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Completion Report for Well ER-4-1 Corrective Action Unit 97: Yucca Flat/Climax Mine

Revision No.: 0

July 2017

U.S. Department of Energy
Environmental Management Nevada Program

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COMPLETION REPORT FOR WELL ER-4-1
CORRECTIVE ACTION UNIT 97:
YUCCA FLAT/CLIMAX MINE

U.S. Department of Energy,
Environmental Management Nevada Program
Las Vegas, Nevada

Revision No.: 0

July 2017

Abstract

Well ER-4-1 was drilled for the U.S. Department of Energy, Nevada National Security Administration Nevada Field Office in support of the Underground Test Area (UGTA) Activity. The well was drilled and completed from March 23 to April 13, 2016, as part of the Corrective Action Investigation Plan (CAIP) for Yucca Flat/Climax Mine Corrective Action Unit (CAU) 97. The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO), Appendix VI, Section 3 (UGTA), 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 (DoD). The primary purpose of the well was to collect hydrogeologic data to assist in validating concepts of the groundwater flow system within the Yucca Flat/Climax Mine CAU, and to test for potential radionuclides in groundwater from the STRAIT (U4a) underground test.

The completed well includes one piezometer (p1), to a depth of 663.16 meters (m) (2,175.71 feet [ft]) below ground surface (bgs) and open from the Alluvial aquifer (AA3) to the Oak Spring Butte confining unit (OSBCU) hydrostratigraphic units; and a main completion (m1), which includes 6.625-inch (in.) casing with slotted interval (m1) installed to 906.80 m (2,975.05 ft) bgs in the Lower carbonate aquifer (LCA). A 13.375-in. diameter surface casing was installed from the surface to a depth of 809.00 m (2,654.21 ft) bgs. Well ER-4-1 experienced a number of technical issues during drilling, including borehole instability and sloughing conditions. An intermediate, 10.75-in./9.625-in. casing string was installed to 856.94 m (2,811.48 ft) bgs to control these issues. Borehole stability and erosion problems appear to be associated with the Tunnel Formation (Tn) and the Older tunnel beds (Ton). Overall efforts to stabilize the borehole were successful.

Data collected during borehole construction include composite drill cutting samples collected every 3.0 m (10 ft), a partial suite of geophysical logs to a maximum depth of 766.57 m (2,515 ft) bgs, water-quality measurements (including tritium), water-level measurements, and two depth-discrete bailer samples collected at 538.89 m and 646.18 m (1,768 ft and 2,120 ft) bgs respectively. The well penetrated 187.45 m (615 ft) of Quaternary/Tertiary alluvium (QTa), 671.47 m (2,203 ft) of Tertiary Volcanic rocks (Tv), and 66.20 m (217.19 ft) of Paleozoic rocks (Pz). The stratigraphy and lithology were generally as expected with some exceptions. The top of Paleozoic rocks (Pz) was predicted to occur at 822.35 m (2,698 ft) bgs and was intercepted at 858.93 m (2,818 ft), a difference of 36.58 m

(120 ft). As expected, the Paleozoic rocks (Pz) are the principal water producing formation in Well ER-4-1.

Depth to water was measured after drilling as follows:

- *In the piezometers:* p1 at 320.39 m (1,051.16 ft) bgs, (measured January 4, 2017)
- *In the main production casing interval:* m1 at 539.17 m (1,768.92 ft) bgs, (measured December 12, 2016)

Geophysical logs and depth-discrete bailer sample analytical results suggest likely zones of prompt injection (underground-test-related) fission products from 472.44 to 481.48 m (1,550 to 1,580 ft) bgs and at approximately 539.50 m (1,770 ft) bgs. Subsequent work at Well ER-4-1 will be included in future reports. Field measurements for tritium were mostly below the *Safe Drinking Water Act* limit (20,000 picocuries per liter) with the exception of two zones showing elevated tritium concentrations. The first zone is located at approximately 365.76 to 390.14 m (1,200 to 1,280 ft) bgs and a second zone at approximately 542.54 to 566.93 m (1,780 to 1,860 ft) bgs. All Fluid Management Plan requirements were met.

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General Acronyms and Abbreviations

ACWP	Actual cost of work performed
amsl	Above mean sea level
API	American Petroleum Institute
ASTM	ASTM International
bbl	Barrel
bbl/hr	Barrels per hour
BCWS	Budgeted cost of work scheduled
bgs	Below ground surface
BHA	Bottom hole assembly
CAIP	Corrective action investigation plan
CAU	Corrective action unit
cm	Centimeter
COLOG	Colog, Inc.
cps	Counts per second
CS	Carbon steel
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
EC	Electrical conductivity
EERF	Eastern Environmental Radiation Facility
EPA	U.S. Environmental Protection Agency
e-tape	Electric tape
°F	Degree Fahrenheit
FAWP	Field activity work package
FFACO	*Federal Facility Agreement and Consent Order*

List of Acronyms and Abbreviations *(Continued)*

FMP	Fluid management plan
ft	Foot
ft^3	Cubic foot
ft^3/ft^3	Cubic feet per cubic foot
ft^3/min	Cubic feet per minute
gal	Gallon
g/cm^3	Grams per cubic centimeter
gpm	Gallons per minute
GR	Gamma ray
HASL	Health and Safety Laboratory
HFM	Hydrostratigraphic framework model
HGU	Hydrogeologic unit
HST	Hydrologic source term
HSU	Hydrostratigraphic unit
id	Inside diameter
ID	Identification
in.	Inch
km	Kilometer
LANL	Los Alamos National Laboratory
Lat	Latitude
lb	Pound
LLNL	Lawrence Livermore National Laboratory
LLW	Low-level waste
Long	Longitude
LSC	Liquid scintillation counter
m	Meter
m^3	Cubic meter

List of Acronyms and Abbreviations *(Continued)*

Ma	Million years ago
MDA	Minimum detectable activity
MDC	Minimum detectable concentration
mg/L	Milligrams per liter
mi	Mile
min/ft	Minutes per foot
mL	Milliliter
mm	Millimeter
M&O	Management and operating
NA	Not available
N/A	Not applicable
NAD 27	North American Datum, 1927
NAD 83	North American Datum, 1983
NAIL	Nuclear annular investigation log
NDEP	Nevada Division of Environmental Protection
NGVD29	National Geodetic Vertical Datum 1929
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NSPC	Nevada State Plane Coordinate
NSTec	National Security Technologies, LLC
NWAS	Northwestern Air Services
od	Outside diameter
ohm/m	Ohms per meter
pCi/L	Picocuries per liter
ppm	Parts per million
psi	Pounds per square inch
QAP	Quality Assurance Plan

List of Acronyms and Abbreviations *(Continued)*

RadCon	Radiological Control
R_c	Cavity radius
RCT	Radiological control technician
RN	Radionuclide
rpm	Rotations per minute
SDWA	*Safe Drinking Water Act*
SGR	Spectral gamma ray
SS	Stainless steel
SU	Standard unit
SW	Solid waste
SWL	Static water level
TD	Total depth
TIH	Trip into hole
TOH	Trip out of hole
TWT	Technical Working Team
UDI	United Drilling, LLC
UGT	Underground test
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WP	Working point
µmhos/cm	Micromhos per centimeter
µS/cm	Microsiemens per centimeter

List of Acronyms and Abbreviations *(Continued)*

Stratigraphic, Geologic, Hydrostratigraphic, and Hydrogeologic Unit Abbreviations and Symbols

AA	Alluvial aquifer
AA3	Alluvial aquifer
ATCU	Argillic tuff confining unit
CA	Carbonate aquifer
Kg	Granitic rocks
LCA	Lower carbonate aquifer
LTCU	Lower tuff confining unit
MDe	Eleana Formation
OSBCU	Oak Spring Butte confining unit
Op	Pogonip Group
Qai	Intermediate alluvial deposits
Qay	Young alluvial deposits
Qeo	Old eolian sand deposits
QTa	Quaternary/Tertiary alluvium
QTc	Quaternary/Tertiary colluvium
Tbg	Grouse Canyon Tuff
Tbgb	Grouse Canyon bedded tuff
Tc	Crater Flat Group
Tcb	Bullfrog Tuff
TCU	Tuff confining unit
Tem	Monotony Tuff
Tes	Shingle Pass Tuff
Tlc/To	Paleocolluvium/older tuffs
Tm	Timber Mountain Group
Tma	Ammonia Tanks Tuff

List of Acronyms and Abbreviations *(Continued)*

Tmab	Ammonia Tanks bedded tuff
TMCC	Timber Mountain caldera complex
TMLVTA	Timber Mountain lower vitric-tuff aquifer
Tmr	Rainier Mesa Tuff
Tmr/Tmrh	Rainier Mesa Tuff/tuff of Holmes Road
Tmrh	Tuff of Holmes Road
Tmrp	Rainier Mesa mafic-poor Tuff
Tmrr	Rainier Mesa mafic-rich Tuff
Tm/Tw	Pre-Timber Mountain Tuff - Post-Wahmonie Tuff
TMUVTA	Timber Mountain upper vitric-tuff aquifer
TMWTA	Timber Mountain welded-tuff aquifer
Tn	Tunnel Formation
Tn3	Tunnel Formation, Tunnel 3 Member
Tn3A	Tunnel 3 Member, bed 3A
Tn4	Tunnel Formation, Tunnel 4 Member
Ton	Older tunnel beds
Ton1	Tunnel bed 1
Ton2	Tunnel bed 2
Tot	Tuff of Twin Peaks
Toy	Tuff of Yucca Flat
To3	Older tunnel bed 3
Tp	Paintbrush Group, undivided
Ttb	Basalt of Black Mountain
Tub	Tub Spring Tuff
Tv	Tertiary Volcanics
Tw	Wahmonie Formation
VA	Volcanic aquifer

List of Acronyms and Abbreviations *(Continued)*

VTA	Vitric-tuff aquifer
WTA	Welded-tuff aquifer
Zj	Johnnie Formation
Zs	Stirling Quartzite
Ꞓbb	Banded Mountain Member
Ꞓbp	Papoose Lake Member
Ꞓc	Carrara Formation
Ꞓn	Nopah Formation
ꞒZ	Zabriskie Quartzite
ꞒZw	Wood Canyon Formation
PIPt	Tippipah Limestone
Pz	Paleozoic rocks

List of Acronyms and Abbreviations *(Continued)*

Symbols for Elements and Compounds

Ac	Actinium
Al	Aluminum
Am	Americium
Be	Beryllium
Bi	Bismuth
C	Carbon
$CaCO_3$	Calcium carbonate
Co	Cobalt
Cs	Cesium
Eu	Europium
HCl	Hydrochloric acid
K	Potassium
LiBr	Lithium bromide
Mn	Manganese
Nb	Niobium
Pb	Lead
Pu	Plutonium
Sb	Antimony
SiO_2	Silica
Th	Thorium
Tl	Thallium
U	Uranium

1.0 Introduction

1.1 Project Description

This report presents field data collected by Navarro between March 23 and April 13, 2016, during drilling and completion of Well ER-4-1 located on the Nevada National Security Site (NNSS), Nye County, Nevada. Well ER-4-1 was identified in the *Yucca Flat Drilling and Completion Criteria, Wells ER-2-2, ER-3-3, and ER-4-1* (Navarro, 2016d). The Yucca Flat hydrogeologic investigation drilling program is part of the *Corrective Action Investigation Plan* (CAIP) *for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada* (DOE/NV, 2000). The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended), Appendix VI, Section 3 (Underground Test Area [UGTA]), 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 (DoD). The hydrogeologic model evaluation drilling program included three new wells (ER-2-2, ER-3-3, and ER-4-1) in Yucca Flat. Figure 1-1 shows the location of the new wells.

Well ER-4-1 drilling operations conformed to NDEP policies and regulations, and to the guidelines and requirements of the CAIP for Yucca Flat/Climax Mine Corrective Action Unit (CAU) 97 (DOE/NV, 2000); *Field Instruction for the Underground Test Area Activity Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015); field activity work packages (FAWPs) for participating contractors; *Underground Test Area Quality Assurance Plan* (QAP), *Nevada National Security Site, Nevada* (NNSA/NFO, 2015a); *Underground Test Area (UGTA) Activity Health and Safety Plan* (NSTec, 2015); *Underground Test Area Project Waste Management Plan*, with *Attachment 1 Fluid Management Plan for the Underground Test Area Project* (NNSA/NSO, 2009); and the FFACO (1996, as amended).

Funding for the project was provided by the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO), Environmental Management Operations Activity. Environmental and hydrogeologic technical and field support services were provided by Navarro. Engineering, inspection, geotechnical, and field support were provided by National Security Technologies, LLC (NSTec) (the NNSS management and operating [M&O] contractor). Drilling and

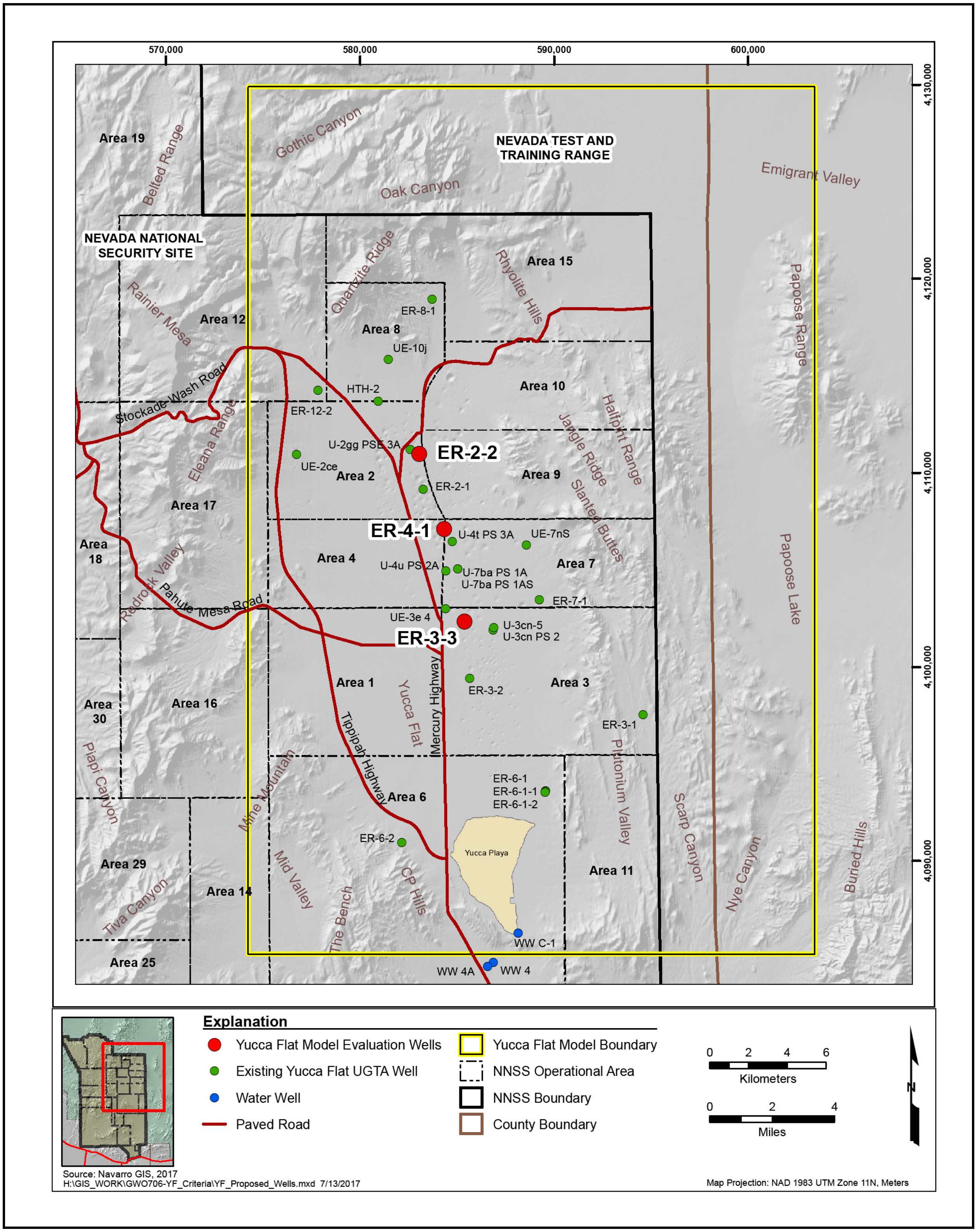


Figure 1-1
Location of Well ER-4-1 and Select Wells

casing operation services were provided by United Drilling, LLC (UDI); Northwestern Air Services (NWAS); and B&L Casing. Geophysical logging was conducted by Schlumberger and Colog, Inc. (COLOG). Navarro and NSTec were the prime contractors to NNSA/NFO. Schlumberger, UDI, NWAS, and B&L Casing performed work as service subcontractors to NSTec.

Well ER-4-1 is completed with one main completion interval (m1) and one piezometer (p1). The completions are as follows:

- **m1,** completed to 906.80 meters (m) (2,975.05 feet [ft]) below ground surface (bgs), installed in the Lower carbonate aquifer (LCA) inside the 12.25-inch (in.) borehole
- **p1,** completed in the Lower tuff confining unit (LTCU) and Oak Spring Butte confining unit (OSBCU) to 663.16 m (2,175.71 ft) bgs inside the 18.5-in. borehole

The 13.375-in. surface casing is installed from the surface to a depth of 809.00 m (2,654.21 ft) bgs. Intermediate casing 10.75 to 9.625-in. extends to 856.94 m (2,811.48 ft) bgs. Completion casing includes 7.625-in. carbon steel (CS) from surface to 519.03 m (1,702.85 ft), and 6.625-in. stainless-steel (SS) blank casing and screen to 906.80 m (2,975.05 ft) bgs.

1.2 Project Organization

Well ER-4-1 was drilled as part of the UGTA Activity. NSTec provided site supervision, engineering, construction, inspection, geologic support, and onsite radiological monitoring. UDI, a subcontractor to NSTec, was the drilling company. Roles and responsibilities of these and other contractors involved in the project are described in FAWP D-003-001.16 (NSTec, 2016) (provided in Appendix D).

Navarro was the principal environmental and technical contractor for the project and was responsible for environmental compliance and waste management on site. Navarro collected and analyzed fluid samples for water quality and chemistry, and for monitoring and documenting the disposition of fluids and drill cuttings produced from the borehole. In addition, Navarro personnel collected geologic, hydrologic, and drilling parameter data; and were responsible for geologic and geophysical interpretations as the well was drilled.

The Technical Working Team (TWT) is a group of scientists and engineers from NNSA/NFO, NDEP, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Desert Research Institute (DRI), the U.S. Geological Survey (USGS), NSTec, and Navarro. The TWT's Drilling Advisory Team—which included the NNSA/NFO UGTA Activity Lead, the CAU Lead, the Navarro Senior Hydrogeologist, the Navarro UGTA Project Manager, the NSTec UGTA Manager/drilling engineer, a hydrologist, a geologist, and a radiochemist—provided technical advice during drilling, design, and construction of the well to ensure that the scientific and technical objectives were achieved.

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 fluid management details are further identified in the well-specific fluid management strategy letter (Navarro, 2016c) (reproduced in Appendix D of this report) as required by the FMP and approved by NDEP before fluids are generated. Estimates of expected production of fluid and drill cuttings for Well ER-4-1 are provided in the drilling and completion criteria document (Navarro, 2016d), 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, 2016; Navarro, 2016a) and the UGTA Activity Health and Safety Plan (NSTec, 2015).

This report presents well construction, environmental compliance, and waste management data; and summarizes scientific data collected during the drilling of Well ER-4-1.

1.3 Location and Significant Nearby Features

Well ER-4-1 is located in the area of Yucca Flat within the northeastern portion of the NNSS, in operational Area 4. The elevation of ER-4-1 is 1,267.39 m (4,158.09 ft) above mean sea level (amsl) in central Yucca Flat as shown in Figure 1-1 and Table 1-1. The well is located approximately southeast of the STRAIT (U4a) underground test (UGT) on the NNSS. Figure 1-2 shows the location of Well ER-4-1 relative to select wells and UGTs in Yucca Flat. The STRAIT UGT was conducted on March 17, 1967, in emplacement hole U4a in north–central Yucca Flat. The working point (WP) of the test was in the OSBCU hydrostratigraphic unit (HSU) and estimated to be within 2 cavity radii (R_c) of the saturated LCA HSU (cavity dimension based on maximum announced yield identified in NV-209-REV 16 [NNSA/NFO, 2015b] and Equation 1 in UCRL-ID-136003 [Pawloski, 1999]).

Well ER-4-1 provided hydrogeologic data that will help verify concepts of the groundwater flow system in Yucca Flat and potential transport of radionuclides (RNs) from the STRAIT UGT.

Table 1-1
Site Data Summary for Well ER-4-1

Site Coordinates [a]	**Nevada State Plane - Central Zone, NAD 27** N 858,360.04 ft E 679,776.03 ft
	Nevada State Plane - Central Zone, NAD 83 N 6,261,629.54 m E 554,717.21 m
	UTM - Zone 11, NAD 83 N 4,107,114.62 E 584,318.82
	UTM - Zone 11, NAD 27 N 4,106,917.22 E 584,398.13
	Geographic - NAD 83 **(Decimal Degrees)** Latitude: N 37.106558 Longitude: W 116.051029
	Township and Range [b] Section 34 Township 09 South, Range 53 East
Surface Elevation [a, c]	1,267.39 m (4,158.09 ft)
Drilled Depth (bgs)	925.13 m (3,035.19 ft)
Fluid Level Depth (bgs) [d]	539.17 m (1,768.92 ft)
Fluid Level Elevation	728.22 m (2,389.17 ft)
Surface Geology	Quaternary/Tertiary Alluvium (QTa)

[a] Measurements made by NSTec Survey on 06/09/2016 using NAD 27 Nevada State Plane coordinates in feet. All other coordinates were calculated from NAD 27 in feet using ArcMap 10.3.1 (ESRI, 2017).
[b] Township and Range coordinates made using Earthpoint (Public Land Survey System BLM, 2017).
[c] Measurement of elevation of ground at the wellhead made by NSTec Survey on 06/09/2016. Elevations are relative to mean sea level and reported in NGVD29.
[d] Measured in the main completion (m1) by Navarro on 12/12/2016.

NAD 27 = North American Datum, 1927
NAD 83 = North American Datum, 1983
NGVD29 = National Geodetic Vertical Datum 1929
UTM = Universal Transverse Mercator

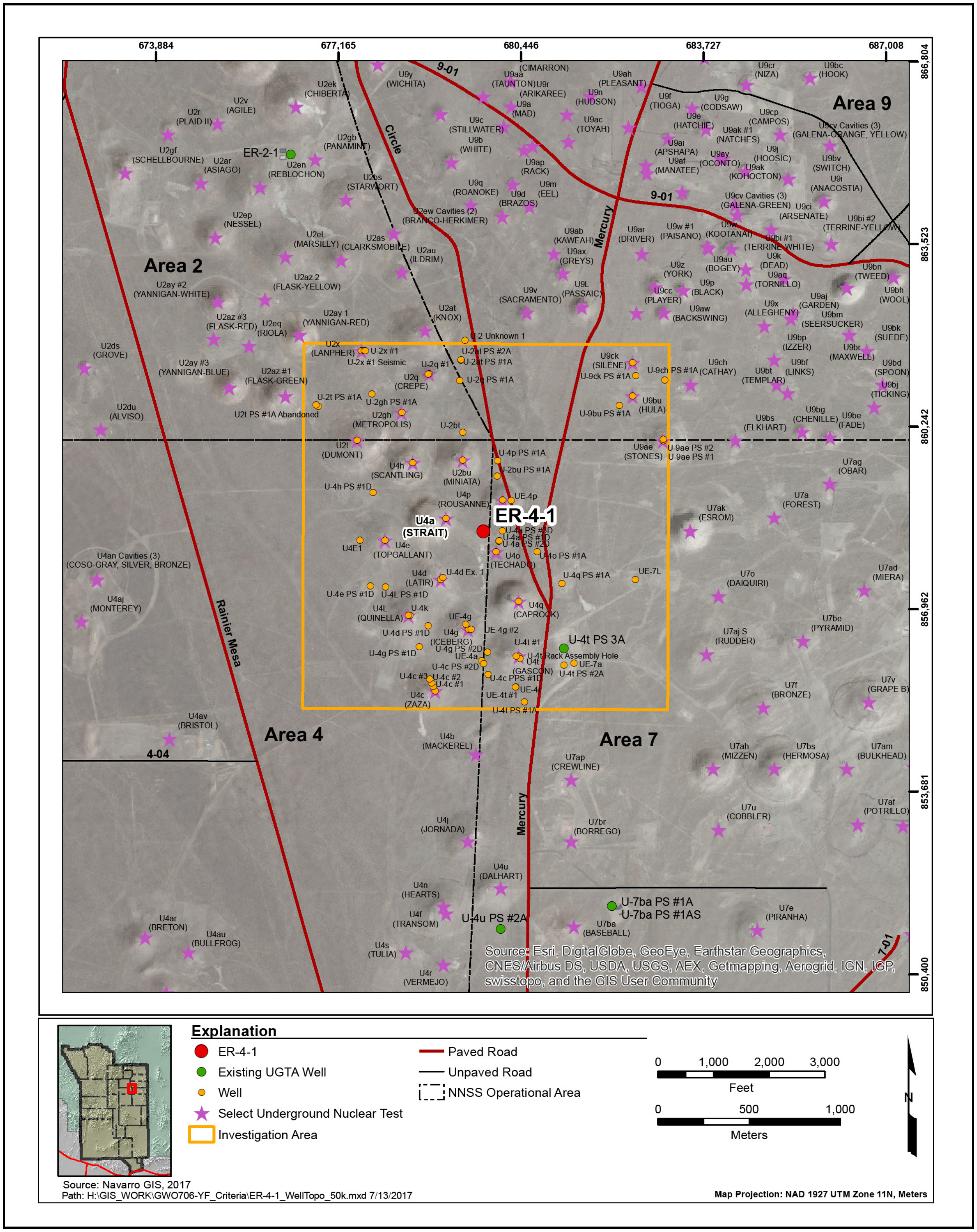


Figure 1-2
Aerial Photo of the Well ER-4-1 Area

1.4 Objectives

The primary purpose of Well ER-4-1 was to provide detailed hydrogeologic information downgradient of the STRAIT (U4a) UGT. The *Yucca Flat Drilling and Completion Criteria*, *Wells ER-2-2*, *ER-3-3, and ER-4-1* (Navarro, 2016d) lists the following scientific objectives for Well ER-4-1:

- Obtain hydrogeologic information that will be used to evaluate the various parameters, assumptions, and models (hydrostratigraphic framework model [HFM], flow and transport, hydrologic, hydrologic source term [HST]):
    - Provide detailed hydrogeologic information for the alluvium, volcanic sections, and the uppermost 100 to 300 m (330 to 990 ft) of the LCA.
    - Because the STRAIT UGT was conducted relatively distant from faults, completion, and testing of Well ER-4-1 will allow assessment of the exchange volume and integrity of the tuff confining unit (TCU) near a major detonation away from faults.
    - Provide detailed geology, including fracture information for the upper portion of the LCA where RN contaminant transport is most likely.
    - Use the data collected to help reduce uncertainties within the Yucca Flat area during any further groundwater flow and transport model runs deemed necessary.
- The lower completion, in the top of the saturated LCA, can be pumped to determine whether the exchange volume has penetrated downward into the LCA, and to investigate the role that faults may have on RN transport to the LCA.
- The well should allow for the testing and refining of conceptual models of groundwater flow and RN transport between the saturated alluvial aquifer (AA)/volcanic aquifer (VA) and carbonate aquifer (CA).
- Obtain water-level data, and investigate potential local groundwater flow downgradient from the STRAIT (U4a) UGT.
- Obtain aqueous geochemistry samples to better define possible groundwater flow paths based on water chemistry.
    - Sample for tritium and other RNs potentially migrating in groundwater from the upgradient STRAIT UGT.

1.5 Project Summary

By industry convention, casing and tubing are identified using English units (e.g., 30-in. casing or 2.875-in. CS tubing), which is usually equivalent to the outside diameter (od) of the pipe. In this report, these descriptors are used to designate the type of casing or tubing (its “name”), and metric conversions are provided.

Mobilization and setup of drilling equipment and site support facilities to the Well ER-4-1 drill pad began on March 16, 2016. Main borehole construction of the well to a total depth (TD) of 925.13 m (3,035.19 ft) bgs began on March 23 and ended on April 13, 2016. Once drilling operations began, work proceeded 7 days per week, 24 hours per day.

After completing pre-drilling safety checks and a site walk-through, drilling operations began on March 23, 2016, by drilling the cement plug in the 30-in. conductor casing with a 18.5-in. bottom hole assembly (BHA) from 35.97 to 822.66 m (118 to 2,699 ft) bgs. The 13.375-in. CS surface casing was then installed from the ground surface to 809.00 m (2,654.21 ft) bgs and cemented in place. A 12.25-in. tricone bit was then used to advance the borehole from 822.66 to 925.13 m (2,699 to 3,035.19 ft) bgs.

As borehole circulation permitted, composite drill cuttings samples were collected across 3.0-m (10-ft) intervals from approximately 39.62 m (130 ft) bgs to the borehole TD. Generally, the collected cuttings were representative of the geologic units penetrated; however, some intervals were variably cross-contaminated with material sloughing in from overlying geologic units and from cuttings not immediately cleared from the borehole during drilling. Cuttings samples were inspected and logged at the drill site by Navarro geologists and then archived at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

One piezometer (p1) was installed in the annulus between the borehole wall and 13.375-in. casing: p1, consisting of 2.375-in. CS blank tubing from the surface to 616.65 m (2,023.13 ft) bgs; a 0.85-ft crossover to 2.875-in. SS blank tubing from 616.65 to 616.91 m (2,023.13 to 2,023.98 ft) bgs; and 2.875-in. SS slotted tubing from 616.91 to 662.52 m (2,023.98 to 2,173.61 ft) with a bullnose termination from 662.52 to 663.16 m (2,173.61 to 2,175.71 ft) bgs.

The main completion interval (m1) consists of 7.625-in. CS blank casing from the surface to 518.34 m (1,700.60 ft) bgs; a crossover to 6.625-in. SS blank casing from 518.34 m to 519.03 m (1,700.60 to 1,702.85 ft) bgs; 6.625-in. SS blank casing from 519.03 to 869.82 m (1,702.85 to 2,853.75 ft) bgs; and 6.625-in. SS slotted casing from 869.82 to 906.10 m (2,853.75 to 2,972.78 ft) bgs with a bullnose termination from 906.10 to 906.80 m (2,972.78 to 2,975.05 ft) bgs.

Schlumberger and COLOG conducted geophysical logging in the open borehole before installation of surface casing. Navarro geologists reviewed the geophysical logs in the field to verify and correlate geologic units encountered within the borehole, aid in characterization of well-site hydrology, and identify potential borehole condition issues. Geophysical logs, in hard copy and electronic versions, are filed at the NSTec office in Mercury, Nevada, and at the Navarro office in Las Vegas, Nevada. Navarro, using a calibrated Solinst electric tape (e-tape), measured fluid levels in the open borehole and the above referenced completions on various dates throughout the drilling and completion program; additional fluid levels were also obtained by Schlumberger and COLOG, using geophysical tools, on March 28 and 29, 2016. Representative water levels are provided in Table 6-1.

Drilling and completion operations concluded on April 13, 2016, and demobilization of drilling equipment and support facilities was initiated.

A detailed summary of drilling operations is presented in Section 2.0. Well completion information is provided in Section 3.0. Geologic data collection activities are described in Section 4.0. Geology and hydrogeology information is presented in Section 5.0. Hydrology and water chemistry data collection activities are described in Section 6.0. Drilling fluid and waste management activities are provided in Section 7.0. Planned and actual costs and scheduling are presented in Section 8.0. Lessons learned based upon observations made during Well ER-4-1 drilling and completion activities are provided in Section 9.0. References are presented in Section 10.0.

2.0 Drilling Summary

General drilling requirements for Well ER-4-1 are outlined in the contract between NSTec and UDI. Well-specific drilling and operational guidance are detailed in the NSTec *Field Activity Work Package, Main Hole Drilling and Completion of Well ER-4-1* (NSTec, 2016); *Navarro Field Activity Work Package (FAWP) for Underground Test Area (UGTA) Drilling Field Operations Wells ER-4-1 and ER-3-3* (Navarro, 2016a); and *Field Instruction for the Underground Test Area Project Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015). Changes to requirements in these documents are documented in records of verbal communication, written modifications to the NSTec FAWP (NSTec, 2016), and Navarro technical change notices. The NSTec FAWP is provided in Appendix D.

This report was prepared using field documentation generated during drilling and completion of Well ER-4-1, including NSTec daily rig operations reports; Navarro morning reports and logbook notes; Schlumberger and COLOG geophysical log data; and other data collected and recorded by Navarro field representatives.

2.1 Well Drilling History

Construction of an access road, drill pad, and two sumps at the Well ER-4-1 site was completed by NSTec construction on December 3, 2015. Before drilling equipment and facilities were mobilized to the site, NSTec advanced a 48-in. diameter, dry-auger borehole to a depth of 35.97 m (118 ft) bgs; installed 30-in. diameter CS conductor casing within the 48-in. borehole to a depth of 35.51 m (116.5 ft) bgs; and cemented the conductor casing in place.

Between March 16 and March 23, 2016, the drill rig, drilling support equipment, and support facilities were mobilized to the site. The UDI equipment included a Wilson Mogul 42B double drum, truck-mounted, air-rotary, drilling rig with a portable sub-base and a maximum rated capacity of 354,000 pounds static hook load. NWAS mobilized three air compressor units rated at 1,500 standard cubic feet per minute (ft^3/min) at a maximum pressure of 2,300 pounds per square inch (psi). These units had a fluid injection system (mist pump) with a rated capacity of 1 to 46.5 gallons per minute (gpm) at 2,500 psi, and two 30-barrel (bbl) capacity mix tanks, to supply air and drilling fluids for drilling operations.

Equipment and facilities were set up, and safety checks were performed including inspection of flow-line welds by an NSTec-certified welding inspector on March 22, 2016. Once formal drilling operations began on March 23, 2016, crews worked 7 days per week, 24 hours per day. Operations began by drilling the cement inside the 30-in. casing. UDI then continued to advance the 18.5-in. borehole. The borehole began experiencing tight hole and other issues (i.e., fill) at approximately 816.56 m (2,679 ft) bgs on March 27, 2016. Navarro personnel noted water production was insignificant at this point. UDI reached a depth of 822.66 m (2,699 ft) bgs on March 27, 2016. UDI made a short trip and tagged fill at approximately 804.37 m (2,639 ft). It was determined that 13.375-in. surface casing would be installed at this time. Drilling of the 18.5-in. borehole took place over five days, as shown in Figure 2-1.

Open borehole geophysical logging operations in advance of the installation of surface casing were started on March 28, 2016, by Schlumberger; the logs were collected in the 18.5-in. borehole to a maximum depth of 766.57 m (2,515 ft) bgs. The Schlumberger logging engineer noted that the tool hung up at approximately 767.49 m (2,518 ft) bgs, per NSTec, Schlumberger began logging up. Schlumberger completed logging and rigged down on March 29, 2016. COLOG then rigged up and ran the Idronaut Chemistry tool from 574.55 m (1,885 ft) to 696.77 m (2,286 ft) bgs. COLOG then rigged down and departed the site. Details of the geophysical logging are discussed in Section 4.0.

On March 30, 2016, after geophysical logging was completed, Navarro personnel rigged up to collect depth-discrete groundwater bailer samples. Depth-discrete bailer samples were collected at 538.89 m (1,768 ft). After deploying the bailer, Navarro personnel noted that the bailer was plugged with fine sediment and the sample was reddish in color with abundant fines. After collecting the first sample, decontamination procedures were completed and a second depth-discrete bailer sample was collected at 646.18 m (2,120 ft). The bailer was plugged with fine sediment as in the previous sample. UDI began tripping in the hole (TIH) on April 1, 2016, in preparation to clean up the borehole for setting a piezometer and surface casing. UDI used fresh water and bentonite mud while washing down and cleaning out the borehole to a depth of approximately 818.69 m (2,686 ft). On April 1, 2016, UDI

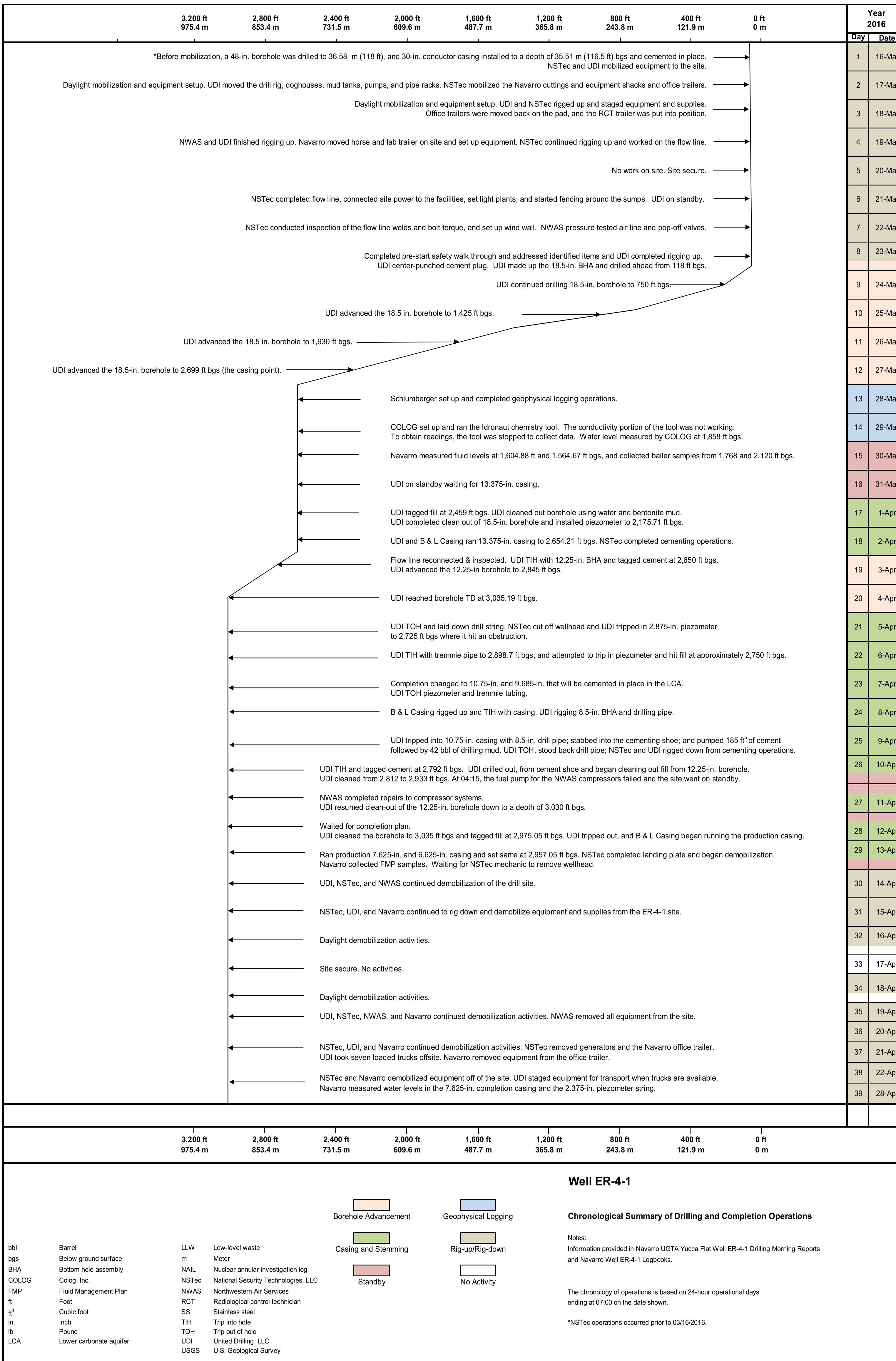


Figure 2-1
Well ER-4-1 Chronological Summary of Drilling and Completion Operations

installed piezometer (p1) to 663.16 m (2,175.71 ft) bgs, and B&L Casing rigged up to install surface casing. B&L Casing installed the 13.375-in. casing to 809.00 m (2,654.21 ft) on April 2, 2016.

After installation of the 13.375-in. surface casing, UDI TIH with the 12.25-in. BHA; tagged cement at 804.37 m (2,650 ft) bgs inside the 13.375-in. casing; and drilled through the cement on April 3, 2016. UDI drilled ahead in Older tunnel beds (Ton), from a depth of 809.00 m (2,654.21 ft) bgs. Borehole stability and sloughing conditions continued as UDI experienced difficulty maintaining returns. On the evening of April 4, 2016, the borehole was at a depth of 858.93 m (2,818 ft) bgs, and a sharp decrease in the rate of penetration along with an increase in the weight on bit was noted indicating the probable contact with the Paleozoic rocks (₽z).

UDI advanced the 12.25-in. borehole, reaching a TD of 925.13 m (3,035.19 ft) bgs on April 4, 2016. UDI then conducted several short trips to check for fill, tight hole conditions, and other issues. UDI noted fill or obstructions on each short trip and circulated to clean out the borehole. Late on April 5, 2016, UDI attempted to install a second 2.875-in. piezometer and hang a tremie for use in the main completion. Obstructions were encountered, and the piezometer was hung-off on the 13.375-in. casing while using the tremie to wash down with bentonite mud to clean out the hole. The attempts to install the second piezometer were unsuccessful.

On April 7, 2016, the TWT’s Drilling Advisory Team (with DOE participation) modified the completion plan for Well ER-4-1. NSTec directed UDI to remove the piezometer and tremie strings from the borehole. An intermediate casing string was installed with the casing point as close to the top of the Paleozoic rocks (₽z) as possible. UDI tripped the piezometer out of the hole, and used the tremie line to wash down and condition the borehole with bentonite mud. The tremie line encountered a bridge at 856.18 m (2,809 ft) bgs and was not advanced further. UDI and B&L Casing rigged up to install intermediate casing (10.75-in. and three pieces of 9.625-in.) on April 8, 2016. Additional bentonite mud was used to wash down the intermediate casing. The casing was landed at 856.94 m (2,811.48 ft) bgs and cemented on April 9, 2016.

On April 9, 2016, UDI TIH with an 8.5-in. BHA and established circulation to the surface in three stages. UDI then drilled out from the cement and began cleaning out the hole. A notable increase in the penetration rate coincided with an observed significant increase in water production at approximately 867.16 m (2,845 ft) bgs on April 10, 2016. As borehole clean-out continued, UDI noted that NWAS was experiencing equipment issues. NSTec directed UDI to pull back into the casing until repairs could be completed. Repairs were completed on April 11, 2016, and UDI cleaned accumulated fill out of the hole to 923.54 m (3,030 ft) bgs.

On the evening of April 12, 2016, the TWT's Drilling Advisory Team (with DOE participation) notified site personnel to set the main production casing. UDI and B&L Casing rigged up and installed the 6.625-in. main completion casing, landing at 906.80 m (2,975.05 ft) bgs. Details of the well completion are provided in Section 3.0.

Figure 2-2 is a graphical depiction of drilling parameters, including weight on the bit, drill bit rotation, pump pressure, estimated water production, and rate of penetration. Table 3-1 presents the abridged borehole statistics. Well completion activities concluded on April 13, 2016. Rigging down and site demobilization then began, ending Well ER-4-1 drilling and completion operations.

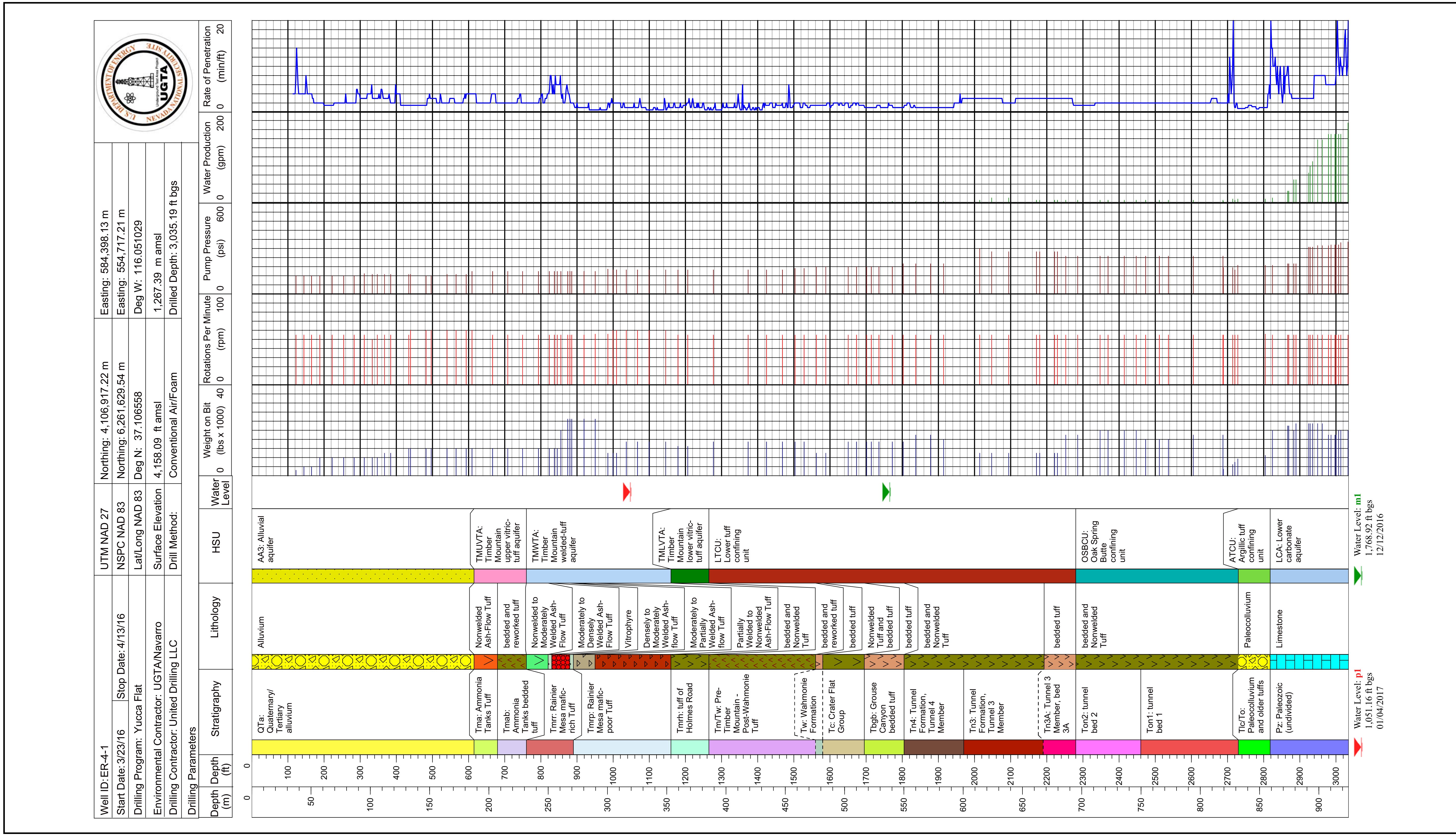


Figure 2-2
Summary of Well Drilling Parameters and Water Production for Well ER-4-1

3.0 Well Completion

3.1 Introduction

The proposed well design for Well ER-4-1 was presented in the addendum to the *Yucca Flat Drilling and Completion Criteria, Wells ER-2-2, ER-3-3, and ER-4-1* (Navarro, 2016d). The proposed well completion plans are summarized in Section 3.2.1, and the actual well completion design (based on the hydrogeology and borehole conditions encountered) is presented in Section 3.2.2. Differences between the planned and actual design are discussed in Section 3.2.3. Completion methods are presented in Section 3.3. Figure 3-1 is a schematic diagram of the well completion as-built. Figure 3-2 shows a plan view and profile of the final wellhead surface completion. Figure 3-3 is a photograph showing the ER-4-1 wellhead at the surface. Table 3-1 provides the abridged borehole statistics, and a construction summary for the main completion and piezometer strings.

Before well completion operations, decontamination procedures were employed to prevent the introduction of potential contaminants into the well. All well casing, tubing strings, and downhole tools were decontaminated using a high-pressure steam washer at the NSTec subdock located in Area 1. After cleaning and decontamination, all components were inspected and approved for cleanliness by Navarro and screened by an NSTec radiological control technician (RCT). Navarro well-site personnel completed a final on site inspection of all equipment before use or installation in the borehole.

3.2 Well Completion Design

The following subsections provide the well completion design for ER-4-1 and the final well completion as-built in the field. The as-built well completion differs from the proposed design.

3.2.1 Proposed Completion Design

Well ER-4-1 was proposed to be drilled to a TD of 944.88 m (3,100 ft) bgs within the Paleozoic rocks (Pz), which comprise the LCA. The Tertiary Volcanics (Tv), which is composed of the volcanic rocks from the Ammonia Tanks Tuff (Tma) to the Paleocolluvium/older tuffs (Tlc/To), static water level (SWL) was predicted to be at a depth of approximately 484.33 m (1,589 ft) in the LTCU, and the

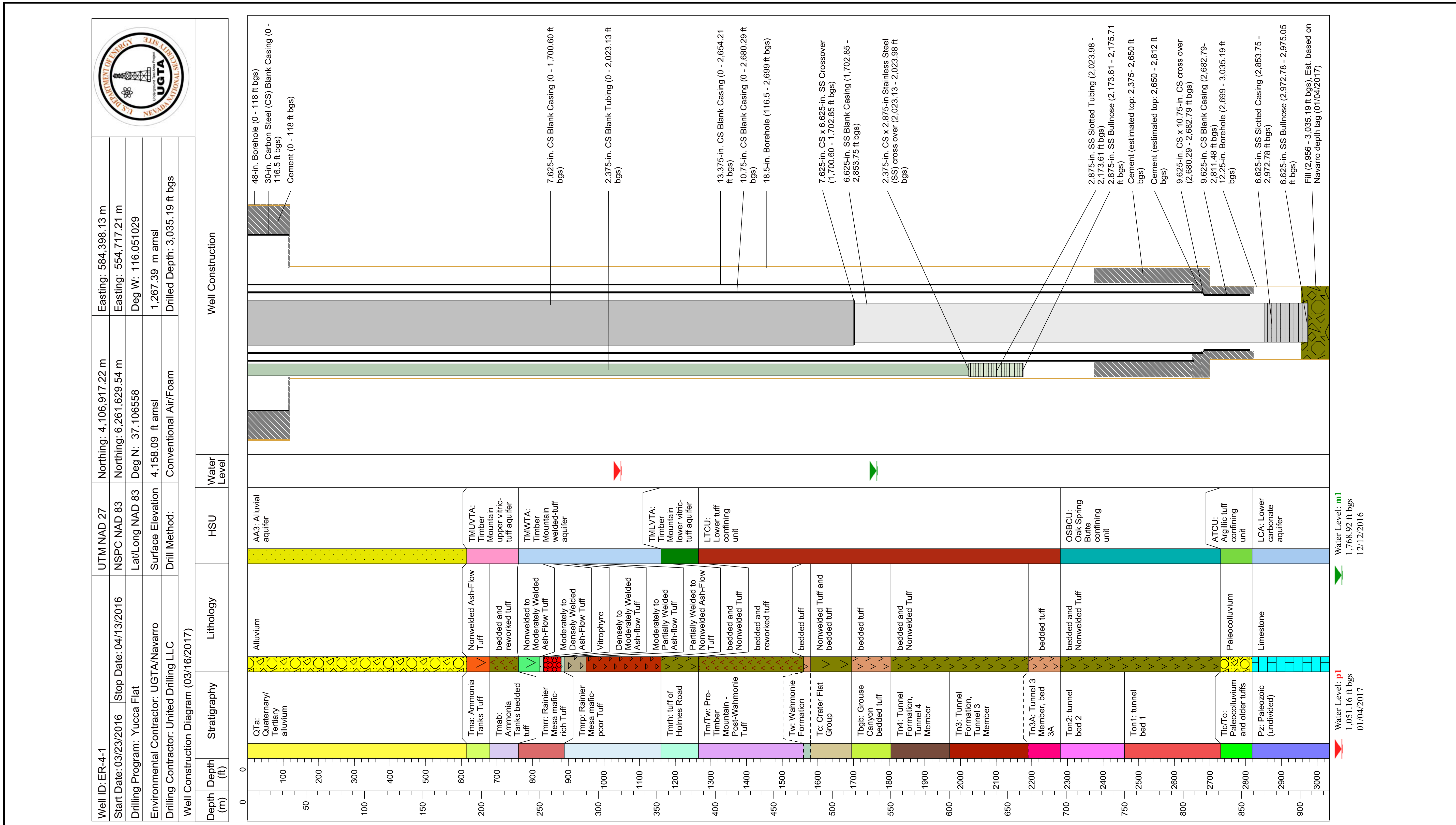


Figure 3-1
Well Completion Diagram for Well ER-4-1

Table 3-1
Abridged Drill-Hole Statistics for Well ER-4-1
(Page 1 of 2)

LOCATION DATA: Coordinates:	Nevada State Plane (NAD 27) — N 858,360.04 ft, E 679,776.03 ft Nevada State Plane (NAD 83) — N 6,261,629.54 m, E 554,717.21 m Universal Transverse Mercator (NAD 27, Zone 11) — N 4,106,917.22 m, E 584,398.13 m Latitude/Longitude (NAD 83) — 37.106558 decimal degrees N, 116.051029 decimal degrees W
Surface Elevation:	1,267.39 m (4,158.09 ft) amsl
DRILLING DATA: Spud Date: Date TD Reached: Date Well Completed: TD:	 03/23/2016 04/04/2016 04/13/2016 925.13 m (3,035.19 ft) bgs
Hole Diameters:	121.92 cm (48 in.) from surface to 35.97 m (118 ft) 46.99 cm (18.5 in.) from 35.97 m (118 ft) to 822.66 m (2,699 ft) 31.12 cm (12.25 in.) from 822.66 m (2,699 ft) to 925.13 m (3,035.19 ft)
Drilling Techniques:	Dry auger drilling using a 121.92-cm (48-in.) diameter bucket style auger bit from surface to 35.97 m (118 ft); to rotary drilling with air-foam and conventional circulation using a 46.99-cm (18.5-in.) chisel tooth tricone button bit to 822.66 m (2,699 ft); rotary drilling with air foam and conventional circulation using a chisel tooth 31.12-cm (12.25-in.) tricone button bit to 925.13 m (3,035.19 ft)
CASING DATA:	<u>Description</u> — <u>Depth Interval</u>
Detail of Conductor Casing:	76.20-cm (30-in.) conductor casing; — +0.49 – 35.51 m (+1.62 – 116.5 ft) Type: CS, Grade: K55, od: 30-in., id: 28.97-in.
Detail of Surface Casing:	33.97-cm (13.375-in.) surface casing; — +0.70 – 809.00 m (+2.30 – 2,654.21 ft) Type: CS, Grade: J55, od: 13.375-in., id: 12.515-in. Type: CS, Grade: J55, od: 13.375-in., id: 12.615-in.
Detail of Intermediate Casing:	27.31-cm (10.75-in.) intermediate casing; — +0.84 - 816.95 m (+2.75 – 2,680.29 ft) Type: CS, Grade: J55, od: 10.75-in., id: 10.05-in. 27.31-cm (10.75-in.) crossover to (9.625-in.): — 816.95 - 817.71 m (2,680.29 – 2,682.79 ft) 24.45-cm (9.625-in.) blank casing; — 817.71 - 856.94 m (2,682.79 – 2,811.48 ft) Type: CS, Grade: J55, od: 9.625-in., id: 8.835-in.
SLOT INFORMATION:	Slots in 6.625-in. casing are saw cut 7.30-cm (2.875-in.) Slots for SS piezometers are machine-cut, 0.18-cm (0.07-in.) by 6.86-cm (2.70-in.), 8 vertical slots per row, approximately 108 rows per joint on 7.62-cm (3.00-in.) centers, each row offset by approximately 22.5 degrees from the next.
TUBING DATA:	2.375-in. piezometer tubing; Type: CS, Grade: N80, od: 2.375-in., id: 1.995-in.
WELL COMPLETION DATA: Detail of Completion Casing:	The completion casing consists of 7.625-in. CS blank casing that runs from +0.95 to 518.34 m (+3.11 - 1,700.60 ft) bgs. This is followed by a crossover to 6.625-in. SS blank casing to 519.03 m (1,702.85 ft) bgs and SS blank casing to 869.82 m (2,853.75 ft) bgs. The slotted interval m1 runs to 906.10 m (2,972.78 ft) bgs. The completion casing is terminated with a bullnose at 906.80 m (2,975.05 ft) bgs. <u>Description</u> — <u>Depth Interval</u> 19.37-cm (7.625-in.) blank casing; Type: CS, Grade K55, od: 7.625-in., id: 6.969-in. Type: SS, Grade: 304L, od: 6.625-in., id: 6.06-in. Blank 19.37-cm (7.625-in.) CS casing — +0.95 – 518.34 m (+3.11 – 1,700.60 ft) 19.37-cm (7.625-in.) crossover to (6.625-in.) SS — 518.34 – 519.03 m (1,700.60 – 1,702.85 ft) 16.83-cm (6.625-in.) Blank SS casing: — 519.03 – 869.82 m (1,702.85 – 2,853.75 ft) 16.83-cm (6.625-in.) Slotted SS casing: — 869.82 – 906.10 m (2,853.75 – 2,972.78 ft) bullnose termination: — 906.10 – 906.80 m (2,972.78 – 2,975.05 ft)
Detail of Piezometer (p1):	Blank 6.03-cm (2.375-in.) CS tubing: — +0.73 m – 616.65 m (+2.38 – 2,023.13 ft) 6.03-cm (2.375-in.) to 7.30-cm (2.875-in.) crossover: — 616.65 – 616.91 m (2,023.13 – 2,023.98 ft) Slotted 7.30-cm (2.875-in.) SS tubing — 616.91 – 662.52 m (2,023.98 – 2,173.61 ft) bullnose termination: — 662.52 – 663.16 m (2,173.61 – 2,175.71 ft)

Table 3-1
Abridged Drill-Hole Statistics for Well ER-4-1
(Page 2 of 2)

Detail of Completion Materials:	3/8-in. Gravel pack: 20/40 Sand pack: Type II neat cement	None None 723.9 – 857.1 m (2,375 – 2,812 ft)
FLUID-LEVEL DATA: Main completion (m1) [a] Piezometer (p1) [b]	Fluid Depth 539.17 m (1,768.92 ft) 320.39 m (1,051.16 ft)	Fluid Elevation 728.22 m (2,389.17 ft) 946.99 m (3,106.93 ft)
DRILLING CONTRACTOR:	United Drilling, LLC	
GEOPHYSICAL LOGS BY:	Schlumberger and COLOG	

[a] Measurement by Navarro using a calibrated Solinst e-tape on 12/12/2016.
[b] Measurement by Navarro using a calibrated Solinst e-tape on 01/04/2017.

cm = Centimeter
id = Inside diameter

LCA SWL was predicted to be at a depth of 527.61 m (1,731 ft) bgs. The well was planned to be drilled at a diameter of 46.99 cm (18.5 in.) from the bottom of the conductor casing through the unsaturated zone to approximately 817 m (2,680 ft) bgs and set 13.375-in. casing into the Argillic tuff confining unit (ATCU). A 6.03-cm (2.375-in.) piezometer string with a slotted interval in the OSBCU was planned to be set in the annulus. From 817 m (2,680 ft) bgs, the well was to be drilled at a diameter of 31.12 (12.25 in.) to the TD. In addition, an optional completion included a second screened interval and retrievable bridge-plug in the 16.83-cm (6.625-in.) production casing and a second 7.30-cm (2.875-in.) piezometer with slotted interval matching the main completion in the LCA.

3.2.2 As-Built Completion Design

The Well ER-4-1 completion design was determined by the TWT's Drilling Advisory Team based on hydrologic data obtained during drilling and was revised to accommodate unstable borehole conditions encountered during drilling. The group modified the initial completion plan based on the onsite evaluation of lithology, water production, water level, borehole conditions, drilling data, geophysical logs, and tritium levels. The final completion design included one piezometer (p1) and one main completion interval (m1) (Figure 3-1).

The main completion string is composed of 19.37-cm (7.625-in.) blank CS casing from surface to 518.34 m (1,700.60 ft) bgs; a CS to SS crossover from 518.34 m to 519.03 m (1,700.60 ft to 1,702.85 ft) bgs; 16.83-cm (6.625-in.) SS blank casing from 519.03 m to 869.82 m (1,702.85 ft to 2,853.75 ft) bgs; and a 16.83-cm (6.625-in.) SS slotted interval (m1) from 869.82 to 906.10 m

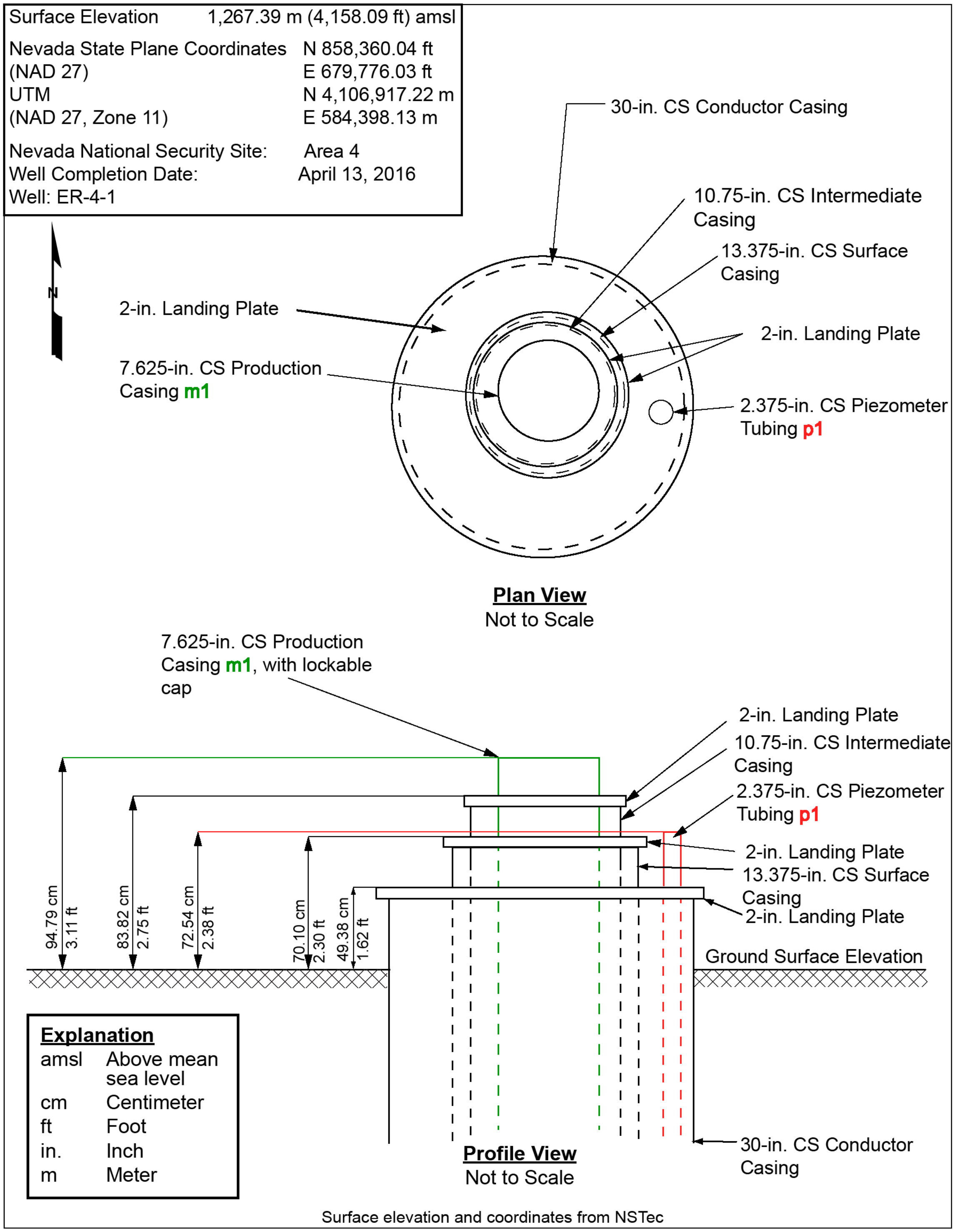


Figure 3-2
Wellhead Completion Diagram for Well ER-4-1

Figure 3-3
Photograph of Well ER-4-1 Wellhead (04/27/2017)

(2,853.75 to 2,972.78 ft) bgs completed within the LCA, with a bullnose termination installed on the bottom of the completion string from 906.10 m to 906.80 m (2,972.78 ft to 2,975.05 ft) bgs. Table 3-1 provides detailed specifications for all of the casings installed as shown in Figure 3-1. Depth intervals for the CS tubing and SS blank and slotted tubing are tabulated in abridged borehole statistics in Table 3-1.

Well completion began with installation of the 13.375-in. CS surface casing from 0.70 m (2.30 ft) above ground surface to a depth of 809.00 m (2,654.21 ft) bgs and cementing the casing in place. A piezometer (p1) was installed in the annulus between the borehole wall and 13.375-in. casing from 0.73 m (2.38 ft) above ground surface to a depth of 663.16 m (2,175.71 ft) bgs. The piezometer (p1) consists of 2.375-in. CS blank tubing and 2.875-in. SS screen interval open to the alluvial aquifer (AA3), Timber Mountain upper vitric-tuff aquifer (TMUVTA), Timber Mountain welded-tuff aquifer (TMWTA), Timber Mountain lower vitric-tuff aquifer (TMLVTA), LTCU, and OSBCU HSUs. Figure 3-1 is a detailed schematic of the well completion, and Table 3-1 provides detailed casing specifications.

Figure 3-2 is a schematic of the wellhead completion details, and Figure 3-3 is a photo of the wellhead. Table 3-1 provides the abridged drill-hole statistics for Well ER-4-1, a detailed description of materials used in completion of Well ER-4-1, and relevant depths.

3.2.3 Rationale for Differences between Planned and Actual Well Design

The original completion design was based on hydrogeologic information from nearby Wells UE-4p, U-4o, U-4e, U-4d Ex.1, and emplacement hole U4a for the STRAIT UGT (Navarro, 2016d); and interpreted geology from the Yucca Flat HFM (BN, 2006). Completion intervals for the piezometer tubing and main completion access point were adjusted to account for unstable borehole conditions as well as to optimize sampling and testing data collection.

The geology and hydrology of Well ER-4-1 are discussed in Sections 5.1 through 5.3.

3.3 Well Completion Method

Completion activities began on April 1, 2016, after the 46.99-cm (18.5-in.) borehole was drilled to 822.66 m (2,699 ft) bgs. UDI ran the (p1) 6.03-cm (2.375-in.) piezometer tubing in the 18.5-in. borehole and landed at 663.16 m (2,175.71 ft) bgs. On April 2, 2016, the B&L Casing crew ran the 33.97-cm (13.375-in.) casing and landed it at 809.00 m (2,654.21 ft). On April 3, 2016, UDI resumed drilling operations with the 31.12-cm (12.25-in.) BHA. Well ER-4-1 reached TD of 925.13 m (3,035.19 ft) bgs on April 4, 2016. After multiple attempts to clean out and stabilize the borehole, continued borehole instability (e.g. tight hole, sloughing) precluded the installation of additional piezometers and the main production casing. The TWT's Drilling Advisory Team modified the completion plan to allow the installation of an intermediate casing string to stabilize the borehole and ensure a successful completion in the LCA.

On April 8, 2016, UDI and B&L Casing began installing the intermediate casing. The intermediate casing consisted of 27.31-cm (10.75-in.) CS blank casing to 816.95 m (2,680.29 ft) bgs; a 27.31-cm (10.75-in.) × 24.45-cm (9.625-in.) crossover to 817.71 m (2,682.79 ft) bgs; followed by 24.45-cm (9.625-in.) CS blank casing (open ended) to 856.94 m (2,811.48 ft) bgs. Once the casing was installed UDI cleaned out the borehole to TD. UDI noted that they were continuing to experience fill and sloughing conditions. On April 12, 2016, UDI tagged fill at approximately 907.39 m (2,977 ft) bgs and the TWT directed NSTec and UDI to set the main production casing. UDI and B&L Casing installed the main production casing on April 13, 2016, landing it at 906.80 m (2,975.05 ft) bgs.

All well construction materials used for the completion were inspected according to relevant procedures, as listed in the Navarro FAWP (Navarro, 2016a). Cementing operations used Type II neat cement. No stemming of sand or gravel was required, due to the nature of the well completion. Cementing was done using the drill pipe, and a stab-in type float shoe placed on the respective casing. Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

After installation of the main casing on April 13, 2016, the UDI drill rig was rigged down in preparation for demobilizing. Hydrologic testing is planned as a separate effort, and no well development or pumping tests were conducted immediately after completion.

4.0 Geologic Data Collection

4.1 Well Geologic Data

Before Well ER-4-1 was drilled, a predicted stratigraphic sequence with unit thicknesses was developed from the Yucca Flat HFM (BN, 2006). During drilling, Navarro personnel prepared preliminary field lithologic descriptions and stratigraphic unit assignments based on the field examination of drill cuttings. Lithologic descriptions are provided in Appendix A. Stratigraphic and lithologic interpretations presented may be revised pending further evaluation of drill cuttings samples by Navarro geologists.

Overall cuttings quality (e.g., size, volume, and purity) was fair. However, zones that were not representative of the drilled interval occurred sporadically throughout the borehole. In general, most of the sloughing zones are associated with bedded and nonwelded tuffs that are variably altered. Drilling of the 18.5-in. borehole was completed on April 1, 2016, at 822.66 m (2,699 ft) bgs. Subsequently 13.375-in. casing was landed at 809.00 m (2,654.21 ft) bgs in an effort to stabilize the borehole. Drilling of the 12.25-in. borehole was initiated on April 3, 2016, from 807.72 m (2,650 ft) bgs. Borehole stability issues continued as the drilling progressed through the remaining Tertiary Volcanic rocks (Tv) and into the Paleozoic rocks (Pz). An intermediate casing string, made up of 10.75-in. and 9.625-in. casing, was installed to 856.94 m (2,811.48 ft) bgs in response to the borehole stability issues.

Cuttings samples generally showed variable contamination from 10 to 30 percent. Higher levels of contamination, from 30 to 50+ percent, were also noted as a result of sloughing bedded and nonwelded volcanic intervals. Contamination consisted primarily of Tertiary Volcanics (Tv) from uphole and some small intervals with significant construction materials (i.e., cement). As the borehole stability deteriorated and sloughing became severe, problems with fill, bridging, and obstructions made cuttings collection difficult.

When the volume of rock cuttings circulated to the surface was sufficient, triplicate sets of composite drill cuttings were collected at 3-m (10-ft) intervals on a continuous basis and stored in pint-sized paper containers. When triplicate samples were successfully collected, one container was sealed with custody tape as a controlled sample, and the remaining two containers were left unsealed and served as uncontrolled samples. Samples were not collected between 0 and 39.62 m (130) ft bgs because this interval was drilled by NSTec personnel and cased before Navarro personnel were present on the well site. A total of 274 sample intervals were collected, and there were 17 intervals where no sample was recovered and 13 intervals not attempted. All triplicate sets were delivered to and are stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

Additionally, when the volume of cuttings was sufficient, a portion of the composite drill cuttings collected at 3-m (10-ft) intervals was placed into chip trays. The chip trays were used by Navarro geologists for preliminary geologic field characterization.

Once the borehole had penetrated into the Paleozoic rocks (Pz), additional composite, paleontologic, samples of the cuttings were collected every 50 ft. These samples were placed in 1-gallon (gal) steel containers, labeled, and sealed with custody tape. These samples are also stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

4.2 Well Geophysical Data

Geophysical logging was conducted by Schlumberger and COLOG in the open borehole. The logs were used to characterize the lithology, structure, and petrophysical character of the rocks penetrated. The geophysical logs were also used to evaluate borehole conditions, establish levels of cement, determine fluid levels, and collect hydrologic data. One geophysical logging session was conducted in Well ER-4-1. Geophysical logging began on March 28, 2016, and was completed on March 29, 2016. Schlumberger conducted a geophysical logging session in Well ER-4-1 within the unsaturated zone to the upper portion of tunnel bed 1 (Ton1). COLOG collected hydrophysical (chemistry) information following the Schlumberger geophysical logging effort. COLOG experienced several equipment related issues and was only partially successful in collecting data from Well ER-4-1. Borehole conditions (i.e tight hole, washouts, and fill) prevented geophysical logging from collecting information below approximately 766.57 m (2,515 ft) bgs. All of the geophysical and hydrophysical logs acquired at Well ER-4-1 are summarized in Table 4-1.

The tight intervals in the borehole that impacted geophysical and hydrophysical logging occurred in the Tunnel Formation (Tn) and Older tunnel beds (Ton). These formations are typically altered to clays and zeolites and subject to swelling as well as borehole erosion.

Table 4-1
Well ER-4-1 Summary of Geophysical Logs

Geophysical Log	Log Purpose	Logging Service	Date Logged	Direction Logged	Top of Logged Interval (ft bgs)	Bottom of Logged Interval[a] (ft bgs)
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	Schlumberger	03/28/2016	Down	1,500	2,514
4-Arm Caliper, Spectral Gamma Ray, Formation Micro Imager, Deviation survey	Formation/Fluid: Water levels; Borehole condition (washouts, fractures); Lithologic/stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Alteration analysis; Borehole orientation and deviation	Schlumberger	03/28/2016	Up	2,148	2,515
Directional Survey, General Purpose Inclinometry Tool, Gamma Ray, Caliper	Formation: Borehole condition (washouts, fractures), Depth calibration check, Borehole orientation and deviation	Schlumberger	03/28/2016	Up	112	2,515
Three Detector Litho-Density, Epithermal Neutron, Gamma Ray, Caliper	Formation: Porosity and lithologic determination, Lithologic/stratigraphic analysis, Alteration analysis, Density, Borehole depth and condition (washouts, fractures)	Schlumberger	03/29/2016	Up	112	2,465
High Resolution Laterlog, Gamma Ray, Spontaneous Potential, Caliper	Formation: Borehole depth and condition (washouts, fractures), Resistivity, Thin bed analysis, Spontaneous Potential	Schlumberger	03/29/2016	Up	112	2,482
Idronaut Chemistry	Formation: Porosity and lithologic determination, Density, Borehole depth and condition (washouts, fractures), Resistivity	COLOG	03/29/2016	Down	1,885	2,286

[a] Bottom logged interval is from Schlumberger or COLOG Log Header Page.

K = Potassium
Th = Thorium
U = Uranium

Upon completion of geophysical logging activities on March 29, 2016, data from the Schlumberger logs were evaluated by Navarro geologists to assist in the selection of lithologic contacts and the final well completion design. Navarro and NSTec personnel noted two high amplitude anomalies in the average gamma track and the spectral gamma ray (SGR) log, indicative of prompt injection (see Figures 4-3a and 4-3b). The peaks are located from 472.44 to 481.48 m (1,550 to 1,580 ft) bgs and at approximately 539.50 m (1,770 ft) bgs. The depth of theses peaks and the depth of the STRAIT WP (782.4 m [2,567 ft] bgs) suggest that these anomalies may be associated with one of the other nearby UGTs. Two nearby tests, TECHADO (U4o) and ROUSANNE (U4p), may be considered sources, as these tests are located within approximately 2.5 R_c of the STRAIT (U4a) test but have WPs that are approximately 250 m (820 ft) shallower than the STRAIT (U4a) test. (Note: Cavity dimension based on maximum announced yield identified in NV-209-REV 16 [NNSA/NFO, 2015b] and Equation 1 in UCRL-ID-136003 [Pawloski, 1999].) The relative shallow gamma anomalies noted in Well ER-4-1 are more likely related to these nearby tests. Additional analytical chemistry was collected and is presented in Section 6.0 (see Tables 6-3 through 6-7).

Figures 4-1 through 4-4 present traces of selected geophysical logs. Geophysical log traces from separate logging runs were merged where possible to represent a continuous trace over the logged portion of the borehole. Note that borehole diameters and logged responses varied between the merged runs accounting for some of the variable quality of the log responses. All four figures present caliper and gamma ray log traces. Figure 4-1 includes temperature. Figure 4-2 includes bulk density, neutron porosity, and neutron counts. Figure 4-3a presents the SGR traces (uranium, thorium, and potassium) and Figure 4-3b presents a detailed view of the gamma peaks. Figure 4-4 presents shallow and deep resistivity log traces. Figure 4-5 presents a borehole deviation diagram for Well ER-4-1. Field copies of the logs in hard copy and digital formats are available from NSTec in Mercury, Nevada, and also from the Navarro office in Las Vegas, Nevada.

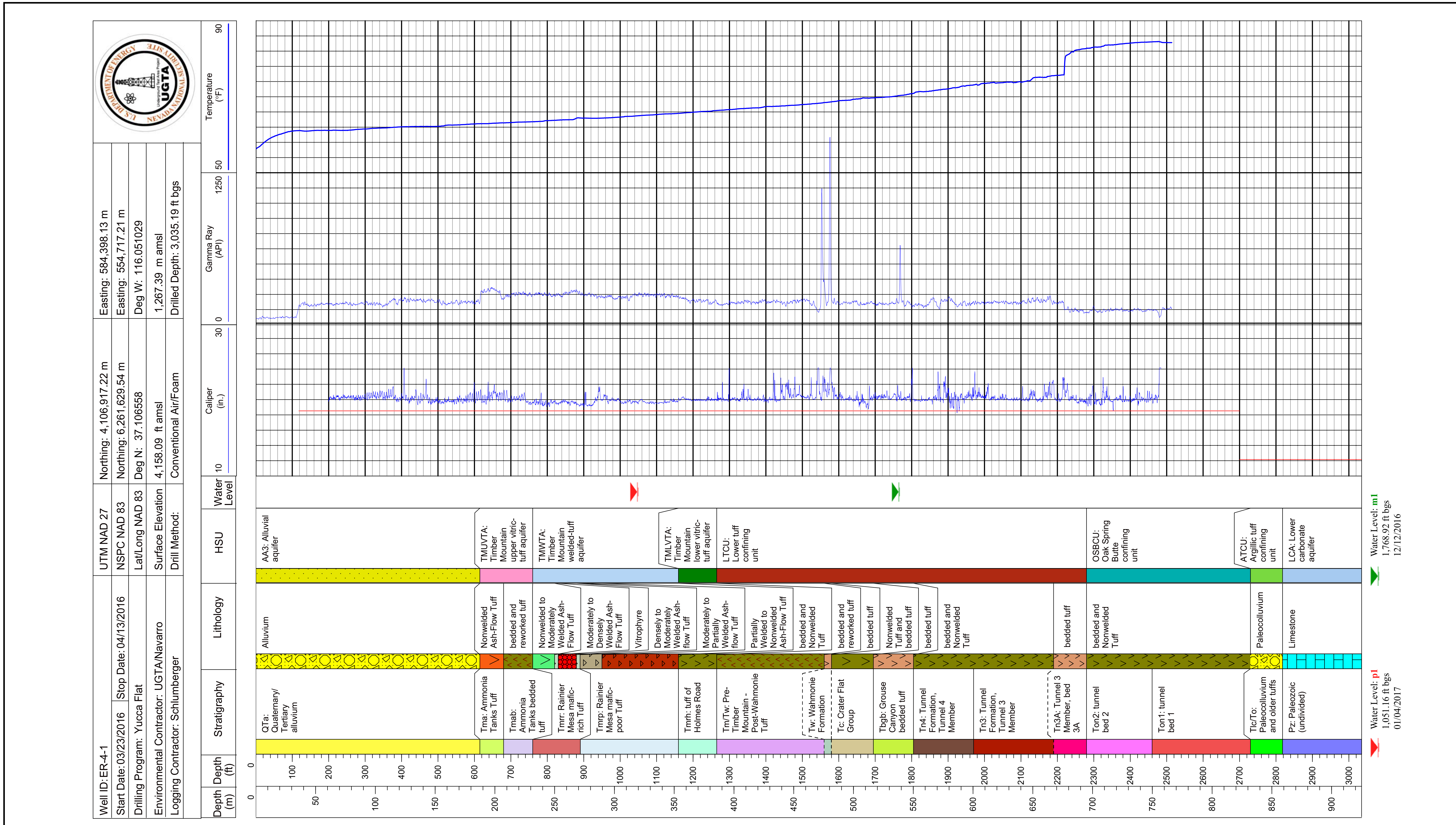


Figure 4-1
Well ER-4-1 Geophysical Log Traces of Caliper Average, Gamma Ray, and Temperature

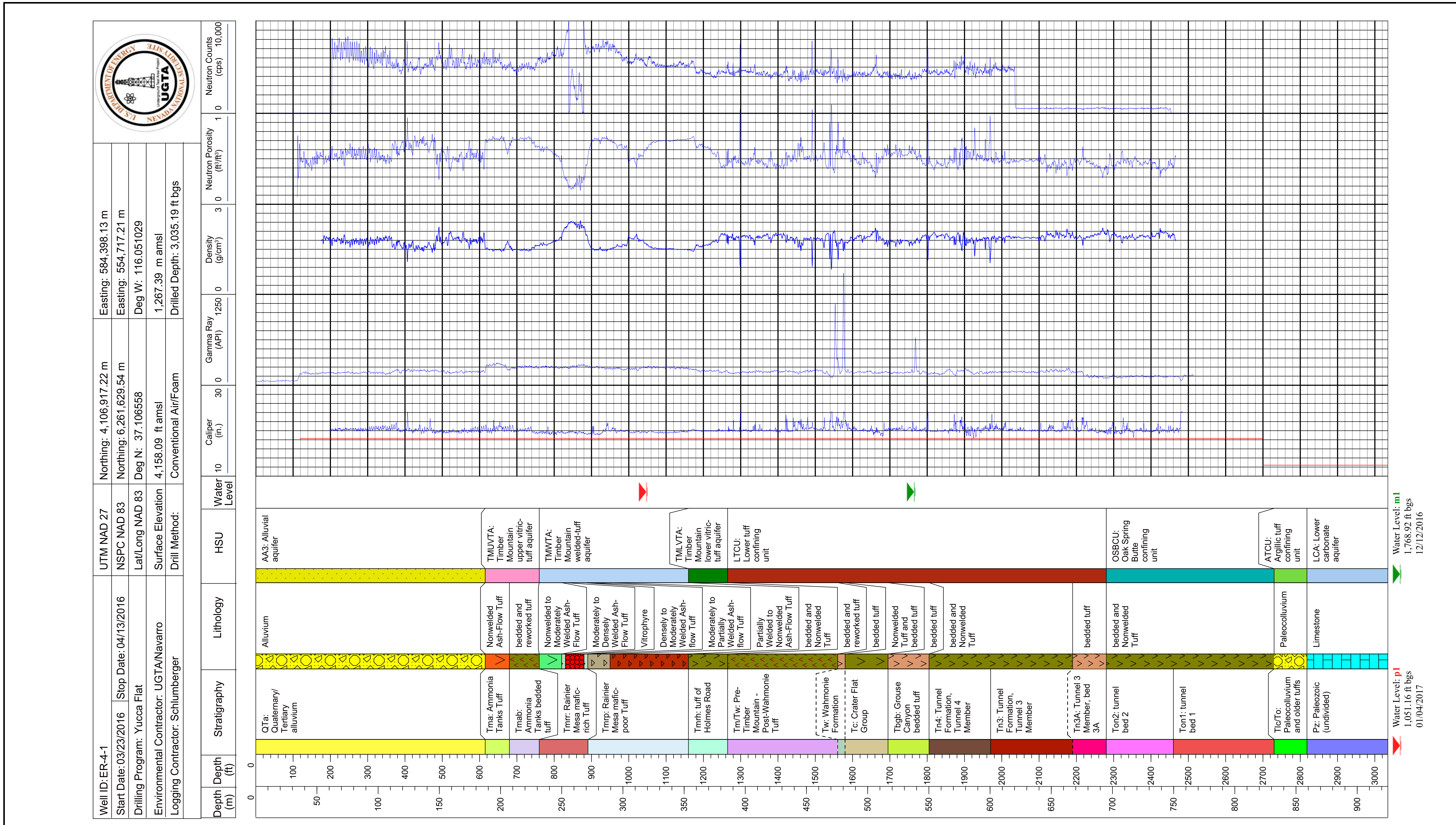


Figure 4-2
Well ER-4-1 Geophysical Log Traces of Caliper Average, Gamma Ray, Bulk Density, Neutron Porosity, and Neutron Counts

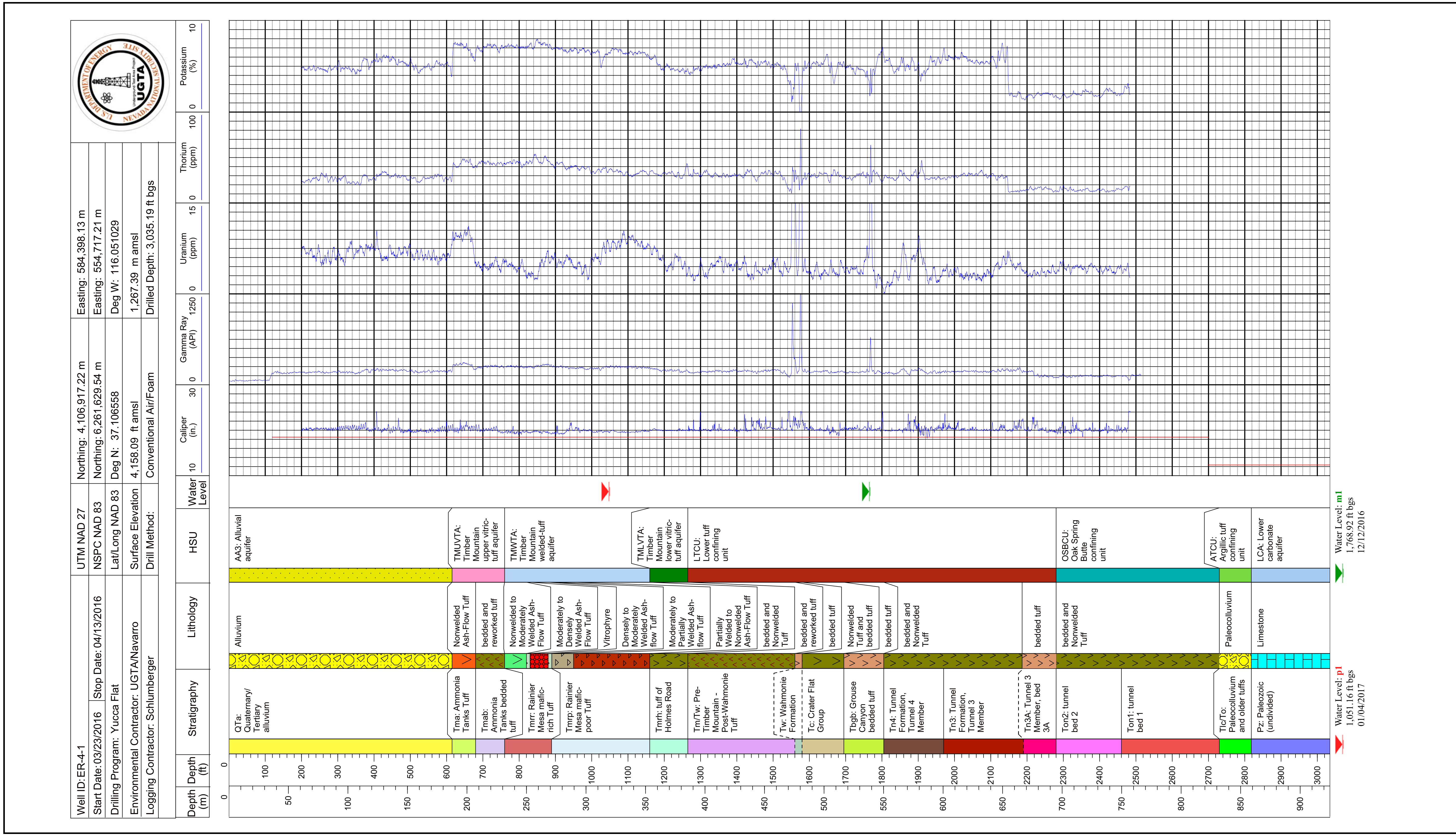


Figure 4-3a
Well ER-4-1 Geophysical Log Traces of Caliper Average, Gamma Ray, and Digital Spectralog

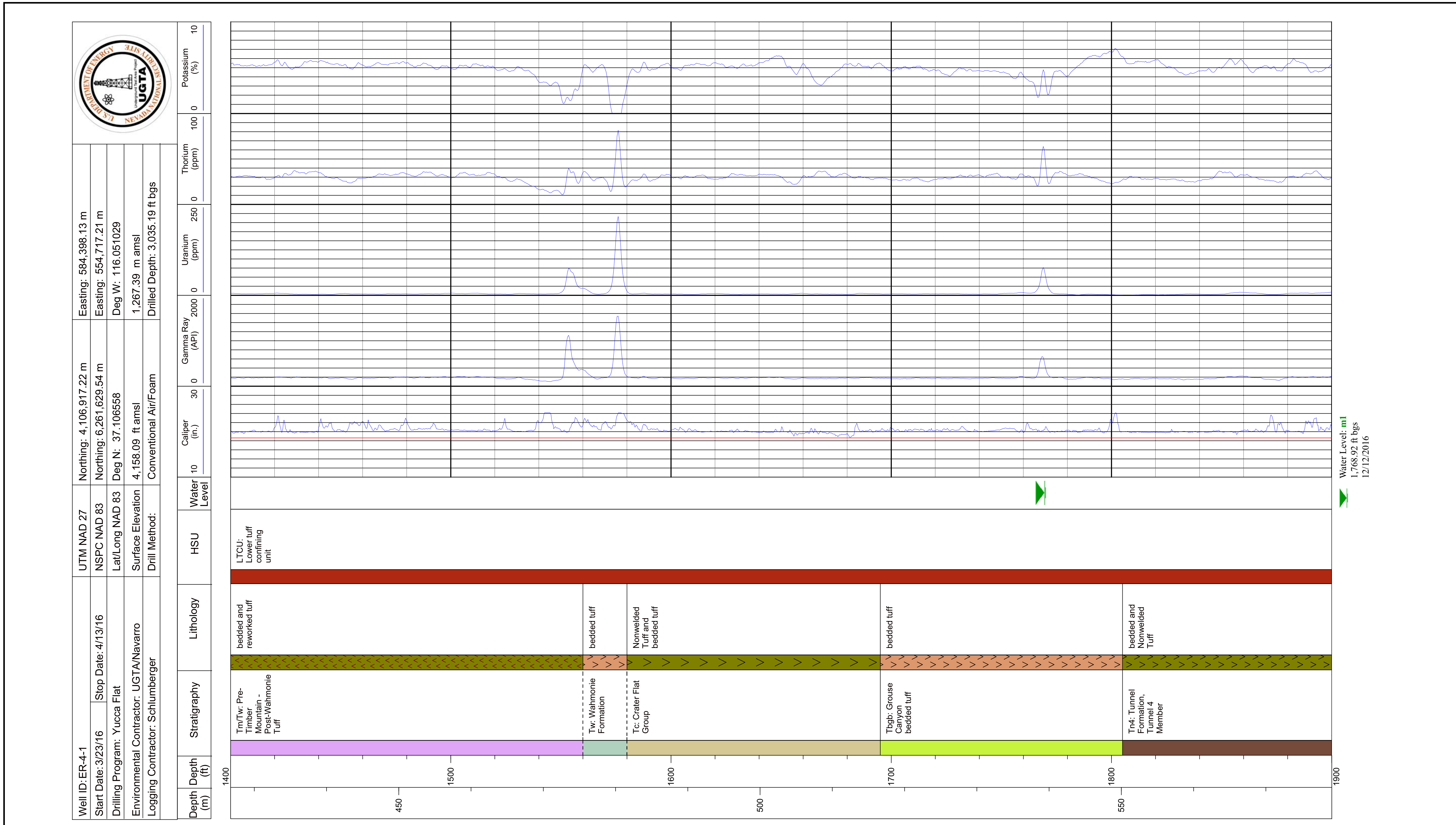


Figure 4-3b
Well ER-4-1 Detail Geophysical Log Traces of Caliper Average, Gamma Ray, and Digital Spectralog from 1,200 to 1,900 ft bgs

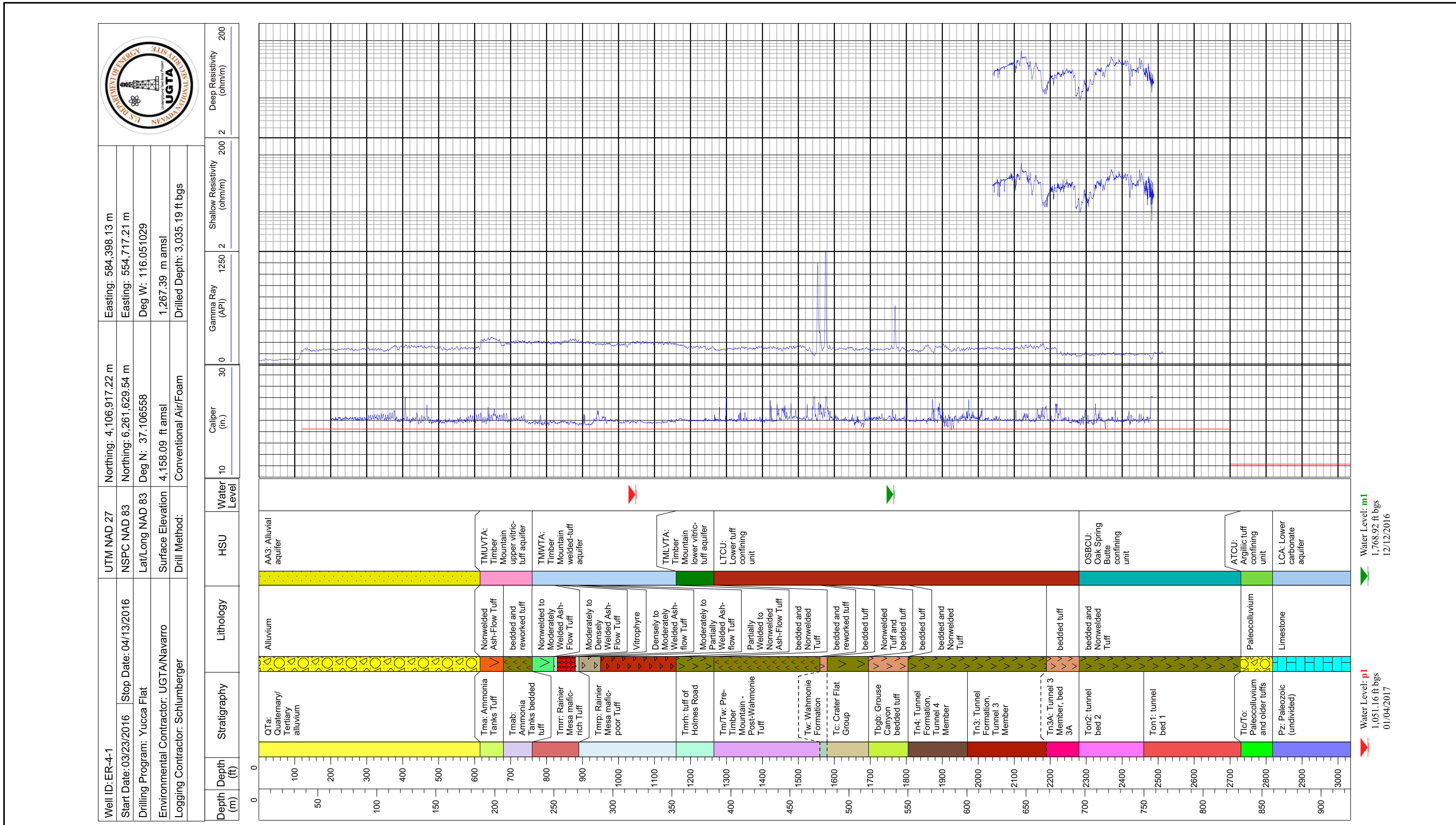


Figure 4-4
Well ER-4-1 Geophysical Log Traces of Caliper Average, Gamma Ray, and Shallow and Deep Resistivity

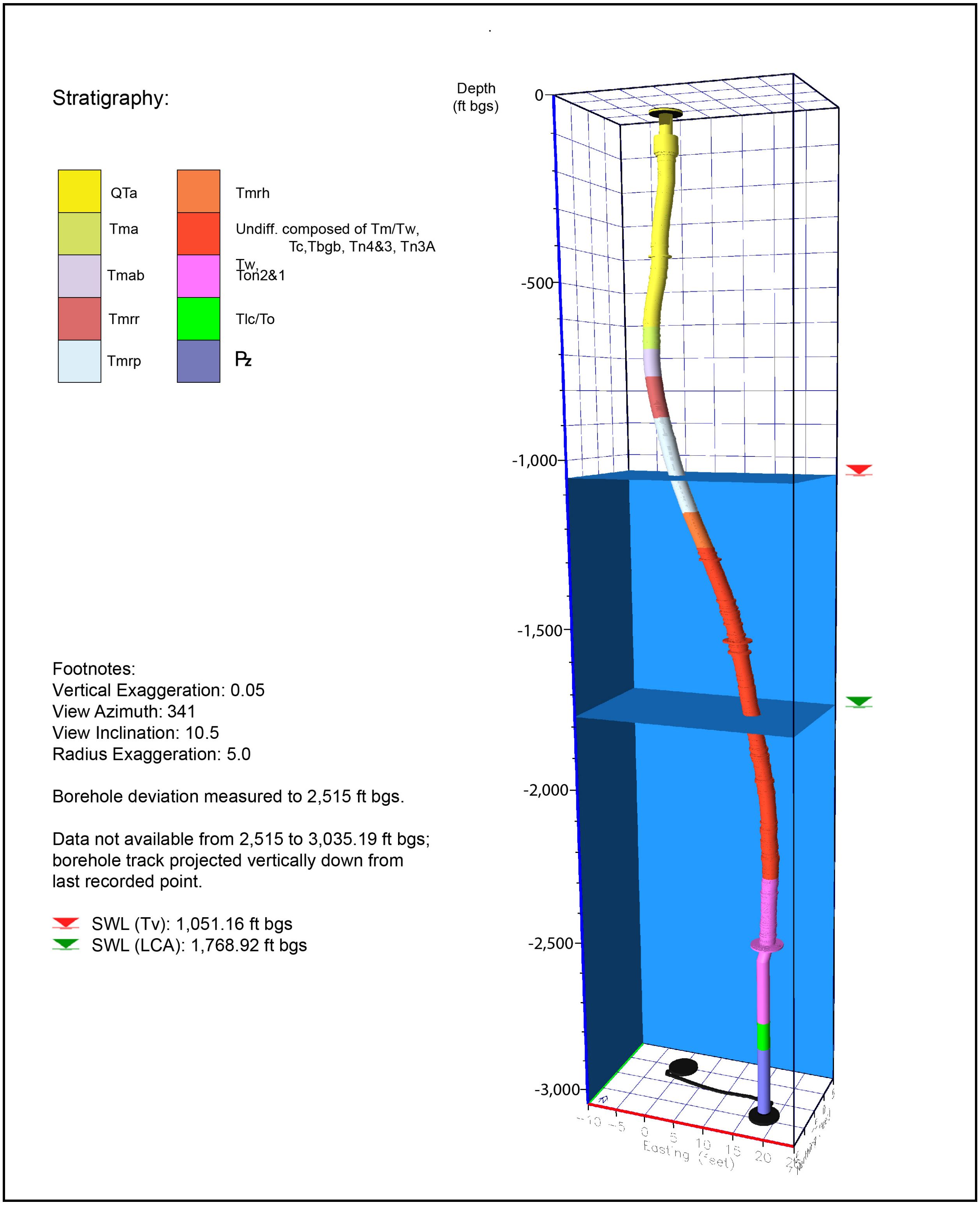


Figure 4-5
Well ER-4-1 Deviation Log and Stratigraphy

5.0 Geology and Hydrogeology

5.1 Geology

The following discussion and interpretations are primarily based on the lithologic log presented in Appendix A. The lithologic log was developed using the drill cuttings and borehole geophysical logs in the field. Figures and text in this report may not match field documents generated during drilling. The information presented in this report supersedes the information in field-generated reports.

During advancement of Well ER-4-1, the following stratigraphic units were encountered beginning at ground surface and down through to TD:

- Quaternary/Tertiary alluvium (QTa)
- Ammonia Tanks Tuff (Tma)
- Ammonia Tanks bedded tuff (Tmab)
- Rainier Mesa mafic-rich Tuff (Tmrr)
- Rainier Mesa mafic-poor Tuff (Tmrp)
- tuff of Holmes Road (Tmrh)
- Pre-Timber Mountain Tuff - Post-Wahmonie Tuff (undifferentiated) (Tm/Tw)
- Wahmonie Formation (Tw)
- Crater Flat Group (Tc)
- Grouse Canyon bedded tuff (Tbgb)
- Tunnel Formation (Tn)
- Older tunnel beds (Ton)
- Paleocolluvium/older tuffs (Tlc/To)
- Paleozoic rocks (₽z)

Surficial geology of the northern portion of Yucca Flat is presented in Figure 5-1. The stratigraphic units encountered in Well ER-4-1 were generally as predicted in the upper portion, and some important differences were noted in the lower portion of the hole. The Paintbrush Group (Tp) was not identified; however, this section was assigned to the Pre-Timber Mountain - Post-Wahmonie Tuff (Tm/Tw). Wahmonie Formation (Tw) and the Crater Flat Group were identified below the Tm/Tw, and no Tub Spring Tuff (Tub), Tuff of Yucca Flat (Toy), Older tunnel bed 3 (To3), or Tuff of Twin Peaks (Tot) were identified. The Grouse Canyon bedded tuff (Tbgb) and the Tunnel Formation (Tn) were notably thicker than predicted.

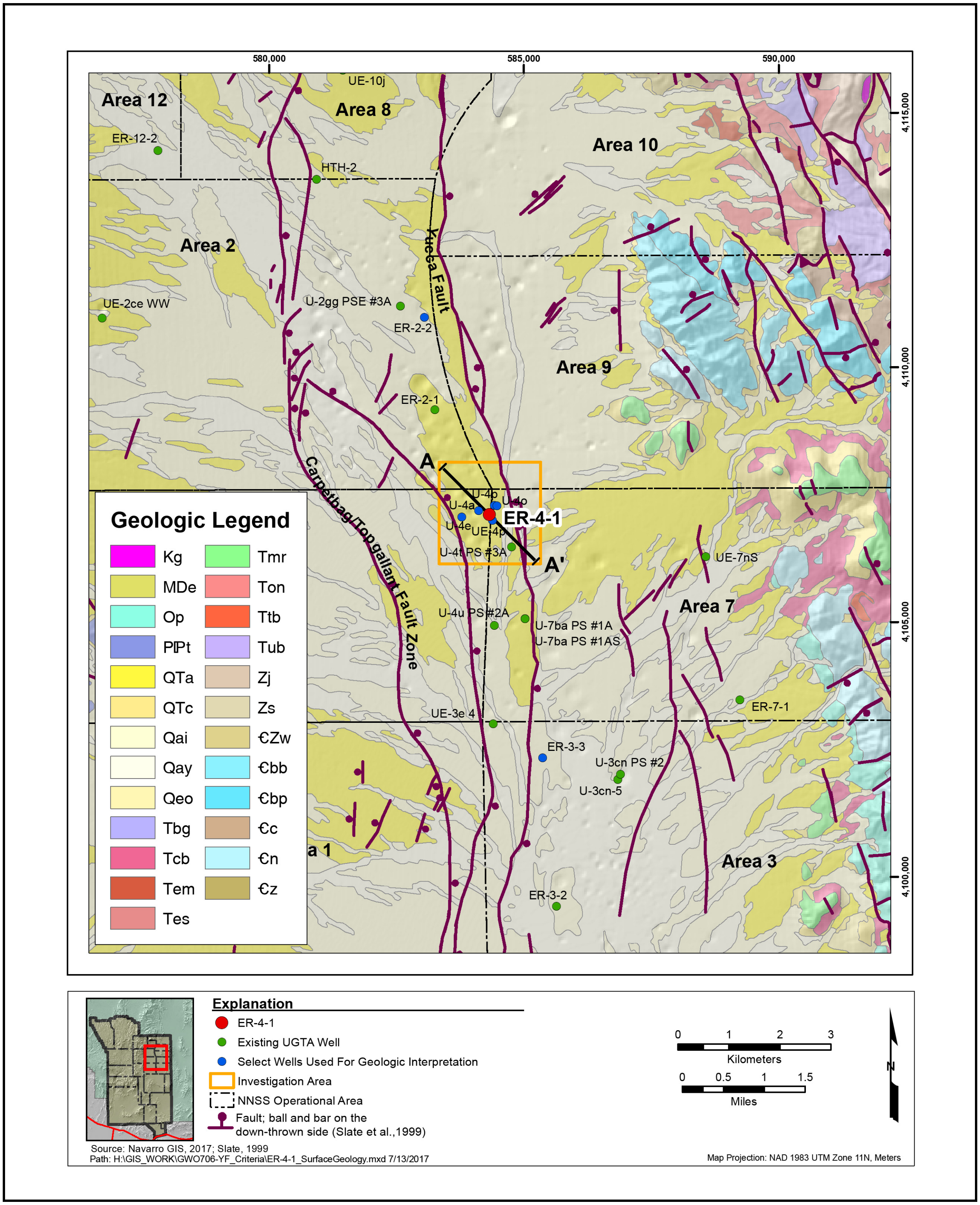


Figure 5-1
Surface Geology at Well ER-4-1

Finally, the top of the Paleozoic rocks (₱z) was predicted to be at a depth of 822.35 m (2,698 ft) bgs. Well ER-4-1 identified the actual top of the Paleozoic rocks (₱z) at 858.93 m (2,818 ft) bgs, a difference of 36.58 m (120 ft). Differences between predicted and actual geology in boreholes are not uncommon and may result from complex relationships between paleotopographic depositional conditions, volcanic, and structural processes associated with basin forming systems.

5.1.1 Geologic Setting

Well ER-4-1 is located in the area of Yucca Flat within the northeastern portion of the NNSS. Yucca Flat is a north–south elongated structural basin (half graben) on the eastern edge of the southwestern Nevada volcanic field and formed in response to basin and range extension. Surface drainage in the vicinity of Well ER-4-1 is generally to the Yucca Flat Playa near the south–central portion of the basin. Physiographically, the well site is located within the north–central portion of Yucca Flat basin.

5.1.2 Stratigraphy and Lithology

The stratigraphic units, lithologic units, and HSUs penetrated in Well ER-4-1 are listed in Tables 5-1 and 5-2. Lithologic descriptions, stratigraphic assignments, and their respective depth intervals can be found in Appendix A. Identification of stratigraphic and lithologic units was aided by correlation with stratigraphic units and lithologies observed in nearby boreholes (U-4a, UE-4p, U-4p, U-4o, U-4e, ER-3-3, and ER-2-1), and in the Yucca Flat HFM presented in *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat–Climax Mine, Lincoln and Nye Counties, Nevada* (BN, 2006).

Drilling at Well ER-4-1 initially penetrated alluvial material (i.e., sand, gravel, and silt) assigned to Quaternary/Tertiary alluvium (QTa), which forms the ground surface in the vicinity of the well. The Quaternary/Tertiary alluvium (QTa) is composed of fragments of various Tertiary Volcanics (Tv) and Paleozoic rocks (₱z) eroded from the surrounding highlands. This unit was generally as predicted. A total of 187.45 m (615 ft) of the Quaternary/Tertiary Alluvium (QTa) was penetrated.

The Timber Mountain Group (Tm) was encountered below the Quaternary/Tertiary Alluvium (QTa). The Timber Mountain Group (Tm), at ER-4-1, is composed of the Ammonia Tanks Tuff (Tma), Ammonia Tanks bedded tuff (Tmab), Rainier Mesa mafic-rich Tuff (Tmrr), Rainier Mesa mafic-poor

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-4-1 Area

Stratigraphic Unit	Map Symbol
Quaternary/Tertiary Alluvium	QTa
Timber Mountain Group	Tm
Ammonia Tanks Tuff	Tma
Ammonia Tanks bedded tuff	Tmab
Rainier Mesa mafic-rich Tuff	Tmrr
Rainier Mesa mafic-poor Tuff	Tmrp
tuff of Holmes Road	Tmrh
Pre-Timber Mountain - Post-Wahmonie Tuff	Tm/Tw
Wahmonie Formation	Tw
Crater Flat Group	Tc
Grouse Canyon bedded tuff	Tbgb
Tunnel Formation	Tn
Older tunnel beds	Ton
Paleocolluvium/Older tuffs	Tlc/To
Paleozoic rocks	Pz

Table 5-2
Key to HSUs and Symbols of the Well ER-4-1 Area

HSU	Map Symbol
Alluvial aquifer	AA3
Timber Mountain upper vitric aquifer	TMUVTA
Timber Mountain welded-tuff aquifer	TMWTA
Timber Mountain lower vitric-tuff aquifer	TMLVTA
Lower tuff confining unit	LTCU
Oak Spring Butte confining unit	OSBCU
Argillic tuff confining unit	ATCU
Lower carbonate aquifer	LCA

Tuff (Tmrp), and the tuff of Holmes Road (Tmrh), which were deposited approximately 11.6 million years ago (Ma) from the Timber Mountain caldera complex (TMCC) (Sawyer et al., 1994), located approximately 18.22 kilometers (km) (11.33 miles [mi]) to the west. The borehole penetrated 198.12 m (650 ft) of Timber Mountain Group (Tm) tuffs from 187.45 to 385.57 m (615 to 1,265 ft) bgs.

The Ammonia Tanks Tuff (Tma) is from 187.45 m (615 ft) to 207.26 m (680 ft) bgs and was identified by its stratigraphic position; high phenocryst content (15 to 20 percent); and mineralogic assemblage, including terminated and dipyramidal quartz, sanidine (chatoyant), and rare sphene. The Ammonia Tanks bedded tuff (Tmab) follows from 207.26 m (680 ft) to 231.65 m (760 ft) bgs and was identified based on stratigraphic position and the bedded/reworked nature of the material. Next in the sequence from 231.65 m (760 ft) to 271.27 m (890 ft) bgs is the Rainier Mesa mafic-rich Tuff (Tmrr), which was identified by its stratigraphic position and the mineralogic assemblage, including the presence of sanidine, terminated and dipyramidal quartz, and common to abundant mafics (e.g., biotite). The Rainier Mesa mafic-poor Tuff (Tmrp) followed from 271.27 m (890 ft) to 353.57 m (1,160 ft), and was identified by its stratigraphic position and the mineralogic assemblage, including the presence of terminated and minor-to-rare dipyramidal quartz and minor-to-rare mafics.

From 353.57 m (1,160 ft) to 385.57 m (1,265 ft) bgs is the tuff of Holmes Road (Tmrh), which marks the base of the Timber Mountain Group (Tm). The tuff of Holmes Road (Tmrh) was identified on the basis of stratigraphic position, phenocryst content less than approximately 10 percent, abundant quartz with minor-to-abundant mafics, and very abundant pumice. Also, the density and SGR geophysical log responses suggest a possible break.

Following the Timber Mountain Group, Well ER-4-1 penetrated a series of indeterminate nonwelded and bedded/reworked tuffs that have been assigned to Pre-Timber Mountain - Post-Wahmonie Tuffs (Tm/Tw). This unit extends from 385.57 m (1,265 ft) to 475.49 m (1,560 ft) bgs. The unit is generally crystal-poor to crystal-moderate with rare quartz and pervasively altered. Cuttings from this interval were not wholly representative of the interval, and no definitive identification could be made on the basis of microscope examination. The Wahmonie Formation (Tw) was encountered next and runs from 475.49 m (1,560 ft) to 481.58 m (1,580 ft) bgs. The Wahmonie was recognized by characteristic geophysical log response (Figure 4-3b) and its abundant mafics. A strong anomalous response was noted in the average gamma ray and SGR logs (uranium and thorium tracks) from approximately 472.44 m (1,550 ft) to 480.06 m (1,575 ft) bgs. The interval corresponds primarily to the Wahmonie Formation (Tw). This anomaly suggests a prompt injection (Figures 4-3a and 4-3b) and is discussed in Section 6.0. Due to contamination from overlying volcanics, the samples are not wholly representative of the interval.

Following the Wahmonie Formation is an interval of nonwelded to bedded tuffs assigned to the Crater Flat Group (Tc) from 481.58 m (1,580 ft) to 516.64 m (1,695 ft) bgs. This assignment was based on stratigraphic position, phenocryst make-up, and lithic content. The Grouse Canyon bedded tuff (Tbgb) was identified in Well ER-4-1 from 516.64 m (1,695 ft) to 550.16 m (1,805 ft) by its stratigraphic position, distinctive color, and peralkaline nature (i.e. no mafics). A second anomalous response in the average gamma ray and SGR logs at approximately 537.97 m (1,765 ft) bgs was noted. This corresponds to the lower portion of the Grouse Canyon bedded tuff. See Figures 4-3a and 4-3b and Section 6.0 for further discussion.

The Tunnel Formation (Tn) was encountered from 550.16 m (1,805 ft) to 694.94 m (2,280 ft) bgs and was recognized on the basis of the following characteristics: stratigraphic position; distinctive multicolor banding; phenocryst poor, scattered lithic-rich (volcanic) intervals; and pervasive alteration. The Tunnel Formation (Tn) is broken out as follows: Tunnel Formation, Member 4, undivided (Tn4) from 550.16 m (1,805 ft) to 600.46 m (1,970 ft) bgs; Tunnel Formation, Member 3, undivided (Tn3) from 600.46 m (1,970 ft) to 667.51 m (2,190 ft) bgs. Due to the poor quality of the cuttings they are distinguished primarily on the basis of following; the Grouse Canyon bedded tuff (Tbgb) and responses of the caliper and SGR geophysical logs. Tunnel Formation, Member 3, bed 3A (Tn3A), is indicated by the pervasive red coloration, small light colored pumice, and sandy texture with silty ash beds, from 667.51 m (2,190 ft) to 694.94 m (2,280 ft) bgs. Cuttings in these intervals have significant contamination.

Older tunnel beds (Ton) were encountered below the Tunnel Formation (Tn) from 694.94 m (2,280 ft) to 832.10 m (2,730 ft) bgs. The Older tunnel beds (Ton) were recognized on the basis of their lithologic character, distinctive alteration, and color. The Older tunnel beds consist of tunnel bed 2 (Ton2) from 694.94 m (2,280 ft) to 749.81 m (2,460 ft) bgs and tunnel bed 1 (Ton1) from 749.81 m (2,460 ft) to 832.10 m (2,730 ft) bgs. The lithologic and alteration types found in the Tunnel

Formation (Tn) and the Older tunnel beds (Ton) contributed to the borehole stability issues, erosion, and tight hole conditions experienced at the well.

Paleocolluvium and older tuffs (Tlc/To) were encountered from 832.10 m (2,730 ft) to 858.93 m (2,818 ft) bgs. The Paleocolluvium appears to consist of a matrix of fine argillically altered ash and pumice with fragments of colluvial material consisting of carbonate, sedimentary, and volcanic rocks. Much of the fines were washed away by the drilling process. This interval also shows significant contamination of the cuttings samples due to sloughing borehole conditions from the intervals above this unit, and due to the nature of the argillic alteration, this interval was the most significant zone of tight hole conditions.

Paleozoic rocks (Pz) were encountered from 858.93 m (2,818 ft) to 925.13 m (3,035.19 ft) bgs for a total of 66.20 m (217.19 ft). The Paleozoic rocks (Pz) were composed of limestone. From approximately 880.87 m (2,890 ft) to 896.11 m (2,940 ft) bgs the cuttings exhibited signs of fracturing, brecciation, and open space filling mineralization indicating a breccia zone. Below 896.11 m (2,940 ft) to TD cuttings were primarily (80 to 90 percent) contamination, from the volcanics above, and less than 2mm in size indicating that they had been re-drilled. As expected, the principal water production occurred within the Paleozoic rocks (Pz).

5.1.3 Alteration

Generally, from 0 to 187.45 m (0 to 615 ft) bgs, the alluvium is unaltered to weakly clay altered with minor caliche. The Ammonia Tanks Tuff (Tma) and Ammonia Tanks bedded tuff (Tmab), from 187.45 m (615 ft) to 231.65 m (760 ft) bgs, are vitric and alteration is nonexistent to minimal. From 231.65 m (760 ft) to 353.57 m (1,160 ft) bgs, the Rainier Mesa Tuff (Tmr) is mostly devitrified with minor vapor phase alteration. From 353.57 m (1,160 ft) to 385.57 m (1,265 ft) bgs, the tuff of Holmes Road (Tmrh) is vitric with alteration gradually increasing with depth. Below 385.57 m (1,265 ft) to 858.93 m (2,818 ft) bgs, beginning in the Pre-Timber Mountain - Post-Wahmonie (Tm/Tw) and continuing through the Older tunnel beds (Ton) and Paleocolluvium (Tlc/To), the nonwelded and bedded tuffs are typically pervasively altered to zeolites, and locally intense argillized zones. Finally, the Paleozoic rocks (Pz) show minor, to locally moderate, alteration.

5.2 Predicted and Actual Geology

Overall, the actual stratigraphic sequence and lithology at Well ER-4-1 showed some differences with the predicted stratigraphic and related lithologic sequence. Figure 5-2 illustrates the differences between predicted and actual geology in Well ER-4-1.

Thicknesses in the Quaternary/Tertiary alluvium (QTa) were slightly less than predicted. The predicted thickness of the alluvium was 199.03 m (653 ft) and the actual thickness of the alluvium (QTa) was found to be 187.45 m (615 ft), a difference of -11.58 m (-38 ft).

Timber Mountain Group (Tm) rocks (i.e., Ammonia Tanks Tuff [Tma], Ammonia Tanks bedded tuff [Tmab], Rainier Mesa mafic-rich Tuff [Tmrr], Rainier Mesa mafic-poor Tuff [Tmrp], and the tuff of Holmes Road [Tmrh]) was thicker than predicted. The predicted thickness for the group was 163.37 m (536 ft) and the actual thickness found was 198.12 m (650 ft), for a difference of 34.75 m (114 ft).

The Paintbrush Group (Tp) was not definitively identified in the well and may be represented by a portion of the identified sequence of the Pre-Timber Mountain - Post-Wahmonie (Tm/Tw), Wahmonie Formation (Tw), and the Crater Flat Group (Tc). The actual thicknesses for these units is as follows: Tm/Tw, an actual thickness of 89.92 m (295 ft); Tw, an actual thickness of 6.10 m (20 ft); and Tc, an actual thickness of 35.05 m (115 ft). The total combined actual thickness for the units is 131.07 m (430 ft) as opposed to the predicted thickness of the Paintbrush Group (Tp) of 166.73 m (547 ft), for a difference of -35.66 m (-117 ft).

The Grouse Canyon bedded tuff (Tbgb) was identified in Well ER-4-1. The actual thickness is 33.53 m (110 ft) as opposed to the predicted thickness of the Grouse Canyon Tuff (Tbg) of 11.89 m (39 ft), for a difference of 21.64 m (71 ft).

The Tunnel Formation (Tn) was identified and subdivided as follows: Tunnel Member 4 (Tn4), Tunnel Member 3 (Tn3), and Tunnel Member 3, bed A (Tn3A). The actual thicknesses for these units is as follows: Tn4, an actual thickness of 50.29 m (165 ft); Tn3, an actual thickness of 67.06 m (220 ft); and Tn3A, an actual thickness of 27.43 m (90 ft).The predicted total thickness of the Tunnel Formation, Members 3&4 (Tn3 and Tn4) was 81.69 m (268 ft), and the actual thickness was 144.78 m (475 ft), a difference of 63.09 m (207 ft). The Tub Spring Tuff (Tub), which had a predicted

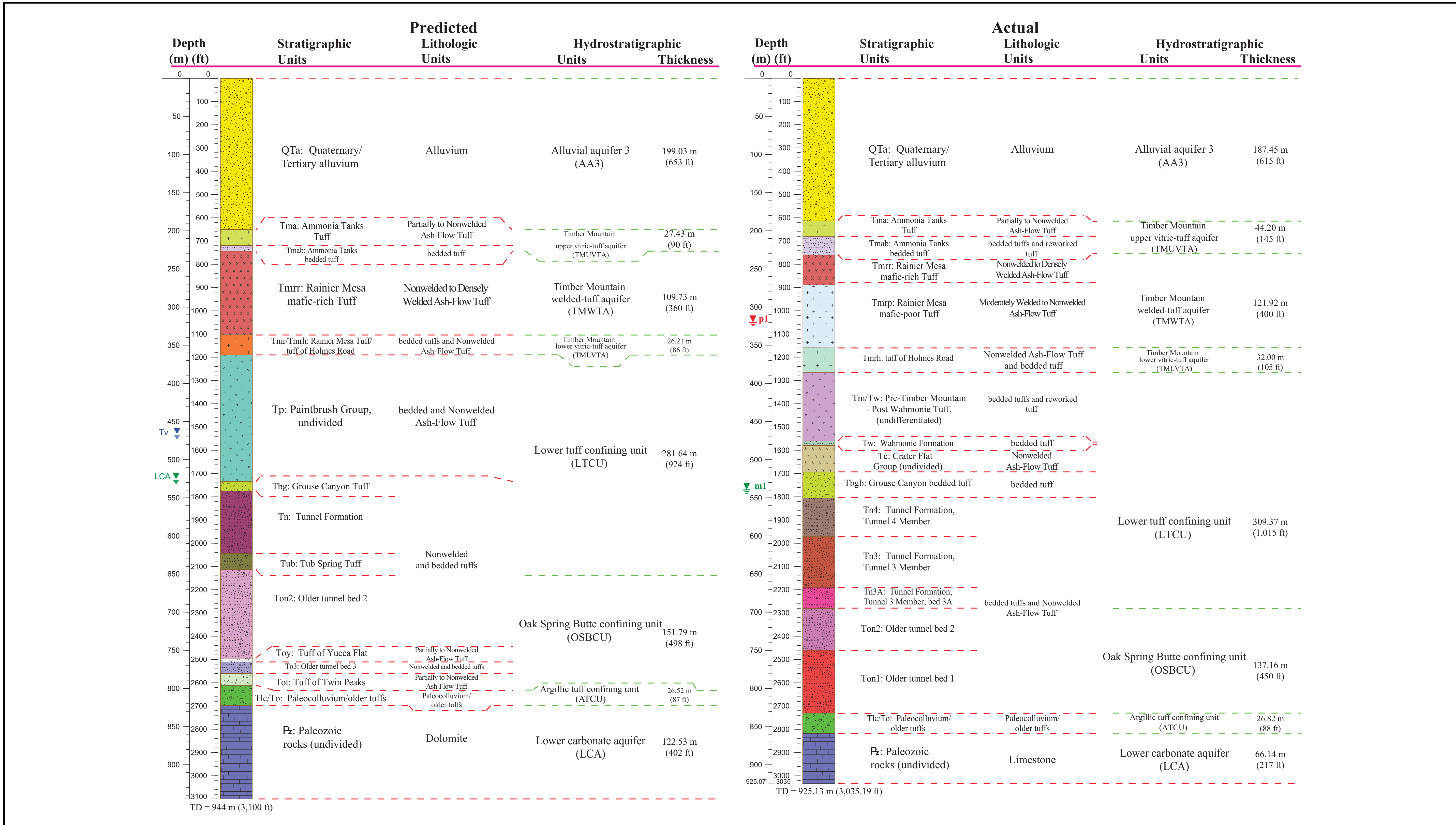


Figure 5-2
Predicted versus Actual Hydrogeology for Well ER-4-1

thickness of 21.34 m (70 ft), was not identified in the well. Preceding the Tunnel Formation (Tn) was the Older tunnel beds (Ton), tunnel bed 2 (Ton2), and tunnel bed 1 (Ton1). The actual thickness of Ton2 was 54.86 m (180 ft) versus a predicted thickness of 113.69 m (373 ft). Ton1 had not been predicted in Well ER-4-1 but had an actual thickness of 82.30 m (270 ft). Ton1 was identified instead of the predicted Toy, To3, and Tot units. The predicted thickness of tunnel bed 2 (Ton2) and the older tuffs (Toy, To3, Tot) was 151.79 m (498 ft); and the actual thickness of the Ton was 137.16 m (450 ft), a difference of -14.63 m (-48 ft). Completing the Tertiary section was the expected Paleocolluvium (Tlc/To). The Paleocolluvium/Older tuffs (Tlc/To) had a predicted thickness of 26.52 m (87 ft), whereas the actual thickness was 26.82 m (88 ft), a difference of 0.3 m (1 ft).

The top of the Paleozoic rocks (Pz) was identified at 858.93 m (2,818 ft) bgs, a total of 36.58 m (120 ft) deeper than predicted. A total of 66.20 m (217.19 ft) of Paleozoic rocks (Pz) were penetrated in Well ER-4-1. Figure 5-3 illustrates the relationship between the stratigraphy, lithology, alteration, and hydrogeologic units (HGUs) identified in Well ER-4-1. Figure 5-4 shows the relationship between Well ER-4-1 and surrounding UGTs; other select wells; and the mapped surface effects from nearby UGTs including the STRAIT test. The stratigraphic units and HSUs in the vicinity of the well are shown in cross section in Figures 5-5 and 5-6. Note in Figure 5-5 that the stratigraphic units below the Timber Mountain Group and above Older tunnel bed 2 (Ton2) are grouped as “Undivided” for the purpose of modeling. These units are only shown in the vicinity of Well ER-4-1 and may not extend across the section. The cross-section line is shown on the surface geology map (Figure 5-1).

5.3 Hydrogeology

HSUs are groups of contiguous stratigraphic units that have a particular hydrogeologic character—such as an aquifer, composite unit, or a confining unit—as defined in the *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat–Climax Mine, Lincoln and Nye Counties, Nevada* (BN, 2006). Therefore, HSUs may cross stratigraphic boundaries where lithologic properties may be similar. HSUs are developed from a system of HGUs that categorize rock units as aquifers or confining units according to their porosity and permeability, primary lithology, type of post-depositional alteration, and propensity to fracture. Figure 5-2 provides a comparison of predicted versus actual geologic units, HGUs, and HSUs found at Well ER-4-1.

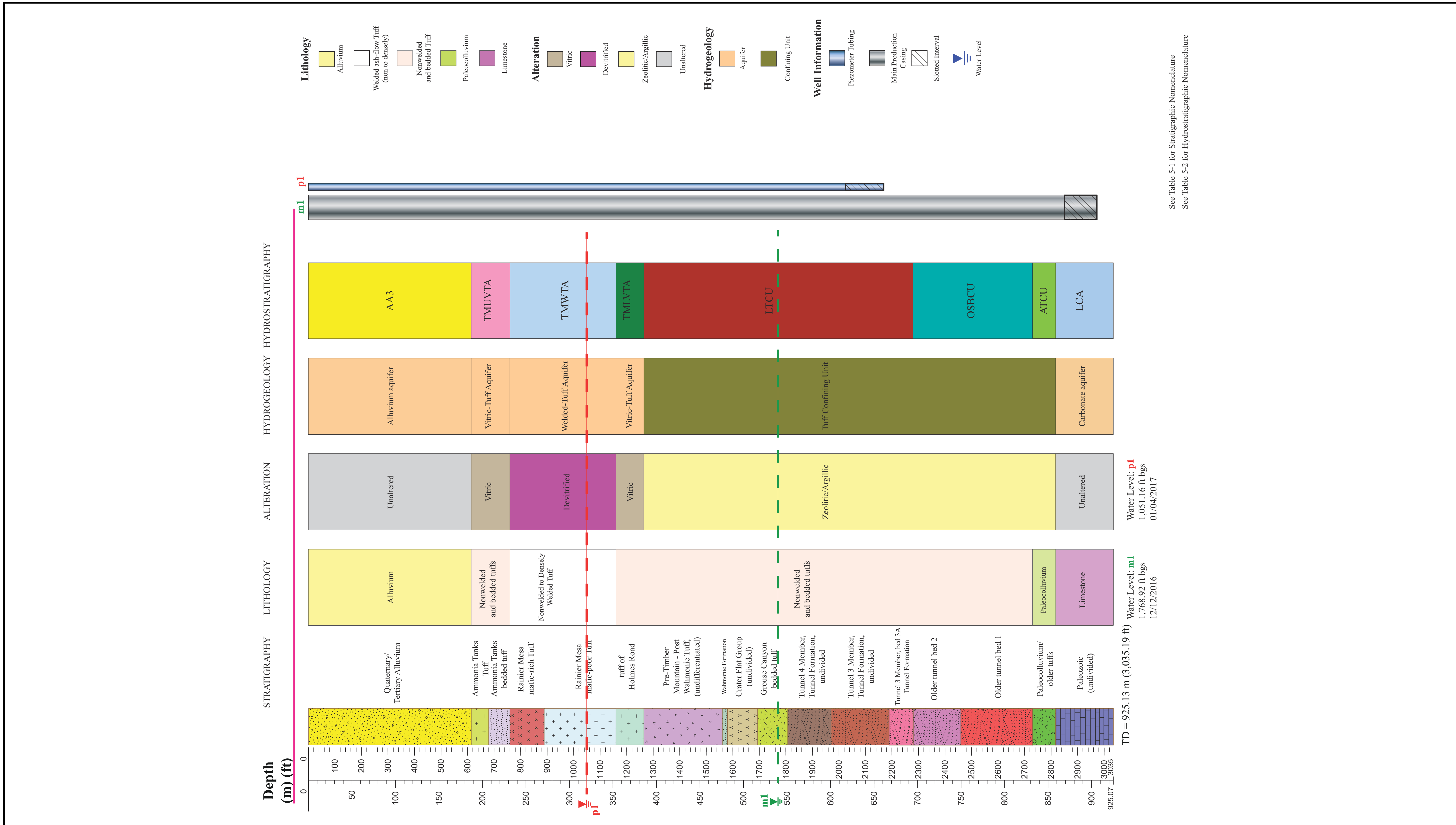


Figure 5-3
Graphical Presentation Showing Geology and Hydrogeology for Well ER-4-1

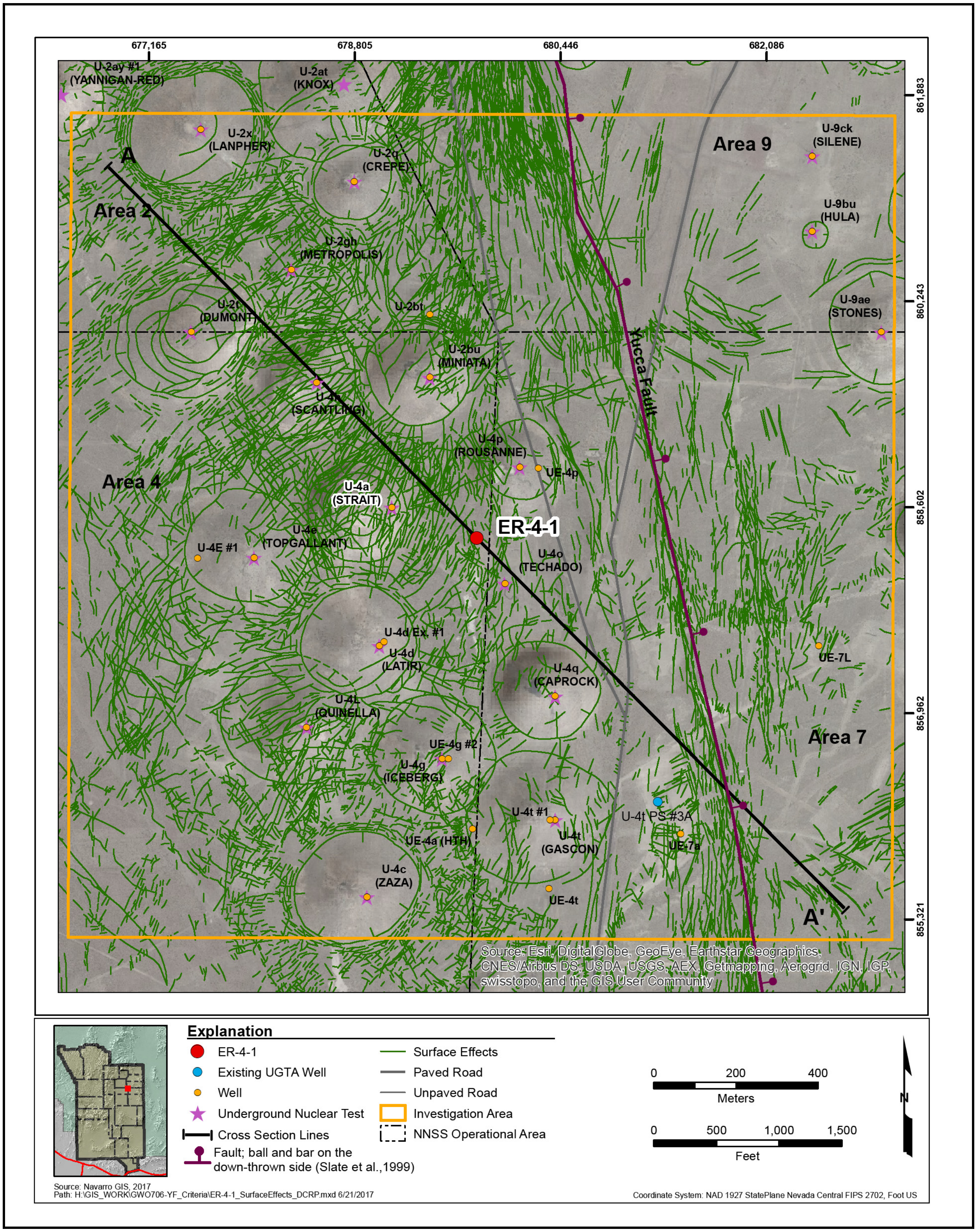


Figure 5-4
Surface Effects Map for the Well ER-4-1 Area

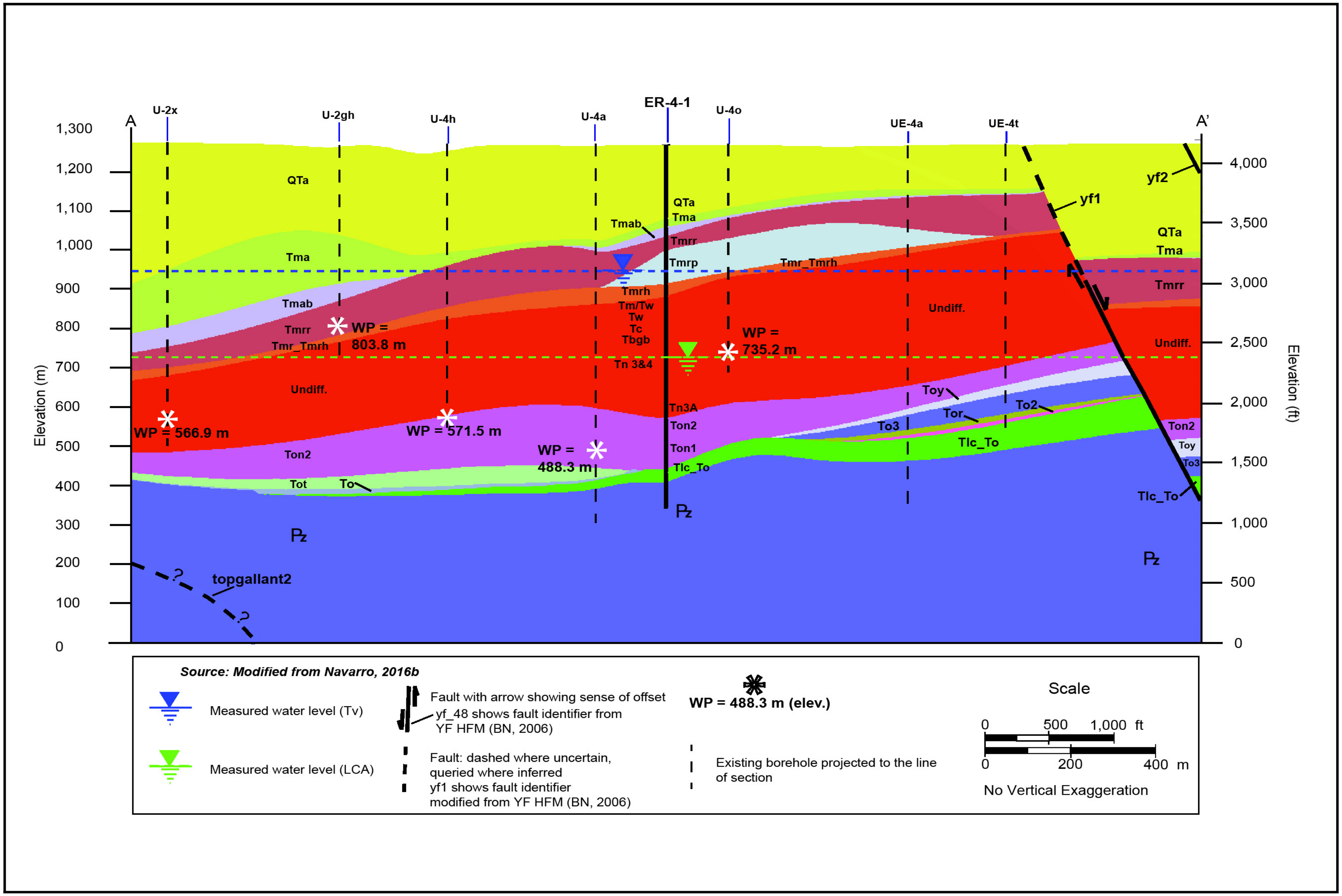


Figure 5-5
Stratigraphic Cross Section Northwest to Southeast

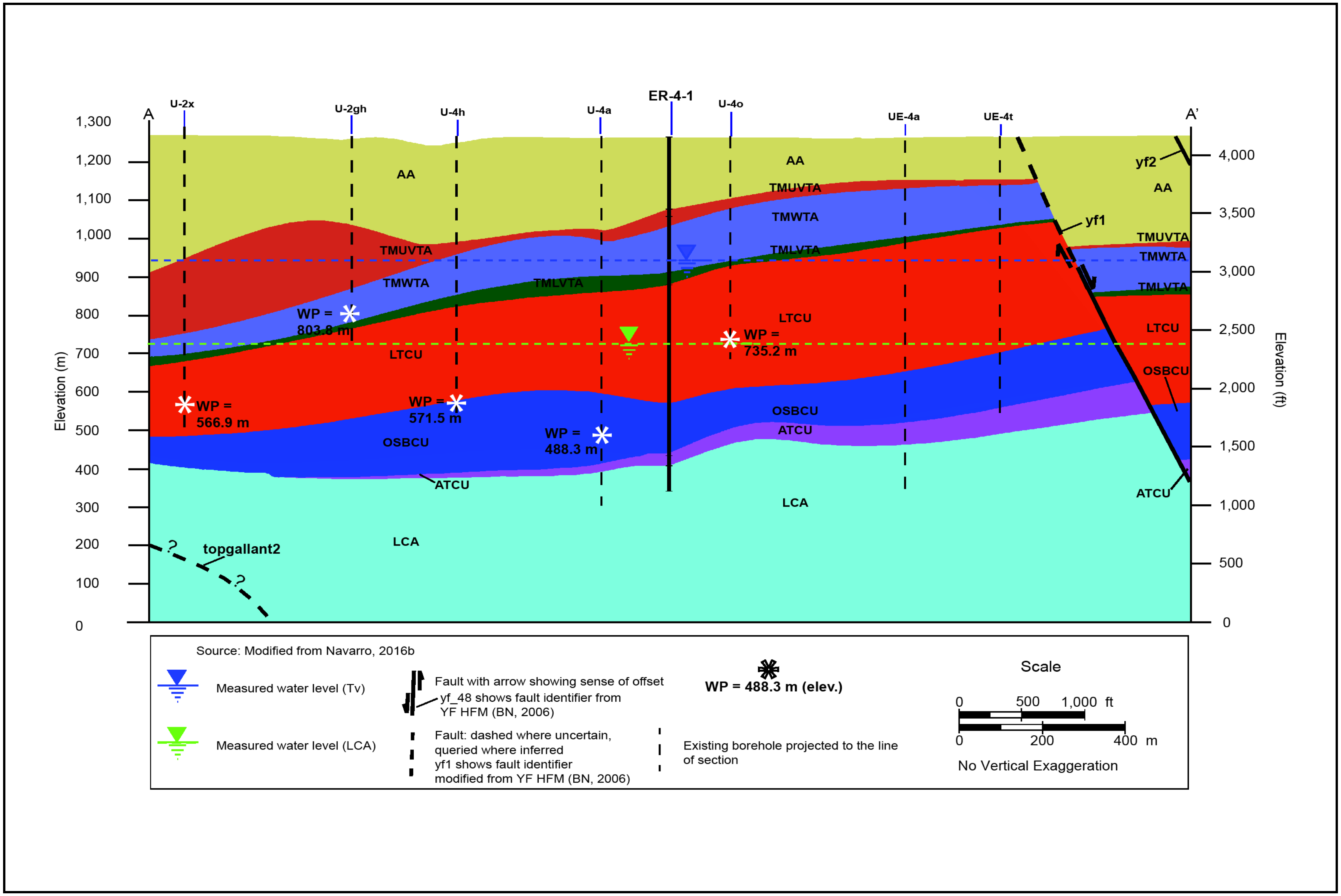


Figure 5-6
Hydrostratigraphic Cross Section Northwest to Southeast

HSUs present were as predicted. Based on the identification of key stratigraphic units (i.e., Ammonia Tanks Tuff [Tma], Rainier Mesa Tuff [Tmr], Wahmonie Formation [Tw], Grouse Canyon bedded tuff [Tbgb] and Paleozoic rocks [Pz]), a high degree of confidence in the HSUs identified and depths assigned to them in Well ER-4-1 is warranted.

The distribution of HSUs in the vicinity of Well ER-4-1 is shown in cross section in Figure 5-6.

The well penetrated a total of eight HSUs: (1) AA3 from 0.00 to 187.45 m (0 to 615 ft) bgs, (unsaturated); (2) TMUVTA from 187.45 to 231.65 m (615 to 760 ft) bgs, (unsaturated); (3) TMWTA from 231.65 to 353.57 m (760 to 1,160 ft) bgs, (unsaturated above 320.39 m [1,051.16 ft] bgs); (4) TMLVTA from 353.57 to 385.57 m (1,160 to 1,265 ft) bgs, (saturated); (5) LTCU from 385.57 to 694.94 m (1,265 to 2,280 ft) bgs, (saturated); (6) OSBCU from 694.94 to 832.10 m (2,280 to 2,730 ft) bgs, (saturated); (7) ATCU from 832.10 to 858.93 m (2,730 to 2,818 ft) bgs, (saturated); and (8) LCA from 858.93 to 925.13 m (2,818 to 3,035.19 ft) bgs, (saturated). The relationship between the HSUs in the vicinity of Well ER-4-1 and the phenomenology of the STRAIT (U4a) UGT is illustrated in Figure 5-7.

The saturated portion of Well ER-4-1 consists of four HGUs, including a portion of the welded-tuff aquifer [WTA] HGU and all of the subsequent HGUs (vitric-tuff aquifer [VTA], TCU, and CA), as shown in Figure 5-3. The package of aquifer-type rock units is divided by TCUs that consist of zeolitically and argillically altered nonwelded ash flows and bedded tuffs and paleocolluvium and are assigned to the LTCU, OSBCU, and ATCU, respectively.

The altered tuffs below the TMUVTA are primarily confining units and showed little to no water production based on LiBr calculations and visual estimates during drilling. The LCA was the productive HSU in Well ER-4-1 as expected. Water production—which had been minimal since penetrating the TMUVTA, at approximately 0 to 10 gpm—increased to approximately 25 to 50 gpm upon penetrating the LCA and increased to an estimated 175 gpm. Lithium bromide (LiBr) calculations presented in Appendix C and discussed in Section 6.0.

Before drilling, it was predicted that the Tertiary Volcanics (Tv) SWL would be encountered at 484.33 m (1,589 ft) bgs within the TMWTA HSU. The depth to water in the Tertiary Volcanics (Tv) units was measured in piezometer p1 on January 4, 2017, at 320.29 m (1,051.16 ft) bgs and was found

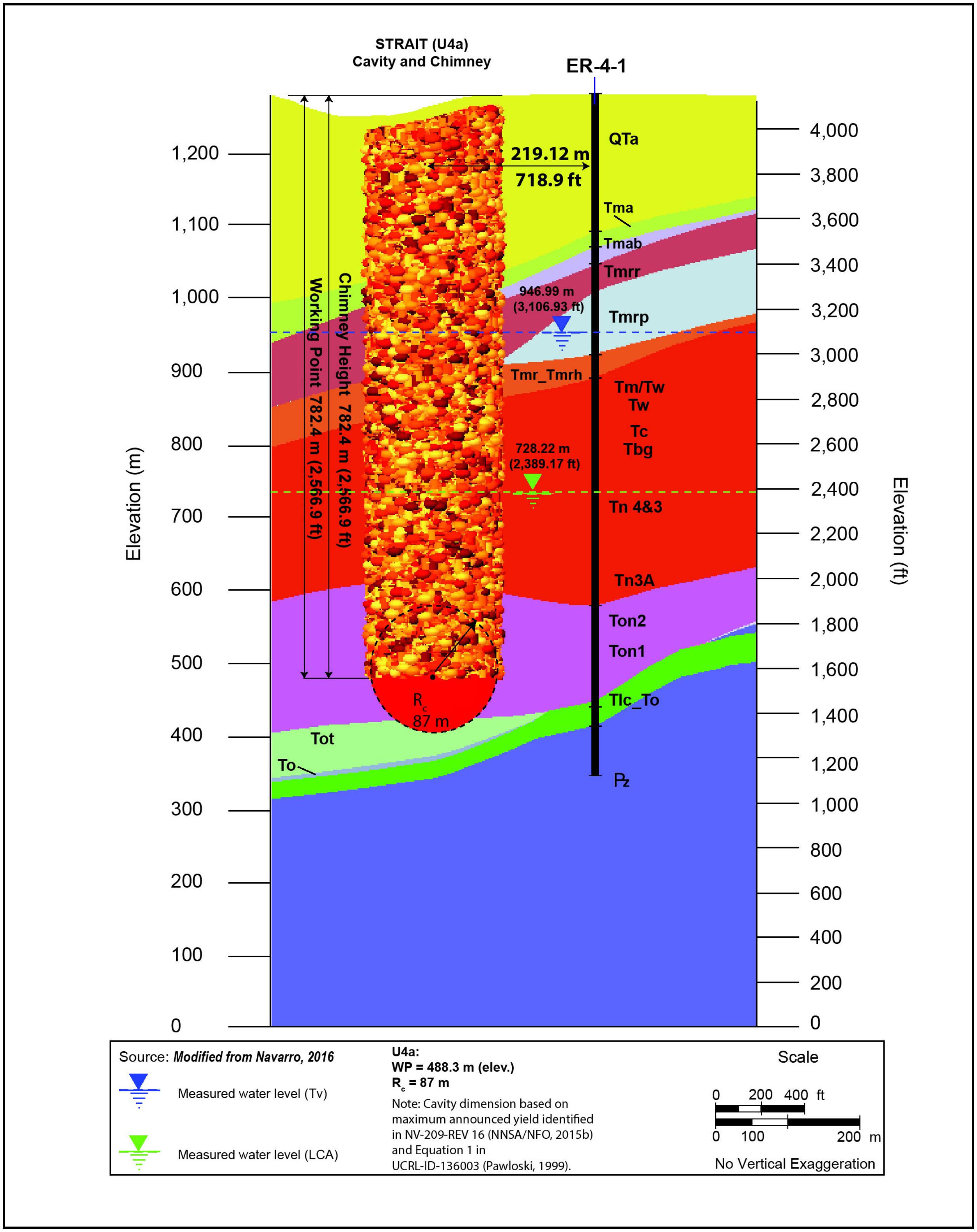


Figure 5-7
Schematic Diagram of the STRAIT Crater, Cavity, and Chimney

to occur higher, than the predicted level, within the TMWTA HSU. On December 12, 2016, Navarro personnel collected a water level from the main production casing slotted interval m1 in the LCA. The water level recorded was 539.17 m (1,768.92 ft) bgs. See Figure 3-1 and Section 6.0 for details.

6.0 Hydrology and Water Chemistry

6.1 Well Hydrology

Hydrologic data collected at the well site included water-level measurements, groundwater production values during drilling, and borehole water-quality measurements from discharged drilling fluids. The following subsections summarize the well hydrology observed during drilling and well completion operations.

6.1.1 Water Levels

The predicted SWL in the volcanic units was 484.33 m (1,589 ft) bgs (Navarro, 2016d). Depth to water in piezometer p1 was measured on January 4, 2017, in the Tertiary Volcanics (Tv) units at 320.39 m (1,051.16 ft) bgs using a calibrated e-tape.

The predicted SWL in the carbonates was 527.61 m (1,731 ft) bgs (Navarro, 2016d). Depth to water in the LCA was measured in the main completion (m1) on December 12, 2016, at 539.17 m (1,768.92 ft) bgs using a calibrated e-tape.

Fluid-level data collected during geophysical logging and by Navarro personnel are summarized in Table 6-1.

6.1.2 Water Production

During drilling operations, an LiBr tracer was added to drilling fluids before being injected downhole. Bromide concentrations in mixing tanks and in discharged fluids were monitored regularly as drilling progressed. Differences between injected and discharged bromide concentrations are used to estimate groundwater production rates. These calculations along with visual estimates of drilling discharge rates and sump level changes are used to estimate groundwater production during drilling presented in Figure 2-2. Appendix C summarizes bromide tracer results and calculated water production rates from Well ER-4-1.

Based on bromide dilution calculations, water production of 5 to 10 gpm was first noted in Well ER-4-1 around 609.6 m (2,000 ft) bgs within the LTCU. Estimated water production rates

Table 6-1
Well ER-4-1 Water-Level Measurements

Date Time	Fluid Depth		Fluid Elevation [a]		Notes
	m bgs	ft bgs	m amsl	ft amsl	
ER-4-1 Main Completion (m1)					
12/12/2016 10:40	539.17	1,768.92	728.22	2,389.17	Navarro measured static water level (LCA) using calibrated Solinst e-tape.
09/08/2016 11:40	539.24	1,769.16	728.15	2,388.93	Navarro measured static water level (LCA) using calibrated Solinst e-tape.
04/20/2016 13:25	539.25	1,769.21	728.13	2,388.88	Navarro measured fluid level (LCA) using calibrated Solinst e-tape.
ER-4-1 Piezometer (p1)					
01/04/2017 14:20	320.39	1,051.16	946.99	3,106.93	Navarro measured static water level (Tv) using calibrated Solinst e-tape.
09/08/2016 10:10	324.94	1,066.08	942.44	3,092.01	Navarro measured static water level (Tv) using calibrated Solinst e-tape.
09/07/2016 10:00	325.03	1,066.38	942.35	3,091.71	Navarro measured static water level (Tv) using calibrated Solinst e-tape.
04/20/2016 13:45	286.96	941.47	980.42	3,216.62	Navarro measured fluid level (Tv) using calibrated Solinst e-tape.
ER-4-1 Open Hole					
04/05/2016 20:00	543.95	1,784.61	723.44	2,373.48	Navarro measured fluid level using calibrated Solinst e-tape. Hole last drilled on 04/04/2016 at 20:10.
04/05/2016 15:50	543.24	1,782.29	724.14	2,375.80	Navarro measured fluid level using calibrated Solinst e-tape. Hole last drilled on 04/04/2016 at 20:10.
04/05/2016 15:10	534.14	1,755.70	732.25	2,402.39	Navarro measured fluid level using calibrated Solinst e-tape. Hole last drilled on 04/04/2016 at 20:10.
03/30/2016 22:04	489.17	1,604.88	778.22	2,553.21	Navarro measured fluid level using calibrated Solinst e-tape.
03/30/2016 09:05	524.26	1,720.01	743.13	2,438.08	Navarro measured fluid level using calibrated Solinst e-tape.
03/29/2016 ~16:30	576.83	1,892.5	690.55	2,265.59	COLOG measured fluid level. Run #1.
03/29/2016 ~06:00	621.18	2,038	646.20	2,120.09	Schlumberger measured fluid level in open hole. Run #3.
03/28/2016 16:35	676.05	2,218	591.34	1,940.09	Schlumberger measured fluid level in open hole. Run #1.

[a] Ground surface used as reference datum. Ground surface elevation survey by NSTec at 1,267.39 m (4,158.09 ft) amsl.

NA = Not available

increased from less than 10 to approximately 175 gpm while drilling through the LCA. Water production from the well increased significantly as drilling progressed into the LCA. Between the top of the LCA to the TD, production rate increased steadily, peaking at an estimated 175 gpm. Figure 6-1 is a plot of bromide tracer injection concentrations versus discharge concentrations and corresponding calculated water production rates.

6.2 Groundwater Chemistry

Discharged drilling fluids were monitored on site by Navarro for pH, temperature, and electrical conductivity (EC) throughout the drilling operations to evaluate changes in groundwater conditions during drilling. Water-quality measurements were affected by cement, drilling foam, and polymer used during drilling operations, and do not reflect natural groundwater quality; however, they may be reflective of changed groundwater or borehole conditions.

Navarro site personnel collected two depth-discrete bailer and duplicate samples from depths of 538.89 m (1,768 ft) bgs and 646.18 m (2,120 ft) bgs in the open borehole on March 30, 2016. Samples were collected using a wireline deployed depth-discrete 6-liter SS bailer. The samples provide initial groundwater chemistry based on select groundwater characterization parameters as identified in the *Field Instructions for the Underground Test Area Activity Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015). The bailer and associated sampling equipment were decontaminated according to appropriate procedures before and after sample collection. Analytical results for the bailed groundwater characterization samples are presented in Tables 6-2 and 6-3.

6.3 RNs Encountered

Navarro site personnel collected discharged drilling fluid samples hourly during borehole advancement. When the predicted water table was close, samples were collected every 10 ft. The samples were analyzed on site for tritium by NSTec Radiological Control (RadCon) personnel for fluid management and worker protection screening purposes. Onsite analyses for tritium were performed using liquid scintillation counters (LSCs). The average minimum detectable activity (MDA) for the LSCs was approximately 1,580 picocuries per liter (pCi/L). Tritium results were generally below the S*afe Drinking Water Act* (SDWA) limit (20,000 pCi/L) (CFR, 2016b) with the

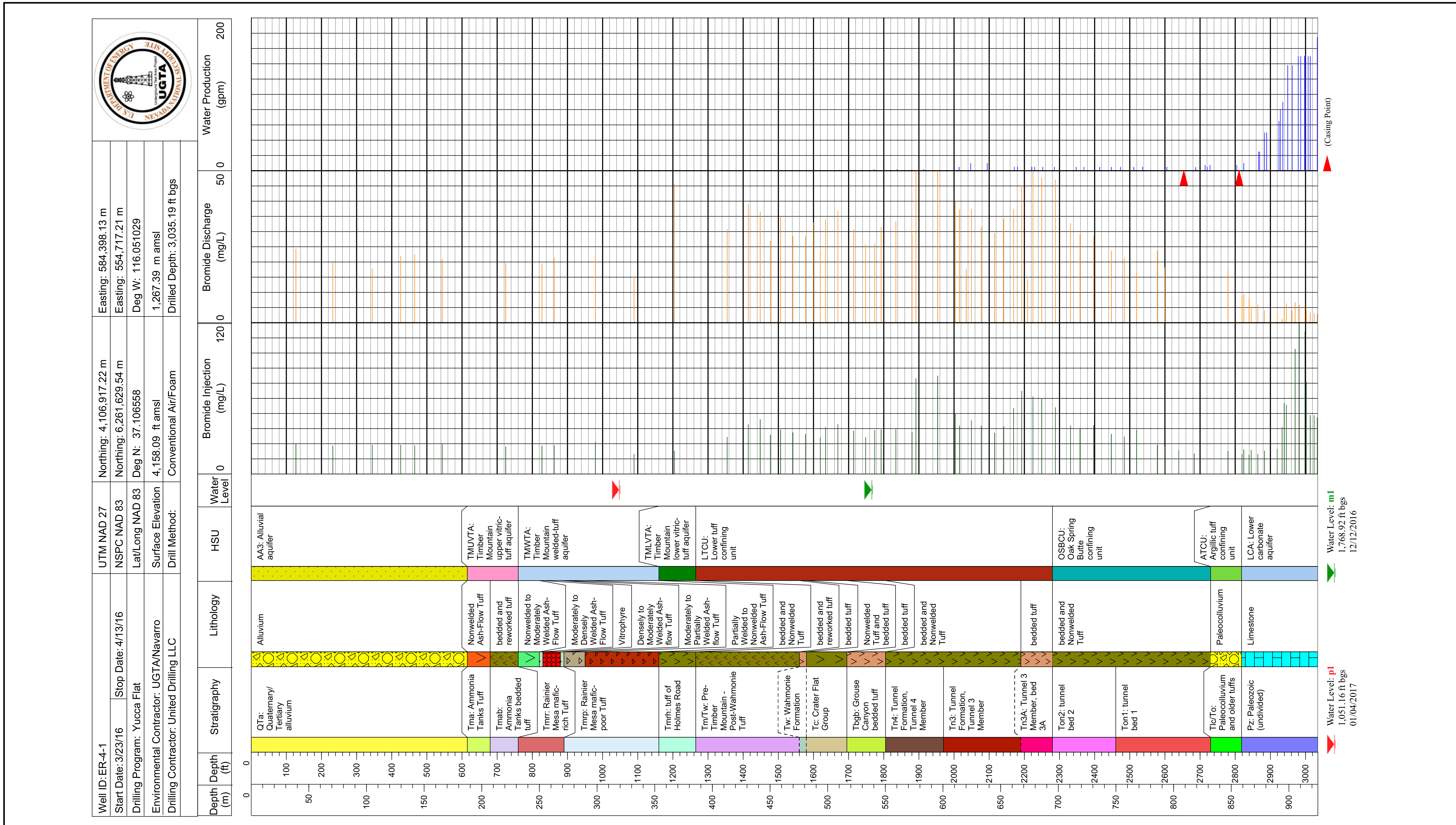


Figure 6-1
Well ER-4-1 Bromide Tracer Monitoring versus Estimated Water Production during Drilling

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (1,768 ft bgs)
(Page 1 of 3)

Analyte	Analytical Method [a]	Detection Limit [b]	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-1 Depth at 1,768 ft bgs		03/30/2016 Sample Number 431-033016-2 (Duplicate) Depth at 1,768 ft bgs	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Aluminum	SW-846 6010 [c]	2.0, 0.2	720	17	760	20
Arsenic		0.01	0.17	0.042	0.17	0.04
Barium		0.1	4.1	0.084 J-	3.9	0.037 J-
Cadmium		0.005	0.0027 J-	0.005 U	0.0026 J-	0.005 U
Calcium		1	250	5.7	230	7.4
Chromium		0.01	0.11	0.01 U	0.11	0.00061 J-
Iron		1.0, 0.1	400	1.8	430	0.89
Lead		0.03, 0.003	0.33	0.0041	0.31	0.0017 J-
Lithium		0.01	1.8	0.27	1.8	0.27
Magnesium		1	110	1.4	100	1.3
Manganese		0.01	8.7	0.13	7.8	0.16
Potassium		10, 1.0	450	13	460	14
Selenium		0.05, 0.005	0.097	0.005 U	0.05 U	0.005 U
Silicon		0.5, 0.05	150	51	170	49
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		10	770	170	750	180
Strontium		0.01	1.5 J	0.037 J	1.5 J	0.045 J
^{238}U	SW-846 6020 [c]	0.0001	0.086	0.012	0.084	0.012

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (1,768 ft bgs)
(Page 2 of 3)

Analyte	Analytical Method [a]	Detection Limit [b]	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-1 Depth at 1,768 ft bgs		03/30/2016 Sample Number 431-033016-2 (Duplicate) Depth at 1,768 ft bgs	
			Total	Dissolved	Total	Dissolved
Inorganics (mg/L unless otherwise noted)						
Bromide	EPA 300.0 [d]	0.2		1.9		1.9
Chloride		0.2, 0.2		9.9		9.9
Fluoride		0.5		33		33
Sulfate		1.0		22		22
Alkalinity as $CaCO_3$	EPA 310.1 [e]	50	190		230	
Bicarbonate as $CaCO_3$		50	190		230	
Carbonate as $CaCO_3$		50	50 U		50 U	
Total Dissolved Solids	EPA 160.1 [e]	400, 2,000 [f]	1,900		7,000	
Total Suspended Solids	EPA 160.2 [e]	200, 2,000 [f]	45,000		62,000	
pH (SU)	EPA 150.1 [e]	0.1	8.7 J-		8.6 J-	
Specific Conductivity (μmhos/cm)	EPA 120.1 [e]	1	720		720	
Radiological Indicator Parameters-Level I (pCi/L)						
		MDC [f]	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [g]	400	58,400	8,900	59,600	9,100
Gross Alpha	EPA 900.0 [g]	100, 90	880	170	840	160
Gross Beta		120,110	2,210	370	1,740	290
^{238}Pu	HASL 300 [h]/ ASTM D3865-02 [i]	0.033, 0.013	0.001 U	0.016	0.009 U	0.019
$^{239/240}Pu$	HASL 300 [h]/ ASTM D3865-02 [i]	0.011, 0.013	0.008 U	0.016	0.014 U	0.019
Gamma Spectroscopy	EPA 901.1 [h]	Varies by Nuclide	ND	Varies by Nuclide	ND	Varies by Nuclide

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (1,768 ft bgs)
(Page 3 of 3)

Analyte	Analytical Method [a]	Detection Limit [b]	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-1 Depth at 1,768 ft bgs		03/30/2016 Sample Number 431-033016-2 (Duplicate) Depth at 1,768 ft bgs	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (pCi/L)						
		MDC	Result	Error	Result	Error
^{14}C	EERF C-01 [j]	370, 350	150 U	220	120 U	210

Source: Navarro, 2016b

[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] Two detection limits: the first corresponds with the total metals result, and the second corresponds with the dissolved metals result.
[c] EPA, 2016
[d] EPA, 1997
[e] EPA, 1983
[f] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 431-033016-1, and the second corresponds with sample number 431-033016-2.
[g] EPA, 1980
[h] DOE, 1997
[i] ASTM, 2015
[j] EPA, 1984

ASTM = ASTM International
C = Carbon
$CaCO_3$ = Calcium carbonate
EERF = Eastern Environmental Radiation Facility
EPA = U.S. Environmental Protection Agency
HASL = Health and Safety Laboratory
MDC = Minimum detectable concentration
mg/L = Milligrams per liter
Pu = Plutonium
SU = Standard unit
SW = Solid waste
µmhos/cm = Micromhos per centimeter

J = Result is estimated.
J- = Result is estimated bias low.
ND = No gamma spectroscopy RNs detected above detection limit.
U = Compound was analyzed for but was not detected (“nondetect”).

exception of two zones. Onsite sampling identified two zones with higher levels of tritium in Well ER-4-1; first from 365.76 to 396.24 m (1,200 to 1,300 ft) bgs and second 542.54 to 576.07 m (1,780 to 1,890 ft) bgs and shown in Figures 6-2a and 6-2b. These intervals were isolated behind the 13.375-in. casing. Results from drilling fluid returns from both the unsaturated and saturated zones ranged from 0 to 247,136 pCi/L. Appendix B provides a summary of field tritium monitoring results, including onsite reanalyses. Tritium concentrations and water production at Well ER-4-1 are shown in Figures 6-2a and 6-2b.

Depth-discrete bailer samples were reanalyzed for radioisotope chemistry due to a spike shown on the spectral gamma geophysical log (Figures 4-3a and 4-3b) and gamma scan results from the

Table 6-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (2,120 ft bgs)
(Page 1 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-3 Depth at 2,120 ft bgs		03/30/2016 Sample Number 431-033016-4 (Duplicate) Depth at 2,120 ft bgs	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Aluminum	SW-846 6010 [b]	0.2	350	11	590	27
Arsenic		0.01	0.11	0.044	0.16	0.04
Barium		0.1	1.7	0.047 J-	2.8	0.13
Cadmium		0.005	0.00037 J-	0.005 U	0.0009 J-	0.005 U
Calcium		1	210	4.8	230	23
Chromium		0.01	0.051	0.001 J-	0.086	0.00083 J-
Iron		0.1	160	1.2	280	1.0
Lead		0.003	0.094	0.0015 J-	0.17	0.0065
Lithium		0.01	0.8	0.23	1.0	0.25
Magnesium		1	57	1.2	88	3.3
Manganese		0.01	3.6	0.059	4.7	0.25
Potassium		1	170	7.4	260	18
Selenium		0.005, 0.05	0.005 U	0.0039 J	0.05 U	0.005 U
Silicon		0.5, 0.05 [j]	130	43	170	47
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		10	470	160	500	180
Strontium		0.01	0.97 J	0.029 J	1.5 J	0.14 J
^{238}U	SW-846 6020 [b]	0.0001	0.053	0.014	0.064	0.016

Table 6-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (2,120 ft bgs)
(Page 2 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-3 Depth at 2,120 ft bgs		03/30/2016 Sample Number 431-033016-4 (Duplicate) Depth at 2,120 ft bgs	
			Total	Dissolved	Total	Dissolved
Inorganics (mg/L unless otherwise noted)						
Bromide	EPA 300.0 [c]	0.2		1.8		1.8
Chloride		0.2[k]		11		11
Fluoride		0.5		31		31
Sulfate		1		24		24
Alkalinity as $CaCO_3$	EPA 310.1 [d]	50	220		210	
Bicarbonate as $CaCO_3$		50	220		210	
Carbonate as $CaCO_3$		50	50 U		50 U	
Total Dissolved Solids	EPA 160.1 [d]	2,000	12,000		14,000	
Total Suspended Solids	EPA 160.2 [d]	2,000	58,000		59,000	
pH (SU)	EPA 150.1 [d]	0.1	8.6 J-		8.6 J-	
Specific Conductivity (μmhos/cm)	EPA 120.1 [d]	1	680		690	
Radiological Indicator Parameters-Level I (pCi/L)						
		MDC [e]	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [f]	390, 400	5,130	860	5,330	890
Gross Alpha	EPA 900.0 [f]	34, 90	331	63	680	140
Gross Beta		20, 120	620	100	1,590	270
^{238}Pu	HASL 300 [g]/ ASTM D3865-02 [h]	0.035, 0.033	-0.001 U	0.019	-0.001 U	0.018
$^{239/240}Pu$	HASL 300 [g]/ ASTM D3865-02 [h]	0.035, 0.027	0.004 U	0.019	0.002 U	0.018
Gamma Spectroscopy	EPA 901.1 [g]	Varies by Nuclide	ND	Varies by Nuclide	ND	Varies by Nuclide

Table 6-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (2,120 ft bgs)
(Page 3 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-4-1			
			03/30/2016 Sample Number 431-033016-3 Depth at 2,120 ft bgs		03/30/2016 Sample Number 431-033016-4 (Duplicate) Depth at 2,120 ft bgs	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (pCi/L)						
		MDC	Result	Error	Result	Error
^{14}C	EERF C-01 [i]	400, 360	0 U	240	90 U	210

Source: Navarro, 2016b

[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, 2016
[c] EPA, 1997
[d] EPA, 1983
[e] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 429-012416-1 and the second corresponds with sample number 429-012416-2.
[f] EPA, 1980
[g] DOE, 1997
[h] ASTM, 2015
[i] EPA, 1984
[j] Silicon has two detection limits, the first corresponds with the total metals result and the second corresponds with the dissolved metals result. This value is calculated from the SiO_2 (silica) result found using SW-846 6010.
[k] Chloride has two detection limits, the first corresponds with the total metals result and the second corresponds with the dissolved metals result.

J = Result is estimated.
J- = Result is estimated bias low.
ND = No gamma spectroscopy RNs detected above detection limit.
U = Compound was analyzed for but was not detected (“nondetect”).

groundwater sample filters. NSTec RadCon ran a gamma scan on the filters used to collect the bailed groundwater samples and the data are provided in Table 6-4. (See Tables 6-6 and 6-7 for the results of the reanalysis of the lab filtered bailer samples.) Most of the results are below the detection limits (U). Results for the naturally occurring isotopes ^{40}K and lead (^{212}Pb and ^{214}Pb) are expected. However, results for fission-related isotopes of cesium (^{137}Cs), actinium (^{228}Ac), and thallium (^{208}Tl) would support the prompt injection interpretation. Enormous pressures generated during a nuclear test may create or enlarge preexisting fractures in rock, injecting radioactive material considerable distances from the WP (Nimz and Thompson, 1992). Fractures may be vertical or subvertical. Laterally continuous geologic units may provide conduits for prompt injection (Navarro, 2016d). Well ER-4-1 is approximately 2.5 R_c from the STRAIT UGT. However, based on the elevation of the WP for STRAIT (490 m and 1,607 ft), prompt injection does not appear to be related to STRAIT.

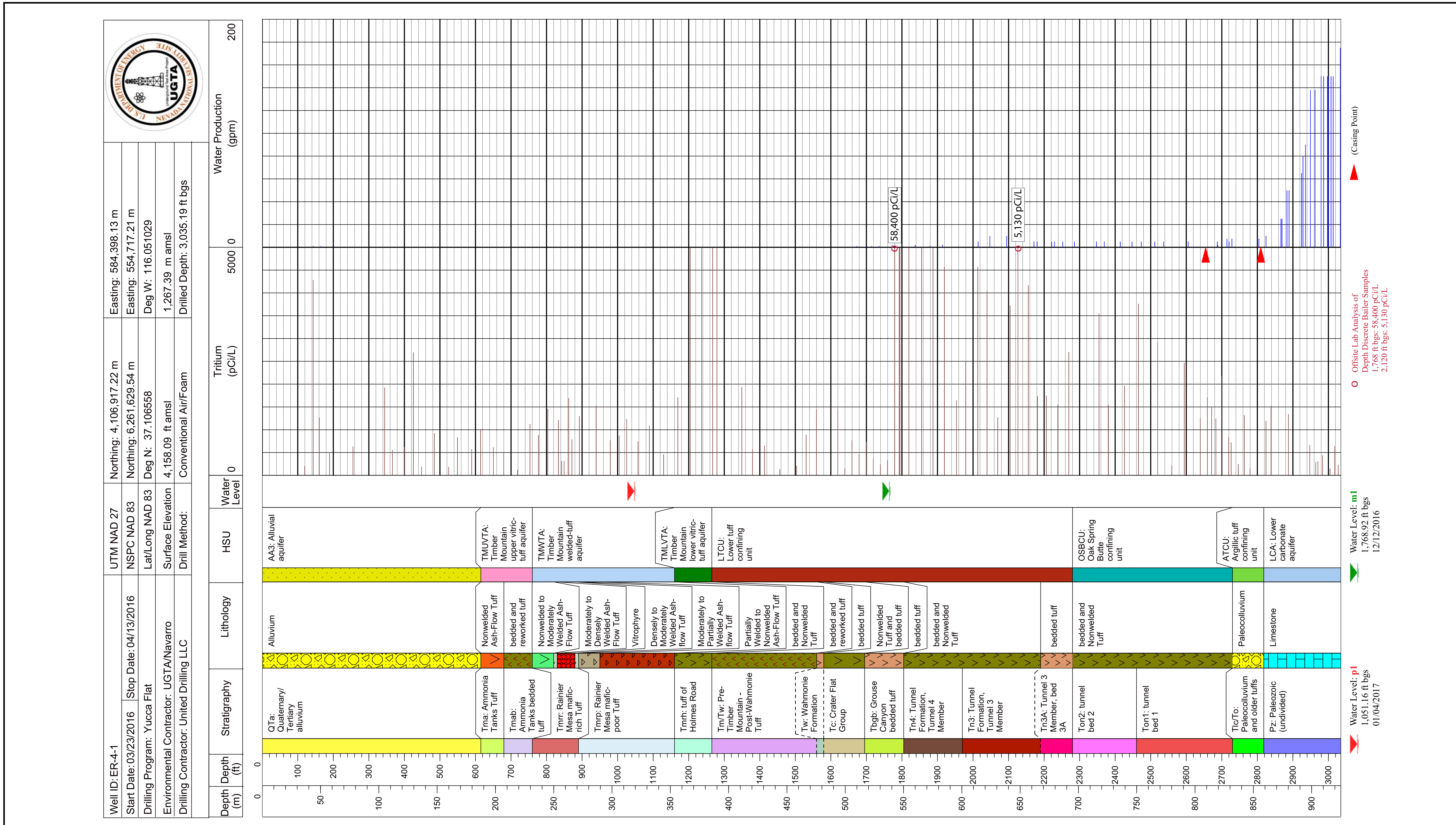


Figure 6-2a
Well ER-4-1 Tritium Concentrations and Estimated Water Production during Drilling

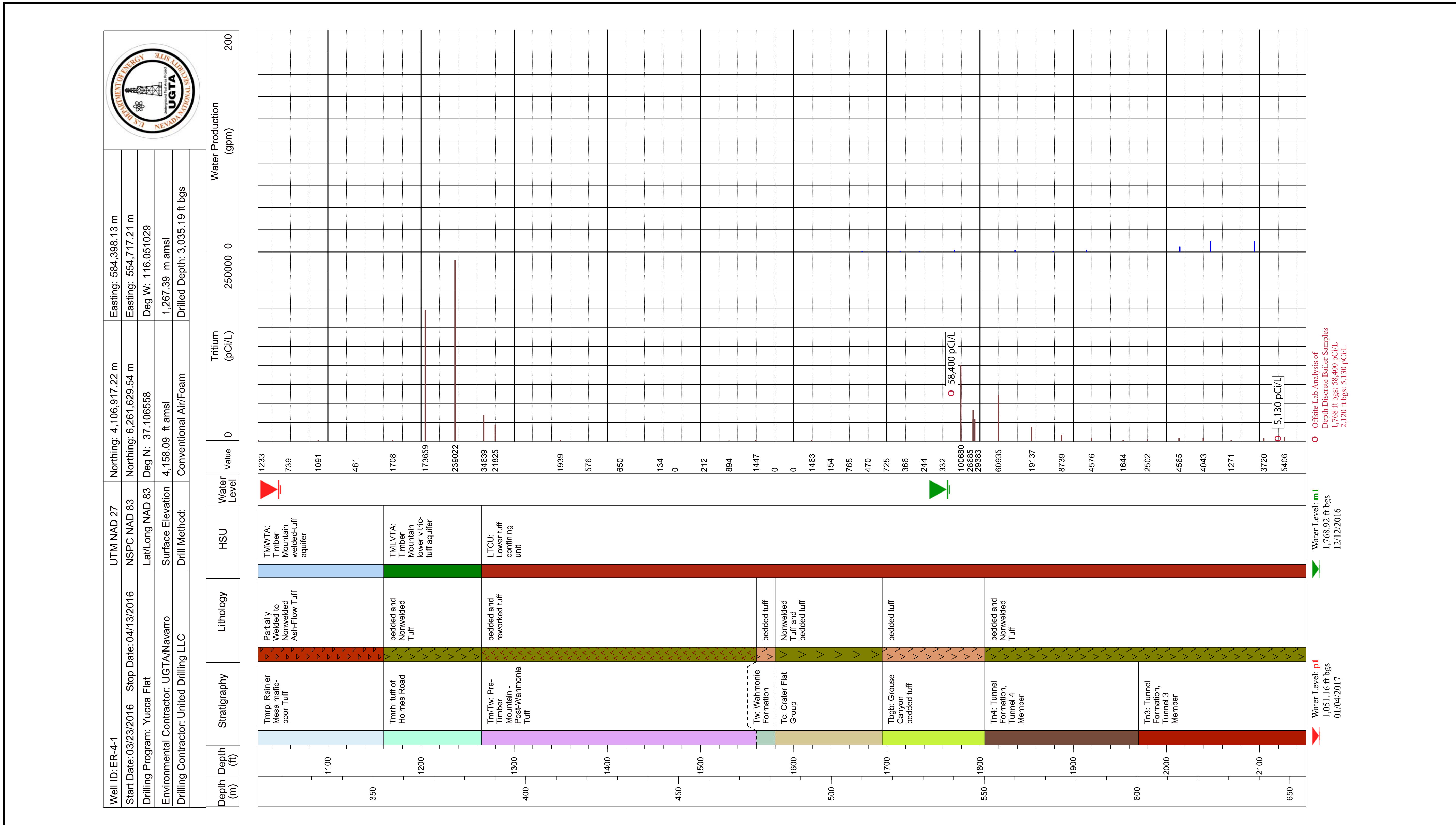


Figure 6-2b
Well ER-4-1 Detail Tritium Concentrations and Estimated Water Production from 1,025 to 2,150 ft bgs

Table 6-4
Summary of Radionuclides in Gamma Scan of Bailed Groundwater Sample Filters

Nuclide	Time of Count Activity (pCi/g)	Time Corrected Activity (pCi/g)	Uncertainty Counting (pCi/g)	MDA
^{40}K	4.6492 E-01	4.6492 E-01	1.19 E-01	1.11 E-02
^{137}Cs	1.9090 E-02	1.9487 E-02	8.477 E-03	2.53 E-03
^{210}Pb	1.8652 E-01	1.9176 E-01	1.28 E-01	6.54 E-02
^{241}Am	1.5693 E-02	1.5715 E-02	1.467 E-02	6.03 E-03

Source: Modified from NSTec, 2016

Am = Americium

A discharge sample was collected while the drill was circulating in the borehole at 3,020 ft bgs in the LCA (Table 6-5). Field water-quality parameters associated with the sample are as follows: pH = 7.88, EC = 1,038 µS/cm and temperature = 23.8 ºC.

Table 6-5
Analytical Results for Discharge Sample from Well ER-4-1 (04/12/2016)

Analyte	Analytical Method	Detection Limit	04/12/2016 Sample Number 431-041216-1 Depth at 3,020 ft bgs	
Radiological Indicator Parameters-Level II (pCi/L)				
		MDC	Result	Error
Low-level Tritium	HASL 300	2.16	1.2 UJ	1.34

Tables 6-6 and 6-7 provide the results of the reanalysis of the lab filtered bailer samples.

Table 6-6
Additional Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (1,768 ft bgs)
(Page 1 of 2)

Analyte	Analytical Method	Depth-Discrete Bailer Samples from Well ER-4-1					
		03/30/2016 Sample Number 431-033016-1 (RR1) [a] Depth at 1,768 ft bgs			03/30/2016 Sample Number 431-033016-2 (RR1) [a] (Duplicate) Depth at 1,768 ft bgs		
Radiological Indicator Parameters-Level I (pCi/L)							
		MDC [b]	Result [b]	Error [c]	MDC [b]	Result [b]	Error [c]
^{7}Be	PAI713R13	116, 128	-38 UJ, -50 U	66, 74	92, 170	30 UJ, -20 U	55, 100
^{26}Al		9.2, 9.9	4.1 UJ, -4.1 U	5.6, 5.5	10.9, 15.3	-1.3 UJ, 1.4 U	5.9, 9
^{40}K		200, 270	1,610 J, -10 U	260,160	160, 320	1,010 J, 10 U	180, 190
^{58}Co		12.4, 15.4	0.3 UJ, -4 U	7.1, 8.9	9.8, 20	2.1 UJ, -5 U	5.8, 11
^{60}Co		10.7, 9.3	-2.3 UJ, 1.2 U	5.8, 5.5	10.5, 13.1	-2.6 UJ, 3.8 U	5.7, 7.9
^{94}Nb		11.2, 8.9	0.4 UJ, 1.7 U	6.5, 5.4	9.3, 11.9	1.9 UJ, -1.9 U	5.5, 7
^{125}Sb		28, 23	1 UJ, -5 U	15, 13	26, 28	8 UJ, 8U	15, 16
Radiological Indicator Parameters-Level II (pCi/L)							
		MDC [b]	Result [c]	Error [d]	MDC [b]	Result [c]	Error [d]
^{134}Cs	PAI713R13	11.3, 9.3	-5.6 UJ, -4.1 U	6.3, 5.4	8.9, 12.6	2.8 UJ, -9 U	4.1, 7.3
^{137}Cs		11, 8.7	171 J, 1.2 U	24, 5.2	10, 12	99 J, 2.9 U	15, 7.2
^{152}Eu		47, 45	11 UJ, -14 U	27, 25	47, 67	14 UJ, -6 U	28, 39
^{154}Eu		58, 49	8 UJ, -20 U	34, 28	55, 64	-1 UJ, 23 U	31, 39
^{155}Eu		32, 35	4 UJ, 9 U	19, 21	40, 30	16 UJ, -1 U	24, 18
^{208}Tl		13, 8.7	50 J, 9.6 U	11, 5.6	14.3, 25	26.4 J, -1 U	9.9, 15
^{212}Bi		112, 121	116 UJ, 75 U	74, 75	119, 154	81 UJ, 155 U	74, 98

Table 6-6
Additional Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (1,768 ft bgs)
(Page 2 of 2)

Analyte	Analytical Method	Depth-Discrete Bailer Samples from Well ER-4-1					
		03/30/2016 Sample Number 431-033016-1 (RR1) [a] Depth at 1,768 ft bgs			03/30/2016 Sample Number 431-033016-2 (RR1) [a] (Duplicate) Depth at 1,768 ft bgs		
		MDC [b]	Result [c]	Error [d]	MDC [b]	Result [c]	Error [d]
^{214}Bi	PAI713R13	28, 43	88 J, 12 U	21, 26	28, 62	43 UJ, -5 U	17, 38
^{212}Pb		21, 31	119 J, 3 U	21, 19	21, 30	75 J, 8 U	17, 18
^{214}Pb		27, 36	52 J, -4 U	16, 22	24, 49	32 UJ, 11 U	14, 29
^{227}Th		58, 66	-40 UJ, 5 U	33, 40	93, 74	39 UJ, 4 U	58, 45
^{228}Ac		54, 61	112 J, -1 U	27, 36	45, 44	83 J, 51 U	26, 24
^{234}Th		260, 540	110 UJ, -10 U	160, 320	300, 300	-190 UJ, 100 U	180, 180
^{235}U		79, 46	37 UJ, 43 U	49, 29	94, 50	8 UJ, 28 U	46, 30
^{241}Am		112, 340	-42 UJ, -110 U	65, 200	260, 65	-10 UJ, -17 U	150, 39

Source: Navarro, 2016b

[a] Samples were filtered and reanalyzed (RR1).
[b] Two detection limits, the first corresponds with the original, and the second corresponds with the reanalyzed result.
[c] Two results, the first corresponds with the original, and the second corresponds with the reanalyzed result.
[d] Two values for error, the first corresponds with the original, and the second corresponds with the reanalyzed result.

Al = Aluminum
Be =Beryllium
Bi = Bismuth
Co = Cobalt
Eu = Europium
Nb = Niobium
Sb = Antimony

J = Result is estimated.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

Table 6-7
Additional Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (2,120 ft bgs)
(Page 1 of 2)

Analyte	Analytical Method	Depth-Discrete Bailer Samples from Well ER-4-1					
		03/30/2016 Sample Number 431-033016-3 (RR1) [a] Depth at 2,120 ft bgs			03/30/2016 Sample Number 431-033016-4 (RR1) [a] (Duplicate) Depth at 2,120 ft bgs		
Radiological Indicator Parameters-Level I (pCi/L)							
		MDC [b]	Result [c]	Error [d]	MDC [b]	Result [c]	Error [d]
^{7}Be	PAI713R13	105, 154	-20 UJ, -47 U	60, 90	77, 92	51, 46	48, 56
^{26}Al	PAI713R13	12.9, 15.1	4.7 UJ, -2.6 U	7.7, 8.7	9.4, 7.8	2.5 UJ, 2.3 U	5.5, 4.7
^{40}K	PAI713R13	180, 280	1,230 J, -40 U	220, 160	180, 190	880 J, 60 U	170, 120
^{58}Co	PAI713R13	12.5, 17	2.3 UJ, 5 U	7.4, 10	9.4, 11.5	-1.3 UJ, -2.1 U	5.3, 6.7
^{60}Co	PAI713R13	12, 12.6	2.5 UJ, 1.3 U	7, 7.4	8.8, 7.2	-0.5 UJ, -2.2 U	4.9, 4
^{94}Nb	PAI713R13	11, 10.7	-3.8 UJ, 1.4 U	6.2, 6.4	8.8, 6.5	2.4 UJ, -1.2 U	5.3, 3.8
^{125}Sb	PAI713R13	25, 26	7 UJ, 2 U	15, 14	25, 16.3	-25 UJ, -1.4 U	14, 8.4
^{134}Cs	PAI713R13	11.5, 10.7	-0.5 UJ, 1.9 U	6.7, 6.4	8.7, 6.7	1.8 UJ, -0.6 U	5.1, 4
^{137}Cs	PAI713R13	11, 10.6	76 J, 2.2 U	14, 6.4	9, 6.5	57 J, -0.6 U	10, 3.8
^{152}Eu	PAI713R13	61, 63	-8 UJ, -13 U	34, 36	42, 36	-6 UJ, -14 U	23, 20
^{154}Eu	PAI713R13	59, 62	21 UJ, 0 U	36, 36	47, 49	-4 UJ, -8 U	26, 29
^{155}Eu	PAI713R13	31, 25	-7 UJ, 4 U	18, 15	37, 11.7	-2 UJ, -0.1 U	22, 7
^{208}Tl	PAI713R13	14, 21	32 J, -3 U	10, 13	11.5, 12.9	26.7 J, 1.5 U	8.5, 7.7
^{212}Bi	PAI713R13	180, 157	140 UJ, 8 U	120, 93	92, 94	92 UJ, 61 U	61, 58
^{214}Bi	PAI713R13	27, 46	29 UJ, 9 U	18, 28	26, 28	21 UJ, 10 U	17, 17
^{212}Pb	PAI713R13	19, 29	106 J, 3 U	19, 18	18, 19	58 J, 2 U	14, 11

Table 6-7
Additional Analytical Results for Depth-Discrete Bailer Samples from Well ER-4-1 (2,120 ft bgs)
(Page 2 of 2)

Analyte	Analytical Method	Depth-Discrete Bailer Samples from Well ER-4-1					
		03/30/2016 Sample Number 431-033016-3 (RR1) [a] Depth at 2,120 ft bgs			03/30/2016 Sample Number 431-033016-4 (RR1) [a] (Duplicate) Depth at 2,120 ft bgs		
		MDC [b]	Result [c]	Error [d]	MDC [b]	Result [c]	Error [d]
^{214}Pb	PAI713R13	25, 43	40 J, 4 U	15, 26	25, 27	24 UJ, -1 U	13, 16
^{227}Th	PAI713R13	1,400, 46	-150 UJ, 10 U	850, 28	1,393, 39	-257 UJ, 17 U	63, 24
^{228}Ac	PAI713R13	58, 40	67 UJ, 28 U	25, 25	45, 51	74 J, -8 U	26, 30
^{234}Th	PAI713R13	240, 290	-20 UJ, 120 U	140, 170	390, 130	20 UJ, -34 U	230, 78
^{235}U	PAI713R13	50, 46	2 UJ, 24 U	30, 28	82, 24	50 UJ,14 U	52, 14
^{241}Am	PAI713R13	76, 60	19 UJ, 10 U	46, 36	320, 6.9	60 UJ, -1.6 U	190, 4.1

Source: Navarro, 2016b

[a] Samples were filtered and reanalyzed (RR1).
[b] Two detection limits, the first corresponds with the original, and the second corresponds with the reanalyzed result.
[c] Two results, the first corresponds with the original, and the second corresponds with the reanalyzed result.
[d] Two values for error, the first corresponds with the original, and the second corresponds with the reanalyzed result.

J = Result is estimated.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

7.0 Fluid and Waste Management

7.1 Fluid Management Strategy

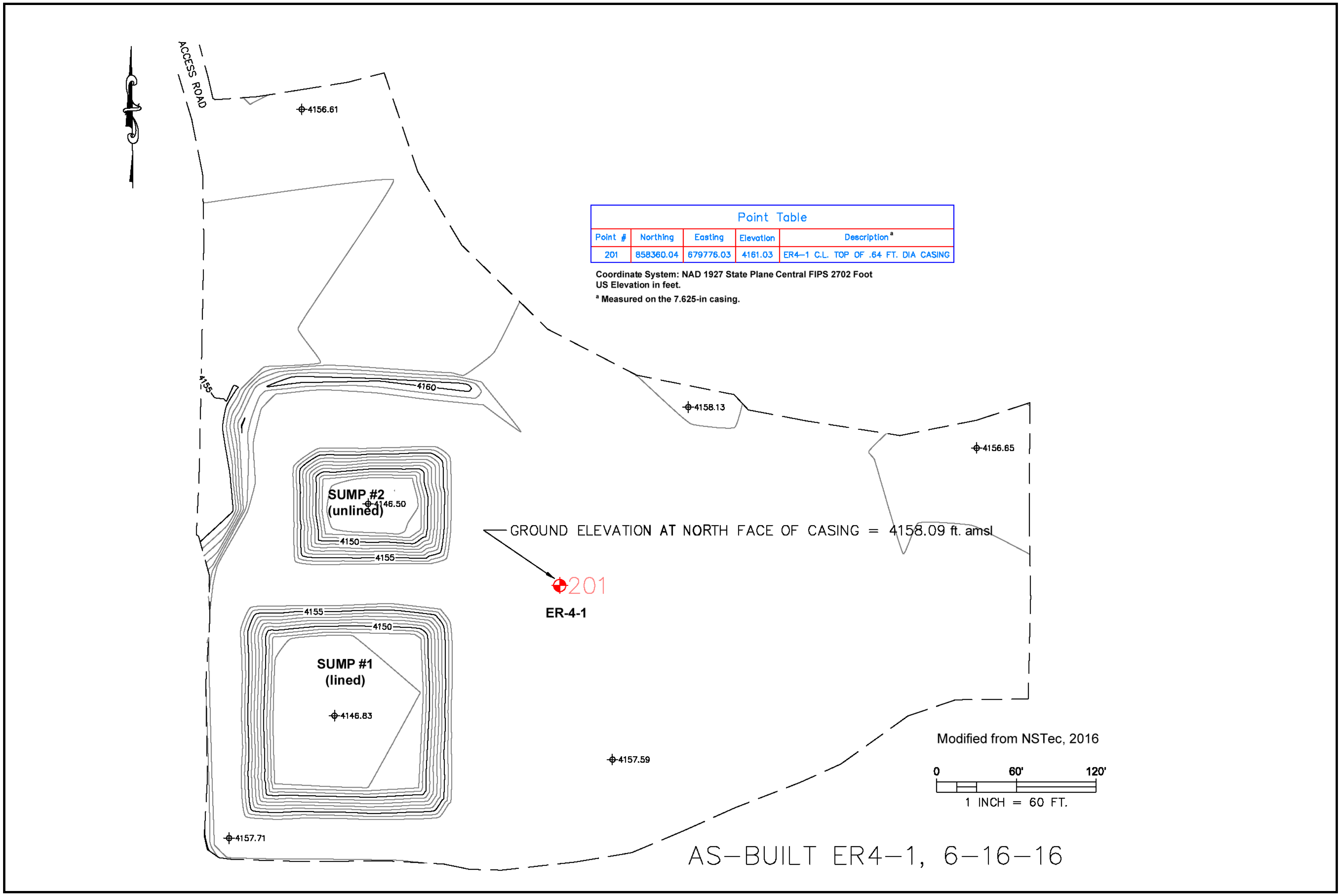
The management of drilling fluids and solid waste (i.e., cuttings) is addressed in the *Underground Test Area Project Waste Management Plan*; *Attachment 1 Fluid Management Plan for the Underground Test Area Project* (NNSA/NSO, 2009). The *Final Well Specific Fluid Management Strategy for UGTA Well ER-4-1, Nevada National Security Site* (Navarro, 2016c; see Appendix D), as required by the UGTA FMP, addresses specific fluid management strategies to be employed at Well ER-4-1 for fluid-generating activities relating to well drilling and well construction. The drilling fluid discharge was monitored routinely during drilling in accordance with these plans to guide operational decisions for proper fluid containment and, ultimately, proper fluid disposal.

Two onsite infiltration basins (Sumps #1 and #2) were constructed to contain fluids and drill cuttings during operations at Well ER-4-1. Sump #1 is lined with an approximate 1.5-million-gal capacity for drilling fluid containment. A second unlined sump (Sump #2) with an estimated 500,000-gal capacity was to be used only in the event that fluid storage capacity was not sufficient. The sumps are approximately 10 ft deep from the floor of the sump to the drill pad surface. Figure 7-1 shows the relative size and positions of Sumps #1 and #2 with respect to Well ER-4-1.

Source water for drilling was provided by Area 6 and 12 fill stands: the water supply for Area 12 fill stand is Water Well 8, and water supply for Area 6 fill stand is Water Well 4 or 4a. These are existing NNSS water supply wells that were last sampled on November 3, 2016. Sample data were reviewed, and results were below the SDWA limit (CFR, 2016b). The water was also analyzed on site for tritium as make-up water as shown in Appendix B.

7.2 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.



Point Table				
Point #	Northing	Easting	Elevation	Description[a]
201	858360.04	679776.03	4161.03	ER4-1 C.L. TOP OF .64 FT. DIA CASING

Coordinate System: NAD 1927 State Plane Central FIPS 2702 Foot US Elevation in feet.

[a] Measured on the 7.625-in casing.

Figure 7-1
Well ER-4-1 Site Diagram

Navarro site personnel collected discharged drilling fluid samples hourly during periods of borehole advancement. When the predicted water table was close, samples were collected every 10 ft. The NSTec RadCon personnel analyzed the fluid samples for tritium on site using NSTec-supplied LSCs for the purpose of fluid management and worker protection. An MDA is associated with the analysis of each sample. The average MDA for the onsite LSCs was approximately 1,580 pCi/L. Samples collected and analyzed for tritium were for screening purposes, and the reported results do not accurately represent lower tritium concentrations (i.e., less than approximately 1,580 pCi/L) due to errors in counting statistics or issues relating to the nature of fluids analyzed (e.g., drilling fluids). In accordance with NSTec RadCon guidelines, many of the onsite fluid samples with initial tritium results greater than the MDA were recounted until the results were below the MDA. As shown in Figure 6-2a and Appendix B, tritium analyses for discharge samples from both the unsaturated and saturated zones in Well ER-4-1 ranged from 0 to 247,136 pCi/L.

After drilling activities were completed, Navarro personnel collected an FMP confirmatory sample and duplicate from Sump #1 on April 13, 2016. 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 are presented in Table 7-1. The results of the FMP samples are below the FMP action limits.

7.3 Disposition of Fluids and Cuttings

The FMP (NNSA/NSO, 2009) and the Well ER-4-1 FMP strategy letter establish concentrations for specified parameters below which drilling fluids may be discharged either to an unlined containment basin, infiltration area, or directly to the ground surface. The monitoring and FMP confirmatory sampling results met the FMP criteria for fluid discharge to a designated infiltration area under a far-field operational strategy. Drilling fluids generated were discharged to lined Sump #1. No discharges were made to the designated infiltration area.

The volumes of fluids produced during vadose and saturated zone drilling are presented in Table 7-2. At the completion of drilling on April 13, 2016, an estimated combined total of 3,464 cubic meters (m^3) (841,390 gal) of drilling fluid and cuttings remained in lined Sump #1.

Table 7-1
Analytical Results for FMP Confirmatory Samples from Sump #1 (Lined) at Well ER-4-1

Analyte	Analytical Method [a]	Detection Limit	FMP Samples from Well ER-4-1 Sump #1			
			Sample Number 431-041316-1		Sample Number 431-041316-2 (Duplicate)	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.0066 J	0.0046 J	0.005 J	0.0042 J
Barium		0.1	0.062 J-	0.044 J-	0.065 J-	0.044 J-
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.0046 J-	0.0033 J-	0.0038 J-	0.0027 J-
Lead		0.003	0.003 U	0.003 U	0.003 U	0.003 U
Selenium		0.005	0.0061 J+	0.0064 J+	0.005 U	0.005 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 U	0.0002 U	0.0002 U	0.0002 U
Radiological Indicator Parameters (pCi/L)						
		MDC [c]	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [d]	330	200 U	200	160 U	200
Gross Alpha	EPA 900.0 [d]	2.0, 1.7	9.2	2.3	7.9	1.9
Gross Beta		2.3, 2.0	10.7	2.4	13.2	2.5

Source: Navarro, 2017

[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, 2016
[c] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 431-041316-1 and the second with 431-041316-2.
[d] EPA, 1980

J = Result is estimated.
J- = Result is estimated bias low.
J+ = Result is estimated bias high.
U = Compound was analyzed for but was not detected (“nondetect”).

Note: Analyses were performed by ALS Laboratory Group.

Table 7-2
Well ER-4-1 Fluid Disposition Reporting Form

Site Identification: ER-4-1
Site Location: Nevada National Security Site
Site Coordinates: (UTM NAD 27, Zone 11) N 4,106,917.22 m; E 584,398.13 m
Well Classification: ER Hydrogeologic Investigation Well
Navarro Project No: UN15-460

Report Date: July 15, 2016
NNSA/NFO UGTA Activity Lead: Bill Wilborn
Navarro Project Manager: Ken Rehfeldt
Navarro Site Representative: Dawn Peterson
Navarro 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	03/23/2016	03/25/2016	2	320.39	206.70	137.00	273.43	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	03/25/2016	04/14/2016	9	604.74	996.93	142.40	2,912.09	N/A	N/A	NA	N/A	Yes
Phase II: Well Development Shallow	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Aquifer Testing Shallow	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Well Development Deep	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Aquifer Testing Deep	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cumulative Production Totals to Date:			11	925.13	1,203.63	279.40	3,185.52	N/A	NA	N/A	N/A	Yes

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.

[b] Solids volume estimates include calculated added volume (50%) attributed to rock bulking factor.

[c] Discharge to an NDEP approved infiltration area as defined in the Well-Specific Fluid Management Strategy Letter for ER-4-1.

[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 = meters; m^3 = cubic meters

Total Facility Capacities (at 8 ft fluid level): Sump # 1 = 3,879 m^3 Sump #2 = 1,306 m^3 Infiltration Area (assuming very low/no infiltration) = N/A

Remaining Facility Capacity (Approximate) as of 04/27/2016: Sump #1 = 805 m^3 (16%) Sump #2 = 1,306 m^3 (100%)

Current Average Tritium activity for FMP samples collected from Sump #1 were <330 pCi/L.

Notes: None

Navarro Authorizing Signature/Date /s/ Jeffrey Wurtz

7.4 Environmental Compliance and Waste Management

Navarro was responsible for environmental compliance and waste management at the Well ER-4-1 site. Periodic site evaluations were conducted during site operations to ensure compliance with the *Occupational Safety and Health Act* (CFR, 2016a), the *Resource Conservation and Recovery Act* (CFR, 2016c), the UGTA Waste Management Plan (NNSA/NSO, 2009), and internal contractor procedures.

7.4.1 Waste Management

Waste generated during drilling operations at the Well ER-4-1 site consisted of hydrocarbon, sanitary, and no low-level radioactive wastes. Table 7-3 summarizes the waste type, volume, and disposition of waste streams generated during drilling. Sanitary waste generated during drilling operations was routinely collected by NSTec and disposed of at the Area 23 solid waste landfill. The hydrocarbon waste was removed from the Well ER-4-1 site and transported by Navarro personnel to Building 6-909 for interim storage until disposal by NSTec. The contents of the 2,000-gal condensate tank were drained and transported by NSTec to the Area 12 surface impoundment for evaporation. All waste was characterized using process knowledge and onsite monitoring results.

Table 7-3
Final Waste Disposition for Well ER-4-1 Drilling Operations

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-4-1-1	03/19/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	Full (50 gal)
ER-4-1-2	03/26/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad	Recycled 05/15/2017	Full (27 gal)
ER-4-1-3	03/26/2016	55 gal	Open-top steel drum	Hydrocarbon Solids	Non-Haz, Non-Rad Hydrocarbon	Pending	Full (50 gal)
ER-4-1-4	03/26/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	Recycled 05/15/2017	Full (50 gal)
ER-4-1-5 (NAVSAA005)	03/26/2016	5 gal	Poly pail	Hach Lead Test Kit Rinsate	Non Haz, Non-Rad	Disposed of 07/19/2016	Contents consumed during waste characterization
ER-4-1-6	03/29/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	Full (50 gal)
ER-4-1-7	04/11/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	Full (50 gal)
ER-4-1-8	04/18/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	Full (40 gal)

mL = Milliliter

8.0 Planned and Actual Costs and Scheduling

This section provides a brief discussion of the planned and actual schedule and costs for the main borehole construction of Well ER-4-1.

The original M&O (NSTec)-approved baseline work package was based on drilling to a planned TD of 1,036.6 m (3,400 ft), installing one production casing string with two main completion zones and two piezometer tubing strings. This estimate was submitted before issuance of the final drilling criteria document (Navarro, 2015) with an updated planned TD of 945.1 m (3,100 ft). The approved baseline estimate included a 34-day schedule for constructing a 1,036.6-m (3,400-ft)-deep well. The baseline estimate included 7 days for the location-to-location move from Well ER-3-3, and 27 days for main borehole construction and completion. The revised criteria called for construction of a 945.1-m (3,100-ft) well with one main production hole completion with a piezometer tube and one piezometer tube on the outside of the surface casing.

The well was drilled 111.3 m (365 ft) shallower than originally planned to a TD of 925.3 m (3,035 ft), and 19.8 m (65 ft) shallower than specified in the final drilling criteria. It took 30 calendar days to construct Well ER-4-1, beginning with the start of the location-to-location move on March 16, 2016, and ending with the installation of the production casing in the open borehole on April 13, 2016. Because the Yucca Flat drilling campaign schedule changed and ER-3-3 was drilled before ER-4-1, final drill rig demobilization off the NNSS followed the completion of the ER-4-1 well, starting on April 15 and ending on April 29, 2016.

The well construction criteria called for constructing an 18.5-in. diameter borehole and setting 33.97-cm (13.375-in.) surface casing at approximately 823.2 m (2,700 ft) rather than opening the borehole to 26 in. and setting a 50.80-cm (20-in.) surface casing. However, due to borehole instability problems (sloughing), the casing was installed higher than planned at 809.1 m (2,654 ft) above the Paleocolluvium, which is found just above the Limestone contact. There were additional borehole instability problems experienced while drilling the 31.12-cm (12.25-in.) borehole below the surface casing to a final TD of 925.3 m (3,035 ft). As a result of this borehole instability, the well bore had to be stabilized using liquid mud and a combination 24.45- and 27.31-cm (9.625- and 10.75-in.) outside-diameter intermediate casing installed through the Paleocolluvium at a depth of 857.0 m

(2,811 ft). The 31.12-cm (12.25-in.) borehole below the intermediate casing was then cleaned out, and a combination CS and SS production casing was installed at a depth of 907.0 m (2,975 ft).

The additional 11 days between the actual and planned construction schedules are primarily due to the final demobilization of the drill rig and associated subcontracted equipment off the NNSS, which was not a part of the original baseline estimate for the construction of this well.

The final M&O actual cost of work performed (ACWP) for the main borehole construction and completion was $4,112,246, $692,599 (14.4 percent) less than the budgeted cost of work scheduled (BCWS) of $4,804,845. The cost difference is primarily the result of (1) time saved not opening the borehole and setting the larger casing; (2) higher-than-estimated penetration rates experienced while drilling the surface borehole; and (3) a reduced suite of geophysical logs run at the surface casing point with no geophysical logging services obtained at the final depth. Figure 8-1 presents the planned drilling construction schedule and costs curves for Well ER-4-1.

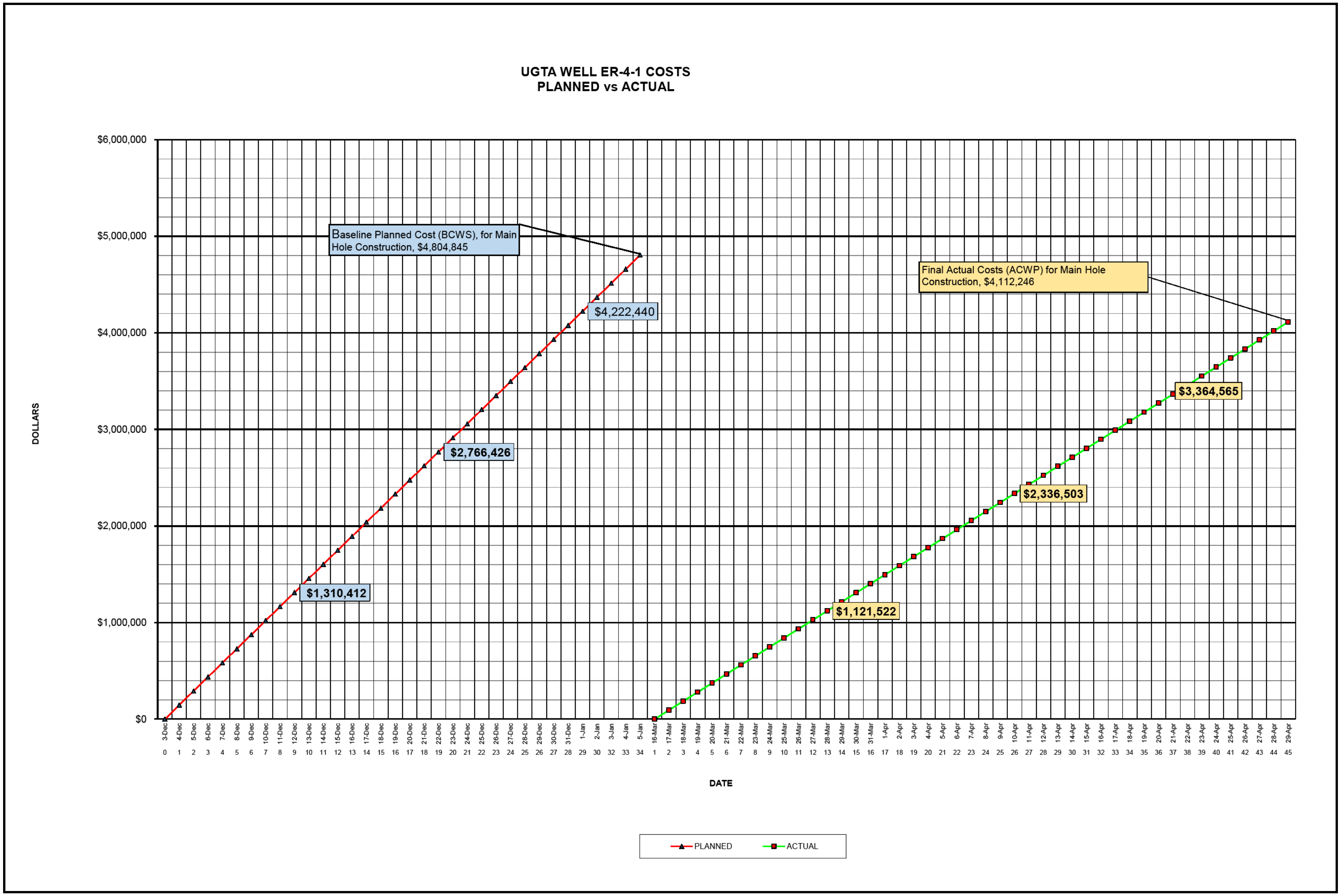


Figure 8-1
Planned vs Actual Cost of Constructing Well ER-4-1

9.0 Lessons Learned and Recommendations

Drilling, well construction, scientific, and environmental compliance activities at Well ER-4-1 were generally executed as planned. The drilling generally encountered the expected stratigraphic units in the saturated zone with some variation. The construction of Well ER-4-1 was similar to the planned design. Well ER-4-1 as-built provides for two hydraulically isolated completion intervals that may be accessed with the piezometer or main completion for the purposes of groundwater sampling or hydraulic testing. However, well development will be necessary before determining the utility of the well for hydrologic testing and sampling. Issues that influenced the final well completion included onsite technical execution, borehole instability, and equipment-related issues that occurred during execution of the work. Future drilling and well completion efforts may benefit from the following summary of lessons learned and operational experiences that were realized during operations at Well ER-4-1.

It should be noted that as with any drilling effort, important geologic and hydrologic information was gained through the drilling process. At Well ER-4-1, targeted HSUs were identified in the borehole—in particular, more than 66.20 m (217 ft) of Paleozoic rocks (Pz) of the LCA was encountered within approximately 36.58 m (120 ft) of the predicted depth. Stratigraphic data collected during drilling may be used to improve the subsurface control of stratigraphic and HSUs in the area of Well ER-4-1. These observations may be used to better interpret and or revise the Yucca Flat HFM as appropriate to improve groundwater flow and transport models in this specific area of Yucca Flat.

The regular monitoring of discharge fluids conducted while drilling provided data with respect to the presence of tritium in the groundwater. Although these are field-screening type analyses, the results indicated that tritium concentrations were generally below the MDA and the SDWA limit (CFR, 2016b), except in two distinct intervals shown in Figure 6-2b. The measurements of water levels during drilling and after completing the well provided depth to water data that suggest that predicted water levels in the saturated Paleozoic rocks (Pz) of the LCA are close to those predicted in the HFM. Water levels in the Tertiary volcanics (Tv) were higher than predicted in the HFM and require further study to determine possible mechanisms contributing to the difference.

9.1 Lessons Learned and Recommendations

9.1.1 Drilling Method

Well ER-4-1 was drilled using a conventional air-foam rotary drilling technique typical of many of the UGTA Activity wells drilled over the years. This drilling method does not require recirculation of drilling fluids, which allows for more reliable estimates of water production while drilling. This drilling method facilitates the collection of monitoring samples for tritium in groundwater without influences from recirculated contaminated groundwater in the drilling fluids. Further, this drilling method is not as sensitive to intervals of lost circulation while advancing the borehole. Other drilling methods relying on recirculation of fluids may encounter severe fluid loss and lost circulation that may severely impact drilling progress. However, the conventional air-foam circulation method does potentially impact the stability of sensitive formations. This drilling method injects drilling fluids and air into the borehole through the drill pipe, and returns entrained drilling fluids and groundwater in an air-driven stream that travels from the bottom of the borehole to the surface in the annular space between the drill pipe and the borehole wall. As depth and groundwater production increases, the air pressure/energy required to clear fluids and rock from the borehole increases. Successful drilling using this method requires close attention to drilling conditions by onsite technical staff and requires maintaining the highest rates of penetration achievable to reduce the time of exposure of potentially sensitive formations to the effects of drilling.

As anticipated, Well ER-4-1 encountered sloughing and unstable borehole conditions as the borehole penetrated bedded tuffs and volcanic sediments of the Older tunnel beds (Ton), and the sediments and bedded tuffs of the Paleocolluvium/Older tuffs (Tlc/To). These units are typically altered (zeolitic/argillic) and are prone to swelling, erosion, formation of ledges, and instability if exposed excessive groundwater or drilling fluids during drilling. Drilling through overlying units did not encounter any significant borehole stability issues.

Lesson Learned/Recommendation: Based on experiences from the drilling of Wells ER-2-2 and ER-3-3, it was recognized that the optimal rates of penetration were critical to maintaining borehole stability. At Well ER-4-1, it was emphasized to drilling and technical staff that advancing the borehole at the highest attainable rates of penetration while maintaining sampling integrity was important to achieving a surface casing point at or near the top of the LCA. Advancing the borehole to this contact was contingent on an expected low groundwater production through the saturated volcanics and maintaining relatively high rates of penetration. Although sloughing borehole conditions limited the depth at which the 13.375-in. casing could be positioned, the borehole maintained sufficient stability to allow for a reduced suite of geophysical and hydrophysical logging services. Subsequent advancement of the 12.25-in. borehole to the TD 925.13 m (3,035.19 ft) bgs within the LCA saw some borehole stability issues, but these were somewhat expected because the ATCU was unstable under the higher water production derived from the LCA. The drilling approach at Well ER-4-1 was successful in terms of maintaining higher rates of penetration and improved borehole stability. As a result, Well ER-4-1 was successfully completed in the LCA (target aquifer) and allowed for the installation of a piezometer within the LTCU.

Consideration should be given when planning drilling programs to allow for various contingencies in drilling, borehole stabilization, and completion methods. These alternative procedures can be implemented based upon the borehole and program-specific priorities. This may offer some benefit for boreholes that encounter stability issues. Under these conditions, higher, possibly deeper, targets would not be jeopardized by attempts to stabilize the borehole for shallower targets with a lower overall priority. Well ER-4-1 was ultimately successful in achieving the planned well completions in the target HSUs of LTCU and LCA. However, if unstable borehole conditions did not warrant the pursuit of a lower-priority completion in the LTCU, the planning should have allowed for options to immediately emplace bentonite-based muds after drilling to the casing point to help ensure more stable borehole conditions and forego the lesser-priority shallow completion.

9.1.2 Geophysical Logging

During geophysical and hydrophysical logging at Well ER-4-1, several issues related to the collection and quality of data collected by the contractors were noted. Geophysical logging was conducted by Schlumberger on March 28 and 29, 2016. In an effort to minimize stand-by time for the drill rig, Schlumberger was instructed to conduct logging at higher logging speeds. Also, Schlumberger "stacked" geophysical tools to allow acquisition of multiple types of logs in a single log run. The stacking of the tools increased the overall tool length. The increased tool length affected the depth of acquisition of data for some geophysical tool types. COLOG experienced tool failure on some of the probes used in the Idronaut Chemistry tool. These equipment issues meant the log failed to collect specific water-quality parameters. Additionally, the tool malfunction when deployed and would not function while logging (trolling) upward in the well. The loss of this typical logging capability required acquisition of hydrophysical data on depth stations. This resulted in a loss of a detailed profile of water-quality measurements in the borehole. No geophysical logging was conducted below the 13.375-in. surface casing due to borehole stability conditions.

Lesson Learned/Recommendation: Planned geophysical logging was impacted through efforts to reduce the logging time and costs. Although the data collected were not as complete or of the typical quality, there were tradeoffs required to allow for the continued drilling and well completion against the smaller than planned budgets. The data acquired were generally sufficient to allow for petrophysical interpretation given these circumstances. Future operations may benefit from eliminating some logging tools from the suite and concentrating on essential logs. Using this approach, tool stacking may be reduced and/or eliminated. Issues relating to the function of the tools can be helped by function testing the tools by the contractor before arrival on site. However, equipment-related issues are a part of this work and can happen at any time.

10.0 References

ASTM, see ASTM International.

ASTM International. 2015. *Standard Test Method for Plutonium in Water,* ASTM D3865-09(2015). West Conshohocken, PA.

BLM, see Bureau of Land Management.

BN, see Bechtel Nevada

Bechtel Nevada. 2006. *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat–Climax Mine, Lincoln and Nye Counties, Nevada*, DOE/NV/11718--1119. Prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Las Vegas, NV.

Bureau of Land Management. 2017. "BLM Public Land Survey System Data for USA." As accessed at http://www.arcgis.com/home/item.html?id=f4a948575875449b8b4284ecaef84bf5 on 15 March.

CFR, see *Code of Federal Regulations*.

Code of Federal Regulations. 2016a. Title 29 Part 1910, "Occupational Safety and Health Standards." Washington, DC: U.S. Government Printing Office.

Code of Federal Regulations. 2016b. Title 40 CFR Part 141, "National Primary Drinking Water Regulations." Washington, DC: U.S. Government Printing Office.

Code of Federal Regulations. 2016c. Title 40 Chapter I "Protection of the Environment." Washington, DC: U.S. Government Printing Office.

DOE, see U.S. Department of Energy.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

EPA, see U.S. Environmental Protection Agency.

ESRI, see Environmental Systems Research Institute, Inc.

Environmental Systems Research Institute, Inc. 2017. *ArcMap,* Version 10.3.1. Redlands, CA: ESRI.

FFACO, see *Federal Facility Agreement and Consent Order.*

Federal Facility Agreement and Consent Order. 1996 (as amended March 2010). Agreed to by the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management. Appendix VI, which contains the Underground Test Area Strategy, was last modified June 2014, Revision No. 5.

Navarro GIS, see Navarro Geographic Information Systems.

NNSA/NFO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office.

NNSA/NSO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office.

NSTec, see National Security Technologies, LLC.

National Security Technologies, LLC. 2015. *Underground Test Area (UGTA) Activity Health and Safety Plan,* Rev. 3. May. Las Vegas, NV.

National Security Technologies, LLC. 2016. *Field Activity Work Package, Main Hole Drilling and Completion of Well ER-4-1,* Work Package Number: D-003-001.16. Las Vegas, NV.

Navarro Geographic Information Systems. 2017. ESRI ArcGIS Software.

Navarro. 2015. *Field Instruction for the Underground Test Area Activity Drilling and Well Completion Operations Nevada National Security Site, Nevada,* N/0002653--050. Las Vegas, NV.

Navarro. 2016a. *Navarro Field Activity Work Package (FAWP) for Underground Test Area (UGTA) Project Drilling Field Operations Wells ER-4-1 and ER-3-3*, NAV-UGTA-020216, Rev. 0. Las Vegas, NV.

Navarro. 2016c. Written communication. Subject: “Analytical Services Database.” Las Vegas, NV.

Navarro. 2016c. Written communication. Subject: *Final Well Specific Fluid Management Strategy for UGTA Well ER-4-1, Nevada National Security Site; Appendix D,* 25 March. Las Vegas, NV.

Navarro. 2016d. *Yucca Flat Drilling and Completion Criteria, Wells ER-2-2*, *ER-3-3, and ER-4-1,* Rev. 1, N/0002653--010-Rev. 1. Las Vegas, NV.

Nimz, G.J., and J.L. Thompson. 1992. *Underground Radionuclide Migration at the Nevada Test Site,* UCRL-ID-111013. Livermore, CA: Lawrence Livermore National Laboratory.

Pawloski, G.A. 1999. *Development of Phenomenological Models of Underground Nuclear Tests on Pahute Mesa, Nevada Test Site—BENHAM and TYBO*, UCRL-ID-136003. Livermore, CA: Lawrence Livermore National Laboratory.

Sawyer, D.A., R.J. Fleck, M.A. Lanphere, R.G. Warren, D.E. Broxton, and M.R. Hudson. 1994. "Episodic Caldera Volcanism in the Miocene Southwestern Nevada Volcanic Field: Revised Stratigraphic Caldera Framework, $^{40}Ar/^{39}Ar$ Geochronology, and Implications for Magmatism and Extension." In *Geological Society of America Bulletin*, Vol. 106(10): pp. 1304–1318.

Slate, J.L., M.E. Berry, P.D. Rowley, C.J. Fridrich, K.S. Morgan, J.B. Workman, O.D. Young, G.L. Dixon, V.S. Williams, E.H. McKee, D.A. Ponce, T.G. Hildenbrand, W.C. Swadley, S.C. Lundstrom, E.B. Ekren, R.G. Warren, J.C. Cole, R.J. Fleck, M.A. Lanphere, D.A. Sawyer, S.A. Minor, D.J. Grunwald, R.J. Laczniak, C.M. Menges, J.C. Yount, and A.S. Jayko. 1999. *Part A. Digital Geologic Map of the Nevada Test Site and Vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California, Revision 4*, Open-File Report 99-554-A, scale 1:120,000. Denver, CO: U.S. Geological Survey.

U.S. Department of Energy. 1997. *The Procedures Manual of the Environmental Measurements Laboratory*, HASL-300. 28th Edition, Vol. I. February. New York, NY.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2014. *Nevada National Security Site Integrated Groundwater Sampling Plan,* Rev. 0, DOE/NV--1525. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2015a. *Underground Test Area Activity Quality Assurance Plan Nevada National Security Site, Nevada,* Rev. 2, DOE/NV--1450-Rev.2. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2015b. *United States Nuclear Tests, July 1945 through September 1992,* DOE/NV--209-REV 16. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009. *Underground Test Area Project Waste Management Plan,* Rev. 3, DOE/NV--343-Rev. 3; *Attachment 1 Fluid Management Plan for the Underground Test Area Project*, Rev. 5, DOE/NV--370-Rev. 5. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 2000. *Corrective Action Investigation Plan for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada,* DOE/NV--659. Las Vegas, NV.

U.S. Environmental Protection Agency. 1980. *Prescribed Procedures for Measurement of Radioactivity in Drinking Water,* EPA 600/4-80-032. Cincinnati, OH: Environmental Monitoring and Support Laboratory Office of Research and Development.

U.S. Environmental Protection Agency. 1983. *Methods for the Chemical Analysis of Water and Wastes,* EPA/600/4-79-020. Cincinnati, OH: Environmental Monitoring and Support Laboratory Office of Research and Development.

U.S. Environmental Protection Agency. 1984. *Eastern Environmental Radiation Facility Radiochemical Procedures Manual,* EPA 520/5-84-006. Montgomery, AL: Office of Radiation Programs, Eastern Environmental Radiation Facility (renamed the National Air and Radiation Environmental Laboratory [NAREL] in 1989).

U.S. Environmental Protection Agency. 1997. *Determination of Inorganic Anions in Drinking Water by Ion Chromatography,* Method 300.1. Cincinnati, OH: National Exposure Research Library Office of Research and Development.

U.S. Environmental Protection Agency. 2016. *SW-846 On-Line, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.* As accessed at http://www.epa.gov/epaoswer/hazwaste/test/main.htm on 25 August.

Appendix A

Lithologic Log for Well ER-4-1

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	Thickness m (ft)	Sample Type [a]	Lithologic Description [b]	Stratigraphic Unit (Map symbol)
0-187.45 (0-615)	187.45 (615)	DA	**Alluvium, From 0-120 ft:** Drilled under NSTec supervision; no samples were collected by Navarro. Lithology inferred from surface exposures, collected cuttings below 120 ft bgs, and geophysical logs. **From 120-615:** cuttings consist of loose, medium to coarse sand size fragments of Tertiary Volcanics (Nonwelded to Welded Tuffs, bedded tuffs, and lavas), rare to minor (2-5%) clastics (siltstone) and carbonates (dolomite and limestone), and loose felsic (sanidine, plagioclase, quartz) crystal fragments. Interbedded(?) zones with clay/caliche coatings, Moderate > Strong reaction with HCl, mostly subangular > sub-rounded followed by angular/platty. Fine silt and ash washed away during drilling/processing. From 610-620, cuttings are heavily contaminated (DB4).	Quaternary/Tertiary Alluvium (QTa)
187.45-207.26 (615-680)	19.81 (65)	DB4/DA	**Nonwelded to Partially Welded Ash-flow Tuff:** crystal-rich, vitric; Matrix color: light reddish brown (2.5YR 6/3) > light reddish brown (5YR 6/3) grading into dominantly pink (7.5YR 7/4); Phenocrysts: (15-30%), sanidine (common chatoyant), quartz (terminated, dipyramidal, clear), plagioclase, sphene (rare>minor?), Mafics (1%): biotite (black, unox), magnetite; Pumice: Percentage uncertain due to drilling/cuttings collection, pink (7.5YR 7/4), vitric; Lithics (1-2%): welded tuff/lava, high uncertainty due to contamination from alluvium; heavy contamination (70-80%) from 620-650 and from 650-680 contamination significant (40-60%). Geophysical logs (GR, Density, Resistivity) used to determine location of contact.	Timber Mountain Ammonia Tanks Tuff (Tma)
207.26-231.65 (680-760)	24.38 (80)	DB4/DA	**bedded and reworked tuff:** crystal-rich, pumice-rich, vitric; Matrix color: pinkish gray (7.5YR 6/2) > brown (7.5YR 5/3); Phenocrysts (15-30%): sanidine (chatoyant), quartz (terminated, dipyramidal, mostly clear), plagioclase, sphene(?), Mafics (1-2%): biotite (black, unox), magnetite (unox.>partially ox.), pyroxene(?); Pumice (5>10%): white (N9) > light gray (N 7/1) > mottled light gray (N 7/1) and weak red (2.5YR 4/2) > mottled light gray (N 7/1), brown (7.5YR 4/2) and black (N 2.5), vitric, fibrous > tubular texture, some white pumice have vitreous > pearlescent surface; Lithics (1-2%): welded tuff/lava and volcanic glass black (N 2.5/1); cuttings are (40-50%) contamination and are not entirely representative of interval, from 730-744 abundant loose felsic crystal fragments, from 740-760 appears to be a reworked bed.	Timber Mountain Ammonia Tanks bedded tuff (Tmab)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
231.65-249.94 (760-820)	18.29 (60)	DA	**Nonwelded to Moderately Welded Ash-flow Tuff:** crystal-rich, mafic-rich, devitrified, vapor phase alteration; Matrix color: light brown (7.5YR 6/4) grading into reddish brown (2.5YR 5/3) > weak red (10R 5/3) > pale red (10R 6/2); Phenocryst (15-20%?): sanidine (minor chatoyant), quartz (terminated, dipyramidal, clear), plagioclase, Mafics (1≤2%): biotite (black, euhedral/ fragments, unox.), magnetite (?), rare pyroxene (?, greenish black); Pumice (10-15%): light red (2.5YR 7/6) > pale red (10R 6/2) > pinkish white (10R 8/2) and white (N8-N9) > pink (7.5YR 8/3), relict vitric texture > partially vitric, some vapor phase corroded; Lithics: (1%?), welded tuff/lava, volcanic glass black (N 2.5), small 1-2 mm or smaller; pumice flattening increasing with depth, mafic content varies widely.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
249.94-252.98 (820-830)	3.05 (10)	DA	**Moderately to Densely Welded Ash-flow Tuff:** crystal-rich, mafic-rich, devitrified > partially vitric; Matrix color: pinkish gray (5YR 6/2) > reddish gray (5YR 5/2) grading into light reddish brown (5YR 6/3) > reddish brown (5YR 5/3) with black (N 2.5) vitric portions (fiamme?); Phenocrysts (10-25%): sanidine (minor chatoyant), quartz (terminated, rare dipyramidal, clear), plagioclase, Mafics (1-3%): biotite (black, unox., euhedral books > fragments), pyroxene (greenish black (10GY 2.5/1); Pumice: (10-15%): pink (7.5YR 8/3) > reddish yellow (7.5YR 7/6) and white (N8-N9), vapor phase corroded/altered, flattened, rare relict vitric texture; Lithics (<1%): welded tuff/lava.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
252.98-268.22 (830-880)	15.24 (50)	DA	**Densely Welded Ash-flow Tuff (vitrophyre):** crystal-rich, mafic-rich, vitric; Matrix color: very dark gray (5Y 3/1) > black (N 2.5) > very dark gray (10YR 3/1); Phenocrysts (15-25%): sanidine, quartz (terminated, dipyramidal, clear), plagioclase, Mafics (2-3%): biotite (black, euhedral books/fragments, unox.), magnetite, pyroxene (?); Pumice (?): possible pumice - small (1 mm?) gray (10YR 5/1), actual percentage indeterminate in vitric - densely welded section; Lithics (1-3%): welded tuff/lava, sand size (1-≤2 mm); very minor incipient crystallization (devitrification) beginning at ~860 and increasing with depth.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
268.22-271.27 (880-890)	3.05 (10)	DA	**Densely to Moderately Welded Ash-flow Tuff:** crystal-rich, mafic-rich, partially vitric > devitrified; Matrix color: weak red (2.5YR 5/2) > reddish brown (2.5YR 5/3); Phenocrysts (7-15%): sanidine (minor chatoyant), quartz (terminated, minor dipyramidal, clear), plagioclase, Mafics (2%): biotite (black, euhedral/fragments, unox.), oxides (magnetite?); Pumice (10-15%): pinkish white (5YR 8/2), rare red (2.5YR 5/6) and light reddish gray (2.5YR 7/1), vapor phase corroded, some vapor phase alteration/mineralization, increasing vitric texture from 890 ft down; Lithics (1-2%): welded tuff; contamination (20-30%), primarily from the vitrophyre, Geophysical log (Density) primary basis used to determine zone.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
271.27-289.56 (890-950)	18.29 (60)	DA/DB4 > DA	**Moderately to Partially Welded Ash-flow Tuff:** mafic-poor, partially vitric > devitrified, vapor phase altered/mineralized; Matrix color: light reddish brown (2.5YR 6/3-6/4) > reddish brown (2.5YR 5/4); Phenocrysts (5-10%): sanidine, quartz (terminated, rare dipyramidal, clear), plagioclase, Mafics (1%): biotite (black, fragments-very small, unox.), magnetite(?); Pumice (10-15%): pinkish white (5YR 8/2) > light reddish brown (2.5YR 6/3), rarely white (N8), vitric to vapor phase corroded/mineralized, rare dark reddish brown (5YR 3/3) coating on some pumice, pumice 2-5 mm (ave. ~2-3 mm); Lithics (≤1%): volcanic(?), ≤1 mm; from 890-950 abundant loose felsic crystal fragments (possibly contamination from above?), contamination variable (40-10%) - mostly from vitrophyre, rare botryoidal silica (≤1%) from 910-950, zone determined from pumice flattening and Geophysical log (Density).	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table A-1
Lithologic Log for Well ER-4-1
(Page 4 of 11)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
289.56-353.57 (950-1,160)	64.01 (210)	DA > DA/DB4	**Partially to Nonwelded Ash-flow Tuff with minor bedded tuff:** mafic-poor, vitric > partially devitrified; **From 950-1,100:** Matrix color: (as in 890-950 above); Phenocrysts: (as in 890-950 above); Pumice: (as in 890-950 above), except pumice from 2-10 mm (average ~4-5 mm); Lithics: (as in 890-950 above); common shard casts, dark reddish brown (5YR 3/3) > black (N 2.5) glass shards and fragments, from 1,000-1,040 strongly altered zone (possible paleosol?), Matrix color: mottled dark red (10R 3/6) and red (7.5R 4/8) with reddish yellow (5YR 7/6) spots on a base that ranges from pale red (10R 7/4) > pale red (10R 6/2); **From 1,100-1,160:** Nonwelded Ash-flow Tuff to bedded tuff: vitric; Matrix color: reddish brown (5YR 5/3) > dark reddish gray (5YR 4/2); Phenocrysts (5-10%): sanidine, quartz (terminated, dipyramidal, clear), plagioclase(?), Mafics (1-≤2%): biotite (black, fragments); Pumice 10-15%): white (5YR 8/1) > white (N 8); Lithics (2-3%): welded tuff/lava weak red (7.5R 5/3) > dusky red (7.5R 3/2); contamination (20-40%) from Nonwelded Tmrp.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table A-1
Lithologic Log for Well ER-4-1
(Page 5 of 11)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
353.57-385.57 (1,160-1,265)	32.00 (105)	DA/DB4 > DA	**bedded tuff and Nonwelded Ash-flow Tuff:** pumice-rich, vitric; **From 1,160-1,205:** bedded tuff: vitric, pumice-rich, moderately indurated; Matrix color: reddish brown (2.5YR 5/3) > light reddish brown (2.5YR 6/4) grading down to > light reddish brown (5YR 6/3) > light gray (10YR 7/2), distinctive mottled appearance with white pumice; Phenocrysts (7-10%): sanidine (very rare chatoyant), quartz (terminated, clear), plagioclase(?), Mafics (≤1%): biotite (black, fragments, unox.), Mn oxides (spots,?), trace pyroxene(?); Pumice (15-30%): white (N9-N8) > very pale brown (10YR 8/2), vitric, fibrous/tubular (woody) texture, some vapor phase corrosion, very small to larger (≤1-10 mm) pumice; Lithics: (1-3%), welded tuff/lava very dusky red (5R 2.5/3) > reddish black (7.5R 2.5/1) > black (N 2.5), distinctive due to larger size (2-4 mm), most lithics very fine sand size (≤1 mm), welded tuff/lava light red (7.5R 6/6) > red (10R 5/6), volcanic glass (shards, bubble fragments), very fine (≤1 mm) black (N 2.5/1) > dark reddish brown (5YR 3/3); contamination (20-30%) from 1,160-1,180 decreasing with depth. **From 1,205-1,265:** Nonwelded Ash-flow Tuff: vitric, crystal-moderate, mafic-rich, moderately indurated; Matrix color: very pale brown (10YR 8/3-8/2) > pale yellow (2.5Y 8/2), distinctive “peppered” appearance; Phenocrysts (5-10%): sanidine, quartz (terminated, trace dipyramidal, clear), Mafics (2-3%): biotite (black, euhedral/fragments(?), unox., typically ≤1 mm rarely to 2 mm), Mn oxide (spots and granular clumps); Pumice (20-30%): very pale brown (10YR 8/4), reddish yellow (7.5YR 8/6), reddish yellow (5YR 7/6), and yellowish red (5YR 5/6), relict pumice mostly removed by vapor phase corrosion, ~30-40% of pumice show incipient alteration rims, commonly vapor phase corroded, typically 1-3 mm; Lithics (1-2%): welded tuff/lava weak red (10R 5/2), very dusky red (10R 2.5/2), and black (N 2.5/1), from 1,250-1,265 slight increase in abundance to 3-5% and size from 2-4 mm.	tuff of Holmes Road (Tmrh)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
385.57-475.49 (1,265-1,560)	89.92 (295)	DA/DB4	**bedded and reworked:** crystal-moderate to crystal-poor, altered (zeolitic) > partially vitric, moderately to poorly indurated; **From 1,265-1,470:** bedded and reworked tuff (interbedded), crystal-poor to moderate, altered (zeolitic) > partially vitric; Matrix color: brown (7.5YR 5/3) > reddish brown (5YR 5/3) grading to light brown (7.5YR 6/3) > brown (7.5YR 5/4) > pale brown (10YR 6/3); Phenocrysts (3-7%): sanidine, plagioclase, quartz (trace), very rare sphene(?), trace apatite (??, yellow 5Y 7/8), Mafics ($\leq$1-2%): biotite (black, euhedral/fragments, unox.>ox.), Mn oxide (spots, dendrites), hornblende (?, greenish black), magnetite (?); Pumice (10-15%): white (N9) > pinkish white (7.5Y 8/2) > pale yellow (5Y 8/2-8/3), pumice mostly $\leq$1-3 mm, altered (zeolitic), relict vitric texture (minor), some vapor phase corroded; Lithics (1-3%): welded tuff/lava weak red (7.5R 5/4) > dusky red (7.5R 3/4) and minor light gray (10R 7/1) > reddish gray (10R 6/1), most $\leq$1 mm occasionally 3 mm+, many loose with little to no matrix, lithics with no matrix may be contamination from above, possible lithic-rich (10-15%) zones from 1,340-1,360(?) and 1,440-1,470(?); contamination from uphole (primarily Tmrh) varies from (15-30%), rare fragments with bluish white (5B 9/1) silica on matrix. **From 1,470-1,560:** bedded tuff: crystal-poor, altered (zeolitic, pervasive), moderately well indurated; Matrix color: very pale brown (10YR 8/3 -8/4) > pale yellow (2.5Y 8/2) > very pale brown (10YR 7/3); Phenocrysts (2-5%): sanidine, plagioclase, trace quartz, trace sphene(?), Mafics (1-2%): biotite (black/brown, euhedral/fragments, unox.>ox.), Mn oxide (spots), hornblende(?); Pumice (5-15%): white (5Y 8/1), pale yellow (5Y 8/3 -8/4), very pale brown (10Y 8/2), typically <1-4 mm+, some rare silicification(?) around pumice; Lithics (2-5%): welded tuffs/lava dark reddish gray (10R 3/1) > dusky red (10R 3/3) > reddish gray (10R 5/1), very fine sand size lithics pale red (7.5R 6/4), lithics are in matrix or have matrix coating, larger lithics may be in zones where fine (pale red) lithics appear evenly distributed in matrix; contamination most significant from 1,470-1,480 (30-40%).	Pre-Timber Mountain Tuff - Post Wahmonie Tuff, undivided (Tm/Tw)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
475.49-481.58 (1,560-1,580)	6.10 (20)	DB4	**bedded tuff:** crystal-rich, mafic-rich, altered (zeolitic/argillic) > partially vitric(?); Matrix color (mottled): pale yellow (2.5Y 7/3 to 7/4) > pale yellow (2.5Y 8/3-8/4) > light gray (2.5YR 7/2) > light brownish gray (2.5Y 6/2); Phenocrysts (7-15%): sanidine, plagioclase (?), quartz (rare), Mafics (3-7%): biotite (black/golden, euhedral/fragments, unox.>ox.), hornblende, magnetite (?), phenocrysts sometimes concentrated in matrix fragments - possibly reworked bed(?) interbedded with pumice-rich beds, strong brown (7.5YR 5/8) stains appear to be associated with some magnetite grains; Pumice (3-15%): pale yellow (2.5Y 8/2-8/3), white (N9), pink (7.5YR 8/3), pumice ≤1 mm, rarely to 2-3 mm(?), some pumice-rich fragments swell and crumble when wet; Lithics (1-2%): welded tuff/lava reddish gray (7.5R 6/1), very fine sand size (≤1 mm); significant contamination (40-50%), cuttings not representative of interval, Geophysical logs (GR, SGR, Density, and Resistivity) used to determine contacts.	Wahmonie Formation (Tw)
481.58-516.64 (1,580-1,695)	35.05 (115)	DA	**Nonwelded Ash-flow Tuff and bedded tuff:** mafic-rich, altered (zeolitic); Matrix color: very pale brown (10YR 7/4) > brown (10YR 5/3), light reddish brown (2.5YR 6/4) > grayish brown (2.5Y 5/2) > white (2.5Y 8/1), distinctive “peppered” appearance; Phenocrysts (5-7%): sanidine, plagioclase, rare quartz, Mafics (3-5%?): hornblende (greenish black), biotite (black>bronze, euhedral/ fragment., unox.>ox.), magnetite (ox.); Pumice (3-7%): white (N9) > white (7.5YR 8/1) > pale brown (10YR 8/2) > pinkish white (7.5YR 8/2), pumice very small (≤1 mm); Lithics (3-7%): welded tuff/lava, fine > very fine (1-2 mm?) rarely larger (4 mm+); possible significant contamination from 1,580-1,590 and 1,670-1,695.	Crater Flat Group, undivided (Tc)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
516.64-550.16 (1,695-1,805)	33.53 (110)	DB4/DA > DA	**bedded tuff:** crystal-poor, altered (zeolitic, pervasive); Matrix color: pale yellow (5Y 8/4) > pale yellow (2.5Y 8/3) and light olive brown (2.5Y 5/4) > yellowish brown (10YR 5/4); Phenocrysts (1-3%): sanidine, plagioclase(?), Mafics (none noted): Mn oxide (spots, dendrites); Pumice (10-15%): olive yellow (2.5Y 6/6), pale yellow (2.5Y 7/4), rare yellow (5Y 8/6), some pumice show signs of vapor phase corrosion, mostly sub-rounded; Lithics (2-5%?): welded tuff/lava dark reddish brown (5YR 2.5/2), dusky red (7.5R 3/4), black (N 2.5/1), rare weak red (7.5R 5/4) - typically very small (≤1 mm), other lithics from 2-5 mm, possible lithic-rich intervals from 1,760-1,775 and 1,795-1,805; contamination (20-30%) from 1,695-1,740 ft bgs decreasing to (20%) or less by 1,805.	Grouse Canyon bedded tuff (Tbgb)
550.16-600.46 (1,805-1,970)	50.29 (165)	DB4 > DA	**bedded tuff and Nonwelded Ash-flow Tuff:** crystal-poor, altered (zeolitic/ argillic) > devitrified(?); Matrix color (mottled/banded?): pale brown (10YR 6/3) > very pale brown (10YR 7/3) and light brown (7.5YR 6/3) > pinkish gray (7.5YR 6/2) interbedded with red (10R 4/6-5/6) > dark red (10R 3/6); Phenocrysts (3-7%): sanidine, quartz (rare>minor), Mafics: (<1-2%), biotite (black>golden, euhedral/fragments., unox.>partially ox.), pyroxene, magnetite; Pumice (10-30%): white (7.5YR 8/1) > pinkish white (2.5YR 8/1) > pink (2.5YR 8/3) > pale yellow (5Y 8/3) > yellow (2.5Y 8/6), pumice typically 1-2 mm, rarely 3 mm+, translucent/waxy appearance; Lithics: (1-3%), welded tuff/lava dusky red (10R 3/4) > weak red (10R 4/3) > pale red (10R 6/4), mostly <1 mm some 2-3 mm, lithic percentage and description only included lithics in matrix or having a matrix coating; significant contamination (40-60%) from 1,805-1,840 ft bgs decreasing to <20%, second zone of significant contamination from 1,920-1,930.	Tunnel Formation, Member 4, undifferentiated (Tn4)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
600.46-667.51 (1,970-2,190)	67.06 (220)	DA	**bedded tuff and Nonwelded Ash-flow Tuff:** crystal-poor, altered (zeolitic/ argillic) > devitrified(?); Matrix color (mottled): red (10R 4/6) > dark red (10R 3/6) > reddish brown (2.5YR 5/4) and pale yellow (2.5Y 8/2) > very pale brown (10YR 7/4), white (2.5YR 8/1), possibly beds with differing color/alteration; Phenocrysts (3-7%): sanidine, plagioclase, quartz (rare), Mafics (≤1%): pyroxene(?), magnetite, biotite (?, very rare); Pumice (5-30%): white (5Y 8/1) > pinkish white (2.5YR 8/2) > red (7.5R 5/8), from ~2,030 becoming dominantly pale yellow (5Y 8/2-8/4) and rare yellow (5Y 8/6), some pumice have distinctive Mn oxide clots, size varies from ≤1-5 mm+, some relict vitric texture; Lithics: (3-7%): welded tuff/lava very dusky red (7.5R 2.5/3), black (N 2.5/1), reddish gray (2.5YR 6/1), size ranges from ≤1-3 mm+; rare molds of glass shards, contamination (15-30%).	Tunnel Formation, Member 3, undifferentiated (Tn3)
667.51-694.94 (2,190-2,280)	27.43 (90)	DA	**bedded tuff:** crystal-poor, altered (zeolitic/argillic), moderately to poorly indurated; Matrix color: dark red (10R 3/6) > red (7.5R 2.5/2) > red (7.5R 5/6); Phenocrysts (3-7%): sanidine, quartz, plagioclase(?), Mafics (≤1%): biotite (?, very small/fine, black, fragments), pyroxene(?), magnetite; Pumice (5-20%): pinkish white (10R 8/2) > light red (7.5R 7/6), white (7.5R 8/1), pumice typically very small (≤1 mm, rarely 2 mm+: Lithics (1-3%): welded tuff/lava very dusky red (7.5R 2.5/2), black (N 2.5/1), and light red (7.5R 6/6); bed has distinctive color and sandy (very fine) texture with rare silty (ash?) layers, from 2,230-2,280 appearance of alternating dusky red and light red layers.	Tunnel Formation, Member 3, bed 3A (Tn3A)
694.94-749.81 (2,280-2,460)	54.86 (180)	DA/DB4	**bedded tuffs and Nonwelded Ash-flow Tuff:** crystal-poor, pumice-rich, altered (zeolitic/argillic); Matrix color (mottled): red (2.5YR 5/8) > reddish brown (2.5YR 5/4) and pink (5YR 7/4) > pale yellow (2.5Y 8/3); Phenocrysts (5-7%): sanidine, plagioclase, quartz, Mafics (<1-2%): biotite (pale brown>bronze), hornblende(?); Pumice: (10-20%): white (N9) to variegated white (N9) and red (2.5YR 5/8) with rare yellow (5Y 7/8), some relict vitric texture; Lithics: (1-3%): lava/welded tuff, rare clastic(?); significant contamination from uphole and within unit.	tunnel bed2 (Ton2)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
749.81-832.10 (2,460-2,730)	82.30 (270)	DB4	**bedded tuff and Nonwelded Ash-flow Tuff:** crystal-poor, pumice-rich, mafic-poor, altered (zeolitic/argillic), poorly indurated; Matrix color: reddish brown (2.5YR 5/4-4/4) > light reddish brown (2.5YR 7/4); Phenocrysts (1-3%): sanidine, plagioclase(?), Mafics (≤1% - trace): biotite(?) (fragments); Pumice (15%): very pale brown (10YR 8/2) and white (N9-N8), variably altered (zeolitic/argillic); Lithics (≤1%): welded tuff/lava(?); from 2,470-2,560, ~10% of sample is a silicified(?) crystal-rich tuff, significant contamination, difficult to distinguish Ton1 from Ton2, hole experienced sloughing/fill related issues, Geophysical log (run down to ~2,510) used to determine contact between Ton2 - Ton1, from 2,700-2,730, ~10-20% contamination with cement.	tunnel bed1 (Ton1)
832.10-858.93 (2,730-2,818)	26.82 (88)	DB4 > DA/DB4	**Paleocolluvium, bedded tuff, and tuffaceous sediments (Interbedded):** altered (argillic): **From 2,730-2,790:** Matrix (clay) color: red (10R 5/6) > reddish brown (2.5YR 5/4) and minor pink (10R 8/3); Colluvium: fragments of altered tuff light red (10R 7/6) > pinkish white (5YR 8/2) > very pale brown (10YR 8/2), carbonates light bluish gray (10B 7/1) > gray (7.5YR 5/1), and loose felsic crystal fragments: crystal fragments are euhedral > subrounded and frosted to clear; contamination is ~(60-80%?), cuttings are not wholly representative of the interval. **From 2,790-2,810:** bedded tuff and Nonwelded Ash-flow Tuff(?): altered (argillic, pervasive); Matrix color: pale red (10R 6/4) > weak red (10R 5/4) > red (2.5YR 5/6); Phenocrysts (5-10%): sanidine. plagioclase(?), Mafics (<1%): biotite (black>golden, euhedral/fragments), thin ash beds with no phenocrysts; Pumice (10-20%): white (N9) > pinkish white (2.5YR 8/2), pervasive alteration, rare relict vitric texture; Lithics (≤1%): welded tuff/lava pale red (7.5R 6/3) rare dark reddish gray (7.5R 4/1); contamination (10-20%) mostly volcanics from uphole. **From 2,810-2,818:** Paleocolluvium, bedded tuff, and tuffaceous sediments: Paleocolluvium: fragments of altered tuffs, carbonates, and loose felsic crystal fragments: Colors and description as in 2,730-2,790 description; contamination (20-40%) or which 10-20% is cement/float shoe fragments, samples may not be representative of interval.	Paleocolluvium/older tuffs (Tlc/To)

Table A-1
Lithologic Log for Well ER-4-1
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
858.93-925.13 (2,818-3,035)	66.14 (217)	DA	**Limestone:** fine > medium grained, minor alteration and recrystallization: **From 2,818-2,890:** Interbedded Limestones: (1) massive to thick bedded limestone: Matrix color: black (N 2.5) > very dark gray (N 3); fine > medium grained, minor argillic/hematitic alteration along fractures, minor fracturing, calcite mineralization and rare pyrite: (2) very thin bedded/laminated limestone: Matrix color: gray (7.5YR 5/1-6/1) > pinkish gray (7.5YR 6/2); very fine grained > micritic, limonite staining along bedding/laminations, laminations ~1 mm to thicker beds(?); all fragments show moderate to strong reaction with HCl; cuttings show 2 major size groupings (~1-3 mm and ~5-15 mm+); contamination varies from 40% and decreasing to 20% around 2,280 and returning to ~40% at 2,290. **From 2,890-2,940:** Limestone and Limestone/ Breccia: Matrix color (Limestone): gray (7.5YR 5/1) > light gray (7.5YR 7/1) with dark grayish brown (10YR 4/2) > dark grayish brown (2.5Y 4/2) > dark gray (2.5Y 4/1); Matrix color (Limestone/Breccia): brownish yellow (10YR 6/6) > yellowish brown (10YR 5/8) > pale yellow (2.5Y 7/3) and light gray (10YR 7/1) > gray (10YR 6/1); fine grained > recrystalized, minor veins with calcite mineralization, spary/coarse calcite fragments, limonite and hematite staining and mineralization (including open space filling, gouge?), very rare chalcedony; contamination varies from 60-20% (mixture of limestone and volcanics), cuttings decreasing in size with increasing depth, possible fault/breccia zone from 2,900-2,940. **From 2,940-3,035:** contamination (80-90%) primarily volcanics from above, material appears to be re-drilled cuttings,90% of cuttings are <2 mm in size.	Paleozoic (undivided) (Pz)

[a] Lithologic samples collected from interval during drilling and logging operations and used for lithologic interpretation. **DA** = drill cuttings that represent lithologic character of interval; **DB4** = drill cuttings that are not wholly representative of interval.
[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 unless otherwise noted.

GR = Gamma ray
HCl = Hydrochloric acid
mm = Millimeter
Mn = Manganese
unox. = Unoxidized
ox. = Oxidized

Appendix B

Tritium Activities during Drilling of Well ER-4-1

Table B-1
Tritium Activities during Drilling of Well ER-4-1
(Page 1 of 6)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
1	03/23/2016	N/A	N/A	591	1,530.53	Make-up water
2	03/23/2016	36.58	120	202	1,581.73	Discharge Line
3	03/24/2016	N/A	N/A	3,097	1,581.73	Make-up water
4	03/24/2016	43.89	144	1,418	1,576.91	Discharge Line
5	03/24/2016	49.07	161	1,265	1,576.91	Discharge Line
6	03/24/2016	57.91	190	485	1,406.19	Discharge Line
7	03/24/2016	68.28	224	1,226	3,022.44	Discharge Line
8	03/24/2016	78.03	256	629	1,406.19	Discharge Line
9	03/24/2016	87.48	287	0	1,453.48	Discharge Line
10	03/24/2016	105.16	345	1,926	1,445.50	Discharge Line
11	03/24/2016	111.86	367	554	1,435.25	Discharge Line
12	03/24/2016	121.92	400	619	1,435.25	Discharge Line
13	03/24/2016	129.84	426	2,696	1,789.11	Discharge Line
14	03/24/2016	136.86	449	189	1,536.54	Discharge Line
15	03/24/2016	147.83	485	924	1,381.68	Discharge Line
16	03/24/2016	160.02	525	184	1,321.95	Discharge Line
17	03/24/2016	167.64	550	831	1,445.50	Discharge Line
18	03/24/2016	179.83	590	572	1,395.39	Discharge Line
19	03/24/2016	187.45	615	1,008	1,357.67	Discharge Line
20	03/24/2016	198.42	651	616	1,359.39	Discharge Line
21	03/24/2016	207.26	680	512	1,406.03	Discharge Line
22	03/24/2016	219.15	719	123	1,381.68	Discharge Line
23	03/24/2016	229.82	754	1,124	1,406.19	Discharge Line
24	03/25/2016	237.13	778	879	1,435.25	Discharge Line
25	03/25/2016	245.36	805	1,454	1,395.39	Discharge Line
26	03/25/2016	N/A	N/A	169	1,453.48	Make-up water
27	03/25/2016	251.76	826	0	1,486.80	Discharge Line
28	03/25/2016	254.20	834	1,209	1,522.24	Discharge Line
29	03/25/2016	256.95	843	316	1,536.54	Discharge Line

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Tritium Activities during Drilling of Well ER-4-1
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
30	03/25/2016	259.08	850	316	2,891.00	Discharge Line
31	03/25/2016	263.04	863	1,689	1,369.42	Discharge Line
32	03/25/2016	265.79	872	788	1,631.25	Discharge Line
33	03/25/2016	272.19	893	1,298	1,629.66	Discharge Line
34	03/25/2016	286.51	940	1,526	1,435.25	Discharge Line
35	03/25/2016	298.70	980	765	1,445.50	Discharge Line
36	03/25/2016	306.32	1,005	869	1,626.19	Discharge Line
37	03/25/2016	312.72	1,026	1,233	1,680.68	Discharge Line
38	03/25/2016	322.48	1,058	739	1,406.43	Discharge Line
39	03/25/2016	332.23	1,090	1,091	1,581.73	Discharge Line
40	03/25/2016	344.42	1,130	461	1,631.30	Discharge Line
41	03/25/2016	356.62	1,170	1,708	1,357.70	Discharge Line
42	03/25/2016	367.28	1,205	174,016	1,536.50	Discharge Line
43	03/25/2016	377.04	1,237	239,022	1,733.20	Discharge Line
44	03/25/2016	386.49	1,268	34,639	1,343.30	Discharge Line
45	03/25/2016	390.14	1,280	21,825	1,629.70	Discharge Line
46	03/25/2016	401.12	1,316	520	1,445.50	Discharge Line
47	03/25/2016	411.48	1,350	1,939	1,406.40	Discharge Line
48	03/25/2016	420.62	1,380	576	1,386.70	Discharge Line
49	03/25/2016	430.99	1,414	650	1,493.86	Discharge Line
50	03/26/2016	N/A	N/A	N/A	N/A	spilled
51	03/26/2016	N/A	N/A	60	1,445.50	Make-up water
52	03/26/2016	444.09	1,457	134	1,486.80	Discharge Line
53	03/26/2016	448.97	1,473	0	1,395.39	Discharge Line
54	03/26/2016	458.42	1,504	212	1,763.45	Discharge Line
55	03/26/2016	466.65	1,531	894	1,536.54	Discharge Line
56	03/26/2016	475.49	1,560	1,447	2,340.17	Discharge Line
57	03/26/2016	481.58	1,580	0	1,755.13	Discharge Line
58	03/26/2016	487.68	1,600	0	3,572.14	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-4-1
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
59	03/26/2016	493.78	1,620	1,463	1,208.97	Discharge Line
60	03/26/2016	499.87	1,640	154	1,631.26	Discharge Line
61	03/26/2016	505.97	1,660	765	1,536.54	Discharge Line
62	03/26/2016	512.06	1,680	470	1,734.80	Discharge Line
63	03/26/2016	518.16	1,700	725	1,357.67	Discharge Line
64	03/26/2016	524.26	1,720	366	1,493.86	Discharge Line
65	03/26/2016	530.35	1,740	244	1,629.66	Discharge Line
66	03/26/2016	536.45	1,760	332	1,626.19	Discharge Line
67	03/26/2016	542.54	1,780	100,680	1,629.66	Discharge Line
68	03/26/2016	546.51	1,793	42,870	1,477.47	Discharge Line
69	03/26/2016	546.51	1,793	28,685	1,445.50	Discharge Line
70	03/26/2016	547.12	1,795	29,383	1,540.60	Discharge Line
71	03/26/2016	554.74	1,820	60,935	1,900.40	Discharge Line
72	03/26/2016	565.71	1,856	19,137	1,381.70	Discharge Line
73	03/26/2016	575.46	1,888	8,739	1,381.68	Discharge Line
74	03/26/2016	585.22	1,920	4,576	1,343.30	Discharge Line
75	03/27/2016	595.58	1,954	1,644	1,778.14	Discharge Line
76	03/27/2016	603.50	1,980	2,502	1,900.41	Discharge Line
77	03/27/2016	N/A	N/A	0	1,714.46	Make-up water
78	03/27/2016	613.87	2,014	4,565	1,453.48	Discharge Line
79	03/27/2016	621.79	2,040	4,043	1,415.23	Discharge Line
80	03/27/2016	630.94	2,070	1,271	1,833.65	Discharge Line
81	03/27/2016	641.60	2,105	3,720	1,958.00	Discharge Line
82	03/27/2016	648.31	2,127	5,406	1,536.54	Discharge Line
83	03/27/2016	657.15	2,156	4,167	1,406.43	Discharge Line
84	03/27/2016	665.07	2,182	1,732	1,672.77	Discharge Line
85	03/27/2016	672.69	2,207	1,747	1,846.12	Discharge Line
86	03/27/2016	682.45	2,239	1,543	1,981.72	Discharge Line
87	03/27/2016	691.90	2,270	2,702	1,536.54	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-4-1
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
88	03/27/2016	717.80	2,355	3,550	1,381.68	Discharge Line
89	03/27/2016	726.03	2,382	1,545	1,900.41	Discharge Line
90	03/27/2016	739.75	2,427	1,965	1,239.97	Discharge Line
91	03/27/2016	751.64	2,466	3,760	1,870.32	Discharge Line
92	03/27/2016	768.10	2,520	2,913	1,415.23	Discharge Line
93	03/27/2016	780.29	2,560	215	1,914.69	Discharge Line
94	03/27/2016	790.96	2,595	2,467	1,343.30	Discharge Line
95	03/27/2016	804.67	2,640	1,254	1,870.32	Discharge Line
96	03/27/2016	814.43	2,672	1,488	1,459.54	Discharge Line
97	03/27/2016	818.08	2,684	1,242	1,805.28	Discharge Line
98	03/28/2016	N/A	N/A	589	1,576.91	Make-up water
99	03/29/2016	N/A	N/A	86	1,581.73	Make-up water
100	03/30/2016	538.89	1,768	65,125	1,778.14	Bailer sample [a]
101	03/30/2016	646.18	2,120	3810	1,631.25	Bailer sample [a]
102	04/02/2016	N/A	N/A	619	1,357.67	Make-up water
103	04/03/2016	N/A	N/A	299	1,210.19	Make-up water
104	04/03/2016	810.77	2,660	1,706	1,486.80	Discharge Line
105	04/03/2016	822.96	2,700	2,173	1,477.47	Discharge Line
106	04/03/2016	829.06	2,720	830	1,445.50	Discharge Line
107	04/04/2016	831.19	2,727	720	1,784.19	Discharge Line
108	04/04/2016	N/A	N/A	0	1,680.68	Make-up water
109	04/04/2016	837.29	2,747	246	1,680.68	Discharge Line
110	04/04/2016	842.47	2,764	1,317	1,824.84	Discharge Line
111	04/04/2016	847.34	2,780	147	1,369.42	Discharge Line
112	04/04/2016	859.54	2,820	0	1,629.96	Discharge Line
113	04/04/2016	861.06	2,825	1,194	1,406.43	Discharge Line
114	04/04/2016	865.33	2,839	1,520	1,435.25	Discharge Line
115	04/04/2016	868.07	2,848	0	1,974.52	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-4-1
(Page 5 of 6)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
116	04/04/2016	873.56	2,866	0	1,778.14	Discharge Line
117	04/04/2016	880.26	2,888	1,337	1,385.39	Discharge Line
118	04/04/2016	890.32	2,921	0	1,784.19	Discharge Line
119	04/04/2016	894.59	2,935	0	1,805.28	Discharge Line
120	04/04/2016	896.11	2,940	0	1,720.56	Discharge Line
121	04/04/2016	898.55	2,948	665	1,445.50	Discharge Line
122	04/04/2016	903.73	2,965	293	1,608.68	Discharge Line
123	04/04/2016	905.56	2,971	310	1,406.43	Discharge Line
124	04/04/2016	909.52	2,984	438	1,453.48	Discharge Line
125	04/04/2016	914.40	3,000	0	1,746.33	Discharge Line
126	04/04/2016	915.92	3,005	148	1,321.95	Discharge Line
127	04/04/2016	919.89	3,018	640	1,395.39	Discharge Line
128	04/04/2016	922.93	3,028	228	1,445.50	Discharge Line
129	04/04/2016	925.07	3,035	0	1,841.75	Discharge Line
130	04/05/2016	N/A	N/A	0	1,576.91	Make-up water
131	04/05/2016	N/A	N/A	0	1,680.68	Sump water
132	04/06/2016	N/A	N/A	0	1,406.03	Make-up water
133	04/09/2016	N/A	N/A	83	1,498.98	Make-up water
134	04/09/2016	N/A	N/A	0	1,730.13	Make-up water
135	04/10/2016	N/A	N/A	94	1,530.53	Make-up water
136	04/10/2016	858.01	2,815	682	1,453.48	Discharge Line
137	04/10/2016	859.54	2,820	0	1,848.75	Discharge Line
138	04/10/2016	860.45	2,823	221	1,576.91	Discharge Line
139	04/10/2016	862.58	2,830	1,034	1,288.05	Discharge Line
140	04/10/2016	864.11	2,835	1,191	1,395.39	Discharge Line
141	04/10/2016	866.55	2,843	55	1,493.86	Discharge Line
142	04/10/2016	868.07	2,848	0	1,584.64	Discharge Line
143	04/10/2016	876.30	2,875	865	1,435.25	Discharge Line
144	04/10/2016	882.40	2,895	0	1,540.62	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-4-1
(Page 6 of 6)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
145	04/10/2016	885.14	2,904	88	1,334.31	Discharge Line
146	04/11/2016	886.36	2,908	774	1,626.19	Discharge Line
147	04/11/2016	N/A	N/A	0	1,733.20	Make-up water
148	04/11/2016	888.19	2,914	542	1,536.54	Discharge Line
149	04/11/2016	889.10	2,917	0	1,536.57	Discharge Line
150	04/11/2016	N/A	N/A	188	1,536.57	Make-up water
150	04/11/2016	N/A	N/A	188	1,536.57	Make-up water
151	04/11/2016	893.37	2,931	0	1,680.59	Discharge Line
152	04/11/2016	896.11	2,940	0	1,841.75	Discharge Line
153	04/11/2016	897.64	2,945	941	1,435.25	Discharge Line
154	04/11/2016	898.55	2,948	309	1,395.39	Discharge Line
155	04/11/2016	900.07	2,953	488	1,631.25	Discharge Line
156	04/11/2016	901.60	2,958	659	1,486.80	Discharge Line
157	04/11/2016	902.82	2,962	750	1,530.53	Discharge Line
158	04/11/2016	904.65	2,968	0	1,631.25	Discharge Line
159	04/11/2016	905.56	2,971	0	1,584.64	Discharge Line
160	04/11/2016	907.39	2,977	0	1,531.73	Discharge Line
161	04/11/2016	910.13	2,986	0	1,486.80	Discharge Line
162	04/11/2016	914.40	3,000	329	1,334.31	Discharge Line
163	04/12/2016	N/A	N/A	417	1,357.67	Make-up water
164	04/12/2016	915.31	3,003	0	1,477.42	Discharge Line
165	04/12/2016	916.53	3,007	1,361	1,530.53	Discharge Line
166	04/12/2016	917.75	3,011	0	1,680.59	Discharge Line
167	04/12/2016	918.97	3,015	261	1,569.81	Discharge Line
168	04/12/2016	920.19	3,019	0	1,833.71	Discharge Line
169	04/12/2016	920.80	3,021	1,786	1,536.54	Discharge Line
170	04/12/2016	922.63	3,027	384	1,584.64	Discharge Line

[a] Value is from NSTec Rad Services in the field.

N/A = Not applicable

Appendix C

Bromide Concentrations and Calculated Water Production during Drilling at Well ER-4-1

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-4-1
(Page 1 of 4)

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
03/23/2016	23:25	128	24.2	24.3	10	7	-0
03/24/2016	03:25	233	22.5	20.4	10	7	1
03/24/2016	07:30	345	23.1	17.8	10	7	2
03/24/2016	10:20	426	23.1	22	12	8	0
03/24/2016	15:00	466	22.7	22.5	12	8	0
03/24/2016	17:20	544	23.6	20.9	12	8	1
03/24/2016	22:10	725	21.7	19.6	12	8	1
03/25/2016	02:10	828	22.4	19.5	12	8	1
03/25/2016	06:10	863	22.8	21.4	12	8	1
03/25/2016	10:30	980	25.6	22.5	16	11	2
03/25/2016	14:30	1,090	15.8	15.30	16	11	0
03/25/2016	17:30	1,205	18.3	45.60	16	11	-7
03/25/2016	21:30	1,355	29.4	30.70	16	11	-0
03/25/2016	23:00	1,415	39.4	39.00	16	11	0
03/26/2016	00:15	1,449	43.3	36.5	16	11	2
03/26/2016	01:25	1,478	31.0	26.9	16	11	2
03/26/2016	02:25	1,507	35.2	34.7	16	11	0
03/26/2016	03:25	1,542	33.0	28.6	16	11	2
03/26/2016	04:25	1,578	31.8	28.4	16	11	1
03/26/2016	05:25	1,600	35.2	33.10	16	11	1
03/26/2016	06:25	1,620	29.0	24.10	16	11	2
03/26/2016	07:30	1,635	37.2	34.00	16	11	1
03/26/2016	08:30	1,670	39.6	36.80	16	11	1
03/26/2016	09:30	1,715	34.3	30.80	16	11	1
03/26/2016	10:30	1,749	29.2	25.70	16	11	2
03/26/2016	11:30	1,775	34.8	26.00	16	11	4

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-4-1
(Page 2 of 4)

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
03/26/2016	12:30	1,793	35.2	31.40	16	11	1
03/26/2016	20:25	1,835	35.6	33.40	16	11	1
03/26/2016	21:25	1,881	33.4	29.30	16	11	2
03/26/2016	22:25	1,892	75.9	68.30	16	11	1
03/26/2016	23:40	1,954	78.0	55.80	18	13	5
03/27/2016	01:40	2,004	47.7	39.90	18	13	2
03/27/2016	02:40	2,016	38.3	23.60	18	13	8
03/27/2016	03:40	2,050	42.6	37.40	18	13	2
03/27/2016	04:40	2,078	38.2	31.30	18	13	3
03/27/2016	05:40	2,116	32.7	29.50	18	13	1
03/27/2016	06:40	2,142	37.8	34.10	18	13	1
03/27/2016	07:40	2,170	52.4	37.40	18	13	5
03/27/2016	08:40	2,193	65.8	45.10	18	13	6
03/27/2016	09:40	2,225	61.5	57.60	18	13	1
03/27/2016	10:40	2,250	59.6	47.70	18	13	3
03/27/2016	11:40	2,289	52.9	47.10	18	13	2
03/27/2016	12:40	2,332	38.5	32.70	18	13	2
03/27/2016	13:40	2,359	36.1	29.20	18	13	3
03/27/2016	14:40	2,398	38.6	28.50	18	13	4
03/27/2016	15:40	2,448	31.8	23.70	18	13	4
03/27/2016	16:40	2,485	29.6	21.30	18	13	5
03/27/2016	17:30	2,520	35.1	16.60	18	13	14
03/27/2016	18:30	2,579	23.1	23.60	18	13	-0
03/27/2016	19:30	2,600	22.0	18.20	18	13	3
03/27/2016	20:35	2,640	19.2	17.60	18	13	1
03/27/2016	22:10	2,684	16.1	14.20	18	13	2

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-4-1
(Page 3 of 4)

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
04/04/2016	03:15	2,780	18.3	17.60	20	14	1
04/04/2016	04:15	2,820	15.7	8.90	20	14	11
04/04/2016	05:15	2,825	19.4	9.40	20	14	15
04/04/2016	06:15	2,840	15.3	7.86	20	14	13
04/04/2016	07:15	2,846	19.2	5.36	20	14	36
04/04/2016	08:15	2,865	15.9	5.96	20	14	23
04/04/2016	09:15	2,884	18.4	4.11	20	14	49
04/04/2016	10:15	2,920	20.0	3.59	20	14	64
04/04/2016	11:15	2,934	37.2	1.23	20	14	409
04/04/2016	12:55	2,940	56.2	4.78	20	14	151
04/04/2016	13:15	2,962	54.8	6.33	20	14	107
04/04/2016	14:15	2,962	58.3	4.16	20	14	182
04/04/2016	15:15	2,971	99.3	6.73	18	13	173
04/04/2016	16:15	2,983	122.0	5.84	16	11	223
04/04/2016	17:15	2,999	113.0	6.16	16	11	194
04/04/2016	18:15	3,003	73.1	3.94	16	11	197
04/04/2016	19:15	3,014	46.6	3.37	16	11	144
04/04/2016	20:15	3,025	46.5	3.16	16	11	154
04/04/1946	21:15	3,034	45.0	2.81	16	11	168
04/10/2016	14:45	2,816	47.4	30.10	10	7	4
04/10/2016	15:30	2,820	53.3	29.70	10	7	6
04/10/2016	17:30	2,831	46.6	25.20	10	7	6
04/10/2016	20:50	2,863	43.4	2.09	10	7	138
04/10/2016	22:10	2,897	44.1	1.56	10	7	191
04/10/2016	23:10	2,903	54.4	1.84	10	7	200
04/11/2016	00:10	2,908	45.8	1.81	10	7	170

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-4-1
(Page 4 of 4)

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
04/11/2016	02:30	2,918	89.8	2.01	10	7	306
04/11/2016	13:10	2,938	68.0	2.01	10	7	230
04/11/2016	14:30	2,945	41.6	1.45	10	7	194
04/11/2016	15:30	2,948	41.9	1.47	10	7	193
04/11/2016	16:30	2,953	42.2	1.26	10	7	227
04/11/2016	17:30	2,958	38.0	1.16	10	7	222
04/11/2016	18:30	2,962	69.9	2.03	10	7	234
04/11/2016	19:40	2,969	71.8	1.90	10	7	258
04/11/2016	21:40	2,980	46.5	1.34	10	7	236
04/11/2016	23:00	2,996	56.9	1.49	10	7	260
04/11/2016	01:00	3,005	56.0	1.40	10	7	273
04/12/2016	03:00	3,013	64.8	1.81	10	7	244
04/12/2016	05:00	3,020	78.3	2.81	12	8	226
04/12/2016	07:00	3,029	65.4	2.94	12	8	178
04/12/2016	08:00	3,035	72.9	3.18	12	8	184

bbl/hr = Barrels per hour
ppm = Parts per million

Appendix D

Work Control Documents

NSTec FAWP, Main Hole Drilling and Completion of Well ER-4-1
(46 Pages)

Final Well Specific Fluid Management Strategy
for UGTA Well ER-4-1
(9 Pages)

National Security Technologies LLC
Vision • Service • Partnership

FIELD ACTIVITY WORK PACKAGE

Work Package Number: D-003-001.16 **Title:** Main Hole Drilling and Completion of Well ER-4-1

Revision Number: 0

Criteria: FY 2016 Task Plan, Yucca Flat Drilling and Completion Criteria, Rev 1 February, 2016

Location: NTS NAD 27
ER-4-1: N 858,360 E 679,776

Date: March 14, 2016

Contents of Work Package:

Approvals:

NSTec UGTA Project Manager: /s/ P.K. Ortego **Date:** 3/16/16
P. K. Ortego

Concurrence:

NNSA/NFO UGTA Activity Lead: /s/ W.R. Wilborn **Date:** 3/17/2016
W. R. Wilborn

Navarro Project Manager: /s/ Ken Rehfeldt **Date:** 3/16/16
K. Rehfeldt

National Security Technologies LLC
Vision • Service • Partnership

FIELD ACTIVITY WORK PACKAGE

Work Package Number: D-003-001.16 Title: Main Hole Drilling and Completion of Well ER-4-1

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Contents of Work Package:

Approvals:

NSTec UGTA Project Manager: ______________________ Date: __________
P. K. Ortego

Concurrence:

NNSA/NFO UGTA Activity Lead: ______________________ Date: __________
W. R. Wilborn

Navarro Project Manager: ______________________ Date: __________
K. Rehfeldt

1.0 INTRODUCTION AND SCOPE

1.1 The Environmental Restoration Division of the National Nuclear Security Administration Nevada Field Office (NNSA/NFO), through its UGTA Activity, is proposing to conduct a well drilling campaign in Fiscal Year (FY) 2015 - 2016 to investigate the Yucca Flat CAU through a Phase II Drilling Initiative at the Nevada Nuclear Security Site (NNSS).

1.2 This Field Activity Work Package documents the objectives of the work, and establishes those requirements for NSTec support for mobilization to the ER-3-3 well site (including mobilization of the drill rig and other drilling equipment from the ER-3-3 well site to the ER-4-1 well site) and main hole construction and completion of the UGTA Yucca Flat ER-4-1 investigation well site. See Exhibit A for well location.

1.3 The surface location of this well is free from any radiological contamination, as evidenced by surface radiological survey results obtained at the time of the construction of the access road, drill pad and sumps.

1.4 All activities will be conducted in accordance with this Field Activity Work Package (FAWP), the UGTA Project Health and Safety Plan (HASP) Revision 3, dated May 2015; National Security Technologies, LLC UGTA Primary REOP No. NSTEC-0145-07 (or latest revision), NSTec Zone 2 Construction activity level work document (ALWD aka work package) #3001935337 and Navarro Secondary REOP No. N-0026-0 (or latest revision).

2.0 OBJECTIVES

2.1 The objectives of drilling and completion of this well include the following:

2.1.1 Obtain hydrogeologic information that will be used to evaluate the various parameters, assumptions, and models (i.e., HFM, flow and transport, hydrologic, and HST).

2.1.1.1 Provide detailed hydrogeologic information for the alluvial and volcanic sections as well as the uppermost 100 to 300 m (330 to 990 ft) of the lower carbonate aquifer (LCA).

2.1.1.2 Improve understanding of the fault and rock properties in the saturated AA/VA model, particularly through the TCU.

2.1.1.3 Because the STRAIT UGT was conducted relatively distant from faults, completion and testing of Well ER-4-1 will allow assessment of the exchange volume and integrity of the TCU near a major detonation away from faults.

2.1.1.4 Provide detailed geology, including fracture information for the upper portion of the LCA where RN contaminant transport in most likely.

2.1.1.5 Use data collected to help reduce uncertainties within the northern Yucca Flat area during in future groundwater flow and transport model runs deemed necessary.

2.2 The lower completion, in the top of the saturated LCA, can be pumped to determine whether the exchange volume has penetrated downward into the LCA, and to investigate the role that faults may have on RN transport to the LCA.

2.3 The well should allow for the testing and refining of conceptual models of groundwater flow and RN transport between the saturated AA/VA and CA.

2.4 Obtain water level data, and investigate potential local groundwater flow downgradient from the STRAIT UGT.

2.5 Obtain aqueous geochemistry samples to better define possible groundwater flow paths based on water chemistry.

2.5.1 Sample for tritium and other RNs potentially migrating from the upgradient STRAIT UGT.

3.0 PRECONSTRUCTION CONDITIONS

3.1 Archaeological and biological surveys have been completed and approved by NNSA/NFO.

3.2 The access road, drill pad, and sumps have been constructed (see Exhibit B for a sketch of the ER-4-1 drill pad and sumps.) No overflow pipes have been installed. One sump is a standard 50 ft by 80 ft bottom, ~10 ft deep, with sides sloped 2:1. The outside dimensions of the sumps are approximately 90 ft by 120 ft. One sump is a larger, lined sump with bottom dimensions approximately 120 ft by 120 ft, ~10 ft deep, with sides sloped 2:1 and outside dimensions approximately 160 ft by 160 ft. The capacity of the sump is approximately 1.0 million gallons and is lined with 45 mil reinforced poly propylene (RPP).

3.3 A 30 inch outside diameter (OD) conductor casing is set and cemented at a depth of 116.5 feet below ground surface (bgs). The annulus of the 30 inch OD conductor has been cemented to surface. The top of the 30 inch conductor is ~2 feet above ground surface.

4.0 LOCATION-TO-LOCATION MOVE AND RIG UP

4.1 This section of the FAWP establishes requirements for the location-to-location move of equipment, temporary facilities, and materials to the ER-4-1 site and installation of temporary services at the ER-4-1 site. The location-to-location move to the ER-4-1 site includes movement of the major drill rig components and all of the air compressor equipment from the ER-3-3 well site on the Nevada

National Security Site (NNSS), transportation of all of United Drilling, LLC (UD) equipment to the ER-4-1 site ; and transportation of any facilities, and materials from other areas of the NNSS such as the Area 1 Drilling Yard to the ER-4-1 site; off- loading and physical placement and setup of the items will be based on the physical features of the ER-4-1 site and will be coordinated by the NSTec Site Supervisor (aka Site Coordinator) with the NSTec Health Physics Supervisor (HP), Navarro Technical Lead, and the Drilling and Air Services Subcontractors; installation of all electrical, fuel, and drilling air supply lines; installation of flow lines for air-foam circulation; installation of all communications systems; and pick-up of the first drilling assembly to be used to drill out of the conductor casing. This mobilization includes moves by the NSTec drilling subcontractors, United Drilling, LLC (UD), and Northwestern Air Services (NWA), the air compressor services subcontractor, and transportation of other project support items by NSTec and Navarro.

4.2 NSTec Site Supervisors will coordinate with UD, NWA, Navarro, and NSTec Zone 2 Construction during the mobilization to ensure that all equipment is transported and rigged up in the proper sequence, and that mobilization efforts of one party do not negatively impact on efforts by another party. If there is an issue or potential impact, mobilization of UD's equipment will have priority.

4.3 UD Mobilization: UD's location-to-location move will be conducted in accordance with their approved Activity Level Work Document (ALWD) UD-172604-02, Rev.1.

4.3.1 UD will move in its Wilson Mogul 42B Double Drum Rig No. 5 and all other associated ancillary equipment, as established by the subcontract. The Wilson rig has a 110-foot derrick (mast) with 354,000 pound capacity, using 10, 1-1/8 inch lines. Other major equipment components include drill pipe, drill collars, generators for UD's power needs, 4,000 gallon fuel storage, a 9 ton forklift, water truck, 1,000 barrels water storage, steam or high pressure washing equipment, and field office facilities.

4.3.2 Prior to or during this location-to-location period, UD may perform non-destructive testing of the drill collars and drill pipe to be used in the construction of this well.

4.3.3 UD will be responsible for the location-to-location move of all items UD is furnishing under the terms of its subcontract. UD's mobilization also includes installation of any anchors required to rig up the drill rig, under laying of minimum 60-mil plastic under any of UD's equipment which contains fuels or hydrocarbons, and installation of the rotating head on the 30-inch conductor casing. The edges of the plastic underneath the equipment will be bermed using sand bags, or other methods, to ensure spills or drips are contained, and do no not run off the plastic onto the ground.

4.3.4 UD's mud mixing and pumping equipment will be moved and rigged up on the ER-4-1 location to support mud mixing and pumping should it be necessary.

4.3.5 During the location-to-location move from the ER-3-3 site to the ER-4-1 site UD will repair or replace the support columns on the substructure "fold-out" platform between the substructure rig floor and the upper dog house in accordance with the NSTec Structural Engineer's recommendations 3 & 4 included in the email provided by the Engineer on 3/2/16. Repairs or replacements will be performed in conjunction with the initial installation and rig up of the substructure over the ER-4-1 conductor casing. The Engineer will re-inspect and approve the repair/replacement of these supports prior to the start of any drilling activity. The following Hold Point will be signed and documented indicating approval of the platform supports.

PKO 3/18/16

Navarro Site Lead	**Hold Point No. 1**	NSTec Structural Engineer, initial & date	NSTec Safety, initial & date	NSTec PM, initial & date	NSTec Site Supervisor, initial & date	United Drilling, Toolpusher, initial & date
CB 3/18/16	1) Repair and/or replacement of rig platform support columns have been completed and are acceptable	TAM 3/18/16	WR 3/21/16	PKO 3/18/16	MP 3-18-16	[illegible] 3-18-16

4.4 Northwestern Air Services Location-to-Location Move:
NSTec will be responsible for moving the compressors and mist units from one site to the other, NWA Services will be responsible for assembling units.

4.4.1 Three (3) skid mounted combination compressor/booster units rated at minimum 1500 SCFM and minimum of 2300 psi.
4.4.2 One skid mounted chemical injection unit equipped with a triplex injection pump rated at 1-46.5 GPM at 2,500 psig
4.4.3 Two (2) 20-barrel steel mixing tanks
4.4.4 One 5,600 gallon fuel tank
4.4.5 One skid-mounted combination storage/office unit.

4.5 After the units are set in place, NWA personnel will rig up the units ready for delivery of compressed air, soap, and polymer to the drill rig.

4.6 NWA will be responsible for installing and testing air supply and bypass lines to the rig stand pipe, installing whip checks on all pressured hose connections, and installing fuel lines from their fuel tank to their equipment.

4.7 NSTec will be responsible to provide the lining material used to underlay all of NWA's equipment.

4.8 The NSTec Site Supervisor will visually inspect NWA's` equipment after it has been installed to ensure that the equipment meets the specifications established by the subcontract and all safety features are in place and operational.

4.9 NSTec Mobilization - NSTec will be responsible for mobilizing required support equipment, facilities, and materials not provided by subcontractors. This includes:

4.9.1 The NSTec UGTA trailer used as the NSTec site office

4.9.2 Two 100-KW generators and fuel tank used to provide power to all facilities/equipment other than the drill rig.

4.9.3 The Construction Superintendent's office transportainer (as necessary)

4.9.4 Water buffalo or other type of hand-washing station

4.9.5 Navarro office trailer. Navarro support (horse) trailer and laboratory trailer (transported by Navarro); NSTec to provide electrical hook-up), Navarro office trailer, storage transportainer and Navarro cuttings shack used for the support of cuttings collection will be rented by NSTec for Navarro use.

4.9.6 NSTec transportainer for miscellaneous tools and equipment storage units

4.9.7 Minimum of eight portable toilets

4.9.8 Minimum of two dumpsters for sanitary waste collection

4.9.9 There will microwave phones available at this location which will be the primary source of communications. NNSS radio, radio phone or cell phones will serve as secondary communications.

4.9.10 Mud materials, downhole hardware including bits, hole openers, stabilizers, roller reamers, shock subs, drilling jars, casing, tubing, and associated cementing equipment

4.9.11 Portable light standards for night time operations as necessary, estimated 10 units will be needed.

4.9.12 Radiological operations base station including a minimum of two liquid scintillation counters (LSCs) installed within the base station.

4.9.13 Two, separate 40-60 kw generators to provide primary & and backup power to Rad base station and/or other portable facilities deployed near the sumps

4.10 NSTec will be responsible for underlying the NSTec generators, and NSTec fuel tank(s) with plastic material to prevent drips or spills to the ground surface. Spill kits with absorbent material and steel drums will be provided by Navarro near the generator/fuel tank location for prompt access and cleanup should there be a drip/spill onto the plastic lining.

4.11 Navarro will be responsible for the placement and maintenance of spill kits in these areas. A hydrocarbon waste storage area shall be provided on the site. The hydrocarbon waste storage area shall also be underlain with plastic, roped off, and properly posted. Navarro waste management personnel will provide guidance on the location and proper posting of the area.

4.12 NSTec will be responsible to install a 16 inch nominal OD air-foam circulation flow line from the wellhead to the large, lined sump used for the drilling both the unsaturated and saturated portions of this well.

4.12.1 The flow line will be installed in accordance with the approved saturated design shown in Exhibit C.

4.12.2 Inspection of the flow line during installation at the ER-4-1 site will be in accordance with the "Work Instruction for the Inspection of the UGTA Flow Line" as shown in Exhibit D.

4.12.3 The 45 degree elbow at the end of the flow line will be positioned such that any surge from the flow line is directed toward the interior or far side of the sump and not toward the edges of the sump or berm between the sumps.

4.12.4 Plastic/rubber matting or conveyor belting, rocks or cement will be placed in the sumps at the point of flow line discharge as necessary to protect the sump liner at the point of flow line discharge.

4.12.5 A sampling port will be provided on the flow line near the edge of the sump to accommodate the collection of drill cuttings and water samples by Navarro. The position of this port when the flow line is initially installed shall be coordinated by the NSTec Site Supervisor with the Navarro Technical Lead to ensure that both Navarro and NSTec are satisfied that the position of the port will allow for the safe and effective collection of samples. Hold Point No. 2 will be signed-off by the appropriate Navarro and NSTec personnel prior to drilling out of the conductor casing documenting agreement of adequacy of the flow line and anchoring system and the arrangement of the port for Navarro's collection of samples from the flow line.

Hold Point No. 2	Navarro Safety, initial & date	Navarro PM, initial & date	Navarro Technical Lead, initial & date	NSTec Safety, initial & date	NSTec PM, initial & date	NSTec Site Supervisor, initial & date
1) Flow line installed in accordance with approved saturated zone						

design and inspection work instruction						
2) Position of sampling port will allow for safe and effective collection of samples						

4.13 After completion of installation of the flow line, NSTec will install wind walls at and adjacent to flow line discharge and sample collection work areas. This is to reduce the risk of worker exposure to wind-blown drilling foam from the flow line discharge. The wind walls shall include provisions for safe access to the flow line cuttings sampling port.

4.14 NSTec will install a grounding grid for all the equipment and facilities on site. The grid will be grounded to the conductor casing. Light standards may or may not need grounding. All fuel tanks will be double grounded on opposite ends of the tanks. The main distribution panel inside the UD generator house will be separately grounded.

4.15 NSTec will install diesel powered centrifugal transfer pump(s) adjacent to large, lined sump to transfer groundwater from the sump to the approved infiltration area per the Nevada Division of Environmental Protection (NDEP) approved fluid management strategy for this site. The location of the pump(s) and pump discharge will be coordinated with Navarro to ensure that groundwater transferred is within the approved infiltration area.

4.16 Near the end of mobilization and prior to starting drilling operations, a Safety Walkthrough shall be performed. This walkthrough shall be a joint effort with participation from NSTec, NSTec on-site Subcontractors, Navarro, and NNSA/NFO. Any ES&H issues discovered as a result of this inspection will be resolved and corrected as soon as possible. The results of the inspection will be documented and will include a list of items that must be corrected prior to the commencement of drilling.

5.0 MAINHOLE CONSTRUCTION

The expected stratigraphic, lithologic, geologic, and hydrologic characteristics for well ER-4-1 are provided in Exhibit E, Table C.5-1, which is an excerpt from Yucca Flat Drilling and Completion Criteria Wells ER-2-2, ER-3-3, and ER-4-1, Revision No. 1 February, 2016 for Well ER-4-1. The geology expected at Well ER-4-1 is predicted to be similar to the geology encountered at emplacement hole U-4a located approximately 222 m (730 ft) to the west-northwest and UE-4p located approximately 196 m (643 ft) to the northeast.

5.1 **Surface Hole**

5.1.1 The hole must be started with light bit weight and higher rotary speeds in order to start and maintain the hole as plumb and straight as possible, at least until the two reamers are below the conductor casing. More bit weight can then be applied to maximize the penetration rate in this portion of the hole. This portion of the hole will be drilled using air-foam circulation.

5.1.2 It is anticipated that because of the large 30-inch conductor at the surface, two compressor units will have to be used to properly remove the cutting from the hole.

5.1.3 The air-foam mixture, while drilling the unsaturated portion of the hole, will be composed of approximately 2 to 20 gallons of foaming agent mixed in 50 barrels of water injected at a rate of approximately 12 to 40 barrels per hour.

5.1.3.1 The polymer additive may be used, as necessary, to stiffen the foam.

5.1.3.2 The concentration of foaming agent and/or polymer can be adjusted based on observations of circulation, fill on connections, or penetration rate. Air volume in this portion of the hole should be maintained at the minimum levels required to clean the hole.

5.1.4 Drilling with any other media other than air-foam is not planned, however, if sloughing zones are encountered while drilling the unsaturated portion of the hole, liquid mud (a combination of just water, bentonite and polymer) may be used to help control the sloughing problems and advance the hole, or to facilitate logging or casing operations.

5.1.5 Conventional bentonite-type liquid mud may be mixed on site.

5.1.6 Compressed air from one or multiple compressors may be injected in the mud flow line to improve lifting capacity of the drilling fluid.

5.1.7 Caution shall be exercised while drilling this portion of the hole. Indications of problems such as fill on connections, tight hole, loss of circulation, extremely high penetration rates, or any other abnormal situations shall be brought to the attention of the NSTec Site Supervisor promptly and documented accordingly.

5.1.8 During the drilling of this portion of the hole, Navarro personnel shall obtain drill cutting samples at 10-foot intervals. Fluid samples will also be collected by Navarro from the flow line on a regular basis for monitoring for groundwater quality, in addition to the collection of fluid samples for tritium monitoring. Collection of fluid samples from the return line for tritium analysis will be accomplished on an hourly basis as the hole is being advanced per the UGTA Fluid Management Plan (FMP). NSTec Radiological Control Technicians (RCTs) will begin on-site analysis on an hourly basis of samples obtained for tritium monitoring using the project liquid scintillation counters (LSCs) when new hole is being drilled starting as the well is being drilled below the 30 inch conductor casing.

5.1.9 The first bottom hole assembly (BHA) will be a center punch assembly:

5.1.9.1 A 26 inch hole opener with an 18-1/2 inch pilot bit (jet-type, sealed journal bearing, chisel tooth button cutters).

5.1.9.2 One float sub with float installed or bottom hole collar with float installed.

5.1.9.3 Full length or pup collars as necessary that can be run below the rotating head.

5.1.9.4 Drill with this assembly until the cutters on the 26 inch hole opener are at the bottom of the 30 inch conductor casing.

5.1.9.5 Remove the center-punch assembly and pick up the second BHA for drilling the surface hole.

5.1.10 The second drilling assembly will be:

5.1.10.1 An 18-1/2 inch bit, soft to medium formation, insert, sealed friction bearing, gauge protected, IADC class 517, 527 or 537.

5.1.10.2 One 18-1/2 inch near bit, button type roller reamer with float installed.

5.1.10.3 One 8-inch drill collar, pup collar 10 to 15 feet long

5.1.10.4 One string, button-type roller reamer, not more than 1/8 inch under gauge of the bit.

5.1.10.5 One 8-inch drill collar

5.1.10.6 One string, button-type roller reamer, not more than 1/8 inch under gauge of the bit.

5.1.10.7 Shock sub (±8-inch OD)

5.1.10.8 Six eight-inch minimum OD drill collars

5.1.10.9 Drilling jars (±8-inch OD)

5.1.10.10 Two eight-inch minimum OD drill collars

5.1.10.11 Fifteen joints of Hevi-Wate drill pipe

5.1.10.12 Remainder of string will be 5 inch OD, 19.50 lb/ft, drill pipe

5.1.10.13 Record the lengths of tools, collars and drill pipe (tally) on the IADC drilling report.

5.1.11 Circulation will be maintained into the large, lined sump. There should not be any groundwater produced while drilling the portion of the surface hole above the water table expected at 1,589 ft. bgs unless perched water is encountered.

5.1.12 The surface hole will be drilled to a minimum depth of approximately 1,690 ft. bgs, which is approximately 100 feet below the static water level. However, the depth of the surface hole may be greater than 1,690 depending on the geology at the water level and tritium concentration of the groundwater. A field determination of the depth of the surface hole will be made based on these factors.

5.1.12.1 If the tritium concentration is above the drinking water standard of 20,000 pci/L the aquifer will have to be isolated prior to the continuation of drilling. Thus the surface hole will be terminated in the confining unit below the first aquifer.

5.1.13 Tritium contamination at or just below the water level may exceed the 400,000 pci/L threshold and drilling activities will have to continue in a contamination area (CA) under an approved radiological work permit (RWP).

5.1.13.1 The top of the water level (including foam) in any sump containing contaminated groundwater with a tritium concentration above the 400,000 pci/L threshold shall not be allowed to rise higher than two feet from the top of the sump. De-foaming agents will be dispersed in the sump(s) if necessary to control the accumulation of foam.

5.1.14 When working inside a CA all personnel will have to meet the training requirements established in the Project HASP for working inside a controlled area of an OSHA 1910.120 regulated site. The contamination area will include the rig floor when removing hardware from the borehole, the substructure below the rig floor, an area along both sides of the flow line and area around the lined sump receiving the contaminated groundwater and air-foam mixture. The appropriate radiological postings will be installed at the point that the groundwater tritium concentration reaches the threshold value of 400,000 pci/l as measured with the on-site project LSCs.

5.1.15 The surface hole will be drilled using air-foam circulation. The concentration of foaming agent and/or polymer can be adjusted based on observations of circulation, fill on connections, or penetration rate. **Air volume in this portion of the hole should be maintained at the minimum levels required to clean the hole and caution shall be**

exercised to identify if upper formations are sloughing, particularly below the static water level when groundwater is being produced.

5.1.16 Indications of problems such as fill on connections, tight hole, loss of circulation, extremely high penetration rates, or any other abnormal situations shall be brought to the attention of the NSTec Site Supervisor promptly and documented accordingly.

5.1.17 The exact depth of the surface hole will be field determined based on information obtained while drilling as discussed in Section 5.1.12 above. This will include information from cutting samples, the actual geology penetrated, the stability of the borehole and the tritium concentrations. This decision will be made based on consultation with Navarro and NSTec, NNSA/NFO and the Scientific Team assigned to this well.

5.1.18 Should hole problems (severe enough to jeopardize continuation of the surface hole as planned), such as sloughing or lost circulation, be experienced prior to reaching the desired surface hole depth, options for repairing the borehole using cement and/or setting casing through the problems areas shall be discussed by NSTec, Navarro, NFO and the Scientific Team.

5.1.19 In any event, the decision on the depth of the surface hole must be approved by the NNSA/NFO UGTA Activity Lead, and geophysical logs must be obtained prior to setting casing.

5.1.20 Upon reaching total depth (TD) of the surface hole and prior to running geophysical logging services, circulate bottoms up twice, short trip four stands, wait ½ hour, and trip back in the hole to check for fill. If there is no fill, or very little fill, trip out of the hole. If there is substantial fill a decision will be made at that point whether the fill will be clean out or not.

5.2 Geophysical Logging in the Surface Borehole or Subsequent Intermediate Boreholes

5.2.1 Mobilize and rig up the geophysical logging subcontractor for logging of the 18-1/2 inch hole. Geophysical logging will be conducted through the saturated and unsaturated intervals of from the well total depth to the bottom of the last casing set, prior to installation of any subsequent casings. The recommended suite of saturated-zone geophysical logs/core includes:

- Caliper
- Spectral gamma ray
- Temperature/differential temperature

- Compensated density
- Neutron porosity
- Resistivity
- Sonic
- Borehole deviation (gyroscopic)
- Sidewall cores (percussion/rotary)
- Video log (optional)
- Acoustic televiewer
- Formation micro-imager/electric micro-imager
- Nuclear magnetic resonance (optional)
- Chemistry log (electrical conductivity [EC], pH, temperature, specific ion)
- Temperature log(s)
- Flow log(s)
    - Thermal flowmeter (low flow rate, ambient conditions)

The recommended suite of geophysical logs for the unsaturated zone includes:

- Borehole deviation
- Caliper (4-6 arm)
- Compensated density
- Induction log
- Neutron porosity log (NPL)
- Nuclear annulus investigation log (NAIL), as required
- Spectral gamma ray (SGR)

5.2.2 The geophysical logging program for any section of borehole will depend on formations penetrated, whether the open borehole is saturated or unsaturated or both, information obtained while drilling and hole conditions. The logging program for any section of borehole will be the primary responsibility of Navarro per discussions with the NSTec logging Subcontract technical representative (STR) and possibly the Scientific Guidance Team and must be approved by the NNSA/NFO UGTA Activity Lead.

5.2.3 A sample of the drilling fluid will be collected and provided to the logging service company, if there is fluid in the hole, so that the resistivity of the drilling fluid, the drilling fluid filtrate, and the temperature can be measured by the logging service company. The drilling fluid must be as representative as possible of the fluid in the borehole while logging operations are being conducted. The sample may be collected from the discharge line at the end of the drilling operations, if there is fluid being discharged at that time. If necessary Navarro will collect bailer samples of fluid in the borehole. Samples should not be collected from the sump.

5.2.3.1 Navarro may collect discrete bailer samples from the borehole after logging services are completed.

5.2.4 As with the drilling of the well, if groundwater contamination exceeds the 400,000 pci/L threshold, removal of the wireline and logging tools from the borehole will have to be conducted under an approved RWP.

5.2.5 All logging tools, wireline, equipment and geologic samples (core) to be demobilized from the site after completion of the geophysical logging suite will be surveyed in accordance with a Radiological Operations Survey Plan, Release of Drilling Equipment from UGTA Water Wells. Form FRM-0894, Radiological Determination for Release of Items must be completed prior to moving any items from the site.

5.3 Possibility of Opening the Surface Borehole Prior to Setting Surface Casing

5.3.1 A decision will be made at the surface casing point whether or not to install a 13-3/8 inch surface casing or open the surface borehole to 26 inches and install a 20 inch surface casing. The decision will be based on a number of factors including the actual geology encounter at that point, whether or not contamination has been encounter, the predicted geology for the remainder of the borehole, water production and borehole conditions.

5.3.2 Should it be necessary to open the surface hole, the bottom hole assembly (BHA) will include:
5.3.2.1 An 18-1/2 inch pilot bit on the bottom of a 26 inch hole opener
5.3.2.2 A minimum of eight 8 inch OD drill collars
5.3.2.3 45 joints of 5 inch OD Hevi Waite drill pipe
5.3.2.4 5 inch OD, 19.50 lb/ft drill pipe

5.4 Piezometer Tube on the Outside of the Surface Casing

5.4.1 Data collected from cutting samples, geophysical logging, water level measurement, tritium concentration and other sources will be used to determine if it is necessary/desirable to install a piezometer tubing string in the surface borehole on the outside of the 13-3/8 inch or 20 inch surface casing. The option may be exercised upon collaboration between Navarro, NSTec and the Scientific Team and approved by the NFO Activity Lead.

5.4.2 The NSTec UGTA Project Manager will provide the detailed tubing information regarding the size, type, depth, slotted interval, connections, make-up torque stemming, etc. when the option is exercised. The tubing size will range from 1.900 inches to 2-7/8 inches outside diameter.

5.5 **Installing the Surface Casing**

5.5.1 After geophysical and other logging services are complete, remove the rotating head from the top of the 30-inch conductor casing and cut off 30-inch conductor casing. Prepare the top of the conductor surface casing stub such that a steel landing plate can be used to land the piezometer tube (if installed) and the 13-3/8 inch or 20 inch OD casing on top of the 30-inch conductor casing stub.

5.5.2 Rig up the casing services subcontractor and run 13-3/8 inch or 20 inch OD casing using a casing crew and pickup/laydown machine. The 13-3/8 inch or 20 inch casing string, from bottom up, shall consist of:

5.5.2.1 Stab-in type weld-on or threaded stab-in type float shoe or combination guide shoe and stab-in float collar (Weatherford Gemoco) welded on or made-up to the bottom joint of casing.

5.5.2.2 Optional bow spring centralizers to be installed just above the float shoe, in the middle of the first joint of casing, and at the top of the first and second joints of casing for a total of four centralizers. The option may be exercised by the NSTec UGTA Project Manager prior to installation of the casing.

5.5.2.3 Spot weld top and bottom of the first five joints of casing.

5.5.2.4 The lower and upper portions of the casing will be as prescribed by the NSTec UGTA Project Manager depending on the size, weight and grade of casing available and the depth the casing is set.

5.5.2.5 Space out and land the casing on the top of the 30-inch casing stub, steel landing plate, and a set off on the casing coupling or gusset to the landing plate on top of the 30 inch conductor casing. The casing should be spaced out so that the bottom of the casing is within 20 ft of the bottom of the hole or top of fill as determined during logging operations, from the short trip or from a physical tag with the bottom of the casing.

5.5.2.6 Maximum string weight at a depth of 1,690 ft. bgs using 13-3/8 inch casing will be approximately 115,000 pounds. The maximum string weight if 20 inch OD casing is used will be approximately 170,000 pounds.

5.5.2.7 All of the casing services Subcontractor's equipment to be demobilized from the site after running the casing will be surveyed in accordance with the Radiological Operations Survey Plan, Release of Drilling Equipment from UGTA Water Wells. Form FRM-0894, Radiological Determination for Release of Items must be completed prior to moving any items from the site.

5.5.3 Run 5-inch drill pipe with stab-in sub on bottom. Check and replace seals, if necessary prior to running. Use centralizer guide above the stab-in sub if necessary, as determined by the NSTec Site Supervisor.

5.5.4 Space out and connect the drill pipe to air. Stab into the float shoe/collar. Set down 10,000 lbs of weight to keep the seal in place and begin the cement job. There will be an option to blow air on after stabbed-in to observed at the surface in the casing by 30-inch annulus or use Navarro transducer in the piezometer string to determine if there is communications through the stab-in shoe with the casing annulus if the groundwater at that point in not contaminated. If contaminated the Navarro transducer will be used to determine if there is communications. The details of the cementing job will be determined at the time of the job. The water volume to be added inside the casing, pre-flush water volume, cement volume, cement additives, and displacement volumes will be discussed and approved by the NSTec UGTA Project Manager. The objective is to bring the top of the cement on the outside of the surface casing to a minimum level above the bottom of the casing to achieve a seal with allowances for the position of the piezometer tube on the outside of the casing. Navarro personnel may run water level measurement instruments inside the casing and/or inside the drill pipe to assist in obtaining fluid level information used to design the cementing program.

5.5.5 After displacing the cement, wait a 10 minutes for the cement to equalize, and then pull the drill pipe out of the casing. Trip out with the drill pipe and lay down the stab-in sub.

5.5.6 After completion of cementing, complete installation of the landing plate and weld landing plate to 30 inch and surface casing.

5.5.7 Cut off the surface casing and install the rotating head.

5.6 **Installation of the Flow line to the Surface Casing**

5.6.1 The flow line as installed per section 4.12 above will remain the same except the flow line will be connected to the 13-3/8 inch or 20 inch surface casing. Welds on the 13-3/8 inch or 20 inch casing to the rotating head and flow line and on the wear plate welded to the 16 inch flow line will be made by qualified welders and subjected to visual and magnetic particle inspection in accordance with the "Work Instruction for the Inspection of the UGTA Flow Line" as shown in Exhibit D.

5.6.2 Hold Point No. 3 will be signed-off by the appropriate Navarro and NSTec personnel prior to drilling out of the surface casing.

Hold Point No. 3	Navarro Safety, initial & date	Navarro PM, initial & date	Navarro Technical Lead, initial & date	NSTec Safety, initial & date	NSTec PM, initial & date	NSTec Site Supervisor, initial & date
Flow line installed in accordance with approved saturated zone design and inspected per work instruction						

5.7 **Production or Intermediate Borehole Drilling**

5.7.1 Gauge and make up the 12-1/4 to 18-1/2 inch drilling assembly. Record the results on the drilling report. This assembly will be the same as the second BHA prescribed in Section 5.1.10 above, but for either the 12-1/4 inch or 18-1/2 inch assemblies.

5.7.2 During the drilling of this portion of the borehole returns will be directed into the primary drilling, large, lined sump. Groundwater produced from drilling this production or intermediate borehole may be contaminated.

5.7.2.1 The volume of groundwater produced during the drilling of this portion of the borehole is not expected to exceed the capacity of the large, lined sump. If the water from this portion of the borehole and previous water from drilling of the surface borehole are below levels for discharge into the infiltration area per the NDEP approved Site Specific Fluid Management Strategy, discharge may be accomplished using transfer pumps.

5.7.2.2 Tritium concentrations in aquifers penetrated in this portion of the borehole, as in the surface borehole, may also be above drinking water standards and above the threshold of 400,000 pci/L.

5.7.2.3 Under these conditions it may be necessary to again isolate the contaminated aquifer by installing another casing.

5.7.2.4 Any drilling with groundwater tritium levels at or above the threshold will again be performed per Sections 5.1.13 and 5.1.14 above.

5.7.3 In any event, Navarro personnel shall obtain drill cutting samples at 10-foot intervals. Fluid samples will be collected by Navarro from the flow line on a regular basis for monitoring for groundwater quality, in addition to the collection of fluid samples for tritium monitoring. Collection of fluid samples from the return line will be accomplished on an hourly basis as the hole is being advanced per the UGTA Fluid Management Plan (FMP). NSTec will continue on-site analysis of samples obtained for tritium monitoring using the project LSCs every hour while the drill hole is being advanced.

5.7.4 Trip in the hole with the drilling assembly, tag cement inside the surface casing (record depth of cement) and drill out the cement and casing shoe.

5.7.5 As with drilling the surface hole, the end of the flow line into the lined sump shall be positioned such that any surge from the flow line is directed toward the interior or far side of the sump and not toward the edges of the sump or berm between the sumps and the top of the water level (including foam) in any sump containing contaminated groundwater with a tritium concentration above the 400,000 pci/L threshold shall not be allowed to rise higher than two feet from the top of the sump. Again, if necessary de-foaming agents may be used to control the accumulation of foam.

5.7.6 The drilling fluid for this portion of the hole will be air/foam. The exact air/foam mixture shall be adjusted, based on observations and performance in the field, and as hole conditions dictate. Any changes in ingredients of basic mix design must be pre-approved by the NSTec Project Manager and the NNSA/NFO UGTA Activity Lead.

5.7.7 During the drilling of this portion of the hole, fluid samples will be obtained at the flow line discharge and analyzed every hour. Samples will be analyzed for tritium using the on-site project LSCs.

5.7.8 The air/foam mixture used in this portion of the hole will include 3 to 20 gallons of foaming agent per 50 barrels of water, with an injection rate of 10 to 50 barrels per hour. Polymer will be added to stiffen the mix, as necessary. It is expected that the polymer concentration will be from 1 to 10 gallons per 50 barrels of water.

5.7.9 The penetration rate in this portion of the borehole (bottom of surface casing to total depth or intermediate casing point) should be maintained as high as possible with consideration given to maintaining circulation and collection of cutting samples. Combinations of weight on the bit (up to 40,000 lbs) and rotary speeds should be used along with adjustments to the air/foam mix, to obtain the optimum penetration rate. Combinations of bit weight and rotary speeds will be consistent with the bit manufacturer's recommendations for the specific bits used.

5.7.10 Drilling air requirements while drilling this portion of the hole are expected to be from 1,500 to 3,000 SCFM, and should be adjusted accordingly to maintain adequate circulation considering factors such as penetration rate, hole cleaning, and the amount of water being produced from the borehole.

5.7.11 The total depth of this well is expected to be approximately 3,100 feet bgs. During the drilling of the saturated zone using air-foam circulation there may be occasions of high energy flow line discharges. The process for determining when high energy discharges exist and for the implementation of additional controls during these events are address in Exhibit F, High Energy Discharge Communications Plan.

5.7.12 Caution shall be exercised while drilling this portion of the hole. Indications of problems such as fill on connections, tight hole, loss of circulation, extremely high penetration rates, or any other abnormal situations shall be brought to the attention of the Site Supervisor promptly and documented accordingly.

5.7.13 The production/intermediate borehole will be drilled to a total depth of approximately 3,100 ft. bgs or to a shallower depth as determined by the necessity to set an intermediate casing to isolate a contaminated aquifer or to mitigate possible borehole problems such as sloughing or clay swelling. The exact depth of the production or intermediate borehole will be determined in the field, based on cutting samples, borehole conditions, aquifers and confining units penetrated and tritium concentrations.

5.7.13.1 If it is necessary to install an intermediate casing, geophysical logs will be obtained in the portion of the borehole from the bottom of the surface casing to the intermediate casing depth prior to installation of the casing. The suite of geophysical logs obtained will be consistent with those identified for the saturated portion of the borehole, see Section 5.2.1 above.

5.7.13.2 A 9-5/8 inch to 13-3/8 inch OD casing will be installed in this portion of the borehole if an intermediate casing is necessary. The process for installing a piezometer tube, and installation and cementing of the casing will be very similar to the process for the surface casing prescribed in Sections 5.3 – 5.5 above. The details of the installation of the piezometer, casing, cementing and wellhead configuration will be covered by a RVC at the time.

5.7.13.3 If the intermediate casing is installed, an 8-1/2 inch to 12-1/4 inch borehole will be drilled below the intermediate casing.

The 8-1/2 inch to 12-1/4 inch BHA will be the same as the 18-1/2 inch or 12-1/4 inch BHA except the bit size and roller reamer sizes reduced to fit the 8-1/2 inch to 12-1/4 inch borehole.

5.7.14 Again, the 8-1/2 inch to 12-1/4 inch production/intermediate borehole will be drilled to a total depth of approximately 3,100 ft. bgs or to a shallower depth as determined by the necessity to set a possible second intermediate casing to isolate a contaminated aquifer. The exact depth of the production or intermediate borehole will be determined in the field, based on cutting samples, borehole conditions, aquifers and confining units penetrated and tritium concentrations.

5.7.15 Upon reaching TD or the depth borehole and prior to pulling out of the borehole circulate bottoms up twice, short trip four stands, and check for fill. If there is no fill, or very little fill, trip out of the hole and lay down the 12-1/4, 9-7/8 or 8-1/2 inch drilling hardware.

5.7.16 If groundwater is contaminated at or above the threshold the drill string will be removed from the well under an approved RWP and washed with clean water and surveyed in accordance with the Radiological Operations Survey Plan, Release of Drilling Equipment from UGTA Water Wells. Prior to conducting any geophysical logging operations in the production hole the rig floor and other areas of the CA to be used for the logging operations will be surveyed and de-posted if the results of the surveys show the removable surface contamination levels to be less than values specified in Table 2-2 of the Radiological Control Manual (RMC) DOE/NV/25946--801.

5.8 Geophysical Logging in the Intermediate or Production Borehole

5.8.1 Mobilize and rig up the geophysical logging subcontractor for logging of the 12-1/4 to 8-1/2 inch production borehole. Run geophysical logging services. The geophysical logging program for the production borehole will be per the guidance and process described above in Section 5.2 for the saturated portion of the borehole.

5.8.2 A sample of the drilling fluid will be collected and provided to the logging service company so that the resistivity of the drilling fluid, the drilling fluid filtrate, and the temperature can be measured by the logging service company. The drilling fluid must be as representative as possible of the fluid in the borehole while logging operations are being conducted. The sample may be collected from the discharge line at the end of the drilling operations, if there is fluid being discharged at that time. If there are no returns, a fluid sample from the borehole will be collected immediately prior to the commencement of logging operations. Samples should not be collected from the sump.

5.8.3 As with the drill string components removed form the hole all logging tools and wireline removed from the hole will be washed with clean water as it is removed from the hole and surveyed in accordance with Radiological Operations Survey Plan, Release of Drilling Equipment from UGTA Water Wells. Form FRM-0894, Radiological Determination for Release of Items must be completed prior to moving any items from the site.

5.8.4 Prior to running production casing in the hole the rig floor and other work areas used for casing & tubing installation operations will be surveyed to ensure that the removable surface contamination levels in casing work areas are less than values specified in Table 2-2 of the Radiological Control Manual (RMC).

5.8.5 Upon completion of geophysical logging Navarro will obtain depth discrete bailer samples using Navarro bailer equipment with assistance from the UD drill crew.

5.9 Installation of Piezometer/Monitoring Tubing and Production Casing

5.9.1 Upon completion of geophysical logging and other wireline services, if fill is minimal, as evidenced by the logging tool TD tags, lay down drill pipe and BHA without running below the surface casing. If fill is excessive and is determined to be a risk to running the monitoring tubing or production casing to the desired depth, the borehole will be cleaned out to an acceptable level using air/foam circulation prior to laying down the drill pipe (reamers can be removed prior to cleaning out). The exact details of fill clean out will be determined in the field, and will depend mainly on the exact amount of fill, an assessment as to the current stability of the hole, and the proximity of the top of the fill to the desired completion interval. If cleanout using air-foam does not appear to be a reasonable option it may be necessary to spot viscous bentonite/polymer mud in the open hole to stabilize it. The NNSA/NFO UGTA Activity Lead must approve the decision of whether or not it is necessary to clean out the fill and/or spot any mud.

5.9.2 Rig down the rotating head and flow line and prepare the top of final casing for running monitor tubing string(s) which will be a combination 2-7/8 stainless steel and 2-3/8 inch carbon steel and one stemming string which will be 2-7/8 inch carbon steel. The exact length and makeup of the monitoring string(s) will be adjusted in the field depending on actual depth of the target zone and desired slotted intervals.

5.9.2.1 The monitor string(s) will be made up of 2-7/8 flush joint stainless steel slotted tubing placed across the production zone, 2-7/8 inch stainless steel blank tubing from the top of the production zone to a depth just above the static fluid level and 2-3/8 inch integral or flush joint carbon steel tubing above the static fluid level to the surface.

5.9.2.1.1 The stainless steel monitor tubing may be 2-7/8 inch OD, 7.66 lb/ft, CBC-2-EN or VP-2-EN, 4 or 6 threads per inch (TPI) flush joint connections, 2.323 inch nominal inside diameter (ID) with drift ID of 2.27 inches. The tubing shall be made up using a set of hydraulic power tongs with an optimum make-up torque of 800 ft-lbs using TP3431 or Mercasol 633-SR or other approved lubricant. The tubing shall be drifted prior to being run in the hole using a rabbit with minimum OD of 2.25 inches. A rod pump top lock assembly for 2-3/8 inch tubing will be run within the 2-7/8 inch stainless steel monitor string and installed just above the slotted tubing. This will allow for rod pumping of the monitor tube.

5.9.2.1.2 The 2-3/8 inch monitor tubing run above the water level will be either 2-3/8 inch OD CS or A-95 Hydril or equivalent, 4.70 lb/ft, J-55 or N-80 grade, ID 1.995", drift ID 1.901" and make-up torque of 1300 ft-lbs TP3431 or Mercasol 633-SR or other approved lubricant. If flush 2-3/8 inch flush joint connections are used the make-up torque is ~ 800 ft-lbs. The tubing shall be drifted prior to being run in the hole using a rabbit with minimum OD of 1.900 inches. This will ensure that a rod pump can be installed inside the 2-3/8 inch tubing.

5.9.2.1.3 The stemming string, run last will be 2-7/8 inch, Hydril CS or A-95, N-80, 6.50 lb/ft, ID 2.441", drift ID 2.347" stemming string to a predetermined depth based on depths of the first completion zone. The tubing shall be made up using a set of hydraulic power tongs with an optimum make-up torque of 1500 ft-lbs using TP3431 or Mercasol 633-SR or other approved lubricant. The tubing shall be drifted prior to being run in the hole using a rabbit with minimum OD of 2.25 inches. The bottom joint of the stemming tubing shall be "muleshoed" with the edges ground off and large slots cut on the bottom 3 feet of tubing.

5.9.2.2 Land the monitoring string(s) and the stemming tubing on the same side, inside the surface casing with provisions which will allow the stemming string to be moved up and down and removed from the hole.

5.9.3 It may be necessary to stem the hole and place a cement plug in the hole below the deepest zone of interest to isolate it from the bottom of the hole. This will be determined in the field, and may be accomplished at this point in the operations, if necessary.

5.9.4 Run a combination 7-5/8 and 6-5/8 or 5-1/2 (aka 5-9/16 inch) inch production casing string alongside the piezometer tubing strings. The final size of the production borehole will determine the size of the production casing.

5.9.4.1 The bottom of the casing string will be 6-5/8 or 5-1/2 inch OD stainless steel with blank joint and bullnose on the bottom and slots over the zone(s) of interest. The exact intervals will be adjusted in the field based on actual conditions.

5.9.4.2 Blank stainless steel casing will run between and above the upper slotted interval to a depth at approximately 50 feet above the measured static water level.

5.9.4.3 7-5/8, 6-5/8 or 5-1/2 inch OD, carbon steel (may or may not be internally epoxy-coated) casing will be run above the stainless steel, form approximately 50 feet above the static water level to the surface and hung off at the surface on the surface or last intermediate casing stub.

5.9.4.4 Rabbit the 7-5/8 inch OD coated and stainless steel casing using a 6.750-6.844 inch OD rabbit, the 6-5/8 inch OD casing using a 5.750-6.000 inch OD rabbit and the 5-1/2 inch OD casing using a 4.75 -4.875 inch OD rabbit prior to running the casing in the hole.

5.9.4.5 The make-up torque ranges for the 7-5/8, 6-5/8 and 5-1/2 inch OD stainless steel casings will be provided later by the NSTec Project Manager based on the type of connections provided on the casing. The 7-5/8, 6-5/8 or 5-1/2 inch carbon steel / coated casing shall be made up using power tongs and TP3431 or Mercasol 633-SR or other approved lubricant to the torque values provided at the time of installation by the UGTA Project Manager.

5.9.5 See Exhibit G for illustration of well completion options with piezometer/monitor tubing and production casing. The final production casing will be determined by the number and sizes of intermediate casings set and the final production borehole size.

5.9.6 Prepare to stem the production casing.

5.10 Stemming the Production Casing

5.10.1 Rig up the Stemming Logging Subcontractor and run the nuclear annual investigation log (NAIL) or other density tool inside the combination 7-5/8 inch and 6-5/8 or 5-1/2 inch production casing or inside the deepest piezometer/monitor tubing string. Obtain background survey confirming the bottom of the casing and water level in the hole. Position the logging tool to monitor the stemming materials level in the annulus behind the production casing and/or deepest monitor tubing.

5.10.2 Rig up stemming hoper on top of the 2-7/8 inch stemming tubing. The annulus shall be stemmed through the tubing as described below:

5.10.2.1 If necessary, stem the bottom of the open hole below the production casing and annulus to 15 ft. (-0, +10 ft.) above the top of the bottom slotted interval with 1/4 to 3/8 inch silica gravel (Trona gravel or equal).

5.10.2.2 Place 15 ft. (-0, +10 ft.) of 6-9 Colorado coarse silica sand on top of the gravel

5.10.2.3 Place 15 ft. (-0, +10 ft.) of 20/40 fine silica sand on top of the 6-9 sand

5.10.2.4 Place a Portland Type II cement plug (mixed at 5.2 gal of water per sack of cement, 15.6 lb/gal) on top of the 20/40 sand to isolate between production zones or above production zones. The top of the cement between zones will be field determined based on distances between zones and other factors. Usually a minimum of 50 feet of cement between zones is desired if possible.

5.10.2.5 A combination of gravel and/or cement will be used to stem the annulus from the top of the first production zone to a point approximately 30-50 feet below the bottom of the next (second) slotted interval.

5.10.2.6 Stem the second slotted interval with 1/4 to 3/8 inch silica gravel (Trona gravel or equal) to 15 ft.(-0, +10 ft.) above the top of the upper slotted interval.

5.10.2.7 Place 15 ft. (-0, +10 ft.) of 6-9 Colorado coarse silica sand on top of the gravel

5.10.2.8 Place 15 ft. (-0, +10 ft.) of 20/40 fine silica sand on top of the 6-9 sand

5.10.2.9 It is not expected that there will be more than two production zones in the production borehole of this well.

5.10.2.10 Stemming above the upper production zone will be field determined base on the position of the top of the zone and whether or not it has to be isolated with cement.

5.10.3 Remove the NAIL tool from the inside of the casing and rig-down the stemming monitoring Subcontractor. Removal of the tool from the well will be under an approved RWP if the tritium concentration of the groundwater is at or above the threshold of 400,000 pci/L. All of the logging tools and wireline removed from the hole will be washed with clean water as it is removed from the hole and surveyed in accordance with Radiological Operations Survey Plan, Release of Drilling Equipment from UGTA Water Wells. Form FRM-0894, Radiological Determination for Release of Items must be completed prior to moving any items from the site.

5.10.4 Pull and lay down the remainder of the stemming tubing from the hole. Again, if the tritium concentration of the groundwater is at or above the threshold of 400,000 pci/L removal of the stemming tubing will be accomplished under an approved RWP.

5.10.5 Seal the production casing by surface casing annulus around the piezometer/monitoring tubing strings and production casing by welding steel plate between the two casings and around the tubing. Install a plug on the top of the production casing and the monitoring tubing strings.

5.10.6 Begin rigging down all equipment and facilities for a location-to-location move.

6.0 RIG DOWN AND PREPARATION TO DEMOBILIZE

6.1 During the rig down process and load out of equipment to be moved off the drilling location and NNSS, NSTec RCTs will be performing radiological surveys of the all necessary equipment, tools, portable facilities, materials, supplies, etc. as determined by the Project Health Physics Supervisor (HPS).

6.2 Form FRM-0894, Radiological Determination for movement of items from this location to off the NNSS must be completed prior to moving items as determined by the HPS.

6.3 This is the fourth and final well in this FY 2015 – FY 2016 drilling campaign, thus all drilling and related equipment, tools, materials and portable facilities will be moved from this location to off the NNSS.

6.3.1 UD and NWA will be responsible for rigging down and moving of all UD equipment, tools, portable facilities and materials from this location in accordance with the terms and conditions of their respective subcontracts.

6.3.2 Rig down of the UD and NWA equipment will take priority since demobilization for these Subcontractors are on a lump sum basis.

6.3.3 All miscellaneous trash and debris shall be removed from the site.

6.3.4 Navarro will be responsible to rig down the equipment, facilities, etc. that Navarro mobilized to the site. NSTec will assist Navarro as requested with their rig down.

6.3.5 NSTec will also make repairs to the access roads as necessary to leave this road in good repair after the drilling activities are completed.

7.0 NAVARRO SCOPE OF WORK

Navarro will be a participant contractor in this field activity. A summary listing of Navarro's work scope during the drilling and completion of the ER-4-1 well is included below:

7.1 Mobilization and setup of the equipment Navarro requires in its office, laboratory, and support facilities on site.

7.2 Obtaining drill cutting samples from the flow line at regular depth intervals of every 10 ft. during the drilling operations.

7.3 Washing, characterizing, packaging, and storing drill cutting samples, and preparing preliminary stratigraphic and lithologic logs of drill cuttings.

7.4 Sampling fluids and solids from the sumps and flow line discharge including the collection of samples for tritium monitoring per the FMP. Performing on-site analysis for lead.

7.5 Collection of samples from the water supply well(s) and distribution of those samples for tritium screening.

7.6 Downhole work, such as measuring water levels with wireline, if necessary.

7.7 Obtaining depth-discrete bailer samples from the borehole after completion of geophysical logging.

7.8 Waste management activities, such as labeling, inspecting, repackaging, sampling, spill response, and movement of waste items.

7.8.1 Provide spill kits with absorbent material and steel drums that will be located near the generator for prompt access and cleanup should there be a drip/spill onto the plastic lining.

7.8.2 Identify and coordinate the lining and roping for the hydrocarbon waste storage area on site.

7.9 Inspecting cleanliness of well construction hardware, such as casing and tubing wireline & wireline tools, prior to installation in the well. Performing lead analysis of paint on downhole hardware if necessary.

7.10 Preparation of tracer solution (Lithium Bromide [LiBr]) to be introduced into drilling and stemming fluids.

7.11 Monitoring/measurement of typical water quality parameters and tracer solutions.

7.12 Measurement/monitoring of drilling fluid discharges to constructed storage sumps, as well as surface discharges.

7.13 Documenting/reporting of site activities pertaining to drilling and well construction; observation regarding geology, geophysical interpretation, fluid management, and monitoring of chemical parameters.

7.14 Maintaining a master MSDS list and approval of any new chemical before use downhole.

8.0 FIELD ACTIVITY ON-SITE ORGANIZATION

The field activity organization for the accomplishment of the work scope specified by this FAWP is illustrated by the organizational chart shown in Exhibit H. Since this is primarily a construction activity NSTec has lead contractor responsibilities and will provide the Site Supervisor. Navarro will provide a Site Lead when Navarro is working on site.

9.0 HAZARD IDENTIFICATION CHECKLIST AND HAZARD ANALYSIS (HA)

The hazard identification checklist and HA for NSTec work scope as specified by this FAWP, are adequately covered within the UGTA Project Health and Safety Plan (HASP). Section A, pages A-2 through A-7. HASP Attachment B addresses the hazards associated with this work scope and identifies the mitigating documents and/or actions necessary to reduce the risks. NSTec will conduct a pre-task hazard review (PTHR) at the start of each work shift which will include participation by all personnel working on site and cover all contact work to be performed during the shift and will be revised during the shift if new work scope, or new hazards are identified. A job hazard analysis (JHA) may be conducted for certain activities in lieu of a revision to the PTHR, however, all on site personnel who may be affected by performance of the work scope covered by the JHA must be involved and/or informed. A JHA for this work scope is included in the NSTec Construction Activity Level Work Document (ALWD/Work Package) (3001935337 Rev. 0), United Drilling Inc. ALWD Nos. UD-172604-02, Rev.1, and Northwestern Air Services ALWD NWA-174009-01 Rev. 1. Navarro will conduct a tail gate safety briefing (TGB) for Navarro personnel at the start of each shift.

10.0 LESSONS LEARNED AND CONTINUOUS IMPROVEMENT

NSTec Pre-task hazard reviews (PTHRs) and/or tailgate safety briefings (TGBs) or post job briefings shall be used by Navarro and NSTec organizations performing the work to provide input into the lessons learned, such that performance of these activities can be improved. Site workers will be encouraged to discuss lessons learned at the PTHRs or TGSBs. Any lessons learned will be documented on the PTHR or TGSB forms.

11.0 COMMUNICATIONS

Primary communications at this remote well site will be microwave telephones, NTS net radios or radio phones, cell phones and/or NSTec or Navarro satellite phones will serve as secondary communications.

12.0 TRAINING

Workers performing work at this site in accordance with Table A-4 of the UGTA HASP, Revision No. 3, May 2015, while working must have a minimum of General Employee Radiological Training (GERT), HASP Orientation, Hantavirus Awareness Video, and participate in the TGB or PTHR. This site is not within a Desert Tortoise area. Workers performing work at this site within a CA and under an approved RWP must also have OSHA 40-Hour Hazardous Waste Site Worker, Radiological Worker II or equivalent and Waste Awareness training.

13.0 FIELD ACTIVITY-SPECIFIC EMERGENCY RESPONSE

13.1 During the conduct of these activities there will be at least two individuals at all times that have First Aid and CPR training; a person with current training in application of an Automated External Defibrillator (AED); and an AED at the work site.

13.2 See Exhibit 1 for a map of the ER-4-1 site with primary and secondary emergency response facilities. The primary emergency response facility for this activity will be the Area 6 Aid Station. The secondary facility will be Mercury Medical.

13.2.1 <u>From the ER-4-1 site to the Area 6 Aid Station</u> – Exit the location to the north onto the pole line road just to the north, turn left (west) and continue west approximately one mile to the intersection with Rainier Mesa Road. Turn left (south) onto the Rainier Mesa Road and continue south on the Rainier Mesa Road and Mercury Hwy, approximately 11 miles to the Area 6 Aid Station. The Area 6 Aid Station is located in the fire station on the northeast corner of the intersection of Tippipah Hwy and Mercury Hwy in building 6-950.

13.2.2 <u>From the ER-4-1 site to Mercury Medical</u> – The secondary hospital/infirmary is Mercury Medical Facility. Follow the same directions as above to the intersection with Tippipah Hwy. and continue south on Mercury Hwy. 20.6 miles into Mercury. Turn east (left) on Trinity Road, and proceed three blocks. Turn south (right) on Buster Road. Mercury Medical Facility is in Building 650 on the east (left) side of the road.

NOTES:

A. Changes to this Field Activity Work Plan can only be executed through formal revision of the plan, or through a Record of Verbal Communication (RVC), with concurrence from the NNSA/NFO UGTA Activity Lead, the Navarro, and NSTec Project Managers, or their designees. Verbal approvals shall be documented on the RVC with approval signatures obtained on the RVC as soon as practical.

B. All tubular goods and hardware including wireline and wireline tools run in the hole will be steam cleaned in Area 1 prior to transport to the location. After cleaning, and before removal from the rack, NSTec and Navarro will inspect the tubular goods / hardware and accept/reject it before it is moved to the ER-4-1 site.

C. Paint on all downhole equipment will be checked for lead by Navarro and approved for use based on the analysis. If paint is not approved, it will be removed from the equipment prior to use in the hole.

D. If other-than-approved drilling fluid additives (foam/polymer) are to be used, a representative sample must be tested, prior to field use, for RCRA-regulated constituents and isotopic radiological parameters according to the well-specific sampling and analysis plan. This sampling and analysis is to be done by Navarro.

E. All fluids introduced into the borehole shall be tagged with 17 to 27 milligrams per liter (mg/l) (parts per million [ppm]) LiBr in accordance with the SOP presented in the letter of understanding between IT Corp. and DOE, dated December 2, 1992. Care must be taken to avoid contact of the LiBr concentrate with mucous membranes, and personnel handling the concentrate must wear rubber gloves. Mixing should only take place in ventilated areas, and personnel involved with the mixing should avoid breathing fumes of the LiBr.

F. Equipment, tools, materials, supplies, etc. brought onto the site must be strictly controlled. The Project HPS and/or RCTs will be consulted any time anything is removed from the site and will determine if radiological surveys are required and if form FRM-0894, Radiological Determination for Release of Items must be completed prior to moving any items from the site.

EXHIBITS

A	Location of ER-4-1 Well Site, 3 pages
B	ER-4-1 Existing Surface Site Layout
C	Saturated Zone Flow Line Design Configuration, 2 pages
D	Work Instruction for the Inspection of the UGTA Flow Line, 2 pages
E	Expected Stratigraphic, Lithologic, Geologic, and Hydrologic Characteristics for Proposed Well ER-4-1
F	High Energy Discharge Communications Plan, 2 pages
G	Illustration of Projected ER-4-1 Well Completion
H	On-Site ER-4-1 Organization Chart
I	Emergency Response for the ER-4-1 Site, 2 pages

EXHIBIT A

Location of the ER-4-1 Well Site (page 1 of 3)

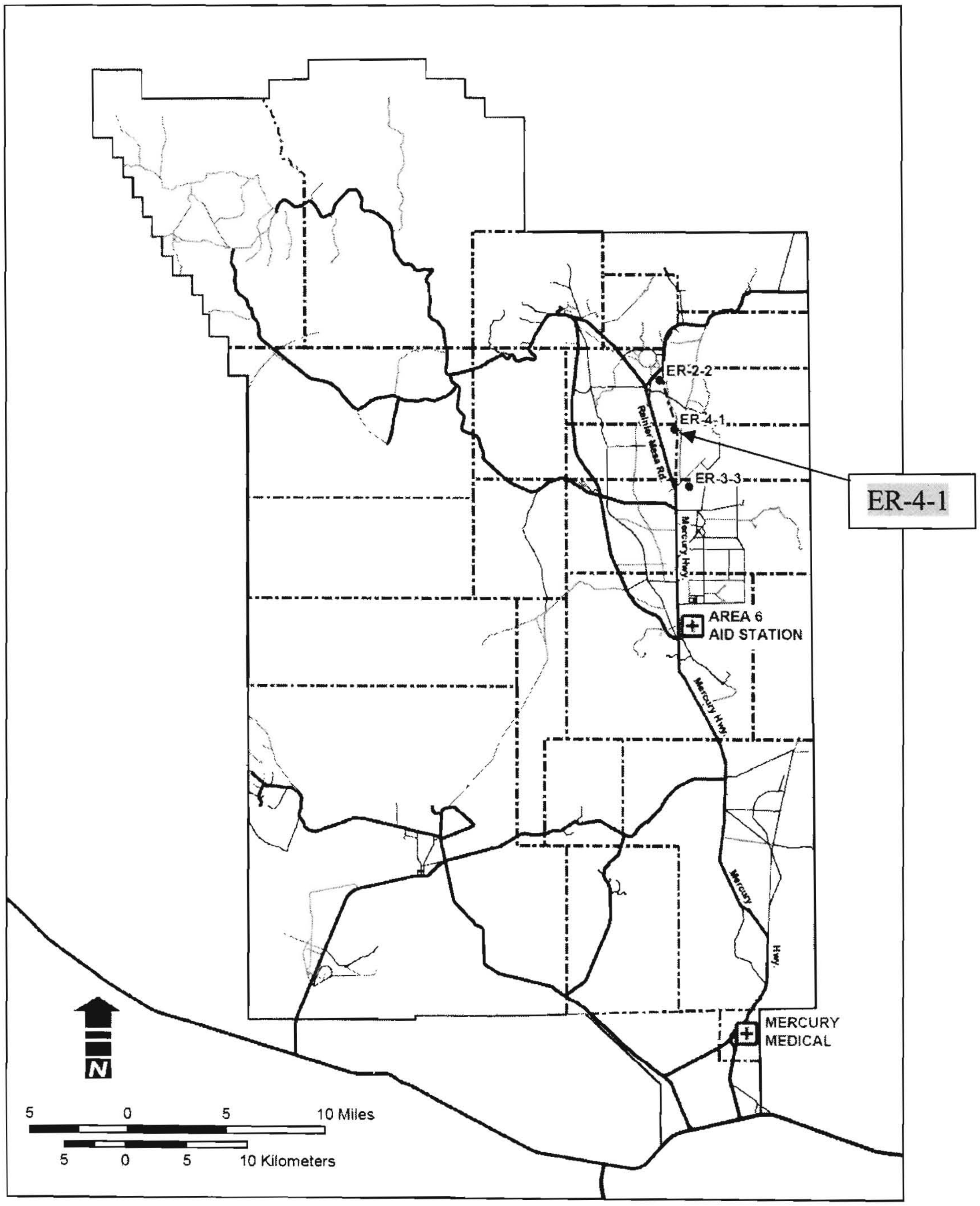


EXHIBIT A

Location of the ER-4-1 Well Site (page 2 of 3)

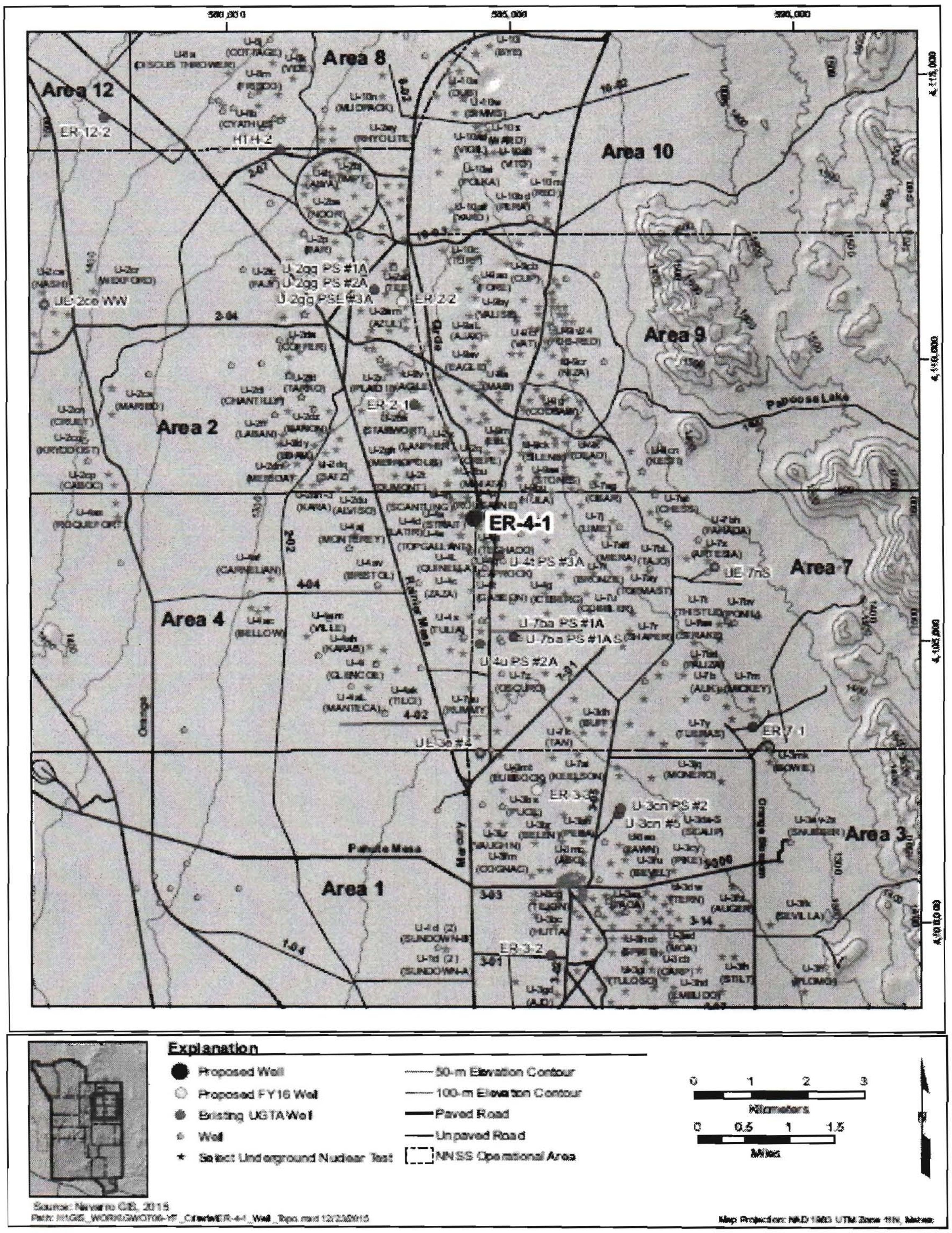


EXHIBIT A

Location of the ER-4-1 Well Site (page 3 of 3)

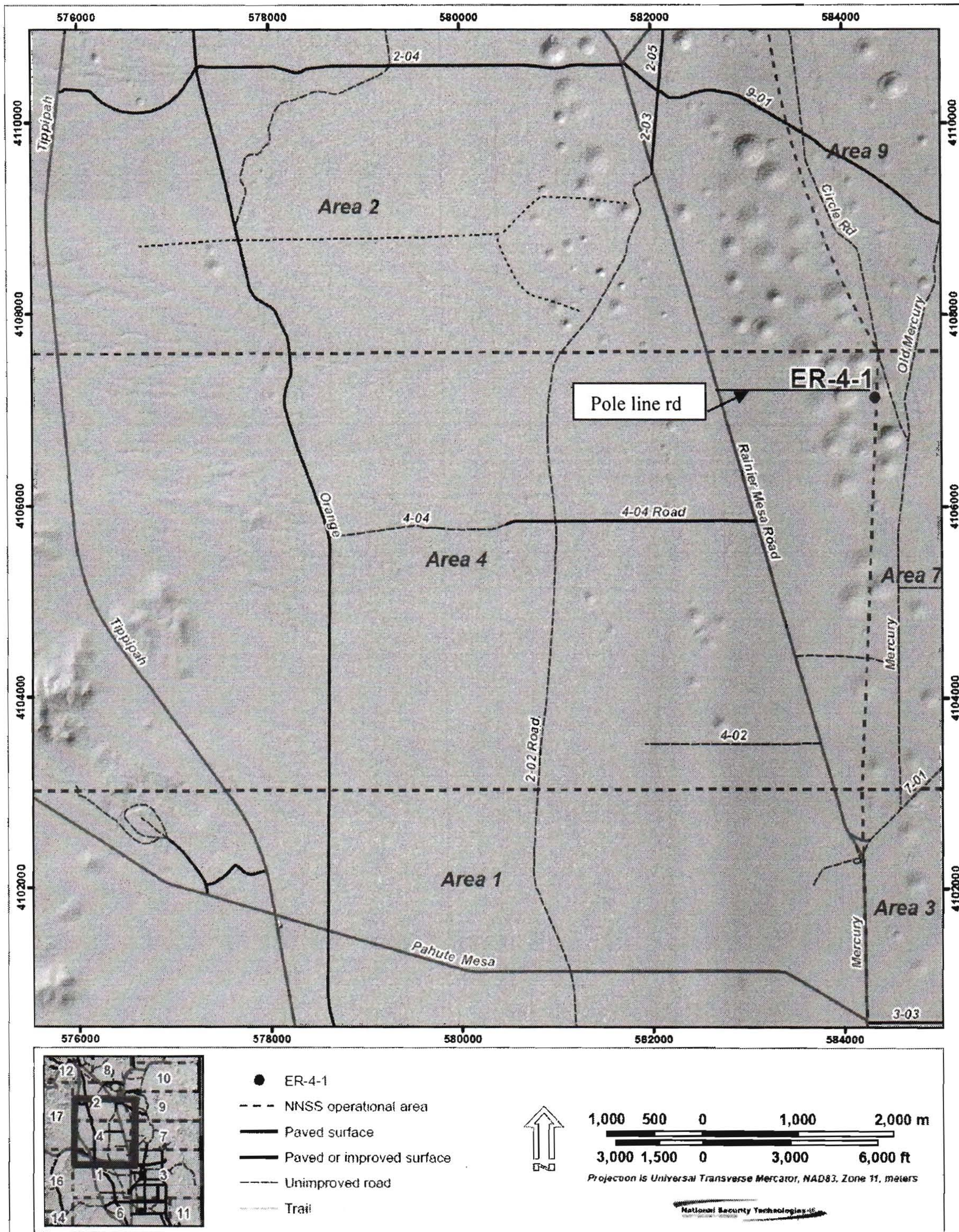
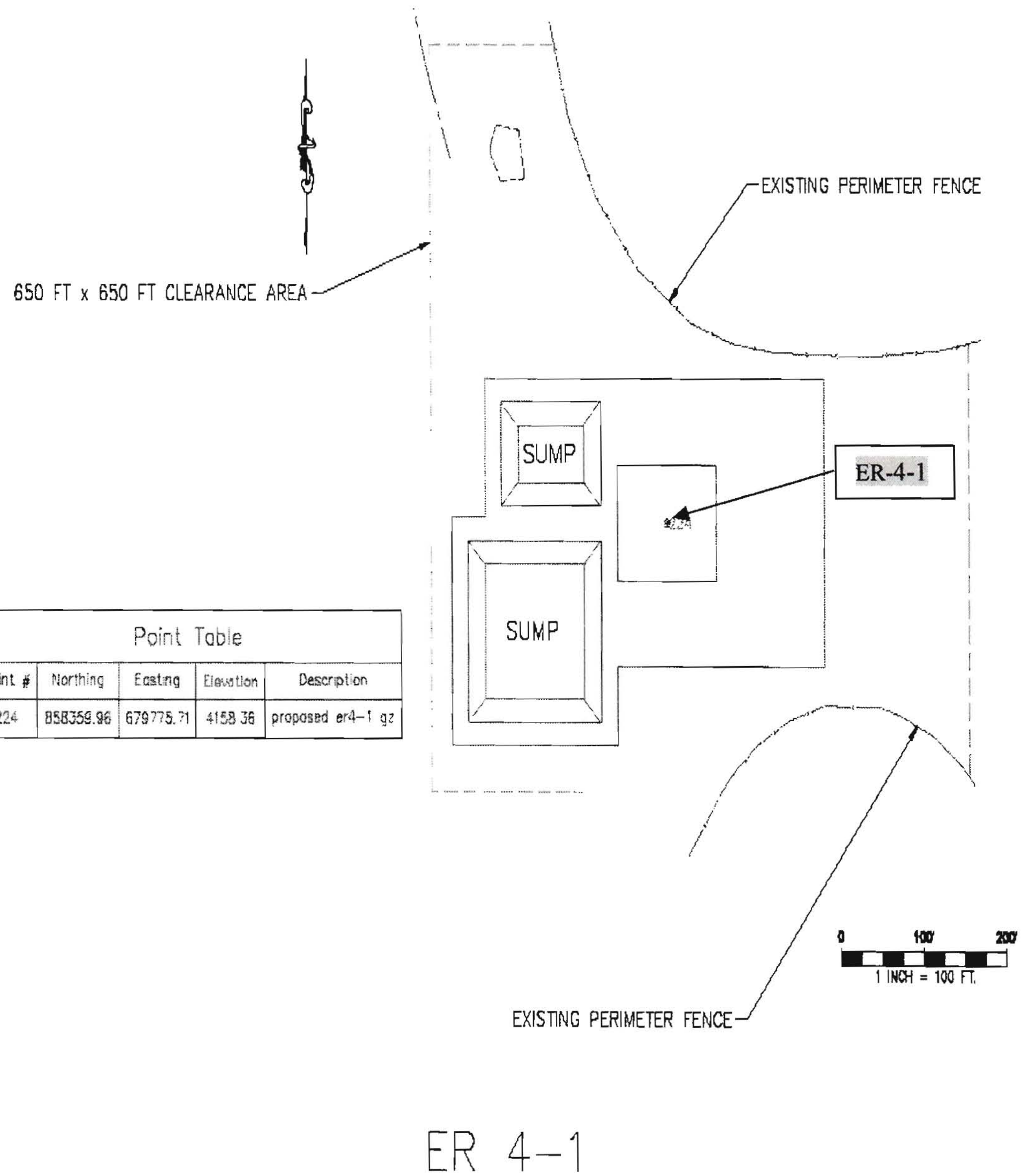


EXHIBIT B

ER-4-1 Existing Surface Site Layout



Point Table				
Point #	Northing	Easting	Elevation	Description
224	858359.96	679775.71	4158.36	proposed er4-1 gz

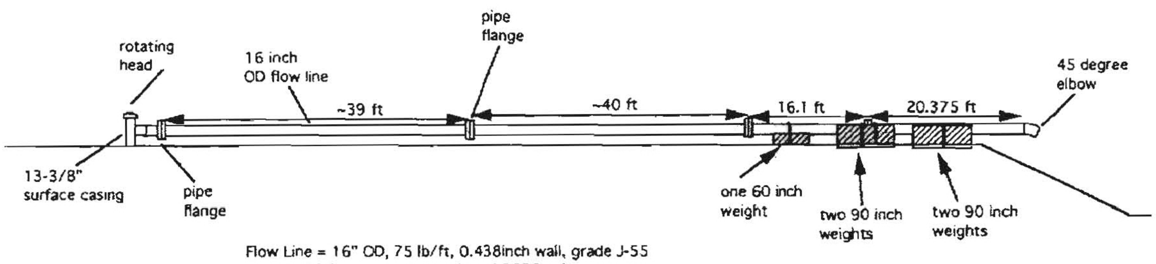
ER 4-1

EXHIBIT C

Saturated Zone Flow Line Design Configuration (page 1 of 2)

UGTA Project: Drilling Flow Line Design

SATURATED ZONE FLOW LINE DESIGN CONFIGURATION



Flow Line = 16" OD, 75 lb/ft, 0.438inch wall, grade J-55 casing with burst pressure rating of 2630 psi
Flanges = ANSI Class 300, minimum 300 psi working pressure with ASTM A194 nuts and ASTM A193 bolts

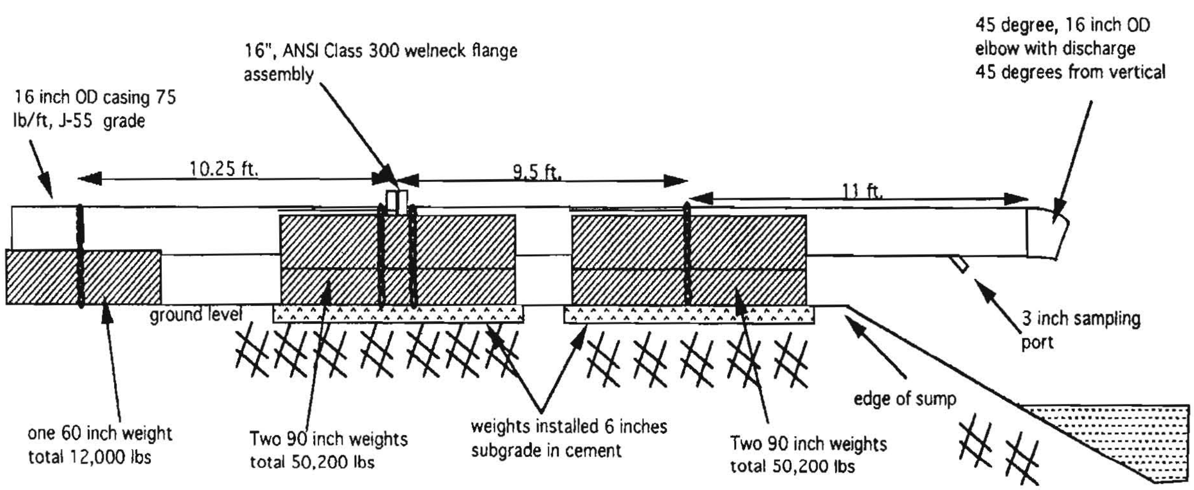
N-I Concurrence:

Jeffrey Wurtz /s/ Jeffrey Wurtz 8-27-10

for Sam Marutzky, N-I UGTA Program Manager Signature Date

EXHIBIT C

Saturated Zone Flow Line Design Configuration (page 2 of 2)



NOTES:
J-55 grade = 55ksi minimum yield strength
75 lb/ft = ID of 15.124", wall thickness 0.438", burst rating 2630 psi

EXHIBIT D

WORK INSTRUCTION FOR THE INSPECTION OF THE UGTA FLOW LINE

SCOPE AND LIMITATIONS

This work inspection provides the requirements for inspection of the discharge flow line used during drilling operations for the Underground Test Area (UGTA) project. This work instruction only provides the requirements for the flow line as installed based on the August 2010 design.

Welding and inspections performed during the construction of the flow line are covered by the appropriate work package, the flow line quality verification plan (QVP), and the NSTec Welding Manual CCD-QA05.002 and are not included here. The NSTec core company document CCD-QA08.001 Inspection and Testing for Acceptance identifies the process for planning and execution of the Quality Control verification process. The QVP identifies the Project/User's Critical Verification Attributes which require Quality Control verification, (i.e., visual weld examination, magnetic particle examination, and ultrasonic thickness testing processes).

RESPONSIBILITIES

NSTec Site Supervisor: Responsible for visual inspection of the flow line, scheduling of inspections with the Non-Destructive Testing personnel and reporting all issues to the UGTA Program Manager or designee for resolution and tracking to closure.

NDT Inspector: Responsible for performing non-destructive inspections and testing of the flow line. Documentation of these results will be provided in the appropriate work package.

UGTA Program Manager: Responsible for ensuring that inspections and testing are performed, and that issues, if identified are immediately resolved or tracked to closure.

WORK INSTRUCTION

Pre/Post Use Inspections: The flow line will be inspected and tested using magnetic particle and ultrasonic thickness testing methods during the location-to-location moves between drill sites and after the last well in a drilling campaign is completed. This inspection will be performed by the NDT Inspector in accordance with the NSTec Welding Manual.

The inspection will determine the flow line thickness at multiple locations on each length of pipe and will focus on areas where more wear is expected, such as immediately downstream of the connection with the well casing and at the discharge locations. Results will be documented in the appropriate work package.

Inspections are required for location to location moves, and for movement of the flow line at the site (i.e., if the flow line is moved to reroute the discharge to a lined sump because of the presence of radioactivity above action levels in the discharge). All new welds made to the wellhead or flow line will require visual and magnetic particle inspections. Visual inspections of flange bolts and nuts, and torque-up inspections of the bolts are required for any flanges un-bolted during the location moves. Results will be documented in the appropriate work package.

In-Use Inspections: During drilling in the saturated zone, the flow line, flanges and tie downs will be visually inspected daily by the NSTec Site Supervisor or designee for signs of weeping, leakage, damage and/or movement. The inspection will note the condition of the elbow on the discharge end of the flow line. Inspections results will be documented in the field logs, and provided to the UGTA Program Manager or designee.

Damage, weeps or leaks will be immediately reported to the UGTA Program Manager or designee. Repairs will be tracked to closure by the UGTA Program Manager or designee. These include but are not limited to the following:

- Any plastic deformation of the pipe or flanges,
- holes, cracks or breaks in the pipe or flanges,
- visible thinning of the pipe walls, such as at the discharge point,
- deviation from the installed flow line direction,
- cracks, breaks or deformation in the chain links,
- breaks in the concrete surrounding the flow line weights that indicate movement of the weights
- visible movement of the flow line during discharge except at the unsecured end of the discharge line,
- weeping or leaking of the flow line at flanges or at any other location except the discharge end, and,
- any other observation that causes concern about the safety of the flow line.

Ultrasonic meters will be used by trained and qualified personnel to determine flow line wall thicknesses at susceptible locations on the flow line during drilling operations if there are extended periods of violent discharge during drilling. These results will be provided to the UGTA Program Manager or designee and the appropriate engineering, welding or pressure vessel SME to determine the actions required to ensure continued safe operations, if any.

Table C.5-1
Expected Stratigraphic, Lithologic, Geologic, and Hydrologic Characteristics for Proposed Well ER-4-1
(Page 1 of 2)

Stratigraphic Unit	Depth Interval		Estimated Thickness		Lithology and Alteration	HGU	HSU [a]
	(m)	(ft)	(m)	(ft)			
Quaternary/Tertiary alluvium (QTa)	0 - 199	0 - 653	199	653	Poorly to moderately sorted gravel and sand; loosely to moderately consolidated	AA (unsaturated)	AA3 [b]
Timber Mountain Ammonia Tanks Tuff (Tma)	199 - 219	653 - 719	20	66	Partially welded to nonwelded ash-flow tuff	VTA (unsaturated)	TMUVTA
Timber Mountain Ammonia Tanks Bedded Tuff (Tmab)	219 - 226	719 - 743	7	24	Bedded tuff	VTA (unsaturated)	TMUVTA
Timber Mountain Rainier Mesa Tuff mafic rich (Tmrr)	226 - 336	743 - 1,103	110	360	Partially welded to densely welded tuff	WTA (unsaturated)	TMWTA
Timber Mountain Rainier Mesa Tuff/tuff of Holmes Road (Tmr/Tmrh)	336 - 362	1,103 - 1,189	26	86	Nonwelded to bedded tuff	VTA (unsaturated)	TMLVTA
Paintbrush Group Undivided (Tp)	362 - 529	1,189 - 1,736	167	547	Nonwelded to bedded tuff	TCU (saturated below 484.3 m [1,589 ft])	LTCU
Grouse Canyon Tuff (Tbg)	529 - 541	1,736 - 1,775	12	39	Nonwelded to bedded tuff	TCU (saturated)	LTCU
Tunnel Formation (Tn3 and Tn4)	541 - 623	1,775 - 2,043	82	268	Nonwelded to bedded tuff	TCU (saturated)	LTCU
Tub Spring Tuff (Tub)	623 - 644	2,043 - 2,113	21	70	Nonwelded to bedded tuff	TCU (saturated)	LTCU
Tunnel Bed 2 (Ton2)	644 - 758	2,113 - 2,486	114	373	Nonwelded to bedded tuff	TCU (saturated)	OSBCU
Tuff of Yucca Flat (Toy)	758 - 764	2,486 - 2,507	6	21	Nonwelded to partially welded tuff	TCU (saturated)	OSBCU
Older Tunnel Bed 3 (To3)	764 - 780	2,507 - 2,560	16	53	Nonwelded to bedded tuff	TCU (saturated)	OSBCU
Tuff of Twin Peaks (Tot)	780 - 796	2,560 - 2,611	16	51	Nonwelded to partially welded tuff	TCU (saturated)	OSBCU
Paleocolluvium and Interbedded Older Tuffs (Tlc/To)	796 - 822	2,611 - 2,698	27	87	Interbedded tuffaceous colluvium and nonwelded tuffs	TCU (saturated)	ATCU
Paleozoic Carbonate Rocks (Pz)	822 - 945	2,698 - 3,100	123	402	Carbonates	CA (saturated)	LCA

HIGH ENERGY DISCHARGE COMMUNICATIONS PLAN

High Energy Drilling Discharges

During drilling a potential exists for high energy discharges of air, foam and mixtures of drilling fluid, cuttings and groundwater from the flow-line (blooie line) as it is directed into the fluid storage sump. These discharges present a particular hazard to personnel near the point of discharge and in the pathway of the discharge. These high energy discharges are very unlikely during unsaturated zone (above the water table) drilling. They are more likely to occur as drilling progresses within the saturated zone (below the water table) and may become more regular as the borehole is advanced to greater depths below the water table. During drilling the energy at which the discharge occurs will be regularly evaluated by Navarro sampling personnel and the Navarro site supervisor as drilling progresses. The discharge will be specifically evaluated for the hazards relating to the energy or force/velocity of the discharge in terms of the estimated volumes and force of the air foam/fluid mixture discharged, cutting sizes and quantity, distance the discharge travels into and across the sump area or any areas surrounding the sump and any expression of physical movement in the flow-line. If discharge energies realized at the flow-line are deemed by Navarro sampling personnel and the Navarro supervisor to present a hazard to personnel due to the nature of the high energy discharge such that cuttings or fluid samples cannot be collected safely, the Navarro supervisor and sampling personnel in coordination with the NSTec Site Supervisor and UD drilling supervisor (tool pusher) will implement the administrative controls as listed below. In any event, if discharge conditions are so energetic that attempts to sample fluids or solids cannot be accomplished using typical sampling methods the administrative controls described below will be mandatory.

- When administrative controls are to be implemented due to potential high energy discharge conditions a special PTHR will be conducted by the NSTec Site Supervisor for all on-site personnel to advise of hazards and controls, define restricted areas and coordinate participation. Navarro will also conduct a supplemental Tailgate Safety Briefing (TSB) and ensure that administrative controls are understood by Navarro personnel and documented on the TSB. If administrative controls relating to high energy discharge are in effect all personnel arriving on-site subsequent to the implementation of the controls will receive PTHRs and TSBs describing the administrative controls and restrictions in place until such time that the hazard is not present.

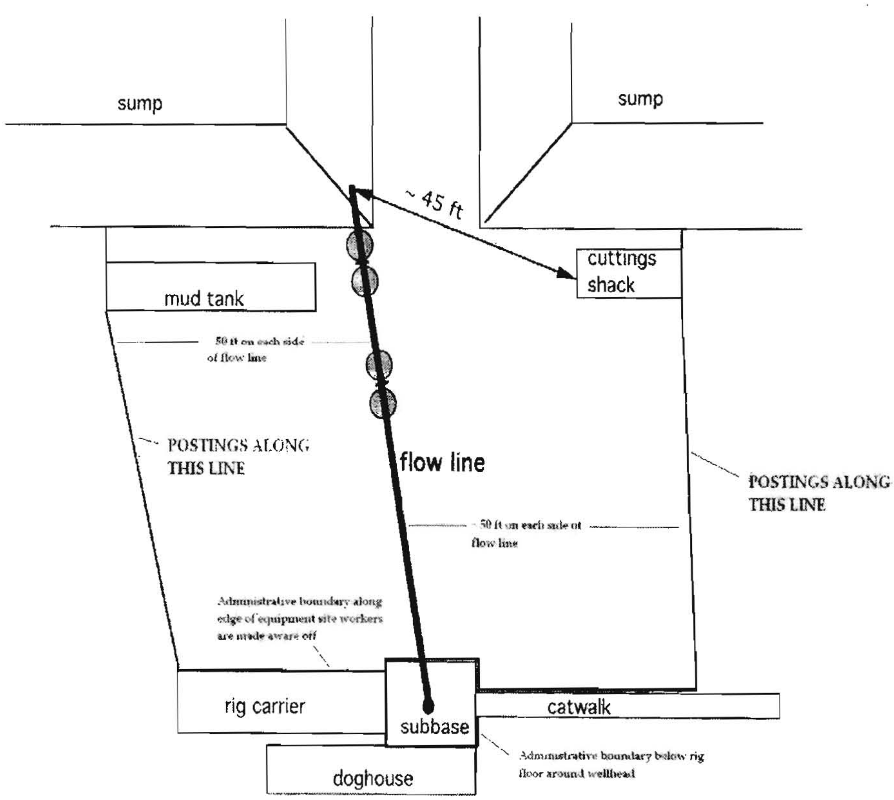
- The sampling area and all areas affected by the high energy discharge will be posted "Caution High Energy Discharge" and "Authorized Personnel Only" and personnel restricted access during imminent or high energy discharges (see Figure below). If a visual alert has been instituted (e.g. flashing light) additional posting may be placed to warn personnel of restricted access (e.g. No Entry When Light is Flashing). Postings will be conspicuously placed along personnel access routes to the discharge area and located to ensure that personnel are safely outside the area of the discharge hazard.

- Audible and visual warnings will be activated by the UD driller to alert site personnel that high energy discharges are imminent. One blast on the rig horn and activation of the flashing light positioned on top of the Navarro cuttings shack will signal a potential for high energy discharge from the flow line.

– During high energy discharges or periods of imminent high energy discharges Navarro sampling personnel assigned to duty in the sampling area will be restricted to the cuttings collection shack or areas outside the posted exclusion area. The cutting shack will have the doors closed during periods of high energy discharge.

- Once discharge energy has subsided the on-duty driller will authorize personnel access into the exclusion area with two blasts of the rig horn, switching off the flashing light and use of radio communications if necessary.

– Radio communication between the rig floor and the Navarro sampling personnel will be established and maintained. Sampling personnel will have a radio on their person at all times.



Restricted Area During High Energy Discharges

EXHIBIT G

ILUSTRATION OF PROJECTED ER-4-1 WELL COMPLETION

Well ID: ER-4-1	UTM NAD 27	Northing: 4,106,944.8 m	Easting: 584,410.1 m
Start Date: TBD Stop Date: TBD	NSPC NAD 83	Northing: 6,261,657.1 m	Easting: 554,729.3 m
Drilling Program: Yucca Flat	Lat/Long NAD 83	Deg N: 37.106806	Deg W: 116.050891
Environmental Contractor: UGTA/Navarro	Surface Elevation	4,158 ft amsl	1,267.4 m amsl
Drilling Contractor: United Drilling Inc.	Drill Method:	Conventional - Air/Foam	Drilled Depth: 3,100 ft bgs
Well Construction Diagram (Current as of 09/22/2015)			

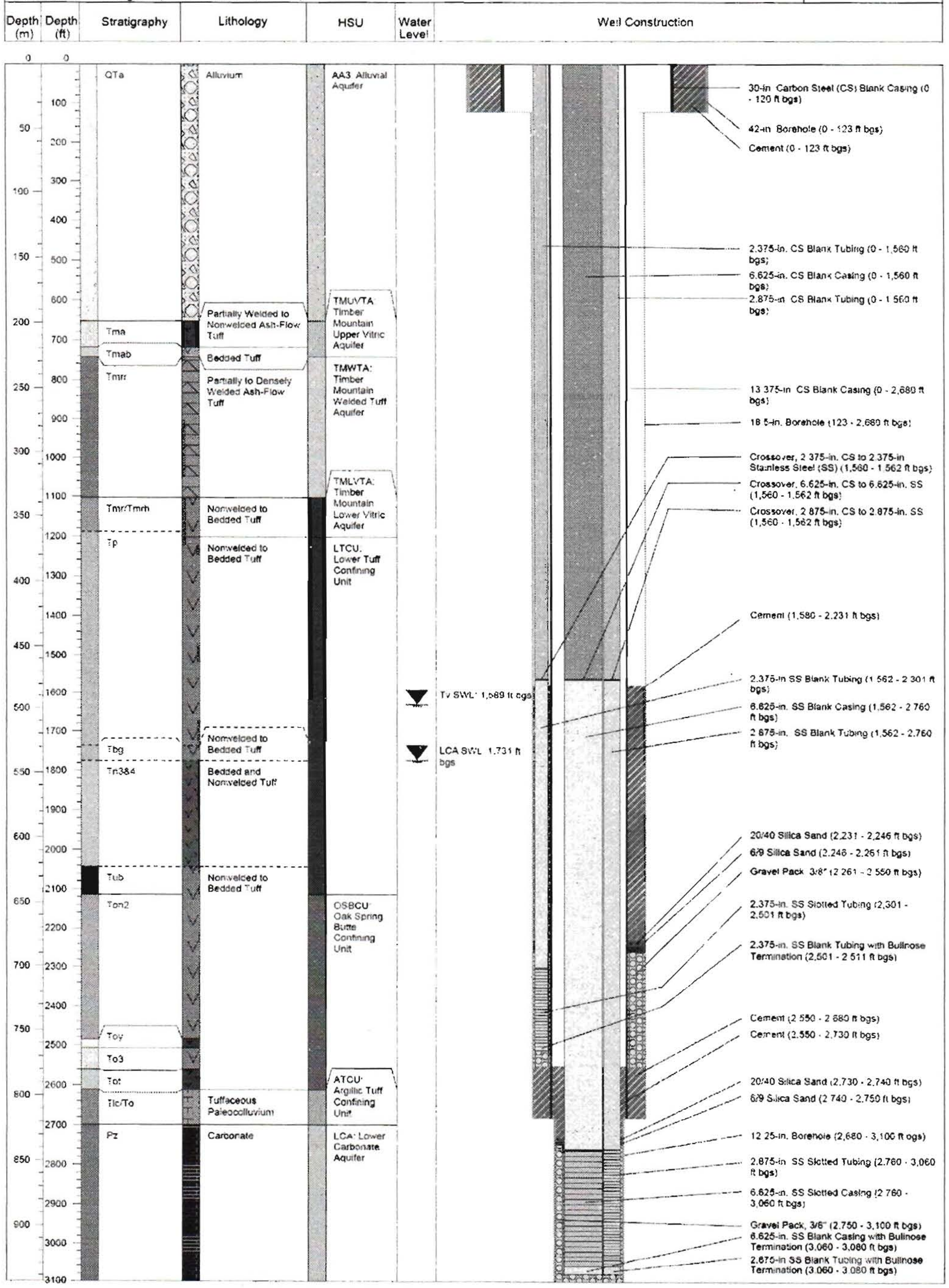


EXHIBIT H
ON-SITE ER-4-1 ORGANIZATION CHART

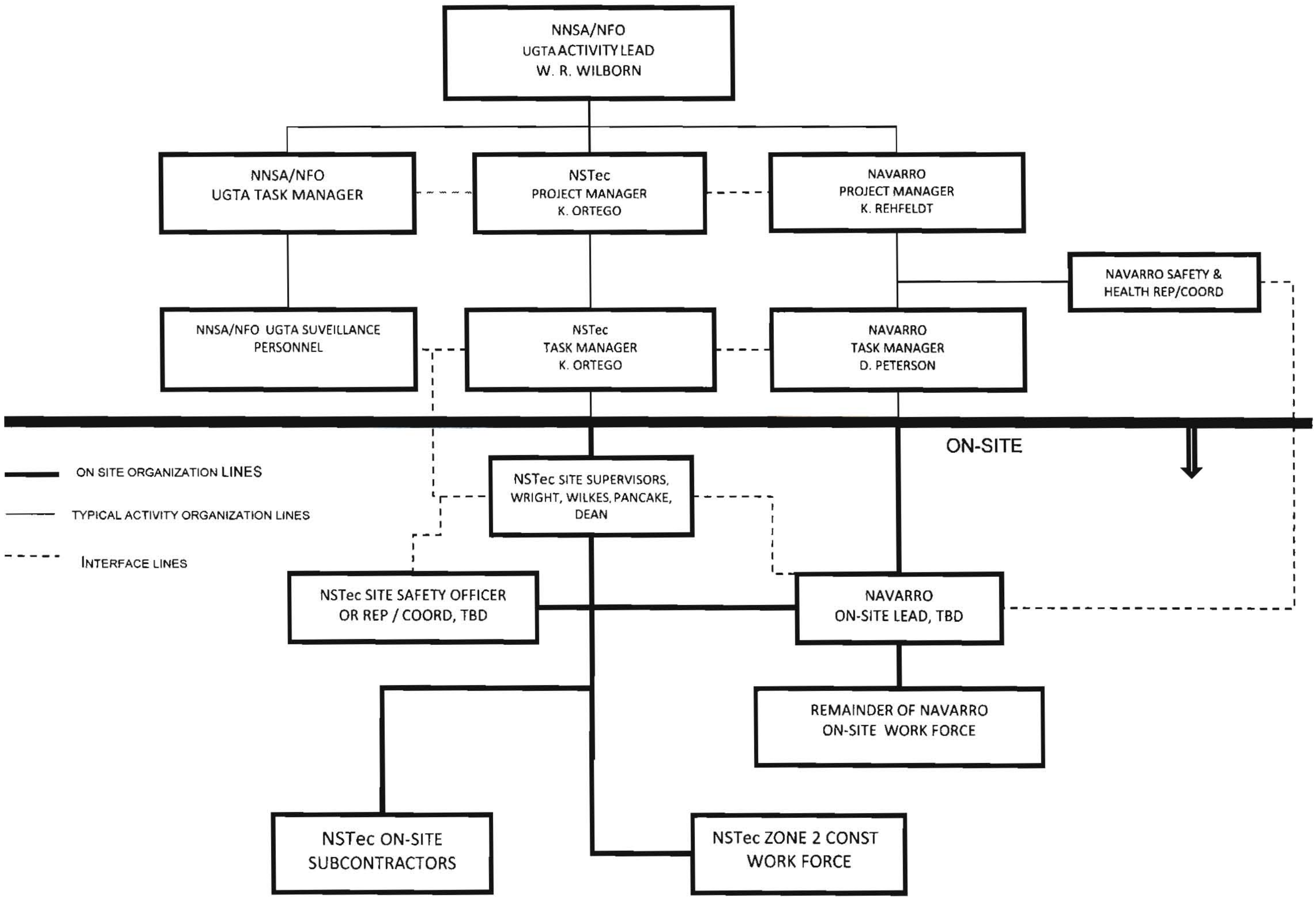


EXHIBIT I
PRIMARY EMERGENCY RESPONSE for ER-4-1 SITE

AREA 6 AID STATION (page 1 of 2)

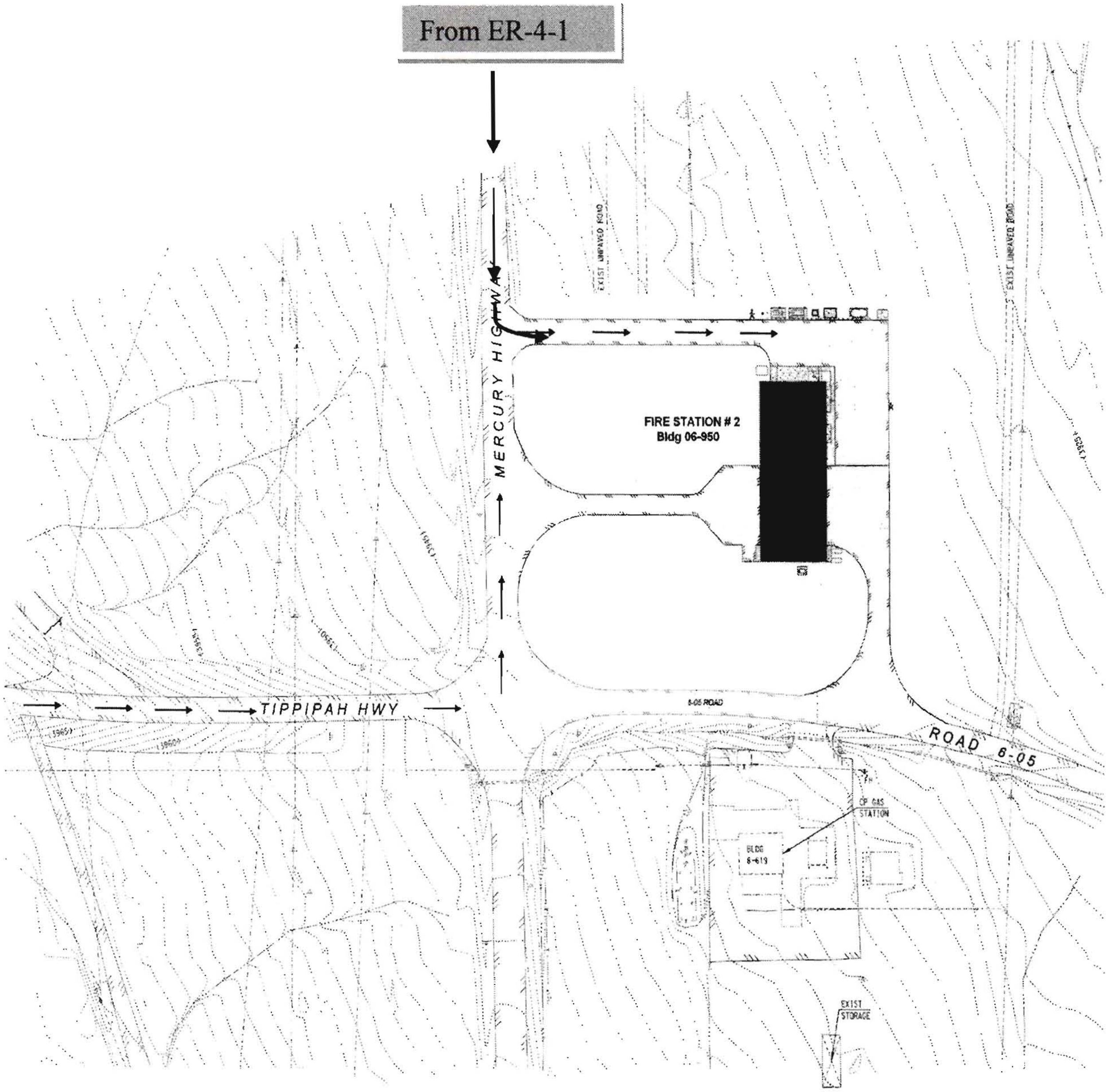
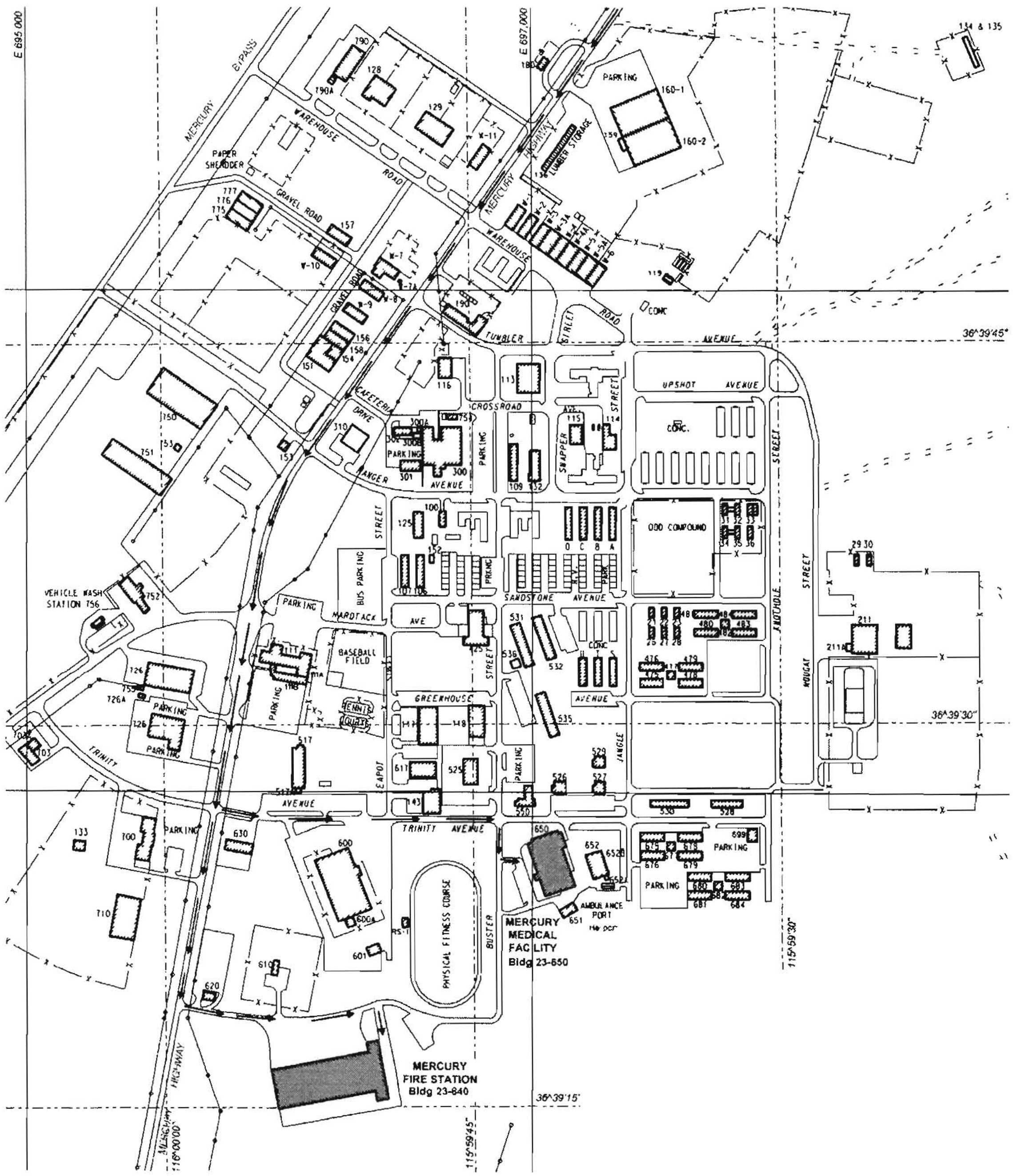


EXHIBIT I
SECONDARY EMERGENCY RESPONSE for ER-4-1 SITE

MERCURY MEDICAL (page 2 of 2)



NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources
Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
David Emme, Administrator

March 25, 2016

Mr. Robert F. Boehlecke
Manager
Environmental Management Operations
National Nuclear Security Administration
Nevada Field Office
P.O. Box 98518
Las Vegas, Nevada 89193-8518

RE: SUBMITTAL OF FINAL WELL SPECIFIC FLUID MANAGEMENT STRATEGY FOR THE UNDERGROUND TEST AREA (UGTA) ER-4-1, AREA 4, NEVADA NATIONAL SECURITY SITE (NNSS), MARCH 2016
Federal Facility Agreement and Consent Order

Dear Mr. Boehlecke:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities has received and reviewed the *Final Well Specific Fluid Management Strategy for UGTA ER-4-1, Area 4, NNSS*, dated March 24, 2016. The strategy describes the monitoring and management of fluids generated during the drilling, pumping, purging and sampling of ER-4-1. The proposed 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 either Mark McLane or me at (702) 486-2850, ext. 226 or 232, respectively.

Sincerely,

/s/ Christine D. Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/MM

ec: EM Records, NNSA/NFO
W. R. Wilborn, NNSA/NFO
Navarro Central Files
Mark McLane, NDEP

cc: EM Records, NNSA/NFO
FFACO Group, NNSA/NFO
J. T. Fraher, DTRA/CXTS, Kirkland AFB, NM
NSTec Correspondence Management

FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY
FOR UGTA WELL ER-4-1
NEVADA NATIONAL SECURITY SITE

March 17, 2016

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO), Underground Test Area Activity (UGTA) is proposing to drill and construct Well ER-4-1, as part of a drilling program for areas of Yucca Flat. The acquisition of hydrogeological data from this specific well will be used evaluate and build confidence in the existing groundwater flow and contaminant transport models of the area, specifically near existing underground test locations. Drilling operations will be conducted in accordance with the *Corrective Action Investigation Plan for Corrective Action Unit 97: Yucca Flat/Climax Mine* (NNSA/NSO 2000).

Proposed Well ER-4-1 is located within the north central area of Yucca Flat, located within Area 4, in the northeastern portion of the Nevada National Security Site (NNSS). Figure 1 shows the location of Well ER-4-1 relative to other wells and the many underground tests conducted in the surrounding area. The closest underground nuclear test to the proposed well site is STRAIT detonated in March of 1976 in emplacement well U-4a. The STRAIT (U-4a) test is located approximately, 222 m (730 ft) to the west of the Well ER-4-1 location. Based on the distance of the proposed well from the STRAIT (U-4a) test and available analytical data from the closest wells, Well ER-4-1 is categorized as a Near-field well location, but will be managed under a Far-field well until monitoring results of the drilling discharge require a transition to Near-field operations. This well specific fluid management strategy letter describes monitoring and management of fluids generated during fluid-producing activities at Well ER-4-1 in accordance with the requirements of the Fluid Management Plan (FMP) for the Underground Test Area, Rev 5 (NNSA/NSO, 2009b). The scope of this fluid management strategy letter includes fluid generating activities relating to drilling, well completion, well development and testing, well purging, and groundwater sampling at Well ER-4-1.

BACKGROUND AND ANALYTICAL DATA

Given the present understanding of groundwater flow in the area of proposed Well ER-4-1, the location is apparently down gradient of the nearest principal underground test STRAIT (U-4a). The proposed Well ER-4-1 will be located approximately 2.22 km (730 ft) east of the STRAIT (U-4a) underground test.

Proposed Well ER-4-1 lies approximately down gradient of the STRAIT (U-4a) underground test which is the principal focus of this hydrogeologic investigation. The STRAIT (U-4a) was detonated in 1976 with a working point located below the present water table at a depth of 782.42 m (2,567 ft), below ground surface (bgs). The reported yield range of the STRAIT (U-4a) test was 200 – 500 kilotons (DOE 2015).

There is some uncertainty with respect to the nature of the groundwater contamination that may be encountered at the Well ER-4-1 location, although the proximity of the Well ER-4-1 to the STRAIT (U-4a) test may suggest that radionuclides in the groundwater may be likely. The nearest sampled well to proposed Well ER-4-1 is Well ER-2-1. Well ER-2-1 is located approximately 2.23 km (1.4 miles) feet north-northwest of the proposed Well ER-4-1 location. This well was drilled to a depth of 792.48 km (2,600 ft) bgs in close proximity to three underground tests. Well ER-2-1 penetrated only the Tertiary volcanic units above and below the water table and is completed in low permeability saturated volcanic rocks. The most recent groundwater sampling from March 2015 indicates low tritium concentrations in the produced groundwater. The reported tritium results were 840 and 920 pCi/L from two samples collected.

Other scenarios may be representative of expected radionuclide contamination at Well ER-4-1. The post-shot well U-2gg PS 3A, which was angle drilled adjacent to the INGOT (U-2gg) test cavity, located 4.41 km (2.7 miles) to the northwest of proposed Well ER-4-1 may be representative of anticipated conditions at Well ER-4-1. The U-2gg PS 3A borehole passed within 10 m (32.8 ft) of the test cavity and extended below the test cavity. Well U-2gg PS 3A was last sampled in 1994, in spite of the proximity to the test cavity the reported tritium activity was only 6,490 pCi/L.

Although, these nearby wells suggest generally low tritium concentrations in groundwater. Well UE-2ce WW located approximately 8.48 km (5.3 miles) west of the proposed Well ER-4-1 suggest tritium concentrations may be much higher. The UE-2ce WW was drilled and completed proximal 183 m (600.4 ft) to the NASH (U-2ce) underground test. Groundwater results from samples collected at Well UE-2-ce in 2008 yielded a tritium concentration of 270,000 pCi/L. Based on these examples, Well ER-4-1 may be expected to contain tritium, above the Safe Drinking Water Act (SDWA) limit of 20,000 picocuries per liter (pCi/L) and potentially in excess of 400,000 pCi/L.

Multiple groundwater aquifers may have been affected as a result of the STRAIT (U-4a) underground test as suggested in the monitoring and sampling results of nearby wells. As a result the proposed Well ER-4-1 will be drilled to a depth of approximately 944.8 m (3,100 ft) bgs and constructed to allow isolated access to multiple aquifers for the purposes of aquifer testing and groundwater sampling. Contaminated groundwater aquifers observed during drilling that exceed Safe Drinking Water Act (SDWA) limit of 20,000 picocuries per liter (pCi/L) will be specifically isolated to prevent the cross communication of contaminated groundwater between aquifers. A proposed well construction diagram for Well ER-4-1 is presented in Figure 2.

WELL OPERATIONS STRATEGY

Based on the information presented above with respect to the location of Well ER-4-1, hydrogeologic setting and proximity of underground testing, Well ER-4-1 is considered to be a potential Near-field well site. However, because it is not certain that Near-field conditions will be encountered in the well, it is proposed that fluid generating activities during the drilling and construction of Well ER-4-1 be conducted using the Far-field well site operations strategy for wells located on the NNSS. Should Near-field conditions be encountered, Well ER-4-1 operations will transition to a Near-field Strategy, as specified in the FMP and this strategy letter.

On-Site Monitoring – In accordance with the FMP, tritium monitoring samples will be collected at a minimum hourly from the discharge line during fluid generating activities at Well ER-4-1. The results of on-site monitoring will be compared to the FMP discharge criteria as results are available. Eight hour on-site monitoring for lead will commence if Near-field conditions (i.e., tritium in excess of 400,000 pCi/L) are encountered.

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

Fluid Containment and Discharge Criteria - The NNSA/NFO proposes the following fluid containment and discharge strategy for Well ER-4-1:

- A single lined sump with an approximate 1 million gallon capacity has been constructed at the Well ER-4-1 site for fluid containment. Groundwater generated from the well during drilling, well completion, well development and testing, pumping, and groundwater sampling will be routed from the well through a well head, well head manifold, through flexible piping or hard piping and ultimately discharged to the lined sump. Based on the projected groundwater production in Well ER-4-1, the sump has the required capacity to contain all fluids expected to be produced during drilling operations.

- A second unlined sump has also been constructed on the Well ER-4-1 site. This sump is not anticipated to be utilized unless fluid storage capacities on the site are limited. In the event this sump is used, it may be lined to accommodate fluids that exceed the Far-field criteria (> 400,000 pCi/L) or remain un-lined to contain those fluids that meet Far-field FMP criteria (i.e. < 400,000 pCi/L) tritium.
- It is anticipated that fluids generated during vadose (unsaturated) zone drilling will not contain tritium above Near-field FMP criteria (i.e., 400,000 pCi/L). Prior to reaching the saturated zone, the level of fluids in the lined sump and the results of on-site tritium monitoring will be reviewed to determine if discharge of fluids from the sump to an infiltration area or an unlined sump is feasible. If on-site monitoring indicates tritium at concentrations less than 400,000 pCi/L, NNSA/NFO may exercise the option to discharge such fluids from the lined sump to the designated infiltration area or an unlined sump using a pump with flexible tubing (e.g., trash pump). The infiltration area is shown on Figure 3.

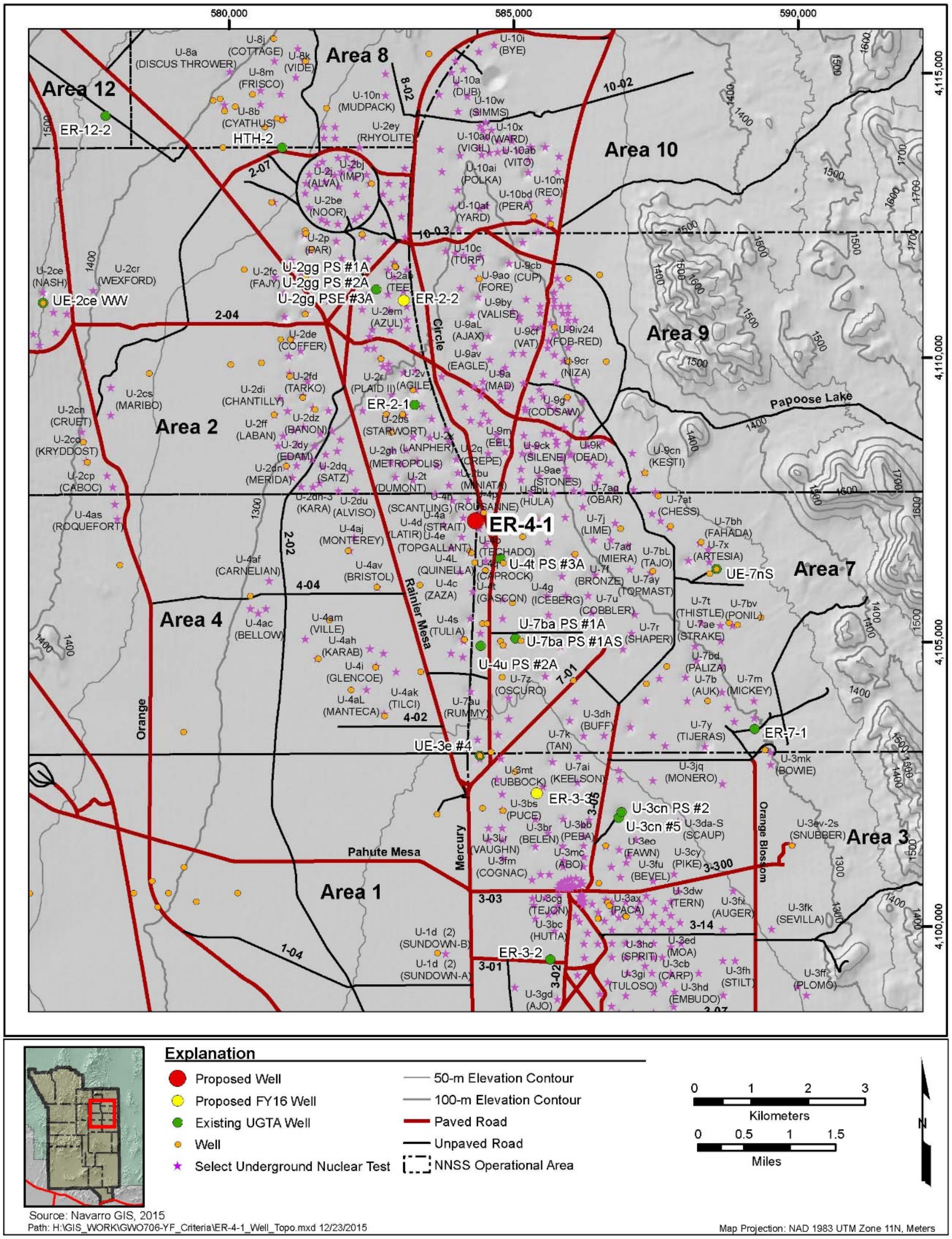


Figure 1
Well ER-4-1 Location Map

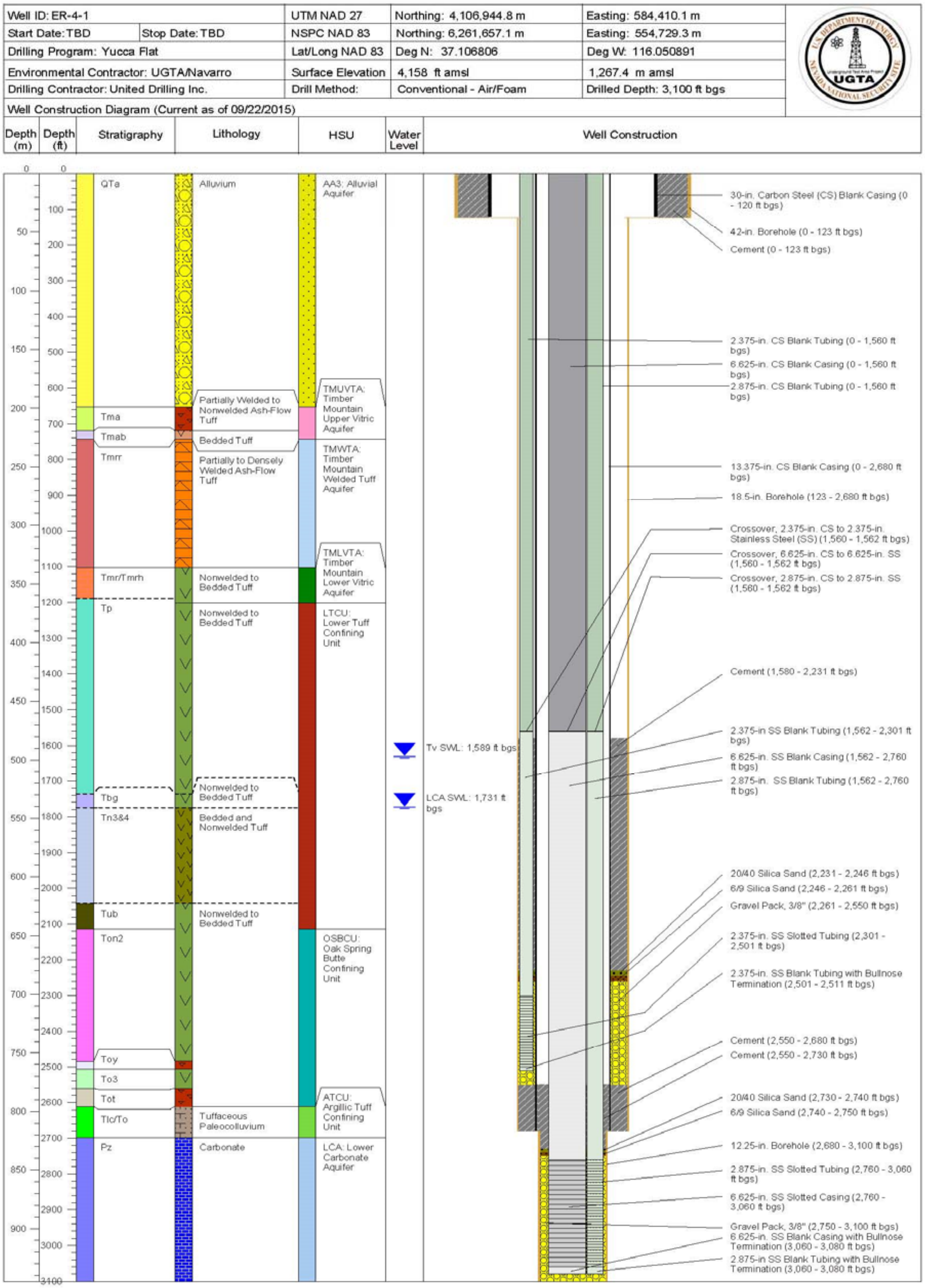


Figure 2
Proposed Well ER-4-1 Construction Diagram

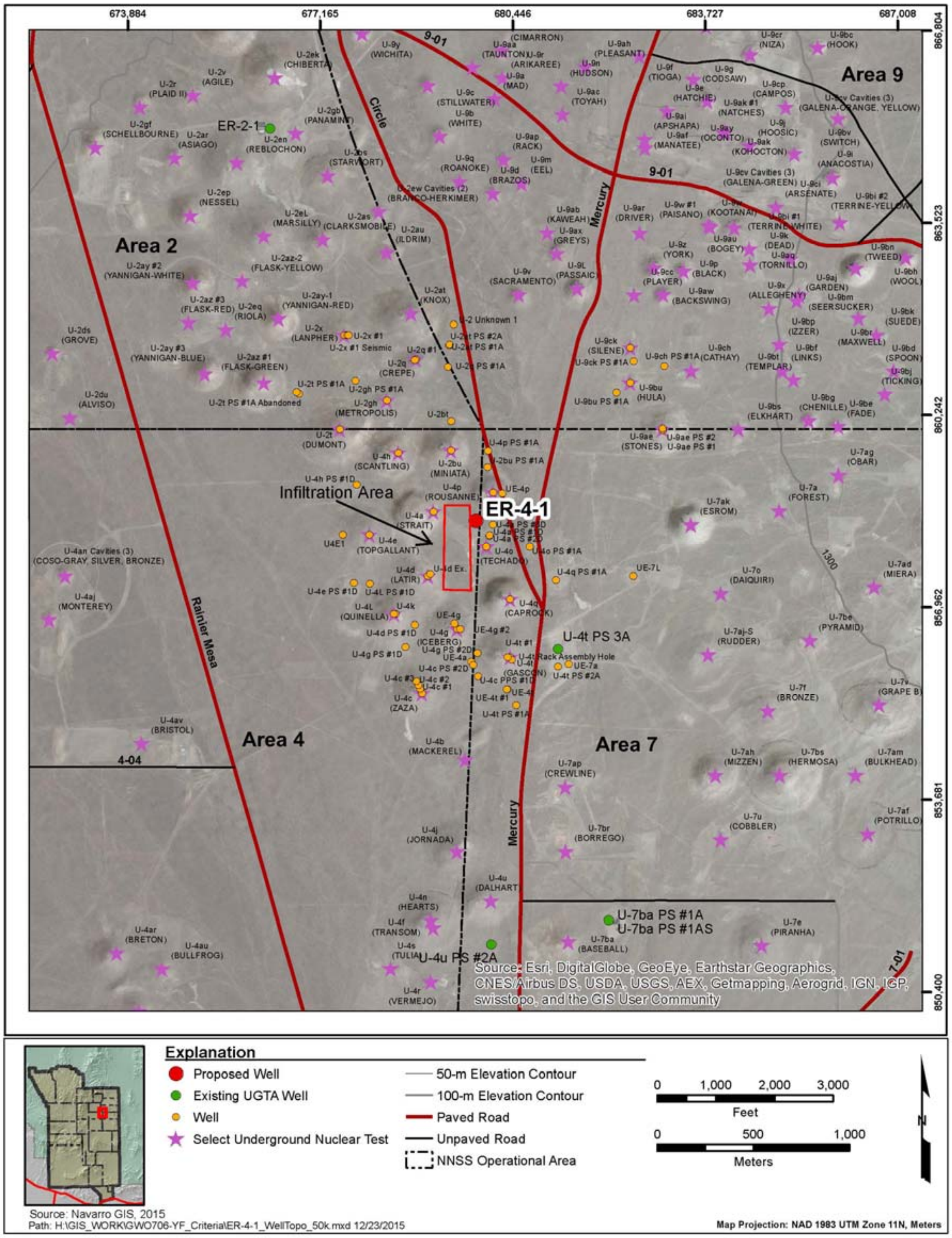


Figure 3
Proposed Infiltration Area at Well ER-4-1

REFERENCES

U.S. Department of Energy, Nevada Operations Office. 2000. *Corrective Action Investigation Plan for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada*, DOE/NV--659. Las Vegas, NV

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009b. *Underground Test Area Project Waste Management Plan*, Rev. 3, DOE/NV--343; *Attachment 1 Fluid Management Plan for the Underground Test Area Project*, Rev. 5; DOE/NV--370-Rev. 5. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1994b. *United States Nuclear Tests, July 1945 through September 1992*, DOE/NV-209, Rev. 15. Las Vegas, NV.

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