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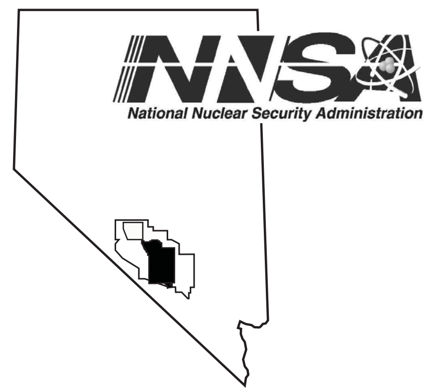

Completion Report for Model Evaluation Well ER-5-5

Corrective Action Unit 98: Frenchman Flat

January 2013

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

DOE/NV--1496

Completion Report for Model Evaluation Well ER-5-5

Corrective Action Unit 98: Frenchman Flat

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

January 2013

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DOE/NV--1496

Completion Report for Model Evaluation Well ER-5-5

Corrective Action Unit 98: Frenchman Flat

Approved by: _[signature]_ Date: 1/16/13

Wilhelm R. Wilborn
Underground Test Area Activity Lead

Approved by: _[signature]_ Date: 1/17/13

Robert F. Boehlecke
Environmental Management Operations Manager

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Abstract

Model Evaluation Well ER-5-5 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office in support of Nevada Environmental Management Operations at the Nevada National Security Site (formerly known as the Nevada Test Site). The well was drilled in July and August 2012 as part of a model evaluation well program in the Frenchman Flat area of Nye County, Nevada. The primary purpose of the well was to provide detailed geologic, hydrogeologic, chemical, and radiological data that can be used to test and build confidence in the applicability of the Frenchman Flat Corrective Action Unit flow and transport models for their intended purpose. In particular, this well was designed to obtain data to evaluate the uncertainty in model forecasts of contaminant migration from the upgradient underground nuclear test MILK SHAKE, conducted in Emplacement Hole U-5k in 1968, which were considered to be uncertain due to the unknown extent of a basalt lava-flow aquifer present in this area. Well ER-5-5 is expected to provide information to refine the Phase II Frenchman Flat hydrostratigraphic framework model, if necessary, as well as to support future groundwater flow and transport modeling.

The 31.1-centimeter (cm) diameter hole was drilled to a total depth of 331.3 meters (m). The completion string, set at the depth of 317.2 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 one slotted interval open to the basalt lava-flow aquifer and limited intervals of the overlying and underlying alluvial aquifer. A piezometer string was also installed in the annulus between the completion string and the borehole wall. The piezometer is composed of 7.3-cm stainless-steel tubing suspended from 6.0-cm carbon-steel tubing. The piezometer string was landed at 319.2 m, to monitor the basalt lava-flow aquifer.

Data collected during and shortly after hole construction include composite drill cuttings samples collected every 3.0 m, various geophysical logs, preliminary water quality measurements, and water-level measurements. The well penetrated 331.3 m of Quaternary–Tertiary alluvium, including an intercalated layer of saturated basalt lava rubble.

No well development or hydrologic testing was conducted in this well immediately after completion; however, a preliminary water level was measured in the piezometer string at the depth of 283.4 m on September 25, 2012. No tritium above the minimum detection limit of the field instruments was detected in this hole. Future well development, sampling, and hydrologic testing planned for this well will provide more accurate hydrologic information for this site.

The stratigraphy, general lithology, and water level were as expected, though the expected basalt lava-flow aquifer is basalt rubble and not the dense, fractured lava as modeled. The lack of tritium transport is likely due to the difference in hydraulic properties of the basalt lava-flow rubble encountered in the well, compared to those of the fractured aquifer used in the flow and transport models.

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List of Acronyms and Abbreviations

AA	alluvial aquifer
BLFA	basalt lava-flow aquifer
BN	Bechtel Nevada
CADD/CAP	Corrective Action Decision Document/Corrective Action Plan
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
cm	centimeter(s)
DOE/NV	U.S. Department of Energy Nevada Operations Office
EPA	U.S. Environmental Protection Agency
FAWP	Field Activity Work Package
FMP	Fluid Management Plan
ft	foot (feet)
ft^3	cubic feet
gpm	gallons per minute
HDIL	high-definition induction log
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
HWDP	heavy-weight drill pipe
id	inside diameter
in.	inch(es)
km	kilometer(s)
lpm	liters per minute
LSC	liquid scintillation counter
m	meter(s)
m^3	cubic meters
MDA	minimum detectable activity
mi	mile(s)
NAD	North American Datum
NAIL	nuclear annulus investigation log
NARA	National Archives and Records Administration
NDEP	Nevada Division of Environmental Protection
N-I	Navarro-Intera, LLC
NNES	Navarro Nevada Environmental Services, LLC

List of Acronyms and Abbreviations (continued)

NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
pCi/L	picocuries per liter
OAA	older alluvial aquifer
OAA1	older alluvial aquifer 1
od	outside diameter
RCT	radiological control technician
TD	total depth
TMLVTA	Timber Mountain lower vitric-tuff aquifer
UDI	United Drilling, Inc.
UGT	underground nuclear test
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

1.0 Introduction

1.1 Project Description

Model Evaluation Well ER-5-5 was constructed for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Management Operations Underground Test Area (UGTA) Activity at the Nevada National Security Site (NNSS) (formerly known as the Nevada Test Site), Nye County, Nevada. Well ER-5-5 was the first of two UGTA model evaluation wells constructed in Frenchman Flat during the summer of 2012.

The Frenchman Flat model evaluation well-drilling program is part of the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) for Frenchman Flat Corrective Action Unit (CAU) 98 (NNSA/NSO, 2011). The CADD/CAP is a requirement of the Federal Facility Agreement and Consent Order (1996, as amended), agreed to by the U.S. Department of Energy, Nevada Operations Office (DOE/NV), the Nevada Division of Environmental Protection (NDEP), and the U.S. Department of Defense. The Frenchman Flat CAU is one of five UGTA CAUs at the NNSS, and the first to progress to the model-evaluation stage.

Two of the goals of the UGTA Activity 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. UGTA scientists have developed computer models of groundwater flow and contaminant migration within and near the Frenchman Flat CAU to forecast contaminant boundaries that enclose areas that may potentially exceed the radiological standards of the Safe Drinking Water Act (Code of Federal Regulations [CFR], 2012a) over 1,000 years. The primary purpose of the model evaluation wells is to collect data that can be used to test and build confidence in the applicability of the Frenchman Flat Corrective Action Unit flow and transport models for their intended purpose, including development of contaminant boundary forecasts.

The specific purpose of Well ER-5-5 was to obtain data that can be used to reduce the uncertainty of contaminant boundary forecasts associated with the upgradient underground nuclear test (UGT) MILK SHAKE, which was conducted in Emplacement Hole U-5k in 1968. Well ER-5-5 also provided detailed hydrogeologic information about the alluvial aquifer and the basalt unit embedded within the alluvium near the water table in northern Frenchman Flat. These data will help reduce uncertainties in the Frenchman Flat hydrostratigraphic framework model (HFM) and any subsequent flow and transport modeling. A later document on the results of the model evaluation well drilling project will include a discussion of how this new information may be used if it is deemed necessary to update the Frenchman Flat flow and transport models.

Well ER-5-5 is located in northern Frenchman Flat on the NNSS, approximately 244 meters (m) (800 feet [ft]) west of the eastern boundary of the NNSS (Figure 1-1).

1.2 Project Organization

The construction of Well ER-5-5 was intended to help fulfill the goals of the Environmental Management Operations UGTA Activity. Several advisory groups function within the UGTA Activity, whose responsibilities include ensuring that UGTA goals are properly planned and achieved. The roles of these groups with regard to the successful construction of Well ER-5-5 are described in this section.

A model evaluation committee was organized to advise NNSA/NSO during the model evaluation phase for the Frenchman Flat CAU (Navarro-Intera, LLC [N-I], 2010a). A drilling advisory team was convened specifically to oversee the drilling and completion of Well ER-5-5. These two groups comprise subject matter experts with significant knowledge of the geology and hydrogeology of the Frenchman Flat CAU, and include scientists and engineers from the following organizations:

- NNSA/NSO
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Desert Research Institute
- NDEP
- N-I (environmental contractor)
- Golder Associates (a subcontractor to N-I)
- National Security Technologies, LLC (NSTec; NNSS management and operating contractor)

See *Frenchman Flat Model Evaluation Wells Drilling and Completion Criteria* (N-I, 2012a) for descriptions of the general plan and goals of the Frenchman Flat evaluation phase as well as specific goals for each well.

Site supervision, engineering, construction, inspection, and geologic support were provided by NSTec. The drilling company was United Drilling, Inc. (UDI), a subcontractor to NSTec. The roles and responsibilities of these and other contractors involved in the project are described in NSTec subcontract number 107553 and in field activity work package (FAWP) numbers D-011-001.12 and D-007-001.12 (NSTec, 2011; 2012).

N-I was the principal environmental contractor for the project and was responsible for general environmental compliance and waste management at the drill site. N-I was responsible for collecting and analyzing fluid samples for water quality and chemistry, and for monitoring and documenting disposition of fluids and drill cuttings produced from the borehole. N-I personnel also collected geologic, hydrologic, and drilling parameter data during drilling.

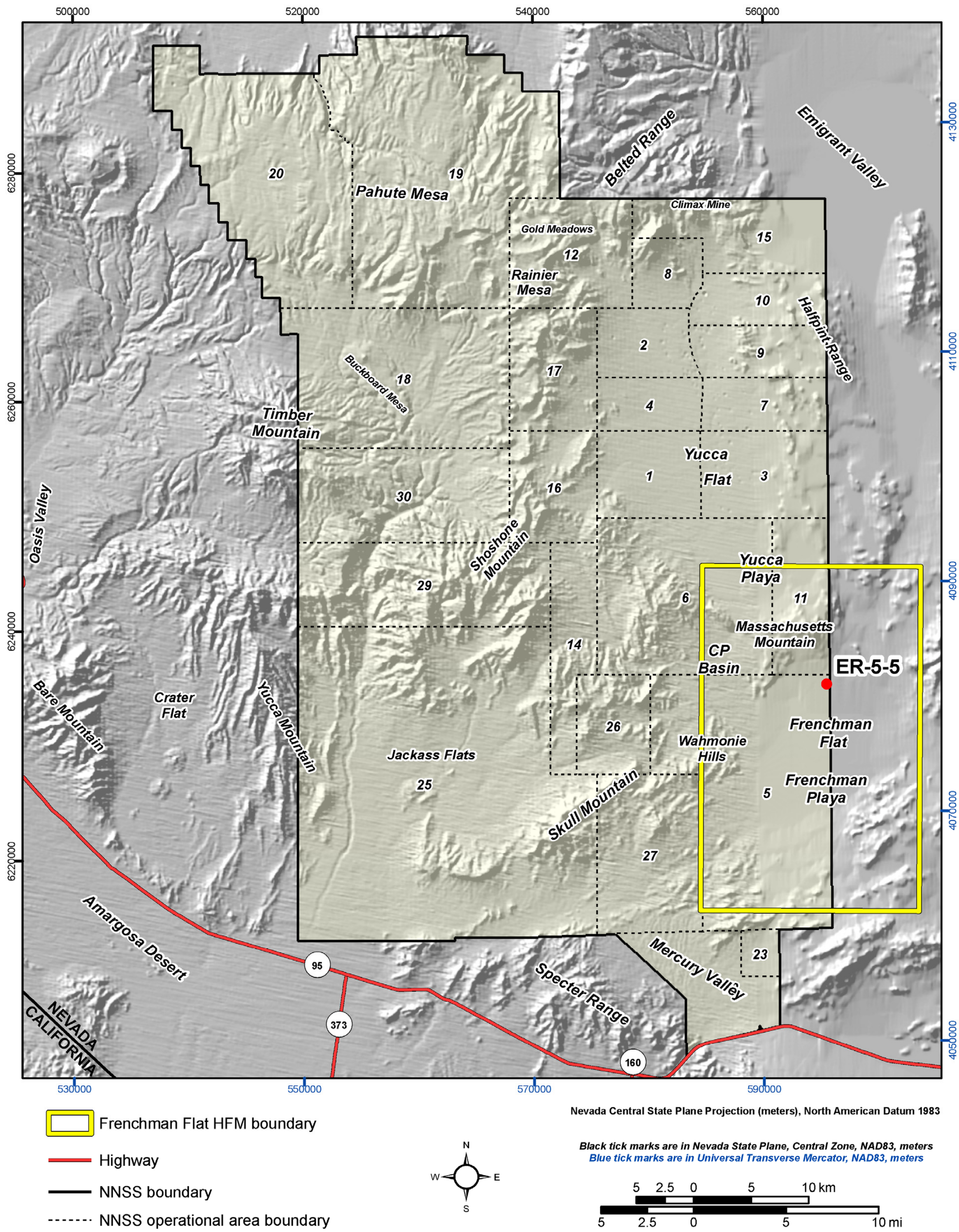

Figure 1-1
Reference Map Showing Location of Well ER-5-5 on the Nevada National Security Site

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, 2009). Well-specific operation strategies for fluid management are further identified in the well-specific fluid management strategy letter (N-I, 2012b; reproduced in Appendix B-2 of this report) as required by the FMP and approved by NDEP before fluid-generating activities are initiated. Estimates of expected production of fluid and drill cuttings for the Frenchman Flat holes are given in Appendix C of the drilling and completion criteria document for the drilling project (N-I, 2012a), 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, 2011; 2012; N-I, 2012c) and the UGTA Project Health and Safety Plan, Revision 2 (NSTec, 2008).

This report presents well-construction, environmental compliance, and waste management data, and summarizes model evaluation data gathered during the drilling of Well ER-5-5. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. Some of these data were obtained from N-I's preliminary Well ER-5-5 data package (N-I, 2012d), which is now superseded by this document. Hydrogeologic information for this area is presented in the data documentation package for the Frenchman Flat HFM prepared by Bechtel Nevada (BN, 2005). Documentation for Phase II flow and transport modeling, which guided this Evaluation Phase data collection activity, can be found in N-I (2010a; 2010b). Pre-drilling geologic information for this area (including any changes in the geologic interpretation since completion of the Frenchman Flat HFM [BN, 2005]) is compiled in the Model Evaluation Wells drilling criteria document (N-I, 2012a). Information on well development, aquifer testing, and groundwater analytical sampling (which are outside the scope of this report) are typically compiled and distributed separately.

1.3 Location and Significant Nearby Features

Well ER-5-5 is located in the northeastern corner of Operational Area 5 of the NNSS at an elevation of 1,017.1 m (3,336.9 ft). It is located just west of the eastern boundary of the NNSS on a relatively flat alluvial surface, 5.8 kilometers (km) (3.6 miles [mi]) north of the Frenchman Lake playa (Figure 1-1). Surface drainage is generally to the south onto the playa. The Area 5 Radioactive Waste Management Site is located about 1,835 m (6,020 ft) west-southwest of the Well ER-5-5 location. The well is located approximately 762 m (2,500 ft) southeast of UGTA Well Cluster ER-5-3 (DOE/NV, 2005a), and 5.9 km (3.7 mi) northeast of UGTA Well Cluster ER-5-4 (DOE/NV, 2005b). Well ER-5-5 is located approximately 2,050 m (6,730 ft) southeast from proposed Model Evaluation Well ER-11-2, which was the second well drilled as part of the CADD/CAP model evaluation drilling program (NNSA/NSO, 2013). The locations of these wells in relation to Well ER-5-5 are shown in Figure 1-2. Additional information about Well ER-5-5 is provided in Table 1-1.

The UGTs closest to Well ER-5-5 are MILK SHAKE (U-5k), DIANA MOON (U-11e), MINUTE STEAK (U-11f), and NEW POINT (U-11c) (Figure 1-2). All four of these tests were conducted above the water table. Table 1-2 provides information pertaining to these tests and others in the area. The Well ER-5-5 site is approximately 195 m (640 ft) south-southeast of the location of the MILK SHAKE UGT, which was conducted 44 years before Well ER-5-5 was drilled. The well site was expected to be within the contaminant plume from the test, based on model forecasts of the 50-, 100-, and 1,000-year contaminant boundaries (Figure 1-3).

1.4 Objectives

The primary purpose for drilling Well ER-5-5 was to obtain data to evaluate uncertainty in the conceptual model of flow and transport and its contaminant boundary forecasts (N-I, 2012a). In particular, the well was intended to produce data that will help characterize the hydrogeology and possible radiological contamination immediately downgradient from the MILK SHAKE UGT, conducted in Emplacement Hole U-5k in 1968. Well ER-5-5 is sited along the centerline of the model-forecasted contaminant boundaries approximately five cavity radii from MILK SHAKE. The cavity radius was calculated using the maximum yield of the announced yield range for the test published in DOE/NV (2000) and equations in Pawloski (1999). The well was also expected to provide information regarding the nature and hydrologic character in the alluvial section, particularly the intercalated basalt flow. These data will allow evaluation of flow paths in northern Frenchman Flat and reduce uncertainty in hydrostratigraphic units near the water table. Well ER-5-5 was planned to be constructed in such a manner that, if desired, it could be used as a long-term monitoring well.

The objectives for Well ER-5-5 are listed in Appendix A of the drilling and completion criteria document for the Frenchman Flat model evaluation wells (N-I, 2012a). The objectives are described below, along with well-specific activities necessary to accomplish the objectives:

- Obtain hydrogeologic information that will be used to evaluate the various parameters, assumptions, and models (HFM, flow and transport models, hydrologic source-term models).
- Use the data collected (listed below) to help reduce uncertainties within the northern Frenchman Flat area during any further groundwater flow and contaminant transport model runs deemed necessary.

Table 1-1
Site Data Summary for Well ER-5-5

Hole Name	**ER-5-5**
Site Coordinates[a]	**Nevada State Plane – Central Zone, NAD 27** N 772,505.1 feet (ft) E 715,396.9 ft **Nevada State Plane – Central Zone, NAD 83** N 6,235,460.4 meters (m) E 565,574.6 m **UTM – Zone 11, NAD 83** N 4,080,990.1 m E 595,265.1 m **UTM – Zone 11, NAD 27** N 4,080,793.1 m E 595,344.3 m **Geographic – NAD 83** (degrees, minutes, seconds) Latitude: 36° 52′ 12.18″ Longitude: 115° 55′ 52.14″ **Township and Range**[c] Northeast ¼ of Northwest ¼ of Section 26 Township 12 south, Range 54 east
Surface Elevation[b]	1,017.1 m (3,336.9 ft)
Drilled Depth	331.3 m (1,087.0 ft)
Preliminary Fluid Level Depth[d]	283.4 m (929.9 ft)
Fluid Level Elevation	733.7 m (2,407.1 ft)
Surface Geology	Alluvium (young alluvial deposits [Qay])

a Measurement made by NSTec Survey on August 28, 2012, 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 of elevation of ground at wellhead made by NSTec Survey on August 28, 2012. National Geodetic Vertical Datum 1929 (NARA, 1973). Elevations are relative to mean sea level.

c Quarter and quarter/quarter section values were visually estimated using data from Public Land Survey System (Bureau of Land Management Cadastral Survey, 2006).

d Measurement made in the piezometer string by N-I on September 25, 2012.

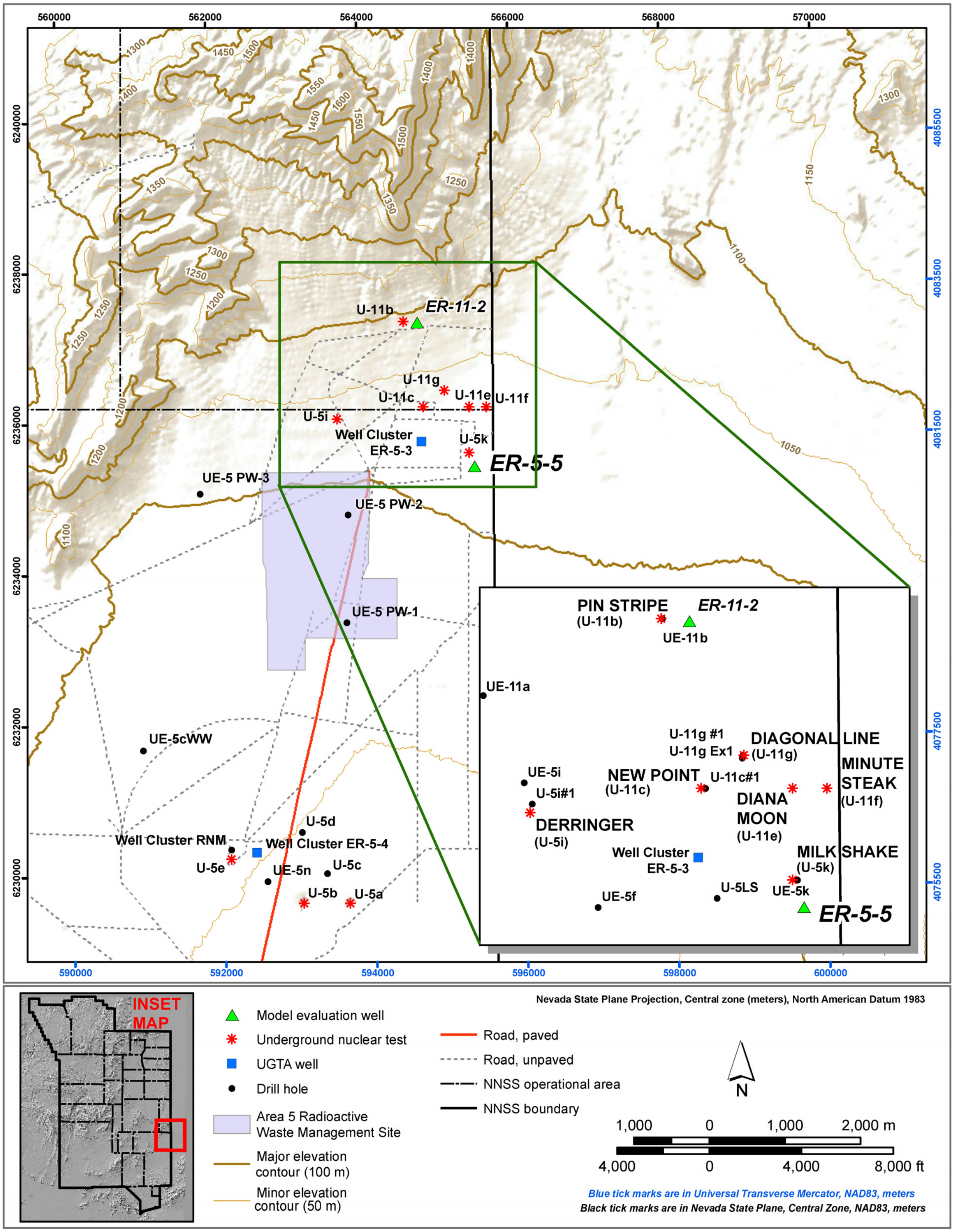

Figure 1-2
Topographic Map of the Well ER-5-5 Area Showing the Locations of Roads and Nearby Drill Holes

Table 1-2
Information for Underground Nuclear Tests Conducted in the Frenchman Flat Northern Test Area

Emplacement Hole Designation	Test Name[a]	Date of Test[a]	Surface Elevation[b] meters (feet)	Announced Yield[a] (kilotons)	Depth of Burial[b] meters (feet)	Estimated Depth to Static Water Level[c] meters (feet)	Working Point Geology[c]	Estimated Alluvium Thickness[c] meters (feet)	Working Point HSU[c, d]	Lateral Distance to Well ER-5-5 Location meters (feet)
U-5i	DERRINGER	9/12/1966	1,034.8 (3,395)	7.8	255.1 (837)	335 (1,100)	Alluvium	305 (1,000)	OAA	1,929.5 (6,330.3)
U-5k	MILK SHAKE	3/25/1968	1,020.8 (3,349)	<20	264.6 (868)	286 (939)	Alluvium	500 (1,640)	OAA	194.6 (638.4)
U-11b	PIN STRIPE	4/25/1966	1,093.0 (3,586)	<20	295.7 (970)	358 (1,176)[e]	Bedded tuff, vitric	58 (190)	TMLVTA	2,140.7 (7,023.4)
U-11c	NEW POINT	12/13/1966	1,030.5 (3,381)	<20	239.3 (785)	299 (980)	Alluvium	479 (1,570)	OAA	1,045.1 (3,428.6)
U-11e	DIANA MOON	8/27/1968	1,031.7 (3,385)	<20	242.0 (794)	305 (1,000)	Alluvium	366 (1,200)	OAA	791.8 (2,597.8)
U-11f	MINUTE STEAK	9/12/1969	1,034.2 (3,393)	<20	264.6 (868)	302 (990)	Alluvium	427 (1,400)	OAA	804.5 (2,639.4)
U-11g	DIAGONAL LINE	11/24/1971	1,037.8 (3,405)	<20	264.6 (867)	301 (988)	Alluvium	341 (1,120)	OAA	1,086.3 (3,563.8)

a DOE/NV (2000)

b N-I (2011)

c BN (2005)

d Hydrostratigraphic nomenclature: AA = older alluvial aquifer; TMLVTA = Timber Mountain lower vitric-tuff aquifer

e N-I (2010b), based on UE-11b

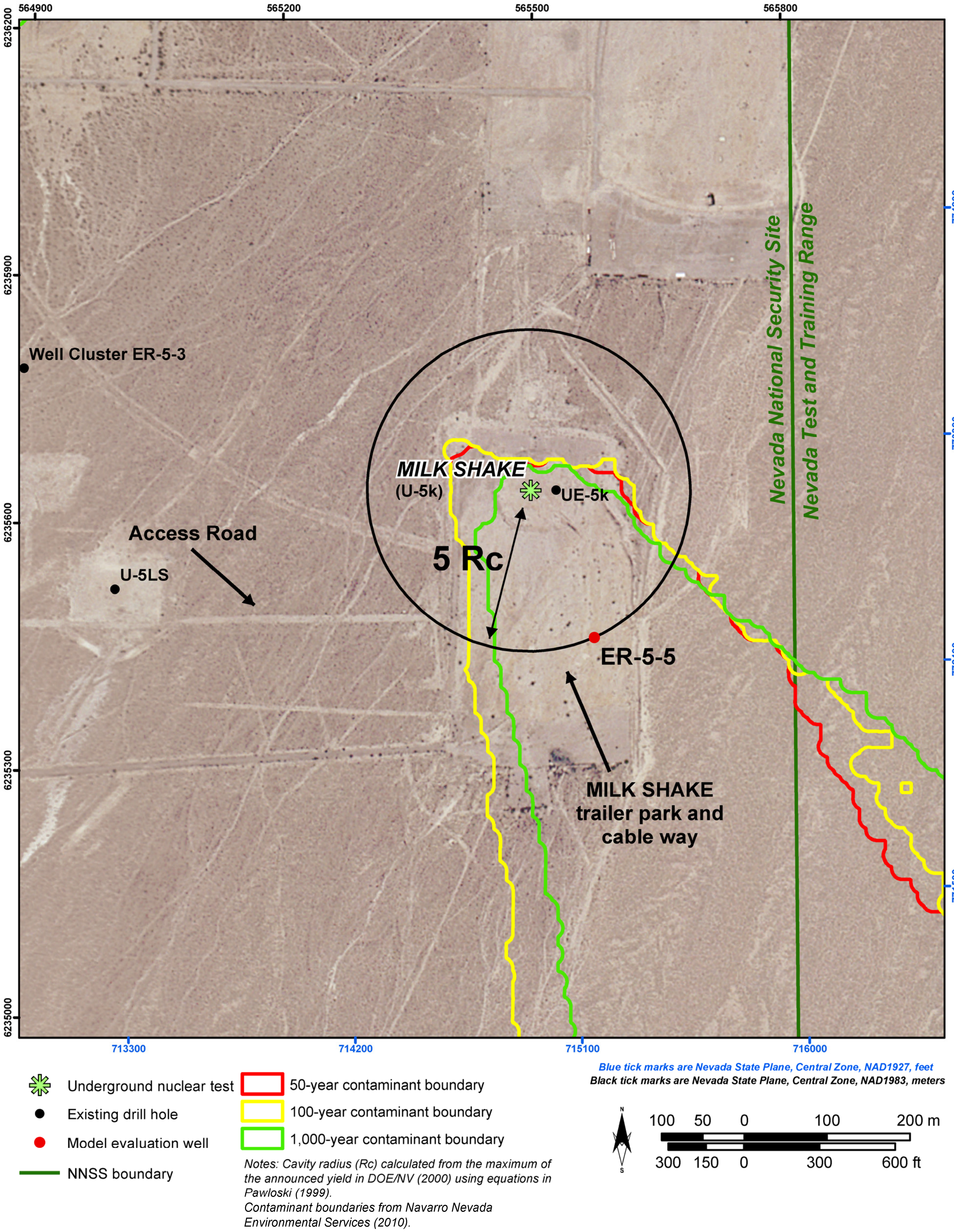

Figure 1-3
Forecast Contaminant Boundaries for the U-5k MILK SHAKE Underground Nuclear Test

- Detailed hydrogeologic information for the shallow-to-moderate-depth alluvial section and intercalated basalt lava-flow aquifer (BLFA).
- Detailed geology, including fracture information for the BLFA in the upper portion of the saturated section where radionuclide contaminant transport is most likely.

- Obtain water level data and investigate potential local groundwater flow downgradient from the MILK SHAKE UGT.
- Obtain aqueous geochemistry samples to better define possible groundwater flow paths based on water chemistry.
  - Sample for tritium and other radionuclides potentially migrating from the upgradient MILK SHAKE UGT.

Additional data that will help characterize the hydrology in the vicinity of the MILK SHAKE UGT will be obtained during later hydraulic testing at this well. Specific criteria for these later tests will be provided elsewhere (e.g., FAWPs and specific hydraulic testing plans); ultimately, Well ER-5-5 is expected to provide the following, as listed in Appendix A of N-I (2012a):

- Data for determination of horizontal and vertical conductivity
- Hydraulic properties of the saturated hydrostratigraphic units (HSUs) penetrated
- Groundwater chemistry

The completed well was expected to accommodate single- or multiple-well hydraulic testing, or to be used as a point for long-term monitoring of groundwater chemistry.

1.5 Project Summary

This section summarizes construction operations for Well ER-5-5; the details are provided in Sections 2.0 through 9.0 of this report.

A surface conductor hole 106.7 centimeters (cm) (42-inches [in.]) in diameter was constructed by drilling to a depth of 36.6 m (120 ft) and installing a string of 20-in. conductor casing to the depth of 35.9 m (117.7 ft). Drilling of the main hole with a 12¼-in. chisel-tooth bit, using an air-foam drilling fluid in conventional circulation, began on July 31, 2012, and continued to the depth of 256.3 m (841 ft) on August 1, 2012. Due to borehole instability problems, the hole was opened to the diameter of 47.0 cm (18.5 in.) to permit installation of a 13⅜-in. surface casing, which was set at the depth of 104.7 m (343.4 ft) on August 3, 2012. Drilling then continued with the 12¼-in. bit to the total depth (TD) of 331.3 m (1,087 ft). Problems with hole stability continued, and 8 days were spent with little advance, cementing, and re-drilling two intervals to stabilize sloughing zones. Drilling was completed on August 10, 2012.

Well ER-5-5 was drilled entirely within Quaternary–Tertiary alluvium that contains an intercalated rubblized basalt flow, which was penetrated between the depths of 290.8 and 297.5 m (954 and 976 ft).

One piezometer string was installed in Well ER-5-5, which is composed of 2⅞-in. stainless-steel tubing that hangs from 2⅜–in. carbon-steel tubing via a crossover sub. The string was landed at 319.2 m (1,047.1 ft), and is slotted from 282.0 to 318.5 m (925.2 to 1,044.9 ft) for monitoring within the BLFA.

The completion casing string, set at the depth of 317.2 m (1,040.6 ft), consists of 6⅝-in. stainless-steel casing hanging from 7⅝-in. internally epoxy-coated carbon-steel casing via a crossover sub. The top of the carbon-steel casing is positioned in the unsaturated zone at a point approximately 5.2 m (17 ft) above the water table. The 6⅝-in. stainless-steel casing has one slotted interval, at 278.2 to 316.5 m (912.7 to 1,038.3 ft), which allows access to the BLFA, the target aquifer for this well. The completion zone, encompassing the slotted intervals of both the piezometer and completion casing, is gravel-packed from the top of fill in the bottom of the hole at the depth of 317.3 m (1,041 ft) to 259.1 m (850 ft), a total thickness of 58.2 m (191 ft).

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 36.6 m (120 ft) to TD, as borehole circulation permitted. Open-hole geophysical logging of the borehole was conducted to help verify the geology and characterize the hydrologic properties of the alluvium and basalt units, some logs also aided in the construction of the well by indicating borehole volume and condition.

A preliminary water level was measured at the depth of 283.4 m (929.9 ft) on September 25, 2012. No radionuclides above levels detectable by field methods were encountered during drilling. No well development or hydrologic testing was conducted in this well immediately after completion. Future well development, sampling, and hydrologic testing planned for this well will provide more accurate hydrologic information for this site.

1.6 Contact Information

Inquiries concerning Well ER-5-5 should be directed to the Federal UGTA Activity Lead at:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Environmental Management Operations
Post Office Box 98518
Las Vegas, Nevada 89193-8518

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2.0 Drilling Summary

2.1 Introduction

This section contains a detailed description of Well ER-5-5 drilling operations. The general drilling requirements for both of the Frenchman Flat model evaluation wells were provided in *Frenchman Flat Model Evaluation Wells Drilling and Completion Criteria* (N-I, 2012a). Specific requirements for Well ER-5-5 were outlined in FAWP numbers D-011-001.12 and D-007-001.12 (NSTec, 2011; 2012).

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-5-5. 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-5-5 began on January 17, 2012, when an NSTec crew set up the hollow-stem auger drill rig "Auger II" and drilled a 106.7-cm (42-in.) diameter conductor hole to the depth of 36.6 m (120 ft). A string of 20-in. conductor casing was set at the depth of 35.9 m (117.7 ft). The conductor casing was cemented in place on January 19, 2012, using 47 cubic meters (m^3) (62 cubic yards) of Redi-Mix Formula 400 (see cement composition in Appendix A-3). A cement plug was set inside the 20-in. conductor casing from top of fill at 36.1 m (118.5 ft) to 33.9 m (111.3 ft). Cement was then pumped into the annulus between the casing and the formation to seal the annulus to ground level. The crew finished preparations for drilling of the main hole by drilling the "rat" and "mouse" holes, and moved off the location on February 1, 2012.

The site remained idle until the UDI crew arrived on July 23, 2012, and began rigging up the Wilson Mogul 42B drill rig. They finished rigging up on July 30, 2012, and began drilling from the top of cement inside the 20-in. casing at 33.9 m (111.3 ft) on July 31, 2012. The drill crew worked through the cement at the bottom of the 20-in. casing with a center-punch assembly that consisted of a 12¼-in. chisel-tooth bit mounted 4.0 m (13 ft) below an 18½-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 40.2 m (132 ft).

Drilling of the surface hole with a 12¼-in. rotary chisel-tooth bit began July 31, 2012. The drilling fluid was an air/water/soap mix in conventional circulation. Drilling continued uneventfully, with little (1.2 m [4 ft]) or no fill reported after stopping to add drill pipe

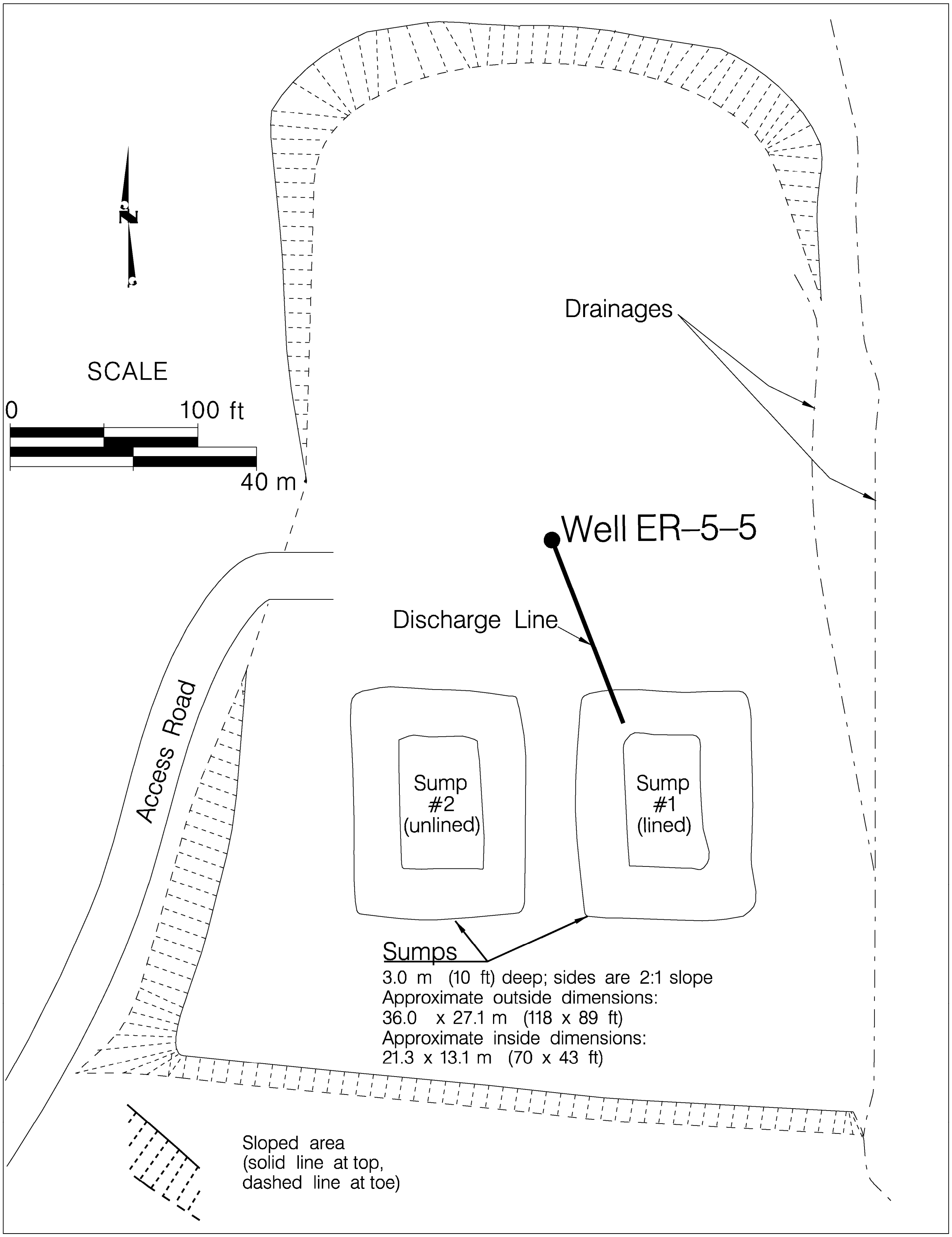
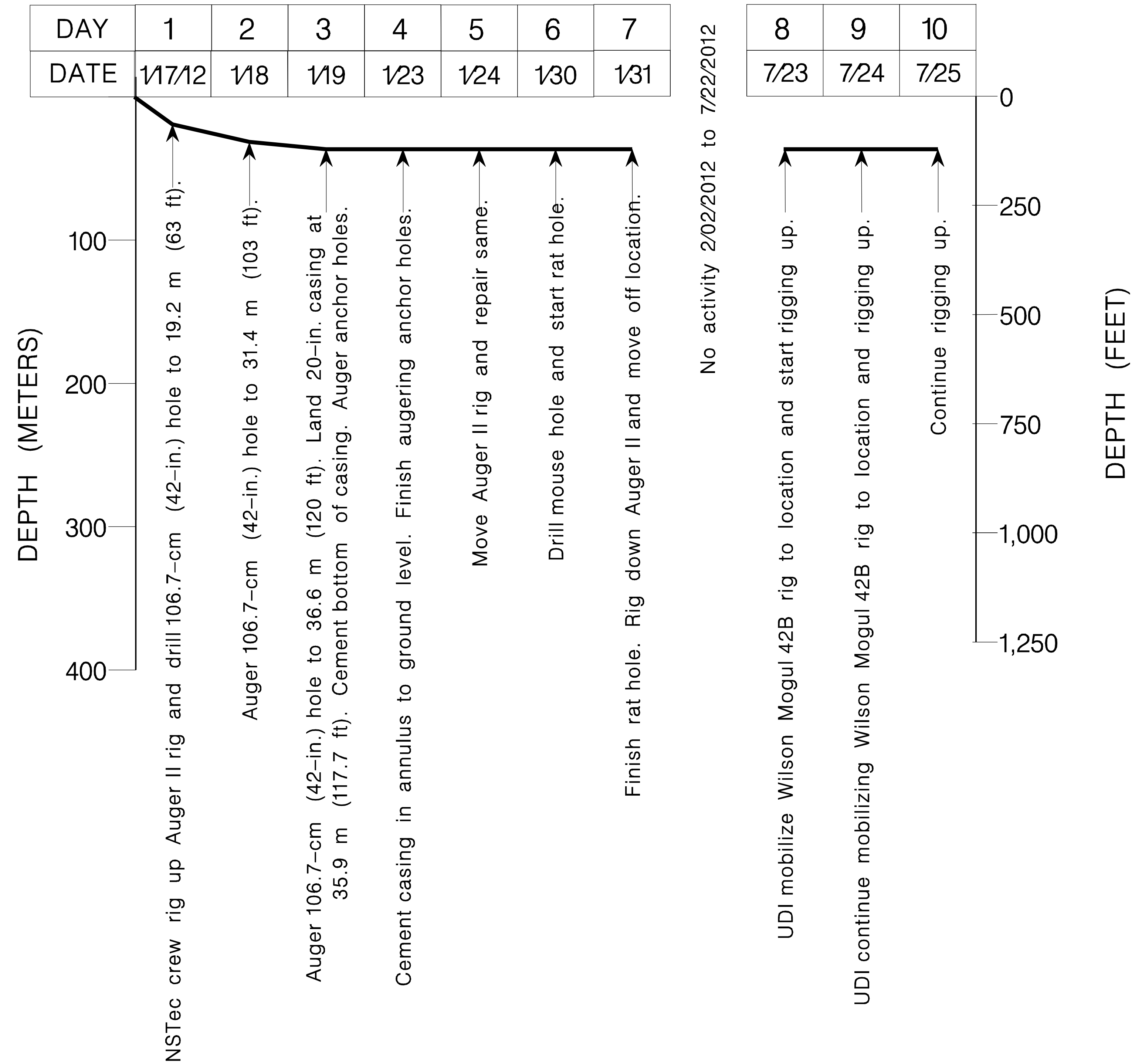


Figure 2-1
Drill Site Configuration for Well ER-5-5

LEGEND

BA	Baker Atlas
BHA	Bottom hole assembly
cm	centimeter(s)
cu ft	cubic feet
ft	Foot (feet)
GR	Gamma ray
HO	Hole opener
HWDP	Heavy–weight drill pipe
in.	Inch(es)
m	Meter(s)
NAIL	Nuclear annulus investigation log
NSTec	National Security Technologies, LLC
RIH	Run in hole
SLM	Steel line measurement
TD	Total depth
TIH	Trip into hole
TOC	Top of cement
TOH	Trip out of hole
UDI	United Drilling, Inc.
WOC	Wait on cement



WELL ER–5–5 SUMMARY

Activity	Date
Begin drilling conductor hole:	01/17/2012
Conductor hole completed and 20–in. casing set to 35.9 m (118 ft):	01/19/2012
Begin drilling 31.1–cm (12.25–in.) hole:	07/31/2012
Upper part of hole opened to 47.0 cm (18 1/2 in.) and surface casing set to 104.7 m (343.4 ft):	08/03/2102
Well completed:	08/12/2012

FIGURE 2–2
WELL ER–5–5
DRILLING AND
COMPLETION HISTORY
SHEET 1 OF 2

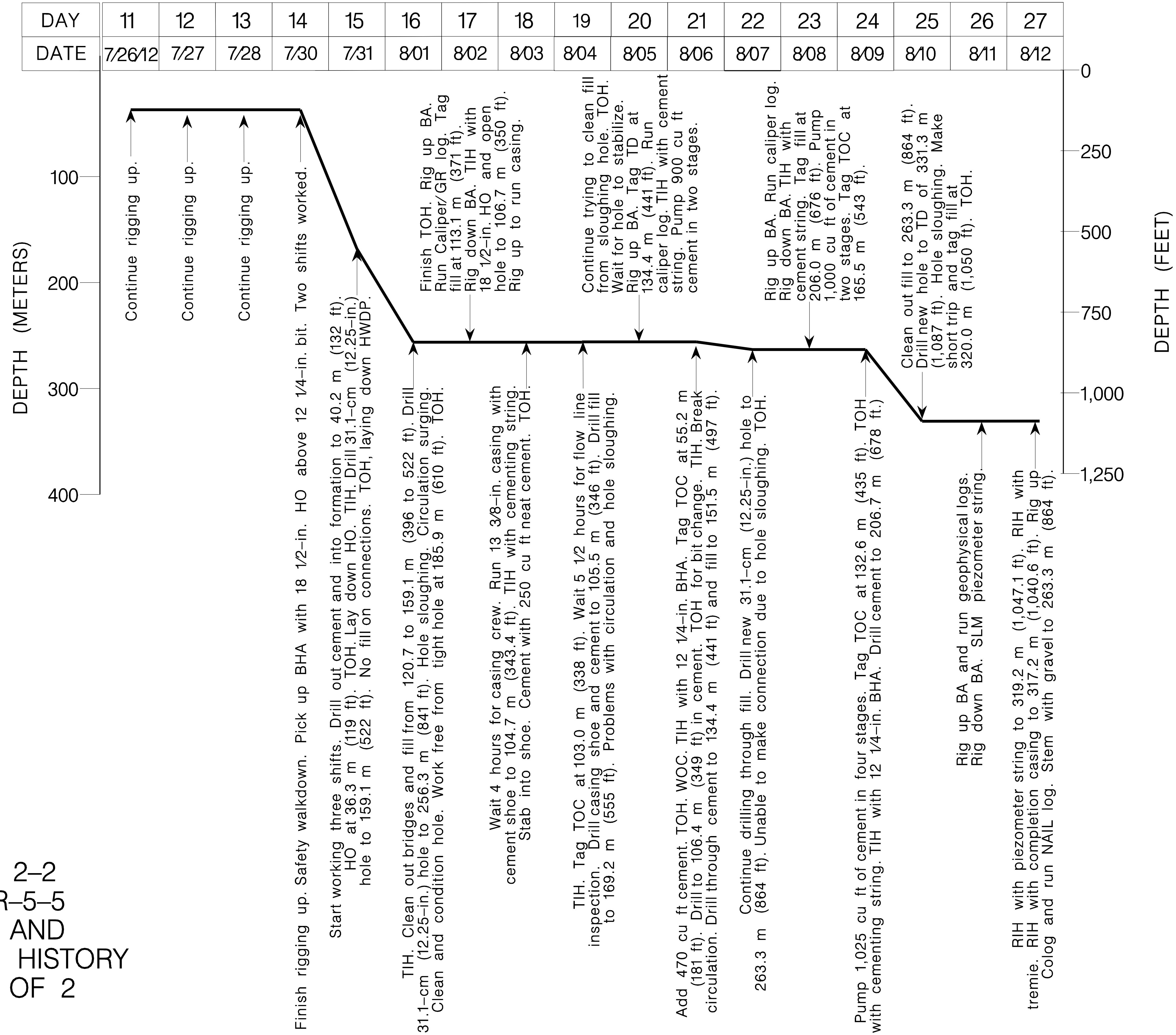


FIGURE 2-2
WELL ER-5-5
DRILLING AND
COMPLETION HISTORY
SHEET 2 OF 2

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

LOCATION DATA

Coordinates:	Nevada State Plane (Central Zone)	(NAD 27)	N 772,505.1 ft	E 715,396.9 ft
	Nevada State Plane (Central Zone)	(NAD83)	N 6,235,460.4 m	E 565,574.6 m
	Universal Transverse Mercator (Zone 11)	(NAD83)	N 4,080,990.1 m	E 595,265.1 m
	Universal Transverse Mercator (Zone 11)	(NAD 27)	N 4,080,793.1 m	E 595,344.3 m

Surface Elevation: 1,017.1 m (3,336.9 ft) [a]

DRILLING DATA

Spud Date:	07/31/2012 (main hole drilling with Wilson Mogul 42B rig)
Total Depth (TD):	331.3 m (1,087 ft)
Date TD Reached:	08/10/2012
Date Well Completed:	08/12/2012 (date completion string was stemmed)
Hole Diameter:	106.7 cm (42 in.) from surface to 36.6 m (120 ft); 47.0 cm (18.5 in.) from 36.6 to 106.7 m (120 to 350 ft); 31.1 cm (12.25 in.) from 106.7 m (350 ft) to TD of 331.3 m (1,087 ft).
Drilling Techniques:	Drill 106.7-cm (42-in.) hole from surface to 36.6 m (120 ft) with dry-hole auger. Center punch with 12¼-in. chisel-tooth bit mounted below a 18½-in. hole opener to 40.2 m (132 ft); rotary drill with a 12¼-in. chisel-tooth tricone bit, using air-foam and polymer (when necessary) in direct circulation from 40.2 m (132 ft) to 256.3 m (841 ft). Widen hole using 18½-in. hole opener to 106.7 m (350 ft); rotary drill with a 12¼-in. chisel-tooth tricone bit, using air-foam and polymer (when necessary) in direct circulation from 106.7 m (350 ft) to TD of 331.3 m (1,087 ft).

CASING DATA

20-in. conductor casing to 35.9 m (117.7 ft); 13⅜-in. surface casing 0 to 104.7 m (0 to 343.4 ft);

WELL COMPLETION DATA

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 is positioned in the unsaturated zone to a point approximately 5.2 m (17 ft) above the water table. The 7⅝-in. outside-diameter (od) casing has an inside diameter (id) of 17.701 cm (6.969 in.). The 6⅝-in. od stainless-steel casing has an id of 15.504 cm (6.104 in.). The completion string was landed at 317.2 m (1,040.6 ft) and has one slotted interval. A string of 2⅞-in. stainless-steel tubing that hangs from 2⅜-in. carbon-steel tubing (id of 5.07 cm [1.995 in.]) was installed adjacent to the completion casing. The 2⅞-in. stainless-steel tubing has one slotted interval and was landed at 319.2 m (1,047.1 ft). Detailed data for the completion interval are provided in Section 8.0 of this report.

Depth of Slotted Sections:

6⅝-in. casing: 278.2 to 316.5 m (912.7 to 1,038.3 ft) (not including bull-nose)

2⅞-in. tubing: 282.0 to 318.5 m (925.2 to 1,044.9 ft) (not including bull-nose)

Depth of Gravel Pack:	259.1 to 317.3 m (850 to 1,041 ft)
Depth of Pump:	Not installed at the time of completion
Water Depth:	Fluid level depths measured by N-I:
	283.3 m (929.4 ft) in the 6⅝-in. production casing on 08/12/2012.
	283.4 m (929.9 ft) in the 2⅞-in. piezometer on 09/25/2012

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Baker Atlas

SURVEY CONTRACTOR: National Security Technologies, LLC

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

(making "connections") to the depth of 159.1 m (522 ft), when the crew stopped to replace the heavy-weight drill pipe (HWDP) with drill collars and jars. When they lowered the drill string back into the hole, they found that an obstruction (bridge and/or fill) consisting of material sloughed from the borehole wall had formed at approximately 120.7 m (396 ft). The drillers cleaned out the bridge and the fill material, then continued drilling. They advanced the 31.1-cm (12.25-in.) borehole to 256.3 m (841 ft) without encountering any fill during connections, but the fluid returns became sporadic at this depth. The crew replaced six more HWDP joints and worked the drill string up and down to try to clear the borehole of accumulated cuttings and regain circulation, but sloughing and circulation problems continued. Due to buildup of pressure and surging, some of the discharge was forceful enough that gravel and rocks carried in the effluent broke the sump staff gauge and punctured the liner in Sump #1 (the liner was repaired on August 3, 2012, before drilling operations continued). UDI continued to condition the borehole in an attempt to regain circulation, but was unsuccessful. On August 1, 2012, the drillers removed the drill string from the borehole in preparation for running a caliper log to evaluate the condition of the borehole and to identify enlarged areas that indicate unstable zones that could be the source of fill material sloughing into the borehole.

The Baker Atlas geophysical logging crew rigged up and ran a 6-arm caliper and gamma ray log to the top of fill at 113.1 m (371 ft). The caliper log indicated that the borehole was enlarged to a diameter of at least 66 cm (26 in.) (the maximum extent of the caliper arms) in many areas, including the area between the depths of approximately 36.6 and 76.2 m (120 and 250 ft).

The decision was made to install a string of casing to seal off the unstable interval. The UDI crew made up an 18½-in. hole-opener assembly with a 12¼-in. bit installed below the hole opener, and ran it into the hole. Tight hole conditions were encountered at 88.4 m (290 ft). After working the hole opener to 106.7 m (350 ft) and the 12¼-in. bit to 110.6 m (363 ft), the crew removed the drill string and prepared to install the casing. A casing subcontractor landed a string of 13⅜-in. casing at the depth of 104.7 m (343.4 ft). The casing was cemented in place with neat type II cement on August 3, 2012.

Before drilling resumed on August 4, 2012, the new welds on the wellhead were inspected, the flange bolts on the reestablished flow-line were tested, and the sump liner was repaired. The drillers made up a 12¼-in. bottom-hole assembly and tagged cement inside the casing at 103.0 m (338 ft). After drilling out the cement and casing shoe from 103.0 to 105.5 m (338 to 346 ft), the drillers cleaned out fill down to 169.2 m (555 ft), where circulation was lost. Another compressor was added to the flow system in an attempt to regain circulation, but returns were still sporadic. The crew cleaned out fill down to 178.3 m (585 ft), but the sloughing and circulation problems persisted, so the drillers removed the drill string from the hole to prepare for another caliper log run.

Baker Atlas ran a 6-arm caliper log from 134.4 to 104.5 m (441 to 343 ft) (top of fill) on August 5, 2012. The results of the caliper log indicated that the borehole was washed out to a diameter greater than 66 cm (26 in.) for a distance of approximately 30 m (98 ft), so it was decided to cement this interval of the borehole in an attempt to stabilize it. NSTec cementers pumped 38.8 m^3 (1,370 cubic feet [ft^3]) of type II neat cement into the borehole from the top of fill at 134.4 m (441 ft) to the depth of 55.2 m (181 ft) inside the surface casing. The cement was placed in three stages, with time allowed between each stage for the cement to set. Based on the known volume of the casing filled, the uncased portion of this washed-out interval took approximately 34.3 m^3 (1,212 ft^3) of cement. The volume of a 29.9-m (98-ft) interval of borehole that is nominally 31.1 cm (12.25 in.) in diameter is 2.3 m^3 (80 ft^3), which indicates that this interval of the borehole had been washed out to approximately 5.8 times its drilled volume.

After cementing, the drill crew made up a modified drilling assembly with drill collars and HWDP; when the 12¼-in. drilling assembly was lowered back into the borehole, it tagged cement at 55.2 m (181 ft). The crew drilled out cement inside the 13⅜-in. surface casing and down to 106.4 m (349 ft). The drillers then removed the drill string from the hole and made up a new drilling assembly, adding roller reamers, a shock sub, and jars. The drillers began drilling the 31.1-cm (12.25-in.) hole through cement from 106.4 m (349 ft). After drilling through the bottom of the cement and into the top of the fill at approximately 134.4 m (441 ft), returns were lost.

Drill fluid was made up using a new batch of soap, the fluid injection rate was increased, and another compressor was added to help regain fluid circulation. After a few minutes, returns reached the surface and the crew continued to clean out fill. Approximately 1.5 to 4.6 m (5 to 15 ft) of fill was typically encountered after making connections. Polymer was added to the drilling fluid at approximately 160.3 m (526 ft). The sloughing problems persisted, and the soap in the drilling fluid mix was changed from Geo Foam to Bachman Drill Foam when the bit was at approximately 216.1 m (709 ft). The change in type of soap increased foam generation significantly and the drillers continued cleaning fill out of the borehole down to the previously drilled depth of 256.3 m (841 ft). The drillers advanced the 31.1-cm (12.25-in.) borehole to 263.3 m (864 ft) on August 7, 2012, but when attempting to make the connection at this depth, 4.6 m (15 ft) of fill was encountered and attempts to clean out the hole failed. The drillers then pulled the drill string from the hole so a caliper log could be obtained.

Baker Atlas tagged the bottom of the 31.1-cm (12.25-in.) borehole at a depth of 181.7 m (596 ft) and logged upward from 180.7 to 104.5 m (593 to 343 ft). The caliper log indicated that the borehole diameter was greater than 66 cm (26 in.) for approximately 45.7 m (150 ft), starting below the previously cemented interval.

It was decided to try to stabilize this enlarged interval with cement. The drill crew ran a string of open-ended drill pipe into the hole and tagged the top of fill at 206.0 m (676 ft). There was no indication of the bridge encountered by the caliper tool at 181.7 m (596 ft). NSTec cementers pumped a total of 70.8 m^3 (2,500 ft^3) of type II neat cement into the borehole from 206.0 to 132.6 m (676 to 435 ft) in six stages, waiting between each stage for the cement to set. The volume of a 72.8-m (239-ft) long interval of borehole that is nominally 31.1 cm (12.25 in.) in diameter is 5.6 m^3 (197 ft^3); comparing the volume of cement used to fill this interval indicates that this interval of the borehole had been washed out to approximately 12.6 times its drilled volume.

The bit was lowered back into the borehole and tagged the cement at the depth of 132.6 m (435 ft). Drilling of the 31.1-cm (12.25-in.) hole continued after the cement and underlying fill material were drilled out. On August 10, 2012, the borehole wall began sloughing at the depth of 331.3 m (1,087 ft), preventing the drillers from making the next connection. Drilling was stopped to prevent further damage to the borehole, and the TD was called at 331.3 m (1,087 ft). The drillers briefly pulled the drill string a short distance off bottom, lowered it and tagged fill at 320.0 m (1,050 ft), then removed the drill string from the borehole in preparation for logging operations. Geophysical logging was conducted by Baker Atlas crews on August 11, 2012.

Tritium analyses conducted at the rig site on samples of drilling effluent indicated that all samples were below levels detectable by field methods (see discussion in Section 3.1.2). The tracer analyses gave an estimated water production rate of less than 49 liters per minute (lpm) (13 gallons per minute [gpm]), starting at the depth of 292.6 m (960 ft) on August 10, 2012. Water production gradually increased to about 340 lpm (90 gpm) at the depth of 310.9 m (1,020 ft) and remained steady to the depth of 331.3 m (1,087 ft). See Section 6.2 for more information on groundwater production.

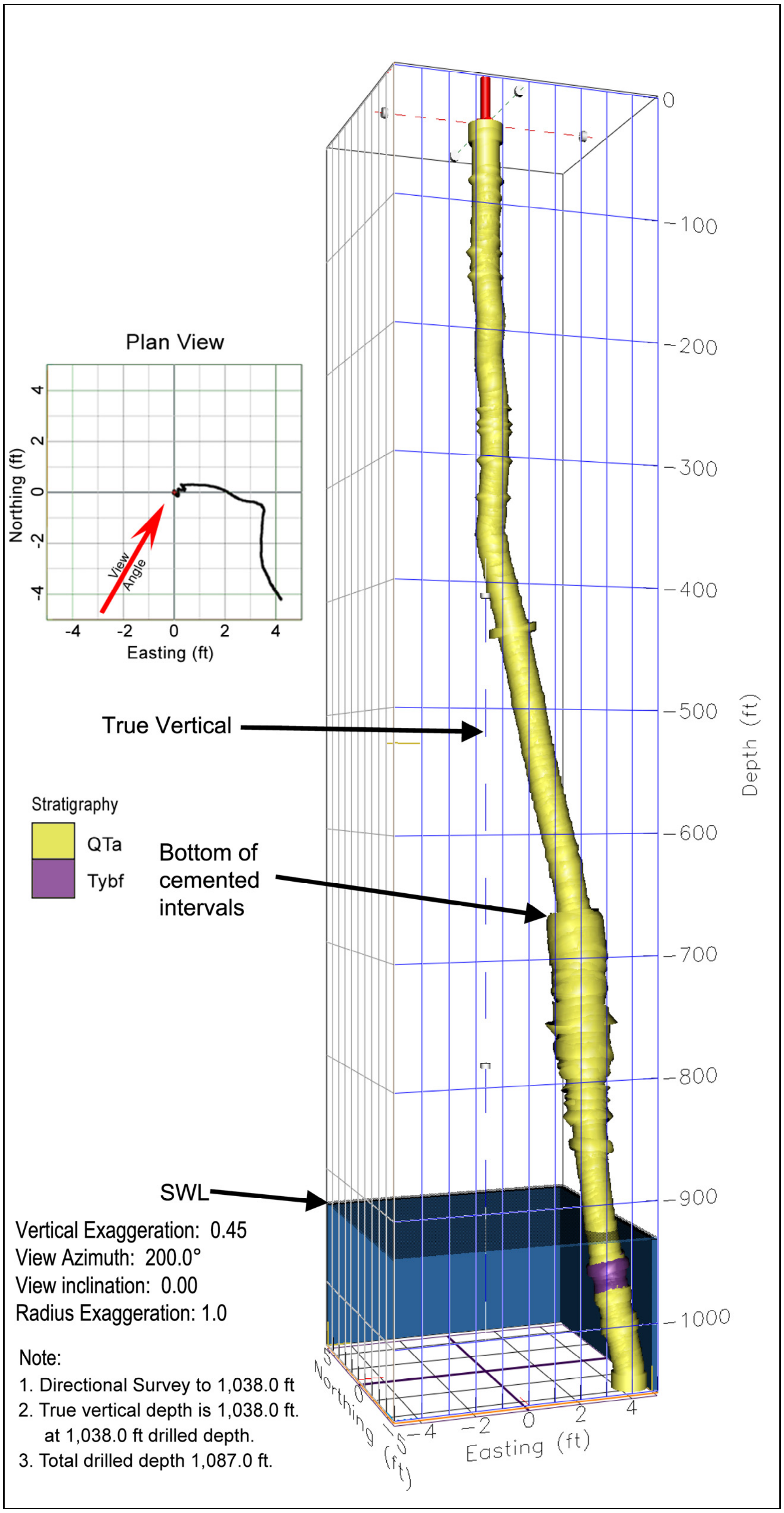
On August 12, 2012, the drill crew installed a 2⅞-in. monitoring string, with one slotted interval, at a depth of 319.2 m (1,047.1 ft). On the same day, the casing subcontractor installed the 6⅝-in. completion casing string, but fill had continued to accumulate at the bottom of the borehole, and had risen to the depth of approximately 317.3 m (1,041 ft). The completion string, with one slotted interval, was landed at a depth of 317.2 m (1,040.6 ft). The completion casing and the piezometer string were gravel-packed (see Section 8.0 for details). Stemming operations were completed on August 12, 2012. The drillers immediately started moving the drill rig and drilling equipment to the next drill site (Model Evaluation Well ER-11-2). Demobilization of all equipment from the Well ER-5-5 site was completed on August 15, 2012.

The directional survey run on August 12, 2012, recorded a borehole deviation of 0.6 degrees at a true vertical depth of 316.4 m (1,038 ft) below ground surface. The final drift distance was 1.8 m (5.8 ft) to the southeast of the collar location along a bearing of 152 degrees. Figure 2-3 is a three-dimensional view of the borehole showing deviation, borehole profile from the caliper logs, and stratigraphy.

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-5-5 are listed in Appendix A-3.

2.3 Drilling Problems

The primary problem during the drilling of Well ER-5-5, as discussed in Section 2.2 above, was severe borehole instability starting immediately below the conductor casing and continuing to the TD of the borehole. The first attempt to mediate this problem was the installation of a 13⅜-in. surface casing down to a depth of 104.7 m (343.4 ft). When the problem persisted below the cased interval, two severely enlarged zones at 104.5 to 134.4 m (343 to 441 ft) and 133.2 to 206.0 m (437 to 676 ft) were cemented and re-drilled. Other methods used to help with the hole sloughing problems were the addition of polymer to the drilling fluid, increasing the fluid injection rate, and changing the foaming agents in the drilling mix. The change from Geofoam to Bachman Foam at 216 m (709 ft) increased foam generation significantly and the hole unloaded a greater volume of cuttings.



Modified from N-I (2012d)

Figure 2-3
Well ER-5-5 Directional Survey Showing Caliper Profile and Stratigraphy

3.0 Management of Fluids, Drill Cuttings, and Waste

This section describes how fluids and drill cuttings produced from the Well ER-5-5 borehole and hydrocarbon and sanitary wastes produced during well construction were managed. The information in this section was obtained from N-I (2012d).

3.1 Fluid and Drill Cuttings Management

3.1.1 Fluid Management Strategy

The management of drilling fluids and solid waste (i.e., cuttings) is addressed in the UGTA FMP (NNSA/NSO, 2009). The *Final Well Specific Fluid Management Strategy for UGTA Well ER-5-5, Area 5, Nevada National Security Site* (reproduced in Appendix B-2), as required by the UGTA FMP, addresses specific fluid management strategies to be employed at Well ER-5-5 for fluid-generating activities relating to well drilling, well construction, and well development and testing activities. The drilling effluent was monitored routinely during drilling in accordance with these plans to guide operational decisions for proper fluid containment and, ultimately, proper fluid disposal.

Radionuclides were expected at Well ER-5-5, based on Phase II flow and transport modeling (Stoller-Navarro Joint Venture, 2006 and 2007; Navarro Nevada Environmental Services [NNES], 2010). To manage the anticipated water production, two containment basins (Sump #1 [lined] and Sump #2 [unlined]) were constructed to contain fluids and drill cuttings during operations at Well ER-5-5 (Figure 2-1). The air-foam drilling fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional, or direct circulation). The drilling effluent was discharged into the lined Sump #1 in case elevated levels of tritium were encountered in the groundwater. Sump #2 was not used.

Water used for preparation of drilling fluids came from a water storage pond supplied by the C-1 Water Well in Area 6. The C-1 Water Well had been pumped and sampled on October 19, 2010. These sample data were reviewed, and all analytes detected were below National Primary Drinking Water Regulations (CFR, 2010) limits.

3.1.2 Fluid Management Sampling Results

An important element of the FMP strategy (NNSA/NSO, 2009) is the onsite monitoring program. This program is intended to provide the timely detection of indicator contaminants, and determines onsite fluid management requirements.

Discharged drilling fluids were collected by N-I site personnel hourly during periods of borehole advancement. NSTec radiological control technicians (RCTs) used NSTec-supplied liquid scintillation counters (LSCs) to analyze the fluid samples on site for tritium for the purpose of fluid management and worker protection. A minimum detectable activity (MDA) was associated with the analysis of each sample. The average MDA for the onsite LSCs at Well ER-5-5 was approximately 1,400 picocuries per liter (pCi/L). Samples collected and analyzed for tritium were for screening purposes, and the reported results are not intended to accurately represent lower concentrations of tritium (i.e., less than approximately 1,400 pCi/L) due to errors in counting statistics or issues relating to the nature of fluids analyzed (e.g., drilling effluent).

The onsite monitoring results for the drilling effluent (listed in Appendix B-1) indicated that tritium levels were well below the drinking water standards limit of 20,000 pCi/L (CFR, 2012a), as measured by field instruments. In accordance with NNSS radiological control guidelines (Radiological Control Managers' Council, 2012), many of the onsite fluid samples with initial tritium results greater than the MDA were re-analyzed until the results stabilized. False high tritium levels measured on several samples were attributed to a chemical interaction between solids (cement and rock) in the effluent and the scintillation cocktail used in the analysis (chemo-luminescence). After these samples were re-analyzed, the tritium levels were found to be below the MDA. Some of the samples for which onsite tritium analysis exceeded the MDA were not re-analyzed due to the low levels measured. Tritium analyses for discharge samples from both the unsaturated and saturated zones in Well ER-5-5 ranged from 0 to 2,468 pCi/L. Tritium levels for discharge samples from the saturated zone were all less than the MDA. As no elevated levels of tritium were detected, drilling operations were conducted under the far-field fluid management strategy.

After drilling activities were completed, N-I personnel collected an FMP (NNSA/NSO, 2009) confirmatory sample and a duplicate from Sump #1 on August 11, 2012. The samples were analyzed by an offsite laboratory for total and dissolved metals, gross alpha and beta, and tritium. The analytical results for the FMP confirmatory samples from Sump #1 are presented in Appendix B-1.

3.1.3 Disposition of Fluid and Drill Cuttings

The FMP (NNSA/NSO, 2009) and the Well ER-5-5 FMP strategy letter (Appendix B-2) established concentrations for specified parameters below which drilling fluids may be discharged either to an unlined containment basin or to a designated infiltration area. All fluid production from Well ER-5-5 was directed into a lined sump in case elevated levels of tritium were encountered. No fluids were discharged to the designated infiltration area. However, the results of monitoring samples and FMP confirmatory samples (Appendix B-1) indicated that fluids generated from drilling the unsaturated and saturated zones met the FMP criteria for discharge to an unlined sump or designated infiltration area.

The volumes of fluids produced during drilling in the unsaturated and saturated zones are presented on the Well ER-5-5 Fluid Disposition Reporting Form, which is reproduced in Appendix B-1. At the completion of drilling on August 10, 2012, an estimated combined total of 837.4 m^3 (837,439 liters) of drilling fluid and cuttings remained in lined Sump #1.

3.2 Environmental Compliance and Waste Management

N-I was responsible for environmental compliance and waste management at the Well ER-5-5 site. Periodic site evaluations were conducted during site operations to ensure compliance with the *Occupational Safety and Health Act* (CFR, 2012b), the *Resource Conservation and Recovery Act* (CFR, 2012c), the UGTA Waste Management Plan (NNSA/NSO, 2009), and internal contractor procedures.

Waste generated during drilling operations at the Well ER-5-5 site consisted of hydrocarbon and sanitary wastes. A summary of the waste types, volume, and disposition of waste streams generated during drilling is provided in Appendix C. Sanitary waste generated at the well site during drilling operations was routinely collected by NSTec and disposed of at the Area 23 solid waste landfill. Hydrocarbon waste generated at the well site was packaged into 208-liter (55-gallon) drums, removed from the Well ER-5-5 drill site, and transported by N-I personnel to N-I Building 6-909 for interim storage pending disposal by NSTec. The 7,571-liter (2,000-gallon) condensate tank was transported by NSTec to the Well ER-11-2 drill site with the oily condensate generated at Well ER-5-5. Three waste containers (listed in Appendix C) were transported to the Well ER-11-2 drill site for continued use during drilling and well construction. All waste was characterized using process knowledge and onsite monitoring results.

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4.0 Geologic Data Collection

4.1 Introduction

This section describes the sources of geologic data obtained from Well ER-5-5 and the methods of data collection. Confirming and characterizing the subsurface structure, stratigraphy, and hydrogeology along the predicted local groundwater flow path were among the primary objectives of Well ER-5-5, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the well-construction project.

Geologic data collected at Well ER-5-5 consist of drill cuttings and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in N-I (2012a).

4.2 Drill Cuttings

Because adequate data exist from nearby boreholes, and because the simple near-surface alluvial geology is well known, no samples were collected during augering of the shallow conductor hole. During the drilling of the main hole, N-I personnel collected composite drill cuttings at 3.0-m (10-ft) intervals. Samples of drill cuttings, each consisting of approximately 550 cubic centimeters of material, were collected from 95 intervals from 36.6 m (120 ft) to TD. When the volume of cuttings circulating to the surface was sufficient, triplicate samples were collected from each interval. No samples were collected from two intervals, 234.7 to 237.7 m (770 to 780 ft) and 243.8 to 246.9 m (800 to 810 ft), due to poor drilling fluid returns. Moderate to minimal cuttings were returned in the following intervals:

- 51.8–82.3 m (170–270 ft)
- 85.3–109.7 m (280–360 ft)
- 112.8–125.0 m (370–410 ft)
- 176.8–182.9 m (580–600 ft)
- 210.3–213.4 m (690–700 ft)
- 228.6–234.7 m (750–770 ft)
- 240.8–243.8 m (790–800 ft)
- 249.9–253.0 m (820–830 ft)
- 274.3–277.4 m (900–910 ft)
- 283.5–286.5 m (930–940 ft)

Quality of the cuttings samples was generally fair to poor because sloughing of the borehole wall caused unpredictable mixing and "contamination" of drill cuttings from different portions of the borehole. In addition, when the 16-in. flow line was reestablished after the surface casing was set, it was noted that the effluent pipe was up to three-quarters full of cuttings that had not been completely discharged during drilling in the unsaturated zone. This was an additional potential cause of contaminated drill cuttings.

These samples are stored under environmentally controlled, secure conditions at the U.S. Geological Survey (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 stored according to standard USGS Core Library procedures. The third set was used by NSTec geologists to construct the detailed lithologic log presented in Appendix D. 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.

4.3 Sidewall Core Samples

No sidewall core samples were collected from Well ER-5-5.

4.4 Sample Analysis

No sample analyses were planned or conducted because the alluvium in this area is considered to be well characterized.

4.5 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. Three separate caliper/gamma ray logs were run during drilling of the upper part of the borehole to locate and evaluate unstable zones. Most of the geophysical logging was conducted in one stage after the TD of 331.3 m (1,087 ft) was reached. A complete listing of the logs, dates they were run, and depths logged is provided in Table 4-1. 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 E.

The geophysical log data collected in the upper section of the borehole were unusable because the borehole had been cemented down to 206.7 m (678 ft), prior to logging. Additionally, severe hole enlargement from the bottom of the cemented interval to the depth of approximately 246.9 m (810 ft) hinders use of geophysical logs for that zone.

Results from the high definition induction log (HDIL) were very good (in the lower, uncemented portion of the borehole), so the Rt eXplorer log was not run as planned. In consideration of the small borehole diameter and limited length of borehole in the saturated zone, the N-I Field Operations Manager, NSTec Logging Engineer, and Baker Atlas Logging Engineer concluded it would not be cost effective to run the cross-multipole array acoustilog, circumferential borehole imaging log, or resistivity imaging log.

Table 4-1
Well ER-5-5 Geophysical Log Summary

Geophysical Log Type [a, b]	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
*Temperature / Gamma Ray	Saturated zone: groundwater temperature / stratigraphic and depth correlation	8/11/2012	TL-1 / GR-4	318.5 (1,045)	6.1 (20)
Borehole Profile (*6-Arm Caliper) / Gamma Ray	Borehole conditions, cement volume calculation / stratigraphic and depth correlation	8/2/2012 8/5/2012 8/8/2012	CA6-1 / GR-1 CA6-2 / GR-2 CA6-3 / GR-3	112.2 (368) 133.5 (438) 180.8 (593)	18.9 (62) 104.6 (343) 0 (0)
*Gamma Ray / *Digital Spectralog	Stratigraphy, mineralogy, and natural and manmade radiation determination	8/11/2012	GR-6 / SGR-1	309.7 (1,016)	5.5 (18)
*High Definition Induction / Gamma Ray	Lithologic determination; saturation of formations; stratigraphic and depth correlation	8/11/2012	HDIL-1 / GR-6	314.6 (1,032)	104.6 (343)
*Compensated Z-Densilog / *Compensated Neutron / Gamma Ray	Stratigraphic and lithologic determination / identification of welding, alteration, rock porosity, and water content	8/11/2012	ZDL-1 / CN-1 / GR-7	317.3 (1,041)	104.6 (343)
*Aligned Borehole Profile (i.e., Oriented 6-Arm Caliper) / Gamma Ray	Borehole conditions, cement volume calculation / lithologic and stratigraphic correlation	8/11/2012	CA6-4 / ORIT-1 / GR-5	316.1 (1,037)	104.6 (343)

a Logs presented in geophysical log summary, Appendix E, are indicated by *. A gamma-ray log is included on each logging run to aid in depth control.

b All logs except the nuclear annulus investigation log (NAIL) were run by Baker Atlas, a division of Baker Hughes, Inc. NAIL was run by Colog, a division of Layne Christensen Company.

c Drilled depth

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5.0 Geology and Hydrogeology

5.1 Introduction

This section describes the geology and hydrogeology of Well ER-5-5. The basis for the discussions here is the detailed geologic characterization of Well ER-5-5 presented as a lithologic log in Appendix D. The detailed lithologic log was developed using drill cuttings, geophysical logs, and drilling parameters.

5.2 Geology

This section is divided into two discussions relating to the geology of Well ER-5-5. Section 5.2.1 briefly describes the geologic setting of the Frenchman Flat area and the Well ER-5-5 site. The stratigraphic and lithologic units penetrated at the well are discussed in Section 5.2.2. Detailed descriptions of the stratigraphy and lithology of the geologic units encountered are provided in the lithologic log presented in Appendix D. Tables 5-1 and 5-2 provide the definitions of stratigraphic units and HSUs used in various figures in this report. See Figure 5-1 for a surface geologic map of the area surrounding the Well ER-5-5 site.

5.2.1 Geologic Setting

Well ER-5-5 lies on a very gently south-sloping surface composed of young alluvium (Figure 5-1) in the northern portion of Frenchman Flat (Figure 1-1). Frenchman Flat is a hydrologically closed, Cenozoic-age basin formed in response to basin-and-range extension. Topographically, the basin is roughly oval-shaped, elongated in a northeast direction, and contains the Frenchman Lake playa, which marks the topographic low point of the basin.

The geology of the Frenchman Flat area is presented in detail in BN (2005) and summarized here. Geophysical data suggest that in its deepest portions, the basin probably contains 2,438 to 3,018 m (8,000 to 9,900 ft) of mostly Tertiary-age alluvium, volcanic rocks, and tuffaceous sedimentary rocks that overlie Paleozoic-age sedimentary rocks that form the "basement" of the basin. No major horst or graben structures appear to disrupt the floor of the basin in its central portion (BN, 2005). Rocks exposed in the highlands around the margins of Frenchman Flat consist of Tertiary-age volcanic and tuffaceous sedimentary rocks that overlie complexly folded and faulted Paleozoic sedimentary rocks. In the center of the basin, the volcanic and sedimentary rocks are buried by thick aprons of alluvial debris shed from the exposed highlands. Alluvial deposits reach a thickness of 1,676 m (5,500 ft) in the central portion of Frenchman Flat, and are estimated to be approximately 457 m (1,500 ft) thick at the Well ER-5-5 location, based on data from nearby borehole UE-5k. One or more thin, localized basalt flows are known to be present within the alluvial deposits, and one of these was the target aquifer at Well ER-5-5.

Table 5-1
Key to Stratigraphic Units and Symbols Used in This Report

Stratigraphic Unit	Map Symbol
Quaternary and Tertiary Deposits	**QTa**
Playa	Qp
Young alluvial deposits	Qay
Intermediate alluvial deposits	Qai
Older alluvial deposits	QTa
Basalt of Frenchman Flat (within QTa)	Tybf
Older alluvial deposits	QTa
Thirsty Canyon Group	**Tt**
Pahute Mesa Tuff	Ttp
Timber Mountain Group	**Tm**
Ammonia Tanks Tuff	Tma
mafic-rich Ammonia Tanks Tuff	Tmar
mafic-poor Ammonia Tanks Tuff	Tmap
bedded Ammonia Tanks Tuff	Tmab
Rainier Mesa Tuff	Tmr
mafic-rich Rainier Mesa Tuff	Tmrr
mafic-poor Rainier Mesa tuff	Tmrp
Tuff of Holmes Road	Tmrh
Paintbrush Group	**Tp**
Topopah Spring Tuff	Tpt
mafic-rich Topopah Spring Tuff	Tptr
Calico Hills Formation	**Th**
Wahmonie Formation	**Tw**
Salyer Member	Tws
Crater Flat Group	**Tc**
Bullfrog Tuff	Tcb
Older Tuffs	**Tn/To**
Tertiary sedimentary rocks	**Tg**
Paleozoic sedimentary rocks	**Pz**
Late Proterozoic metasedimentary rocks	**Z**

Table 5-2
Key to Hydrostratigraphic Units and Symbols Used in This Report

Hydrostratigraphic Unit	Symbol
Alluvial aquifer	AA
Playa confining unit	PCU2T
Basalt lava-flow aquifer	BLFA
Older altered alluvial aquifer	OAA and OAA1
Timber Mountain welded-tuff aquifer	TMWTA
Upper tuff confining unit	UTCU
Topopah Spring aquifer	TSA
Lower tuff confining unit	LTCU
Lower carbonate aquifer	LCA

Qay young alluvial deposits
Qai intermediate alluvial deposits
QTa old alluvial deposits
Tmr Rainier Mesa Tuff
Model evaluation well
UGTA well
Drill hole
Underground nuclear test
Major elevation contour (100 m)
Minor elevation contour (50 m)
Fault, dashed where inferred or buried (bar and ball on downthrown side)
NNSS boundary
NNSS operational area boundary
Cross section/model profile line

Figure 5-1
Surface Geologic Map of the Well ER-5-5 Area

5.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-5-5 are illustrated in Figure 5-2, and an interpretation of the distribution of stratigraphic units in the vicinity of the well is shown in the geologic cross sections presented in Figures 5-3 and 5-4.

5.2.2.1 Alluvium

Quaternary–Tertiary alluvium with a thin intercalated basalt layer (see Section 5.2.2.2) was penetrated from the surface to the TD of 331.3 m (1,087 ft). The alluvium consists mostly of poorly to moderately sorted gravel and sand associated with alluvial fan deposits. The gravel clasts consist predominantly of volcanic rocks above approximately 274.3 m (900 ft). These clasts are mostly welded ash-flow tuff from the Ammonia Tanks, Rainier Mesa, and Topopah Spring Tuffs, and are most likely derived from the French Peak/Massachusetts Mountain area located north and west of the well location, where those units are extensively exposed. Below approximately 274.3 m (900 ft), the gravel clasts are predominantly Paleozoic sedimentary rocks, particularly quartzite. These clasts are derived from highlands east and northeast of Frenchman Flat, where Paleozoic sedimentary rocks, including the Eureka Quartzite, and Cretaceous or early Tertiary conglomerate composed chiefly of Cambrian quartzite pebbles and cobbles, are exposed (Tschanz and Pampeyan, 1970).

Petrographic and mineralogic analyses of sidewall core samples from nearby Wells ER-5-3 and ER-5-3#2 indicate that the matrix of the alluvium is tuffaceous, and that above the depth of 179.8 m (590 ft) the alluvial matrix has not been significantly altered since deposition (Warren, 2000). Below 179.8 m (590 ft) alteration of the alluvial matrix is indicated by the presence of zeolite minerals replacing the original vitric constituents (Warren, 2000). At Well ER-5-5 this transition occurs at the depth of approximately 176.8 m (580 ft). The unaltered alluvium above 176.8 m (580 ft) is assigned to the alluvial aquifer (AA) HSU, and the altered alluvium below that depth is assigned to the older altered alluvial aquifer (OAA) HSU. The older altered alluvium beneath the intercalated basalt layer is assigned to the HSU OAA1 (see Section 5.4).

5.2.2.2 Basalt

At the depth of 290.8 m (954 ft), within the altered alluvium, Well ER-5-5 encountered a rubbly basalt lava flow approximately 6.7 m (22 ft) thick. This unit was difficult to characterize in cuttings samples because the samples were compromised by borehole sloughing (see discussion in Section 4.2) and because the unit is so thin. The cuttings samples contain clasts of basalt, tuff, and various sedimentary rocks. The upper and lower contacts of the unit were determined mainly from geophysical logs, as described in Appendix D.

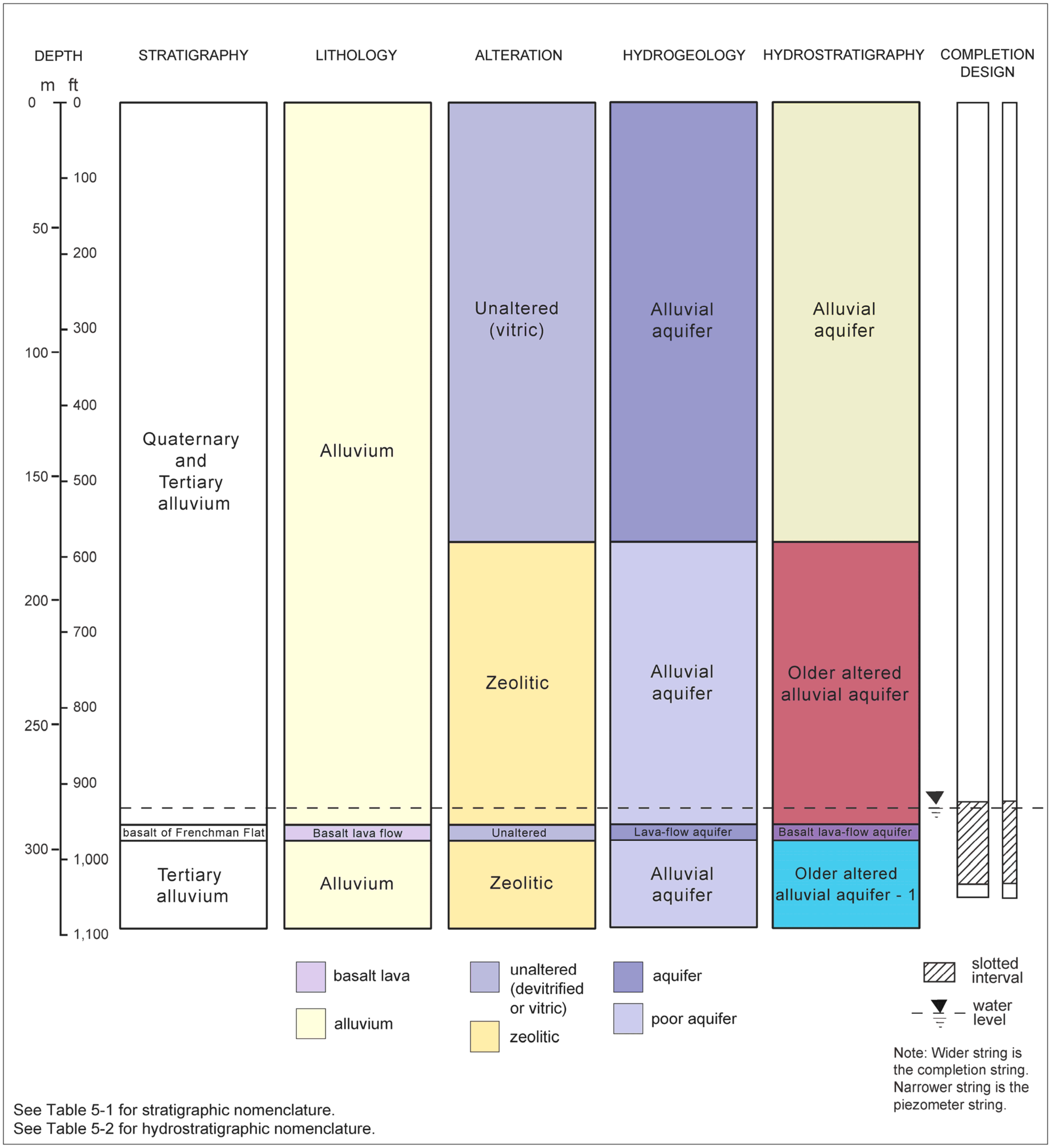


Figure 5-2
Geology and Hydrogeology of Well ER-5-5

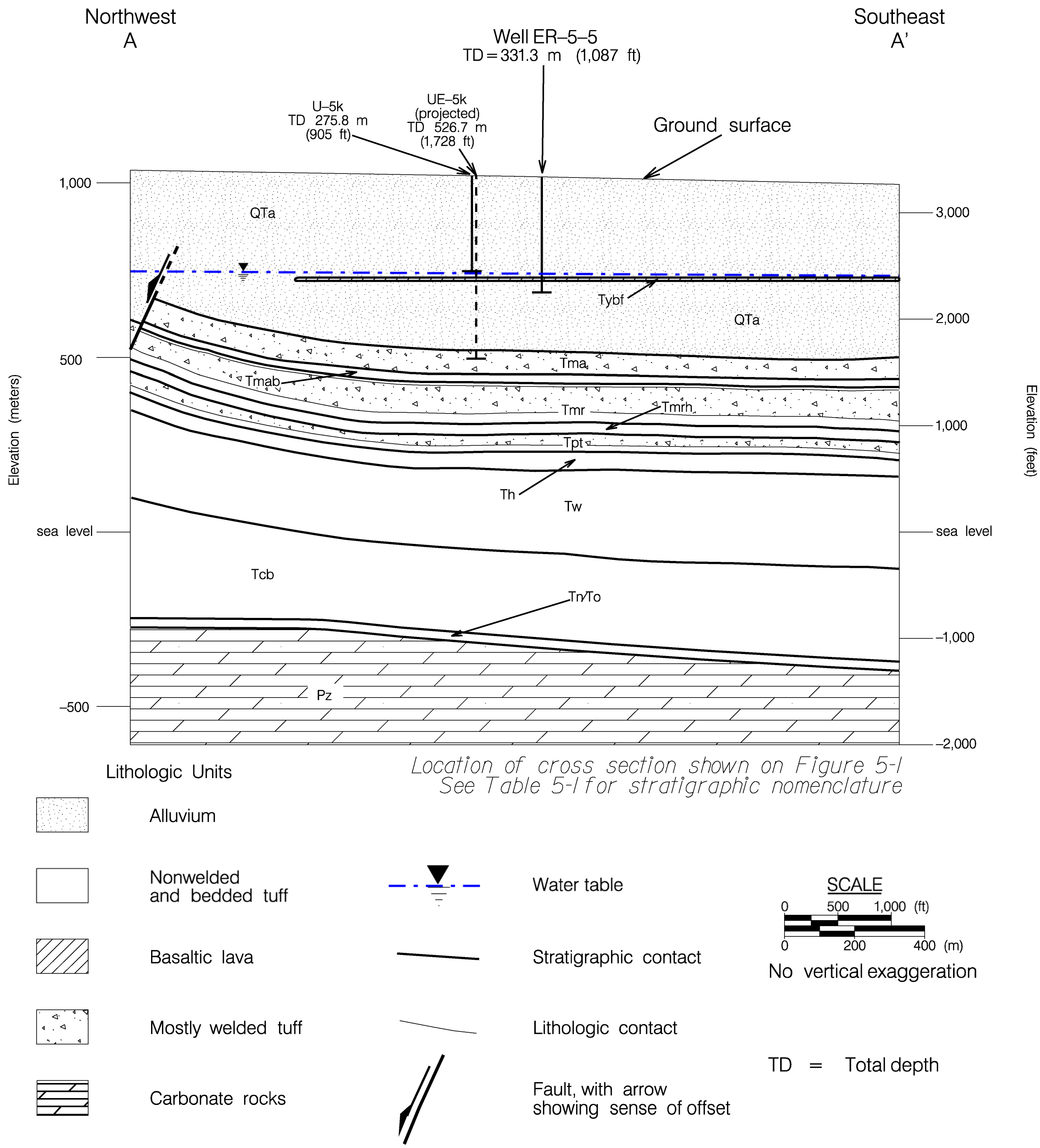


Figure 5-3
Northwest–Southeast Geologic Cross Section A–A' through Model Evaluation Well ER-5-5

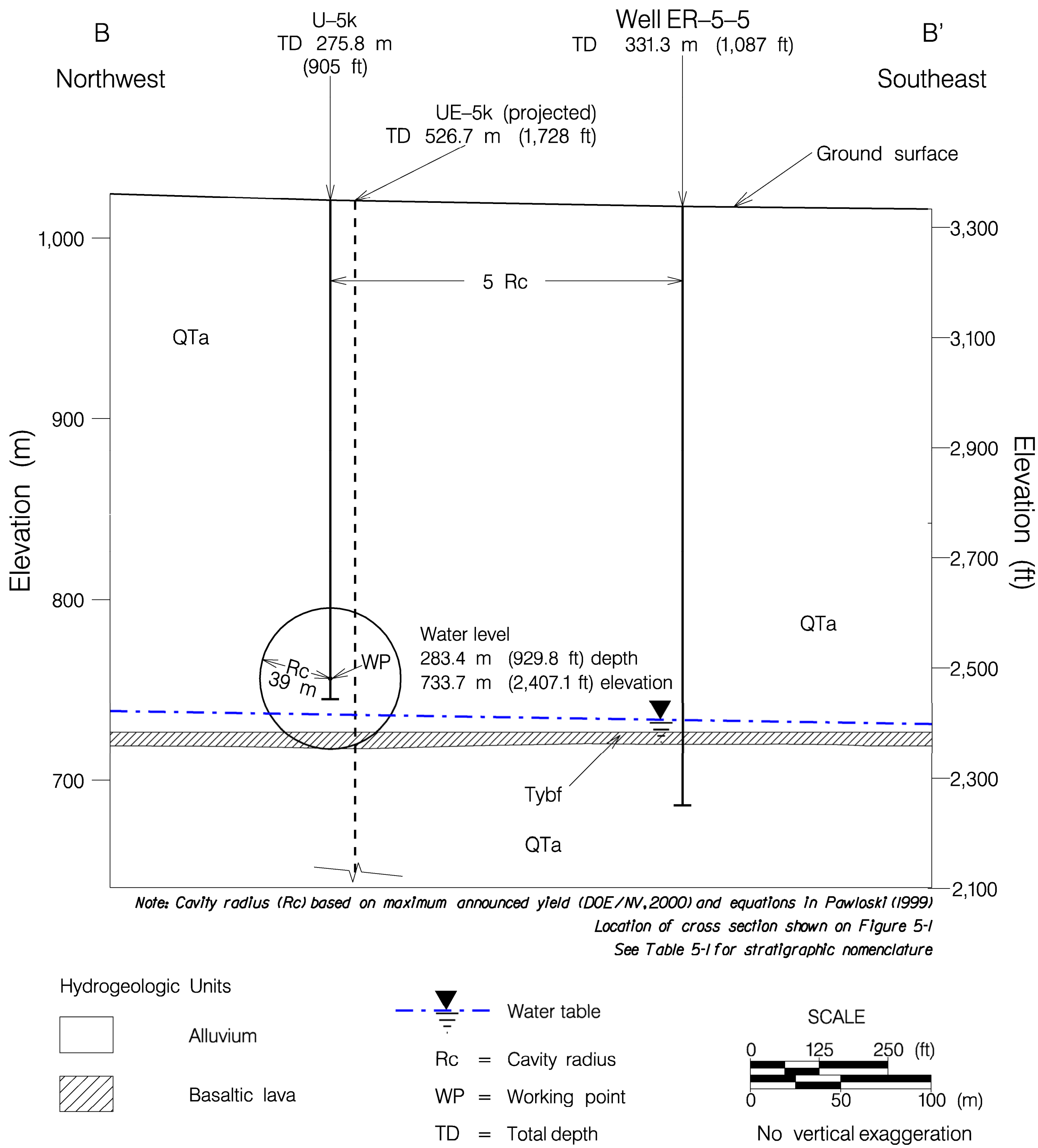


Figure 5-4
Northwest–Southeast Geologic Cross Section B–B' through Emplacement Hole U-5k and Model Evaluation Well ER-5-5

This unit is thought to be similar to an "aa" type basalt flow, composed mainly of rough lava blocks or clinker that formed as the viscous lava flowed along the ground surface. The basalt unit in Well ER-5-5 may be hydrologically similar to alluvium, but it is in the position of the BLFA layer in the HFM (BN, 2005), and is considered a lava-flow aquifer in the context of the HFM.

The BLFA, which consists of the basalt of Frenchman Flat, was the target aquifer at this well. The BLFA is important because it is modeled as the most likely conduit for contaminant migration away from the nearby MILK SHAKE UGT conducted in Emplacement Hole U-5k (N-I, 2012a). However, the lateral extent, continuity, and character of the BLFA are not precisely known and are a source of model uncertainty.

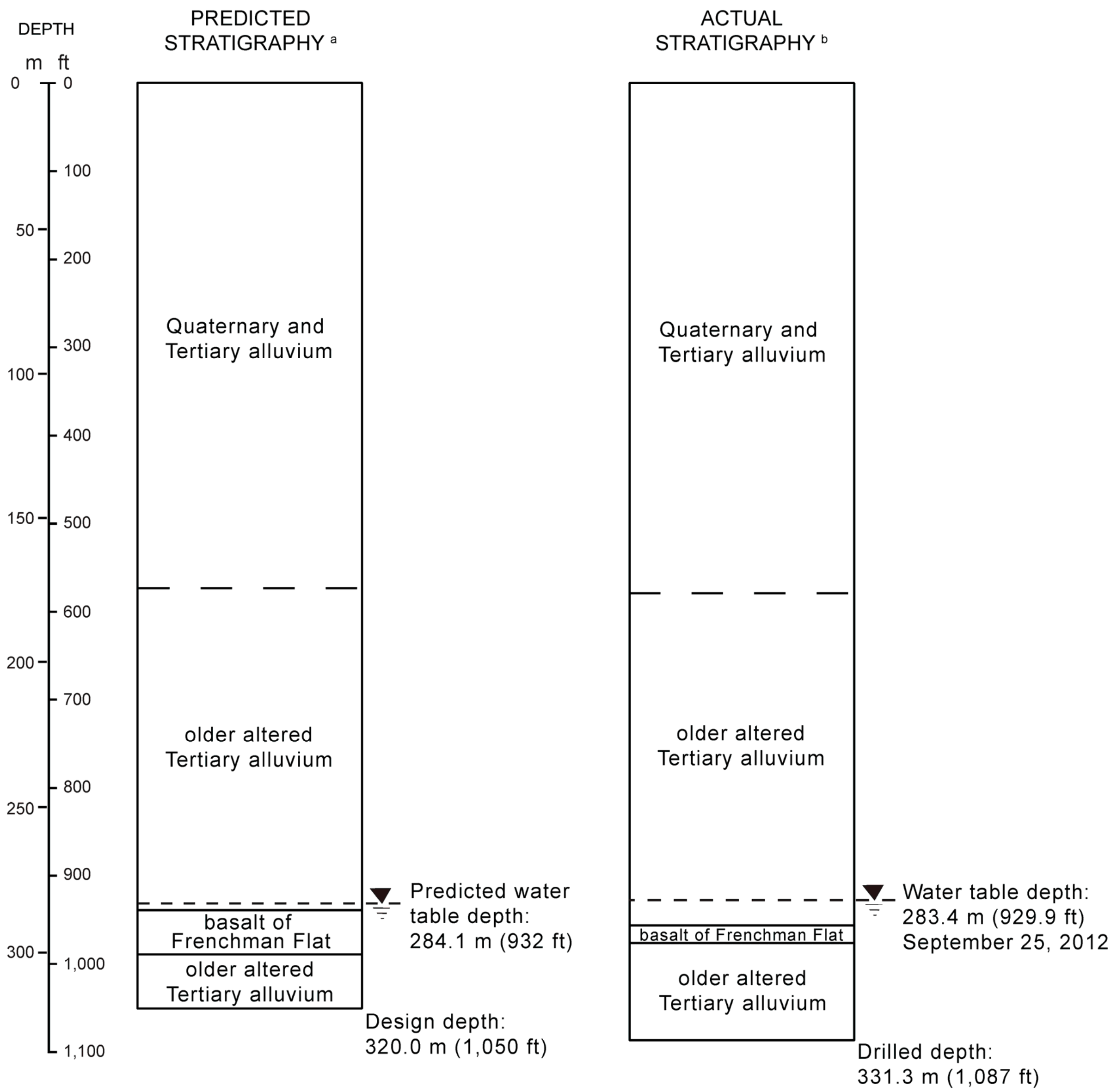
In 2010, a ground magnetic survey was conducted in northern Frenchman Flat in part to better define the lateral extent of the BLFA (Phillips et al., 2011). Preliminary analysis of the magnetic data (Phillips et al., 2011) indicated that the BLFA is present in the vicinity of the MILK SHAKE UGT, as depicted in the Frenchman Flat HFM (BN, 2005), and it may be quite extensive to the east and southeast as explored in the "more extensive BLFA" alternative interpretation presented in BN (2005).

5.3 Predicted and Actual Geology

Well ER-5-5 reached TD at 331.3 m (1,087 ft) within older alluvium, 33.8 m (111 ft) below a 6.7-m (22-ft) thick basalt rubble layer.

Figure 5-5 provides a comparison of the geology predicted for Well ER-5-5 prior to drilling and the geology actually encountered in the well. The geologic prediction for Well ER-5-5 was based on projection of the geology at nearby Exploratory Hole UE-5k, where basalt is present. Based on the lithologic log for UE-5k by Byers and Miller (1966) and listed in the USGS lithologic database (Wood, 2009), this unit was assumed to be a lava flow (with associated basalt rubble) approximately 15.2 m (50 ft) thick. A dense, jointed lava flow was modeled for this area, based on that description (NNES, 2010), though it was recognized that the properties of the basalt could be variable (N-I, 2012a). As described in Section 5.2.2.2, the character of the basalt in Well ER-5-5 was a thin rubbly flow, rather than a dense, jointed lava flow.

These differences prompted NSTec geologists to reevaluate samples and data from Exploratory Hole UE-5k. Based on examination of the drill cuttings, Hunt sidewall samples, and geophysical logs (especially total gamma and density logs), the basalt at UE-5k was found to be about 9.1 m (30 ft) thick, significantly thinner than 15.2 m (50 ft) reported by Byers and Miller (1966) and



[a] N-I (2012a)
[b] See Appendix D for lithologic descriptions

Figure 5-5
Predicted and Actual Stratigraphy at Well ER-5-5

listed in Wood (2009). The NSTec geologists also determined that the unit in UE-5k is more similar to a lava flow than basalt rubble only, as indicated by the “baked” appearance of the alluvium where it is in contact with the base of the basalt in the sidewall sample collected at the depth of 301.8 m (990 ft).

Well ER-5-5 was expected to provide data that will reduce the uncertainty in the location and characteristics of the BLFA near MILK SHAKE. Though a thin layer of rubbly basalt, rather than a dense, highly jointed lava flow, was encountered at the well, the geologic data from Well ER-5-5 have provided a “hard” data point for the BLFA and improved the understanding of the basalt in this area. These data suggest possible hydrologic heterogeneity of the BLFA in northern Frenchman Flat. Future hydrologic testing and modeling may provide additional information about the character of the BLFA at Well ER-5-5, as will be discussed in a later document on the results of the Frenchman Flat Model Evaluation Well drilling.

5.4 Hydrogeology

The rocks in the Well ER-5-5 area have been subdivided into HSUs, as illustrated in the cross section in Figure 5-6. The unaltered alluvium above 176.8 m (580 ft), although unsaturated, is classified hydrogeologically as an alluvial aquifer based on its lithologic character. Below 176.8 m (580 ft) the alluvium has undergone low-grade zeolitic alteration. Although still considered an aquifer, this section of altered alluvium probably has somewhat less ability to transmit water than the overlying unaltered alluvium, and is assigned to a separate HSU, the OAA.

The basalt rubble encountered within the alluvium from 290.8 to 297.5 m (954 to 976 ft) is assigned to the BLFA. However, this unit may be more similar to an alluvial aquifer and dominated by flow processes associated more with porous media rather than with fractured rock.

The section of alluvium beneath the BLFA is also assigned to the OAA but is designated OAA1 to accommodate modeling software requirements.

As predicted prior to drilling, the water table was encountered just above the BLFA. The water table was measured by N-I on September 25, 2012, at the depth of 283.4 m (929.9 ft) in the piezometer string. This depth corresponds to an elevation of 733.7 m (2,407.1 ft)

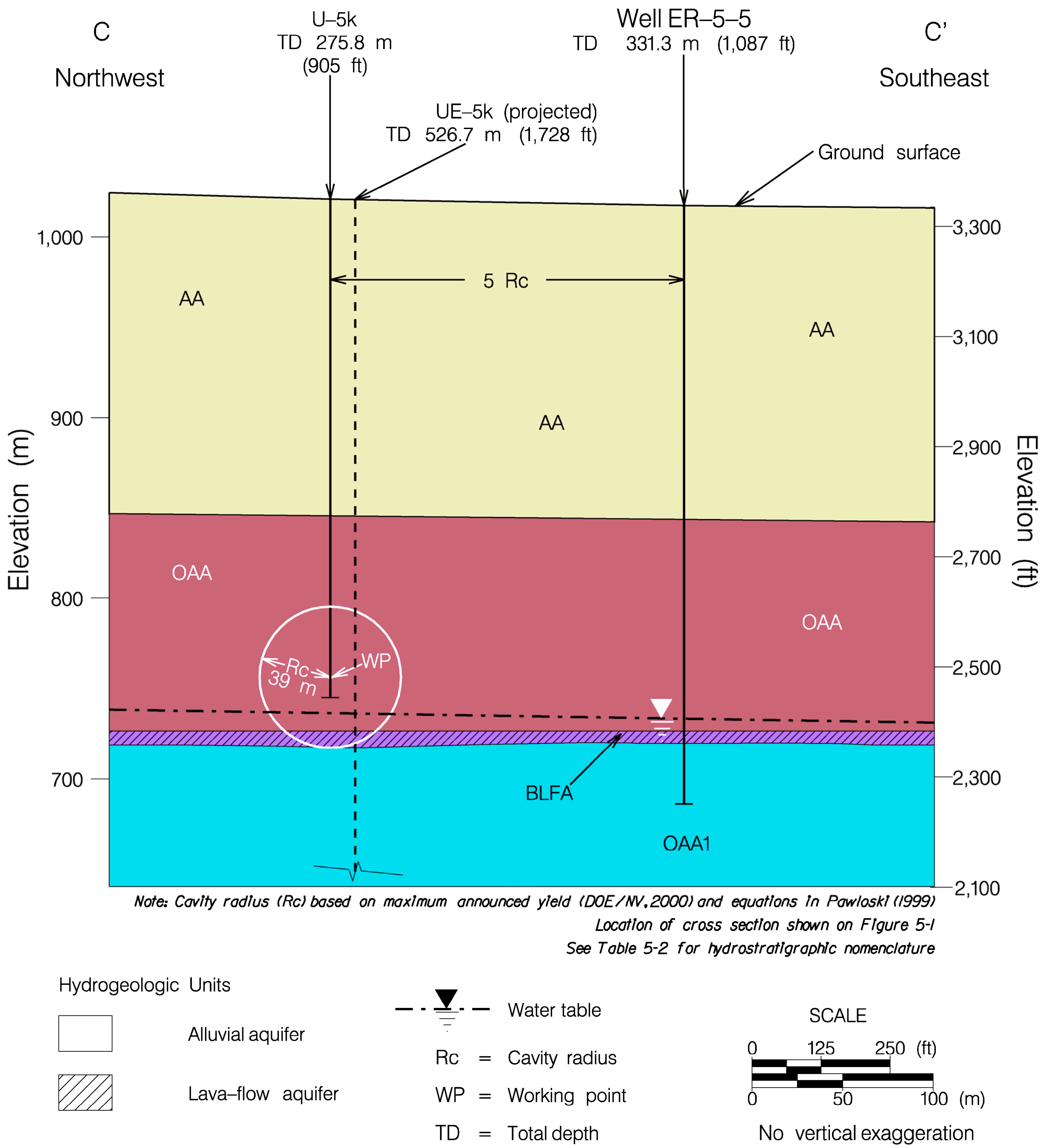


Figure 5-6
Northwest–Southeast Hydrostratigraphic Cross Section C–C' through Emplacement Hole U-5k and Model Evaluation Well ER-5-5

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6.0 Hydrology

Hydrologic data collected at the well site included water-level measurements, groundwater production estimates during drilling, and borehole water quality measurements from discharged drilling fluids. The following paragraphs summarize the well hydrology observed during drilling and well completion operations, as modified from N-I (2012d). The saturated portion of Well ER-5-5 consists of OAA, BLFA, and OAA1. An interpretation of the possible distribution of the hydrostratigraphic units in the vicinity of Well ER-5-5 is shown in cross section in Figure 5-6.

6.1 Water Levels

Prior to drilling, the water level at the Well ER-5-5 location was estimated to be 284.1 m (932 ft) below ground surface, near the top of the basalt of Frenchman Flat (N-I, 2012a). The pre-drill estimate of the water-level elevation was 733.3 m (2,406 ft), based on a ground surface elevation estimated to be 1,017.4 m (3,338 ft), prior to construction of the drill pad.

Fluid level measurements made in the borehole are summarized in Table 6-1. During the fourth episode of geophysical logging, Baker Atlas recorded fluid levels on several geophysical logs at the depth of approximately 283.5 m (930 ft), within the Quaternary–Tertiary alluvium. N-I made water-level measurements using a calibrated Solinst e-tape in the Well ER-5-5 completion casing 3 hours after completion of the well, on August 12, 2012, and in the piezometer string on September 25, 2012, before transducer installation.

Table 6-1
Well ER-5-5 Water-Level Measurements

Date Time	Fluid Depth [a]		Fluid Elevation [b]		Notes
	meters	feet	meters	feet	
08/11/2012 08:15	283.5	930	733.6	2,406.9	Fluid level reported by Baker Atlas on the temperature log.
08/11/2012 15:15	283.5	930	733.6	2,406.9	Fluid level reported by Baker Atlas on the compensated density log.
08/12/2012 20:05	283.3	929.4	733.8	2,407.5	Fluid level measured by N-I within the 6⅝-in. completion casing using a calibrated Solinst e-tape.
09/25/2012 14:25	283.4	929.9	733.7	2,407.0	Fluid level measured by N-I within the 2⅞-in. piezometer tubing using a calibrated Solinst e-tape.

Modified from N-I (2012d)

a Depths are below ground surface.

b The ground surface reference datum was surveyed by NSTec on August 28, 2012, at 1,017.1 m (3,336.9 ft) above mean sea level.

The fluid levels presented here should be considered preliminary, and may not represent natural groundwater levels. Well development and hydrologic testing at Well ER-5-5, which will provide more accurate water level data, are planned to take place in February 2013.

6.2 Water Production

Water production was estimated during drilling of Well ER-5-5 on the basis of dilution of a lithium-bromide tracer, as measured by N-I field personnel. The tracer was added to drilling fluids before being injected down-hole. Concentrations of bromide in mixing tanks and in discharged fluids were monitored regularly as drilling progressed. Differences between injected and discharged bromide concentrations were used to calculate groundwater production rates. When appropriate, visual estimates of water production were used to support calculated fluid production rates from the flow line. The bromide tracer results and calculated water production rates from Well ER-5-5 are listed in Appendix F.

The first indications of water production of approximately 7.6 lpm (2 gpm), based on bromide dilution calculations, were noted in Well ER-5-5 at the depth of approximately 285.3 m (936 ft) within the lower portion of the alluvium, above the BLFA. Estimated water production rates increased from 7.6 to 49.2 lpm (2 to13 gpm) while drilling in alluvium and through the BLFA, from the depth of 285.3 to 297.5 m (936 to 976 ft), and gradually increased to approximately 340.7 lpm (90 gpm) within the older alluvium beneath the BLFA, between approximately 297.5 m (976 ft) and TD at 331.3 m (1,087 ft). A plot of water production rates is shown with drilling parameters and borehole stratigraphy in Appendix A-1. More accurate water production information may become available after limited hydraulic testing (i.e., bailing and monitoring recovery) is conducted.

6.3 Flow Meter Data

Thermal flow and chemistry logs were not run in Well ER-5-5. Because of the simple hydrologic setting and because a single completion zone was planned, the drilling advisory team decided that these logs would contribute little to the scientific objectives of the well.

6.4 Groundwater Chemistry

N-I monitored drilling effluent on site for pH, temperature, and electrical conductivity throughout the drilling operations, and used these data to evaluate changes in groundwater conditions during drilling. Water-quality measurements were affected by cement and the use of drilling foam and polymer during drilling operations, and do not accurately reflect natural groundwater quality; however, they may be reflective of changed conditions within the borehole during drilling.

No preliminary groundwater characterization samples were collected that could provide initial groundwater chemistry data from the well. Sampling is planned to take place after well development.

6.5 Radionuclides Encountered

N-I site personnel collected discharged drilling fluid samples hourly during periods of borehole advancement. NSTec RCTs analyzed the samples on site for tritium for purposes of fluid management and worker protection, as described in Section 3.1.2. Tritium results for drilling fluid samples from the unsaturated zone in Well ER-5-5 ranged from 0 to 2,468 pCi/L, and thus were all well below the limit of 20,000 pCi/L established in the *National Primary Drinking Water Regulations* (CFR, 2012a). Tritium analyses for discharge samples from the saturated zone were all less than the MDA of the field analytical equipment. The results of all the tritium analyses are listed in Appendix B-1.

These field monitoring data should not be considered representative of the groundwater at Well ER-5-5. More sensitive laboratory methods will be used on samples to be collected later during well development and sampling activities.

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7.0 Precompletion and Open-Hole Development

Initial well development was not conducted after TD was reached at Well ER-5-5 due to concerns related to borehole stability.

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8.0 Well Completion

8.1 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 screened or slotted intervals and impervious materials such as cement placed between or above the slotted or open intervals to isolate them. The string(s) serve 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-5-5 was presented in the criteria document (N-I, 2012a). The original completion plans are summarized in Section 8.2.1 of this report, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 8.2.2. The rationale for differences between the planned and actual design is discussed in Section 8.2.3, and the completion methods are presented in Section 8.3. Figure 8-1 is a schematic diagram of the well completion design. Figure 8-2 shows a plan view and profile of the final wellhead surface completion. Figure 8-3 is a photograph showing the ER-5-5 wellhead. Table 8-1 is a construction summary for the completion strings.

8.2 Well Completion Design

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

8.2.1 Proposed Completion Design

The original proposed well completion design (N-I, 2012a) for Well ER-5-5 was based on the possibility that radionuclides would be present, that the borehole would penetrate the water table just above the BLFA within the OAA, and reach TD just below the BLFA in the OAA1. On the basis of these expectations, Well ER-5-5 was planned to be completed with a single string of 6⅝-in. casing extending through the BLFA, and open to the BLFA and underlying OAA1. A 2⅞-in. piezometer string was to be placed within the annulus outside the completion casing, open to the same target zone as the production casing.

The proposed completion design for Well ER-5-5 was intended to provide groundwater data from the BLFA and to provide access to groundwater for monitoring and sampling.

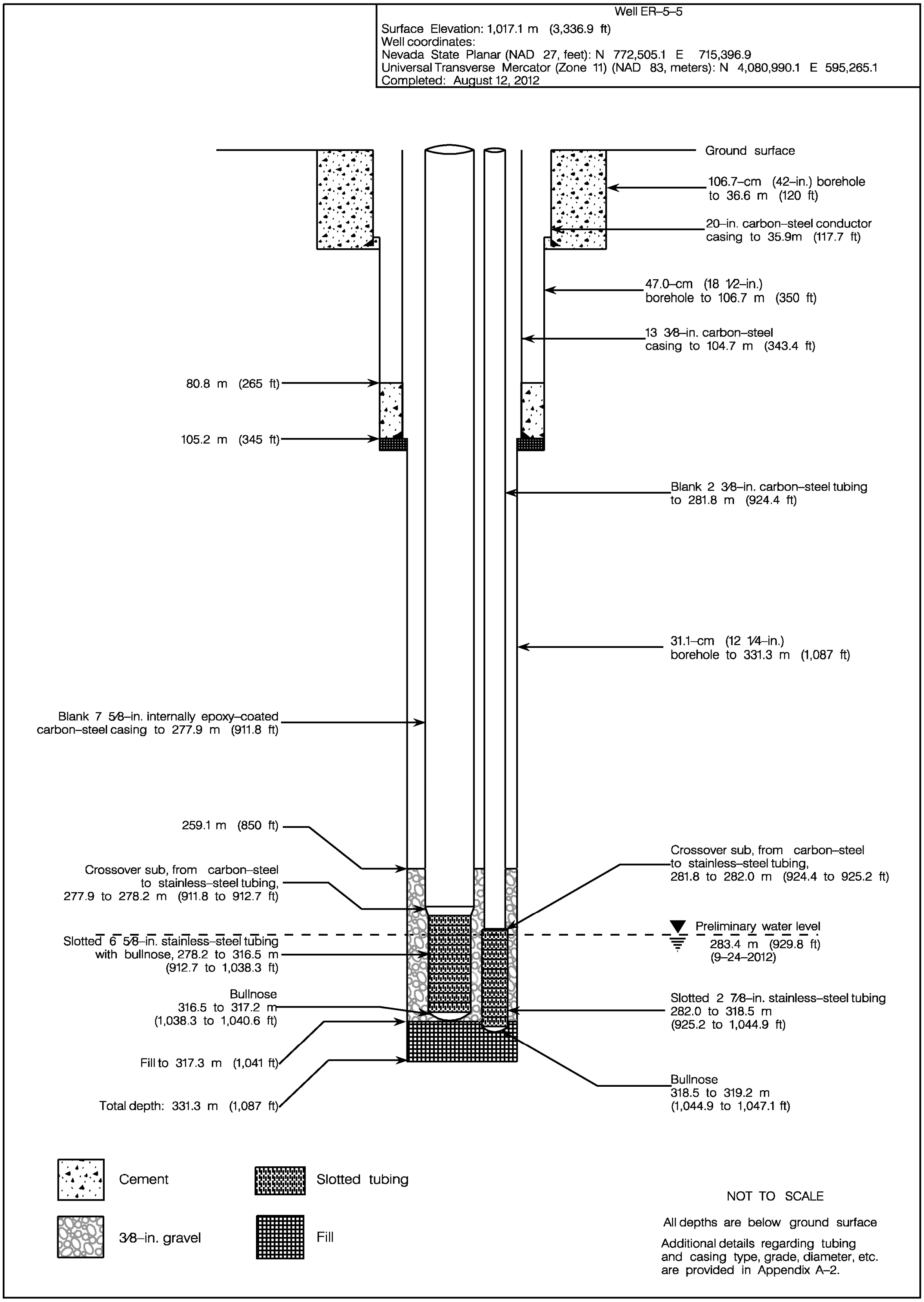
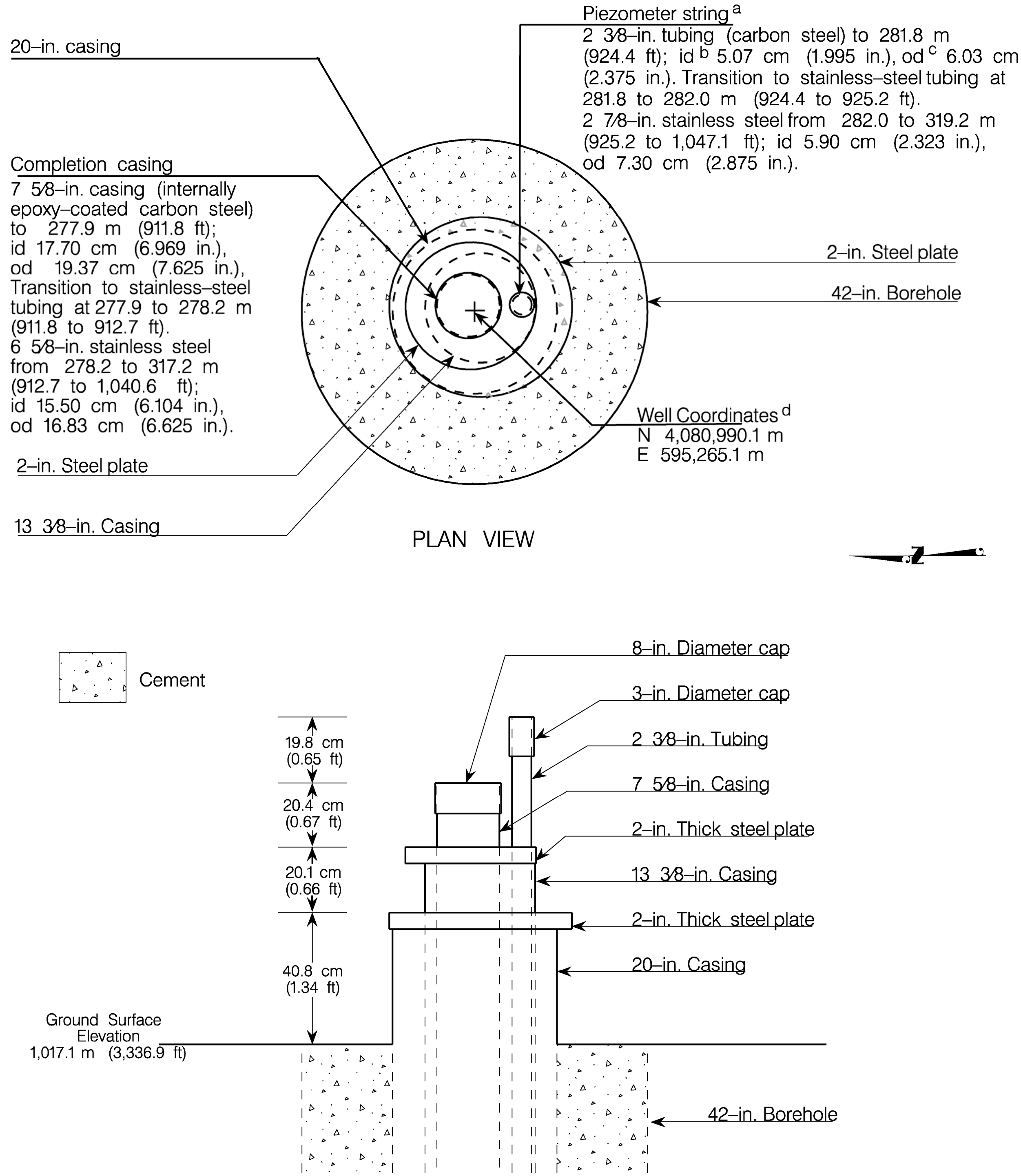


Figure 8-1
As-Built Completion Schematic for Well ER-5-5



a See Appendix A–2 for casing data.
b id = inside diameter
c od = outside diameter
d NAD 83 Universal Transverse Mercator zone 11 Coordinates

Figure 8-2
Wellhead Diagram for Well ER-5-5

Photograph by NSTec, August 30, 2012

Figure 8-3
Photograph of the Well ER-5-5 Wellhead

Table 8-1
Well ER-5-5 Completion String Construction Summary

Casing and Tubing	**Configuration** meters (feet)		**Cement** meters (feet)	**Sand/Gravel meters (feet)**
2⅜-in. carbon-steel tubing with crossover sub	0 to 282.0 (0 to 925.2)	Blank	None	⅜-in. washed gravel 259.1 to 317.2 (850.0 to 1,041.0)
2⅞-in. stainless-steel tubing	282.0 to 319.2 (925.2 to 1,047.1)	Slotted and bullnosed [a]		
7⅝-in. epoxy-coated carbon-steel production casing with crossover sub	0 to 278.2 (0 to 912.7)	Blank		
6⅝-in. stainless-steel production casing	278.2 to 317.2 (912.7 to 1,040.6)	Slotted and bullnosed [b]		

a Vertical slots in each joint are 0.159 cm (0.0625 in.) wide and 5.40 cm (2.125 in.) long, arranged in 69 rows, on 7.6-cm (3.0-in.) centers. The 8 slots per row are positioned radially around the tubing at 45 degrees. Each row is offset by 22.5 degrees from the next.

b Vertical slots in each joint are 0.159 cm (0.0625 in.) wide and 7.0 cm (2.75 in.) long, arranged in 32 rows, on 5.2-cm (6.0-in.) centers. The 12 slots per row are positioned radially around the casing at 30 degrees. Each row is offset by 15 degrees from the next.

8.2.2 As-Built Completion Design

The final Well ER-5-5 completion design was determined by the UGTA Well ER-5-5 Topical Committee after the TD of 331.3 m (1,087 ft) was reached. The committee endorsed the initial completion plan on the basis of onsite evaluation of data such as lithology, water production, borehole condition, drilling data, and data from geophysical logs.

The main completion string consists of a string of 6⅝-in. stainless-steel casing suspended from 7⅝-in. internally epoxy-coated carbon-steel casing, connected via a crossover sub. The bottom of the string was set at the depth of 317.2 m (1,040.6 ft). The 7⅝-in. internally epoxy-coated carbon-steel casing and crossover sub extend from the surface to the depth 278.2 m (912.7 ft), which is about 5.2 m (17 ft) above the water table. The stainless-steel 6⅝–in. casing is slotted in the interval 278.2 to 317.2 m (912.7 to 1,040.6 ft) across the BLFA and includes a few meters of both the overlying OAA and underlying OAA1. The slotted section consists of six consecutive slotted joints and terminates with a 0.7-m (2.25-ft) length of stainless-steel bullnosed casing that functions as a sediment sump. The machine-cut openings in each slotted casing joint are 0.159 cm (0.0625 in.) wide and 7.0 cm (2.75 in.) long. The vertical slots in each joint are arranged in 32 rows, on 5.2-cm (6.0-in.) centers. The 12 slots per row are positioned radially around the casing at 30 degrees. Each row is offset by 15 degrees from the next. The slotted section of the casing string is gravel-packed from 259.1 to 317.3 m (850 to 1,041 ft). The annulus above the gravel pack was left open.

Photo by N-I, October 13, 2012

Figure 8-4
Photograph Showing an Example of Slotted Casing

Figure 8-4 illustrates a typical arrangement of slots on casing joints as an aid for visualizing the described slot configuration for the casing and tubing in Well ER-5-5.

The piezometer string consists of a section of 2⅞–in. stainless-steel tubing that hangs from 2⅜-in. carbon-steel tubing via a crossover sub. The bottom of the piezometer string was set at the depth of 319.2 m (1,047.1 ft). The 2⅜-in. carbon-steel tubing (with crossover sub) extends from the surface to the depth of 282.0 m (925.2 ft), which is 1.4 m (4.6 ft) above the water table. The stainless-steel 2⅞-in. tubing is slotted in the interval from 282.0 to 319.2 m (925.2 to 1,047.1 ft) within the BLFA and parts of the overlying OAA and underlying OAA1. The slotted section consists of three slotted joints and was terminated with a section of bullnosed tubing 0.65 m (2.13 ft) long. The openings in the slotted tubing joints are 0.159 cm (0.0625 in.) wide and 5.40 cm (2.125 in.) long. The vertical slots in each joint are arranged in 69 rows, on 7.6-cm (3.0-in.) centers. The 8 slots per row are positioned radially around the tubing at 45 degrees. Each row is offset by 22.5 degrees from the next. The slotted portion of the piezometer string lies within the same gravel pack as the slotted section of the 6⅝-in. production casing.

8.2.3 Rationale for Differences between Planned and Actual Well Design

The planned completion design for Well ER-5-5 was based on expected hydrogeology for the site, which was predicted using data from nearby Emplacement Hole U-5k and its associated Exploratory Hole UE-5k, both located approximately 195.1 m (640 ft) to the northeast. The hydrogeology of Well ER-5-5 was not significantly different than expected, so minimal adjustment had to be made, and Well ER-5-5 was constructed generally as planned.

8.3 Well Completion Method

The completion strings were installed and gravel emplaced on August 12, 2012. The UDI crew installed the 2⅞-in. piezometer string, landing it at the depth of 319.2 m (1,047.1 ft). The drillers next inserted the tremie string, consisting of 2⅞-in. Hydril tubing, which was used to emplace the gravel (this string was removed from the borehole after gravel emplacement). The top of fill in the borehole had been tagged at the depth of 320.0 m (1,050 ft) prior to the last geophysical logging run, but continued to accumulate, and had risen to the depth of approximately 317.3 m (1,041 ft) by the time the casing subcontractor installed the production casing, which was landed at 317.2 m (1,040.6 ft). A layer of ⅜-in. washed gravel 58.2 m (191 ft) thick was emplaced around the completion strings, from the top of fill to the depth of 259.1 m (850 ft) (Figure 8-1). Colog ran a Nuclear Annulus Investigation Log in the 2⅞-in. piezometer string to monitor placement of the gravel. No sand or cement was used in the completion.

The UDI drill rig was released after the production casing was installed and stemming operations were complete. Well development and hydrologic testing are planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion. All well construction materials used for the completion were inspected according to relevant procedures, as listed in N-I (2012a). Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

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9.0 Planned and Actual Costs and Scheduling

This section provides brief discussions of the planned and actual schedule and costs for constructing Well ER-5-5.

The original NSTec-approved baseline work package cost estimate for drilling and completing Well ER-5-5 was based on drilling to a planned TD of 457.2 m (1,500 ft) and installing one production casing string and one piezometer string. This estimate was submitted before the drilling criteria document (N-I, 2012a) was issued with an updated planned TD of 320.0 m (1,050 ft). In the baseline estimate, a 10-day schedule for constructing a 457.2-m (1,500-ft) deep well was used.

It took 15 days to construct Well ER-5-5, starting with the drilling of the 31.12-cm (12.25-in.) surface hole. The final TD of the borehole, at 331.3 m (1,087 ft) was 11.3 m (37 ft) deeper than the planned depth, as specified in the drilling criteria document (N-I, 2012a). The final geophysical logging and well completion proceeded as expected, but additional logging runs (caliper) were made to assess borehole instability problems during drilling. The sloughing problems added about 5 extra days to the drilling time, including time to install a surface casing and to conduct remedial cementing operations. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 9-1.

The cost analysis for Well ER-5-5 begins with the mobilization of the UDI drill rig to the site, where the conductor hole had already been constructed. The total construction costs for Well ER-5-5 includes all drilling costs: charges by the drilling subcontractor, charges by other support subcontractors (including compressor services, drilling fluids, casing services, down-hole tools, and geophysical logging), and charges by NSTec for mobilization and demobilization of equipment, cementing services, RCT services, inspection services, site supervision, and geotechnical consultation. The cost of constructing the access roads, drill pad, sumps, and conductor hole is not included, nor is the cost of well-site support by N-I personnel.

The total planned cost for constructing Well ER-5-5 with a planned TD of 457.2 m (1,500 ft) was $2,772,136. The actual cost for constructing the well with the TD of 331.3 m (1,087 ft) was $2,354,321, or 15.1 percent less than the revised estimated cost. Figure 9-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-5-5. The baseline cost (and schedule) was adjusted during well construction due to realization of risk associated with the drilling problems encountered due to an unstable (sloughing) borehole. Thus, Figure 9-2 shows a 15-day schedule for both the baseline and actual costs.

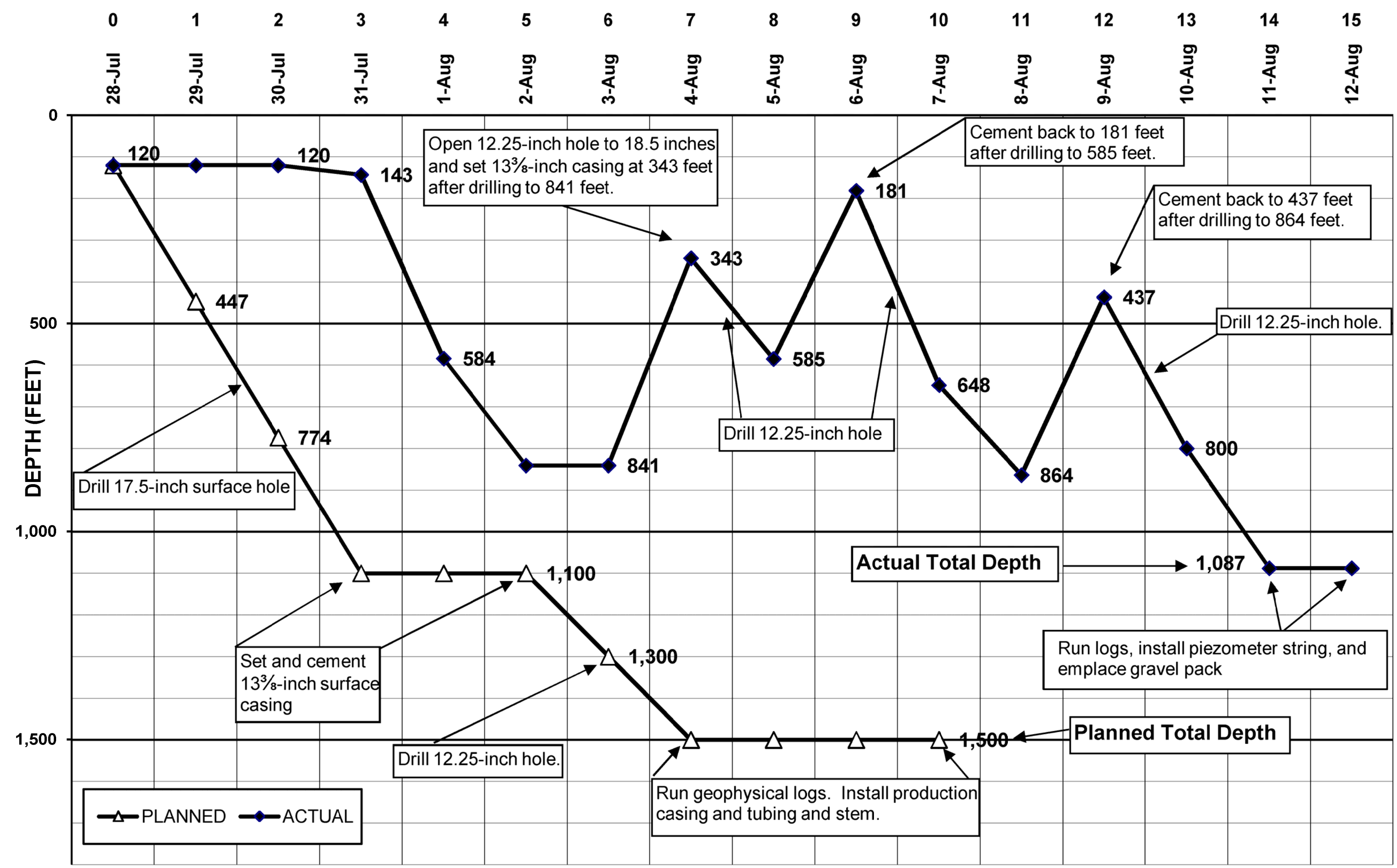

Figure 9-1
Planned and Actual Construction Progress for Well ER-5-5

Note that the planned TD is based on a preliminary plan developed prior to issue of the drilling criteria document (N-I, 2012a)

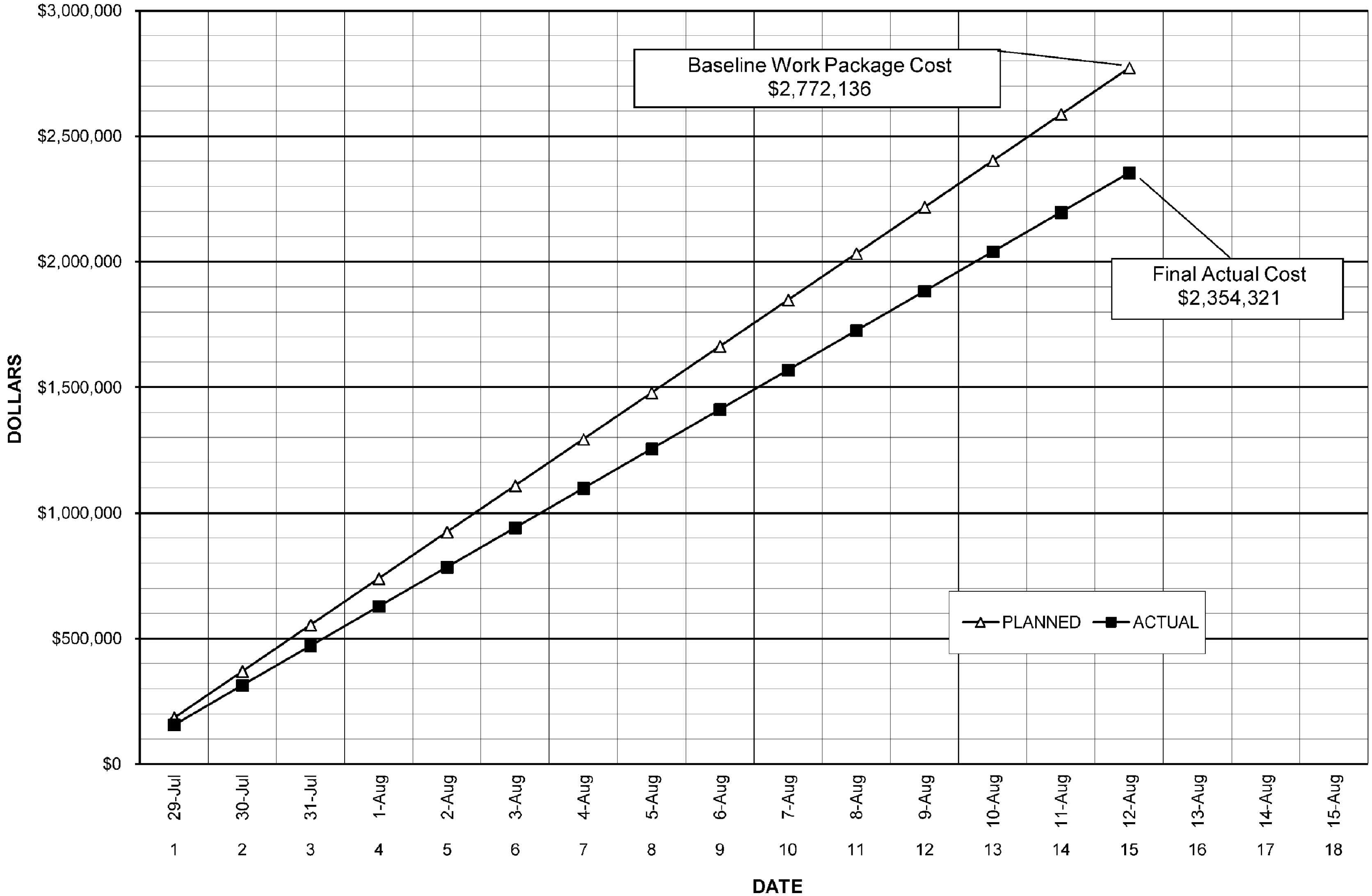

Figure 9-2
Planned and Actual Cost of Constructing Well ER-5-5

Note that the planned cost is based on a preliminary plan developed prior to issue of the drilling criteria document (N-I, 2012a).

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10.0 Summary, Recommendations, and Lessons Learned

10.1 Summary

Drilling of the main hole at Model Evaluation Well ER-5-5 commenced on July 31, 2012, and concluded on August 12, 2012, at a total drilled depth of 331.3 m (1,087 ft). The borehole reached TD within older alluvium and was completed within the BLFA. At this location the BLFA consists of basalt rubble, not a dense fractured lava flow aquifer as was expected. Several problems were encountered during drilling. Borehole instability caused several delays due to severe sloughing of material from the borehole walls. Borehole enlargement occurred from about 36.6 to 243.8 m (120 to 800 ft) below ground surface. A 13⅜-in. surface casing was installed to a depth of 104.7 m (343.4 ft) to stabilize the borehole from below the conductor casing to this depth. Two zones with severe hole enlargement (one at 104.5 to 134.4 m [343 to 441 ft] and the other at 132.6 to 206.0 m [435 to 676 ft]) had to be cemented and re-drilled.

The completion string consists of a string of 6⅝-in. stainless-steel casing suspended from 7⅝-in. internally epoxy-coated carbon-steel casing. The carbon-steel casing extends to a depth that is 5.2 m (17 ft) above the water table. The 6⅝-in. casing is slotted in the interval 278.2 to 317.2 m (912.7 to 1,040.6 ft), providing access to the BLFA and a few meters of alluvium above and below the basalt for monitoring and sampling. The slotted section consists of six consecutive stainless-steel slotted joints.

The well has one piezometer string that provides access to the BLFA. A string of 2⅞-in. stainless-steel tubing hangs from a string of 2⅜-in. carbon-steel tubing, connected via a crossover sub. The tubing is slotted from 282.0 to 319.2 m (925.2 to 1,047.1 ft), encompassing the same interval as the slotted production casing. Gravel packing was placed around the slotted intervals of the completion strings from the top of fill at 317.3 m (1,041 ft) to 259.1 m (850 ft). No sand or cement was used in the completion. No well development or hydrologic testing was conducted.

Data collected during and shortly after construction of Well ER-5-5 include composite drill cuttings samples collected every 3.0 m (10 ft) from 36.6 to 331.3 m (120 to 1,087 ft). No sidewall samples were collected. Open-hole geophysical logging was conducted in the portion of the hole below the surface casing after TD was reached to help verify the geology and determine the hydrologic characteristics of the alluvium and basalt rubble. However, the log data collected above the depth of 206.7 m (678 ft) were unusable because much of the borehole had been cemented during drilling to stabilize sloughing zones.

Well ER-5-5 was collared in and penetrates Quaternary–Tertiary alluvium and an intercalated basalt rubble layer. The fluid level was measured in the piezometer string on September 25, 2012, at the depth of 283.4 m (929.9 ft), which equates to an elevation of 733.7 m (2,407.1 ft). This should be considered a preliminary value until the well is developed and hydrologic testing is conducted.

The geology encountered and the water level were generally as expected. However, the target aquifer, the BLFA is thinner and more like a rubblized lava flow than expected. Tritium levels in the drilling fluid were below the MDA of the field instruments used during drilling of Well ER-5-5. Data for samples of drilling effluent may not be representative of the groundwater. Representative groundwater data will not be available until the well is developed and re-sampled.

10.2 Recommendations

It is important that appropriate well development, sampling, and hydrologic testing at Well ER-5-5 be conducted to assure that the goals of the CADD/CAP model evaluation project can be completed.

10.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA Activity continues to improve as experience is gained with each new well. Because difficult drilling conditions were encountered, several new lessons were learned during the construction of Well ER-5-5:

- Periodic checks on the drilling effluent might have given an earlier indication that the foam used in the drill fluid was not performing as desired. More attention should be paid to the quality of drilling fluids used, as the performance of additives can vary or deteriorate over time.
- Caliper logs were an effective tool for assessing the sloughing that occurred throughout drilling of the upper part of the borehole, and for planning subsequent remedial cementing operations.
- Cementing, while time consuming and costly, eventually stabilized the borehole so that the desired depth could be reached without loss or damage to drilling equipment. Because this occurred within the unsaturated zone, scientific objectives were not compromised.
- An effort should be made to periodically flush or otherwise clear the flow line of accumulated drill cuttings. These are an additional potential source of "contamination" of cutting samples in boreholes where sloughing has already caused mixing of cuttings from overlying intervals.

- Even though the drilling criteria document (N-I, 2012a) included a large suite of recommended geophysical logs, initial plans for Well ER-5-5 called for an abbreviated suite of logs because the area is geologically well known. However, it was difficult to characterize the target aquifer (BLFA) in Well ER-5-5 because the unit was thinner than expected and because the drill cuttings were of poor quality due to borehole stability problems. The drilling advisory team and field personnel were able to quickly modify the planned logging suite to include logs that proved extremely helpful for identifying the basalt. The ability to quickly evaluate and modify data collection plans based on unexpected field conditions demonstrated the value of the team's flexible approach to assuring that the scientific objectives are met despite the extreme drilling problems.

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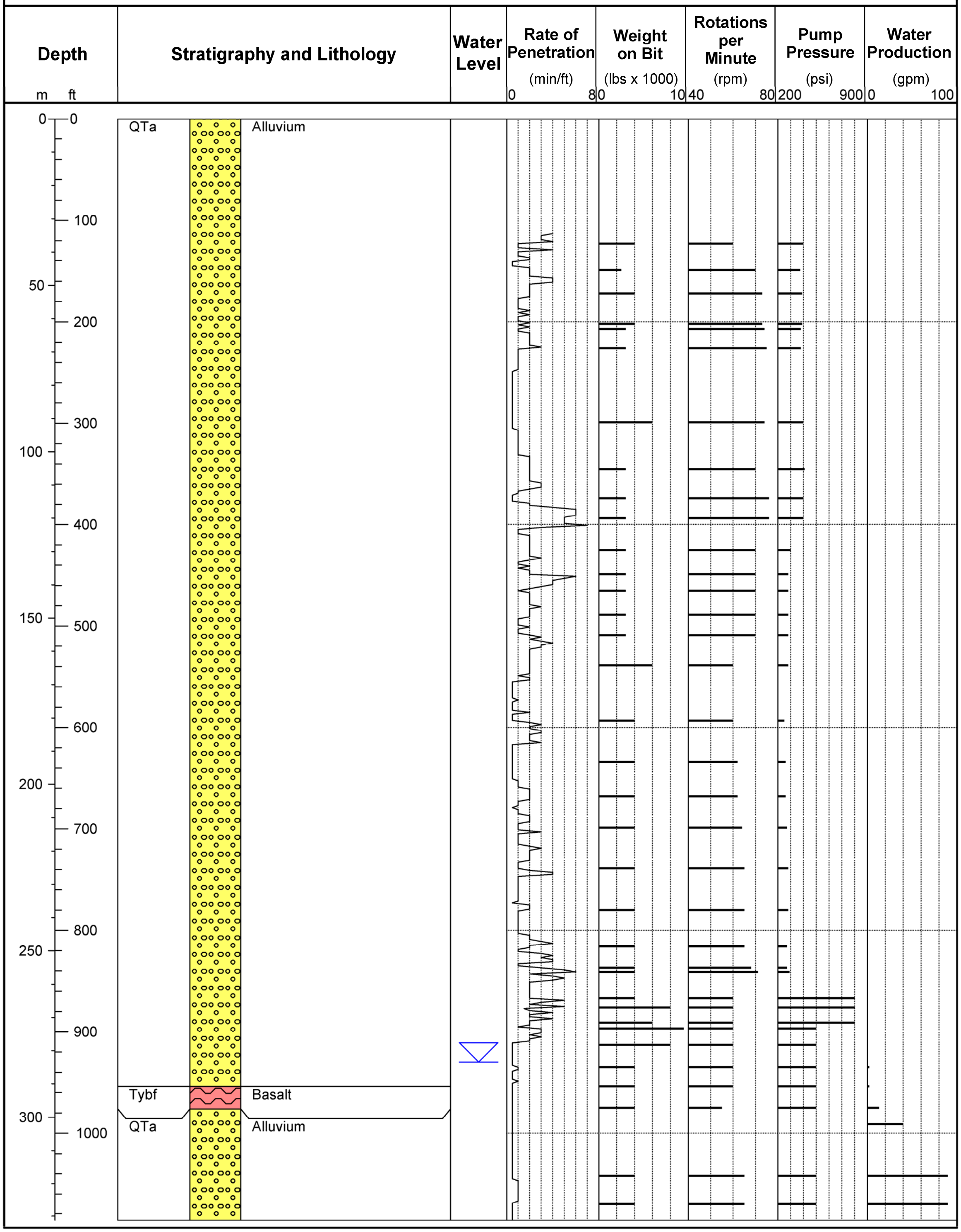
Appendix A
Drilling Data

Appendix A-1
Drilling Parameter Log for Well ER-5-5

Well ER-5-5

Logging Company: Baker Atlas
Drilled Depth: 331.3 m (1,087 ft)
Date TD Reached: August 10, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,017.1 m (3,336.9 ft)
Coordinates (UTM [NAD 83]): N 4,080,990.1 m
E 595,265.1 m
Water Level: 283.4 m (929.9 ft) on September 25, 2012



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Appendix A-2
Tubing and Casing Data for Well ER-5-5

Table A-2-1
Tubing and Casing Data for Well ER-5-5

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 35.9 (0 to 117.7)	Carbon steel	K55	50.80 (20)	48.57 (19.12)	1.113 (0.438)	94
Surface	0 to 104.7 (0 to 343.4)	Carbon steel	K55	33.97 (13.375)	32.042 (12.615)	0.965 (0.380)	54.5
Completion (with crossover)	0 to 278.2 (0 to 912.7)	Epoxy-coated carbon steel	J55	19.368 (7.625)	17.701 (6.969)	0.834 (0.328)	26.4
Completion	278.2 to 317.2 (912.7 to 1,040.6)	Stainless steel	304L	16.828 (6.625)	15.504 (6.104)	0.663 (0.261)	NR[a]
Piezometer (with crossover)	0 to 280.01 (0 to 925.2)	Carbon steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Piezometer	280.01 to 319.2 (925.2 to 1,047.1)	Stainless steel	SS	7.303 (2.875)	5.90 (2.323)	0.701 (0.276)	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-5-5 Drilling Fluids and Cement Composition

Table A-3-1
Drilling Fluids Used in Well ER-5-5

Typical Air-Foam/Polymer Mix	
Drilling to 216 m (710 ft)	56.8 to 132.5 liters (15 to 35 gallons) Geofoam [a] 0 to 3.8 liters (0 to 1 gallons) LP701 [b] per 7,949 liters (50 barrels) water
Drilling from 216 m (710 ft) to TD	56.8 liters (15 gallons) Bachman Foam [c] 1.9 liters (0.5 gallons) LP701 [b] per 7,949 liters (50 barrels) water

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

b. LP701® polymer additive is a product of Geo Drilling Fluids, Inc.

c. Bachman® foaming agent is a product of Bachman Services, Inc.

Notes:
1. All water used to mix drilling fluids for Well ER-5-5 came from Water Well C-1.
2. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids (1 LiBr per 50 barrels of fluid), to make up a final concentration of approximately 20 to 30 parts per million LiBr.

Table A-3-2
Well ER-5-5 Cement Composition

Cement Composition	20-inch Conductor Casing	13⅜-inch Surface Casing	Cemented Sloughing Zones	6⅝-inch Completion Casing	2⅞-inch Piezometer String
Redi-Mix Formula 400: 998 kg [a] (2,200 lb [b]) sand, 326 kg (719 lb) Portland cement, and 232 liters (61 gallons) water per cubic yard	0 to 36.6 m [c] (0 to 120 ft [d])	None	None	None	None
Type II Neat	None	80.8 to 105.2 m (265 to 345 ft)	38.8 m^3 (1,370 ft^3) [e, f] In depth interval: 104.5 to 134.4 m (343 to 441 ft) 70.8 m^3 (2,500 ft^3) In depth interval: 132.6 to 206.1 m (435 to 676 ft)	None	None

a. kilograms b. pounds c. meters d. feet e. m^3 = cubic meters f. ft^3 = cubic feet

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Appendix B
Well ER-5-5 Fluid Management Data

Appendix B-1
Fluid Management Data for Well ER-5-5

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-5-5
(Page 1 of 2)

Sample ID Number	**Depth**		**Tritium Results**			**Sample Description**
	Meters	Feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	
ER 5 5 073012-01	N/A	N/A	395	1,272.60	–	Baker Tank
ER 5 5 073112-02	39.3	129	1,737	1,620.45	532	Discharge Line
ER 5 5 073112-03	42.7	140	3,772	1,422.32	792	Discharge Line
ER 5 5 073112-04	44.2	145	832	2,334.64	–	Discharge Line
ER 5 5 073112-05	N/A	N/A	12,675	2,039.08	0	Baker Tank
ER 5 5 073112-06	52.7	173	4,909	1,469.11	806	Discharge Line
ER 5 5 073112-07	57.9	190	2,397	1,300.95	–	Discharge Line
ER 5 5 073112-08	61.9	203	975	1,406.43	–	Discharge Line
ER 5 5 073112-09	66.8	219	11,029	2,039.08	324	Discharge Line
ER 5 5 073112-10	70.1	230	1,085	1,288.05	–	Discharge Line
ER 5 5 073112-11	85.3	280	755	1,496.11	–	Discharge Line
ER 5 5 073112-12	100.0	328	0	1,369.42	–	Discharge Line
ER 5 5 073112-13	109.4	359	605	1,321.95	–	Discharge Line
ER 5 5 073112-14	120.1	394	504	1,321.95	–	Discharge Line
ER 5 5 073112-15	127.7	419	716	1,272.60	–	Discharge Line
ER 5 5 073112-16	136.9	449	427	1,369.42	–	Discharge Line
ER 5 5 073112-17	141.7	465	814	1,357.67	–	Discharge Line
ER 5 5 073112-18	150.6	494	0	1,445.50	–	Discharge Line
ER 5 5 073112-19	159.1	522	434	1,674.46	–	Discharge Line
ER 5 5 080112-20	164.6	540	0	1,445.50	–	Discharge Line
ER 5 5 080112-21	176.2	578	378	1,445.50	–	Discharge Line
ER 5 5 080112-22	N/A	N/A	0	1,300.95	–	Baker Tank
ER 5 5 080112-23	184.4	605	1,088	1,300.95	–	Discharge Line
ER 5 5 080112-24	196.6	645	1,026	1,300.95	–	Discharge Line
ER 5 5 080112-25	206.0	676	1,503	1,108.96	–	Discharge Line
ER 5 5 080112-26	215.8	708	413	1,179.49	–	Discharge Line
ER 5 5 080112-27	224.0	735	2,468	1,288.05	–	Discharge Line
ER 5 5 080112-28	230.7	757	573	1,334.31	–	Discharge Line
ER 5 5 080112-29	237.7	780	2,234	1,343.30	–	Discharge Line
ER-5-5-080112-30	243.8	800	2,161	1,321.95	–	Discharge Line
ER-5-5-080112-31	249.9	820	719	1,272.60	–	Discharge Line
ER-5-5-080112-32	N/A	N/A	558	1,395.39	–	Baker Tank
ER-5-5-080612-33	N/A	N/A	13,772	1,406.43 [a]	621	Baker Tank
ER-5-5-080712-34	N/A	N/A	0	1,334.31	–	Baker Tank
ER-5-5-080712-35	256.0	840	2,282	1,395.59	–	Discharge Line

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-5-5
(Page 2 of 2)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results			Sample Description
	Meters	Feet	Tritium Results (pCi/L)	MDA (pCi/L)	Re-Analysis #1 (pCi/L)	
ER-5-5-080712-36	262.1	860	692	1,321.95	–	Discharge Line
ER-5-5-080912-37	N/A	N/A	102	1,453.48	–	Baker Tank
ER-5-5-081012-38	N/A	N/A	0	1,415.23	–	Baker Tank
ER-5-5-081012-39	268.2	880	0	1,415.23	–	Discharge Line
ER-5-5-081012-40	274.3	900	29	1,453.48	–	Discharge Line
ER-5-5-081012-41	277.4	910	477	1,255.85	–	Discharge Line
ER-5-5-081012-42	280.4	920	0	1,498.98	–	Discharge Line
ER-5-5-081012-43	283.5	930	1,168	1,357.67	–	Discharge Line
ER-5-5-081012-44	286.5	940	1,128	1,357.67	–	Discharge Line
ER-5-5-081012-45	292.6	960	675	1,160.10	–	Discharge Line
ER-5-5-081012-46	295.7	970	609	1,406.43	–	Discharge Line
ER-5-5-081012-47	298.7	980	313	1,406.43	–	Discharge Line
ER-5-5-081012-48	301.8	990	1,083	1,160.10	–	Discharge Line
ER-5-5-081012-49	304.8	1,000	901	1,321.95	–	Discharge Line
ER-5-5-081012-50	307.8	1,010	66	1,321.95	–	Discharge Line
ER-5-5-081012-51	310.9	1,020	148	1,141.68	–	Discharge Line
ER-5-5-081012-52	313.9	1,030	0	1,421.11	–	Discharge Line
ER-5-5-081012-53	317.0	1,040	49	1,344.47	–	Discharge Line
ER-5-5-081012-54	320.0	1,050	0	1,344.47	–	Discharge Line
ER-5-5-081012-55	329.2	1,080	297	1,453.48	–	Discharge Line
ER-5-5-081012-56	331.3	1,087	1,210	1,288.05 [a]	631	Discharge Line

Data from N-I, 2012d

Notes:

NSTec = National Security Technologies, LLC
Baker tank is the holding tank from which water is obtained for mixing the down-hole drilling fluids
N/A = not applicable
MDA = Minimum detectable activity
pCi/L = Picocuries per liter
– = Recount not performed

a. MDA is for the recounted tritium result

Table B-1-2
Analytical Results for Fluid Management Plan Confirmatory Samples from Sump #1 (Lined) at Well ER-5-5

Analyte	Analytical Method [a]	Detection Limit	08/11/2012 FMP Samples from Well ER-5-5 Sump #1			
			Sample No. 206-081112-1 Sump #1		Sample No. 206-081112-2 Sump #1 Duplicate	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.01 U	0.01 U	0.01 U	0.01 U
Barium		0.1	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.13	0.12	0.12	0.12
Lead		0.003	0.003 U	0.003 U	0.003 U	0.003 U
Selenium		0.005	0.011 U	0.014 U	0.013 U	0.0095 U
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Mercury	SW-846 7470 [b]	0.0002	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.0002 UJ
Radiological Indicator Parameters (pCi/L)						
		MDC [c]	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [d]	380, 380	40 U	230	-140 U	220
Gross Alpha	EPA 900.0 [d]	4.80, 4.80	3.4 U	3.00	2.7 U	3.00
Gross Beta		7.00, 7.00	55	10.0	54	10.0

Source: N-I, 2012d

a. For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.

b. EPA, 2011

c. MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 206-081112-1 and the second with 206-081112-2.

d. EPA, 1980

EPA = U.S. Environmental Protection Agency

FMP = Fluid Management Plan

MDC = Minimum detectable concentration

mg/L = Milligrams per liter

U = Compound was analyzed for but was not detected ("non-detect")

UJ = Compound was non-detect, but result is biased low

Note: Analyses were performed by ALS Laboratory Group.

Table B-1-3

UGTA FLUID DISPOSITION REPORTING FORM

Site Identification: **Well ER-5-5**
Site Location: **Nevada National Security Site**
Site Coordinates: (UTM NAD 27, Zone 11) **N 4,080,793.13 m, E 595,344.27 m**
Well Classification: **Frenchman Flat Model Evaluation Well**
N-I Project No: **UG12-201**

Report Date: **November 9, 2012**
NNSA/NSO UGTA Activity Lead: **Bill Wilborn**
N-I Project Manager: **Sam Marutzky**
N-I Site Representative: **Jeff Wurtz**
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 [c] (m^3)	Other [d] (m^3)	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids [b]	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	07/31/2012	08/10/2012	6.25	283.42	678	53	682	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	08/10/2012	08/10/2012	0.25	331.48	62	5	150	N/A	N/A	N/A	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			6.50	331.48	740	58	832	N/A	N/A	N/A	N/A	N/A

[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] Discharge to an NDEP-approved infiltration area as defined in the Final Well-Specific Fluid Management Strategy for UGTA Well ER-5-5

[d] Other refers to fluid conveyance to other fluid management devices or facilities: e.g., baker tank or transported to another well site for storage.

N/A = Not applicable; m = Meter; m^3 = Cubic meter

Total Facility Capacities (at 8 ft fluid level): Sump # 1 (lined) = 1,547 m^3 Sump #2 (unlined) = 1,547 m^3 Infiltration Area (assuming very low/no infiltration) = N/A

Remaining Facility Capacity (Approximate) as of 08/15/2012: Sump #1 (lined) = 751 m^3 Sump #2 (unlined) = 1,547 m^3

Sump #1 FMP samples were below the MDC (380 pCi/L) for tritium.

Notes: Sump #1 did not discharge to the approved infiltration area.

N-I Authorizing Signature/Date: [signature] 11-15-12

Appendix B-2

Final Well Specific Fluid Management Strategy for UGTA Well ER-5-5, Area 5, Nevada National Security Site

(9 pages)

ndep
NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

STATE OF NEVADA

Department of Conservation & Natural Resources
DIVISION OF ENVIRONMENTAL PROTECTION

Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
Colleen Cripps, Ph.D., Administrator

July 27, 2012

Mr. Robert F. Boehlecke
EM Operations Activity Manager
National Nuclear Security Administration
Nevada Site Office
P.O. Box 98518
Las Vegas, Nevada 89193-8518

RE: Submittal of the Final Well-Specific Fluid Management Strategy for UGTA Well ER-5-5, Area 5, Nevada National Security Site
Federal Facility Agreement and Consent Order

Dear Mr. Boehlecke:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities staff (NDEP) has reviewed the "Final Well Specific Fluid Management Strategy for UGTA Well ER-5-5, Area 5, Nevada National Security Site," (strategy), dated July 23, 2012 and received, via email, on July 25, 2012. The strategy describes the monitoring and management of fluids generated during the drilling, well development, testing and sampling of Well ER-5-5. This strategy is in accordance with the Fluid Management Plan for the Underground Test Area Project, Revision 5 and is hereby approved for use.

If you have questions regarding this matter, please contact Chris Andres of my staff at (702) 486-2850, ext. 232.

Sincerely,

Chris Andres for

T. H. Murphy
Chief
Bureau of Federal Facilities

THM/CDA

cc: FFACO Group, PSG, NNSA/NSO, Las Vegas, NV
J. T. Fraher, DTRA/CXTS, Kirkland AFB, NM
N-I Central Files, MS NSF 156, Las Vegas, NV
NSTec Correspondence Control, MS NLV008, Las Vegas, NV
W. R. Wilborn, ERP, NNSA/NSO, Las Vegas, NV

FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY
FOR UGTA WELL ER-5-5, AREA 5, NEVADA NATIONAL SECURITY SITE

July 16, 2012

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO), Underground Test Area Activity (UGTA) is proposing to drill and construct model evaluation Well ER-5-5. This well is part of the Frenchman Flat Model Evaluation Drilling Program as specified by the Corrective Action Decision Document (CADD)/Corrective Action Plan (CAP) for the Frenchman Flat Corrective Action Unit (CAU) 98. (NNSA/NSO 2011). This well specific fluid management strategy letter describes the monitoring and management of fluids generated during the drilling, well development, testing and sampling of the well in accordance with the requirements of the Fluid Management Plan (FMP) for the Underground Test Area Project, Rev. 5., (NNSA/NSO 2009b).

The planned Well ER-5-5 is located in northern Frenchman Flat within Area 5 of the Nevada National Security Site (NNSS), approximately 245.7 meters (806 feet) west of the boundary between the NNSS and the Nevada Test and Training Range (NTTR). The drilling and construction of Well ER-5-5 will acquire geologic, hydrologic and groundwater chemistry data from an area located to the south of areas of historic underground nuclear testing. However, the primary purpose of the well is to collect data to specifically evaluate uncertainty in the flow and transport numeric model and its contamination boundary forecasts; and to detect radionuclides in groundwater from the nearby and upgradient MILK SHAKE underground test, conducted in emplacement hole U-5k as described in the CADD/CAP (NNSA/NSO 2011).

Well ER-5-5 is one of 2 proposed “model evaluation” wells to be drilled and constructed by the NNSA/NSO UGTA project as part of the Frenchman Flat Model Evaluation drilling initiative at this time. A second model evaluation well ER-11-2 is planned and located north of the ER-5-5 location near the Pin Stripe (U-11b) underground test. Figure 1 shows the location of planned Well ER-5-5 relative to proposed and existing wells. Figure 2 provides an orthophoto view of the planned Well ER-5-5 location, showing the general physiographic character of the area and the proposed infiltration area. The planned completed depth of Well ER-5-5 is approximately 320 meters (1,050 ft), below ground surface (bgs) with the predicted water table located at an approximate depth of 284.1 m (932 ft) bgs.

The potential for encountering radionuclide contamination exceeding the SDWA for tritium (20,000 pCi/L) in groundwater resulting from fluid generating activities associated with well drilling, well construction, well pumping, hydraulic testing, monitoring and sampling activities is high. This is based on the results of the probalistic groundwater flow and transport model forecast. Well ER-5-5 is located 195.1 m (640 ft) south- southwest of the MILK SHAKE (U-5k) test in a location believed to be downgradient from the test. The well is located within 5 cavity radii from the working point of the test (Figure 2). The MILK SHAKE (U-5k) test was conducted in Tertiary and Quaternary Alluvial gravel and sand deposits above the water table with a depth of burial of 264.6 m (868 ft) bgs, however the cavity of the test is believed to have potentially intersected the water table located at 284.1 m (932 ft) bgs. The MILK SHAKE (U-5k) test was detonated in 1968 and had an announce yield of < 20 kilotons (DOE/NV 2000)

Based on the present understanding of the groundwater flow and transport model, the radionuclide concentrations to be encountered within the groundwater at Well ER-5-5 are expected to exceed the SDWA limit for tritium (20,000 pCi/L) however it is not certain that tritium concentrations in groundwater will exceed 400,000 pCi/L. This knowledge supports the conductance of Well ER-5-5 well drilling, construction, pumping and monitoring under a FMP Far-field fluid management strategy. In the case that contaminated groundwater in excess of the FMP criteria for Far-field operations (tritium in excess of 400,000 pCi/L) on the NNSS were encountered the site operations would be transitioned to a FMP Near-field strategy for operations on the NNSS.

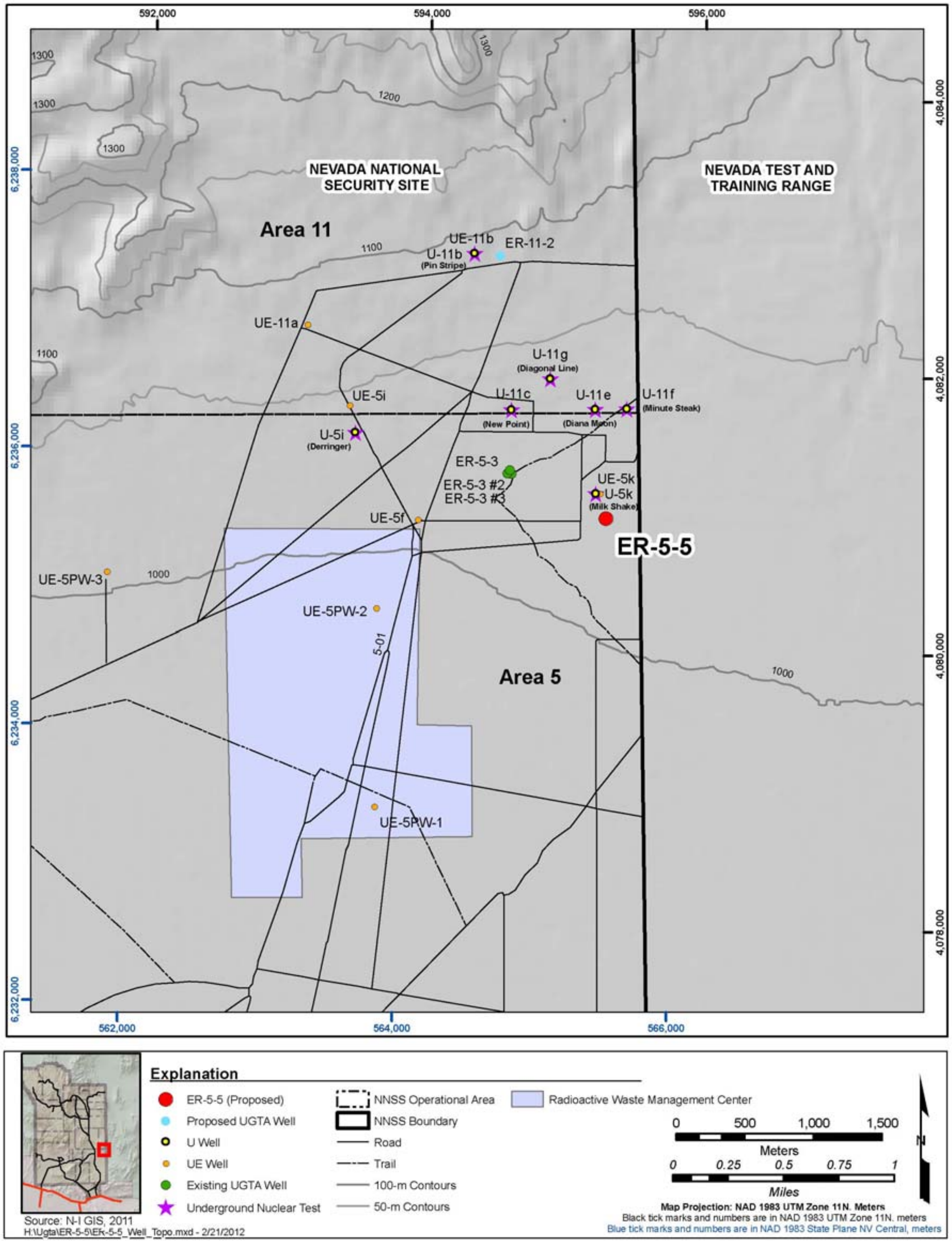

Figure 1
Well ER-5-5 Location Map

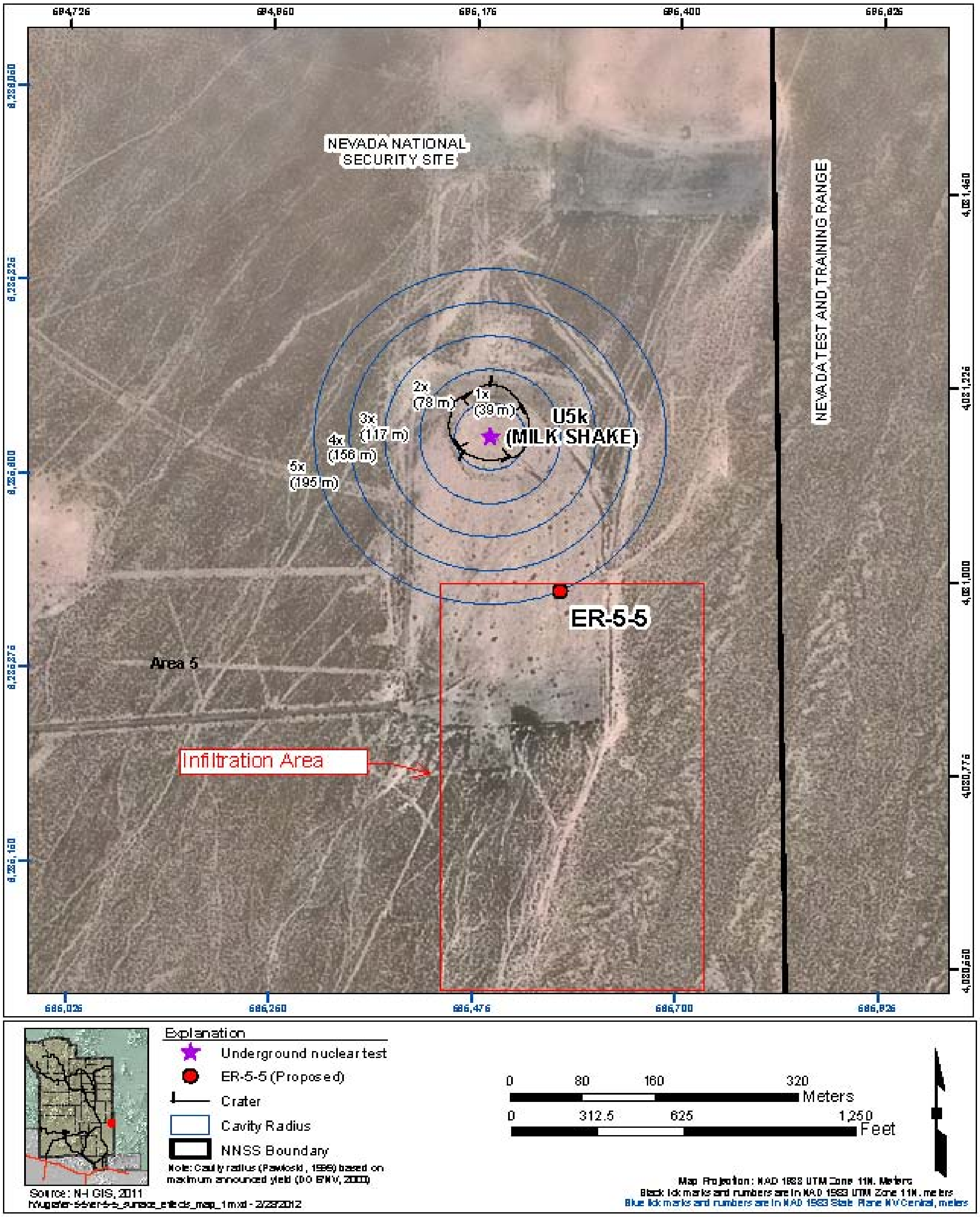

Figure 2
Orthophoto Map of Proposed Well ER-5-5 Showing Proposed Infiltration Area

BACKGROUND AND ANALYTICAL DATA FROM NEARBY WELLS

As shown in Figure 1, several existing wells are in the vicinity of the Well ER-5-5 location. The following provides a summary of these wells and their groundwater chemistry. These wells generally provide background analytical data for groundwater that is contained within alluvial volcanic aquifers near or at the water table. However, these data may not reflect the groundwater chemistry that may be encountered at Well ER-5-5 due to its close proximity to underground testing.

Well ER-5-3: The ER-5-3 well cluster was drilled in 2000 as part of the Frenchman Flat Drilling Program. Well ER-5-3 is one of 3 wells drilled at this site as a well cluster designed for multiple well aquifer testing and the well was drilled to a depth of 794.3 m (2,606 ft) and completed with two completion intervals, one within the alluvium near the water table and a deep completion interval within the saturated welded tuff aquifer. The ER-5-3 well cluster consists of Wells ER-5-3, ER-5-3 #2 and ER-5-3 #3 and is located in northeast Area 5 approximately 800 m (2,625 ft) northwest and upgradient of the Well ER-5-5. Drilling at Well ER-5-3 well cluster was conducted under a Far-field FMP strategy. During drilling, on-site monitoring indicated no tritium in excess of the Minimum Detectable Activity (MDA). Subsequent well development and sampling did not detect tritium or other parameters in excess of the FMP criteria. The results of laboratory analysis of groundwater from ER-5-3 are shown in Exhibit 1.

Wells UE-5PW-1/2: Wells UE-5PW-1 and UE-5PW-2 were drilled in 1992 as part of several monitoring wells established for the Area Radioactive Waste Management Site (RWMS). These wells were drilled to depths 839 ft and 919 ft respectively within Quaternary and Tertiary deposits. Well UE-5PW-1 is located approximately 2.67 km (1.66 mi) from the Well ER-5-5 location and Well UE-PW-2 is located approximately 1.79 km (1.11 mi) from the Well ER-5-5 location. These wells are not sampled for all FMP parameters; however the radionuclides analyzed meet the FMP criteria for ground surface discharge (Exhibit 1).

WELL OPERATIONS STRATEGY

Based on the information presented above, it is proposed that fluid generating activities related to drilling, well construction, pumping and sampling at Well ER-5-5 will be conducted using the Far-field well site operations strategy for wells located on the NNSS as specified in the FMP. This strategy may be transitioned to a Near-field strategy based on results of on-site monitoring as specified in the FMP and detailed below.

Fluid Containment and Discharge Criteria- The NNSA/NSO proposes the following fluid containment and discharge strategy for Well ER-5-5:

- Fluids or groundwater generated from the well during drilling, well construction, well pumping and sampling will be routed from the well through a well head, well head manifold, through a flow line (drilling) or flexible piping (pumping operations) and discharged to an unlined or lined sump constructed on the Well ER-5-5 drill pad based on the FMP discharge criteria for wells located on the NNSS.

- In the event that on-site monitoring results do not exceed the FMP Far-field criteria for tritium (400,000 pCi/L) for wells located on the NNSS, operations will be conducted under a FMP Far-field operational strategy and both the unlined and lined sumps may be utilized to contain generated fluids.

- Fluids that do not exceed the FMP criteria for tritium (400,000 pCi/L) for wells located on the NNSS may also be discharged or conveyed from the existing lined or unlined sump to a designated posted (or fenced) infiltration area as shown in Figure 2. Fluids will be routed and discharged to this infiltration area in a manner that minimizes the degradation or erosion of the natural ground surface.

- In the event that on-site monitoring results exceed the FMP Far-field criteria for tritium (400,000 pCi/L) for wells located on the NNSS, operations are to be conducted under a FMP Near-field operational strategy. Fluids generated will be contained within an on-site lined sump.

- In the unlikely case that on-site fluid containment capacity (lined sump) may be exceeded under a Near-field operational strategy well site operations will be suspended until sufficient suitable fluid storage can be made available.

On-Site Monitoring – In accordance with the FMP, tritium monitoring samples will be collected from the discharge line during fluid generating activities. Tritium monitoring samples will be collected and analyzed hourly at a minimum during drilling operations, except during periods where the borehole is not being advanced (e.g. circulating, well construction etc.). The results of on-site tritium monitoring will be compared to the FMP discharge criteria as results are available. For other fluid or groundwater generating well activities, tritium monitoring samples will be collected from the discharge line and analyzed on a daily basis.

In accordance with the FMP, lead monitoring samples will be collected during drilling from the discharge and analyzed every eight hours if tritium monitoring results exceed 200,000 pCi/L. The results of on-site lead monitoring will be compared to the FMP discharge criteria as results are available.

Notifications – NDEP will be notified of on-site monitoring results that exceed action levels as specified in the FMP.

REFERENCES

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2011. *Corrective Action Decision Document/Corrective Action Planfor Corrective Action Unit 98: Frenchman Flat Nevada National Security Site, Nevada,* DOE/NV--1455. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 2009b. Attachment 1, Fluid Management Plan for the Underground Test Area Project. Rev. 5. DOE/NV-370

U.S. Department of Energy, Nevada Operations Office. 2000b. *United States Nuclear Tests, July 1945 through September 1992,* DOE/NV--209-REV 15. Las Vegas, NV.

Exhibit 1
Analytical Data for Wells ER-5-3, UE-5PW-1 and UE-5PW-2

Analysis Performed	ER-5-3 [a]	UE-5PW-1 [b, c]	UE-5PW-2 [c, d]
	(mg/l)		
Aluminum	*0.2 U*	--	--
Arsenic	*0.035*	--	--
Barium	0.1 UJ	--	--
Cadmium	0.005 UJ	--	--
Calcium	1	16.8	16.4
Chloride	14	9.2 J	9.5 J
Chromium	0.0048	--	--
Fluoride	5.4	1 J	1 J
Iron	0.021 U	0.045 U	0.045 U
Lithium	0.0017	--	--
Lead	0.003 U	--	--
Magnesium	0.089 U	7.02	6.05
Manganese	0.0037	0.002	0.0009 U
Mercury	0.0002 UJ	--	--
Potassium	6	5.68 J	4.54 J
Selenium	0.005 U	--	--
Silicon	26	28.2	27.5
Silver	0.01 U	--	--
Sodium	130	52.7	56.4
Strontium	0.0032 U	--	--
Sulfate	36	28.7J	35.9 J
Total Organic Carbon	1 U	--	--
^{238}U	0.2 U	--	--
Alkalinity (as $CaCo_3$)	210	--	--
Bicarbonate Alkalinity (as $CaCo_3$)	110	125	135
Carbonate Alkalinity (as $CaCo_3$)	100	0.5 U	0.5 U
Specific Conductance□mhos/cm)	590	352	364
pH (SU)	9.6 J	8.27	8.31
Total Dissolved Solids	360	297	285
Radionuclides (pCi/L)			
Gross Alpha	3.1 U	3.87	3.13
Gross Beta	4.6	3.65 U	3.87
^{99}Tc	1.2 U	6.35 U	6.33 U
Tritium	-70 U	21.9 U	21.8 U
^{90}Sr	0.09 U	0.55 U	0.63 U
^{238}Pu	-0.016 U	0.062 U	0.046 U

Source: N-I, 2011a
[a] Composite GWC sample collected by IT on 07/17/2001.
[b] Samples collected on 04/19/2005, 10/11/2005, and 09/10/2008.
[c] Specific conductance reported in S/cm.
[d] Samples collected on 04/19/2005, 10/11/2005, and 09/10/2008.
J = Estimated value.
U = Compound was analyzed for, but was not detected (“Non-detect”).
UJ = Compound was Non-detect, but result is biased low.
SU = Standard unit
mhos/cm = Micromhos per centimeter
S/cm = Microsiemens per centimeter
$CaCO_3$ = Calcium carbonate

Appendix C
Waste Disposition Data for Well ER-5-5

Table C-1
Final Waste Disposition for Well ER-5-5 Drilling Operations

Container ID Number	Contents	Container Type and Size Liters (Gallons)	Estimated Volume Liters (Gallons)	Disposition	Status/Comments
ER-5-5-01	Hydrocarbon solids; absorbent pads, debris	Open-top steel drum; 208 (55)	201 (53)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-02	Used oil	Closed-top steel drum; 208 (55)	6 (1.5)	Moved to the Well ER-11-2 drill site on 08/15/2012	New container ID is ER-11-2-04
ER-5-5-03	Hydrocarbon solids; absorbent pads, soil, debris, and used oil/fuel filters	Open-top steel drum; 208 (55)	189 (50)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-04	Used oil	Closed-top steel drum; 208 (55)	8 (2)	Moved to the Well ER-11-2 drill site on 08/15/2012	New container ID is ER-11-2-02
ER-5-5-05	Used oil (synthetic)	Open-top steel drum; 208 (55)	23 (6)	Moved to the Well ER-11-2 drill site on 08/15/2012	New container ID is ER-11-2-05
ER-5-5-06	Hydrocarbon solids; absorbent pads and soil	Open-top steel drum; 208 (55)	197 (52)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-07	Hydrocarbon solids; absorbent pads, rags, soil, and sandbags	Open-top steel drum; 208 (55)	189 (50)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-08	Hydrocarbon solids; absorbent pads, rags, hydrocarbon-stained soil, and sandbags	Open-top steel drum; 208 (55)	189 (50)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-09	Hydrocarbon solids; hydrocarbon-stained soil, and sandbags	Open-top steel drum; 208 (55)	189 (50)	Transferred to UGTA Building 6-909 on 08/15/2012	Temporary storage pending disposal
ER-5-5-10	Oily condensate from compressors	Condensate tank 7,571 (2,000)	2,233 (590)	Moved to the Well ER-11-2 drill site on 08/15/2012 with contents	New container ID is ER-11-2-06
Total Waste Containers					
Hydrocarbon solids: 6 Used oils (liquid): 3					
Total number of 208-liter (55-gallon) waste containers: 9 Total number of 7,571-liter (2,000-gallon) waste containers: 1					

Data from N-I, 2012d

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Appendix D
Detailed Lithologic Log for Well ER-5-5

Table D-1
Detailed Lithologic Log for Well ER-5-5

Logged by Jose Gonzales
National Security Technologies, LLC
August 2012

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type**[a]	**Lithologic Description**[b]	**Stratigraphic Unit**
0–176.8 (0–580)	176.8 (580)	No samples 0 to 36.6 m (120 ft) DB1	**Alluvium:** Gravelly sand and sandy gravel; calcareous. Cuttings are mostly coarse to very coarse sand with scattered pebble size clasts up to 8 millimeters (mm) in diameter. Larger clasts are sub-angular to sub-rounded, moderate yellowish brown (10YR5/4), moderate reddish orange (10R 6/6), and olive gray (5Y 4/1) vitric tuffs. Sand size cuttings are mostly euhedral quartz and feldspar crystals. Approximately 1 percent small clasts of limestone, quartzite, and black basalt are also present.	Quaternary and Tertiary alluvium
176.8–290.8 (580–954)	114.0 (374)	DB1	**Alluvium:** Gravelly sand and sandy gravel; calcareous; pale yellowish brown (10YR6/2) to moderate yellowish brown (10YR 5/4). Cuttings are mostly very coarse sand size, with zeolitic tuff clasts up to 2 to 5 mm in diameter. Larger clasts are sub-angular to sub-rounded, predominantly tuff but carbonate rock, quartzite, and black basalt clasts are also present (approximately 5 percent). The cuttings in the interval from 256.0 to 274.3 meters (m) (840 to 900 feet [ft]) are very large (2 to 20 mm) mostly rounded, zeolitic, tuffaceous clasts. The tuff fragments are light olive gray (5Y 6/1), grayish olive (10Y 4/2), and dusky yellow (5Y 6/4). The limestone, dolomite, and quartzite clasts vary from approximately 20 to 40 percent within this interval. About 1 percent basalt clasts are present. Below 274.3 m (900 ft) cuttings become smaller and the volume of the cutting samples decreases (presumably fewer cuttings were produced within this interval).	

Table D-1
Detailed Lithologic Log for Well ER-5-5, continued

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type**[a]	**Lithologic Description**[b]	**Stratigraphic Unit**
290.8–297.5 (954–976)	6.7 (22)	DB1	**Basalt Rubble:** Grayish black (N2), well indurated, finely crystalline groundmass with conspicuous small (1 to 2 mm) vesicles filled with white mineral. Few of the basalt clasts also contain moderate reddish brown (10R 4/6) crystals. Cuttings consist mostly of tuff, limestone, dolomite, and quartzite clasts 2 to 20 mm in size. The basalt clasts make up only about 5 to 10 percent of the cuttings in this interval. Some of the basalt clasts are sub-angular to sub-rounded, but many have flat freshly broken looking edges. A detailed analysis and correlation of the geophysical logs from this and other Frenchman Flat wells that penetrate basalt (such as Well ER-5-3), suggests that Well ER-5-5 encountered basalt within this depth interval. The upper and lower contacts were mainly determined from the thorium curve (from the Digital Spectralog). This basalt, encountered at similar depths in other holes in Frenchman Flat, seems to have a characteristically low thorium content relative to over- and underlying alluvium. An increase in the density log also occurs within this interval.	Basalt of Frenchman Flat
297.5–331.3 (976–1,087) TD	33.8 (111)	DA, DB1	**Alluvium:** Sandy gravel to gravelly sand; calcareous, grayish orange pink (5YR 7/2), light olive gray (5Y 5/2), and light brown (5YR 6/4) sub-rounded to rounded and sub-angular zeolitic tuff clasts make up 85 to 90 percent of the sample. Quartzite, limestone, dolomite, and basalt make up about 10 to 15 percent of the cutting samples. The basalt clasts represent only about 1 to 2 percent of the non-tuff clasts. The larger clasts within this interval are 2 to 15 mm in diameter.	Pliocene through Miocene alluvium

a. **DA**: Drill cuttings that represent lithologic character of interval; **DB1**: Drill cuttings enriched in hard components

b. 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.

Appendix E
Geophysical Logs Run in Well ER-5-5

Appendix E contains plots of selected geophysical logs run in Well ER-5-5. Table E-1 summarizes the logs presented. See Table 4-1 for more information.

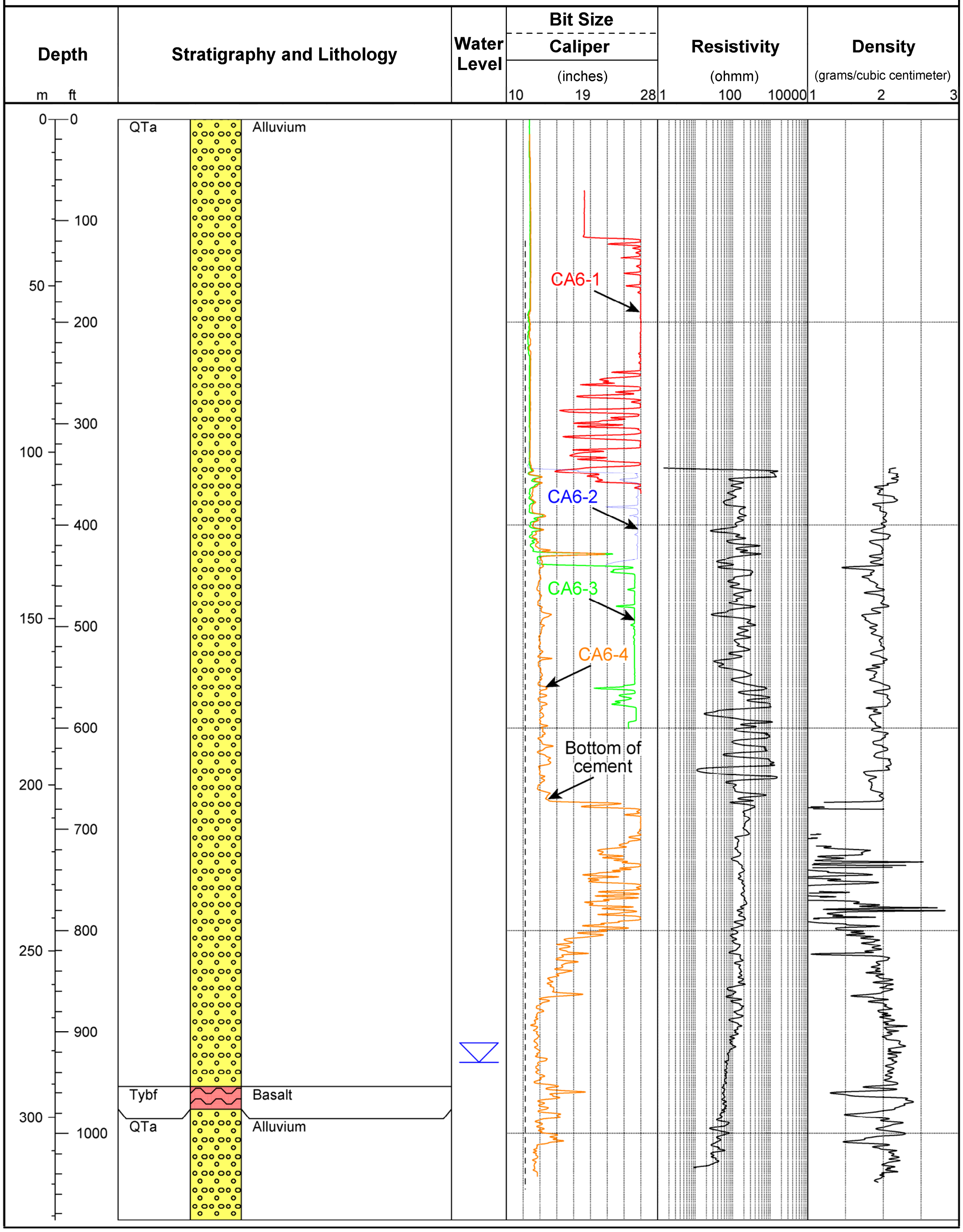
Table E-1
Well ER-5-5 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval	
			meters	feet
Caliper	CA6-1	8/2/2012	18.9–112.2	62–368
	CA6-2	8/5/2012	104.6–133.5	343–438
	CA6-3	8/8/2012	0–180.8	0–593
	CA6-4	8/11/2012	104.6–316.1	343–1,037
Temperature	TL-1	8/11/2012	6.1–318.5	20–1,045
Gamma Ray	GR-6	8/11/2012	5.5–309.7	18–1,016
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1	8/11/2012	5.5–309.7	18–1,016
High Definition Induction (resistivity)	HDIL-1	8/11/2012	104.6–314.6	343–1,032
Density	ZDL-1	8/11/2012	104.6–317.3	343–1,041
Compensated Neutron	CN-1	8/11/2012	104.6–317.3	343–1,041

Well ER-5-5

Logging Company: Baker Atlas
Date Logged: August 2, 5, 8, and 11, 2012
Drilled Depth: 331.3 m (1,087 ft)
Date TD Reached: August 10, 2012
Drill Method: Rotary/Air foam

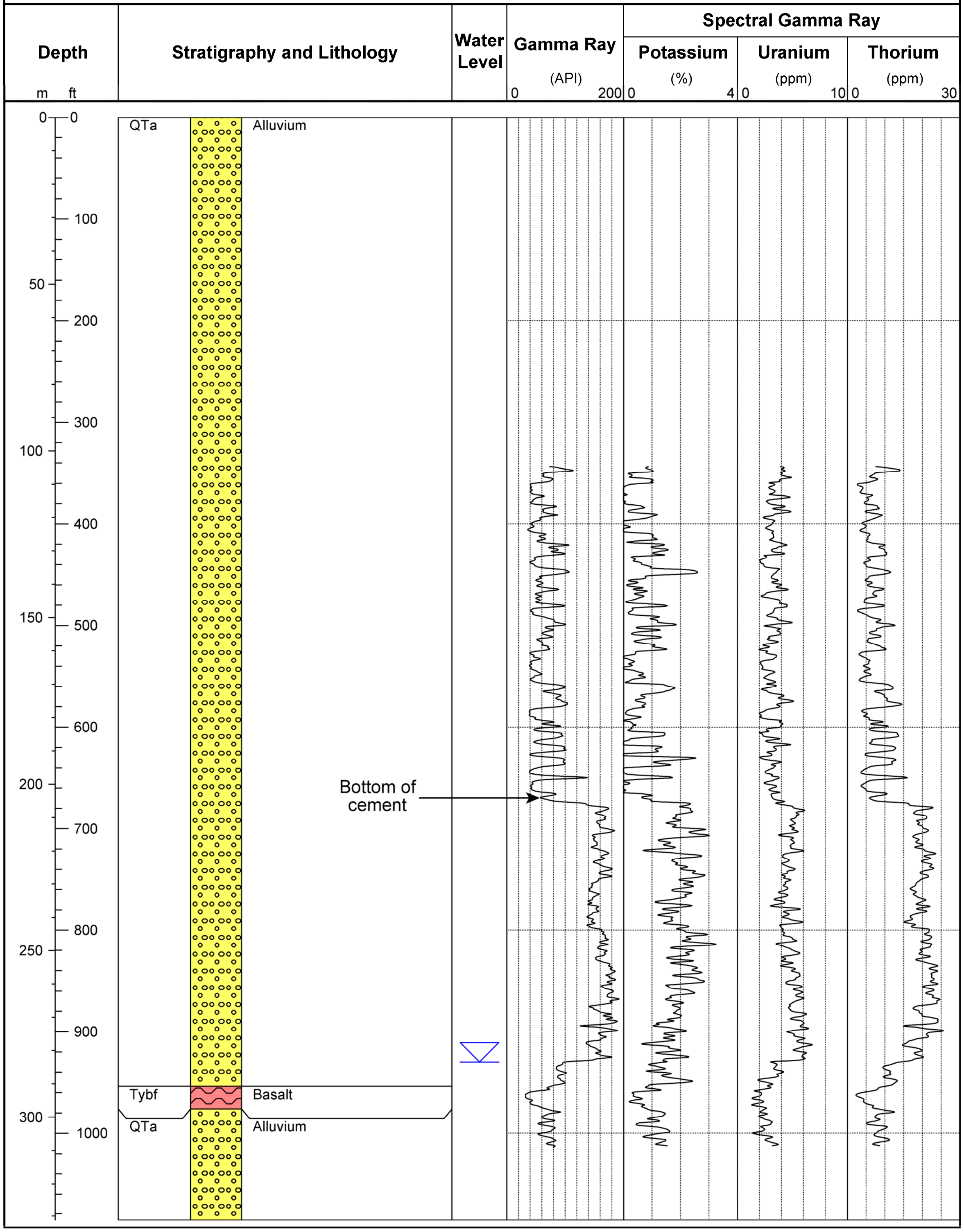
Surface Elevation: 1,017.1 m (3,336.9 ft)
Coordinates (UTM [NAD 83]): N 4,080,990.1 m
E 595,265.1 m
Water Level: 283.4 m (929.9 ft) on September 25, 2012



Well ER-5-5

Logging Company: Baker Atlas
Date Logged: August 11, 2012
Drilled Depth: 331.3 m (1,087 ft)
Date TD Reached: August 10, 2012
Drill Method: Rotary/Air foam

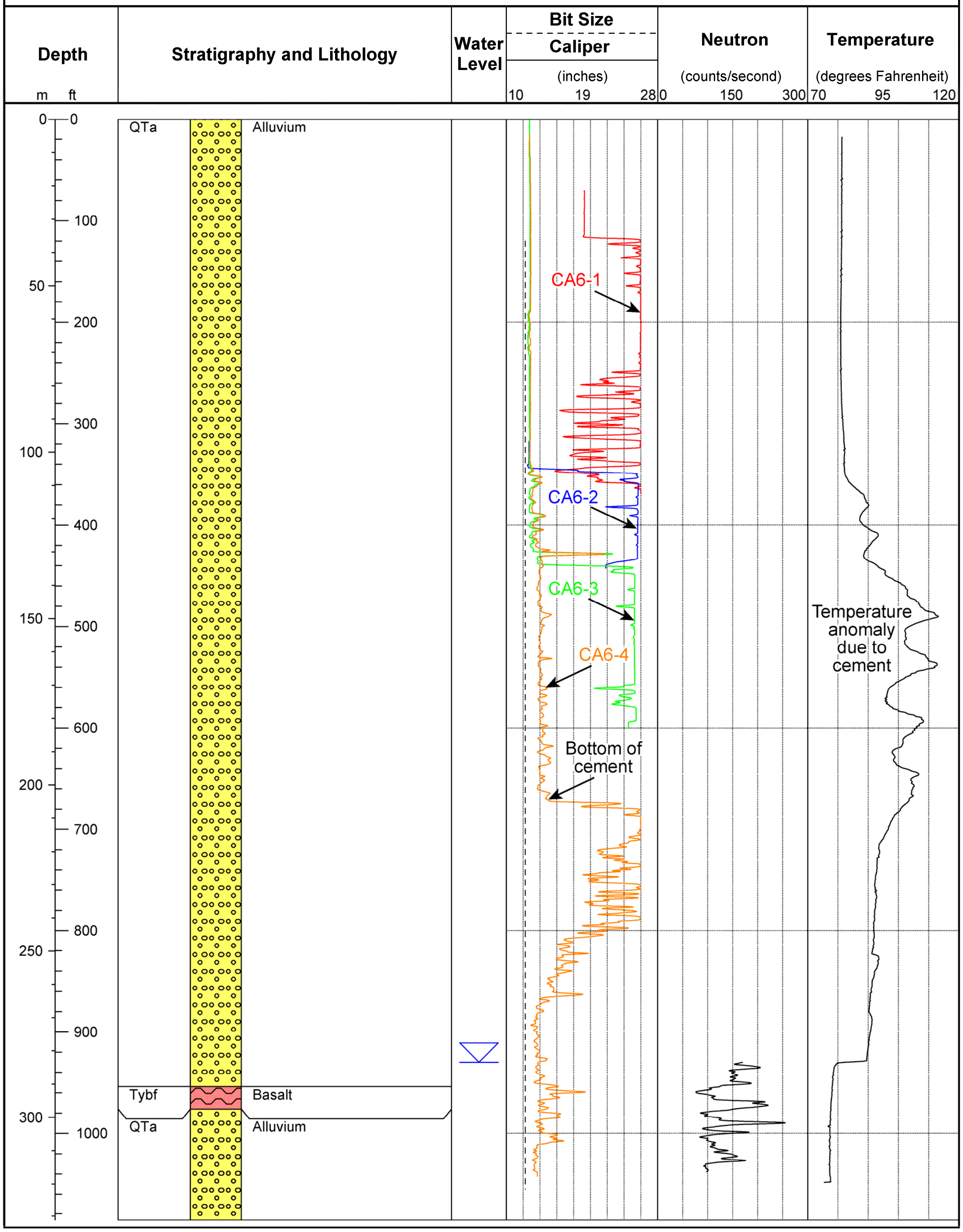
Surface Elevation: 1,017.1 m (3,336.9 ft)
Coordinates (UTM [NAD 83]): N 4,080,990.1 m
E 595,265.1 m
Water Level: 283.4 m (929.9 ft) on September 25, 2012



Well ER-5-5

Logging Company: Baker Atlas
Date Logged: August 2, 5, 8, and 11, 2012
Drilled Depth: 331.3 m (1,087 ft)
Date TD Reached: August 10, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,017.1 m (3,336.9 ft)
Coordinates (UTM [NAD 83]): N 4,080,990.1 m
E 595,265.1 m
Water Level: 283.4 m (929.9 ft) on September 25, 2012



Appendix F
Water Production Data for Well ER-5-5

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling of Well ER-5-5

Date	Time	Depth below Ground Surface		Bromide Concentration (milligrams/liter)		Injection Rate (barrels per hour)	Water Production[a] (gallons per minute)
		meters	feet	Mixing Tank	Discharge Line		
07/31/2012	13:00	39.0	128	14.7	17.2	12	-1
07/31/2012	07:24	43.3	142	11.1	12.0	12	-1
07/31/2012	09:23	54.6	179	11.2	12.8	12	-1
07/31/2012	13:54	71.6	235	10.3	10.4	12	0
07/31/2012	17:05	110.6	363	20.9	20.6	12	0
07/31/2012	20:05	136.9	449	23.9	17.5	12	3
08/01/2012	05:43	161.8	531	25.7	24.4	18	1
08/01/2012	09:25	200.3	657	25.5	25.2	18	0
08/01/2012	12:16	225.2	739	23.2	23.9	18	0
08/01/2012	15:40	249.9	820	26.3	18.3	18	6
08/07/2012	19:30	258.8	849	30.4	29.8	35	0
08/10/2012	13:15	264.6	868	29.0	40.5	20	-4
08/10/2012	14:15	270.7	888	27.7	32.6	20	-2
08/10/2012	15:15	276.1	906	37.6	43.1	20	-2
08/10/2012	16:25	285.3	936	39.7	33.7	20	2
08/10/2012	17:30	297.5	976	34.5	18.1	20	13
08/10/2012	18:30	310.9	1,020	32.2	4.35	20	90
08/10/2012	19:30	321.6	1,055	26.7	3.74	20	86
08/10/2012	20:30	331.6	1,088	28.2	3.76	20	91

Data from N-I, 2012d

a. Calculated water production values above the water table are not indicative of water yield from the formation.

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