Environmental
Management
Nevada Program

DOE/NV--1569

Completion Report for Well ER-3-3

Corrective Action Unit 97: Yucca Flat/Climax Mine

Revision No.: 0

April 2017

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COMPLETION REPORT FOR WELL ER-3-3

CORRECTIVE ACTION UNIT 97:
YUCCA FLAT/CLIMAX MINE

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

Prepared by:
Underground Test Area Activity
Navarro
Las Vegas, Nevada

Revision No.: 0

April 2017

Abstract

Well ER-3-3 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 February 21 to March 15, 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 flow system within the Yucca Flat/Climax Mine CAU, and to test for potential radionuclides in groundwater from the WAGTAIL (U3an) underground test.

As completed, the well includes three piezometers: (1) p1, to a depth of 943.02 meters (m) (3,093.90 feet [ft]) below ground surface (bgs) installed in the Lower carbonate aquifer (LCA); (2) p2, to 745.71 m (2,446.57 ft) bgs installed across the upper portion of the Lower Tuff confining unit (LTCU), Timber Mountain lower vitric-tuff aquifer (TMLVTA), and the lower portion of the Timber Mountain welded-tuff aquifer (TMWTA); and (3) p3, to 573.65 m (1,882.07 ft) bgs installed in the Timber Mountain upper vitric-tuff aquifer (TMUVTA). The main completion includes 6.625-inch (in.) casing with slotted interval (m2) installed to 744.15 m (2,441.44 ft) bgs in the LTCU, TMLVTA, and TMWTA; and slotted interval (m1) installed to 944.82 m (3,099.79 ft) bgs in the LCA separated by a bridge plug at 2,560 ft bgs. A 13.375-in. diameter surface casing is installed from the surface to a depth of 621.71 m (2,039.72 ft) bgs. Well ER-3-3 experienced a number of issues, including intercepting a nearly vertical geologic feature in the Rainier Mesa Tuff (Tmr), borehole instability, and erosion. A rapid and significant change in water production is associated with this feature, and it apparently contributed to some of the early borehole stability problem. Substantial effort was put forth in an attempt to control the stability problem. Additional borehole stability problems were noted in several of the deeper stratigraphic units. Efforts to control and stabilize the borehole were only partially 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 927.81 m (3,044 ft) bgs, water-quality measurements (including tritium), and water-level measurements. The well penetrated 505.97 m (1,660 ft) of Quaternary/Tertiary alluvium (QTa), 403.86 m (1,325 ft) of Tertiary volcanic rocks (Tv), and 63.37 m (207.9 ft) of Paleozoic rocks (Pz). The stratigraphy and lithology were generally as expected with some minor exceptions. The Quaternary/Tertiary alluvium (QTa) and Timber Mountain stratigraphic units were slightly to significantly thicker than predicted. The remaining deeper stratigraphic units were mostly thinner than expected with the exception of the Paleocolluvium/older tuffs. The top of Paleozoic rocks (Pz) was predicted to occur at 894.59 m (2,935 ft) bgs and was intercepted at 909.83 m (2,985 ft), a difference of 15.24 m (50 ft).

Fluid depths were measured after drilling as follows:

- *In the piezometers:* p1 at 502.29 m (1,647.92 ft) bgs; p2 at 504.09 m (1,653.83 ft) bgs; and p3 at 427.88 m (1,403.82 ft) bgs
- *In the main production casing interval:* m1 and m2 at 504.09 m (1,653.84 ft) bgs

After well completion, a bridge plug was installed on March 30, 2016, at a depth of 780.29 m (2,560 ft) bgs. The bridge plug was temporarily installed to prevent cross communication of groundwater between the open completion intervals via the completion casing. Subsequent work at Well ER-3-3 will be included in future reports. Field measurements for tritium were below the *Safe Drinking Water Act* limit (20,000 picocuries per liter). All Fluid Management Plan requirements were met.

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List of Acronyms and Abbreviations

General Acronyms and Abbreviations

ACWP	Actual cost of work performed
amsl	Above mean sea level
API	American Petroleum Institute
bbl	Barrel
bbl/hr	Barrels per hour
BCWP	Budgeted cost of work performed
bgs	Below ground surface
BHA	Bottom hole assembly
CAIP	Corrective action investigation plan
CAU	Corrective action unit
cm	Centimeter
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
EM	Environmental Management
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*
FMI	Formation MicroImager
FMP	Fluid management plan

List of Acronyms and Abbreviations *(Continued)*

ft	Foot
ft^3	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
HCl	Hydrochloric acid
HFM	Hydrostratigraphic framework model
HGU	Hydrogeologic unit
HST	Hydrologic source term
HSU	Hydrostratigraphic unit
id	Inside diameter
ID	Identification
in.	Inch
K	Potassium
km	Kilometer
LANL	Los Alamos National Laboratory
Lat	Latitude
lb	Pound
lb/ft	Pounds per foot
LiBr	Lithium bromide
LLNL	Lawrence Livermore National Laboratory
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
Mn	Manganese
M&O	Management and operating
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
NGVD 29	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
ohms/m	Ohms per meter
pCi/L	Picocuries per liter
PPE	Personal protective equipment
ppm	Parts per million
psi	Pounds per square inch

List of Acronyms and Abbreviations *(Continued)*

QAP	Quality Assurance Plan
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
SWL	Static water level
TD	Total depth
Th	Thorium
TIH	Trip into hole
TOH	Trip out of hole
TW-7	Test Well 7
TWT	Technical Working Team
U	Uranium
UDI	United Drilling, LLC
UGT	Underground test
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WP	Working point

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
Ds	Simonson Dolomite
DSsl	Sevy and Laketown Dolomite, undivided
LCA	Lower carbonate aquifer
LTCU	Lower tuff confining unit
MDe	Eleana Formation
Oe	Eureka Quartzite
Op	Pogonip Group
Qai	Intermediate alluvial deposits
Qay	Young alluvial deposits
Qeo	Old eolian sand deposits
QTa	Quaternary/Tertiary alluvium
QTc	Quaternary/Tertiary colluvium
TCU	Tuff confining unit
Tgy	Basin-fill sediments, undivided
Tlc	Paleocolluvium
Tlc/To	Paleocolluvium/Older tuffs
Tm	Timber Mountain Group
Tma	Ammonia Tanks Tuff
Tmab	Ammonia Tanks bedded tuff
TMCC	Timber Mountain caldera complex
TMLVTA	Timber Mountain lower vitric-tuff aquifer
Tmr	Rainier Mesa Tuff

List of Acronyms and Abbreviations *(Continued)*

Tmrh	Tuff of Holmes Road
Tmrp	Rainier Mesa mafic-poor Tuff
Tm/Tw	Pre-Timber Mountain Tuff - Post-Wahmonie Tuff (undifferentiated)
TMUVTA	Timber Mountain upper vitric-tuff aquifer
TMWTA	Timber Mountain welded-tuff aquifer
Tn	Tunnel Formation
Ton	Older Tunnel Beds
Tp	Paintbrush Group
Tpt	Topopah Spring Tuff
Ttb	Basalt of Black Mountain
Tv	Tertiary Volcanics
Tw	Wahmonie Formation
VA	Volcanic aquifer
VTA	Vitric-tuff aquifer
WTA	Welded-tuff aquifer
Ꞓbb	Banded Mountain Member
Ꞓbp	Papoose Lake Member
Ꞓc	Carrara Formation
Ꞓn	Nopah Formation
ꞒZw	Wood Canyon Formation
Pz	Paleozoic rocks

1.0 Introduction

1.1 Project Description

This report presents field data collected by Navarro between February 11 and March 19, 2016, during drilling and completion of Well ER-3-3 located on the Nevada National Security Site (NNSS), Nye County, Nevada. Well ER-3-3 was identified in the *Yucca Flat Drilling and Completion Criteria, Wells ER-2-2, ER-3-3, and ER-4-1* (Navarro, 2016b). 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 investigation drilling program includes 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-3-3 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

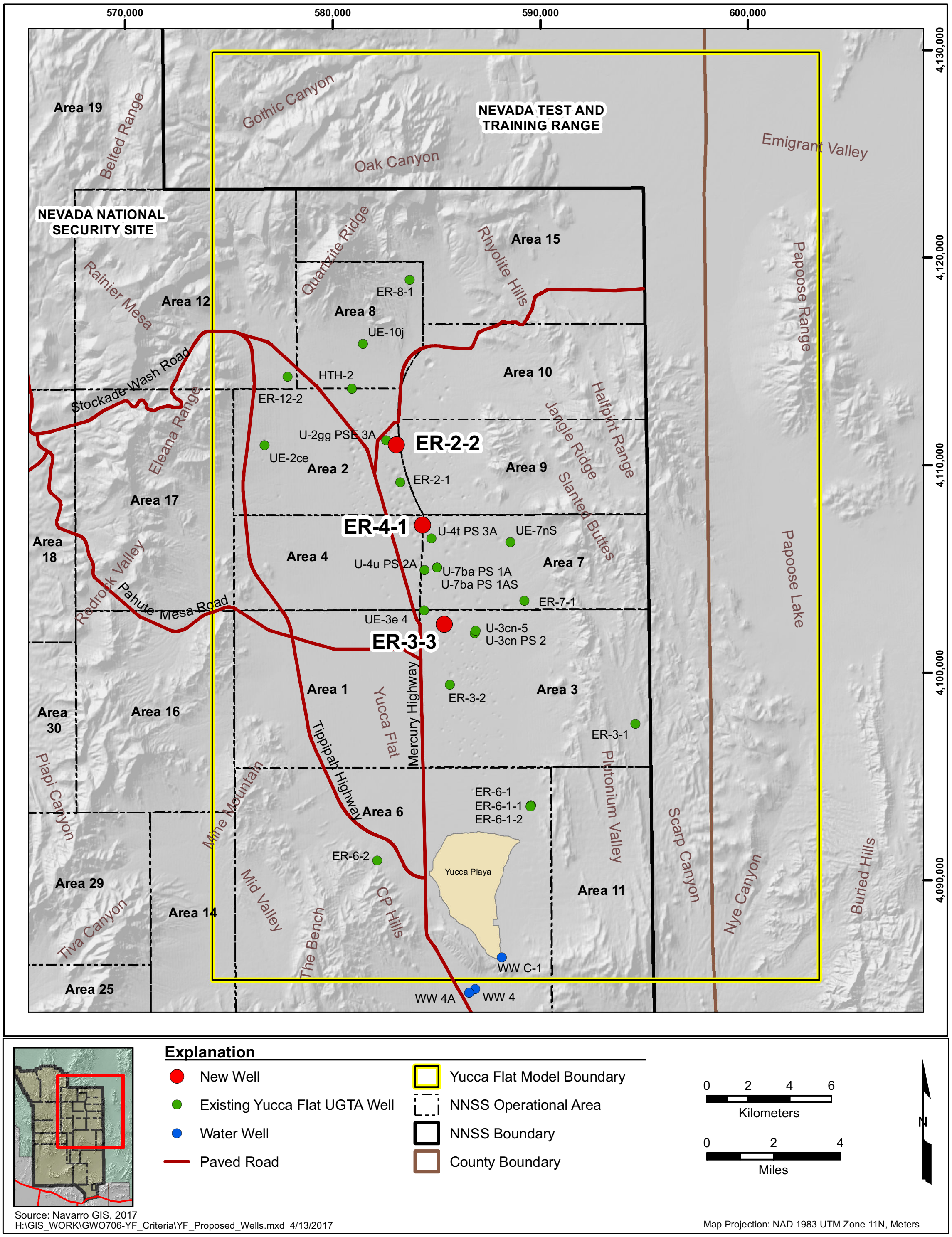


Figure 1-1
Location of Well ER-3-3 and Select Wells in Yucca Flat

casing operation services were provided by United Drilling, LLC (UDI), Northwestern Air Services (NWAS), and B&L Casing. Geophysical logging was conducted by Schlumberger, COLOG, and the U.S. Geological Survey (USGS). 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-3-3 is completed with two main completion intervals (m1 and m2) and three piezometers (p1, p2, and p3). Beginning with the deepest completions, they are as follows:

- **m1** to 944.82 meters (m) (3,099.79 feet [ft]) below ground surface (bgs), installed in the Lower carbonate aquifer (LCA) inside the 12.25-inch (in.) borehole
- **p1** to 943.02 m (3,093.90 ft) bgs, installed in the LCA inside the 12.25-in. borehole
- **m2** completed across the Timber Mountain welded-tuff aquifer (TMWTA) and the Lower tuff confining unit (LTCU) to 744.15 m (2,441.44 ft) bgs inside the 12.25-in. borehole
- **p2** completed across the TMWTA and the LTCU to 745.9 m (2,446.57 ft) bgs inside the 12.25-in. borehole
- **p3** completed to 573.65 m (1,882.07 ft) bgs in the Timber Mountain upper vitric-tuff aquifer (TMUVTA) outside the 13.375-in. diameter carbon-steel (CS) casing in the annulus of the 18.5-in. borehole

The 13.375-in. surface casing is installed from the surface to a depth of 621.71 m (2,039.72 ft) bgs.

1.2 Project Organization

Well ER-3-3 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-002-001.16 (NSTec, 2016) (provided in Appendix D).

Navarro was the principal environmental 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 disposition of fluids and drill cuttings produced from the borehole. In addition, Navarro personnel collected geologic, hydrologic, and drilling parameter data.

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), 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, 2016a) (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-3-3 are provided in the drilling and completion criteria document (Navarro, 2016b), 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, 2016c) 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-3-3.

1.3 Location and Significant Nearby Features

Well ER-3-3 is located in the area of Yucca Flat within the northeastern portion of the NNSS, in operational Area 3. The elevation of ER-3-3 is 1,236.51 m (4,056.80 ft) above mean sea level (amsl) in central Yucca Flat as shown in Figure 1-1 and Table 1-1. The well is in an area believed to be approximately located downgradient of the WAGTAIL (U3an) underground test (UGT) on the NNSS. Figure 1-2 shows the location of Well ER-3-3 relative to select wells and underground tests in Yucca Flat. The WAGTAIL UGT was conducted on March 3, 1965, in emplacement hole U3an in northern Yucca Flat. The working point (WP) of the test was in the TMUVTA 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-3-3 provided hydrogeologic data that will help verify

Table 1-1
Site Data Summary for Well ER-3-3

Site Coordinates [a]	**Nevada State Plane - Central Zone, NAD 27** N 842,667.74 ft E 683,150.79 ft
	Nevada State Plane - Central Zone, NAD 83 N 6,256,846.41 m E 555,745.86 m
	UTM - Zone 11, NAD 83 N 4,102,336.32 E 585,363.98
	UTM - Zone 11, NAD 27 N 4,102,139.02 E 585,443.27
	Geographic - NAD 83 (Decimal Degrees) Latitude: N 37.063397 Longitude: W 116.039811
	Township and Range [b] Section 14 Township 10 South, Range 53 East
Surface Elevation [c]	1,236.51 m (4,056.80 ft)
Drilled Depth	973.20 m (3,192.9 ft)
Fluid Level Depth [d]	502.29 m (1,647.92 ft)
Fluid Level Elevation	734.23 m (2,408.88 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, 2015).
[b] Township and Range coordinates made using Earthpoint (Public Land Survey System [BLM, 2015]).
[c] Ground level reference marker set on east face of casing. Calculated by subtracting stickup from surveyed top of production casing (see Figures 3-2 and 7-1). On 06/09/2016, NSTec as-built survey measured ground level elevation on the north side of the casing at 4,056.85 ft. Elevations are relative to mean sea level and reported in NGVD 29.
[d] Measured in the piezometer (p1) by Navarro on 03/18/2016.

NAD 27 = North American Datum, 1927
NAD 83 = North American Datum, 1983
NGVD 29 = National Geodetic Vertical Datum, 1929
UTM = Universal Transverse Mercator

concepts of the groundwater flow system in Yucca Flat and subsequent transport of radionuclides (RNs) from the WAGTAIL UGT.

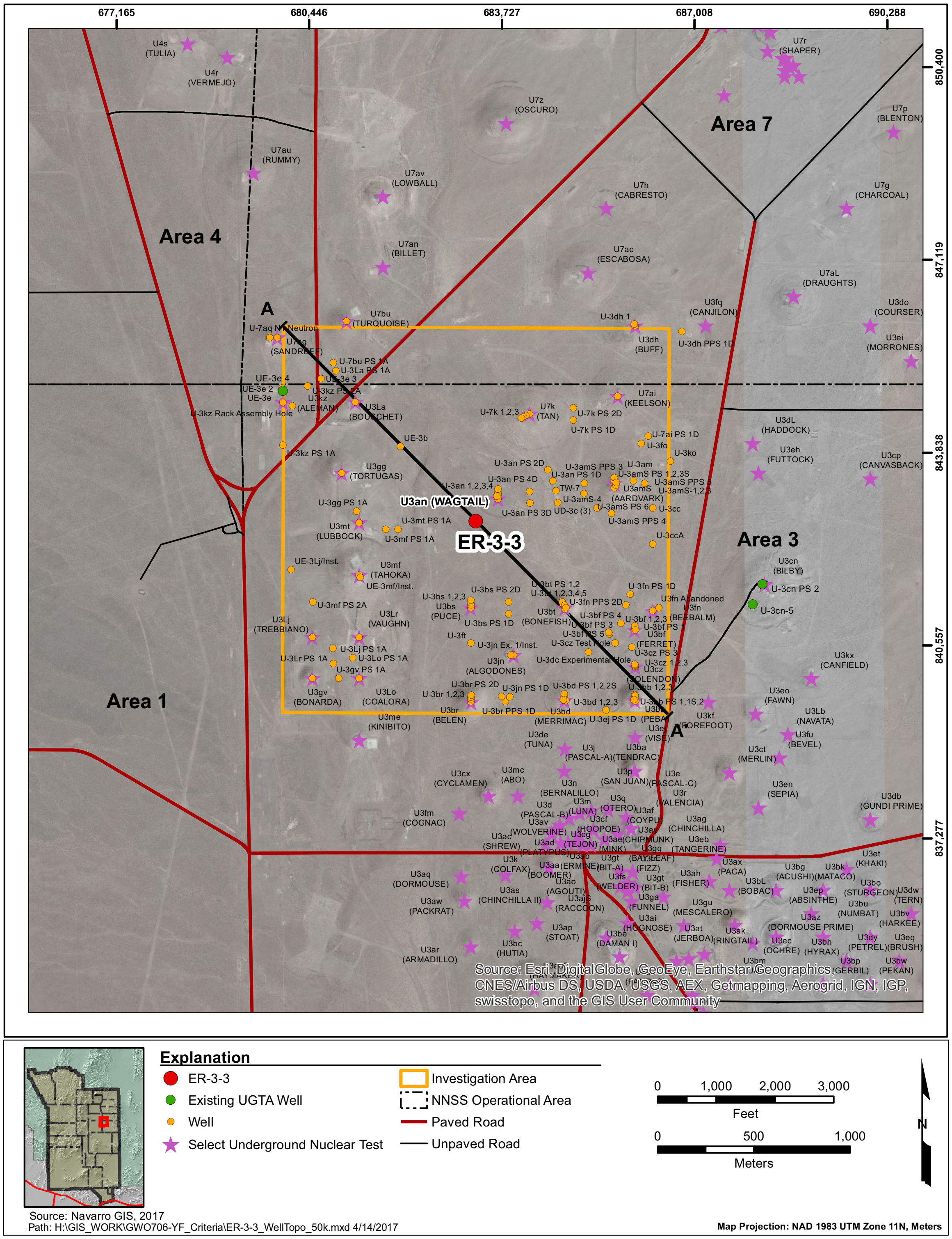


Figure 1-2
Aerial Photo of the Well ER-3-3 Area

1.4 Objectives

The primary purpose of Well ER-3-3 was to provide detailed hydrogeologic information downgradient of the WAGTAIL (U3an) UGT. The *Yucca Flat Drilling and Completion Criteria*, *Wells ER-2-2*, *ER-3-3, and ER-4-1* (Navarro, 2016b) plan lists the following scientific objectives for Well ER-3-3:

- 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 200 m (330 to 656 ft) of the LCA.
    - 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.
- Complete the well with three zones:
    - Shallow completion in the TMWTA to monitor for lateral migration of RNs above the WAGTAIL WP and serve as a monitoring interval in the Volcanic aquifer (VA) during hydraulic tests in the LCA.
    - Intermediate completion in the LTCU to evaluate the horizontal exchange volume in the LTCU.
    - Deep completion in the LCA to look for RNs in the LCA as a result of the drainage of contaminated water from the LTCU down faults and to conduct LCA hydraulic testes near major strands of the Yucca Fault.
- Investigate the hydraulic connection between the tuff aquifers and the LCA hypothesized to exist in the vicinity of Test Well 7 (TW-7).
- Investigate the potential for hydraulic overpressures measured in the LTCU at TW-7 to produce enhanced drainage and RN migration down faults to the LCA.
- Obtain water-level data, and investigate potential local groundwater flow downgradient from the WAGTAIL (U3an) UGT.

- Obtain aqueous geochemistry samples to better define possible groundwater flow paths based on water chemistry.
  - Sample for tritium and other RNs potentially migrating from the upgradient WAGTAIL 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 of the pipe. In this report, these descriptors are used to designate the type of casing or tubing (its "name"), and no metric conversion is provided. The same is true for drill bits (e.g., 12.25-in. bit), but when the size of the resulting hole is mentioned, both metric and English units are given.

Mobilization and setup of drilling equipment and site support facilities to the Well ER-3-3 drill pad began February 10, 2016. Main borehole construction of the well to a total depth (TD) of 973.20 m (3,192.9 ft) bgs began on February 21 and ended on March 15, 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 by drilling the cement plug in the 30-in. conductor casing with a 18.5-in. bottom hole assembly (BHA) from 35.97 to 671.47 m (118 to 2,203 ft) bgs. The 13.375-in. CS surface casing was then run from the ground surface to 621.71 m (2,039.72 ft) bgs and cemented in place. A 12.25-in. tricone bit was then used to advance the borehole from 671.47 to 973.20 m (2,203 to 3,192.9 ft) bgs.

As borehole circulation permitted, composite drill cutting samples were collected across 3.0-m (10-ft) intervals from approximately 36.58 m (120 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.

Two piezometers were installed in the annulus between the borehole wall and 12.25-in. borehole: (1) p1, consisting of 2.375-in. CS blank tubing from the surface to 534.73 m (1,754.35 ft) bgs, a crossover to 2.875-in. stainless-steel (SS) blank tubing from 534.98 to 914.15 m (1,755.20 to 2,999.17 ft) bgs, and 2.875-in. SS slotted tubing from 914.15 to 942.38 m (2,999.17 to 3,091.8 ft) bgs with a bullnose termination from 942.38 to 943.02 m (3,091.80 to 3,093.90 ft); and (2) p2, consisting of 2.375-in. CS blank tubing from the surface to 467.47 m (1,533.69 ft) bgs, a crossover to 2.875-in. SS blank tubing from 467.73 to 671.65 m (1,534.53 to 2,203.58 ft) bgs, and 2.875-in. SS slotted tubing from 671.65 to 745.06 m (2,203.58 to 2,444.43 ft) bgs with a bullnose termination from 745.06 to 745.71 m (2,444.43 to 2,446.57 ft) bgs. A third piezometer (p3) consisting of 2.375-in. CS blank tubing from the surface to 536.43 m (1,759.93 ft) bgs a crossover to SS slotted tubing was installed from 536.69 to 572.98 m (1,760.78 to 1,879.87 ft) bgs with a bullnose termination from 572.98 to 573.65 m (1,879.87 to 1,882.07 ft) bgs.

The main completion consists of two screened intervals separated by blank casing. From surface to 486.29 m (1,595.44 ft) bgs is 7.625-in. CS blank casing followed by a crossover to 6.625-in. SS blank casing to 671.53 m (2,203.18 ft) bgs; (m2) SS slotted casing from 671.53 to 744.15 m (2,203.18 to 2,441.44 ft) bgs; SS blank casing from 744.15 to 919.95 m (2,441.44 to 3,018.20 ft) bgs; and (m1) SS slotted casing from 919.95 to 944.13 m (3,018.20 to 3,097.54 ft) bgs with a bullnose termination from 944.13 to 944.82 m (3,097.54 to 3,099.79 ft) bgs.

Schlumberger, USGS, and COLOG conducted geophysical logging. 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) and a Mt. Sopris wireline with a float switch to measure water levels in both the open and completed borehole (see Table 6-1).

Drilling operations concluded on March 15, 2016, and demobilization of drilling equipment and support facilities was initiated. Subsequent to the completion of the well, on March 30, 2016, a bridge plug was installed in the 6.625-in. SS completion casing at a depth of 780.29 m (2,560 ft) bgs. The bridge plug prevents cross communication of groundwater between the open completion intervals through the completion casing.

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-3-3 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-3-3 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-3-3* (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, 2016c); 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-3-3, including NSTec daily rig operations reports; Navarro morning reports and logbook notes; Schlumberger, COLOG, and USGS 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-3-3 site was completed by NSTec construction on October 27, 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 35.36 m (116 ft) bgs; and cemented the conductor casing in place.

Between February 10 and February 21, 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 minimum 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 February 20, 2016. Once formal drilling operations began on February 21, 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 hole stability issues (i.e., fill and sloughing) at approximately 651.97 m (2,139 ft) bgs on February 25, 2016. Also, Navarro personnel noted a sharp increase in water production, from approximately 25 to 30 gpm to approximately 150 to 200 gpm at a depth of approximately 624.84 m (2,050 ft) bgs. UDI reached a depth of 671.47 m (2,203 ft) bgs on February 25, 2016. It was determined that 13.375-in surface casing would be installed at this point. Drilling of the 18.5-in. borehole took place over four days, as shown in Figure 2-1.

Open borehole geophysical logging operations in advance of the installation of surface casing were started on February 25, 2016, by COLOG; and the first run of logs were collected in the 18.5-in. borehole to a depth of 437.7 m (1,436 ft) bgs, where the tool hit an obstruction. USGS conducted video logging to 425.5 m (1,396 ft) bgs but was not able to see the obstruction. Schlumberger discontinued geophysical logging. UDI began pumping bentonite mud in the borehole to help stabilize the borehole wall. UDI made several attempts to clean and condition the unstable borehole to allow geophysical logging; however, this was not successful. On February 28 and 29, 2016, UDI installed a piezometer to 573.65 m (1,882.07 ft) bgs and the 13.375-in. casing to 621.71 m (2,039.72 ft) bgs.

After installation of the 13.375-in. surface casing, UDI tripped in the hole (TIH) with the 12.25-in. BHA; cleared bentonite mud from the 13.375-in. casing; and drilled through the cement on March 1, 2016. UDI began drilling at a depth of 671.47 m (2,203 ft) bgs, late on March 1, 2016. Borehole stability and sloughing conditions continued as UDI noted fill while attempting to make connections. On the morning of March 2, 2016, the borehole was at a depth of 700.43 m (2,298 ft) bgs, and stability was again an issue. UDI completed a “Short Trip,” tagging approximately 118 ft of fill. Water production was approximately 250 to 300 gpm made by combination of visual estimate and

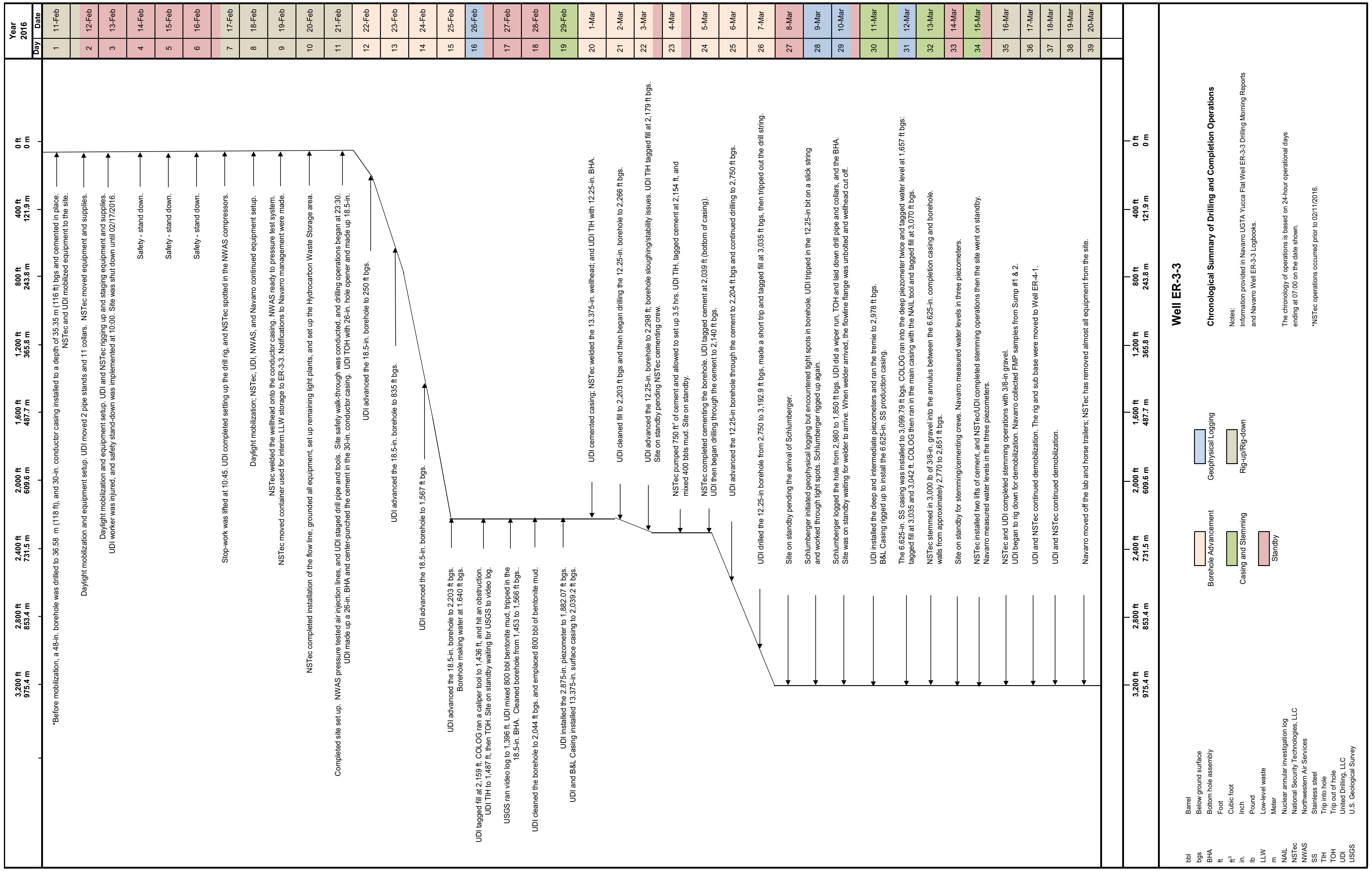


Figure 2-1
Well ER-3-3 Chronological Summary of Drilling and Completion Operations

lithium bromide (LiBr) data. Subsequently, the TWT's Drilling Advisory Team provided a plan in an effort to stabilize the borehole, control water production, and reduce sloughing.

According to the plan, on March 3, 2016, UDI made up and TIH, with the 8.5-in. BHA, reentering the existing 12.25-in. borehole, tagging fill at approximately 2,178 ft bgs. UDI used the 8.5-in. BHA to clean out and condition the borehole to approximately 2,290 ft bgs. UDI was pumping bentonite mud to help stabilize borehole sloughing. UDI pumped approximately 700 bbl of bentonite mud during this phase of the operation. Upon cleaning out the borehole and stabilizing with bentonite mud, NSTec and UDI tripped out of hole (TOH) with the 8.5-in. BHA and conducted cementing operations. Cementing operations were completed on March 4, 2016. Approximately 1,500 cubic feet (ft^3) of cement was pumped in three operations. Early in the morning of March 5, 2016, UDI TIH, tagged cement at 2,039 ft bgs, and resumed drilling with the 12.25-in. BHA.

UDI advanced the 12.25-in. borehole, reaching a TD of 973.20 m (3,192.9 ft) bgs on March 7, 2016. UDI then conducted several short trips to check for fill and possible obstructions and circulated to clean out the borehole. Schlumberger conducted geophysical logging between March 8 and 9, 2016, from 563.88 to 908.3 m (1,850 to 2,980 ft) bgs. Details of the geophysical logging are discussed in Section 4.0.

On March 10, 2016, NSTec and UDI ran and landed the intermediate piezometer at 745.71 m (2,446.57 ft) bgs and deep piezometer at 943.02 m (3,093.90 ft) bgs. B&L Casing rigged up to install the main completion casing. The main completion casing, with two slotted intervals, was landed at 944.82 m (3,099.79 ft) bgs on March 11, 2016. 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 March 15, 2016. Rigging down and site demobilization then began, ending Well ER-3-3 drilling and completion operations.

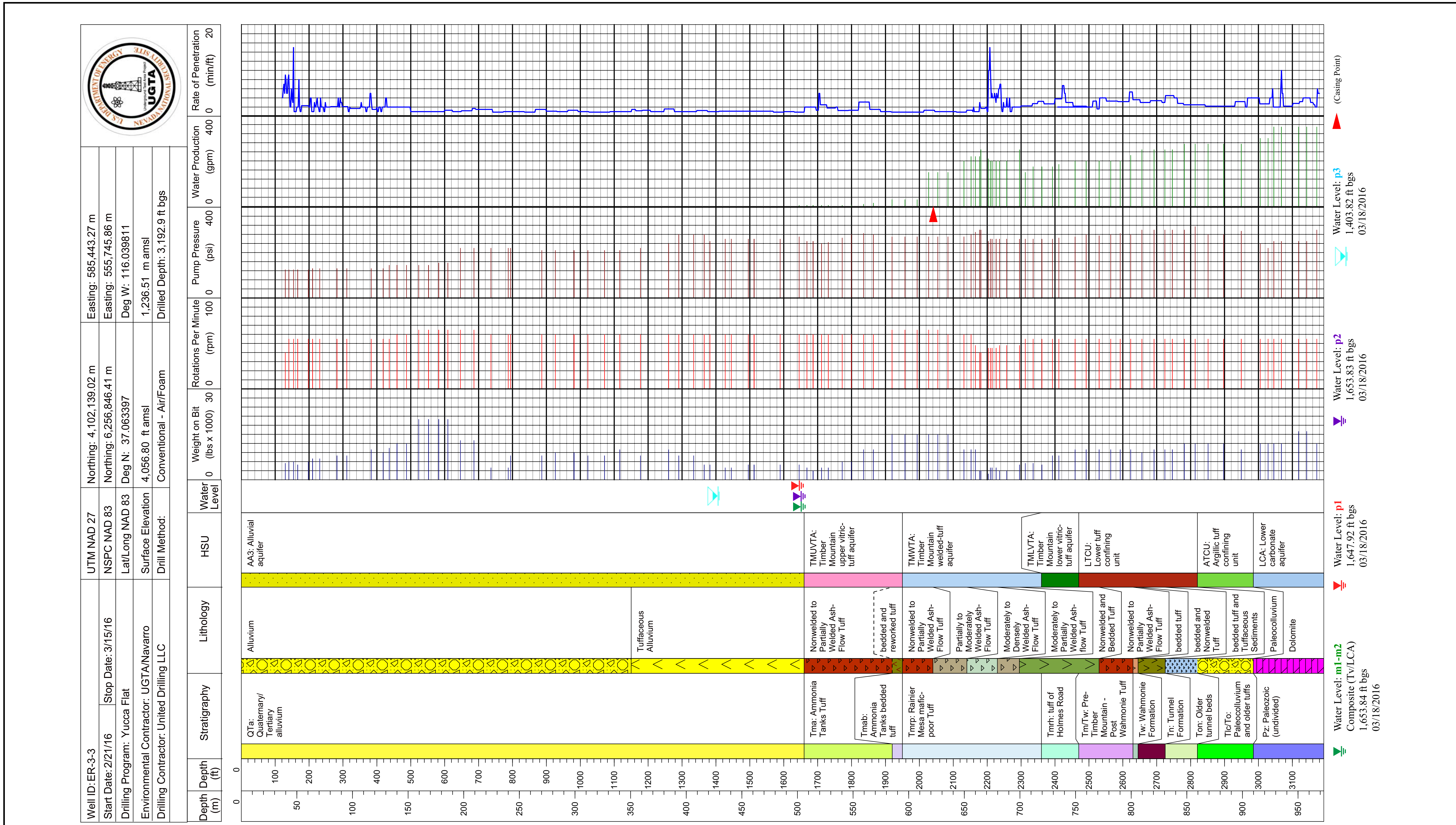


Figure 2-2
Summary of Well Drilling Parameters and Water Production for Well ER-3-3

3.0 Well Completion

3.1 Introduction

The proposed well design for Well ER-3-3 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, 2016b). The proposed well completion plans are summarized in Section 3.2.1, and the actual well completion design (based on the hydrogeology encountered in the borehole) 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-3-3 wellhead at the surface. Table 3-1 provides the abridged borehole statistics, and a construction summary for the main completion and piezometer strings. Figure 3-4 is a photograph of the slotted casing or tubing of different sizes installed into Well ER-3-3.

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 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 Well ER-3-3 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-3-3 was proposed to be drilled to a TD of 1,021.1 m (3,350 ft) bgs within the Paleozoic rocks (Pz), which consists of the LCA. The static water level (SWL) was predicted to be at a depth of approximately 508.4 m (1,668 ft) in the TMWTA. The well was planned to be drilled at a diameter of

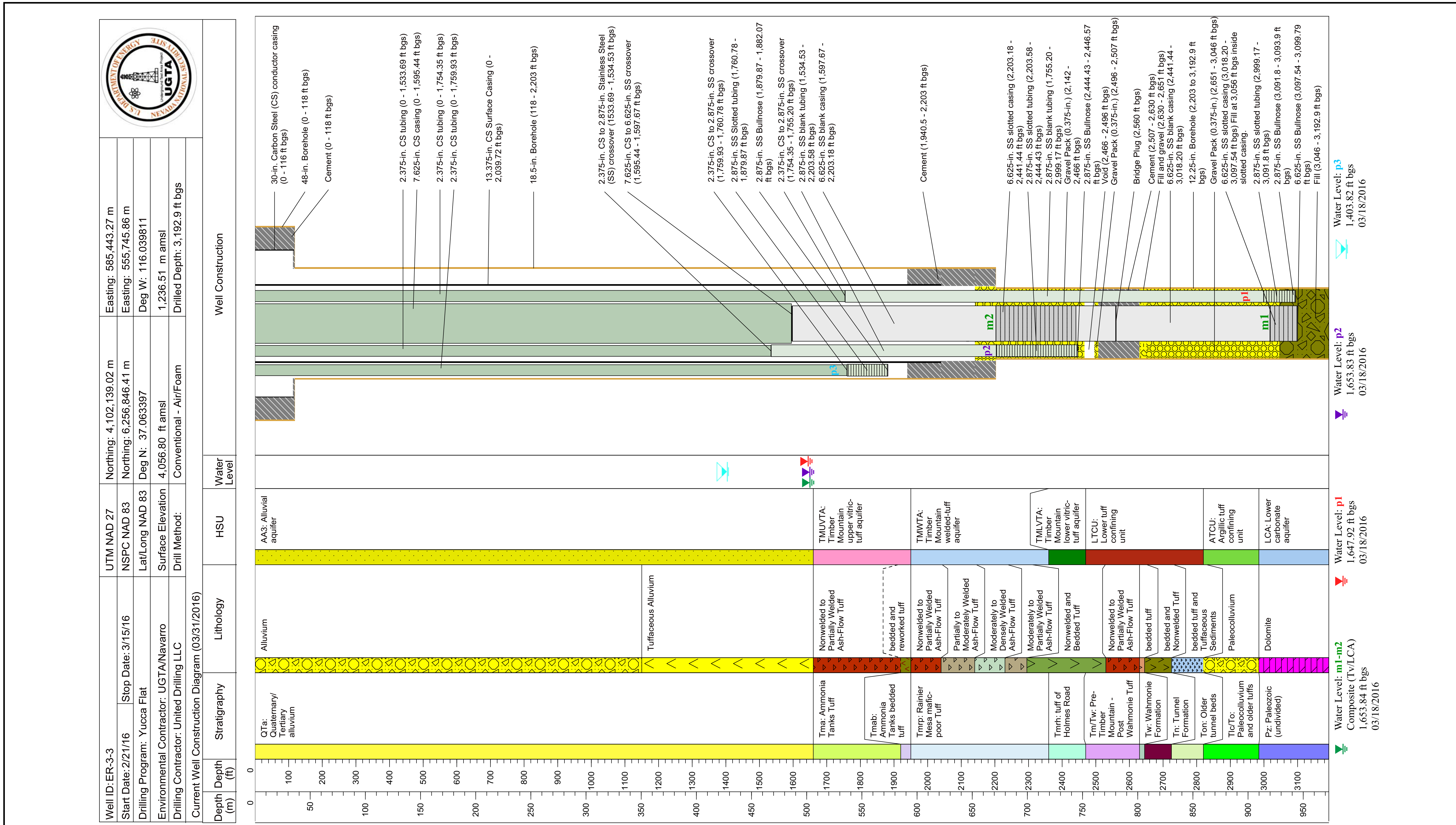


Figure 3-1
Well Completion Diagram for Well ER-3-3

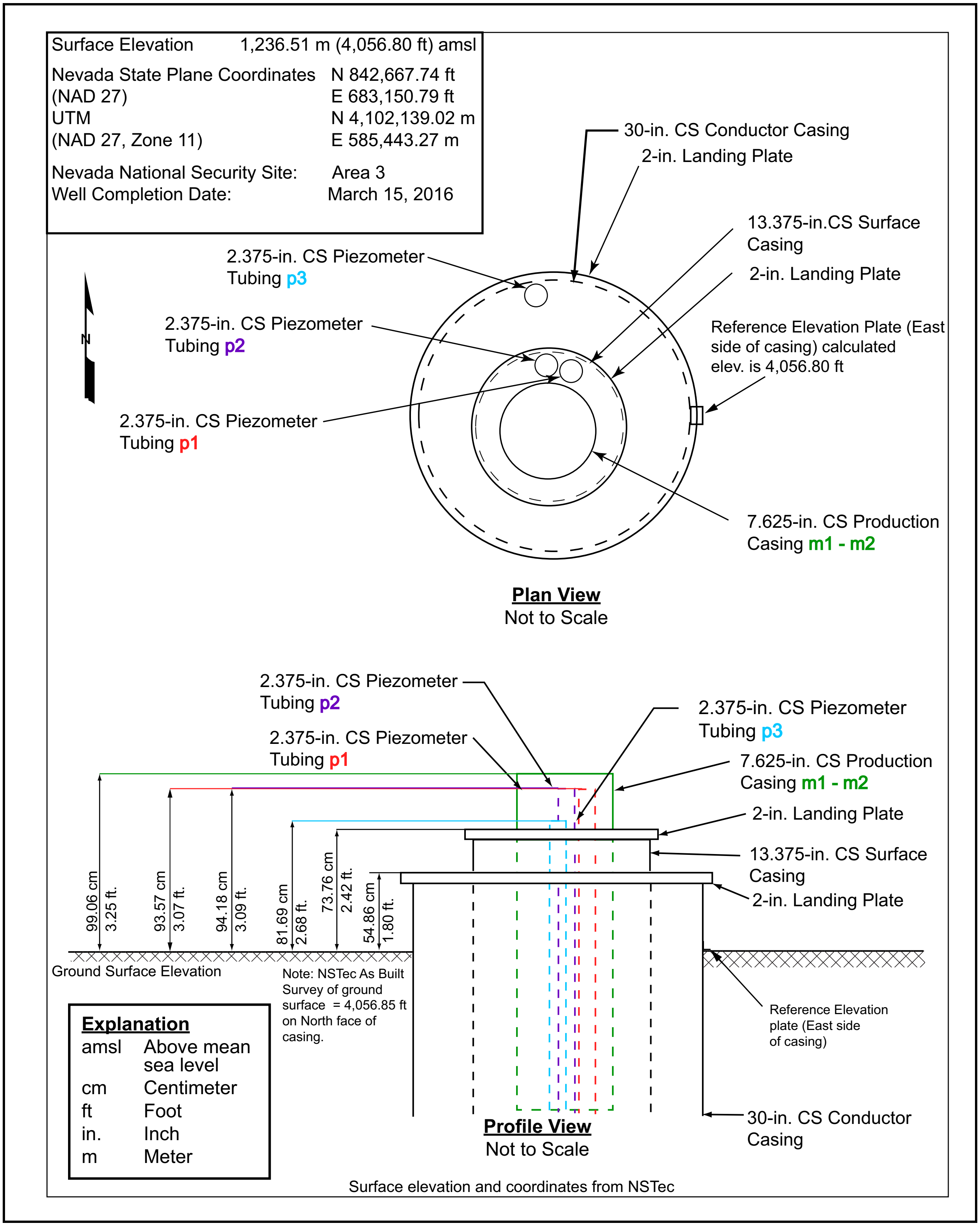


Figure 3-2
Wellhead Completion Diagram for Well ER-3-3

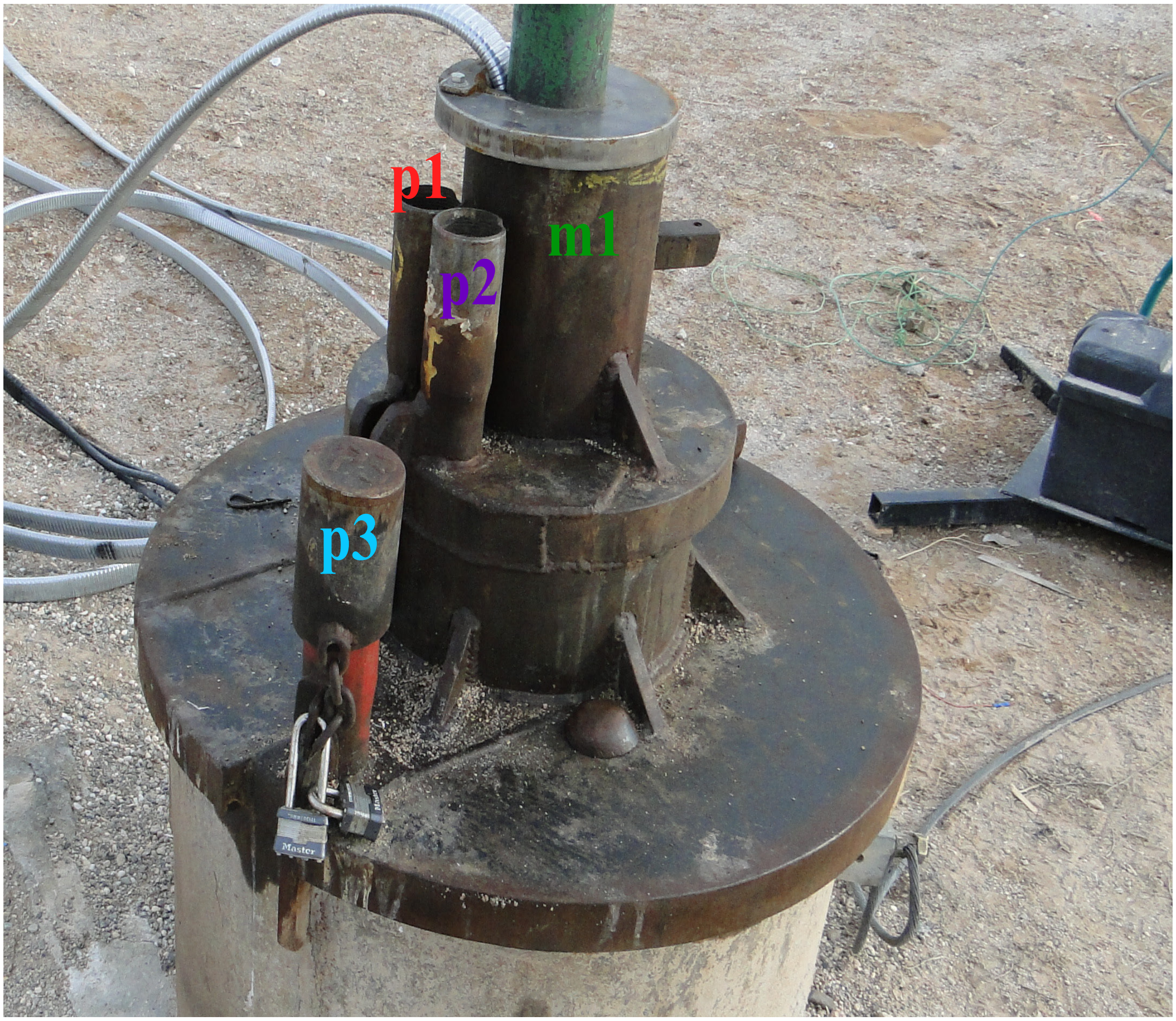


Figure 3-3
Photograph of Well ER-3-3 Wellhead (01/03/2017)

46.99 centimeters (cm) (18.5 in.) from the bottom of the conductor casing through the unsaturated zone to approximately 600 m (1,970 ft) bgs and set 13.375-in. casing into the top of the LTCU. A 6.03-cm (2.375-in.) piezometer string with a slotted interval in the TMWTA was planned to be set in the annulus. From 600 m (1,970 ft) bgs, the well was to be drilled at a diameter of 31.12 cm (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.

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

LOCATION DATA:		
Coordinates:	Nevada State Plane (NAD 27)	N 842,667.74 ft E 683,150.79 ft
	Nevada State Plane (NAD 83)	N 6,256,846.41 m E 555,745.86 m
	Universal Transverse Mercator (NAD 27, Zone 11)	N 4,102,139.02 m E 585,433.27 m
	Latitude/Longitude (NAD 83)	37.063397 decimal degrees N 116.039811 decimal degrees W
Surface Elevation:	1,236.51 m (4,056.80 ft) amsl	
DRILLING DATA:		
Spud Date:	02/21/2016	
Date TD Reached:	03/07/2016	
Date Well Completed:	03/15/2016	
TD:	973.20 m (3,192.9 ft) bgs	
Hole Diameters:	121.92 cm (48 in.) from surface to 35.97 m (118 ft) bgs 46.99 cm (18.5 in.) from 36.96 m (118 ft) to 671.47 m (2,203 ft) bgs 31.11 cm (12.25 in.) from 671.47 m (2,203 ft) to 973.2 m (3,192.9 ft) bgs	
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 671.47 m (2,203 ft); rotary drilling with mud and conventional circulation using a chisel tooth 31.11-cm (12.25-in.) tricone button bit to 973.20 m (3,192.9 ft).	
CASING DATA:	76.2 cm (30-in.) CS conductor casing; Blank 76.20 cm (30-in.) CS casing: +0.55 – 35.36 m (+1.8 – 116 ft) Type: CS, Grade: K55, od: 30-in., id: 28.97-in. 33.97 cm (13.375-in) CS surface casing; Blank 33.97-cm (13.375-in.) CS casing: +0.74 – 621.71 m (+2.42 – 2,039.72 ft) Type: CS, Grade: J55, od: 13.375-in., id: 12.415-in., Type: CS, Grade: J55, od: 13.375-in., id: 12.515-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, 0.15-cm (0.06-in.) by 6.67-cm (2.625-in.), 8 vertical slots per row, 108 rows per joint on 7.62-cm (3.00-in.) centers, each row offset by 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. 2.875-in. piezometer tubing; Type: SS, Grade: 304L, od: 2.875-in., id: 2.36-in.	
WELL COMPLETION DATA:	The completion casing consists of 7.625-in. CS blank casing that runs from surface to 486.29 m (1,595.44 ft) bgs. This is followed by a crossover to 6.625-in SS blank casing to 671.53 m (2,203.18 ft) bgs and slotted interval m2 to 744.15 m (2,441.44 ft) bgs. A second interval of SS blank casing runs to 919.95 m (3,018.20 ft) bgs and is followed by slotted interval m1 to 944.13 m (3,097.54 ft) bgs. The completion casing is terminated with a bullnose at 944.82 m (3,099.79 ft) bgs.	
Detail of Completion Casing:	19.37 cm (7.625-in.) CS casing; Type: CS, Grade: K55, od: 7.625-in., id: 6.969-in. 16.83 cm (6.625-in.) SS blank casing; includes slotted intervals; Type: SS, Grade: 304L, od: 6.625-in., id: 6.06-in.	
	<u>Description</u>	<u>Depth Interval</u>
	Blank 19.37-cm (7.625-in.) CS casing	+0.99 – 486.29 m (+3.25 – 1,595.44 ft)
	19.37-cm (7.625-in.) crossover to (6.625-in.) SS	486.29 – 486.97 m (1,595.44 – 1,597.67 ft)
	16.83-cm (6.625-in.) Blank SS casing:	486.97 – 671.53 m (1,597.67 – 2,203.18 ft)
	16.83-cm (6.625-in.) Slotted SS casing:	671.53 – 744.15 m (2,203.18 – 2,441.44 ft)
	16.83-cm (6.625-in.) Blank SS casing:	744.15 – 919.95 m (2,441.44 – 3,018.2 ft)
	16.83-cm (6.625-in.) Slotted SS casing	919.95 – 944.13 m (3,018.2 – 3,097.54 ft)
	bullnose termination:	944.13 – 944.82 m (3,097.54 – 3,099.79 ft)

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

Detail of Piezometer (p3):	Blank 6.03-cm (2.375-in.) CS tubing: 7.30-cm (2.875-in.) SS crossover: Slotted 7.30-cm (2.875-in.) SS tubing bullnose termination:	+0.82 – 536.43 m (+2.68 – 1,759.93 ft) 536.43 – 536.69 m (1,759.93 – 1,760.78 ft) 536.69 – 572.98 m (1,760.78 – 1,879.87 ft) 572.98 – 573.65 m (1,879.87– 1,882.07 ft)
Detail of Piezometer (p2):	Blank 6.03-cm (2.375-in.) CS tubing: 7.30-cm (2.875-in.) SS crossover: Blank 7.30-cm (2.875-in.) SS Slotted 7.30-cm (2.875-in.) SS tubing bullnose termination:	+0.94 – 467.47 m (+3.09 – 1,533.69 ft) 467.47 – 467.73 m (1,533.69 – 1,534.53 ft) 467.73 – 671.65 m (1,534.53 – 2,203.58 ft) 671.65 – 745.06 m (2,203.58 – 2,444.43 ft) 745.06 – 745.71 m (2,444.43 – 2,446.57 ft)
Detail of Piezometer (p1):	Blank 6.03-cm (2.375-in.) CS tubing: 7.30-cm (2.875-in.) CS to SS crossover: Blank 7.30-cm (2.875-in.) SS Slotted 7.30-cm (2.875-in.) SS tubing bullnose termination:	+0.94 m – 534.73 m (+3.07 – 1,754.35 ft) 534.73 – 534.98 m (1,754.35 – 1,755.20 ft) 534.98 – 914.15 m (1,755.20 – 2,999.17 ft) 914.15 – 942.38 m (2,999.17 – 3,091.80 ft) 942.38 – 943.02 m (3,091.80 – 3,093.90 ft)
Detail of Completion Materials:	3/8-in. Gravel pack: 20/40 Sand pack: Type II neat cement	653 – 764.13 m (2,142 – 2,507 ft) [a] 808 – 928 m (2,630 – 3,046 ft) [b] None 591.46 – 671.47 m (1,940.5 – 2,203 ft) [c] 764.13 – 801.6 m (2,507 – 2,630 ft)
FLUID-LEVEL DATA: Main completion (m1 & m2) [d] Piezometer (p3) [d] Piezometer (p2) [d] Piezometer (p1) [d]	<u>Fluid Depth</u> 504.09 m (1,653.84 ft) 427.88 m (1,403.82 ft) 504.09 m (1,653.83 ft) 502.29 m (1,647.92 ft)	<u>Fluid Elevation</u> 732.42 m (2,402.96 ft) 808.63 m (2,652.98 ft) 732.43 m (2,402.97 ft) 734.23 m (2,408.88 ft)
DRILLING CONTRACTOR:	United Drilling, LLC	
GEOPHYSICAL LOGS BY:	Schlumberger, COLOG, and USGS	

[a] Void from 2,466 – 2,946 ft bgs as determined from COLOG NAIL from 03/12/2016 to 03/15/2016.
[b] From 2,630 – 2,651 ft bgs fill and gravel mix, as determined from COLOG NAIL.
[c] Calculated elevation based on hole volume, cement pumped, and estimated overage.
[d] Measurement by Navarro using a calibrated Solinst e-tape on 03/18/2016. Reference elevation of 4,056.80 ft using marker on east side of casing (see Figures 3-2 and 7-1).

id = Inside diameter
od = Outside diameter
NAIL = Nuclear annular investigation log

3.2.2 As-Built Completion Design

The Well ER-3-3 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 required three piezometers and two main completion intervals.

The main completion string is composed of 19.37-cm (7.625-in.) blank CS casing to 486.29 m (1,595.44 ft) bgs, 16.83-cm (6.625-in.) SS blank to 671.53 m (2,203.18 ft) bgs, and an SS slotted interval (m2) from 671.53 to 744.15 m (2,203.18 to 2,441.44 ft) bgs completed within the base of the

Top left and right 7.30-cm (2.875-in.) SS slotted tubing in p3; Middle left and right 7.30-cm (2.875-in.) SS slotted tubing in p2 & p1; Bottom left and right 16.83-cm (6.625-in.) SS slotted main production casing

Figure 3-4
Well ER-3-3 Photograph of Slots in the Casing (March 2016)

TMWTA and the TMLVTA. Below (m2) is a section of blank SS casing from 744.15 to 919.95 m (2,441.44 to 3,018.20 ft) bgs. A second slotted interval (m1) within the LCA is completed with 16.83-cm (6.625-in.) SS blank casing from 919.95 to 944.13 m (3,018.20 to 3,097.54ft) bgs with a bullnose termination to 944.81 m (3,099.79 ft). 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.

The 13.375-in. CS surface casing was installed from 0.74 m (2.42 ft) above ground surface to a depth of 621.71 m (2,039.72 ft) bgs and cemented in place. A piezometer (p3) was installed the annulus between the borehole wall and 13.375-in. casing from 0.82 m (2.68 ft) above ground surface to a depth of 573.65 m (1,882.07 ft) bgs. The piezometer (p3) consists of 2.375-in. CS blank tubing and 2.875-in. SS screen interval completed in the TMUVTA. Figure 3-1 is a detailed schematic of the well completion, and Table 3-1 provides detailed casing specifications.

An intermediate piezometer (p2) was completed within the TMWTA and TMLVTA (welded tuffs) and consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (2.375-in.) diameter CS blank tubing from 0.94 m (3.09 ft) above ground surface to 467.47 m (1,533.69 ft) with a crossover to 7.30-cm (2.875-in.) SS blank tubing to a depth of 671.53 m (2,203.58 ft) bgs. The slotted SS tubing consists of nominally 9.14-m (30-ft) lengths of 7.30-cm (2.875-in.) for 240 ft with a bullnose termination extending to 745.71 m (2,466.57 ft). Figure 3-1 is a detailed schematic of the well completion, and Table 3-1 provides detailed casing specifications.

The deep piezometer (p1) was completed within the LCA and consists of nominal 9.45-m (31-ft) lengths of 6.03-cm (2.375-in.) diameter CS tubing with upset couplings extending from 0.94 m (3.07 ft) above ground surface to 534.73 m (1,754.35 ft). The crossover, from 6.03-cm (2.375-in.) CS tubing to 7.30-cm (2.875-in.) SS blank tubing, extends to 534.98 m (1,755.20 ft) bgs. Blank SS tubing extends from 534.98 to 914.15 m (1,755.20 to 2,999.17 ft) bgs. The slotted SS tubing consists of nominally 9.14-m (30-ft) lengths of 7.30-cm (2.875-in.) diameter with flush joint couplings, and a bullnose termination, extending to 943.02 m (3,093.90 ft). Figure 3-4 provides a photo of the slotted casing. Depth intervals for the CS blank and SS slotted tubing are shown in Figure 3-1 and tabulated in Table 3-1.

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-3-3, a detailed description of materials used in completion of ER-3-3, 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 (TW-7, ER-3-2, and WW-A), emplacement hole U3an for the WAGTAIL UGT, and from interpreted geology from the Yucca Flat HFM (BN, 2006). Completion intervals for piezometer tubing and main completion access points were adjusted to account for unstable borehole conditions, differences from expected geology, and to optimize sampling and testing data collection.

The geology and hydrology of Well ER-3-3 are discussed in Sections 5.1 through 5.3.

3.3 Well Completion Method

Completion activities began on February 29, 2016, after the 46.99-cm (18.5-in.) borehole was drilled to 623.01 m (2,044 ft) bgs. UDI ran the shallow (p3) 6.03-cm (2.375-in.) piezometer tubing in the annulus between the 18.5-in. borehole and the 33.97-cm (13.375-in.) casing and landed at 573.65 m (1,882.07 ft) bgs. On March 11, 2016, the UDI and B&L Casing crews ran the deep (p1) and intermediate (p2) piezometers, and then ran the 16.83-cm (6.625-in.) casing and landed it at 944.81 m (3,099.79 ft) bgs. On March 12, 2016, COLOG ran the NAIL in the deep piezometer to determine depths of stemming materials. After geophysical logging was completed, NSTec stemmed in the gravel and completion operations continued through March 15, 2016.

All well construction materials used for the completion were inspected according to relevant procedures, as listed in the Navarro FAWP (Navarro, 2016c). Stemming operations used 0.95-cm (0.375-in.) gravel pack across the open intervals and Type II Neat Cement. Materials were placed using a CS 7.30-cm (2.875-in.) tremie. Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

After installation of the main casing on March 15, 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-3-3 was drilled, a predicted stratigraphic sequence with unit thicknesses was developed from the Yucca Flat HFM (BN, 2006). During drilling, Navarro personnel prepared the field lithologic descriptions and stratigraphic unit assignments based on the field examination of drill cuttings. Final 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 initially good to fair. However, below 651.97 m (2,139 ft) bgs, the condition of the borehole began to deteriorate with increasing amounts of cross contamination of cuttings resulting from sloughing intervals of the borehole above the actual drilled intervals. Drilling of the 18.5-in. borehole ended on February 28, 2016, at 671.5 m (2,203 ft) bgs. UDI and B&L Casing began setting 13.375-in. surface casing later that evening. Drilling of the 12.25-in. borehole was initiated on March 1, 2016. Borehole stability issues continued as the borehole progressed through the remaining Tertiary Volcanics (Tv) and into the Paleozoic rocks (Pz). Cuttings samples from surface to approximately 752.86 m (2,470 ft) bgs generally showed variable cross contamination from 5 to 25 percent. Below 752.86 m (2,470 ft) bgs, cuttings exhibited variable but higher levels of uphole contamination, from 20 to 50+ percent. Contamination consisted primarily of Tertiary Volcanics (Tv) and some intervals with significant construction materials (i.e., cement). As the borehole stability deteriorated and sloughing became severe, problems with bridging and obstructions made cutting 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 36.58 m (120 ft) bgs because this interval was drilled by NSTec personnel and cased before Navarro personnel were present on the well site. A total of 299 sample intervals were collected, and there were 20 intervals where no sample was recovered. 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 COLOG and Schlumberger in the open and cased 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 stemming materials, determine fluid levels, and collect hydrologic data. Three separate geophysical logging efforts were conducted in Well ER-3-3. First, the borehole was logged by COLOG (caliper) and USGS (downhole video), on February 25 through February 27, 2016, to evaluate the condition of the borehole in the alluvial section. Second, Schlumberger conducted a geophysical logging effort in Well ER-3-3 on March 8 and 9, 2016, within the unsaturated zone to the lower portion of the Paleocolluvium/Older Tuffs (Tlc/To). On the third effort, March 12 through 15, 2016, COLOG conducted a NAIL to monitor the heights of stemming material used in construction of the well. All of the geophysical logs acquired at Well ER-3-3 are summarized in Table 4-1.

COLOG ran the three-arm caliper tool on February 25, 2016, and hit an obstruction at 438.6 m (1,439 ft) bgs. The caliper log was run up from 438.21 m (1,437.7 ft) as shown in Table 4-1. A centralizer was added to the tool to try and get past the obstruction, but it was not successful. On February 26, 2016, USGS conducted a downhole video from the surface to 425.50 m (1,396 ft). COLOG returned on February 27, 2016, and ran the caliper log up from 457.81 m (1,502.0 ft) bgs, where a bridge was encountered.

Table 4-1
Well ER-3-3 Summary of Geophysical Logs
(Page 1 of 2)

Geophysical Log	Log Purpose	Logging Service	Date Logged	Direction Logged	Top of Logged Interval (ft bgs)	Bottom of Logged Interval [a] (ft bgs)
3-Arm Caliper	Formation: Borehole condition (washouts, fractures)	COLOG	02/25/2016	Up	99.5	1,437.7
Downhole Video	Formation: Borehole condition (washouts, fractures)	USGS	02/26/2016	Down/Up	0	1,396
3-Arm Caliper	Formation: Borehole condition (washouts, fractures)	COLOG	02/27/2016	Up	98.2	1,502.0
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	Schlumberger	03/08/2016	Down	1,950	2,780
8-Arm Caliper, Gamma Ray, Formation Micro Imager, Deviation survey	Formation/Fluid: Water levels, Water movement in/out of borehole, depth calibration check, borehole condition (washouts, fractures), borehole orientation and deviation	Schlumberger	03/08/2016	Up	2,041	3,044
Directional Survey, General Purpose Inclinometry Tool	Formation: Borehole condition (washouts, fractures), depth calibration check, Lithologic/stratigraphic analysis, Alteration analysis, borehole orientation and deviation	Schlumberger	03/08/2016	Up	2,041	3,044
Spectral Gamma Ray, Natural Gamma Ray	Formation: Lithologic/stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations, Alteration analysis	Schlumberger	03/08/2016	Up	0	3,044
High Resolution Laterlog, Gamma Ray, Spontaneous Potential	Formation: Borehole depth and condition (washouts, fractures), Resistivity, Thin bed analysis, Spontaneous Potential	Schlumberger	03/09/2016	Up	2,041	2,975

Table 4-1
Well ER-3-3 Summary of Geophysical Logs
(Page 2 of 2)

Geophysical Log	Log Purpose	Logging Service	Date Logged	Direction Logged	Top of Logged Interval (ft bgs)	Bottom of Logged Interval [a] (ft bgs)
Epithermal Neutron, Three Detector Litho Density, Caliper, Gamma Ray	Formation: Porosity and lithologic determination, Density, Borehole depth and condition (washouts, fractures), Resistivity	Schlumberger	03/09/2016	Up	2,041	2,978
Nuclear Annular Investigation	Determine the final height of annular completion materials	COLOG	03/12-15/2016	Down/Up	1,900	3,064

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

K = Potassium
Th = Thorium
U = Uranium

Obstructions (i.e., ledges, bridges, tight hole conditions) were encountered again in the borehole during the second geophysical logging run on March 8, 2016. Schlumberger could not get the tool past 848.56 m (2,784 ft) bgs on their first run. Schlumberger tripped out of the hole and changed the tool. The tool for the second pass was longer and heavier than the first tool combination used. Schlumberger was able to advance the second geophysical tool through the borehole to 927.81 m (3,044 ft) bgs.

The tight interval in the borehole includes portions of the Older Tunnel Beds (Ton) and the Paleocolluvium/Older tuffs (Tlc/To). These formations are typically pervasively altered to clays and zeolites. During the return pass, Schlumberger experienced difficulties deploying the caliper arms, possibly due to heavy clay accumulations restricting arm travel. Navarro and NSTec requested that UDI reenter the borehole to clean and condition the borehole prior to a second attempt to log by Schlumberger. On March 9, 2016, upon successful completion of the cleaning and conditioning the borehole, Schlumberger resumed geophysical logging.

Upon completion of geophysical logging activities on March 8 and 9, 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. From March 12 through March 15, 2016, COLOG conducted a NAIL to determine depth intervals of stemming material used in the construction of Well ER-3-3.

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 4-3 presents the spectral gamma ray traces (uranium, thorium, and potassium). Figure 4-4 presents shallow and deep resistivity log traces. 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.

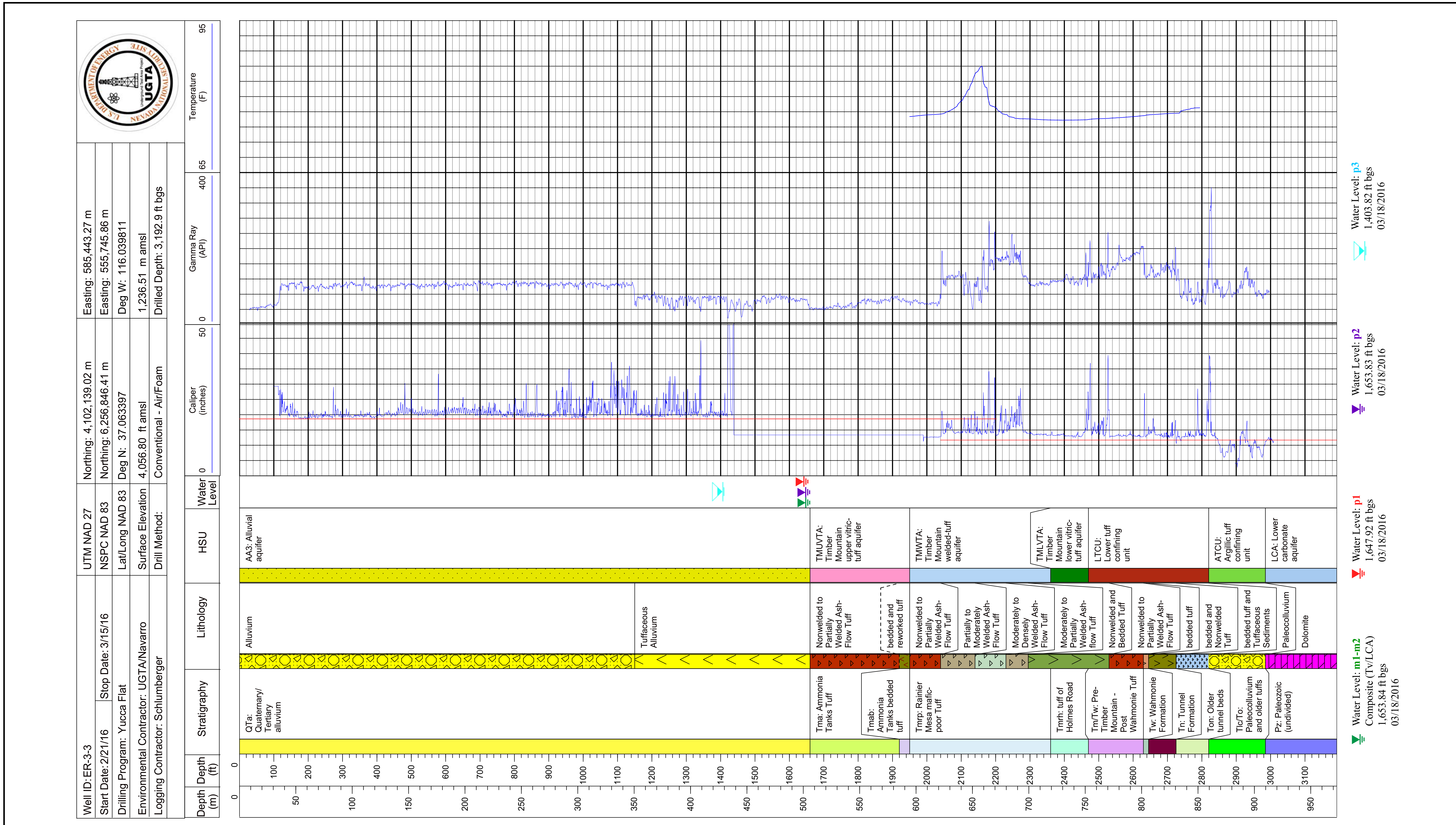


Figure 4-1
Well ER-3-3 Geophysical Log Traces of Caliper Average, Gamma Ray, and Temperature

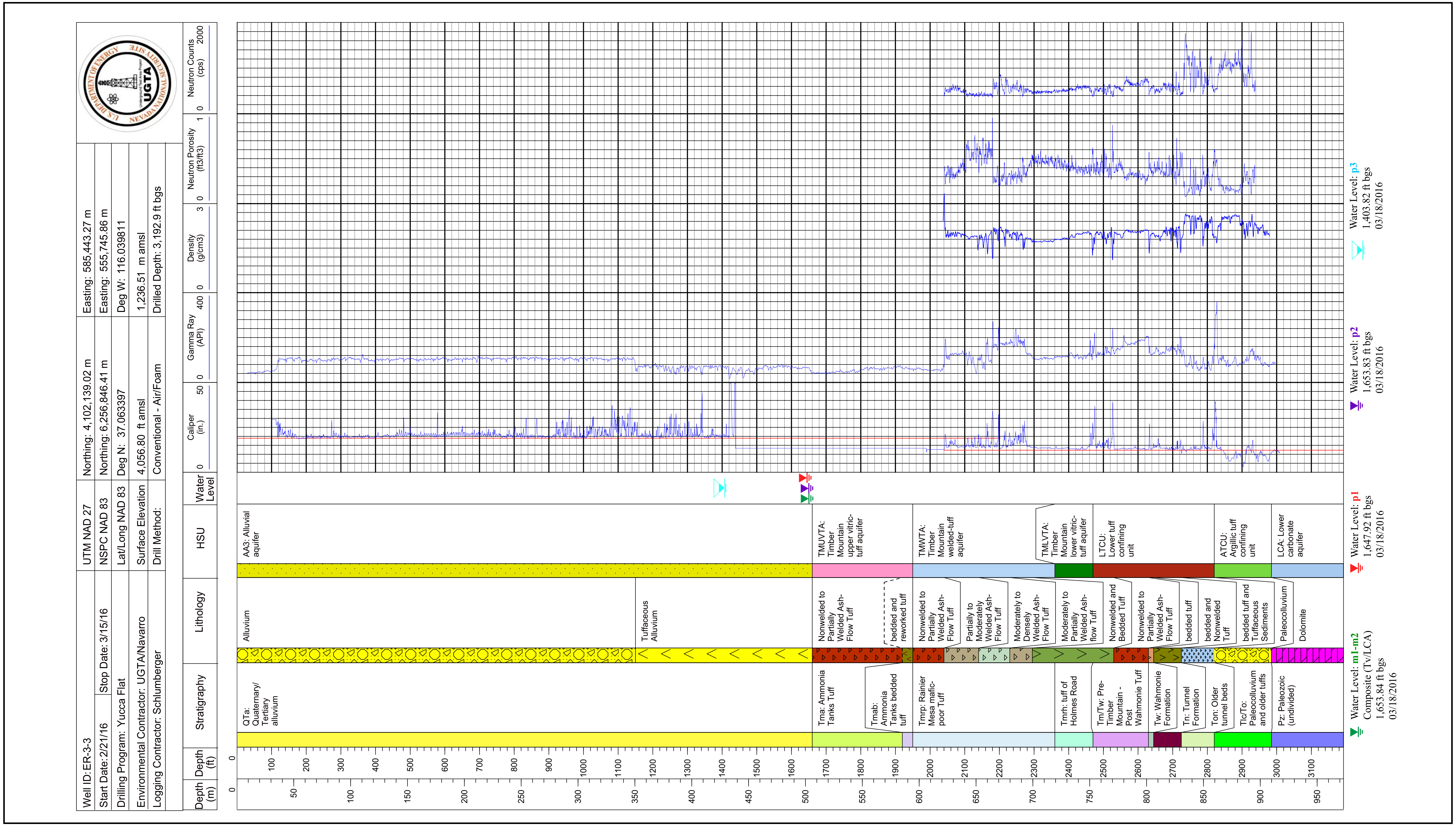


Figure 4-2
Well ER-3-3 Geophysical Log Traces of Caliper Average, Gamma Ray, Bulk Density, Neutron Porosity, and Neutron Counts

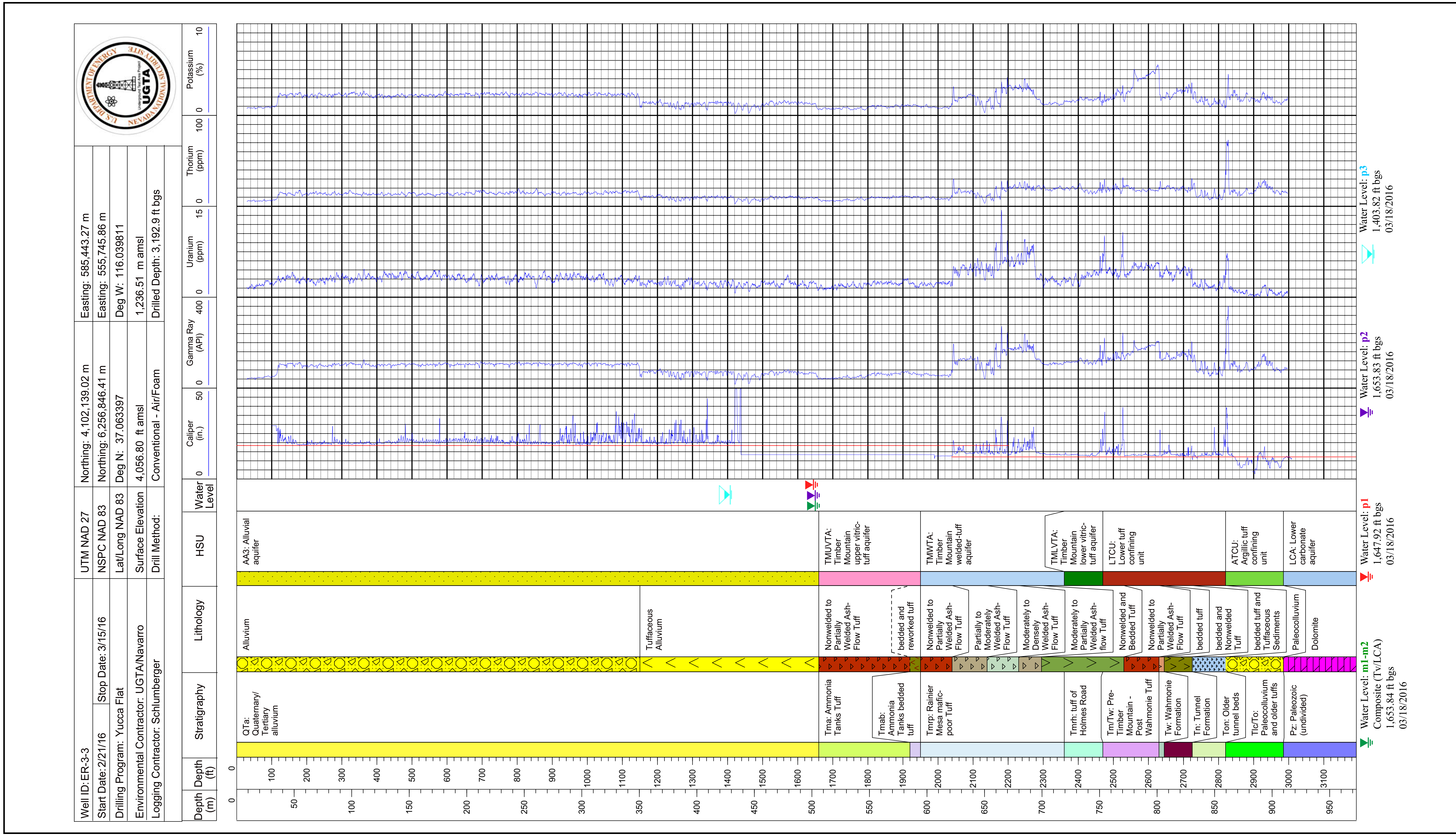


Figure 4-3
Well ER-3-3 Geophysical Log Traces of Caliper Average, Gamma Ray, and Digital Spectralog

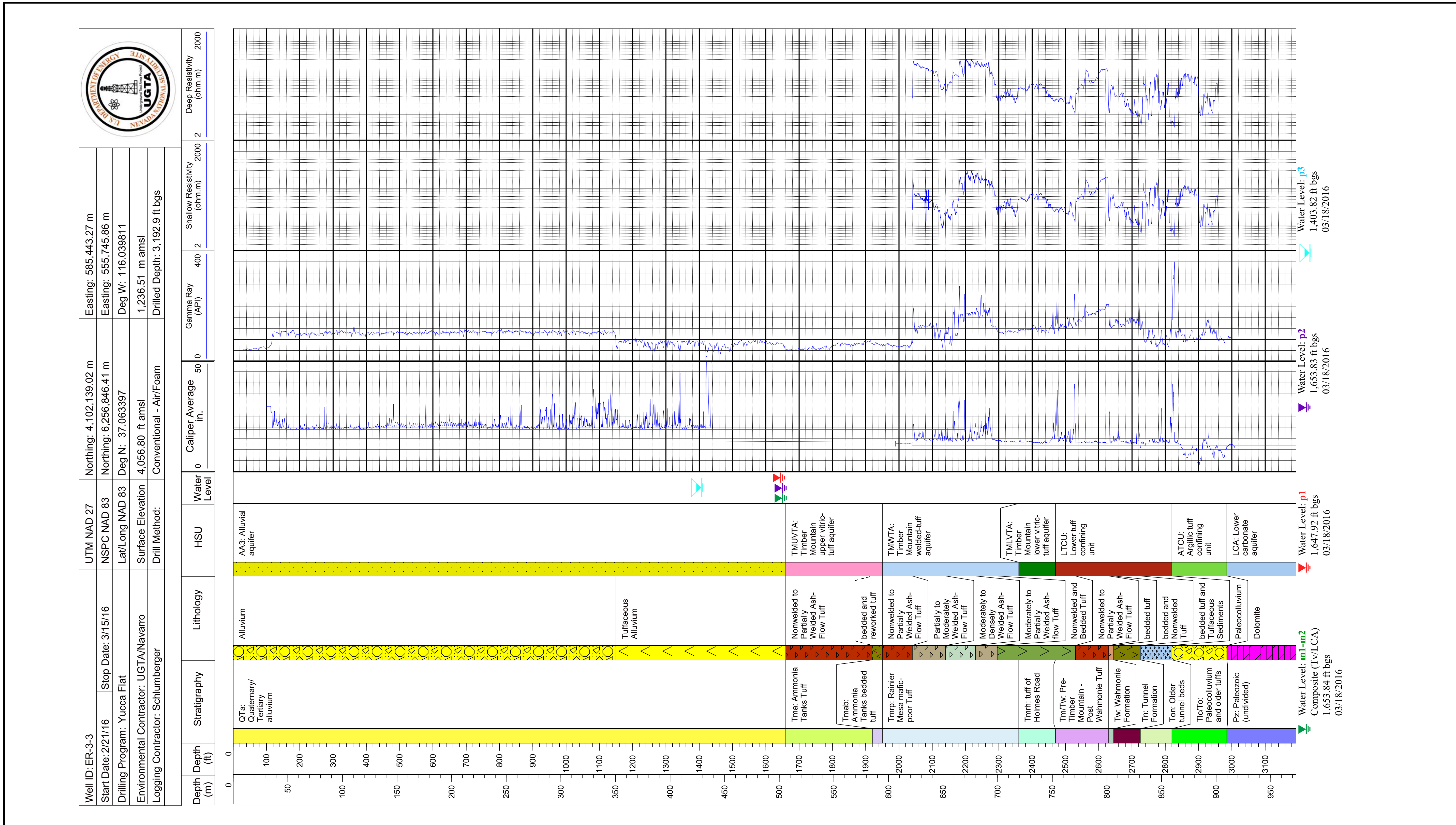


Figure 4-4
Well ER-3-3 Geophysical Log Traces of Caliper Average, Gamma Ray, and Shallow and Deep Resistivity

5.0 Geology and Hydrogeology

5.1 Geology

The following discussion and interpretations are primarily based on the final lithologic log presented in Appendix A. The final 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-3-3, 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-poor Tuff (Tmrp)
- tuff of Holmes Road (Tmrh)
- Pre-Timber Mountain Tuff - Post-Wahmonie Tuff (undifferentiated) (Tm/Tw)
- Wahmonie Formation (Tw)
- Tunnel Formation (Tn)
- Older Tunnel Beds (Ton)
- Paleocolluvium/older tuffs (Tlc/To)
- Paleozoic rocks (Pz)

Surficial geology of the northern portion of Yucca Flat is presented in Figure 5-1. Well ER-3-3 is located approximately 400 m (1,312 ft) east of the Yucca Fault, which is a prominent basin forming normal fault. The stratigraphic units encountered in Well ER-3-3 were generally as predicted, although there are significant differences in unit thicknesses noted. The units were as predicted, with the following exceptions: The Paintbrush Group (Tp) was not identified; however, this section was determined to be the Pre-Timber Mountain - Post-Wahmonie Tuff (Tm/Tw), and the Wahmonie Formation (Tw) was identified below the Tm/Tw.

In general, the Alluvium (QTa) and Timber Mountain Group (Tm) were significantly thicker than predicted, and the Pre-Timber Mountain - Post Paleocolluvium (i.e., Pre-Timber Mountain - Post-Wahmonie Tuff [Tm/Tw], Wahmonie Formation [Tw], and Tunnel Formation [Tn]) were

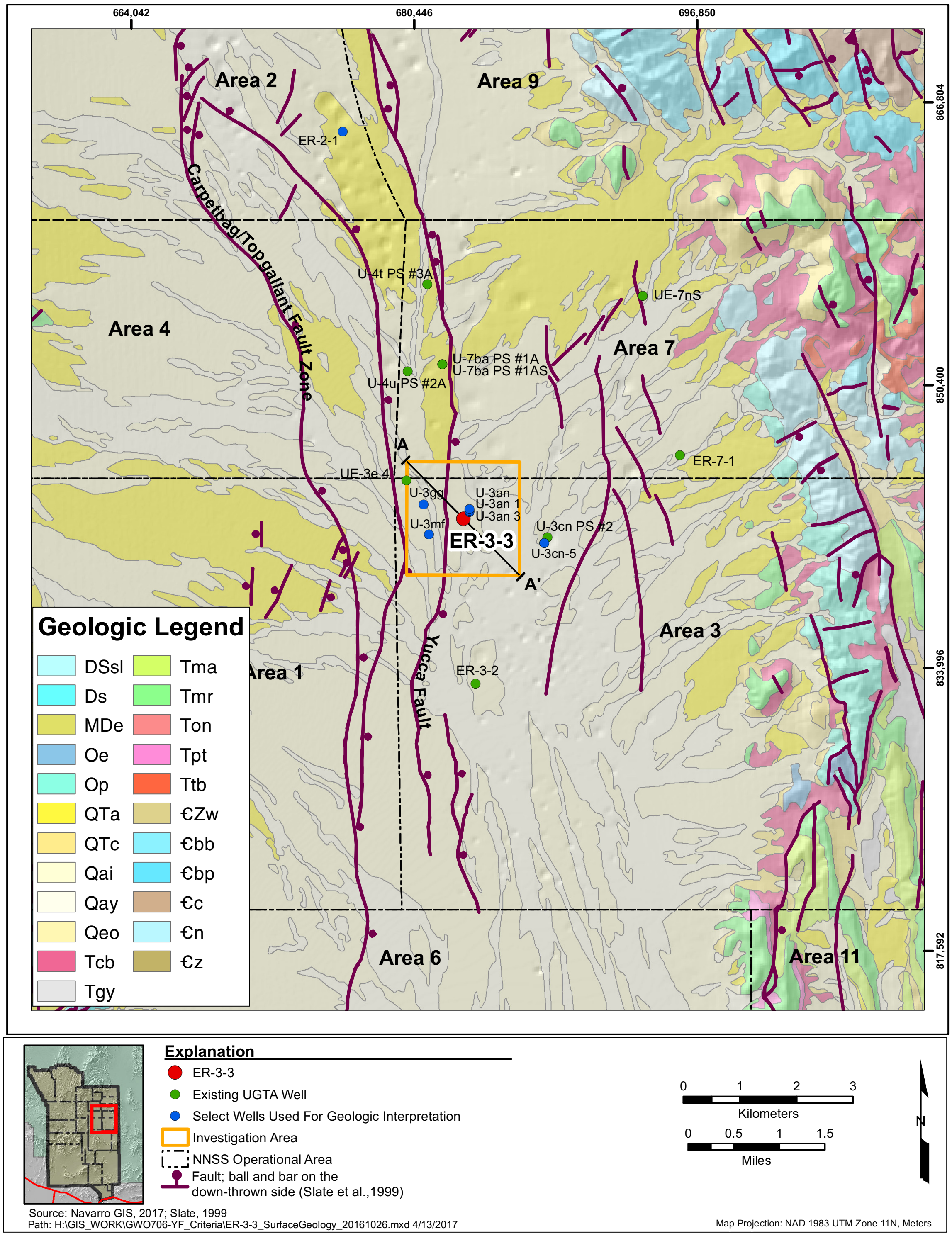


Figure 5-1
Surficial Geology at Well ER-3-3

significantly thinner than predicted. Specific differences include the Quaternary/Tertiary Alluvium (QTa) was predicted to be 401.73 m (1,318 ft) and the actual was 505.97 m (1,660 ft), a difference of 104.24 m (342 ft); and Timber Mountain Group (Tm) was predicted to be 188.06 m (617 ft) and the actual thickness was 246.89 m (810 ft), a difference of 58.83 m (193 ft). The Pre-Timber Mountain - Post Paleocolluvium portion of the section showed some minor variation in the stratigraphic units noted. These included Pre-Timber Mountain - Post-Wahmonie Tuff (Tm/Tw), Wahmonie Formation (Tw), Tunnel Formation (Tn), and Older Tunnel Beds (Ton). The predicted thickness of this section was 286.82 m (941 ft), whereas the actual thickness was 106.68 m (350 ft), a difference of 180.14 m (591 ft). Finally, the top of the Paleozoic rocks (Pz) was predicted to be at a depth of 894.59 m (2,935 ft) bgs. Well ER-3-3 identified the actual top of the Paleozoic rocks (Pz) at 909.83 m (2,985 ft) bgs, a difference of 15.24 m (50 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-3-3 is located in the east–central portion of the NNSS, within the topographical margins of Yucca Flat. 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. The prominent Yucca Fault normal fault is located immediately west of the well and has down dropped units to the east in the area of Well ER-3-3.Surface drainage in the vicinity of Well ER-3-3 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 and east of the topographic expression of the Timber Mountain caldera and its structural margin.

5.1.2 Stratigraphy and Lithology

The stratigraphic units, lithologic units, and HSUs penetrated in Well ER-3-3 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-3an, U-3an 1, U-3an 3, U-3gg, U-3mf, U-3cn5, ER-2-1), and in the Yucca Flat HFM presented in *A Hydrostratigraphic Model and*

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-3-3 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-poor Tuff	Tmrp
tuff of Holmes Road	Tmrh
Pre-Timber Mountain - Post-Wahmonie Tuff	Tm/Tw
Wahmonie Formation	Tw
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-3-3 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
Argillic tuff confining unit	ATCU
Lower carbonate aquifer	LCA

Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Yucca Flat–Climax Mine, Lincoln and Nye Counties, Nevada (BN, 2006).

Drilling at Well ER-3-3 initially penetrated alluvial material (i.e., sand, gravel, and fines) 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 (Pz) eroded from the surrounding highlands. This unit was significantly thicker than predicted. A total of 505.97 m (1,660 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 Well ER-3-3, is composed of the Ammonia Tanks Tuff (Tma), Ammonia Tanks bedded tuff (Tmab), Rainier Mesa mafic-poor Tuff (Tmrp), and the tuff of Holmes Road (Tmrh), which was deposited approximately 11.6 million years ago (Ma) from the eruption of the Timber Mountain caldera complex (TMCC) (Sawyer et al., 1994), located approximately 18.25 kilometers (km) (11.34 miles [mi]) to the west. The borehole penetrated 246.89 m (810 ft) of Timber Mountain Group (Tm) tuffs from 505.97 to 752.86 m (1,660 to 2,470 ft) bgs.

The Ammonia Tanks Tuff (Tma) is from 505.97 m (1,660 ft) to 585.22 m (1,920 ft) bgs and was identified by its stratigraphic position; high phenocryst content (15 to 20 percent); and mineralogic assemblage, including terminated and dipyramidal quartz (some partially resorbed), sanidine, and rare sphene. The Ammonia Tanks bedded tuff follows from 585.22 m (1,920 ft) to 594.36 m (1,950 ft) bgs and was identified based on stratigraphic position and the bedded/reworked nature of the material. Next in the sequence from 594.36 m (1,950 ft) to 719.33 m (2,360 ft) bgs is the Rainier Mesa mafic-poor Tuff (Tmrp), which was identified by its stratigraphic position and the mineralogic assemblage, including the presence of terminated and dipyramidal quartz and minor to rare mafics.

Observations in the cuttings and a sharp increase in water production indicated that a geologic feature had been intercepted by the borehole. A significant geologic feature (e.g. tension fracture) cuts the Rainier Mesa mafic-poor Tuff (Tmrp) from 624.84 m (2,050 ft) to 655.32 m (2,150 ft) bgs and was observed in the Schlumberger Formation MicroImager log (FMI). The FMI log shows a strong resistivity low, indicating an open or strongly fractured feature and thinly bedded material on either side with little to no apparent offset. It is interpreted that this structural feature extends into overlying units including the QTa; however, observations in the geologic cuttings and geophysical logs were generally inconclusive.

From 719.33 m (2,360 ft) to 752.86 m (2,470 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, abundant quartz with minor mafics, and geophysical log response.

Following the Timber Mountain Group, drilling at Well ER-3-3 penetrated a series of older stratigraphic units that were generally as predicted in the drilling and completion criteria document (Navarro, 2016b). Immediately following the tuff of Holmes Road (Tmrh) was a series of indeterminate Nonwelded to Partially Welded and bedded/reworked tuffs that have been assigned to Pre-Timber Mountain - Post-Wahmonie Tuffs (Tm/Tw). This unit extends from 752.86 m (2,470 ft) to 801.62 m (2,630 ft) bgs. 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 801.62 m (2,630 ft) to 806.20 m (2,645 ft) bgs. The Wahmonie was recognized by characteristic geophysical log response and its mafic-rich nature. Due to contamination from overlying volcanics, the samples are not wholly representative of the interval.

The Tunnel Formation (Tn) was encountered from 806.20 m (2,645 ft) to 830.58 m (2,725 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) was 24.38 m (80 ft) thick. Predicted thickness was 126.19 m (414 ft), a difference of 101.80 m (334 ft). Cuttings in this interval have significant contamination from material in the upper hole. Older Tunnel Beds (Ton) were encountered below the Tunnel Formation (Tn) from 830.58 m (2,725 ft) to 859.54 m (2,820 ft) bgs. The Older Tunnel Beds (Ton) were recognized on the basis of their lithologic character, distinctive alteration, and color. The lithologic and alteration types found in the Tunnel Formation (Tn) and the Older Tunnel Beds (Ton) contributed to the borehole stability issues and tight hole conditions experienced at the well.

Paleocolluvium and older tuffs (Tlc/To) were encountered from 859.54 m (2,820 ft) to 909.83 m (2,985 ft) bgs. The Paleocolluvium appears to consist of a matrix of fine altered ash and pumice with fragments of colluvial material consisting of carbonate, sedimentary, and volcanic rocks. Much of the fines and clays were likely 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.

Paleozoic rocks (Pz) were encountered from 909.83 m (2,985 ft) to 973.20 m (3,192.9 ft) bgs for a total of 63.37 m (207.9 ft). The Paleozoic rocks (Pz) were composed of dolomites with minor interbedded limestone. Many of the cuttings exhibited signs of fracturing, brecciation, and micro-stockwork veining. Additionally, an unusual bluish black, sooty mineral (possibly manganese [Mn] oxide) was noted on some fracture surfaces as well as fine to coarse grained pyrite. As expected, significant increases in water production were identified within this interval.

5.1.3 Alteration

Generally, from 0 to 505.97 m (0 to 1,660 ft) bgs, the alluvium is unaltered to weakly clay altered with minor caliche. Once in the Tertiary Volcanics (Tv) section, alteration is minimal from 505.97 m (1,660 ft) to 719.33 m (2,360 ft) bgs. From 719.33 m (2,360 ft) to 752.86 m (2,470 ft) bgs, zeolitic/argillic alteration gradually increases with depth, becoming pervasive below 752.86 m (2,470 ft) bgs. Below 752.86 m (2,470 ft) bgs, beginning in the Pre-Timber Mountain - Post-Wahmonie (Tm/Tw) and continuing through the Older Tunnel Beds (Ton), the nonwelded and bedded tuffs are typically pervasively altered to zeolites, and locally intense argillized zones. Finally, the Paleozoic rocks (Pz) show only minor alteration.

5.2 Predicted and Actual Geology

Overall, the actual stratigraphic sequence and lithology at Well ER-3-3 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-3-3. Thicknesses in the Quaternary/Tertiary alluvium (QTa) and the Timber Mountain Group (Tm) were significantly different than predicted. The predicted thickness of the Alluvium was 401.73 m (1,318 ft) and the actual thickness of the Alluvium (QTa) was found to be 505.97 m (1,660 ft), a difference of 104.24 m (342 ft). Timber Mountain Group (Tm) rocks (i.e., Ammonia Tanks Tuff [Tma], Ammonia Tanks bedded tuff [Tmab], Rainier Mesa mafic-poor Tuff [Tmrp], and the tuff of Holmes Road [Tmrh]) were also thicker than predicted. The predicted thickness for the group was 188.06 m (617 ft) and the actual thickness found was 246.89 m (810 ft), for a difference of 58.83 m (193 ft).

The Paintbrush Group (Tp) was not definitively identified in the well and may be represented by a portion of the Pre-Timber Mountain - Post-Wahmonie (Tm/Tw). The Tm/Tw had an actual thickness of 48.77 m (160 ft) as opposed to the predicted thickness of the Paintbrush Group (Tp) of 151.49 m (497 ft), for a difference of -102.72 m (-337 ft). No Grouse Canyon Tuff (Tbg) was identified in Well

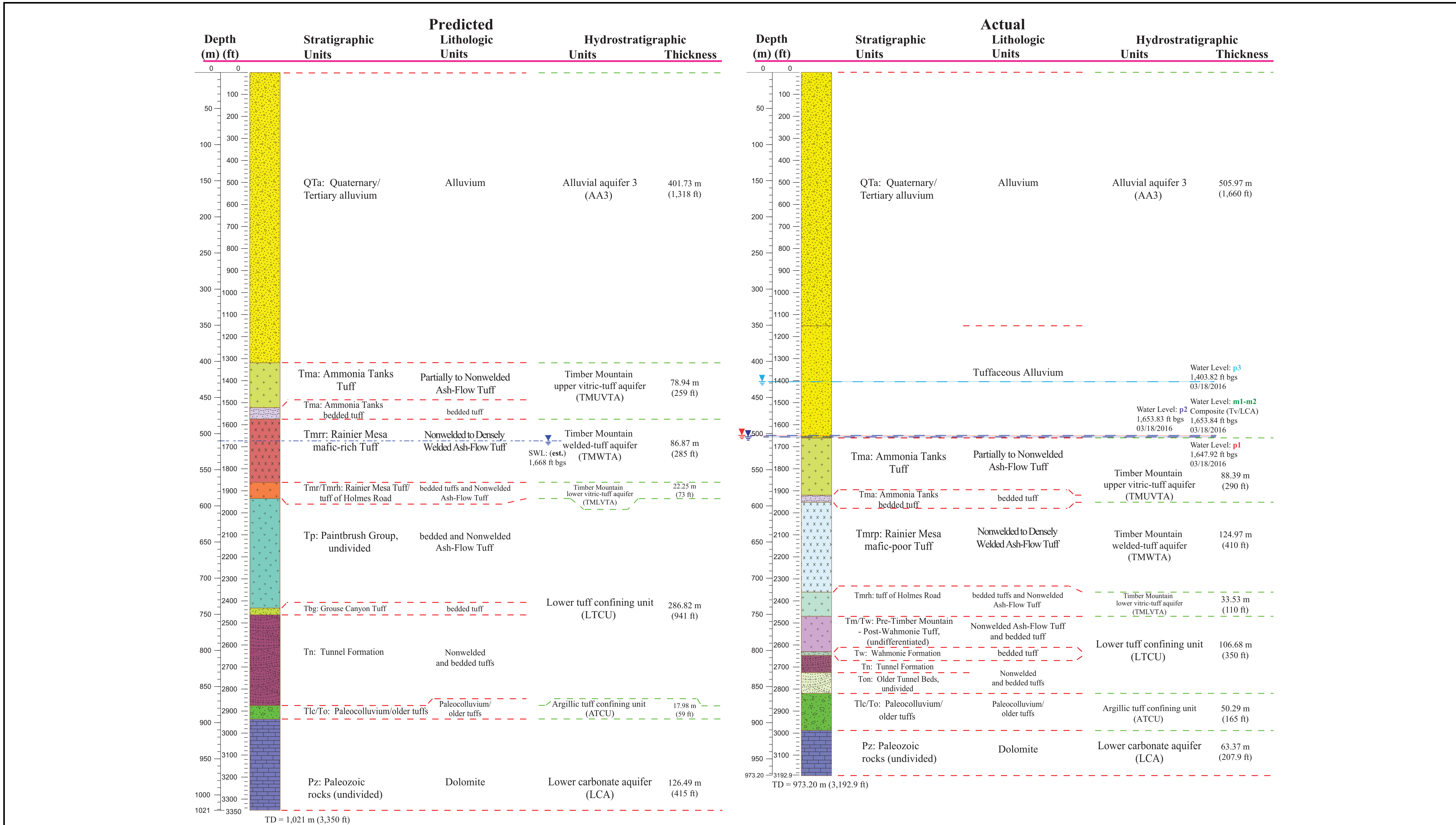


Figure 5-2
Predicted versus Actual Hydrogeology for Well ER-3-3

ER-3-3. The Wahmonie Formation (Tw), however, was identified, and the actual thickness is 4.57 m (15 ft) as opposed to the predicted thickness of the Grouse Canyon Tuff (Tbg) of 9.14 m (30 ft).

The Tunnel Formation (Tn) was identified but could not be further subdivided based on the quality and character of the cuttings from this interval. The predicted thickness of the Tunnel Formation (Tn) was 126.19 m (414 ft), and the actual thickness was 24.38 m (80 ft), a difference of -101.80 m (-334 ft). Preceding the Tunnel Formation (Tn) was the Older Tunnel Beds (Ton). This unit had not been predicted in Well ER-3-3 but had an actual thickness of 28.96 m (95 ft). Completing the Tertiary section was the expected Paleocolluvium (Tlc/To). The Paleocolluvium/Older tuffs (Tlc/To) had a predicted thickness of 17.98 m (59 ft), whereas the actual thickness was 50.29 m (165 ft).

The top of the Paleozoic rocks (Pz) was identified at 909.83 m (2,985 ft) bgs, a total of 15.24 m (50 ft) deeper than predicted. A total of 63.37 m (207.9 ft) of Paleozoic rocks (Pz) were penetrated in Well ER-3-3. Figure 5-3 illustrates the relationship between the stratigraphy, lithology, alteration, and hydrogeologic units (HGUs) identified in Well ER-3-3. Figure 5-4 shows the relationship between Well ER-3-3 and surrounding underground nuclear tests; other select wells; and the mapped surface effects from nearby underground tests, including the WAGTAIL test. The stratigraphic units in the vicinity of the well are shown in cross section in Figures 5-5 and 5-6. Cross-section lines are 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 and confining units according to their porosity and permeability, based on their 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-3-3.

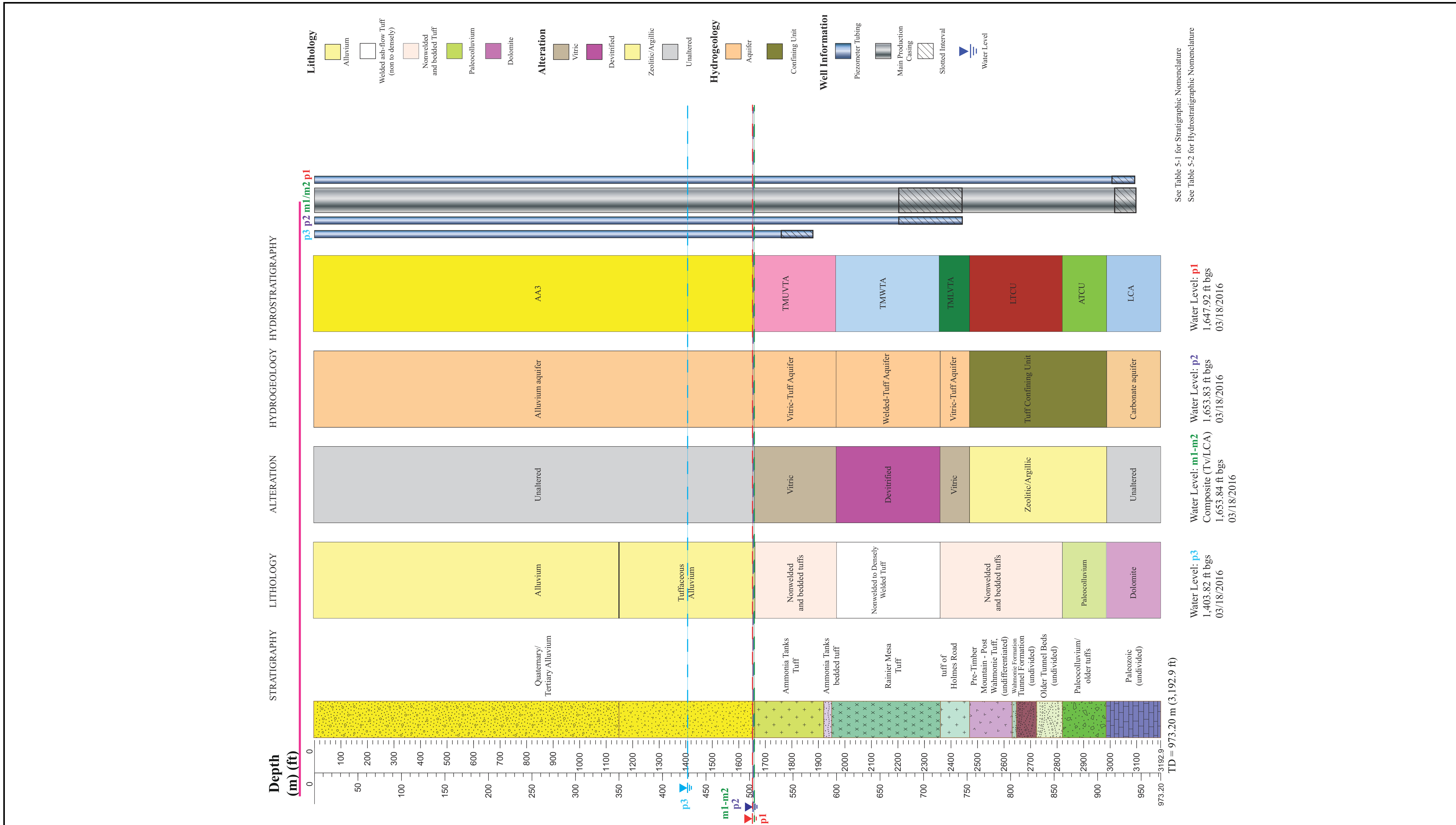


Figure 5-3
Graphical Presentation Showing Geology and Hydrogeology for Well ER-3-3

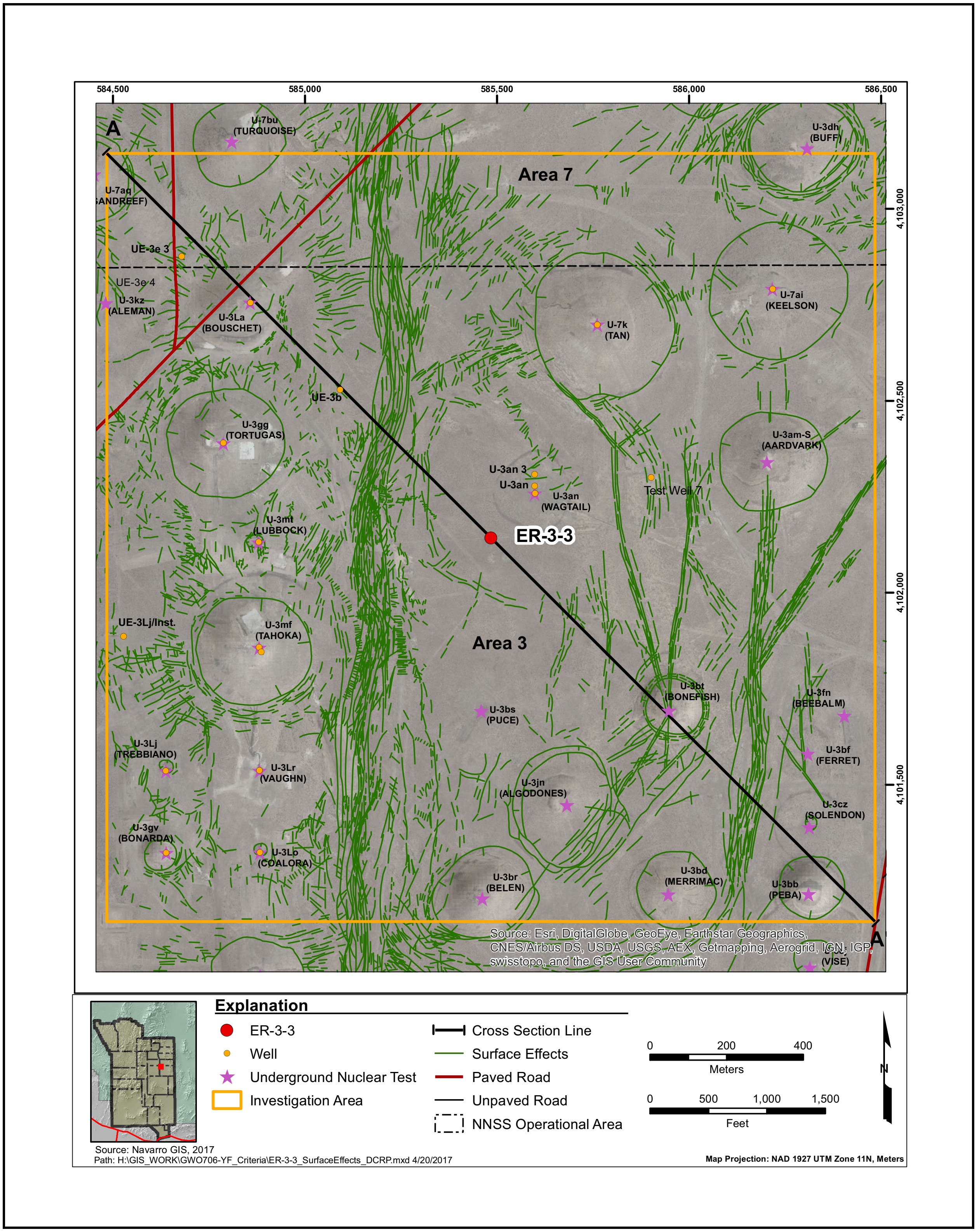


Figure 5-4
Surface Effects Map for the Well ER-3-3 Area

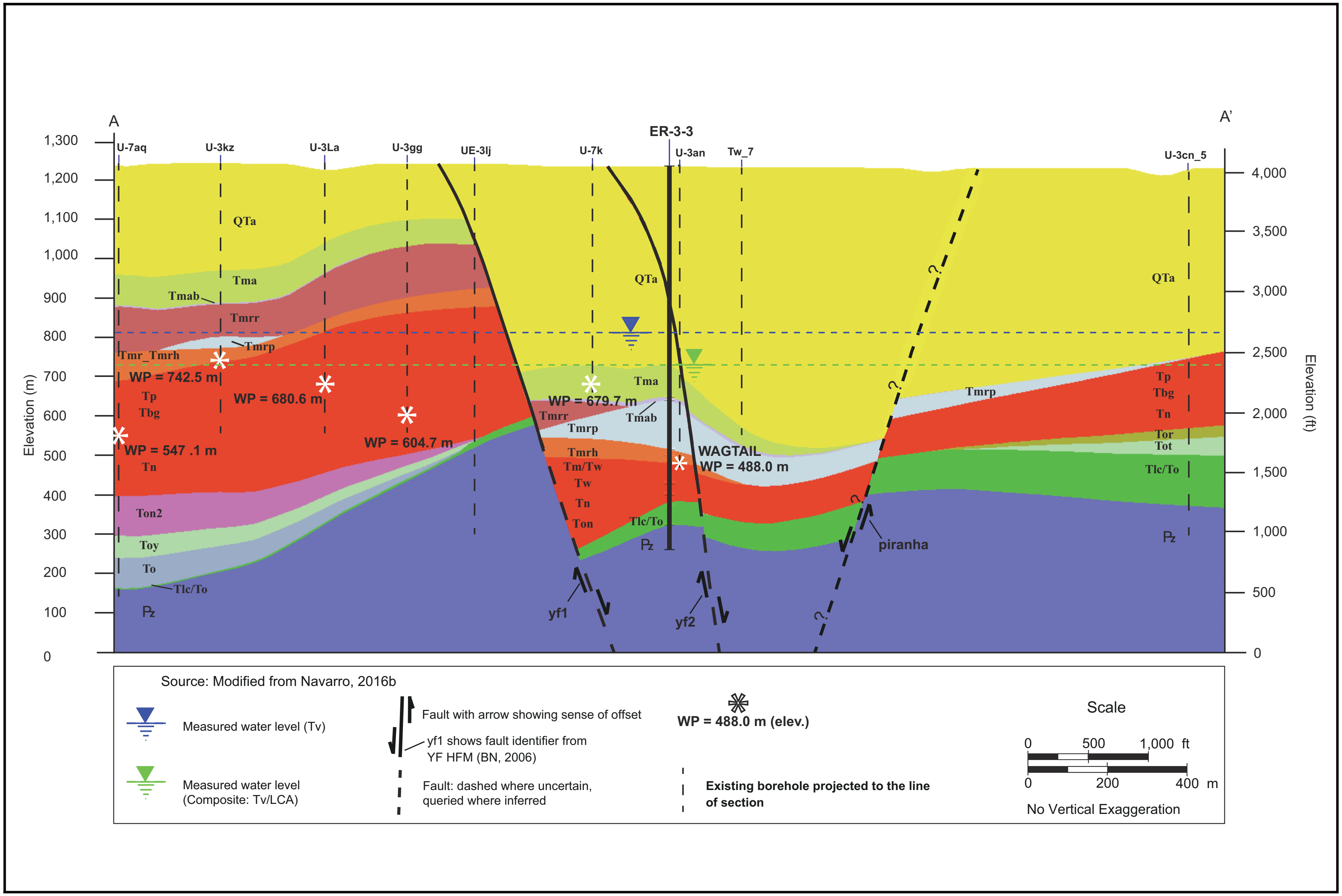


Figure 5-5
Stratigraphic Cross Section Northwest to Southeast

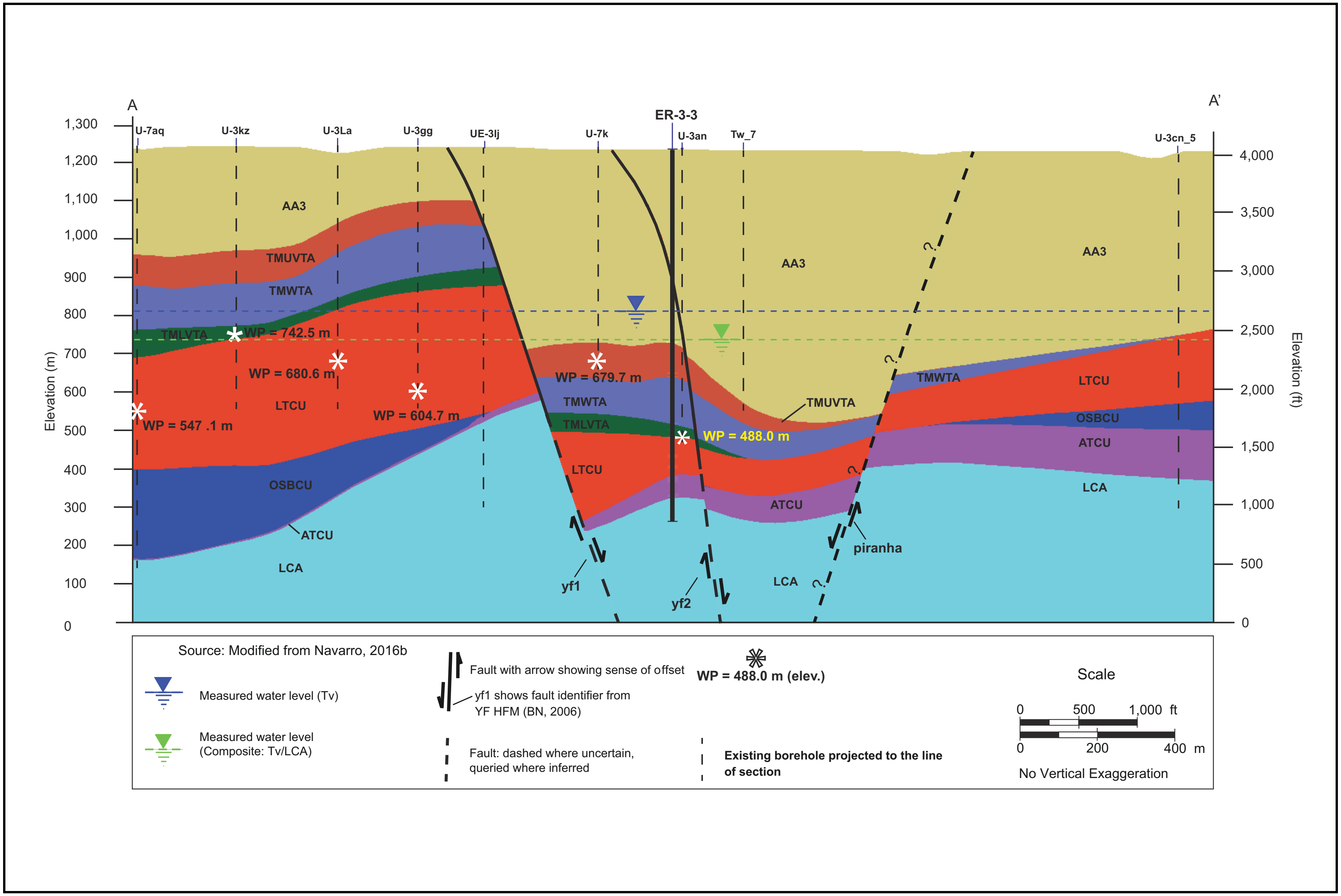


Figure 5-6
Hydrostratigraphic Cross Section Northwest to Southeast

HSUs present were generally as predicted. Based on the identification of key stratigraphic units (i.e., Ammonia Tanks Tuff [Tma], Rainier Mesa Tuff [Tmr], Wahmonie Formation [Tw], and Paleozoic rocks [Pz]), a high degree of confidence in the HSUs as identified and their assigned depths in Well ER-3-3 is warranted. Especially notable were the variations in actual versus predicted thickness of the AA3 and LTCU HSUs. The predicted thickness of the AA3 was 401.73 m (1,318 ft). Based on geophysical and lithologic information, the actual thickness was found to be 505.97 m (1,660 ft). The LTCU was predicted to be 286.82 m (941 ft) but was found to be 106.68 m (350 ft).

The distribution of HSUs in the vicinity of Well ER-3-3 is shown in cross section in Figure 5-6. The well penetrated a total of seven HSUs: (1) AA3 from 0.00 to 505.97 m (0 to 1,660 ft) bgs (unsaturated above 427.88 m [1,403.82 ft] bgs); (2) TMUVTA from 505.97 to 594.36 m (1,660 to 1,950 ft) bgs (saturated); (3) TMWTA from 594.36 to 719.33 m (1,950 to 2,360 ft) bgs (saturated); (4) TMLVTA from 719.33 to 752.86 m (2,360 to 2,470 ft) bgs (saturated); (5) LTCU from 752.86 to 859.54 m (2,470 to 2,820 ft) bgs (saturated); (6) ATCU from 859.54 to 909.83 m (2,820 to 2,985 ft) bgs (saturated); and (7) LCA from 909.83 to 973.20 m (2,985 to 3192.9 ft) bgs (saturated). Based on the HFM, the Tunnel Formation (Tn) and Older Tunnel Beds (Ton) have been assigned to the LTCU for Well ER-3-3. The relationship between the HSUs in the vicinity of Well ER-3-3 and the phenomenology of the WAGTAIL (U3an) is illustrated in Figure 5-7.

The saturated portion of Well ER-3-3 consists of HGUs including the Alluvial aquifer (AA), Vitric-tuff aquifer (VTA), and Welded-tuff aquifer (WTA) interbedded with Tuff confining units (TCUs) and the Lower Carbonate Aquifer (LCA), as shown in Figure 5-3. A significant geologic feature (possible tension fracture or other fault-related feature) was observed in the Schlumberger FMI, and this feature appears to significantly influence water production in the WTA. 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 and ACTU, respectively. The altered tuffs of the Wahmonie Formation (Tw) and Tunnel Formation (Tn) that underlie the Timber Mountain Group (Tm), although altered, appear to be somewhat productive based on water production estimates during drilling. This productivity may be related to possible fracturing within this unit.

The LCA was also productive in Well ER-3-3 as expected. Water production—which had been relatively steady since penetrating the TMWTA, at approximately 150 to 200 gpm—increased to approximately 300 to 350 gpm, by LiBr calculations presented in Appendix C and discussed in Section 6.0.

Before drilling, it was predicted that the Tertiary Volcanics (Tv) SWL in Well ER-3-3 would be encountered at 508.41 m (1,668 ft) bgs within the TMWTA HSU. Depth to water was measured in piezometer p3, which is open to the TMUVTA, on March 18, 2016, at 427.88 m (1,403.82 ft) bgs and was found to occur higher than the predicted level (within the AA3 HSU). Depth to water in piezometer p2—which is open across the lower TMWTA, TMLVTA, and upper LTCU—was measured on March 18, 2016, at 504.09 m (1,653.83 ft) bgs. On March 18, 2016, Navarro personnel collected a water level from piezometer p1 in the LCA. The water level recorded was 502.29 m (1,647.92 ft) bgs. The slotted intervals of the main completion m1 and piezometer p1 are within the LCA. See Figure 3-1 for details.

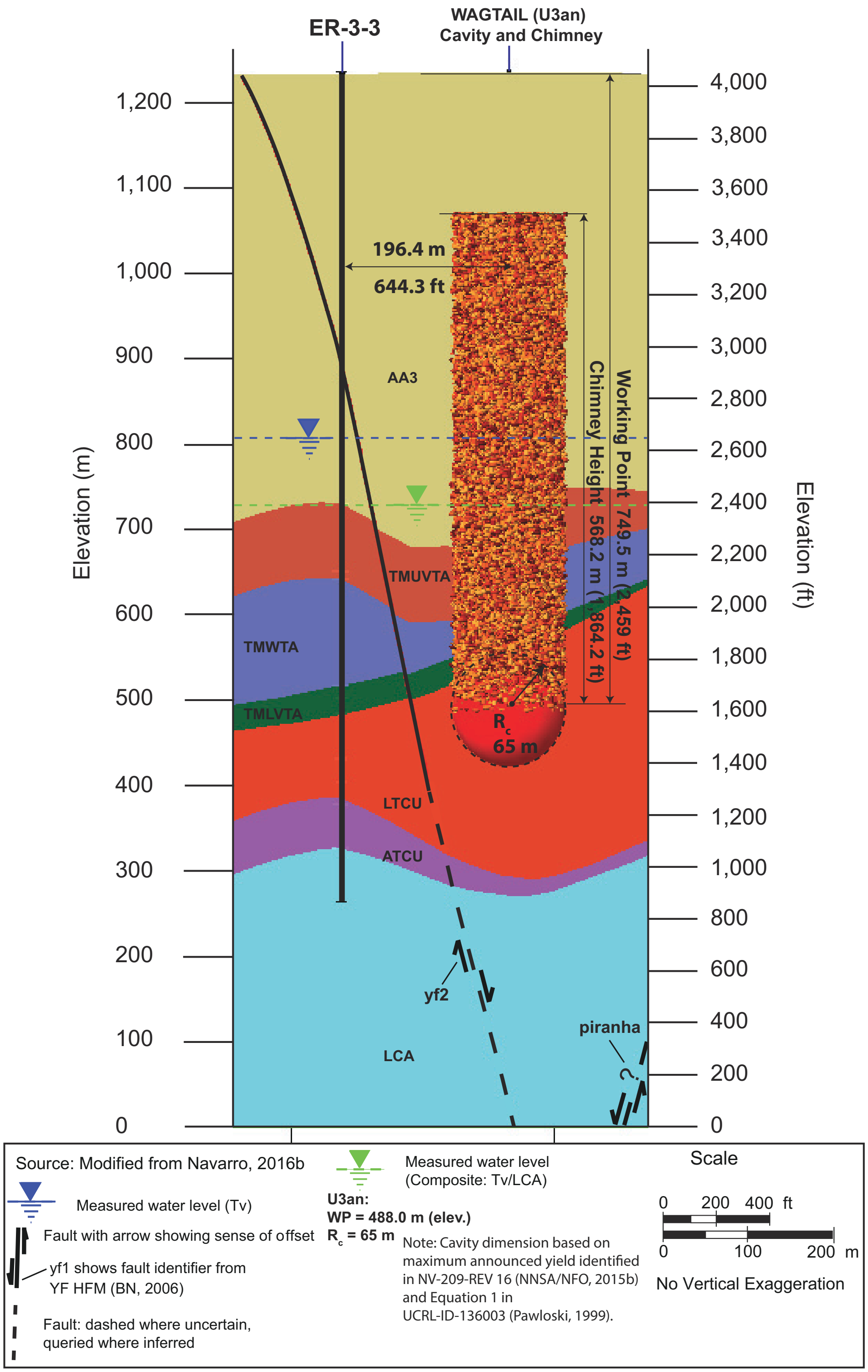


Figure 5-7
Schematic Diagram of the WAGTAIL Crater, Cavity, and Chimney

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 508.41 m (1,668 ft) bgs (Navarro, 2016b). Depth to water in piezometer p3 was measured on March 18, 2016, in the AA3 and TMUVTA at 427.88 m (1,403.82 ft) bgs using a calibrated e-tape. Depth to water in piezometer p2 was measured on March 18, 2016, at 504.09 m (1,653.83 ft) bgs across the TMLVTA and LTCU.

The predicted SWL in the LCA was 508.41 m (1,668 ft) bgs (Navarro, 2016b). Depth to water was measured in the main completion m1 and m2 open on March 18, 2016, at 504.09 m (1,653.84 ft) bgs, and is a composite measurement of TMWATA, TMLVTA, LTCU, and LCA. In piezometer p1 on March 18, 2016, the water level was measured at 502.29 m (1,647.92 ft) bgs using a calibrated e-tape in the LCA. 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 calculate groundwater production rates. When appropriate, visual estimates of water production from the flow line are used to support calculated fluid production rates. Appendix C summarizes bromide tracer results and calculated water production rates from Well ER-3-3.

Based on bromide dilution calculations, water production of 5 to 10 gpm was first noted in Well ER-3-3 around 548.6 m (1,800 ft) bgs within the TMUVTA. Estimated water production rates

Table 6-1
Well ER-3-3 Water-Level Measurements

Date-Time	Fluid Depth		Fluid Elevation [a]		Notes
	m bgs	ft bgs	m amsl	ft amsl	
ER-3-3 Main Completion					
03/02/2016 20:05:00	491.81	1,613.57	744.71	2,443.28	Piezometer not isolated. Open to 2,298 ft.
03/07/2016 13:30:00	514.05	1,686.50	722.48	2,370.35	Approximate fluid level after borehole TD reached. Composite water level in open borehole.
03/08/2016 04:00:00	510.54	1,675.00	725.99	2,381.85	Measured using a calibrated Solinst e-tape. Composite fluid level inside 13.375-in. with open borehole from 2,203 to 3,192.9 ft bgs.
03/15/2016 18:15:00	500.79	1,643.00	735.74	2,413.85	COLOG measured fluid level m1 and m2 open (composite fluid level).
03/18/2016 12:40:00	504.09	1,653.84	732.42	2,402.96	Measured using a calibrated Solinst e-tape. m1 and m2 open (composite fluid level) [b].
ER-3-3 Piezometer (p1)					
03/14/2016 01:40:00	493.27	1,618.34	743.26	2,438.51	Piezometer not isolated, composite measurement. Open from 2,203 to 3,192.9 (TD) Measured using a calibrated Solinst e-tape.
03/18/2016 11:35:00	502.29	1,647.92	734.23	2,408.88	Measured using a calibrated Solinst e-tape [b].
ER-3-3 Piezometer (p2)					
03/15/2016 01:38:00	490.53	1,609.35	746.00	2,447.50	Measured using a Mt. Sopris wireline #4.
03/18/2016 11:00:00	504.09	1,653.83	732.43	2,402.97	Measured using a calibrated Solinst e-tape [b].
ER-3-3 Piezometer (p3)					
03/13/2016 23:30:00	400.11	1,312.69	836.42	2,744.16	Measured using a Mt. Sopris wireline #4.
03/14/2016 23:02:00	408.43	1,340.00	828.10	2,716.85	Measured using a Mt. Sopris wireline #4.
03/18/2016 12:05:00	427.88	1,403.82	808.63	2,652.98	Measured using a calibrated Solinst e-tape [b].

[a] Ground surface used as reference datum. Ground surface elevation survey by NSTec at 1,236.53 m (4,056.85 ft) amsl.
[b] Measurement by Navarro using a calibrated Solinst e-tape on 03/18/2016. Reference elevation of 4,056.80 ft using marker on east side of casing (see Figures 3-2 and 7-1).

increased from less than 10 to approximately 200 gpm while drilling through the TMWTA. 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 around 350 gpm. Figure 6-1 is a plot of bromide tracer injection concentrations versus discharge concentrations and corresponding estimated 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.

Groundwater chemistry samples are typically collected using a wireline deployed depth-discrete bailer during drilling. These samples provide initial groundwater chemistry based on select groundwater characterization parameters as identified in the Integrated Sampling Plan (NNSA/NFO, 2014). Due to borehole instability and the use of large amounts of bentonite-based mud, bailer samples were not collected in Well ER-3-3.

6.2.1 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 1,860 picocuries per liter (pCi/L). Tritium results were below the S*afe Drinking Water Act* (SDWA) limit (20,000 pCi/L) (CFR, 2016b). Results from drilling fluid returns from both the unsaturated and saturated zones ranged from 0 to 4,558 pCi/L. Appendix B provides a summary of tritium monitoring results, including onsite reanalyses. Tritium concentrations and water production at Well ER-3-3 are shown in Figure 6-2.

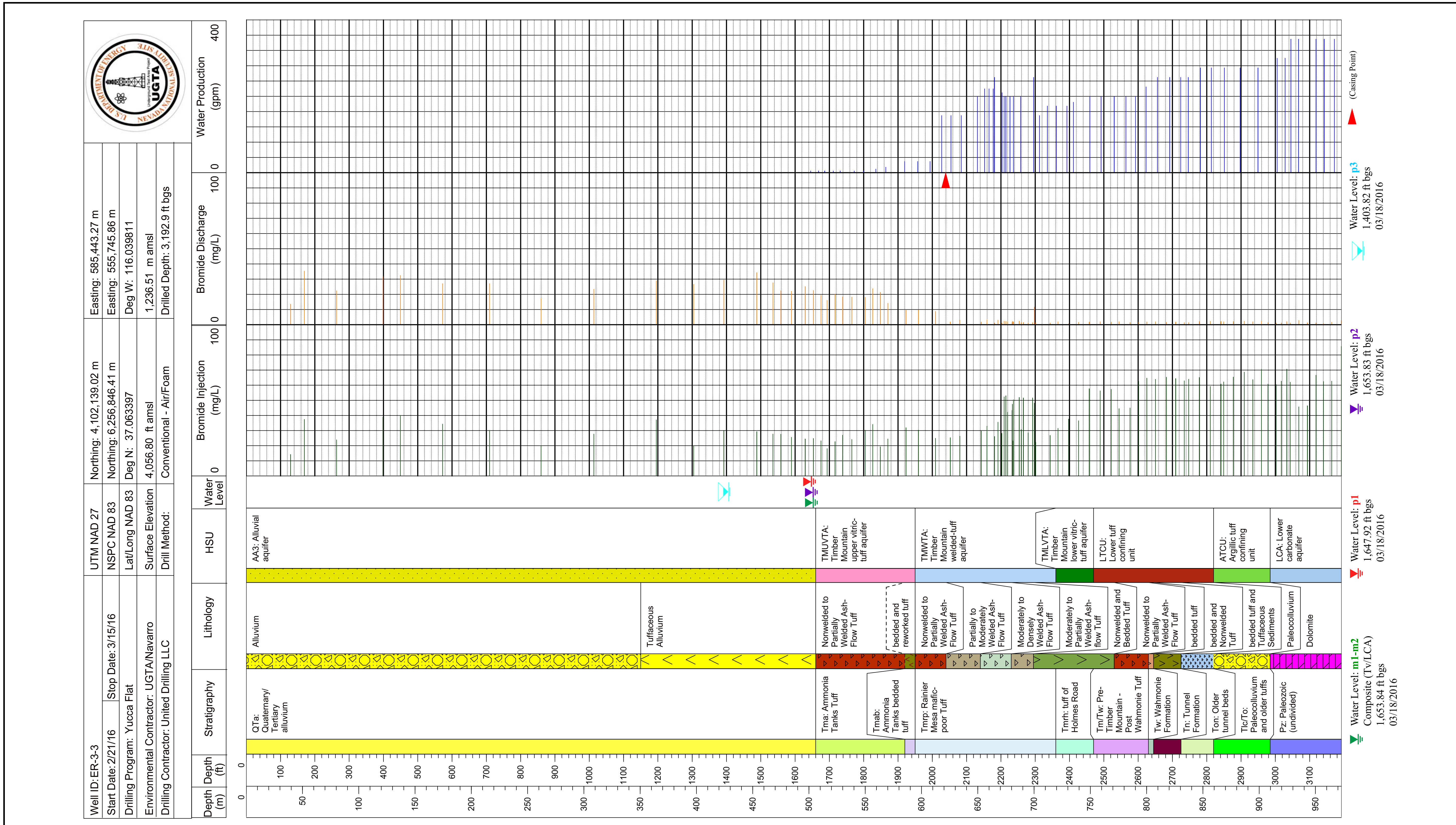


Figure 6-1
Well ER-3-3 Bromide Tracer Monitoring versus Estimated Water Production during Drilling

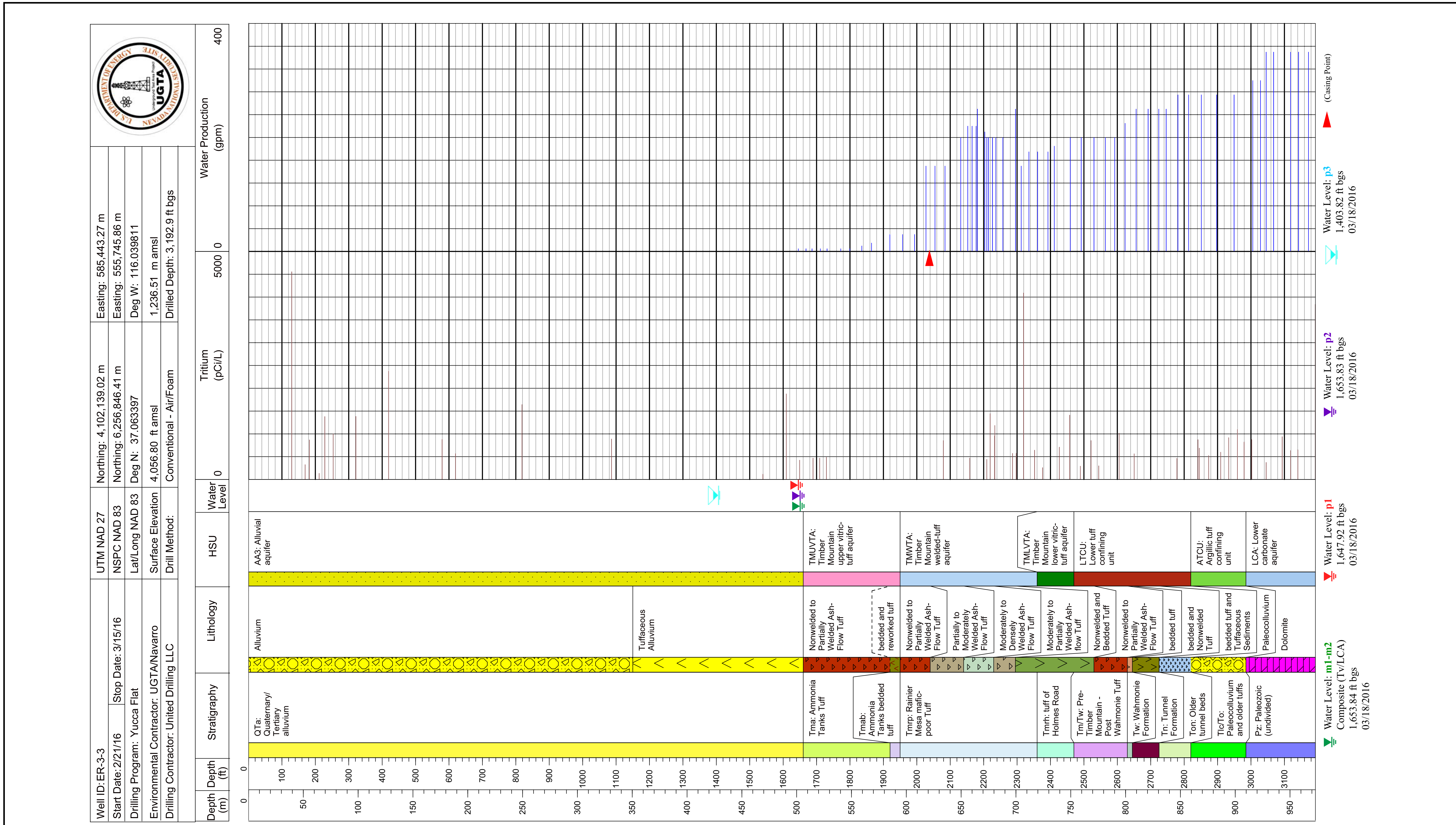


Figure 6-2
Well ER-3-3 Tritium Concentrations and Estimated Water Production during Drilling

7.0 Fluid and Waste Management

7.1 Fluid Management Strategy

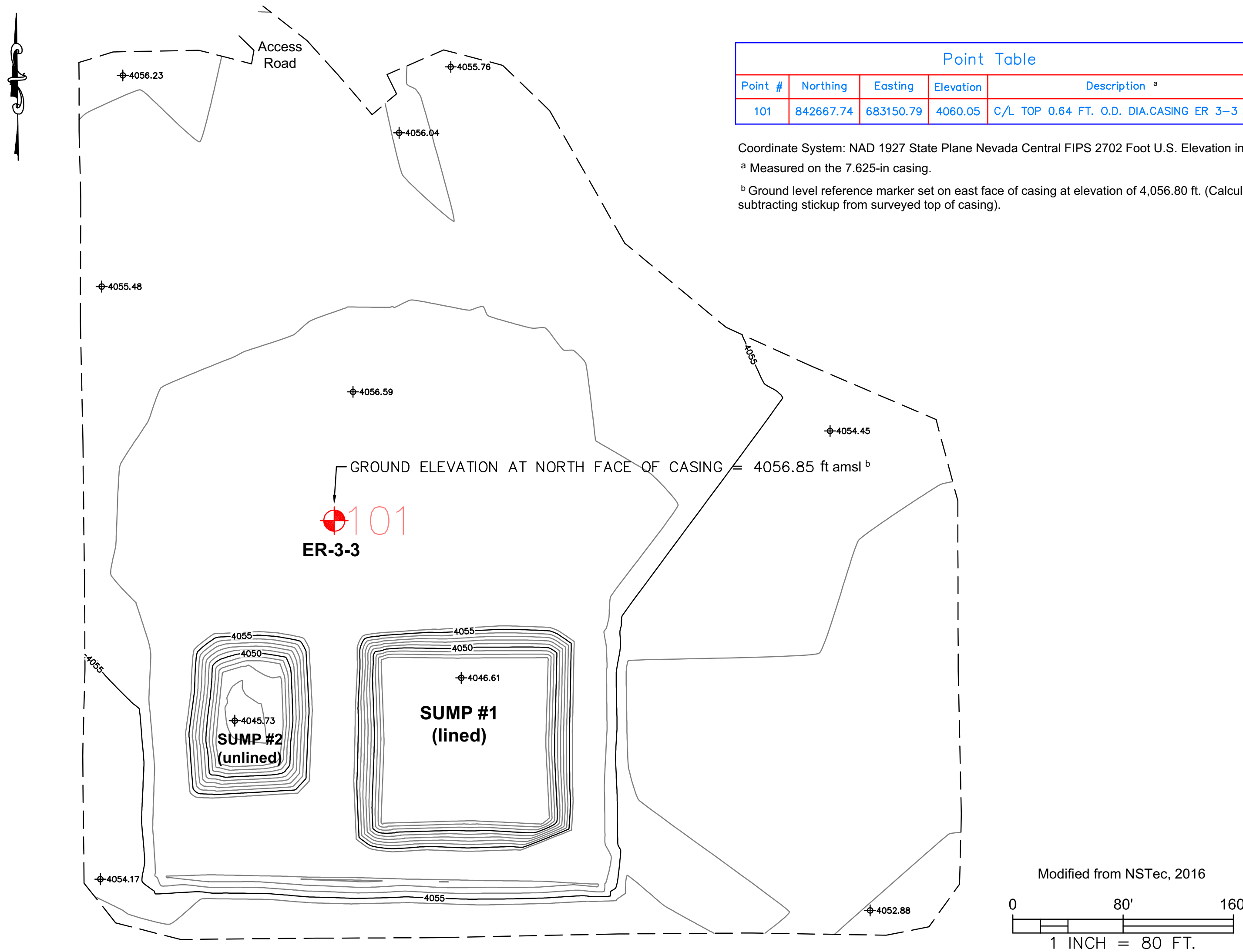
The management of drilling fluids and solid waste (i.e., cuttings) is addressed in the *Underground Test Area Project Waste Management Plan*; *Attachment 1 Fluid Management Plan for the Underground Test Area Project* (NNSA/NSO, 2009). The *Final Well Specific Fluid Management Strategy for UGTA Well ER-3-3, Nevada National Security Site* (Navarro, 2016a; see Appendix D), as required by the UGTA FMP, addresses specific fluid management strategies to be employed at Well ER-3-3 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-3-3. 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 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-3-3.

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, 2015. Sample data were reviewed, and results were below the SDWA limit (CFR, 2016b). The water was also analyzed 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]
101	842667.74	683150.79	4060.05	C/L TOP 0.64 FT. O.D. DIA.CASING ER 3–3

Coordinate System: NAD 1927 State Plane Nevada Central FIPS 2702 Foot U.S. Elevation in feet.

[a] Measured on the 7.625-in casing.

[b] Ground level reference marker set on east face of casing at elevation of 4,056.80 ft. (Calculated by subtracting stickup from surveyed top of casing).

Figure 7-1
Well ER-3-3 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 1,846 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 1,846 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 6-2 and Appendix B, tritium analyses for discharge samples from both the unsaturated and saturated zones in Well ER-3-3 ranged from 0 to 4,558 pCi/L.

After drilling activities were completed, Navarro personnel collected an FMP confirmatory sample and duplicate from Sump #1 and Sump #2 on March 15, 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 Tables 7-1 and 7-2.

7.3 Disposition of Fluids and Cuttings

The FMP (NNSA/NSO, 2009) and the Well ER-3-3 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 and unlined Sump #2. No discharges were made to the designated infiltration area.

The volumes of fluids produced during vadose and saturated zone drilling are presented in Table 7-3. At the completion of drilling on March 8, 2016, an estimated combined total of 2,806 cubic meters (m^3) (741,267 gal) of drilling fluid and cuttings remained in lined Sump #1 and unlined Sump #2.

Table 7-1
Analytical Results for FMP Confirmatory Samples from Sump #1 (Lined) at Well ER-3-3

Analyte	Analytical Method [a]	Detection Limit	FMP Samples from Well ER-3-3 Sump #1			
			Sample Number 430-031516-1		Sample Number 430-031516-3 (Duplicate)	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.0066 J	0.0076 J	0.01 U	0.0071 J
Barium		0.1	0.063 J-	0.0078 J-	0.039 J-	0.0057 J-
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.027	0.024	0.027	0.024
Lead		0.003	0.0035	0.003 U	0.0044	0.003 U
Selenium		0.005	0.006	0.005 U	0.005 U	0.0051
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]	400	-180	230	-350	230
Gross Alpha	EPA 900.0 [d]	1.9, 1.8	3.9	1.7	3.7	1.6
Gross Beta		2.3, 2.1	7.8	2.1	9.5	2.2

Source: Navarro, 2016a

[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 430-031516-1 and the second with 430-031516-3.
[d] EPA, 1980

EPA = U.S. Environmental Protection Agency
MDC = Minimum detectable concentration

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

Note: Analyses were performed by ALS Laboratory Group.

Table 7-2
Analytical Results for FMP Confirmatory Samples from Sump #2 (Unlined) at Well ER-3-3

Analyte	Analytical Method [a]	Detection Limit	FMP Samples from Well ER-3-3 Sump #2			
			Sample Number 430-031516-2		Sample Number 430-031516-4 (Duplicate)	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.006 J	0.01 U	0.0078 J	0.0069 J
Barium		0.1	0.039 J-	0.011 J-	0.039 J-	0.015 J-
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.031	0.027	0.03	0.025
Lead		0.003	0.0034	0.002 J-	0.0025	0.0027 J-
Selenium		0.005	0.0053	0.006	0.005 U	0.0059
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]	400, 280	-140 U	230	-60 U	170
Gross Alpha	EPA 900.0 [d]	1.9, 2.1	4.5	1.8	3.2	1.7
Gross Beta		2.4, 1.9	9.3	2.2	10.8	2.4

Source: Navarro, 2016a

[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 430-031516-2 and the second with 430-031516-4.
[d] EPA, 1980

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

Note: Analyses were performed by ALS Laboratory Group.

Table 7-3
Well ER-3-3 Fluid Disposition Reporting Form

Site Identification: ER-3-3
Site Location: Nevada National Security Site
Site Coordinates: (UTM NAD 27, Zone 11) N 4,102,139.02 m; E 583,443.27 m
Well Classification: ER Hydrogeologic Investigation Well
Navarro Project No: UN16-460

Report Date: December 20, 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	02/21/2016	02/24/2016	2	499.87	289.38	183.68	154.81	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	02/24/2016	03/15/2016	7	473.32	519.93	79.06	1,726.38	N/A	662.19	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:			9	973.2	809.31	262.75	1,881.19	N/A	662.19	0	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-3-3.

[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 3/19/2016: Sump #1 = 1,345 m^3 (35%) Sump #2 = 1,070 m^3 (82%)

Current Average Tritium activity for FMP samples collected from Sump #1 and Sump #2 were <400 and <280 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-3-3 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-3-3 site consisted of hydrocarbon, sanitary, and low-level radioactive wastes. Table 7-4 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-3-3 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 7-4
Final Waste Disposition for Well ER-3-3 Drilling Operations

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-3-3-1	02/11/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	In Process (45 gal)
ER-3-3-2	02/25/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	Pending	In Process (20 gal)
ER-3-3-3	02/25/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	Pending	In Process (15 gal)
ER-3-3-4	02/22/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: Oil filters, absorbent	Non-Haz, Non-Rad Hydrocarbon	Pending	In Process (45 gal)
ER-3-3-5 (NAVSAA004)	02/22/2016	5 gal	Poly pail	Hach Lead Test Kit Rinsate	Pending Haz/Rad	Pending	In Process (50 mL)

mL = Milliliter

8.0 Planned and Actual Costs and Scheduling

This section provides a brief discussion of the planned and actual costs and schedule for the main borehole construction of Well ER-3-3.

The original M&O contractor (NSTec)-approved baseline work package was based on drilling to a planned TD of 1,097.6 m (3,600 ft), installing one production casing string with two main completion zones and two piezometer tubing strings. This estimate was submitted before the final drilling criteria document (Navarro, 2016b) was issued, with an updated planned TD of 1,021.3 m (3,350 ft). The baseline estimate included a 30-day schedule for constructing a 1,097.6-m (3,600-ft)-deep well. The baseline estimate included seven days for the location-to-location move from Well ER-2-2 and 23 days for main borehole construction and completion.

The well was drilled 124.1 m (407 ft) shallower than originally planned to a TD of 973.20 m (3,192.90 ft), and 47.9 m (157 ft) shallower than specified in the final drilling criteria. It took 36 calendar days to construct Well ER-3-3, beginning with the start of the location-to-location move on February 9, 2016, and ending with the removal of the tubing used for stemming the production casing on March 15, 2016.

The additional six days between the actual and planned construction schedules are primarily due to (1) a safety stand-down associated with hand injuries during mobilization to the site and (2) borehole stability issues experienced while drilling the surface and production boreholes between depths of approximately 609.60 and 701.04 m (2,000 and 2,300 ft). The borehole problems required use of liquid mud, and cementing and re-drilling.

The final actual M&O contractor costs (actual cost of work performed [ACWP]) for the main borehole construction and completion was $3,881,937, which is $183,734 (4.5 percent) less than the planned costs (budgeted cost of work performed [BCWP]) of $4,065,671. The cost difference is primarily the result of actual geophysical logging services less than planned, the actual drilled depth 124.1 m (407 ft) less than planned, and production casing stemming activities less than planned. Figure 8-1 presents a comparison of the planned and actual schedule, by day, for construction of Well ER-3-3. The planned drilling construction schedule and costs curves are presented in Figure 8-2.

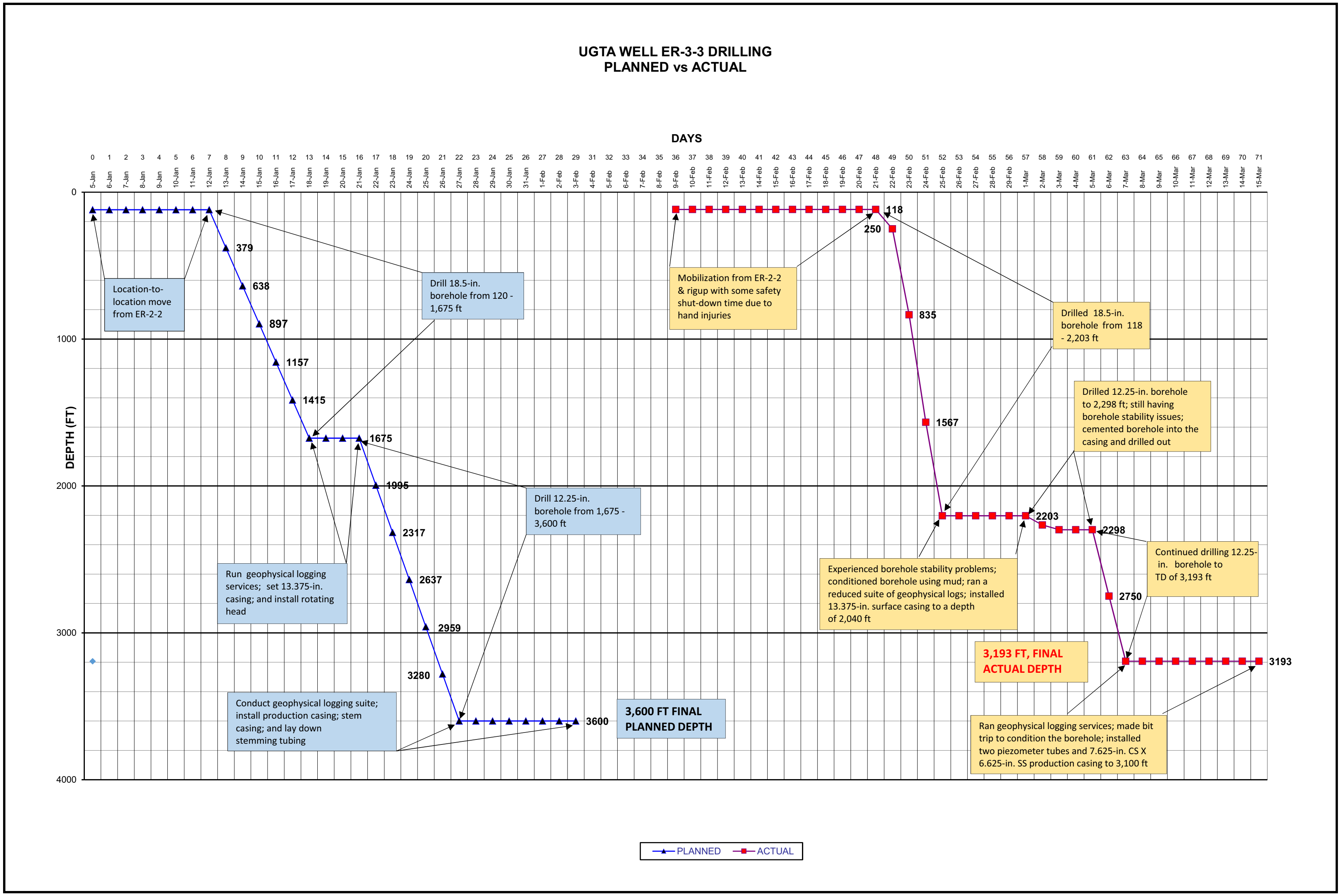


Figure 8-1
Planned vs. Actual Construction Progress for Well ER-3-3

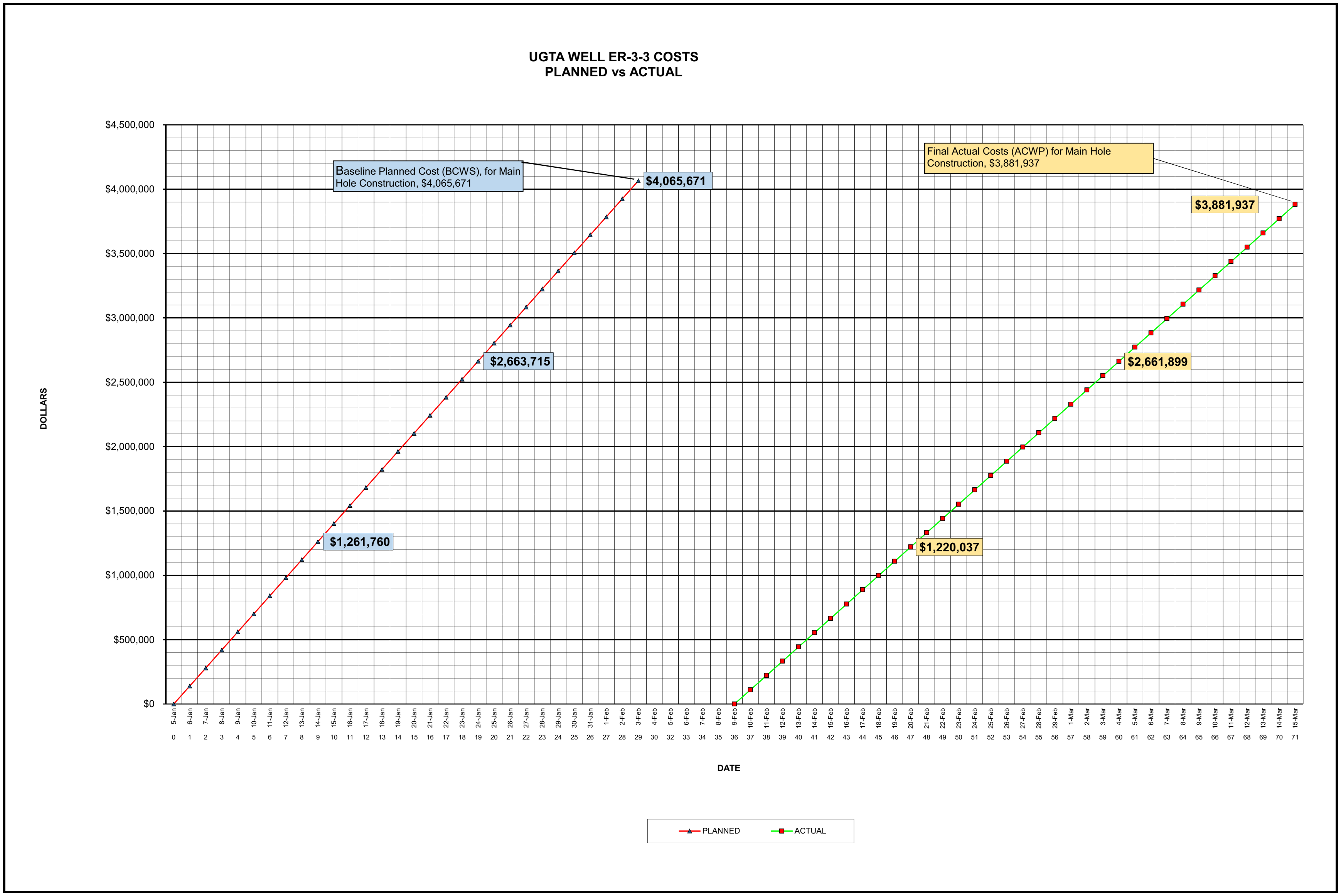


Figure 8-2
Planned vs Actual Cost of Constructing Well ER-3-3

9.0 Lessons Learned and Recommendations

Drilling, well construction, scientific, and environmental compliance activities at Well ER-3-3 were generally executed as planned. The drilling generally encountered the expected stratigraphic units in the saturated zone. The construction of Well ER-3-3 was similar to the planned design. Well ER-3-3 as-built provided for three hydraulically isolated completion intervals that may be accessed with piezometers or casing for the purposes of water-level measurements, groundwater sampling, or limited hydraulic testing. However, the well completion was affected by unstable and sloughing borehole conditions and operational concerns that impacted the construction of the well and will affect the utility of the well in the longer term. Issues that impacted 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-3-3.

It should be noted that as with any drilling effort, some significant geologic and hydrogeologic information was gained through the drilling process. At Well ER-3-3, targeted HSUs were identified in the borehole—in particular, more than 61 m (200 ft) of Paleozoic rocks (Pz) of the LCA were encountered within approximately 15.2 m (50 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-3-3. In addition, observations from the drilling suggested structural features including faults and fracturing that may be used to better define the geometry of structures in the area. These observations may be used to 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 analyses, the results indicated that tritium concentrations were generally below the MDA and were below the SDWA limit (CFR, 2016b) over the depth interval penetrated during drilling. The measurements of water levels during drilling and after completing the well provided depth to water data that indicated water levels in the saturated Tertiary volcanics (Tv) and in the Paleozoic rocks (Pz) of the LCA were near those predicted in the HFM.

9.1 Lessons Learned and Recommendations

9.1.1 Drilling Method

Well ER-3-3 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.

Well ER-3-3 encountered sloughing and unstable borehole conditions coupled with an interval of high water production apparently associated with a structure (e.g., fault, tension fracture) intercepted in the borehole as it penetrated the Timber Mountain Rainier Mesa Tuff (Tmr). This structural feature was only recognized in the Timber Mountain Rainier Mesa Tuff (Tmr) and is interpreted to have affected both younger and older units, but the borehole did not directly encounter them. In addition, similar unstable conditions affected the borehole as it penetrated the Wahmonie Formation (Tw), Tunnel Formation (Tn), 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.

As a result of the excessive fill, tight hole conditions, sloughing/bridging, and ledges/washouts, the uncased borehole below 621.8 m (2,040 ft) bgs required multiple cleanout runs to clear bridging zones and to condition the borehole for geophysical logging and well completion. The extended drilling operations, and multiple trips in and out of the borehole—along with high-energy discharges of drilling fluid/groundwater and extended periods of circulation—ultimately required the use of bentonite mud and several episodes of cementing to in part stabilize the borehole. The use of bentonite based muds and cemented intervals have detrimental effects to the natural hydrologic character of the formations. In some cases, these effects may be reversed through later well development activities; however, many of these intervals may not have sufficient groundwater yields to facilitate later pumping.

Lesson Learned/Recommendation: Well ER-3-3 drilling conditions were somewhat expected, based on prior experiences for drilling operations conducted in the area and the anticipated behavior of several of the stratigraphic units predicted to be encountered in the drilling. During drilling operations, it was determined that the rate of penetration would be restricted to accommodate the collection of fluid and cutting samples as drilling progressed. This slowing of the drilling rate extended the drilling time and allowed in part for formations susceptible to borehole erosion to be affected and become unstable due to prolonged exposure to drilling fluids and produced groundwater. Future drilling operations should consider maintaining the highest optimal rates of penetrations while still allowing for collection of monitoring samples. This will serve to reduce the drilling time and will likely be of greatest benefit when groundwater production is significant.

Future well drilling and well completions may also benefit from the use of alternate drilling techniques. Given the borehole sizes typical to meet the technical and scientific objectives of project wells, the use of flooded reverse circulation drilling techniques may provide improved borehole stability by minimizing drilling-induced damage to the formations. This reverse circulation approach may not be optimal for collection of discharge samples for the reliable monitoring of groundwater production or tritium contamination as drilling advances. However, this drilling may likely allow for more stable borehole conditions and potentially shorter drilling periods in formations that are not primary well completion targets (i.e., LTCU).

9.1.2 Safety Incident Resulting in Worker Injury

During site setup for Well ER-3-3 operations on the morning of February 12, 2016, a worker for the drilling contractor (UDI) sustained a hand injury when his hand was pinched between two pieces of equipment. The incident occurred as the worker was supporting a flammable cabinet that was being transported on a forklift. NNSS paramedics responded to the site, and the injured worked was subsequently transported off site for medical evaluation. The injury was minor and did not require hospitalization. Immediately after the incident, NSTec management suspended work at the site. After initial investigation, it was determined that site operations would be suspended until the incident was fully evaluated and appropriate corrective actions could be identified. The site was secured, and personnel did not return to the site to continue operations until the morning of February 17, 2016. The site operations were placed on standby for a period of approximately five days as a result of the incident.

Lesson Learned/Recommendation: Drilling activities, by the nature of the work performed, can be hazardous. In many cases, the hazards presented during the rig up and rig down present some of the greatest risk to personnel. Work activities performed during these periods are not typical day-to-day drilling tasks where the safety elements are recognized and controlled. Regarding this specific incident, two contributing factors were identified to have contributed to the injury/incident. (1) *Operational Awareness:* The worker and the forklift operator needed to be more aware of the work surroundings. If more attention was given to the work situation, the two pieces of equipment would not have become in contact. Further, the individual guiding the load on the forklift should have ensured that his hands were in safe positions and not placed in potential pinch points. (2) *Personal Protective Equipment (PPE).* Appropriate PPE (gloves) could have help prevented or minimized the extent of injury.

Corrective actions were taken by the drilling contractor before operations resumed and were emphasized during operations to reinforce awareness and compliance. Special gloves with added back-of-the-hand protection were distributed to workers. Signs were placed conspicuously in areas where pinch hazards may be present, to remind workers of PPE and awareness of the work environment. Pre-job safety briefings emphasized the use of proper PPE and awareness of operational settings. There were no further safety incidents reported during the execution of Well ER-3-3 drilling and well completion operations. Key personnel of the principal organizations should meet before drilling begins to discuss operations, issues, and concerns along with requested information, scenarios, and possible indications of problem conditions.

9.1.3 Operational Delays

UGTA drilling and well completion operations are executed on a 7-day-per-week, 24-hour-per-day schedule to maximize the efficiency of the activities and minimize the potential for borehole stability issues that may affect drilling and completion operations. Good planning and logistics are essential to meeting the objectives of the well and reducing the cost and time required to drill and complete the well. Drilling and well completion operations require that the purpose and schedule of work activities be well understood in terms of scope, sequence of activities, and respective duration. In general, typical day-to-day drilling operations do not present difficult challenges. However, service contractors and personnel necessary to perform specific work activities that are beyond the typical onsite drilling capabilities need to be scheduled and available to minimize the time that onsite drilling equipment and personnel remain idle (i.e., “standby”). The time waiting for specific personnel and/or equipment to become available to perform needed and or planned operations (i.e., casing, stemming, geophysical logging) has significant costs to the project in terms of hourly rates for the drill rig, support equipment, and site personnel necessary for typical operations. It is recognized that in some cases, standby time cannot be anticipated due to unforeseen circumstances such as mechanical breakdowns or weather conditions (e.g., lightning, winds). However, the amount of standby time can be minimized though appropriate planning and scheduling. Well ER-3-3 operations were conducted over a total duration of 39 days (including mobilization and demobilization). Standby time accounted for approximately 11.5 days of the total duration of the Well ER-3-3 operations, or approximately 30 percent of the time expended over the entire operation. Although some standby time should always be anticipated, the proportion of standby time to the total duration of the work suggests opportunities for improvement.

Lesson Learned/Recommendation: The total amount of standby time at Well ER-3-3 was dominated by two factors: (1) A worker safety incident/injury that resulted in approximately five days of standby time as the incident was investigated and evaluated, and corrective measures identified and implemented to prevent potential reoccurrence. (2) There were cumulative delays that resulted from the availability of the M&O stemming/cementing crews and geophysical logging service contractors.

There is a significant potential for safety incidents and or worker injuries in the execution of drilling and drilling-related operations. Much effort is placed by all participating contractors on mitigating workplace hazards and emphasizing safe work practices. However, in this specific instance, the process of investigating and evaluating the incident and implementing corrective actions required a substantially longer period than might be expected for an incident of this nature. Incidents in the workplace should never be minimized in importance. However, it should be recognized that there are budgetary and schedule considerations relating to a suspension in operations standby that should place a priority on the timely and adequate resolution of the safety incident or concern.

Standby time associated with the availability the M&O contractor stemming/cementing crews and, to a lesser extent, geophysical logging service contractors also impacted the operations. Services of this nature are typically on a "call-out" basis, dependent on the specific needs at the well site. Scheduling and confirming availability with these contractors should be a priority and should be initiated within a reasonable time frame in advance of their anticipated arrival on site. Stemming and cementing operations as executed by the M&O contractor had several situations where personnel engaged in these activities were impacted by work hour restrictions that created standby periods for the site. For example, in a single instance, more than 30 hours of site standby resulted from a stemming/cementing personnel work hour restriction. After returning to the site some 30 hours later, the crew required only approximately 1 hour to complete the cementing operation. In the future, consideration should be given to providing reasonable and practical relief from the work hour requirements for M&O personnel who are involved in activities such as stemming and cementing.

9.2 Suggested Follow-on Activities

As noted previously, difficulties were encountered during the drilling and completion at Well ER-3-3. These issues (e.g., drilling fluids and sloughed material in the main completion casing) will likely impact the ability to produce groundwater from the m1 completion interval situated in the LCA. Rehabilitation of the affected LCA completion may be possible using air-lift techniques and or dual-wall reverse circulation techniques. The design of a program of this nature should be considered before installing an electric submersible pump and attempting to produce groundwater from this interval for aquifer testing or groundwater sampling. Given the anticipated longer-term use of this well in groundwater monitoring, work of this nature may also benefit the use of the well for years into the future.

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Appendix A

Lithologic Log for Well ER-3-3

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
0-505.97 (0-1,660)	505.97 (1,660)	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 120-1,150 ft:** cuttings consist of loose, medium to coarse sand-size fragments of welded and nonwelded tuff, lavas, and minor (2-5%) carbonates (dolomite) and clastics (siltstone). Matrix (overall color): yellow (10YR 7/6) > yellowish brown (10YR 5/6); Most fragments are sub-rounded to rounded with minor flattened pieces. Weakly to moderately reactive with HCl (minor caliche?). **From 1,150-1,420 ft:** Tuffaceous Alluvium, moderately > poorly indurated, caliche coating/matrix; Matrix color: pinkish white (7.5YR 8/2) > brownish yellow (10YR 6/6); Approximately 98% volcanic fragments, (1-2%) carbonate/clastics, and the remainder is caliche and silica? Crystal fragments (loose and in clayey matrix), sanidine, quartz (mostly term., some dipyramidal, minor pink tint), plagioclase, mafics (preserved only in volcanic fragments); 50% coarse sand > gravel size (angular > rounded) and 50% silt/sand-size (ash, loose crystal fragments), strong to moderate reaction with HCl; **From 1,420-1,500 ft:** Tuffaceous Alluvium; Matrix (overall): light brown (7.5YR 6/4) > light yellowish brown (10YR 6/4) > pinkish white (7.5YR 8/2) > light olive brown (2.5Y 5/4); carbonate/clastic fragments <1%, gradually increasing (with depth) caliche/ clayey (altered matrix) coating; **From 1,500-1,660 ft:** Tuffaceous Alluvium; carbonate/clastics increasing to between (2-4%); Geophysical logs (GR and SGR) indicate a clear break at 1,660 ft bgs marking the alluvium/bedrock contact, abundant cement fragments from 120-130 ft and no sample from 330-380 ft.	Quaternary/Tertiary Alluvium (QTa)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	Thickness m (ft)	Sample Type [a]	Lithologic Description [b]	Stratigraphic Unit (Map symbol)
505.97-585.22 (1,660-1,920)	79.25 (260)	DA	**Nonwelded to Partially Welded Ash-flow Tuff:** crystal-rich, vitric/partially altered; Matrix color: reddish gray (5R 6/1) > reddish gray (2.5YR 6/1) > light gray (5YR 7/1); Phenocrysts: (15-20%), sanidine (mod. chatoyant), quartz (terminated, some dipyramidal, clear, rare pink tint, rare resorbed texture), plagioclase, rare sphene?, Mafics (1%): biotite (black>bronze, unoxidized>oxidized?), rare pyroxene?, oxide (magnetite?); Pumice (7-15%): white (5YR 8/1) > pinkish white (5YR 8/2), vitric > relict vitric texture, some plucked/vapor phase corroded; Lithics (2-5%): welded tuff, light red (10R 7/6) > pale red (7.5YR 7/4), lava? red (7.5YR 5/8), basalt very dark gray (N 3/1) > dark gray (N 4/1); glass shards black (N 2.5/1), minor to moderate contamination from 1,660-1,730 ft.	Timber Mountain Ammonia Tanks Tuff (Tma)
585.22-594.36 (1,920-1,950)	9.14 (30)	DA	**bedded and reworked tuff:** crystal-rich, vitric/partially altered; Matrix color: reddish yellow (5YR 7/6) > reddish yellow (7.5YR 6/8) > dark gray (7.5YR 4/1) > pinkish white (7.5YR 8/2); Phenocrysts (10-15%): quartz (terminated, rare dipyramidal, mostly clear, rare pink tint), sanidine (mod. chatoyant), plagioclase, Mafics (≤1%): biotite (black>bronze, unoxidized>oxidized), oxides (magnetite); Pumice (≥10%): white (7.5YR 8/1) > pinkish white (2.5YR 8/2), vitric>vapor phase corroded>altered (with relict vitric texture); Lithics (5-7%): welded tuff/ lava reddish brown (5YR 5/4) > reddish yellow (5YR 6/6); beds(?) with abundant glass shards and bubbles black (N 2.5/1) > reddish black (2.5YR 2.5/1), very poor recovery over this interval.	Timber Mountain Ammonia Tanks bedded tuff (Tmab)
594.36-621.79 (1,950-2,040)	27.43 (90)	DA	**Nonwelded to Partially Welded Ash-flow Tuff:** crystal-rich, mafic-poor, devitrified, vapor phase mineralized/altered, poorly to mod. indurated; Matrix color: light reddish brown (2.5YR 6/4) > reddish brown (2.5YR 4/4) > light red (10R 7/6) > pale red (10R 7/3); Phenocryst (10-15%?): sanidine (rare chatoyant), quartz (terminated, rare>minor dipyramidal, rare pink tint), plagioclase, Mafics (1%): biotite (black/unoxidized, euhedral), magnetite; Pumice (10-15%): white (7.5YR 8/1) > pinkish white (5YR 8/2), mostly 1-2 mm, relict vitric/vapor phase altered; Lithics: (3-5%?), welded tuff red (2.5YR 5/6) > pale red (2.5YR 7/2); volcanic glass (shards?) black (5YR 2.5/1), contamination (10-20%?) including alluvium and nonwelded/bedded tuff (Tma?).	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
621.79-664.46 (2,040-2,180)	42.67 (140)	DA	**Partially to Moderately Welded Ash-flow Tuff (Breccia Zone):** crystal-rich, mafic-poor, devitrified, partially altered (silica/limonite), vapor phase mineralized; Matrix color: reddish brown (5YR 5/4) > light reddish brown (5YR 6/4) > pinkish gray (5YR 7/2), ~ (10-15%) of cuttings are yellowish red (5YR 5/8 to 4/4) and red (10R 4/6); Phenocrysts (10-15%): sanidine (rare chatoyant), quartz (terminated, rare dipyramidal, rare pink tint), plagioclase, Mafics (≤1%): biotite (black, unoxidized, euhedral>fragments), oxides (magnetite?); Pumice: (10-15%): white (7.5YR 8/1) > pinkish white (5YR 8/2) > light gray (7.5YR 7/1), relict vitric texture, minor to mod. flattening; Lithics (1-3%): welded tuff red (2.5YR 5/6) > pale red (2.5YR 7/2), lava/basalt black (N 2.5/1) > dark reddish gray (5R 3/1); Possible Breccia/Fault zone shows both angular breccia and rounded/ground material cemented, with open space. Open space coated/filled with drussy quartz, limonite(?), and unknown minerals. Contamination varies from (10-20%) possibly higher, mixed alluvium and tuffs. specially noticeable from 2,090-2,180. Casing was set at 2,039 ft.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
664.46-679.70 (2,180-2,230)	15.24 (50)	DA	**Densely Welded Ash-flow Tuff:** crystal-rich, mafic-poor, devitrified, partially altered (silica/limonite), vapor phase mineralized; Description as listed above (from 2,040-2,180 ft); Pumice flattening between 4:1 to 6:1 or greater.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
679.70-691.90 (2,230-2,270)	12.19 (40)	DA	**Moderately to Partially Welded Ash-fall Tuff:** crystal-rich, mafic-poor, devitrified, vapor phase mineralized: Matrix color: reddish brown (2.5YR 5/3) > light reddish brown (2.5YR 6/4) > red (2.5YR 5/8); Phenocrysts (10-15%): sanidine (rare chatoyant), quartz (terminated, rare dipyramidal, clear), plagioclase, Mafics (≤1%): biotite (black, unoxidized), oxides (magnetite), trace hornblende(?); Pumice (10-15%): white (10R 8/1) > light gray (5YR 7/1), devitrified/vapor phase altered with relict vitric textures, mostly 1-2 mm - rare to 5 mm; Lithics (3-5%): welded tuff/lava red (2.5YR 5/6) > pale red (2.5YR 7/2); rare/unknown mineral (analcime?) (<1-2%) white (N9) > light pink (10R 8/2) - fracture/void filling?, minor cement contamination (up to 5%?).	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
691.90-719.33 (2,270-2,360)	27.43 (90)	DA	**Partially to Nonwelded Ash-flow Tuff:** crystal-rich, mafic-poor, devitrified>partially vitric, minor alteration (argillic/zeolitic); Matrix color: light reddish brown (5YR 6/4) > light red (2.5YR 6/6) becoming mottled (2,295-2,360) light red (10R 7/6) > pale red (10R 7/4) and white (7.5YR 8/1) > white (N9) interbedded with pale red (10R 6/3) > light reddish brown (2.5YR 6/4); Phenocrysts (5-15%): sanidine, quartz (term., rare>minor dipyramidal, clear, rare pink tint), plagioclase, Mafics (1%): biotite (black/unoxidized?), Mn oxides, magnetite(?); Pumice (5-15%): light gray (5YR 7/1)>white (10R 8/1)> white (N9) > pink (2.5YR 8/4), mostly 1-2 mm - rare to 5 mm, near base of interval (2,270-2,295) some pumice have glassy core; Lithics (1-5%): welded tuff/lava red (10R 4/6) > weak red (7.5YR 5/4) > weak red (2.5YR 4/2), volcanic glass black (5YR 2.5/1) grading down into black 7.5YR 2.5/1) > black (10G 2.5/1);cement contamination variable (1-5%?).	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
719.33-752.86 (2,360-2,470)	33.53 (110)	DA	**bedded tuff and Nonwelded Ash-flow Tuff:** crystal-moderate, vitric>altered (argillic/zeolitic); Matrix color: light brown (7.5YR 6/4) > pink (7.5YR 7/4) > very pale brown (10 YR 8/3) interbedded with white (N9) > white (2.5YR 8/1) porcelainous ash-fall beds; Phenocrysts (5-10%): sanidine, quartz (terminated, dipyramidal, clear), plagioclase, Mafics (≤0.5%): biotite (black, unoxidized), Mn oxides (spots,?), white ash-fall beds (0%) phenocrysts; Pumice (10-20%): white (N9) > pinkish white (2.5YR 8/2) > pale yellow (2.5Y 8/2) rare, alteration (zeolitic/argillic) increasing with depth; Lithics: (1%), welded tuff/lava red (7.5R 4/8) typically very small (≤1 mm), volcanic glass black (5YR 2.5/1); One, possibly more, fine (porcelainous) ash beds (weakly silicified), some material appears bedded/reworked and have a higher phenocryst content, distinctive “peppered” appearance from pale matrix with very small black spots.	tuff of Holmes Road (Tmrh)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
752.86-771.14 (2,470-2,530)	18.29 (60)	DA/DB4	**bedded and reworked:** crystal-poor, altered (zeolitic/argillic/silicification?); Matrix color: light brown (7.5YR 6/4 to 6/3) > brown (7.5YR 5/3) > reddish brown (7.5YR 6/6); Phenocrysts (3-5%): sanidine, plagioclase, quartz (<1%, terminated, rare dipyramidal), Mafics (1%): Mn oxide (spots), biotite (black, unoxidized, euhedral), hornblende (?, greenish black), magnetite (?); Pumice (10-15%): white (N9) > white (2.5Y 8/1) > pale yellow (5Y 8/4), pumice mostly 1-2 mm, some relict vitric texture; Lithics (2-3%): welded tuff/lava red (10R 4/8) > light red (7.5YR 6/6) and rare very dark gray (N 3/1), most lithics <2 mm, volcanic glass black (5GY 2.5/1) - very small (≤1 mm); some fragments appear to be altered (silica/opal [?]) fine ash beds. Overall, beds weakly to moderately indurated and pervasively altered, many fragments have a waxy to vitreous luster and some relict vitric textures preserved. From 2,460-2,540 ft heavy cement contamination (10-20%) and pyroclastic material from uphole (Tmr?), overall 20-40% contamination.	Pre-Timber Mountain Tuff - Post-Wahmonie Tuff, undivided (Tm/Tw)
771.14-781.81 (2,530-2,565)	10.67 (35)	DA	**Nonwelded Ash-flow Tuff and bedded tuff:** crystal-poor, mafic-rich(?), pervasively altered (zeolitic/argillic); Matrix color (mottled): pale yellow (2.5Y 7/3 to 7/4) > very pale brown (10YR 7/4) with bands/spots of red (7.5R 4/6) > light red (7.5YR 6/6); Phenocrysts (3-5%): sanidine (rare chatoyant), quartz (terminated, rare dipyramidal, clear), Mafics (1-2%): biotite (black, unoxidized, euhedral), pyroxene (?, granular), Mn oxides, magnetite (?); Pumice (10-15%+?): pale yellow (5Y 8/3 to 8/4) > pale yellow (2.5Y 8/2) > red (7.5R 4/6), some relict vitric texture, blocky to flattened (?); Lithics (1-2%): welded tuff/lava red (7.5R 5/6) > pale red (7.5R 6/3) and rare basalt (?) black (N 2.5/1); Overall distinctive appearance with pale yellow mass and red bands/spots. Possible bedding/change noted on geophysical logs (Density, Resistivity, GR, and Caliper).	Pre-Timber Mountain Tuff - Post-Wahmonie Tuff, undivided (Tm/Tw)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
781.81-801.62 (2,565-2,630)	19.81 (65)	DA	**Nonwelded to Partially Welded Ash-flow Tuff:** crystal-rich, mafic-rich (?), altered (vapor phase, quartzo-feldspathic [?]); Matrix (spotted) color: weak red (7.5R 5/4 to 5/3) > pale red (7.5R 6/2 to 6/3) and red (7.5R 4/8 to 5/6) spots and larger patches, by 2,610 ft 50% of sample is dominantly red and by 2,620 ft 70%; Phenocrysts (3-5%): sanidine, quartz (terminated, clear), Mafics (<1-2%): biotite (black>golden, unoxidized euhedral>fragment, books/sheets), magnetite (oxidized), hornblende (?); Pumice (5-10%): white (7.5R 8/1) > light pink (7.5R 8/2) > white (N9), mostly 1-2 mm, blocky>minor flattening, vapor phase corroded cavities many with relict vitric texture; Lithics (1-3%): lava (aphanitic?) very dusky red (7.5R 2.5/2), welded tuff/lava red (7.5R 4/6) > reddish brown (2.5YR 4/4), rare basalt (vesicular) dusky red (7.5R 3/3), vesicle in basalt filled with clusters of black acicular crystals; Rare to minor preserved (altered) ash-shards and bubbles. Hematite (?) coating on surfaces of fragments indicating open space, base picked from strong geophysical log (Density, Resistivity, GR, and Caliper) response, spots (5-25%) increasing downward. Zone of intense oxidation and bleaching, possible fault or breccia zone with some vapor phase corrosion.	Pre-Timber Mountain Tuff - Post-Wahmonie Tuff, undivided (Tm/Tw)
801.62-806.20 (2,630-2,645)	4.57 (15)	DB4	**bedded tuff:** bedded tuff: crystal-poor, mafic-rich, altered (vitric to partially zeolitic, vapor phase; Matrix (mottled - salt & pepper) color: (overall) gray (5YR 5/1), made up of white (7.5YR 8/1) and black (7.5YR 2.5/1) > very dark brown (10YR 2/2); Phenocrysts (5-7%): felsic (plagioclase?), Mafics (2-5%): biotite (black, unoxidized, euhedral>fragment, books/sheets, some biotite has “birds-eye” texture and sooty appearance), hornblende (?, dark grayish green 5G 3/2); Pumice (5-10%): white 5YR 8/1) > gray (5YR 5/1), pumice content uncertain due to poor cuttings; Lithics (<1%): volcanic (?) yellowish brown (10YR 5/6) high uncertainty; Abundant glass shards and partially vitric pumice (very dark brown (10YR 2/2) > black [7.5YR 2.5/1]) possibly up to 20-30%? Zone located primarily based on geophysical logs (Resistivity, Density, and Caliper). Cuttings are not representative of interval (60-70%) contamination?	Wahmonie Formation (Tw)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
806.20-816.86 (2,645-2,680)	10.67 (35)	DA	**bedded tuff and Nonwelded Ash-flow Tuff:** mafic-rich, pervasively altered (zeolitic); Matrix color: pale yellow (5Y 7/3) > pale yellow (5Y 8/2) > very pale brown (10YR 8/3), ash bed (porcelainous) pinkish white (7.5YR 8/2), approximately 5% of sample from 2,670-2,680 ft; Phenocrysts (3-7%): sanidine, plagioclase, quartz (?, trace), Mafics: (1-3%), biotite (black>golden, euhedral/ fragment, books/sheets), hornblende (dark grayish green 5G 3/2), magnetite (?); Pumice (5-10%): pale yellow (2.5Y 7/4) > white (5Y 8/1) > pale yellow (5Y 7/4 to 8/3), mostly 1-2 mm, rare relict vitric texture; Lithics: (<1%), volcanic; Small patches (pumice?) of olive yellow (5Y 6/6) sometime appear associated with phenocrysts? Altered/oxidation layer possibly related to pumice?	Tunnel formation, undifferentiated (Tn)
816.86-830.58 (2,680-2,725)	13.72 (45)	DA/DB4	**bedded tuff and Nonwelded Ash-flow Tuff:** crystal-poor, mafic-poor, pumice-rich, pervasively altered (zeolitic), oxidized; Matrix color: dusky red (10R 3/4) > weak red (10R 4/4) > pale red (10R 6/4); Phenocrysts (2-3%): feldspar (sanidine?), Mafics (≤1%): biotite (?, black), magnetite (partially oxidized); Pumice (20-40%): white (N9) > pinkish white (2.5YR 8/2), very small (≤1 mm) and blocky, rare relict vitric texture, vapor phase corroded (?); Lithics: (≤1%): volcanic, basalt (vesicular, trace); Matrix color changes from 2,645-2,725 ft possibly indicate bedding(?), Geophysical Logs (Density, Resistivity, GR, and Caliper) indicate a break, base of Tn.	Tunnel formation, undifferentiated (Tn)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
830.58-859.54 (2,725-2,820)	28.96 (95)	DA/DB4	**bedded tuffs and volcanoclastic sediments: From 2,725-2,790 ft:** crystal-poor, lithic-rich, altered (matrix, argillic); Matrix (bedded tuff) color: white (5Y 8/1) > white (N8) > white (2.5Y 8/1), Matrix (sediments) color: dark reddish brown (2.5YR 3/4) > dark red (2.5YR 3/6) > dark reddish brown (2.5YR 2.5/4); Phenocrysts (bedded tuff) (2-5%): sanidine, plagioclase (?), Mafics (1-2%): biotite (black, euhedral, books), hornblende (?, pyroxene), magnetite (?); Pumice: (20-40%?): white (N9) > light bluish gray (5PB 8/1), very small ($\leq$1 mm) and rarely larger; Lithics: (2-7%+?), volcanic, clastic, and carbonate, distinctive dark greenish gray (5GY 4/1) > dark greenish gray (5G 4/1) to grayish green (5G 5/2) siltstone, alters/oxidizes to a light olive brown (2.5Y 5/4) (rare) and rare red (7.5R 4/6) spots/patches, all lithics have a matrix coating of white or dark reddish brown material; Sediments: interbeded siltstone and sandstone (size) material; Siltstone: very fine grained, fissile/thin bedded, Sandstone: fine sand-size crystal fragments (feldspars) with red (7.5R 4/6) > dusky red (7.5R 3/4) matrix; Lithics (2-5%): clastic (including distinctive siltstone mentioned above), volcanic (?); **From 2,790-2,8200 ft:** crystal-poor, lithic-rich, altered (matrix, argillic); Matrix color: dark reddish brown (2.5YR 3/4) > dark red (2.5YR 3/6) > dark reddish brown (2.5YR 2.5/4); Phenocrysts: as above; Lithics (10-20%): carbonates/clastics gray (2.5Y 6/1) > dark olive gray (5Y 3/2) > light gray (2.5Y 7/1), most lithics are coarse sand to gravel size, are subrounded with at least one broken face, and matrix coating on unbroken surfaces.	Older Tunnel Beds (Ton)
859.54-909.83 (2,820-2,985)	50.29 (165)	DA/DB4	**Colluvium and Nonwelded Ash-flow Tuff, minor bedded tuff (?):** altered (argillic): Matrix color: red (2.5YR 5/6) > dark reddish brown (2.5YR 3/4); Colluvium: dominantly carbonate/clastic material (~3-10 mm), gray (2.5Y 6/1) > light gray (2.5Y 7/1), rare quartzite white (N9) and siltstone light gray (5Y 7/2), cemented/incorporated in clay to fine ash (?); fragments are subangular>subrounded; From 2,830-2,900 ft distinct change in cuttings: cuttings are much smaller (~1-4 mm) and palmate to flat chips with sharp edges (typical of drilled/spalled material with no visible matrix material on any fragments. Small rare pieces of clay (?) dark greenish gray (5BG 4/1). Possibly a slide block of Paleozoic material? Samples are heavily contaminated (50%) with volcanics from uphole.	Paleocolluvium/older tuffs (Tlc/To)

Table A-1
Lithologic Log for Well ER-3-3
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
909.83-973.20 (2,985-3,192.9)	63.37 (207.9)	DA	**Dolomite and minor interbedded Limestone:** Matrix color (Dolomite): gray (2.5Y 6/1) > light gray (2.5Y 7/1) > dark olive gray (5Y 3/2), Matrix color (Limestone): gray (N4); Dolomite: recrystallized (fine>medium grain), minor>moderate brecciation(?), veining (calcite?), fracturing, with incipient clay alteration along fractures/bedding planes, rock has weak reaction with HCl when scratched, Limestone is fine grained to micritic with minor to rare pyrite, thin to platty fragments (some larger fragments exhibit conchoidal or horsetail patterns); Approximately 10% of material is comprised of brecciated material (rotated (?) clasts supported by fine to coarse grained calcite (or dolomite after calcite), additional fragments appear to be made up of ground material and small clasts with apparent bedding planes, bedding planes have “sooty” bluish black (10B 2.5/1) material (Mn oxide or carbon??) coating portions of open (?) surfaces. Fine to coarse grained pyrite is visible on some of these surfaces and within the matrix. Fragments show moderate to strong reaction with HCl.	Paleozoic rocks (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
SGR = Spectral gamma ray

Appendix B

Tritium Activities during Drilling of Well ER-3-3

Table B-1
Tritium Activities during Drilling of Well ER-3-3
(Page 1 of 5)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
1	02/21/2016	N/A	N/A	437	2,392.00	Make-up water
2	02/22/2016	N/A	N/A	3,239	1,932.07	Make-up water
3	02/22/2016	39.62	130	4,558	10,046.78	Discharge line
4	02/22/2016	42.06	138	0	1,674.46	Discharge line
5	02/22/2016	46.94	154	0	1,168.23	Discharge line
6	02/22/2016	51.82	170	328	1,321.95	Discharge line
7	02/22/2016	55.78	183	871	1,794.07	Discharge line
8	02/22/2016	64.62	212	138	1,629.66	Discharge line
9	02/22/2016	69.80	229	1,383	1,667.55	Discharge line
10	02/22/2016	77.42	254	1,003	1,569.81	Discharge line
11	02/22/2016	84.12	276	0	1,733.20	Discharge line
12	02/22/2016	90.83	298	0	1,870.32	Discharge line
13	02/22/2016	98.15	322	1,386	3,588.14	Discharge line
14	02/22/2016	106.68	350	0	1,881.87	Discharge line
15	02/22/2016	115.52	379	0	1,974.52	Discharge line
16	02/22/2016	120.40	395	0	1,974.52	Discharge line
17	02/22/2016	128.02	420	2,379	1,530.53	Discharge line
18	02/22/2016	134.11	440	0	1,725.84	Discharge line
19	02/22/2016	138.38	454	0	1,720.56	Discharge line
20	02/22/2016	N/A	N/A	0	1,858.37	Make-up water
21	02/22/2016	144.17	473	0	1,381.68	Discharge line
22	02/22/2016	152.40	500	0	1,914.69	Discharge line
23	02/22/2016	163.68	537	0	1,359.39	Discharge line
24	02/22/2016	176.78	580	883	1,435.25	Discharge line
25	02/23/2016	188.98	620	572	1,400.46	Discharge line
26	02/23/2016	N/A	N/A	0	1,720.56	Make-up water
27	02/23/2016	198.73	652	0	2,019.19	Discharge line
28	02/23/2016	210.31	690	0	1,468.77	Discharge line
29	02/23/2016	216.71	711	0	2,316.14	Discharge line
30	02/23/2016	226.47	743	0	1,794.84	Discharge line

Table B-1
Tritium Activities during Drilling of Well ER-3-3
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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)	
31	02/23/2016	249.63	819	1,645	1,343.30	Discharge line
32	02/23/2016	263.65	865	0	1,624.23	Discharge line
33	02/23/2016	271.88	892	0	2,062.86	Discharge line
34	02/23/2016	292.61	960	0	2,059.71	Discharge line
35	02/23/2016	304.50	999	0	1,941.51	Discharge line
36	02/23/2016	321.87	1,056	0	1,958.00	Discharge line
37	02/23/2016	331.32	1,087	891	1,343.30	Discharge line
38	02/23/2016	341.07	1,119	0	1,870.32	Discharge line
39	02/23/2016	350.82	1,151	0	1,289.00	Discharge line
40	02/23/2016	360.58	1,183	0	2,041.78	Discharge line
41	02/23/2016	370.33	1,215	0	1,395.49	Discharge line
42	02/23/2016	381.61	1,252	0	2,188.44	Discharge line
43	02/23/2016	390.75	1,282	0	1,395.39	Discharge line
44	02/24/2016	N/A	N/A	0	1,886.04	Make-up water
45	02/24/2016	417.58	1,370	0	2,230.36	Discharge line
46	02/24/2016	429.77	1,410	0	1,990.99	Discharge line
47	02/24/2016	444.70	1,459	0	2,527.39	Discharge line
48	02/24/2016	450.19	1,477	0	2,430.18	Discharge line
49	02/24/2016	463.30	1,520	0	2,041.78	Discharge line
50	02/24/2016	469.39	1,540	118	1,486.80	Discharge line
51	02/24/2016	477.93	1,568	0	2,105.58	Discharge line
52	02/24/2016	490.73	1,610	1,881	2,001.46	Discharge line
53	02/24/2016	493.78	1,620	0	2,062.86	Discharge line
54	02/24/2016	496.82	1,630	0	2,173.50	Discharge line
55	02/24/2016	499.87	1,640	0	2,173.50	Discharge line
56	02/24/2016	502.92	1,650	428	1,255.85	Discharge line
57	02/24/2016	505.97	1,660	0	1,543.09	Discharge line
58	02/24/2016	509.02	1,670	0	2,041.78	Discharge line
59	02/24/2016	512.06	1,680	0	1,900.41	Discharge line
60	02/24/2016	515.11	1,690	471	1,522.24	Discharge line

Table B-1
Tritium Activities during Drilling of Well ER-3-3
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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)	
61	02/24/2016	518.16	1,700	0	2,228.07	Discharge line
62	02/24/2016	521.21	1,710	471	1,522.24	Discharge line
63	02/24/2016	524.26	1,720	0	2,153.80	Discharge line
64	02/24/2016	527.30	1,730	490	1,530.53	Discharge line
65	02/24/2016	530.35	1,740	0	2,216.70	Discharge line
66	02/24/2016	533.40	1,750	0	2,228.68	Discharge line
67	02/24/2016	539.50	1,770	0	2,019.19	Discharge line
68	02/24/2016	545.59	1,790	0	2,188.44	Discharge line
69	02/24/2016	554.74	1,820	0	2,062.86	Discharge line
70	02/24/2016	557.78	1,830	0	1,536.54	Discharge line
71	02/24/2016	563.88	1,850	0	1,968.77	Discharge line
72	02/24/2016	570.89	1,873	0	1,629.66	Discharge line
73	02/24/2016	584.30	1,917	0	2,019.19	Discharge line
74	02/24/2016	594.97	1,952	0	1,486.80	Discharge line
75	02/24/2016	611.73	2,007	0	1,841.75	Discharge line
76	02/24/2016	623.32	2,045	0	1,325.83	Discharge line
77	02/24/2016	633.98	2,080	856	1,422.32	Discharge line
78	02/25/2016	N/A	N/A	0	1,846.12	Make-up water
79	02/25/2016	649.22	2,130	0	1,846.12	Discharge line
80	02/25/2016	658.06	2,159	471	1,920.67	Discharge line
81	02/25/2016	665.07	2,182	0	1,676.53	Discharge line
82	02/25/2016	671.78	2,204	0	1,870.32	Discharge line
83	02/25/2016	671.78	2,204	0	1,778.14	Discharge line
84	02/26/2016	N/A	N/A	0	1,730.13	Make-up water
85	02/26/2016	453.24	1,487	710	2,195.93	Cleaning out hole - discharge line
86	02/27/2016	N/A	N/A	0	1,676.53	Make-up water
87	02/28/2016	N/A	N/A	182	1,486.80	Make-up water
88	02/29/2016	N/A	N/A	972	1,667.55	Make-up water
89	03/01/2016	N/A	N/A	0	2,068.42	Make-up water
90	03/01/2016	673.61	2,210	443	1,445.50	Discharge line

Table B-1
Tritium Activities during Drilling of Well ER-3-3
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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)	
91	03/02/2016	N/A	N/A	0	1,815.32	Make-up water
92	03/02/2016	675.13	2,215	0	1,928.77	Discharge line
93	03/02/2016	676.66	2,220	1,442	1,422.32	Discharge line
94	03/02/2016	680.62	2,233	957	1,435.25	Discharge line
95	03/02/2016	680.92	2,234	1,187	2,133.17	Discharge line
96	03/02/2016	681.84	2,237	0	2,256.59	Discharge line
97	03/02/2016	687.02	2,254	0	2,245.95	Discharge line
98	03/02/2016	690.68	2,266	0	2,105.58	Discharge line
99	03/02/2016	697.08	2,287	575	1,272.60	Discharge line
100	03/02/2016	700.43	2,298	577	1,958.00	Discharge line
101	03/02/2016	700.43	2,298	496	1,536.54	Discharge line
102	03/02/2016	700.43	2,298	0	2,019.19	Discharge line
103	03/03/2016	N/A	N/A	0	2,150.70	Make-up water
104	03/04/2016	N/A	N/A	3,930	1,730.13	Make-up water
105	03/05/2016	N/A	N/A	0	1,730.13	Make-up water
106	03/05/2016	694.33	2,278	2,891	1,343.30	Discharge line
107	03/05/2016	701.04	2,300	0	1,627.56	Discharge line
108	03/05/2016	707.14	2,320	244	1,493.90	Discharge line
109	03/05/2016	717.19	2,353	646	1,445.50	Discharge line
110	03/05/2016	724.51	2,377	262	1,459.50	Discharge line
111	03/05/2016	733.35	2,406	0	1,493.90	Discharge line
112	03/05/2016	739.75	2,427	712	1,369.40	Discharge line
113	03/05/2016	749.20	2,458	221	1,357.70	Discharge line
114	03/05/2016	758.95	2,490	296	1,406.40	Discharge line
115	03/05/2016	768.71	2,522	856	1,369.40	Discharge line
116	03/05/2016	775.72	2,545	303	1,493.90	Discharge line
117	03/05/2016	785.47	2,577	0	1,453.48	Discharge line
118	03/06/2016	N/A	N/A	861	1,395.39	Make-up water
119	03/06/2016	794.31	2,606	1,017	1,435.25	Discharge line
120	03/06/2016	800.40	2,626	0	1,536.54	Discharge line

Table B-1
Tritium Activities during Drilling of Well ER-3-3
(Page 5 of 5)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
121	03/06/2016	808.02	2,651	566	1,445.50	Discharge line
122	03/06/2016	817.78	2,683	0	1,540.62	Discharge line
123	03/06/2016	826.01	2,710	0	1,395.39	Discharge line
124	03/06/2016	833.63	2,735	0	1,540.62	Discharge line
125	03/06/2016	837.59	2,748	0	1,395.39	Discharge line
126	03/06/2016	847.04	2,779	466	2,114.60	Discharge line
127	03/06/2016	856.79	2,811	0	2,571.70	Discharge line
128	03/06/2016	866.24	2,842	876	1,733.20	Discharge line
129	03/06/2016	867.46	2,846	692	1,435.25	Discharge line
130	03/06/2016	876.00	2,874	527	1,536.54	Discharge line
131	03/06/2016	886.97	2,910	602	1,406.43	Discharge line
132	03/06/2016	894.28	2,934	921	1,734.80	Discharge line
133	03/06/2016	902.21	2,960	1,099	1,445.50	Discharge line
134	03/06/2016	908.30	2,980	824	1,784.19	Discharge line
135	03/06/2016	915.31	3,003	879	1,530.53	Discharge line
136	03/06/2016	924.15	3,032	0	1,771.17	Discharge line
137	03/06/2016	928.42	3,046	376	1,631.25	Discharge line
138	03/06/2016	935.43	3,069	0	1,870.32	Discharge line
139	03/06/2016	943.05	3,094	942	1,381.68	Discharge line
140	03/06/2016	950.67	3,119	637	1,824.84	Discharge line
141	03/06/2016	957.38	3,141	652	1,445.50	Discharge line
142	03/06/2016	964.69	3,165	0	1,737.14	Discharge line
143	03/07/2016	973.23	3,193	3,842	1,542.62	Discharge line
144	03/07/2016	N/A	N/A	765	1,542.62	Make-up water
145	03/12/2016	N/A	N/A	0	4,022.53	Make-up water
146	03/14/2016	N/A	N/A	351	4,397.77	Make-up water

N/A = Not applicable

Appendix C

Bromide Concentrations and Calculated Water Production during Drilling at Well ER-3-3

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

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
02/22/2016	0:30	130	14.3	13.6	10	7	0.4
02/22/2016	4:00	170	37.5	35.4	10	7	0.4
02/22/2016	8:00	264	24.0	22.4	10	7	1
02/22/2016	13:30	399	39.0	31.6	12	8	2
02/22/2016	19:20	450	40.2	32.5	12	8	2
02/22/2016	23:20	573	34.4	27.1	12	8	2
02/23/2016	03:20	710	30.3	27.1	12	8	1
02/23/2016	07:20	860	20.0	17.4	12	8	1
02/23/2016	11:35	1,014	27.8	23.5	12	8	2
02/23/2016	17:30	1,196	37.2	29.0	15	11	3
02/23/2016	21:50	1,305	19.9	26.6	15	11	-3
02/24/2016	1:30	1,393	30.2	29.5	18	13	0
02/24/2016	4:30	1,489	29.4	34.3	18	13	-2
02/24/2016	5:30	1,536	27.8	27.7	18	13	0
02/24/2016	6:30	1,559	27.7	22.4	18	13	3
02/24/2016	8:00	1,590	25.7	22.1	20	14	2
02/24/2016	8:50	1,630	24.6	25.2	20	14	0
02/24/2016	9:30	1,654	24.9	22.6	20	14	1
02/24/2016	10:30	1,676	23.3	19.4	20	14	3
02/24/2016	11:30	1,694	18.2	16.1	20	14	2
02/24/2016	12:30	1,717	22.8	20.2	20	14	2
02/24/2016	13:30	1,739	27.1	18.5	20	14	7
02/24/2016	14:30	1,766	24.2	18.3	20	14	5
02/24/2016	15:30	1,805	30.4	18.1	20	14	10
02/24/2016	16:30	1,827	34.2	23.8	20	14	6
02/24/2016	17:30	1,849	19.4	21.4	20	14	-1
02/24/2016	18:30	1,871	24.6	14.2	20	14	10
02/24/2016	19:30	1,924	32.00	9.61	20	14	33
02/24/2016	20:30	1,960	30.40	9.74	20	14	30
02/24/2016	21:30	2,010	25.00	8.88	20	14	25

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-3-3
(Page 2 of 3)

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
02/24/2016	22:30	2,053	25.40	1.95	20	14	168
02/24/2016	23:30	2,081	26.40	3.08	20	14	106
02/25/2016	00:30	2,143	29.80	1.86	20	14	210
02/25/2016	01:30	2,160	28.80	1.72	20	14	220
02/25/2016	04:30	2,182	26.20	1.27	20	14	275
03/01/2016	18:00	2,203	42.20	1.61	12	8	212
03/01/2016	21:30	2,203	40.90	1.90	12	8	172
03/01/2016	23:30	2,210	52.40	2.11	12	8	200
03/02/2016	00:30	2,215	53.10	2.28	12	8	187
03/02/2016	01:30	2,220	42.20	1.96	12	8	172
03/02/2016	02:30	2,233	43.40	1.58	12	8	222
03/02/2016	03:30	2,234	47.50	2.26	12	8	168
03/02/2016	04:30	2,237	50.50	1.84	12	8	222
03/02/2016	06:30	2,266	51.70	1.55	12	8	272
03/02/2016	07:30	2,293	51.70	1.48	12	8	285
03/02/2016	08:30	2,298	44.10	1.26	12	8	286
03/05/2016	07:50	2,160	33.00	3.37	10	7	62
03/05/2016	09:00	2,192	35.60	3.11	10	7	73
03/05/2016	10:10	2,210	24.60	2.37	10	7	66
03/05/2016	11:10	2,236	23.30	1.98	10	7	75
03/05/2016	12:10	2,260	30.80	1.60	10	7	128
03/05/2016	13:10	2,280	28.70	1.33	10	7	144
03/05/2016	14:10	2,302	22.30	1.38	10	7	106
03/05/2016	15:20	2,344	26.90	1.21	10	7	149
03/05/2016	16:20	2,367	31.60	1.99	10	7	104
03/05/2016	17:20	2,398	37.70	0.70	10	7	372
03/05/2016	18:20	2,427	36.60	1.72	10	7	142
03/05/2016	19:30	2,548	57.80	1.83	10	7	214
03/05/2016	20:30	2,490	56.40	2.07	10	7	184
03/05/2016	21:30	2,522	57.40	1.85	10	7	210

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

Date	Time	Depth (ft)	LiBr, Mixing Tank (ppm)	LiBr, Discharge Line (ppm)	Injection Rate (bbl/hr)	Injection Rate (gpm)	Water Production (gpm)
03/05/2016	22:30	2,545	44.60	1.99	10	7	150
03/05/2016	23:30	2,577	45.00	1.57	10	7	194
03/06/2016	00:30	2,602	62.70	1.76	10	7	242
03/06/2016	01:30	2,626	64.80	1.93	10	7	228
03/06/2016	02:30	2,651	64.00	2.01	10	7	216
03/06/2016	03:30	2,683	65.40	1.73	10	7	258
03/06/2016	04:30	2,710	64.50	1.85	10	7	237
03/06/2016	05:30	2,735	63.00	1.52	10	7	283
03/06/2016	06:30	2,748	64.10	1.53	10	7	286
03/06/2016	07:30	2,779	65.20	2.16	10	7	204
03/06/2016	08:30	2,811	59.30	2.33	10	7	171
03/06/2016	09:30	2,842	60.90	2.18	10	7	189
03/06/2016	10:30	2,850	62.30	2.08	10	7	203
03/06/2016	11:30	2,878	65.50	2.17	10	7	204
03/06/2016	12:30	2,910	68.80	2.47	10	7	188
03/06/2016	13:30	2,935	63.80	2.02	10	7	214
03/06/2016	14:30	2,960	70.60	2.34	10	7	204
03/06/2016	15:30	2,979	60.80	1.51	10	7	275
03/06/2016	16:30	3,003	60.50	1.19	10	7	349
03/06/2016	17:05	3,018	62.80	1.25	10	7	345
03/06/2016	17:45	3,034	70.70	2.11	10	7	228
03/06/2016	18:20	3,044	62.10	1.21	10	7	352
03/06/2016	19:30	3,069	45.80	2.92	10	7	103
03/06/2016	20:30	3,094	46.50	1.32	10	7	240
03/06/2016	21:30	3,119	66.70	1.29	10	7	355
03/06/2016	22:30	3,141	62.60	0.79	10	7	548
03/06/2016	23:30	3,165	62.80	1.78	10	7	240
03/07/2016	00:30	3,193	85.70	2.89	10	7	201

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

Appendix D

Work Control Documents

NSTec FAWP, Main Hole Drilling and Completion of Well ER-3-3
(43 Pages)

Final Well Specific Fluid Management Strategy
for UGTA Well ER-3-3
(9 Pages)

National Security Technologies LLC
Vision • Service • Partnership

Work Package Number: D-002-001.16 **Title:** Main Hole Drilling and Completion of Well ER-3-3

Revision Number: 0

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

Location: NTS NAD 27
ER-3-3: N 842,668 E 683,150

Date: February 8, 2016

Contents of Work Package:

Approvals:

NSTec UGTA Project Manager: /s/ P.K. Ortego Date: 2/9/16
P. K. Ortego

Concurrence:

NNSA/NFO UGTA Activity Lead: /s/ Wilhelm R. Wilborn Date: 2/9/2016
W. R. Wilborn

Navarro Project Manager: /s/ Ken Rehfeldt Date: 2/9/16
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-3-3 well site) and main hole construction and completion of the UGTA Yucca Flat ER-3-3 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, HST).

2.1.1.1 Provide detailed hydrogeologic information for the alluvial and volcanic sections as well as the uppermost 100 to 200 m (330 to 656 ft) of the lower carbonate aquifer (LCA).

2.1.1.2 Provide detailed geology, including fracture information for the upper portion of the LCA where radionuclide (RN) contaminant transport is most likely.

2.1.1.3 Use the data collected to help reduce uncertainties within the Yucca Flat area during any further groundwater flow and transport model runs deemed necessary.

2.2 Complete the well with three zones.

2.2.1 Shallow completion in the TMWTA to monitor for lateral migration of RNs above the WAGTAIL WP and serve as a monitoring interval in the VA during hydraulic tests in the LCA.

2.2.2 Intermediate completion in the LTCU to evaluate the horizontal exchange volume in the LTCU.

2.2.3 Deep completion in the LCA to look for RNs in the LCA as a result of drainage of contaminated water from the LTCU down faults and to conduct LCA hydraulic tests near major strands of the Yucca Fault.

2.3 Investigate the hydraulic connection between the tuff aquifers and the LCA hypothesized to exist in the vicinity of Test Well 7 (TW-7).

2.4 Investigate potential for hydraulic overpressures measured in the LTCU at TW-7 to produce enhanced drainage and RN migration down faults to the LCA.

2.5 Obtain water-level data, and investigate potential local groundwater flow downgradient from the WAGTAIL UGT.

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

2.6.1 Sample for tritium and other RNs potentially migrating from upgradient WAGTAIL 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-3-3 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 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-3-3 site and installation of temporary services at the ER-3-3 site. The location-to-location move to the ER-3-3 site includes movement of the major drill rig components and all of the air compressor equipment from the ER-2-2 well site on the Nevada National Security Site (NNSS), transportation of all of United Drilling, LLC (UD) equipment to the ER-3-3 site ; and transportation of any facilities, and materials from other areas of the NNSS such as the Area 1 Drilling Yard to the ER-3-3 site; off- loading and physical placement and setup of the items will be based on the physical features of the ER-3-3 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.

4.4 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.

4.5 UD's mud mixing and pumping equipment will be moved and rigged up on the ER-3-3 location to support mud mixing and pumping should it be necessary.

4.6 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.

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

4.7 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.

4.8 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.

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

4.10 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.

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

4.11.1 The NSTec UGTA trailer used as the NSTec site office
4.11.2 Two 100-KW generators and fuel tank used to provide power to all facilities/equipment other than the drill rig.
4.11.3 The Construction Superintendent's office transportainer (as necessary)

4.11.4 Water buffalo or other type of hand-washing station

4.11.5 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.

4.11.6 NSTec transportainer for miscellaneous tools and equipment storage units

4.11.7 Minimum of eight portable toilets

4.11.8 Minimum of two dumpsters for sanitary waste collection

4.11.9 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.

4.11.10Mud materials, downhole hardware including bits, hole openers, stabilizers, roller reamers, shock subs, drilling jars, casing, tubing, and associated cementing equipment

4.11.11Portable light standards for night time operations as necessary, estimated 10 units will be needed.

4.11.12Radiological operations base station including a minimum of two liquid scintillation counters (LSCs) installed within the base station.

4.11.13Two, separate 40-60 kw generators to provide primary & and backup power to Rad base station and/or other portable facilities deployed near the sumps

4.12 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.

4.13 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.

4.14 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.

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

4.14.2 Inspection of the flow line during installation at the ER-3-3 site will be in accordance with the "Work Instruction for the Inspection of the UGTA Flow Line" as shown in Exhibit D.

4.14.3 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.

4.14.4 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.

4.14.5 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. 1 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. A portable handrail will be installed in the cuttings collection area for fall protection.

Hold Point No. 1	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						

4.15 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.

4.16 NSTec will install a grounding grid for all the equipment and facilities on site. The grid will be grounded to the conductor casing. All light standards will be either attached to the grid or grounded individually. 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.

4.17 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.

4.18 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-3-3 are provided in Exhibit E, Table B.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-3-3. The geology expected at Well ER-3-3 is well is predicted to be similar to the geology encountered at emplacement hole U-3an used for the WAGTAIL test, located approximately 163 m (534 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 15 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 1,668 ft. bgs unless perched water is encountered.

5.1.12 The surface hole will be drilled to a minimum depth of approximately 1,970 ft. bgs, which is approximately 300 feet below the static water level. However, the depth of the surface hole may be greater than 1,970 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 Piezometer Tube on the Outside of the Surface Casing

5.3.1 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 surface casing. The option may be exercised upon collaboration between Navarro, NSTec and the Scientific Team and approved by the NFO Activity Lead.

5.3.2 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 2-3/8 inches outside diameter.

5.4 Installing the Surface Casing

5.4.1 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 OD casing on top of the 30-inch conductor casing stub.

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

5.4.2.1 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.

5.4.2.2 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.

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

5.4.2.4 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.

5.4.2.5 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.

5.4.2.6 Maximum string weight at a depth of 1,970 ft. bgs using 13-3/8 inch casing will be approximately 120,000 pounds.

5.4.2.7 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.

5.4.3 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.

5.4.4 Space out and connect the drill pipe to air. Blow air through the drill pipe and observe return air at the surface in the casing × drill pipe annulus. . 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 13-3/8 inch 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 13-3/8 inch OD casing to a minimum level approximately 100 feet above the bottom 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.

5.4.4.1 The target level of cement above the casing shoe may be adjusted base on the need for a piezometer tubing, its depth and the depth of the static water level.

5.4.5 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.

5.4.6 After completion of cementing, complete installation of the landing plate and weld landing plate to 30 inch and 13-3/8 inch casing.

5.4.7 Cut off the 13-3/8 inch surface casing and install the rotating head.

5.5 **Installation of the Flow line to the 13-3/8 inch Surface Casing**

5.5.1 The flow line as installed per section 4.14.5 above will remain the same except the flow line will be connected to the 13-3/8 inch surface casing. Welds on the 13-3/8 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.

5.5.2 Hold Point No. 2 will be signed-off by the appropriate Navarro and NSTec personnel prior to drilling out of the surface casing.

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
Flow line installed in accordance with approved saturated zone design and inspected per work instruction						

5.6 **Production or Intermediate Borehole Drilling**

5.6.1 Gauge and make up the 12-1/4 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 a 12-1/4 inch assembly rather than an 18-1/2 inch assembly.

5.6.2 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.

5.6.2.1 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.

5.6.2.2 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.

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

5.6.2.4 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.

5.6.3 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.

5.6.4 Trip in the hole with the drilling assembly, tag cement inside the 13-3/8 inch casing (record depth of cement) and drill out the cement and casing shoe.

5.6.5 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.

5.6.6 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.

5.6.7 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.

5.6.8 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 5 gallons per 50 barrels of water.

5.6.9 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.

5.6.10 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.

5.6.11 The total depth of this well is expected to be approximately 3,350 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.

5.6.12 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.

5.6.13 The 12-1/4 inch production/intermediate borehole will be drilled to a total depth of approximately 3,350 ft. bgs or to a shallower depth as determined by the necessity to set an 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.

5.6.13.1 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.

5.6.13.2 A 9-5/8 inch to 10-3/4 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 13-3/8 inch OD surface casing prescribed in Sections 5.3 above. The details of the installation of the piezometer, casing, cementing and wellhead configuration will be covered by a RVC at the time.

5.6.13.3 If the 9-5/8 inch to 10-3/4 inch OD intermediate casing is installed, an 8-1/2 inch to 9-7/8 inch borehole will be drilled below the intermediate casing. The 8-1/2 inch to 9-7/8 inch BHA will be the same as the 12-1/4 inch BHA except the bit size and roller reamer sizes reduced to fit the 8-1/2 inch to 9-7/8 inch borehole.

5.6.14 Again, the 8-1/2 inch to 9-7/8 inch production/intermediate borehole will be drilled to a total depth of approximately 3,350 ft. bgs or to a shallower depth as determined by the necessity to set an 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.

5.6.15 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.

5.6.16 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.

5.7 Geophysical Logging in the Production Borehole

5.7.1 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.

5.7.2 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.

5.7.3 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.

5.7.4 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).

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

5.8 Installation of Monitoring Tubing and Production Casing

5.8.1 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.

5.8.2 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.

5.8.2.1 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.

5.8.2.1.1 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.

5.8.2.1.2 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.

5.8.2.1.3 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 "mule-shoed" with the edges ground off and large slots cut on the bottom 3 feet of tubing.

5.8.2.2 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.

5.8.3 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.

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

5.8.4.1 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.

5.8.4.2 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.

5.8.4.3 7-5/8, 6-5/8 or 5-1/2 inch OD, carbon steel, 26.4 lb/ft, J-55 or N-80, LT&C, Range 3 (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.

5.8.4.4 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.

5.8.4.5 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.

5.8.5 See Exhibit G for illustration of well completion options with 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.

5.8.6 Prepare to stem the production casing.

5.9 **Stemming the Production Casing**

5.9.1 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 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.

5.9.2 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:

5.9.2.1 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).

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

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

5.9.2.4 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.

5.9.2.5 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.

5.9.2.6 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.

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

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

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

5.9.2.10 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.

5.9.3 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.

5.9.4 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.

5.9.5 Seal the production casing by surface casing annulus around the 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.

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

6.0 RIG DOWN AND PREPARATION TO MOVE

6.1 During the rig down process and load out of equipment to be moved off the drilling location 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 the next location must be completed prior to moving items as determined by the HPS.

6.3 This is the third well in this FY 2015 – FY 2016 drilling campaign, but may be the final well, thus all drilling and related equipment, tools, materials and portable facilities will be moved from this location to the next location, ER-4-1 on the NNSS in Area 4 or off the NNSS.

6.3.1 UD 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 equipment will take priority since location-to-location moves for this Subcontractor is 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-3-3 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 I for a map of the ER-3-3 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-3-3 site to the Area 6 Aid Station</u> – Travel south to the nearest existing road (3-03 Road), turn right (west) and continue west to the intersection with Mercury Hwy and then south to the Area 6 Aid Station a total of approximately 7 miles. 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 From the ER-3-3 site to Mercury Medical – 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), approved by 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-3-3 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-3-3 Well Site, 3 pages
B ER-3-3 Existing Surface Site
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-3-3
F High Energy Discharge Communications Plan, 2 pages
G Illustration of Projected ER-3-3 Well Completion
H On-Site ER-3-3 Organization Chart
I Emergency Response for the ER-3-3 Site, 2 pages

EXHIBIT A

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

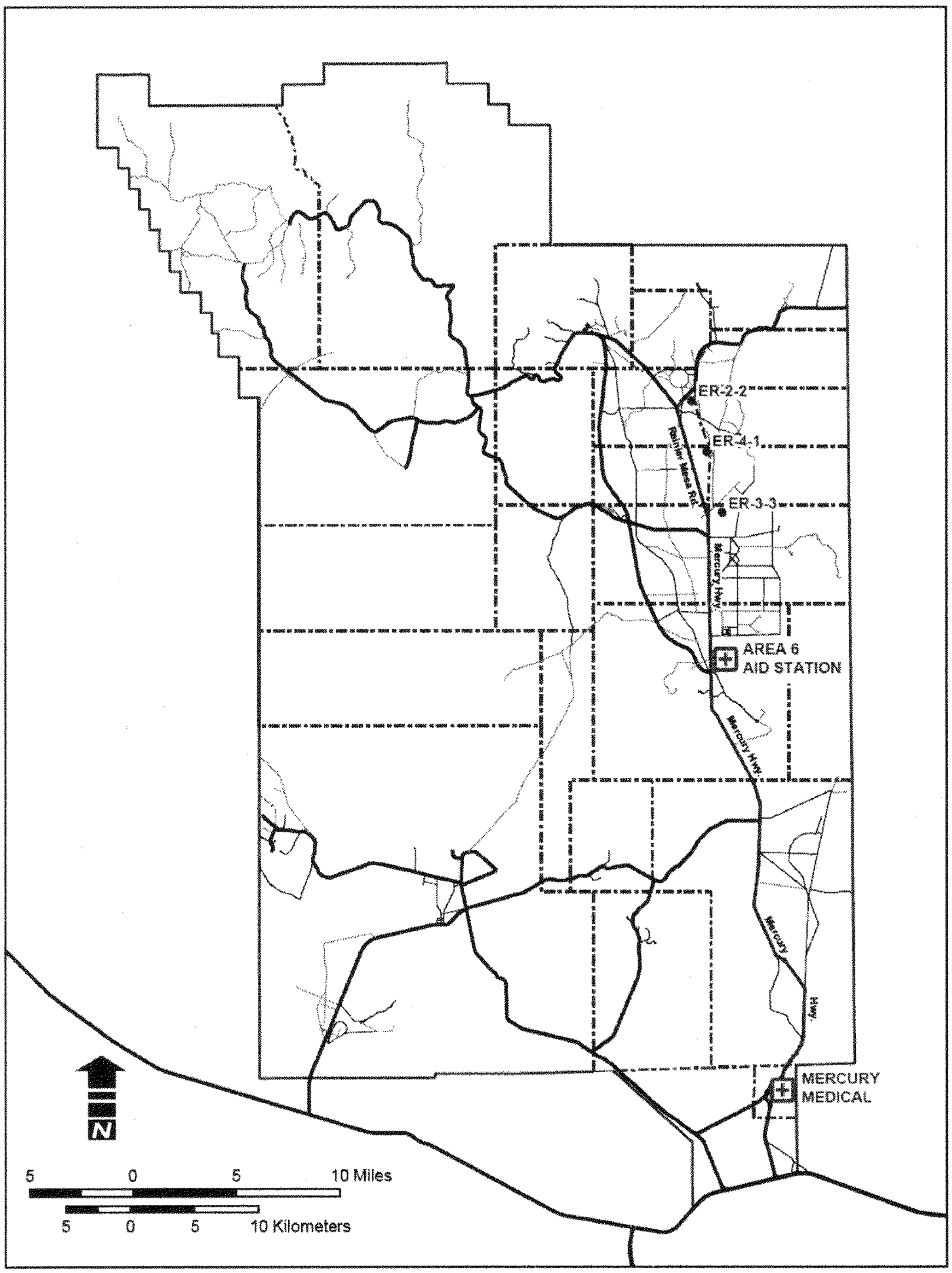
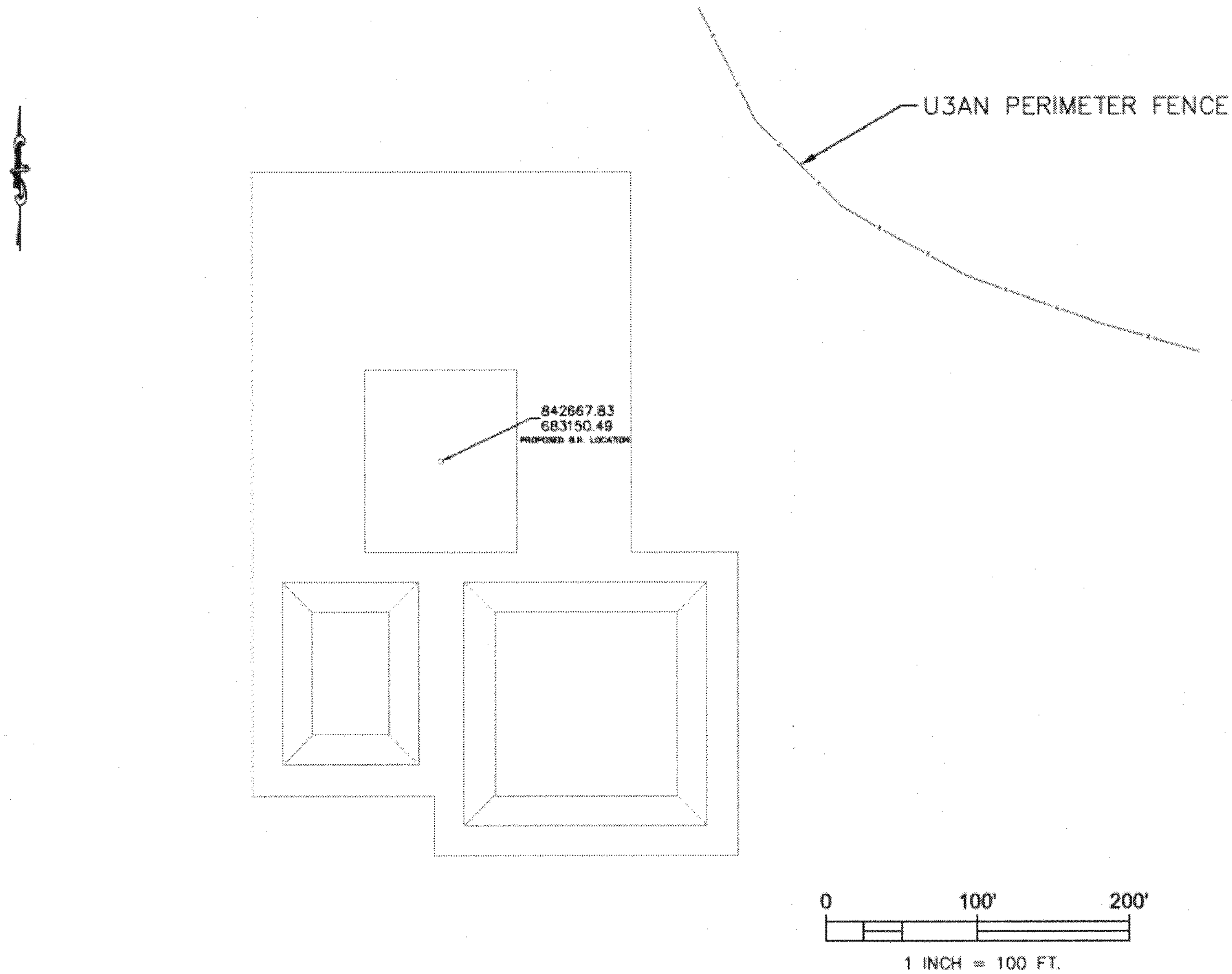


EXHIBIT A

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

EXHIBIT B

ER-3-3 Existing Surface Site



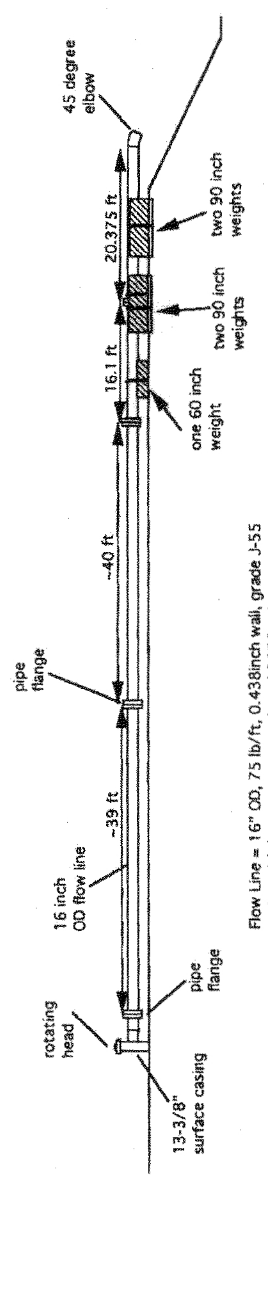
ER 3-3 STAKED 5-19-15

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 for Sam Marutzky, N-I UGTA Program Manager

/s/ Jeffrey Wurtz Signature

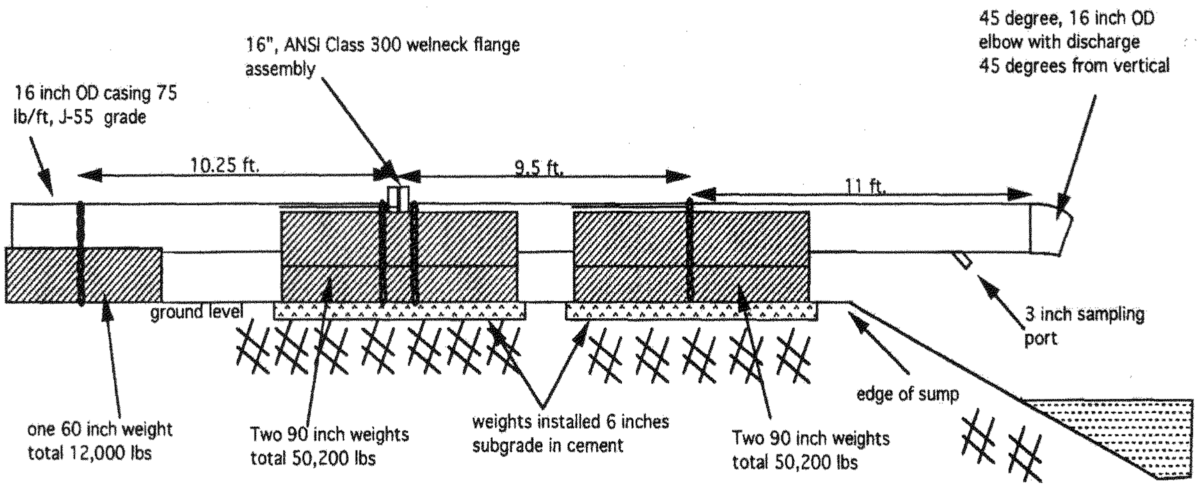
8-27-10 Date

NNSA National Nuclear Security Administration

National Security Technologies LLC
Vision • Service • Partnership

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.

EXHIBIT E

Table B.5-1
Expected Stratigraphic, Lithologic, Geologic, and Hydrologic Characteristics for Proposed Well ER-3-3

Stratigraphic Unit	Depth Interval (m)	Depth Interval (ft)	Estimated Thickness (m)	Estimated Thickness (ft)	Lithology and Alteration	HGU	HSU [a]
Quaternary/Tertiary alluvium (QTa)	0 - 402	0 - 1,318	402	1,318	Poorly to moderately sorted gravel and sand; loosely to moderately consolidated; tuffaceous alluvium	AA (unsaturated)	AA3 [b]
Ammonia Tanks Tuff (Tma)	402 - 464	1,318 - 1,523	62	205	Partially to nonwelded ash-flow tuff	VTA (unsaturated)	TMUVTA
bedded Ammonia Tanks Tuff (Tmab)	464 - 481	1,523 - 1,577	17	54	Bedded tuff		
mafic-rich Rainier Mesa Tuff (Tmrr)	481 - 568	1,577 - 1,862	87	285	Partially to moderately to densely welded ash-flow tuff	WTA (unsaturated to 508 m [1,668 ft])	TMWTA
Rainier Mesa Tuff/tuff of Holmes Road (Tmr/Tmrh)	568 - 590	1,862 - 1,935	22	73	Nonwelded to bedded tuff	VTA (saturated)	TMLVTA
Paintbrush Group, undivided (Tp)	590 - 741	1,935- 2,432	151	497	Bedded, reworked, and nonwelded tuff	TCU (saturated)	LTCU
Grouse Canyon tuff (Tbg)	741 - 750	2,432 - 2,462	9	30	Interbedded paleocolluvium and nonwelded tuff		
Tunnel Formation (Tn)	750 - 877	2,462 - 2,876	127	414			
Paleocolluvium/ Older Tuffs (Tlc/To)	877 - 895	2,876 - 2,935	18	59			ATCU
Paleozoic rocks (Pz)	895 - 1,021	2,935 - 3,350 (Planned TD = 3,350 ft)	126	415	Limestone and dolomite	CA (saturated)	LCA

Source: Modified from NSTec, 2009, 2010, and 2011

[a] See Table B.6-1 for hydrostratigraphic nomenclature.
[b] This term is also used to designate an HGU.

EXHIBIT F
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.

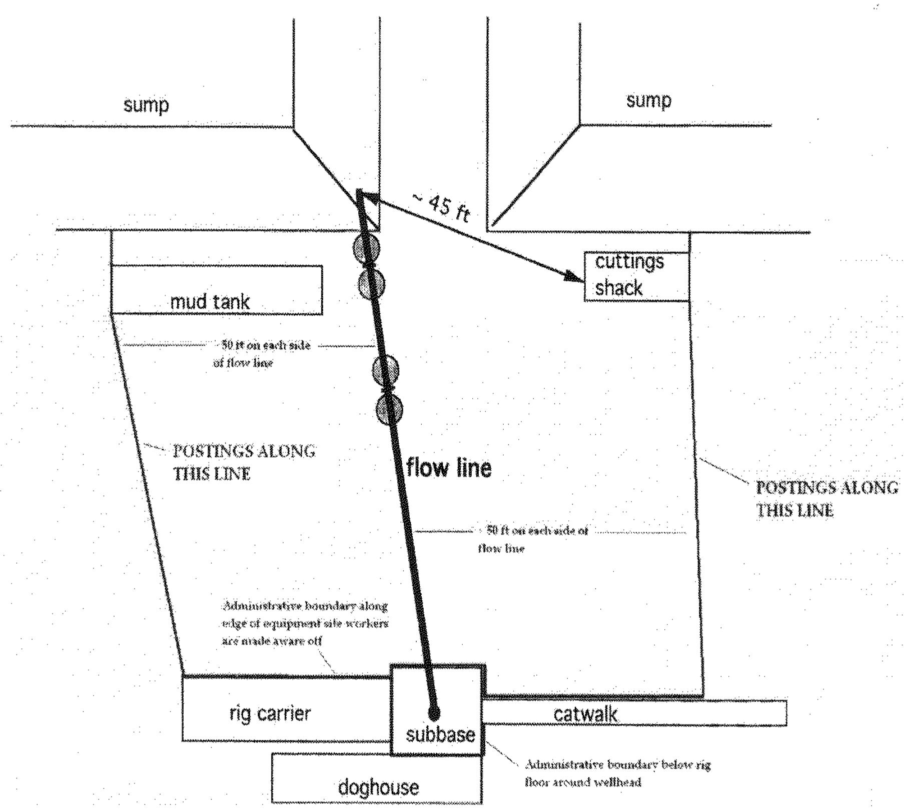
- When administrative controls are to be implemented due to potential high energy discharge conditions a special PTHR will be conducted by the NSTec Site Supervisor for all on-site personnel to advise of hazards and controls, define restricted areas and coordinate participation. Navarro will also conduct 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-3-3 WELL COMPLETION

Well ID: ER-3-3		UTM NAD 27	Northing: 4,102,144.0 m	Easting: 585,484.0 m
Start Date: TBD	Stop Date: TBD	NSPC NAD 83	Northing: 6,256,851.2 m	Easting: 555,786.6 m
Drilling Program: Yucca Flat		Lat/Long NAD 83	Deg N: 37.063437	Deg W: 116.039352
Environmental Contractor: UGTA/Navarro		Surface Elevation	4,054 ft amsl	1,235.7 m amsl
Drilling Contractor: United Drilling Inc.		Drill Method:	Conventional - Air/Foam	Drilled Depth: 3,350 ft bgs
Well Construction Diagram (Current as of 09/22/2015)				

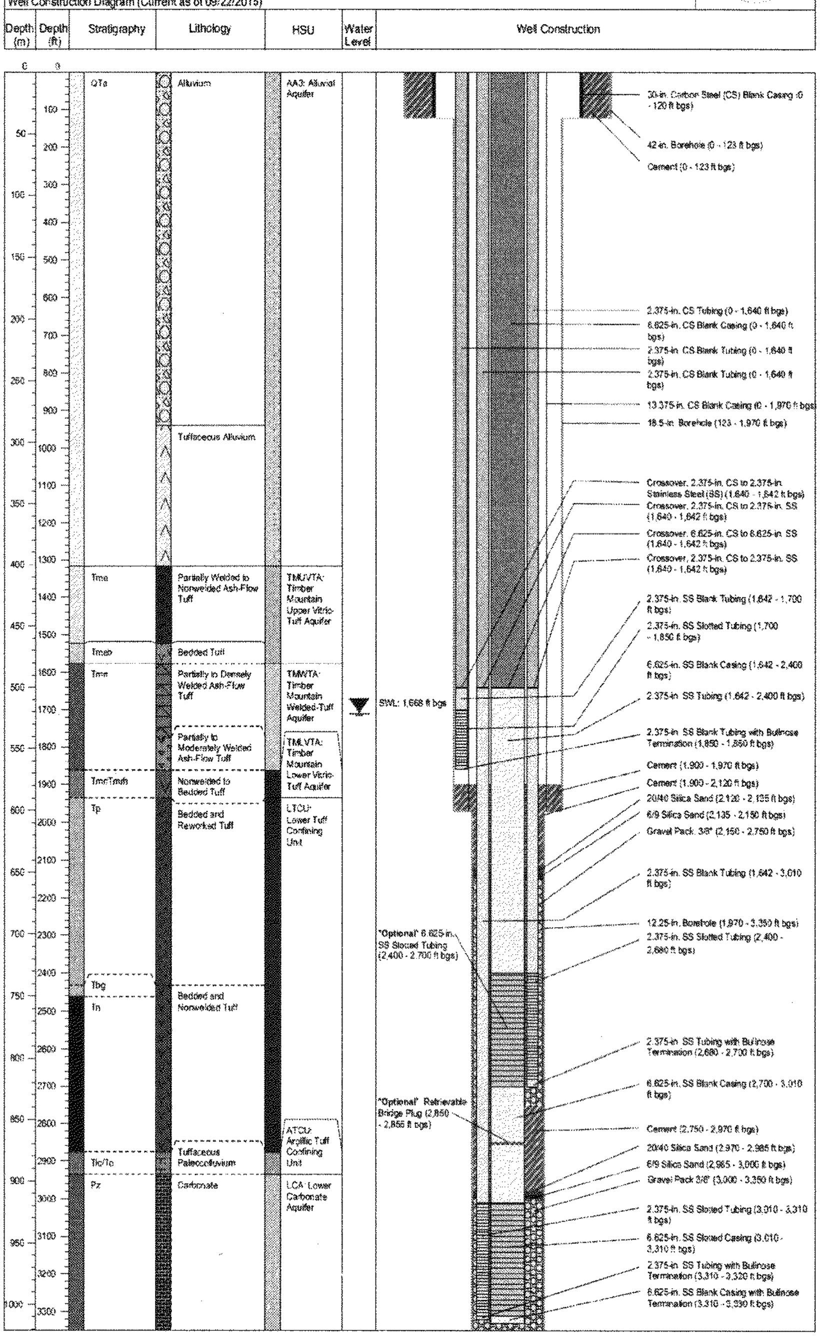


EXHIBIT H
ON-SITE ER-3-3 ORGANIZATION CHART

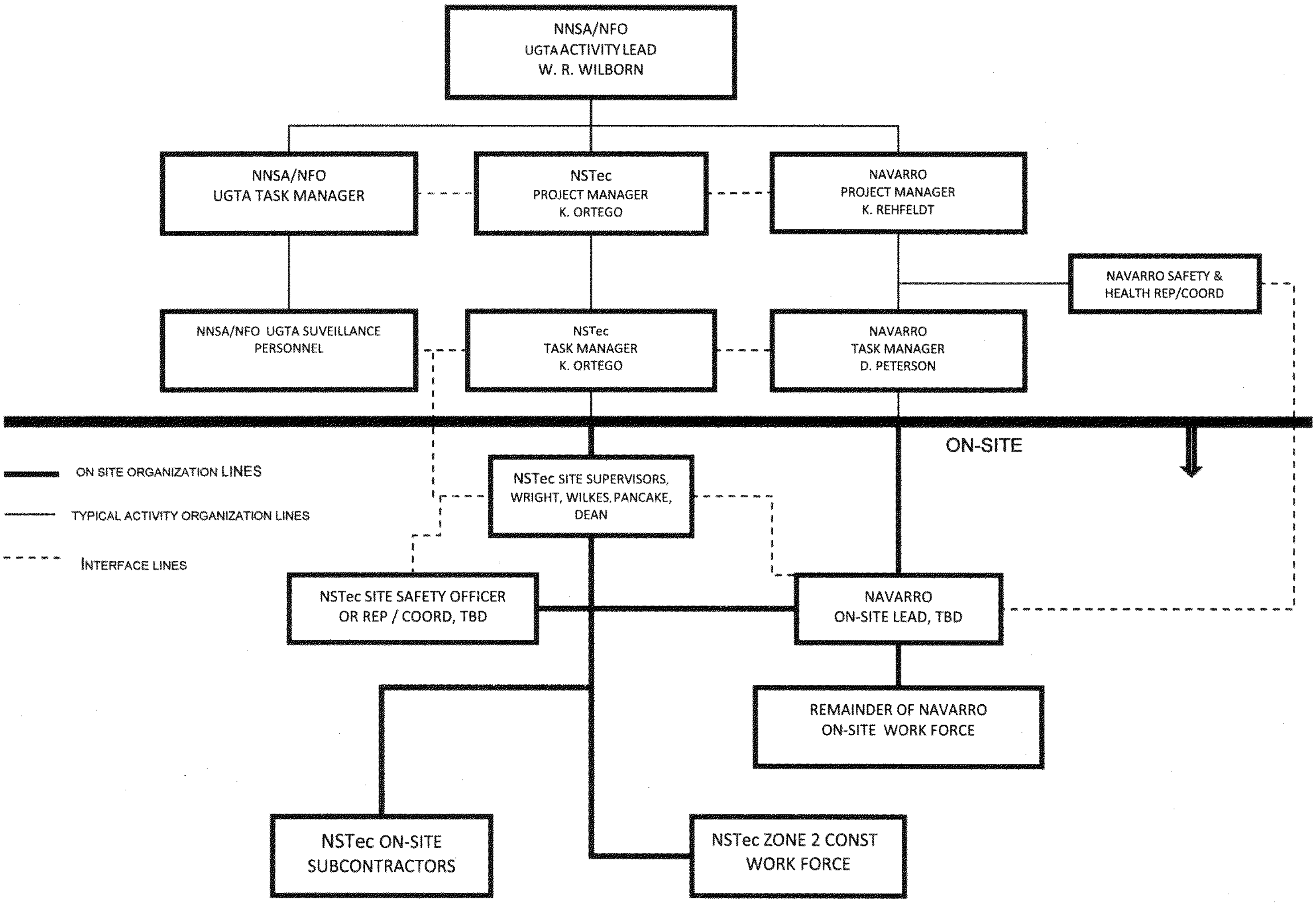


EXHIBIT I
PRIMARY EMERGENCY RESPONSE for ER-3-3 SITE
AREA 6 AID STATION (page 1 of 2)

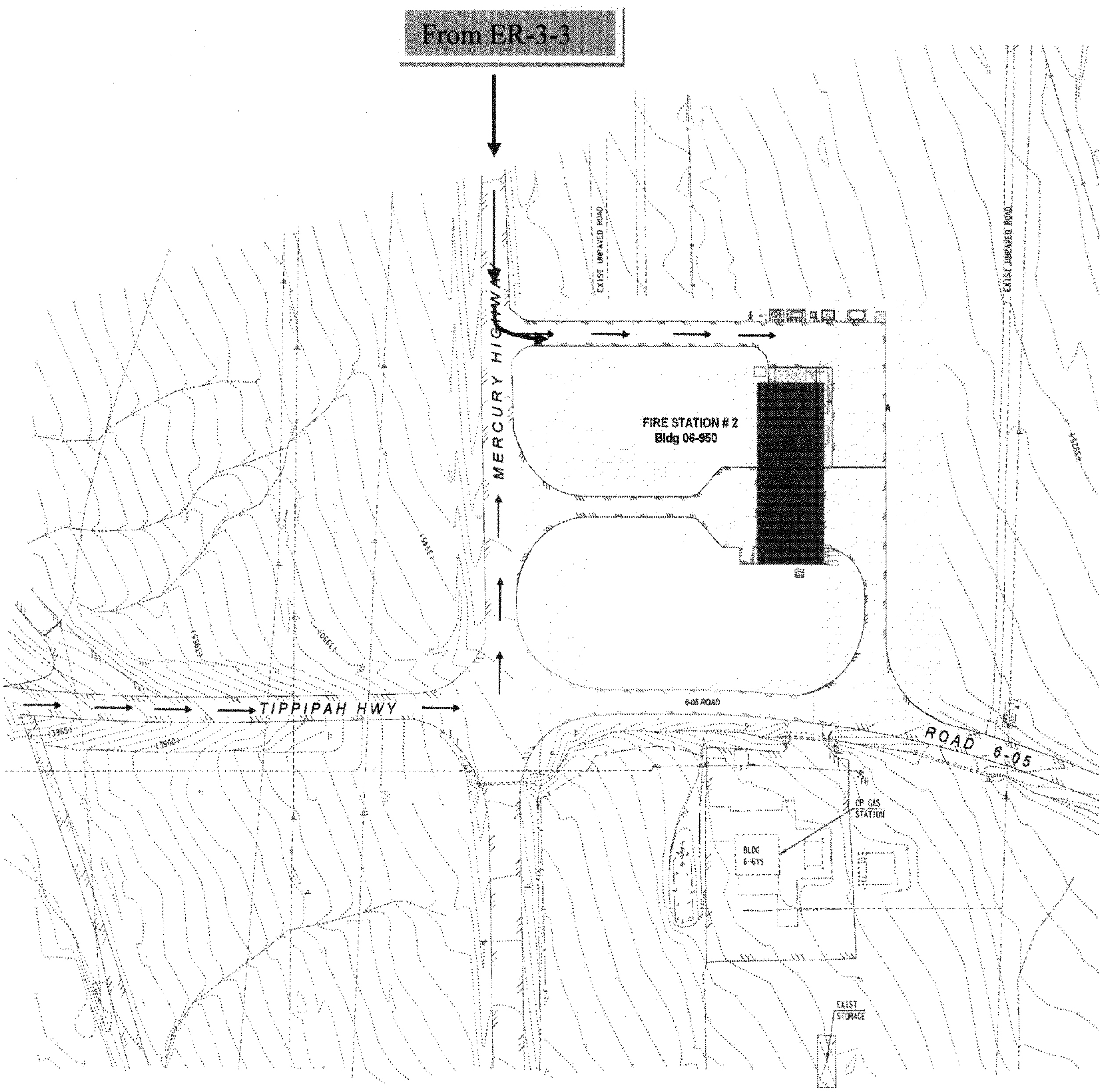
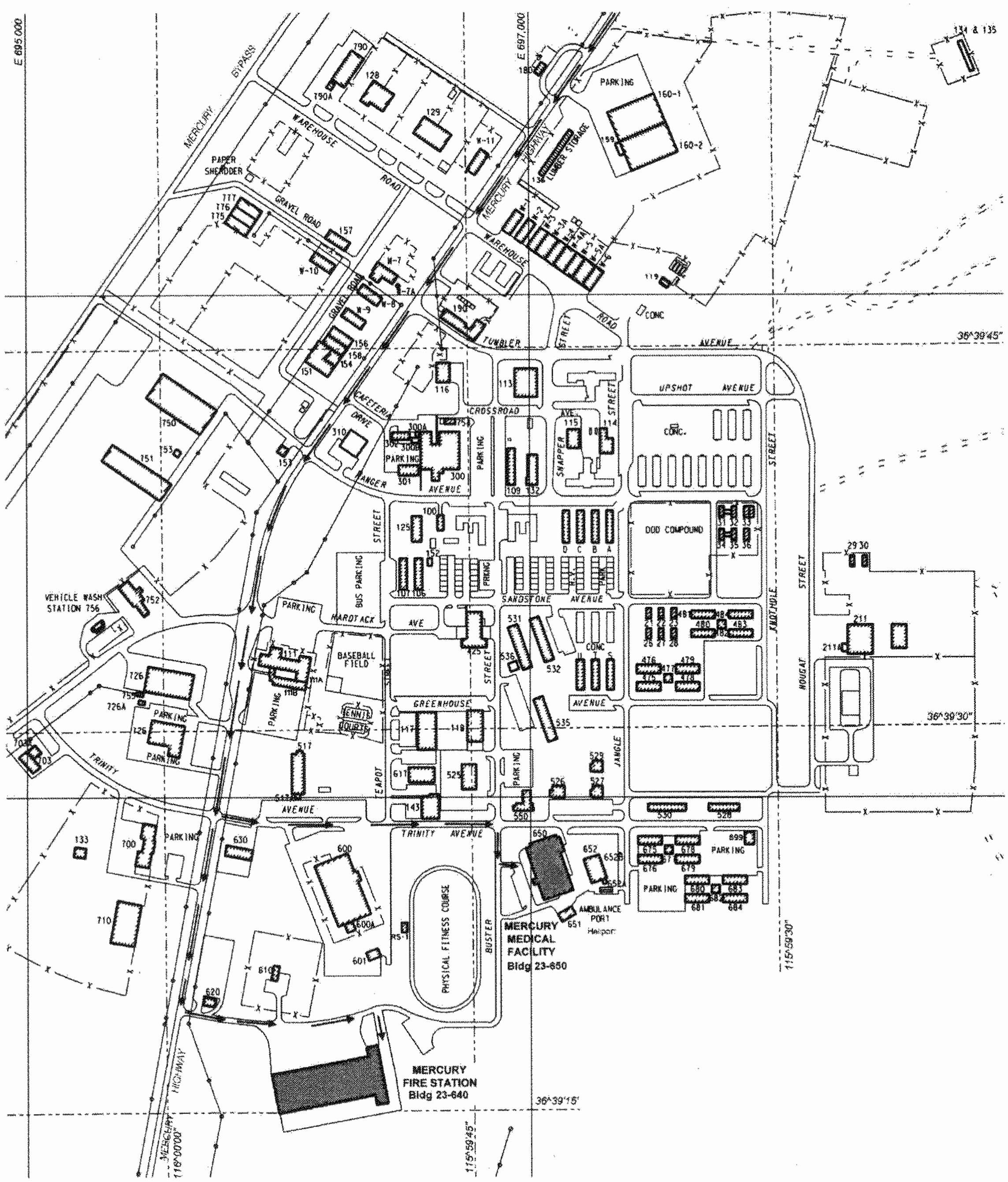


EXHIBIT I
SECONDARY EMERGENCY RESPONSE for ER-3-3 SITE
MERCURY MEDICAL (page 2 of 2)



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

February 17, 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-3-3, AREA 3, NEVADA NATIONAL SECURITY SITE (NNSS), FEBRUARY 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-3-3, Area 3, NNSS*, dated February 16, 2016. The strategy describes the monitoring and management of fluids generated during the drilling, pumping, purging and sampling of ER-3-3. 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
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J. T. Fraher, DTRA/CXTS, Kirkland AFB, NM
NSTec Correspondence Management

FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY
FOR UGTA WELL ER-3-3
NEVADA NATIONAL SECURITY SITE

February 1, 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-3-3, 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-3-3 is located within the central area of Yucca Flat, located within Area 3, in the northeastern portion of the Nevada National Security Site (NNSS). Figure 1 shows the location of Well ER-3-3 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 WAGTAIL detonated in March of 1965 in emplacement well U-3an. The WAGTAIL (U-3an) test is located approximately, 161 m (528 ft) to the northeast of the Well ER-3-3 location. Based on the distance of the proposed well from the WAGTAIL (U-3an) test and available analytical data from the closest wells, Well ER-3-3 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 the monitoring and management of fluids generated during fluid-producing activities at Well ER-3-3 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-3-3.

BACKGROUND AND ANALYTICAL DATA

Given the present understanding of groundwater flow in the area of proposed Well ER-3-3, the location is believed to be down gradient of a single principal underground test, although there are more than 2 dozen underground test locations near the Well ER-3-3 proposed location. Only two other nearby tests TAHOKA (U-3mf) and BILBY (U-3cn) were detonated below the water table. The proposed Well ER-3-3 will be located approximately 163 m (534 ft) southwest of the principal test of interest WAGTAIL (U-3an).

Proposed Well ER-3-3 lies approximately down gradient of the WAGTAIL (U-3an) underground test which is the focus of this hydrogeologic investigation. The WAGTAIL (U-3an) was detonated in 1965 with a working point within tertiary volcanic units located below the present water table at a depth of 2,051ft bgs. The reported yield of the WAGTAIL test was between 20 and 200 kilotons (DOE 2000). The WAGTAIL (U-3an) test impacted the saturated volcanics and the test cavity may have affected the Lower Carbonate Aquifer (LCA) to some extent as the cavity extended to near the LCA. There is also the possibility that normal faulting related to the Yucca Fault may have created potential fracture pathways near and within the cavity/chimney to allow transport for radionuclides.

The BILBY (U-3cn) underground test is a similar and well-studied underground test nearby the proposed Well ER-3-3 location and lies approximately 1,496 meters 4,908 ft east of the WAGTAIL (U-3an) test as shown in Figure 3. The BILBY (U-3cn) underground test detonated in 1963 with a working point below the water table at a depth of 2,344 ft bgs and an announced yield range of 249 kilotons. The BILBY (U-3cn) test impacted the saturated volcanics and the test cavity affected the Lower Carbonate Aquifer (LCA) to some extent as the cavity extended to near the LCA. The BILBY test may represent a reasonable example of test related hydrogeologic conditions that may be expected at Well ER-3-3.

There is some uncertainty with respect to the nature of the groundwater contamination that may be encountered at the Well ER-3-3 location, although the proximity of the Well ER-3-3 to the WAGTAIL (U-3an) test may suggest that radionuclides in the groundwater are likely. The nearest sampled well to proposed Well ER-3-3 is the post-shot Well U-3cn #5, which was angle drilled adjacent to the BILBY (U-3cn) test cavity. The Well U-3cn #5 is located approximately 122 m (400 ft) southwest of the BILBY surface and the borehole is open to the LCA below the test cavity. Initial groundwater samples collected from this location in December of 1965, indicated tritium concentrations as 95,000,000 pCi/L. The tritium concentrations have declined substantially as the well was last sampled in March of 2011 and tritium concentrations reported were less than 192 pCi/L. Similarly, the UGTA project Well ER-2-1 located approximately 7.1 kilometers (4.41 miles) to the north of the proposed well was drilled in close proximity to three underground tests and provided similar water chemistry from saturated volcanic rocks. Sampling of Well ER-2-1 conducted in 2015 measured a tritium activity of 840 pCi/L. Although, these nearby wells suggest generally low tritium concentrations in groundwater, Well UE-2ce WW located approximately 12.2 kilometers (7.57 miles) northwest of the proposed Well ER-3-3 and drilled and completed proximal 183 meters (600.4 ft) to the NASH (U-2ce) underground test indicates that tritium concentrations can be much higher. Samples collected from this well in 2008 yielded a tritium concentration of 270,000 pCi/L. Well ER-3-3 is 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 WAGTAIL (U-3an) underground test as suggested in the monitoring and sampling results of nearby wells. As a result the proposed Well ER-3-3 will be drilled to a depth of approximately 1021.1 meters (3,350 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-3-3 is presented in Figure 2.

WELL OPERATIONS STRATEGY

Based on the information presented above with respect to the location of Well ER-3-3, hydrogeologic setting and proximity of underground testing, Well ER-3-3 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-3-3 be conducted using the Far-field well site operations strategy for wells located on the NNSS. Should Near-field conditions be encountered, Well ER-3-3 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-3-3. 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-3-3:

- A single lined sump with an approximate 1 million gallon capacity has been constructed at the Well ER-3-3 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-3-3, 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-3-3 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.

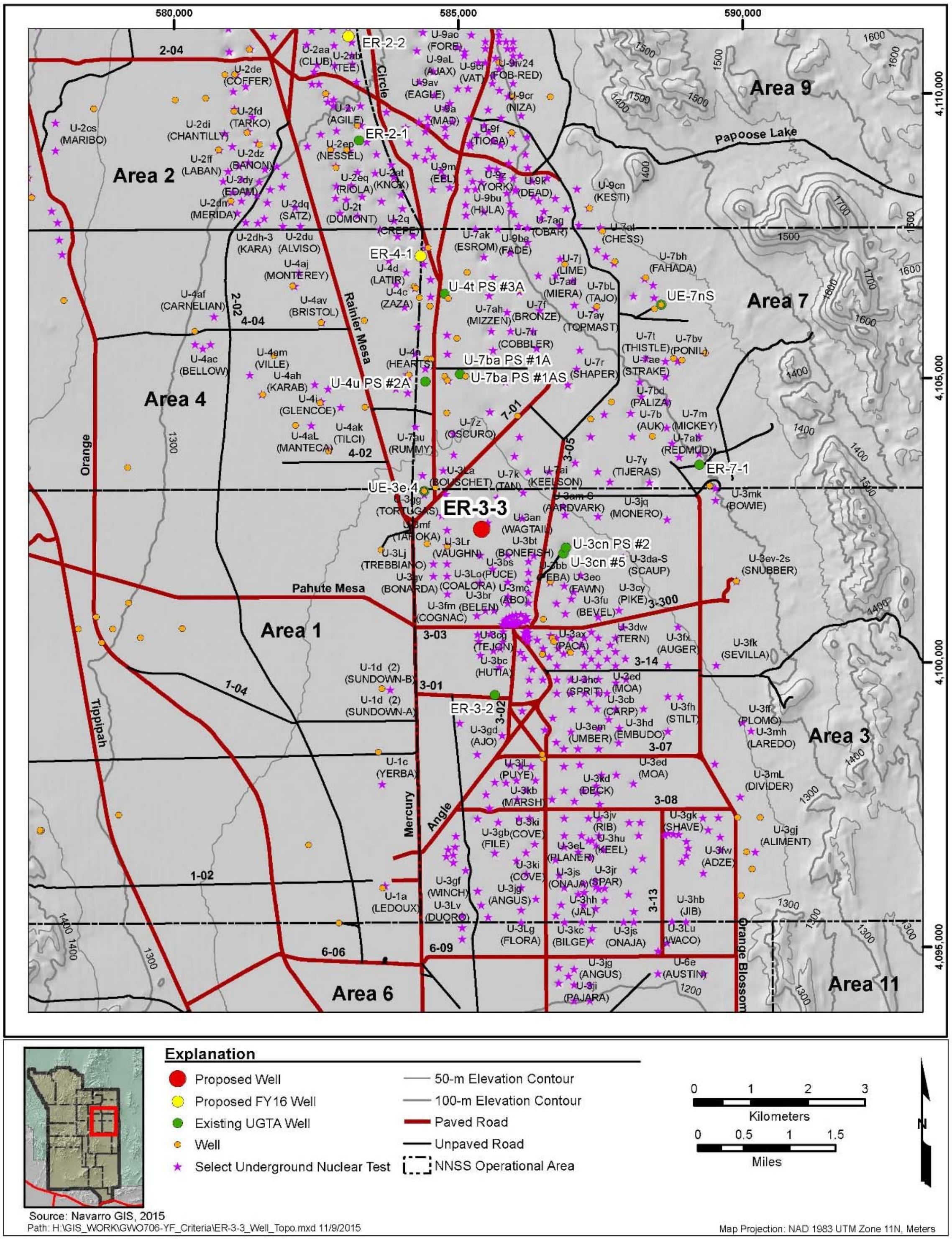

Figure 1
Well ER-3-3 Location Map

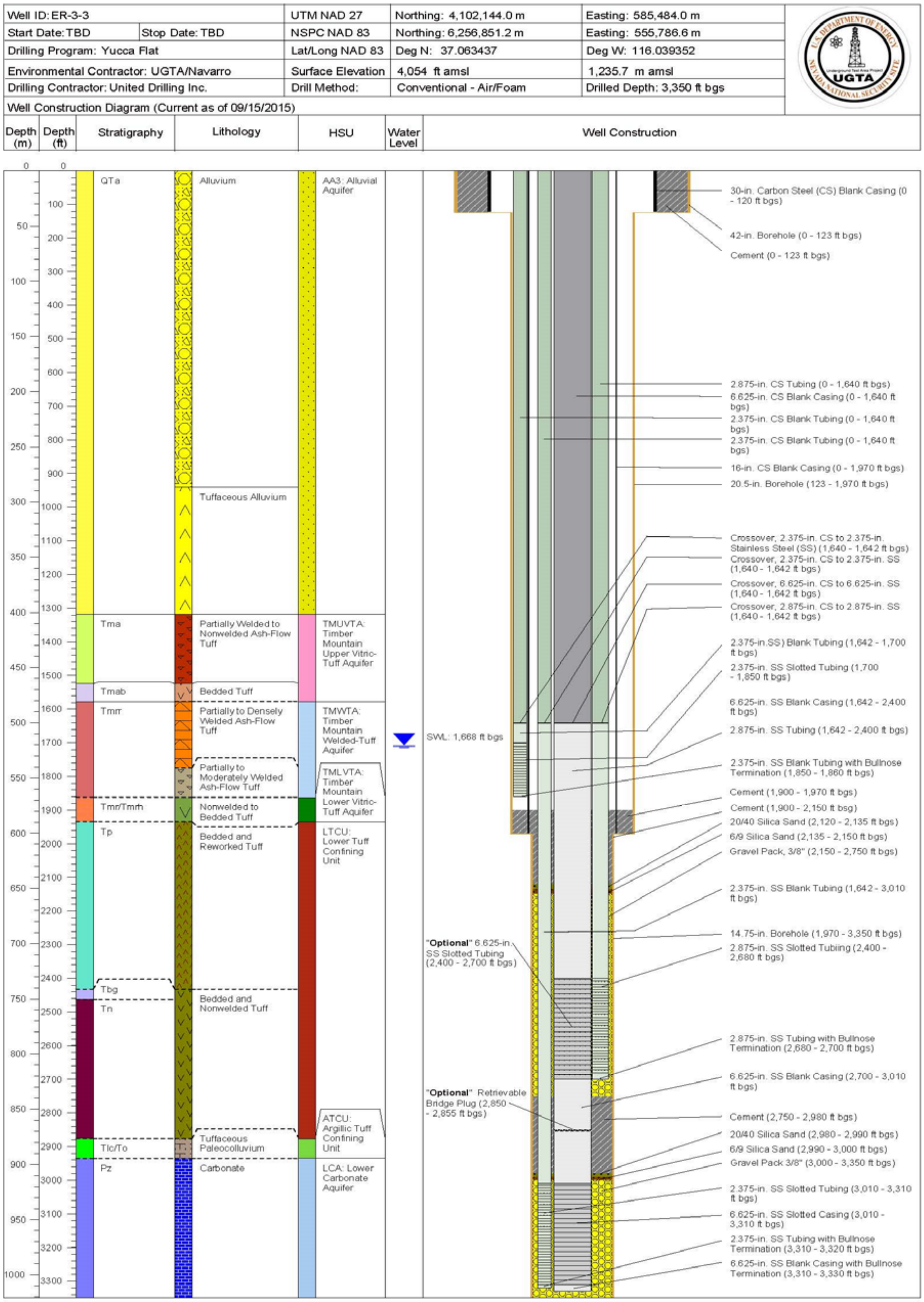

Figure 2
Proposed Well ER-3-3 Construction Diagram

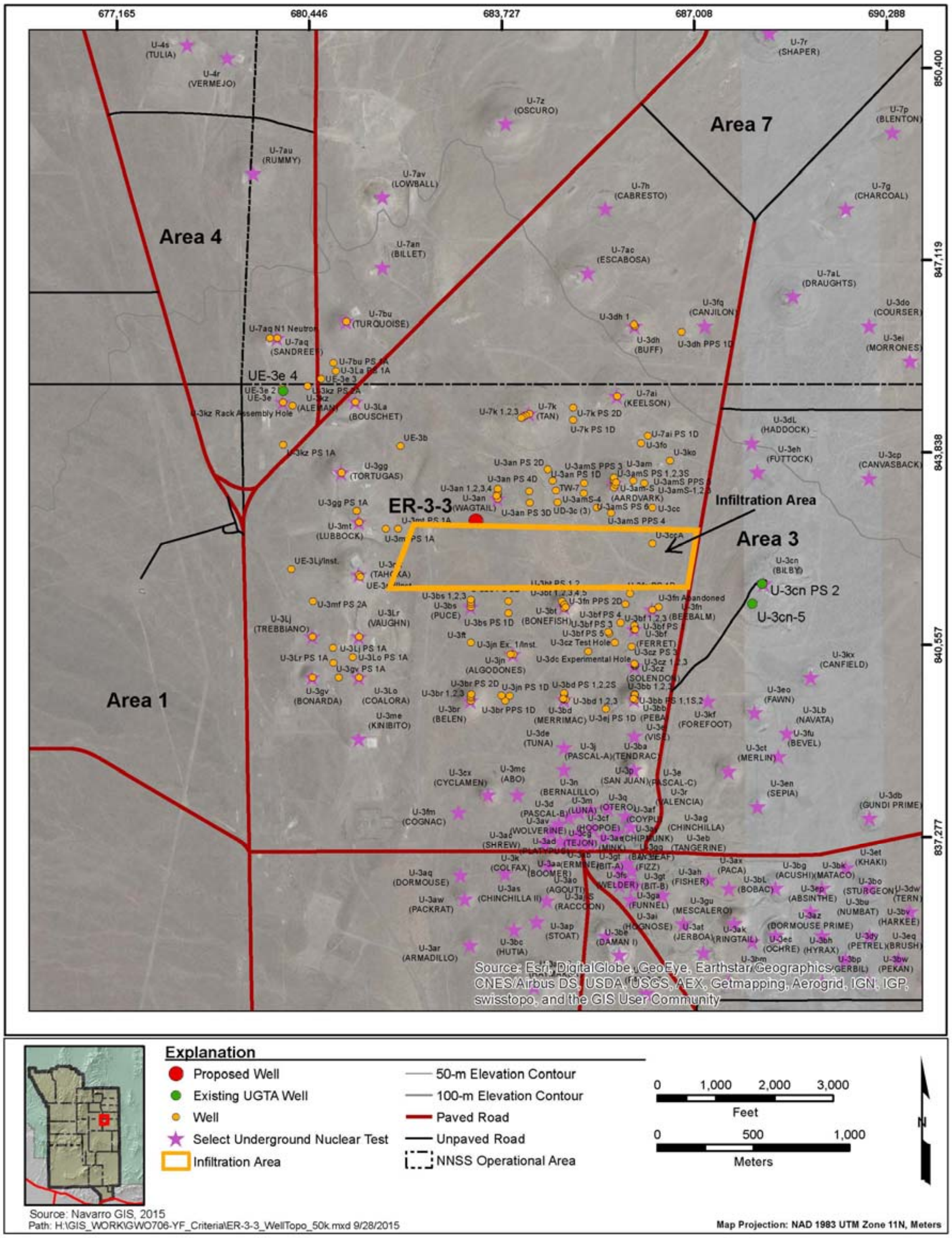

Figure 3
Proposed Infiltration Area at Well ER-3-3

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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