LMS/SHL/S07117

2010 Groundwater Monitoring Report Project Shoal Area, Corrective Action Unit 447

February 2011

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1.0 Introduction

This report presents the 2010 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Project Shoal Area (PSA) Subsurface Corrective Action Unit (CAU) 447 in Churchill County, Nevada. Responsibility for the environmental site restoration of the PSA was transferred from the DOE Office of Environmental Management to LM on October 1, 2006. The environmental restoration process and corrective action strategy for CAU 447 are conducted in accordance with the Federal Facility Agreement and Consent Order (FFACO 1996, as amended March 2010) entered into by DOE, the U.S. Department of Defense, and the State of Nevada. The corrective action strategy for the site includes monitoring in support of site closure. This report summarizes the results from the groundwater monitoring program during fiscal year 2010.

2.0 Site Location and Background

The PSA is south of U.S. Highway 50, approximately 30 miles southeast of Fallon, in Churchill County, Nevada (Figure 1). The Project Shoal underground nuclear test was performed on October 26, 1963, as part of the Vela-Uniform program sponsored jointly by the U.S. Department of Defense and the U.S. Atomic Energy Commission. The test consisted of detonating a 12-kiloton nuclear device in granitic rock at a depth of approximately 1,211 feet (ft) below ground surface (bgs) (AEC 1964). A cavity created by the test collapsed shortly after the detonation and formed a rubble chimney (Pohll et al. 1998). The radius of the cavity is reported to be 85 ft (26 meters) (Hazelton-Nuclear Science Corporation 1965).

Site deactivation and post-shot drilling activities began on October 28, 1963. Re-entry drilling indicated that the Shoal rubble chimney extended approximately 356 ft above the shot point (Hazleton-Nuclear Science Corporation 1965). A radioactive materials survey conducted at the site in 1970 indicated that there were no radiological levels that exceeded background for the area (AEC 1970). The decontamination and restoration activities were minimal, because no large areas of surface radiological contamination were found during or following the test. During this effort the emplacement shaft was covered with a concrete slab and the Particle Motion (PM), Exploratory Core Holes (ECH), and U.S. Bureau of Mines (USBM) boreholes on the site were plugged and abandoned (AEC 1970).

2.1 Summary of Corrective Action Activities

Surface and subsurface contamination resulted from the underground nuclear test at PSA. To address these areas of contamination, surface and subsurface CAUs were identified and the areas of contamination were addressed through separate corrective action processes. The surface CAU included three Corrective Action Sites that consisted of a mud pit with drilling mud impacted by petroleum hydrocarbons; a muckpile of granite that remained from excavation of the emplacement shaft; and housekeeping areas that consisted of approximately 20 rusted and empty oil cans. Remediation of surface CAU 416 was completed in 1998 and is summarized in the *Closure Report for CAU No. 416, Project Shoal Area* (DOE/NV 1998). The Nevada Division of Environmental Protection (NDEP) approved the Closure Report on February 13, 1998, stating that no post-closure monitoring is required and no land use restrictions apply at CAU 416 (NDEP 1998).

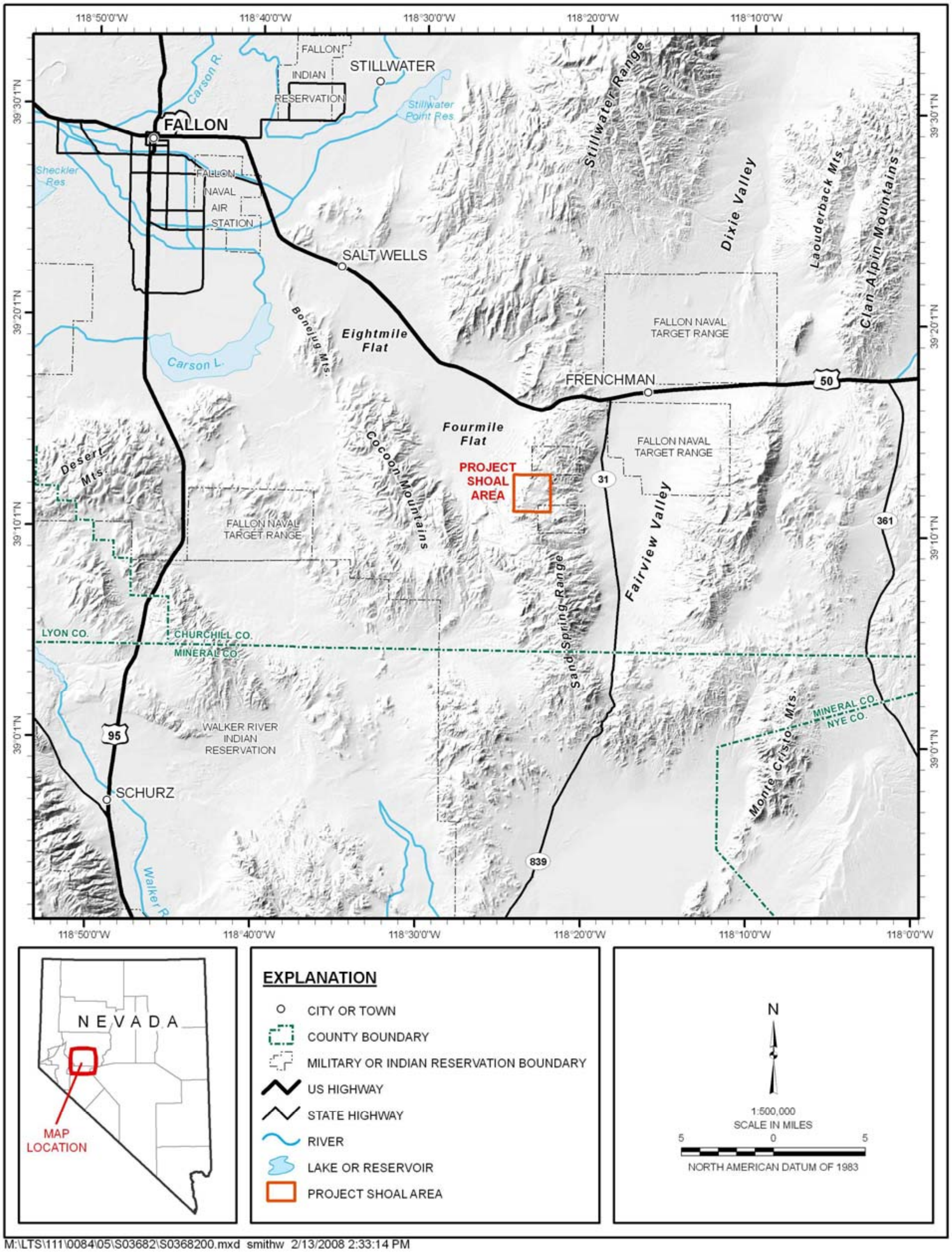

Figure 1. Location Map of the Project Shoal Area

The corrective action process for the subsurface has not been completed and there is currently no known technology to remediate the remaining subsurface radioactive contamination at the site. A groundwater flow and transport model was developed by Desert Research Institute to assist in the evaluation of data and the selection of a corrective action alternative. The model results were used to determine a contaminant boundary and establish a restricted region surrounding the site. The contaminant boundary (Figure 2) is a probabilistic forecast of the maximum extent over 1,000 years of radionuclide transport where groundwater outside the boundary has a 5% or less likelihood of exceeding the radiological standards of the Safe Drinking Water Act. The NDEP approved the contaminant boundary as the compliance boundary in their letter dated January 19, 2005 (NDEP 2005). The corrective action alternative selected for the site includes monitoring with institutional controls and is presented in the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP; DOE/NNSA 2006). The recommendation for the selected corrective action alternative was based largely on the results of the numerical model that was developed for the PSA.

Three wells (MV-1, MV-2, and MV-3) were installed in 2006 for the dual purpose of monitoring and evaluating the flow and transport model results. Based on the comparisons of monitoring data and modeling results, and pursuant to the FFACO process (FFACO 1996, as amended March 2010), LM is developing a new closure strategy for the PSA. In September 2009, DOE submitted a short-term data acquisition plan to NDEP detailing the proposed data collection and field investigation activities to support development of a new closure strategy. Proposed activities include (1) the use of geophysical methods to better define the water table and identify faults and fracture zones with the potential to affect groundwater flow and (2) an enhanced monitoring system for the collection of hydrologic and geochemical data (DOE/LM 2009). When the new closure strategy is developed it will be provided to NDEP in an addendum to the CADD/CAP for review and approval.

3.0 Geologic and Hydrologic Setting

The PSA is in the northern portion of the Sand Springs Range in west-central Nevada's Churchill County. The Sand Springs Range is the southern extension of the Stillwater Range, a north-northeast-trending fault block range that traverses Churchill County. The Sand Springs Range rises to an elevation of approximately 6,751 ft above mean sea level (amsl) and is flanked by Fourmile Flat to the west and Fairview Valley to the east (Figure 1). The Shoal Site is in Gote Flat at an elevation of approximately 5,250 ft amsl and is within an area that is part of the Cretaceous-age Sand Springs granitic batholith.

The Sand Springs batholith is composed of granodiorite and granite, aplite and pegmatite dikes, andesite dikes, rhyolite dikes, and rhyolitic intrusive breccia. Internal deformation of the Sand Springs granite is largely by high-angle normal faults that strike northeast and northwest, joints that parallel the northwest-trending faults, and fractures that generally parallel the northeast-trending faults. These faults, joints, and fractures are distributed between two dominant structural trends that generally strike N 50^{o} W and N 30^{o} E and are vertical to steeply dipping. Several dikes of varying composition predominantly follow the same two orientations and intrude along these lines of preexisting weakness. These orthogonal-type sets of faults and fractures appeared early in the history of the Sand Springs granite and affected much of the subsequent structural and chemical evolution of this large intrusion (Beal et al. 1964).

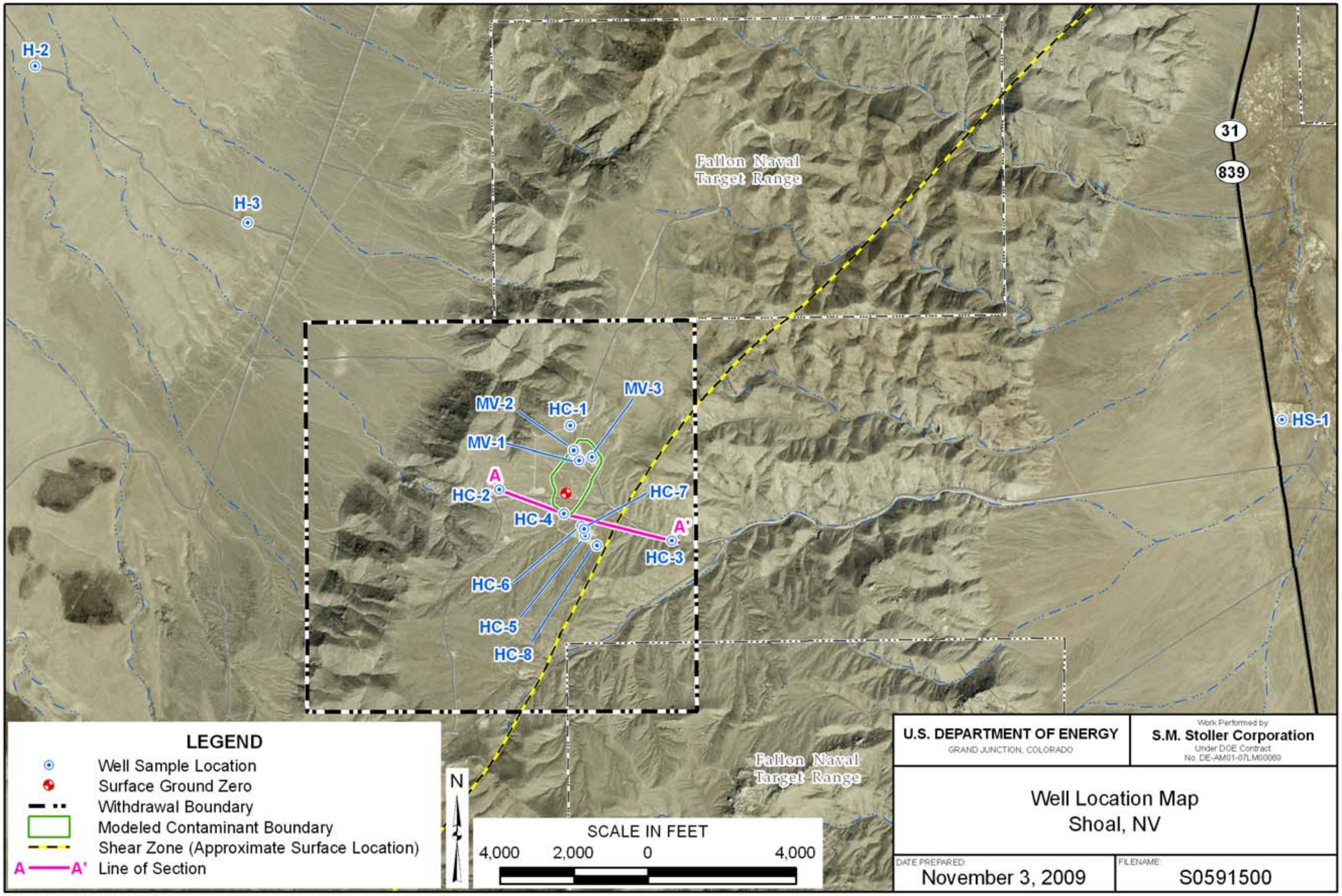

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Figure 2. Well Location Map Shoal, NV

The water table beneath the site (near surface ground zero and west of the shear zone) occurs at depths ranging from approximately 975 to 1,090 ft bgs and groundwater moves primarily through fractures in the granite. Recharge occurs by infiltration of precipitation on the mountain range and regional discharge occurs in the adjacent valleys. A groundwater divide along the upland area of the range west of the site separates flow to the east and west. A shear zone, located about 1,500 ft east of surface ground zero (Figure 2 and Figure 3), was interpreted as a barrier to groundwater flow due to disparate head levels in wells separated by the shear zone (Rosemary W.H. Carroll et al. 2001). Groundwater within Fairview Valley to the east, has been used for ranching, seasonal residential purposes, and military purposes within the last 5 years.

4.0 Monitoring Program and Objectives

The groundwater monitoring program was enhanced in 2010 as specified in the short-term data acquisition plan approved by NDEP (DOE/LM 2009). The enhanced monitoring included collection of samples from all on-site wells (HC-1 through HC-8, MV-1, MV-2, and MV-3) and collection of hydraulic head data from the on-site wells/piezometers and off-site wells (H-2 and H-3) (Figure 2). Access was not obtained to off-site well HS-1 for the collection of hydraulic head data. All samples collected during the annual monitoring event were analyzed for the analytes specified in the CADD/CAP (DOE/NNSA 2006). The general objectives of the monitoring are (1) "detection monitoring" to identify any migration of radiologic contamination from the test cavity and (2) "system monitoring" to obtain hydraulic head data for monitoring the overall stability (quasi-steady state) of the hydrogeologic system. The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/S04351) is used to guide the quality assurance/quality control of the annual sampling and monitoring program. Well construction information and hydraulic head data obtained in 2010 are presented in Table 1.

4.1 Radioisotopic Monitoring

Groundwater samples were collected from wells MV-1 through MV-3 and HC-1 through HC-8 for radioisotopic analyses during March 2010. Monitoring wells MV-1, MV-2, MV-3, HC-4, HC-5, HC-7, and HC-8 were purged prior to sampling using dedicated submersible pumps. At least one well volume was removed, and field parameters (temperature, pH, and specific conductance) were allowed to stabilize before samples were collected. Samples were collected from wells HC-1, HC-2, HC-3, and HC-6 using a depth-specific bailer because these wells are not completed with dedicated submersible pumps. The final set of field parameters and well purge volumes are presented in Appendix A.

Groundwater samples collected as part of the annual monitoring were analyzed for tritium, carbon-14 (C-14), iodine-129 (I-129), uranium isotopes, gross alpha, and mass concentrations of uranium as specified in the CADD/CAP (DOE/NNSA 2006). The frequency for analyzing samples for C-14 and I-129 was reduced to every 5 years beginning after the 2010 sampling event as specified in the short-term data acquisition plan approved by NDEP (DOE/LM 2009). Tritium is the analyte selected as an indicator of contaminant migration from the cavity due to its mobility and abundance in the first 100 years of the post-shot monitoring period. However, because of tritium's short half-life, monitoring of C-14 and I-129 is also conducted in support of long-term post-closure monitoring. Gross alpha is included in the analytical suite because

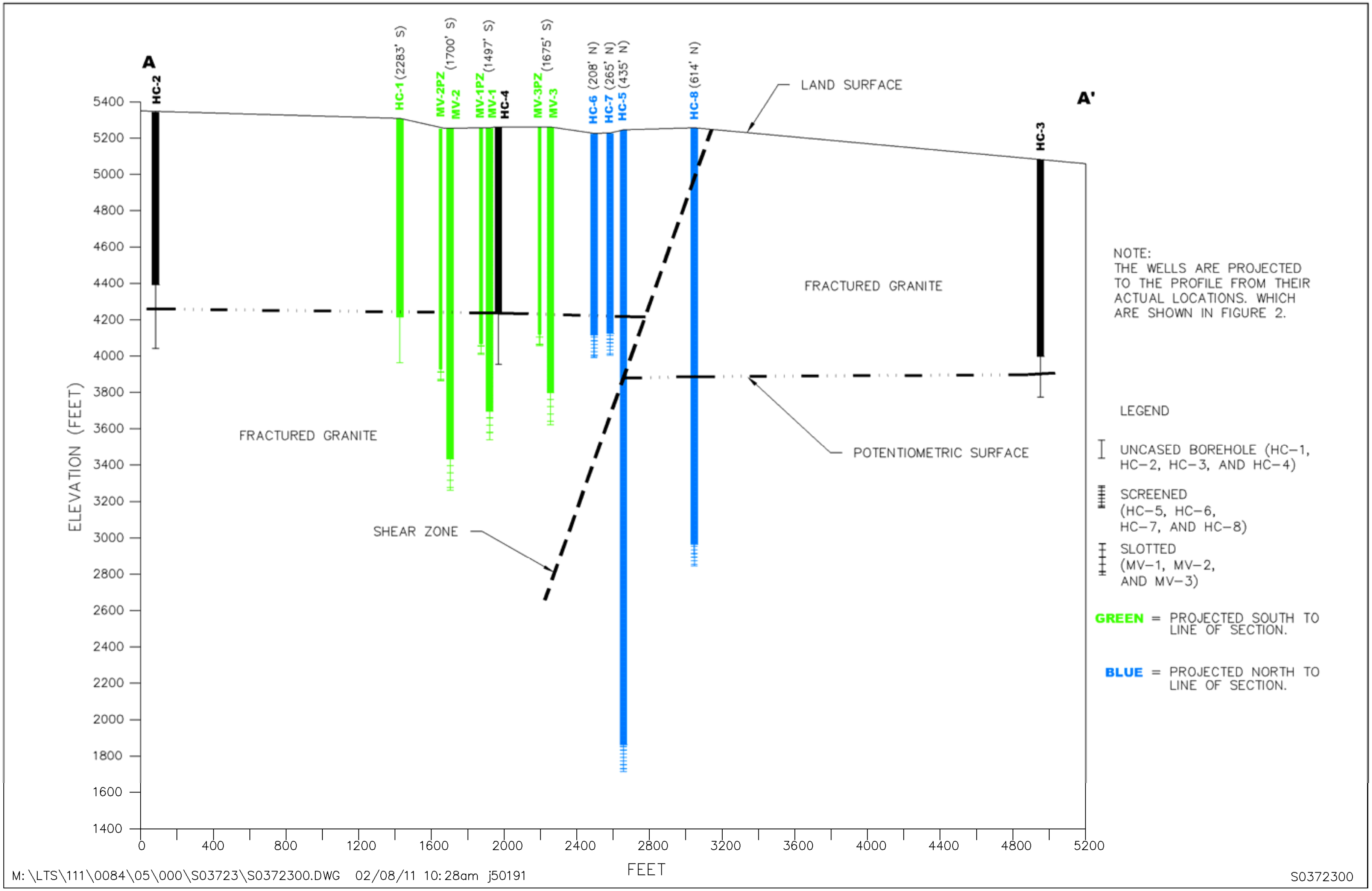

Figure 3. Cross Section A-A' Depicting Monitor Well and Shear Zone Location, Shoal, NV

Table 1. Well Construction Details and Head Data for Wells at the PSA

Well/Piezometer	TOC Elevation (ft amsl)	Water Depth (ft)[a]	Date	Elevation Water (ft amsl)[b]	Elevation TSZ (ft amsl)	Elevation BSZ (ft amsl)	Screen Length (ft)
MV-1	5,257.54	992.51	8/19/2010	4,265.03	3,684.81	3,531.00	153.81
MV-1 PZ	5,257.30	978.41	8/19/2010	4,278.89	3,919.80	3,859.80	60.00
MV-2	5,266.62	1,001.90	8/19/2010	4,264.72	3,446.75	3,275.98	170.77
MV-2 PZ[c]	5,266.51	1,156.50[d]	8/19/2010	4,110.01[d]	4,078.82	4,019.32	59.50
MV-3	5,261.50	975.68	8/19/2010	4,285.82	3,797.91	3,626.75	171.16
MV-3 PZ	5,261.17	975.28	8/19/2010	4,285.89	4,120.75	4,060.72	60.03
HC-1	5,309.21	1,063.45	8/19/2010	4,266.97	4,236.01	3,997.12	238.89
HC-2	5,347.12	1,085.75	8/19/2010	4,261.81	4,392.12	4,124.12	268.00
HC-3	5,081.52	1,180.81	8/19/2010	3,920.71	3,918.52	3,898.02	20.50
HC-4	5,260.90	1,010.91	8/19/2010	4,253.79	4,247.90	3,957.90	281.00
HC-5	5,247.37	1,368.32	8/19/2010	3,879.05	1,862.37	1,716.77	145.60
HC-6	5,228.68	969.12	8/19/2010	4,260.45	4,112.70	3,996.38	116.32
HC-7	5,229.72	969.25	8/19/2010	4,260.70	4,123.25	4,006.12	117.13
HC-8	5,259.91	1,371.15	8/19/2010	3,889.32	2,965.51	2,848.99	116.52
H-2	4,017.06[e]	110.11	8/19/2010	3,906.95	3,377.06	3,237.06	140.00
H-3	4,232.30[e]	325.63	8/19/2010	3,906.67	3,919.30	3,762.30	157.00

TOC = Top of casing (well/piezometer)
NM = Not measured
Elevation Water (TVD corrected), Water Depth (not TVD corrected)
TSZ, BSZ (top and bottom of open interval; screened, perforated, or open hole)
[a] Depth-to-water measurements not corrected for borehole deviation.
[b] Corrected for borehole deviation.
[c] Indicates that a transducer was not installed in the piezometer.
[d] Indicates the water level and/or groundwater elevation have not recovered from bailing.
[e] Indicates land surface elevation because TOC elevations are not available.

elevated concentrations of gross alpha have been detected in the past at the PSA. The MCL for gross alpha is exclusive of uranium and radon. Including uranium and uranium-isotopic analyses as part of the analytical suite provides data to demonstrate the elevated concentrations of gross alpha are from natural sources. Radon is not included in the analytical suite because it volatilizes during analysis and is an insignificant contributor to gross alpha.

The CADD/CAP established regulatory levels for site groundwater of 20,000 pCi/L tritium, 2,000 pCi/L C-14, and 1 pCi/L I-129 (DOE/NNSA 2006). These levels are not to be exceeded outside the compliance boundary, which is the modeled contaminant boundary (Figure 2). Modeling results indicate with a 95 percent certainty that groundwater will not pose a human health risk outside the contaminant/compliance boundary (Pohl and Pohlmann 2004). The MCLs for adjusted gross alpha and uranium are 15 pCi/L and 30 micrograms per liter (µg/L), respectively. These constituents are believed to be naturally elevated in groundwater in the region (see further discussion in Section 5.1).

4.2 Hydraulic Head Monitoring

Monitoring of the groundwater flow system is performed by measuring hydraulic head in the on-site wells/piezometers (MV-1 through MV-3 and HC-1 through HC-8) and off-site wells (H-2 and H-3) (Figure 2). Heads are measured every 3 hours by transducers installed in these wells/piezometers. The transducers are downloaded in the spring, as part of the annual sampling, and in the fall as part of a scheduled monitoring event and site inspection. The off-site well H-3 was recently added to the hydraulic head monitoring network. This well was previously not monitored because the water access tube associated with the submersible pump has been plugged. The water access tube and submersible pump, which has not worked for several years, were removed and a new transducer was installed in March 2010. The MV-2 piezometer has previously not been monitored because remnant drilling fluid in the piezometer tubing prevents access with a water level indicator and/or transducer. An attempt was made to redevelop the piezometer using a small diameter bailer in March 2010. The piezometer was bailed dry after removing approximately 11 gallons of drilling fluid/materials. A depth to water was obtained during the August 2010 monitoring event; however, the screened interval of the piezometer produces very little water and the water level was not fully recovered from the redevelopment, which occurred 6 months earlier (Table 1).

5.0 Monitoring Program Results

Groundwater monitoring conducted in 2010 consisted of annual sampling and hydraulic head monitoring. The monitoring program requires the measurement of seven parameters—concentrations of tritium, C-14, I-129, uranium isotopes, and gross alpha; mass concentrations of uranium, and measurements of hydraulic head as described in the CADD/CAP. Radioisotopic and concentration data are presented in Section 5.1, and head data are presented in Section 5.2.

5.1 Radioisotopic Results

Analytical results from the 2010 monitoring event indicate that all constituents in all wells are below established regulatory levels. A sample collected from well HC-4 was the only sample with tritium detected above the laboratory method detection limit. Tritium levels in well HC-4 were typically above detection limits from the mid-1990's until 2006, though some duplicate analyses were below detection limits. Tritium levels have been trending lower and were below the detection limit for the 2005 and 2007 sampling events (Figure 4). Of the two samples analyzed in 2008 (one by EPA and one by Paragon) results were above detection for one sample and below detection for the other. Results for 2010 are back to 2008 levels. The presence of tritium in HC-4 is due to its close proximity to the nuclear detonation (nearest well to the detonation, Figure 2). This is supported by the elevated level of C-14 in HC-4 compared to levels in the other monitoring wells. The elevated concentration of C-14 in well HC-4 is likely the result of its migration in the gas phase near the water table, as part of the CO2 molecule, where it dissolved into groundwater in the upper saturated zone near the detonation. Estimated activities of C-14 and I-129 are comparable to previous sampling results and continue to provide a baseline for long-term monitoring. Data used to calculate radioisotope activities for C-14 are provided in Appendix A.

Table 2 presents a summary of analytical results for C-14, I-129, tritium, uranium, and gross alpha from the sampling event in March 2010 along with the results back to 2007 for comparison. Uranium (U) mass concentrations detected in samples collected from wells MV-1 and MV-2 exceeded the MCL of 30 μg/L in 2007 but declined below that level in 2008 and have remained relatively constant since then. Wells HC-2 and HC-6 were sampled for the first time in 2010. Total uranium in HC-6 slightly exceeded the standard at 35 μg/L. HC-2 was more than four times the standard at 140 μg/L.

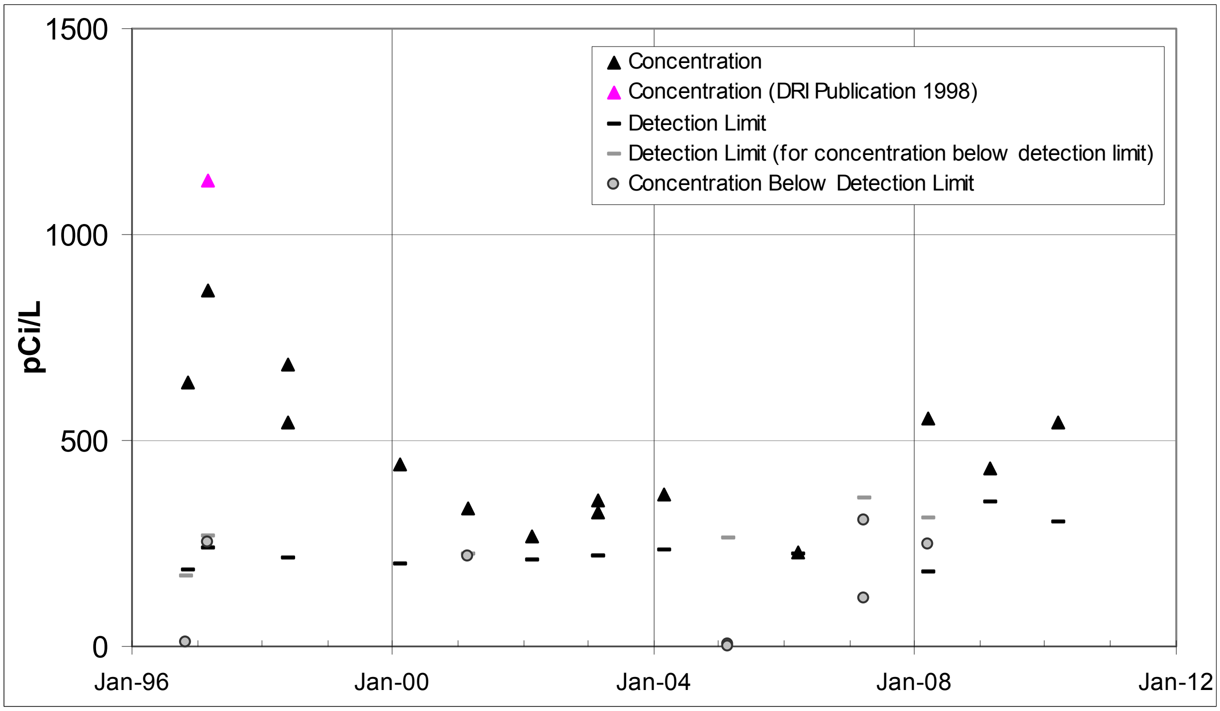

Figure 4. Time-Concentration Plot of Tritium at Well HC-4

Unadjusted gross alpha activities shown in Table 2 are below the MCL of 15 pCi/L for all samples collected during the 2010 sampling event with the exception of samples collected from wells HC-2 and HC-6. If gross alpha values for HC-2 and HC-6 are adjusted by subtracting activities of ^{234}U and ^{238}U shown in Table 3, values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity. The elevated concentrations of uranium observed in the past are believed to be naturally occurring. It has been demonstrated that ambient groundwater in the region surrounding the site is elevated in concentrations of gross alpha and uranium, among others (Bevans et al. 1998). Elevated uranium concentrations are attributed to leaching from granitic bedrock and associated sediments.

Isotopic ratios of uranium further support a natural source of uranium in groundwater as opposed to a nuclear-test-related source. Natural uranium-bearing systems typically have $^{234}U/^{238}U$ activity ratios near 1 (Cowart and Osmond 1977), which is indicative of secular equilibrium between the two isotopes. Table 3 indicates that most ratios observed in the PSA samples range from 0.91 to 1.85—consistent with a natural uranium source. Very few samples have ratios exceeding 1.2. In contrast, average estimates of radionuclides resulting from nuclear tests at the Nevada National Security Site suggest a residual source term with a $^{234}U/^{238}U$ activity ratio of approximately 56.25 (Smith 2001).

Table 2. Radioisotopic and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L, total unadjusted)
MV-1	3/21/2007	<RDL (5.83E-03) [a]	<RDL (7.3E-11)	<359	42	25.6
	3/21/2007	NA	NA	NA	41 [b]	21.5 [b]
	3/11/2008	<RDL (2.49E-02)	<RDL (19.0E-11)	<180	21	14.0
	2/26/2009	<RDL (1.95E-02)	<RDL (10.5E-11)	<350	21	12.6
	3/11/2010	<RDL (1.93E-02)	<RDL (7.8E-11)	<300	21	11.3
MV-2	3/21/2007	<RDL (1.77E-02) [a]	<RDL (8.3E-11)	<361	34	16.3
	3/21/2007	NA	NA	NA	34 [b]	17.3 [b]
	3/11/2008	<RDL (2.44E-02)	<RDL (29.5E-11)	<180	23	11.1
	2/26/2009	<RDL (2.13E-02)	NR	<360	24	12
	3/11/2010	<RDL (3.31E-02)	<RDL16.5 (E-11)	<300	21	13.8
MV-3	3/21/2007	<RDL (5.90E-03) [a]	<RDL (13.5E-11)	<357	14	10.2
	3/21/2007	NA	NA	NA	14 [b]	9.57 [b]
	3/11/2008	<RDL (1.37E-02)	<RDL (18.0E-11)	<320	3.8	2.11
	2/26/2009	<RDL (8.37E-03)	<RDL (10.7E-11)	<360	3.8	<1.5
	3/12/2010	<RDL (1.29E-02)	<RDL (6.5E-11)	<300	4.2	2.63
HC-1	3/21/2007	<RDL (1.52E-02) [a]	<RDL (9.6E-11)	<355	3.3	3.9
	3/21/2007	NA	NA	NA	3.4 [b]	4.46 [b]
	3/11/2008	<RDL (2.35E-02)	<RDL (4.9E-11)	<320	4.8	12.5
	2/26/2009	<RDL (2.01E-02)	NR	<360	1.4	<1.4
	3/24/2010	<RDL (3.18E-02)	<RDL (11.9E-11)	<310	3.3	4.93
HC-2	3/24/2010	<RDL(1.90E-02)	<RDL (2.5E-11)	<300	140	63.8
HC-3	3/24/2010	<RDL (2.37E-02)	<RDL (541E-11)	<300	4.3	2.57
HC-4	3/21/2007	<RDL (0.565) [a]	<RDL (32.4E-11)	<359	0.75	1.41
	3/21/2007	NA	NA	NA	0.85 [b]	1.93 [b]
	3/21/2007 [c]	<RDL (0.436) [a]	<RDL (34.2E-11)	<359	0.69	1.75
	3/21/2007 [c]	NA	NA	NA	0.81 [b]	<0.876 [b]
	3/11/2008	<RDL (2.06)	<RDL (21.5E-11)	555	4.5	2.88
	2/26/2009	<RDL (3.20)	<RDL (0.6E-11)	434	2.0	<1.4
	3/11/2010	<RDL (2.93)	<RDL (38.7E-11)	544	6.4	1.79[b]
HC-5	3/11/2010	<RDL (5.11E-03)	<RDL (1.1E-11)	<300	0.48	<1.5
HC-6	3/24/2010	<RDL (1.14E-02)	<RDL (5.6E-11)	<300	35	25.7
HC-7	3/11/2010	<RDL (5.31E-03)	<RDL (3.0E-11)	<300	7.4	5.77
HC-8	3/10/2010	<RDL (9.63E-03)	<RDL (1.3E-11)	<300	0.25	<1.3

[a] Estimated based on sample volume of 200 milliliters for 2007 samples.
[b] Indicates the sample was filtered.
[c] Indicates a duplicate sample.
<RDL = below required detection limit with laboratory result in parentheses; RDL is 5 pCi/L for C-14, 0.1 pCi/L for I-129, 300 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006)
NR = not run, because sample bottle was broken during shipment to the laboratory
NA = not applicable

Table 3. Uranium Isotopic Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	U^{234}/U^{238}
MV-1	3/21/2007	16.8[a]	14.2[a]	1.18[a]
	3/21/2007	15.4	12.6	1.22
	3/11/2008	7.35	6.2	1.19
	2/26/2009	8.75	6.98	1.25
	3/11/2010	9.06	7.64	1.19
MV-2	3/21/2007	13.6[a]	11.4[a]	1.19[a]
	3/21/2007	13.2	11.7	1.13
	3/11/2008	8.95	7.89	1.13
	2/26/2009	8.64	6.7	1.29
	3/11/2010	9.66	8.32	1.16
MV-3	3/21/2007	4.64[a]	4.37[a]	1.06[a]
	3/21/2007	5.47	4.68	1.17
	3/11/2008	1.47	1.17	1.25
	2/26/2009	1.33	0.998	1.33
	3/12/2010	1.7	1.42	1.20
HC-1	3/21/2007	1.28[a]	1.19[a]	1.08[a]
	3/21/2007	1.4	1.19	1.18
	3/11/2008	1.84	1.51	1.21
	2/26/2009	0.572	0.385	1.49
	3/24/2010	1.24	1.05	1.18
HC-2	3/24/2010	45.1	45.3	0.996
HC-3	3/24/2010	1.16	1.21	0.96
HC-4	3/21/2007	0.349[a]	0.308[a]	1.12[a]
	3/21/2007[b]	0.313[a]	0.33[a]	0.95[a]
	3/21/2007	0.293	0.305	0.96
	3/21/2007[b]	0.31	0.336	0.92
	3/11/2008	1.53	1.63	0.94
	2/26/2009	0.654	0.722	0.91
	3/11/2010	2.27[a]	1.95[a]	1.16[a]
HC-5	3/11/2010	0.295	0.173	1.71
HC-6	3/24/2010	14.4	12.2	1.18
HC-7	3/11/2010	3.43	3.08	1.11
HC-8	3/10/2010	0.187	0.101	1.85

[a] Indicates the sample was filtered.
[b] Indicates a duplicate sample.

5.2 Hydraulic Head Results

Hydrographs of hydraulic head data from site wells and piezometers are shown in Figure 5, Figure 6, and Figure 7. Head data collected using a water level tape appear as individual symbols, and data collected with transducers appear as lines due to the recording frequency of every few hours. The hydrographs are grouped according to the location of the open interval of each well relative to the north-northeast trending shear zone that transects the site. Monitoring locations west of the shear zone include the MV-1, MV-2, and MV-3 wells and piezometers, and wells HC-1, HC-2, HC-4, HC-6, and HC-7 (Figure 5). Head levels east of the shear zone are monitored by wells HC-3, HC-5, and HC-8 (Figure 6). Monitoring locations in Fourmile Flat (west of the site) include the H-2 and H-3 wells (Figure 7). Head levels in wells on-site and west of the shear zone (detonation side) continue to rise at a rate of approximately 1.2 to 2.4 ft per year and are generally 300 to 400 ft higher than those in wells east of the shear zone and in Fairview Valley.

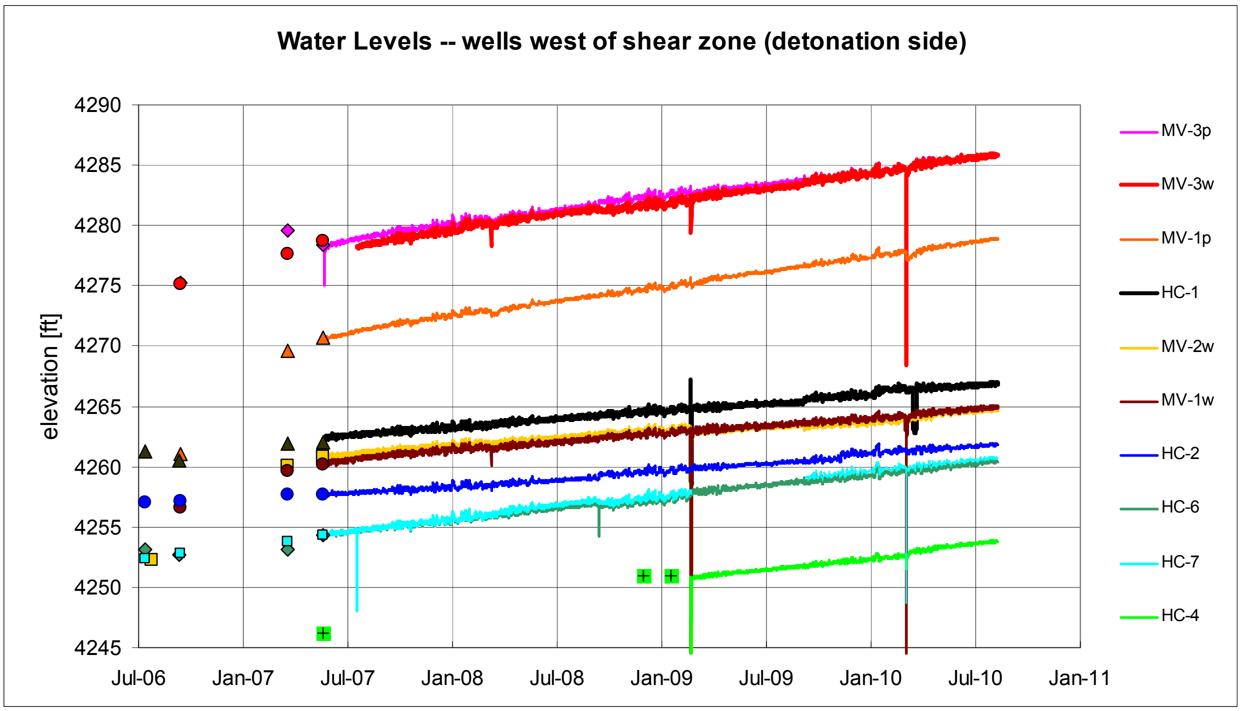

Figure 5. Hydrographs for Wells West of the Shear Zone

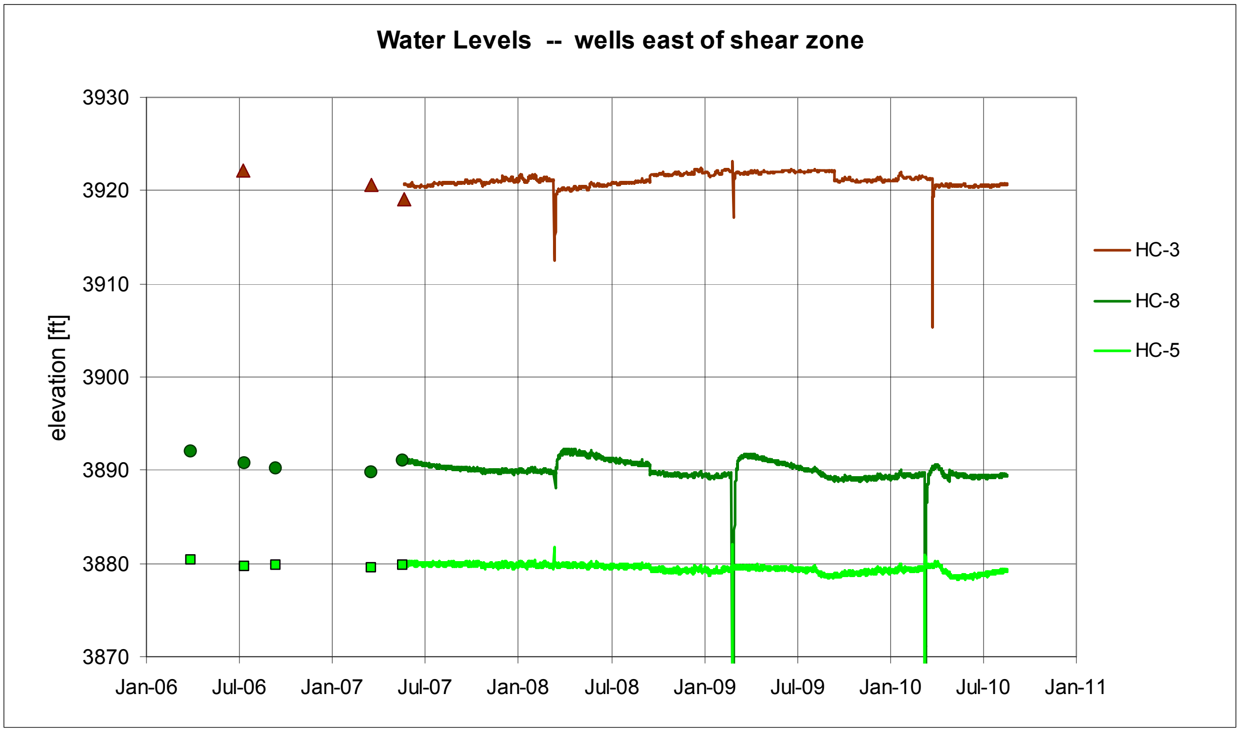

Figure 6. Hydrographs for Wells East of the Shear Zone

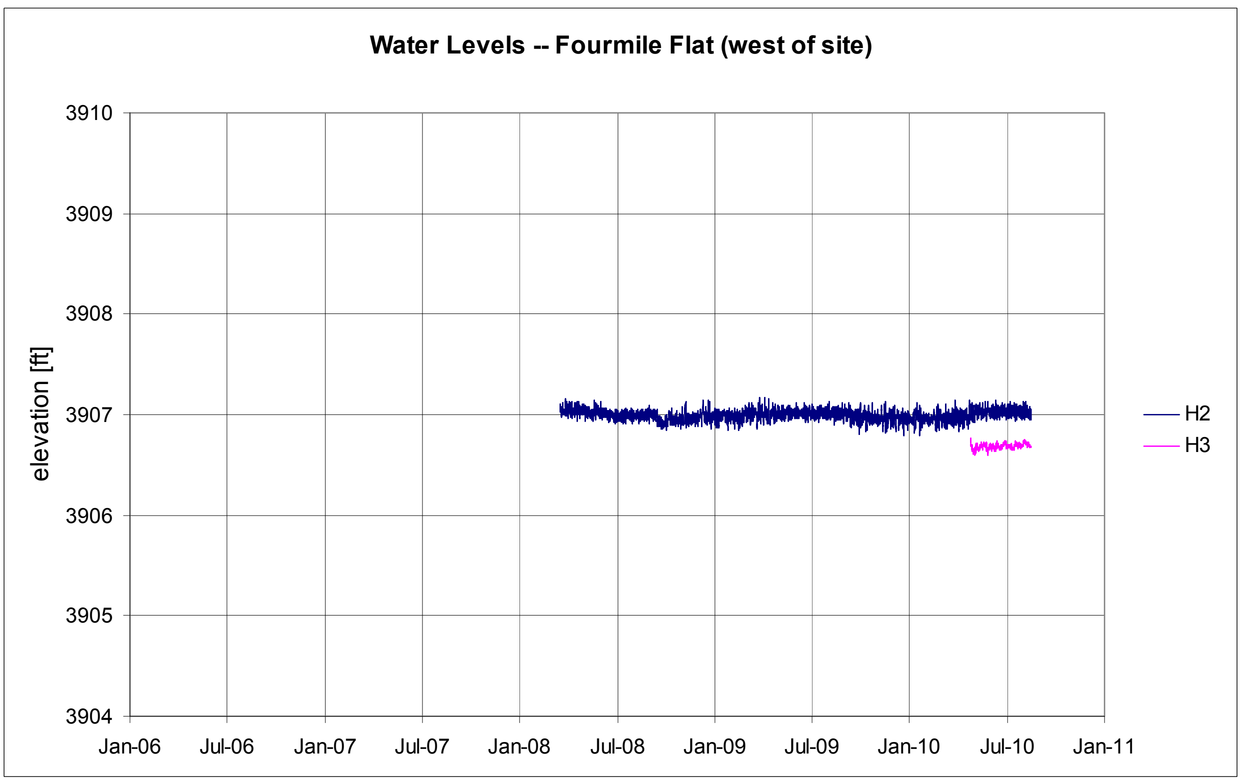

Figure 7. Hydrographs for Wells in Fourmile Flat

6.0 Summary

Sample analytical results from monitoring wells sampled in 2010 indicate that concentrations of tritium, C-14, and I-129 in groundwater remain below established regulatory levels. Analytical results from well HC-4 have a nuclear-test-related signature for C-14; however, concentrations are below the established regulatory level of 2,000 pCi/L. The concentration of tritium in the sample collected from well HC-4 was above the laboratory method detection limit but below the high of 1,130 pCi/L that was reported in 1998 (Pohll et al. 1998) and is below the tritium MCL of 20,000 pCi/L. Uranium and unadjusted gross alpha in all wells were below the MCL in 2010; with the exception of samples collected from wells HC-2 and HC-6. If the gross alpha values obtained from these samples are adjusted by subtracting activities of ^{234}U and ^{238}U the values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity. Isotopic ratios of uranium obtained from these samples further support a natural source of uranium in groundwater as opposed to a nuclear-test-related source. An evaluation of the stability of the hydrologic system will be made after data have been collected over a longer period of time because heads on-site and west of the shear zone continue to rise and have yet to stabilize.

7.0 References

AEC (U.S. Atomic Energy Commission/Nevada Operations Office), 1964. *Project Manager's Report, Project Shoal*, NVO-11, Las Vegas, Nevada, May.

AEC (U.S. Atomic Energy Commission/Nevada Operations Office), 1970. *Site Disposal Report Fallon Nuclear Test Site (Shoal) Churchill County, Nevada*, NVO-73, Las Vegas, Nevada.

Beal, L.H., S.E. Jerome, I. Lutsey, R.H. Olson, and J.H Schilling, 1964. "Geology of the Sand Springs Range," *Nevada Bureau of Mines and Geology, Final Report, Geological, Geophysical, Chemical and Hydrological Investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Nevada, for Shoal Event, Project Shade, Vela Uniform Program*, United States Atomic Energy Commission.

Bevans, H.E., M.S. Lico, and S.J. Lawrence, 1998. *Water quality in the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California, 1992–96*, Circular 1170, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada.

Cowart, J.B., and J.K. Osmond, 1977. "Uranium Isotopes in Groundwater: Their Use in Prospecting for Sandstone-type Uranium Deposits," *Journal of Geochemical Exploration*, 8: 365−379.

DOE/LM (U.S. Department of Energy, Office of Legacy Management), 2009. Final Path Forward: *Short-Term Data Acquisition Plan for New Closure Strategy Subsurface Corrective Action Unit 447, Project Shoal Area, Nevada*, Grand Junction, Colorado, November.

DOE/NNSA (U.S. Department of Energy, National Nuclear Security Administration), 2006. *Corrective Action Decision Document/Corrective Action Plan for Corrective Action Unit 447: Project Shoal Area, Subsurface*, *Nevada*, DOE/NV-1025, Rev. 3, Las Vegas, Nevada.

DOE/NV (U.S. Department of Energy/Nevada Operations Office), 1998. *Closure Report for Corrective Action Unit 416: Project Shoal Area*, DOE/NV-11718-179-Rev. 0, Las Vegas, Nevada, January.

Hazleton-Nuclear Science Corporation, 1965. *Vela Uniform Project Shoal Fallon, Nevada*, VUF-1014, Post-Shot Hydrologic Safety, October.

NDEP (Nevada Division of Environmental Protection), 1998. Letter of Acceptance of Closure Report for CAU 416, Project Shoal Area Surface, Nevada Division of Environmental Protection, Las Vegas, Nevada, February.

Pohll, G, J. Chapman, A. Hassan, C. Papelis, R. Andricevic, and C. Shirley, 1998. *Evaluation of Groundwater Flow and Transport at the Shoal Underground Nuclear Test: An Interim Report*, Publication No. 45162, DOE/NV/11508-35, UC-703, July.

Pohll, G., and K. Pohlmann, 2004. *Contaminant Boundary at the Shoal Underground Nuclear Test*, Letter Report, DOE/NV-993, August.

Rosemary W.H. Carroll, Karl Pohlmann, Greg Pohll, and Todd Mihevc, 2001. *Investigation of Hydraulic Properties and Groundwater Levels Related to the Shear Zone at the Project Shoal Site*, Publication No. 45183, DOE/NV/13609-12, September.

Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites, LMS/PLN/S04351, continually updated, prepared by S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction, Colorado.

Smith, D.K., 2001. *Unclassified Radiological Source Term for the Nevada Test Site Areas 19 and 20*, URCL-ID-141706. Lawrence Livermore National Laboratory, Livermore, California.

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Appendix A

Carbon-14 Calculation Data and Well Purge Data

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Table A−1. Monitor Well Purge Data

Well	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (µmhos/cm)
MV-1	3/11/2010	930	22.2	7.70	727
			22.2	7.67	722
			22.2	7.67	730
MV-2	3/11/2010	1240	22.4	7.73	492
			22.4	7.69	494
			22.5	7.65	497
MV-3	3/12/2010	840	21.8	7.66	750
			21.8	7.65	753
			21.9	7.72	753
HC-1	3/24/2010	na	19.2	--	498
HC-2	3/24/2010	na	18.7	--	667
HC-3	3/24/2010	na	24.9	--	550
HC-4	3/11/2010	350	21.0	6.90	742
			21.1	6.91	759
			21.2	6.89	767
HC-5	3/11/2010	5180	29.7	7.86	977
			29.7	7.87	977
			29.7	7.85	977
HC-6	3/24/2010	na	21.1	7.22	965
HC-7	3/11/2010	320	19.3	8.11	1071
			20.1	8.06	1062
			21.1	8.03	1080
HC-8	3/10/2010	1760	27.7	7.81	829
			27.6	7.84	829
			27.6	7.82	830

s.u. = Standard Unit
µmhos/cm = micromhos per centimeter
na= not applicable; sample collected with depth-specific bailer because well is not equipped with submersible pump.
-- = indicates no result because pH meter not working.

Table A−2. Carbon-14 Radioisotope Calculation Data

Well ID	Sample Date	Mass Concentration C (mg)	Fraction mc	±1 s	pCi/L[a]
HC-1	3/24/2010	13.8	0.3760	0.0021	3.18E-02
HC-2	3/24/2010	12.6	0.2457	0.0018	1.90E-02
HC-3	3/24/2010	15.8	0.2449	0.0018	2.37E-02
HC-4	3/11/2010	19.6	24.3610	0.077	2.93E+00
HC-5	3/11/2010	9.5	0.0876	0.0013	5.11E-03
HC-6	3/24/2010	10.6	0.1749	0.0015	1.14E-02
HC-7	3/11/2010	7.9	0.1096	0.0013	5.31E-03
HC-8	3/10/2010	12.8	0.1226	0.0014	9.63E-03
MV-1	3/11/2010	13.4	0.2352	0.0017	1.93E-02
MV-2	3/11/2010	16.4	0.3290	0.0020	3.31E-02
MV-3	3/12/2010	9.6	0.2196	0.0017	1.29E-02

[a] Modern C-14 standard at 1950 AD has activity of 13.6 dpm/gram C = 2.27 × $^{-4}$ dps/mg C.
1 µCi = 3.7 × 10^4 dps; therefore, modern C-14 standard at 1950 AD has activity of 6.135 × 10^{-9} µCi/mg.
pmc = percent modern carbon; mc = modern carbon; s = standard deviation

Example activity calculation (HC-1)

$$13.8\,\frac{mg\ C}{1\,L}\left(0.2457\,\frac{mg\ MC}{mg\ C}\right)\left(6.135*10^{-9}\ \frac{\mu Ci}{mg\ MC}\right)\left(1*10^{6}\ \frac{pCi}{\mu Ci}\right)=3.18*10^{-2}\ \ \frac{pCi}{L}$$

Appendix B

NDEP Correspondence with Record of Review and Response to Comments

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STATE OF NEVADA
Department of Conservation & Natural Resources
DIVISION OF ENVIRONMENTAL PROTECTION
NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations
Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
Colleen Cripps, Ph.D., Administrator

January 12, 2011

Mr. Mark Kautsky
Site Manager
U.S. Department of Energy
Office of Legacy Management
2597 B ¾ Road
Grand Junction, CO 81503

RE: Draft 2010 Groundwater Monitoring Report, Project Shoal Area, Corrective Action Unit 447
November 2010
Federal Facility Agreement and Consent Order

Dear Mr. Kautsky:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities staff (NDEP) has received and reviewed the report titled "Draft *2010 Groundwater Monitoring Report Project Shoal Area, Corrective Action Unit* 447, *November 2010*," dated December 20, 2010. The NDEP has the following comments:

1. Page 1, Section 1.0, Third Sentence and Page 3, Section 2.1, Last Paragraph, Second Sentence: The FFACO citation should be "(FFACO 1996, as amended March 2010) to reflect the version that is currently in use.

2. Page 9, Figure 4: Two different colored lines for "Detection Limit" are shown in the Figure and its Legend. Page 8, Section 5.1, First Paragraph, Fifth Sentence indicates that two samples were analyzed for tritium in 2008, one by EPA and one by Paragon. Therefore, the assumption is that one detection limit on the Figure is for EPA and the other is for Paragon. If this assumption is correct, then the Figure Legend needs to indicate which detection limit corresponds to which laboratory. If this is not a correct assumption, then some other explanation is needed for the different colored lines.

3. Page 9, Section 5.1, Last Paragraph, Last Sentence: "Nevada Test Site" should be changed to "Nevada National Security Site" to reflect the recent name change.

4. Page 14, Section 6.0: In regards to the last sentence, because the hydraulic heads are still changing as stated in Section 5.2, an additional phrase or sentence specifically indicating this fact would help clarify the use of "stability of the hydrologic system."

If you have questions regarding these comments, please contact Chris Andres at (702) 486-2850, ext. 232.

Sincerely,

T. H. Murphy
Chief
Bureau of Federal Facilities

THM/CDA: *cda*

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Record of Review

Due Date	Review No.	Project	Type of Review
2/15/2011	1	Legacy Managment	Technical

Document Title and\or Number and Revision
2010 Groundwater Monitoring Report Project Shoal Area, Corrective Action Unit 447 (S07117)

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Reviewers' Recommendation

- ☐ Release Without Comment
- ☐ Consider Comments
- ☐ Resolve Comments and Reroute for Review

Signature of Reviewer and Date

- ☒ Comments Have Been Addressed — [signature] 2011.02.17 07:26:50 -07'00'

Signature of Author and Date

- ☒ Comment Resolution Satisfactory
- ☐ Comment Resolution Unsatisfactory

Christi Andres 2/17/11

Signature of Reviewer and Date

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
1	Page 1, Section 1.0, Third Sentence and Page 3, Section 2.1, Last Paragraph, Second Sentence: The FFACO citation should be "(FFACO 1996, as amended March 2010)" to reflect the version that is currently in use.	Y	1	The change was made as requested.
2	Page 9, Figure 4: Two different colored lines for "Detection Limit" are shown in the Figure and its Legend. Page 8, Section 5.1, First Paragraph, Fifth Sentence indicates that two samples were analyzed for tritium in 2008, one by EPA and one by Paragon. Therefore, the assumption is that one detection limit on the Figure is for EPA and the other is for Paragon. If this assumption is correct, then the Figure Legend needs to indicate which detection limit corresponds to which laboratory. If this is not a correct assumption, then some other explanation is needed for the different colored lines.	Y	2	Two different colored lines were used for the detection limit symbol on Figure 4 to represent different detection limits for samples collected on the same day (duplicate or split sample). The detection limit identified as a gray line corresponds to the sample result that is below the detection limit. The detection limit identified as a black line corresponds to the sample result that is above the detection limit. The Figure 4 Legend has been revised to provide this clarification.
3	Page 9, Section 5.1, Last Paragraph, Last Sentence: "Nevada Test Site" should be changed to "Nevada National Security Site" to reflect the recent name change.	Y	3	The change was made as requested.

Record of Review (continuation)

Review No.	Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
4	Page 14, Section 6.0: In regards to the last sentence, because the hydraulic heads are still changing as stated in Section 5.2, an additional phrase or sentence specifically indicating this fact would help clarify the use of "stability of the hydrologic system".	Y	4	The last sentence of the paragraph has been revised as follows: "An evaluation of the stability of the hydrologic system will be made after data have been collected over a longer period of time because heads on-site and west of the shear zone continue to rise and have yet to stabilize."

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