DOE/NV/0000939-23

Handbook: Collecting Groundwater Samples from Monitoring Wells in Frenchman Flat, CAU 98

Prepared by

Jenny Chapman, Brad Lyles, Clay Cooper, Ron Hershey, and John Healey

Submitted to

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

June 2015

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Nevada System of Higher Education

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LIST OF ACRONYMS

AA	Alluvial Aquifer
BLFA	Basalt Lava Flow Aquifer
BLS	below land surface
COC	contaminant of concern
COPC	Contaminants of Potential Concern
CADD	Corrective Action Decision Document
CAP	Corrective Action Plan
CAU	Corrective Action Unit
DOE	U.S. Department of Energy
DOD	U.S. Department of Defense
EC	electrical conductance
EPA	U.S. Environmental Protection Agency
FFACO	Federal Facility Agreement and Consent Order
MCL	maximum contaminant levels
MSL	mean sea level
NGVD29	National Geodetic Vertical Datum of 1929
NNSS	Nevada National Security Site
NTU	nephelometric turbidity units
OAA	Older Alluvium Aquifer
QA	Quality Assurance
SDWA	Safe Drinking Water Act
UGTA	Underground Test Area

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INTRODUCTION

Frenchman Flat basin on the Nevada National Security Site (NNSS) contains Corrective Action Unit (CAU) 98, which is comprised of ten underground nuclear test locations. Environmental management of these test locations is part of the Underground Test Area (UGTA) Activity conducted by the U.S. Department of Energy (DOE) under the Federal Facility Agreement and Consent Order (FFACO) (1996, as amended) with the U.S. Department of Defense (DOD) and the State of Nevada.

A Corrective Action Decision Document (CADD)/Corrective Action Plan (CAP) has been approved for CAU 98 (DOE, 2011). The CADD/CAP reports on the Corrective Action Investigation that was conducted for the CAU, which included characterization and modeling. It also presents the recommended corrective actions to address the objective of protecting human health and the environment. The recommended corrective action alternative is “Closure in Place with Modeling, Monitoring, and Institutional Controls.” The role of monitoring is to verify that Contaminants of Concern (COCs) have not exceeded the Safe Drinking Water Act (SDWA) limits (Code of Federal Regulations, 2014) at the regulatory boundary, to ensure that institutional controls are adequate, and to monitor for changed conditions that could affect the closure conditions. The long-term closure monitoring program will be planned and implemented as part of the Closure Report stage after activities specified in the CADD/CAP are complete.

Groundwater at the NNSS has been monitored for decades through a variety of programs. Current activities were recently consolidated in an NNSS Integrated Sampling Plan (DOE, 2014). Although monitoring directed by the plan is not intended to meet the FFACO long-term monitoring requirements for a CAU (which will be defined in the Closure Report), the objective to ensure public health protection is similar. It is expected that data collected in accordance with the plan will support the transition to long-term monitoring at each CAU. The sampling plan is designed to ensure that monitoring activities occur in compliance with the UGTA Quality Assurance Plan (DOE, 2012). The sampling plan should be referenced for Quality Assurance (QA) elements and procedures governing sampling activities.

The NNSS Integrated Sampling Plan specifies the groundwater monitoring that will occur in CAU 98 until the long-term monitoring program is approved in the Closure Report. The plan specifies the wells that must be monitored and categorizes them by their sampling objective with the associated analytical requirements and frequency. Possible sample collection methods and required standard operating procedures are also presented. The intent of this handbook is to augment the NNSS Integrated Sampling Plan by providing well-specific details for the sampling professional implementing the Sampling Plan in CAU 98, Frenchman Flat.

This handbook includes each CAU 98 well designated for sampling in the NNSS Integrated Sampling Plan. The following information is provided in the individual well sections:

1. The purpose of sampling.
2. A physical description of the well.
3. The chemical characteristics of the formation water.
4. Recommended protocols for purging and sampling.

The well-specific information has been gathered from numerous historical and current sources cited in each section, but two particularly valuable resources merit special mention. These are the USGS NNSS website (http://nevada.usgs.gov/doe_nv/ntsarea5.cfm) and the UGTA Field Operations website (https://ugta.nv.doe.gov/sites/Field%20Operations/default.aspx).

Land surface elevation and measuring point for water level measurements in Frenchman Flat were a focus during CAU investigations (see Appendix B, Attachment 1 in Navarro-Intera, 2014). Both websites listed above provide information on the accepted datum for each well. A summary is found on the home page for the well on the USGS website. Additional information is available through a link in the “Available Data” section to an “MP diagram” with a photo annotated with the datum information. On the UGTA Field Operations well page, the same information is in the “Wellhead Diagram” link. Well RNM-2s does not have an annotated photo at this time.

All of the CAU 98 monitoring wells are located within Area 5 of Frenchman Flat, with the exception of ER-11-2 in Area 11 (Figure 1). The wells are clustered in two areas: the northern area (Figure 2) and the central area (Figure 3). Each well is discussed below in geographic order from north to south as follows: ER-11-2, ER-5-3 shallow piezometer, ER-5-3-2, ER-5-5, RNM-1, RNM-2s, and UE-5n.

References for Introduction

Code of Federal Regulations, 2014. Title 40 CFR Part 141. National Primary Drinking Water Regulations. Washington D.C., U.S. Government Printing Office.

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

Navarro-Intera, 2014. Model Evaluation Report for Corrective Action Unit 98: Frenchman Flat, Nevada National Security Site, Nye County, Nevada, N-I/28091—088.

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

U.S. Department of Energy, 2012. Underground Test Area Activity Quality Assurance Plan, Nevada National Security Site, Nevada, Rev. 1. National Nuclear Security Administration, Nevada Site Office, DOE/NV-1450-REV. 1.

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

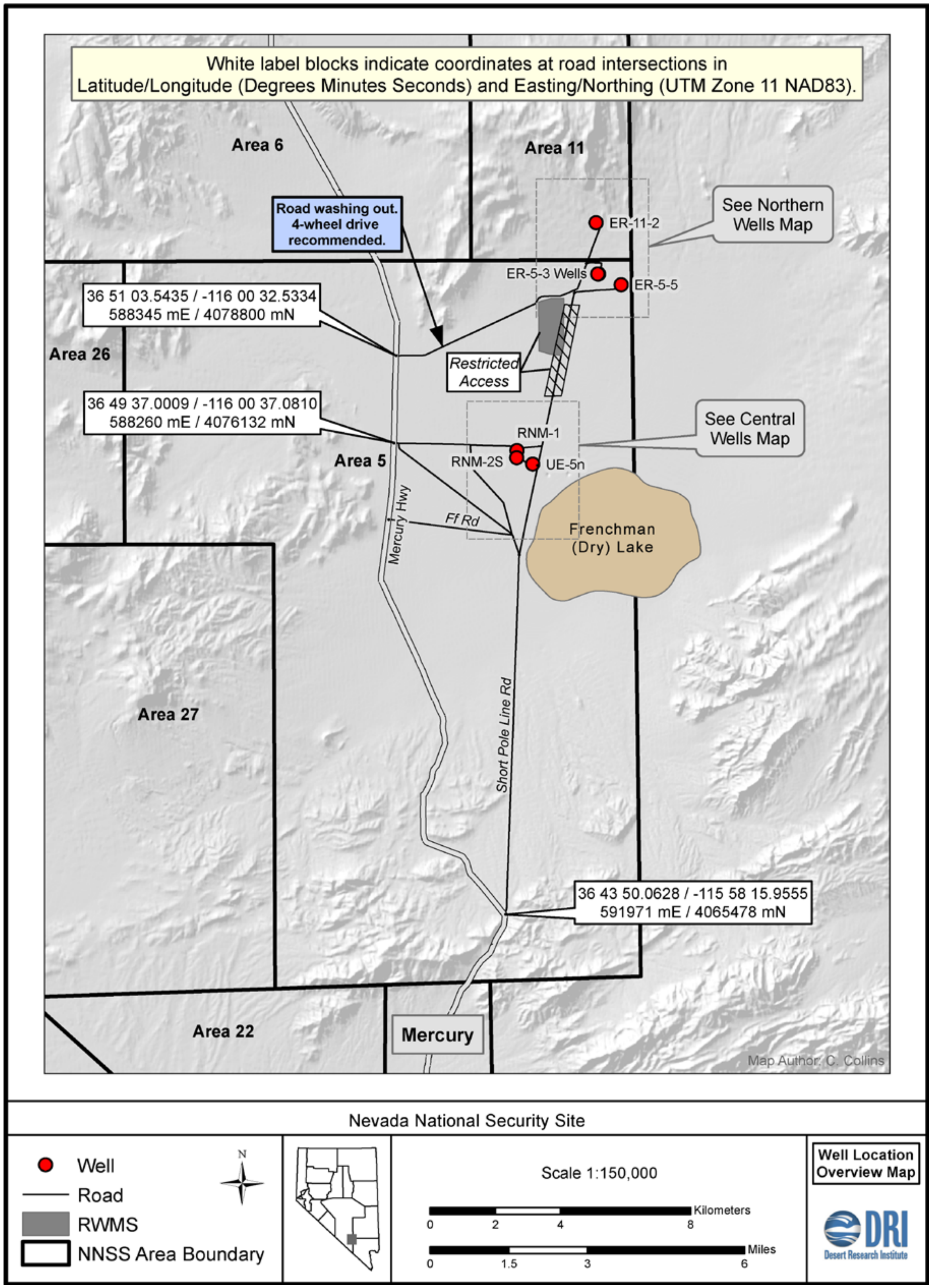

Figure 1. Location of wells in Frenchman Flat included in the NNSS Integrated Sampling Plan.

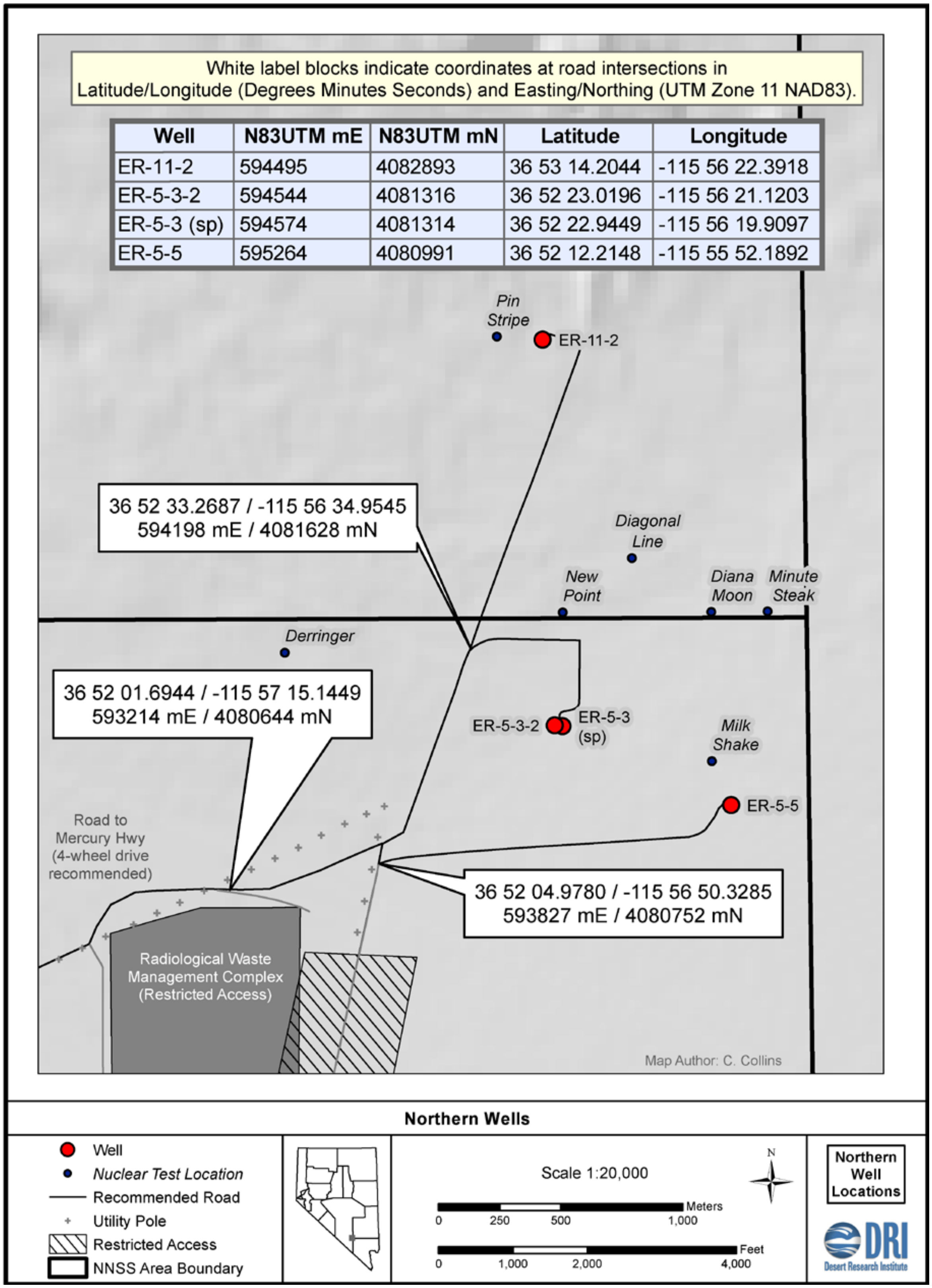

Figure 2. Location of monitoring wells in the northern area of Frenchman Flat.

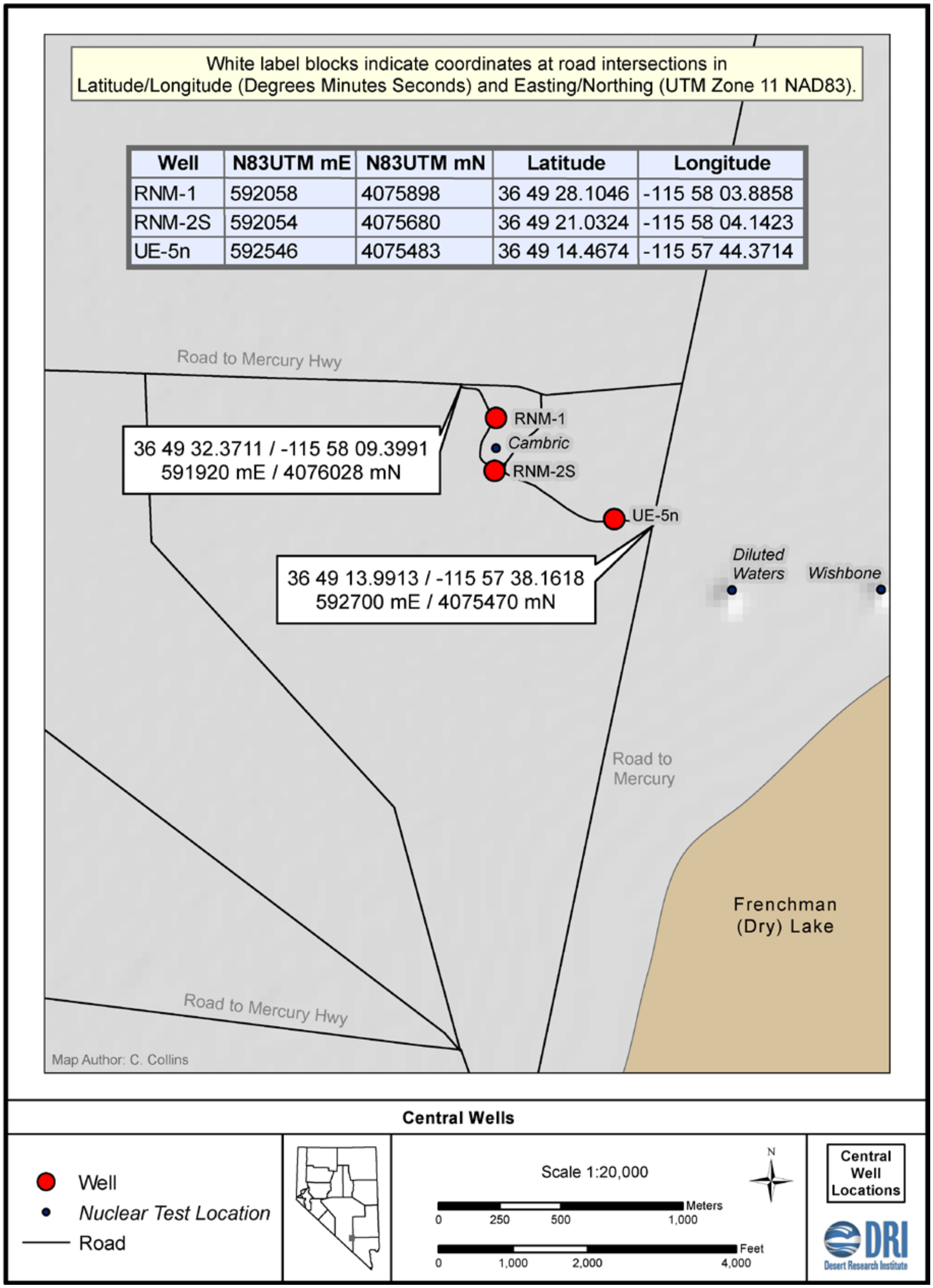

Figure 3. Location of wells in the central area of Frenchman Flat.

WELL ER-11-2

Integrated Sampling Plan ID: ER-11-2_m1

Type of UGTA groundwater sampling point: Early detection well

Sampling Frequency: 5 years

Analytes:

- ^{3}H (using low-level methods)

Role in Sampling Plan

Well ER-11-2 was drilled as a model evaluation well for Frenchman Flat. As such, the well was initially sampled to support flow and transport model evaluation and to monitor COCs downgradient from the PIN STRIPE UGT, which was conducted in the U-11b borehole in 1966. The well did not encounter the expected Topopah Spring Aquifer in the saturated zone. Due to faulting, the water table occurs in the very low hydraulic conductivity Wahmonie Formation. As an Early Detection well, the objective of monitoring ER-11-2 is to continue to support model evaluation and to detect plume migration from PIN STRIPE.

Physical Description of Well

Well ER-11-2 is located nearby the PIN STRIPE underground nuclear test in the southeastern corner of Area 11 in northern Frenchman Flat (Figure 2). The wellhead is located on a pad on a hillside bordering the northern edge of the basin, almost 5 miles north of the playa (Figure 4). It is accessed from a dirt road (Figure 2). The latitude and longitude for the well location, referencing NAD 83 are 36.88726818º, -115.93952765º. The land surface elevation at the wellhead is 3,573.22 ft, referencing NGVD29. Its USGS Site ID is 364805115580801.

The total depth of the borehole was 1,310.9 ft when drilled in 2012. It was completed with a single piezometer tube slotted from 1,167.62 to 1,294.18 ft below land surface (BLS) (Figure 5). The tubing diameter is 2.375 in from ground to 1,125.95 ft, and 2.875 in from 1,125.95 to 1,294.18 ft BLS. The bottom of the tubing is a bullnose. The slots are 0.06-in wide by 2.125-in long with the annular space filled with 0.375-in gravel (N-I, 2012). The well accesses the Lower Vitric Tuff Aquifer (LVTA) in the low-hydraulic-conductivity Tertiary Wahmonie Formation, a zeolitized tuff. Based on bromide dilution calculations—bromide was added with the drilling fluid—estimated water production ranged from 2-3 gpm (DOE, 2013).

There is no pump in the well and the well has not been developed. Prior to installation of the piezometer string, the static water level was 1,269 ft BLS on August 22, 2012. Since completion, a gradual rise in the water table has resulted in a static water level of 1,154 ft BLS on March 3, 2015.

Chemical Description of the Formation Waters of ER-11-2

As reported in the UGTA Geochemistry Database, the well was sampled for general, trace, and isotopic chemistry in July of 2013 (Table 1). Though fluid discharge was monitored during drilling, water quality measurements were affected by cement and the use of drilling foam and polymer so that analytical results are not believed representative of natural groundwater quality (N-I, 2014).

All radionuclide measurements are below the U.S. EPA Safe Drinking Water Act maximum contaminant levels (EPA SDWA MCL) or in the case of gross beta, below the Level of Concern (Table 2).

Recommended Sampling Procedures

Sampling Method: No submersible pump is installed in the well. Based on the borehole diameter (2.36 in), two sampling methods have been identified: (1) use a discrete bailer to sample from the screened interval of the well or (2) use a sucker rod (lift jack) pump.

Sampling Depth: Ideally, hydrologic logging would be performed in the well to identify the optimum sampling horizon. Otherwise, samples should be collected from the middle of the screen interval at approximately 1,229 ft BLS. The available sampling zone is between 1,154 ft BLS (static water level) and 1,304 ft BLS (bottom of screen). The entire screen extent is within the Wahmonie Formation. Chemistry samples were previously collected at 1,200 ft BLS in July 2013.

Purging recommendations: Given the low productivity of the well, purging three well volumes (881 gal; Table 3) is not practical. If a sucker rod pump is installed, pumping should proceed until field parameters stabilize and at least one well volume has been purged. If bailing, a discrete bailer can be used in the absence of purging.

Field measurement and stability indicators: There is concern that chemical data from ER-11-2 remain affected by drilling fluids and therefore may not provide an accurate representation of formation water. With that caveat, a specific conductivity of 1,100 µS/cm and a pH of 8.6 may be used as general guidelines for purging stability indicators.

References for ER-11-2

Note: Incomplete report numbers (e.g., “XXX”) indicate an unpublished, internal UGTA document.

Navarro-Intera, 2012. Frenchman Flat Model Evaluation Well ER-11-2 Data Package, N-I/28091-XXX.

Navarro-Intera, 2014. Model Evaluation Report for Corrective Action Unit 98: Frenchman Flat, Nevada National Security Site, Nye County, Nevada, Revision No. 1. Report prepared for the U.S. Department of Energy, N-1/28091-088.

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

U.S. Department of Energy, Nevada Operations Office, 2013, Completion Report for Model Evaluation Well ER-11-2, Corrective Action Unit 98: Frenchman Flat, DOE/NV-1497. Las Vegas, NV.

U.S. Department of Energy (DOE), 2014. Underground Test Area Geochemistry Database. https://ugta.nv.doe.gov/sites/Geochemistry%20Database/DataPages/Geochem.aspx. Not available for public access.

Table 1. ER-11-2 chemical data. All units are mg/L unless otherwise noted.

Ref.	Date	pH (standard units)	Specific Conductance (μS/cm)	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	Br
DOE, 2014	7/12/2013	8.6	1100	5	2.1	200	5.4	50	100	<20	310	1.1

Table 2. ER-11-2 radiochemical data.

Ref.	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/l)	Tritium (pCi/l)	C-14 (pCi/L)	Cl-36 (pCi/l)	Tc-99 (pCi/L)	I-129 (pCi/L)
DOE, 2014	7/12/2013	13.6	8.6					
DOE, 2014	7/13/2013						3.5*	
DOE, 2014	7/14/2013			0.34*	0.2429	9.54E-04		2.8E-06

* Value below analytical detection limit.

Table 3. ER-11-2 well volume calculations. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1294	bottom of well (ft)
12.25	borehole diameter (in)
1154.03	depth to water (ft)
2.875	casing OD (in)
2.36	casing ID (in)
1132	top of gravel (ft)
1304	bottom of gravel (ft)
0.3	gravel porosity
120.4	casing volume (L)
31.9	casing volume (gal)
1154	effective top of gravel (ft)
3475.8	total borehole volume (L)
989.1	gravel vol less interference (L)
1109.5	casing plus net gravel water volume (L)
293.5	casing plus net gravel water volume (gal)
881	three well volumes (gal)

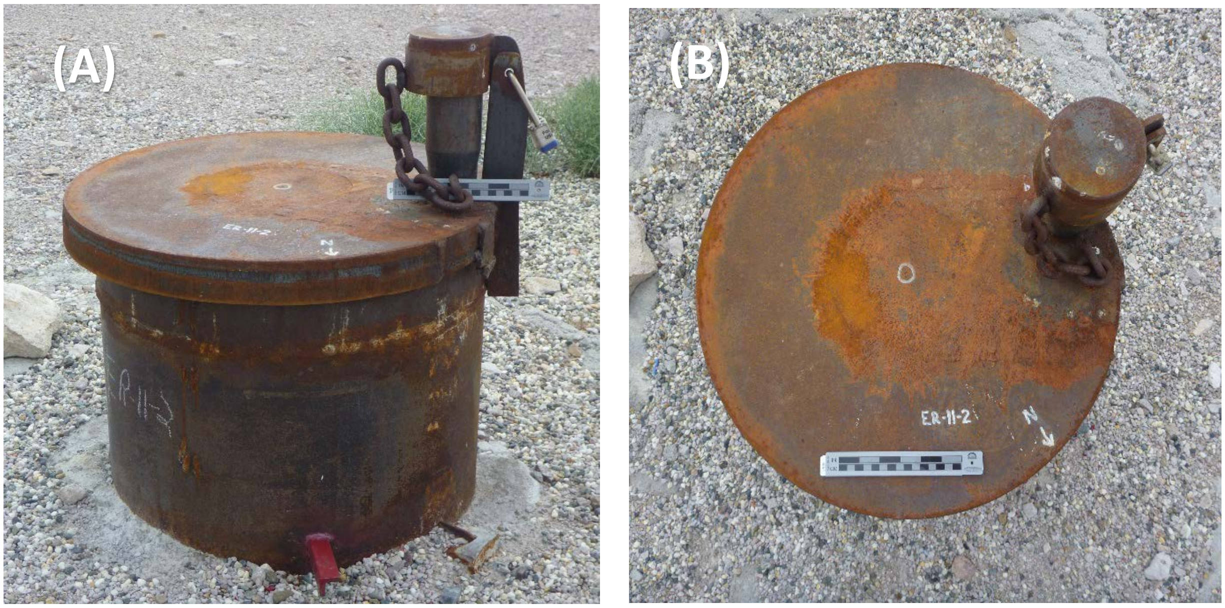

Figure 4. Photo of ER-11-2 wellhead configuration: (a) view to the south and (b) top-down view.

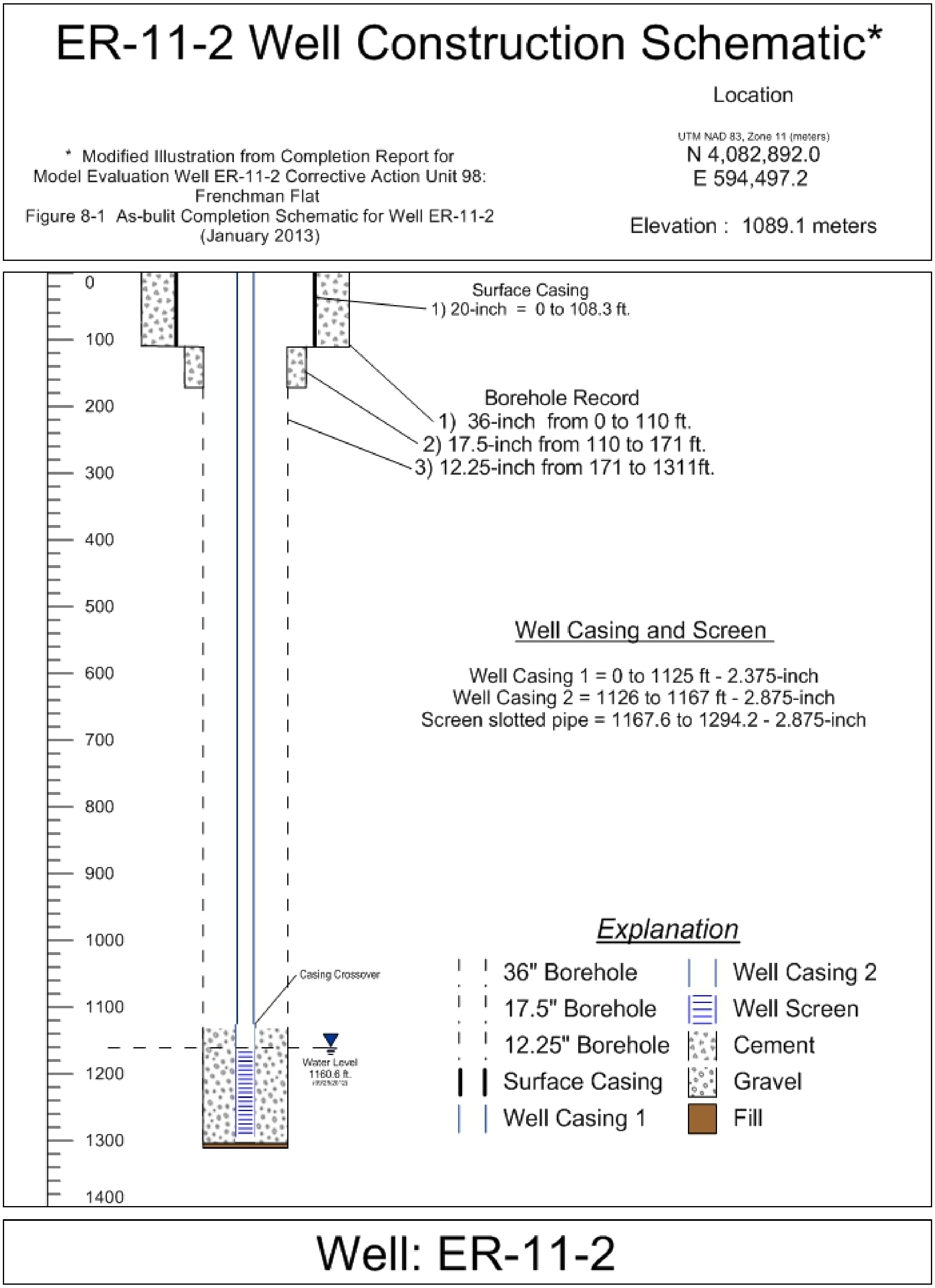

Figure 5. ER-11-2 well completion diagram.

WELL ER-5-3 SHALLOW PIEZOMETER

Integrated Sampling Plan ID: ER-5-3_p2

Type of UGTA groundwater sampling point: Characterization well

Sampling Frequency: 3 years, as needed

Analytes:

- Field parameters (alkalinity, pH, specific conductance)
- Anions (Br, Cl, F, SO_4)
- Total metals (Ag, Al, As, Ba, Ca, Cd, Cr, Fe, K, Li, Mg, Mn, Na, Pb, Se, Si, Sr, U)
- Gross alpha and gross beta
- Gamma emitters (^{26}Al, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)
- ^{3}H (standard or low-level method)
- ^{14}C, ^{36}Cl, ^{99}Tc, ^{90}Sr, ^{129}I, ^{238}Pu, ^{239}Pu, ^{240}Pu

Role in Sampling Plan

The ER-5-3 Shallow Piezometer provides a water table monitoring point near five underground nuclear tests. The UGTA Sampling Plan defines characterization wells as wells for which insufficient baseline data exist. The objective of sampling is to support flow and transport model development and/or evaluation, identify groundwater flow paths, establish the presence or absence of COCs and Contaminants of Potential Concern (COPC), and estimate contaminant travel time. Characterization wells will transition to another type and be sampled according to the new type of groundwater sampling point once the characterization objectives are met and a sufficient baseline (a minimum of three samples) is established to support categorization.

Physical Description of Well

The ER-5-3 Shallow Piezometer wellhead is located on the ER-5-3 well pad (Figure 6). The well pad is located in northern Frenchman Flat and is accessed from Short Pole Line Road (Figure 2). The latitude and longitude for the well location, referencing NAD 83, are 36.87304603º, -115.93884973º. The land surface elevation at the wellhead is 3,335.10 ft, referencing NGVD29. Its USGS Site ID is 365223115561703 and it is also known as ER-5-3_p2 in UGTA databases.

The ER-5-3 Shallow Piezometer is constructed with 2.875-in stainless steel tubing to a total depth of 1,235.1 ft with a screened interval from 949.4 to 1,028.1 ft BLS (Figure 7). The piezometer is screened across the Basalt Lava Flow Aquifer and Older Alluvium Aquifer (BLFA/OAA1). There is no pump in the ER-5-3 Shallow Piezometer and the piezometer has not undergone development.

Additional Completion and Development Information

Well cluster ER-5-3 consists of three wells designed specifically to perform aquifer hydraulic tests as part of the UGTA Activity (Figure 7). Well ER-5-3 was spudded on February 22, 2000. It was at total depth on March 7, 2000, and then construction was completed on March 16, 2000. A conventional rotary drilling technique was used with air-foam and a polymer additive from 45 to 1,250 ft BLS (approximately 300 ft below the water table). First water production was noted at 960 ft BLS.

Tight spots in ER-5-3 were encountered during the installation of the 13.375-in intermediate casing. The driller used water to wash down the casing, which most likely affected the geochemical conditions in the aquifer sampled by the shallow piezometer. Cement was pumped through a sub-in-sub seated in a float shoe at the bottom of the 13.375-in casing. Geophysical logging indicated the top of cement to be 1,048 ft BLS (approximately 20 ft below the bottom of the piezometer screen). Sand and gravel were emplaced via a tremie pipe to 900 ft BLS (approximately 50 ft above the top of the screen). A mix of gypsum cement and neat cement was then emplaced via the tremie from a cement basket from 65 ft BLS to land surface. No well development or pumping was performed immediately after drilling was completed (IT Corporation, 2001). Therefore, the annular space from 900 to 65 ft was left unfilled. The construction water that was used for drilling fluid was supplied from Water Well 5-b and Water Well C-1 and was tagged with lithium bromide (LiBr).

Hydraulic testing was performed in the deep piezometer and at ER-5-3#3, but failed in the ER-5-3 Shallow Piezometer because of an obstruction in the tubing. Alternatively, a 5 gal slug of LiBr-tagged water was poured down the well, which produced a 1.3 ft change in head that returned to the static water level in 25 minutes (Figure 8). Although the shallow piezometer has not been developed, a slug test performed shortly after installation indicates that the piezometer is hydraulically connected to the OAA1 and BLFA zones. Diurnal fluctuations were small and the water level changes were directly proportional to barometric pressure changes. Analysis of the slug-test data produced hydraulic conductivity values ranging from 0.6 to 2.1 m/d as shown in Figures 9 and 10 (note that this slug test was performed only to demonstrate that the screen is open to the formation, the actual hydraulic conductivity may vary) (Stoller-Navarro, 2004).

Chemical Description of the Formation Waters of ER-5-3

Water-chemistry data from the main well are listed in Table 4, but no chemical analyses are available for the ER-5-3 Shallow Piezometer specifically. The upper zone samples are probably most representative of the water accessed by the shallow piezometer. All radionuclide measurements from ER-5-3 shallow zone are below EPA SDWA MCLs (Table 5).

Recommended Sampling Procedures

Sampling Method: The inside diameter of the piezometer is approximately 2.1 in, but an obstruction was found during aquifer testing. A mandrill test should be performed to determine the maximum diameter suitable for sampling the shallow piezometer. Based on the borehole diameter, two sampling methods have been identified: (1) use a discrete bailer to sample from the screened interval of the well (UGTA Sampling Document, 2013) or (2) use a sucker rod (lift jack) pump.

Sampling Depth: Based on the monitoring objectives and available hydraulic data, it is recommended that the sample be collected near the top of the screened interval at a depth of 955 ft BLS. It has been observed during hydrophysical logging in numerous piezometers that the highest flow rates occur near the top of the piezometer's screened intervals. In piezometers that have been poorly developed, it is hypothesized that gravity causes solids to settle downward, thereby reducing the permeability in lower sections of the screened interval.

No hydrophysical logging was performed near the water table in this well to indicate flow in the well. However, vertical head differences show no gradient between the upper zone of the main well and the shallow piezometer, and they show only a very slight downward gradient between the shallow piezometer and the deep piezometer.

Purging recommendations: For the discrete bailer technique, purging and field measurement stabilization are impractical. It is recommended that hydrologic logging be conducted prior to bailer sampling to identify suitable "self-purging" sampling intervals. If a sucker-rod pump is used, a minimum of three well volumes (total of 1130 gal) must be removed and field parameters stabilized prior to sampling (DOE, 2014b). The well volume estimate was computed in a spreadsheet and a summary of the calculation is listed in Table 6.

Field measurement and stability indicators: Although no water chemistry measurements are available from the shallow piezometer, the water chemistry should be similar to the upper zone in the main well as shown in Table 4. Field measurements of pH and electrical conductance (EC) should be compared with the upper zone values listed in Table 4 and monitored over time to determine when they have stabilized per the procedures listed in the UGTA Sampling Plan (DOE, 2014b). The pH in the upper zone (9.6 standard units) is elevated compared to water from similar units, which probably reflects contact with the cement. Given the lack of development, it is strongly recommended that a sample be collected for LiBr analysis to quantify the amount of residual drilling fluid that may still be contaminating the groundwater sample.

References for ER-5-3 Shallow Piezometer

Bechtel Nevada, 2005. Completion Report for Well Cluster ER-5-3. U.S. DOE, Nevada Site Office, DOE/NV/11718-1093.

IT Corp., 2001. Frenchman Flat Well Cluster ER-5-3 Data Report for Development and Hydraulic Testing. Preliminary report prepared under contract DE-AC08-97NV13052.

Stoller-Navarro, 2004. Interpretation of Hydraulic Test and Multiple-Well Aquifer Test Data at Frenchman Flat Well Cluster ER-5-3. U.S. DOE, Nevada Site Office, S-N/99205-028.

U.S. Department of Energy (DOE), 2014a. Underground Test Area Geochemistry Database. https://ugta.nv.doe.gov/sites/Geochemistry%20Database/DataPages/Geochem.aspx accessed June 4, 2014. Not available for public access.

U.S. Department of Energy (DOE), 2014b. Nevada National Security Site Integrated Groundwater Sampling Plan. National Nuclear Security Administration, Nevada Field Office, DOE/NV-1525.

Table 4. ER-5-3 chemical data. All units are mg/L unless otherwise noted. The upper zone is thought to be most representative of the composition of water in the shallow piezometer (from DOE, 2014a).

Zone	Date	pH (standard units)	Specific Conductance (µmhos/cm)	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3
Upper	7/17/2001	9.60	590	1.11	0.089	130	5.2	14	36	60	134
Lower	3/29/2001	8.80	270	13	3.4	60	4.6	15	41	6.0	183
Lower	3/28/2001	8.25	445	14.3	3.9	78.9	4	15.5	40		
Lower	3/16/2001	8.40	330	13	3.1	61	4.9	15	41	13.2	146
Composite	3/12/2000	8.00	424					12	30	15	219

Table 5. ER-5-3 upper zone radiochemical data (from DOE, 2014a).

Zone	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/l)	Tritium (pCi/l)	C-14 (pCi/L)	Cl-36 (pCi/l)	Tc-99 (pCi/L)	I-129 (pCi/L)
Upper	7/17/2001	3.3	4.6	<280	<460	NA	<4.8	<5

"NA" indicates the parameter was not analyzed.

Table 6. ER-5-3 shallow piezometer well volume calculations. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1235.1	bottom of well (ft)
18.5	borehole diameter (in)
928	depth to water (ft)
2.875	casing OD (in)
2.4	casing ID (in)
927	top of gravel (ft)
1080	bottom of gravel (ft)
0.3	gravel porosity
273.1962	casing volume (L)
72.27411	casing volume (gal)
928	effective top of gravel (ft)
8034.509	total borehole volume (L)
1150.486	gravel vol less interference (L)
1423.682	casing plus net gravel water volume (L)
376.6354	casing plus net gravel water volume (gal)
1130	three well volumes (gal)

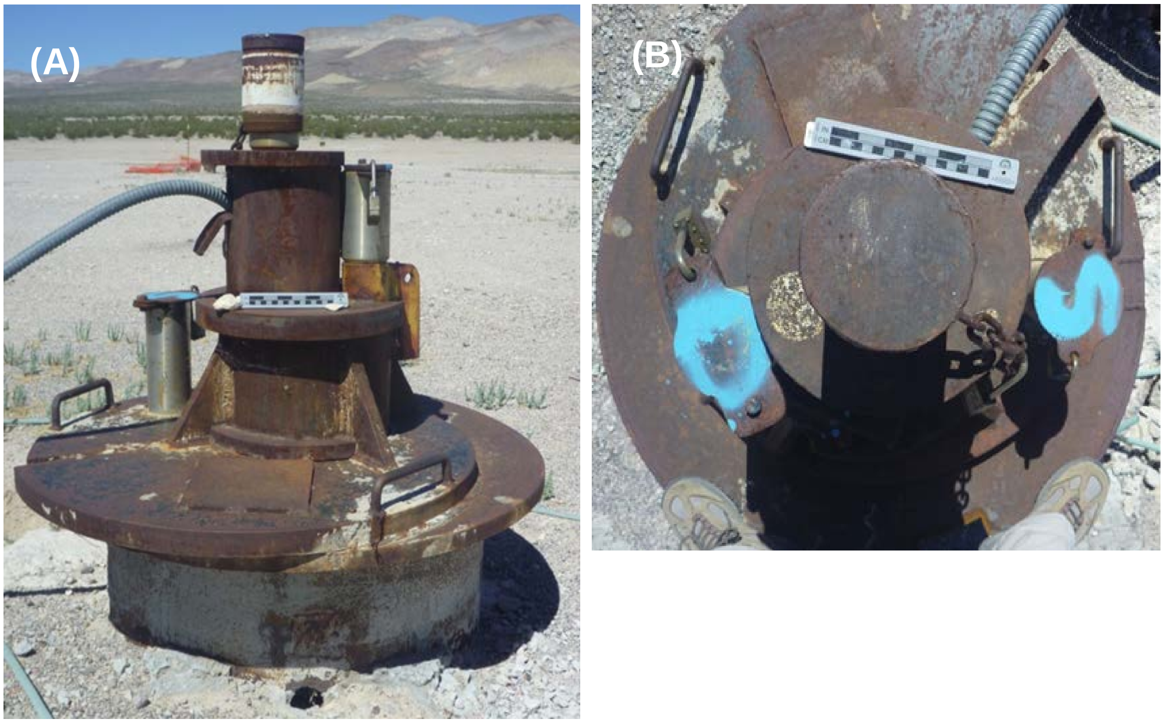

Figure 6. Photo of ER-5-3 wellhead configuration: (a) view to the north with the shallow piezometer tube on the left and (b) top-down view facing south with the shallow piezometer on the right.

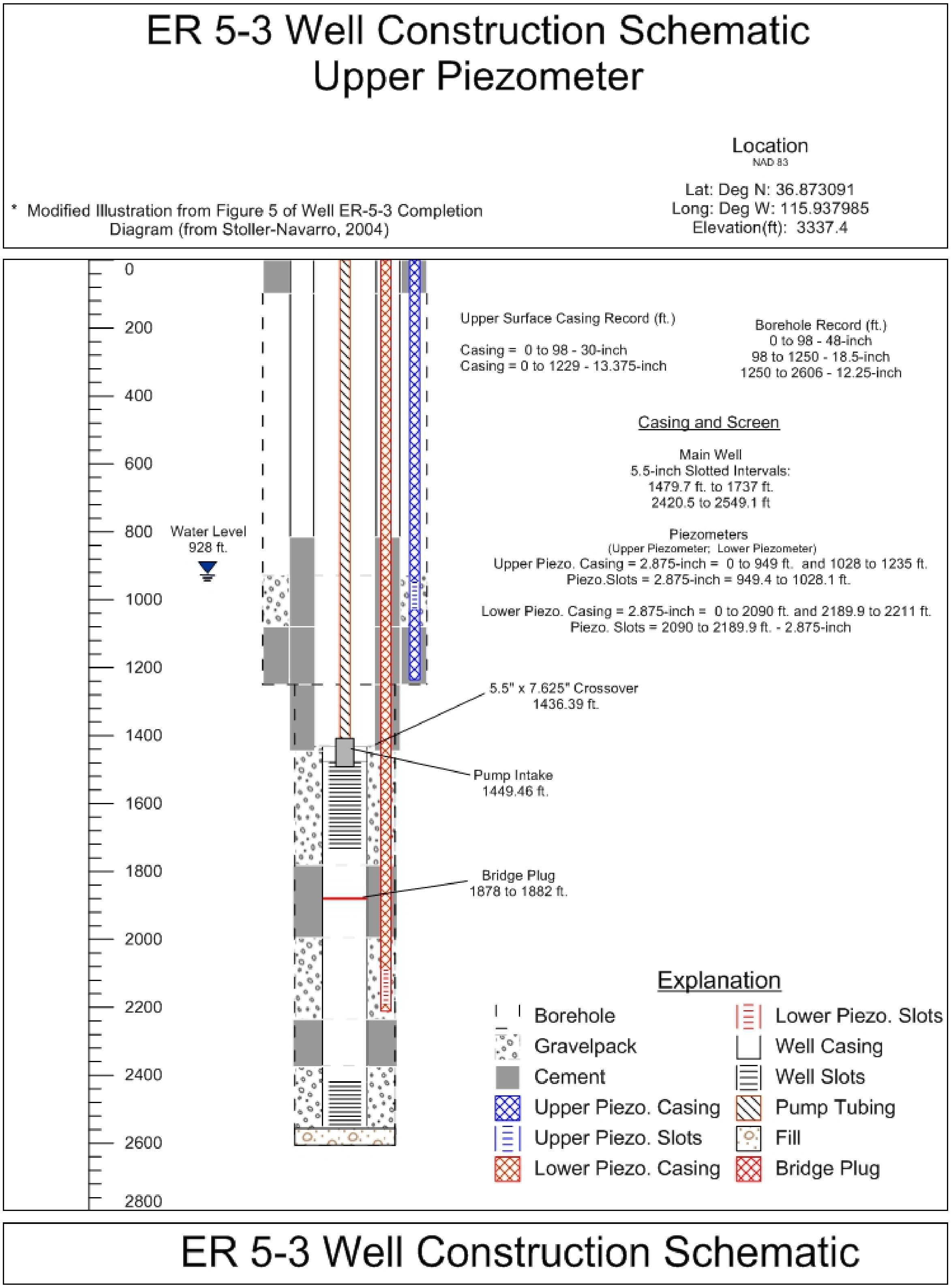

Figure 7. ER-5-3 well completion diagram.

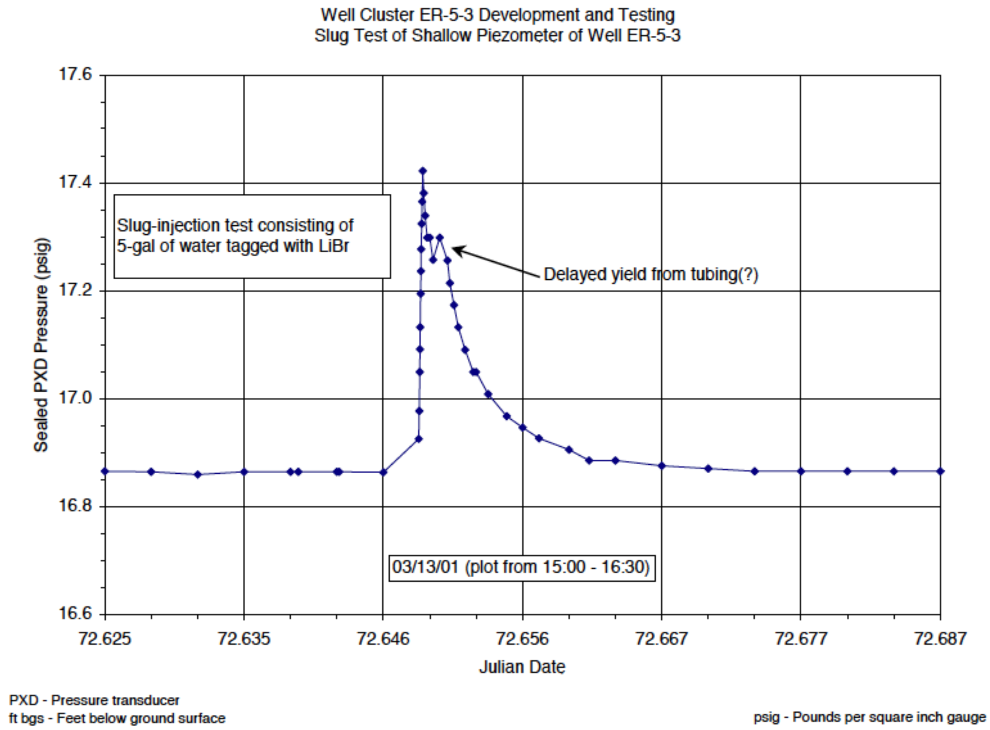

Figure 8. Slug-test response in the shallow piezometer of ER-5-3 (Stoller-Navarro, 2004). Julian Date refers to the day of the year.

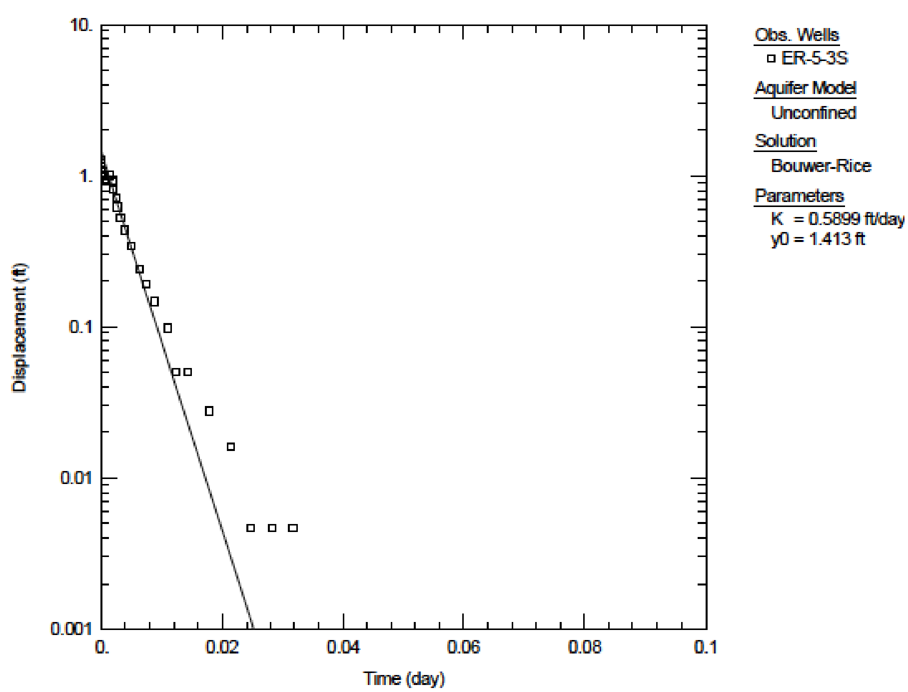

Figure 9. Fit of the Bouwer and Rice solution to the slug test in the ER-5-3 Shallow Piezometer (Stoller-Navarro, 2004).

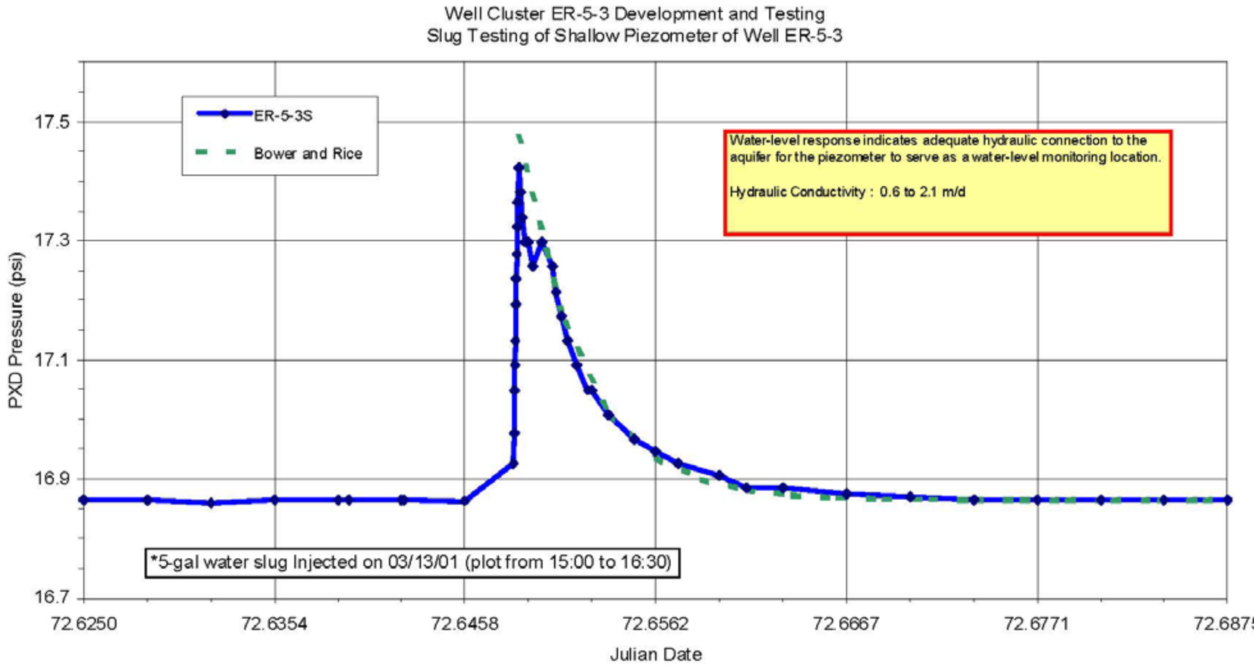

Figure 10. Hydraulic test model results for the ER-5-3 Shallow Piezometer slug test. Julian Date refers to the day of the year. Stoller-Navarro (2004).

WELL ER-5-3#2

Integrated Sampling Plan ID: ER-5-3-2_m1

Type of UGTA Groundwater Sampling Point: Characterization well

Sampling Frequency: 3 years, as needed

Analytes:

- Field parameters (alkalinity, pH, specific conductance)
- Anions (Br, Cl, F, SO_4)
- Total metals (Ag, Al, As, Ba, Ca, Cd, Cr, Fe, K, Li, Mg, Mn, Na, Pb, Se, Si, Sr, U)
- Gross alpha and gross beta
- Gamma emitters (^{26}Al, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)
- ^{3}H (standard or low-level method)
- ^{14}C, ^{36}Cl, ^{99}Tc, ^{90}Sr, ^{129}I, ^{238}Pu, ^{239}Pu, ^{240}Pu

Role in Sampling Plan

Well ER-5-3#2 has two roles in the UGTA sampling plan. For Frenchman Flat, it is a characterization well and for Yucca Flat, it is a distal sampling well. Well ER-5-3#2 provides groundwater samples from the Lower Carbonate Aquifer. Within Frenchman Flat, contaminants from underground testing are forecast to remain in the alluvium and volcanic units overlying the carbonate aquifer. Data from ER-5-3#2 will support flow and transport model evaluation in Frenchman Flat, including identification of groundwater flow paths and contaminant travel times, and also establish the presence or absence of COCs and COPCs. According to the NNSS Integrated Sampling Plan, characterization wells will transition to another sampling type when a sufficient baseline (a minimum of three samples) is established to support categorization. With radionuclide transport out of Yucca Flat only possible through the Lower Carbonate Aquifer, ER-5-3#2 is considered a distal sampling point along the transport path from that CAU.

Physical Description of Well

Well ER-5-3#2 is on the ER-5-3 well pad (Figures 11 and 12). The pad is located in northern Frenchman Flat and is accessed from Short Pole Line Road (Figure 2). The latitude and longitude of the well, referencing NAD 83, is 36.87307103°, -115.93919140°. The land surface elevation is 3335.17 ft (referenced to NGVD29). The USGS Site ID for ER-5-3#2 is 365223115561801.

Well ER-5-3#2 is open to the Lower Carbonate Aquifer from 4,674 to 5,683 ft BLS. The lower portion of this (4,908 to 5,683 ft) is open hole below the constructed well tubing (Figure 13). The borehole was drilled in 2000 to characterize the geology and hydrogeology through the Lower Carbonate Aquifer. A 12 1/4-in hole was drilled to 5,683 ft BLS. From the land surface to 2,474.7 ft is 7 5/8-in blank carbon-steel casing with internal epoxy coating. Between 2,474.7 to 2,476.8 ft, a cross-over sub connects the 7 5/8-in casing to 5 ½-in stainless steel production casing that terminates at 4,908.2 ft. The blank casing extends from the land surface to 4,563.3 ft BLS; the casing was slotted from 4,563.3 to 4,680.0 ft, although this interval is now sealed with cement to block access to the Tertiary rocks. Slotted casing currently exists from 4,680.0 to 4,906.1 ft BLS (Figure 13). The slot openings are 0.078 in wide by 3 in long and cut in rings of 18 slots spaced 20 degrees apart around the joint and the rings are spaced 6 in apart. There is no sand or gravel pack in the well, though the open hole from the Tertiary Tuff-Lower Carbonate Aquifer contact at 4,678 ft to total depth contains fill.

Hydrophysical logging performed by DRI on May 10, 2001, indicated slight downward flow. The Chemistry Log shows a uniform temperature gradient from 4,500 to 4,870 ft, indicative of little or no vertical flow, and a steep gradient from 4,870 to 4,899 ft, indicative of downward flow (Figure 14). The Chemistry Log also shows a pH bulge at 4,625 ft, indicative of cement contamination, and more neutral pH near the bottom of the well, indicative of water that is more consistent with formation water (Figure 15). The Thermal Flow Meter log indicated no flow from 4,500 to 4,750 ft and 1.8 gallons per minute of downward flow at 4,890 ft deep (Table 7). The total depth measured during this logging was 4,899 ft.

The measuring point for water levels is 3.72 ft above land surface and was set on May 18, 2001. The last water level measurement was made on November 21, 2015, and was 941.20 ft below the measuring point. A time history of water levels is presented in Figure 16. Based on a constant rate aquifer test run with a high-capacity pump, the hydraulic conductivity of the carbonate rocks is 4.8×10^{-4} m/day.

A dedicated low-capacity sampling pump was installed in 2001 and maintained a production rate of 39 gpm. The pump is landed at 2,503.26 ft BLS, with the intake at 2,483.3 ft BLS.

Chemical Description of Well

Water chemistry data are available from field monitoring and from groundwater samples collected in conjunction with aquifer testing. Data regarding field parameters are available for several time frames and methods of collection (grab samples during development, in-line samples, hydrochemical logging) (Table 8). Field pH values tend to range from 6.75 to 7.0. Electrical conductivity is measured between 1,150 and 1,200 µS/cm. Dissolved oxygen in grab samples had a large range of 0.2 to 1.85 mg/L, whereas the in-line data varied from 0.65 to 0.75 mg/L. Inline measurements of turbidity were about 11.5 NTU. Bromide was used as a drilling fluid tag and was present at concentrations below 0.2 mg/L in the characterization samples. Water temperature ranges from 33.8 to 44.2 ºC in grab samples. It was 46 ºC from inline measurements during the constant rate pumping test, coincident with chemical logging results that found temperature to increase from 44.3 to 46 ºC with depth.

Comprehensive chemical analyses were performed on samples collected by discrete bailer and composite samples collected with the dedicated sampling pump (Table 9).

Radionuclide measurements other than gross alpha are below the U.S. EPA Safe Drinking Water Act MCLs or in the case of gross beta, below the Level of Concern (Table 10). Though gross alpha slightly exceeds the 15 pCi/l MCL, the MCL is exclusive of uranium, which has not been factored out of the gross alpha value.

A change in the character of the water is evident with depth and with production, most notably in terms of temperature, but also pH. Higher temperature, approximately 46 ºC, is measured at the bottom of the well and after development, whereas cooler temperatures have been measured at the onset of pumping and higher in the well. The presence of residual cement contamination may be the primary reason that high pH values are observed in the hydrochemical logging between depths of 4,600 and 4,700 ft and decrease with depth.

Recommended Sampling Procedures

Sampling Method: Well ER-5-3#2 has a permanently installed electric submersible pump that can be used for sampling. If the pump must be removed in the future, the well could be a good candidate for bailing. The flow within the screened interval identified by hydrophysical logging effectively creates a self-purging zone in the lower screen.

Sampling Depth: The borehole and well configuration provide flow to the well from the depth interval of 4,674 to 5,683 ft BLS. Stressed flow logging found that all of the flow in the well originates in the lower half of the slotted casing, regardless of production rate.

Impacts to the chemistry from cement have been noted in the pH log (values in excess of 10.5 S.U.) in the depth range of 4,580 to 4,660 ft. These effects noticeably diminish below 4,710 ft BLS.

Purging Recommendations: Pump until three well volumes are removed (18,552 gallons as described below), continue pumping, and check field parameters as described below. Pump a maximum of five well volumes. If field parameters have still not stabilized, it is to the discretion of the project lead(s) to determine if the well is sufficiently purged.

A wellbore volume of 6,184 gallons was computed in a spreadsheet (Table 11) and includes the water volume in the 7.5-in pump chamber, the 5.5-in casing, and the gravel pack/fill at the screen (assuming 0.1 porosity for the fill from the top of the screen to the bottom of the borehole). The purge recommendation of three well volumes would therefore equal 18,552 gallons.

If the pump is removed, a discrete bailed sample from the lower section of screen can be collected with no purging as a result of the active flow in that zone.

Field Measurement and Stability Indicators: Temperature is the most sensitive stability indicator in ER-5-3#2. Water temperature should be 46 ºC from the discharge line, though it can be expected to be initially lower until sufficient purging has occurred. Temperature is sensitive to ambient conditions, so it must be measured as quickly and as close to the discharge port as possible. The pH should be close to 7.0 and electrical conductivity near 1,100 µS/cm.

References for ER-5-3#2

IT Corp., 2001. Frenchman Flat Well Cluster ER-5-3 Data Report for Development and Hydraulic Testing. Preliminary report prepared under contract DE-AC08-97NV13052.

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

Table 7. Thermal flow-meter logging results in ER-5-3#2, performed by DRI May 10, 2001.

DEPTH (FT)	DIAMETER (IN)	FLOW RATE (GPM)	FLOW DIRECTION	FLAG
4500	5	No Flow		*
4650	5	No Flow		*
4750	5	No Flow		*
4850	5	0.345±0.068	Downward	
4890	5	1.849±0.193	Downward	

* - Logging sensor response below detection limit.

Table 8. ER-5-3#2 field parameters as reported in IT (2001).

Sample Type	Date	pH (standard units)	Specific Conductance (μS/cm @ 25 °C)	Water Temp. (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Br (mg/L)
Grab	4/18/2001 Time of discrete sampling	6.70	1187	42.8	0.56	6.12	0.594
Grab	5/01/2001 End of high-rate test	6.83	1189	43.4	0.52	5.03	0.36
In-line	April-May 2001	7.0	1050	46	0.65-0.75	11.5	
Chem-Tool	5-10-2001		1200	46			

Table 9. ER-5-3#2 chemical data from groundwater characterization samples (IT, 2001). All units are mg/L unless otherwise noted.

Type	Date	pH (standard units)	Specific Conductance (μmhos/cm)	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	Si	Br
Discrete Bailed	4/18/2001	7.1	1100	78	28	110	17	38	72		530	13	0.19
Pumped composite	5/17/2001	7.3	1100	77	29	130	17	39	69		520	14	0.15

Table 10. ER-5-3#2 radiochemical data from IT (2001) and the UGTA Geochemical Database.

Type	**Date**	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/l)**	**Tritium (pCi/l)**	**C-14 (pCi/L)**	**Cl-36 (pCi/l)**	**Tc-99 (pCi/L)**	**I-129 (pCi/L)**
Discrete Bailed	4/18/2001	16.3	19.3	<280	<350	NA	NA	NA
Pumped	5/17/2001	15.5	13.4	<1.5	<460	0.00029	<3.5	8.6*

* Estimated value. Another analysis is <1.3 pCi/L.
"NA" indicates the parameter was not analyzed.

Table 11. ER-5-3#2 well volume calculations. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
4908.2	bottom of well (ft)
12.25	borehole diameter (in)
937.48	depth to water (ft)
5.5	casing OD (in)
5	casing ID (in)
4674	top of gravel (ft)
5683	bottom of gravel (ft)
0.1	gravel porosity
21037.14	casing volume (L)
5565.38	casing volume (gal)
4674	effective top of gravel (ft)
23384.91	total borehole volume (L)
2338.491	gravel vol less interference (L)
23375.63	casing plus net gravel water volume (L)
6184.028	casing plus net gravel water volume (gal)
18552	three well volumes (gal)
4680	top of screen (ft)
4906.1	bottom of screen (ft)
873	screen volume (L)
230.95	screen volume (gallons)
3211.49	screen plus net gravel water volume (L)
849.6	screen plus net gravel water volume (gal)

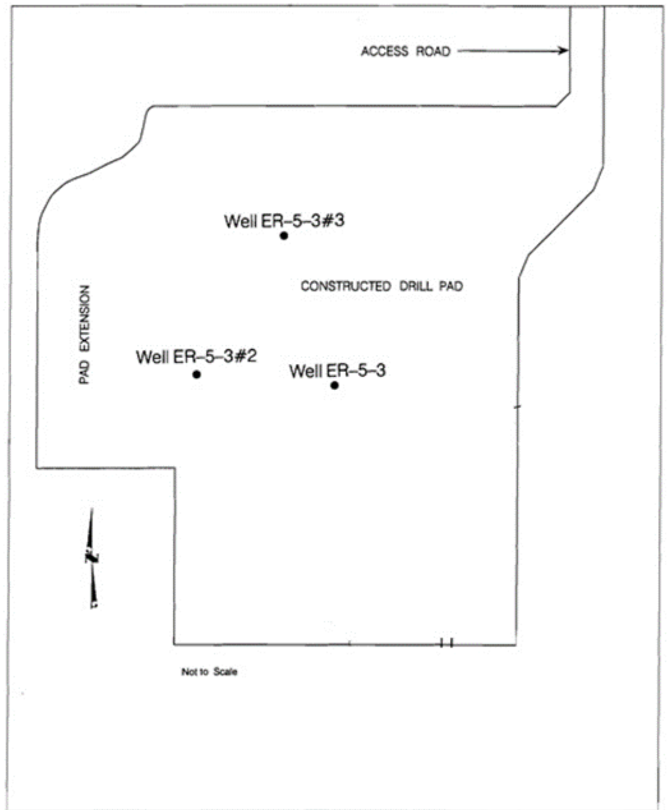

Figure 11. Location of Well ER-5-3#2 in relation to the other two wells on the same pad.

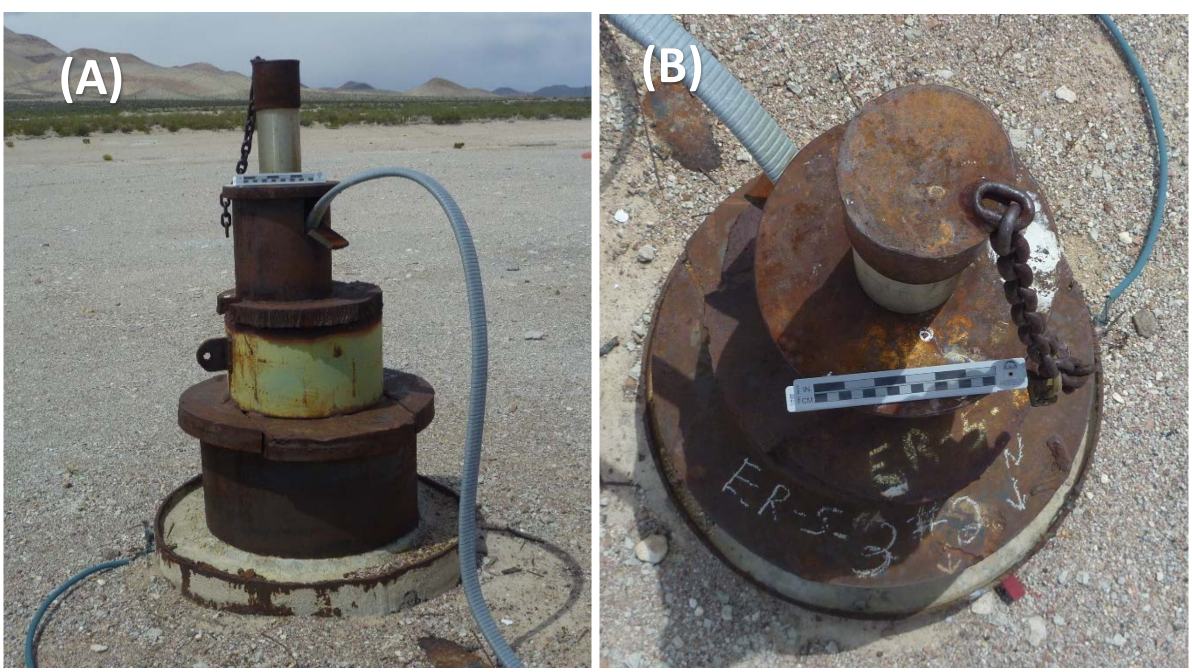

Figure 12. Photo of ER-5-3#2 wellhead configuration: (a) view to the north and (b) top-down view.

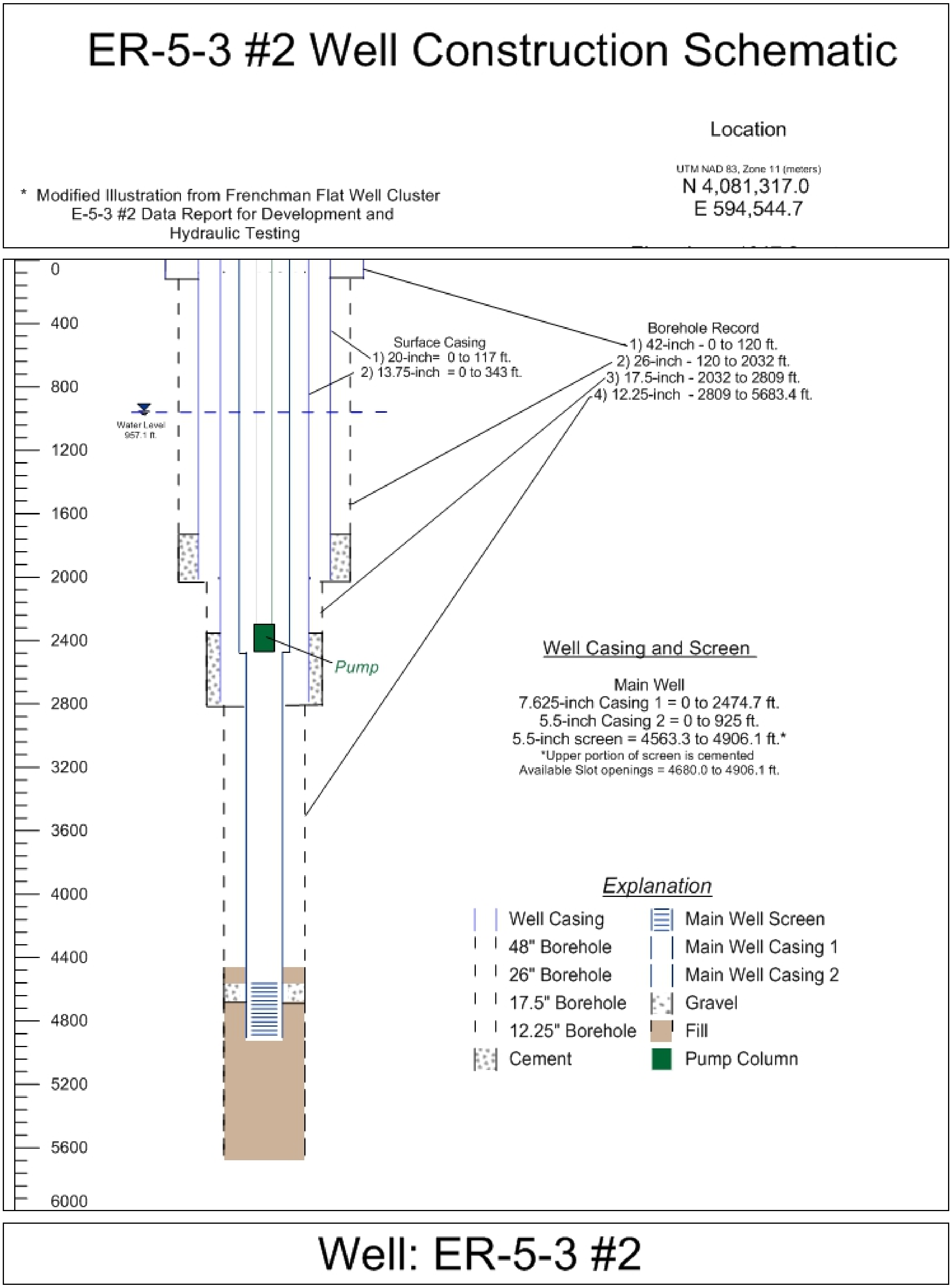

Figure 13. Well ER-5-3#2 well completion diagram.

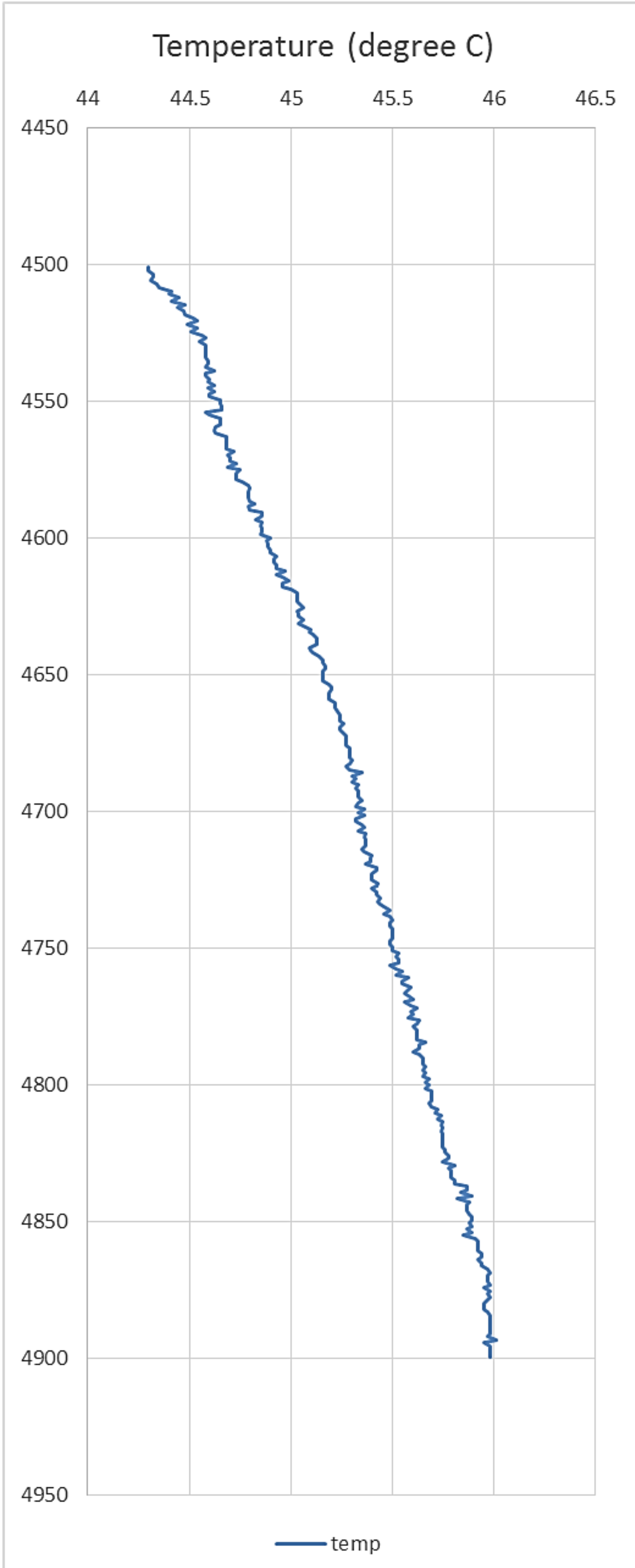

Figure 14. ER-5-3#2 Temperature log performed by DRI on May 10, 2001

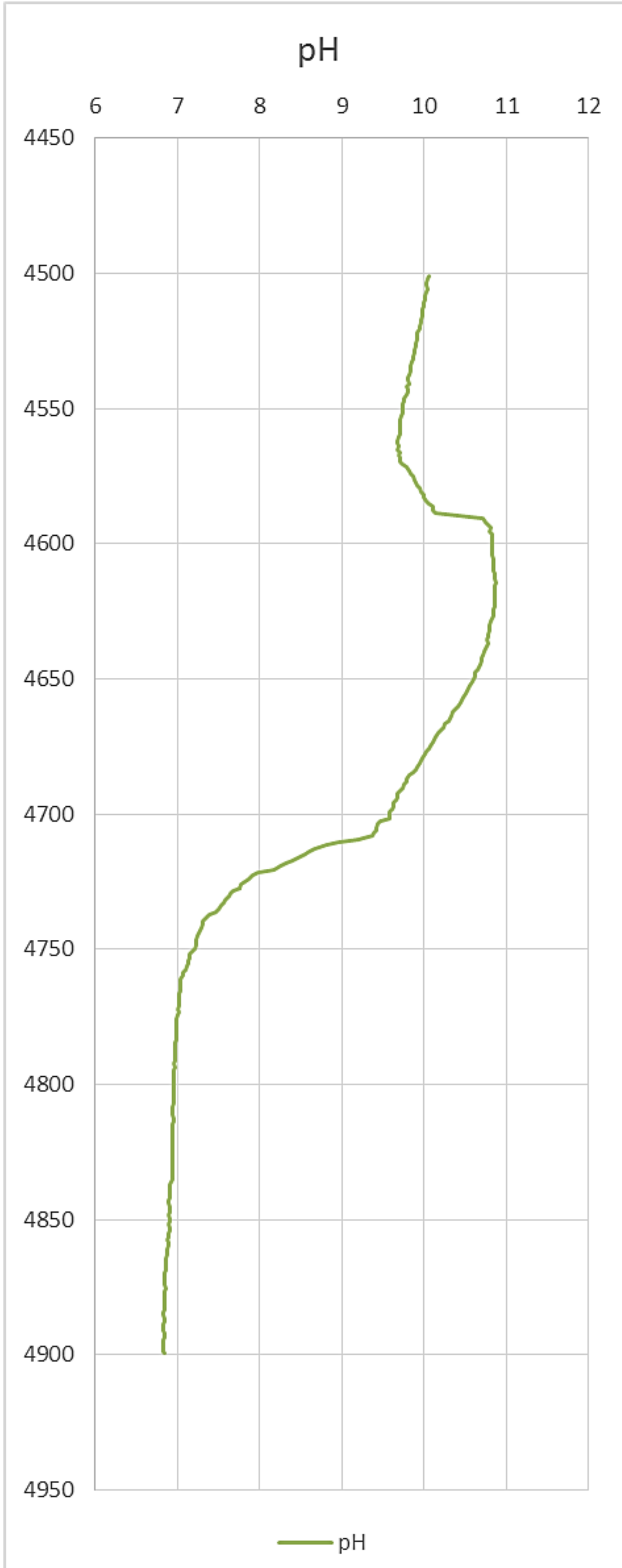

Figure 15. ER-5-3#2 pH log performed by DRI on May 10, 2001

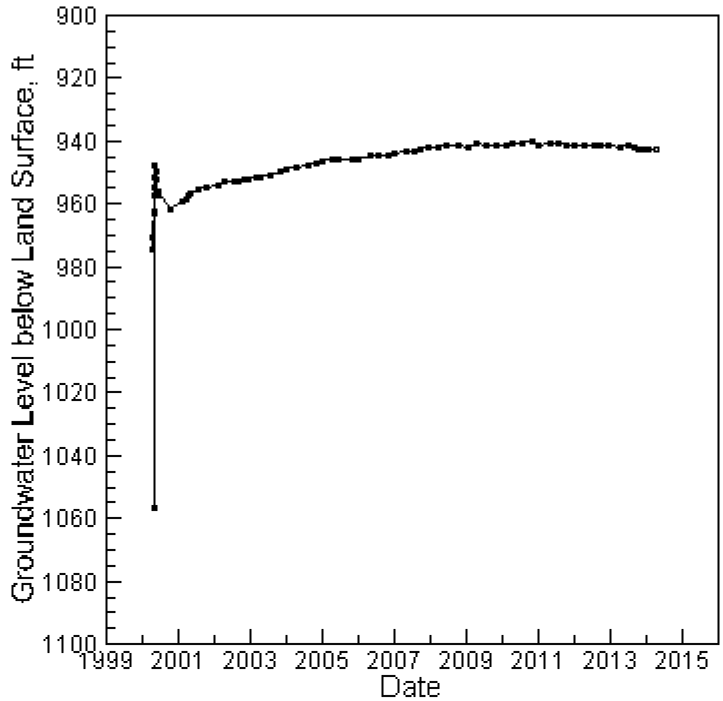

Figure 16. Water level depth below ground surface from 2000 to 2013.

WELL ER-5-5

Integrated Sampling Plan ID: ER-5-5_m1

Type of UGTA groundwater sampling point: Characterization well

Sampling Frequency: 3 years, as needed

Analytes:

- Alkalinity, pH, specific conductance
- Anions (Br, Cl, F, SO_4)
- Total metals (Ag, Al, As, Ba, Ca, Cd, Cr, Fe, K, Li, Mg, Mn, Na, Pb, Se, Si, Sr, U)
- Gross alpha and gross beta
- Gamma emitters (^{26}Al, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)
- ^{3}H (using standard and/or low-level methods)
- ^{14}C, ^{36}Cl, ^{99}Tc, ^{90}Sr, ^{129}I, ^{238}Pu, ^{239}Pu, ^{240}Pu

Role in Sampling Plan

Well ER-5-5 was drilled as a model evaluation well for Frenchman Flat. The well was initially sampled to support flow and transport model evaluation and to establish COC and COPC presence or absence. According to the NNSS Integrated Sampling Plan, characterization wells will transition to another sampling type when a sufficient baseline (a minimum of three samples) is established to support categorization.

Physical Description of Well

Well ER-5-5 is located approximately 650 ft to the south-southeast of the Milk Shake underground nuclear test site in northern Frenchman Flat (Figure 2). The well is northeast of the Radioactive Waste Management Site on generally flat lying terrain (Figure 17). It is accessed from Short Pole Line Road (Figure 1). The latitude and longitude for the well location, referencing NAD 83, are 36.87005171°, -115.93115226°. The land surface elevation is 3,337.27 ft (referenced to NGVD29). The USGS Site ID for ER-5-5 is 365212115554901.

The total depth of the borehole was 1,087.52 ft when drilled in 2012 (Figure 18). The borehole encountered alluvium from land surface to a depth of 580 ft, older alluvium (distinguishable by a low-grade zeolitic alteration) from 580 to 954 ft BLS, a thin zone with basalt rubble from 954 to 976 ft BLS, and then older alluvium from 976 ft to total depth. A well and piezometer were constructed in the borehole with a single-screen interval that targeted the basalt-clast zone but also included portions of the older alluvium above and below the basalt clasts. The well is constructed with 7.625-in carbon steel pipe down to 911.80 ft BLS where it crosses over to a screen section with 0.25 slots. The well screen is between 912.68 and 1,038.30 ft BLS. The piezometer is constructed with 2.375-in tubing to 924.38 ft BLS, and then it crosses over to a 2.875-in screen. The piezometer is screened between 925.23 and 1,044.94 ft BLS. The bottoms of both the well and the piezometer are completed with bullnoses. The slots in the screen interval in the main well are variously reported as 0.08-in wide by 3.00-in long and 0.0625-in wide by 2.75-in long (Navarro-Intera, 2012; DOE, 2013). The annular space is filled with 0.375-in gravel from total depth to 80 ft above the water table.

The water level measured in the well on April 15, 2013, was 929.81 ft BLS (an elevation of 2,407.46 ft relative to mean sea level [MSL]). That same day, the water level in the piezometer was 929.60 ft BLS (elevation of 2,407.67 ft MSL). Well ER-5-5 has an electric submersible pump installed at a depth of 1,025.02 ft, with the intake at 1,007.83 ft. A flow rate of about 30 gpm is reported from function tests on the pump at the time of installation (Navarro-Intera, 2013). Transmissivity estimates range from 25 to 47 m^2/d.

Chemical Description of the Formation Waters of ER-5-5

Water-chemistry data are available from field monitoring (Table 12) and groundwater samples collected in conjunction with aquifer testing in the well (Table 13). Data regarding field parameters are available for several time frames and sources (Table 12). The groundwater temperature in the well is close to 25 °C. The pH ranged from 7.1 to 8.9 and the EC ranged from 375 to 472 µmho/cm at 25 °C in the later samples. Dissolved oxygen ranged from 4 to 7 mg/L. By the end of development and testing, turbidity approached zero and Br concentrations were approximately 0.4 mg/L.

All radionuclide measurements are below the U.S. EPA Safe Drinking Water Act maximum contaminant levels (MCL) or in the case of gross beta, below the Level of Concern (Table 14). A low-level ^{3}H analysis of 1.1 ± 0.4 pCi/L suggests that the leading edge of a radionuclide plume from the nearby Milk Shake test (Navarro-Intera, 2014) has reached ER-5-5. This interpretation is supported by elevated levels of the nonradiogenic ^{3}He, which is a decay product of tritium.

Recommended Sampling Procedures

Sampling Method: Previously installed submersible pump.

Sampling Depth: The pump is located at a depth of 1,025 ft. It is assumed that water enters from the entire saturated section because the screen is gravel packed from the bottom of the hole to above the water table. This includes the Alluvial Aquifer (AA), OAA, and the thin BLFA embedded within the OAA.

Purging recommendations: Three well volumes (total of 894 gal) should be pumped from the well prior to sample collection or more if needed for the field parameters to stabilize (DOE, 2014). Well volume calculations were performed in a spreadsheet and included fluid in the casing, fluid in the gravel pack, and the interference volume caused by the co-located piezometer (Table 15).

Field measurement and stability indicators: General targets for field parameters are a temperature of 25 °C, a pH of 8, an EC of 400 µmho/cm at 25 °C, a dissolved oxygen content of 6 mg/L, and a Br level of less than 1 mg/L. The range of values in Table 12 can be referred to as a guide for possible variability.

References for ER-5-5

Note: Incomplete report numbers (e.g., “XXX”) indicate an unpublished, internal UGTA document.

National Security Technologies, LLC, 2013. Completion Report for Model Evaluation Well ER-5-5, Corrective Action Unit 98: Frenchman Flat. U.S. Department of Energy, Nevada Site Office report DOE/NV-1496.

Navarro-Intera, 2012. Frenchman Flat Model Evaluation Well ER-5-5 Data Package. N-I/28091-XXX.

Navarro-Intera, 2013. Frenchman Flat Model Evaluation Well ER-5-5 Well Development, Testing, and Sampling Data Report. N-I/28091-XXX.

Navarro-Intera, 2014. Model Evaluation Report for Corrective Action Unit 98: Frenchman Flat, Nevada National Security Site, Nye County, Nevada. Report prepared for the U.S. Department of Energy, N-1/28091-088.

U.S. Department of Energy (DOE), 2013. Completion Report for Model Evaluation Well ER-5-5. Nevada Site Office report DOE/NV—1496. U.S. Department of Energy (DOE), 2014. Nevada National Security Site Integrated Groundwater Sampling Plan. National Nuclear Security Administration, Nevada Field Office, DOE/NV-1525.

Table 12. ER-5-5 field parameters as reported in Navarro-Intera (2013).

Sample Type	Date	pH (standard units)	Specific Conductance (μS/cm @ 25 °C)	Water Temp. (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Br (mg/L)
Grab	Step Drawdown Test	7.17-8.40	339-457		3.91-7.05	0.0-11.6	0.12-1.21
In-line	Step Drawdown Test	8.22-8.35	391-446		3.88-6.79	7.0-20.0	
I-CHEM log	5-03-2013	8.10-8.94	272-425	24.03-24.95	1.35-2.70		
Depth Discrete Bailed	5-03-2013	8.4	390				0.13
Grab	Constant Rate Test	7.11-8.30	375-459		3.72-8.44	0.0-13.3	0.09-0.76
In-line	Constant Rate Test	8.09-8.44	379-395		1.30-6.25	5.1-36.6	
Final Grab	5-16-2013	7.91	437	25.8	6.82	3.5	
Ambient logging	8-28-2013	7.44-8.43	419-472	24.72-24.98			

Table 13. ER-5-5 chemical data from groundwater characterization sample (Navarro-Intera, 2013). All units are mg/L unless otherwise noted.

Ref.	Date	pH (standard units)	Specific Conductance (μS/cm)	Ca	Mg	Na	K	Cl	SO_4	HCO_3	Br
N-I, 2013	5/16/2013	8.50	470	7.1	3.3	74	7.1	16	41	140	0.13

Table 14. ER-5-5 radiochemical data.

Ref.	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/l)	Tritium (pCi/l)	C-14 (pCi/L)	Cl-36 (pCi/l)	Tc-99 (pCi/L)	I-129 (pCi/L)
N-I, 2013	5/16/2013	8.2	7.8					
N-I, 2014				1.1	0.1413	3.37E-04	<0.00086	2.5E-06

Table 15. ER-5-5 well volume calculations. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1040.55	bottom of well (ft)
12.25	borehole diameter (in)
929	depth to water (ft)
6.625	casing OD (in)
6	casing ID (in)
850	top of gravel (ft)
1040.55	bottom of gravel (ft)
0.3	gravel porosity
620.2	casing volume (L)
164.1	casing volume (gal)
929	effective top of gravel (ft)
2585.3	total borehole volume (L)
506	gravel vol less interference (L)
1126.2	casing plus net gravel water volume (L)
297.9	casing plus net gravel water volume (gal)
894	three well volumes (gal)

Figure 17. Photo of ER-5-5 wellhead configuration: (a) view to the north and (b) top-down view.

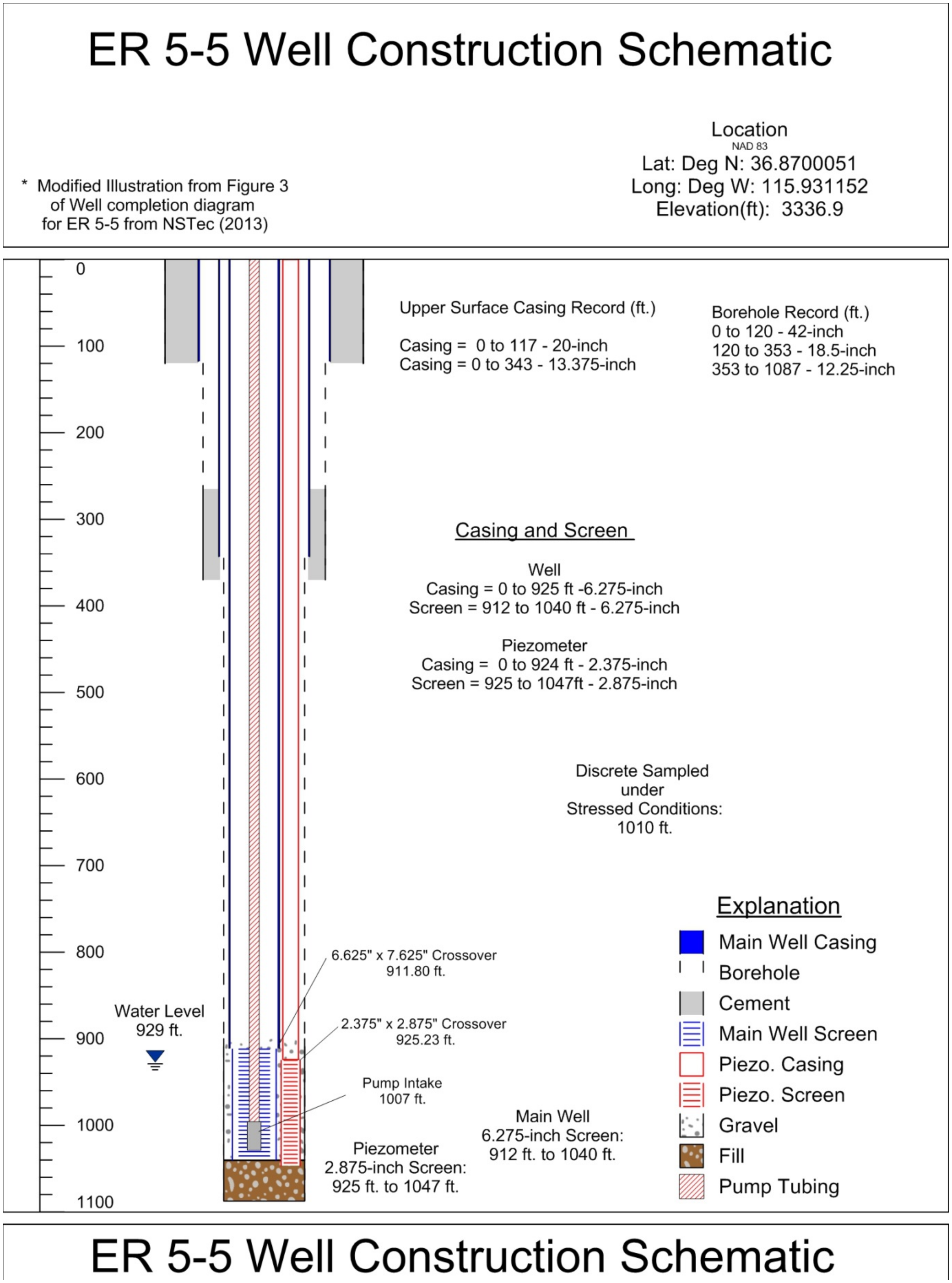

Figure 18. ER-5-5 well completion diagram.

WELL RNM-1

Integrated Sampling Plan ID: RNM-1_m5

Type of UGTA groundwater sampling point: Source/plume well

Sampling Frequency: 4 years

Analytes: ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I

Role in Sampling Plan

The objective of sampling RNM-1, a source/plume well, is to provide a long-term dataset to monitor contaminant migration and natural attenuation. Information from the well also identifies COCs and supports evaluation of transport models. Source/plume wells have detectable radionuclides that have been verified to originate from NNSS underground nuclear testing.

Physical Description of Well

Well RNM-1 is located northwest of Frenchman Lake in Frenchman Flat (Figure 19). The wellhead is accessed from the Road 5-07 off of Mercury Highway. The latitude and longitude for the well location are 36.82445416°, -115.96768903° in reference to NAD83. The land surface elevation of the well is 3,135.17 ft, referenced to NGVD29. Its USGS Site ID is 364928115580101 (USGS, 2014). Well RNM-1 was constructed in a slant hole (average deviation is 21° S) that penetrates the Cambric nuclear test cavity and is open below the water table to approximately 210 ft of alluvium.

Well RNM-1 was originally named U-5e PS #1A when it was drilled in 1965 (NTS, 1990). Well U-5e PS #1A was drilled to a depth of 1,228 ft with a borehole diameter of 9.875 in. The surface casing was completed to 112 ft BLS with the remaining left as open borehole (NTS, 1990). In 1974, U-5e PS #1A was recompleted and renamed RNM-1. Although it is not stated in any available records, it appears that U-5e PS #1A was deepened in 1974 to 1,260 ft BLS with a borehole diameter of 9.875 in (Figure 20). Then, a 5.5-in casing was installed to 1,259 ft BLS (NTS, 1990). The casing is cemented below an external casing packer from 1,059 to 1,260 ft BLS. The borehole was apparently then deepened to a total depth of 1,302 ft with a diameter of 4.75 in (NTS, 1990). A series of drillable packers and perforated zones exist in the lower part of the casing (Figure 20). The lower two perforated zones are packed off from the upper part of the well and are no longer accessible. The well is open to groundwater with perforations from 919 to 995 ft BLS. The water level measured in the well on March 10, 2014, was 729.72 ft BLS (an elevation of 2,405.5 ft MSL) and it is reported to range from 728.40 to 730.43 ft BLS (USGS, 2014).

Additional Completion and Development Information

Stoller-Navarro (2004a) noted that two hydraulic test results in RNM-1 had significantly different values. This is attributed to the differences in test interpretation and indicates analysis uncertainty. The two different results are from different aquifer testing techniques: the first test was a slug test reported in 1999 and the second was an aquifer test reported in 2003. According to slug test interpretation, the hydraulic conductivity of the alluvial aquifer of RNM-1 (completed in a nuclear cavity) was interpreted as 0.15 to 0.22 m/d with a transmissivity of 0.57 to 1.46 m^2/d (IT, 1999).

Well RNM-1 showed a clear response to a multiwell aquifer test in RNM-2s in 2003 with a maximum drawdown of 3.5 ft (Figure 21). Well RNM-2s was pumped for 75 days at an average rate of 595.5 gpm. Well RNM-1 is 706 ft from RNM-2s at the ground surface. The pumped horizon in RNM-2s was several hundred feet deeper than the monitored horizon in RNM-1. The UGTA Groundwater Database reports representative hydraulic properties from aquifer-test analysis as a hydraulic conductivity of 0.0334 to 0.046 m/d and a transmissivity of 0.27 to 0.71 m^2/d (Navarro-Intera, 2012).

Chemical Description of the Formation Waters of RNM-1

Water-chemistry analytical results for samples from RNM-1 are listed in Table 16. Field parameter data, used as a point of reference for future groundwater sampling, include temperature, pH, and EC. Between 1974 and 2007, eight temperature measurements ranged from 20 to 25 °C. The pH measurements are highly variable and have ranged from 7.76 to 11.4. The high pH measurements (above 9.4) occurred over two days in 1974. These measurements appear to be anomalous when compared with other measurements before and after 1974 and may reflect cement contamination from well completion. Three more recent pH measurements between 2000 and 2007 ranged from 7.76 to 7.95 and likely reflect current conditions in the well. The EC measurements are consistent with pH measurements because EC increased dramatically (400 to 50,000 µS/cm at 25 °C) over the same time period that pH increased, which is also consistent with cement contamination. Three recent EC measurements between 2000 and 2007 ranged from 420 to 430 µS/cm at 25 °C. In summary, stable parameters during a sampling exercise should range between the following: temperature 20 to 25 °C, pH 7.76 to 7.95, and EC 420 to 430 µS/cm at 25 °C.

Because RNM-1 is a source/plume well that contains radionuclides from the Cambric test (emplacement hole U-5e), considerable radionuclide data exist from the well. Select radionuclide data are shown in Table 17. All radionuclide measurements are below the U.S. EPA Safe Drinking Water Act MCLs or in the case of gross beta, below the Level of Concern. For the five radionuclides designated for continued sampling, previously measured ^{3}H activities ranged from 340 to 1,081 pCi/L, one ^{14}C activity was 2.44 pCi/L, ^{36}Cl activities ranged from 3.6e^{-4} to 4.4e^{-4} pCi/L, one ^{99}Tc activity was 7.3e^{-4} pCi/L, and ^{129}I activities ranged from 4.2e^{-4} to 6e^{-4} pCi/L (Table 16).

Recommended Sampling Procedures

Sampling Method: Well RNM-1 has a dedicated electric submersible pump that should be used for sampling.

Sampling Depth: Perforations in the casing interval open to the pump are between the depths of 919 to 927 ft and 938 to 947 ft. There is a packer below these screened zones at 953 ft BLS.

Purging recommendations: For pumped sample collection, it is recommended that three well volumes (3,902 gal) be removed or more until field parameters stabilize (DOE, 2014b). During pumping in 2014, field parameters were monitored and sampling began when

12,677 gallons had been removed (Navarro-Intera, 2014). Well volume calculations were performed with a spreadsheet (note that because there is no gravel pack, the effective porosity is 100 percent) (Table 18).

Field measurement and stability indicators: The expected values indicating that groundwater quality has stabilized during purging include a temperature between 24 and 26 °C, a pH between 7.7 and 8.0, and an EC at approximately 420 μS/cm at 25 °C.

References for RNM-1

Note: Incomplete report numbers (e.g., "XX") indicate an unpublished, internal UGTA document.

IT, 1999. Underground Test Area Project Corrective Action Unit 98: Frenchman Flat, Volume II – Groundwater Data Documentation Package Draft, Revision No. 0. DOE/NV/13052-044-V2.

Navarro-Intera, LLC. 2012. Written communication. Subject: "UGTA Groundwater Database," UGTA Technical Data Repository Database Identification Number UGTA-4-146. Las Vegas, NV. As accessed on June 11, 2014.

NTS, 1990. Nevada Test Site Drilling and Mining Summary Through December 1990. U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada. Prepared by Raytheon Services Nevada.

Stoller-Navarro, 2004a. Phase II Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Nye County, Nevada. S-N/99205-032.

Stoller-Navarro, 2004b. Integrated Data Report for the RNM-2s Multi-Well Aquifer Test at Frenchman Flat, Nevada Test Site, Nevada. Preliminary. Revision No. 0. Stoller-Navarro Joint Venture, 7710 W. Cheyenne, Building 3, Las Vegas, NV 89129. S-N/99205-XX. Prepared for U.S. Department of Energy under Contract No. DE-AC52-03NA99205.

U.S. Department of Energy (DOE), 2014a. Underground Test Area Geochemistry Database. https://ugta.nv.doe.gov/sites/Geochemistry%20Database/DataPages/Geochem.aspx accessed June 4, 2014. Not available for public access.

U.S. Department of Energy (DOE), 2014b. Nevada National Security Site Integrated Groundwater Sampling Plan. National Nuclear Security Administration, Nevada Field Office, DOE/NV-1525.

U.S. Geological Survey (USGS), 2014. http://nevada.usgs.gov/doe_nv/ntsarea5.cfm

Table 16. RNM-1 chemical data. All units are mg/L unless otherwise noted (DOE, 2014a).

Ref.	Date	pH (standard units)	Specific Conductance (µS/cm)	Water Temp. (°C)	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3
LLNL	3/06/2007	7.76	412.7	24	25.8	10.0	43.4	7.22	12.1	38		
LLNL	6/03/2004	7.8	432		26.8	10.4	45.5	7.46	9.7	34.7		
LLNL	6/28/2000	8	416	26	26	9.4	44	8	12.3	36.5		
Bechtel	6/28/2000	7.95	416	26.4	24.5	9.19	38.3	7.28	11	38		196

Table 17. Select RNM-1 radiochemical data (DOE, 2014a). All units are pCi/L.

Date	Gross Alpha	Gross Beta	^{3}H	^{14}C	^{36}Cl	^{99}Tc	^{129}I	^{90}Sr	^{137}Cs	^{234}U	^{235}U
3/06/07			866		3.58e-4	7.28e-4	4.21e-5			3.19	0.059
6/03/04			340	2.44	4.42e-4		5.96e-4		19.7	3.18	0.060
6/28/00	7.51	24.6	<540		4.3e-4			5.8		3.32	
9/13/94									5.41		
8/31/94	3.32	8.33									
8/03/94			1081								
9/14/93									6.84		
4/10/85									54.6		0.178
10/5/81								13.8	15.9		0.068
9/4/79									37.7		0.144

Table 18. RNM-1 well volume calculations. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1075	bottom of well (ft)
9.875	borehole diameter (in)
730	depth to water (ft)
5.5	casing OD (in)
5	casing ID (in)
730	top of gravel (ft)
1075	bottom of gravel (ft)
1	gravel porosity
1332.1	casing volume (L)
352.4	casing volume (gal)
730	effective top of gravel (ft)
5196	total borehole volume (L)
3584.1	gravel vol less interference (L)
4916.2	casing plus net gravel water volume (L)
1300.6	casing plus net gravel water volume (gal)
3902	Three well volume (gal)

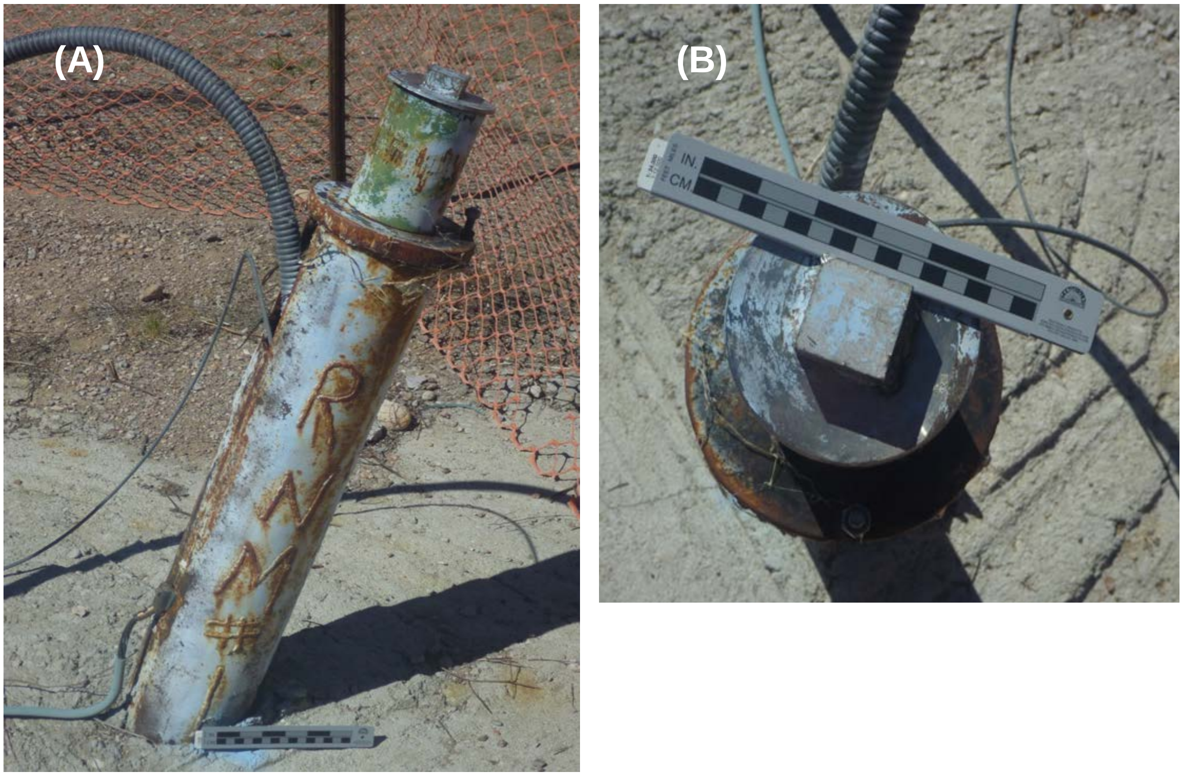

Figure 19. Photo of wellhead configuration RNM-1: (a) view looking west and (b) top-down view.

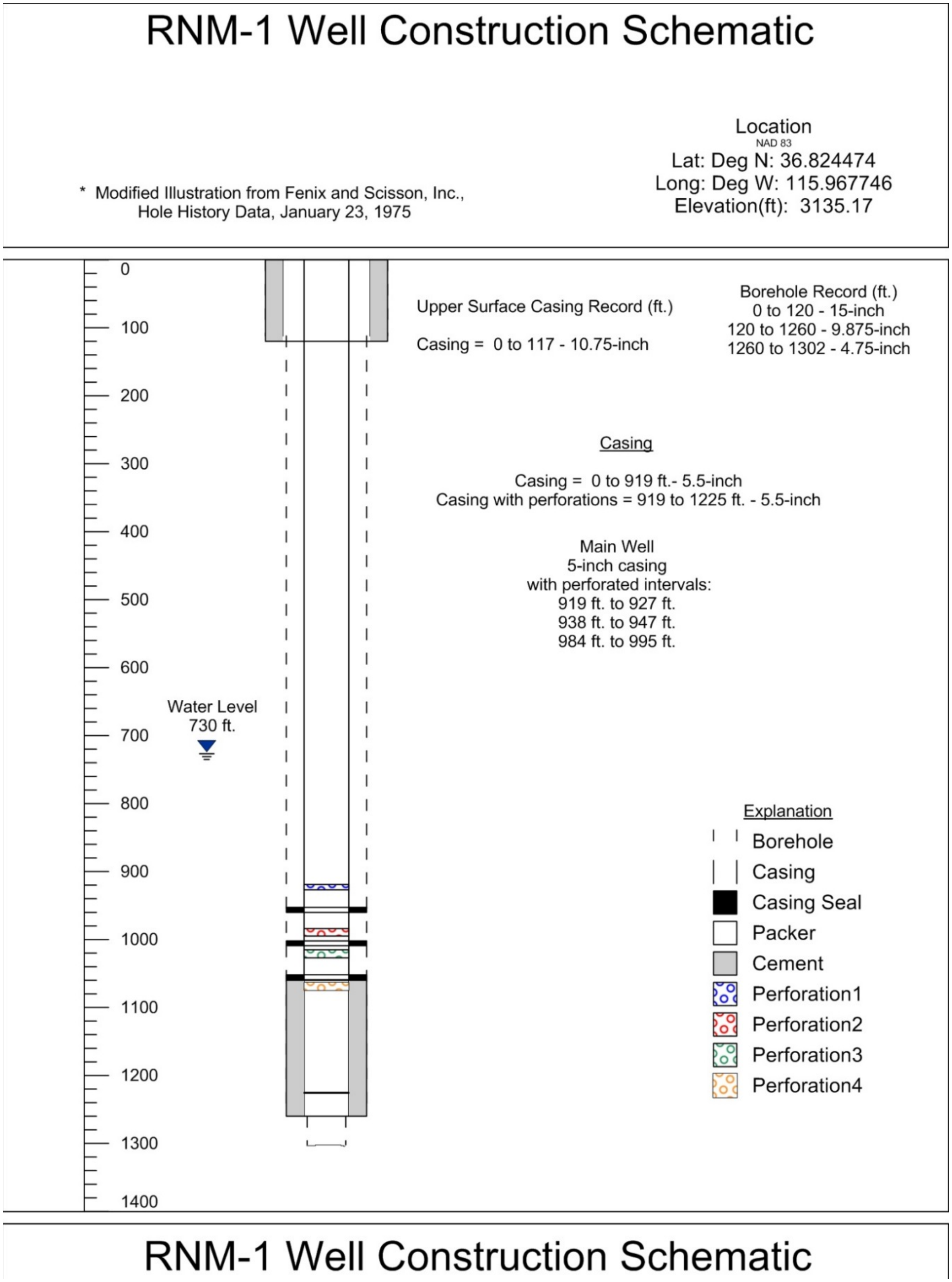

Figure 20. RNM-1 well completion diagram.

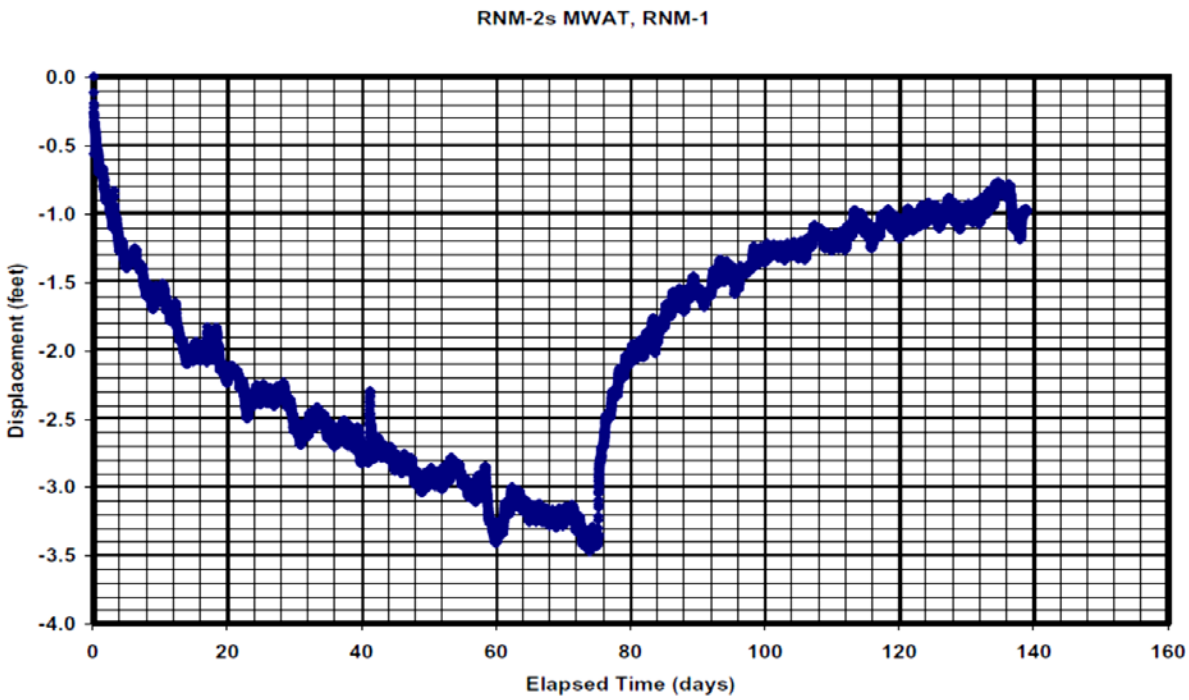

Figure 5-7
Drawdown Response Recorded for RNM-1 Corrected to True Vertical Depth

Figure 21. Drawdown response recorded for RNM-1 (corrected to true vertical depth) during pumping of RNM-2s (Stoller-Navarro, 2004b).

WELL RNM-2S

Integrated Sampling Plan ID: RNM-2S_m1

Type of UGTA groundwater sampling point: Source/plume well

Sampling Frequency: 4 years

Analytes: ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I

Role in Sampling Plan

The objective of sampling RNM-2s, a source/plume well, is to provide a long-term dataset to monitor contaminant migration and natural attenuation. Source/plume wells have detectable radionuclides that have been verified to originate from NNSS underground nuclear testing.

Physical Description of Well

Well RNM-2s is located northwest of Frenchman Lake in Frenchman Flat (Figure 22). The wellhead is accessed from Road 5-07 off of Mercury Highway (Figure 2). The Nevada state plane coordinates for the well location are N 755,262 and E 705,088 (NTS, 1990). The latitude and longitude for the well location are 36.82273750°, -115.96778069°, to the NAD83 reference. The elevation of the wellhead is 3,130.22 ft MS, referenced to NGVD29. The USGS Site ID for RNM-2S is 364922115580101 (USGS, 2014).

The 17.5-in hole was drilled to 1,156 ft BLS in March 1974 (Figure 23). Blank steel surface casing (9.625 in) extends from the land surface to 1,038 ft BLS. Slotted steel casing (9.625 in) extends from the bottom of the blank casing (1,038 ft BLS) to 1,120 ft BLS. Two piezometers of 1.9-in blank tubing extend from 0 to 954 ft BLS (east piezometer, although an obstruction has been reported at 54 ft BLS) and 0 to 1,038 ft BLS (west piezometer, welded to the 9.625-in surface casing). An access line of 2.375-in blank tubing extends from 0 to 969 ft BLS. A second 2.375-in blank tubing extends from 0 to 980.70 ft BLS and a 6.75-in electric submersible pump is attached to the bottom of this tubing. The pump intake is positioned at 992.75 ft BLS.

The well was pumped continuously from October 1975 to August 1991, during the month of October 1999, and between April and July 2003. It had not been pumped since July 2003 until sampled in 2014. A total of about 4.5 billion gallons of water was pumped through 2003. Hydraulic conductivity measurements, based on constant flow-rate aquifer tests, range from 0.0185 to 0.11 m/d. The water level in the well has remained steady at 723 ± 1 ft BLS since November 2003.

Chemical Description of the Formation Waters of RNM-2s

The field parameters of pH, temperature, and EC are shown in Tables 19 through 21. Laboratory measurements between 1975 and 2007 are: a pH range of 7.8 to 8.3 (Table 19), an EC range of 405 to 450 µS/cm at 25 °C (Table 20), and a temperature range of 24 to 26 °C (Table 21). The major ion composition of the well water is presented in Table 22. Well RNM-2s is a source/plume well with a tritium concentration above the MCL. The most recent tritium analyses range from 77,000 ± 12,000 pCi/L after pumping 745 gal to 48,200 ± 7,400 pCi/L after pumping 85,069 gal, and then increasing to 74,000 ± 11000 pCi/L after pumping 159,477 gal (Table 23). It is unclear why the values varied by a factor of two even though the well had been sufficiently purged (Navarro-Intera, 2014). Radiochemical measurements other than tritium are presented in Table 24.

Recommended Sampling Procedures

Sampling Method: Samples should be collected with the existing Centrilift 225-HP pump.

Sampling Depth: The Centrilift pump is currently installed at 992.75 ft BLS.

Purging recommendations: Three well volumes (7,171 gallons) should be purged or more if needed for the field parameters stabilize (DOE, 2014b). Well volume calculations were performed in a spreadsheet and a summary of the results are listed in Table 25.

Field measurement and stability indicators: The general targets for the field parameters are a temperature range of 23 to 26 °C, a pH range of 7.7 to 8.5, and an EC range of 360 to 500 µmho/cm at 25 °C. Bromide is not a useful indicator at RNM-2s because it was not added to the drilling fluids (Navarro-Intera, 2014).

References for RNM-2S

Note: Incomplete report numbers (e.g., “XXX”) indicate an unpublished, internal UGTA document.

Navarro-Intera, 2014. Well RNM-2s Groundwater Sampling Data Report, Revision No. 0, N-I/28091-XXX

NTS, 1990. Nevada Test Site Drilling and Mining Summary Through December 1990. U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada. Prepared by Raytheon Services Nevada.

U.S. Department of Energy (DOE), 2014a. Underground Test Area Geochemistry Database. https://ugta.nv.doe.gov/sites/Geochemistry%20Database/DataPages/Geochem.aspx Accessed June 4, 2014. Not available for public access.

U.S. Department of Energy (DOE), 2014b. Nevada National Security Site Integrated Groundwater Sampling Plan. National Nuclear Security Administration, Nevada Field Office, DOE/NV-1525.

U.S. Geological Survey (USGS), 2014. http://nevada.usgs.gov/doe_nv/ntsarea5.cfm

Table 19. pH measurements RNM-2s (DOE, 2014a).

Sample Date	Sample depth, ft	Lab or field measurement	pH
10/08/1975		Field	8.2
10/08/1975		Field	8.3
100/9/1975		Field	8.1
10/10/1975		Field	8.1
11/10/1982	316-340 m	Lab	8.1
10/11/1999	316-340 (?) m	Lab	8.2
06/14/2000	316-340 (?) m	Lab	7.8
05/09/2003		Lab	8.2
07/10/2003		Lab	8.2
07/10/2003		Lab	8.2
07/10/2003		Lab	8
03/07/2007		Field	8
05/14/2014		Field	[1]7.70 – 8.46

[1] Eleven samples collected over a 24-hour period May 14 and 15, 2014 (Navarro-Intera, 2014).

Table 20. Electrical conductivity RNM-2s (DOE, 2014a).

Sample Date	Sample depth, ft	Lab or field measurement	EC, µS/cm
10/08/1975		Lab	405
10/08/1975		Lab	413
10/09/1975		Lab	443
10/09/1975		Lab	443
10/10/1975		Lab	425
10/10/1975		Lab	425
10/11/1999	316-340 (?) m	Field	440
06/14/2000	316-340 (?) m	Lab	429
05/09/2003		Lab	450
07/10/2003		Lab	430
07/10/2003		Lab	440
07/10/2003		Lab	418
03/07/2007		Field	416
05/14/2014		Field	[2]362 – 502

[2] Based on eleven samples collected May 14 and 15, 2014 (Navarro-Intera, 2014).

Table 21. Temperature RNM-2s (DOE, 2014a).

Sample Date	Sample depth, ft	T, °C
10/8/1975		25
10/8/1975		25
10/9/1975		25.5
10/10/1975		25.5
10/11/1999	316-340 (?) m	24.6
5/9/2003		24
3/7/2007		26
5/14/2014		[3]19.9 – 23.76

[3] Based on eleven samples collected May 14 and 15, 2014 (Navarro-Intera, 2014).

Table 22. RNM-2s chemical data (DOE, 2014a). All units are mg/L unless otherwise noted.

Date	pH (standard units)	Specific Conductance (μS/cm)	Ca	Mg	Na	K	Cl	SO_4	HCO_3
3/7/2007	8	416	17.8	6.82	55.0	8.65	12.1	37.0	NA
7/10/2003	8.2	440	15	5.0	52	8.8	15	37	170

NA indicates analysis not available.

Table 23. Laboratory values of tritium activity from samples collected May 14 and 15, 2014 (Navarro-Intera, 2014).

Tritium (pCi/L)	Uncertainty (pCi/L)	Volume of water purged, (gal)
77,000	12,000	745
76,000	12,000	745
46,900	7,200	85,069
48,200	7,400	85,069
73,000	11,000	159,477
74,000	11,000	159,477

Table 24. RNM-2s radiochemical data. For tritium values, refer to Table 23.

Ref.	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/l)	C-14 (pCi/L)	Cl-36 (pCi/l)	Tc-99 (pCi/L)	I-129 (pCi/L)
DOE, 2014a	3/7/2007				0.0454	8.6×10^{-4}	6.91×10^{-4}
DOE, 2014a	7/10/2003	<2.4	9.3	0.735			

Table 25. RNM-2s well volume calculation summary. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1120	bottom of well (ft)
17.5	borehole diameter (in)
723.68	depth to water (ft)
9.625	casing OD (in)
9.2	casing ID (in)
690	top of gravel (ft)
1120	bottom of gravel (ft)
0.3	gravel porosity
5179.2	casing volume (L)
1370.6	casing volume (gal)
723.8	effective top of gravel (ft)
18739.7	total borehole volume (L)
3856.7	gravel vol less interference (L)
9035.9	casing plus net gravel water volume (L)
2390.5	casing plus net gravel water volume (gal)
7171	three well volumes (gal)

Figure 22. Photo of wellhead configuration for RNM-2s with view looking north.

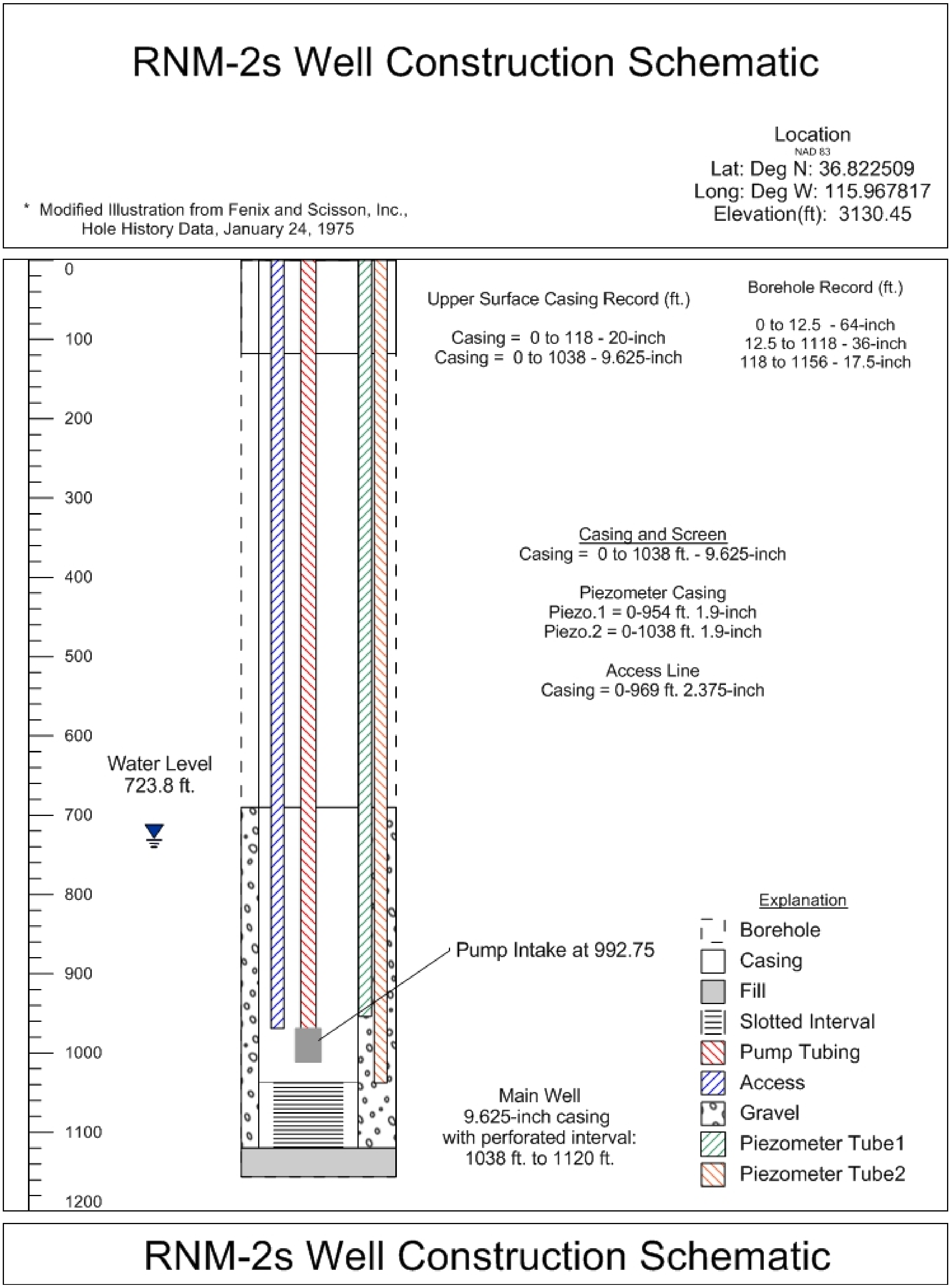

Figure 23. RNM-2s well completion diagram.

WELL UE-5N

Integrated Sampling Plan ID: UE-5n_m1

Type of UGTA groundwater sampling point: Source/plume well

Sampling Frequency: 4 years

Analytes: ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I

Role in Sampling Plan

The objective of sampling UE-5n, a source/plume well, is to provide a long-term dataset to monitor contaminant migration and natural attenuation. Source/plume wells have detectable radionuclides that have been verified to originate from NNSS underground nuclear testing.

Physical Description of Well

Well UE-5n is located to the north of Frenchman Lake in Frenchman Flat (Figure 24). Access to the wellhead is from the Road 5-07 off of Mercury Highway (Figure 3). The latitude and longitude of the well in NAD83 are 36.82067370° and -115.96231107°, respectively. The elevation of the wellhead is 3,113.04 ft in reference to NGVD29.The USGS Site ID is 364915115574101 (USGS, 2014). The well is approximately 1,770 ft southeast of well RNM-2s.

The 15-in hole was drilled in 1976 to a depth of 1,687 ft (NTS, 1990). Steel surface casing (20 in) extends to 79.5 ft BLS (Navarro-Intera, 2014) and 10.75-inch steel casing extends from the land surface to 1,523 ft BLS (NTS, 1990) (Figure 25). The open interval is reported to be between 82 and 1,460 ft BLS by Elliott and Fenelon (2013), but perforations are shown between 720 and 730 ft BLS in the 10.75-inch casing by Navarro-Intera (2014). This information is consistent with the well diagram indicating that the casing is only cemented below 1,437 ft BLS (Navarro-Intera, 2014). The measuring point for water levels is 2.7 ft above ground surface, or at the top of the 10.75-in casing.

Hydraulic conductivity was calculated as 1.42 m/d for the interval 720 to 1,687 ft BLS based on a 90 minute constant rate drawdown test conducted in 1999. All water level measurements in 2013 were 706.0 and 706.5 ft BLS. Since 1994, the depth of water has ranged from 704 to 706.5 ft BLS. In 1991, DRI personnel encountered an obstruction at 1,185 ft BLS (Elliott and Fenelon, 2013). A dedicated submersible pump was installed in UE-5n in preparation for a groundwater sampling event in 2014 (Navarro-Intera, 2014). The pump intake is at 847.04 ft BLS.

Chemical Description of the Formation Waters of UE-5n

The field parameters pH, temperature, and EC are shown in Tables 26 through 28 and Figures 26 through 28. Laboratory measurements of pH range from 8.2 to 9.0 between 1986 and 2004 (Figure 26 and Table 26). The data are sparse, but prior to the most recent sampling, the laboratory values were generally above 8.7. The 2014 sampling event found pH to range from 6.62 to 7.61 (Navarro-Intera, 2014). The EC has been relatively stable between 1986 and 2004, ranging from 365 to 459 μS/cm at 25 °C (Figure 27 and Table 27) and was 348 to 382 μS/cm at 25 °C in the 2014 sampling. The temperature in 2014 varied from 21.0 to 22.48 (Navarro-Intera, 2014) and has ranged from 23 to 28.5 °C between 1993 and 2001 (Figure 28 and Table 28). The major ion composition of UE5n well water is presented in Table 29.

Well UE-5n is a source/plume well with tritium values above the EPA SDWA MCL, ranging from 151,000 to 157,000 pCi/L (±23000 pCi/L) (Navarro-Intera, 2014) for six samples collected in June 2014. Radiochemical results are presented in Table 30.

Recommended Sampling Procedures

Sampling Method: Samples should be collected with the submersible pump currently installed in well.

Sampling Depth: The effective sampling depth is the slotted interval between 720 and 730 ft BLS. As of August 2014, the pump intake is located 847.04 ft BLS.

Purging recommendations: Three well volumes (19,509 gal) should be removed from the well or more if required for the field parameters to stabilize (DOE, 2014b). Well volumes were calculated with a spreadsheet and a summary of the calculations is listed in Table 31.

Field measurement and stability indicators: The expected values that indicate the field parameters have stabilized after purging are a temperature between 21 and 23 °C and an EC between 350 and 460 μS/cm at 25 °C. The range in pH observed in sampling events is large, from 6.6 to 9.03, so it is not diagnostic for stability. Bromide was not used to tag fluids during drilling and development of UE-5n, so bromide is not a purge indicator.

References for UE-5N

Note: Incomplete report numbers (e.g., “XXX” and “XX”) indicate an unpublished, internal UGTA document.

Elliott, P.E., and J.M. Fenelon, 2013, Database of Groundwater Levels and Hydrograph Descriptions for the Nevada Test Site Area, Nye County, Nevada, Data Series 533, Version 4.0, November 2013.

IT, 1999. Underground Test Area Project Corrective Action Unit 98: Frenchman Flat, Volume II – Groundwater Data Documentation Package Draft, Revision No. 0. DOE/NV/13052-044-V2.

Navarro-Intera, 2014. Well UE-5n Groundwater Sampling Data Report, N-I/28091-XXX.

NTS, 1990. Nevada Test Site Drilling and Mining Summary Through December 1990. U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada. Prepared by Raytheon Services Nevada.

Stoller-Navarro, 2004a. Phase II Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Nye County, Nevada. S-N/99205-032.

Stoller-Navarro, 2004b. Integrated Data Report for the RNM-2s Multi-Well Aquifer Test at Frenchman Flat, Nevada Test Site, Nevada. Preliminary. Revision No. 0. Stoller-Navarro Joint Venture, 7710 W. Cheyenne, Building 3, Las Vegas, NV 89129. S-N/99205-XX. Prepared for U.S. Department of Energy under Contract No. DE-AC52-03NA99205.

U.S. Department of Energy (DOE), 2014a. Underground Test Area Geochemistry Database. https://ugta.nv.doe.gov/sites/Geochemistry%20Database/DataPages/Geochem.aspx Accessed June 4, 2014. Not available for public access.

U.S. Department of Energy (DOE), 2014b. Nevada National Security Site Integrated Groundwater Sampling Plan. National Nuclear Security Administration, Nevada Field Office, DOE/NV-1525.

U.S. Geological Survey (USGS), 2014. http://nevada.usgs.gov/doe_nv/ntsarea5.cfm.

Table 26. pH measurements from UE-5n (DOE, 2014a).

Sample Date	Sample depth, ft	Lab or field measurement	pH
6/10/1986	719.2	Lab	8.77
2/10/1993	n/a	Lab	9.03
5/24/1993	724.5	Lab	8.82
9/9/1999	730	Field	7.6
9/9/1999	720.2 – 730.0	Lab	8.7
4/19/2001	720.2 – 730.0	Lab	8.7
2/12/2004	n/a	Lab	8.2

Table 27. Electrical conductivity measurements from UE-5n (DOE, 2014a).

Sample Date	Sample depth, ft	Lab or field measurement	EC, µS/cm
6/10/1986	719.2 m	Field	459
2/10/1993	n/a	Lab	365
5/24/1993	724	Lab	427
9/9/1999	730	Field	360
9/9/1999	n/a	Field	402
9/9/1999	720.2 – 730.0	Field	453
4/19/2001	720.2 – 730.0	Field	408
2/12/2004	n/a	Lab	452

Table 28. Temperature measurements from UE-5n (DOE, 2014a).

Sample Date	Sample depth, ft	T, °C
5/24/1993	724.5	25.7
9/9/1999	730	27.9
9/9/1999	720.2 – 730.0	28.5
4/19/2001	720.2 – 730.0	23

Table 29. UE-5n chemical data (DOE, 2014a). All units are mg/L unless otherwise noted.

Date	pH (standard units)	Specific Conductance (µS/cm)	Ca	Mg	Na	K	Cl	SO_4	HCO_3
1/19/2010	7.8	426	7	1.8	79	7.8	15	39.8	NA
3/20/2007	NA	NA	7.1	1.7	79	8.0	13.4	36.9	178

NA indicates analysis not available.

Table 30. UE-5n radiochemical data (DOE, 2014a).

Date	Gross Alpha (pCi/L)	Gross Beta (pCi/l)	Tritium (pCi/L)	C-14 (pCi/L)	Cl-36 (pCi/l)	Tc-99 (pCi/L)	I-129 (pCi/L)
1/19/2010			186,000	0.0564	0.31	<0.0006	1.48×10^{-5}
3/20/2007	1.2	8.72					

Table 31. Well UE5n wellbore volume estimate. The calculation method is detailed in the Appendix.

0	**top of well (ft)**
1437	bottom of well (ft)
15	borehole diameter (in)
695	depth to water (ft)
10.75	casing OD (in)
10.25	casing ID (in)
680	top of gravel (ft)
1437	bottom of gravel (ft)
1	gravel porosity
12039.9	casing volume (L)
3185.2	casing volume (gal)
695	effective top of gravel (ft)
25784.5	total borehole volume (L)
12541.3	gravel vol less interference (L)
24581.2	casing plus net gravel water volume (L)
6503	casing plus net gravel water volume (gal)
19509	Three well volumes (gal)

Figure 24. UE-5n wellhead, view to the south.

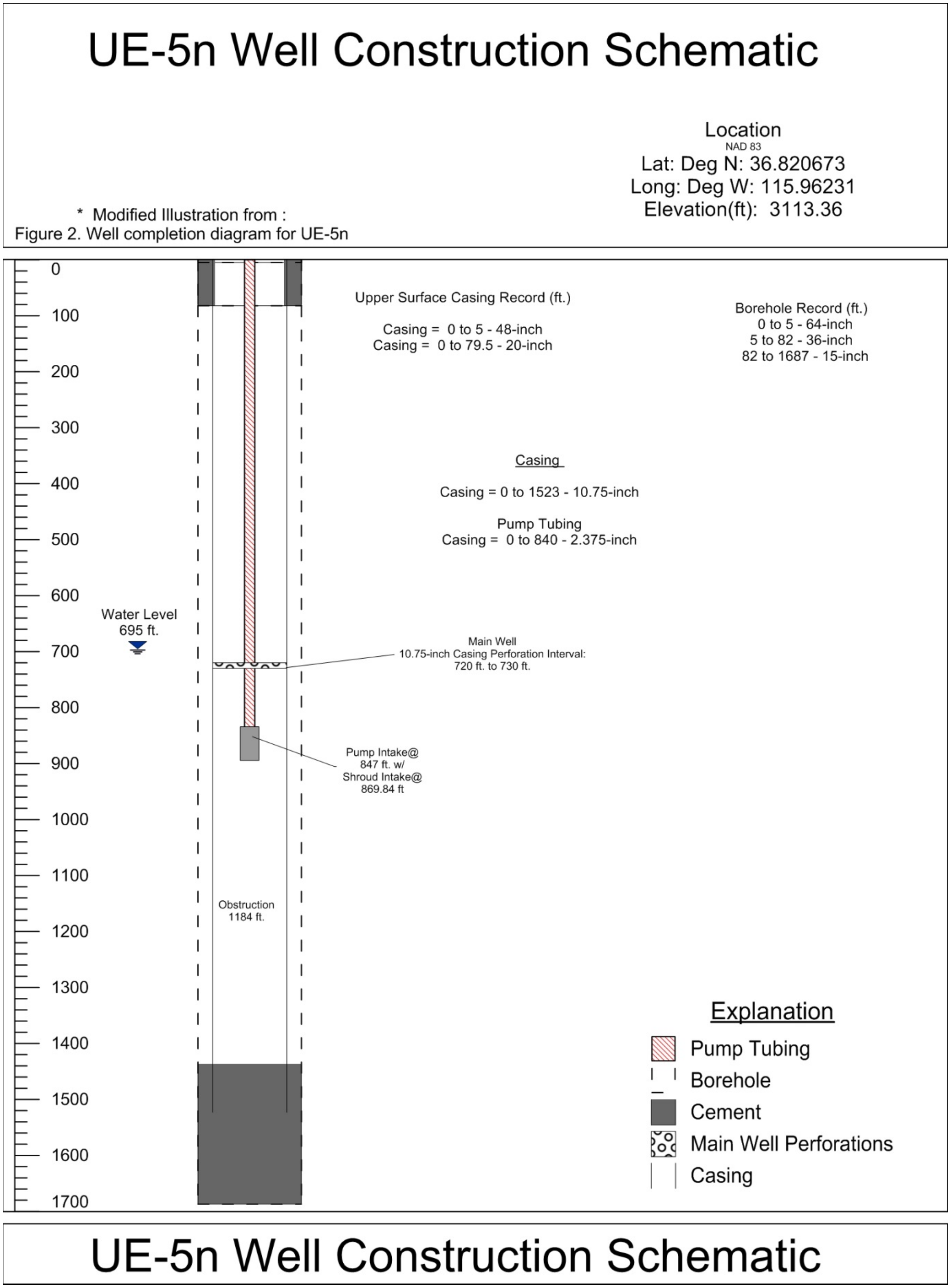

Figure 25. UE-5n well completion diagram.

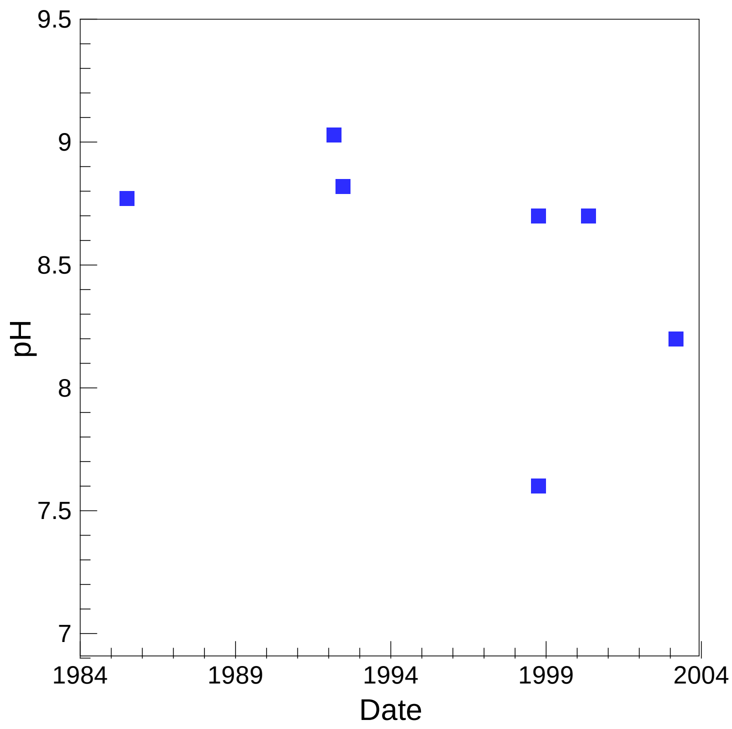

Figure 26. pH values for UE-5n (DOE, 2014).

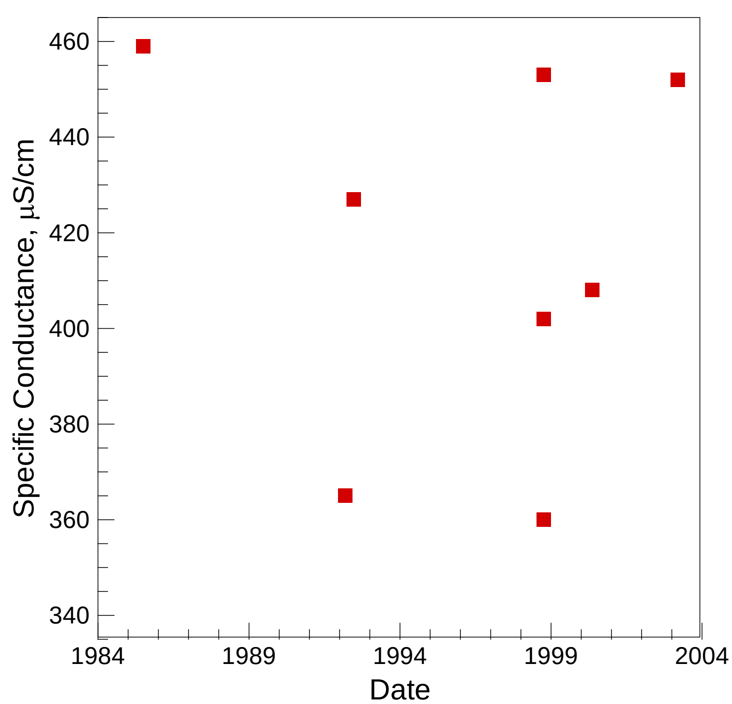

Figure 27. Measurements of specific conductance from UE-5n.

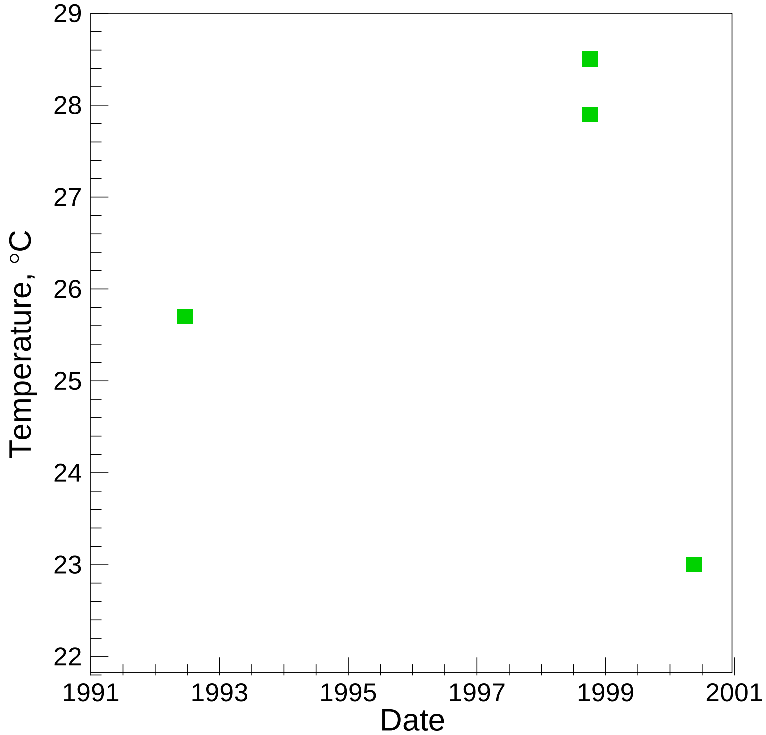

Figure 28. Temperature measurements from UE-5n.

CONCLUSIONS

Table 32 summarizes the recommendations for sampling the Frenchman Flat wells included in the NNSS Integrated Sampling Plan. The recommendations are based on historical accounts and consider construction details, aquifer hydraulic testing, and previous geochemical sampling. All field personnel completing the sampling task should be well trained and follow the Standard Operating Procedures associated with the Sampling Plan (DOE, 2014).

Table 32. Summary of sampling recommendations for Frenchman Flat wells.

Well Name	Sampling Technique	Purge Volume Requirement (gallons)	Parameters		
			EC Range (µS/cm at 25 °C)	Temperature Range (°C)	pH Range
ER-11-2	Discrete Bailer or lift jack pump	881	1,100	NA	8.6
ER-5-3 Shallow Piezometer	Discrete Bailer or lift jack pump	1130	270 to 590*	26.9 to 30.0*	8.4 to 9.6*
ER-5-3#2	Installed Pump	18,552	1100	46	7.0
ER-5-5	Installed Pump	894	400	25	8
RNM-1	Installed Pump	3,902	420	24 to 26	7.7 to 8.0
RNM-2s	Installed Pump	7,171	360 to 500	23 to 26	7.7 to 8.5
UE-5n	Installed Pump	19,509	350 to 460	21 to 23	NA

* Parameters of upper zone of ER-5-3.

NA indicates analysis not available.

APPENDIX: WELL VOLUME CALCULATIONS

Well volume calculations were performed in an Excel spreadsheet. The most recent water level measurements were used, as well as the best-known construction details. Care was taken to remove interference volumes, such as piezometer strings that occupy dead volume in the gravel pack, and well casing thickness. Fluid in the gravel pack was included in the total well volume. In wells where the gravel extended above the water table, the effective top of the gravel was set to the water table, and the gravel porosity was assumed to be 30 percent in most cases. Calculation details are as follows:

Casing Volume (L) = $\pi r^2 h$ (where, *r* is the radius and *h* is the height)
= (π*(casing ID(in)/2*2.54)^2*(bottom of casing (ft) - depth to water (ft))*12*2.54))/1000

Casing Volume (gal) = Casing Volume (L) / 3.78

Effective Top of Gravel (ft) = if (top of gravel > water level) then = water level

Total Borehole Volume (L) = $\pi r^2 h$ = (π*(borehole diameter (ft)/2*2.54)^2*(bottom of gravel (ft) - effective top of gravel (ft))*12*2.54)/1000

Interference Volume(s) (L) = $\pi r^2 h$(outside diameter of casing/piezometer(s))

Gravel Volume Less Interferences (L) = (Total Borehole Volume (L) - Interference Volume(s) (L)) * Gravel Porosity

Casing Plus Net Gravel Volume (L) = Casing Volume (L) + Gravel Volume Less Interferences (L)

Casing Plus Net Gravel Volume (gal) = Casing Plus Net Gravel Volume (L) / 3.78

Three Well Volumes (gal) = Casing Plus Net Gravel Volume (gal) * 3

The parameter values assigned for each well and results of the calculations are summarized in Table A-1.

Table A-1. Input parameters and well volume calculations for the Frenchman Flat wells included in the NNSS Sampling Plan.

ER-11-2	**ER-5-3 shallow piezometer**	**ER-5-3#2**	**ER-5-5**	**RNM-1**	**RNM-2s**	**UE-5n**	
0	0	0	0	0	0	0	top of well (ft)
1294	1235.1	4908.2	1040.55	1075	1120	1437	bottom of well (ft)
12.25	18.5	12.25	12.25	9.875	17.5	15	borehole diameter (in)
1154.03	928	937.48	929	730	723.8	695	depth to water (ft)
2.875	2.875	5.5	6.625	5.5	9.625	10.75	casing OD (in)
2.36	2.4	5	6	5	9.2	10.25	casing ID (in)
1132	927	4674	850	730	690	680	top of gravel (ft)
1304	1080	5683	1040.55	1075	1120	1437	bottom of gravel (ft)
0.3	0.3	0.1	0.3	1	0.3	1	gravel porosity*
120	273	21037	620	1332	5179	12040	casing volume (L)
32	72	5565	164	352	1370	3185	casing volume (gal)
1154.03	928	4674	929	730	723.8	695	effective top of gravel (ft)
3476	8035	23385	2585	5196	18740	25784	total borehole volume (L)
989	1150	2338	506	3584	3857	12541	gravel vol less interference (L)
1110	1424	23376	1126	4916	9036	24581	casing plus net gravel water vol. (L)
294	377	6184	298	1301	2390	6503	casing plus net gravel water vol. (gal)
881	1130	18552	894	3902	7171	19509	three well volumes (gal)

* Porosity of 30% or 0.3, indicates gravel pack in the annular space; 100% or 1.0 is assumed when there is no gravel pack; 10% or 0.1 is assumed when there is fill in the annular space.

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