistry and temperature	DRI	7/14/2010	Chem-1 / TL-2	1,197.6 (3,929)	417.0 (1,368)
* Heat Pulse Flow Log	Groundwater flow rate and direction	DRI	7/14/2010	HPFlow-1	816.9 (2,680)	432.8 (1,420)

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

b BA = Baker Atlas; DRI = Desert Research Institute.

c Drilled depth.

d A gamma-ray log is included on each logging run to aid in depth control.

4.0 Geology and Hydrogeology

4.1 Introduction

This section describes the geology and hydrogeology of Well ER-EC-12. The basis for the discussions here is the detailed geologic characterization of Well ER-EC-12 presented as a lithologic log in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling characteristics. Petrographic, mineralogic, and chemical analyses on selected lithologic samples from Well ER-EC-12 were incorporated into the detailed lithologic log. Petrographic analyses were particularly important in deciphering the stratigraphic units encountered because of the intensity of secondary alteration and because the stratigraphic section was considerably different than predicted prior to drilling.

4.2 Geology

This section is divided into three discussions relating to the geology of Well ER-EC-12. Section 4.2.1 briefly describes the geologic setting of the Pahute Mesa and Bench areas and the Well ER-EC-12 site. The stratigraphic and lithologic units penetrated at the well are discussed 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-EC-12 site.

4.2.1 Geologic Setting

Well ER-EC-12 is 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 well was drilled south of the southern rim of Pahute Mesa (Figure 1-1), a high volcanic plateau composed of lava and tuff of generally rhyolitic composition. The volcanic rocks that compose Pahute Mesa bury the 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).

Table 4-1
Key to Stratigraphic Units of the Well ER-EC-12 Area

Stratigraphic Unit	Map Symbol
Quaternary and Tertiary Alluvial Deposits	**QTa**
Young alluvial deposits	Qay
Colluvium	QTc
Intermediate alluvial deposits	Qai
Caldera moat-filling sediments	Tgc
Thirsty Canyon Group	**Tt**
Trail Ridge Tuff	Ttt
Pahute Mesa Tuff	Ttp
Rocket Wash Tuff	Ttr
Volcanics of Fortymile Canyon	**Tf**
Beatty Wash Formation	Tfb
Timber Mountain Group	**Tm**
Ammonia Tanks Tuff	Tma
mafic-rich Ammonia Tanks Tuff	Tmar
mafic-poor Ammonia Tanks Tuff	Tmap
debris-flow breccia	Tmax
bedded Ammonia Tanks Tuff	Tmab
rhyolite of Tannenbaum Hill	Tmat
landslide deposits	Tmatx
Rainier Mesa Tuff	Tmr
mafic-rich Rainier Mesa Tuff	Tmrr
mafic-poor Rainier Mesa Tuff	Tmrp
rhyolite of Fluorspar Canyon	Tmrf
Paintbrush Group	**Tp**
hornblende-bearing rhyolite of ER-EC-15	Tph
rhyolite of Benham	Tpb
rhyolite of Scrugham Peak	Tps
tuff of Pinyon Pass	Tpcy
crystal-poor tuff of Pinyon Pass	Tpcyp
Tiva Canyon Tuff	Tpc
Pahute Mesa lobe of Tiva Canyon Tuff	Tpcm
crystal-poor Tiva Canyon Tuff	Tpcp
rhyolite of Delirium Canyon	Tpd
Topopah Spring Tuff	Tpt
Pahute Mesa lobe of Topopah Spring Tuff	Tptm
Calico Hills Formation	**Th**
mafic-poor Calico Hills Formation	Thp
mafic-rich Calico Hills Formation	Thr

Table 4-1
Key to Stratigraphic Units and Symbols for the Well ER-EC-12 Area (continued)

Stratigraphic Unit	Map Symbol
Crater Flat Group	**Tc**
rhyolite of Inlet	Tci
rhyolite of Jorum	Tcpj
rhyolite of Sled	Tcps
rhyolite of Kearsarge	Tcpk
Bullfrog Tuff	Tcb
Belted Range Group	**Tb**
Dead Horse Flat Formation	Tbd
Grouse Canyon Tuff	Tbg
pre-Grouse Canyon caldera units	**To**
Paleozoic sedimentary rocks	**Pz**

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

Hydrostratigraphic Unit	Symbol
Thirsty Canyon volcanic aquifer	TCVA
Fortymile Canyon composite unit	FCCM
Tannenbaum Hill lava-flow aquifer	THLFA
Tannenbaum Hill composite unit	THCM
Timber Mountain composite unit	TMCM
Timber Mountain aquifer	TMA
Fluorspar Canyon confining unit	FCCU
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

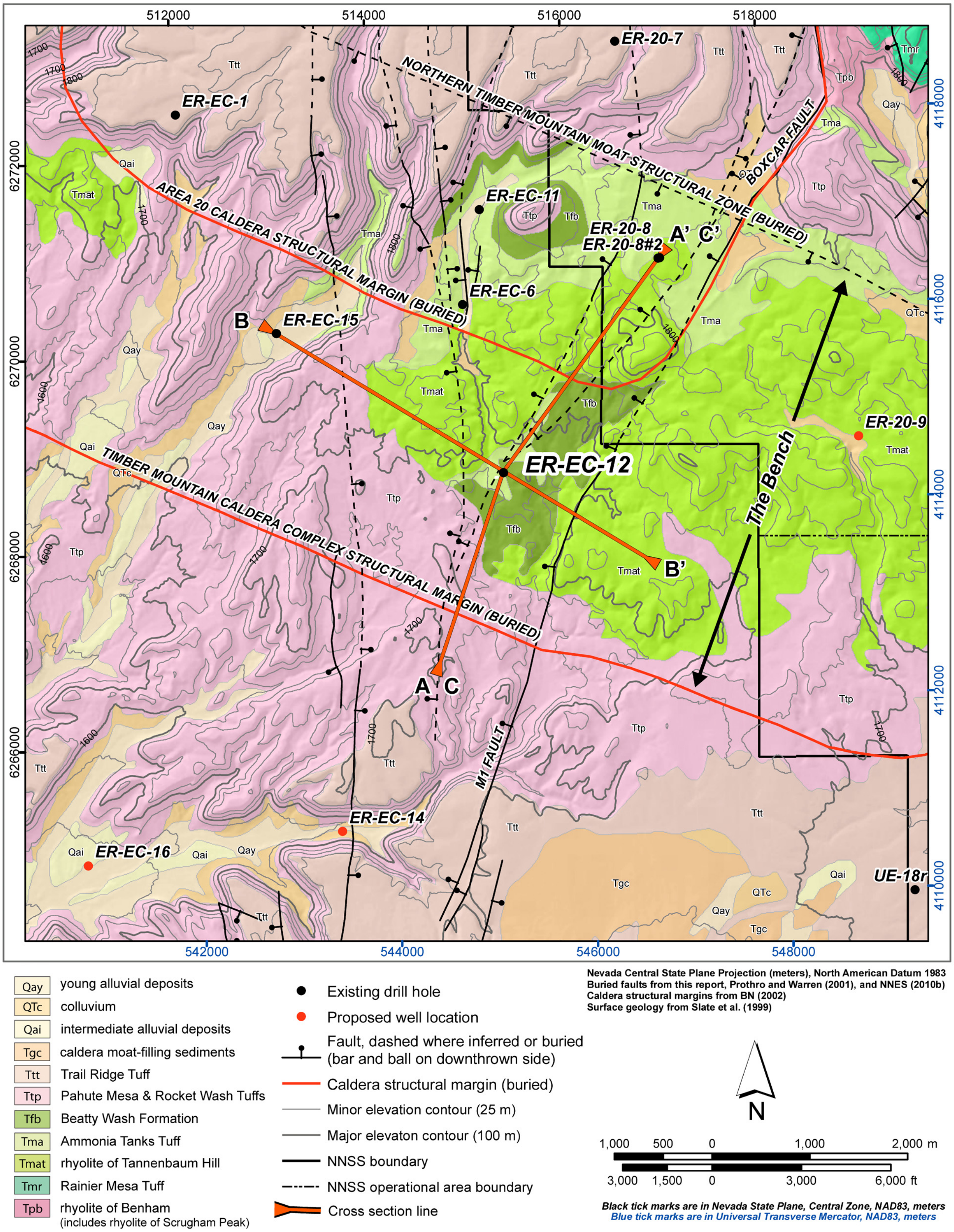

Figure 4-1
Surface Geologic Map of the Well ER-EC-12 Area

The TMCC, the buried structural margin of which is located approximately 1,463.0 m (4,800 ft) southwest of Well ER-EC-12 (BN, 2002), formed as a result of the eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff, 11.6 and 11.45 Ma, respectively (Sawyer et al., 1994). At this location, the structural margin of the TMCC is interpreted to represent the northern structural boundaries of both the Rainier Mesa and Ammonia Tanks calderas (BN, 2002). The youngest volcanic units in the area are a series of ash-flow tuffs erupted from the Black Mountain caldera, located approximately 12.9 kilometers (8 miles) northwest of the well. These tuffs include the 9.4-Ma Rocket Wash and Pahute Mesa Tuffs and the 9.3-Ma Trail Ridge Tuff (Slate et al., 1999).

The well site is constructed on the Ammonia Tanks Tuff (Slate et al., 1999), which consists of ash-flow tuff that flowed onto a structural bench formed 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; NNES, 2010b; NNSA/NSO, 2010a; NNSA/NSO, 2010b), 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 west-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) and the recent Phase II drilling (e.g., Well ER-20-7 [NNSA/NSO, 2010a] and Well ER-EC-11 [NNSA/NSO, 2010b]). 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, with the larger faults dipping west. Based on surface exposures, many of these faults appear to die out or become obscured south of Pahute Mesa (Slate et al., 1999). Initial results from Phase II drilling suggest that, like much of Pahute Mesa, the Bench is also dissected by generally north-striking normal faults, but these faults are poorly exposed and buried in many places by younger, post-fault deposits (NNSA/NSO, 2010a; NNSA/NSO, 2011a; NNSA/NSO, 2010b; this report). Several of these faults are interpreted to occur in the vicinity of Well ER-EC-12 (Figure 4-1). The inferred southwestern extension of a large normal fault known as the Boxcar fault on Pahute Mesa, but referred to as the M1 fault within the moat of the TMCC, is located 502.9 m (1,650 ft) southeast of Well ER-EC-12 (Byers and Cummings, 1967). Other northward-striking inferred normal faults are located nearby, to the west.

4.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-EC-12 are illustrated in Figure 4-2, and an 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.

Drilling at Well ER-EC-12 began in the nonwelded Ammonia Tanks Tuff of the Timber Mountain Group, which forms the ground surface in the immediate vicinity of the well (Slate et al., 1999; Figure 4-1). The Ammonia Tanks Tuff erupted 11.45 Ma from the Timber Mountain caldera (Sawyer et al., 1994), located approximately 1,463.0 m (4,800 ft) to the southwest. The Ammonia Tanks Tuff in the vicinity of Well ER-EC-12 typically consists of nonwelded to welded ash-flow tuff and bedded ash-fall deposits (Byers and Cummings, 1967). The Ammonia Tanks Tuff was encountered from the surface to a depth of 107.3 m (352 ft). The Ammonia Tanks Tuff at Well ER-EC-12 consists of 85.3 m (280 ft) of nonwelded to vitrophyric ash-flow tuff overlying 21.9 m (72 ft) of bedded tuff. Both the mafic-rich and mafic-poor members of the Ammonia Tanks Tuff were recognized in the well. The stratigraphic assignment of the Ammonia Tanks Tuff is based on outcrop data (Byers and Cummings, 1967; Slate et al., 1999), stratigraphic position above the rhyolite of Tannenbaum Hill, ash-flow tuff lithology, and mineralogic assemblage, including the presence of quartz phenocrysts, minor to abundant biotite, and the presence of sphene.

Below the Ammonia Tanks Tuff, Well ER-EC-12 penetrated 320.6 m (1,052 ft) of rhyolite lava, nonwelded to partially welded ash-flow tuff, and nonwelded tuff of the rhyolite of Tannenbaum Hill, from 107.3 to 427.9 m (352 to 1,404 ft). The upper two-thirds of the unit at Well ER-EC-12 consists of vitric and devitrified rhyolitic lava overlying a basal flow breccia. Perlitic structures, spherulites, and flow banding, common features of rhyolitic lava, were observed. The lava and flow breccia overlie nonwelded to partially welded ash-flow tuff, and the lowermost 8.8 m (29 ft) of the rhyolite of Tannenbaum Hill consists of quartzo-feldspathic nonwelded tuff. The stratigraphic assignment of the rhyolite of Tannenbaum Hill is based on its lava-flow lithology, comparison with nearby surface exposures, and mineralogic assemblage, including the presence of quartz phenocrysts, rare to minor biotite, and the presence of sphene. The rhyolite of Tannenbaum Hill was deposited onto the Bench during a time period between the caldera-forming eruptions of the Rainier Mesa and Ammonia Tanks Tuffs.

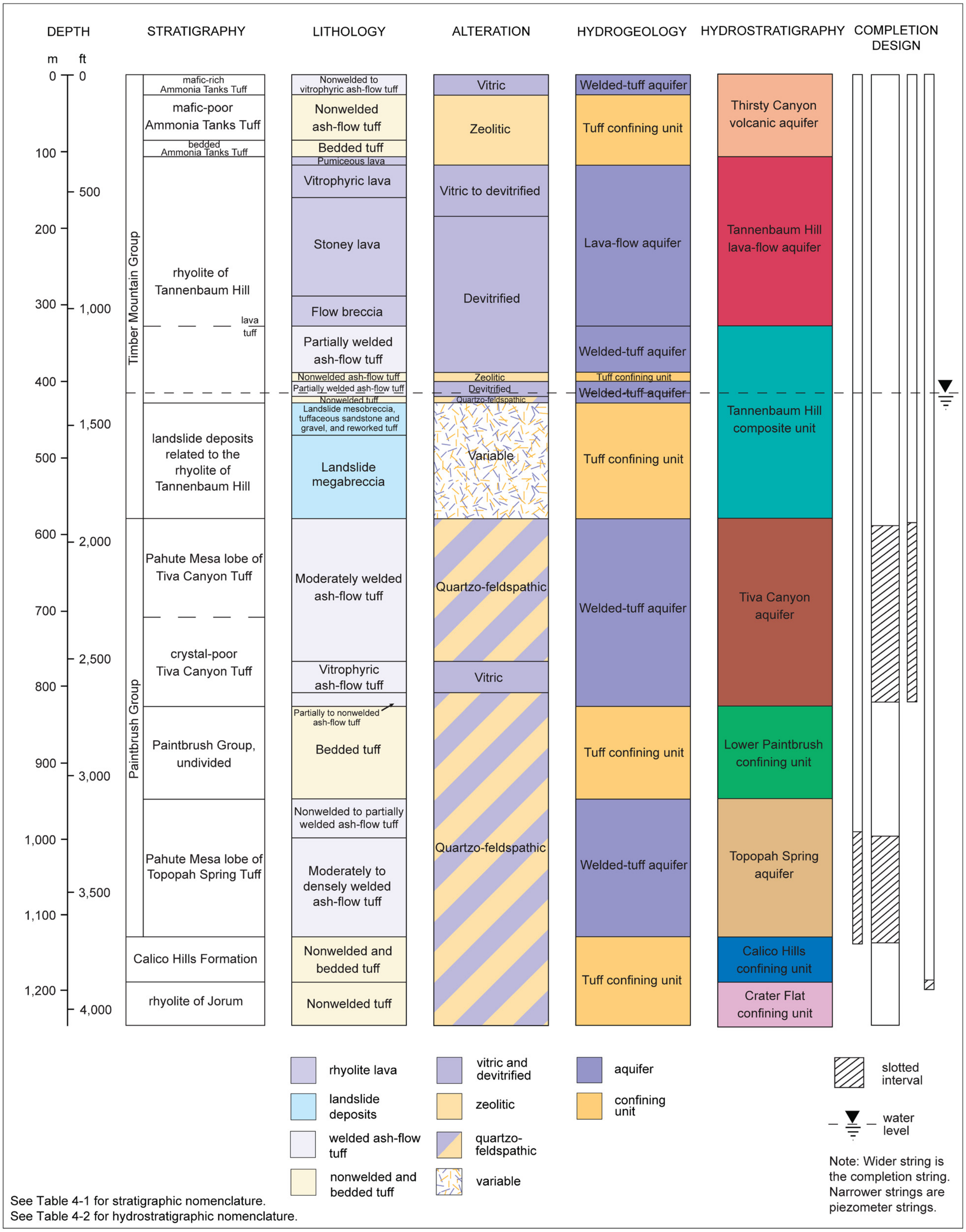

Figure 4-2
Graphical Presentation Showing Geology and Hydrogeology for Well ER-EC-12

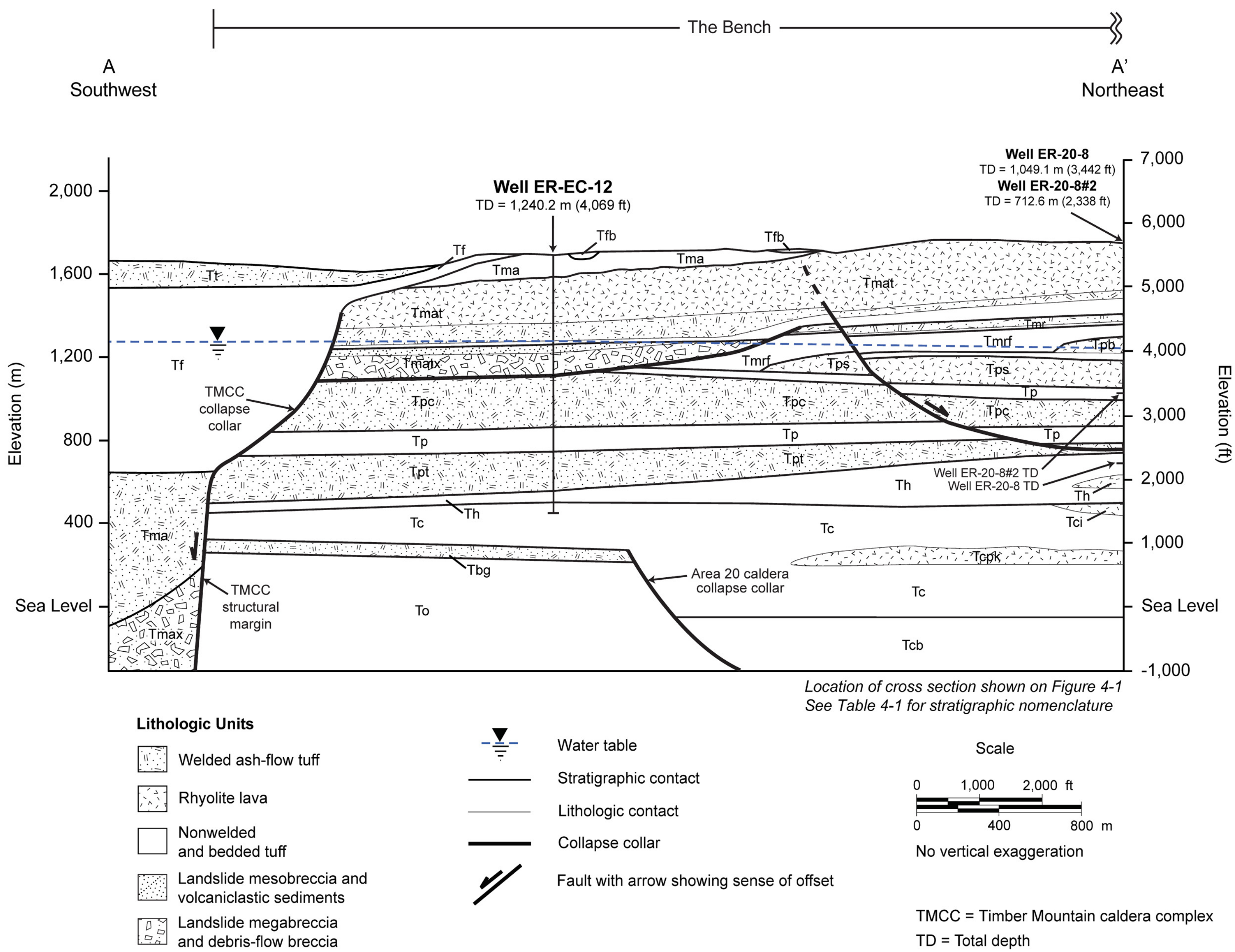

Figure 4-3
Southwest–Northeast Geologic Cross Section A–A' through Well ER-EC-12

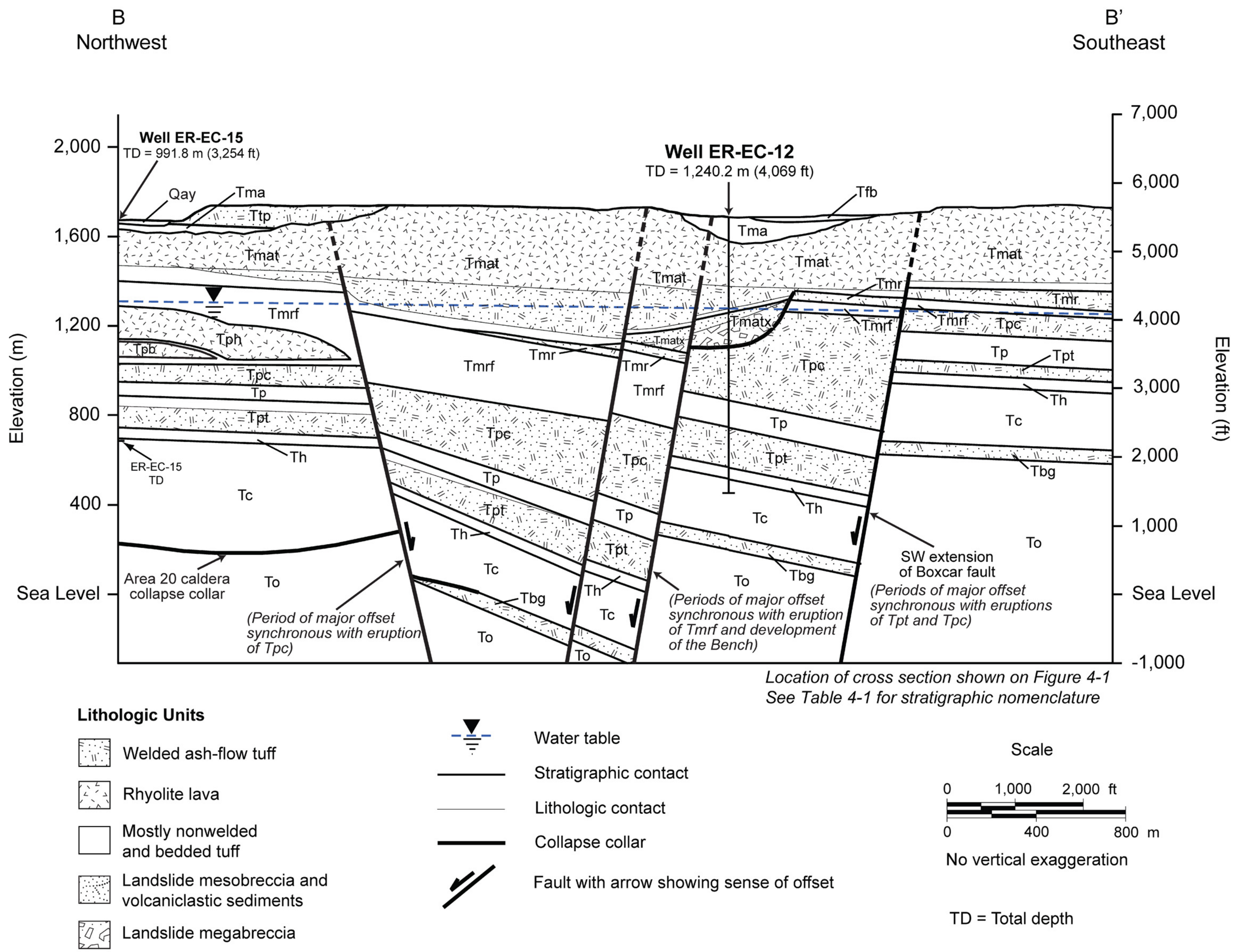

Figure 4-4
Northwest–Southeast Geologic Cross Section B–B' through Well ER-EC-12

Below the rhyolite of Tannenbaum Hill, from 427.9 to 578.5 m (1,404 to 1,898 ft), Well ER-EC-12 penetrated 150.6 m (494 ft) of mostly landslide deposits related to the structural development of the Bench. Landslide mesobreccia, tuffaceous sandstone and gravel, and reworked tuff comprise the top 41.5 m (136 ft) of the unit in the interval 427.9 to 469.4 m (1,404 to 1,540 ft). Underlying these upper deposits is a landslide megabreccia that is 109.1 m (358 ft) thick and composed mainly of large blocks of welded Tiva Canyon Tuff. This entire interval is tentatively assigned stratigraphically as landslide deposits related to the rhyolite of Tannenbaum Hill (Tmatx) because they directly underlie the rhyolite of Tannenbaum Hill. See discussion in Section 4.3 and Appendix C for more details.

The next major stratigraphic interval in Well ER-EC-12 is the Paintbrush Group, which includes two prominent welded ash-flow tuffs, the Tiva Canyon Tuff and the Topopah Spring Tuff. All units of the Paintbrush Group are characterized by the almost complete absence of quartz phenocrysts (Slate et al., 1999). The Paintbrush Group was erupted from calderas and related vents that are approximately spatially coincident with the younger TMCC, between 12.7 and 12.8 Ma (Sawyer et al., 1994). Well ER-EC-12 encountered ash-flow tuff of the Tiva Canyon Tuff in the interval from 578.5 to 824.2 m (1,898 to 2,704 ft). The ash-flow tuff is moderately welded to vitrophyric to 807.1 m (2,648 ft), and the lower 17.1 m (56 ft) of the unit is partially welded to nonwelded. Detailed petrographic analyses indicate that both the Pahute Mesa lobe and crystal-poor members are present (Warren, 2011). The Tiva Canyon Tuff was identified by its ash-flow tuff lithology and its mineralogic assemblage, which includes sphene and hornblende, but only trace amounts of 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).

Below the Tiva Canyon Tuff, the well penetrated a 120.7-m (396-ft) thick interval of quartzo-feldspathic, pyritic, and chloritic bedded tuff, from 824.2 to 944.9 m (2,704 to 3,100 ft). The interval's stratigraphic position between two Paintbrush Group units (the Tiva Canyon Tuff and the underlying Topopah Spring Tuff) indicates that the bedded tuff belongs to the Paintbrush Group. Detailed petrographic analyses indicate that the interval can be more precisely assigned to four different units: crystal-poor Tiva Canyon Tuff, Yucca Mountain Tuff, rhyolite of Black Glass Canyon, and crystal-poor bedded Topopah Spring Tuff (Warren, 2011). However, for the purpose of this well completion report, these bedded tuff units are collectively referred to as the Paintbrush Group, undivided.

The Topopah Spring Tuff was encountered at the base of the Paintbrush Group at the depth of 944.9 m (3,100 ft). This unit consists of about 51.8 m (170 ft) of quartzo-feldspathic and pyritic nonwelded to partially welded ash-flow tuff at the top, with 129.5 m (425 ft) of quartzo-feldspathic, pyritic, and calcareous moderately welded ash-flow tuff composing the rest of the unit. Detailed petrographic analyses indicate that the Topopah Spring Tuff in Well ER-EC-12 consists of the Pahute Mesa lobe member of the formation (Warren, 2011). The Topopah Spring Tuff was identified by its ash-flow tuff lithology, trace of quartz phenocrysts, and its stratigraphic position at the base of the Paintbrush Group section. 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).

Below the Topopah Spring Tuff, the well encountered 47.2 m (155 ft) of quartzo-feldspathic and weakly calcareous nonwelded tuffs of the mafic-poor Calico Hills Formation. At 1,173.5 m (3,850 ft), Well ER-EC-12 penetrated the mafic-rich Calico Hills Formation, which consists of quartzo-feldspathic bedded tuff. The Calico Hills Formation was identified by its stratigraphic position below the Topopah Spring Tuff and the presence of quartz phenocrysts.

Well ER-EC-12 reached TD at 1,240.2 m (4,069 ft), within the rhyolite of Jorum, which consists of quartzo-feldspathic and weakly calcareous nonwelded tuff. Other secondary minerals noted in thin section include pyrite, chlorite, and fluorite (Warren, 2011). The rhyolite of Jorum is part of the Crater Flat Group.

4.2.3 Alteration

The volcanic rocks penetrated at Well ER-EC-12 are generally unaltered or devitrified above 387.7 m (1,272 ft), although from 26.8 to 115.8 m (88 to 380 ft) the nonwelded ash-flow tuff, bedded tuff, and pumiceous rhyolite lava are zeolitic. The unaltered rocks include nonwelded and bedded tuffs and portions of rhyolite lava that have retained their original vitric (i.e., glassy) character. The welded portions of ash-flow tuffs and interior portions of rhyolite lava above 387.7 m (1,272 ft) are mostly devitrified as a result of recrystallization of the original glass matrix to microcrystalline quartz and feldspar during cooling and degassing. More intense quartzo-feldspathic alteration was noted as shallow as 419.1 m (1,375 ft) in a thin nonwelded tuff at the base of the rhyolite of Tannenbaum Hill, but becomes generally ubiquitous below 578.5 m (1,898 ft). The intensity of secondary alteration increases with depth. Below 824.2 m (2,704 ft), pyritic, chloritic, and calcareous alteration is observed in the quartzo-feldspathic rocks.

4.3 Predicted and Actual Geology

The geology encountered at Well ER-EC-12 is significantly different than predicted prior to drilling (Figure 4-5). The Tiva Canyon Tuff is more than twice as thick as predicted and includes both the Pahute Mesa lobe and crystal-poor members of the formation (Warren, 2011). Based on the total thickness of the Tiva Canyon Tuff in Well ER-EC-12 and other wells on the Bench, the Tiva Canyon Tuff appears to thicken south and east of Wells ER-EC-11 and ER-EC-15 (NNSA/NSO, 2010b, 2011b) towards the Boxcar fault, which may have partly controlled the distribution of the Tiva Canyon Tuff in the area.

An alternative interpretation for the anomalous thickness and relatively high structural position of the Tiva Canyon Tuff in Well ER-EC-12 is presented in Warren (2011). Warren (2011) suggests that this site is located just inside the northwestern portion of a caldera, and that the anomalously thick Tiva Canyon Tuff in Well ER-EC-12 represents intra-caldera tuff deposited within this caldera. Later resurgence of the caldera would account for both the higher structural elevation of the Tiva Canyon Tuff in the well and the absence of post-Tiva Canyon Tuff lavas such as the rhyolite of Benham and the rhyolite of Scrugham Peak.

Another significant difference is the complete absence in Well ER-EC-12 of volcanic units that typically occur stratigraphically between the rhyolite of Tannenbaum Hill and the Tiva Canyon Tuff, including the rhyolite of Fluorspar Canyon and the rhyolite of Benham. This missing stratigraphic interval is occupied in Well ER-EC-12 by almost 152.4 m (500 ft) of landslide deposits that include thick megabreccia overlain by finer-grained mesobreccia, tuffaceous sediments, and reworked tuff. The megabreccia consists almost exclusively of clasts of welded tuff, some possibly as large as 9.1 m (30 ft). Most of the megabreccia clasts appear to be Tiva Canyon Tuff, but welded Rainier Mesa Tuff clasts are conspicuous in the upper portion of the megabreccia. Clasts of Paintbrush Group rhyolite lava are notably absent within the megabreccia. The overlying finer-grained deposits probably represent continued, but less intense, mass wasting and erosion of a nearby topographic scarp.

The presence of Rainier Mesa Tuff clasts within the megabreccia indicates that the megabreccia was deposited after the eruption of the Rainier Mesa Tuff, so the breccia is probably not related to the formation of the Rainier Mesa caldera. The stratigraphic position of the landslide deposits directly below the rhyolite of Tannenbaum Hill seems to indicate that rapid faulting, which occurred after the eruption of the Rainier Mesa Tuff but before the main eruptions of the rhyolite of Tannenbaum Hill, resulted in collapse of an over-steepened fault scarp and deposition of the

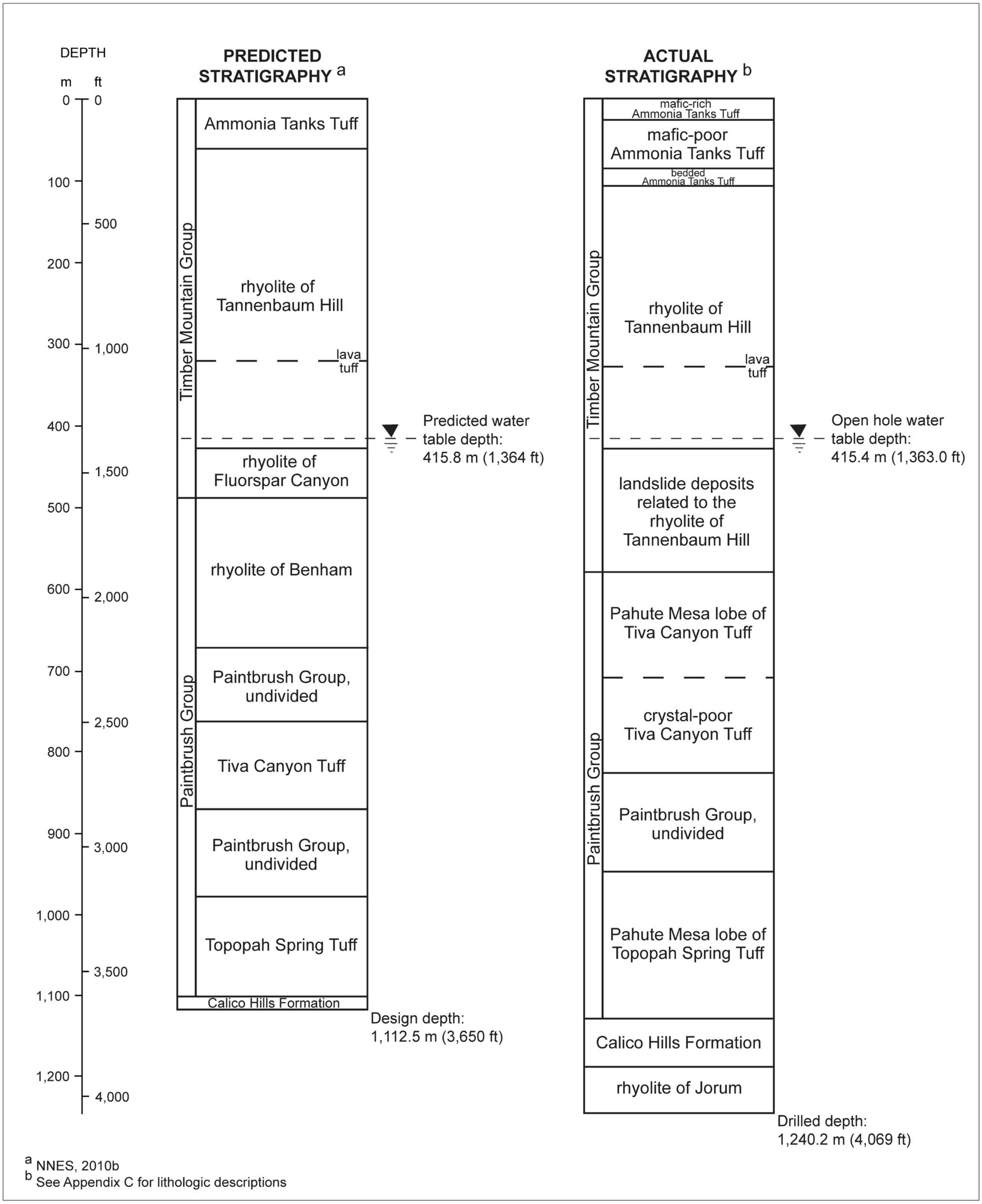

Figure 4-5
Predicted and Actual Stratigraphy at Well ER-EC-12

landslide deposits. The time frame for this faulting coincides with the latest movement of the NTMMSZ and development of the Bench. However, the absence of stratigraphically equivalent landslide deposits in holes north of Well ER-EC-12, and the thick megabreccia dominated by blocks of Tiva Canyon Tuff, seem to indicate that the landslide deposits in Well ER-EC-12 did not originate from the up-thrown side of the NTMMSZ, where Tiva Canyon Tuff is probably too thin to supply such a thick landslide deposit. Therefore, the landslide deposits in Well ER-EC-12 likely originated from a nearby fault that also collapsed rapidly during development of the Bench. This suggests that the Bench did not collapse as a coherent block along only the NTMMSZ, but likely in a more piecemeal fashion, with other faults also rapidly moving during the development of the Bench.

4.4 Hydrogeology

Most of the saturated portion of Well ER-EC-12 consists of an alternating sequence of welded-tuff aquifers and tuff confining units (Figure 4-2). Welded ash-flow tuffs of the Tiva Canyon Tuff and Topopah Spring Tuff form two distinct welded-tuff aquifers in the well, while the quartzo-feldspathic bedded and nonwelded tuffs that occur between and below the two welded-tuff aquifers form tuff confining units. The landslide and related deposits that occur in the upper portion of the saturated section are best considered as tuff confining units, based on the low water production during drilling of these rocks. An interpretation of the possible distribution of the HSUs in the vicinity of Well ER-EC-12 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 415.8 m (1,364 ft) and within tuff confining unit of the rhyolite of Tannenbaum Hill. The actual water table depth, measured on August 5, 2010 in the shallow piezometer string, was 415.4 m (1,363.0 ft) and was within welded-tuff aquifer of the rhyolite of Tannenbaum Hill.

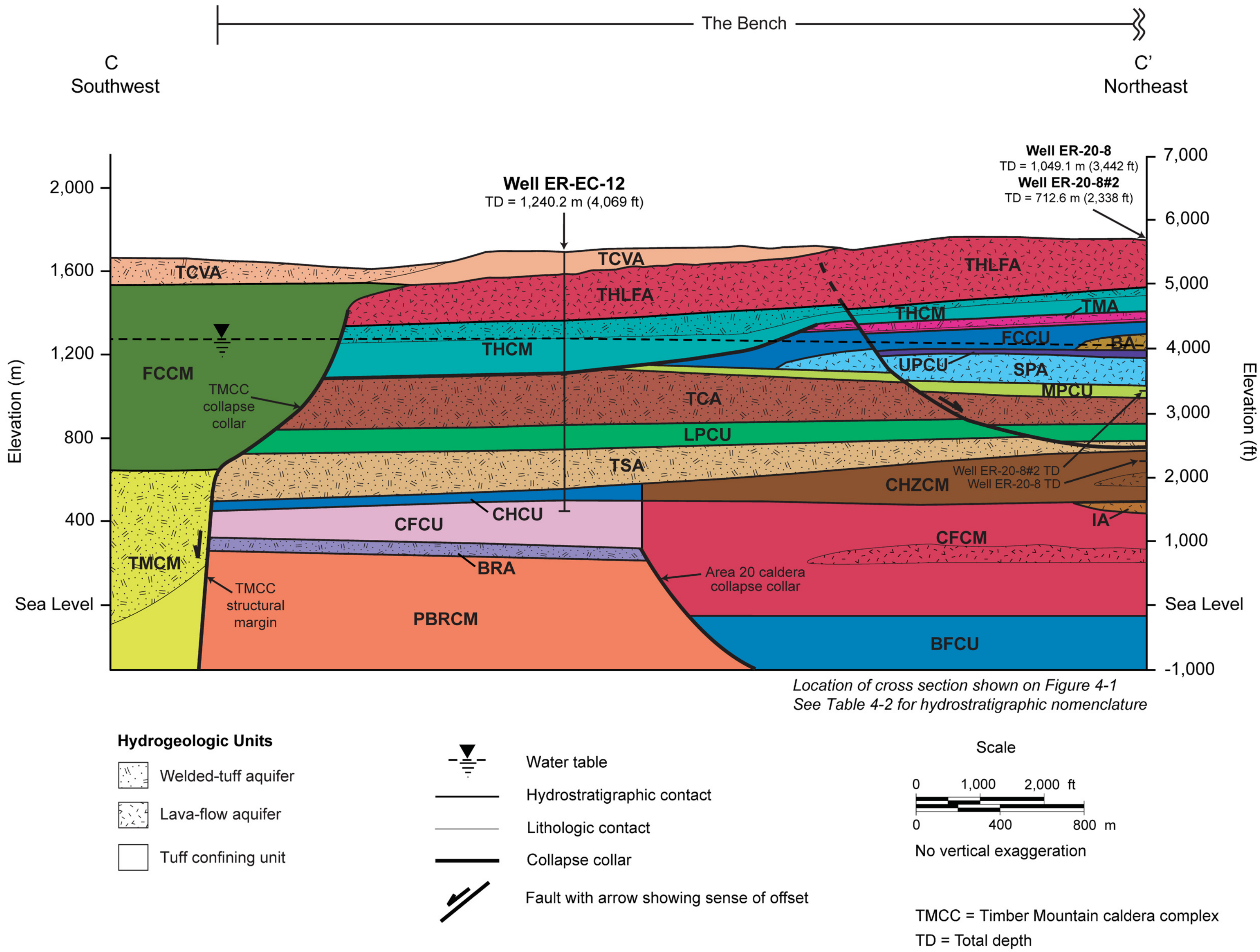

Figure 4-6
Southwest–Northeast Hydrostratigraphic Cross Section C–C' through Well ER-EC-12

5.0 Hydrology

5.1 Water Level Information

Prior to drilling, the water level at Well ER-EC-12 was estimated to be within the Tannenbaum Hill composite unit at a depth of 415.8 m (1,364 ft) below ground surface. The last open-hole fluid level measured prior to installation of the completion string was 416.4 m (1,366 ft) on July 14, 2010, during geophysical logging. Approximately one month later, on August 5, 2010, fluid levels were measured by N-I in the three piezometers. In the shallow piezometer (accessing the TCA), the fluid level was 415.4 m (1,363.0 ft). In the intermediate piezometer (accessing the TSA), the fluid level was 415.8 m (1,364.3). In the deep piezometer (accessing the CFCU), the fluid level was 413.6 m (1,356.9 ft).

5.2 Water Production

Water production was estimated during drilling of Well ER-EC-12 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 June 30, 2010, at the approximate depth of 420.6 m (1,380 ft). Estimated water production ranged from zero to 1,135.6 liters per minute (300 gallons per minute) while drilling the TCA. Estimated water production through the TSA ranged from 946.4 to 2,119.8 liters per minute (250 to 560 gallons per minute).

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.

5.3 Flow Meter 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 shortly after TD was reached (see plot of log data in Appendix D, page D-6). The chemistry log measured temperature, electrical conductivity, and pH in the interval 417.0 to 1,197.6 m (1,368 to 3,929 ft) on July 14, 2010. However, after running the chemistry log, DRI reported that the electrical conductivity portion of the logging tool malfunctioned and that the electrical conductivity data cannot be used.

DRI personnel measured the fluid flow rate and direction using their Heat Pulse Flow log at seven depths between 432.8 and 816.9 m (1,420 and 2,680 ft) within the landslide deposits related to the rhyolite of Tannenbaum Hill and Tiva Canyon Tuff, on July 14, 2010. The logging tool encountered a bridge of fill material at the depth of 832.1 m (2,730 ft), preventing any deeper measurements. The DRI flow log indicated no flow to very low upward flow on an average of 1.8 liters per minute (0.47 gallons per minute) between 432.8 and 816.9 m (1,420 and 2,680 ft).

5.4 Groundwater Characterization Samples

Following geophysical logging on July 14, 2010, DRI collected groundwater characterization samples within the open borehole (pre-completion/pre-development) at the depths of 832.1 and 1,182.6 m (2,730 and 3,880 ft). The sample at 832.1 m (2,730 ft) included a duplicate sample. These water samples were sent to LLNL and LANL for analysis, and the results will be 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).

6.0 Precompletion and Open-Hole Development

Initial open-hole well development using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole is typically conducted immediately after the borehole has reached TD. However, because of a leak in the flow line, drilling and fluid circulation operations at Well ER-EC-12 were terminated on July 9, 2010 (see Subsection 2.2). Consequently, open-hole well development was not conducted at Well ER-EC-12.

A bentonite/polymer mud had been placed in the borehole to stabilize it for the insertion of casing and tubing (Subsection 2.2). Since well development and testing was not scheduled for as much as a year, it was decided to clean out as much mud as possible from the well using a submersible pump. On July 24, 2010, a submersible pump was temporarily installed inside the completion string, with the pump intake at the depth of approximately 516.0 m (1,693 ft). The well was pumped until July 26, 2010, at which time the effluent appeared to have cleared up significantly, and then the pump was removed.

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7.0 Well Completion

7.1 Introduction

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 insertion of a pump in the well, for inserting devices for measuring the 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-EC-12 was presented in the addendum to the criteria document (NNES, 2010b) and in the NSTec FAWP (NSTec, 2010b). The original completion plans are summarized in Section 7.2.1 of this report, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 7.2.2. The rationale for differences between the planned and actual design is discussed in Section 7.2.3, and the completion methods are presented in Section 7.3. Figure 7-1 is a schematic diagram of the well completion design. Figure 7-2 shows a plan view and profile of the final wellhead surface completion. Table 7-1 is a construction summary for the completion strings.

7.2 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.

7.2.1 Proposed Completion Design

The original completion design (presented in NNES, 2010b) was based on the assumption that Well ER-EC-12 would penetrate the water table near the base of the Tannenbaum Hill composite unit and reach TD just below the TSA within the Calico Hills confining unit. 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 406.9 m (1,335 ft) and isolate the near-surface units from the underlying BA, TCA, and TSA.

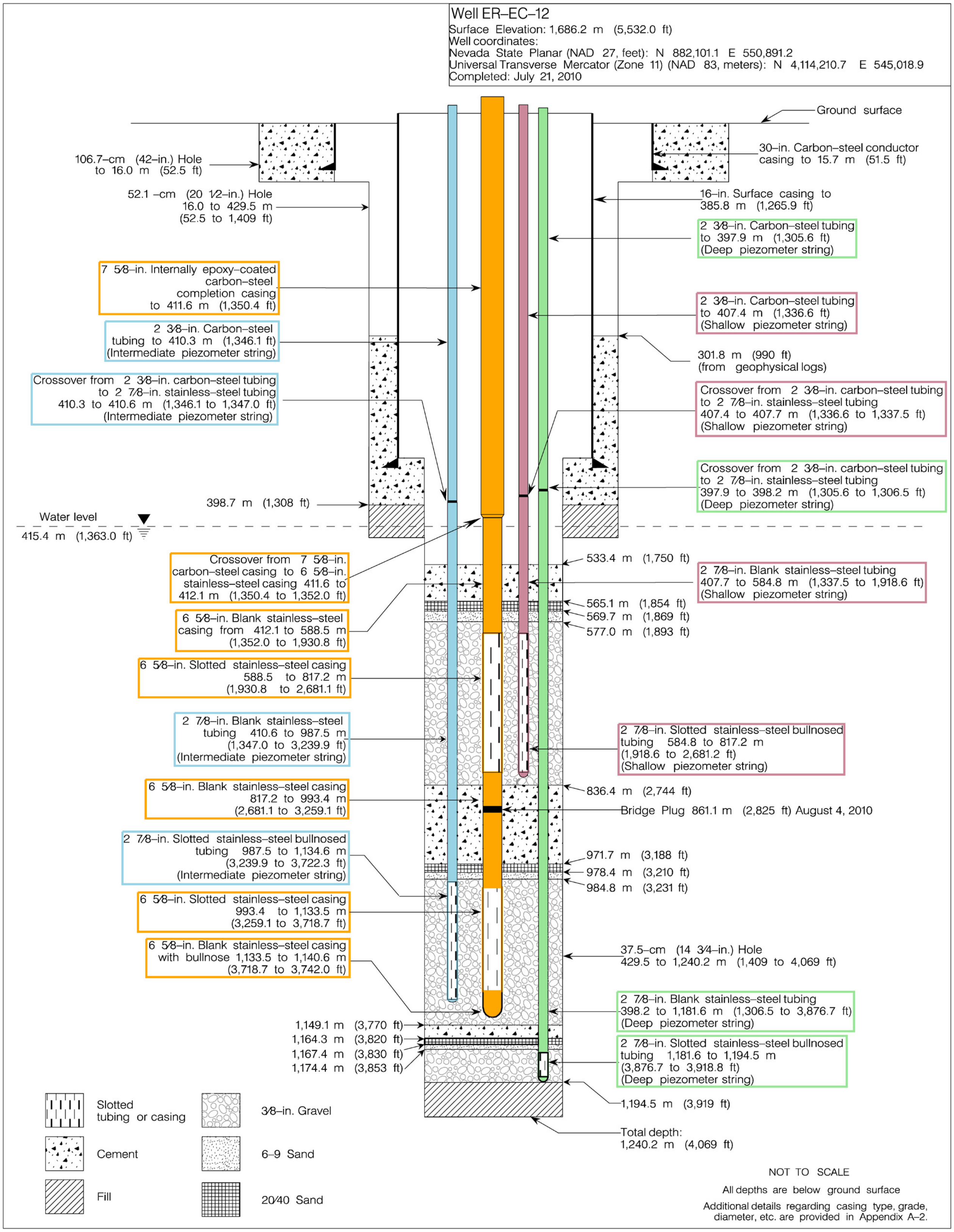

Figure 7-1
As-Built Completion Schematic for Well ER-EC-12

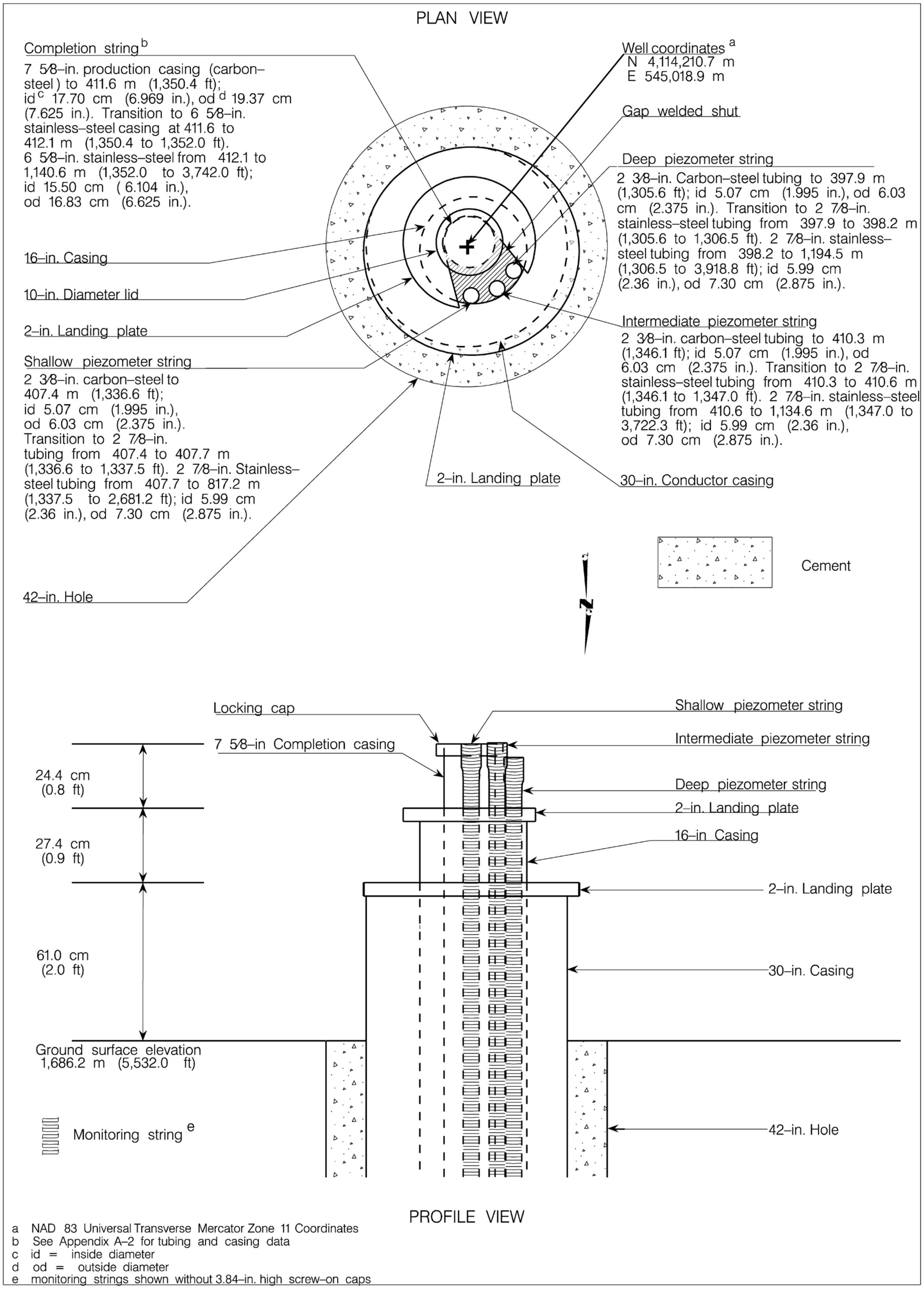

Figure 7-2
Wellhead Diagram for Well ER-EC-12

Table 7-1
Well ER-EC-12 Completion String Construction Summary

String	Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
Shallow Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 407.7 (0 to 1,337.5)	**Blank**	None	
	2⅞-in. stainless-steel tubing	407.7 to 817.2 (1,337.5 to 2,681.2)	**Blank** 407.7 to 584.8 (1,337.5 to 1,918.6)	**Type II Neat Cement** 533.4 to 565.1 (1,750 to 1,854)	**20/40 Sand** 565.1 to 569.7 (1,854 to 1,869) **6–9 Sand** 569.7 to 577.0 (1,869 to 1,893) **⅜-in. Washed Gravel** 577.0 to 836.4 (1,893 to 2,744)
			Slotted and Bullnosed [a] 584.8 to 817.2 (1,918.6 to 2,681.2)	None	
Intermediate Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 410.6 (0 to 1,347.0)	**Blank**	None	
	2⅞-in. stainless-steel tubing	410.6 to 1,134.6 (1,347.0 to 3,722.3)	**Blank** 410.6 to 987.5 (1,347.0 to 3,239.9)	**Type II Neat Cement** 836.4 to 971.7 (2,744 to 3,188)	**20/40 Sand** 971.7 to 978.4 (3,188 to 3,210) **6–9 Sand** 978.4 to 984.8 (3,210 to 3,231) **⅜-in. Washed Gravel** 984.8 to 1,149.1 (3,231 to 3,770)
			Slotted and Bullnosed [a] 987.5 to 1,134.6 (3,239.9 to 3,722.3)	None	

Table 7-1
Well ER-EC-12 Completion String Construction Summary (continued)

String	Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
Deep Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 398.2 (0 to 1,306.5)	**Blank**	None	
	2⅞-in. stainless-steel tubing	398.2 to 1,194.5 (1,306.5 to 3,918.8)	**Blank** 398.2 to 1,181.6 (1,306.5 to 3,876.7)	**Type II Neat Cement** 1,149.1 to 1,164.3 (3,770 to 3,820)	**20/40 Sand** 1,164.3 to 1,167.4 (3,820 to 3,830) **6–9 Sand** 1,167.4 to 1,174.4 (3,830 to 3,853) **⅜-in. Washed Gravel** 1,174.4 to 1,194.5 (3,853 to 3,919 [c])
			Slotted and Bullnosed [a] 1,181.6 to 1,194.5 (3,876.7 to 3,918.8)	None	
Completion String [d]	7⅝-in. carbon-steel, internally epoxy-coated casing and crossover sub with stainless-steel double pin	0 to 412.1 (0 to 1,352.0)	**Blank**	None	
	6⅝-in. stainless-steel casing	412.1 to 1,140.6 (1,352.0 to 3,742.0)	**Blank** 412.1 to 588.5 (1,352.0 to 1,930.8)	Same as for Shallow Piezometer String	Same as for Shallow Piezometer String
			36 Consecutive Slotted Joints [b] 588.5 to 817.2 (1,930.8 to 2,681.1)	None	
			Blank 817.2 to 993.4 (2,681.1 to 3,259.1)	Same as for Intermediate Piezometer String	
			22 Consecutive Slotted Joints [b] 993.4 to 1,133.5 (3,259.1 to 3,718.7)	None	Same as for Intermediate Piezometer String
			Blank and Bullnosed 1,133.5 to 1,140.6 (3,718.7 to 3,742.0)		

Table 7-1
Well ER-EC-12 Completion String Construction Summary (continued)

Notes:

a Slots are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long, arranged in 8 rows, on staggered 10.2-cm (4.0-in.) centers.

b Slots are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long, arranged in 18 rows, on staggered 15.2-cm (6.0-in.) centers.

c The NAIL log conducted during stemming operations indicates there is a possible “void” between fill and gravel from 1,189.3 to 1,194.5 m (3,902 to 3,919 ft).

d A bridge plug was set within the completion casing at 861.1 m (2,825 ft) on August 4, 2010.

The well was planned to be completed with a string of 6⅝-in. completion casing hung from a string of 7⅝-in. casing, and extending through the three target aquifers. This casing string was to be slotted and gravel-packed at each of the three 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 37.5-cm (14.75-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 piezometer strings were to be separated by the same cement isolation intervals as in the completion string.

7.2.2 As-Built Completion Design

The final Well ER-EC-12 completion design was determined by the UGTA Well ER-EC-12 drilling advisory team after the TD of 1,240.2 m (4,069 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 main completion string consists of a string of 6⅝-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing, and was set at the depth of 1,140.6 m (3,742.0 ft). The 7⅝-in.

epoxy-coated carbon-steel casing and crossover sub extend from the surface to the depth of 412.1 m (1,352.0 ft), which is 3.4 m (11 ft) above the water table. The stainless-steel 6⅝-in. casing is slotted in the intervals 588.5 to 817.2 m (1,930.8 to 2,681.1 ft) and 993.4 to 1,133.5 m (3,259.1 to 3,718.7 ft), which are open to the TCA and TSA, respectively. The upper slotted section consists of 36 consecutive slotted joints, and the lower slotted section consists of 22 consecutive slotted joints. The two slotted sections are separated by 176.2 m (578 ft) of blank casing. The completion string was terminated with 7.1 m (23.3 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 5.72 cm (2.25 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 aquifers.

Three 2⅞-in. piezometer strings were installed in Well ER-EC-12. The stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs, and each string is bullnosed. The shallow piezometer string was landed at 817.2 m (2,681.2 ft) for monitoring within the TCA, and is slotted from 584.8 to 817.2 m (1,918.6 to 2,681.2 ft). The intermediate piezometer string was landed at 1,134.6 m (3,722.3 ft) for monitoring within the TSA, and is slotted in the interval 987.5 to 1,134.6 m (3,239.9 to 3,722.3 ft). The deep piezometer string was landed at 1,194.5 m (3,918.8 ft) for monitoring within the CFCU, and is slotted from 1,181.6 to 1,194.5 m (3,876.7 to 3,918.8 ft). The machine-cut openings in each slotted joint of all three 2⅞-in. tubing strings are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long. The slots in each joint are arranged in rows of 8, 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.

A bridge plug was installed inside the 6⅝-in. casing at 861.1 m (2,825 ft), between the two slotted intervals, to isolate the two upper aquifers from each other.

7.2.3 Rationale for Differences between Planned and Actual Well Design

The proposed well completion design for Well ER-EC-12 (NNES, 2010b; NSTec, 2010b) was based on the expectation that the hole would penetrate the three primary aquifers typically present in the Bench area (the BA, TCA, and TSA). The BA is not present at Well ER-EC-12. Therefore, the final well design has only two completion intervals that access the two target aquifers present. A deep piezometer string is included to monitor the deepest unit penetrated, the CFCU.

7.3 Well Completion Method

The main completion casing and three piezometers were installed after the final geophysical logging had been conducted. The UDI crew installed the three piezometer strings described above on July 16–17, 2010, then inserted a 2⅞-in. Hydril tremie line to be used as a conduit for stemming materials during their emplacement (the tremie line was pulled up as stemming progressed). The casing crew then began running the main completion string on July 18, 2010, and landed the string at 1,140.6 m (3,742.0 ft) the same day. Colog, Inc. ran a Nuclear Annular Investigation Log (NAIL) tool in the 6⅝-in. completion string to monitor placement of stemming materials.

The two completion zones in the 6⅝-in. completion string and the bottom portion of the deep 2⅞-in. piezometer string were gravel-packed and then isolated from each other with sand and cement barriers. First, a layer of ⅜-in. washed gravel 20.1 m (66 ft) thick was emplaced on top of fill at 1,194.5 m (3,919 ft). Then a section of sand was placed above the gravel to prevent cement from infiltrating the gravel pack. A 7.0-m (23-ft) layer of 6–9 coarse silica sand and a 3.0-m (10-ft) layer of 20/40 fine silica sand were placed on the gravel surrounding the slotted portion of the deep 2⅞-in. piezometer string. Type II neat cement was placed on top of the sand from 1,149.1 to 1,164.3 m (3,770 to 3,820 ft). Next, a layer of ⅜-in. washed gravel 164.3 m (539 ft) thick was emplaced around the slotted portion of the intermediate piezometer string and lower completion zone of the 6⅝-in. completion string. A 6.4-m (21-ft) layer of 6–9 coarse silica sand and a 6.7-m (22-ft) layer of 20/40 fine silica sand were placed above the gravel that surrounds the lower completion zone, and a section of Type II neat cement was placed on the sand layers from 836.4 to 971.7 m (2,744 to 3,188 ft). The uppermost gravel layer, which is 259.4 m (851 ft) thick, was placed on the cement layer, and surrounds both the slotted portion of the shallow piezometer string and the upper completion zone of the 6⅝-in. completion string. A 7.3-m (24-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 Type II neat cement was placed from 533.4 to 565.1 m (1,750 to 1,854 ft) on these sand layers to seal the completion zones (see Figure 7-1 and Table 7-1).

The UDI drill rig was rigged down after the pump was pulled from the hole, several days after final cementing and stemming operations in preparation for moving the rig to the Well ER-20-4 site. Hydrologic testing is planned as a separate effort, so the pump was removed after cleaning the mud from 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.

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8.0 Planned and Actual Costs and Scheduling

The original NSTec-approved baseline task plan cost estimate for drilling and completing Well ER-EC-12 was based on drilling to a planned TD of 1,112.5 m (3,650 ft). Because the geology encountered in the borehole was significantly different than expected, the borehole was drilled deeper than planned to confidently establish the stratigraphy and structure of the deepest geologic units. The final TD of Well ER-EC-12 is 1,240.2 m (4,069 ft), which is 127.7 m (419 ft) deeper than planned. However, due to favorable drilling conditions the drilling operation remained several days ahead of schedule, so changes to the baseline were deemed unnecessary.

It took 31 days to construct Well ER-EC-12, starting with the drilling of the 52.1-cm (20.5-in.) surface hole. Even though the production hole was drilled deeper than planned, the hole reached TD six days ahead of schedule. However, several additional days were spent constructing the well due to bridging problems during geophysical logging and the running and removal of a pump used to purge mud from the well. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 8-1.

The cost analysis for Well ER-EC-12 begins with the mobilization of the UDI drill rig to the drill site, where the conductor hole had already been constructed. The total construction cost for Well ER-EC-12 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, radiological control technician services, inspection services, site supervision, and geotechnical consultation. The cost of building the 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-EC-12 was $4,022,259. The actual cost was $4,120,006, or 2.4 percent more than the planned cost. Figure 8-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-EC-12.

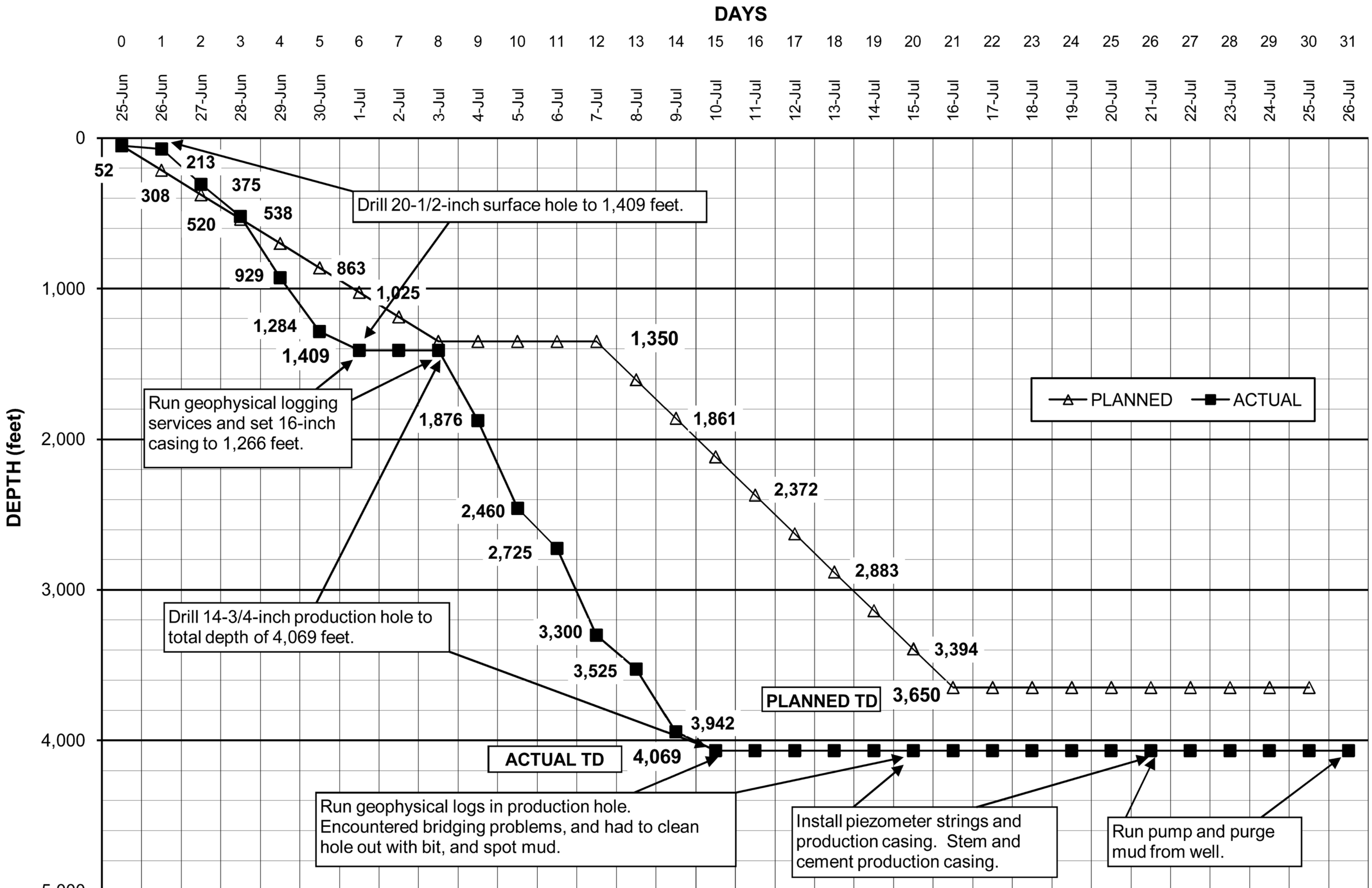

Figure 8-1
Planned and Actual Construction Progress for Well ER-EC-12

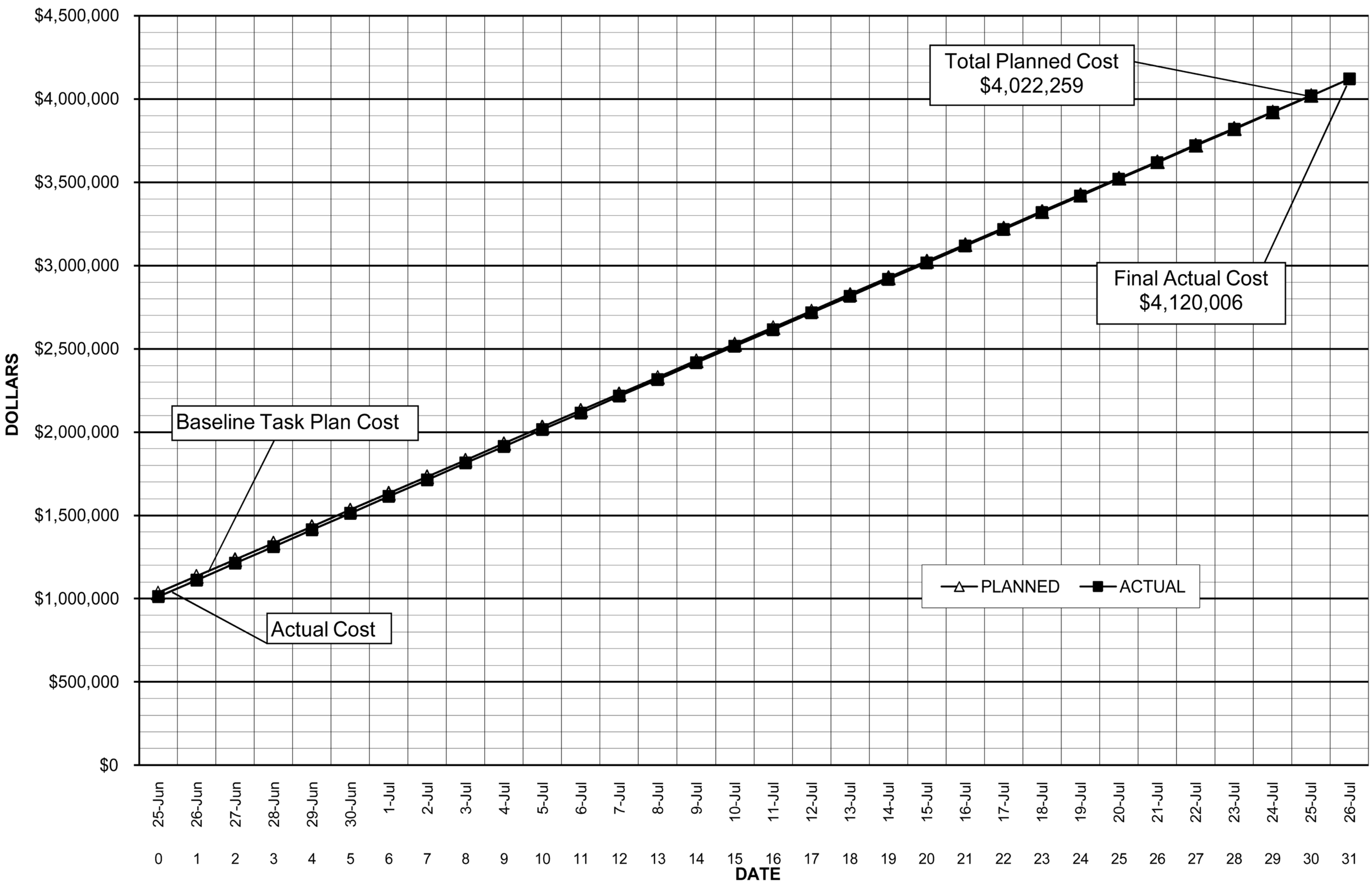

Figure 8-2
Planned and Actual Cost of Constructing Well ER-EC-12

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Main hole drilling at Well ER-EC-12 commenced on June 25, 2010, and concluded on July 9, 2010, at a total drilled depth of 1,240.2 m (4,069 ft). The borehole reached TD within altered, nonwelded tuffs of the Crater Flat Group. Several problems were encountered during drilling. Tight hole conditions at 26.5 m (87 ft) caused a minor delay in installation of the surface casing. A high-pressure surge of drilling fluid caused the flow line to separate, and operations were stopped to investigate and install a newly designed flow line. When a leak developed at the 10¾-in. section of the flow line near the 16-in. surface casing (wellhead), the decision was made to terminate the hole at its current depth. The sloughing zone between 823.0 and 853.4 m (2,700 and 2,800 ft) and the bridges it created caused several problems and delays during logging operations. Problems with the liquid scintillation counters also caused minor delays.

The completion string consists of 6⅝-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing. The carbon-steel casing extends to a depth that is 3.4 m (11 ft) above the water table. The 6⅝-in. casing is slotted in the intervals 588.5 to 817.2 m (1,930.8 to 2,681.1 ft) and 993.4 to 1,133.5 m (3,259.1 to 3,718.7 ft), providing access to the TCA and TSA, respectively, for monitoring and sampling. The top slotted section consists of 36 consecutive stainless-steel slotted joints, and the bottom slotted section consists of 22 consecutive stainless-steel slotted joints. The slotted intervals are gravel-packed and separated by cement. A bridge plug was placed within the main completion string at 861.1 m (2,825 ft) on August 4, 2010, to isolate the two slotted intervals.

The well has three 2⅞-in. piezometer strings that access the two target aquifers and the deepest unit penetrated by the well. The three stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs. The shallow piezometer string is slotted from 584.8 to 817.2 m (1,918.6 to 2,681.2 ft) for monitoring within the TCA. The intermediate piezometer string is slotted from 987.5 to 1,134.6 m (3,239.9 to 3,722.3 ft) for monitoring within the TSA. The deep piezometer string is slotted from 1,181.6 to 1,194.5 m (3,876.7 to 3,918.8 ft) for monitoring within the CFCU.

Data collected during drilling of Well ER-EC-12 include composite drill cuttings samples collected every 3.0 m (10 ft) from 15.8 to 1,240.2 m (52 to 4,069 ft). In addition, 26 sidewall core samples were collected in the interval 332.2 to 1,193.3 m (1,090 to 3,915 ft). Open-hole geophysical logging was conducted in the upper portion of the borehole before installation of the surface casing, and in the lower portion after the TD of the well was reached. 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.

Well ER-EC-12 is collared in Ammonia Tanks Tuff and penetrated Tertiary volcanic rocks through its entire depth. These rocks consist largely of rhyolitic lava, bedded and nonwelded tuff, nonwelded to vitrophyric ash-flow tuffs, and landslide deposits. Water levels were measured in the well on August 5, 2010. In the shallow piezometer string (accessing the TCA), the water level was 415.4 m (1,363.0 ft). In the intermediate piezometer string (accessing the TSA), the water level was 415.8 m (1,364.3). In the deep piezometer string (accessing the CFCU), the water level was 413.6 m (1,356.9 ft). The elevation of the water level for the uppermost aquifer, the TCA, is 1,270.7 m (4,169 ft).

Tritium levels in the drilling fluid were below the MDC of the field instruments during drilling of Well ER-EC-12. Laboratory measurements on drilling effluent samples taken during drilling in the upper two aquifers were generally at or below the MDC.

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.

9.2 Recommendations

All the geologic and hydrologic data and interpretations from Well ER-EC-12 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. Updating the HFM will also allow better predictions for any future drilling, well development and testing, and aquifer testing.

The water level in Well ER-EC-12 should be monitored during the drilling and testing of nearby wells. Groundwater chemistry should be monitored on a routine basis to establish a baseline for the aquifers encountered and to learn more about possible groundwater flow systems. These data will also improve the understanding of aquifer connectivity. It is important that all completion zones in the well be tested and that all zones be monitored during pumping tests.

9.3 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 Well ER-EC-12, the first well in the 2010 Pahute Mesa Phase II drilling initiative, which built upon those learned during drilling in the 2009 initiative:

- The CAU guidance teams and hole-specific drilling advisory teams continued to provide timely assistance and guidance for addressing "surprises" and assessing their impacts on the overall program.

- The flow line separation incident (NSTec Incident Report Case #2010-116) led to the creation of a new safety procedure while drilling. When the borehole is unloading, personnel are not to be in the vicinity of the flow line. The UDI driller will communicate to personnel when it is safe to go about activities near the flow line. N-I personnel are to carry a net radio when working in the cuttings collection area so they can communicate directly with the driller about when the borehole is going to unload and when it is safe to return. As an extra precaution, one blast of the drill rig horn will serve as notification that the borehole is going to unload if N-I personnel cannot be contacted by radio.

- The flow line separation incident also led to the creation of a new flow line design to be used for all future UGTA drilling projects. In the new design, the flow line will be constructed using 16-in. outside diameter casing for its entire length (with no gate valves), and will be secured by chains and binders to large weights. Weights will be increased in size from 152.4 cm (60 in.) in diameter (5,443.1 kilograms [12,000 pounds] each) to 228.6 cm (90 in.) in diameter (11,385.2 kilograms [25,100 pounds] each). The number of weights will also increase, from two to five (one 60-in. and four 90-in. weights total). The 90-in. weights will be stacked two high, with the ones on the bottom partially buried and cemented into the ground.

- The drilling of UGTA holes has generally gone very well. However, the encounters with sloughing zones and bridges in Well ER-EC-12 were reminders that field personnel must always be prepared for unexpected or unfavorable down-hole conditions. At Well ER-EC-12, bentonite mud was placed in the well bore to stabilize the borehole during casing and stemming operations. This remedy allowed casing and stemming operations to proceed smoothly.

- Predicting the geology in a structurally complex caldera setting is associated with considerable uncertainty. Sometimes the target geologic units are deeper than expected.

It is prudent, therefore, to have extra casing and stemming materials on-hand to allow for deepening the well and avoid delays waiting on material deliveries.

- Geologists learn more with every hole drilled in the geologically complex Pahute Mesa area, and modify their conceptual models as necessary when new holes are drilled.

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Appendix A
Drilling Data

A-1 Drilling Parameter Log for Well ER-EC-12
A-2 Tubing and Casing Data for Well ER-EC-12
A-3 Well ER-EC-12 Drilling Fluids and Cement Composition

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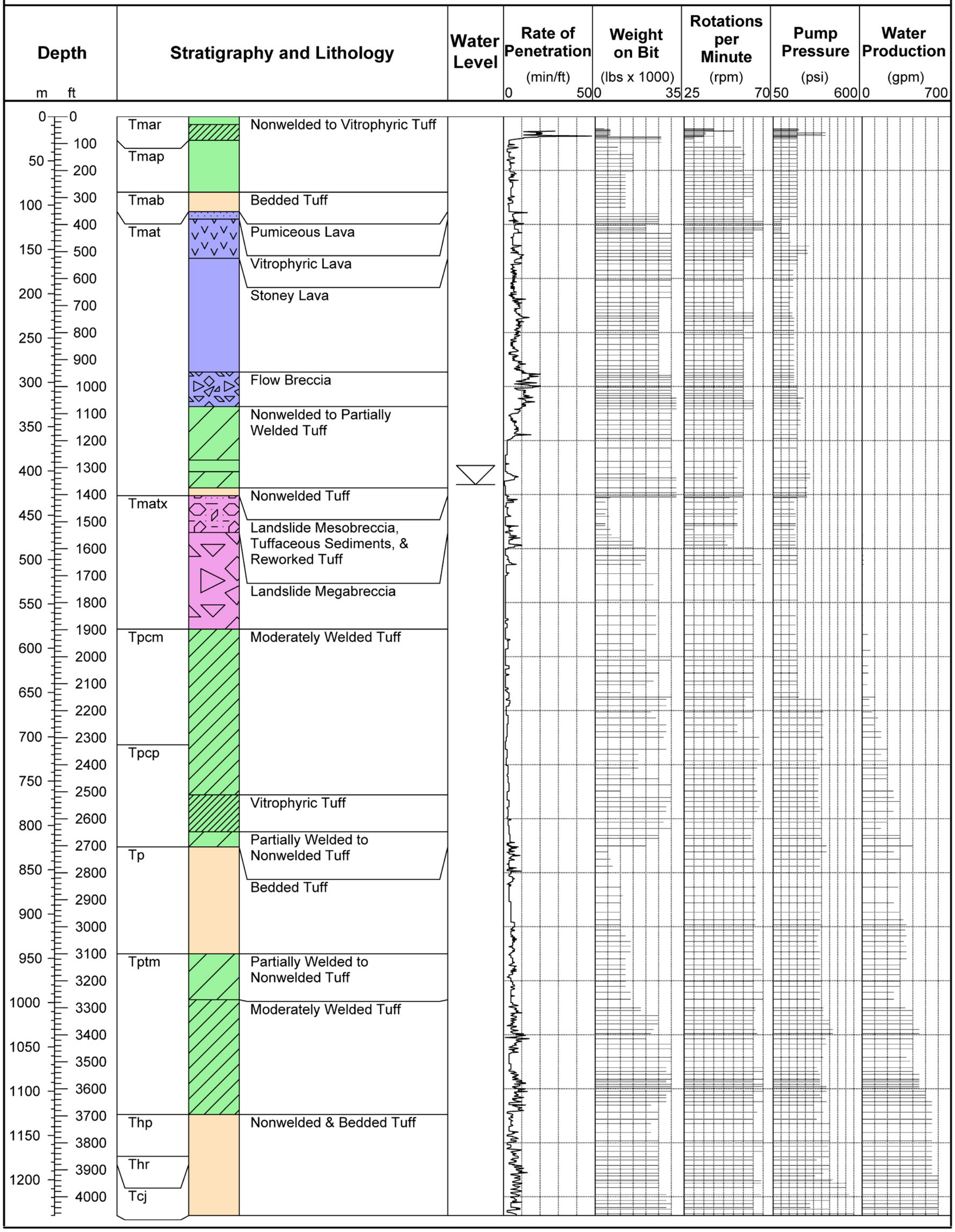
Appendix A-1
Drilling Parameter Log for Well ER-EC-12

Well ER-EC-12

Logging Company: Baker Atlas
Drilled Depth: 1,240.2 m (4,069 ft)
Date TD Reached: July 9, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,686.2 m (5,532.0 ft)
Coordinates (UTM [NAD 83]): 4,114,210.7 m
545,018.9 m
Water Level: 415.4 m (1,363.0 ft) on August 5, 2010



See legend for lithology symbols on Page D-2.

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Appendix A-2
Tubing and Casing Data for Well ER-EC-12

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Table A-2
Tubing and Casing Data for Well ER-EC-12

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 15.7 (0 to 51.5)	Carbon Steel	B	76.20 (30)	73.66 (29)	1.270 (0.500)	157.8
Surface	0 to 385.8 (0 to 1,265.9)	Carbon Steel	K55	40.64 (16)	38.415 (15.124)	1.113 (0.438)	75.0
Completion (with crossover)	0 to 412.1 (0 to 1,352.0)	Epoxy-Coated Carbon-Steel	N80	19.368 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4
Completion	412.1 to 1,140.6 (1,352.0 to 3,742.0)	Stainless Steel	SSTP304	16.828 (6.625)	15.504 (6.104)	0.663 (0.261)	NR [a]
Shallow Piezometer (with crossover)	0 to 407.7 (0 to 1,337.5)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Shallow Piezometer	407.7 to 817.2 (1,337.5 to 2,681.2)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66
Intermediate Piezometer (with crossover)	0 to 410.6 (0 to 1,347.0)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Intermediate Piezometer	410.6 to 1,134.6 (1,347.0 to 3,722.3)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66
Deep Piezometer (with crossover)	0 to 398.2 (0 to 1,306.5)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Deep Piezometer	398.2 to 1,194.5 (1,306.5 to 3,918.8)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66

a NR = not recorded. Schedule 40 stainless-steel casing of this size may range in weight from approximately 18 to 19 pounds per foot.

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Appendix A-3
Well ER-EC-12 Drilling Fluids and Cement Composition

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Table A-3-1
Drilling Fluids Used in Well ER-EC-12

Typical Air-Foam/Polymer Mix
56.8 to 132.5 liters (15 to 35 gallons) Geofoam® [a]
0 to 3.8 liters (0 to 1 gallons) 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-EC-12 came from Water Well 8 (WW-8).

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-EC-12 Cement Composition

Cement Composition	30-inch Conductor Casing	16-inch Surface Casing	6⅝-inch Completion Casing	2⅞-inch Deep Piezometer String
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 16.0 m [a] (0 to 52.5 ft) [b]	none	none	none
Type II neat	none	301.8 to 398.7 m (990 to 1,308 ft)	533.4 to 565.1 m (1,750 to 1,854 ft) 836.4 to 971.7 (2,744 to 3,188 ft)	1,149.1 to 1,164.3 m (3,770 to 3,820 ft)

a meter(s)
b foot (feet)

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Appendix B
Well ER-EC-12 Fluid Management Data

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Table B-1
Well ER-EC-12 Fluid Disposition Reporting Form

Site Identification: ER-EC-12
Site Location: Nevada Test and Training Range
Site Coordinates (UTM NAD 27, Zone 11): N 4,114,013.57 m, E 545,099.15 m
Well Classification: ER Hydrogeologic Investigation Well
N-I Project No: UG10-410

Report Date: 02/01/2011
NNSA/NSO Federal Sub-Project Director: Bill Wilborn
N-I Project Manager: Sam Marutzky
N-I Site Representative: Michael Pitterle
N-I Field 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)		Infiltration Area [d] (m^3)	Other [e] (m^3)	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids [b]	Liquids [c]	Liquids		
Phase I: Vadose Zone Drilling	06/26/10	06/30/10	5	415.4	434	133	288	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	07/03/10	07/09/10	7	1,240.3	351	139	1,451	N/A	288	6,866	N/A	Yes
Phase II: Initial Well Development	07/24/10	07/26/10	3	1,240.3	N/A	N/A	972	N/A	N/A	N/A	N/A	Yes
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			15	1,240.3	785	272	2,711	N/A	288	6,866	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.
[b] Solids volume estimates include calculated added volume attributed to rock bulking factor.
[c] Fluid being discharged into Sump #1 overflowed into Sump #2 during high pressure/high volume discharges.
[d] Ground surface discharge.
[e] Other refers to fluid conveyance to other fluid management devices or facilities; e.g., baker tank or transport to another well site for storage.
N/A = 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 very low/no infiltration) = N/A

Remaining Facility Capacity (Approximate) as of 07/29/2010: Sump #1 = 0 m^3 (0%) Sump #2 = 1,260 m^3 (81%)

Current Tritium, Sump #1 FMP sample = 70 pCi/L (less than the minimum detectable concentration)

Notes: None

N-I Authorizing Signature/Date: 2-14-11

Table B-2
Analytical Results for Fluid Management Sample for Well ER-EC-12

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act (RCRA)* Metals (mg/L)							
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
ER-EC-12-071710-1	07/17/2010	Sample from Sump #1	Total	0.01 U	0.1	0.005 U	0.01 U	0.003 U	0.005 U	0.01 U	0.0002 U
			Dissolved	0.01 U	0.0012 J-	0.005 U	0.0015 J-	0.0029 U	0.0037 U	0.01 U	0.0002 U
ER-EC-12-071710-2	07/17/2010	Quality-Control Rinsate Sample	Total	0.0043	0.032 J-	0.005 U	0.0044 J-	0.017	0.005 U	0.01 U	0.0002 U
			Dissolved	0.01 U	0.1 U	0.005 U	0.01 U	0.003 U	0.005 U	0.01 U	0.0002 U
			Detection Limit	0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002
			Nevada Drinking Water Standard	0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002

Sample Number	Date Collected	Comment		Radiological Indicator Parameters (pCi/L)		
				Tritium	Gross Alpha	Gross Beta
ER-EC-12-071710-1	07/17/2010	Sample from Sump #1	Result	70	4.8	4.5
			Error	220	1.5	1.6
			MDC	370	1.4	2.2
ER-EC-12-071710-2	07/07/2010	Quality-Control Rinsate Sample	Result	80 U	0.46 U	0.2 U
			Error	220	0.84	1.4
			MDC	370	1.46	2.5
			Nevada Drinking Water Standard	15	50	20,000

Analyses for metals and radionuclides performed by ALS Laboratory Group.
Data provided by Navarro-Intera, LLC (N-I, 2011)

Sump #1 is an unlined sump located on the Well ER-EC-12 drill pad.

Notes: U = Compound analyzed for but not detected (“nondetect”).
J- = Result is estimated bias low.
MDC (minimum detectable concentration) varies by matrix, instrument, and count rates.
mg/L = milligrams per liter   pCi/L = picocuries per liter

Analytical methods: All metals except mercury: Environmental Protection Agency (EPA) *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Method 6010 (SW-846, 6010)
Mercury: EPA SW-846, 7470
Tritium: EPA Method 906.0
Gross alpha and gross beta: EPA Method 900.0

Appendix C
Detailed Lithologic Log for Well ER-EC-12

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Table C-1
Detailed Lithologic Log for Well ER-EC-12
Logged by Jennifer Mercadante, Lance Prothro, and Sigmund Drellack, National Security Technologies, LLC, in September 2010. Updated to incorporate analytical data, January 2011.

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
0–9.1 (0–30)	9.1 (30)	AC	None	**Nonwelded Ash-Flow Tuff:** Very pale orange (10YR 8/2); vitric; minor pumice; minor felsic phenocrysts of quartz and feldspar; common biotite; rare lithic fragments.	mafic-rich Ammonia Tanks Tuff (Tmar)
9.1–26.8 (30–88)	17.7 (58)	AC DA	None	**Densely Welded Ash-Flow Tuff to Vitrophyre:** Moderate brown (5YR 4/4) to olive black (5Y 2/1) (vitrophyre); mostly vitric and lesser silicic; rare pumice; common felsic phenocrysts of quartz and feldspar; common to abundant biotite, trace clinopyroxene; rare lithic fragments. Vitrophyre is perlitic.	
26.8–47.9 (88–157)	21.0 (69)	DA	42.7 (140)	**Nonwelded Ash-Flow Tuff:** Grayish yellow (5Y 8/4) to pale greenish yellow (10Y 8/2); zeolitic; minor to common pumice; minor felsic phenocrysts of quartz (including dipyramidal quartz) and feldspar; minor biotite; rare to minor lithic fragments; sphene is present; rare manganese oxide stains.	mafic-poor Ammonia Tanks Tuff (Tmap)
47.9–85.3 (157–280)	37.5 (123)	DA	70.1 (230)	**Nonwelded Ash-Flow Tuff:** Light brown (5YR 6/4) to 76.2 m (250 ft), color change at 76.2 m (250 ft) to grayish orange (10YR 7/4); zeolitic; common to abundant pumice; minor felsic phenocrysts of quartz (including dipyramidal quartz) and feldspar; rare to minor biotite and magnetite; rare lithic fragments; sphene is present.	
85.3–107.3 (280–352)	21.9 (72)	DA	106.7 (350)	**Bedded Tuff:** Grayish orange (10YR 7/4) to very pale orange (10YR 8/2); zeolitic; minor pumice; minor felsic phenocrysts of quartz and feldspar; rare to minor biotite; abundant to very abundant lithic fragments, increasing in abundance towards base of interval; sphene is present.	bedded Ammonia Tanks Tuff (Tmab)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
107.3–115.8 (352–380)	8.5 (28)	DA	None	**Pumiceous Rhyolite Lava:** Dusky yellow (5Y 6/4); zeolitic, becoming vitric in part towards base of interval; rare to minor felsic phenocrysts of quartz and feldspar; rare to minor biotite and magnetite; sphene is present; manganese oxide stains.	rhyolite of Tannenbaum Hill (Tmat)
115.8–160.0 (380–525)	44.2 (145)	DA	None	**Vitrophyric Rhyolite Lava:** Light olive gray (5Y 6/1) to olive gray (5Y 4/1) becoming dark gray (N3) towards base of interval; vitric; perlitic; rare to minor felsic phenocrysts of quartz and feldspar; rare biotite. Possible intercalated flow breccia from 147.5 to 155.4 m (484 to 510 ft): grayish red (10R 4/2) and pale yellowish brown (10YR 6/2), devitrified, spherulitic.	
160.0–184.4 (525–605)	24.4 (80)	DA	None	**Stoney Rhyolite Lava:** Light olive gray (5Y 6/1), dark gray (N3), grayish red (10R 4/2), moderate brown (5YR 3/4), and light olive gray (5Y 6/1); vitric and devitrified, partially silicic to 179.8 m (590 ft), becoming mostly devitrified from 179.8 to 184.4 m (590 to 605 ft); perlitic and flow banded; rare to minor felsic phenocrysts of quartz and feldspar; rare biotite. Interval likely represents a transition zone from the upper vitrophyre to the stoney interior of the flow.	
184.4–288.3 (605–946)	103.9 (341)	DA	None	**Stoney Rhyolite Lava:** Medium light gray (N6), mottled with light brown (5YR 6/4); devitrified; minor felsic phenocrysts of quartz and feldspar; rare to minor biotite (bronze and black), decreasing towards the base; weakly flow banded.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
288.3–327.4 (946–1,074)	39.0 (128)	DA	None	**Basal Flow Breccia:** Brownish gray (5YR 4/1), pale brown (5YR 5/2), and grayish red (10R 4/2); devitrified; minor felsic phenocrysts of quartz and feldspar; rare biotite; sphene is present. Scarce black vitric fragments may represent a thin lower vitrophyre not seen on the geophysical logs.	rhyolite of Tannenbaum Hill (Tmat)
327.4–360.6 (1,074–1,183)	33.2 (109)	DA	350.5 (1,150)	**Partially Welded Ash-Flow Tuff:** Pale yellowish brown (10YR 6/2); devitrified, with vapor-phase mineralization; minor pumice; minor felsic phenocrysts of quartz and feldspar; rare biotite (bronze and black); rare to minor lithic fragments.	
360.6–387.7 (1,183–1,272)	27.1 (89)	DA PSWC	None	**Partially Welded Ash-Flow Tuff:** Pale yellowish brown (10YR 6/2); devitrified, with vapor-phase mineralization; common to abundant pumice; minor to common felsic phenocrysts of quartz and feldspar; rare biotite (black and bronze); minor lithic fragments; sphene is present.	
387.7–400.8 (1,272–1,315)	13.1 (43)	DA	390.1 (1,280)	**Nonwelded Ash-Flow Tuff:** Pale yellowish brown (10YR 6/2) and light brown (5YR 6/4); zeolitic; minor pumice; minor felsic phenocrysts of quartz and feldspar; rare to minor biotite (bronze and black); rare to minor lithic fragments; sphene is present.	
400.8–419.1 (1,315–1,375)	18.3 (60)	DA PSWC	None	**Partially Welded Ash-Flow Tuff:** Moderate yellowish brown (10YR 5/4); devitrified, with vapor-phase mineralization; minor to common pumice; minor to common felsic phenocrysts of quartz and feldspar; rare biotite (black and bronze); minor lithic fragments.	
419.1–427.9 (1,375–1,404)	8.8 (29)	DA PSWC	426.7 (1,400)	**Nonwelded Tuff:** Dark yellowish orange (10YR 6/6); quartzo-feldspathic; common pumice; minor felsic phenocrysts of quartz and feldspar; minor biotite (pseudomorphic pyroxene, hornblende, and sphene observed in thin section); 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)
427.9–469.4 (1,404–1,540)	41.5 (136)	DA RSCW PSWC	432.8 (1,420)	**Landslide Mesobreccia, Tuffaceous Sandstone and Gravel, and Reworked Tuff:** Vari-colored ranging from grayish orange (10YR 7/4) to moderate brown (5YR 3/4); mostly angular to sub-angular, lesser sub-rounded; very poorly to moderately sorted; very coarse to fine sand and gravel; clasts of pumice, felsic crystal fragments, and rock fragments of lava and welded tuff; weakly to moderately calcareous. The interval is a lithologically heterogeneous sequence of mostly immature tuffaceous clastic deposits that likely represent the deposition of volcanic debris by mass wasting and alluvial fan deposition from a collapse collar associated with a nearby fault.	landslide deposits related to the rhyolite of Tannenbaum Hill (Tmatx)
469.4–578.5 (1,540–1,898)	109.1 (358)	DA RSWC PSWC	475.5 (1,560) 493.8 (1,620) 520.6 (1,708) 570.0 (1,870)	**Landslide Megabreccia:** Drill cuttings samples are a heterogeneous mixture of various devitrified welded-tuff fragments. The welded-tuff fragments are angular and "fresh-looking" with no adhering matrix, suggesting the presence of large blocks. The dominance of a single welded-tuff lithology in several consecutive 3.0 m (10 ft) sample containers suggests that blocks greater than 9.1 m (30 ft) thick may be present. Most fragments appear to be Tiva Canyon Tuff. However, in the upper portion of the interval, above approximately 487.7 m (1,600 ft), fragments of partially welded mafic-poor Rainier Mesa Tuff are conspicuous. Numerous quartz-filled fractures observed in drill cuttings fragments and thin sections suggest internal shattering of blocks. Occasional drill cuttings fragments of breccia likely represent basal or internal brecciation of individual blocks as observed in image logs of the well. Density and resistivity logs also suggest heterogeneity within the interval. The interval likely represents a complex and heterogeneous sequence of mostly landslide megabreccia deposits formed as a result of large-scale mass wasting of a collapse collar associated with a nearby fault.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
578.5–709.0 (1,898–2,326)	130.5 (428)	DA RSWC	606.6 (1,990) 701.0 (2,300)	**Moderately Welded Ash-Flow Tuff:** Mostly grayish brown (5YR 3/2) becoming mottled with grayish brown (5YR 3/2) and moderate brown (5YR 4/4); quartzo-feldspathic; minor to common pumice; minor partially to completely dissolved feldspar phenocrysts; minor biotite (pseudomorphic pyroxene and sphene observed in thin section); rare lithic fragments.	Pahute Mesa lobe of Tiva Canyon Tuff (Tpcm)
709.0–765.7 (2,326–2,512)	56.7 (186)	DA RSWC	755.9 (2,480.1)	**Moderately Welded Ash-Flow Tuff:** Moderate brown (5YR 4/4); quartzo-feldspathic; minor to common pumice; rare to minor partially dissolved feldspar phenocrysts (trace of quartz observed in thin section); rare to minor biotite (pseudomorphic hornblende and sphene observed in thin section); no lithic fragments observed with binocular microscope, however, trace of lithic fragments observed in thin section. An increase in density below 742.2 m (2,435 ft) is observed on the density log.	crystal-poor Tiva Canyon Tuff (Tpcp)
765.7–807.1 (2,512–2,648)	41.5 (136)	DA RSWC	804.7 (2,640)	**Vitrophyric Ash-Flow Tuff:** Light brown (5YR 5/6) to 777.2 m (2,550 ft), moderate brown (5YR 4/4), grayish brown (5YR 3/2), and lesser olive black (5Y 2/1) from 777.2 to 801.6 m (2,550 to 2,630 ft), olive black (5Y 2/1) and grayish brown (5YR 3/2) from 801.6 to 807.1 m (2,630 to 2,648 ft); vitric, devitrified, and silicic; no pumice clearly distinguishable in cuttings (pumice observed in thin section); rare to minor feldspar phenocrysts (trace of quartz observed in thin section); rare biotite (hornblende and sphene observed in thin section); no lithic fragments clearly distinguishable in cuttings (lithic fragments observed in thin section).	
807.1–824.2 (2,648–2,704)	17.1 (56)	DA RSWC	None	**Partially Welded to Nonwelded Ash-Flow Tuff:** Brownish gray (5YR 4/1) becoming light brownish gray (5YR 6/1) with grayish green (10GY 5/2) mottling towards base of interval; quartzo-feldspathic; minor to common pumice; minor felsic phenocrysts of pseudomorphs after feldspar; rare biotite; rare lithic fragments.	crystal-poor Tiva Canyon Tuff (Tpcp)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
824.2–944.9 (2,704–3,100)	120.7 (396)	DA RSWC PSWC	838.2* (2,750)* 845.8 (2,775) 856.5 (2,810) 935.7 (3,070)	**Bedded Tuff:** Grayish green (10GY 5/2) to 859.5 m (2,820 ft), mostly grayish yellow green (5GY 7/2) from 859.5 to 944.9 m (2,820 to 3,100 ft); quartzo-feldspathic, also pyritic and chloritic; minor to common pumice; rare to minor felsic phenocrysts of quartz and altered feldspars; rare biotite; minor to common lithic fragments. *Sample was taken from drill cuttings recovered at the depth of 1,069.8 m (3,510 ft), but represents material sloughed from the borehole wall at the depth of 838.2 m (2,750 ft). Warren (2011) calls this sample 3,510DB(1.	Paintbrush Group, undivided (Tp)
944.9–996.7 (3,100–3,270)	51.8 (170)	DA RSWC	966.2 (3,170)	**Nonwelded to Partially Welded Ash-Flow Tuff:** Light brownish gray (5YR 6/1) to grayish orange pink (5YR 7/2); quartzo-feldspathic and pyritic; minor to common grayish yellow green (5GY 7/2) pumice; minor partially altered feldspar phenocrysts and pseudomorphs after feldspars, trace quartz; minor to common biotite; rare lithic fragments.	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)
996.7–1,025.7 (3,270–3,365)	29.0 (95)	DA RWSC	1,018.0 (3,340)	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2); quartzo-feldspathic, minor pyritic, and weakly calcareous; minor to common pumice; minor to common feldspar phenocrysts of altered feldspar, trace quartz; common biotite; rare lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice 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)
1,025.7–1,126.2 (3,365–3,695)	100.6 (330)	DA RSWC	1,030.2 (3,380) 1,091.2 (3,580) 1,109.5 (3,640)	**Moderately Welded Ash-Flow Tuff:** Medium dark gray (N4) to dark gray (N3) and mottled with dark reddish brown (10R 3/4), becoming grayish red (10R 4/2) below 1,118.6 m (3,670 ft); quartzo-feldspathic, minor pyritic, and weakly calcareous; spherulitic; minor to common pumice; minor to common feldspar phenocrysts of altered feldspars and lesser quartz; common biotite and pseudomorphs after biotite; rare lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice fragments.	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)
1,126.2–1,154.6 (3,695–3,788)	28.3 (93)	DA RSWC	1,150.3 (3,774)	**Nonwelded Tuff:** Medium light gray (N6) to light brownish gray (5YR 6/1); quartzo-feldspathic, weakly calcareous; rare to minor pumice; rare to minor felsic phenocrysts of quartz and altered feldspars; rare pseudomorphic biotite (pseudomorphic pyroxene and hornblende observed in thin section); rare to minor lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice fragments.	mafic-poor Calico Hills Formation (Thp)
1,154.6–1,173.5 (3,788–3,850)	18.9 (62)	DA RSWC	1,167.4 (3,830.1)	**Nonwelded Tuff:** Light brownish gray (5YR 6/1) to medium light gray (N6); quartzo-feldspathic; rare to minor pumice; rare felsic phenocrysts of quartz and altered feldspars; rare pseudomorphic biotite (pseudomorphic pyroxene observed in thin section); minor to common lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice 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)
1,173.5–1,182.6 (3,850–3,880)	9.1 (30)	DA RSWC	1,179.6 (3,870.1)	**Bedded Tuff:** Pale brown (5YR 5/2) and grayish red (10R 4/2); quartzo-feldspathic; minor to common pumice, some conspicuously grayish green (10GY 5/2); minor to common altered feldspar phenocrysts; minor to common small dark minerals that appear to be secondary minerals, some of which likely represent pseudomorphs after biotite; rare to minor lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice fragments.	mafic-rich Calico Hills Formation (Thr)
1,182.6–1,240.2 (3,880–4,069) Total Depth	57.6 (189)	DA RSWC	1,222.2 (4,010)	**Nonwelded Tuff:** Dark gray (N3); quartzo-feldspathic, weakly calcareous (other secondary minerals observed in thin section include pyrite, chlorite, and fluorite); rare to minor pumice; minor altered feldspar phenocrysts (quartz observed in thin section); minor pseudomorphs after biotite; rare lithic fragments. Moderate yellow green (5GY 7/4) to dusky yellowish green (10GY 3/2) secondary mineral replaces some feldspars and pumice fragments.	rhyolite of Jorum (Tcj)

NOTES:

a Lithologic samples collected from interval during drilling and logging operations and utilized for lithological interpretation. **AC =** auger cuttings; **DA** = drill cuttings that represent lithologic character of interval. Note: The upper 3.0 to 6.1 m (10 to 20 ft) of most intervals contain cuttings from the overlying interval, particularly in the bottom half of the hole, due to drilling lag time; **PSWC** = percussion-gun sidewall core; **RSWC =** rotary sidewall core. See Table 3-1 in this report for more information about sidewall samples.

NOTES, continued:

b Depth of lithologic samples selected for laboratory analyses (for drill cuttings samples, depths represent base of 3.0-m [10-ft] sample interval). Laboratory analyses include petrography (from polished thin sections), mineralogy (x-ray diffraction), and chemistry (x-ray fluorescence). See Table 3-2 in this report for a complete list of laboratory analyses. Analysis results are presented in Warren (2011) and WoldeGabriel et al. (2010).

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%.

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Appendix D
Geophysical Logs Run in Well ER-EC-12

Appendix D contains plots of selected geophysical logs run in Well ER-EC-12. Table D-1 summarizes the logs presented. See Table 3-3 for more information.

Table D-1
Well ER-EC-12 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	feet
Caliper	CA6-1 CA6-3	6/30/2010 7/11/2010	15.2–425.8 301.8–1,206.7	50–1,397 990–3,959
X-Multipole Array Acoustilog (sonic)	XMAC-1	7/12/2010	420.3–1,198.5	1,379–3,932
Gamma Ray	GR-1 GR-7	6/30/2010 7/11/2010	2.7–418.2 301.8–1,198.8	9–1,372 990–3,933
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	6/30/2010 7/11/2010	2.7–418.2 301.8–1,198.8	9–1,372 990–3,933
High Definition Induction and R_t Explorer (resistivity)	HDIL-1 RTEX-1	7/1/2010 7/13/2010	15.7–425.2 416.4–1,193.6	51.5–1,395 1,366–3,916
Density	ZDL-1 ZDL-2	7/1/2010 7/12/2010	3.0–425.8 266.7–1,203.4	10–1,397 875–3,948
Compensated Neutron	CN-2	7/12/2010	266.7–1,203.4	875–3,948
Chemistry (pH and conductivity) Temperature	Chem-1 TL-2	7/14/2010	417.0–1,197.6	1,368–3,929
Heat Pulse Flow Log	HPFlow-1	7/14/2010	432.8–816.9	1,420–2,680

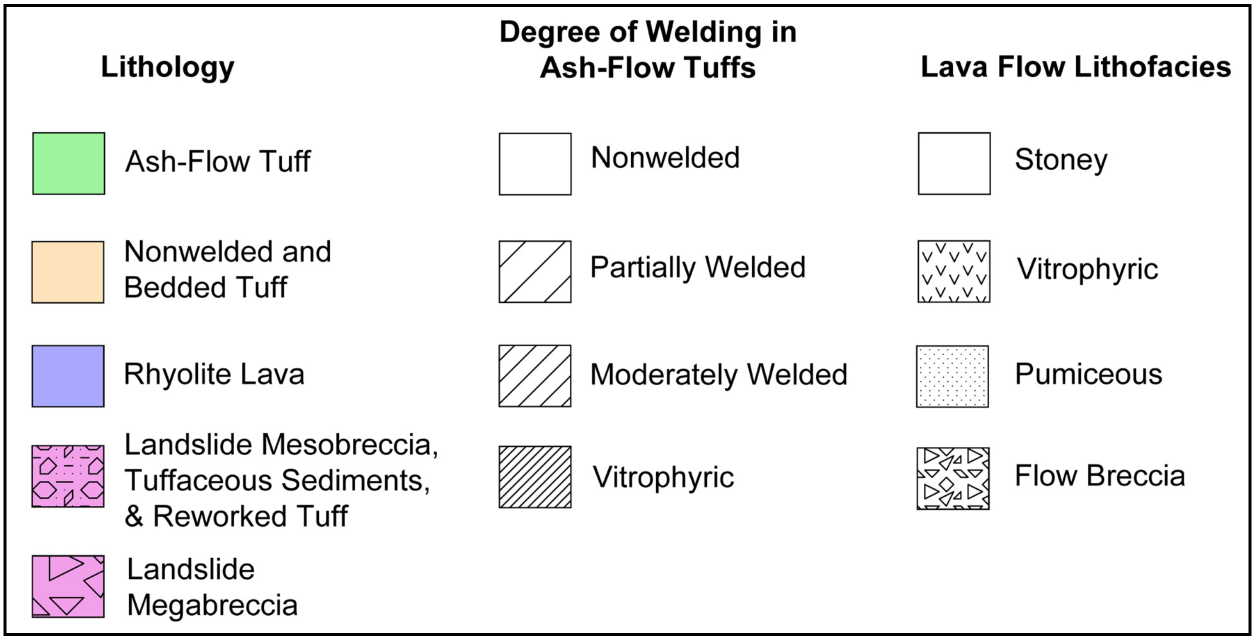
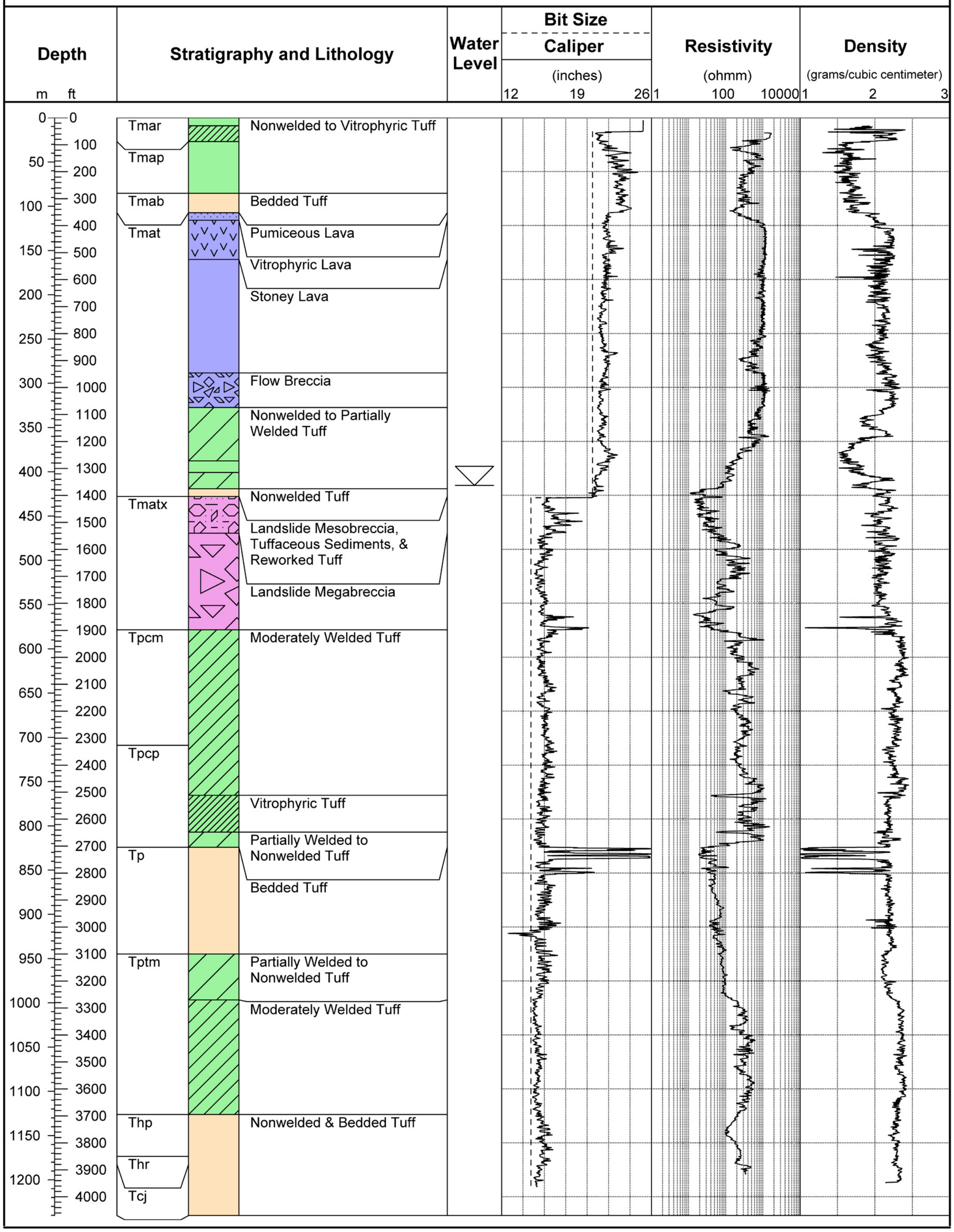


Figure D-1
Legend for Lithology Symbols Used on Log Plots

Well ER-EC-12

Logging Company: Baker Atlas
Date Logged: June 30 and July 1, 11, 12, and 13, 2010
Drilled Depth: 1,240.2 m (4,069 ft)
Date TD Reached: July 9, 2010
Drill Method: Rotary/Air foam

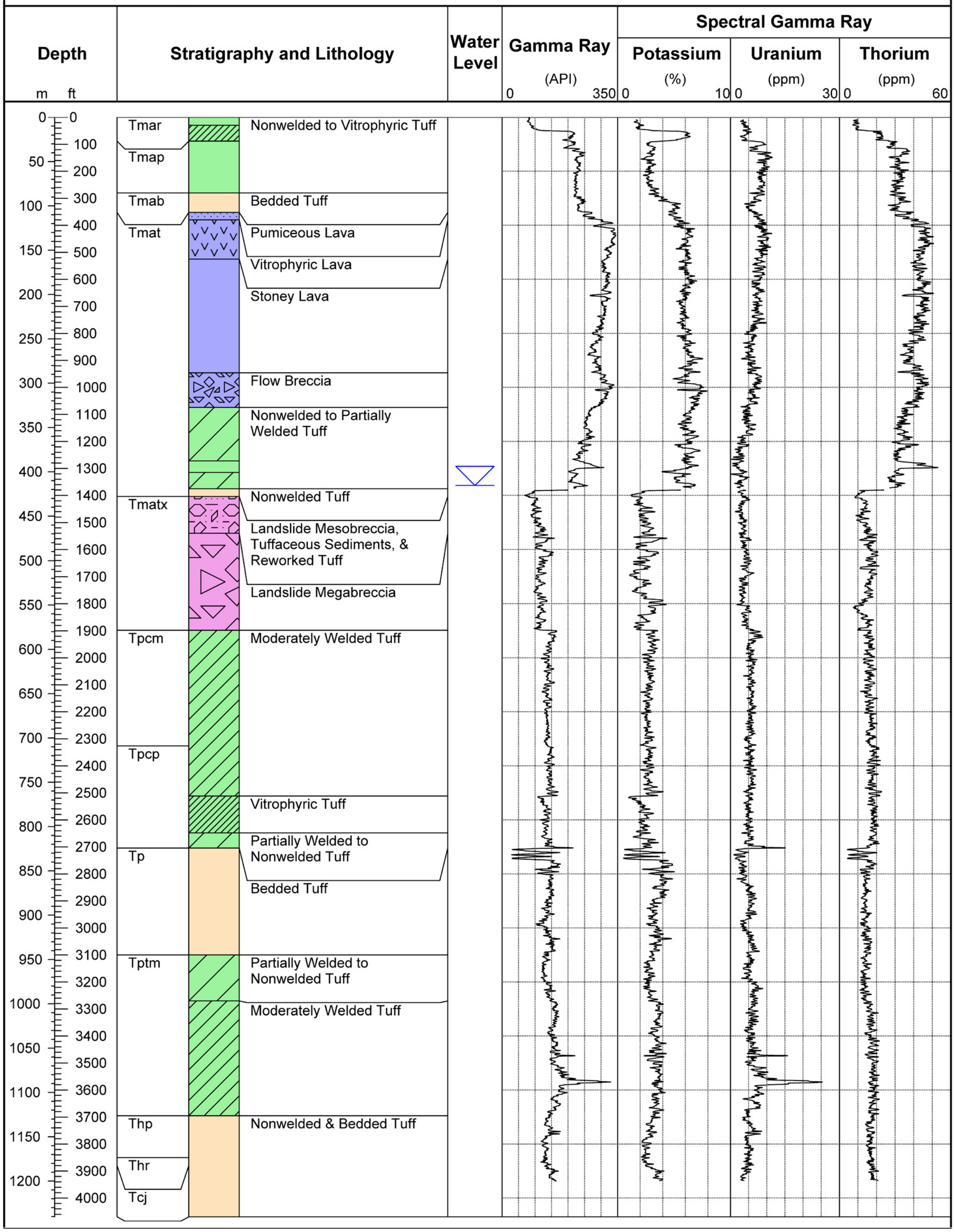
Surface Elevation: 1,686.2 m (5,532.0 ft)
Coordinates (UTM [NAD 83]): 4,114,210.7 m
545,018.9 m
Water Level: 415.4 m (1,363.0 ft) on August 5, 2010



Well ER-EC-12

Logging Company: Baker Atlas
Date Logged: June 30 and July 11, 2010
Drilled Depth: 1,240.2 m (4,069 ft)
Date TD Reached: July 9, 2010
Drill Method: Rotary/Air foam

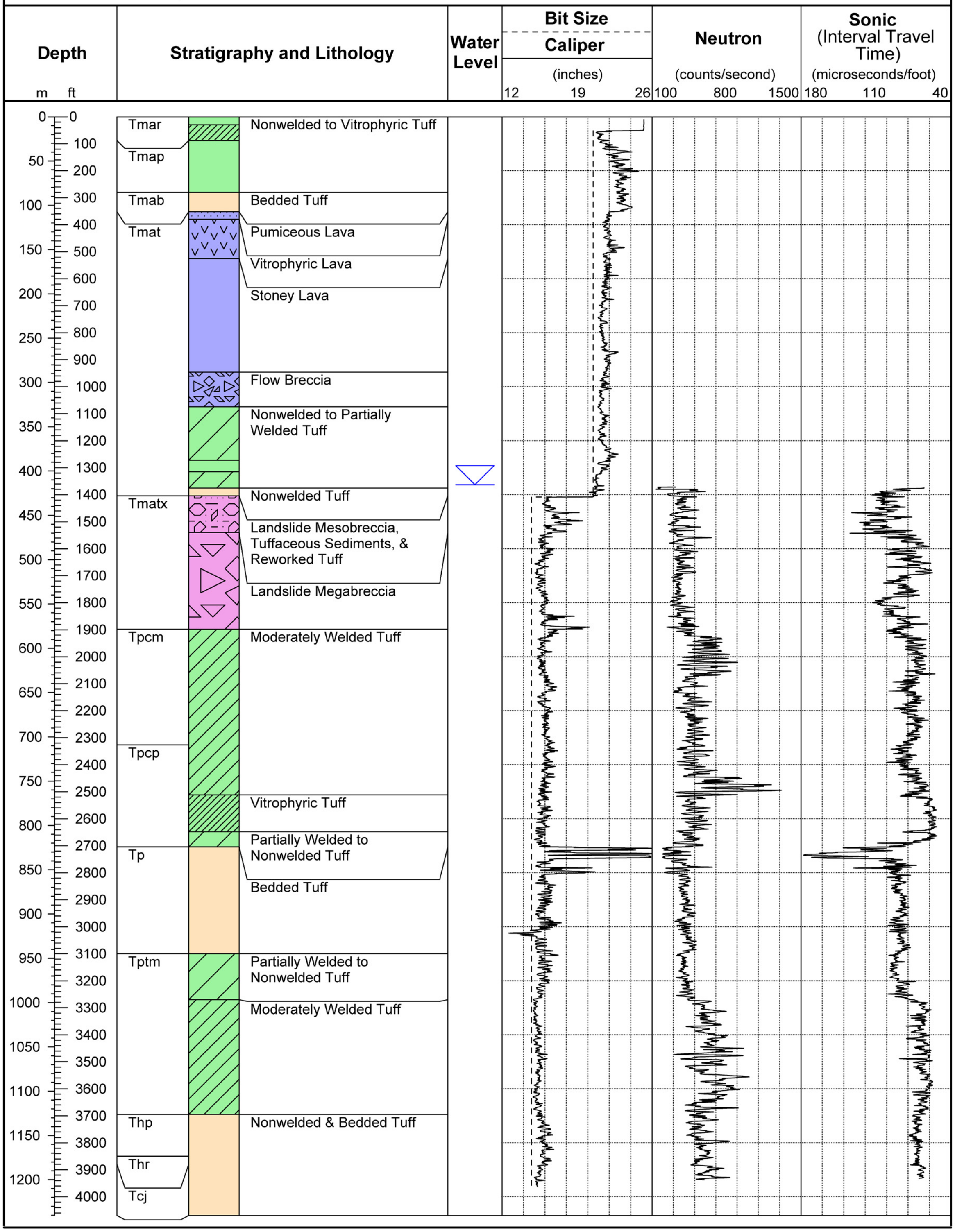
Surface Elevation: 1,686.2 m (5,532.0 ft)
Coordinates (UTM [NAD 83]): 4,114,210.7 m
545,018.9 m
Water Level: 415.4 m (1,363.0 ft) on August 5, 2010



Well ER-EC-12

Logging Company: Baker Atlas
Date Logged: June 30 and July 11 and 12, 2010
Drilled Depth: 1,240.2 m (4,069 ft)
Date TD Reached: July 9, 2010
Drill Method: Rotary/Air foam

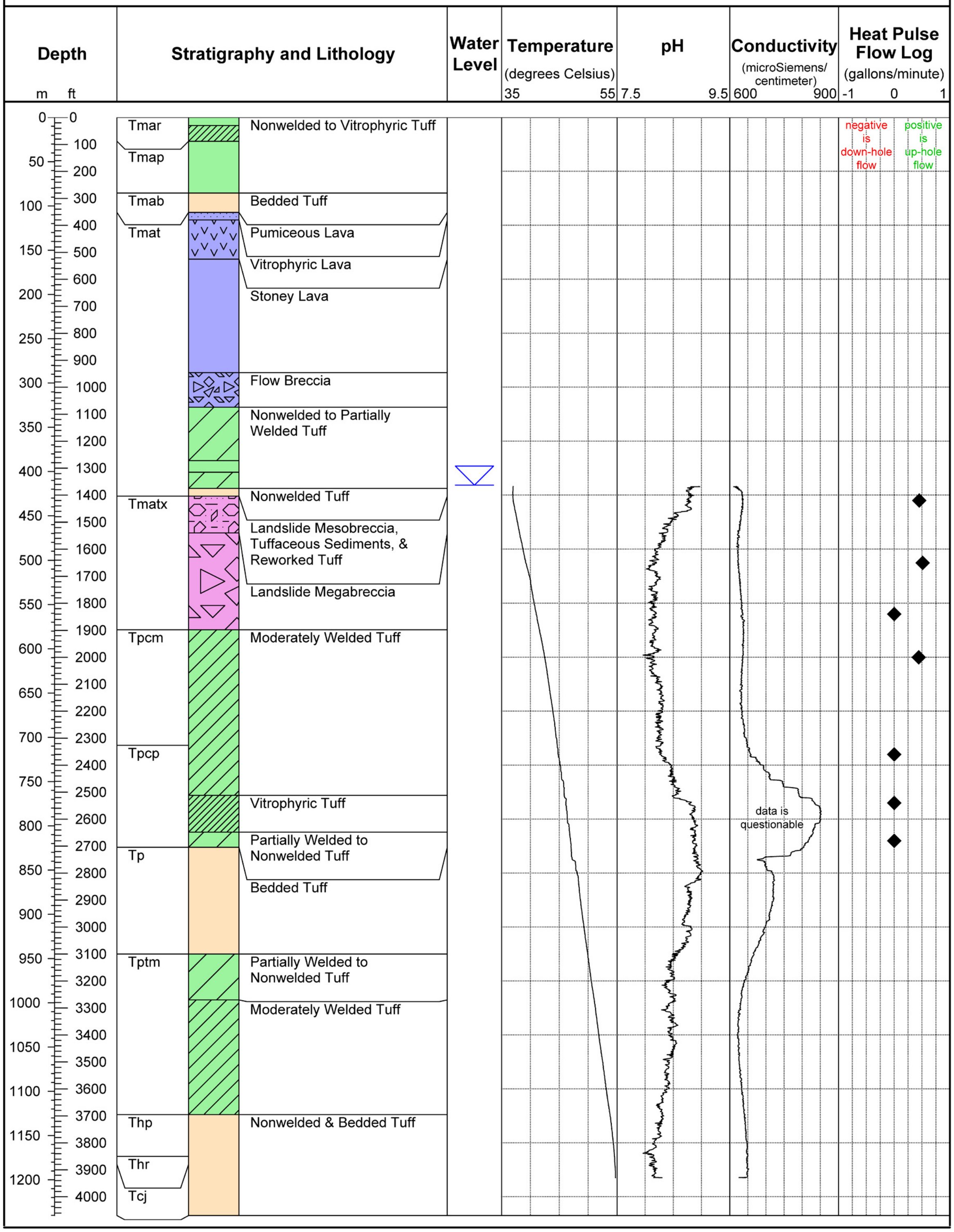
Surface Elevation: 1,686.2 m (5,532.0 ft)
Coordinates (UTM [NAD 83]): 4,114,210.7 m
545,018.9 m
Water Level: 415.4 m (1,363.0 ft) on August 5, 2010



Well ER-EC-12

Logging Company: Desert Research Institute
Date Logged: July 14, 2010
Drilled Depth: 1,240.2 m (4,069 ft)
Date TD Reached: July 9, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,686.2 m (5,532.0 ft)
Coordinates (UTM [NAD 83]): 4,114,210.7 m
545,018.9 m
Water Level: 415.4 m (1,363.0 ft) on August 5, 2010



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