2018 Groundwater Monitoring and Inspection Report
Gnome-Coach, New Mexico, Site

May 2019

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Abbreviations

BLM  U.S. Bureau of Land Management
137Cs  cesium-137
DOE  U.S. Department of Energy
EPA  U.S. Environmental Protection Agency
ft  feet
GEMS  Geospatial Environmental Mapping System
131I  iodine-131
LM  Office of Legacy Management
LTHMP  Long-Term Hydrologic Monitoring Program
LTS&M Plan  Long-Term Surveillance and Maintenance Plan
m/day  meters per day
pCi/L  picocuries per liter
90Sr  strontium-90
USGS  U.S. Geological Survey
WIPP  Waste Isolation Pilot Plant
Executive Summary

The Gnome-Coach site in southeastern New Mexico was the location of an underground nuclear test in 1961 and a groundwater tracer test in 1963 that 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 (LM)’s 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 from the August 2017 through August 2018 reporting period. The U.S. Bureau of Land Management was notified during the site inspection on February 6, 2018, that the water storage tank at well USGS-1 was overflowing and a water discharge line from the tank was damaged and spilling water. A sign near the emplacement shaft was replaced, but the remaining signs near well USGS-1 and around the perimeter of the site were found in good condition, as were the roads, wellheads, and the Project Gnome monument. No new applications were received nor were any permits granted to drill groundwater extraction wells or oil and gas wells on the site or in the sections that surround the site during this reporting period. Two salt water disposal wells in Section 33, west of the site, were plugged in February 2018.

Groundwater elevation data from the wells completed in the Culebra Dolomite continue to confirm 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 foot (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 recovered from the well’s last sampling event in January 2011. Water levels in reentry well DD-1, which monitors the detonation cavity, continued to rise at a rate of approximately 10 ft per year. Water levels in LRL-7 and DD-1 might not be representative of the Salado Formation and are likely influenced by remnant effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities.

Samples were collected from wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) on February 6, 2018, to monitor radionuclide concentrations associated with the tracer test. Laboratory radiochemical results were consistent with the previous year’s results. Samples were not collected from wells DD-1 and LRL-7 (completed in the Salado Formation) during the 2018 reporting period. Copies of this report are sent to the individuals on the distribution list provided as Appendix C and is available on the LM public website at https://www.lm.doe.gov/gnome/Sites.aspx.
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&M Plan) for the site describes LM’s plan for monitoring groundwater, inspecting the site, maintaining the institutional controls, evaluating and reporting data, and documenting the site’s records and data management processes (DOE 2016a). Figure 1 is a map showing the site location.

This report summarizes the results of the groundwater monitoring and site inspection activities conducted during the August 2017 through August 2018 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&M Plan 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) (Figure 2). A horizontal drift (Gnome drift) was mined...
Figure 1. Location Map for the Gnome-Coach, New Mexico, Site
Figure 2. Site Map for the Gnome-Coach, New Mexico, Site
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 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, 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 there were no additional underground nuclear detonations at the site. The site is still referred to as the Gnome-Coach site. Figure 2 is a map showing the site and site features (monitoring wells, emplacement shaft, and the Project Gnome monument). 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.

In 1963, USGS conducted a groundwater tracer test in the Culebra Dolomite, a fractured carbonate aquifer that is the most prolific aquifer near the site (Figure 3) and is at a depth of approximately 500 ft. 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 were used for the tracer test and are approximately 3100 ft west of the Project Gnome monument, which is directly above the detonation cavity (Figure 2). Water from the extraction well (USGS-4) was mixed with four dissolved radionuclides (tritium, iodine-131 [\(^{131}\)I], strontium-90 [\(^{90}\)Sr], and cesium-137 [\(^{137}\)Cs]), and the solution was pumped into the injection well (USGS-8). The tracer test experiment was performed in two separate phases over 21 days in February and March 1963. Samples were collected at the extraction well (USGS-4) during the test to record the arrival and concentration of each tracer.

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). 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 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 (USGS-1, USGS-4, and USGS-8) (Figure 2) 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 $2.7 \times 10^{-3}$ 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 $6.5 \times 10^{-9}$ 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; there are also fluids 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 completed 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 for those that were 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 evaluate the effectiveness of the monitoring network (Figure 1) 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), $^{90}$Sr, 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 contamination related to nuclear tests. 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 purpose for monitoring, the unit monitored, and the frequency for monitoring (sampling and water levels).

Table 1. Gnome-Coach Site Monitoring Well Network

<table>
<thead>
<tr>
<th>Well Identification</th>
<th>Purpose for Monitoring</th>
<th>Formation/Unit Monitored</th>
<th>Monitoring Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>USGS-1*</td>
<td>Point of access</td>
<td>Culebra Dolomite</td>
<td>Annual</td>
</tr>
<tr>
<td>USGS-4</td>
<td>Tracer test</td>
<td></td>
<td>Annual</td>
</tr>
<tr>
<td>USGS-8</td>
<td></td>
<td>Salado Formation</td>
<td>Periodic</td>
</tr>
<tr>
<td>LRL-7</td>
<td>Coach drift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD-1</td>
<td>Detonation cavity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 
* 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.
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 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.

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 at wells USGS-4 and USGS-8) and the detonation (at a depth of 1184 ft) 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 seismic survey results are summarized in the groundwater monitoring and inspection report (DOE 2013).

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 wellhead survey data are summarized in the 2014 groundwater monitoring and inspection report (DOE 2015b).

Repairs were made to the wellhead of reentry well DD-1 and a totalizing flow meter was installed at well USGS-1 in January 2015. Repairs to DD-1 were necessary because of vandalism in July 2014 (DOE 2015b). The flow meter was installed in the flow system of water-supply well USGS-1 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&M Plan 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 6, 2018, 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 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 (Section 34 within Township 23 South, Range 30 East) 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 in the sections surrounding and including the site to ensure those activities do not impact the site (Figure 4). 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. Figure 4 is a map showing the site (Section 34) and surrounding sections that are monitored for drilling activity.

The site inspection for this reporting period was conducted on February 6, 2018. At the time of the site inspection, the water storage tank near well USGS-1 was overflowing. A buried water line connected to the water storage tank was found damaged and spilling water. The pump in well USGS-1 that provides water to the tank was shut off and BLM was notified of the incident. The totalizing flow meter at well USGS-1 used to monitor the total gallons removed from the well was replaced with a new flow meter. A sign near the emplacement shaft was missing, so a new sign was installed. 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. Appendix A provides photographs of the monument and reentry well DD-1, concrete cap that covers the emplacement shaft, and the tank at well USGS-1 that was overflowing at the time of the site visit.

Additional inspection activities and the results are provided below:

- The New Mexico Office of the State Engineer website was accessed to determine whether any new groundwater extraction wells had been permitted in the nine sections in and surrounding the site (Figure 4). No new groundwater extraction wells were permitted in the referenced sections during this reporting period (OSE 2018).
Figure 4. Sections Surrounding the Gnome-Coach, New Mexico, Site
• The New Mexico Oil Conservation Division website was accessed to determine whether any new oil and gas well applications had been received or permitted in the nine sections in and surrounding the site (Figure 4). These wells extract oil and gas at depths ranging from 7600 to 10,500 ft, which is much deeper than the depth of the nuclear test (1184 ft). No new applications were permitted for the sections in and surrounding the site during this reporting period (OCD 2018). The two salt water disposal wells (API numbers 30-015-26084 and 30-015-31744) in Section 33 were plugged in February 2018 and are no longer active wells. The permit for the salt water disposal well (API number 30-015-43801) with a surface location in the southwest quarter of Section 26 was revised in March 2018, so the proposed surface location is in the northwest quarter of Section 35 (Figure 4). Drill dates for this well and the oil well (API number 30-015-42299) in the southwest quarter of Section 35 have not yet been established. These two permits were issued during the 2016 reporting period (DOE 2017).

• 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 2018).

• The LM public website was updated during this reporting period to include the 2017 groundwater monitoring and inspection report (DOE 2018).

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 depth-to-water 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 transducer life and the absence of short-term variations in the water levels observed by the past transducer data. Table 2 presents the depth-to-water data with groundwater elevations measured during the February 2018 inspection, along with the top-of-casing elevations, the top and bottom screen-zone elevations, and the formation monitored for the wells.

The transducer data were downloaded and water levels were measured manually in the site wells on February 6, 2018. The transducer data were downloaded again on August 29, 2018. 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 to show data from the time monitoring began in 2008 (Figure 5 and Figure 7). 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, so groundwater elevation data from these wells are corrected to true vertical depth (Figure 5 and Figure 6). Borehole deviation data are not available for wells DD-1 and LRL-7, so groundwater elevations from these wells are approximate (Figure 7).
Table 2. Gnome-Coach Site Monitoring Well Network Water Levels

<table>
<thead>
<tr>
<th>Well</th>
<th>Date</th>
<th>DTW (ft) (^a)</th>
<th>TOC Elevation (ft amsl)</th>
<th>TSZ Elevation (ft amsl)</th>
<th>BSZ Elevation (ft amsl)</th>
<th>Formation/Unit Monitored</th>
<th>Groundwater Elevation (ft amsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USGS-1</td>
<td>2/6/2018</td>
<td>439.00 (^b)</td>
<td>3426.60</td>
<td>2907(^c)</td>
<td>2875(^c)</td>
<td>Culebra Dolomite</td>
<td>2987.69(^c)</td>
</tr>
<tr>
<td>USGS-4</td>
<td>2/6/2018</td>
<td>430.18</td>
<td>3413.72</td>
<td>2940(^c)</td>
<td>2907(^c)</td>
<td></td>
<td>2988.47(^c)</td>
</tr>
<tr>
<td>USGS-8</td>
<td>2/6/2018</td>
<td>422.96</td>
<td>3411.25</td>
<td>2947(^c)</td>
<td>2915(^c)</td>
<td></td>
<td>2988.29(^c)</td>
</tr>
<tr>
<td>LRL-7</td>
<td>2/6/2018</td>
<td>461.45</td>
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<td>2653(^d)</td>
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Notes:
The TOC elevations are provided in U.S. State Plane, Zone New Mexico East, coordinate system, with vertical data based on NGVD 29 (DOE 2015b).
\(^a\) Depth to water has not been corrected for true vertical depth.
\(^b\) Well USGS-1 has a dedicated submersible pump that was not operating at the time of the water-level measurement.
\(^c\) Elevation has been corrected for true vertical depth. (At the current water-level depths, the deviation correction for USGS-1 is 0.09 ft; the deviation correction for USGS-4 is 4.93 ft; and no correction is required for USGS-8 because it did not deviate from vertical.)
\(^d\) 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:
BSZ = bottom of screen zone, uncased, open, or perforated interval in ft amsl
DTW = depth to water (all measurements obtained from north top-of-casing)
ft amsl = feet above mean sea level
NGVD 29 = National Geodetic Vertical Datum of 1929
TOC = top-of-casing elevation in ft amsl (NGVD 29)
TSZ = top of screen zone, uncased, open, or perforated interval in ft amsl
U/NM = unknown or not measured (the construction and open intervals of reentry well DD-1 are unknown)

Groundwater elevation data 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. The pump in well USGS-1 cycles on and off to maintain a constant volume in the nearby water tank that supplies water to livestock in the area. The volume of water in the tank is maintained by a float switch, which activates the pump in well USGS-1 and supplies water to the tank at a rate of approximately 15 gallons per minute. The totalizing flow meter installed at this well on July 12, 2017, to monitor total gallons removed, indicated that approximately 13 acre-feet of water was removed during this reporting period. Historical information on the totals gallons removed from well USGS-1 is limited, because of difficulties with maintaining the flow meter. Groundwater elevation data from the Culebra wells show that pumping in well USGS-1 produces an almost immediate water-level drawdown response in wells USGS-4 and USGS-8 which are about 2350 ft to the northwest. The average groundwater elevation in these wells decreased by approximately 1 ft during this reporting period, with the majority of the decrease occurring from February 2018 through the end of the reporting period of late August 2018 (Figure 6). Since historical data on the total gallons removed from well USGS-1 is limited, it is difficult to attribute the decreasing water levels solely to the pumping at well USGS-1. Figure 6 is the hydrograph showing groundwater elevations for the Culebra wells during this reporting period.
Figure 5. Hydrograph Showing Water Elevations in Culebra Wells

Figure 6. Hydrograph Showing Water Elevations in Culebra Wells for 2018 Reporting Period
A review of the on/off cycle of the pump does not indicate a dramatic increase in pumping during this reporting period. The trend of decreasing groundwater elevations in the Culebra wells may be the result of increased pumping from water supply wells outside the 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.

Wells DD-1 and LRL-7 monitor large openings (the detonation cavity and Coach drift) within the Salado Formation. The hydrographs of water elevations in these wells (Figure 7) are likely not indicative of Salado Formation water elevations in general. Water elevations in well LRL-7 (primary vertical axis) indicate that water levels are no longer rising and have recovered from the last sampling event in January 2011. Water elevations in well DD-1 (secondary vertical axis) indicate that water levels continue to rise in this well at a rate of approximately 10 ft/year. Factors that influence water levels in wells LRL-7 and DD-1 include slow refilling of the detonation cavity due to limited groundwater flow within the Salado, remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and injections of liquefied material associated with past disposal activities. Figure 7 is the hydrograph showing groundwater elevations for the wells completed in 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). The monitoring of these wells was initiated in 1972. The monitoring wells completed in the Culebra Dolomite (USGS-1, USGS-4, and USGS-8) are sampled annually for the radionuclides of interest (tritium, $^{137}\text{Cs}$, and $^{90}\text{Sr}$) 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 6, 2018. Samples were not collected from wells DD-1 and LRL-7 during this monitoring event. 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), $^{90}\text{Sr}$, and tritium (using conventional methods). The analytical results were validated in accordance with Section 5.0, “Validation of Environmental Data” in the Environmental Data Validation Procedures (LMS/PRO/S15870). 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 memo is available upon request.

Laboratory radiochemical results from the February 2018 monitoring event were consistent with the previous year’s results (Table 3). Concentrations of tritium, $^{137}\text{Cs}$, and $^{90}\text{Sr}$ in the samples collected from wells USGS-4 and USGS-8 are the result of radionuclides injected during the tracer test in 1963. Concentrations are higher in well USGS-8, the tracer-test injection well, than in well USGS-4, the tracer-test extraction well. A field duplicate sample was collected from well USGS-4. The duplicate result for tritium was in poor agreement with the sample and historical trend, so it was determined to be an outlier due to either a field or laboratory error and was rejected. Laboratory results of the sample from well USGS-1 indicate no detection of radionuclides above the laboratory minimum detectable concentration. Table 3 presents a summary of laboratory radiochemical results from 2010 through 2018 for comparison.

Figures B-1 through B-7 in Appendix B show temporal plots of radionuclide concentrations (1972–2018) 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), $^{90}\text{Sr}$, and $^{137}\text{Cs}$ have not been detected above the laboratory minimum detectable concentration in this well since monitoring began in 1972. The detection of $^{90}\text{Sr}$ in the February 2017 sample collected from USGS-1 was attributed to laboratory contamination (DOE 2018). 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
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**Note:**
<sup>a</sup> Indicates a field duplicate sample.

**Abbreviations:**
NA = not analyzed  
pCi/L = picocuries per liter
(12.3 years), $^{90}$Sr (28.8 years), and $^{137}$Cs (30.2 years) have been included on the charts for reference. The increases in tritium concentrations in samples collected from well LRL-7 (Figure B-1) and $^{137}$Cs concentrations in samples collected from wells USGS-8 and LRL-7 (Figure B-4 and Figure B-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 (Figure B-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 6, 2018. At the time of the site inspection, the water storage tank at well USGS-1 was overflowing and a water discharge line from the tank was found damaged and spilling water. These issues were reported to BLM and a sign near the emplacement shaft was replaced. The remaining signs near well USGS-1 and around the perimeter of the site were observed in good condition, as were the roads, wellheads, and the Project Gnome monument. No new applications were received nor were any permits granted to drill groundwater extraction wells or oil and gas wells on the site or in the sections that surround the site during this reporting period. Two salt water disposal wells west of the site in Section 33 were plugged in February 2018. It was determined in March 2018 that the salt water disposal well (API number 30-015-43801) planned with a surface location in the southwest quarter of Section 26 would be moved to the northwest quarter of Section 35. Drill dates for this well and the oil well (API number 30 015-42299) in the southwest quarter of Section 35 have not yet been established. These two permits were issued during the 2016 reporting period.

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 average groundwater elevation in these wells trended lower by approximately 1 ft during this reporting period. The 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.

Groundwater elevation data from well LRL-7, which monitors the Coach drift, indicate that water levels have recovered from the well’s last sampling event in January 2011. Water levels in reentry well DD-1, which monitors the detonation cavity, continued to rise at a rate of approximately 10 ft/year. Water levels in LRL-7 and DD-1 might not be representative of the Salado Formation and are likely influenced by remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities.

Samples were collected from wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) on February 6, 2018, to monitor radionuclide concentrations associated with the tracer test. Samples were not collected from wells DD-1 and LRL-7 (completed in the Salado Formation) during the 2018 reporting period. Laboratory radiochemical results obtained from the February 2018 monitoring event were consistent with the previous year’s results. Copies of this report are sent to the individuals on the distribution list provided as Appendix C and is available on the LM public website at [https://www.lm.doe.gov/gnome/Sites.aspx](https://www.lm.doe.gov/gnome/Sites.aspx).
5.0 References


Appendix A

Photographic Documentation
Photograph A-1. Looking northeast at the Project Gnome monument and reentry well DD-1

Photograph A-2. Looking north at the concrete cap that covers the Project Gnome emplacement shaft
Photograph A-3. Looking southeast at the water storage tank near well USGS-1 and the overflowing water from the tank
Appendix B

Well Concentration Plots
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Figure B-1. Tritium Concentrations at Wells USGS-4, USGS-8, and LRL-7
Figure B-2. Cesium-137 Concentrations at Well USGS-4

Figure B-3. Strontium-90 Concentrations at Well USGS-4
**Figure B-4. Cesium-137 Concentrations at Well USGS-8**

**Figure B-5. Strontium-90 Concentrations at Well USGS-8**
Figure B-6. Cesium-137 Concentrations at Well LRL-7

Figure B-7. Strontium-90 Concentrations at Well LRL-7
Appendix C

Report Distribution List
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