Nevada
Environmental
Management
Operations Activity

DOE/NV--1559

Completion Report for Well ER-2-2

Corrective Action Unit 97: Yucca Flat/Climax Mine

January 2017

U.S. Department of Energy
National Nuclear Security Administration
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COMPLETION REPORT FOR WELL ER-2-2

CORRECTIVE ACTION UNIT 97: YUCCA FLAT/CLIMAX MINE

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

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

January 2017

COMPLETION REPORT FOR WELL ER-2-2

CORRECTIVE ACTION UNIT 97:
YUCCA FLAT/CLIMAX MINE

Approved by: /s/ Wilhelm R. Wilborn Date: 01/25/2017

Wilhelm R. Wilborn
Underground Test Area Activity Lead

Approved by: /s/ Robert F. Boehlecke Date: 01/25/2017

Robert F. Boehlecke
Environmental Management Operations Manager

Abstract

Well ER-2-2 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 from January 17 to February 8, 2016, as part of the *Corrective Action Investigation Plan* (CAIP) *for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada*. 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 evaluate uncertainty in the flow and transport conceptual model and its contamination boundary forecasts, and to detect radionuclides in groundwater from the CALABASH (U2av) underground test.

Well ER-2-2 was not completed as planned due to borehole stability problems. As completed, the well includes a piezometer (p1) to 582 meters (m) (1,909 feet [ft]) below ground surface (bgs) installed in the Timber Mountain lower vitric-tuff aquifer (TMLVTA) and a 12.25-inch (in.) diameter open borehole to 836 m (2,743 ft) bgs in the Lower tuff confining unit (LTCU). A 13.375-in. diameter carbon-steel casing is installed from the surface to a depth of 607 m (1,990 ft) bgs.

Data collected during borehole construction include composite drill cutting samples collected every 3.0 m (10 ft), geophysical logs to a depth of 672.4 m (2,206 ft) bgs, water-quality measurements (including tritium), water-level measurements, and slug test data. The well penetrated 384.05 m (1,260 ft) of Quaternary alluvium, 541.93 m (1,778 ft) of Tertiary Volcanics (Tv) rocks, and 127.71 m (419 ft) of Paleozoic carbonates. The stratigraphy and lithology were generally as expected. However, several of the stratigraphic units were significantly thicker then predicted—principally, the Tunnel formation (Tn), which had been predicted to be 30 m (100 ft) thick; the actual thickness of this unit was 268.22 m (880 ft).

Fluid depths were measured in the borehole during drilling as follows: (1) in the piezometer (p1) at 552.15 m (1,811.53 ft) bgs and (2) in the main casing (m1) at 551.69 m (1,810.01 ft) bgs. As expected, field measurements for tritium were above 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

amsl	Above mean sea level
API	American Petroleum Institute
ASTM	ASTM International
bbl	Barrel
bbl/hr	Barrels per hour
BCR	Baseline change request
bgs	Below ground surface
BHA	Bottom hole assembly
C	Carbon
$CaCO_3$	Calcium carbonate
CAIP	Corrective action investigation plan
CAU	Corrective action unit
CD	Certificate of disposal
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
EERF	Eastern Environmental Radiation Facility
EPA	U.S. Environmental Protection Agency
e-tape	Electric tape
°F	Degree Fahrenheit
FAWP	Field activity work package

List of Acronyms and Abbreviations *(Continued)*

FFACO	*Federal Facility Agreement and Consent Order*
FMP	Fluid management plan
ft	Foot
ft^3	Cubic foot
ft^3/min	Cubic feet per minute
gal	Gallon
gpm	Gallons per minute
HASL	Health and Safety Laboratory
HCl	Hydrochloric acid
HFM	Hydrostratigraphic framework model
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
LiBr	Lithium bromide
LLNL	Lawrence Livermore National Laboratory
LLW	Low-level waste
Long	Longitude
LSC	Liquid scintillation counter
m	Meter
m^3	Cubic meter

List of Acronyms and Abbreviations *(Continued)*

Ma	Million years ago
MDA	Minimum detectable activity
MDC	Minimum detectable concentration
mg/L	Milligrams per liter
mi	Mile
min/ft	Minutes per foot
mm	Millimeter
M&O	Management and operating
MR	Management Reserve
N/A	Not applicable
NAD 27	North American Datum, 1927
NAD 83	North American Datum, 1983
NDEP	Nevada Division of Environmental Protection
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
Pu	Plutonium
PXD	Pressure transducer
QAP	Quality Assurance Plan

List of Acronyms and Abbreviations *(Continued)*

RadCon	Radiological Control
R_c	Cavity radius
RCT	Radiological control technician
RN	Radionuclide
rpm	Rotations per minute
RWP	Radiological work permit
SS	Stainless steel
SU	Standard unit
SW	Solid waste
SWL	Static water level
TD	Total depth
Th	Thorium
TIH	Trip into hole
TOH	Trip out of hole
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
µmhos/cm	Micromhos per centimeter

List of Acronyms and Abbreviations *(Continued)*

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

AA	Alluvial aquifer
AA3	Alluvial aquifer
ATCU	Argillic tuff confining unit
LCA	Lower carbonate aquifer
LTCU	Lower tuff confining unit
MDe	Eleana Formation
Op	Pogonip Group
Qai	Intermediate alluvial deposits
Qay	Young alluvial deposits
Qeo	Old eolian sand deposits
QTa	Quaternary/Tertiary alluvium
QTc	Quaternary/Tertiary colluvium
SCCC	Silent Canyon caldera complex
Tb	Belted Range Group
Tbg	Grouse Canyon Tuff
Tbgb	Grouse Canyon bedded tuff
Tc	Crater Flat Group (undivided)
Tcb	Bullfrog Tuff
Tclt	Crater Flat lower tuff
Tem	Monotony Tuff
Tes	Shingle Pass Tuff
TCU	Tuff confining unit
Tlc	Paleocolluvium
Tlc/To	Paleocolluvium/Older tuffs
Tm	Timber Mountain Group

List of Acronyms and Abbreviations *(Continued)*

TMCC	Timber Mountain caldera complex
TMLVTA	Timber Mountain lower vitric-tuff aquifer
Tmr	Rainier Mesa Tuff
Tmrh	Tuff of Holmes Road
Tmrp	Rainier Mesa mafic-poor Tuff
Tmrr	Rainier Mesa mafic-rich Tuff
TMWTA	Timber Mountain welded-tuff aquifer
Tn	Tunnel Formation
Tn3	Tunnel 3 Member
Tn4	Tunnel 4 Member
Tn4k	Tunnel 4 Member, bed k
To	Older Volcanics
Tob	Older basalt
Ton	Older tunnel beds
Tor	Redrock Valley Tuff
Tot	Tuff of Twin Peaks
Tp	Paintbrush Group
Tub	Tub Spring Tuff
Tv	Tertiary Volcanics
Tw	Wahmonie Formation
VA	Volcanic aquifer
Zs	Stirling Quartzite
Ꞓbb	Banded Mountain Member
Ꞓbp	Papoose Lake Member
Ꞓc	Carrara Formation
Ꞓn	Nopah Formation
Ꞓz	Zabriskie Quartzite

List of Acronyms and Abbreviations *(Continued)*

ꞒZw	Wood Canyon Formation
PIPt	Tippipah Limestone
Pz	Paleozoic rocks (undivided)

1.0 Introduction

1.1 Project Description

This report presents preliminary field data collected by Navarro between January 17 and February 8, 2016, during drilling and completion of Well ER-2-2 located on the Nevada National Security Site (NNSS), Nye County, Nevada. Well ER-2-2 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* (CAU) *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 wells.

Well ER-2-2 drilling operations conformed to the NDEP policies and regulations, and to the guidelines and requirements of the CAIP (DOE/NV, 2000); *Field Instruction for the Underground Test Area Activity Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015a); 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

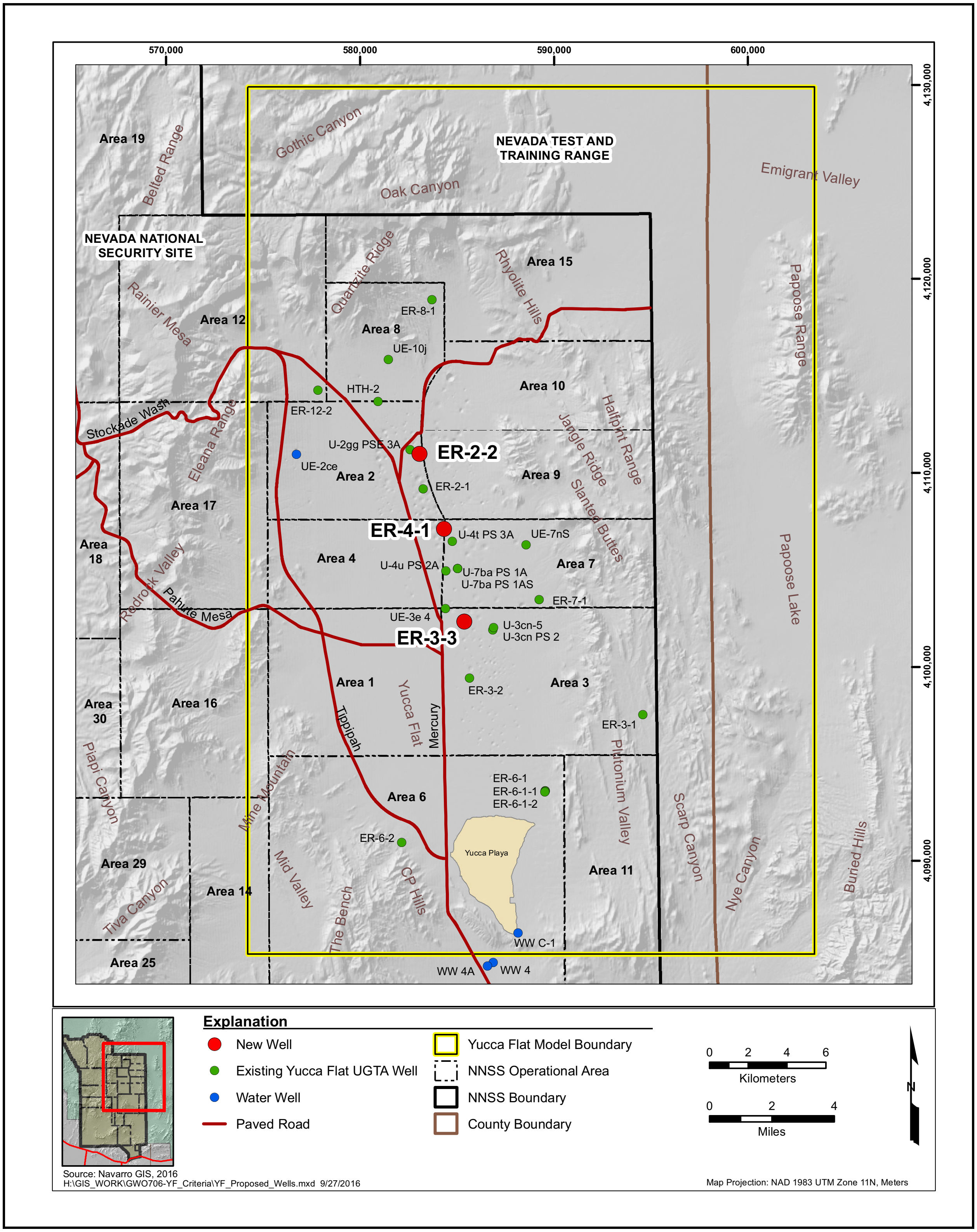


Figure 1-1
Location of Well ER-2-2 and Select Wells

casing operation services were provided by United Drilling, LLC (UDI), Northwestern Air Services (NWAS), and B&L Casing. Geophysical logging was conducted by Schlumberger. 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-2-2 could not be completed as planned due to borehole stability issues. The well, as completed, includes a piezometer (p1) to 582 meters (m) (1,909.36 feet [ft]) below ground surface (bgs) installed in the Timber Mountain lower vitric-tuff aquifer (TMLVTA). The piezometer is located in the annular space between the 13.375-inch (in.) surface casing and the 46.99-centimeter (cm) (18.5-in.) borehole. The 13.375-in. diameter carbon-steel (CS) casing is installed from the surface to a depth of 606.5 m (1,990.14 ft) bgs. Below the surface casing, a 31.12-cm (12.25-in.) diameter borehole was advanced to the total depth (TD) of the well to 1,053 m (3,457 ft). Due to unstable borehole conditions, the borehole was plugged below a depth of 836 m (2,743 ft) bgs. An open 31.12-cm (12.25-in.) borehole exists below the cement plug at 612.04 m (2,008 ft) bgs to the estimated top of bentonite drilling mud located at 836 m (2,743 ft) bgs. The borehole is open to the Lower tuff confining unit (LTCU).

1.2 Project Organization

Well ER-2-2 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-001-001.16 (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.

Scientific direction during the siting, planning and design stages leading up to the drilling and completion of the well was provided by the Technical Working Team (TWT). The 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), U.S. Geological Survey (USGS), NSTec, and Navarro. During the drilling and completion 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-2-2 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, 2015b) 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-2-2.

1.3 Location and Significant Nearby Features

Well ER-2-2 is located in the northeastern portion of the NNSS, within operational Area 2. The elevation of ER-2-2 is 1,302.97 m (4,274.85 ft) above mean sea level (amsl) in central Yucca Flat as shown in Figure 1-1 and Table 1-1. The well is located in an area considered to be downgradient of the CALABASH (U2av) underground test (UGT) on the NNSS. Figure 1-2 shows the location of Well ER-2-2 relative to select wells and underground tests in Yucca Flat. The CALABASH UGT was conducted on October 29, 1969, in emplacement hole U2av in northern Yucca Flat. The working point (WP) of the test was in the Lower tuff confining unit (LTCU) hydrostratigraphic unit (HSU) and estimated to be within 2 cavity radii (R_c) of the saturated Lower carbonate aquifer (LCA) HSU (cavity dimension based on maximum announced yield identified in NV-209-REV 16

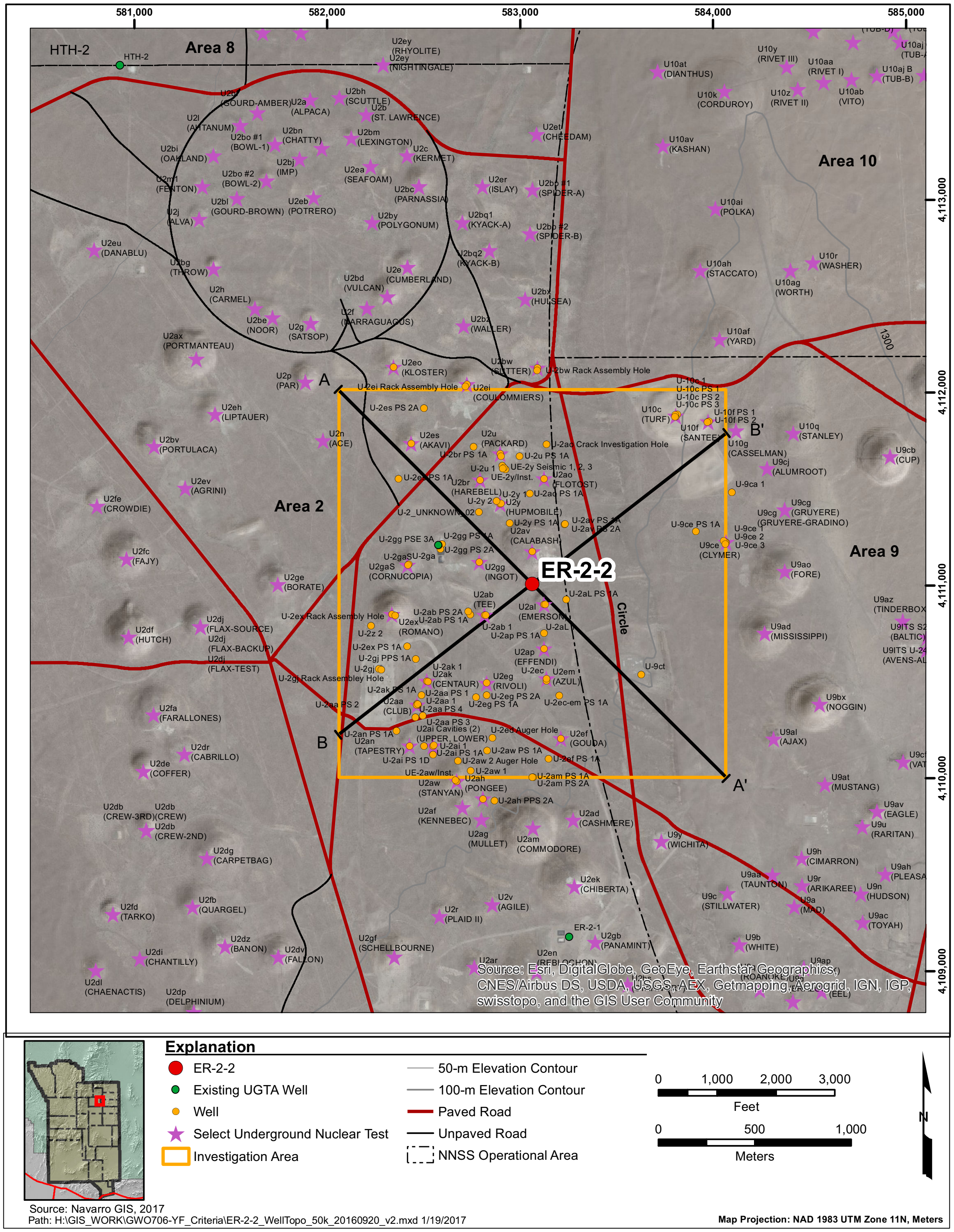


Figure 1-2
Aerial Photo of the Well ER-2-2 Area

Table 1-1
Site Data Summary for Well ER-2-2

Site Coordinates [a]	**Nevada State Plane - Central Zone, NAD 27** N 871,065.13 ft E 675,645.76 ft
	Nevada State Plane - Central Zone, NAD 83 N 6,265,502.14 m E 553,458.28 m
	UTM - Zone 11, NAD 83 N 4,110,981.81 E 583,046.61
	UTM - Zone 11, NAD 27 N 4,110,784.32 E 583,125.95
	Geographic - NAD 83 (degrees, minutes, seconds) Latitude: N 37° 08' 29.50" Longitude: W 116° 03' 53.70"
	Township and Range [b] Section 22 Township 9 South, Range 53 East
Surface Elevation [a, c]	1,302.97 m (4,274.85 ft)
Drilled Depth	1,053.69 m (3,457.00 ft)
Preliminary Fluid Level Depth [d]	552.15 m (1,811.53 ft)
Fluid Level Elevation	750.82 m (2,463.32 ft)
Surface Geology	Quaternary/Tertiary Alluvium (QTa)

[a] Measurements made by NSTec Survey on 06/08/2016 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] Quarter and quarter/quarter section values were made using Public Land Survey System (BLM, 2015).
[c] Measurement of elevation at the ground surface on the north side of the wellhead made by NSTec Survey on 06/08/2016. Elevations are relative to mean sea level.
[d] Measured in the piezometer (p1) by Navarro on 01/26/2016.

NAD = North American Datum
UTM = Universal Transverse Mercator

[NNSA/NFO, 2015b] and Equation 1 in UCRL-ID-136003 [Pawloski, 1999]). Well ER-2-2 was expected to produce data that would verify concepts of the groundwater flow system in Yucca Flat and subsequent transport of radionuclides from the CALABASH UGT.

1.4 Objectives

The primary purpose of Well ER-2-2 was to provide detailed hydrogeologic information downgradient of the CALABASH (U2av) 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-2-2.

- 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 330 to 990 ft of the LCA.
  - Improve understanding of the fault and rock properties in the saturated alluvial aquifer (AA)/volcanic aquifer (VA) model, particularly through the TCU.
  - Provide detailed geology, including fracture information for the upper portion of the LCA where radionuclide (RN) contaminant transport is most likely.
  - Use the data collected to help reduce uncertainties within the northern Yucca Flat area during any further groundwater flow and transport modeling.
- Use the uppermost piezometer completion at Well ER-2-2 in the saturated VA near the CALABASH UGT to evaluate whether RNs have migrated up the chimney into the overlying aquifer.
- Use the piezometer completion in the TMLVTA to evaluate the horizontal extent of the exchange volume in the TMLVTA.
- Pump the lower production completion, in the top of the saturated LCA, to determine whether the exchange volume has penetrated downward into the LCA, including any role that nearby faults may have on the RN transport to the LCA.
- Allow for the testing and refining of conceptual models of groundwater flow and transport between the saturated AA/VA and LCA.
- Obtain water-level data, and investigate potential local groundwater flow downgradient from the CALABASH 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 CALABASH 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-2-2 drill pad began January 9, 2016. Main borehole construction of the well to a TD of 1,053.69 m (3,457.00 ft) bgs began on January 17 and ended on February 8, 2016. Once drilling operations began, work proceeded 7 days per week, 24 hours per day.

After completing pre-drilling safety checks and a site walk-through, drilling operations began on January 17, 2016, by drilling the cement plug in the 30-in. conductor casing with a 18.5-in. bottom hole assembly (BHA) from 36.58 to 614.48 m (120 to 2,016 ft) bgs. The 13.375-in. CS surface casing was then run from the ground surface to 605.59 m (1,990.14 ft) bgs and cemented in place. A 12.25-in. tricone bit was then used to advance the borehole from 614.48 to 1,054 m (2,016 to 3,457 ft) bgs.

As borehole circulation permitted, composite drill cuttings 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.

A piezometer (p1) consisting of 1.9-in. CS blank tubing from the surface to 562.84 m (1,846.59 ft) bgs, and 1.9-in. CS slotted tubing with an orange-peeled termination from 562.84 to 581.97 m (1,846.59 to 1,909.36 ft) bgs was installed in the annulus between the borehole wall and 13.375-in. casing. While NSTec was cementing the 13.375-in. casing, Navarro installed a pressure transducer (PXD) in piezometer (p1) and collected data to monitor the casing cementing and record hydrologic data. Navarro attempted to remove the PXD from the 1.9-in. piezometer (p1) but was not successful.

Schlumberger conducted geophysical logging on January 23, February 1, and February 4, 2016. 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. Schlumberger, using geophysical tools, and Navarro, using a calibrated Solinst electric tape (e-tape), measured fluid levels in the open borehole on February 2, 2016, at 653 and 651.75 m (2,142 and 2,138.3 ft) bgs, respectively.

Drilling operations concluded on February 8, 2016, and demobilization of drilling equipment and support facilities was initiated.

A detailed summary of drilling operations is presented in Section 2.0. Well completion information is provided in Section 3.0. Geologic data collection activities are described in Section 4.0. Geology and hydrogeology information is presented in Section 5.0. Hydrology and water chemistry data collection activities are described in Section 6.0. Drilling fluid and waste management activities are provided in Section 7.0. Planned and actual costs, and scheduling are presented in Section 8.0. Lessons learned based upon observations made during Well ER-2-2 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-2-2 are outlined in the contract between NSTec and UDI of Roswell, New Mexico. Well-specific drilling and operational guidance are detailed in the NSTec *Field Activity Work Package, Main Hole Drilling and Completion of Well ER-2-2* (NSTec, 2016); *Navarro Field Activity Work Package (FAWP) for Underground Test Area (UGTA) Drilling Field Operations Wells ER-20-12 and ER-2-2* (Navarro, 2015b); and *Field Instruction for the Underground Test Area Project Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015a). 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-2-2, including NSTec daily rig operations reports, Navarro morning reports and logbook notes, Schlumberger geophysical logs, 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-2-2 site was completed on October 27, 2015. NSTec advanced a 48-in. diameter, dry-auger borehole to a depth of 36.58 m (120 ft) bgs; installed 30-in. diameter CS conductor casing within the 48-in. borehole to a depth of 36.58 m (120 ft) bgs; and cemented the conductor casing in place.

Between January 10 and January 17, 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 fluid 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 January 16, 2016. Once formal drilling operations began on January 17, 2016, crews worked 7 days per week, 24 hours per day. Drilling and completion of the well took place over 22 days, after which the site was demobilized to the Well ER-3-3 location, as shown in Figure 2-1.

Drilling operations were initiated on January 17, 2016, by UDI at NSTec direction. Operations began by drilling the cement inside the 30-in. casing. UDI then continued to advance the 18.5-in. borehole reaching a depth of 614.48 m (2,016 ft) bgs on January 22, 2016. Near-field conditions were encountered at 566.93 m (1,860 ft) bgs; the radiological work permit (RWP) was implemented; and then preparations were made for geophysical logging.

Geophysical logging operations were conducted by Schlumberger, and the first run of logs were collected on January 23, 2016, in the 18.5-in. borehole to a depth of 614.18 m (2,015 ft) bgs. After completing geophysical logging operations and evaluating the geophysical logs with the borehole geology, Navarro collected two depth-discrete bailer groundwater samples, duplicates, and low-level tritium from a depth of 1,858 ft bgs for groundwater characterization parameters as defined in the *Nevada National Security Site Integrated Groundwater Sampling Plan* (NNSA/NFO, 2014).

UDI installed the 1.9-in. piezometer (p1) tubing to a depth of 1,909.36 ft bgs on January 24, 2016; and B&L Casing installed 13.375-in. CS casing to a depth of 1,990.14 ft bgs on January 25, 2016. The NSTec cementing crew then pumped 500 cubic feet (ft^3) of Type II neat cement to the base of the 13.375-in. casing. UDI tripped into the borehole with a new 12.25-in. bit and resumed drilling from the top of the cement. UDI continued to advance the borehole with a 12.25-in. bit, reaching a TD of 1,053.69 m (3,457 ft) bgs on February 1, 2016. Details of the well completion activities are discussed in Section 3.0.

UDI then conducted several short trips to check for fill and possible obstructions. UDI also circulated to clean out the hole and clear obstructions before geophysical logging. A reduced set of geophysical logs were collected between February 1 and 4, 2016, from 614.18 to 655.33 m (2,015 to 2,150 ft) bgs. Details of the geophysical logging are discussed in Section 4.0. On February 3, 2016, NSTec and UDI placed approximately 400 ft^3 of cement downhole in an attempt to stabilize the borehole. UDI tripped in the hole and began drilling through the cemented zone. However, no cement was encountered by

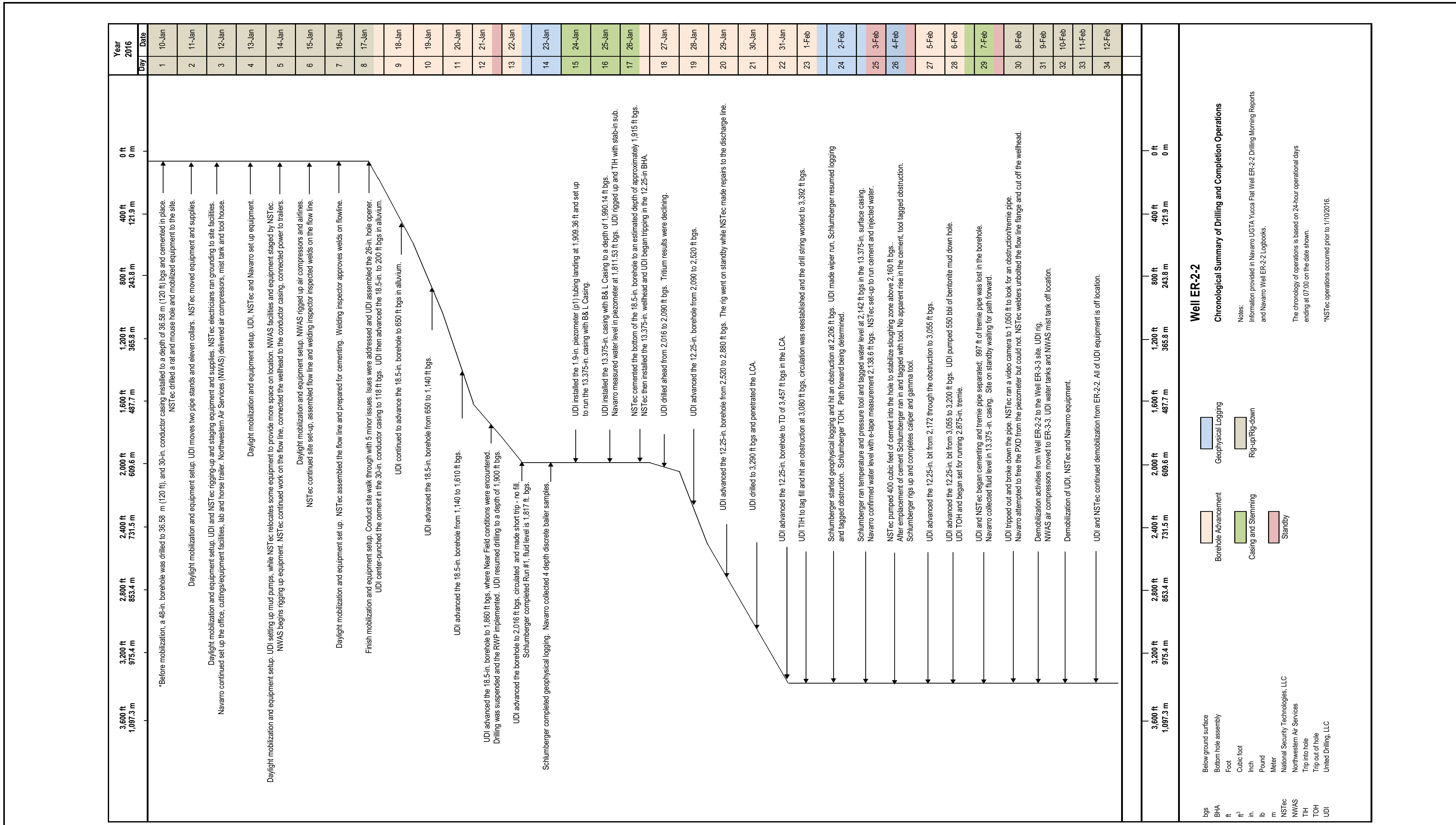


Figure 2-1
Well ER-2-2 Chronological Summary of Drilling and Completion Operations

the drill, and the cement was possibly lost to the formation or a washed out zone. On February 4, 2016, the decision was made by NNSA/NFO and the UGTA Technical Team to plug the bottom of the 12.25-in. borehole in Well ER-2-2 to eliminate any possible cross communication of groundwater between the Tertiary Volcanics (Tv) and the LCA. Between February 5 and 6, 2016, the 12.25-in. borehole was advanced to a depth of 3,200 ft bgs to stabilize the borehole for cementing operations. Approximately 550 bbl of bentonite mud was pumped, and the drill string was removed from the well to allow for a 2.875-in. tremie to be placed in the borehole to facilitate cementing operations. On February 7, cementing operations were conducted. After completing the cementing operations, the tremie line separated when being removed from the well. A portion of the tremie line was left in the well, as it was determined that a retrieval effort would not be warranted. Details of the well plugging are provided in Section 3.0. On February 8, 2016, site rig-down and mobilization activities were initiated. The demobilization of the well site was completed on February 12, 2016.

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 borehole and casing dimensional statistics.

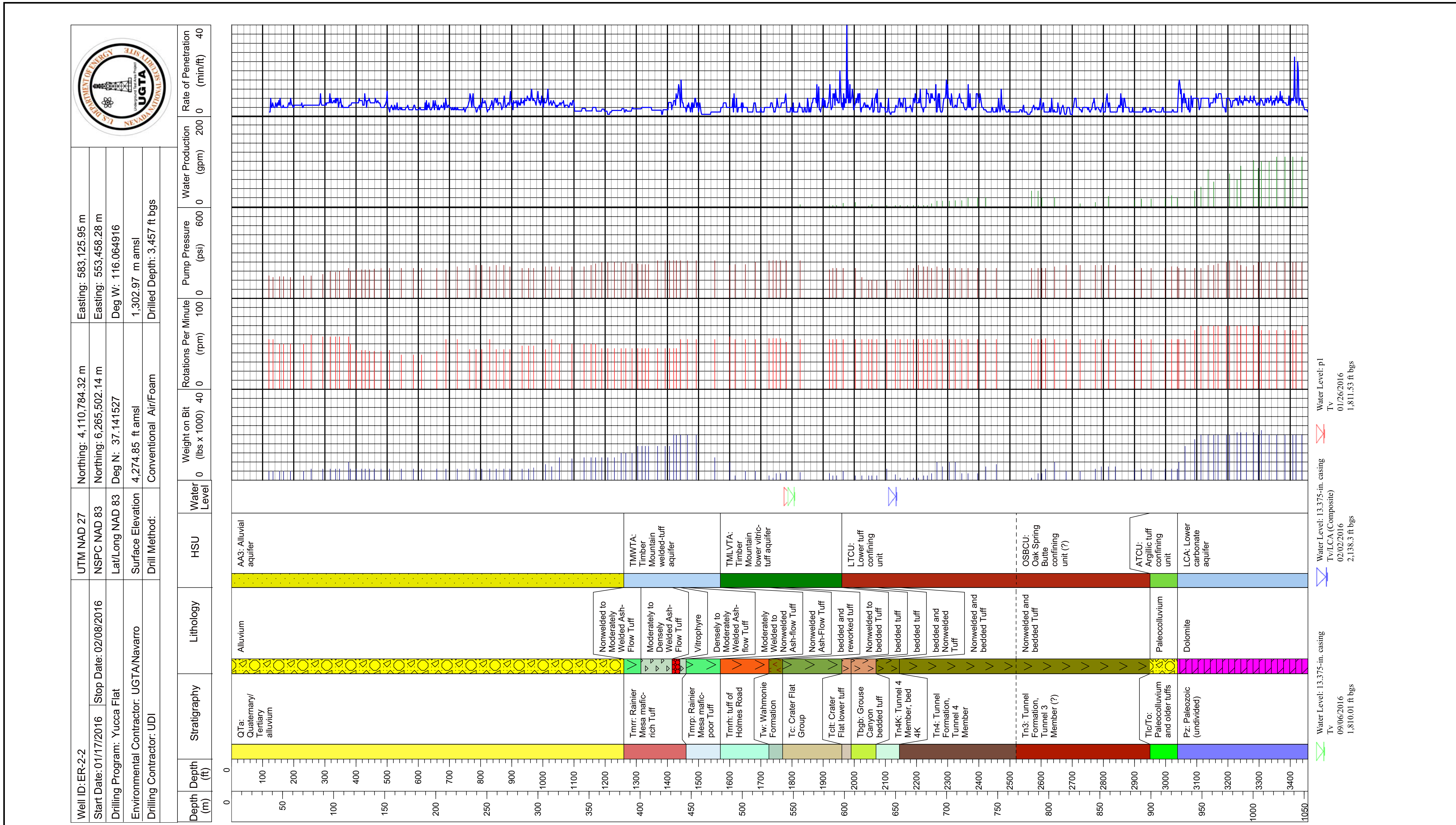


Figure 2-2
Summary of Well Drilling Parameters and Water Production for Well ER-2-2

3.0 Well Completion

Before 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 sub-dock 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.

The initial phase of the completion for Well ER-2-2 was initiated when 13.375-in. CS casing was installed from surface to a depth of 607 m (1,990 ft) bgs and cemented in place. Also, a 1.9-in. piezometer (p1) was installed between the borehole wall and 13.375-in. casing, and landed at 582 m (1,909.36 ft) bgs. The piezometer (p1) is completed in the TMLVTA. Figure 3-1 is a detailed schematic of the well completion details. 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-2-2, a detailed description of materials used in completion of ER-2-2, and relevant depths.

Due to problems with tight hole conditions and borehole stability issues, Well ER-2-2 was not constructed as planned. A plan to stabilize the borehole was developed through discussions with the Yucca Flat TWT, NNSA/NFO, NSTec, and Navarro personnel. The attempts to stabilize the borehole were unsuccessful, and the decision was made to plug the borehole below a depth of approximately 883.92 m (2,900 ft bgs) to isolate the LCA from the overlying LTCU. From February 6 to 7, 2016, UDI washed down and pumped approximately 550 bbl of bentonite mud to support the hole while preparations for cementing were completed. UDI tripped in the hole with 2.875-in. tremie to 946 m (3,104 ft) bgs and pumped 25 bbl of bentonite mud followed by 350 ft^3 of neat cement. The top of the cement is estimated to be at 897 m (2,943 ft) bgs. The cement plug successfully isolated the LCA from the LTCU. While attempting to tag the top of the cement plug, the tremie pipe separated, and 304 m (997 ft) of 2.875-in. tremie remains in the borehole. Depth to the top to the tremie pipe is uncertain but is estimated at 616 m (2,020 ft) bgs. The borehole is open to the LTCU and Oak Spring

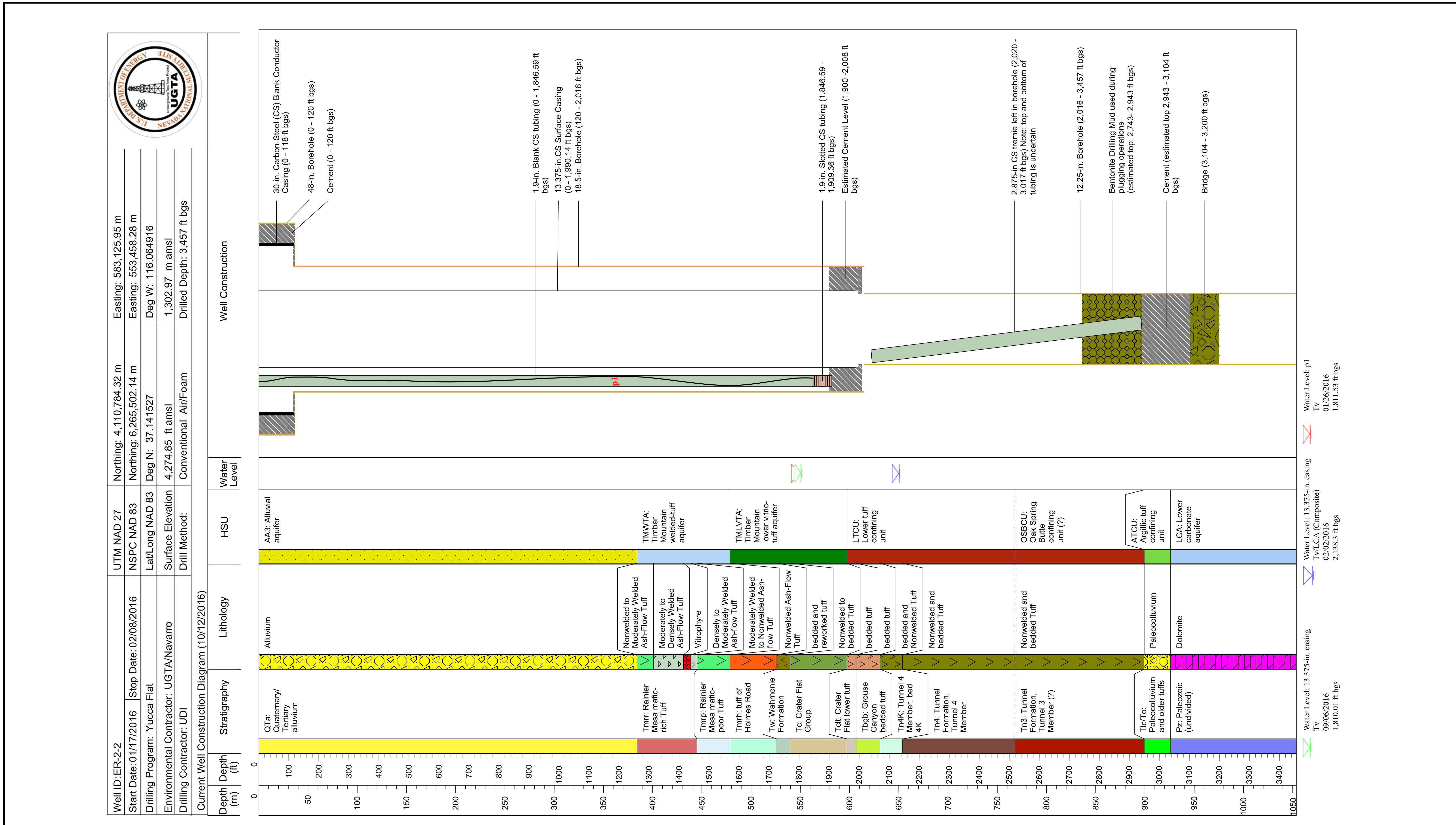


Figure 3-1
Well Completion Diagram for Well ER-2-2

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

LOCATION DATA:		
Coordinates:	Nevada State Plane (NAD 27)	N 871,065.13 ft E 675,645.76 ft
	Nevada State Plane (NAD 83)	N 6,265,502.14 m E 553,458.28 m
	Universal Transverse Mercator (NAD 27, Zone 11)	N 4,110,784.32 m E 583,125.95 m
	Latitude/Longitude (NAD 83)	37.141527 decimal degrees N 116.064916 decimal degrees W
Surface Elevation:	1,302.97 m (4,274.85 ft) amsl	
DRILLING DATA:		
Spud Date:	01/17/2016	
Date TD Reached:	01/31/2016	
Date Well Completed:	02/08/2016	
TD:	1,053.69 m (3,457.00 ft) bgs	
Hole Diameters:	121.92 cm (48 in.) from surface to 36.58 m (120 ft); 46.99 cm (18.5 in.) from 36.58 m (120 ft) to 614.48 m (2,016 ft); 31.12 cm (12.25 in.) from 614.48 m (2,016 ft) to 1,053.69 m (3,457 ft)	
Drilling Techniques:	Dry auger drilling using a 121.92-cm (48-in.) diameter bucket style auger bit from surface to 36.58 m (120 ft); rotary drilling with air-foam and conventional circulation commenced at 36.58 m (120 ft) using a 46.99-cm (18.5-in.) bit to 614.48 m (2,016 ft); from 614.48 m (2,016 ft) to TD at 1,053.69 m (3,457 ft), the borehole was drilled with a 31.12-cm (12.25-in.) chisel tooth tricone button bit.	
CASING DATA:	76.2-cm (30-in.) CS conductor casing from ground surface to 36.58 m (120 ft); 33.97-cm (13.375-in.) CS surface casing from 0.61 m above ground surface to 606.59 m (+2.0 - 1,990.14 ft).	
WELL COMPLETION DATA:		
Description of Completion Casing:	None installed.	
Description of Piezometer Strings:	The piezometer (p1) consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) od by 3.83-cm (1.51-in.) id CS hydrill tubing with upset couplings extending from 0.71 m (2.33 ft) above ground surface to 562.84 m (1,846.59 ft). The slotted CS tubing consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) od by 3.83-cm (1.51-in.) id tubing with upset couplings and an orange-peeled termination, extending to 581.97 m (1,909.36 ft). Depth intervals for the hydril blank and slotted tubing are tabulated below.	
SLOT INFORMATION:	Slots for the CS piezometers are machine-cut, 0.20-cm (0.08-in) by 5.58-cm (2.2-in.), 4 vertical slots per row, 99 rows per joint (396 slots).	
TUBING DATA:	1.9-in. piezometer tubing; Type: CS, Grade: L80, OD: 1.9-in., ID: 1.51-in., Wall Thickness: 0.195-in., lb/ft: 2.90	
WELL COMPLETION DATA:	<u>Description</u>	<u>Depth Interval</u>
Detail of Conductor Casing:	Blank 76.20 cm (30-in.) CS casing:	+0.51 - 35.97 m (+1.67 - 118 ft)
Detail of Surface Casing:	Blank 33.97-cm (13.375-in.) CS casing:	+0.61 - 606.59 m (+2.0 - 1,990.14 ft)
Detail of Piezometer (p1):	Blank 4.82-cm (1.9-in.)CS hydril tubing:	+0.71 - 572.47 m (+2.33 - 1,846.59 ft)
	Slotted 4.82-cm (1.9-in.) CS hydrill tubing with orange-peeled termination:	572.47- 581.97 m (1,846.59 - 1,909.36 ft)
Detail of Completion Materials:	3/8-in. Gravel pack:	None
	20/40 Sand pack:	None
	Type II neat cement [a]	579.12 - 612.04 m (1,900 - 2,008 ft) 897.03 - 946.10 m (2,943 - 3,104 ft)
FLUID-LEVEL DATA:	<u>Fluid Depth</u>	<u>Fluid Elevation</u>
Open borehole [b]	551.46 m (1,809.25 ft)	751.51 m (2,465.60 ft)
Open borehole [c]	651.75 m (2,138.30 ft)	651.22 m (2,136.55 ft)
Piezometer (p1) [d]	552.15 m (1,811.53 ft)	750.82 m (2,463.32 ft)
DRILLING CONTRACTOR:	United Drilling, LLC	
GEOPHYSICAL LOGS BY:	Schlumberger	

[a] Measurements are estimated.
[b] Measurement by USGS using downhole video 03/18/2016 (open borehole).
[c] Measurement by Navarro using a calibrated Solinst e-tape on 02/02/2016 in the Tv/LCA composite open borehole.
[d] Measurement by Navarro using a calibrated Solinst e-tape on 01/26/2016 (piezometer).

id = Inside diameter
od = Outside diameter
NAD 27 = North American Datum, 1927
NAD 83 = North American Datum, 1983

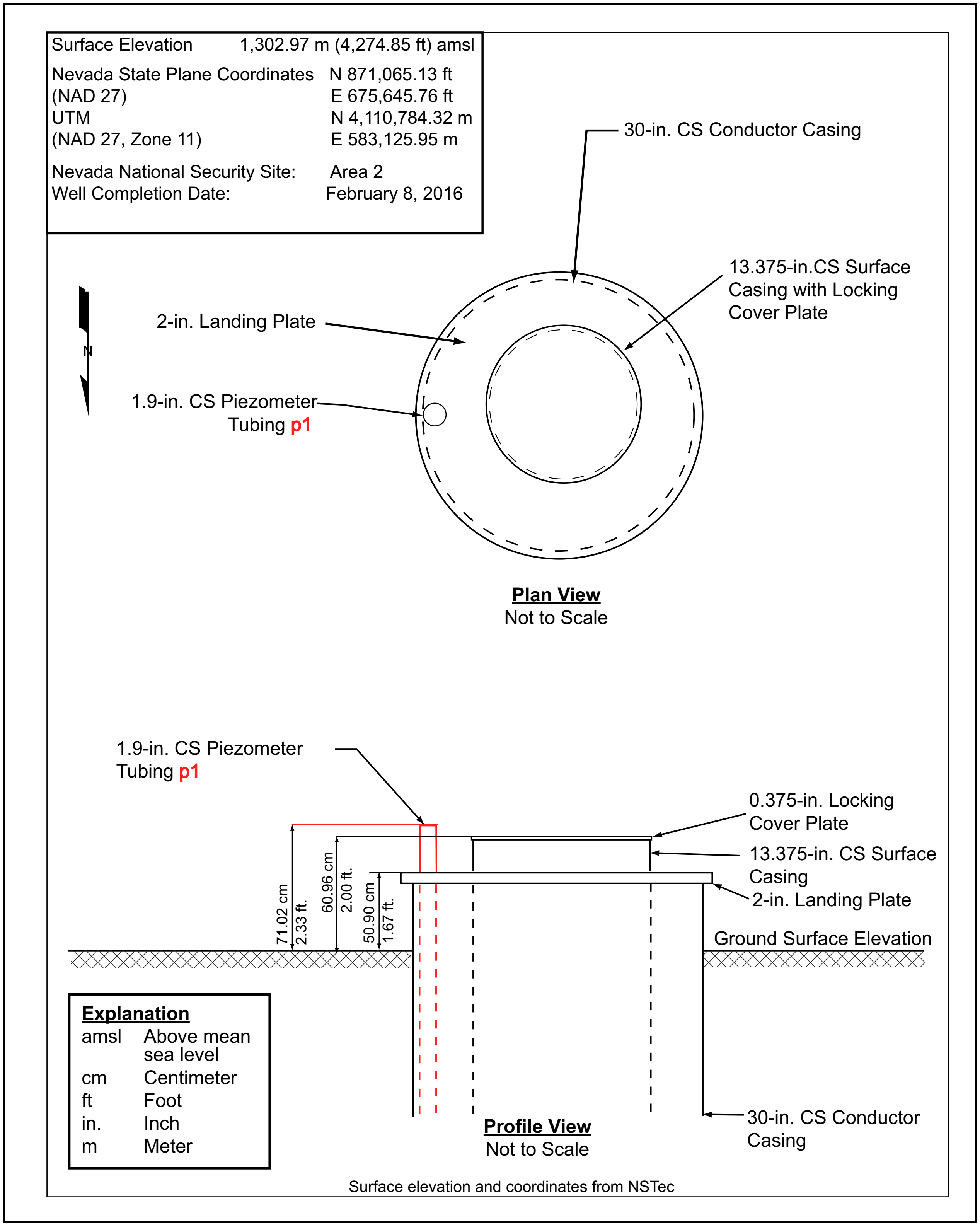


Figure 3-2
Wellhead Completion Diagram for Well ER-2-2

Figure 3-3
Photograph of Well ER-2-2 Wellhead

Butte confining unit (OSBCU) from 612.04 m (2,008 ft) bgs to approximately 836.07 m (2,743 ft) bgs.

A PXD was installed in the 1.9-in. piezometer (p1) at approximately 579 m (1,900 ft) bgs to monitor the fluid level rise during the emplacement of the cement seal for the 13.375-in. casing and collect hydrologic data. Subsequent attempts to retrieve the PXD were unsuccessful. It appears that the PXD is cemented in the piezometer as a result of an unexpected rise in the level of the cement during stemming. At the time of the preparation of this document, the PXD remains connected to the surface via a length of wireline.

4.0 Geologic Data Collection

4.1 Well Geologic Data

Before Well ER-2-2 was drilled, a predicted stratigraphic sequence with unit thicknesses was developed from the Yucca Flat HFM (BN, 2006). During drilling, Navarro personnel prepared preliminary field lithologic descriptions and stratigraphic unit assignments based on the field examination of drill cuttings. Final lithologic descriptions are provided in Appendix A.

Overall cuttings quality (e.g., size, volume, and purity) was initially fair. However, once the Grouse Canyon bedded tuff (Tbgb) and Tunnel Formation (Tn) had been drilled through, the condition of the borehole began to deteriorate. As the borehole progressed into the Paleozoic carbonates, cuttings samples were generally mixed more than 50 percent with Grouse Canyon bedded tuff (Tbgb) and Tunnel Beds (Tn). As the borehole stability deteriorated, problems with bridging and obstructions made cutting collection difficult. Deterioration of the borehole eventually led to plugging and isolation of the Paleozoic carbonates from the overlying carbonates.

When the volume of rock cuttings circulating 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 120 ft bgs because this interval was drilled and cased before Navarro personnel mobilized to the site. 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 carbonates, additional composite, paleontologic, samples of the cuttings were collected every 50 ft. The samples were placed in 1-gallon (gal) steel containers, labeled, and sealed with custody tape. These samples are stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

4.2 Well Geophysical Data

Geophysical logging was conducted by Schlumberger in the open borehole and was used to characterize the lithology, structure, and petrophysical character of the rocks penetrated. The geophysical logs were also used to evaluate borehole conditions, determine fluid levels, and collect preliminary hydrologic data. Three separate geophysical logging efforts were conducted in Well ER-2-2. A suite of geophysical logs were run on January 23, 2016, within the unsaturated zone and upper portion of the saturated zone before installation of the 13.375-in. CS surface casing. The borehole was logged on February 1 and then again on February 4, 2016, to evaluate the condition of the borehole. Only the gamma, 4-arm caliper and directional tools were run on February 1, 2016. On February 4, 2016, only the gamma and 4-arm caliper tools were run. The geophysical logs acquired are summarized in Table 4-1.

An obstruction was encountered in the borehole during the final geophysical log run on January 23, 2016. Previous logging runs had gone as deep as 614.17 m (2,015 ft) bgs; however, Schlumberger could not get the logging tools past 599.24 m (1,966 ft) bgs on the last run. The borehole had been advanced to a depth of 1,033.88 m (3,392 ft) bgs, and during the logging run on February 1, 2016, Schlumberger was unable to lower the geophysical tool in the borehole past 669.04 m (2,195 ft) bgs. After work to stabilize the borehole, Schlumberger again ran the gamma and 4-arm caliper tools on February 4, 2016, and hit another obstruction in the borehole, which prevented lowering the tools beyond a depth of 649.22 m (2,130 ft) bgs.

Upon completion of geophysical logging activities on January 23, 2016, data from Schlumberger logs were evaluated by Navarro geologists to assist in the selection of a depth-discrete bailer sample location. Based on the selection, a depth-discrete bailer sample and duplicate sample were collected from 566.32 m (1,858 ft) bgs on January 24, 2016, and the analytical results are discussed in Section 6.0.

Table 4-1
Well ER-2-2 Summary of Geophysical Logs

Geophysical Log	Log Purpose	Logging Service	Date Logged	Direction Logged	Top of Logged Interval (ft bgs)	Bottom of Logged Interval (ft bgs)
Borehole: 0 to 2,006 ft bgs						
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels; water movement in/out of borehole; depth calibration	Schlumberger	01/23/2016	Down	1,700	1,972
8-Arm Caliper, Powered Positioning Device, API Gamma Ray, Directional Survey, General Purpose Inclinometry Tool	Formation: Borehole condition (washouts, fractures); depth correlation; lithologic/stratigraphic analysis; alteration analysis; borehole orientation and deviation	Schlumberger	01/23/2016	Down	20	2,006
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 and depth correlation	Schlumberger	01/23/2016	Down	20	2,006
Caliper, Array Induction, Gamma Ray, Spontaneous Potential	Formation: Borehole depth correlation and condition (washouts, fractures); resistivity; thin bed analysis; spontaneous potential	Schlumberger	01/23/2016	Up	20	1,966
Compensated Neutron, Three Detector Litho Density, Caliper, Gamma Ray, Spontaneous Potential, Photoelectric Factor	Formation: Porosity and lithologic determination; density; borehole depth and condition (washouts, fractures); resistivity; thin bed analysis; spontaneous potential	Schlumberger	01/23/2016	Up	20	1,966
Borehole: 1,994 to 2,195 ft bgs						
4-Arm Caliper, Gamma Ray	Formation: Borehole condition (washouts, fractures); depth correlation	Schlumberger	02/01/2016	Down and up	1,994	2,195
Borehole: 1,990 to 2,130 ft bgs						
4-Arm Caliper, Gamma Ray	Formation: Borehole condition (washouts, fractures); depth correlation	Schlumberger	02/04/2016	Down and up	1,990	2,130

API = American Petroleum Institute
K = Potassium
Th = Thorium
U = Uranium

Figures 4-1 through 4-4 present traces of selected geophysical logs. 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.

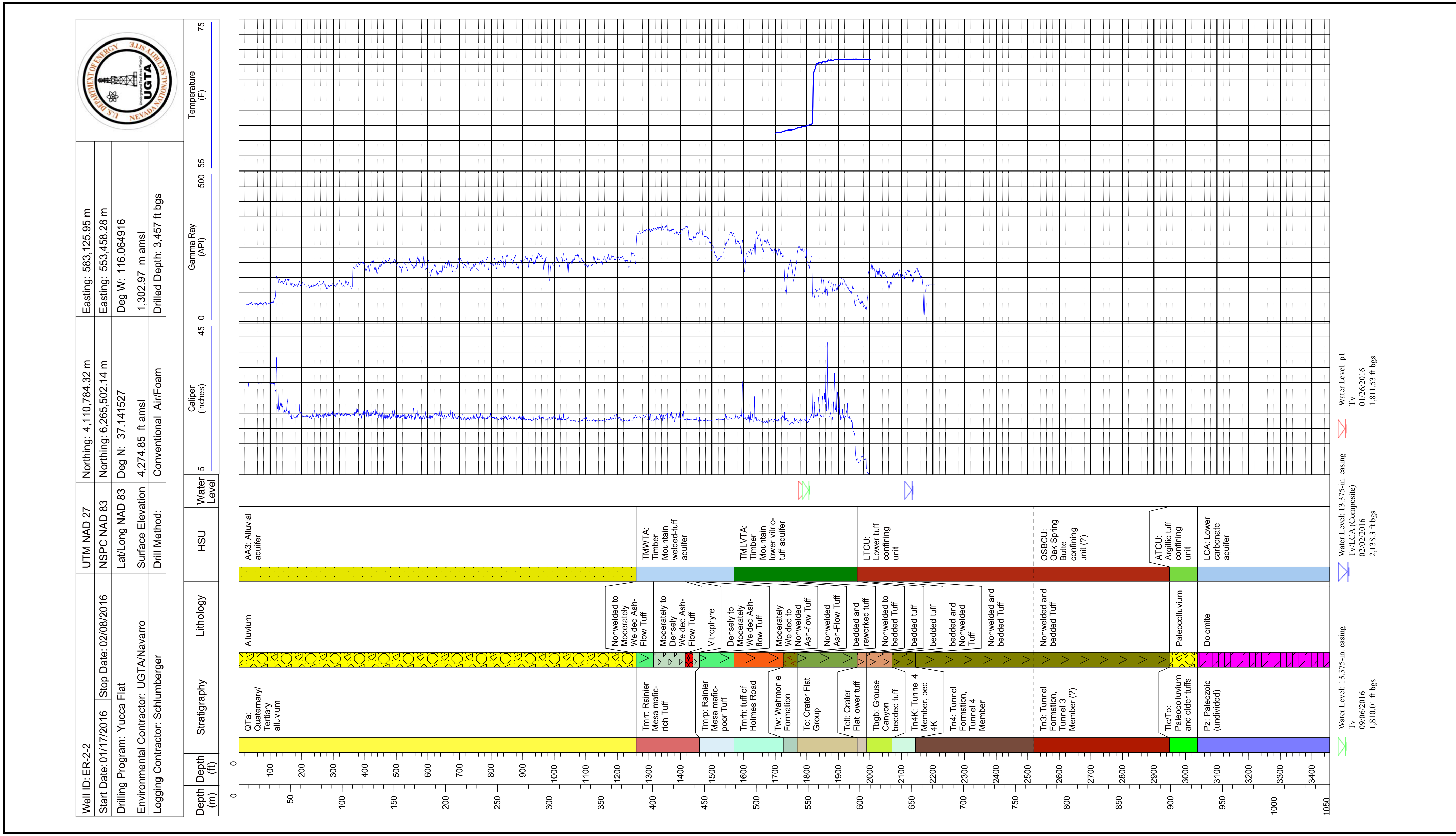


Figure 4-1
Well ER-2-2 Geophysical Log Traces of Caliper Average, Gamma Ray, and Temperature

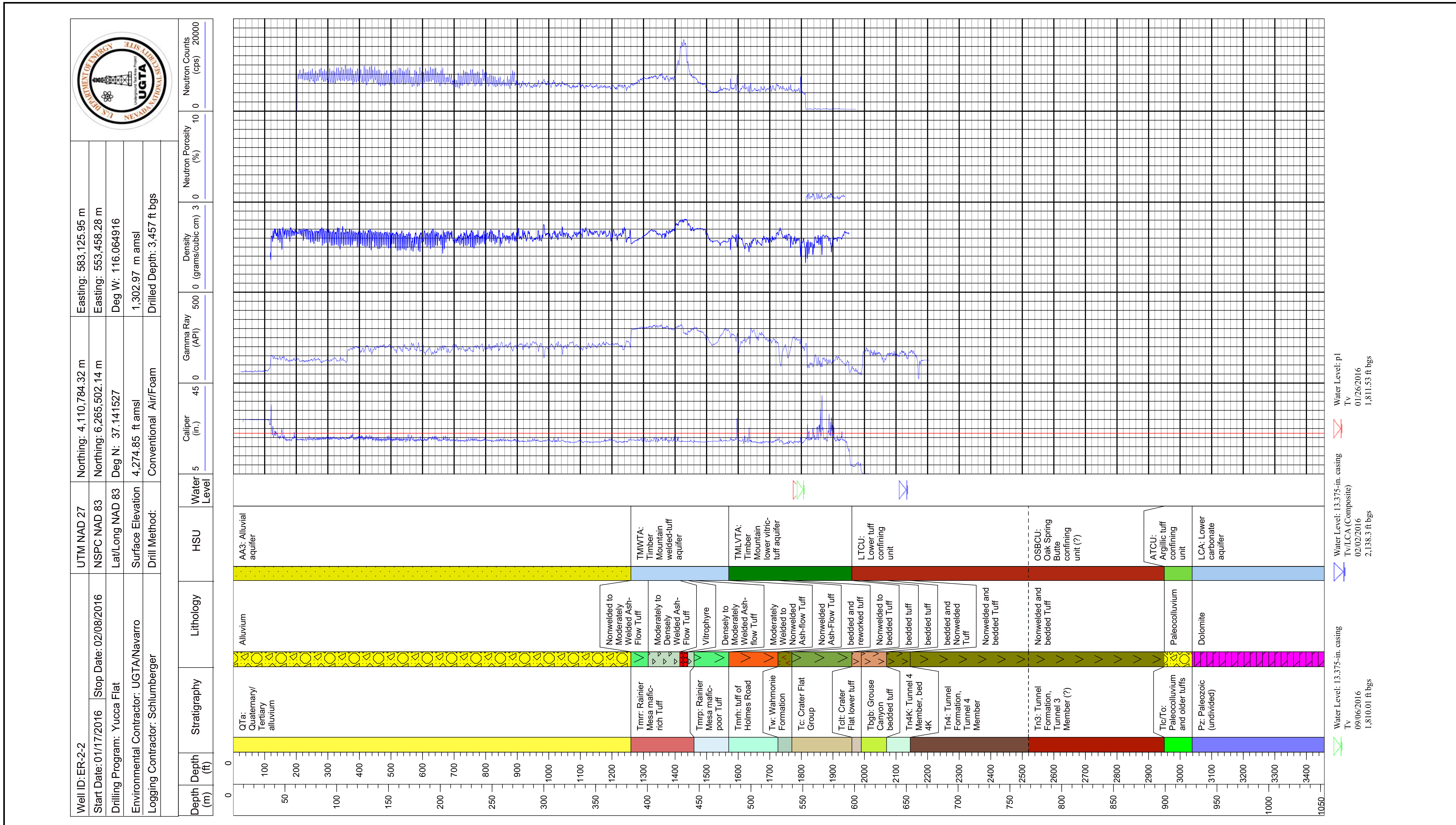


Figure 4-2
Well ER-2-2 Geophysical Log Traces of Caliper Average, Gamma Ray, Bulk Density, Neutron Porosity, and Neutron Counts

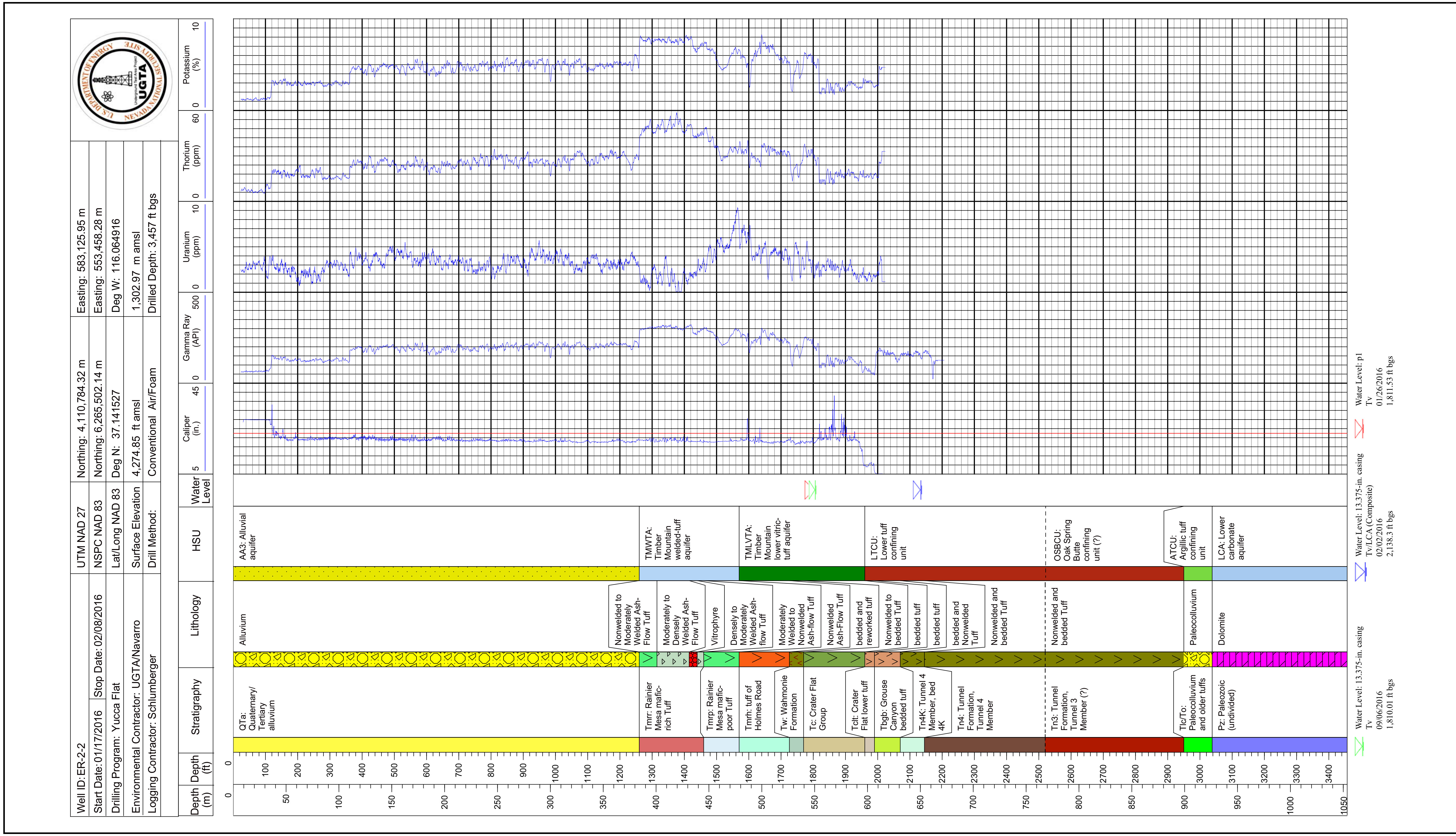


Figure 4-3
Well ER-2-2 Geophysical Log Traces of Caliper Average, Gamma Ray, and Digital Spectralog

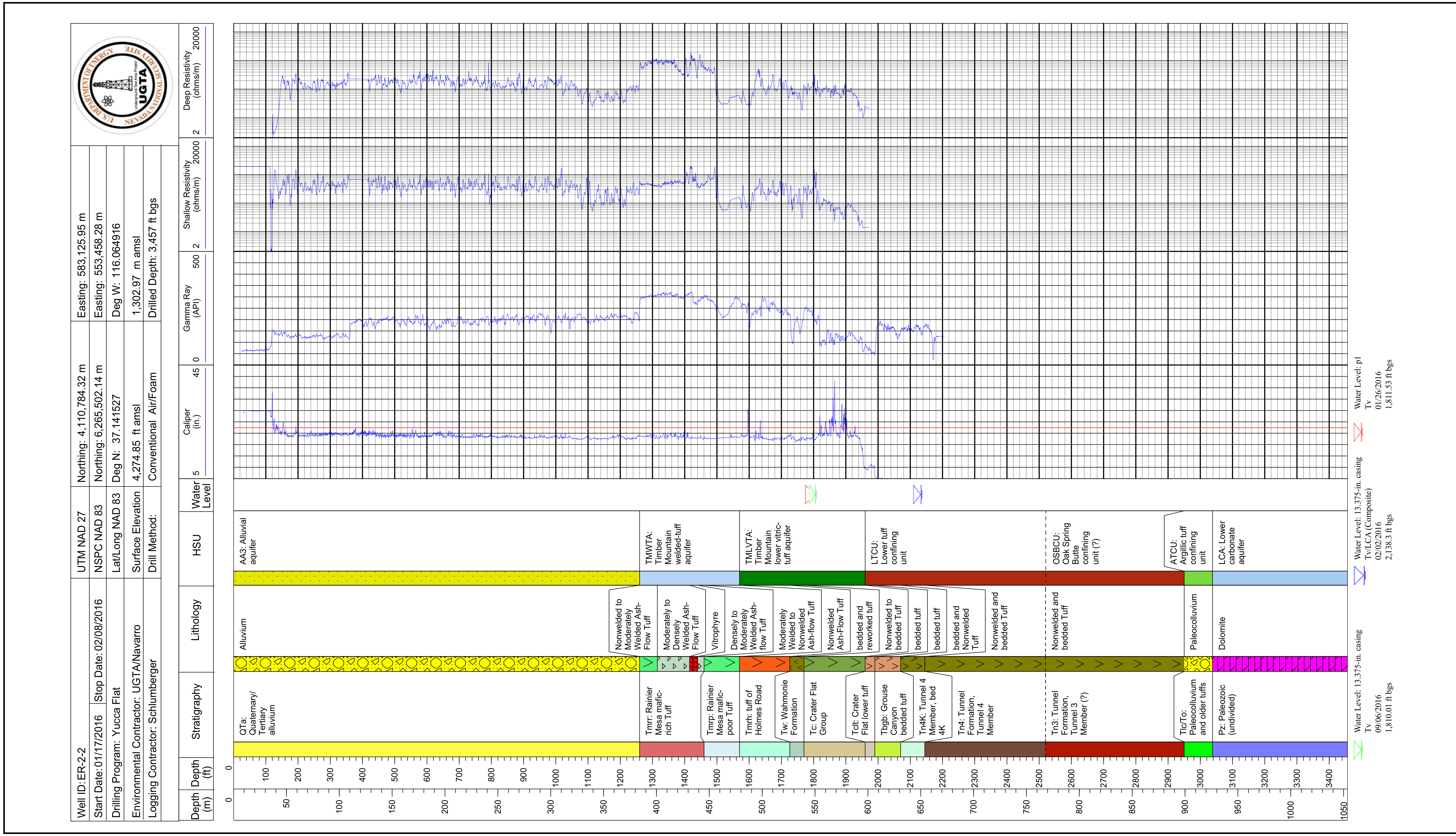


Figure 4-4
Well ER-2-2 Geophysical Log Traces of Caliper Average, Gamma Ray, Shallow and Deep Resistivity

5.0 Geology and Hydrogeology

5.1 Geology

The following discussion and interpretations are primarily based on the lithologic log presented in Appendix A. A preliminary lithologic log was developed using the drill cuttings and borehole geophysical logs in the field. Subsequent to drilling, Navarro geologists completed additional hydrogeologic analysis and interpretive work. This section and the lithologic log in Appendix A have been modified accordingly. 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-2-2, the following stratigraphic groups and units were encountered beginning at ground surface and down through to TD:

- Quaternary/Tertiary alluvium (QTa)
- Timber Mountain Group (Tm)
- Wahmonie Formation (Tw)
- Crater Flat Group (Tc)
- Grouse Canyon bedded tuff (Tbgb)
- Tunnel Formation (Tn)
- Paleocolluvium/older tuffs (Tlc/To)
- Paleozoic (undivided) (Pz)

Surficial geology of the northern portion of Yucca Flat is presented in Figure 5-1. The stratigraphic units encountered in Well ER-2-2 were generally as predicted (see Figure 5-3). However, significant differences within the units observed were noted, particularly actual thicknesses. In terms of sequence, the units were as predicted except that the Paintbrush Group (Tp) was not present, and stratigraphic units of the Wahmonie Formation (Tw) and Crater Flat Group (Tc) preceded the Timber Mountain Group (Tm). The most significant difference noted was the actual versus predicted thicknesses of the Tunnel Formation (Tn). The predicted thickness was 30.48 m (100 ft), whereas the actual thickness was 268.22 m (880 ft). Differences in the predicted versus actual unit thicknesses led to a significant difference in the depth at which the Paleozoic (Pz) was found. The top of the Paleozoic (Pz) was predicted to be at a depth of 669.7 m (2,197 ft) bgs. Drilling in Well ER-2-2 identified the actual top of the Paleozoic (Pz) at 925.99 m (3,038 ft) bgs. Differences between

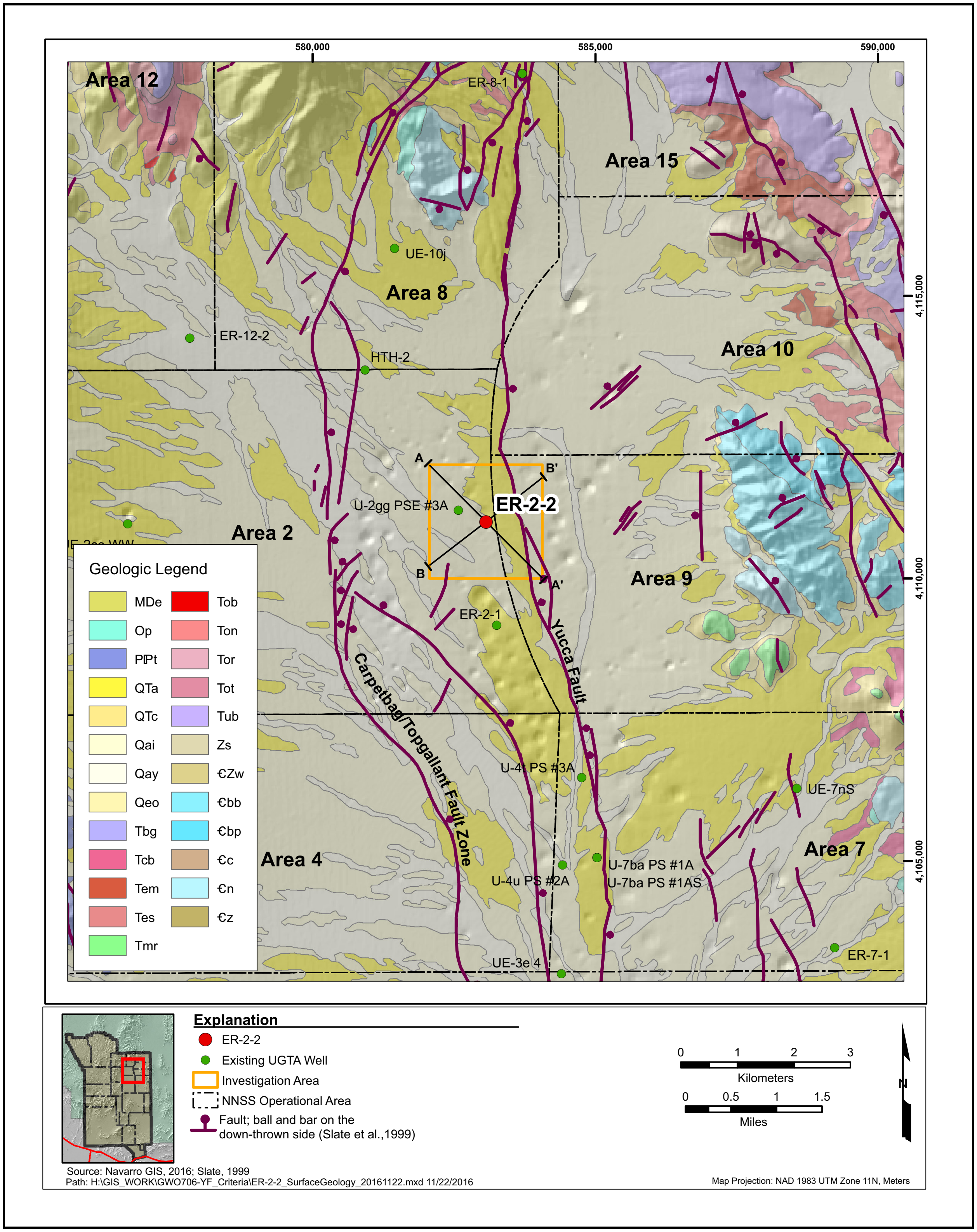


Figure 5-1
Surficial Geology at Well ER-2-2

predicted and actual geology in boreholes are not uncommon and may result from complex relationships between topographic, volcanic, and structural processes associated with basin-forming systems.

5.1.1 Geologic Setting

Well ER-2-2 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 Yucca Flat Basin and surrounding areas are dominated by Tertiary Volcanics (Tv) rocks that erupted from volcanic vents in the southwestern Nevada volcanic field located on and adjacent to the northwest portion of the NNSS. Underlying these volcanic rocks are variably folded and faulted Paleozoic aged sedimentary rocks including dolomite, limestones, and quartzite. Surface drainage in the vicinity of Well ER-2-2 is generally to the Yucca Flat Playa near the south–central portion of the basin. Physiographically, the well site lies at the north–central end of Yucca Flat.

5.1.2 Stratigraphy and Lithology

The stratigraphic units, lithologic units, and HSUs penetrated in Well ER-2-2 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 nearby boreholes (U-2av, U-2gg, U-2z 2, U-2z 3, U-9ca1, ER-2-1) (Drellack et al., 2010), and in the Yucca Flat HFM presented in *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Yucca Flat–Climax Mine, Lincoln and Nye Counties, Nevada* (BN, 2006).

Drilling at Well ER-2-2 started in 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 minor amounts of Paleozoic sediments eroded from the surrounding highlands. This unit was slightly thicker than predicted. A total of 384.05 m (1,260 ft) of the Quaternary/Tertiary Alluvium (QTa) was penetrated.

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-2-2 Area

Stratigraphic Unit	Map Symbol
Quaternary/Tertiary Alluvium	**QTa**
Timber Mountain Group	**Tm**
Rainier Mesa mafic-rich Tuff	Tmrr
Rainier Mesa mafic-poor Tuff	Tmrp
tuff of Holmes Road	Tmrh
Wahmonie Formation	**Tw**
Crater Flat Group (undivided)	**Tc**
Crater Flat lower tuff	Tclt
Belted Range Group	**Tb**
Grouse Canyon bedded tuff	Tbgb
Tunnel Formation	Tn
Tunnel 4 Member, bed k	Tn4k
Tunnel 4 Member	Tn4
Tunnel 3 Member	Tn3
Paleocolluvium/Older tuffs	**Tlc/To**
Paleozoic Rocks	Pz **(undivided)**

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

HSU	Map Symbol
Alluvial aquifer	AA3
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

The Timber Mountain Group (Tm) was encountered below the Quaternary/Tertiary Alluvium (QTa). The Timber Mountain Group (Tm), at ER-2-2, is composed of the Rainier Mesa Tuff (Tmr) and the tuff of Holmes Road (Tmrh), which erupted 11.6 million years ago (Ma) from the Timber

Mountain caldera complex (TMCC) (Sawyer et al., 1994) located approximately 16.90 kilometers (km) (10.50 miles [mi]) to the west. The borehole penetrated 142.04 m (466 ft) of Timber Mountain Group (Tm) tuffs from 384.05 to 526.08 m (1,260 to 1,726 ft).

The Rainier Mesa Tuff (Tmr) was identified by its stratigraphic position and the mineralogic assemblage, including the presence of terminated and dipyramidal quartz and biotite. The Rainier Mesa Tuff (Tmr) is subdivided into three units. The unit from 384.05 to 445.01 m (1,260 to 1,460 ft) is assigned to the Rainier Mesa mafic-rich Tuff (Tmrr). A densely welded vitrophyre occurs within this unit from 431.29 to 438.91 m (1,415 to 1,440 ft). The unit from 438.91 to 478.54 m (1,440 to 1,570 ft) is assigned to the Rainier Mesa mafic-poor Tuff (Tmrp). Also, this portion of the borehole, from the vitrophyre and below, is vitric with a gradual downward transition to zeolitic/argillic alteration. The unit from 478.54 to 526.08 m (1,570 to 1,726 ft) 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, high phenocryst content (~15%), including abundant quartz with minor mafics. This stratigraphic assignment and others were aided by correlation to various geophysical log responses, due to the generally poor quality of drill cuttings that were not representative of the lithologies encountered within the respective stratigraphic formations.

Following the Timber Mountain Group (Tm), Well ER-2-2 penetrated a series of stratigraphic units that were not predicted in the drilling and completion criteria document (Navarro, 2016b). This included 13.41 m (44 ft) of Wahmonie Formation (Tw) from 526.08 to 539.50 m (1,726 to 1,770 ft). The Wahmonie Formation (Tw) was recognized by its mafic-rich nature and characteristic geophysical log response. Subsequently, the Crater Flat Group (Tc), was encountered from 539.50 to 597.41 m (1,770 to 1,960 ft) for a total of 57.91 m (190 ft) penetrated. The unit consists of crystal-moderate to crystal-rich ash-flow tuffs with variable pumice and lithic content. The tuffs are vitric with alteration (zeolitic/argillic) increasing with depth. The Crater Flat lower tuff (Tclt) was identified and extends from 597.41 to 606.55 m (1,960 to 1,990 ft) for a total of 9.14 m (30 ft). The Tertiary Volcanics (Tv) water table occurs within the Tc with an observed depth to water of approximately 552.16 m (1,811.53 ft) bgs.

Well ER-2-2 penetrated a total of 24.38 m (80 ft) bgs of Grouse Canyon bedded tuff (Tbgb).
The Grouse Canyon bedded tuff (Tbgb) extends from 606.55 to 630.94 m (1,990 to 2,070 ft) bgs and

was recognized on the basis of stratigraphic position, phenocryst poor nature, no mafic phenocrysts, and relatively abundant manganese oxide spots. This unit was also thicker than predicted. The Grouse Canyon Formation was erupted from the Silent Canyon caldera complex (SCCC), located 25.35 km (15.75 mi) to the northwest approximately 13.7 Ma.

The Tunnel Formation (Tn) was encountered from 630.94 to 899.16 m (2,070 to 2,950 ft) bgs for a total of 268.22 m (880 ft) penetrated. The Tunnel Formation (Tn) was subdivided as follows: (1) Tunnel 4 Member, bed k (Tn4k) from 630.94 to 653.80 m (2,070 to 2,145 ft); (2) Tunnel 4 Member (Tn4), undifferentiated from 653.80 to 768.10 m (2,145 to 2,520 ft); and tentatively (3) Tunnel 3 Member (Tn3), undifferentiated from 768.10 to 899.16 m (2,520 to 2,950 ft) (Hoover and Magner, 1990). The Tunnel Formation (Tn) was recognized on the basis of stratigraphic position; distinctive multicolor banding; phenocryst poor, scattered lithic-rich (volcanic) intervals; and pervasive alteration. At the probable base of Tn4k, a silicified zone from 652.27 to 653.80 m (2,140 to 2,145 ft) was noted. This zone consisted of fine ash (porcelaneous) and thin layers of hydroclastic shards, and bubbles and fragments tended to be much larger than the average cuttings size and with blocky angular faces, indicating possible structural influence. The Tunnel Formation (Tn) was significantly thicker than predicted, which implies an active fault possibly of the Yucca Flat Fault system or other structure. The lithologic and alteration types found in the Tunnel Formation (Tn) contributed to the borehole stability issues and tight hole conditions experienced at the well.

Paleocolluvium and older tuffs (Tlc/To) were encountered next from 899.16 to 925.98 m (2,950 to 3,038 ft). The Paleocolluvium appears to consist of fine altered ash and pumice, with less altered fragments and other material. Much of the fines and most likely the clay were washed away by the drilling process. Paleozoic (Pz) rocks were encountered from 925.98 to 1,053.69 m (3,038 to 3,457 ft) bgs for a total of 127.71 m (419 ft). The Paleozoic (undivided) (Pz) rocks were composed of dolomites with possible limey dolomite interbeds. Many of the cuttings exhibited signs of fracturing, brecciation, and micro-stockwork veining. During completion, a number of obstructions were noted within this interval, providing additional evidence for brecciation and fracturing.

Due to the substantial differences in depth and thickness of Tertiary Volcanics (Tv) from the Grouse Canyon Formation, Tunnel Formation (Tn), and Paleozoics (Pz), there is evidence for greater relief in paleotopographic surface of the Paleozoics in the area of Well ER-2-2 than previously suggested.

Further, it is suspected that much of this relief may be influenced by normal faulting as part of basin extension, particularly given the close proximity of the Yucca Fault. As expected, the most significant water production encountered during drilling can be attributed to the Paleozoic units found within this interval.

5.1.3 Alteration

Figure 5-2 shows the alteration zones encountered in Well ER-2-2. Generally, from 0 to 384.05 m (0 to 1,260 ft) bgs, the alluvium is unaltered to weakly clay altered. Once in the Tertiary Volcanics (Tv) section, alteration is minimal from 384.05 to 597.41 m (1,260 to 1,930 ft) bgs. From 588.26 to 597.41 m (1,930 to 1,960 ft) bgs, zeolitic/argillic alteration increases becoming pervasive. Nonwelded and bedded tuffs are vitric to partially devitrified with some minor argillic and zeolitic alteration and/or vapor phase alteration; densely to moderately welded tuffs at Well ER-2-2 are mostly devitrified. The exception to this is the Rainier Mesa mafic-rich Tuff (Tmrr) vitrophyre and portions of the Rainier Mesa mafic-poor Tuff (Tmrp) lower moderately to nonwelded subzones, and tuff of Holmes Road (Tmrh), which are vitric to partially vitric. Below 597.41 to 925.98 m (1,960 to 3,038 ft) bgs, beginning in the Crater Flat Group (Tc) and continuing through the Grouse Canyon bedded tuff (Tbgb), and the Tunnel Formation (Tn), the nonwelded and bedded tuffs are typically pervasively to variably altered to zeolites, and locally intense argillized zones. A thin, approximately 1.52-m (5-ft) thick zone of possible silicification was noted at the base of Tn4k. Finally, the Paleozoic (Pz) rocks show little apparent alteration.

5.2 Predicted and Actual Geology

Overall, the actual stratigraphic sequence and lithology at Well ER-2-2 showed a number of differences with the predicted stratigraphic and related lithologic sequence. However, there were significant differences in the predicted versus actual unit thickness. Figure 5-3 illustrates the differences between predicted and actual geology in Well ER-2-2. Thicknesses in the Quaternary/Tertiary alluvium (QTa) and the Timber Mountain Group (Tm) were generally as predicted. However, the Paintbrush Group (Tp) was not identified in the well, and instead the Wahmonie Formation (Tw), Crater Flat Group (Tc), and Crater Flat lower tuff (Tclt) were noted. Grouse Canyon bedded tuff (Tbgb) and the Tunnel Formation (Tn) were all thicker than originally predicted. The Tunnel Formation (Tn)—including Tunnel 4 Member, bed k (Tn4k), Tunnel 4

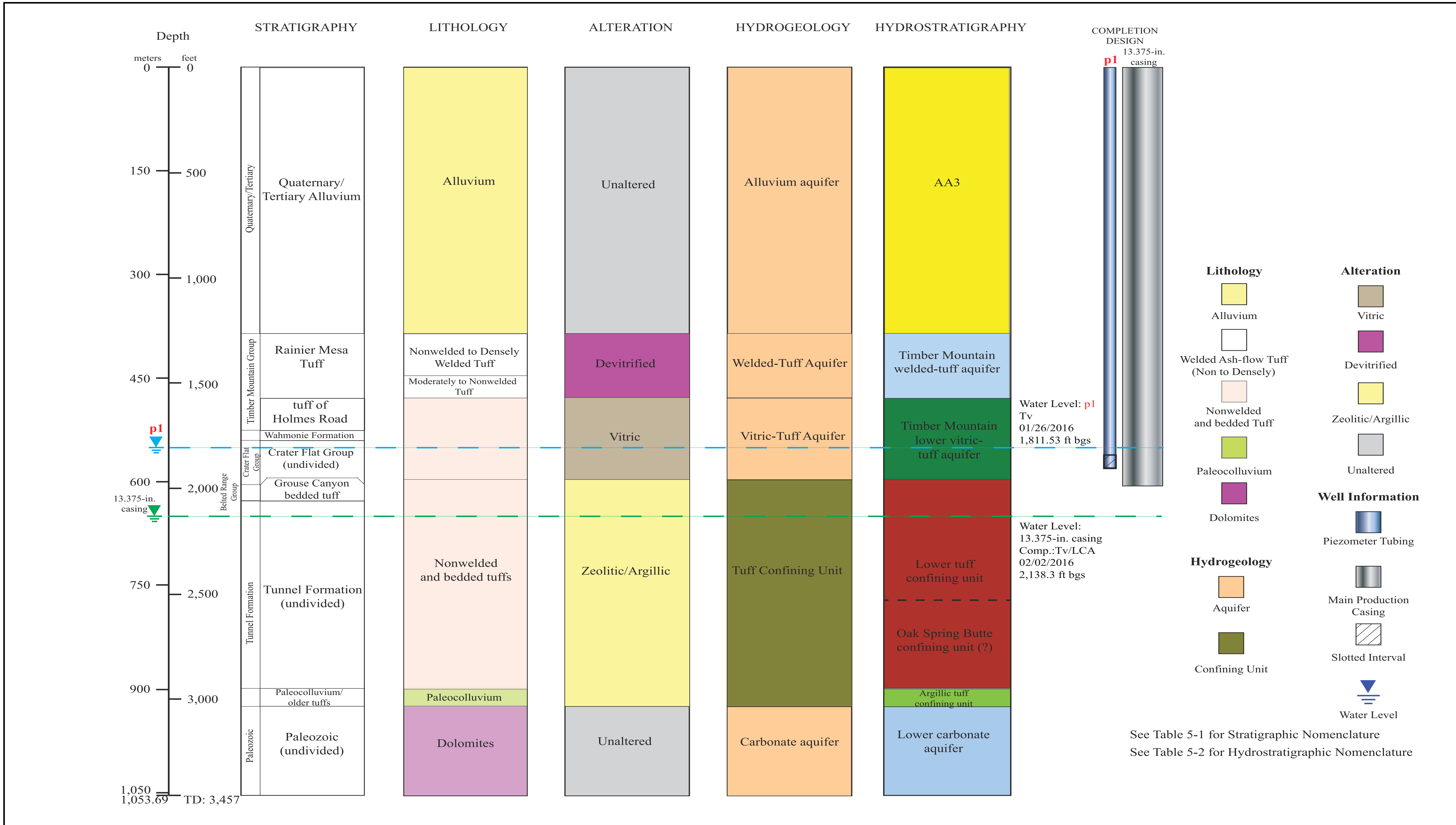


Figure 5-2
Graphical Presentation Showing Geology and Hydrogeology for Well ER-2-2

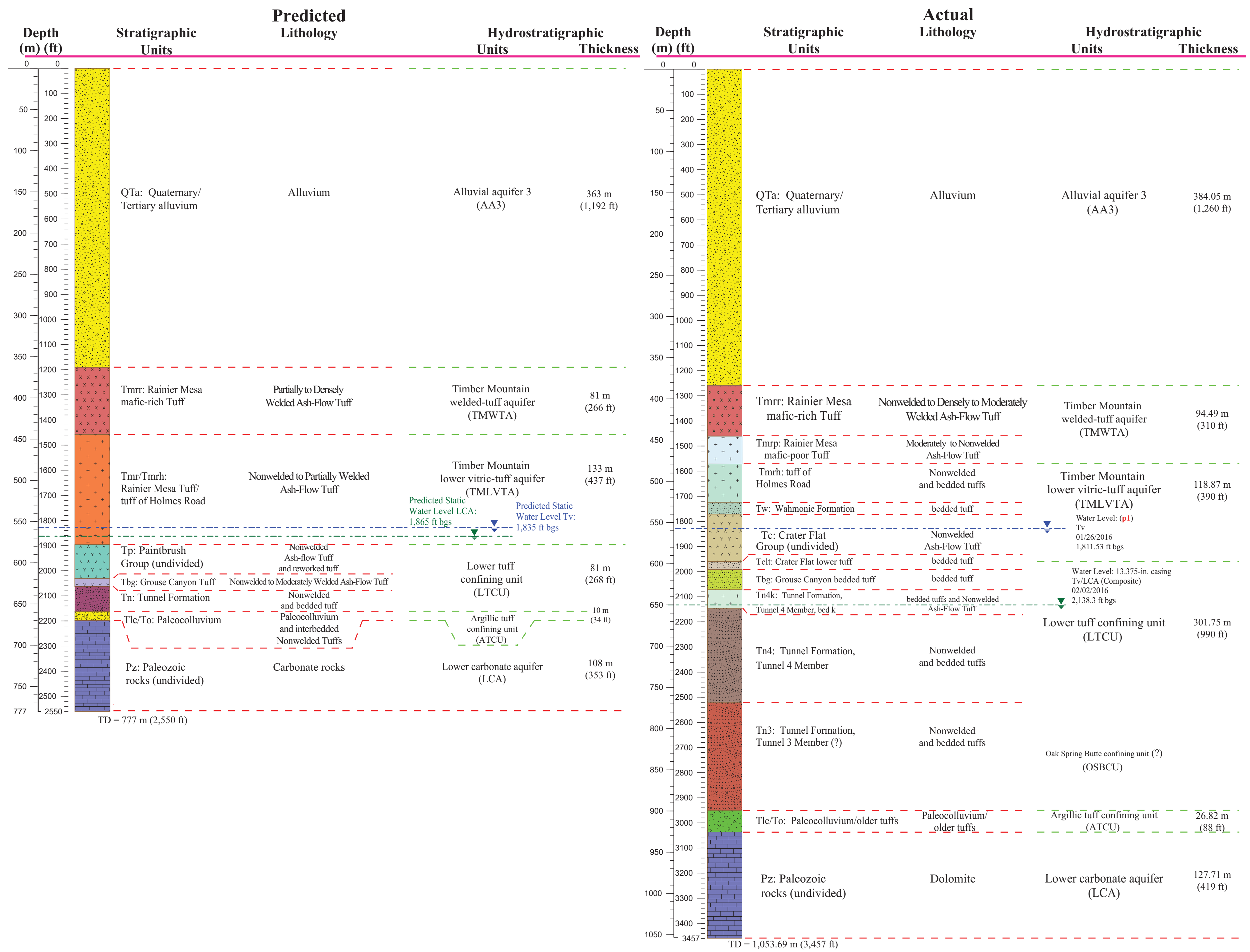


Figure 5-3
Predicted versus Actual Hydrogeology for Well ER-2-2

Member (Tn4), and Tunnel 3 Member (Tn3)—was the most significant departure from the predicted thickness. The predicted thickness of the Tunnel Formation (Tn) was 30.48 m (100 ft), and the actual thickness was 268.22 m (880 ft). Also, the Paleocolluvium/Older tuffs (Tlc/To) had a predicted thickness of 10.36 m (34 ft) (see Appendix A) whereas the actual thickness was 26.82 m (88 ft). The top of the Paleozoic (Pz) rocks was identified at 925.98 m (3,038 ft) bgs, a total of 256.34 m (841 ft) deeper than predicted. Figure 5-2 illustrates the relationship between the stratigraphy, lithology, alteration, and hydrogeologic units identified in Well ER-2-2. The distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figures 5-4 and 5-5. Cross-section lines are shown on the surface geology map (Figure 5-1).

The consistent and regular pattern of greater-than-predicted thicknesses from the Grouse Canyon bedded tuff (Tbgb) through the Paleocolluvium/Older tuffs (Tlc/To) deposited on the LCA surface suggests an active structural area during the deposition of the previously mentioned units. The structures identified in Figures 5-4 and 5-5 as yf_46a and yf_46b may be the controlling structures. If so, they may have much greater offset than illustrated. An alternate interpretation is that there is a previously unrecognized fault structure.

5.3 Hydrogeology

HSUs are groupings 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 are similar. Table 5-2 and Figure 5-3 provide a comparison of predicted versus actual geologic and hydrogeologic information found at Well ER-2-2.

Actual HSUs were generally as predicted. Based on the identification of key stratigraphic units (i.e., Rainier Mesa Tuff [Tmr], Grouse Canyon bedded tuff [Tbgb], and Paleozoic rocks [Pz]), a high degree of confidence in the HSUs identified and depths assigned in Well ER-2-2 is warranted. However, significant variations in actual versus predicted thickness of the alluvial aquifer 3 (AA3) and the LTCU HSUs were noted. The predicted thickness of the LTCU was 81 m (268 ft). Based on the lithologic log (see Appendix A), the actual thickness was found to be 301.75 m (990 ft). Primarily

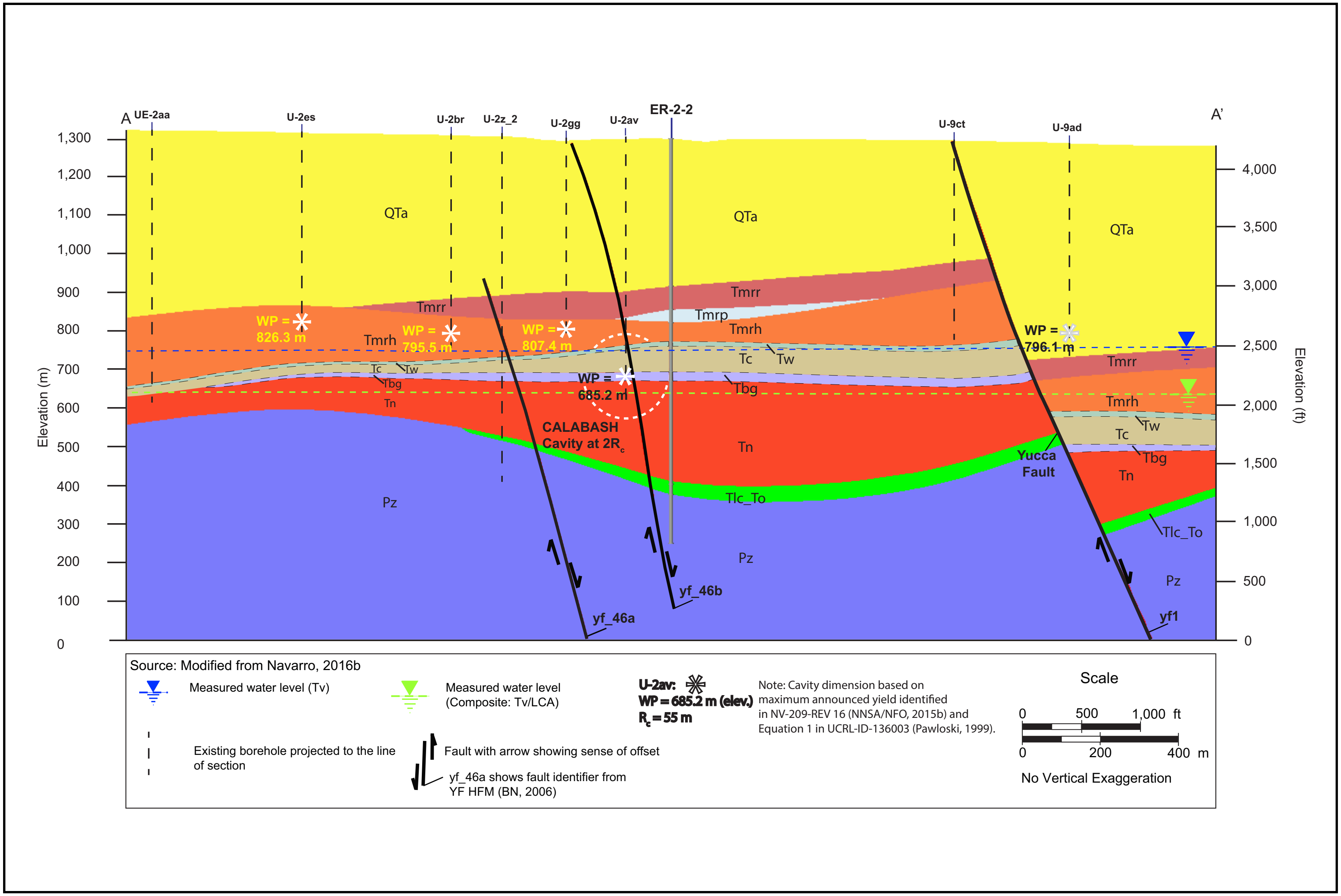


Figure 5-4
Stratigraphic Cross Section Northwest to Southeast

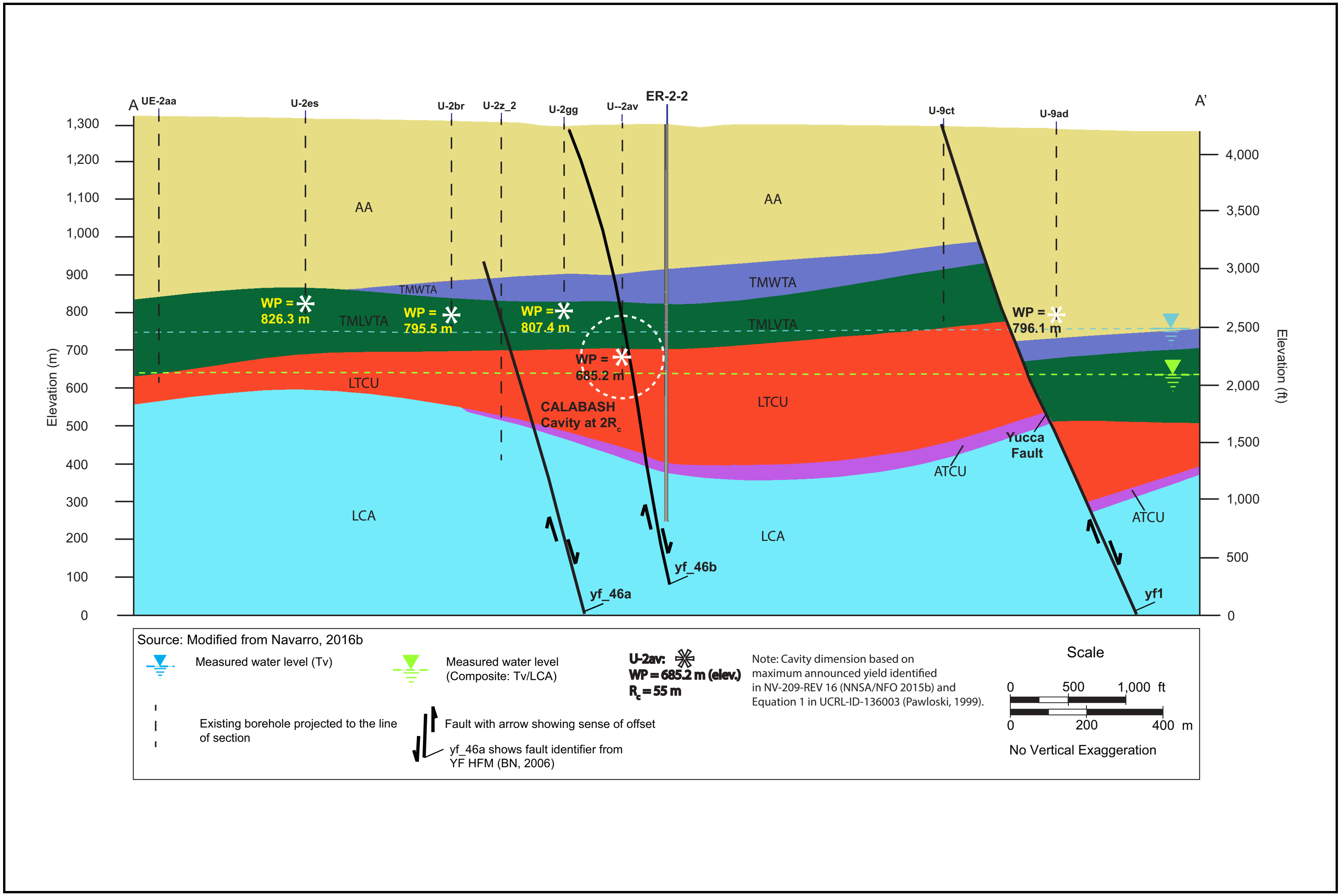


Figure 5-5
Hydrostratigraphic Cross Section Northwest to Southeast

as the result of the increased thickness of AA3 and the LTCU, the LCA was approximately 256 m (841 ft) deeper than expected.

The distribution of HSUs in the vicinity of Well ER-2-2 is shown in cross section in Figure 5-5. The well penetrated a total of six HSUs: the AA3 (unsaturated), TMWTA (saturated below 552.16 m [1,811.53 ft] bgs), TMLVTA (saturated), LTCU (saturated), ATCU (saturated), and LCA (saturated). Note that the OSBCU is shown on Figure 5-3 with dotted contact and queried, contingent on Tunnel 3 Member (tn3) assignment to either LTCU or OSBCU. Based on the HFM, all Tunnel Formation (Tn) members have been assigned to the LTCU for ER-2-2, and the OSBCU is shown for informational purposes only. The relationship between the HSUs in the vicinity of ER-2-2 and the phenomenology of the CALABASH (U2av) UGT is illustrated in Figure 5-6.

The saturated portion of Well ER-2-2 consists of a series of interbedded aquifers and confining-type rocks. The aquifers are hydrogeologically assigned to the WTA, VTA, and LCA. 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 are assigned to the LTCU. The altered bedded tuffs of the Grouse Canyon Formation and Tunnel Formation (Tn) that underlie the Crater Flat Group (undivided) (Tc) and the Crater Flat lower tuff (Tclt), 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. As predicted, the LCA was the most productive water zone encountered in Well ER-2-2. Water production, which had been relatively steady at approximately 15 to 40 gpm, increased to 90 to 130 gpm, by lithium bromide (LiBr) calculations presented in Appendix C and discussed in Section 6.0.

Before drilling, it was predicted that the Tertiary Volcanics (Tv) static water level (SWL) would be encountered at 559.31 m (1,835 ft) bgs within the TMLVTA portion of the Rainier Mesa Tuff (Tmr)/tuff of Holmes Road (Tmrh). The observed water level measured on January 26, 2016, was 552.16 m (1,811.53 ft) bgs and was found to occur at a somewhat higher than predicted level but still within the TMLVTA portion of the Crater Flat Group (Tc). After isolation of the LCA from the Tertiary section, on March 18, 2016, USGS collected a water level in the 13.375-in. casing. USGS used a downhole video system and recorded a water level of 551.46 m (1,809.25 ft) bgs,

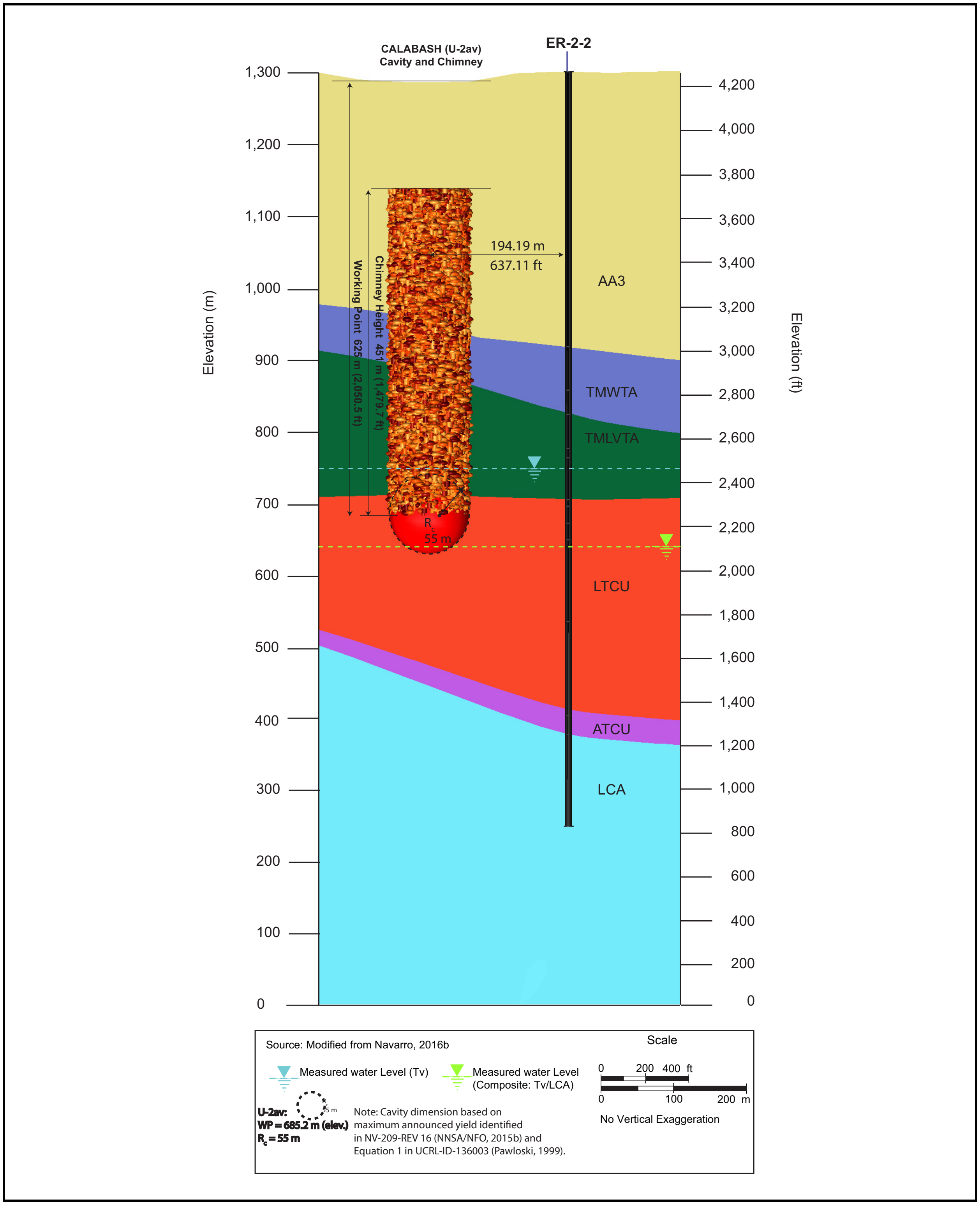


Figure 5-6
Schematic Diagram of the CALABASH Crater, Cavity, and Chimney

corroborating the January 26, 2016 measurement for the Tertiary Volcanics (Tv) section (details provided in Section 6.0).

On February 2, 2016, Navarro personnel collected a water level after the LCA had been penetrated and before the attempts to isolate the Tertiary section from the LCA and complete the well. The composite (Tv/LCA) water level recorded was 651.75 m (2,138.3 ft) bgs. The LCA has since been completely isolated from the Tertiary Volcanics (Tv) section.

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 559.3 m (1,835 ft) bgs (Navarro, 2015b). The depth to water in the piezometer (p1) was measured on January 26, 2016, and represents the SWL of the Tertiary Volcanics (Tv) units. The depth to water was measured at 552.15 m (1,811.53 ft) bgs using a calibrated e-tape.

The predicted SWL in the carbonates was 567.5 m (1,865 ft) bgs (Navarro, 2015b). The depth to water was measured in the open borehole before placement of a cement plug that hydraulically sealed the Paleozoic carbonates from the volcanics. This water level is a composite level representing the Tv and the LCA, and was measured at 650.85 m (2,135.35 ft) bgs on February 7, 2016, using a calibrated e-tape.

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

6.1.2 Slug Tests

Slug test data were collected during cementing of the 13.375-in. surface casing; the data are presented in Figure 6-1. The slug test was conducted to obtain data for estimating hydraulic parameters for the TMLVTA and to monitor the placement of the cement at the base of the casing. The TMLVTA remained open and available for water-level monitoring through a piezometer located in the annular space between the 13.375-in. casing and the 18.5-in. borehole. The slug test was conducted by introducing known volumes of cement and fresh water required as part of cementing the 13.375-in. casing in place. The casing was configured with a stab-in style float shoe located at a depth of

Table 6-1
Well ER-2-2 Water-Level Measurements

Date-Time	Fluid Depth		Fluid Elevation [a]		Notes
	m bgs	ft bgs	m amsl	ft amsl	
ER-2-2 Main Completion					
02/02/2016 13:00	652.88	2,142 [b]	650.09	2,132.85	Approximate fluid level based on Schlumberger temperature/pressure logging tool after 20 bbl of water had been pumped into the borehole.
02/02/2016 13:48	651.75	2,138.30	651.22	2,136.55	Measured using a calibrated Solinst e-tape. Borehole for the main completion had been advanced into the LCA but was obstructed in the overlying volcanics at 2,164 ft bgs.
02/07/2016 05:50	541.23	1,775.70	761.74	2,499.15	Measured using a calibrated Solinst e-tape after 500 bbl of bentonite mud had been pumped into the boring.
02/07/2016 17:00	438.60	1,438.96	864.37	2,835.89	Measured using a calibrated Solinst e-tape after 350 ft^3 of cement had been placed from 2,943 to 3,104 ft bgs to hydraulically seal the borehole off from the LCA.
09/06/2016 11:50	551.69	1,810.01	751.28	2,464.84	Measured using a calibrated Solinst e-tape.
ER-2-2 Piezometer					
01/26/2016 01:30	552.15	1,811.53	750.82	2,463.32	Measured using a calibrated Solinst e-tape in preparation for setting a PXD to monitor fluid levels during cementing operations.
ER-2-2 Tremie Pipe Used for Cementing Borehole					
02/07/2016 12:30	650.85	2,135.35	652.12	2,139.50	Measured using a calibrated Solinst e-tape through the tremie pipe to be used to place cement plug at top of LCA. Borehole open to the LCA at the time of measurement.

[a] Ground surface used as reference datum. Ground surface elevation survey by NSTec at 1,302.97 m (4,274.85 ft) amsl.
[b] Accuracy from a geophysical tool is only to the nearest foot.

606.5 m (1,990 ft) bgs that allowed pumping of fluid and cement through the shoe directly at the base of the 13.375-in. casing. The float shoe by design acts as a one-way valve, so that once the cement and fluids are pumped, the valve closes and does not allow for fluids/cement to return inside the casing. The rise of fluids/cement in the annular space was monitored with a wireline-deployed PXD located within the 1.9-in. CS piezometer. The results of the slug test provided some general information of the hydraulic character of the open interval, but pressure readings recorded by the PXD suggested that the float shoe did not close as designed. The addition of 8 bbl of chase water to flush the drill pipe after cementing operations should not have resulted in an observed pressure response at the PXD. These pressure responses recorded by the PXD indicate that the float shoe remained open and did not close as designed. As a result, cement existing in the annular space between the borehole and the surface casing was driven by the pressure of the additional water (8 bbl) and pushed higher than anticipated into the slotted portion of the piezometer. This rise in the cement level engulfed the PXD in cement, resulting in the PXD being cemented within the piezometer tubing. It is believed that the cement level did not rise to the extent to fill the entire slotted portion of the piezometer. The responses of the PXD during the cementing activity are presented in Figure 6-1.

6.1.3 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-2-2.

Based on bromide dilution calculations, water production of less than 10 gpm was first noted in Well ER-2-2 around 548.6 m (1,800 ft) bgs within the TMLVTA. Estimated water production rates increased from less than 10 to around 20 gpm while drilling through the LTCU. Water production from the well increased significantly as drilling progressed into the LCA. Between the top of the LCA at 3,040 ft bgs to a depth of 3,360 ft bgs, the production rate increased steadily to around 110 gpm. Below 1,024 m (3,360 ft) bgs to the TD of the borehole at 1,053.69 m (3,457 ft) bgs, no additional production was noted. Figure 6-2 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.

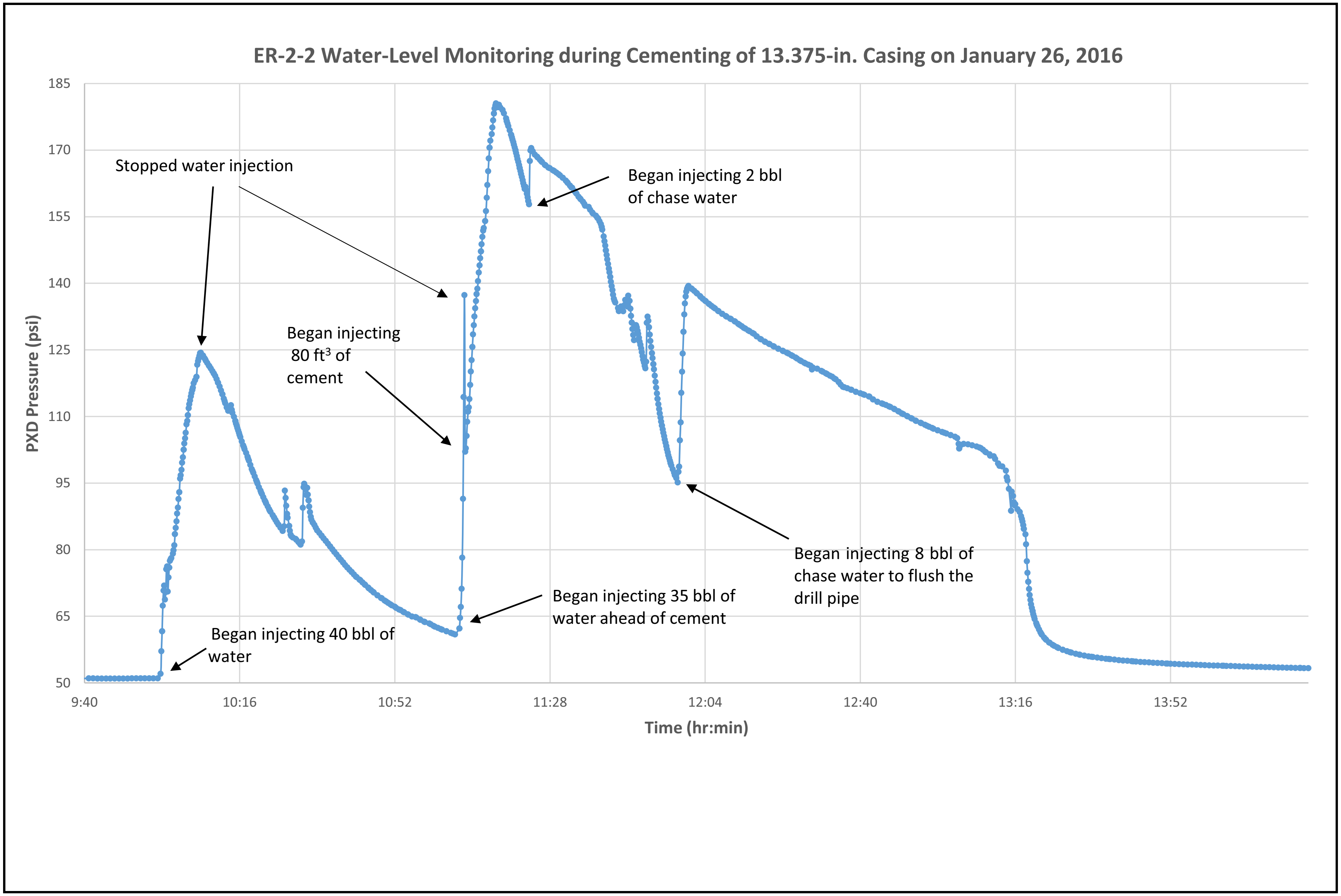


Figure 6-1
Well ER-2-2 Slug Test Data

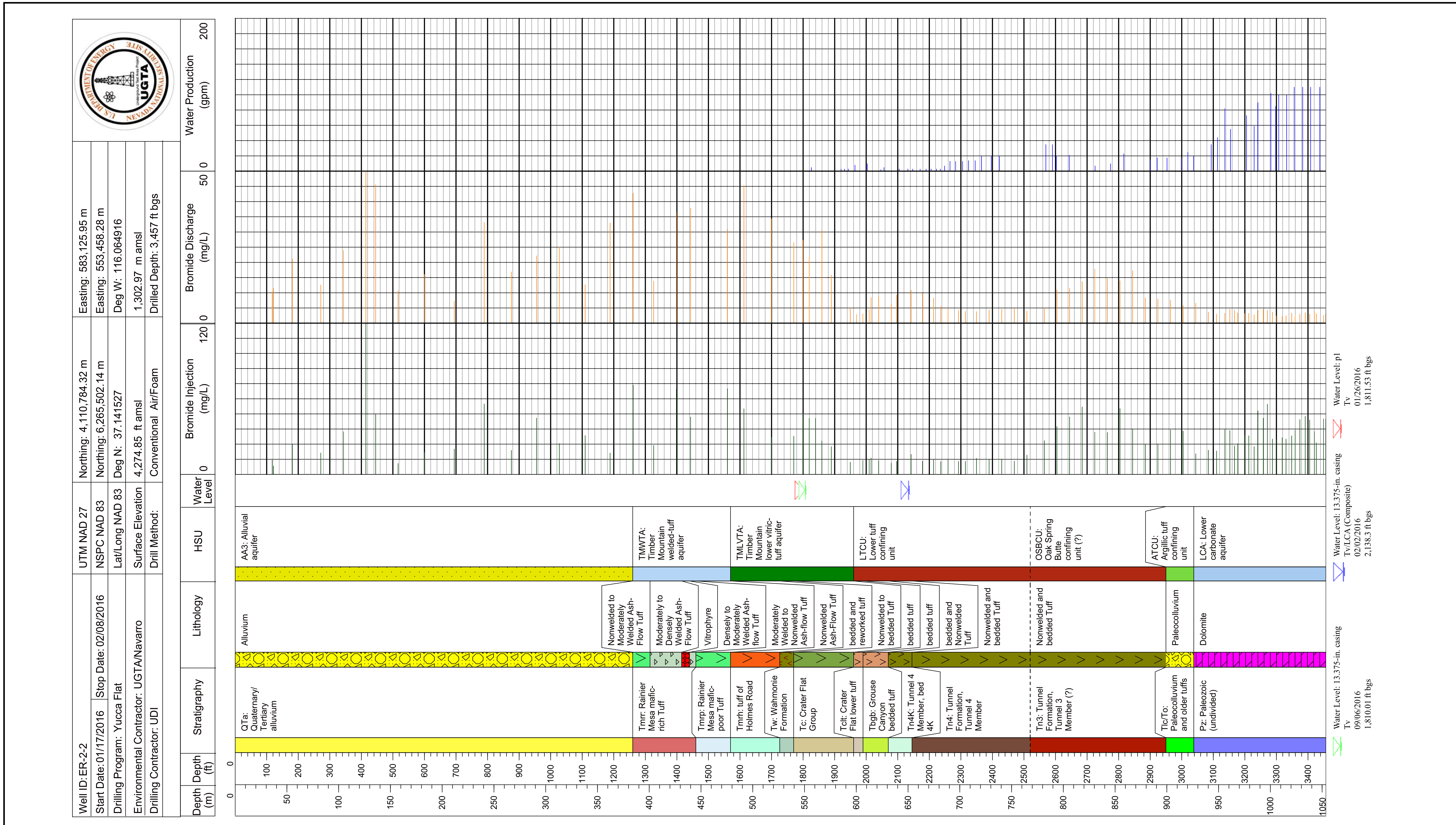


Figure 6-2
Well ER-2-2 Bromide Tracer Monitoring versus Estimated Water Production during Drilling

Navarro site personnel collected a depth-discrete bailer sample and a duplicate sample from a depth of 566.3 m (1,858 ft) bgs, in the open borehole on January 24, 2016. Samples were collected using a wireline deployed depth-discrete 1-liter stainless steel (SS) bailer. The samples provide initial groundwater chemistry based on select groundwater characterization parameters as identified in the Integrated Sampling Plan (NNSA/NFO, 2014.). The bailer and associated sampling equipment were decontaminated according to appropriate procedures before and after sample collection. The analytical results for the bailed groundwater characterization samples are presented in Table 6-2.

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-2-2 (01/24/2016)
(Page 1 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-2-2			
			01/24/2016 Sample Number 429-012416-1 Depth at 1,858 ft bgs		01/24/2016 Sample Number 429-012416-2 (Duplicate) Depth at 1,858 ft bgs	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Aluminum	SW-846 6010 [b]	0.2	180	1.1	180	0.9
Arsenic		0.01	0.029	0.01 U	0.036	0.01 U
Barium		0.1	1.6	0.1 U	1.5	0.1 U
Cadmium		0.005	0.00028 J	0.005 U	0.005 U	0.005 U
Calcium		1	100	21	97	21
Chromium		0.01	0.052	0.01 U	0.043	0.01 U
Iron		0.1	77	0.17	70	0.13
Lead		0.003	0.17	0.003 U	0.088	0.003 U
Lithium		0.01	0.72 J+	0.38 J+	0.71 J+	0.38 J+
Magnesium		1	76	6	74	5.8
Manganese		0.01	1.4 J	0.019 J	1.3 J	0.015 J
Potassium		1	77	9	76	9.1
Selenium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Silicon		0.25, 0.05 [c]	120	32	110	31
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		1	90	61	89	62
Strontium		0.01	0.69	0.057	0.65	0.054
^{238}U	SW-846 6020 [b]	0.0001	0.0086 J	0.002 J	0.0079 J	0.0023 J

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-2-2 (01/24/2016)
(Page 2 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-2-2			
			01/24/2016 Sample Number 429-012416-1 Depth at 1,858 ft bgs		01/24/2016 Sample Number 429-012416-2 (Duplicate) Depth at 1,858 ft bgs	
			Total	Dissolved	Total	Dissolved
Inorganics (mg/L unless otherwise noted)						
Bromide	EPA 300.0[d]	0.2		2		2
Chloride		0.2, 2 [e]		20		19
Fluoride		0.1		0.72		0.72
Sulfate		1		22 J-		22 J-
Alkalinity as $CaCO_3$	EPA 310.1 [f]	20	160		160	
Bicarbonate as $CaCO_3$		20	160		160	
Carbonate as $CaCO_3$		20	20 U		20 U	
Total Dissolved Solids	EPA 160.1 [f]	20	410		390	
Total Suspended Solids	EPA 160.2 [f]	20	10,000		12,000	
pH (SU)	EPA 150.1 [f]	0.1	7.9 J-		7.9 J-	
Specific Conductivity (μmhos/cm)	EPA 120.1 [f]	1	400		400	
Radiological Indicator Parameters-Level I (pCi/L)						
		MDC [g]	Result	Error	Result	Error
Tritium	EPA 906.0 [h]	0	23,400,000	3,600,000	23,300,000	3,500,000
Gross Alpha	EPA 900.0 [h]	23, 22	216 J	42	193 J	38
Gross Beta		22, 22	411	68	385	64
^{238}Pu	HASL 300 [i]/ ASTM D3865-02 [j]	0.023, 0.027	-0.001 U	0.013	0.002 U	0.012
$^{239/240}Pu$	HASL 300 [i]/ ASTM D3865-02 [j]	0.009, 0.021	0.022 U	0.017	0.002 U	0.012
Gamma Spectroscopy	EPA 901.1 [i]	Varies by Nuclide	ND	Varies by Nuclide	ND	Varies by Nuclide

Table 6-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-2-2 (01/24/2016)
(Page 3 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-2-2			
			01/24/2016 Sample Number 429-012416-1 Depth at 1,858 ft bgs		01/24/2016 Sample Number 429-012416-2 (Duplicate) Depth at 1,858 ft bgs	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (pCi/L)						
		MDC	Result	Error	Result	Error
^{14}C	EERF C-01 [k]	510	900 J+	360	1,270 J+	400

Source: Navarro, 2016

[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] Silicon has two detection limits; the first corresponds with the total metals result, and the second corresponds with the dissolved metals result.
[d] EPA, 1997
[e] Chloride has two detection limits; the first corresponds with the total metals result, and the second corresponds with the dissolved metals result.
[f] EPA, 1983
[g] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 429-012416-1, and the second corresponds with sample number 429-012416-2.
[h] EPA, 1980
[i] DOE, 1997
[j] ASTM, 2002
[k] EPA, 1984

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

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

6.2.1 RNs Encountered

Navarro site personnel collected discharged drilling fluid samples hourly during borehole advancement. In circumstance where drilling was advancing to near the predicted water table, the sampling frequency was increased to every 10 minutes. 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 pCi/L. Tritium results were not below the S*afe Drinking Water Act* limit (20,000 pCi/L)

(CFR, 2016b). Results from drilling fluid returns from both the unsaturated and saturated zones ranged from 0 to 24,773,267 pCi/L. Appendix B provides a summary of tritium monitoring results, including onsite reanalyses. Tritium concentrations and water production at Well ER-2-2 are shown in Figure 6-3.

Onsite tritium analysis was also performed on fluid samples collected from other sources. Samples were also collected by the depth-discrete bailer deployed by wireline techniques. The results of drilling discharge and depth-discrete bailer samples collected and analyzed are presented in Figure 6-3. Analyses for RNs were performed by an offsite laboratory, and the results are presented in Table 6-2. Gross alpha, gross beta, ^{14}C, tritium, and ^{238}U were reported above the minimum detection limits. Results for gross alpha, ^{14}C, and ^{238}U are estimated.

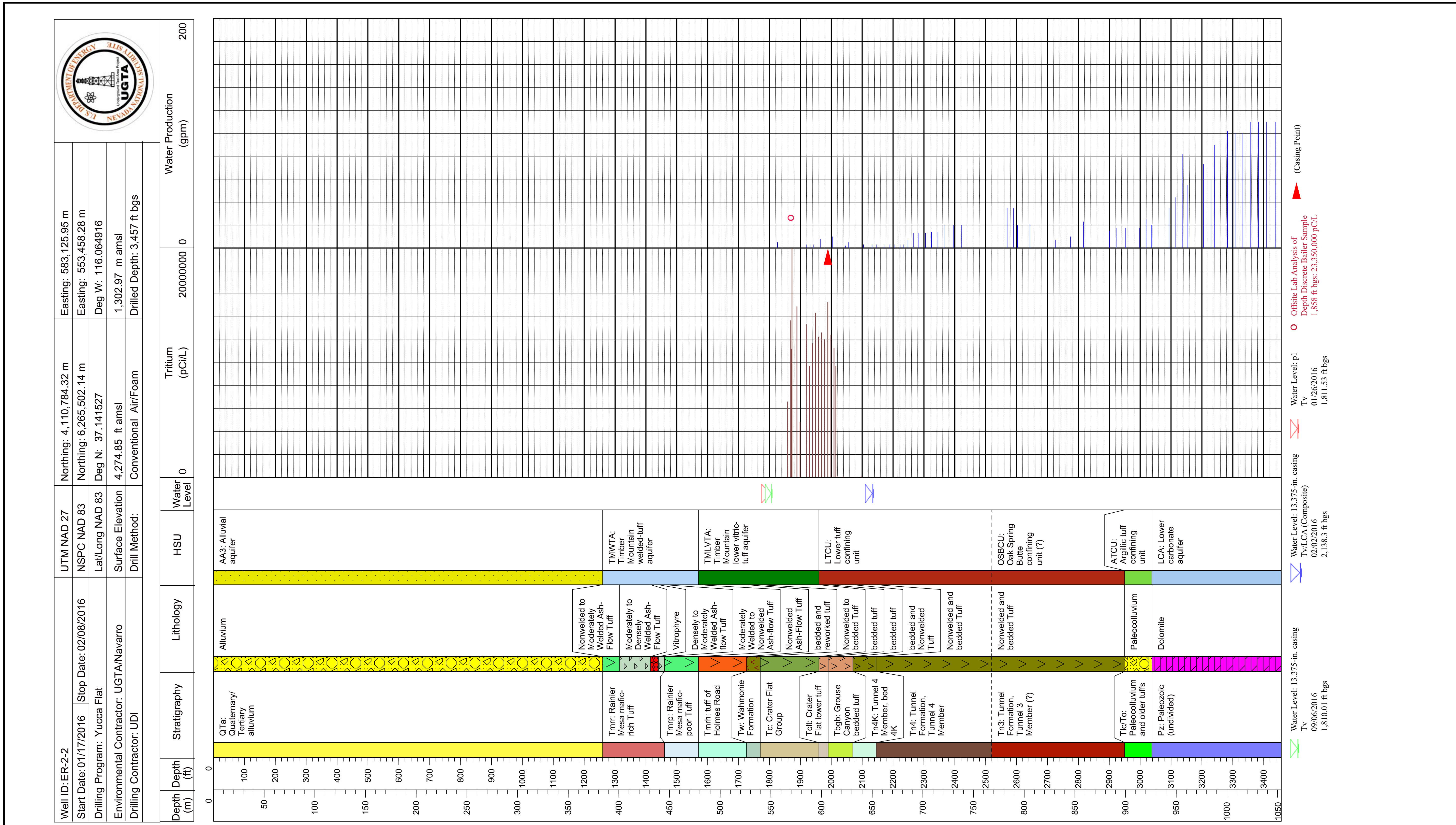


Figure 6-3
Well ER-2-2 Tritium Concentrations and Estimated Water Production during Drilling

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-2-2, 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-2-2 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 basins (Sumps #1 and #2) were constructed to contain fluids and drill cuttings during operations at Well ER-2-2. Sump #1 is lined with an approximate 1.5-million-gal capacity for drilling fluid containment. A second unlined sump (Sump #2) 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-2-2.

Source water for drilling was obtained from the fill stand located in Area 12; the water supply that services this fill stand is Water Well 8, an existing NNSS water supply well that was last sampled on November 5, 2013. Sample data were reviewed, and all analytes detected were below the *Safe Drinking Water Act* limit (CFR, 2016b).

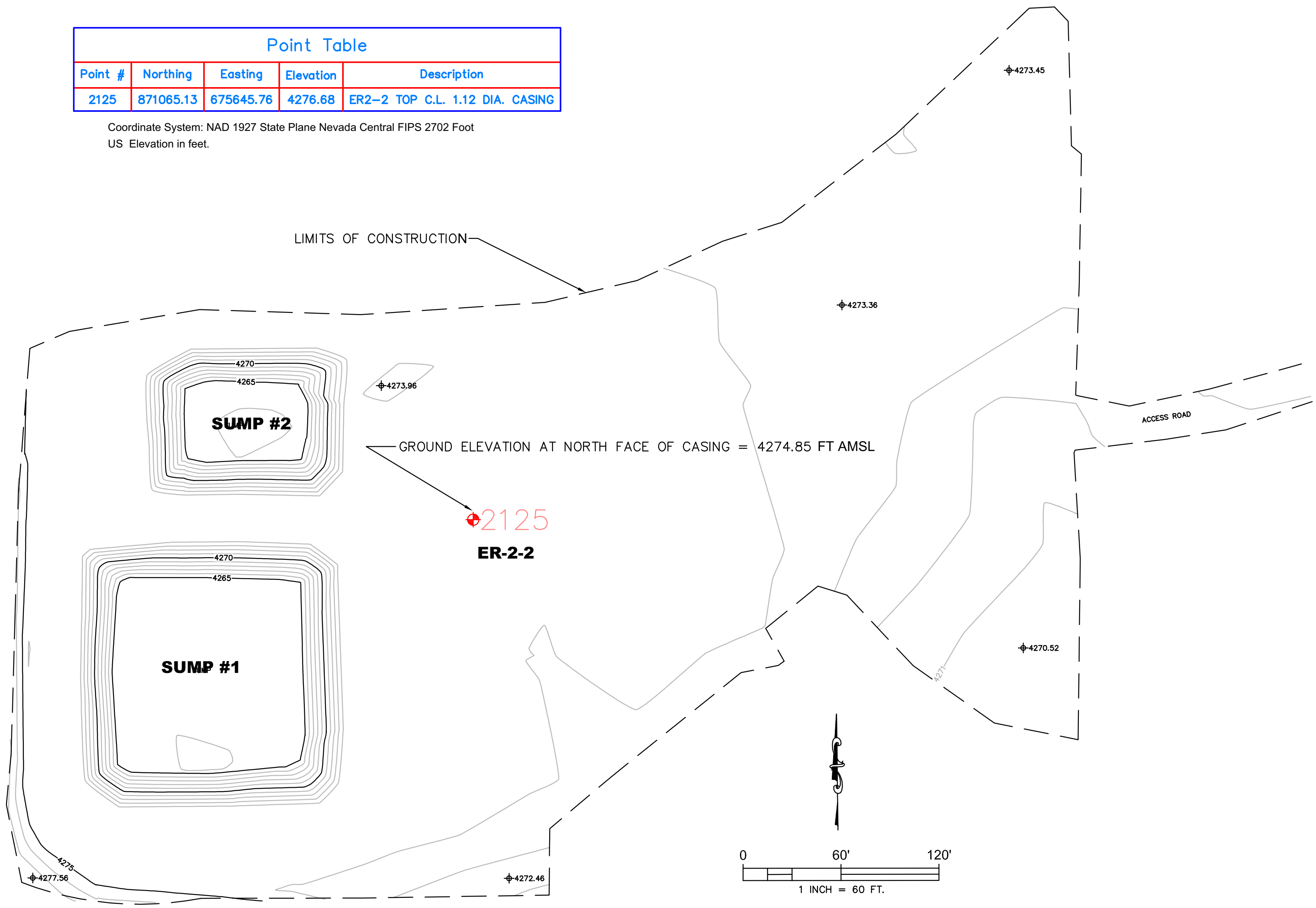
7.2 Fluid Management Sampling Results

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.

Navarro site personnel collected discharged drilling fluid samples hourly during periods of borehole advancement. As the borehole was advanced and when the predicted water table was being

Point Table				
Point #	Northing	Easting	Elevation	Description
2125	871065.13	675645.76	4276.68	ER2–2 TOP C.L. 1.12 DIA. CASING

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



Modified from NSTec, 2016

Figure 7-1
Well ER-2-2 Site Diagram

approached, samples were collected every 10 minutes. 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 1,860 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 1,860 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. A number of sample results were still above the MDA even after being recounted two or three times. Beginning at a depth of 566.93 m (1,860 ft) bgs and continuing to approximately 675.13 m (2,215 ft) bgs, sample results indicated elevated tritium activities ranging from 9,299 to 24,773,267 pCi/L. As shown in Figure 6-3 and Appendix B, tritium analyses for discharge samples from both the unsaturated and saturated zones in Well ER-2-2 ranged from 0 to 24,773,267 pCi/L.

In order for drill cuttings to be released from the Well ER-2-2 site to the USGS Core Library, the water used to rinse the cuttings was also collected and analyzed for tritium. As shown in Appendix B, tritium analyses for the rinse water ranged from 14,142 to 766,011 pCi/L.

After drilling activities were completed, Navarro personnel collected an FMP confirmatory sample and duplicate from Sump #1 on February 5, 2016. The samples were analyzed by an offsite laboratory for total and dissolved metals, gross alpha and beta, and tritium. The analytical results for the FMP confirmatory samples are presented in Table 7-1.

7.3 Disposition of Fluids and Cuttings

The FMP (NNSA/NSO, 2009) and the Well ER-2-2 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 did not meet the FMP criteria for fluid discharge to a designated infiltration area. As such, the drilling fluids remained in the lined Sump #1.

Table 7-1
Analytical Results for FMP Confirmatory Samples from Sump #1 (Lined) at Well ER-2-2

Analyte	Analytical Method [a]	Detection Limit	FMP Samples from Well ER-2-2 Sump #1			
			Sample Number 429-020516-1		Sample Number 429-020516-2 (Duplicate)	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.027	0.01 U	0.032	0.01 U
Barium	SW-846 6010 [b]	0.1	1.6 J	0.1 UJ	1.4 J	0.1 UJ
Cadmium	SW-846 6010 [b]	0.005	0.005 U	0.005 U	0.005 U	0.00022 J
Chromium	SW-846 6010 [b]	0.01	0.041 J-	0.017 J-	0.039 J-	0.017 J-
Lead	SW-846 6010 [b]	0.003	0.11 J	0.0028 J	0.11 J	0.0066 J
Selenium	SW-846 6010 [b]	0.005	0.005 U	0.005 U	0.005 U	0.005 U
Silver	SW-846 6010 [b]	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]	1,000	422,000	64,000	426,000	65,000
Gross Alpha	EPA 900.0 [d]	2.5, 2.8	5.4	1.9	4.1 U	1.9
Gross Beta	EPA 900.0 [d]	3.6, 3.6	6.9	2.5	9.7	2.8

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 429-020516-1 and the second with 429-020516-2
[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.

The volumes of fluids produced during vadose and saturated zone drilling are presented in Table 7-2. At the completion of drilling on February 8, 2016, an estimated combined total of 2,146 cubic meters (m^3) (566,913 gal) of drilling fluid and cuttings remained in lined Sump #1.

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

Site Identification: ER-2-2
Site Location: Nevada National Security Site
Site Coordinates: (UTM NAD 27, Zone 11) N 4,110,784.32 m; E 583,125.95 m
Well Classification: ER Hydrogeologic Investigation Well
Navarro Project No: UN15-460

Report Date: July 15, 2016
NNSA/NFO UGTA Activity Lead: Bill Wilborn
Navarro Project Manager: Ken Rehfeldt
Navarro Site Representative: Dawn Peterson
Navarro Field Environmental Specialist: Mark Heser

Well Construction Activity	Activity Duration		#Ops. Days [a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Infiltration Area [c] (m^3)	Other [d] (m^3)	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids [b]	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	01/17/2016	01/21/2016	4	551.99	310.05	198.20	154.81	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	01/21/2016	02/08/2016	8	501.70	496.08	66.40	1,726.38	N/A	N/A	NA	N/A	Yes
Phase II: Well Development Shallow	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Aquifer Testing Shallow	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Well Development Deep	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase II: Aquifer Testing Deep	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cumulative Production Totals to Date:			12	1,053.69	806.13	264.60	1,881.19	N/A	NA	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-2-2.

[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 2/3/2016: Sump #1 = 2,152 m^3 (55%) Sump #2 = 1,306 m^3 (100%)

Current Average Tritium activity for FMP samples collected from Sump #1 were 424,000 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-2-2 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-2-2 site consisted of hydrocarbon, sanitary, and low-level radioactive wastes (LLW). Table 7-3 summarizes the waste type, volume, and disposition of waste streams generated during drilling. Sanitary waste generated during drilling operations was routinely collected by NSTec and disposed of at the Area 23 solid waste landfill. The hydrocarbon waste was removed from the Well ER-2-2 site and transported by Navarro personnel to Building 6-909 for interim storage until disposed of by NSTec. The LLW, consisting of personal protective equipment (PPE) and disposable sampling equipment, was disposed of at the Area 5 Radioactive Waste Management Complex. The contents of the 2,000-gal condensate tank were drained and transported by NSTec to the Area 12 surface impoundment for evaporation. All waste was characterized using process knowledge and onsite monitoring results.

Table 7-3
Final Waste Disposition for Well ER-2-2 Drilling Operations
(Page 1 of 2)

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-2-2-1	01/14/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-2	01/18/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-3	01/17/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-4	02/03/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-5 (NAVSAA003)	01/22/2016	5 gal	Poly pail	Hach Lead Test Kit Rinsate	Non-Haz, Non-Rad Hydrocarbon	Contents consumed during sampling 07/19/2016	Completed
ER-2-2-6	02/09/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-7	02/09/2016	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-2-2-08	02/21/2016	55 gal	Open-top steel drum	PPE, disposable sampling equipment	LLW	Disposed 07/21/2016	Completed CD
ER-2-2-09	02/21/2016	55 gal	Open-top steel drum	PPE, disposable sampling equipment	LLW	Disposed 07/21/2016	Completed CD

Table 7-3
Final Waste Disposition for Well ER-2-2 Drilling Operations
(Page 2 of 2)

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-2-2-10	02/21/2016	55 gal	Open-top steel drum	PPE, disposable sampling equipment	LLW	Disposed 07/21/2016	Completed CD

Total Waste Containers
Lab Analytical Waste: 1 Pads/Debris: 3 Used Oil (liquid): 3
Low-Level Radiological PPE Waste: 3
Total number of 5-gal waste containers: 1
Total number of 55-gal waste containers: 9 Total number of 2,000-gal waste containers: 1

CD = Certificate of Disposal

8.0 Planned and Actual Costs, and Scheduling

This section provides a brief discussion of the planned and actual schedule and costs for the main borehole construction of Well ER-2-2.

The original M&O contractor (NSTec) approved baseline work package was based on drilling to a planned TD of 838.4 m (2,750 ft), installing one production casing string and one piezometer tubing string. This estimate was submitted before issuance of the drilling criteria document (Navarro, 2016b) with an updated planned TD of 777.2 m (2,550 ft). The baseline estimate with approved baseline change requests (BCRs) included a 24-day schedule for constructing an 838.4-m (2,750-ft)-deep well. The baseline estimate included 7 days for the location-to-location move to Well ER-2-2 from Well ER-20-12, and 17 days for main borehole construction and completion.

The well was drilled 215.5 m (707 ft) deeper than originally planned, to a TD of 1,053.9 m (3,457 ft), and 276.5 m (907 ft) deeper than specified in the drilling criteria. It took 33 calendar days to construct Well ER-2-2, beginning with the start of the location-to-location move on January 7, 2016, and ending with the removal of the tubing used for cementing on February 8, 2016. Figure 8-1 presents a comparison of the planned and actual schedule, by day, for construction of Well ER-2-2.

The baseline plan for the construction schedule and costs was changed through an approved management reserve BCR submitted in the February 2016 change control cycle. The BCR was submitted to address the added/unplanned borehole depth and the realization of risks associated with the added/unplanned borehole depth and borehole stability problems experienced during construction of this well. The planned drilling construction schedule and costs curves presented in Figure 8-2 reflect the final approved final baseline after approval of the February BCR.

The changes made to the baseline through this BCR are summarized as follows:

- Deleted activities
    - Conduct logging services in the 12.25-in. production hole.
    - Install the 7.625-by-6.625-in. production casing.
    - Stem the production casing, and lay down the stemming tubing.

- Added activities as a result of increased borehole depth and borehole stability problems, including the following:
  - Drill additional production borehole from the original planned depth of 838.4 m (2,750 ft) to the actual depth of 1,053.9 m (3,457 ft).
  - Add additional time and resources associated with standing by for logging services due to borehole stability problems.
  - Add additional time and resources associated with cleaning out the borehole due to sloughing.
  - Add additional time and resources associated with cementing to stabilize the borehole.
  - Add additional time and resources associated with drilling out the cement and using liquid mud to stabilize the borehole.
  - Install and remove tremie tubing, and place a cement plug to isolate the bottom of the borehole.

The cumulative impact of this BCR increased the main hole construction schedule from 24 days to 29 days, and increased the costs by $244,403.

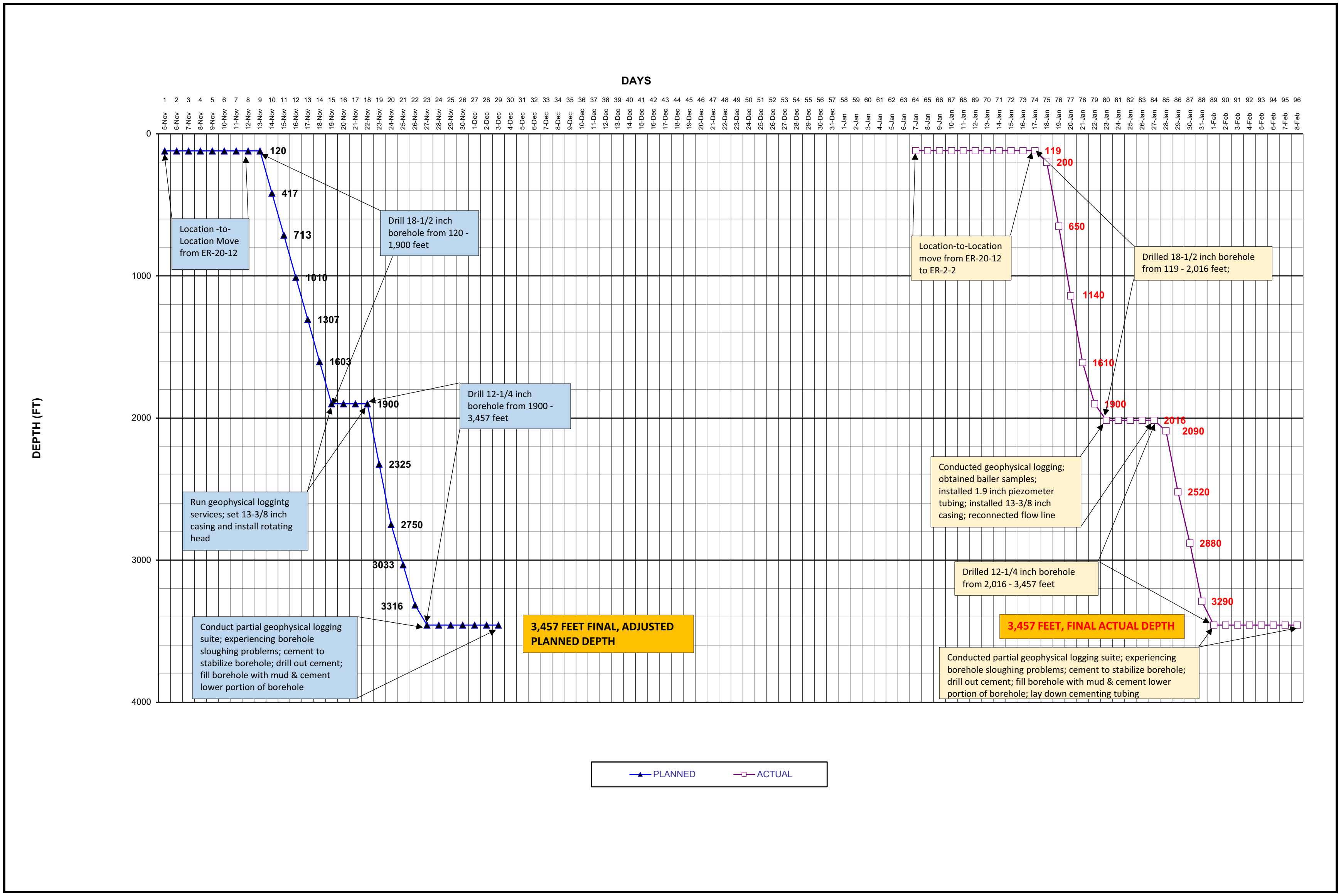


Figure 8-1
Planned and Actual Construction Progress for Well ER-2-2

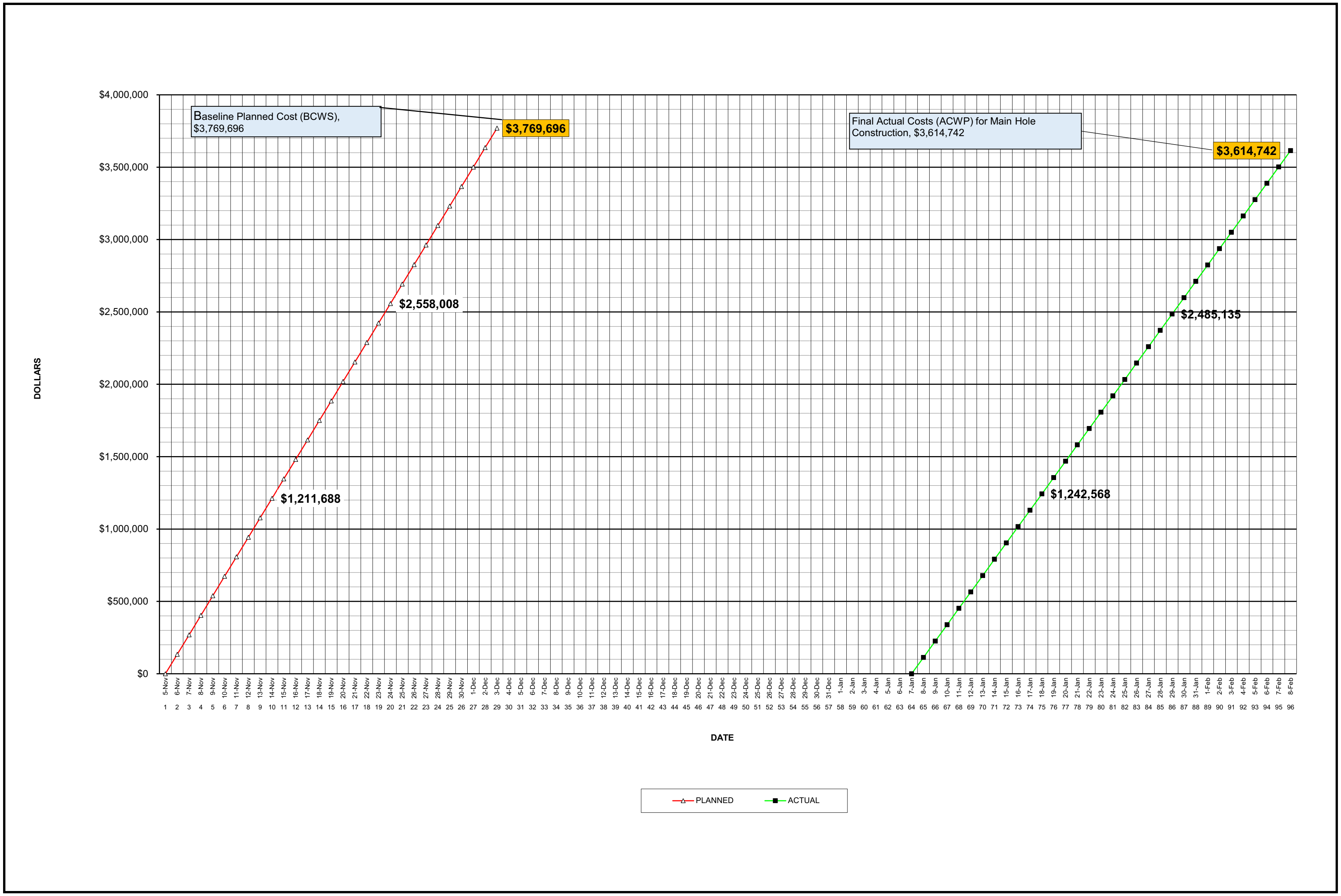


Figure 8-2
Planned and Actual Cost of Constructing Well ER-2-2

9.0 Lessons Learned and Recommendations for Future Work

Drilling, construction, scientific, and environmental compliance activities at Well ER-2-2 were generally executed as planned. However, Well ER-2-2 could not be completed as planned due to borehole stability issues. The drilling and completion of the well was impacted by various elements relating to unstable borehole conditions; operational decisions and approaches; 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 occurred while conducting operations at Well ER-2-2.

9.1 Lessons Learned and Recommendations

9.1.1 Drilling Approach and Method

Well ER-2-2 was drilled using an air-foam rotary drilling conventional circulation technique. The conventional circulation method injects drilling fluids and/or makeup water into the borehole through the drill string, and return fluids travel between the outside of the drill pipe and the borehole annulus. As depth and water production increase, the pressure/energy required to clear fluids and rock from the borehole increases. In Well ER-2-2, the bedded tuffs of the Crater Flat lower tuff (Tclt) and the Grouse Canyon bedded tuff (Tbgb), and the nonwelded and bedded tuffs of the Tunnel Formation (Tn) are frequently altered (zeolitic/argillic) and may be susceptible to swelling, erosion, and instability. These units occur from 597 to 926 m (1,960 to 3,038 ft) bgs, which corresponds to the interval of Well ER-2-2 that experienced most of the tight hole, ledges, and washout conditions. As a result of the tight hole conditions, sloughing/bridging, and ledges/washouts, Well ER-2-2 required multiple cleanout runs, clearing obstructions, and hole conditioning. The conventional circulation drilling approach may not have been an ideal method, but many wells have been drilled in Yucca Flat employing this technique. In the case of Well ER-2-2, the exposure of some formations to the effects of conventional air-foam circulation was greatly exacerbated through restrictions implemented on the part of the lead technical contractor to slow the rates of penetration during drilling to accommodate fluid and cuttings sampling. The slowing of the rates of penetration resulted in extended drilling time, allowing for the open borehole to be subjected to the effect of circulation, and contributing to a deterioration in the borehole stability. The extended drilling operations, multiple trips in and out of the borehole, along with high-energy discharges contributed to the loss of borehole stability and ultimately the loss of the borehole.

Lesson Learned/Recommendation: For future well completions, the use of alternate drilling techniques (i.e., reverse circulation) may be advisable. In fact due to the above mentioned conditions much of the early drilling in Yucca Flat used the reverse circulation method. The use of reverse circulation drilling techniques may provide increased borehole stability by minimizing drilling-induced damage to the formations. Alternatively, if direct conventional circulation is selected, drilling rates should be maintained at the highest rates and most optimal rates of penetrations achievable to collect geologic data and to minimize the overall durations of drilling and circulation. Once the desired total depth or target depth of the borehole is achieved, a bentonite-based mud may be introduced to the borehole to aid in maintaining borehole stability. An abbreviated geophysical logging suite may also be considered after the introduction of mud to the borehole to obtain essential petrophysical data. Once complete, the installation of casing and or piezometer tubing should follow directly and completed as quickly as possible. These techniques or approaches may also allow for a shorter elapsed drilling and completion time frame due to fewer borehole stability issues, which may result in a planned well completion at the lowest possible cost.

9.1.2 Technical Communication and Consideration of Operational Contingencies

Hydrogeologic observations including formation stability, alteration (swelling clay), borehole sloughing, and erosion susceptibility issues in Yucca Flat are not new concerns and are known to exist in the subsurface in Yucca Flat. Typically, these issues are not major concerns in the unsaturated zone and can be controlled. However, once the water table is reached, these issues may become problematic in a short period of time. Because it is not possible to predict where they will occur or with what severity, it is important that onsite technical staff be keenly aware of these potential types of conditions and collect, monitor information, and assess and communicate these observations to appropriate technical personnel (on and off site) in a timely manner. In the case of Well ER-2-2, borehole sloughing issues within the Tertiary Volcanics (Tv) developed and worsened after penetrating Paleozoic carbonates. This principally resulted due to the influx of additional groundwater to the borehole from the Paleozoics. The severity of this borehole sloughing was not recognized as being a serious concern until the sloughing and tight hole conditions were severe.

Frequently, these sloughing conditions require immediate action to minimize further borehole deterioration or loss of the borehole. Both onsite and offsite technical staff should be aware of potential contingency plans that may be acted upon based on the knowledge and determination of key personnel directly involved in the drilling and completion of the well.

Lesson Learned/Recommendation: Onsite technical staff need to recognize and communicate potentially developing borehole stability concerns, particularly with respect to issues relating to water production, cross contamination of cuttings returns, sloughing conditions, and tight drilling conditions. The technical staff should be trained or mentored by experienced senior technical staff to recognize the importance of specific data collection and observations that allow for determination of the potential severity of these conditions.

Drilling and completion criteria that are prepared to provide scientific and engineering guidance with respect to individual well design and construction. These criteria discuss potential drilling and completion concerns, but might include potential contingency plans that could be further developed at the well specific work package level. These contingency plans would consider appropriate options for curing borehole stability issues while maximizing the technical and scientific objectives. In advance of formal drilling operations, the UGTA technical team could review and discuss these options so that they would be current and pertinent to the expected drilling operations. Many of the conditions experienced at Well ER-2-2 have previously been experienced at other well locations. Implementing contingency plans that were described in drilling and criteria as well as detailed in planning documents and technical; discussions may lead to a more timely resolution and a better understanding by all parties of the impacts of these actions. Technical discussions to determine the specifics of particular actions on a case-by-case basis would not be eliminated; however, the basis and understanding for these actions would be considered well in advance of the actual drilling operations and would be available for reference.

9.1.3 Monitoring and Data Collection during Cementing Operations

At Well ER-2-2, Navarro personnel attempted to collect hydrologic data (slug test) while monitoring cementing operations for the 13.375-in. surface casing. Monitoring the progress of cementing operations and collecting hydrologic test data is best accomplished through the use of a PXD. A PXD was placed in the 1.9-in. piezometer (p1) to monitor fluid levels in the annulus between the borehole wall and 13.375-in. surface casing as the casing was cemented in place. Data were recorded during the initial water injection, cementing, and chase injection phases. The data indicated that the cementing operation had been successful and the additional hydrologic (slug test) data had been collected. However, when attempting to retrieve the PXD, the PXD could not be brought to the surface. Indications are that the PXD is cemented in place.

Lesson Learned/Recommendation: In this case, the PXD was impacted as a result of a malfunctioning float shoe, or potential channelling of the cement between the surface casing and the borehole wall above the float shoe. The malfunction of the float shoe seems plausible, as suggested by the PXD data collected during these operations. The data suggest that float shoe may not have fully closed and allowed displacement of fresh water during cementing to affect the emplacement depth of the cement. Future installations should consider this possibility, and the PXD should be set above the screened interval in order to avoid possible issues with drilling fluid or borehole completion material infiltrating the piezometer. In addition, if there is any question as to the height to which the cement has risen in the piezometer, the PXD should be retrieved before the cement has the opportunity to set.

9.2 Suggested Follow-on Activities

As noted previously, difficulties were encountered during the work at Well ER-2-2. In particular, tremie line was left in the borehole, and a PXD could not be removed from the piezometer (p1). These conditions warrant follow-on activities to improve future use of this well.

9.2.1 Tremie Pipe

Condition: On February 7, 2016, a tremie pipe was tripped into the borehole to a depth of 946 m (3,104 ft) bgs. Approximately 350 ft^3 of cement was placed to depth through the tremie line to hydraulically seal the LCA from the overlying Tertiary Volcanics (Tv). After tagging operations to determine the top depth of the cement and during the retrieval of the tremie line, 304 m (997 ft) of tubing separated and remains in the borehole.

Suggested Action: A wireline-deployed downhole video camera may be used to determine the depth to the top of the tremie pipe and borehole condition. It is not known whether the portion of the tremie pipe that separated is a single string or in multiple pieces. Determining the status of the tremie line and where it is located along with the borehole condition will establish the potential depths to which tools and instruments can be lowered in the borehole without issue. Given the existing borehole size, if the condition borehole and depth of the tremie were determined, potentially a tubing string could be installed to permit water-level measurements and or the installation of a rod-type pump.

9.2.2 PXD in the Piezometer

Condition: A PXD was installed on January 16, 2016, to a depth of 579 m (1,900 ft) bgs in piezometer (p1) at Well ER-2-2 to monitor fluid pressure changes during cementing operations. Subsequently, when an attempt was made to retrieve the PXD, it could not be brought to the surface, and it appears to have been cemented in place. Approximately 100 ft of wireline was spooled off and secured at the surface, and the wireline cut. Access to piezometer (p1) is currently obstructed by the presence of the wireline.

Suggested Action: To allow access to the piezometer, a wireline-deployed cutter should be lowered down the piezometer (p1) around the wireline and the wireline cut off as close as possible to the top of the PXD. The wireline cutter will allow measurement to the top of the cement within the piezometer (p1); this will also likely be the point where the wireline connecting the PXD will be cut. Based on the depth determination to the top of the cement, an estimate of the available open slots above this point will allow for an assessment of the open portion of the slotted tubing that may be in communication with formation groundwater. If open screen remains, the piezometer should still be in hydraulic communication with the TMLVTA, allowing the collection of representative water levels and groundwater samples.

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Appendix A

Lithologic Log for Well ER-2-2

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
0-384 (0-1,260)	384 (1,260)	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, and geophysical logs. **From 120-530 ft:** cuttings consist of medium to coarse sand size fragments of nonwelded to lesser welded tuff and minor carbonates. Colors vary from reddish-yellow (7.5YR 7/6), light-bluish-gray (5PB 8/1), pale yellowish-pink (7.5YR 9/2), white (10YR 8.5/2). Most fragments are sub-rounded to rounded with minor flattened pieces. Weakly to moderately reactive with HCl. (minor caliche?) Minor <3% loose felsics- quartz and sanidine. **From 530-1,020 ft:** cuttings show common matrix(?) coating (ash/fine grained sediment?) with crystal fragments and other material. Coarse sand, mostly rounded to sub-rounded. Fragments consist of non to partially welded tuff, densely welded, bedded and rare siliclastics and carbonates (?) with loose felsics (2-4%), quartz (some dipyramidal with pink tint increasing downward), sanidine and plagioclase, Very pale brown (10YR 8/2) >yellow (10YR 8/6). Lithic fragments very pale brown (10YR 7/3) >brownish-yellow (10YR 6/6) >dark gray (10YR 4/1) >reddish-brown (2.5YR 5/4). Mod to weak reaction with HCl. **From 1,020-1,180 ft:** Increase in dark gray (10YR 4/1) >reddish-gray (2.5YR 6/1) >reddish-black (2.5YR 2.5/1) >pale red (10R 7/2) fragments (siltstone and dolomite?), vitrophyric lava, basalt (with filled-white mineral), welded tuffs constitute ~40-50% of sample, loose felsics ~2-4%, sanidine, quartz (mostly terminated, some dipyramidal with pink tint). Weak-no reaction with HCl. **From 1,180-1,260 ft:** Tuffaceous Alluvium. Matrix color: very pale brown (10YR 8/3)>light yellowish brown (10YR 6/4), followed by lesser pinkish gray (5YR 6/2) and minor light gray (N 7/1) and black (N 2.5/1); Crystal fragments (loose and in matrix) (10%), sanidine quartz (mostly terminated, some dipyramidal, some with pink tint), plagioclase, mafics (preserved only in matrix of volc. fragments); Fragments mostly subrounded>subangular with minor platty fragments consisting of nonwelded to densely welded tuffs, siliciclastic/carbonate (some pyritic), and minor blocky basalt/lavas; Moderate reaction with HCL, possibly indicating caliche; Geophysical logs (GR, Density, and Resistivity) indicate a sharp break at 1,260 ft marking the alluvium/bedrock contact, possibly from 1,250-1,260 ft the weathered top of the Rainier Mesa Tuff?	Quaternary/Tertiary Alluvium (QTa)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
384.0-400.8 (1,260-1,315)	16.8 (55)	DA	**Nonwelded to Moderately Welded Ash-flow Tuff:** crystal-rich, mafic-rich, devitrified, minor vapor phase alteration; Matrix color: reddish brown (5YR 5/4)>light reddish brown (5YR 6/4) and lesser reddish yellow (5YR 6/6), Phenocrysts: (10-15%), sanidine (minor chatoyant), quartz (mostly terminated, some dipyramidal, minor pink tint), plagioclase, mafics: 2-3%, biotite (black, euhedral, unoxidized>rare oxidized), oxide (magnetite?), hornblende; Pumice: (3-5%), light gray (5YR 7/1)>pink (5YR 7/4), blocky>rounded, vapor phase corroded, rare relict vitric texture, frequent plucked/rounded cavities; Lithics: rare>minor, lava/welded tuff?, dark red (2.5YR 3/6)>yellowish red (5YR 4/6), larger fragments maybe contamination (no matrix).	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
400.8-431.3 (1,315-1,415)	30.5 (100)	DA	**Moderately to Densely Welded Ash-flow Tuff:** crystal-rich, mafic-rich, devitrified, vapor phase alteration/mineralization; Matrix color: reddish brown (5YR 5/2)>light reddish brown (5YR 6/4) and minor yellowish red (5YR 5/6): Phenocrysts: (15-20%), sanidine (minor chatoyant), quartz (terminated, dipyramidal, rare pink tint, rare resorption texture?), plagioclase (twining common), mafics: (2-3%), biotite (black, unox.), oxides (magnetite), hornblende: Pumice: (3-5%), light gray (5YR 7/1), rounded to flattened cavities, some hollow/plucked; Lithics: (3-5%), welded tuff/lava (?) red (2.5YR 5/6)>very dusky red (2.5YR 2.5/2)>reddish yellow (5YR 6/6); Densely welded shows some alternation with moderately welded zones.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
431.3-438.9 (1,415-1,440)	7.6 (25)	DA	**Densely Welded Ash-flow Tuff, (Vitrophyre):** crystal-rich, mafic-rich, vitric: Matrix color: reddish black (10R 2.5/1)>dark reddish gray (2.5YR 4/1)>reddish gray (2.5YR 6/1); Phenocryst (15-20%?), sanidine, quartz (terminated, clear, dipyramidal?), plagioclase, mafics: (2%+?), difficult to observe in dark matrix, biotite (black, euhedral, unox.), hornblende(?); Pumice: rare flattened features?, light reddish brown (2.5YR 6/3); Lithics: (1-2%?), lava/welded tuff, red (10R 4/6), lithics are mostly ~1mm rarely to 2-3mm; Phenocrysts loose and in matrix.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
438.9-445.0 (1,440-1,460)	6.1 (20)	DA	**Densely to Moderately Welded Ash-flow Tuff: From 1,440-1,460 ft:** crystal-rich, mafic-rich, devitrified with minor vitric near top, vapor phase alteration: Matrix color: light reddish brown (2.5YR 6/3)>reddish brown (2.5YR 5/3) grading down to pinkish gray (5YR 7/2)>reddish brown (5YR 5/4); Phenocrysts: (10-15%?), sanidine, quartz (terminated, dipyramidal?, clear, euhedral>fractured), plagioclase, mafics: (2%), biotite (black, unox., fragments), oxides (magnetite?), hornblende; Pumice: (5-10%), white (7.5YR 8/1)>pinkish white (7.5YR 8/2), most vapor phase corroded/devitrified; Lithics: (1-3%), volcanic dark reddish brown (2.5YR 3/4)>light reddish brown (5YR 6/4)>gray (5YR 5/1), mostly 1-2mm rarely larger?, rare black (10G 2.5/1) volcanic glass (some spherules), rare silica (chalcedony). Interval from 1,440-1,450 ft has significant contamination (20-30%?) most likely from flowline, rounded sand/gravel.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
445.0-478.5 (1,460-1,570)	33.5 (110)	DA	**Moderately to Nonwelded Ash-flow Tuff: From 1,460-1,570 ft:** devitrified, crystal-rich, mafic-poor, vapor phase altered: Matrix color: weak red (2.5YR 5/2)>light reddish brown (2.5YR 6/4)>reddish brown (2.5YR 5/4); Phenocrysts: (7-15%), sanidine (rare chatoyant), plagioclase, quartz (term., dipyramidal, clear), mafics: (<1%), biotite (black, unox., fragments), oxides (magnetite?), hornblende (very rare?); Pumice: (3-5%), light gray (5YR 7/1)>pinkish gray (5YR 6/2), vapor phase corroded, rare relict vitric texture; Lithics: (1-3%), volcanics red (7.5YR 5/1)>reddish gray (7.5YR 5/1), ≤1mm minor to 1-2mm; top of the nonwelded interval is 1,510 ft.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
478.5-526.1 (1,570-1,726)	47.5 (156)	DB4	**Nonwelded Ash-fall Tuff (Tephra?) to bedded tuff:** devitrified to vitric, crystal-rich, pumice-rich: Matrix color: (interbedded?) gray (7.5YR 5/1)>reddish gray (5YR 5/2), white (7.5YR 8/1), and brown (7.5YR 5/2); Phenocrysts: (10-15%), sanidine (rare chatoyant), quartz (term., minor dipyramidal, clear), plagioclase, mafics: (1%?), oxides (magnetite), hornblende(?), appear mostly in white (pumice/bedded material); Pumice: (15-30%), variable zones?, white (N9 to 5Y 8/1), brown (7.5YR 5/4), and pinkish gray (7.5YR 7/2), vitric>relict vitric textures, significant alteration rims around pumice; Lithics: (5%), volcanics red (10R 4/6)>reddish gray (10R 5/1); Common volcanic glass black (N 2.5/1)>dark reddish brown (5YR 2.5/2), bedded tuff (reworked?) appears as granular mixture of ash, lithics, phenocrysts (felsics, magnetite, and biotite); abundant welded tuff contamination from uphole which decreases with depth, 1,600-1,610 ft contamination (30-50%) and no sample 1,610-1,620 ft, cuttings may not be representative of interval?	tuff of Holmes Road (Tmrh)
526.1-539.5 (1,726-1,770)	13.4 (44)	DA	**bedded/reworked tuff to Nonwelded Ash-flow Tuff:** reworked tuff: Matrix color: grayish brown (10YR 5/2)>light brown(7.5YR 6/3)>pinkish gray (7.5YR 6/2); Phenocrysts: (10-15%) sanidine, quartz (term., clear), plagioclase, mafics: (2-5%), biotite (black>golden, euhedral/frag, unox.?), oxides, hornblende; Pumice: (2-4%), light gray (7.5YR 7/1)>white (7.5YR 8/1), vitric to minor waxy appearance; Lithics: (2-5%), volcanic gray (5YR 5/1) and red (7.5YR 5/6), fine sand size similar to crystal fragments, no visible black volcanic glass as above.	Wahmonie Formation (Tw)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
539.5-597.4 (1,770-1,960)	57.9 (190)	DA	**Nonwelded Ash-flow to bedded tuff: From 1,770-1,850 ft:** Matrix color: white (7.5YR 8/1)>very pale brown (10 YR 8/2), rare pink (7.5YR 7/3); Phenocrysts: (5-10%), sanidine, plagioclase, quartz (term., clear), mafics: (1%?), biotite (black, frag/euhedral, unox.), hornblende, oxides (very fine); Pumice: (1-10%), white (7.5YR 8/1 to N 8/1)>pink (7.5YR 7/3), vitric to relict vitric texture, increasing alteration (zeolitic/argillic) with depth; Lithics: (1-2%), volcanic gray(7.5YR 5/1)>red (2.5YR 5/8), very fine (≤0.5mm); One, possibly more, fine (porcelainous) ash beds (weakly silicified), zones of graded bedding; **From 1,850-1,960 ft:** Nonwelded Ash-flow Tuff and reworked tuffs: Matrix color: brown (10YR 5/3)>pale brown (10YR 6/3)>pale yellow (2.5YR 8/2)>white (2.5YR 8/1), possibly separate beds; Phenocrysts: (5-15%), sanidine, plagioclase, quartz (term., dipyramidal, clear), mafics: (highly variable), biotite (black>golden, frag./euhedral), hornblende (greenish black, vitreous, euhedral/frag.), oxides (fine grained, some ox.); Pumice: (5-10%), white (N9 to 7.5YR 8/1), pale brown (10YR 8/2), light gray (10YR 7/1), and rare pale yellow (5YR 8/3) increasing with depth, alteration (possibly zeolitic) of pumice increasing with depth; Lithics: (3-10%), welded tuff/lava, two apparent size distributions(?): fine sand: light red (2.5YR 6/6)>dark gray (5YR 4/1) and coarse (2-4mm): dusky red (10R 3/2)>dark reddish gray (7.5YR 4/1), fine sand size material is in matrix and coarse have matrix coatings; Appears to be “thin” alternating beds (smaller than sample interval), approximately 15-30% contamination (average in ea. interval).	Crater Flat Group (Tc)
597.4-606.6 (1,960-1,990)	9.1 (30)	DA	**bedded tuff with minor Nonwelded Ash-flow Tuff?:** crystal-poor, altered (argillic/zeolitic): Matrix color: very pale brown (10YR 7/3); Phenocrysts: (2-4%), sanidine (somewhat rounded and frosted)?, plagioclase?, mafics: none observed; Pumice: (2-3%) white, altered; Lithics: consists of very fine fragments of volcanics.	Crater Flat lower tuff (Tclt)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
606.6-630.9 (1,990-2,070)	24.4 (80)	DA	**bedded tuff and minor Nonwelded Ash-flow Tuff:** bedded tuff: crystal-poor, altered (zeolitic, pervasive): Matrix color: pale yellow (5Y 8/3)>yellow (5Y 8/3)>yellowish brown (10YR 5/4); Phenocrysts: ($\leq$1-3%), felsic (sanidine?), mafics: none noted, common to abundant Mn oxide spots/dendrites, very small (<0.5mm) black (N 2.5/1)>dark grayish green (5G 3/2) hydroclastic glass (shards/bubbles); Pumice: (15-20%), pale yellow (5Y 8/2) to pale yellow (5Y 7/4)>olive yellow (5Y 6/6), strong brown (7.5YR 4/6), relict to partially vitric textures; Lithics: none observed; casing set at 1,990 ft from 1,990 to 2,040 ft ~10% cement contamination increasing to ~30% and then diminishing to trace by 2,080 ft.	Grouse Canyon bedded tuff (Tbgb)
630.9-653.8 (2,070-2,145)	22.9 (75)	DA	**bedded tuff and Nonwelded Ash-flow Tuff: From 2,070-2,140 ft:** bedded tuff and Nonwelded Ash-flow Tuff: crystal-poor, altered (zeolitic/argillic): Matrix color: very pale brown (10YR 7/3)>light yellowish brown (10YR 6/4) and white (N9 to 10YR to 7.5YR 8.1)>light gray (2.5YR 7/1); Phenocrysts: (3-5%), sanidine (?, clear>frosted), quartz (trace, in matrix-possibly contamination?), sphene (?), mafics: ($\leq$1%), biotite (black>bronze, frag./euhedral) oxides, hornblende (?); Pumice: (10-15%) white (N9)>pale yellow (5Y 8/2 to 8/3); partially altered (zeolitic/argillic), occasional relict vitric texture; Lithics: (5-7%), volcanic red (2.5YR 5/6), gray (5YR 5/1), reddish yellow (7.5YR 7/6), most <0.5 mm; noted rare volcanic glass fragments and spherules black (N 2.5/1) to dark greenish gray (10 BG 4/1) no matrix. **From 2,140-2,145 ft:** bedded tuff: crystal-poor, vitric, thin bedded, shard/glass rich layers separated by porcelainous (fine ash) layer: Matrix color: greenish gray (10Y 5/1) and light olive gray (5Y 6/2)>pale olive (5Y 6/4), mixed with pale yellow beds (porc.) (5Y 8/4); Phenocrysts: (<1%, trace?), sanidine (?), mafics: (trace>rare?), Mn oxide spots (possibly contamination from above?); Pumice: rare (?),vitric, possibly shards and spherules?, light greenish gray (10G 7/1), greenish black (10G 2.5/1), and black (10YR 2/1); Lithics: none observed in matrix; fragments vary from $\leq$0.25 to 0.5-in., fragments show angular faces and conchoidal breaks.	Tunnel Formation, Tunnel 4 Member, beds K (Tn4k)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
653.8-768.1 (2,145-2,520)	114.3 (375)	DB4	**Nonwelded Ash-flow to Ash-fall Tuffs and bedded tuffs:** crystal poor, pumice rich, altered (zeolitic/argillic) pervasive to incomplete: (General Description) Matrix color: very pale brown (10YR 8/2) with interbeds(?) red (2.5YR 5/8)?, phenocrysts: (2-3%), sanidine, mafics: (<1%), biotite, Lithics: (3-10%), various volcanics, Pumice:(20-30%), very pale brown (10YR 8/2), pale yellow (5Y 8/3), and white (7.5YR 9/1); **From 2,145-2,230 ft:** bedded tuff: crystal-poor, pumice-rich, altered (zeolitic) to partially vitric: Matrix color: pale yellow (2.5Y 8/3)>yellow (5Y 8/6)>very pale brown (7.5YR 8/4); Phenocrysts: (trace?), sanidine (?), mafics: none observed, rare Mn oxide spots; Pumice: (30%?), possibly greater matrix and some pumice possibly washed away by drilling process, see Matrix color, zeolitic/partially vitric (or relict vitric texture?); Lithics: none noted; contamination varies from ~20% to 40% from uphole, from 2,210 to 2,220 ft: ~10% to 20% of interval is cement contamination, from 2,190 to 2,220 ft zone of larger fragments (~0.25 to 0.75-in) of Tbgb, cement, and other material coming into hole. During drilling intervals of minor to significant fill noted, possible hole erosion and instability, hole is tight in some intervals, issue with flow line blockage/contamination; **From 2,230-2,350 ft:** pumice-rich, crystal-poor, altered (zeolitic/argillic?) to partially vitric: Matrix color: very pale brown (10YR 8/3)>light yellowish brown (10YR 6/4)>yellow (10YR 8/6); Phenocrysts: (2-4%), sanidine, quartz (trace/rare), mafics: (<1%), biotite, volcanic glass (frag./spherules) black to dark gray; Pumice: (20-30%), pinkish white (5YR 8/2)>white (N9), light gray (10YR 7/1), and pale yellow (2.5YR 8/4); Lithics: (2-3%) welded tuffs/lava light reddish brown (5YR 6/4)>red (10R 5/6)>dark reddish gray ((10R 3/1), and rare sedimentary (quartzite?) reddish brown (2.5YR 4/4); white pumice show tubular texture but have been altered (argillic/zeolitic?) and rare ones show apparent silicification, contamination (~15-20%); **From 2,350-2,490 ft:** lithic-rich, pumice-rich, crystal-poor: Lithics: (5-10%), colors and other properties as listed in 2,230 to 2,350 ft interval, contamination significant (30-50%?); **From 2,490-2,520 ft:** pumice-rich, crystal-poor: Matrix color: very pale brown (10YR 7/3 to 8/4)>light gray (7.5YR 7/1); Pumice: (15-30%); Lithics: (2-4%); contamination significant (20-40%).	Tunnel Formation, Tunnel 4 Member, undifferentiated (Tn4)

Table A-1
Lithologic Log for Well ER-2-2
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Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
768.1-899.2 (2,520-2,950)	131.1 (430)	DB4	**Nonwelded Ash-flow to Ash-fall Tuffs and bedded tuffs: From 2.520-2,600 ft:** Nonwelded Ash-flow Tuff: pumice-rich, crystal-poor, lithic-poor: Matrix color: red (10R 4/8), pale red (10R 6/4), very pale brown (10YR 8/3); Pumice: (15-30%?); Lithics: (1-2%), volcanic dark gray (10YR 4/1) and reddish brown (2.5YR 4/3); **From 2,600-2,720 ft:** Nonwelded Ash-flow and minor bedded tuff (?): lithic-rich, pumice-rich, crystal-poor: Matrix color: very pale brown (10YR 8/2) and reddish brown (2.5YR 5/4)>reddish gray (2.5YR 5/2); Lithics: (5-10%), volcanic; **From 2,720-2,910 ft:** Nonwelded Ash-flow and bedded tuff: mottled appearance, pumice-rich, crystal-poor, altered (argillic/ zeolitic?): Matrix color: reddish brown (2.5YR 3/6)>white (7.5YR 8/1)>very pale brown (10YR 8/3); significant contamination?; **From 2,910-2,950 ft:** Nonwelded Ash-flow Tuff: pumice-rich, crystal-poor: Matrix color: dark red (2.5YR 3/6)>red (2.5YR 4/8)>light red (2.5YR 5/8); Pumice: (15-20%?), white (10R 8/1 to N9)>pale red (10R 7/3), pumice may be greater small fragments and drilling issues may have changed (?); contamination significant (40%,?).	Tunnel Formation, Tunnel 3 Member (?) (Tn3)

Table A-1
Lithologic Log for Well ER-2-2
(Page 9 of 9)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Lithologic Description** [b]	**Stratigraphic Unit** (Map symbol)
899.2-926.0 (2,950-3,038)	26.3 (88)	DB4	**Nonwelded Ash-flow Tuff and bedded tuff (?):** pumice-rich, altered (argillic/ zeolitic?): Matrix color: pinkish white (5YR 8/2), light red (2.5YR 6/6), pinkish gray (5YR 6/2), and light brownish yellow (10YR 6/4); Pumice: (15-30%??), white (10YR 8/1)>pinkish white (5YR 8/2)>pale yellow (2.5YR 8/2).	Paleocolluvium/ older tuffs (Tlc/To)
926.0-1,053.7 (3,038-3,457)	127.7 (419)	DB4	**Dolomite: From 3,038-3,180 ft:** upper contact based on sharp drilling break: Matrix color: very pale brown (10YR 8/2)>white (7.5YR 8/1)>pale yellow (2.5YR 8/3); recrystallized (fine>medium grain), minor oxidation (he/lm), weak to moderate reaction with HCl (on scratched surfaces). **From 3,180-3,457 ft:** Matrix color: gray (7.5YR 6/1), dark bluish gray (5PB 3/1), interbeds of Limey Dolomite, gray (N 5/1)>white (10YR 8/1), recrystalized (medium>coarse); minor>moderate microstockwork veining, fracturing, brecciation(?) with vein filling material (medium>fine, white [N9]) crystaline (dolomite?), rock has weak reaction with HCL when scratched, contamination from uphole material (~30-50%).	Paleozoic (undivided) (Pz)

[a] Lithologic samples collected from interval during drilling and logging operations and used for lithologic interpretation. **DA** = drill cuttings that represent lithologic character of interval, **DB4** = drill cuttings that are not wholly representative of interval.
[b] Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs. Colors describe wet sample color unless otherwise noted.

HCl = Hydrochloric acid
mm = Millimeter

Appendix B

Tritium Activities during Drilling of Well ER-2-2

Table B-1
Tritium Activities during Drilling of Well ER-2-2
(Page 1 of 9)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
1	01/17/2016	N/A	N/A	31	1,536.54	Makeup Water
2	01/18/2016	N/A	N/A	2,281	1,522.24	Makeup Water
3	01/18/2016	36.27	119	3,763	1,576.91	Discharge Line
4	01/18/2016	37.19	122	1,744	1,576.91	Discharge Line
5	01/18/2016	41.45	136	1,830	1,678.65	Discharge Line
6	01/18/2016	48.16	158	490	1,629.66	Discharge Line
7	01/18/2016	55.47	182	0	1,536.54	Discharge Line
8	01/18/2016	60.35	198	1,003	1,530.53	Discharge Line
9	01/18/2016	68.28	224	953	1,626.19	Discharge Line
10	01/18/2016	75.90	249	903	1,536.54	Discharge Line
11	01/18/2016	82.91	272	1,488	1,626.16	Discharge Line
12	01/18/2016	88.39	290	1,685	1,626.19	Discharge Line
13	01/18/2016	93.88	308	1,118	1,486.80	Discharge Line
14	01/18/2016	99.06	325	1,054	1,576.91	Discharge Line
15	01/18/2016	104.85	344	1,846	1,620.45	Discharge Line
16	01/18/2016	110.03	361	552	1,406.43	Discharge Line
17	01/18/2016	115.21	378	5,072	1,494.50	Discharge Line
18	01/18/2016	120.70	396	2,132	1,320.91	Discharge Line
19	01/18/2016	126.49	415	1,524	1,778.14	Discharge Line
20	01/18/2016	131.06	430	176	1,284.21	Discharge Line
21	01/18/2016	133.81	439	2,105	1,438.89	Discharge Line
22	01/18/2016	138.99	456	903	1,629.66	Discharge Line
23	01/19/2016	144.48	474	475	1,576.91	Discharge Line
24	01/19/2016	N/A	N/A	745	1,477.47	Makeup Water
25	01/19/2016	152.40	500	95	1,674.46	Discharge Line
26	01/19/2016	160.02	525	1,886	1,734.60	Discharge Line
27	01/19/2016	168.55	553	2,587	6,504.76	Discharge Line
28	01/19/2016	177.09	581	1,002	1,734.60	Discharge Line
29	01/19/2016	185.93	610	1,395	1,626.19	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
30	01/19/2016	192.94	633	826	1,054.64	Discharge Line
31	01/19/2016	199.95	656	434	1,486.80	Discharge Line
32	01/19/2016	206.35	677	1,334	1,854.44	Discharge Line
33	01/19/2016	211.84	695	105	1,629.66	Discharge Line
34	01/19/2016	220.07	722	2,138	1,629.66	Discharge Line
35	01/19/2016	227.38	746	1,278	1,493.86	Discharge Line
36	01/19/2016	235.31	772	1,317	1,422.32	Discharge Line
37	01/19/2016	240.79	790	863	1,357.67	Discharge Line
38	01/19/2016	248.11	814	273	1,493.86	Discharge Line
39	01/19/2016	253.90	833	1,093	1,343.30	Discharge Line
40	01/19/2016	262.13	860	2,606	1,406.43	Discharge Line
41	01/19/2016	267.61	878	2,076	1,453.48	Discharge Line
42	01/19/2016	272.80	895	2,601	1,676.53	Discharge Line
43	01/19/2016	279.81	918	1,287	1,406.43	Discharge Line
44	01/19/2016	285.29	936	1,112	1,530.53	Discharge Line
45	01/19/2016	291.39	956	1,718	1,870.32	Discharge Line
46	01/19/2016	296.27	972	1,700	1,459.54	Discharge Line
47	01/19/2016	302.97	994	646	1,680.68	Discharge Line
48	01/20/2016	307.85	1,010	77	1,629.66	Discharge Line
49	01/20/2016	313.03	1,027	828	1,321.95	Discharge Line
50	01/20/2016	318.52	1,045	330	1,334.31	Discharge Line
51	01/20/2016	324.61	1,065	413	1,631.25	Discharge Line
52	01/20/2016	332.84	1,092	868	1,406.43	Discharge Line
53	01/20/2016	338.33	1,110	130	1,968.77	Discharge Line
54	01/20/2016	343.81	1,128	401	1,453.48	Discharge Line
55	01/20/2016	N/A	N/A	0	1,631.26	Makeup Water
56	01/20/2016	350.52	1,150	0	1,631.26	Discharge Line
57	01/20/2016	355.70	1,167	910	1,435.25	Discharge Line
58	01/20/2016	362.41	1,189	0	1,679.24	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
59	01/20/2016	365.76	1,200	0	1,679.24	Discharge Line
60	01/20/2016	371.86	1,220	385	1,381.68	Discharge Line
61	01/20/2016	380.09	1,247	908	1,254.17	Discharge Line
62	01/20/2016	384.66	1,262	1,430	1,422.32	Discharge Line
63	01/20/2016	390.75	1,282	563	1,730.13	Discharge Line
64	01/20/2016	396.24	1,300	0	1,445.50	Discharge Line
65	01/20/2016	400.81	1,315	850	1,435.25	Discharge Line
66	01/20/2016	404.47	1,327	1,084	1,160.10	Discharge Line
67	01/20/2016	408.43	1,340	264	1,453.48	Discharge Line
68	01/20/2016	414.83	1,361	604	1,343.30	Discharge Line
69	01/20/2016	420.32	1,379	0	1,486.80	Discharge Line
70	01/20/2016	425.81	1,397	215	1,530.53	Discharge Line
71	01/20/2016	429.77	1,410	709	1,435.25	Discharge Line
72	01/20/2016	432.82	1,420	1,506	2,365.37	Discharge Line
73	01/21/2016	436.17	1,431	0	2,444.49	Discharge Line
74	01/21/2016	N/A	N/A	789	1,406.43	Makeup Water
75	01/21/2016	440.13	1,444	0	1,734.80	Discharge Line
76	01/21/2016	448.67	1,472	0	1,980.80	Discharge Line
77	01/21/2016	454.15	1,490	0	1,824.54	Discharge Line
78	01/21/2016	462.69	1,518	0	1,914.69	Discharge Line
79	01/21/2016	477.01	1,565	0	1,974.52	Discharge Line
80	01/21/2016	482.19	1,582	356	1,860.52	Discharge Line
81	01/21/2016	488.59	1,603	0	1,536.54	Discharge Line
82	01/21/2016	489.81	1,607	0	1,824.84	Discharge Line
83	01/21/2016	491.64	1,613	N/A	N/A	No Sample
84	01/21/2016	498.35	1,635	0	1,858.37	Discharge Line
85	01/21/2016	505.97	1,660	265	1,486.80	Discharge Line
86	01/21/2016	511.15	1,677	546	1,815.32	Discharge Line
87	01/21/2016	518.16	1,700	0	3,589.67	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
88	01/21/2016	524.87	1,722	623	1,445.50	Discharge Line
89	01/21/2016	529.13	1,736	0	1,858.37	Discharge Line
90	01/21/2016	536.45	1,760	602	1,357.67	Discharge Line
91	01/21/2016	539.80	1,771	636	1,415.23	Discharge Line
92	01/21/2016	545.59	1,790	1,028	1,255.85	Discharge Line
93	01/21/2016	548.64	1,800	1,152	1,581.73	Discharge Line
94	01/21/2016	551.69	1,810	523	1,445.50	Discharge Line
95	01/21/2016	554.74	1,820	0	1,585.95	Discharge Line
96	01/21/2016	557.78	1,830	0	1,631.26	Discharge Line
97	01/21/2016	560.83	1,840	656	1,493.86	Discharge Line
98	01/21/2016	563.88	1,850	0	1,543.09	Discharge Line
99	01/21/2016	566.93	1,860	6,613,639	2,082.35	Discharge Line
100	01/21/2016	569.98	1,870	13,691,062	1,395.39	Discharge Line
101	01/21/2016	570.59	1,872	11,216,060	1,435.25	Discharge Line
102	01/22/2016	570.59	1,872	20,358,334	1,486.80	Discharge Line
103	01/22/2016	576.07	1,890	14,905,321	1,668.13	Discharge Line
104	01/22/2016	579.12	1,900	4,815,287	1,371.57	Discharge Line
R-1	01/22/2016	579.12	1,900	156,311	2,057.36	Water Rinsed through Cuttings [a]
R-2	01/22/2016	582.17	1,910	94,707	1,870.39	Water Rinsed through Cuttings [a]
105	01/22/2016	585.22	1,920	13,345,167	1,908.82	Discharge Line
R-3	01/22/2016	585.22	1,920	57,898	2,021.11	Water Rinsed through Cuttings [a]
106	01/22/2016	588.26	1,930	9,732,718	2,593.71	Discharge Line
R-4	01/22/2016	588.26	1,930	71,083	2,188.44	Water Rinsed through Cuttings [a]
107	01/22/2016	591.31	1,940	11,678,574	1,925.10	Discharge Line
R-5	01/22/2016	591.31	1,940	74,374	2,105.58	Water Rinsed through Cuttings [a]
108	01/22/2016	594.36	1,950	14,354,864	2,161.14	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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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)	
R-6	01/22/2016	594.36	1,950	76,081	2,161.14	Water Rinsed through Cuttings [a]
109	01/22/2016	597.41	1,960	12,264,193	2,097.58	Discharge Line
R-7	01/22/2016	597.41	1,960	95,084	2,161.14	Water Rinsed through Cuttings [a]
110	01/22/2016	600.46	1,970	12,636,387	2,084.32	Discharge Line
R-8	01/22/2016	600.46	1,970	100,490	1,900.41	Water Rinsed through Cuttings [a]
111	01/22/2016	603.50	1,980	12,037,057	1,900.41	Discharge Line
R-9	01/22/2016	603.50	1,980	77,208	2,692.25	Water Rinsed through Cuttings [a]
112	01/22/2016	606.55	1,990	15,298,048	2,105.58	Discharge Line
R-10	01/22/2016	606.55	1,990	45,111	2,041.78	Water Rinsed through Cuttings [a]
113	01/22/2016	609.60	2,000	12,435,255	1,981.72	Discharge Line
R-11	01/22/2016	609.60	2,000	116,684	2,041.78	Water Rinsed through Cuttings [a]
114	01/22/2016	612.65	2,010	11,307,129	2,105.58	Discharge Line
R-12	01/22/2016	612.65	2,010	143,350	1,928.77	Water Rinsed through Cuttings [a]
115	01/22/2016	614.48	2,016	9,697,581	2,105.58	Discharge Line
R-13	01/22/2016	614.48	2,016	76,958	1,928.77	Water Rinsed through Cuttings [a]
116	01/22/2016	N/A	N/A	0	1,679.24	Makeup Water
117	01/24/2016	566.32	1,858	24,773,267	1,511.22	Discharge Line
118	01/24/2016	N/A	N/A	22,597,890	1,435.25	Bailer Sample
119	01/25/2016	N/A	N/A	814	1,369.42	Makeup Water
120	01/26/2016	N/A	N/A	529	4,020.82	Makeup Water
121	01/27/2016	606.86	1,991	53,786	3,803.48	Discharge Line
122	01/27/2016	608.38	1,996	28,028	3,909.13	Discharge Line
R-14	01/27/2016	608.99	1,998	15,707	3,909.13	Water Rinsed through Cuttings [a]
123	01/27/2016	612.65	2,010	3,270,381	4,139.08	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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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)	
124	01/27/2016	613.87	2,014	3,043,824	4,139.08	Discharge Line
R-15	01/27/2016	613.87	2,014	488,767	4,020.82	Water Rinsed through Cuttings [a]
125	01/27/2016	614.48	2,016	5,276,740	3,909.13	Discharge Line
R-16	01/27/2016	614.48	2,016	766,011	3,703.39	Water Rinsed through Cuttings [a]
126	01/27/2016	614.48	2,016	4,771,867	4,555.19	Discharge Line
127	01/27/2016	614.48	2,016	2,307,740	3,669.46	Discharge Line
128	01/27/2016	614.48	2,016	2,463,693	4,128.14	Discharge Line
129	01/27/2016	614.48	2,016	924,264	4,671.33	Discharge Line
130	01/27/2016	614.48	2,016	774,345	4,137.46	Discharge Line
131	01/27/2016	614.48	2,016	772,453	4,525.35	Discharge Line
132	01/27/2016	614.48	2,016	458,088	3,506.23	Discharge Line
133	01/27/2016	614.48	2,016	262,887	3,067.95	Discharge Line
134	01/27/2016	614.48	2,016	370,707	3,316.70	Discharge Line
135	01/28/2016	615.70	2,020	103,215	1,255.85	Discharge Line
136	01/28/2016	618.74	2,030	43,016	1,255.85	Discharge Line
137	01/28/2016	621.79	2,040	99,247	1,732.20	Discharge Line
138	01/28/2016	624.84	2,050	12,942	1,068.81	Discharge Line
R-17	01/28/2016	624.84	2,050	14,142	1,395.39	Water Rinsed through Cuttings [a]
139	01/28/2016	627.89	2,060	21,193	1,321.95	Discharge Line
R-18	01/28/2016	627.89	2,060	20,023	1,357.67	Water Rinsed through Cuttings [a]
140	01/28/2016	630.94	2,070	18,925	1,255.85	Discharge Line
R-19	01/28/2016	630.94	2,070	20,955	2,790.77	Water Rinsed through Cuttings [a]
141	01/28/2016	633.98	2,080	20,279	1,196.05	Discharge Line
142	01/28/2016	N/A	N/A	1,269	1,116.31	Makeup Water
143	01/28/2016	634.59	2,082	46,147	1,357.67	Discharge Line
144	01/28/2016	639.17	2,097	166,538	1,395.39	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
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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)	
145	01/28/2016	646.48	2,121	86,137	1,395.39	Discharge Line
146	01/28/2016	654.41	2,147	62,875	1,435.25	Discharge Line
147	01/28/2016	660.50	2,167	9,299	1,771.17	Discharge Line
148	01/28/2016	665.07	2,182	13,233	1,771.17	Discharge Line
149	01/28/2016	670.56	2,200	19,870	1,536.54	Discharge Line
150	01/28/2016	675.13	2,215	69,132	1,445.50	Discharge Line
151	01/28/2016	679.70	2,230	3,523	1,631.26	Discharge Line
152	01/28/2016	683.36	2,242	1,293	1,784.19	Discharge Line
153	01/28/2016	685.80	2,250	571	1,858.37	Discharge Line
154	01/28/2016	690.68	2,266	1,960	2,105.58	Discharge Line
155	01/28/2016	695.55	2,282	3,708	1,631.25	Discharge Line
156	01/28/2016	699.82	2,296	0	2,000.35	Discharge Line
157	01/28/2016	703.17	2,307	39	2,105.58	Discharge Line
158	01/28/2016	708.66	2,325	2,586	1,477.47	Discharge Line
159	01/28/2016	713.54	2,341	0	1,714.46	Discharge Line
160	01/28/2016	716.28	2,350	0	2,419.39	Discharge Line
161	01/29/2016	719.33	2,360	0	4,269.51	Discharge Line
162	01/29/2016	725.42	2,380	2,047	2,501.08	Discharge Line
163	01/29/2016	731.22	2,399	0	2,750.47	Discharge Line
164	01/29/2016	737.62	2,420	0	1,300.95	Discharge Line
165	01/29/2016	746.46	2,449	556	1,886.04	Discharge Line
166	01/29/2016	754.08	2,474	1,804	1,269.22	Discharge Line
167	01/29/2016	761.70	2,499	1,948	1,626.19	Discharge Line
168	01/29/2016	771.14	2,530	0	2,357.55	Discharge Line
169	01/29/2016	781.20	2,563	2,193	1,486.80	Discharge Line
170	01/29/2016	788.82	2,588	3,962	1,706.09	Discharge Line
171	01/29/2016	794.00	2,605	2,525	1,631.25	Discharge Line
172	01/29/2016	800.71	2,627	3,541	1,445.50	Discharge Line
173	01/29/2016	806.81	2,647	5,406	1,435.25	Discharge Line

Table B-1
Tritium Activities during Drilling of Well ER-2-2
(Page 8 of 9)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
174	01/29/2016	813.82	2,670	3,275	1,415.23	Discharge Line
175	01/29/2016	822.05	2,697	2,749	1,493.86	Discharge Line
176	01/30/2016	827.23	2,714	4,896	1,406.19	Discharge Line
177	01/30/2016	836.68	2,745	10,464	1,629.66	Discharge Line
178	01/30/2016	845.52	2,774	68	1,680.59	Discharge Line
179	01/30/2016	N/A	N/A	341	1,453.48	Makeup Water
180	01/30/2016	851.00	2,792	773	1,912.50	Discharge Line
181	01/30/2016	858.32	2,816	1,132	2,014.86	Discharge Line
182	01/30/2016	868.38	2,849	957	1,415.23	Discharge Line
183	01/30/2016	873.56	2,866	26,600	1,626.19	Discharge Line
184	01/30/2016	882.40	2,895	0	2,393.11	Discharge Line
185	01/30/2016	893.06	2,930	0	1,990.99	Discharge Line
186	01/30/2016	900.68	2,955	0	1,824.84	Discharge Line
187	01/30/2016	909.83	2,985	0	1,914.69	Discharge Line
188	01/30/2016	917.45	3,010	487	1,778.14	Discharge Line
189	01/30/2016	926.59	3,040	840	1,629.66	Discharge Line
190	01/30/2016	928.73	3,047	0	1,955.96	Discharge Line
191	01/30/2016	929.64	3,050	1,649	2,316.14	Discharge Line
192	01/30/2016	933.91	3,064	0	1,928.77	Discharge Line
193	01/30/2016	938.78	3,080	118	1,453.48	Discharge Line
194	01/30/2016	944.88	3,100	0	1,498.98	Discharge Line
195	01/30/2016	949.76	3,116	560	1,334.31	Discharge Line
196	01/30/2016	955.85	3,136	184	1,445.50	Discharge Line
197	01/30/2016	960.73	3,152	290	1,307.00	Discharge Line
198	01/30/2016	965.61	3,168	1,159	1,307.00	Discharge Line
199	01/30/2016	968.65	3,178	82	1,406.43	Discharge Line
200	01/30/2016	975.36	3,200	953	1,272.60	Discharge Line
201	01/31/2016	979.32	3,213	1,773	1,307.00	Discharge Line
202	01/31/2016	N/A	N/A	0	1,725.84	Makeup Water

Table B-1
Tritium Activities during Drilling of Well ER-2-2
(Page 9 of 9)

Sample ID Number	Date	Depth (bgs)		NSTec Onsite Tritium Analysis Results		Sample Description
		m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	
203	01/31/2016	984.20	3,229	1,895	1,325.83	Discharge Line
204	01/31/2016	987.55	3,240	1,487	1,445.50	Discharge Line
205	01/31/2016	993.34	3,259	0	1,824.84	Discharge Line
206	01/31/2016	996.70	3,270	698	1,536.54	Discharge Line
207	01/31/2016	1,001.57	3,286	654	1,435.25	Discharge Line
208	01/31/2016	1,005.84	3,300	0	1,778.14	Discharge Line
209	01/31/2016	1,011.94	3,320	434	1,493.86	Discharge Line
210	01/31/2016	1,015.29	3,331	0	1,824.84	Discharge Line
211	01/31/2016	1,020.78	3,349	2,009	1,631.25	Discharge Line
212	01/31/2016	1,024.13	3,360	0	1,824.84	Discharge Line
213	01/31/2016	1,028.70	3,375	0	1,870.32	Discharge Line
214	01/31/2016	1,033.88	3,392	0	1,824.84	Discharge Line
215	01/31/2016	1,038.15	3,406	0	1,725.84	Discharge Line
216	01/31/2016	1,042.72	3,421	0	1,544.18	Discharge Line
217	01/31/2016	1,044.55	3,427	144	1,453.48	Discharge Line
218	01/31/2016	1,051.56	3,450	0	1,415.23	Discharge Line
219	01/31/2016	1,053.69	3,457	102	1,584.64	Discharge Line
220	01/31/2016	1,053.69	3,457	0	1,502.48	Discharge Line
221	02/01/2016	N/A	N/A	0	1,536.54	Makeup Water
222	02/03/2016	N/A	N/A	1,464	1,581.73	Makeup Water
223	02/04/2016	N/A	N/A	598	1,343.30	Makeup Water
224	02/04/2016	637.34	2,091	1,742	1,288.05	Discharge Line
225	02/05/2016	N/A	N/A	0	1,486.80	Makeup Water
226	02/05/2016	N/A	Sump	354,882	1,395.40	Sump
227	02/06/2016	N/A	N/A	519	1,124.63	Makeup Water
228	02/06/2016	N/A	N/A	526	1,435.25	Makeup Water
229	02/06/2016	975.36	3,200	1,506	1,732.20	Discharge Line

[a] Water rinsed through cuttings and analyzed for tritium so that the cuttings could be released to USGS. (Sample numbers begin with “R-”.)

N/A = Not applicable

Appendix C

Bromide Concentrations and Calculated Water Production during Drilling at Well ER-2-2

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-2-2
(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)
01/17/2016	21:30	118	11.6	10.4	14	10	1
01/18/2016	02:30	122	6.7	11.6	14	10	-4
01/18/2016	05:30	182	23.8	21.2	14	10	1
01/18/2016	13:30	344	34.0	23.9	10	7	3
01/18/2016	17:30	415	130.0	63.2	12	8	9
01/18/2016	23:00	446	47.8	45.6	12	8	0
01/19/2016	02:00	517	8.8	10.7	12	8	-2
01/19/2016	05:00	600	17.6	16.1	12	8	1
01/19/2016	09:30	695	20.3	7.3	20	14	25
01/19/2016	13:30	790	56.0	33.2	12	8	6
01/19/2016	17:30	876	19.2	16.9	13	9	1
01/19/2016	21:30	956	44.8	22.2	12	8	9
01/20/2016	01:30	1,028	24.6	25.0	12	8	0
01/20/2016	05:30	1,110	30.9	12.7	12	8	12
01/20/2016	09:30	1,189	17.0	33.0	12	8	-4
01/20/2016	13:30	1,262	71.1	42.8	12	8	6
01/20/2016	17:30	1,327	23.1	13.9	13	9	6
01/20/2016	21:30	1,399	67.7	36.4	15	11	9
01/21/2016	01:30	1,444	45.7	37.8	13	9	2
01/21/2016	05:30	1,561	68.1	30.9	13	9	11
01/21/2016	09:30	1,613	52.2	45.4	13	9	1
01/21/2016	13:30	1,700	29.7	34.4	14	10	-1
01/21/2016	17:30	1,771	30.5	26.5	13	9	1
01/21/2016	19:05	1,800	48.3	27.3	13	9	7
01/21/2016	19:40	1,820	44.7	21.8	12	8	9
01/21/2016	22:05	1,860	26.6	30.6	12	8	-1
01/22/2016	06:55	1,890	22.2	15.8	12	8	3
01/22/2016	10:20	1,950	9.75	5.13	13	9	8
01/22/2016	13:45	1,990	11.3	3.12	13	9	24
01/22/2016	15:00	2,010	11.9	4.49	13	9	15

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-2-2
(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)
01/27/2016	19:40	2,016	11.2	6.35	12	8	6
01/27/2016	21:15	2,016	10.7	8.32	12	8	2
01/27/2016	22:10	2,016	13.10	8.44	12	8	5
01/28/2016	02:50	2,040	11.00	8.74	12	8	2
01/28/2016	05:40	2,080	9.08	6.29	12	8	4
01/28/2016	07:40	2,097	10.05	9.38	12	8	1
01/28/2016	09:15	2,143	16.00	10.90	12	8	4
01/28/2016	11:15	2,179	10.60	9.86	12	8	1
01/28/2016	13:50	2,214	11.90	8.25	12	8	4
01/28/2016	16:00	2,237	10.30	5.52	12	8	7
01/28/2016	18:00	2,260	12.40	4.97	12	8	13
01/28/2016	20:00	2,293	10.50	4.21	12	8	13
01/28/2016	22:00	2,315	10.50	3.95	12	8	14
01/29/2016	00:00	2,350	12.90	3.84	12	8	20
01/29/2016	01:50	2,390	11.60	4.38	12	8	14
01/29/2016	03:45	2,430	12.40	4.61	12	8	14
01/29/2016	05:15	2,470	10.70	4.92	12	8	10
01/29/2016	06:50	2,510	15.40	4.01	12	8	24
01/29/2016	08:40	2,565	26.90	5.00	12	8	37
01/29/2016	10:30	2,605	38.00	11.00	12	8	21
01/29/2016	21:25	2,645	40.30	11.50	12	8	21
01/29/2016	23:00	2,685	53.60	13.70	12	8	24
01/30/2016	00:55	2,725	33.60	17.80	12	8	7
01/30/2016	02:15	2,765	33.40	15.00	12	8	10
01/30/2016	04:00	2,805	52.40	14.00	12	8	23
01/30/2016	05:30	2,845	36.30	17.30	12	8	9
01/30/2016	07:15	2,885	23.80	8.26	12	8	16
01/30/2016	08:25	2,925	24.30	7.99	12	8	17
01/30/2016	09:25	2,965	35.40	7.60	12	8	31
01/30/2016	11:10	3,005	34.50	5.85	12	8	41

Table C-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-2-2
(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)
01/30/2016	13:10	3,045	16.50	6.61	12	8	13
01/30/2016	16:40	3,085	19.30	3.68	12	8	36
01/30/2016	18:15	3,111	18.70	3.02	12	8	44
01/30/2016	19:30	3,137	35.60	3.30	12	8	82
01/30/2016	20:30	3,153	34.90	4.64	12	8	55
01/30/2016	21:30	3,168	22.80	4.32	12	8	36
01/30/2016	22:30	3,178	24.50	3.45	12	8	51
01/30/2016	23:30	3,200	31.00	3.19	12	8	73
01/31/2016	00:30	3,213	30.80	3.26	12	8	71
01/31/2016	01:30	3,230	22.20	2.75	12	8	59
01/31/2016	03:30	3,242	50.50	4.30	12	8	90
01/31/2016	04:30	3,259	44.70	4.68	12	8	72
01/31/2016	05:30	3,272	55.80	4.26	12	8	102
01/31/2016	06:30	3,288	28.20	3.72	12	8	55
01/31/2016	07:30	3,300	27.30	2.47	12	8	84
01/31/2016	08:30	3,319	29.20	2.26	12	8	100
01/31/2016	09:30	3,331	28.10	2.51	12	8	86
01/31/2016	10:30	3,349	30.70	3.36	12	8	68
01/31/2016	11:30	3,360	35.2	2.33	12	8	119
01/31/2016	12:30	3,375	43.6	3.01	12	8	113
01/31/2016	13:30	3,392	46.2	3.54	12	8	101
01/31/2016	14:30	3,406	43.3	3.03	12	8	112
01/31/2016	15:30	3,421	34	3.93	12	8	64
01/31/2016	16:30	3,427	25.20	3.17	12	8	58
01/31/2016	17:30	3,450	44.10	2.63	12	8	132
01/31/2016	18:05	3,457	43.80	3.11	12	8	110

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

Appendix D

Work Control Documents

NSTec FAWP, Main Hole Drilling and Completion of Well ER-2-2
(43 Pages)

Final Well Specific Fluid Management Strategy
for UGTA Well ER-2-2
(10 Pages)

National Security Technologies LLC
Vision • Service • Partnership

FIELD ACTIVITY WORK PACKAGE

Work Package Number: D-001-001.16 | **Title: Main Hole Drilling and Completion of Well ER-2-2**

Revision Number: 0

Criteria: FY 2015 Task Plan, Yucca Flat Drilling and Completion Criteria September, 2015

Location: NTS NAD 27 ER-2-2: N 871,065 E 675,646

Date: January 2, 2016

Contents of Work Package:

Approvals:

NSTec UGTA Project Manager: /s/ P. K. Ortego **Date:** 1/3/16
P. K. Ortego

Concurrence:

NNSA/NFO UGTA Activity Lead: /s/ Wilhelm Wilborn **Date:** 1/7/16
W. R. Wilborn

Navarro Project Manager: /s/ Ken Rehfeldt **Date:** 1/6/16
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-2-2 well site (including mobilization of the drill rig and other drilling equipment from off the NNSS to the ER-2-2 well site) and main hole construction and completion of the UGTA Yucca Flat ER-2-2 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 (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 300 m (330 to 990 ft) of the lower carbonate aquifer (LCA).

2.1.1.2 Improve understanding of the fault and rock properties in the saturated alluvial aquifer/volcanic aquifer (AA/VA) model, particularly through the tuff confining unit (TCU).

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

2.1.1.4 Use the date collected to help reduce uncertainties within the northern Yucca Flat area during any further groundwater flow and transport modeling.

2.2 Evaluate whether RNs have migrated up the chimney into the overlying aquifer.

2.3 Evaluate the horizontal extent of the exchange volume in the TMLVTA.

2.4 Help determine if the exchange volume has penetrated downward into the LCA, including any role that nearby faults may have on RN transport to the LCA.

2.5 Testing and refining of conceptual models of groundwater flow and RN transport between the saturated AA/VA and LCA.

2.6 Obtain water level data and investigate potential local groundwater flow downgradient from CALABASH (U-2av) underground test (UGT).

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

2.7.1 Sample for tritium and other RNs potentially migrating from upgradient CALABASH 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-2-2 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 118 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-2-2 site and installation of temporary services at the ER-2-2 site. The location-to-location move to the ER-2-2 site includes movement of the major drill rig components and all of the air compressor equipment from the ER-20-12 well site on the Nevada National Security Site (NNSS), transportation of all of United Drilling, LLC (UD) equipment to the ER-2-2 site ; and transportation of any facilities, and materials from other areas of the NNSS such as the Area 1 Drilling Yard to the ER-2-2 site; off- loading and physical placement and setup of the items will be based on the physical features of the ER-2-2 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-2-2 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.

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

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

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

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

4.12 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-2-2 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-2-2 are provided in Exhibit E, Table A.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 0 September 2015 for Well ER-2-2. The geology expected at Well ER-2-2 is well known and is predicted to be similar to the geology encountered at emplacement hole U-2av used for the CALABASH test, located approximately 169 m (555 ft) to the north

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 1,835 ft. bgs unless perched water is encountered.

5.1.12 The surface hole will be drilled to a minimum depth of approximately 1,885 ft. bgs, which is approximately 50 feet below the static water level. However, the depth of the surface hole may be greater than 1,885 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.

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.

5.2.4 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 Optional 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.

5.3.3 Details will be include/documented in an email from the NSTec UGTA Project Manager.

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 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 an even joint, if possible, on the top of the 30-inch casing stub, steel landing plate, and a set off 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 1,885 ft. bgs using 13-3/8 inch casing will be approximately 115,000 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. Air returns in the casing annulus should stop and some air should be observed at the surface in the 13-3/8 inch by 30-inch annulus. This will verify that the drill pipe is stabbed into the float shoe/collar. 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 150 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 20 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 1,000 to 2,000 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 2,550 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 2,550 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.

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 2,550 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 "muleshoed" 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 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 second well in this FY 2015 – FY 2016 drilling campaign, thus all drilling and related equipment, tools, materials and portable facilities will be moved from this location to the next location, ER-4-1 on the NNSS in Area 4.

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-2-2 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-2-2 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-2-2 site to the Area 6 Aid Station</u> – Travel west to the nearest existing road and continue west to the intersection with the Rainier Mesa Road and then south to Mercury Hwy and south on Mercury Hwy to the Area 6 Aid Station a total of approximately 13 miles from ER-2-2. The Area 6 Aid Station is located in the fire station on the northeast corner of the intersection of Tippipah Hwy and Mercury Hwy in building 6-950.

13.2.2 <u>From the ER2-2 site to Mercury Medical</u> – The secondary hospital/infirmary is Mercury Medical Facility. Follow the same directions as above to the intersection with Tippipah Hwy. and continue south on Mercury Hwy. 20.6 miles into Mercury. Turn east (left) on Trinity Road, and proceed three blocks. Turn south (right) on Buster Road. Mercury Medical Facility is in Building 650 on the east (left) side of the road.

NOTES:

A. Changes to this Field Activity Work Plan can only be executed through formal revision of the plan, or through a Record of Verbal Communication (RVC), 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-2-2 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-2-2 Well Site, 3 pages
B ER-2-2 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-2-2
F High Energy Discharge Communications Plan, 2 pages
G Illustration of Projected ER-2-2 Well Completion
H On-Site ER-2-2 Organization Chart
I Emergency Response for the ER-2-2 Site, 2 pages

EXHIBIT A

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

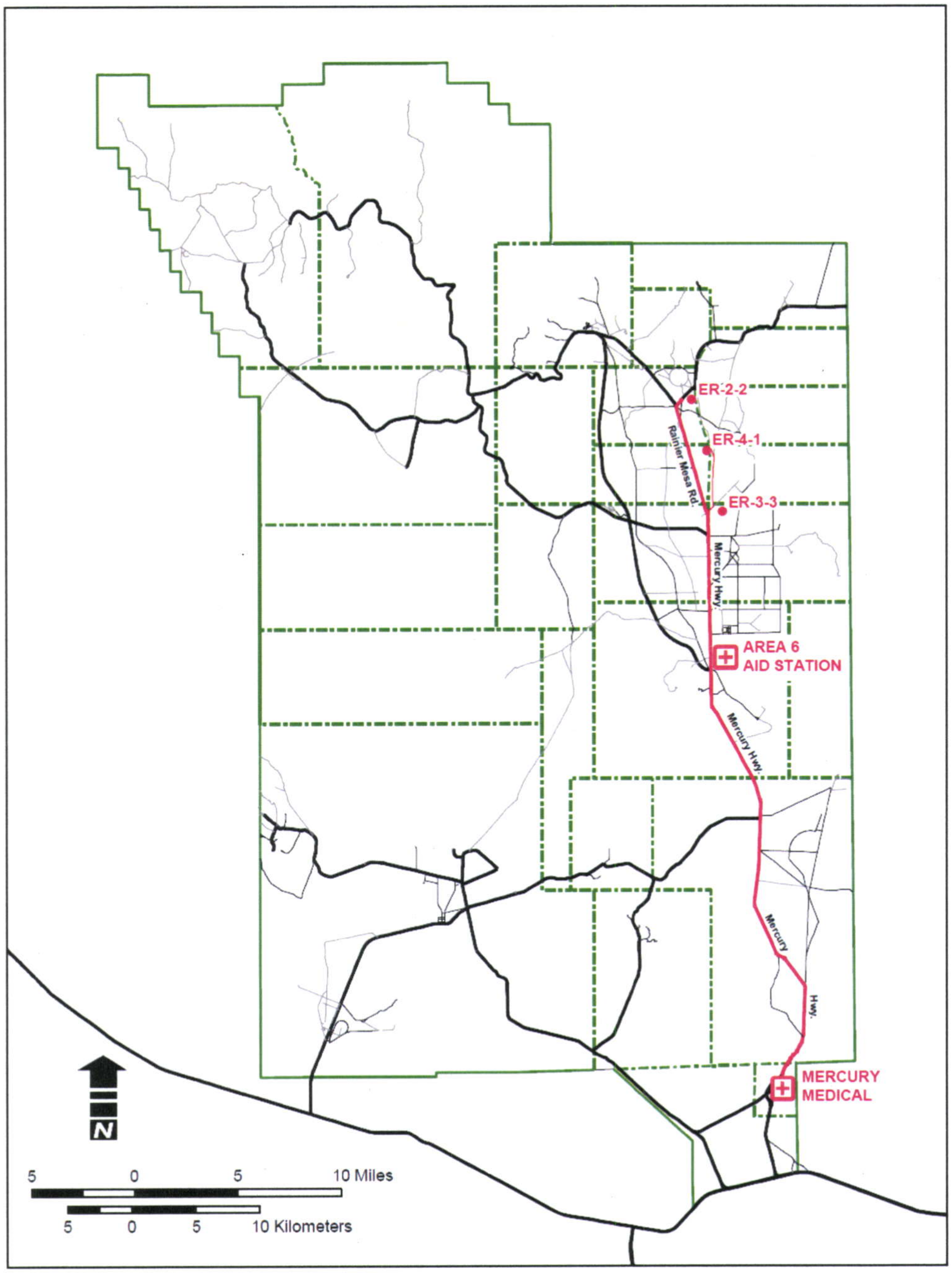
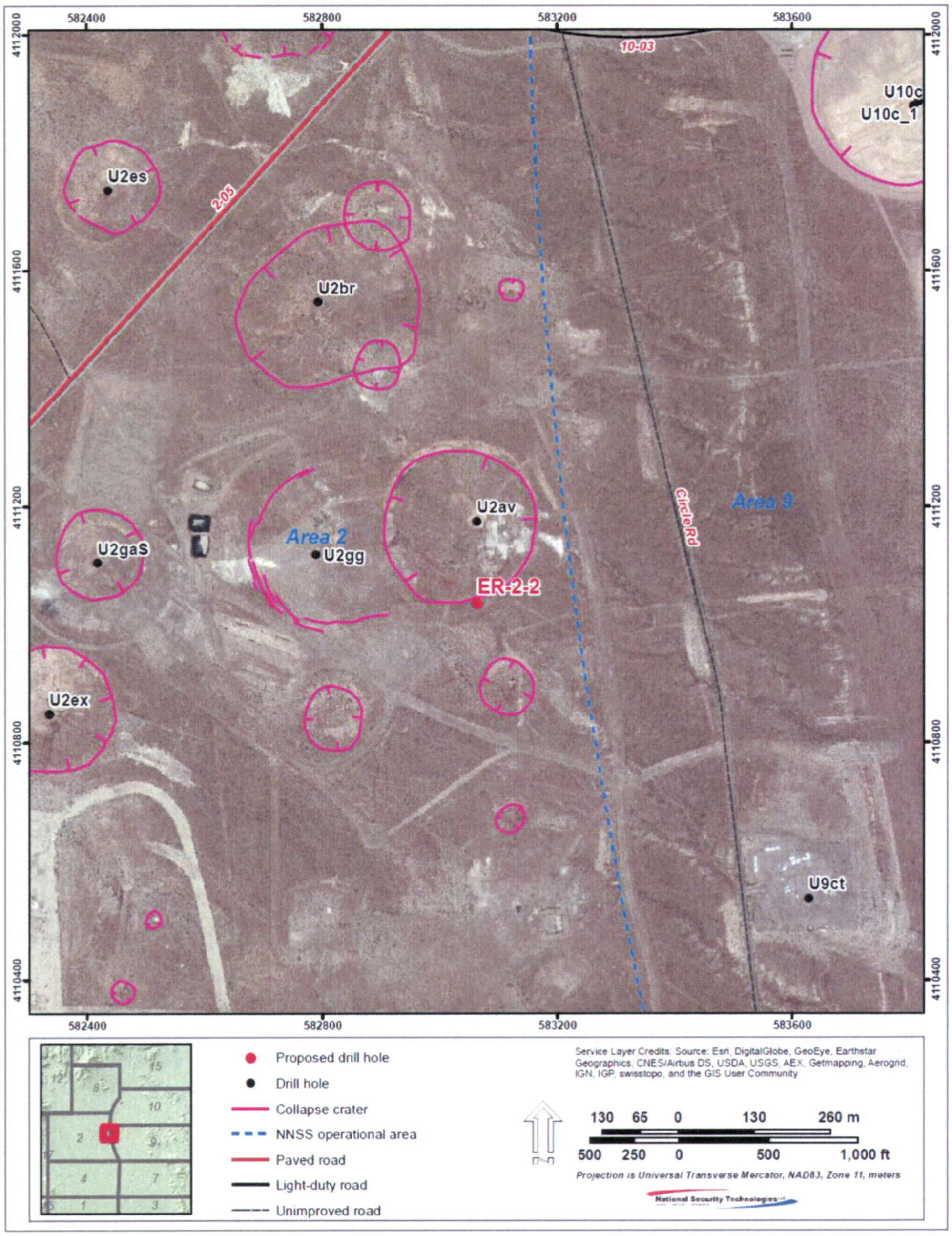


EXHIBIT A

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



Satellite Image for the Proposed ER-2-2 and CALABASH (U-2av) Area

EXHIBIT A

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

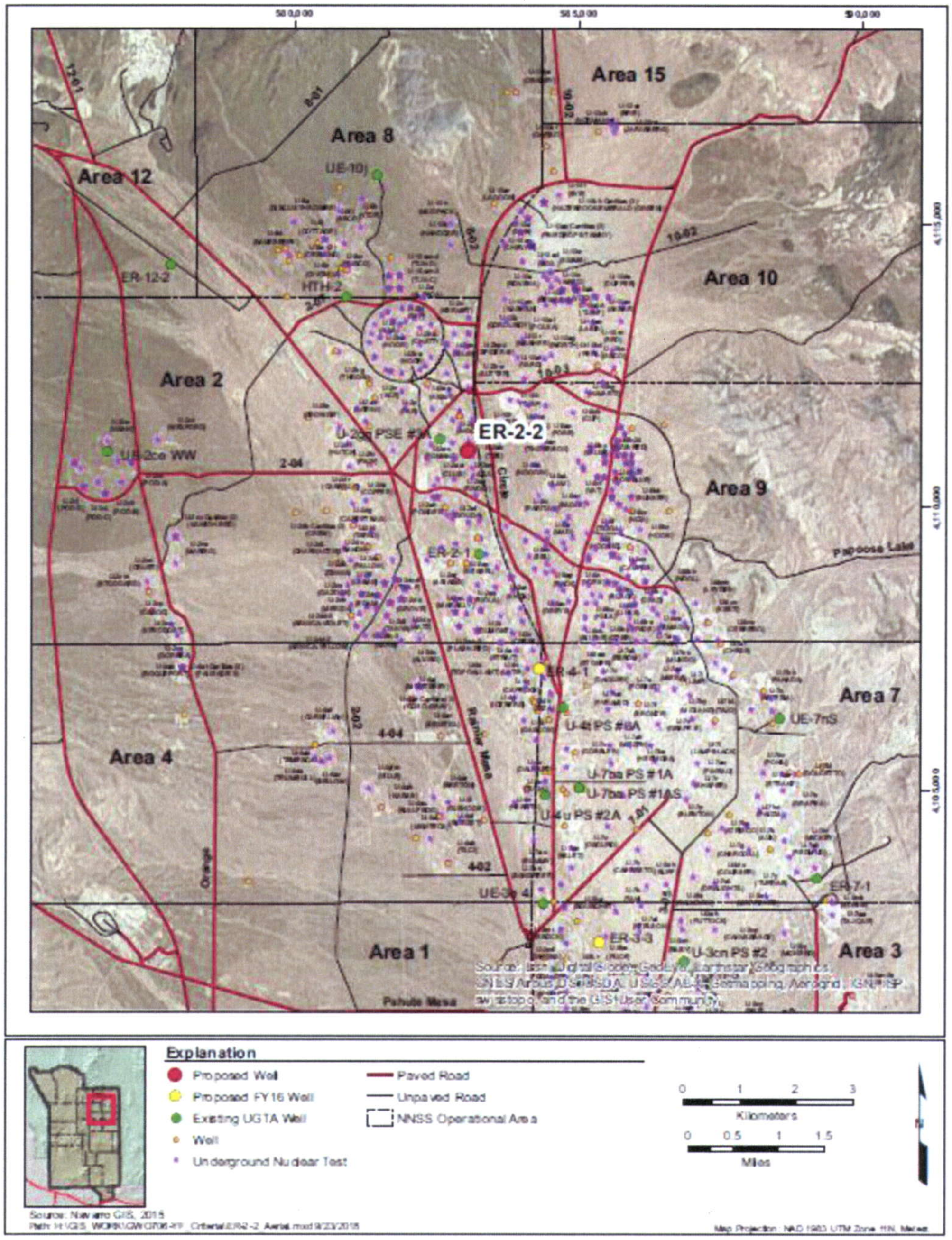


EXHIBIT B

ER-2-2 Existing Surface Site

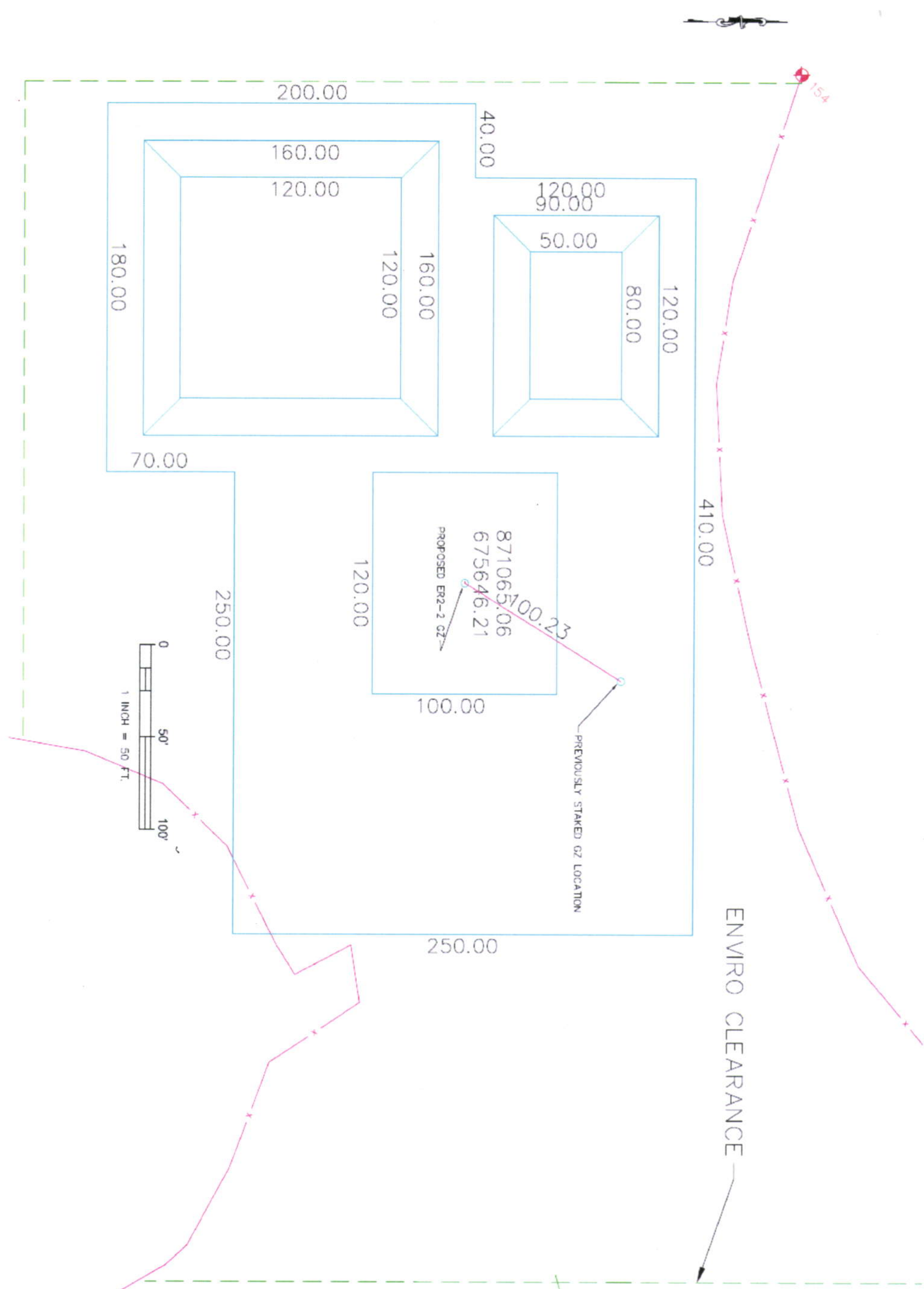
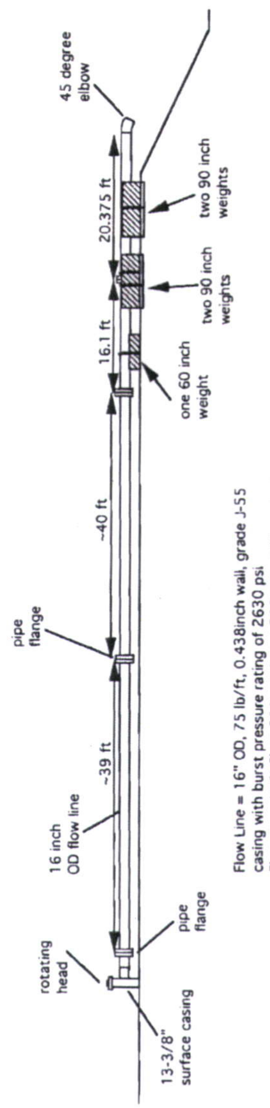


EXHIBIT C

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

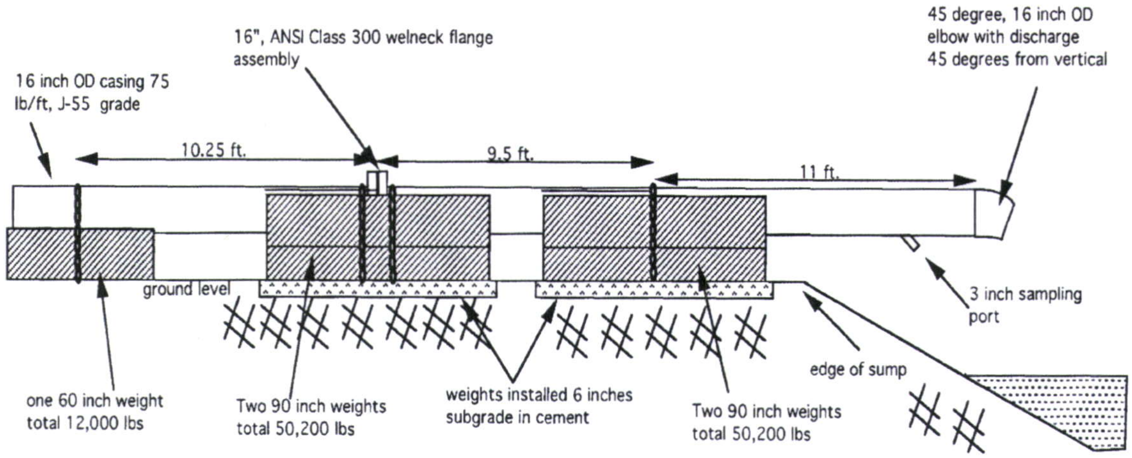
N-I Concurrence: Jeffrey Wurtz for Sam Marutzky, N-I UGTA Program Manager

/s/ Jeffrey Wurtz
Signature

8-27-10
Date

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 A.5-1
Expected Stratigraphic, Lithologic, Geologic, and Hydrologic Characteristics for Proposed Well ER-2-2

Stratigraphic Unit	Depth Interval		Estimated Thickness		Lithology and Alteration	HGU	HSU [a]
	(m)	(ft)	(m)	(ft)			
Quaternary/ Tertiary alluvium (QTa)	0 - 363	0 - 1,192	363	1,192	Poorly to moderately sorted gravel and sand; loosely to moderately consolidated	AA (unsaturated)	AA3 [b]
Mafic-rich Rainier Mesa tuff (Tmrr)	363 - 444	1,192 - 1,458	81	266	Partially to densely welded ash-flow tuff	WTA (unsaturated)	TMWTA
Rainier Mesa tuff/ Tuff of Holmes Road (Tmr/Tmrh)	444 - 578	1,458 - 1,895	133	437	Nonwelded to partially welded ash-flow tuff	VTA (saturated below 559 m [1,835 ft])	TMLVTA
Paintbrush group (Tp)	578 - 620	1,895 - 2,033	42	138	Nonwelded and reworked tuff	TCU (saturated)	LTCU
Grouse Canyon tuff (Tbg)	620 - 629	2,033 - 2,063	9	30	Nonwelded, partially to moderately welded ash-flow tuff	TCU (saturated)	LTCU
Tunnel formation (Tn)	629 - 659	2,063 - 2,163	30	100	Nonwelded to bedded tuff	TCU (saturated)	LTCU
Paleocolluvium/ Older Volcanics (Tlc/To)	659 - 670	2,163 - 2,197	10	34	Interbedded Paleocolluvium and Nonwelded tuffs	TCU (saturated)	ATCU
Paleozoic (Pz)	670 - 777.2	2,197 - 2,550+ (Planned TD = 2,550 ft)	108	353	Carbonate	CA (saturated)	LCA

Source: Modified from Navarro, 2015d

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.

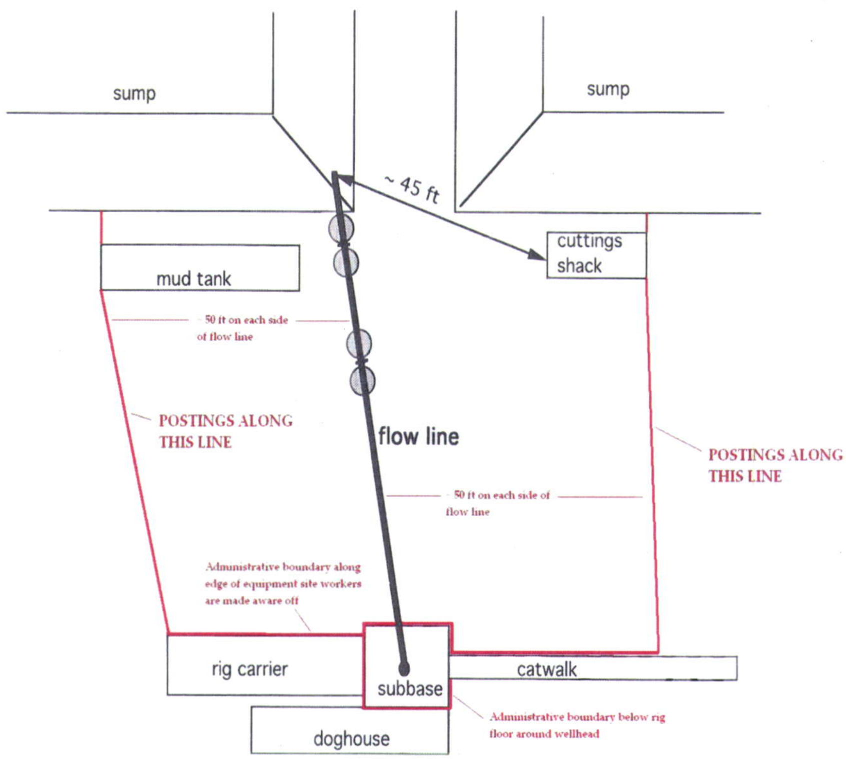
- When administrative controls are to be implemented due to potential high energy discharge conditions a special PTHR will be conducted by the NSTec Site Supervisor for all on-site personnel to advise of hazards and controls, define restricted areas and coordinate participation. Navarro will also conduct 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-2-2 WELL COMPLETION

Well ID: ER-2-2		UTM NAD 27	Northing: 4,110,810.3 m	Easting: 583,142.1 m
Start Date: TBD	Stop Date: TBD	NSPC NAD 83	Northing: 6,265,528.1 m	Easting: 553,474.5 m
Drilling Program: Yucca Flat		Lat/Long NAD 83	Deg N: 37.141761	Deg W: 116.064728
Environmental Contractor: UGTA/Navarro		Surface Elevation	4,272.9 ft amsl	1,302.4 m amsl
Drilling Contractor: United Drilling Inc.		Drill Method:	Conventional - Air/Foam	Drilled Depth: 2,550 ft bgs
Well Construction Diagram (Current as of 09/16/2015)				

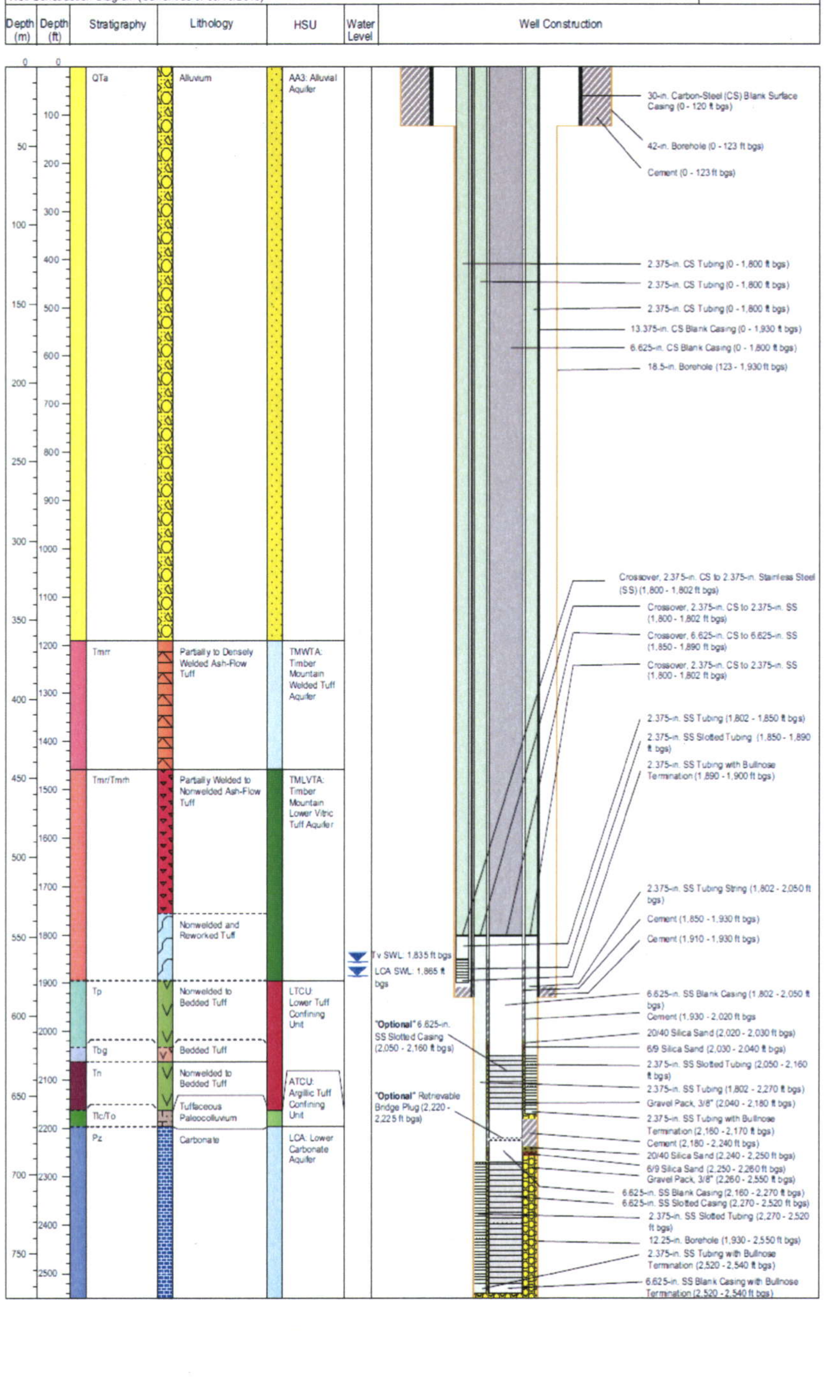


EXHIBIT H
ON-SITE ER-2-2 ORGANIZATION CHART

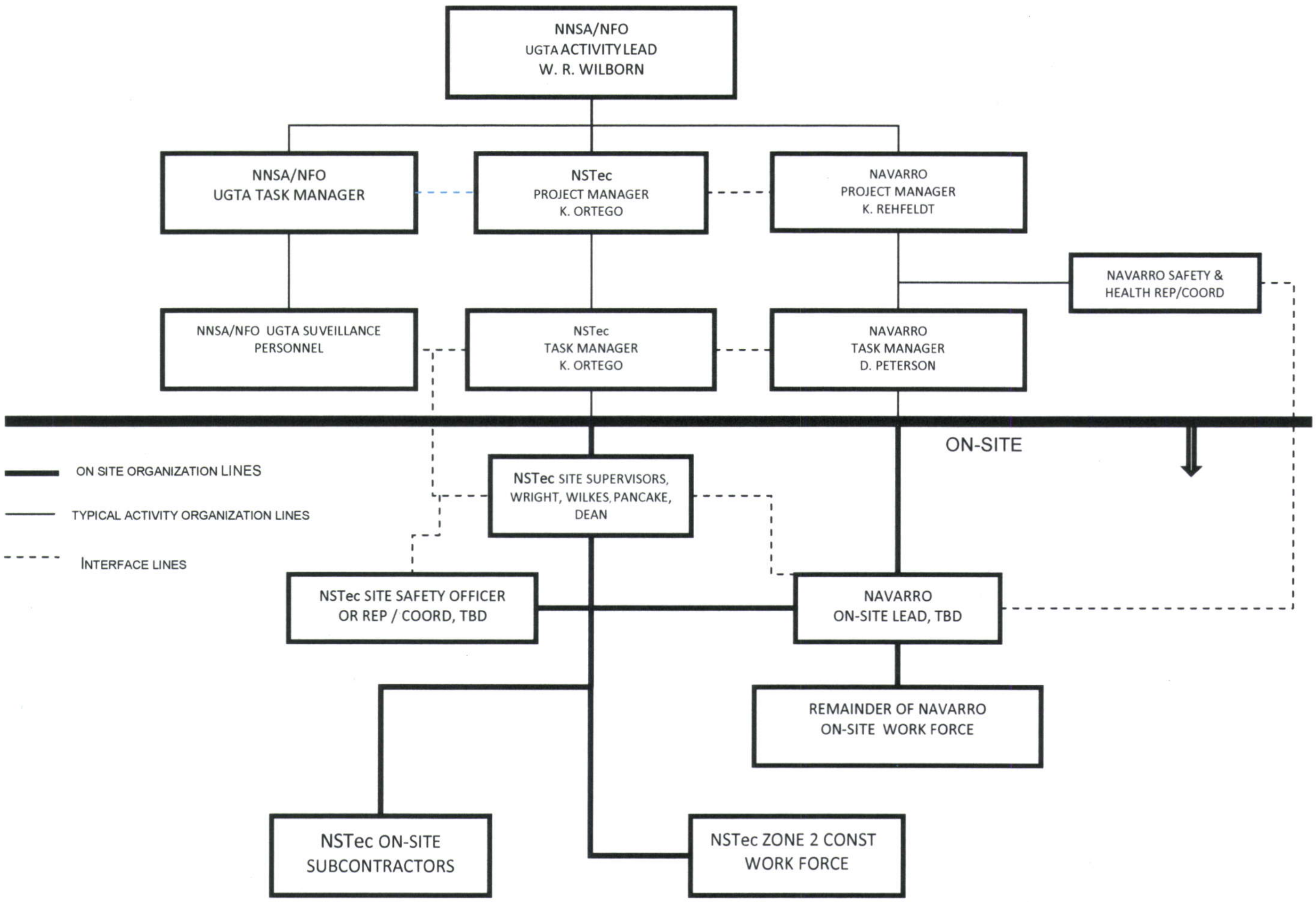


EXHIBIT I
PRIMARY EMERGENCY RESPONSE for ER-2-2 SITE
AREA 6 AID STATION (page 1 of 2)

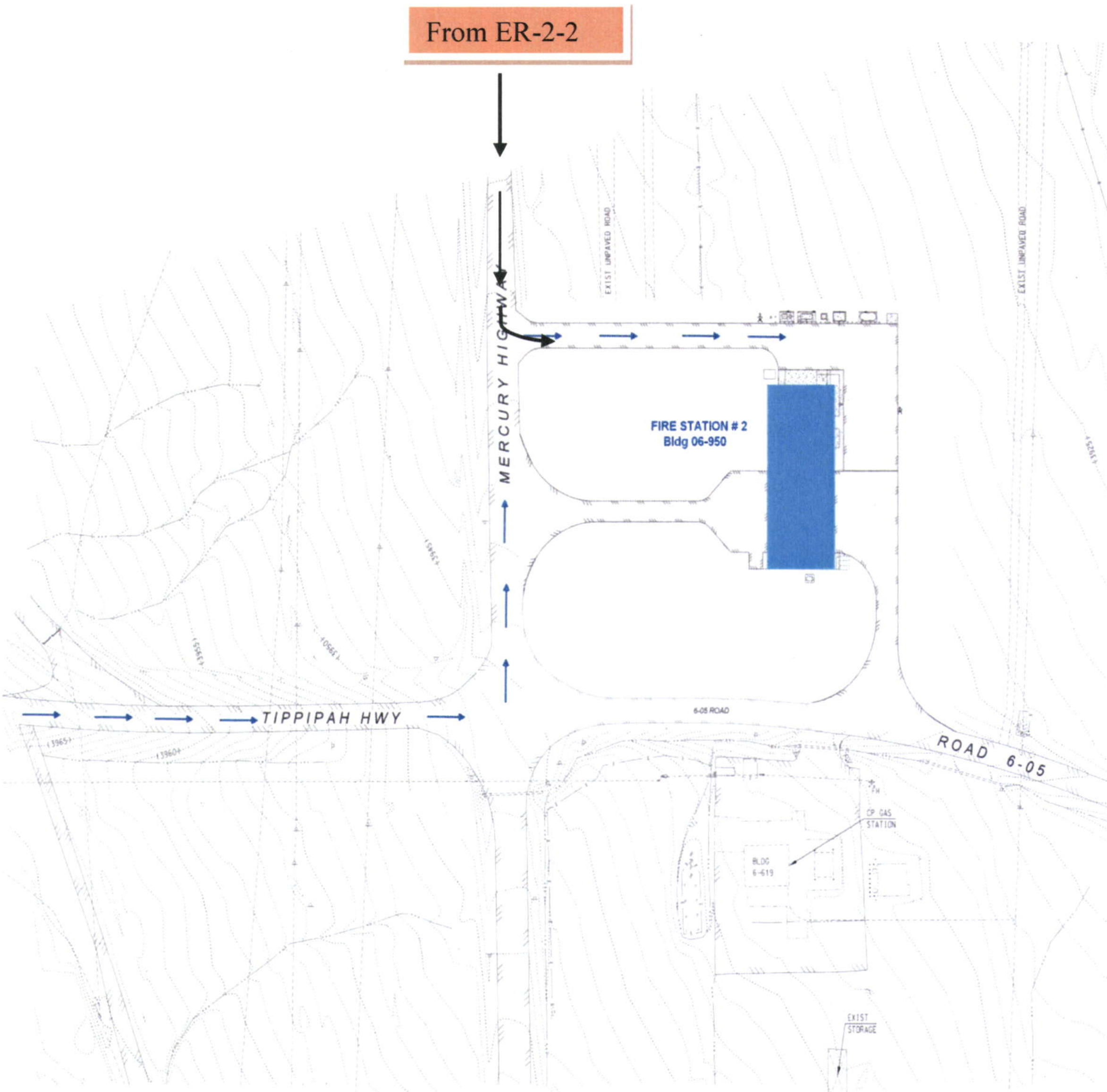
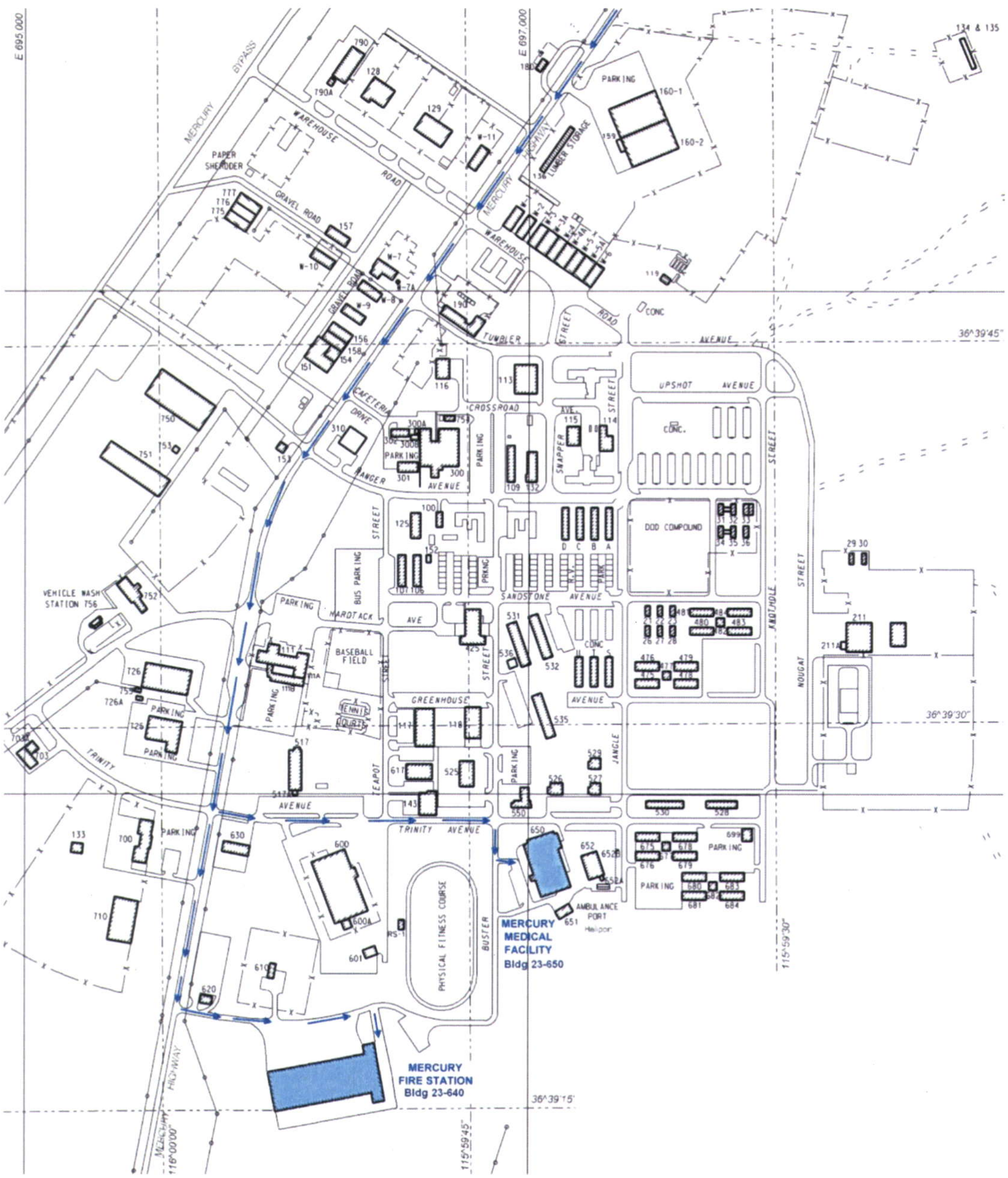


EXHIBIT I
SECONDARY EMERGENCY RESPONSE for ER-2-2 SITE
MERCURY MEDICAL (page 2 of 2)



FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY
FOR UGTA WELL ER-2-2
NEVADA NATIONAL SECURITY SITE

January 5, 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-2-2, 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-2-2 is located within the north central area of Yucca Flat, located within Area 2, in the northeastern portion of the Nevada National Security Site (NNSS). Figure 1 shows the location of Well ER-2-2 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 CALABASH detonated in October of 1969 in emplacement well U-2av. The CALABASH (U-2av) test is located approximately, 167 m (548 ft) to the north of the Well ER-2-2 location. Based on the distance of the proposed well from the CALABASH (U-2av) test and available analytical data from the closest wells, Well ER-2-2 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-2-2 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-2-2.

BACKGROUND AND ANALYTICAL DATA

Given the present understanding of groundwater flow in the area of proposed Well ER-2-2, the location is down gradient of two principal underground tests. The proposed Well ER-2-2 will be located approximately (550 ft) south of the CALABASH (U-2av) test and (963 ft) southeast of the INGOT (U-2gg) test.

Proposed Well ER-2-2 lies approximately down gradient of the CALABASH (U-2av) underground test which is the principal focus of this hydrogeologic investigation. The CALABASH (U-2av) was detonated in 1969 with a working point located below the present water table at a depth of 2,051ft bgs. The reported yield of the CALABSH test was 110 kilotons (DOE 2000).

The INGOT (U-2gg) underground test is also proximal to the proposed Well ER-2-2 location and lies approximately 915 ft west of the CALABASH (U-2av) test. The INGOT (U-2gg) underground test detonated in 1989 with a working point above the water table at a depth of 1,640 ft bgs and a yield range of 20 to 150 kilotons. The INGOT test likely impacted the water table to some extent as the cavity extended to near the water table located at approximately 1,835 ft bgs,

There is some uncertainty with respect to the nature of the groundwater contamination that may be encountered at the Well ER-2-2 location, although the proximity of the Well ER-2-2 to the CALABASH test may suggest that radionuclides in the groundwater are likely. The nearest sampled well to proposed

Well ER-2-2 is the post-shot well U-2gg PS 3A, which was angle drilled adjacent to the INGOT (U-2gg) test cavity. The borehole passed within 10 meters of the cavity and extended below the cavity. This well was last sampled in 1994, in spite of the proximity to the test cavity the reported tritium activity was only 6,490 pCi/L. Similarly, Well ER-2-1 located approximately 1,844 meters (6,050 ft) to the south 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 6.4 kilometers (4 miles) west of the proposed Well ER-2-2 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-2-2 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 CALABASH (U-2av) underground test as suggested in the monitoring and sampling results of nearby wells. As a result the proposed Well ER-2-2 will be drilled to a depth of approximately 777.2 meters (2,550 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-2-2 is presented in Figure 2.

WELL OPERATIONS STRATEGY

Based on the information presented above with respect to the location of Well ER-2-2, hydrogeologic setting and proximity of underground testing, Well ER-2-2 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-2-2 be conducted using the Far-field well site operations strategy for wells located on the NNSS. Should Near-field conditions be encountered, Well ER-2-2 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-2-2. 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-2-2:

- A single lined sump with an approximate 1 million gallon capacity has been constructed at the Well ER-2-2 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-2-2, 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-2-2 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.

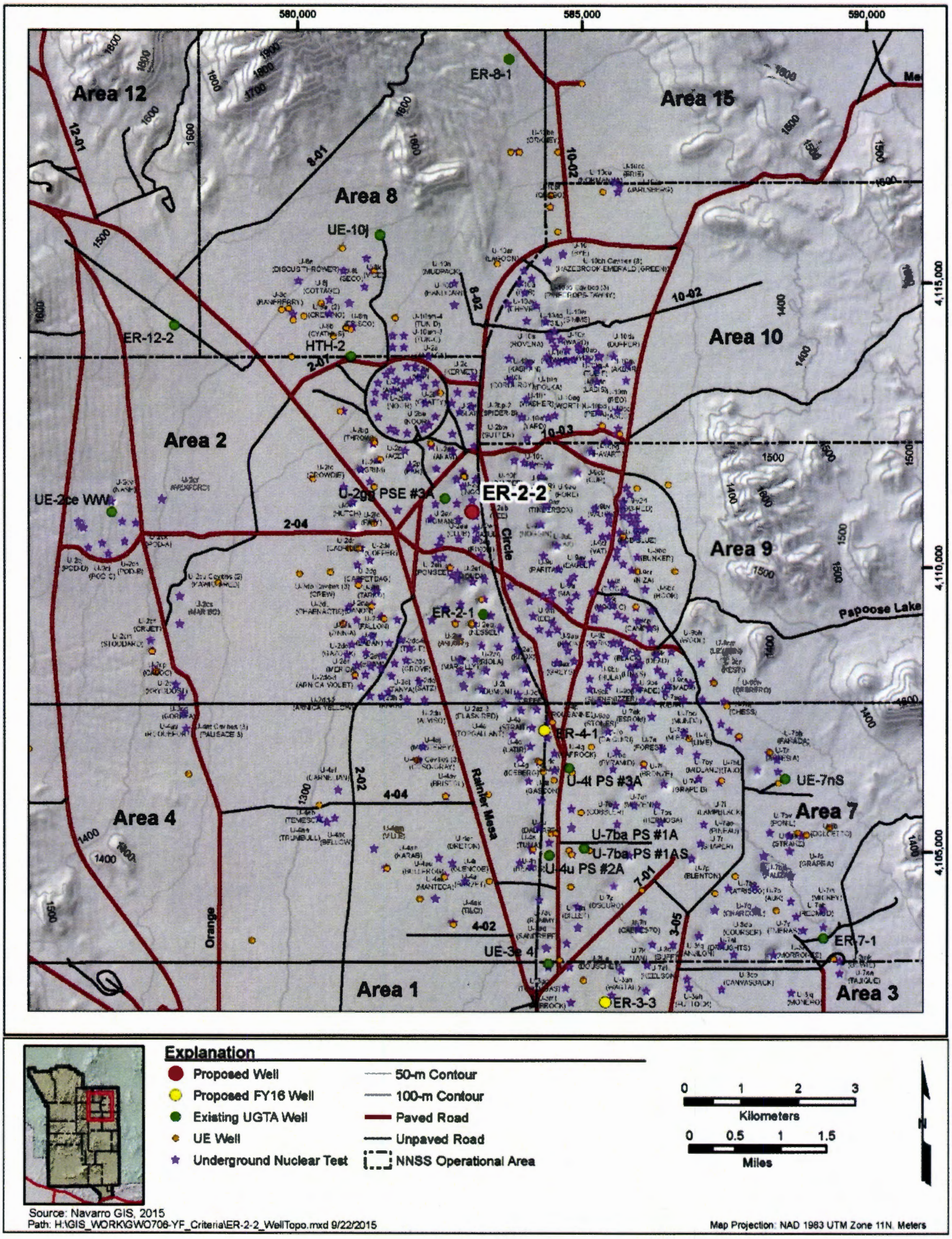


Figure 1
Well ER-2-2 Location Map

Well ID: ER-2-2		UTM NAD 27	Northing: 4,110,810.3 m	Easting: 583,142.1 m
Start Date: TBD	Stop Date: TBD	NSPC NAD 83	Northing: 6,265,528.1 m	Easting: 553,474.5 m
Drilling Program: Yucca Flat		Lat/Long NAD 83	Deg N: 37.141761	Deg W: 116.064728
Environmental Contractor: UGTA/Navarro		Surface Elevation	4,272.9 ft amsl	1,302.4 m amsl
Drilling Contractor: United Drilling Inc.		Drill Method:	Conventional - Air/Foam	Drilled Depth: 2,550 ft bgs
Well Construction Diagram (Current as of 09/16/2015)				

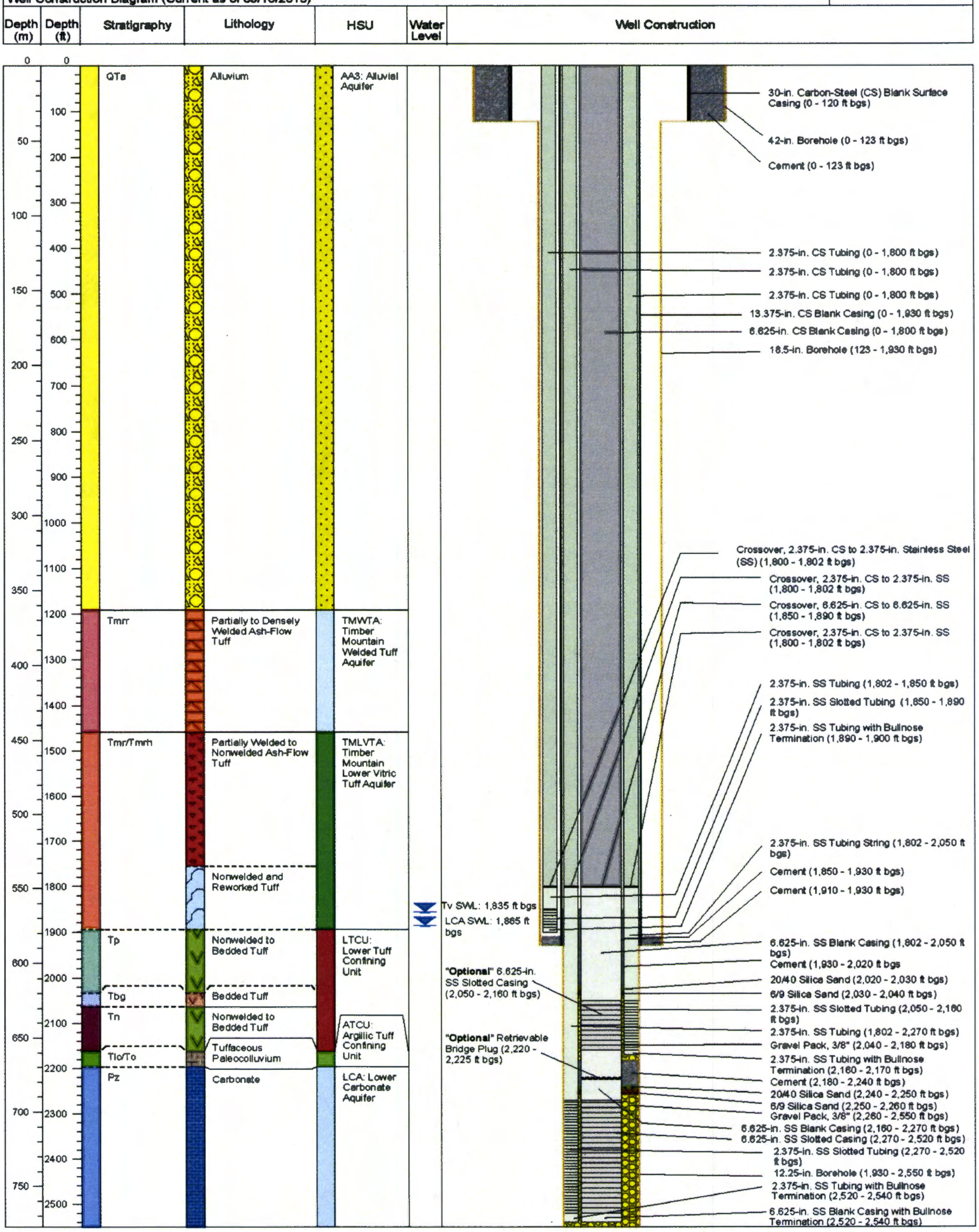


Figure 2
Proposed Well ER-2-2 Construction Diagram

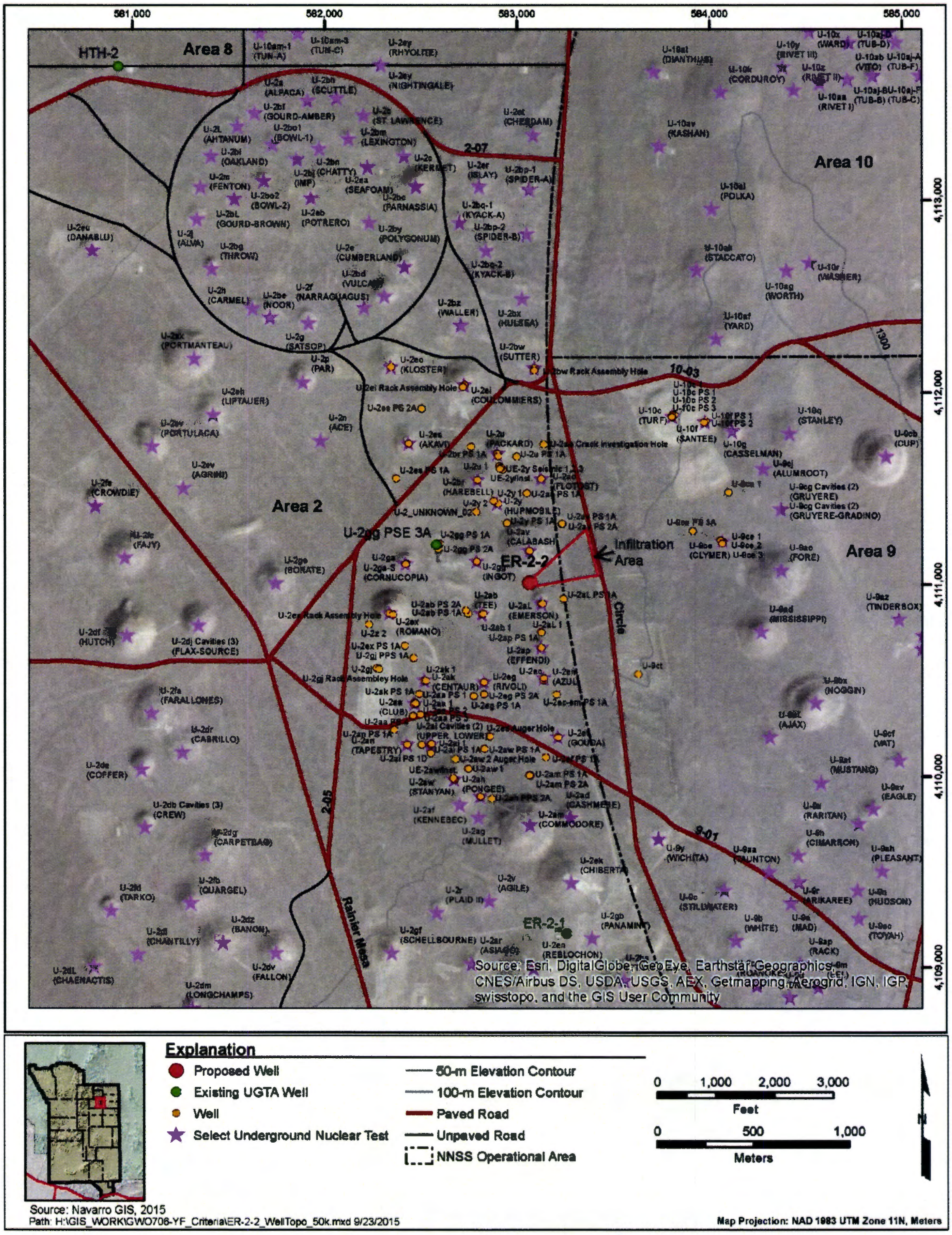


Figure 3
Proposed Infiltration Area at Well ER-2-2

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.

Department of Energy
National Nuclear Security Administration
Nevada Field Office
P.O. Box 98518
Las Vegas, NV 89193-8518

JAN 0 7 2016

Christine Andres, Chief
Bureau of Federal Facilities
Division of Environmental Protection
2030 East Flamingo Road, Suite 230
Las Vegas, NV 89119-0818

SUBMITTAL OF THE FINAL WELL SPECIFIC FLUID MANAGEMENT STRATEGY FOR THE UNDERGROUND TEST AREA (UGTA) WELL ER-2-2, AREA 2, NEVADA NATIONAL SECURITY SITE (NNSS), JANUARY 2016

Enclosed are two copies of the Final subject report for your review and approval.

Please direct comments and questions to Bill Wilborn, of my staff, at (702) 295-3188.

/s/ Robert Boehlecke

Robert F. Boehlecke, Manager
Environmental Management Operations

EMO:11629.CD

Enclosures:
As stated

cc w/encl. via e-mail:
Mark McLane, NDEP
J. T. Fraher, DTRA/CXTS
Navarro Central Files
NSTec Correspondence Management
W. R. Wilborn, NFO
FFACO Group, NFO
NFO Read File

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

January 7, 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-2-2, AREA 2, NEVADA NATIONAL SECURITY SITE (NNSS), January 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-2-2, Area 2, NNSS*, Rev 0, dated January 7, 2016. The strategy describes the monitoring and management of fluids generated during the drilling, pumping, purging and sampling of ER-2-2. 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/ Chris Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/MM

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

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

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