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2017 Groundwater Monitoring and Inspection Report Gnome-Coach, New Mexico, Site

October 2018

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Abbreviations

bgs	below ground surface
BLM	U.S. Bureau of Land Management
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GEMS	Geospatial Environmental Mapping System
LM	Office of Legacy Management
LTHMP	Long-Term Hydrologic Monitoring Program
LTS&MP	Long-Term Surveillance and Maintenance Plan
m/day	meters per day
pCi/L	picocuries per liter
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

Executive Summary

The Gnome-Coach, New Mexico, Site was the location of an underground nuclear test in 1961 and a groundwater tracer test in 1963 that has resulted in residual radionuclide contamination at the site. The Long-Term Surveillance and Maintenance Plan for the site describes the U.S. Department of Energy Office of Legacy Management's (LM) plan for monitoring groundwater (radiochemical sampling and water-level measurements), inspecting the site, maintaining site institutional controls, evaluating and reporting data, and documenting site records and data management processes. These activities are reported annually, and this report summarizes the results obtained during the September 2016 through July 2017 reporting period. The site inspection and annual sampling were conducted on February 7, 2017. A second site visit was conducted on July 12, 2017. At the time of the inspections, the site features were observed as being in good condition. No new applications were received or permits granted to drill groundwater extraction wells or oil and gas wells in the sections that surround and include the site during this reporting period. One permit to drill an oil well in Section 35 was canceled.

Groundwater elevation data continued to show that pumping in well USGS-1 produces a water-level drawdown response in wells USGS-4 and USGS-8, which are also completed in the Culebra Dolomite. Groundwater elevations in these Culebra wells trended lower by approximately 1 foot (ft) during this reporting period but still support a groundwater flow direction that is generally toward the south. Groundwater elevation data from well LRL-7, which monitors the Coach drift in the Salado Formation, indicated that water levels have nearly recovered from the well's last sampling event in January 2011. Groundwater elevation data obtained from the reentry well DD-1, which monitors the detonation cavity in the Salado Formation, indicate that water levels continue to rise in this well at a rate of approximately 10 ft/year.

Laboratory radiochemical results obtained from the February 2017 monitoring event were consistent with the previous year's results, with the exception of the sample collected from well USGS-1. Strontium-90 was detected in this sample at a concentration that was above the laboratory minimum detectable concentration. To verify the result, a portion of the sample used for tritium analysis by the enriched method was reanalyzed for strontium-90. The laboratory results indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration. Well USGS-1 was resampled on July 12, 2017. The laboratory results for this sample also indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration. The detection of strontium-90 in the initial sample collected from USGS-1 is likely the result of laboratory contamination obtained during the analysis of the USGS-4 and USGS-8 samples, which continue to have detections of strontium-90 above the laboratory minimum detectable concentration.

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1.0 Introduction

This report presents the groundwater monitoring and site inspection data collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Gnome-Coach, New Mexico, Site (Figure 1). The site was the location of an underground nuclear test in 1961 and a radionuclide groundwater tracer test in 1963, which resulted in residual radionuclide contamination in the groundwater and post-detonation features that require long-term oversight. Long-term responsibility for the site was transferred from the DOE National Nuclear Security Administration Nevada Site Office to LM on October 1, 2006. The Long-Term Surveillance and Maintenance Plan (LTS&MP) for the site describes LM's plan for monitoring groundwater, inspecting the site and maintaining the institutional controls, evaluating and reporting data, and documenting the site's records and data management processes (DOE 2016a).

This report summarizes the results of the groundwater monitoring and site inspection activities conducted during the September 2016 through July 2017 reporting period. The purpose of these activities is to monitor the groundwater and ensure that the institutional controls are protective of the site and human health and the environment. This annual report and the LTS&MP are available on the LM public website at https://www.lm.doe.gov/gnome/Sites.aspx. Data collected during this and previous monitoring events (including laboratory results and water-level data) are available on the Geospatial Environmental Mapping System (GEMS) website at https://gems.lm.doe.gov/#site=GNO.

2.0 Site Location and Background

The Gnome-Coach site is approximately 25 miles southeast of Carlsbad in Eddy County, New Mexico (Figure 1). The U.S. Atomic Energy Commission (AEC), a predecessor agency to DOE, acquired the site through a land withdrawal from the U.S. Bureau of Land Management (BLM) in the early 1960s for underground nuclear testing through the Plowshare Program (AEC 1962). The Plowshare Program was a research and development initiative started in 1957 to determine the technical and economic feasibility for peaceful applications of nuclear energy. The withdrawal comprises two parcels of land of approximately 680 acres. The larger parcel (640 acres) is where the underground nuclear test and radionuclide tracer test occurred and consists of Section 34 within Township 23 South, Range 30 East. The smaller parcel (40 acres) was used for observation during the underground test and is in Section 10, Township 23 South, Range 30 East. The focus of this report is the 640-acre parcel identified as the Gnome-Coach site, where the underground nuclear test and radionuclide tracer test occurred (Figure 1).

The purpose of the underground nuclear test, identified as Project Gnome, was to study the possibility of converting the energy from nuclear detonations into electricity, investigate the production and retrieval of radioisotopes, measure neutron activation cross sections of specific isotopes, collect data on the characteristics of nuclear explosions in salt formations, and collect data for use in future Plowshare projects (AEC 1962). Preparation for the test began in 1958 and involved multiple agencies. The U.S. Geological Survey (USGS) installed several wells and boreholes to assess the geologic and hydrologic conditions at the site (Section 2.1). The site was determined suitable for the experiment, and a 10-foot-diameter vertical emplacement shaft was excavated to a depth of 1216 feet (ft) below ground surface (bgs) (Figure 2).

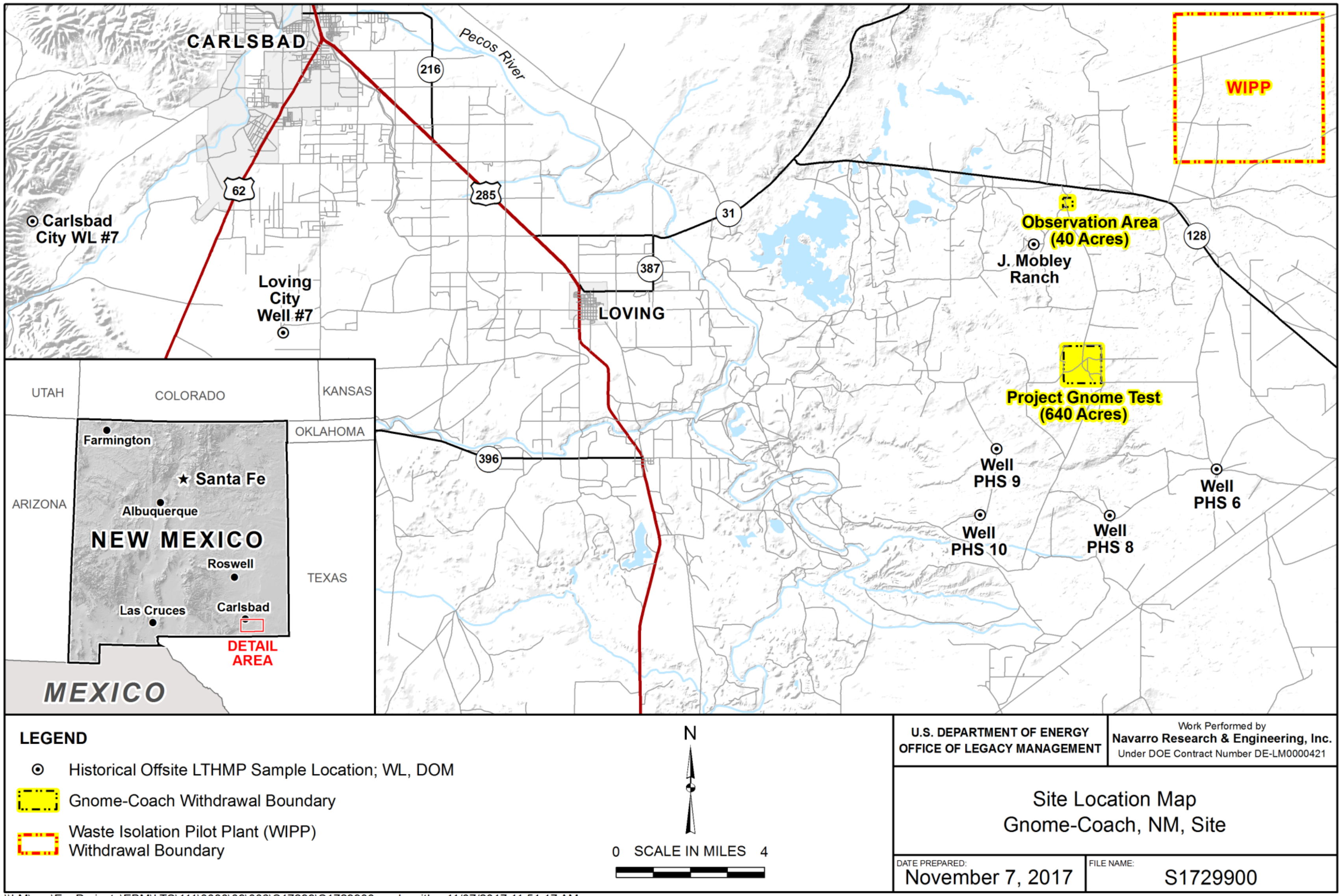

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Figure 1. Location Map for the Gnome-Coach, New Mexico, Site

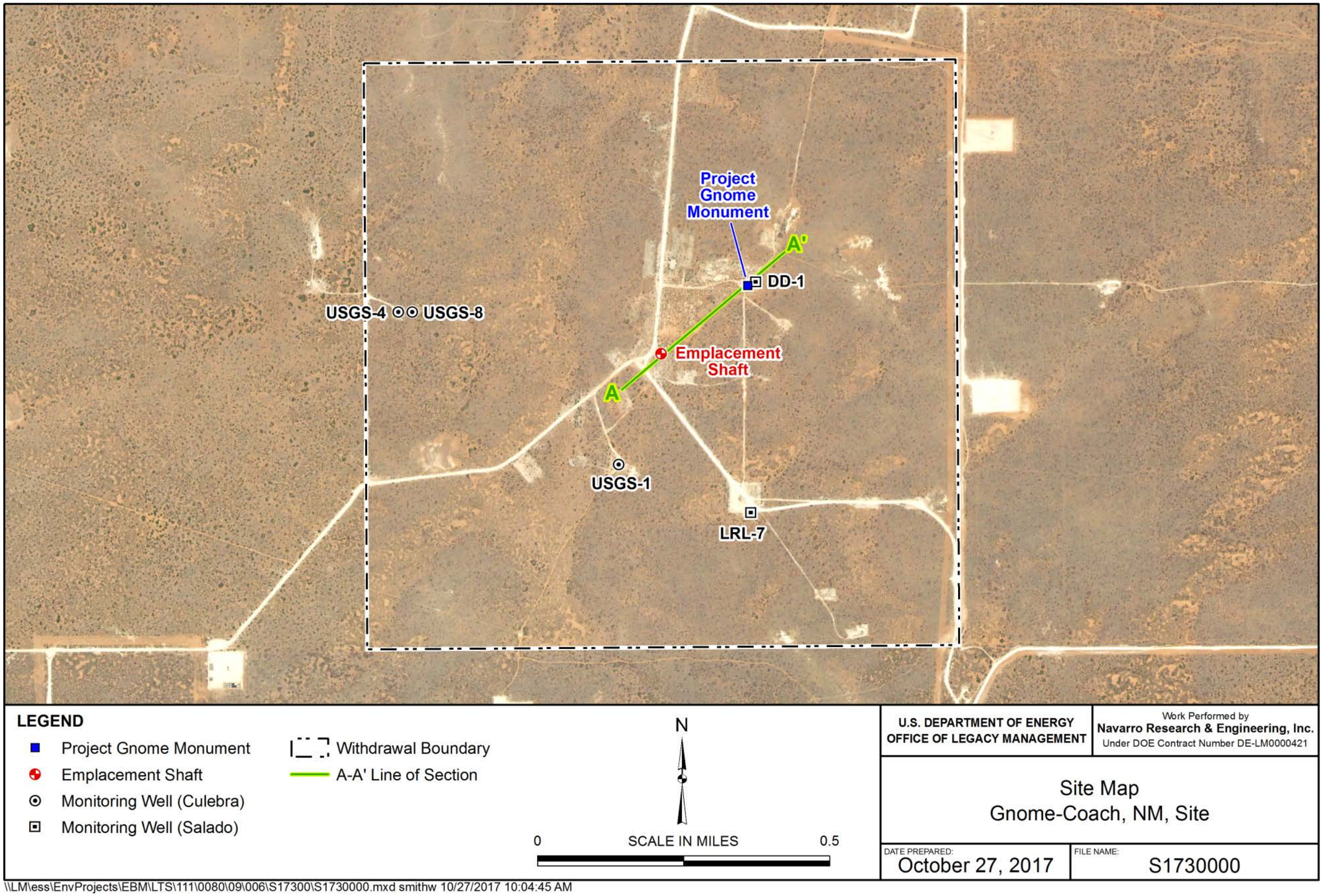

Figure 2. Site Map for the Gnome-Coach, New Mexico, Site

A horizontal drift (Gnome drift) was mined from the bottom of the shaft, extending 1116 ft to the northeast, ending in a hook shape that was completed in the Salado Formation. The hook shape was designed for placement of the nuclear device and was intended to be self-sealing following the detonation that occurred at a depth of 1184 ft bgs on December 10, 1961. The nuclear device had a reported yield of 3 kilotons (DOE 2015a). Immediately following the detonation, close-in stemming materials failed, and gases from the detonation cavity vented to the atmosphere through the Gnome drift and the emplacement shaft (AEC 1962). The emplacement shaft cleared, and a new drift was excavated after the detonation to inspect the effects of the detonation. The cavity that resulted from the detonation has dimensions that are well documented because scientists entered the cavity 5 months after the test in May 1962 (Figure 3). Post-test drilling operations and preparations for another underground nuclear test, identified as Project Coach, began shortly after the Gnome test. The emplacement shaft was restored and deepened to a depth of 1284 ft bgs, and a second horizontal drift, which is called the Coach drift, was mined 1945 ft southeast from the shaft (AEC 1969). The Coach experiment was initially scheduled for 1963 but was canceled, and no additional underground nuclear detonations occurred at the site. The site is still referred to as the Gnome-Coach site.

In 1963, USGS conducted a groundwater tracer test in the Culebra Dolomite, a fractured carbonate aquifer that is at a depth of approximately 500 ft and the most prolific aquifer near the site (Figure 3). The tracer test was designed to estimate the dispersion coefficient and effective porosity of the Culebra for evaluating the potential movement of radionuclides (Beetem and Angelo 1964). Wells USGS-4 and USGS-8 located approximately 3100 ft west of the Project Gnome monument, which is directly above the detonation cavity, were used for the test (Figure 2). Water from the extraction well (USGS-4) was mixed with four dissolved radionuclides (tritium, iodine-131, strontium-90, and cesium-137), and the solution was pumped into the injection well (USGS-8). The tracer test experiment was performed in two separate phases for a duration of 21 days in February and March 1963. Samples were collected during the tracer test to measure concentrations at the extraction well (USGS-4).

2.1 Geology and Hydrology

The Gnome-Coach site is in the northwestern part of the Delaware Basin, a deep, oval, sedimentary basin 75 miles wide and 135 miles long in southeastern New Mexico. The geology and hydrology of this basin are well studied because of oil and gas exploration, mining, and the presence of the Waste Isolation Pilot Plant (WIPP) approximately 8.5 miles north-northeast of the site (measured from the approximate center of each withdrawal boundary). The basin lithology comprises crystalline sedimentary rocks overlain by evaporites that were deposited during the late Permian Period when a warm, shallow sea was blocked from seawater circulation. As the seawater evaporated, the transition from a deep marine environment (limestone and dolomite) to a shallow marine and later dry environment (gypsum, halite, anhydrite, and potassium salts [potash]) resulted in several thousand feet of deposits accumulating on the basin floor (USGS 1962). The basin deposits and the lithostratigraphic units they compose are almost flat to gently dipping to the east and southeast in the vicinity of the Gnome site (USGS 1962).

The lithostratigraphic units beneath the Gnome site were defined during the pretest drilling and mining of the emplacement shaft. Figure 3 is a cross section that shows these units with the emplacement shaft, the Gnome drift, and the cavity that resulted from the nuclear detonation.

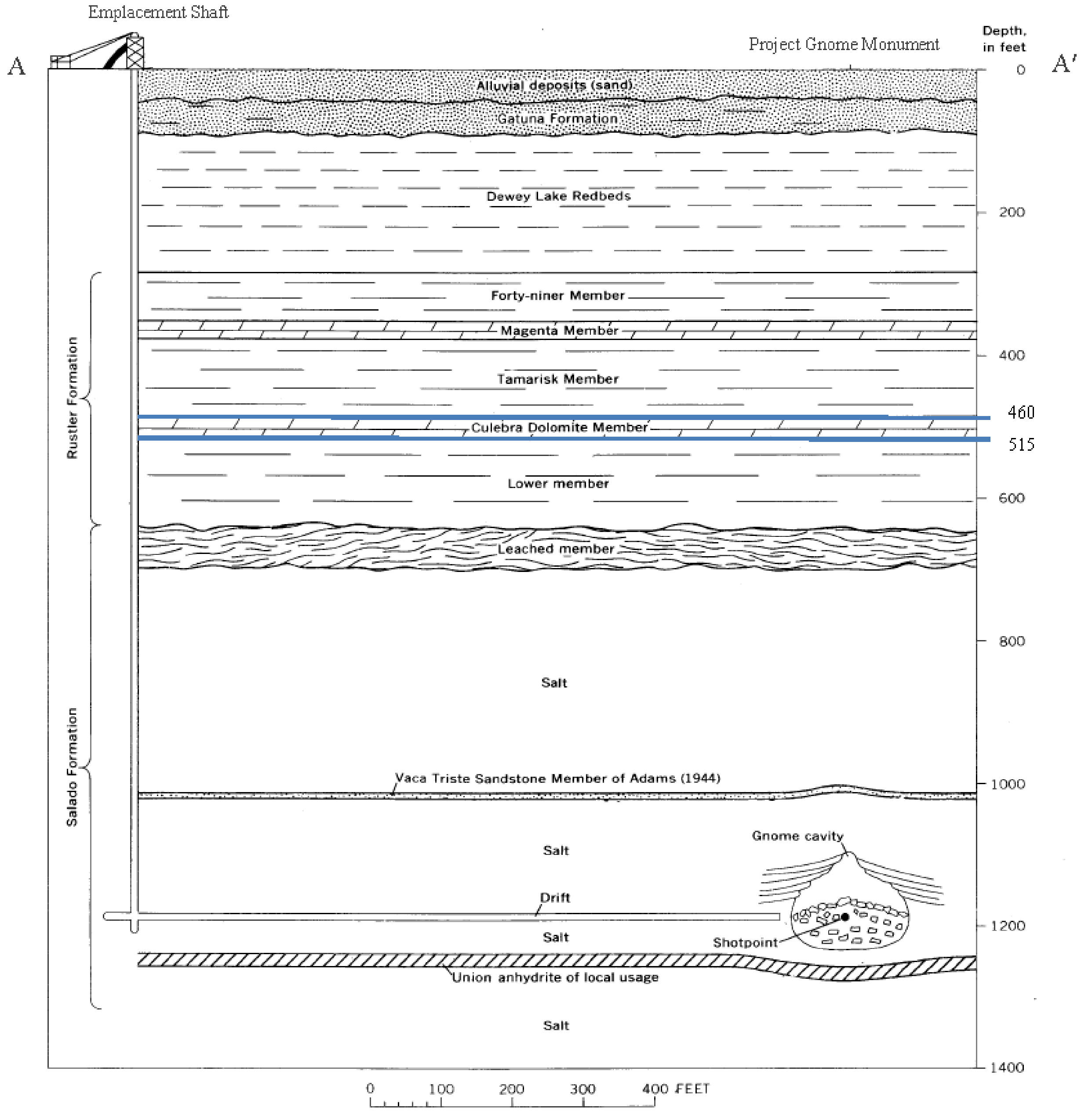

Figure 3. Stratigraphic Cross Section at the Gnome-Coach, New Mexico, Site

The Salado Formation, in which the detonation took place, is an approximately 1500 ft thick bed of halite with potassium minerals and minor amounts of sandstone, siltstone, shale, anhydrite, and gypsum that formed at the site during the Permian Period (USGS 1968). Overlying the Leached Member of the Salado Formation are five thinly bedded members of the Rustler Formation (Figure 3). In ascending order, these are the Lower Member (now referred to as the Los Medanos Member), which primarily consists of clay and silt with some gypsum and anhydrite; the Culebra Dolomite Member; the Tamarisk Member, which consists of anhydrite and gypsum; the Magenta Member, which consists of silty dolomite; and the Forty-Niner Member, a mixture of gypsum and anhydrite (USGS 1968). The youngest Permian sequences in the site area are the thinly bedded siltstones of the Dewey Lake Redbeds Formation. Overlying the Dewey Lake Redbeds Formation are the Gatuna Formation, which was deposited after the Permian Period, and the alluvial sand deposits, which are Quaternary deposits (USGS 1968).

The Culebra Dolomite Member of the Rustler Formation is a widespread, laterally continuous, fractured carbonate aquifer in which the radionuclide tracer test took place. It is approximately 30 ft thick and is present at depths ranging from approximately 460 to 515 ft bgs at the site (Figure 3). The Culebra is the most prolific aquifer in the vicinity of the site; despite the poor water quality associated with high concentrations of dissolved solids (Mercer 1983), ranchers access it to provide water to their livestock throughout the area. Water-level data collected from wells completed in the Culebra (Figure 2; USGS-1, USGS-4, and USGS-8) prior to and after the underground test indicate that the Culebra aquifer is confined (under artesian conditions) at the site. These data (historical and recent) also indicate that the aquifer is sensitive to pressure changes. Water-level responses were seen in the observation wells (USGS-1 and USGS-4) immediately following the underground nuclear test (USGS 1962), and more recently, wells USGS-4 and USGS-8 have responded to changes in the pumping of groundwater from well USGS-1 (DOE 2017). Groundwater within the Culebra moves through fractures in the dolomite, which is fairly permeable at the site, with hydraulic conductivities measuring approximately 4 meters per day (m/day) (USGS 1971). The hydraulic conductivity generally decreases to the northeast near the WIPP facility, ranging from 0.27 to 2.7×10^{-3} m/day (DOE 2012b). It is reported that groundwater flow within the Culebra near the WIPP facility is generally to the south (DOE 2012a).

The Salado Formation, in which the nuclear detonation took place, is characterized as a regional aquiclude because of the hydraulic properties of the bedded halite within the formation (DOE 2012b). The plastic nature of salt under pressure of its own weight and that of overlying units results in movement over time that closes openings (fractures and void spaces) within the deposit, making any continuous movement of water through the formation highly unlikely. Permeability testing conducted in the Salado Formation near the WIPP facility measured hydraulic conductivities that were less than 6.5×10^{-9} m/day (DOE 2012b). The low permeability, low porosity, and plastic nature of salt are characteristics that supported the determination that the bedded halite of the Salado Formation is an optimal geologic material to host a nuclear waste repository (SNL 1997). These same characteristics also limit the transport potential of any residual contamination associated with the Gnome detonation cavity, and the assumption is that the detonation cavity and drifts will close over time. Fluids associated with the Salado Formation occur mainly as small fluid inclusions in the halite crystals and also occur between crystal boundaries (interstitial fluid) of the massive crystalline salt formation; fluids also occur in clay seams and anhydrite beds. Wastes were mixed with water and injected into the test cavity for disposal during surface cleanup activities (Section 2.2). Fluid levels in the detonation cavity are monitored by the reentry well DD-1 and in the Coach drift by well LRL-7, both of which are in the Salado Formation.

2.2 Summary of Reclamation and Remediation Activities

Cleanup of the surface and shallow subsurface contamination resulting from the underground nuclear testing, post-test drilling, and groundwater tracer test was conducted in 1968 and 1969. A second major cleanup was conducted from 1977 to 1979 (REECO 1981). During this phase of the cleanup, liquid waste was pumped into the cavity through existing boreholes; contaminated material was disposed of in the emplacement shaft and the Coach drift through existing drill holes; uncontaminated equipment was moved offsite; and boreholes were plugged except those retained for use as groundwater monitoring wells (AEC 1969). While conducting a survey and sampling event in 1994, the U.S. Environmental Protection Agency (EPA) identified radiological contamination on the surface and in the shallow subsurface. The DOE National Nuclear Security Administration Nevada Site Office conducted a corrective action investigation to assess the extent of contamination at the site. The field investigations were performed from February through June 2002 and in May 2003. Contamination identified during the field investigation was excavated and disposed of offsite. A post-remediation surface radiological survey identified areas having radiological concentrations above background, but none of the concentrations were above the action levels determined to be safe for the public. The Corrective Action Investigation Report (DOE/NNSA 2004) summarizes the results of the investigation. After discussions with the State of New Mexico, it was decided that the site would be administered under the Voluntary Remediation Program. DOE prepared a Completion Report in accordance with the Voluntary Remediation Program (DOE/NNSA 2005), and a Conditional Certificate of Completion documents that surface remediation activities have been completed in accordance with the Voluntary Remediation Program (NMED 2014).

Subsurface activities have consisted of annual sampling and monitoring of groundwater as part of the Long-Term Hydrologic Monitoring Program (LTHMP). EPA began the LTHMP in 1972 (EPA 1972) and conducted the sampling until 2008, when LM assumed responsibility for sampling. In 2009, LM evaluated the LTHMP to determine the effectiveness of the monitoring network and determine future monitoring at the site. The evaluation considered potential transport pathways for contaminant migration from the detonation zone and tracer test area to surrounding receptors. Samples collected from these locations have generally been analyzed for gamma-emitting radionuclides (using high-resolution gamma spectrometry), strontium-90, and tritium (using conventional and electrolytic enrichment methods). Analytical results from more than 30 years of monitoring indicate that groundwater at sample locations outside the land-withdrawal boundary (Figure 1) was not impacted by nuclear-test-related contamination. For this reason, the monitoring was focused on the monitoring wells within the site boundary in 2010 (Figure 2). Table 1 provides the monitoring network wells with the unit monitored, purpose for monitoring, and frequency for monitoring (sampling and water levels).

Low-flow bladder pumps were installed in wells USGS-4, USGS-8, and LRL-7 in June 2008 to enhance monitoring at the site. The dedicated bladder pumps were installed to replace the previous sampling method that used a depth-specific bailer and allow the collection of more representative samples using the low-flow sampling method. Pressure transducers were also installed in the onsite monitoring wells in 2008, 2009, and 2010 to monitor water-level changes. Geophysical well logging was conducted in onsite wells USGS-1, USGS-4, and USGS-8 in April 2010. The well logging was conducted to obtain borehole deviation data from wells USGS-1 and USGS-4, natural gamma radiation data from wells USGS-4 and USGS-8, and downhole video logs from wells USGS-4 and USGS-8. The borehole deviation data allow measured depths to be corrected to true vertical depths to support the calculation of groundwater elevations at site wells that deviate from vertical. The gamma ray logs provide geologic information that can be used to correlate with other wells in the area. The video log images suggest that the well casings are generally in good condition. The 2010 Groundwater Monitoring and Inspection Report (DOE 2011) summarizes the well-logging results.

Table 1. Gnome-Coach Site Monitoring Well Network

Well Identification	Purpose for Monitoring	Formation/ Unit Monitored	Monitoring Frequency	
			Sampling	Water Levels
USGS-1[a]	Point of Access	Culebra Dolomite	Annual	Annual
USGS-4	Tracer Test			
USGS-8				
LRL-7	Coach Drift	Salado Formation	Periodic	
DD-1	Detonation Cavity			

Note:
[a] This well has been used since the early 1980s as a point of diversion to provide water for livestock belonging to area ranchers under the BLM water right C01901.

A seismic reflection survey was conducted at the site in early 2011. Seven seismic reflection profiles totaling approximately 13.9 miles were acquired to assist in the interpretation of subsurface conditions (geology and hydrogeology) at and near the site. The survey was designed to image the upper few thousand feet of the section, which includes the Culebra Dolomite (at a depth of about 475 ft bgs at wells USGS-4 and USGS-8) and the detonation (at a depth of 1184 ft bgs) within the Salado Formation. A check-shot survey was acquired in well USGS-4 to calibrate the seismic profiles to the subsurface lithology. Significant features identified that would influence groundwater flow were areas of collapse in the evaporites overlying the Salado Formation and possible faults that cross the site. The 2012 Groundwater Monitoring and Inspection Report (DOE 2013) summarizes the seismic survey results.

Well boxes were installed at USGS-4, USGS-8, LRL-7, and DD-1 in 2012 and 2013 to improve wellhead security at the site. This resulted in modifications to the USGS-4 and USGS-8 wellheads. The USGS-1 wellhead was also modified in 2013 to repair damage received from a water truck (DOE 2013). The wellhead modifications established new measuring points on the top of casing for measuring depth to groundwater in these wells. To account for these modifications, the monitoring wells were surveyed by a registered land surveyor in 2014 to provide northings and eastings with new top-of-casing elevations. The 2014 Groundwater Monitoring and Inspection Report (DOE 2015b) summarizes the wellhead survey data.

Repairs were made to the DD-1 wellhead and a totalizing flow meter was installed at well USGS-1 in January 2015. Repairs to the reentry well DD-1 were necessary because of vandalism that occurred in July 2014 (DOE 2015b). Well USGS-1 has a submersible electric pump, and a totalizing flow meter was installed to monitor total gallons removed from the well. Signs were also installed at the site in April 2015 to inform the public that ground-disturbing activities are not allowed at the site without permission from LM. These signs were installed near the emplacement shaft, near well USGS-1, and around the perimeter of the site. The signs fulfill a requirement of the Conditional Certificate of Completion that was issued by the New Mexico Environment Department. The 2015 Groundwater Monitoring and Inspection Report (DOE 2016b) summarizes these activities.

3.0 Groundwater Monitoring and Inspection Results

The LTS&MP provides guidance for groundwater monitoring and inspection activities at the site (DOE 2016a). These activities include working with local agencies and frequent monitoring of public websites to maintain the institutional controls and ensure protectiveness of the site (Section 3.1). The field activities, which were conducted on February 7 and July 12, 2017, included a site inspection (Section 3.1), downloading data from pressure transducers (Section 3.2), measuring depth-to-groundwater (Section 3.2), and collecting groundwater samples (Section 3.3). The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351) provides the procedures used to guide the quality assurance/quality control of the annual sampling and monitoring program. These procedures incorporate standards and guidance from EPA, DOE, and ASTM International. The Sampling and Analysis Plan can be accessed on the LM website at https://energy.gov/sites/prod/files/2015/02/f19/S04351_SAP.pdf. The site inspection and monitoring results are summarized in the following sections.

3.1 Site Inspection and Results

The Gnome-Coach site lands are under federal jurisdiction and administered by BLM. On October 26, 1961, the site was withdrawn from all forms of appropriation associated with mining laws and leasing through Public Land Order 2526 (Volume 26 *Federal Register* page 10279), which prohibits future oil and gas leasing or mineral claims at the site. LM monitors drilling activities near the site to ensure those activities do not impact the site. This includes inspecting the site for evidence of land use changes or significant land disturbances. It also includes evaluating the site roads and inspecting the monitoring well network, the signs that inform the public that ground-disturbing activity is not allowed, the concrete cap that covers the emplacement shaft, and the Project Gnome monument for signs of damage, natural deterioration from weather, or vandalism.

The site inspection for this reporting period was conducted on February 7, 2017. A second site visit was conducted on July 12, 2017. At the time of the site inspection in February, the signs near the emplacement shaft had been removed, so two new signs were installed as replacements. The signs near well USGS-1 and around the perimeter of the site were observed as being in good condition, as were the roads, wellheads, and Project Gnome monument. It was determined after the site inspection in February that the totalizing flow meter installed at well USGS-1 to monitor total gallons removed was not operational. The flow meter was replaced during the site visit on July 12, 2017. Appendix A provides photographs of the monument, reentry well DD-1, and concrete cap that covers the emplacement shaft.

Additional inspection activities and the results are provided below:

- The New Mexico Office of the State Engineer website was accessed to determine if any new groundwater extraction wells had been permitted in the nine sections surrounding and including the site (Figure 4). No new groundwater extraction wells were permitted in the referenced sections during this reporting period (OSE 2017).

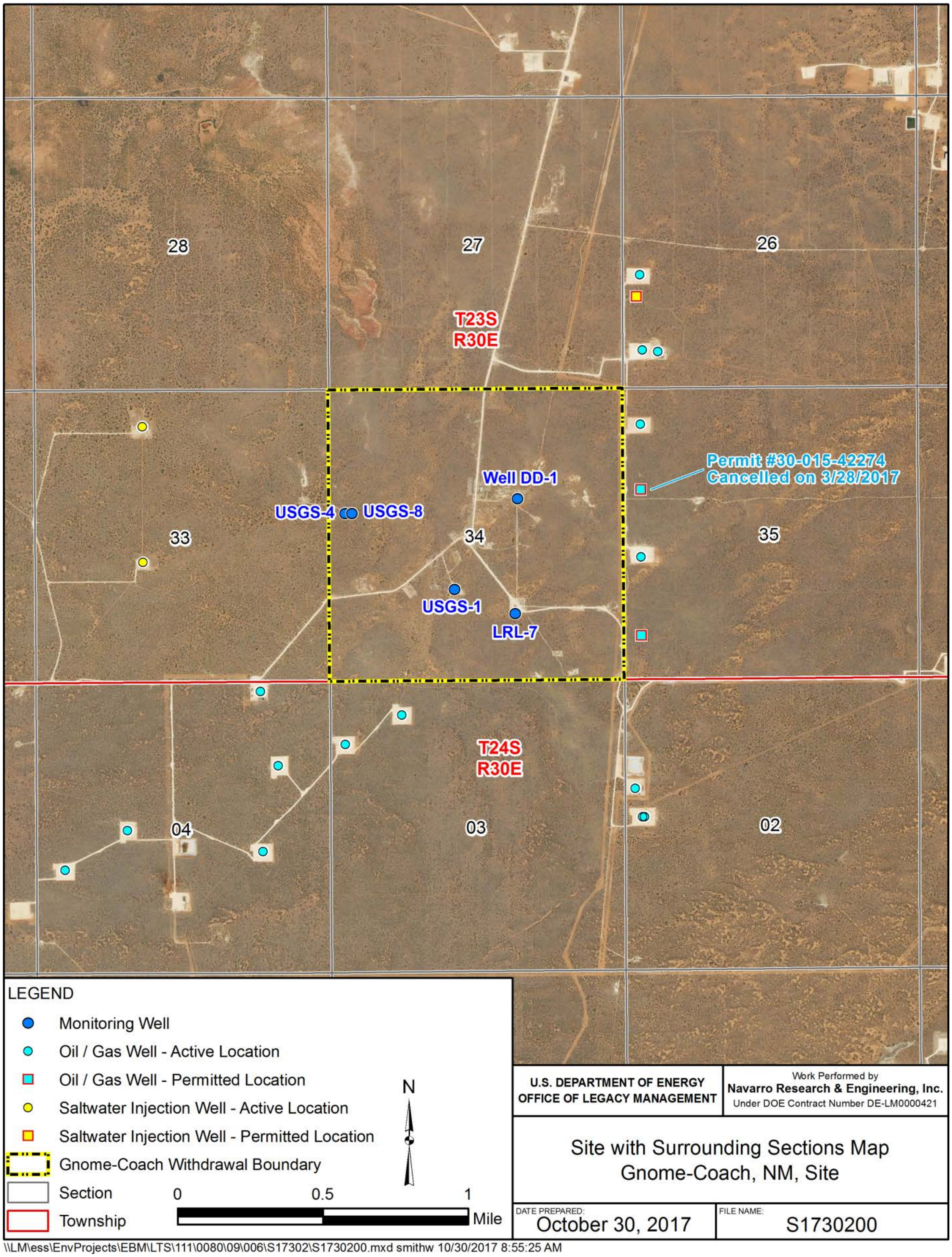

Figure 4. Sections Surrounding the Gnome-Coach, New Mexico, Site

- The New Mexico Oil Conservation Division website was accessed to determine if any new oil and gas well applications had been received or permitted in the nine sections surrounding and including the site. These wells generally target and produce oil and gas at depths ranging from 7600 to 10,500 ft bgs, which is much deeper than the depth of the underground nuclear test (1184 ft bgs). No new applications were permitted for the sections surrounding and including the site during this reporting period (OCD 2017). The permit to drill the oil well (API number 30-015-42274) in the northwest quarter of section 35 was canceled on March 28, 2017. Drill dates have not yet been established for the oil well (API number 30-015-42299) in the southwest quarter of section 35 or for the salt water disposal well (API number 30-015-43801) in the southwest quarter of Section 26, which is 0.8 miles northeast of the Project Gnome monument (Figure 4). These three permits were issued during a previous reporting period.
- The USGS Earthquake Hazards Program provides notifications of any seismic events near the site. No seismic events having a magnitude of 1.5 or greater were reported near the Gnome-Coach site during this reporting period (USGS 2017).
- The LM public website was updated during this reporting period to include the updated Fact Sheet and the 2016 Groundwater Monitoring and Inspection Report (DOE 2017).

3.2 Water-Level Monitoring and Results

The monitoring well network consists of three wells completed in the Culebra Dolomite (USGS-1, USGS-4, and USGS-8) and two wells completed in the Salado Formation (DD-1 and LRL-7). LM began monitoring water levels in these wells in 2008, shortly after assuming responsibility for the site. This includes measuring water levels manually in all wells in the network during the site visits. Water levels in the Culebra wells are recorded more frequently using pressure transducers to detect short-term and long-term flow changes in the aquifer. Water levels in the Salado wells are no longer recorded using pressure transducers due to the high-salinity water that limits the life of the transducer and the absence of short-term variations in the water levels observed by the past transducer data.

The transducer data were downloaded and water levels were measured manually in the site wells on February 7, 2017. The transducer data were downloaded again on July 12, 2017. The manual water levels were used with the top-of-casing elevations to convert the transducer data to groundwater elevations, which are presented as hydrographs (Figure 5 and Figure 6) showing data from the time monitoring began in 2008. The hydrographs are grouped according to each well’s open interval and formation monitored. Groundwater elevations obtained from manual water-level measurements are shown as individual data point symbols, and transducer data appear as lines. These data were corrected for the different specific gravity of water for each screened unit. The specific gravity of water from Culebra-screened wells is approximately 1.0035, and the specific gravity of water from Salado-screened wells is approximately 1.15. Borehole deviation data are available for wells USGS-1, USGS-4, and USGS-8 (Table 2), so groundwater elevation data from these wells are corrected to true vertical depth. Borehole deviation data are currently not available for wells DD-1 and LRL-7, so groundwater elevations depicted in Figure 6 are approximate. Table 2 presents the water-level data and measured groundwater elevations obtained from the February 2017 inspection, along with the top-of-casing elevations, the top and bottom screen-zone elevations, and the hydrostratigraphic unit monitored for the wells.

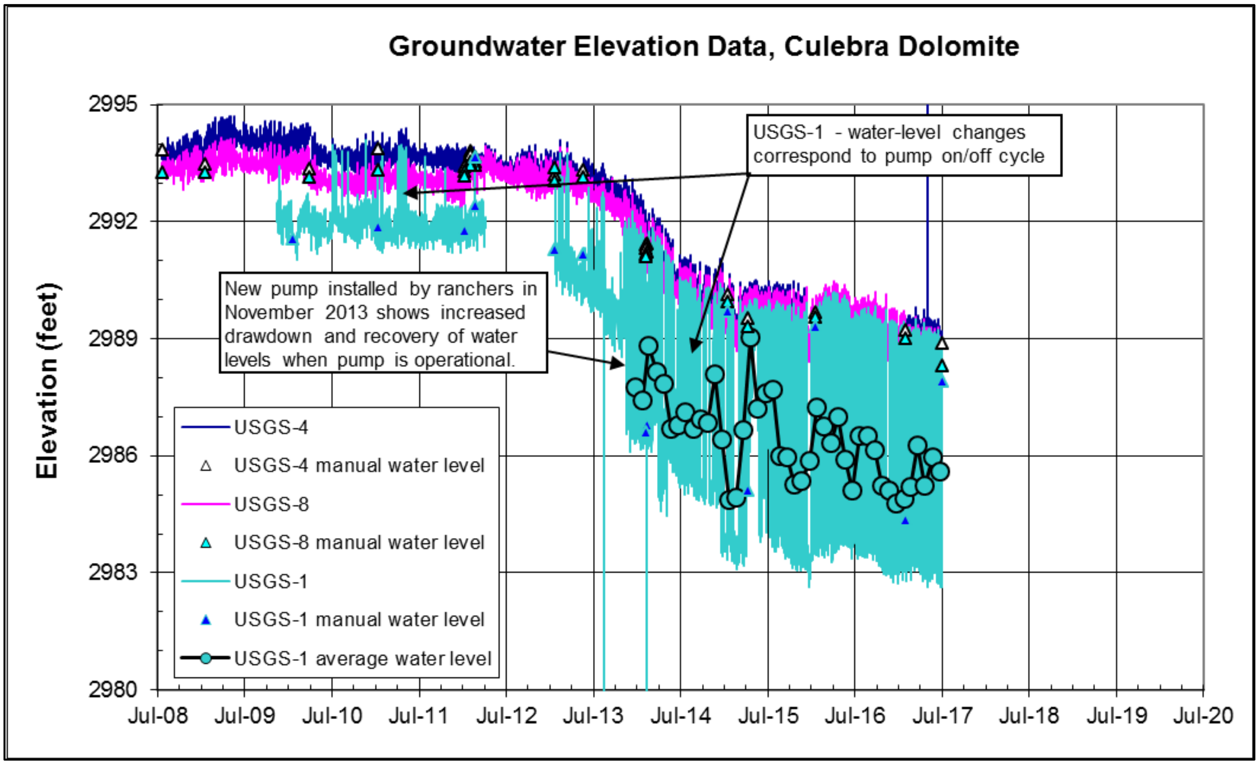

Figure 5. Hydrograph Showing Water Elevations in Wells USGS-1, USGS-4, and USGS-8

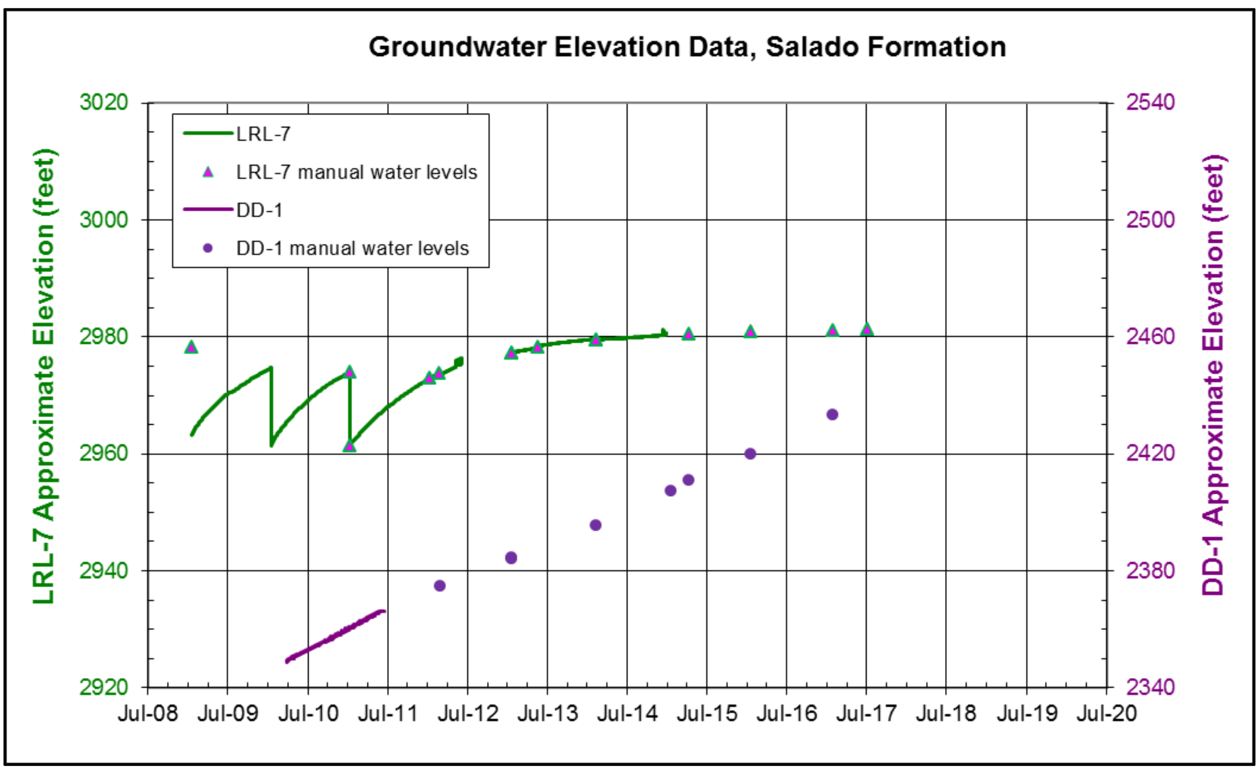

Figure 6. Hydrograph Showing Water Elevations in Reentry Wells DD-1 and LRL-7

Table 2. Gnome-Coach Site Monitoring Well Network Water Levels

Well	Date	DTW (ft)[a]	TOC Elevation (ft amsl)	TSZ Elevation (ft amsl)	BSZ Elevation (ft amsl)	Formation/ Unit Monitored	Groundwater Elevation (ft amsl)
USGS-1	2/7/2017	442.35[c]	3426.60	2907[b]	2875[b]	Culebra Dolomite	2984.34[b]
USGS-4	2/7/2017	429.39	3413.72	2940[b]	2907[b]	Culebra Dolomite	2989.25[b]
USGS-8	2/7/2017	422.24	3411.25	2947[b]	2915[b]	Culebra Dolomite	2989.01[b]
LRL-7	2/7/2017	461.36	3442.52	2653[d]	2127[d]	Salado Formation	2981.16[d]
DD-1	2/7/2017	964.10	3397.49[e]	2259[d]	U/NM	Salado Formation	2433.29[d]

Notes:
The TOC elevations are provided in U.S. State Plane, Zone New Mexico East, coordinate system, with vertical data based on the National Geodetic Vertical Datum of 1929 (NGVD 29) (DOE 2015b).
[a] Depth to water has not been corrected for true vertical depth.
[b] Elevation has been corrected for true vertical depth. (At the water-level depth, the deviation correction for USGS-1 is 0.09 ft; the deviation correction for USGS-4 is 4.90 ft; and no correction is required for USGS-8 because it did not deviate from vertical.)
[c] Well USGS-1 has a dedicated submersible pump that was not operating at the time of the water-level measurement.
[d] Elevations for LRL-7 and DD-1 have not been corrected for true vertical depth because borehole deviation corrections are not available for these wells.
[e] TOC elevation is estimated because of repairs to the wellhead after the well was vandalized in 2014 (DOE 2016b).

Abbreviations:
ft amsl = feet above mean sea level
BSZ = bottom of screen zone, uncased/open interval, or perforated interval in feet above mean sea level
DTW = depth to water (all measurements obtained from north top-of-casing)
TOC = top-of-casing elevation in feet above mean sea level (NGVD 29)
TSZ = top of screen zone, uncased/open interval, or perforated interval in feet above mean sea level
U/NM = unknown or not measured (the construction and open intervals of reentry well DD-1 are unknown)

Groundwater elevation data from this reporting period were evaluated with the historical data to assess changes in the groundwater flow system. The hydrographs for wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) are shown in Figure 5. Well USGS-1 has a submersible electric pump that local ranchers use to supply water to their livestock in the area. Groundwater elevation data from the Culebra wells continue to show that pumping in well USGS-1 produces a water-level drawdown response in wells USGS-4 and USGS-8. Groundwater elevations in these wells decreased by approximately 1 ft during this reporting period that began in September 2016 and ended in July 2017. These decreases start in late May to early June 2016 (Figure 5). The totalizing flow meter installed at well USGS-1 in 2015 to monitor total gallons removed was not operational at the time of the inspection on February 7, 2017, but was replaced on July 12, 2017. The on-and-off cycle of the pump in USGS-1 does not indicate a dramatic increase in pumping during this reporting period. The recent trend of decreasing groundwater elevations may be the result of increased pumping from other water supply wells outside the Gnome-Coach site study area. Groundwater elevation data from the Culebra wells continue to support a regional groundwater flow direction that is generally toward the south, but is locally influenced by the pumping in well USGS-1.

Figure 6 shows the hydrographs for wells (DD-1 and LRL-7) completed in the Salado Formation. Water levels are measured manually in well DD-1 and LRL-7, which are completed in the detonation cavity and the Coach drift, respectively. Water-level data from well LRL-7 indicate that the rate of water-level recovery since the well was last sampled in January 2011 continues to decrease and that water levels may be nearing static conditions.

Water-level data obtained from well DD-1 indicate that water levels continue to rise in this well at a rate of approximately 10 ft/year. Water levels in wells LRL-7 and DD-1 might be influenced by remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities and might not be representative of the Salado Formation.

3.3 Groundwater Sampling and Results

The well network is designed to monitor the sources of radionuclide contamination (underground nuclear test and tracer test) and the point of access (well USGS-1). Sampling of these wells began in 1972, and LM assumed responsibility for the sampling in 2008. The monitoring wells completed in the Culebra Dolomite (USGS-1, USGS-4, and USGS-8) are sampled annually for the radionuclides of interest (tritium, cesium-137, and strontium-90) used during the tracer test in 1963. Iodine-131 was also used during the tracer test, but because of its short half-life (8 days) it is no longer present at the site. Wells completed in the Salado Formation (LRL-7 and DD-1) are sampled less frequently because of the low permeability of the Salado Formation and limited potential for transport.

The monitoring wells USGS-1, USGS-4, and USGS-8 were sampled on February 7, 2017. Samples were not collected from wells DD-1 and LRL-7 during this monitoring event because the presence of radionuclides at these locations is well documented. Well USGS-1 was resampled on July 12, 2017. Wells USGS-4 and USGS-8 were sampled using dedicated low-flow submersible bladder pumps. The tubing inlets of the bladder pumps are located in the screened or open interval to allow water to be collected directly from the adjacent geologic formation. The samples from well USGS-1 were collected as a grab sample using the dedicated pump that fills the nearby water tank. Samples were analyzed for gamma-emitting radionuclides (using high-resolution gamma spectrometry), strontium-90, and tritium (using conventional methods). The analytical results were validated in accordance with the "Standard Practice for Validation of Environmental Data" section in the *Environmental Procedures Catalog* (LMS/POL/S04325). Samples were analyzed using accepted procedures based on the specified methods. The laboratory radiochemical minimum detectable concentrations reported with these data are an estimate of the predicted detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected. A copy of the data validation package is available on the LM website at https://www.lm.doe.gov/gnome/Sites.aspx.

Laboratory radiochemical results obtained from the February 2017 monitoring event were consistent with the previous year's results, with the exception of the sample collected from well USGS-1 (Table 3). Strontium-90 was detected in this sample at a concentration of 1.78 picocuries per liter (pCi/L), which is above the laboratory minimum detectable concentration of 0.628 pCi/L. To verify the result, a portion of the sample used for tritium analysis by the enriched method was reanalyzed for strontium-90. The laboratory results indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration. Well USGS-1 was also resampled on July 12, 2017. The laboratory results for this sample also indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration (Table 3). Concentrations of tritium, cesium-137, and strontium-90 in the samples collected from wells USGS-4 and USGS-8 are consistent with previous years and are the result of radionuclides injected during the tracer test in 1963. Concentrations are higher in well USGS-8 because it was used as the injection well for the tracer test (well USGS-4 was used as the extraction well during the tracer test). The detection of strontium-90 in the initial sample collected from well USGS-1 is likely the result of laboratory contamination obtained during the analysis of the USGS-8 sample. Table 3 presents a summary of laboratory radiochemical results from 2010 through 2017 for comparison.

Table 3. Radiochemical Analytical Results 2010–2017

Sample Location	Collection Date	Tritium (pCi/L)	Tritium Enriched Method (pCi/L)	Cesium-137 (pCi/L)	Strontium-90 (pCi/L)	Formation/ Unit Monitored
USGS-1	1/26/2010	<146	7.6	<2.1	<0.89	Culebra Dolomite
	1/26/2010[a]	<146	<3.4	<1.4	<1.9	
	1/19/2011	<150	NA	<2.2	<3.6	
	1/19/2011[a]	<150	NA	<2.4	<1.1	
	1/18/2012	<240	<2.33	<5.69	<0.728	
	1/18/2012[a]	<243	NA	<6.82	<0.794	
	1/29/2013	<371	<2.18	<4.68	<0.909	
	1/29/2013[a]	<371	NA	<5.97	<0.716	
	2/19/2014	NA	<2.4	<5.68	<0.987	
	2/19/2014[a]	<298	NA	<4.81	<1.08	
	1/27/2015	NA	<2.24	<6.77	<0.722	
	1/27/2016	<364	<2.91	<6.08	<0.974	
	2/7/2017	<357	<3.1	<4.92	1.78, <0.85	
	7/12/2017	<365	NA	NA	<0.689	
USGS-4	1/26/2010	13,200	NA	<1.4	2540	Culebra Dolomite
	1/19/2011	11,300	NA	<2.4	2650	
	1/18/2012	9110	NA	<5.62	884	
	1/30/2013	10,200	NA	<5.33	987	
	2/19/2014	7680	NA	<5.85	1780	
	1/27/2015	6030	NA	<4.85	1740	
	1/27/2016	5240	NA	<6.03	1420	
	2/7/2017	4470	NA	<3.09	1050	
USGS-8	1/27/2010	25,500	NA	181	3320	Culebra Dolomite
	1/19/2011	21,200	NA	150	3650	
	1/18/2012	21,700	NA	154	1400	
	1/29/2013	20,900	NA	174	1580	
	2/19/2014	18,400	NA	176	1640	
	1/27/2015	17,400	NA	123	2650	
	1/27/2015[a]	16,400	NA	128	2480	
	1/27/2016	16,400	NA	142	2410	
	1/27/2016[a]	16,100	NA	166	2270	
	2/7/2017	11300	NA	149	1640	
	2/7/2017	11600	NA	141	1670	
LRL-7	1/26/2010	4350	NA	129	<33	Salado Formation
	1/19/2011	3910	NA	134	<29	

Note:
[a] Indicates a field duplicate sample.

Abbreviation:
NA = not analyzed

Charts 1–7 in Appendix B show temporal plots of radionuclide concentrations (1972–2017) in samples collected from wells LRL-7, USGS-4, and USGS-8. Sample results from well USGS-1 are not included because concentrations of tritium (using conventional methods), strontium-90, and cesium-137 have not been detected above the laboratory minimum detectable concentration in this well since monitoring began in 1972. The recent detection of strontium-90 in the February 2017 sample is attributed to laboratory contamination (the result was not reproducible with an analysis of another sample collected at the same time but analyzed later or with an analysis of a sample collected in July 2017). Concentrations are plotted on a semilogarithmic scale, and all sample results, including nondetects, are plotted. Several results from sampling events before the late 1980s had no reported detection limit, as shown in the charts. For interpretation purposes, relatively high concentrations (i.e., concentrations significantly higher than detection limits associated with subsequent sampling) should be considered detections. The natural decay rates for tritium (12.3 years), strontium-90 (28.8 years), and cesium-137 (30.2 years) have been included on the charts for reference. The increases in tritium concentrations in samples collected from well LRL-7 (Chart 1) and cesium-137 concentrations in samples collected from wells USGS-8 and LRL-7 (Chart 4 and Chart 6) after the 2007 sampling event are attributed to changes in the sampling method. Prior to 2008, EPA collected samples using a depth-specific bailer, and starting in 2008 LM collected samples from dedicated bladder pumps using the low-flow sampling method. Tritium concentrations in samples collected from well USGS-4 (Chart 1) continue to decrease at a rate that is greater than the natural decay rate for tritium.

4.0 Summary and Conclusions

The site inspection and annual sampling were conducted on February 7, 2017. A second site visit was conducted on July 12, 2017, to resample well USGS-1. At the time of the site inspection in February, the signs near the emplacement shaft had been removed and were therefore replaced with two new signs. The remaining signs near well USGS-1 and around the perimeter of the site were observed as being in good condition, as were the roads, wellheads, and Project Gnome monument. No new applications were received or permits granted to drill groundwater extraction wells or oil and gas wells in the sections that surround and include the site during this reporting period (September 2016 through July 2017). Three permitted locations (obtained during a prior reporting period) have yet to be drilled. The permit to drill the oil well in the northwest corner of section 35 was canceled on March 28, 2017. Drill dates have not yet been established for the oil well in the southwest quarter of section 35 or for the salt water disposal well in the southwest quarter of Section 26.

Groundwater elevation data from the wells completed in the Culebra Dolomite continue to show that pumping in well USGS-1 produces a water-level drawdown response in wells USGS-4 and USGS-8. The groundwater elevations in these wells trended lower by approximately 1 ft during this reporting period. These decreases may be the result of increased pumping of other water supply wells outside the Gnome-Coach site study area. The groundwater elevation data from the Culebra wells continue to support a regional groundwater flow direction that is generally toward the south, but is influenced locally by the pumping in well USGS-1. Water-level data from well LRL-7, which monitors the Coach drift, indicate that water levels have nearly recovered from the well’s last sampling event in January 2011. Water levels in reentry well DD-1, which monitors the detonation cavity, continue to rise at a rate of approximately 10 ft/year. Water levels in LRL-7 and DD-1 might be influenced by remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities and might not be representative of the Salado Formation.

Samples were collected from wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) on February 7, 2017, to monitor radionuclide concentrations associated with the tracer test. Samples were not collected from the wells (DD-1 and LRL-7) completed in the Salado Formation during the 2017 reporting period. Laboratory radiochemical results obtained from the February 2017 monitoring event were consistent with the previous year's results, with the exception of the sample collected from well USGS-1. Strontium-90 was detected in this sample at a concentration of 1.78 pCi/L. To verify the result, a portion of the sample used for tritium analysis by the enriched method was reanalyzed for strontium-90. The laboratory results indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration. Well USGS-1 was also resampled on July 12, 2017. The laboratory results for this sample also indicated no detections of strontium-90 or tritium above the laboratory minimum detectable concentration. The detection of strontium-90 in the initial sample collected from well USGS-1 is likely the result of laboratory contamination obtained during the analysis of the USGS-8 sample. Copies of this report are sent to the individuals on the distribution list provided as Appendix C.

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Appendix A

Photographic Documentation

Looking northeast at the Project Gnome monument and reentry well DD-1.

Looking northwest at the concrete cap that covers the Project Gnome emplacement shaft.

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Appendix B

Well Concentration Plots

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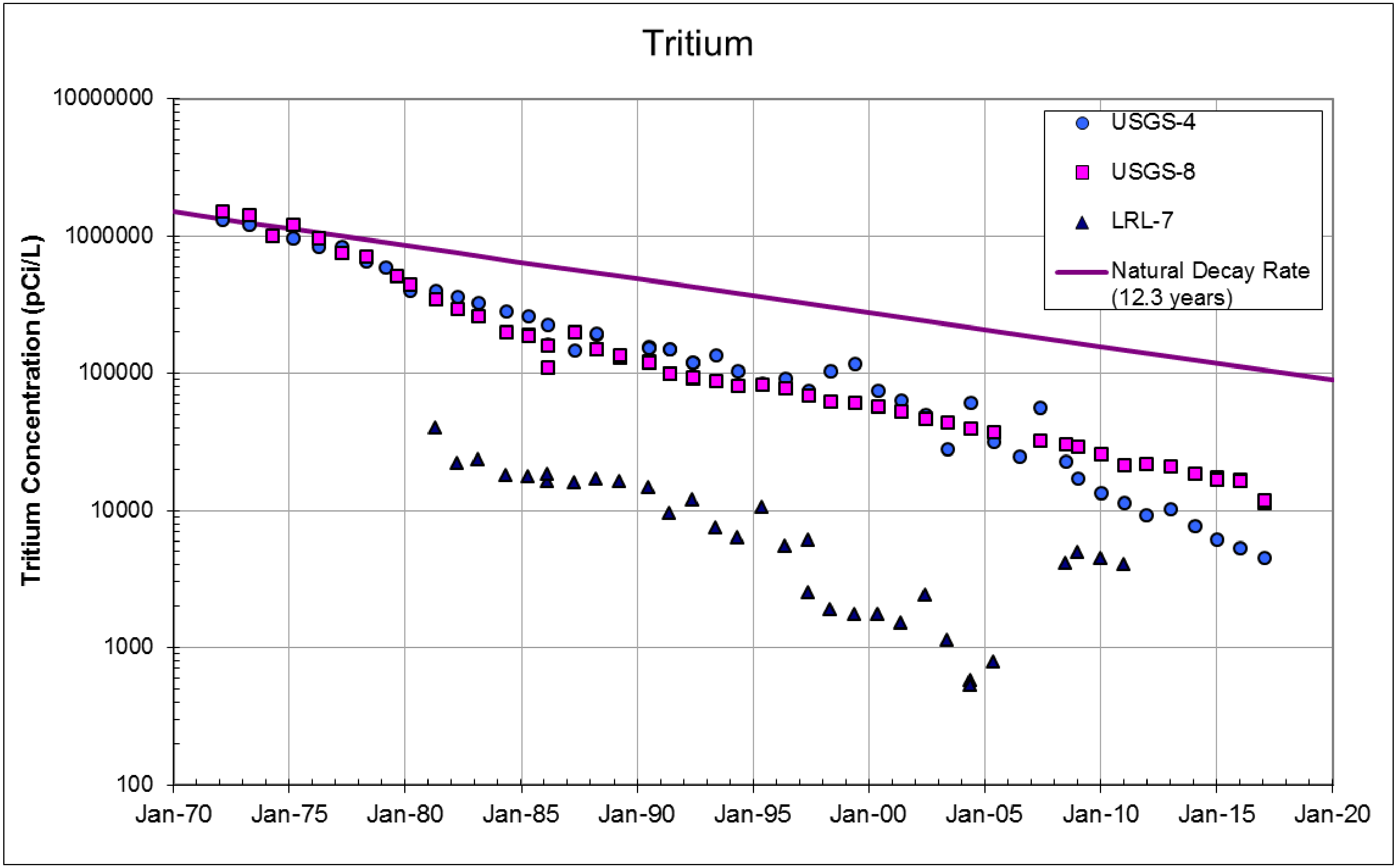

Chart 1. Tritium Concentrations at Wells USGS-4, USGS-8, and LRL-7

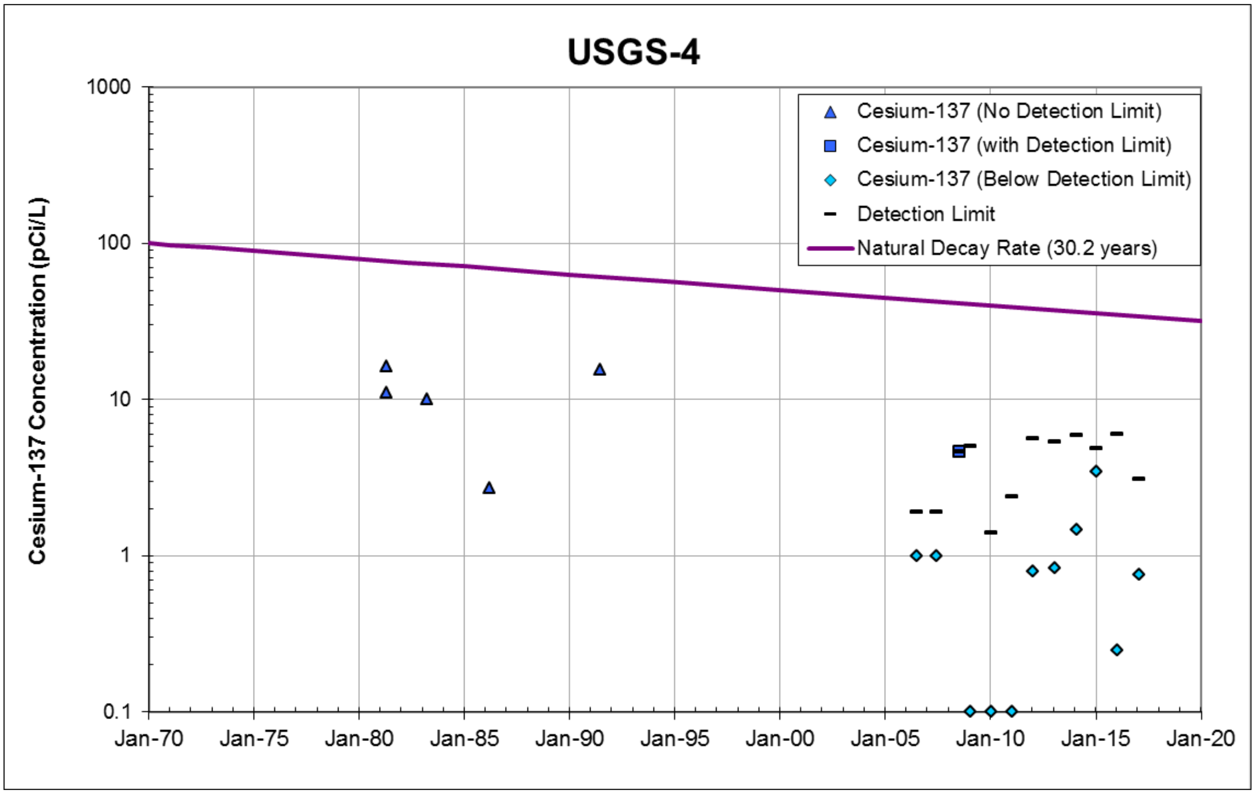

Chart 2. Cesium-137 Concentrations at Well USGS-4

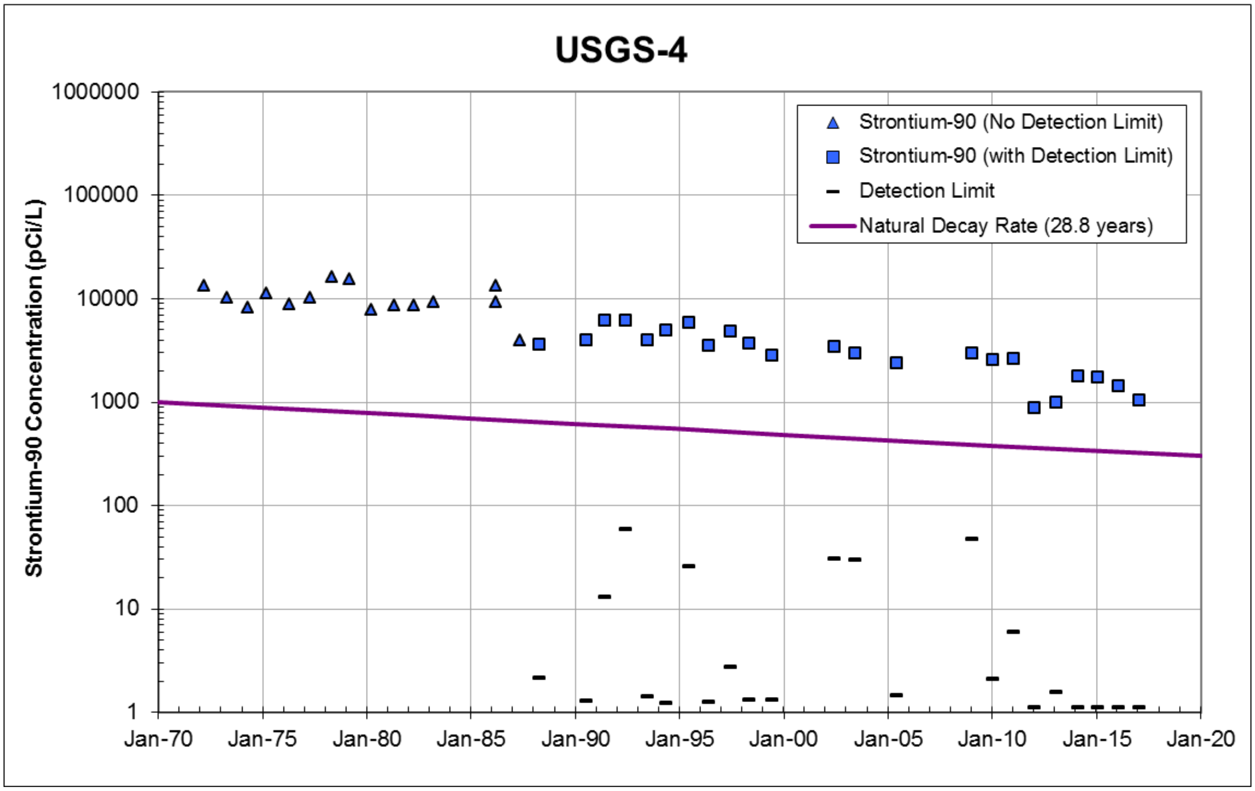

Chart 3. Strontium-90 Concentrations at Well USGS-4

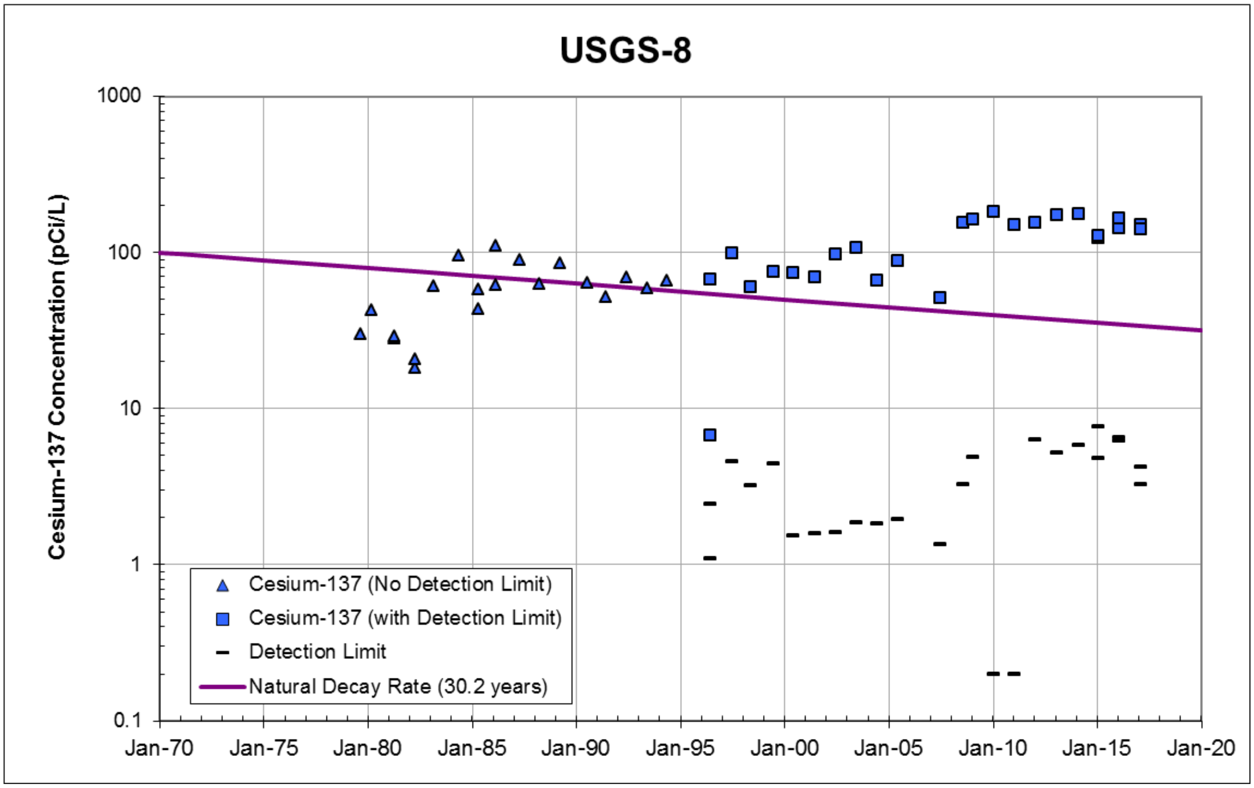

Chart 4. Cesium-137 Concentrations at Well USGS-8

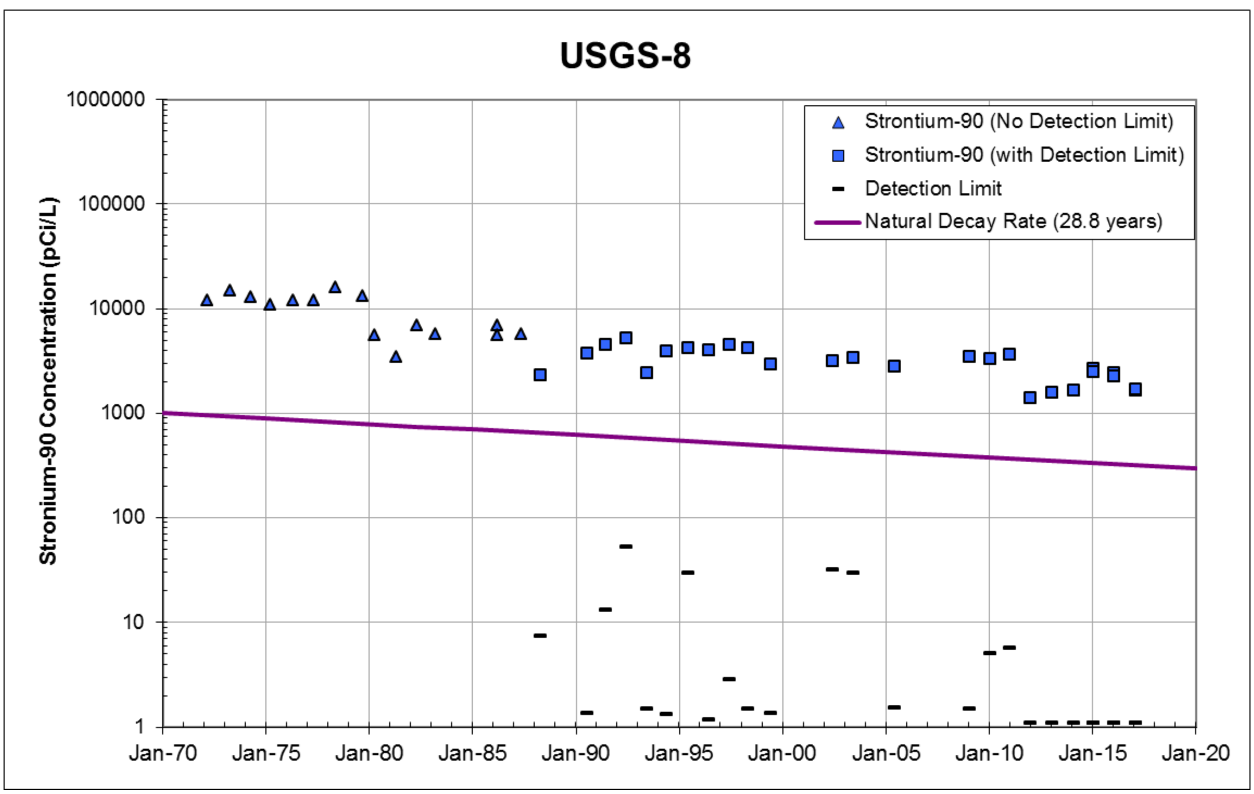

Chart 5. Strontium-90 Concentrations at Well USGS-8

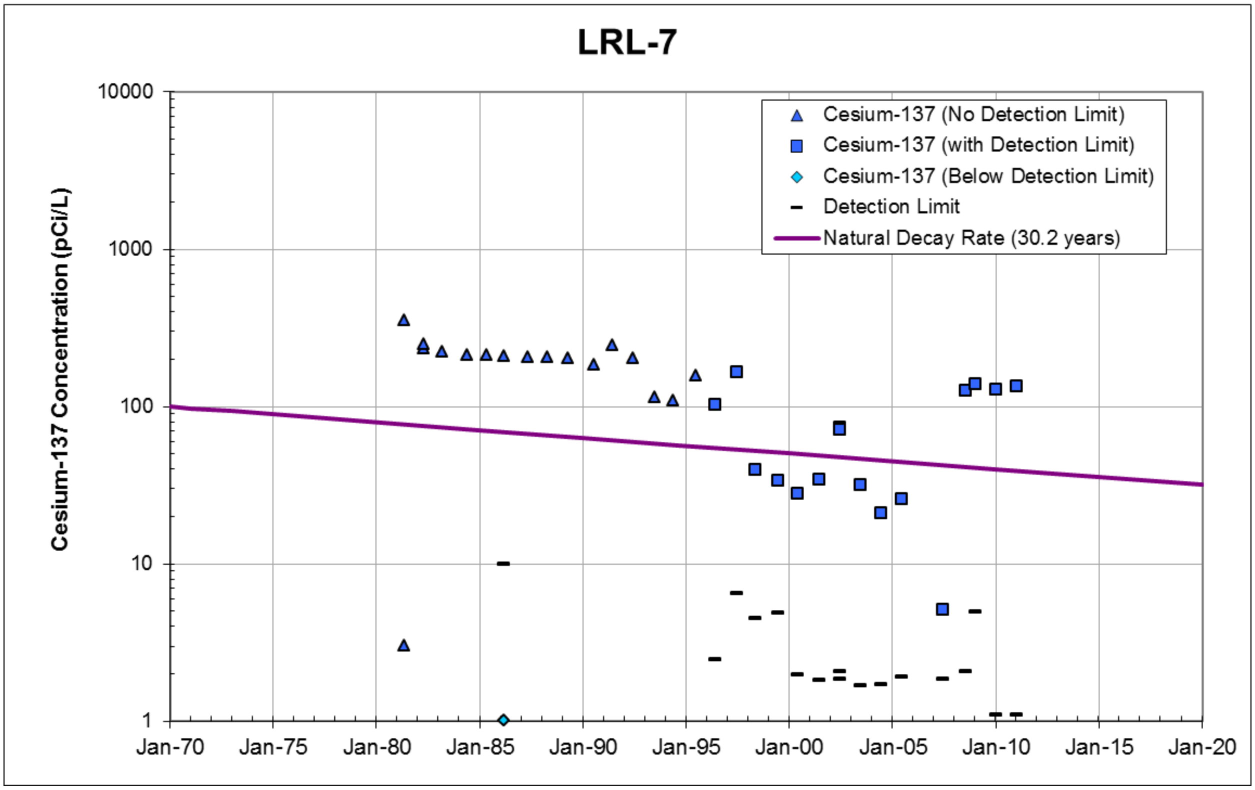

Chart 6. Cesium-137 Concentrations at Well LRL-7

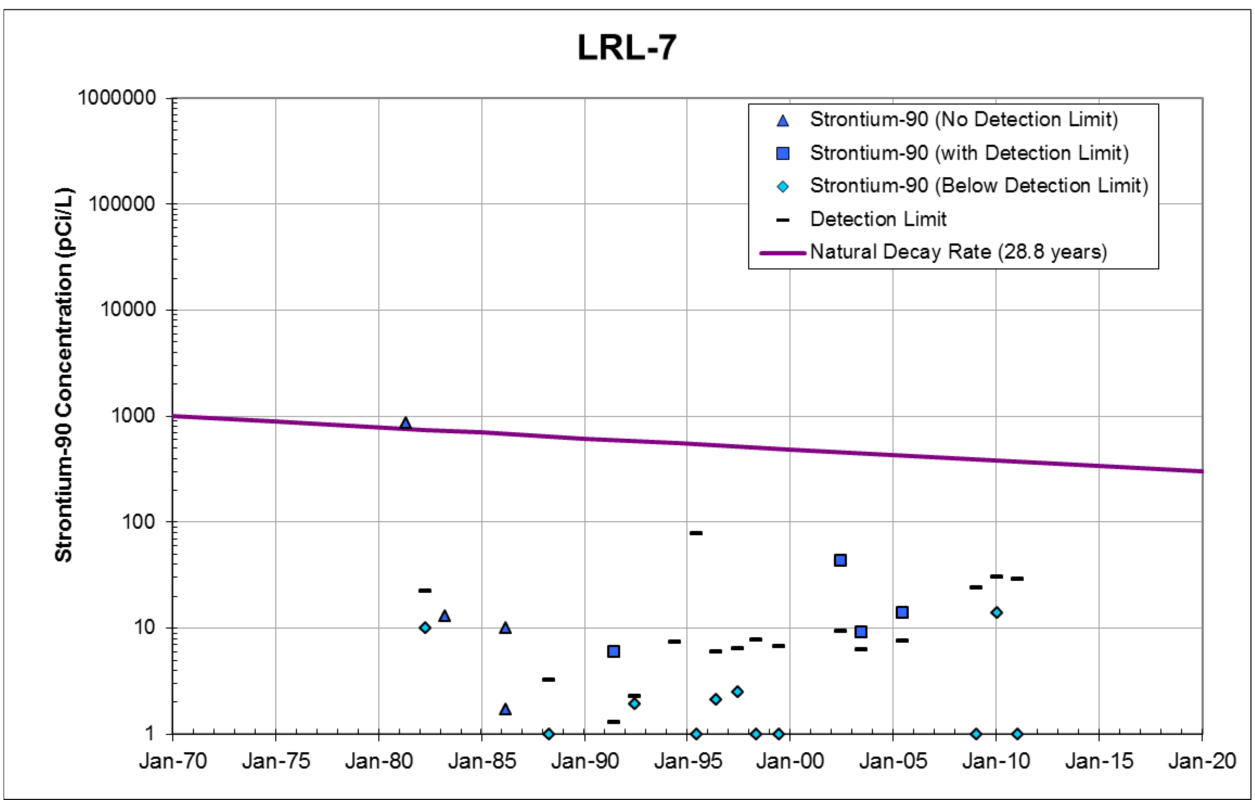

Chart 7. Strontium-90 Concentrations at Well LRL-7

Appendix C

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