LMS/CNT/S05935

2009 Groundwater Monitoring Report Central Nevada Test Area, Corrective Action Unit 443

September 2010

U.S. DEPARTMENT OF ENERGY | Legacy Management

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1.0 Introduction

This report presents the 2009 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) for the Central Nevada Test Area (CNTA) Subsurface Corrective Action Unit (CAU) 443. Responsibility for the environmental site restoration of CNTA 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 443 are conducted in accordance with the Federal Facility Agreement and Consent Order entered into by DOE, the U.S. Department of Defense, and the State of Nevada. The corrective action strategy for the site includes proof-of-concept monitoring in support of site closure. This report summarizes investigation activities associated with CAU 443 that were conducted at the site from October 2008 through December 2009. It also represents the first year of the enhanced monitoring network and begins the new 5-year proof-of-concept monitoring period that is intended to validate the compliance boundary.

2.0 Site Location and Background

CNTA is north of U.S. Highway 6, approximately 30 miles north of Warm Springs in Nye County, Nevada (Figure 1). The U.S. Atomic Energy Commission (predecessor to DOE) acquired CNTA in the early 1960s to develop sites for underground nuclear testing that could serve as alternatives to the Nevada Test Site. Three emplacement boreholes—UC-1, UC-3, and UC-4—were drilled at CNTA for underground nuclear weapons testing. The initial underground nuclear test, Project Faultless, was conducted in borehole UC-1 at a depth of 3,199 feet (ft) (975 meters) below ground surface on January 19, 1968. The yield of the Project Faultless test was estimated to be 0.2 to 1 megaton. The test resulted in a down-dropped fault block visible at land surface (Figure 2). No further nuclear testing was conducted at CNTA, and the site was decommissioned as a testing facility in 1973.

2.1 Summary of Corrective Action Activities

Surface and subsurface contamination resulted from the underground nuclear test at CNTA. Contamination at the surface was identified as CAU 417. Surface restoration was completed in 1999, and the remediation activities are described in the *Closure Report for Corrective Action Unit 417: Central Nevada Test Area Surface, Nevada* (DOE 2001). Contamination in the subsurface is identified as CAU 443. The corrective action process for the subsurface CAU 443 has not yet been completed. Site restoration activities associated with CAU 443 are summarized in the remainder of this section.

A Corrective Action Investigation Plan was developed and approved for CAU 443 in 1999. The objectives outlined in that document are provided below:

- Determine the characteristics of the groundwater flow system, sources of contamination, and transport processes, to acceptable levels of uncertainty;
- Develop a credible numerical model of groundwater flow and contaminant transport for the UC-1 Subsurface Corrective Action Site and downgradient areas; and
- Develop stochastic predictions of the contaminant boundary, at an acceptable level of uncertainty (DOE 1998).

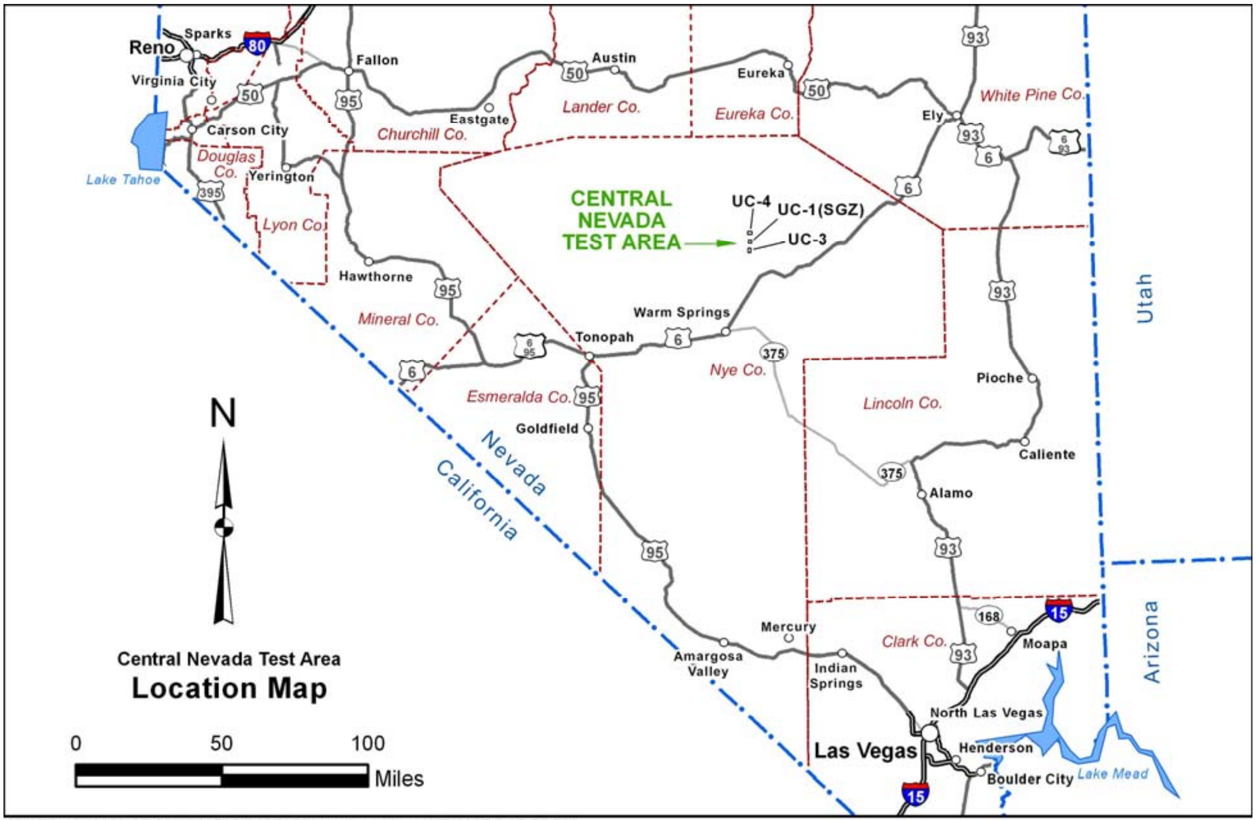

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Figure 1. Central Nevada Test Area Location Map

These objectives were accomplished by conducting a corrective action investigation. As part of the investigation, site data were used to develop a numerical flow and transport model, which was then used to calculate a site contaminant boundary (Pohlmann et al. 1999, Pohll et al. 2003).

Results of the corrective action investigation and the corrective action evaluation were presented in the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) (DOE 2004). Modeling indicated that groundwater velocities at the site were very low (due to very low hydraulic conductivities) and predicted that the contaminant boundary would be very small (within two to three radii of the cavity from the working point [DOE 2004]). A compliance boundary was negotiated that factored in modeling results and associated uncertainties, especially with respect to the potential effects of the nuclear test within the down-dropped fault block. The compliance boundary corresponds approximately to the surface expression of the fault block and is generally contained within the land withdrawal boundary (Figure 2). The preferred corrective action alternative selected in the CADD/CAP was proof-of-concept and monitoring with institutional controls.

Three wells (MV-1, MV-2, and MV-3) were installed in 2005 to monitor radioisotopic concentrations and hydraulic heads in groundwater and to validate the flow and transport model. Hydraulic heads observed in these wells were in significant disagreement with those predicted by the groundwater flow model, which meant that the model could not be validated. Instead of additional modeling, DOE proposed a new corrective action strategy in which the monitoring

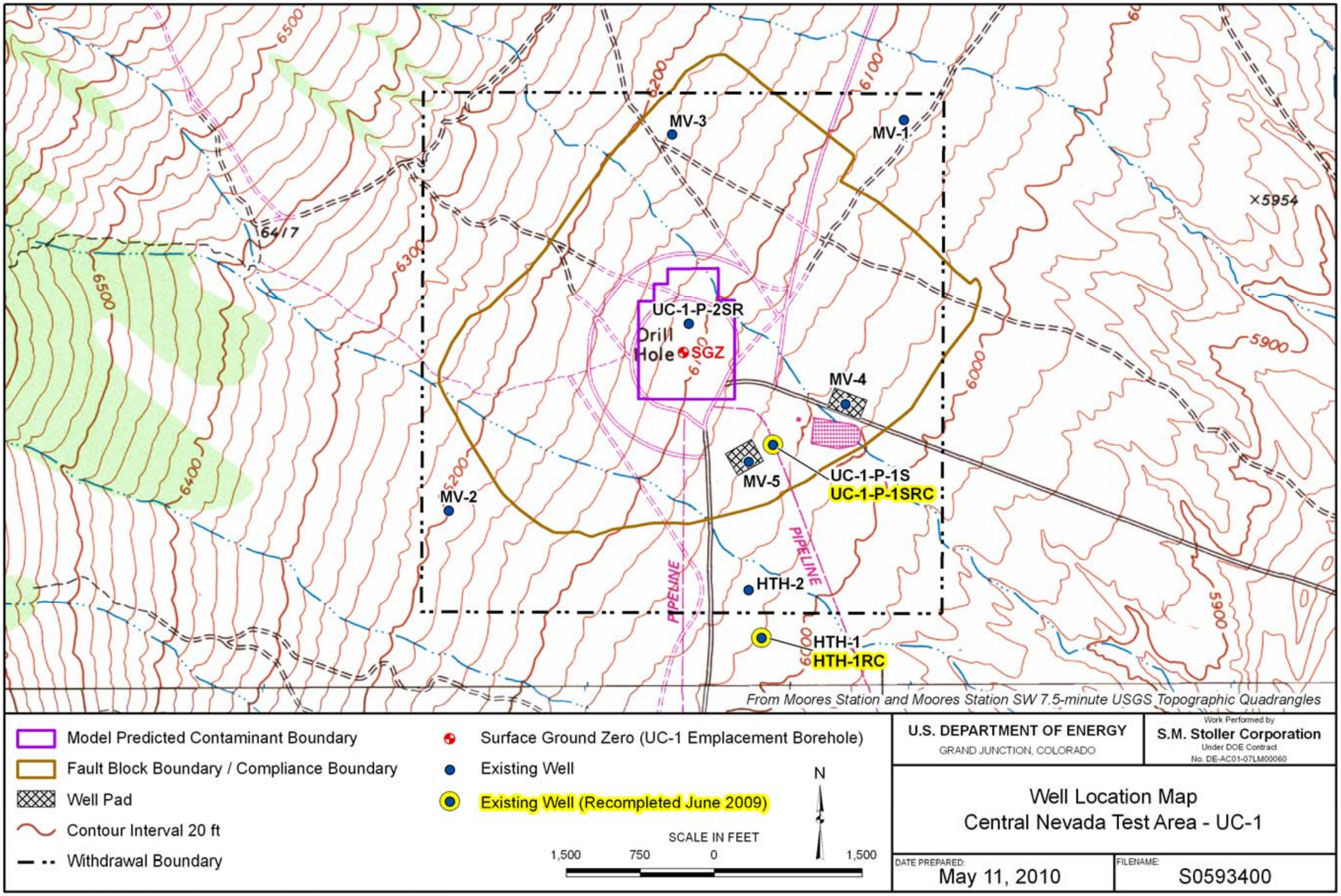

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Figure 2. Location Map of Monitoring Wells and Boundaries at the CNTA

network would be enhanced by installing two new monitoring wells (MV-4 and MV-5), recompleting the existing wells HTH-1 (volcanic section) and UC-1-P-1S (upper alluvium), and initiating a new 5-year proof-of-concept monitoring period to validate the compliance boundary (DOE 2007). The revised approach is described in a CADD/CAP addendum (DOE 2008a) that was approved by the Nevada Department of Environmental Protection (NDEP 2008).

The new corrective action strategy was designed to enhance the monitoring of the alluvial aquifer. The alluvial aquifer was previously not monitored except for water levels in the upper piezometers of wells MV-1, MV-2, and MV-3. Hydraulic heads from different depths at these locations (upper piezometer, lower piezometer, and well) indicate that the most likely transport direction from the UC-1 detonation zone is down, toward densely welded tuff units below the detonation cavity. The well network was designed to monitor this most likely potential transport pathway. However, given the potential for processes like prompt injection and convective mixing in the nuclear chimney, migration into the alluvial aquifer cannot be ruled out. Alluvial wells are typically more productive than those in the deeper volcanic section, making the alluvial aquifer the most likely source for future groundwater development and, therefore, the most likely access path to potential receptors.

Two wells (MV-4 and MV-5) were installed, and two existing wells (HTH-1 and UC-1-P-1S) were recompleted in 2009 for the dual purposes of monitoring the alluvial aquifer and validating the compliance boundary at the site. The MV-4 and MV-5 wells were designed and positioned not only to monitor for potential contaminant migration in the alluvial aquifer, but also to confirm that the southeast bounding graben fault acts as a flow barrier. The wells were drilled in locations where they would penetrate the downthrown block within the graben, and cross the fault into the upthrown block outside the graben. The wells were dually completed with a piezometer in the shallow alluvial aquifer within the graben (downthrown block) and a well in the lower alluvial aquifer outside the graben (upthrown block). The wells were completed with dedicated electric submersible pumps for collecting groundwater samples and aquifer testing. Monitoring of the existing wells MV-1, MV-2, and MV-3 was also enhanced in 2009 by removing the electric submersible pumps and installing low-flow bladder pumps.

Well UC-1-P-1S (“P” – post-shot hole, “S” – substitute hole, surface location was moved so not a sidetrack) was recompleted to provide a reliable monitoring location within the upper alluvial aquifer inside the graben (downthrown block). The recompleted well UC-1-P-1SRC (“RC” – recompleted) included the installation of an electric submersible pump for collecting groundwater samples. Well HTH-1 was recompleted with two piezometers (upper and lower alluvial aquifer) and a well (upper volcanic section) to allow the monitoring of three distinct hydrostratigraphic units at this location. Hydraulic head data from the well and piezometers can be used to determine the vertical flow direction within the alluvial aquifer and between the upper volcanic section and lower alluvial aquifer. The horizontal flow direction in the lower alluvial aquifer southeast of the graben can be estimated using head data from the HTH-1 lower piezometer along with head data from the MV-4 and MV-5 wells. A low-flow bladder pump was installed in the HTH-1RC (“RC” – recompleted) well for collecting water samples from the volcanic section south of the detonation. Initial monitoring results from HTH-1RC support a previous identification (based on flow logging) of an upward hydraulic gradient from the volcanic section to the alluvium. Refer to Figure 2 for a map view of the locations included in the enhanced monitoring network.

3.0 Geologic and Hydrologic Setting

CNTA is in Hot Creek Valley (Figure 3), a north-south trending graben that is 68 miles long and located in the Basin and Range physiographic province. Hot Creek Valley varies in width from 5 to 19 miles and contains two major stratigraphic units—a thick sequence of Quaternary- and Tertiary-age alluvial deposits (alluvium) underlain by a thick section of Tertiary-age volcanic rocks (volcanics). Log information from wells MV-1, MV-2, and MV-3 indicates that the thickness of the alluvium in the vicinity of UC-1 (location of the Faultless test) ranges from 1,960 ft to 2,410 ft. The Tertiary volcanics below the alluvium include tuffaceous sediments, welded and nonwelded tuffs, and rhyolite lavas.

The Faultless test took place in the very low permeability volcanic section, creating a cavity and a subsequent collapse chimney that extends into the overlying alluvium. The water levels in reentry well UC-1-P-2SR ("P" – post-shot hole, "SR" – re-sidetrack hole), drilled into the chimney, continue to exhibit a recovery curve from the dewatering effects of the detonation (Figure 4). The water level has increased over 1800 ft in the last forty years and about 15 ft in 2009. Well UC-1-P-2SR was drilled a few weeks after the detonation in 1968 so no pre-detonation water levels are available. It was perforated from 1148 – 2790 ft below ground surface and water levels will apparently rise to at least the elevation of the alluvial aquifer water level in this region (to ~5765 – 5770 ft above mean sea level or another 180 ft from the elevation of 5585 ft measured in late 2009). The depressed water levels in and near the test cavity inhibit the movement of contamination horizontally and vertically away from the detonation zone. As previously mentioned, the most likely migration path for contamination moving away from the detonation zone is down toward more permeable densely welded tuff units. At the MV-1, MV-2, and MV-3 locations, densely welded tuff units were thinner and less permeable than originally expected. Hydraulic head measurements in wells MV-1, MV-2, and MV-3 suggest that the flow direction in the volcanics below the detonation zone is to the north-northeast.

4.0 Monitoring Objectives and Activities

The monitoring network at CNTA consists of wells and piezometers in MV-1, MV-2, MV-3, MV-4, MV-5, HTH-1RC, HTH-2, and UC-1-P-1SRC (Table 1). The monitoring activities as specified in the CADD/CAP addendum (DOE 2008a) include the collection of hydraulic head data and groundwater samples for radioisotopic analyses. The two major objectives of the annual monitoring program are to (1) detect any migration of contaminants from the detonation zone and (2) ensure the overall stability (quasi-steady state) of the groundwater flow system. The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2008b) is used to guide quality assurance and quality control of the annual monitoring. Table 1 lists the wells and piezometers that comprise the monitoring network along with the screened interval elevations, screened geologic unit, and the most recent water level data. Piezometers are distinguished from the wells at these monitoring locations with a "PZ" subscript. For locations with two piezometers, "UPZ" and "LPZ" are used to denote the upper piezometer and lower piezometer.

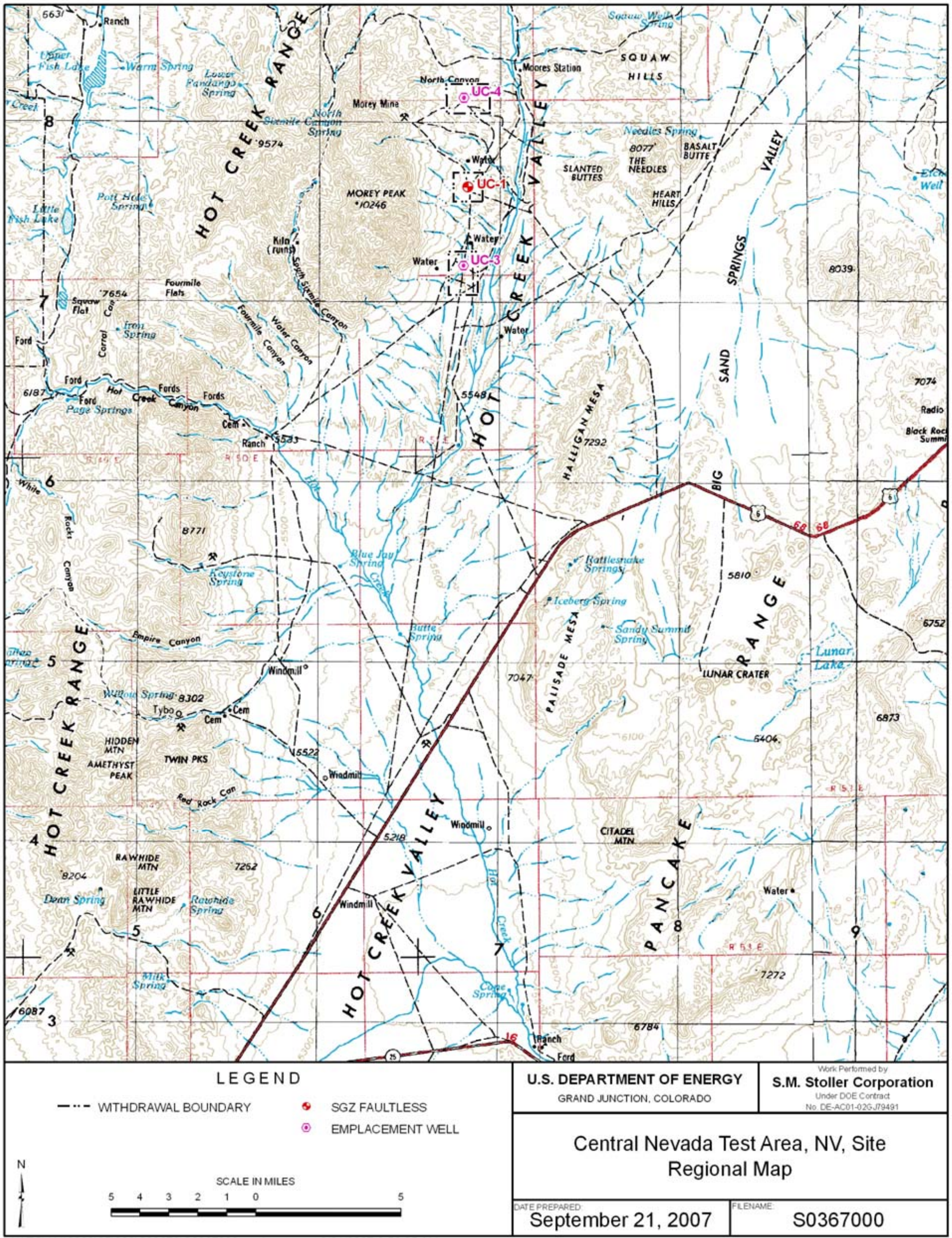

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Figure 3. Physiographic Features Near the Central Nevada Test Area

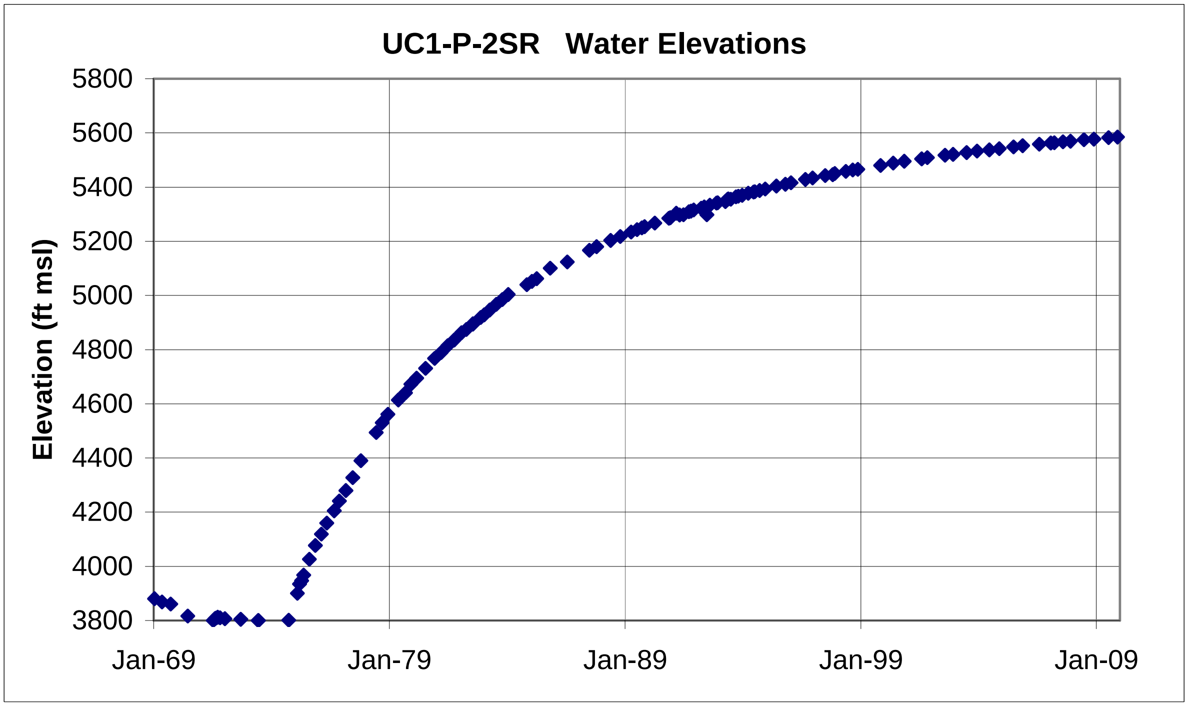

Figure 4. Water Elevations in Reentry Well UC-1-P-2SR (http://nevada.usgs.gov/doe_nv/sitepage_temp.cfm?site_id=383806116125951)

Table 1. Construction and 2009 Hydraulic Head Data for Wells in the CNTA Monitoring Network

Well/ Piezometer	**TSZ Elevation[a] (ft)**	**BSZ Elevation[a] (ft)**	**Geologic Unit**	**TOC Elevation[a] (ft)**	**Date**	**Water Depth (ft)**	**Water Level Elevation[a] (ft)**
MV-1UPZ	5,190.19	5,130.19	Alluvium	6,069.94	12/5/2009	317.18	5752.76
MV-1LPZ	3,067.19	3,007.19	Volcanics	6,069.88	12/5/2009	46.40	6023.48
MV-1	2,319.19	2,159.63	Volcanics	6,070.54	12/5/2009	506.85	5563.69
MV-2UPZ	5,229.73	5,179.73	Alluvium	6,190.62	12/5/2009	407.33	5783.29
MV-2LPZ	2,643.23	2,583.23	Volcanics	6,190.35	12/5/2009	386.34	5804.01
MV-2	3,150.24	2,987.49	Volcanics	6,190.62	12/5/2009	346.38	5844.23
MV-3UPZ	5,286.98	5,226.98	Alluvium	6,167.75	12/5/2009	372.61	5795.14
MV-3LPZ	2,866.98	2,746.98	Volcanics	6,167.70	12/5/2009	187.78	5979.92
MV-3	2,120.98	1,959.23	Volcanics	6,168.28	12/5/2009	599.71	5568.57
MV-4[b]	4,300.32	3,996.22	Alluvium	6,019.65	12/5/2009	511.45	5508.20
MV-4PZ[b]	5,101.20	5,041.20	Alluvium	6,019.45	12/5/2009	274.71	5744.74
MV-5[b]	4,203.12	3,878.69	Alluvium	6,041.69	12/5/2009	562.29	5479.40
MV-5PZ[b]	5,023.17	4,963.17	Alluvium	6,040.87	12/5/2009	288.83	5752.04
HTH-1RC[b]	3,653.90	3,353.60	Volcanics	6,011.65	12/5/2009	511.05	5500.60
HTH-1UPZ[b]	5,032.63	4,972.63	Alluvium	6,011.23	12/5/2009	542.20	5469.03
HTH-1LPZ[b]	4,112.66	4,052.66	Alluvium	6,011.26	12/5/2009	540.59	5470.67
HTH-2	5,521.70	5,025.70	Alluvium	6,026.44	12/5/2009	555.66	5470.21
UC-1-P-1SRC[b]	5,519.55	5,457.81	Alluvium	6,031.59	12/5/2009	281.05	5750.54

[a] All elevations reported in units of feet above sea level
[b] Added in 2009
TOC = Top of casing
TSZ, BSZ = top and bottom of open interval

Water sampling at the site occurred in June 2009. Wells with submersible pumps (HTH-2, MV-4, MV-5, and UC-1-P-1SRC) were purged prior to sample collection. Wells with bladder pumps (MV-1, MV-2, MV-3, and HTH-1RC) were purged to remove stagnant water from the bladder pump tubing prior to sample collection. The *Fluid Management Plan, Central Nevada Test Area Corrective Action Unit 443* (DOE 2009) was used to guide the handling and discharge of the monitor well purge water during the annual monitoring. Water level data are monitored in all wells and piezometers in the network by pressure transducers with real-time telemetry capability.

4.1 Radioisotope Monitoring

Water samples collected from monitoring network wells (MV-1, MV-2, MV-3, MV-4, MV-5, HTH-1RC, HTH-2, and UC-1-P-1SRC in 2009) are analyzed for the presence of radionuclides. Tritium is currently the primary analyte of concern because of its initial abundance and mobility. After a few hundred years tritium will decay to insignificant levels (12.3 year half-life), and the longer-lived radionuclides, carbon-14 (C-14) and iodine-129 (I-129), will become the primary focus of long-term post-closure monitoring. Concentration data currently being collected for C-14 and I-129 provide background levels of these constituents for comparison with long-term monitoring results. During the 5-year proof-of-concept period that began with the 2009 sampling event, the CADD/CAP addendum (DOE 2008a) specifies that water samples will be analyzed for tritium every year and for C-14 and I-129 in the first and fifth years. Inadequate sample volumes were collected in 2009 for I-129 analysis, and, as a result, water samples collected in 2010 will be analyzed for I-129.

The CADD/CAP (DOE 2004) established groundwater compliance levels for CNTA of 20,000 picocuries per liter (pCi/L) for tritium, 2,000 pCi/L for C-14, and 1 pCi/L for I-129. Transport modeling (Pohlmann et al. 1999, Pohll et al. 2003) was used to establish a contaminant boundary (DOE 2004) at which predicted concentrations of these constituents would remain below current compliance levels. The contaminant boundary is well within the compliance boundary (Figure 2), the boundary beyond which compliance levels of these constituents are not to be exceeded. Although the flow model was not validated by data from wells MV-1, MV-2, and MV-3, the model-predicted contaminant boundary is supported by hydraulic conductivity data from these wells.

4.2 Hydraulic Head Monitoring

Hydraulic head is monitored by transducers installed in the wells and piezometers included in the site monitoring network (Table 1). As stated in the CADD/CAP, “Hydraulic head will be used to monitor the quasi steady-state of the groundwater system; i.e., to determine if mean hydraulic head values remain constant through time, given fluctuations caused by natural temporal stresses and stresses related to well drilling, construction, and testing. This requires first determining when heads have stabilized following drilling and testing activities, then quantifying the natural mean and temporal variation in hydraulic head, and finally comparing subsequent monitoring measurements to that range.” Table 1 lists hydraulic heads measured manually in December 2009 at all monitoring locations; Section 5.2 presents more detailed assessments of temporal hydraulic head behavior.

5.0 Monitoring Results

The monitoring activities consisted of annual sampling and downloading transducer data in wells included in the enhanced monitoring network. Section 5.1 presents radioisotopic data, and Section 5.2 presents head measurements.

5.1 Radioisotopic Results

Radioisotopic sampling results for 2009 are presented in Table 2 along with the results from previous sampling events dating back to 2006. Tritium and C-14 concentrations for 2009 continue to be below detection limits, as in previous sampling events. Estimated activities of tritium and C-14 are comparable to previously reported values. Appendix A provides the field parameter measurements obtained during well-purging activities. Appendix B provides the data used to calculate the radioisotope activity presented in Table 2.

Table 2. Radioisotopic Sampling Results

Well Name	Date	Carbon-14 (pCi/L)[a]	Iodine-129 (pCi/L)[a]	Tritium (pCi/L)[a]
MV-1	2/14/2006 [c]	<RDL (1.12E-02)	<RDL (1.51E-7)	<3
	9/21/2006 [c]	<RDL (5.61E-02)	<RDL (2.9E-7)	<45
	2/22/2007	NS	NS	NS
	10/10/2007	<RDL (7.40E-03[f])	<RDL (5.7E-11[f])	<313
	3/19/2008	NS	NS	NS[d]
	6/26/2009	<RDL (2.46E-02)	NS	<370
MV-2	3/16/2006 [c]	<RDL (9.92E-02)	<RDL (2.58E-7)	<3
	9/22/2006 [c]	<RDL (1.3E-02)	<RDL (2.6 E-7)	<45
	2/22/2007	<RDL (1.54E-03[f])	<RDL (9.7E-11)	<357
	2/22/2007[e]	<RDL (1.84E-03[f])	<RDL (11.1E-11)	<353
	3/19/2008	NS	NS	<320
	6/26/2009	<RDL (5.55E-03)	NS	<380
MV-2LPZ[b] – Sample depth 490 ft	8/5/2008	NS	NS	<8,000
MV-2LPZ[b] – Sample depth 3,471 ft	8/5/2008	NS	NS	<8,000
MV-3	3/16/2006 [c]	<RDL (3.95E-02)	<RDL (2.10E-7)	<3
	9/22/2006 [c]	<RDL (5.11E-02)	<RDL (2.2 E-7)	<45
	2/22/2007	<RDL (1.01E-02[f])	<RDL (14.0E-11)	<359
	3/19/2008	NS	NS	<320
	6/25/2009	<RDL (3.87E-02)	NS	<380
MV-4	6/24/2009	<RDL (9.17E-04)	NS	<370
MV-5	6/25/2009	<RDL (2.30 E-03)	NS	<370
HTH-1RC	6/25/2009	<RDL (2.75E-03)	NS	<390
HTH-2	6/25/2009	<RDL (7.98E-02)	NS	<380
UC-1-P-1SRC	6/24/2009	<RDL (1.07E-01)	NS	<360

[a] pCi/L = picocuries per liter.

[b] Indicates sample was collected from lower piezometer of MV-2 using a depth-specific bailer; sample depths are provided with the well name.

[c] Indicates sample results were obtained from DRI Monitoring Report (DRI 2006).

[d] Indicates well was not sampled because of pump failure.

[e] Indicates a duplicate sample.

[f] Estimated based on sample volume of 200 milliliters.

NS = not sampled.

<RDL = below requested detection limit (RDL) with laboratory result in parentheses; RDL is 300 pCi/L for tritium, 5 pCi/L for C-14, and 0.1 pCi/L for I-129 (DOE 2004).

5.2 Hydraulic Head Results

Figure 5 through Figure 8 present hydrographs of hydraulic head data. A continuous line indicates water levels from a transducer. Table 1 shows the screened horizon, top of screened zone, and bottom of screened zone for each location. The hydrographs are grouped by comparable monitored interval and location: alluvial wells southeast of the southeast-bounding graben fault, including well HTH-1RC in the upper volcanic section (Figure 5), alluvial wells northwest of the southeast-bounding graben fault (Figure 6),volcanic section with open interval near the detonation level (Figure 7), and volcanic section with open interval below the detonation level (Figure 8). Piezometers MV-2LPZ, MV-1UPZ, and MV-3UPZ were further developed as part of the spring 2009 drilling program. Data gaps in the hydrographs from late spring to early summer 2009 are the result of transducers being removed for well-site activities.

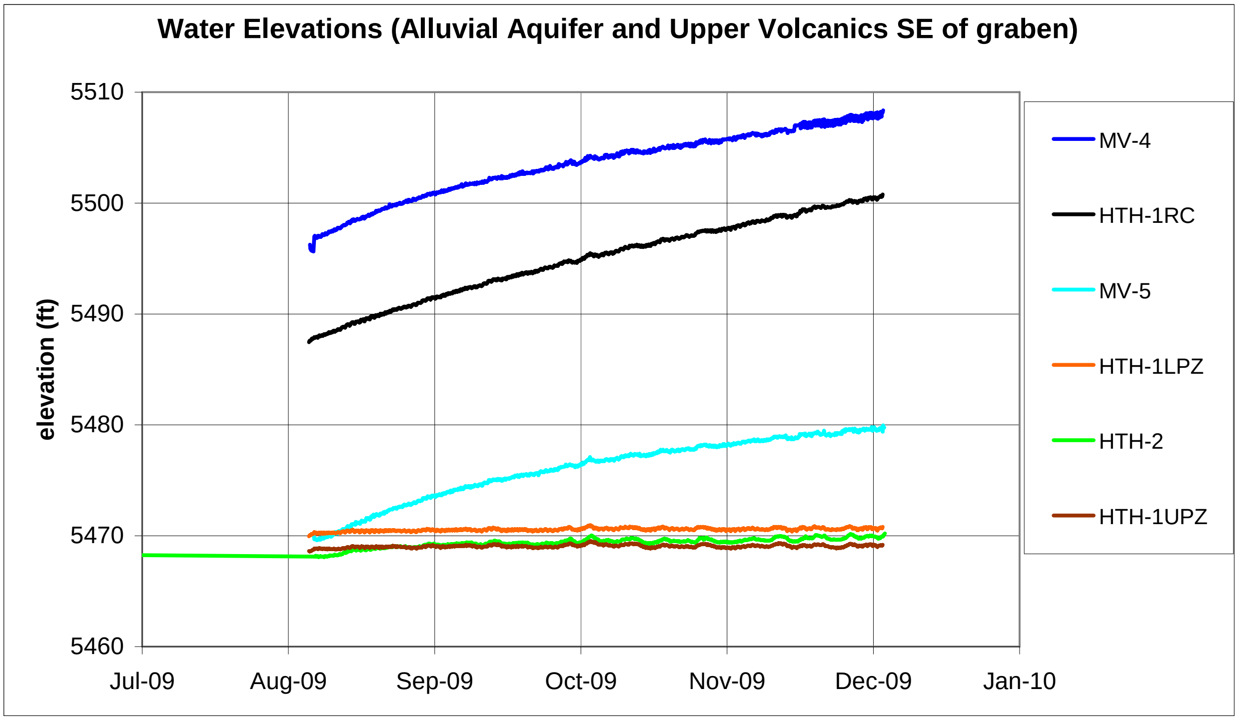

Figure 5. Water Level Elevations for the Alluvial Wells and well HTH-1RC (upper volcanics) Southeast of the Down-Dropped Graben at the Screened Horizon

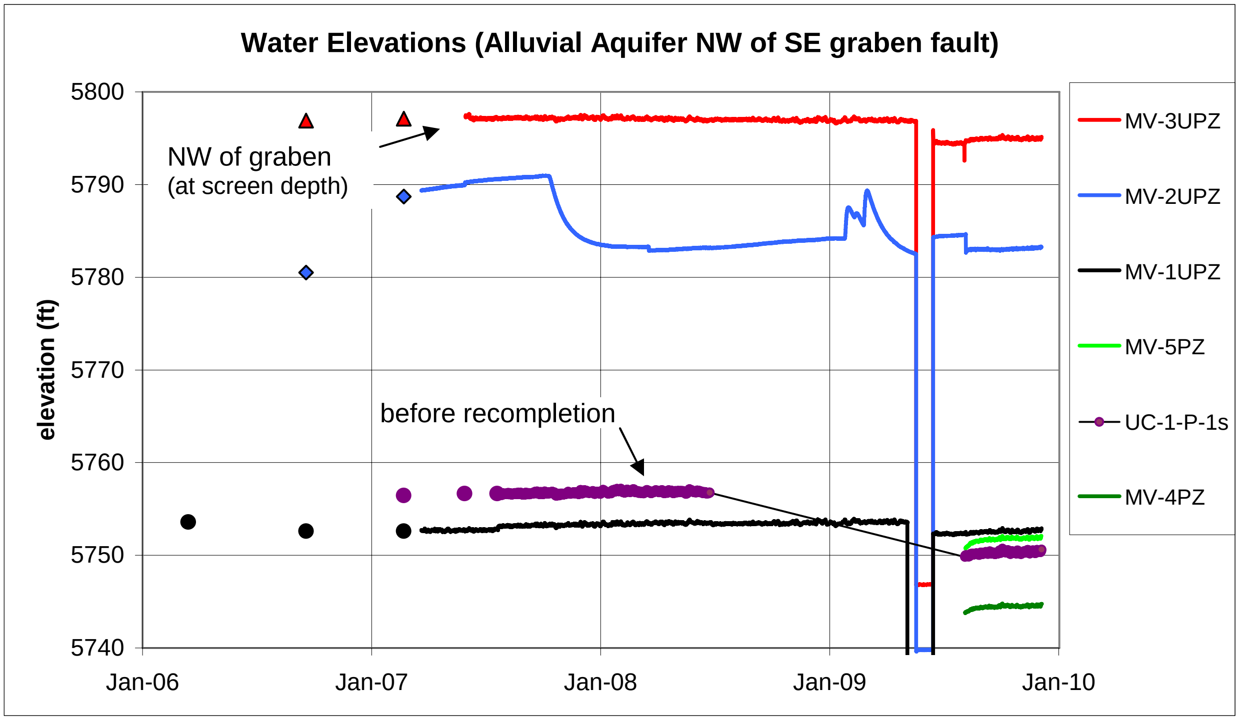

Figure 6. Water Level Elevations for the Alluvial Wells Northwest of the Southeast-Bounding Graben Fault

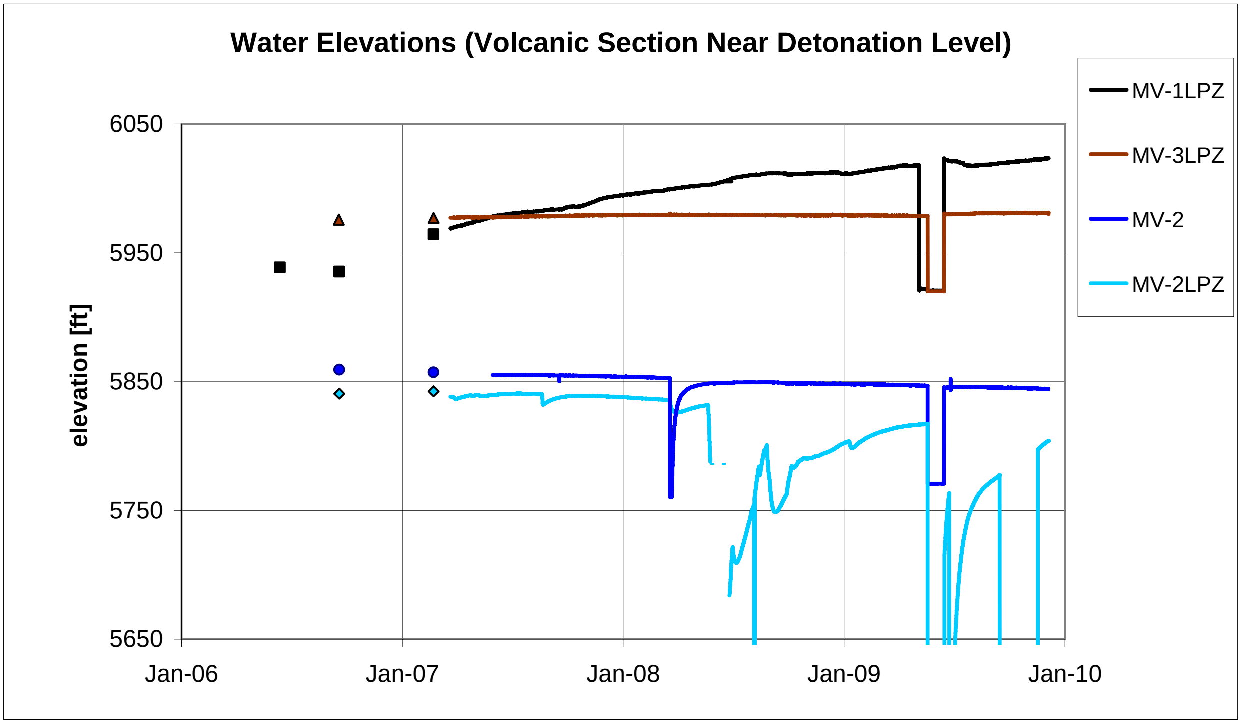

Figure 7. Water Level Elevations for the Well and Piezometers Screened in the Volcanic Section, at or near the Level of the Detonation

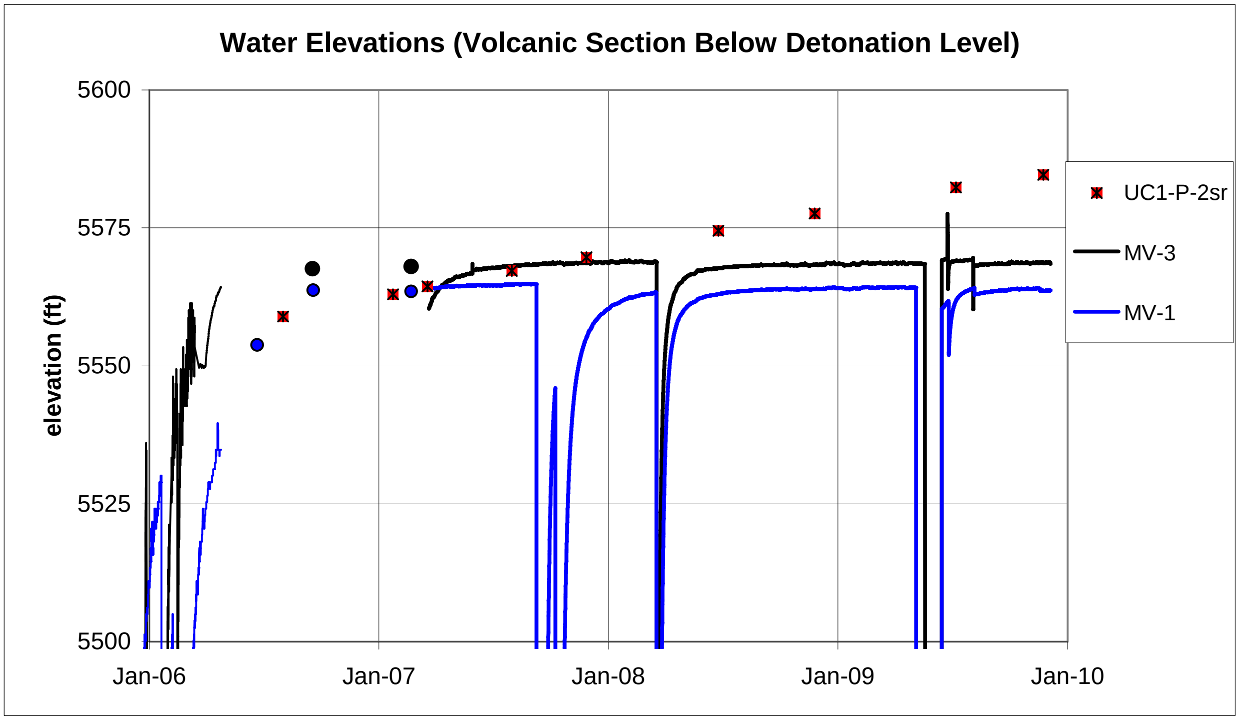

Figure 8. Water Level Elevations for the Wells Screened in the Volcanic Section Below the Level of the Detonation
Water level elevations for re-entry well UC-1-P-2SR (drilled into the chimney) are shown for reference.

Hydraulic head data from the MV-4 and MV-5 wells and piezometers support the conceptual model that the southeast-bounding graben fault acts as a barrier to flow at the site. The hydraulic heads in the MV-4 and MV-5 piezometers (screened inside the down-dropped graben block) are approximately 250 ft higher than those in the corresponding wells that are screened in the upthrown block southeast of the graben. Given these results, alluvial aquifer hydrographs were separated into two groups based on their location (at screen depth) relative to the southeast-bounding graben fault.

Figure 5 shows the hydrographs of alluvial wells and piezometers southeast of the graben (MV-4, MV-5, HTH-2, HTH-1UPZ, and HTH-1LPZ) along with well HTH-1RC (screened in the upper volcanic section below the alluvium). These data indicate that wells MV-4, MV-5, and HTH-1RC are still recovering from well development and sampling. Prior to its recompletion, HTH-1 was perforated across its entire saturated section and displayed a composite water level that could not be attributed to one particular hydrogeologic unit. The recompletion isolated zones in the upper and lower alluvium (HTH-1UPZ and HTH-1LPZ) and in the upper volcanic section (HTH-1RC). The hydraulic head in the volcanic portion of HTH-1 is higher than water levels measured in both the upper and lower alluvial piezometers at this location. This observation confirms that an upward gradient from the volcanic section to the alluvium exists in this area, as indicated by flow logging performed by Desert Research Institute in HTH-1 prior to its recompletion (DOE 2008a).

Figure 6 shows the hydrographs of alluvial piezometers and wells within and northwest of the graben. Erratic water levels in MV-2UPZ (Figure 6) are attributed to damage during its installation. The lower hydraulic heads observed after mid 2009 in MV-1UPZ and MV-3UPZ are the result of attempts to further develop these piezometers. The recompletion of UC-1-P-1S resulted in a roughly 7–8 ft decrease in hydraulic head (Figure 6). This suggests that the well is now isolated from the influence of deeper horizons where hydraulic heads have typically been larger.

A hand contoured potentiometric map of the upper part of the alluvial aquifer within the graben (Figure 9) was constructed using the December 5, 2009 head levels from the MV-4 and MV-5 piezometers, UC-1-P-1SRC well, and MV-1 and MV-2 upper piezometers, all of which are screened at depths ranging from 600 – 1000 ft. Contouring of the potentiometric surface (Figure 9) was restricted to the area within the graben. It should be noted that there is an inherent degree of uncertainty in the depiction of groundwater flow directions when the minimum number of three points are used. Reentry well UC-1-P-2SR is not completed in the upper part of the alluvium but in the chimney. The interpretation shown on Figure 9 suggests horizontal flow in the upper part of the alluvial aquifer is generally to the east-southeast and is likely deflected by the southeast-bounding graben fault. The new wells MV-4 and MV-5 were completed in the lower part of the alluvial aquifer outside the graben block (at depth) to confirm that the southeast-bounding graben fault acts as a flow barrier and for compliance monitoring at a depth nearer the detonation zone.

In previous annual monitoring reports, the hydrographs of wells and piezometers screened in volcanics were grouped according to their lowest and highest open interval. In this report, hydrographs for these monitoring points are regrouped by their position relative to the detonation level based on the observation that open intervals at or near the detonation level have higher heads than those below the detonation level. The differences between hydraulic heads at the detonation horizon and those in overlying and underlying volcanic sections are possibly attributable to high pressures created by the detonation, which appear to persist in the low-permeability volcanics at the detonation horizon.

Figure 7 shows the hydrographs of wells and piezometers with open intervals near the detonation level. Water levels in MV-1LPZ continue to rise, though at a slower rate than previously observed. On August 5, 2008, DRI ran a temperature log, collected a bailed sample, and measured the depth of the MV-2LPZ to investigate the cause of rapid water level declines and recoveries at this location. Sediment was found 75 ft above the top of the screened interval. In the summer of 2009, MV-2LPZ was further developed, lowering the sediment fill to the top of the screen. Water levels are still recovering from the development efforts. The transducer was not functioning in MV-2LPZ from September to November of 2009.

Figure 8 shows the hydrographs of wells with open intervals below the detonation level and reentry well UC-1-P-2SR (perforated from 1178 ft to 2790 ft below ground surface). The composite head level from UC-1-P-2SR (chimney and alluvium overlying the detonation area) is now higher than in the densely welded tuff units below the detonation zone.

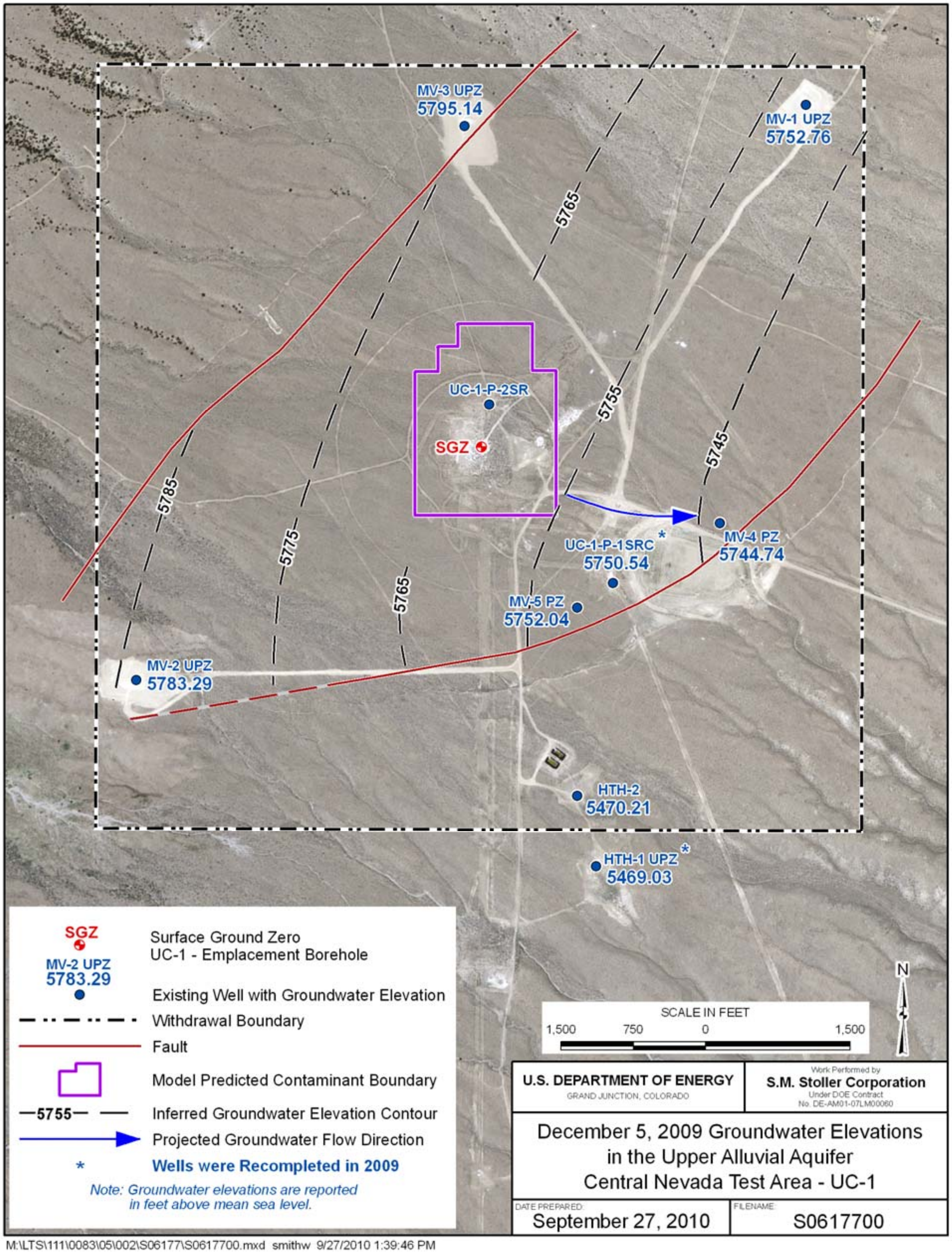

Figure 9. Potentiometric Map for the Upper Part of the Alluvial Aquifer, CNTA

6.0 Summary

The 2009 drilling program enhanced the CNTA monitoring network with seven new monitoring locations (wells and piezometers) in the alluvial aquifer and one in the upper volcanic section. Detection monitoring results indicate that radioisotope levels in groundwater continue to remain below detection limits. Water level data indicate that hydraulic heads are still recovering for wells installed during the 2009 drilling project. Aquifer testing of wells MV-4 and MV-5 is scheduled for the spring of 2010. Continued monitoring will determine if the head drops in the MV-2LPZ were eliminated by the additional development activities. The submersible pumps in wells MV-1, MV-2, and MV-3 were removed and replaced by low-flow bladder pumps. Large drawdowns seen at these wells during past sampling events will be limited to a few feet in future sampling events.

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Appendix A

Well Purging Data

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Table A−1. Monitor Well Purge Data

Well Identification	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (µmhos/cm)
HTH-1RC	6/25/2009	25	21.65	8.82	515
			19.77	8.67	531
			19.36	8.58	546
			19.88	8.61	551
HTH-2	6/25/2009	850	19.73	7.07	331
			19.40	6.88	324
			19.44	6.90	346
			19.45	6.95	335
MV-1	6/26/2009	10	16.1	9.31	780
MV-2	6/26/2009	8	16.3	9.81	1020
MV-3	6/25/2009	10.0	20.0	7.21	810
MV-4	2/26/2009	1860	28.22	9.84	282
			28.35	9.84	287
			28.48	9.84	285
MV-5	6/25/2009	1810	28.17	10.12	493
			28.29	10.11	466
			28.28	10.04	450
UC-1-P-1SRC	6/24/2009	700	18.54	8.09	263
			18.54	8.21	260
			18.58	8.23	262

s.u. = Standard Unit
µmhos/cm = micromhos per centimeter

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Appendix B

Carbon-14 Radioisotope Calculation Data

Table B−1. Carbon-14 Radioisotope Calculation Data

Well ID	Sample Date	Conc. C (mg/L)	C-14 (pmc)	Fraction mc[a]	±1 s	pCi/L
MV-1	6/26/2009	12.9	31.11	0.3111	0.0023	2.46E-02
MV-2	6/26/2009	22.1	4.09	0.0409	0.0012	5.55E-03
MV-3	6/25/2009	20.3	31.05	0.3105	0.0016	3.87E-02
MV-4	6/24/2009	3.2	4.67	0.0467	0.0008	9.17E-04
MV-5	6/25/2009	11.6	3.23	0.0323	0.0007	2.30E-03
HTH-1RC	6/25/2009	24.8	1.81	0.0181	0.0007	2.75E-03
HTH-2	6/25/2009	17.5	74.32	0.7432	0.0031	7.98E-02
UC-1P-1S-RC	6/24/2009	22.4	78.14	0.7814	0.0033	1.07E-01

[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 (MV-1)

$$12.9\,\frac{mg\ C}{L}\left(0.3111\,\frac{mg\ MC}{mg\ C}\right)\left(6.135*10^{-9}\ \frac{\mu Ci}{mg\ MC}\right)\left(1*10^{6}\ \frac{pCi}{\mu Ci}\right)=2.46*10^{-2}\ \ \frac{pCi}{L}$$

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