19.0 Tuba City, Arizona, Disposal Site

19.1 Compliance Summary

The Tuba City, Arizona, Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I Disposal Site was inspected on May 2, 2023. No significant changes were observed on the disposal cell or in the associated drainage features. Inspectors identified maintenance needs but found no cause for a follow-up inspection.

The U.S. Department of Energy (DOE) Office of Legacy Management (LM) conducts semiannual groundwater monitoring at the site to compare current conditions to baseline postconstruction groundwater quality. Evaluative groundwater monitoring is performed instead of normal point of compliance (POC) monitoring, as preexisting milling-related groundwater contamination may mask contamination leaching from the disposal cell. The most recent semiannual sampling events occurred in February and August 2023. The corresponding results are presented in Section 19.7.

19.2 Compliance Requirements

Requirements for the long-term surveillance and maintenance of the site are specified in the site-specific Long-Term Surveillance Plan (DOE 1996) (LTSP) in accordance with procedures established to comply with the requirements of the U.S. Nuclear Regulatory Commission (NRC) general license at Title 10 *Code of Federal Regulations* Section 40.27 (10 CFR 40.27). Table 19-1 lists these requirements.

Table 19-1. License Requirements for the Tuba City, Arizona, Disposal Site

Requirement	LTSP	This Report	10 CFR 40.27
Annual Inspection and Report	Section 6.0	Section 19.4	(b)(3)
Follow-Up Inspections	Section 7.0	Section 19.5	(b)(4)
Maintenance and Repairs	Section 8.0	Section 19.6	(b)(5)
Environmental Monitoring	Section 5.2	Section 19.7	(b)(2)
Corrective Action	Section 9.0	Section 19.8	—

19.3 Institutional Controls

The 145-acre site, defined by the property boundary shown in Figure 19-1, is held in trust by the U.S. Bureau of Indian Affairs. The Navajo Nation retains title to the land. UMTRCA authorized DOE to enter into a Cooperative Agreement (DE-FC04-85AL26731) with the Navajo Nation to perform remedial actions at the former uranium processing sites (DOE 1984). DOE and the Navajo Nation executed a Custodial Access Agreement that conveys to the federal government title to the residual radioactive materials stabilized at the site and ensures that DOE has perpetual access to the site.

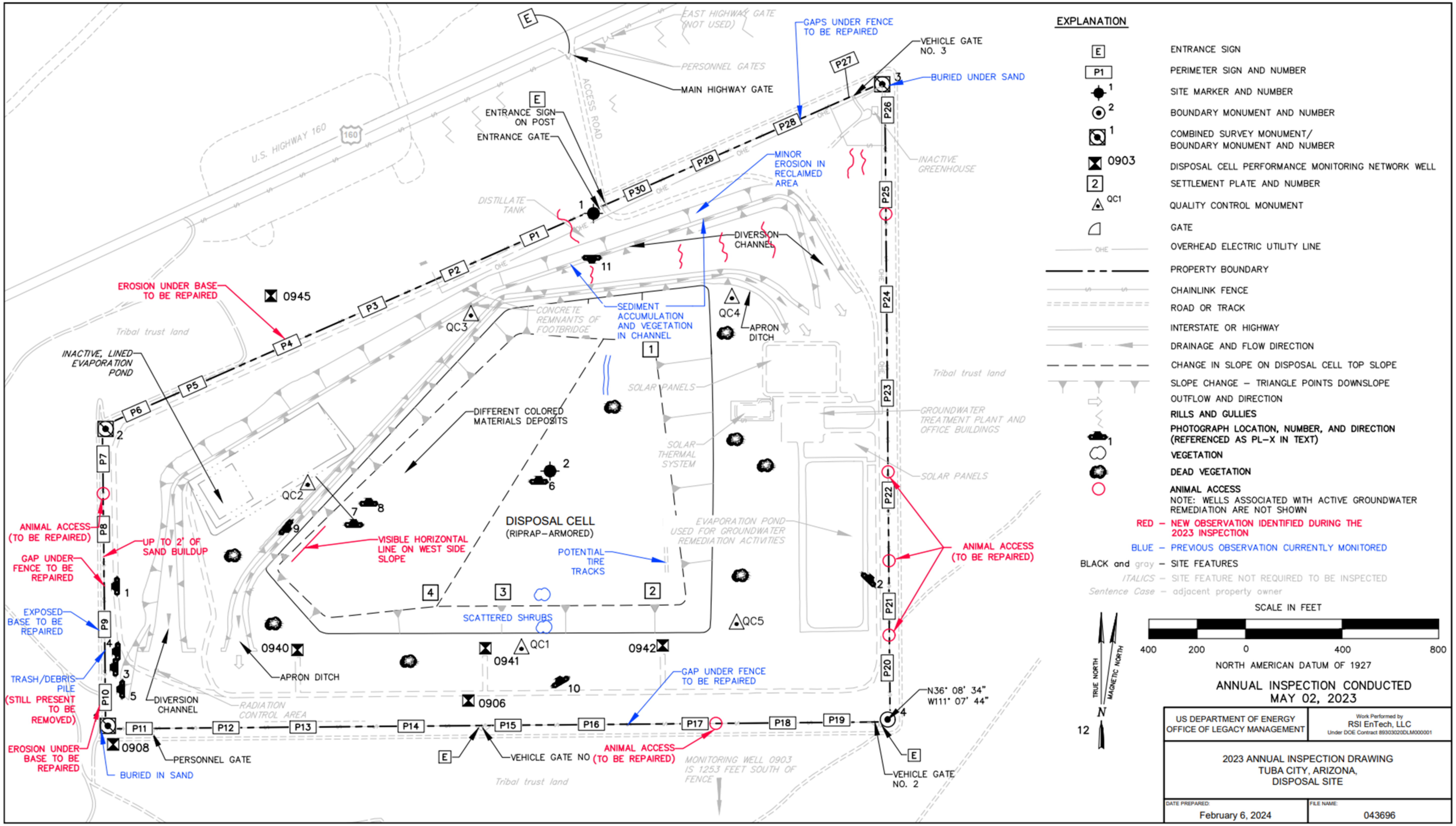


Figure 19-1. 2023 Annual Inspection Drawing for the Tuba City, Arizona, Disposal Site

The site was accepted under the NRC general license in 1996. DOE is the licensee and, in accordance with the requirements for UMTRCA Title I sites, LM is responsible for the custody and long-term care of the site. Institutional controls (ICs) at the site include federal custody of the disposal cell and its engineered features, administrative controls, and the following physical ICs that are inspected annually: the disposal cell and associated drainage features, entrance gate and sign, perimeter fence and signs, site markers, survey and boundary monuments, and wellhead protectors.

19.4 Inspection Results

The site, 6 miles northeast of Tuba City, Arizona, was inspected on May 2, 2023. The inspection was conducted by D. Marshall, H. Katz, and N. Lind of the Legacy Management Support contractor. B. Frazier (LM), M. De Lurdes Dinis (visitor of LM), R. Lamson (Hopi Tribe Department of Natural Resources, Office of Mining and Mineral Resources), D. Scott (Tuba City Chapter), and N. Baheshone (Diné Uranium Remediation Advisory Commission) also attended the inspection. The purposes of the inspection were to confirm the integrity of visible features at the site, identify changes in conditions that might affect conformance with the LTSP, and evaluate whether maintenance or follow-up inspection and monitoring are needed.

19.4.1 Site Surveillance Features

Figure 19-1 shows the locations of site features, including site surveillance features and inspection areas, in black and gray font. Some site features that are present but not required to be inspected are shown in italic font. Observations from previous inspections that are currently monitored are shown in blue, and new observations identified during the 2023 annual inspection are shown in red. Inspection results and recommended maintenance activities associated with site surveillance features are described in the following subsections. Photographs to support specific observations are noted in the text and in Figure 19-1 by photograph location (PL) numbers. The photographs and photograph log are presented in Section 19.10.

19.4.1.1 Access Road, Entrance Gates, and Entrance Signs

Access to the site is from U.S. Highway 160. Perpetual access to the site is granted by the Custodial Access Agreement. A gate in a chainlink fence on the main highway right-of-way (Figure 19-1) allows access to the site via a gravel road. The entrance gate is in the inner chainlink perimeter fence between perimeter signs P1 and P30. Both gates were operational at the time of the inspection. Vehicle gates are also present in the northeast corner of the site and along the southern fence line to facilitate access for offsite activities. All gates were secured and functional.

Entrance signs are posted on the main highway gate, near the entrance gate, and on two vehicle gates (No. 1 and No. 2). Vehicle Gate No. 3, in the northeast corner of the site, purposefully does not have a sign. An informational sign exists on the main entrance gate. No maintenance needs were identified.

19.4.1.2 Perimeter Fence and Signs

A chainlink perimeter fence encloses the site. Windblown sand and tumbleweeds regularly accumulate along the perimeter fence line. Wind scouring also occurs, which results in gaps under the fence (PL-1). Also noted are several gaps under the fence from animal access (PL-2). These areas will be repaired before the next inspection. A sediment deposition gage was installed before the annual inspection. It should be read every year to quantify sand deposition (PL-3). Trash and debris have accumulated outside the fence near perimeter sign P9 (P-4). The debris will be removed following the inspection.

Thirty pairs of perimeter signs, designated P1 through P30, are attached to steel posts set in concrete directly inside and along the perimeter fence. One of the sign pairs is textual, and the other is pictorial. The base of perimeter signs P4, P9, and P10 were undercut by wind erosion and will be repaired following the inspection (PL-5). Two faded signs that warn of high voltage near perimeter sign P12 were replaced before the inspection. No other maintenance needs were identified.

19.4.1.3 Site Markers

The site has two granite site markers. Site marker SMK-1 is just inside the entrance gate, and site marker SMK-2 is on the top slope of the disposal cell (PL-6). No maintenance needs were identified.

19.4.1.4 Survey and Boundary Monuments

One boundary monument and three combined survey and boundary monuments delineate the corners of the site. Combined survey and boundary monuments SM/BM-1 and SM/BM-3 tend to get covered with windblown sand and are marked with steel T-posts. All other survey and boundary monuments were located and in good condition. No maintenance needs were identified.

19.4.1.5 Aerial Survey Quality Control Monuments

Five aerial survey quality control monuments were located and in good condition (PL-7). No maintenance needs were identified.

19.4.1.6 Monitoring Wells

Seven monitoring wells (wells 0903, 0906, 0908, 0940, 0941, 0942, and 0945) constitute the disposal cell performance monitoring network. Monitoring wells 0906, 0908, 0940, 0941, and 0942 are inside or immediately outside the perimeter fence. Inspectors checked the wellhead protectors (with the exception of wells 0903 and 0945, which are offsite). All were found to be undamaged and locked. No other maintenance needs were identified.

19.4.2 Inspection Areas

In accordance with the LTSP, the site is divided into three inspection areas (referred to as "transects" in the LTSP) to ensure a thorough and efficient inspection. The inspection areas are (1) the disposal cell, (2) the area between the disposal cell and the site boundary, and (3) the outlying area. Inspectors examined specific site surveillance features within each area and looked for evidence of erosion, settling, slumping, or other modifying processes that might affect the site's conformance with LTSP requirements.

19.4.2.1 Disposal Cell

The disposal cell, completed in 1989, occupies 50 acres. The disposal cell is armored with riprap to control erosion and deter animal and human intrusion. Inspectors confirmed parallel tracks on the top slope of the disposal cell that were reported in previous annual reports. An evaporative mineral, caused by water pooling and subsequent evaporation, on top of windblown deposited sediment within riprap matrixes was noted on the top of the disposal cell (PL-8). These areas will continue to be monitored. There was no evidence of erosion, settling, slumping, or other modifying processes on the disposal cell.

The riprap-covered side slopes were in good condition. There were visible horizontal channels along the southwest slopes (PL-9). The channels are most likely formed from surface flow from melting snow cover or precipitation, or both. These features do not currently pose a threat to the integrity of the disposal cell; however, continued monitoring is recommended to ensure that erosion features do not create any problems that could undermine the soil and rock interface or the rock side slope below.

In accordance with the LTSP, deep-rooted vegetation is controlled to prevent potential penetration of the radon barrier. Windblown sediments continue to accumulate on the rock-covered surfaces, providing a favorable environment for plant growth. Periodic spot application of herbicide has been effective in controlling deep-rooted vegetation growth on the disposal cell cover. No deep-rooted shrubs were observed on top of the disposal cell, but some shrubs have become established on the side slopes (PL-10), as noted in previous inspections. This area will continue to be monitored. No maintenance needs were identified.

19.4.2.2 Area Between the Disposal Cell and the Site Boundary

The disposal cell is protected from stormwater runoff by a disposal cell apron ditch and a diversion channel, both of which are armored with riprap run along the north and northwest sides of the disposal cell. Windblown sand and vegetation accumulate in the apron ditch and the diversion channel along the north and northwest sides of the disposal cell. The sand deposition and associated vegetation establishment have not adversely affected the performance of these structures.

The north slope above the diversion channel consists of noncohesive sandy soil and is subject to erosion from stormwater runoff. Erosion repair conducted in this area in 2013 reduced the rate of erosion and subsequent soil deposition in the channel. Some erosion and deposition continue near the northeast corner of the diversion channel—an erosion gully and soil accumulation were observed (PL-11). Erosion will be monitored, and erosion control repairs will be performed as needed.

Similar to last year, inspectors noted that much of the woody vegetation, in reclaimed areas around the disposal cell was dead. In 2022, these areas were of concern to tribal officials (Mr. Honie) as they could present a potential fire hazard. The dead vegetation will be removed before the next inspection to reduce potential fire hazards at the site.

Two of the three evaporation ponds near the northwest side of the disposal cell were removed in 2007. The area was reclaimed and seeded with a native seed mix in 2007 and again in 2013.

The remaining historical evaporation pond, containing windblown sand and evaporites, is retained as a backup for the main evaporation pond on the east side of the site. The steel cable and caution signs surrounding the pond and the high-density polyethylene liner were intact. What was previously thought to be a plastic geofabric that stabilizes the south-facing slope of the pond is actually the geocell erosion-prevention grid. The visual exposure is the grid material. Vegetation was establishing in the geocells, and the slope is stable. Inspectors will continue to monitor this area. No other maintenance needs were identified.

Erosional gullies were noted along the northern perimeter fence. These gullies are originating near the main highway and are most prominent between the highway and the inner chainlink perimeter fence. This erosional area will be monitored but does not currently affect the integrity of the disposal cell. No maintenance needs were identified.

There are multiple structures and features associated with the former groundwater treatment system. Beginning in 2002, contaminated groundwater was extracted and treated through ion-exchange and distillation processes then returned to the aquifer through an infiltration trench upgradient of the disposal cell. Operation of the groundwater treatment plant (GWTP) was suspended in September 2014 due to hydrologic constraints on extraction and maintenance challenges. The structures associated with the GWTP remain onsite and include a Control Building; Lab and Shop Building; ion-exchange building, external tanks, and distillation skid; solar water-heating system; two photovoltaic panel arrays for utility power generation; evaporation ponds; network of extraction, injection, and monitoring wells; and treated water infiltration trench. An inactive greenhouse previously associated with the site was removed in 2023. No maintenance needs were identified.

19.4.2.3 Outlying Area

The 0.25-mile area beyond the site boundary was visually observed for erosion, changes in land use, or other phenomena that might affect the long-term integrity of the site. No evidence of changed land use or maintenance needs were identified.

19.5 Follow-Up Inspections

LM will conduct follow-up inspections if (1) a condition is identified during the annual inspection or other site visit that requires a return to the site to evaluate the condition or (2) LM is notified by a citizen or outside agency that conditions at the site are substantially changed. No need for a follow-up inspection was identified.

19.6 Maintenance and Repairs

The following maintenance items that were identified in the 2022 inspection will be completed before the next inspection:

- Repair the gaps in the fence near perimeter signs P9, P16, and P28
- Implement habitat enhancements to reduce potential fire hazards at the site

Installation of the sand deposition gage at perimeter sign P9 was completed before the inspection.

Inspectors noted the following maintenance items in 2023 that will be completed before the next inspection:

- Repair the eroding base at perimeter signs P4, P9, and P10
- Remove the trash and debris near perimeter sign P9
- Repair the animal access areas along the eastern and southern perimeter fence

19.7 Environmental Monitoring

In accordance with the LTSP, semiannual groundwater monitoring is conducted at the locations shown in Figure 19-2 to compare current conditions at the site to baseline postconstruction groundwater quality. Groundwater quality beneath and downgradient of the disposal cell has been degraded by contamination from former uranium-processing activities. This preexisting milling-related contamination might mask contamination leaching from the disposal cell, which limits the effectiveness of normal POC groundwater monitoring as a reliable indicator of disposal cell performance (40 CFR 192 Subpart A).

19.7.1 Groundwater Monitoring Program

Instead of POC monitoring, groundwater monitoring is performed in accordance with Section 5.2.2 of the LTSP and is defined as evaluative monitoring. Evaluative monitoring is performed to "(1) evaluate trends in ground water quality, (2) monitor the downgradient extent of contamination in ground water, (3) analyze the impacts of transient drainage and surface runoff, and (4) assess the effects of ground water restoration measures associated with containing the contamination related to uranium processing activities" (DOE 1996). Evaluative groundwater monitoring was conducted in February and August 2023 at the locations shown in Figure 19-2. Before addressing the most recent results of the evaluative groundwater monitoring program, a summary of historical and current groundwater remediation approaches is warranted.

Groundwater remediation is being conducted by an active treatment system that includes the operation of extraction wells and discharge of extracted (contaminated) groundwater to the onsite evaporation pond for volume reduction. The progress of groundwater remediation is evaluated and reported routinely (typically annually), separate from this compliance reporting (e.g., DOE 2023b). The remediation approach has changed over the years, from the continuous high-volume pumping approach applied at the start of active remediation in 2002 to the short-duration, high-intensity pumping regime applied currently. Details of historical pumping regimes are addressed in recent groundwater remedy performance evaluations (DOE 2022; DOE 2023b).

Pumping tests were performed in 2017 to determine groundwater drawdown and recovery rates and to characterize variations in hydraulic conductivity. Results were reported in the *Interim Treatment System Evaluation Report, Tuba City, Arizona, Disposal Site* (DOE 2020). Since June 2018, the remediation system has operated in high-volume, short-duration campaigns during periods of highest potential for evaporative flux that typically begin in July and end in October. As many as 11 extraction wells are operating during this period. The annual extraction volume is currently constrained to about 5 million gallons due to the evaporation pond capacity and the average annual evaporation rate of the pond (DOE 2023b).

Note: Well 0942 was converted from a monitoring well to an extraction well in 2015.

Figure 19-2. Evaluative Groundwater Monitoring Network at the Tuba City, Arizona, Disposal Site

Seven wells (Figure 19-2 and Table 19-2) identified in the LTSP are monitored for four hazardous constituents: molybdenum, nitrate, selenium, and uranium (Table 19-2) (DOE 1996). As a baseline for cell performance evaluation, provisional upper baseline limits (UBLs) for the four constituents were calculated in accordance with the U.S. Environmental Protection Agency's *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989) and documented in the LTSP (DOE 1996). The UBLs are listed in Table 19-3.

Table 19-2. LTSP Groundwater Monitoring Network at the Tuba City, Arizona, Disposal Site

Monitoring Well	Hydrologic Relationship	Monitoring Frequency
0903	Downgradient (offsite)	Annually
0906	Downgradient	Semiannually
0908	Downgradient	Semiannually
0940[a]	Downgradient	Semiannually
0941	Downgradient	Semiannually
0942[b]	Downgradient	No Longer Monitored[b]
0945	Upgradient (background)	Annually

Notes:
[a] Between August 2004 and February 2010, samples from well 0940 could not be obtained because of an insufficient volume of water. This explains the data gaps in Figure 19-3 through Figure 19-6.
[b] Well 0942 was converted from a monitoring well to an extraction well in 2015 and, therefore, has not been sampled since then.

Table 19-3. Provisional UBLs for Groundwater at the Tuba City, Arizona, Disposal Site

Constituent	Provisional UBL (mg/L)[a]	MCL (mg/L)[b]
Molybdenum	0.14	0.10
Nitrate (as nitrogen)	311[c]	10
Selenium	0.05	0.01
Uranium	1.17	0.044

Notes:
[a] As documented in the LTSP (DOE 1996).
[b] MCLs as listed in 40 CFR 192 Subpart A.
[c] UBL for nitrate as nitrogen converted from the original UBL cited in the LTSP.

Abbreviations:
MCL = maximum concentration limit
mg/L = milligrams per liter

UBLs were described in the LTSP as provisional because "baseline conditions were established for locations other than the disposal cell monitor wells." Establishing baseline conditions at wells 0906 and 0908 was conducted to determine "transient excursions from baseline conditions, potential chemical gradients between baseline and disposal cell locations, and stabilization of postclosure disposal cell hydrology" (DOE 1996). UBLs are concentrations that, with 95% confidence, would be exceeded less than 5% of the time during long-term monitoring if groundwater conditions near the monitoring well did not change.

Because the four constituents are present in tailings material, relatively mobile in groundwater, and found in low concentrations in background groundwater quality, exceedance of UBLs in more than 5% of sampling events over the long term could indicate that the disposal cell is not performing to design standards. However, the LTSP also notes that elevated concentrations could result from transient drainage of tailings fluid into the subsurface (directly beneath the cell) or from rainfall infiltrating through contamination in the unsaturated zone in the mill ponds area not covered by the disposal cell. Elevated concentrations attributed to transient drainage or infiltration would not be indicative of substandard performance for the cell.

Active groundwater remediation was anticipated when the LTSP was prepared in 1996, and it was expected that deviations from anticipated disposal cell performance could be detected even with ongoing groundwater remediation. However, the LTSP also noted that (1) POC sampling and analysis protocol to monitor cell performance could not be established until groundwater restoration was complete and (2) the LTSP would be revised at that time.

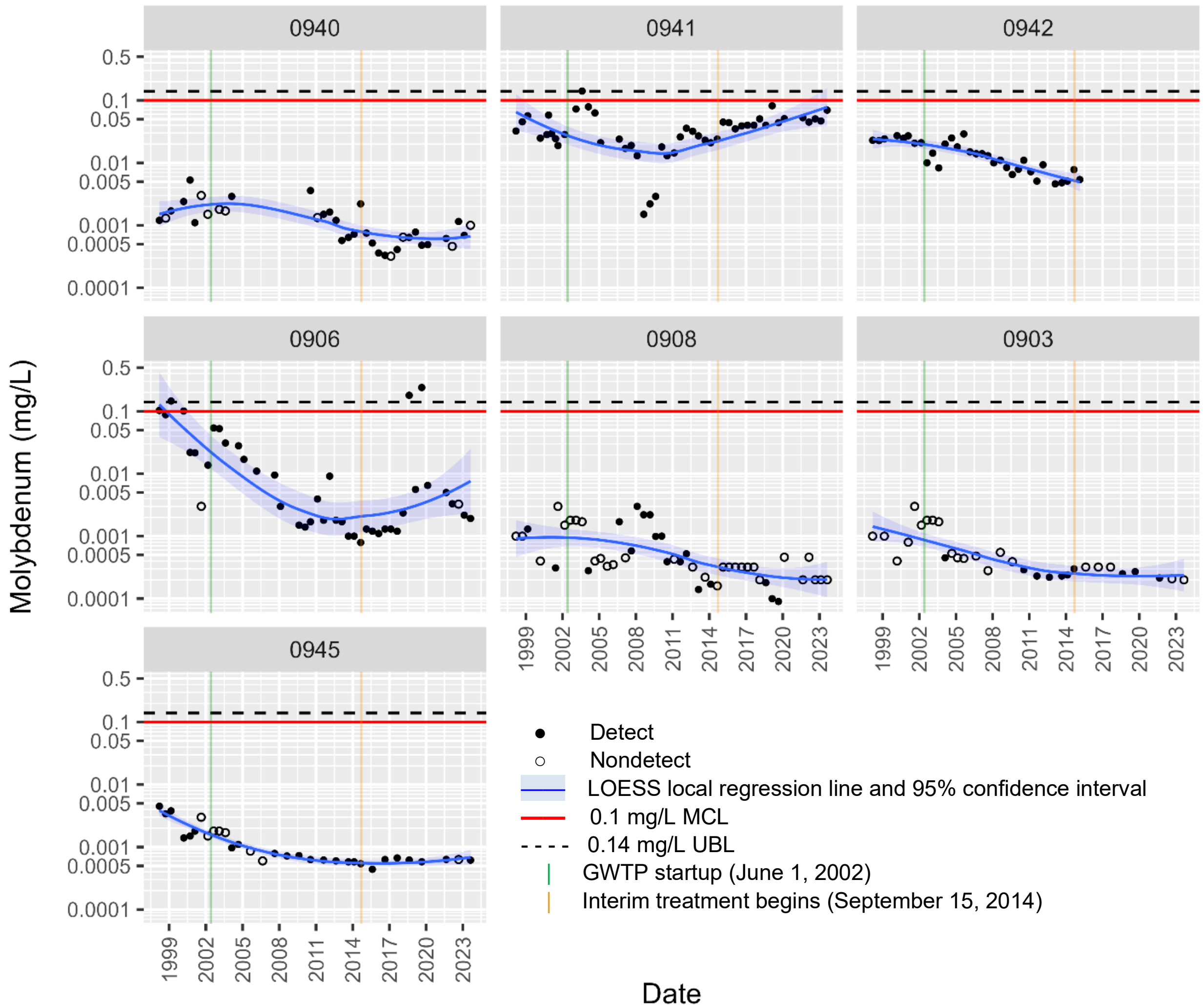
As noted in the LTSP, the UBL value should not be exceeded more than 5% of the time as long as conditions near the monitoring well do not change. Due to implementation of active remediation (2002–2014) and interim treatment (2015 to present), the conditions near the LTSP cell performance wells have constantly been affected, and exceedance of UBLs cannot be attributed to disposal cell performance. Recent operation of the interim treatment system, which potentially affects concentrations of target analytes in the LTSP-specified evaluative monitoring wells, is described in the following paragraphs.

19.7.2 Groundwater Monitoring Results

Figure 19-3 through Figure 19-6 show time-concentration plots for the four target analytes (molybdenum, nitrate, selenium, and uranium) along with corresponding UBLs and maximum concentration limits (MCLs). In these figures, data are plotted from 1998 to the present, consistent with the time frame evaluated in previous annual compliance reports (DOE 2023a). In each of these figures, downgradient wells (from Table 19-2) are ordered in the general direction of groundwater flow or the distance from the disposal cell (Figure 19-2). Data for the upgradient background well (0945) are plotted last. Interpretations of the analyte-specific data follow each figure.

Although data are plotted for the entire evaluative monitoring network, because well 0942 was converted from a monitoring well to an extraction well in 2015 (precluding sampling), corresponding trends are no longer discussed. All groundwater monitoring results for the site are reported and published on the LM Geospatial Environmental Mapping System (GEMS) website (https://gems.lm.doe.gov/#site=TUB). In this section, the MCLs shown are presented for informational purposes only. The LTSP requirement related to disposal cell performance is for evaluative monitoring over time, in comparison with the UBLs listed in Table 19-3.

In accordance with LTSP requirements to evaluate analyte concentration trends in the monitoring wells (Section 5.2.2 of DOE 1996), Mann-Kendall trend analysis was conducted for all analyte-well combinations to characterize the direction of the concentration trends. Table 19-4 identifies analyte-well combinations with statistically significant increasing (or decreasing) trends based on the full monitoring period addressed in Figure 19-3 through Figure 19-6 (1998–2023). To facilitate interpretation of more recent trends, Table 19-5 presents the same information, since interim treatment began (2015 to present).



Note: Downgradient wells (from Table 19-2) are ordered in general direction of groundwater flow or distance from the disposal cell (Figure 19-2). Data for the upgradient background well are plotted last.
Abbreviations: LOESS = locally estimated scatterplot smoothing, mg/L = milligrams per liter

Figure 19-3. Time-Concentration Plots of Molybdenum in Groundwater at the Tuba City, Arizona, Disposal Site, 1998–2023

Since 1998, molybdenum concentrations have been mostly at or below the 0.14 milligram per liter (mg/L) UBL, and in most cases the 0.1 mg/L MCL, in all LTSP evaluative monitoring wells (Figure 19-3). The few exceptions apply to well 0906: 0.15 mg/L in February 1999 and 0.18–0.24 mg/L in 2018–2019. The latter spikes coincide with the short-duration, high-intensity pumping campaigns. Although a statistically significant decreasing trend is found for the 1998–2023 time frame (Table 19-4), molybdenum concentrations in well 0906 have been increasing since 2015 (Figure 19-3). That trend is not statistically significant, however (Table 19-5), and the most recent result, 0.0019 mg/L, is well below both the UBL and the MCL. Molybdenum concentrations in well 0941 have increased since 2015, accounting for the statistically significant trend overall, and are approaching the MCL (most recent result of 0.070 mg/L). Molybdenum concentrations in wells 0940, 0908, and 0903 have been comparable to concentrations in background well 0945. Most results for wells 0908 and 0903 have been below detection limits (Figure 19-3) (Table 19-4).

Table 19-4. Mann-Kendall Trend Analysis Results for Target Analytes in Tuba City, Arizona, Disposal Site Monitoring Wells, 1998–2023

Parameter[a]	Well	Number of Samples[b]	Number of Nondetects	Kendall's tau[c,d]	p-value[c,d]	Trend[c,d]
Molybdenum	0903	31	21	−0.07	0.58	No Trend
Molybdenum	0906	43	2	−0.37	0.001	Decreasing
Molybdenum	0908	48	30	−0.18	0.073	No Trend
Molybdenum	0940	36	10	−0.29	0.011	Decreasing
Molybdenum	0941	48	0	0.21	0.039	Increasing
Molybdenum	0945	32	8	−0.45	<0.001	Decreasing
Nitrate as N	0903	31	0	0.47	<0.001	Increasing
Nitrate as N	0906	43	0	0.13	0.24	No Trend
Nitrate as N	0908	48	0	0.64	<0.001	Increasing
Nitrate as N	0940	36	0	0.08	0.48	No Trend
Nitrate as N	0941	48	0	0.72	<0.001	Increasing
Nitrate as N	0945	32	0	0.52	<0.001	Increasing
Selenium	0903	31	0	0.19	0.14	No Trend
Selenium	0906	43	0	0.35	0.001	Increasing
Selenium	0908	48	1	−0.27	0.006	Decreasing
Selenium	0940	36	0	−0.23	0.051	No Trend
Selenium	0941	48	0	0.51	<0.001	Increasing
Selenium	0945	32	2	0.45	<0.001	Increasing
Uranium	0903	31	0	0.54	<0.001	Increasing
Uranium	0906	43	0	0.03	0.79	No Trend
Uranium	0908	48	0	−0.64	<0.001	Decreasing
Uranium	0940	36	0	0.27	0.021	Increasing
Uranium	0941	48	0	0.57	<0.001	Increasing
Uranium	0945	32	0	−0.21	0.10	No Trend

Notes:

[a] For all well-parameter combinations, the initial trend analysis date is March 1998 (March 11–14, depending on location) and the final trend analysis date is August 2023 (August 21–23, depending on location). Trends for well 0942 are not shown because sampling was discontinued in 2015.

[b] Duplicate sample results were excluded from the trend analysis.

[c] Trend tests were performed using the "NADA: Nondetects and Data Analysis for Environmental Data" package in R, version 1.6-1.1 (Lee 2020). The NADA trend test is similar to the traditional Mann-Kendall trend test except that it accounts for the presence of nondetects at multiple detection limits.

[d] Trend analyses were conducted at the 0.05 significance level using a two-sided test. A calculated p-value of less than 0.05 indicates that a significant trend in the time series exists. The test statistic, Kendall's tau, is a measure of the strength of the association between two variables, with values always falling between −1 and +1.

Abbreviation:

N = nitrogen

Table 19-5. Mann-Kendall Trend Analysis Results for Target Analytes in Tuba City, Arizona, Disposal Site Monitoring Wells, 2015–2023

Parameter	Well[a]	Initial Trend Analysis Date	Number of Samples[b]	Number of Nondetects	Kendall's tau[c,d]	p-value[c,d]	Trend[c,d]
Molybdenum	0903	8/12/2015	8	5	−0.25	0.37	No Trend
Molybdenum	0906	2/16/2015	16	1	0.25	0.19	No Trend
Molybdenum	0908	2/16/2015	16	13	−0.03	0.91	No Trend
Molybdenum	0940	2/17/2015	16	4	0.17	0.38	No Trend
Molybdenum	0941	2/17/2015	16	0	0.45	0.016	Increasing
Molybdenum	0945	8/11/2015	8	1	−0.07	0.90	No Trend
Nitrate as N	0903	8/12/2015	8	0	0.68	0.025	Increasing
Nitrate as N	0906	2/16/2015	16	0	−0.47	0.013	Decreasing
Nitrate as N	0908	2/16/2015	16	0	0.46	0.015	Increasing
Nitrate as N	0940	2/17/2015	16	0	0.29	0.13	No Trend
Nitrate as N	0941	2/17/2015	16	0	−0.1	0.62	No Trend
Nitrate as N	0945	8/11/2015	8	0	−0.18	0.62	No Trend
Selenium	0903	8/12/2015	8	0	0.75	0.013	Increasing
Selenium	0906	2/16/2015	16	0	0.53	0.005	Increasing
Selenium	0908	2/16/2015	16	1	−0.32	0.092	No Trend
Selenium	0940	2/17/2015	16	0	0.68	0.0003	Increasing
Selenium	0941	2/17/2015	16	0	−0.13	0.50	No Trend
Selenium	0945	8/11/2015	8	0	−0.04	1	No Trend
Uranium	0903	8/12/2015	8	0	0.79	0.009	Increasing
Uranium	0906	2/16/2015	16	0	0.85	<0.001	Increasing
Uranium	0908	2/16/2015	16	0	−0.39	0.037	Decreasing
Uranium	0940	2/17/2015	16	0	−0.16	0.42	No Trend
Uranium	0941	2/17/2015	16	0	−0.09	0.65	No Trend
Uranium	0945	8/11/2015	8	0	−0.25	0.42	No Trend

Notes:

[a] For all well-parameter combinations, the final trend analysis date is August 21–23, depending on location. Trends for well 0942 are not shown because sampling was discontinued in 2015.

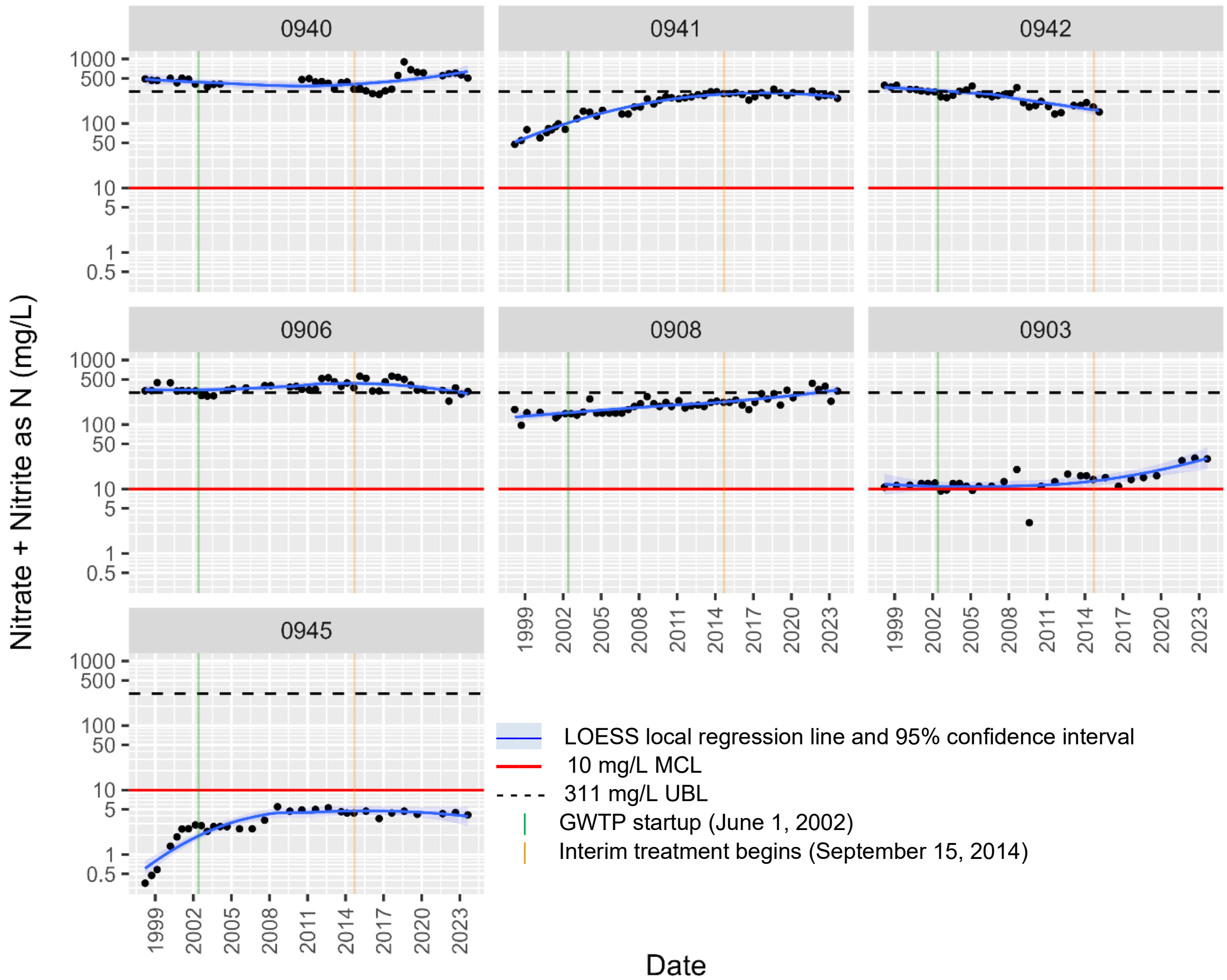
[b] Duplicate sample results were excluded from the trend analysis.

[c] Trend tests were performed using the "NADA: Nondetects and Data Analysis for Environmental Data" package in R, version 1.6-1.1 (Lee 2020). The NADA trend test is similar to the traditional Mann-Kendall trend test except that it accounts for the presence of nondetects at multiple detection limits.

[d] Trend analyses were conducted at the 0.05 significance level using a two-sided test. A calculated p-value of less than 0.05 indicates that a significant trend in the time series exists. The test statistic, Kendall's tau, is a measure of the strength of the association between two variables, with values always falling between −1 and +1.

Abbreviation:

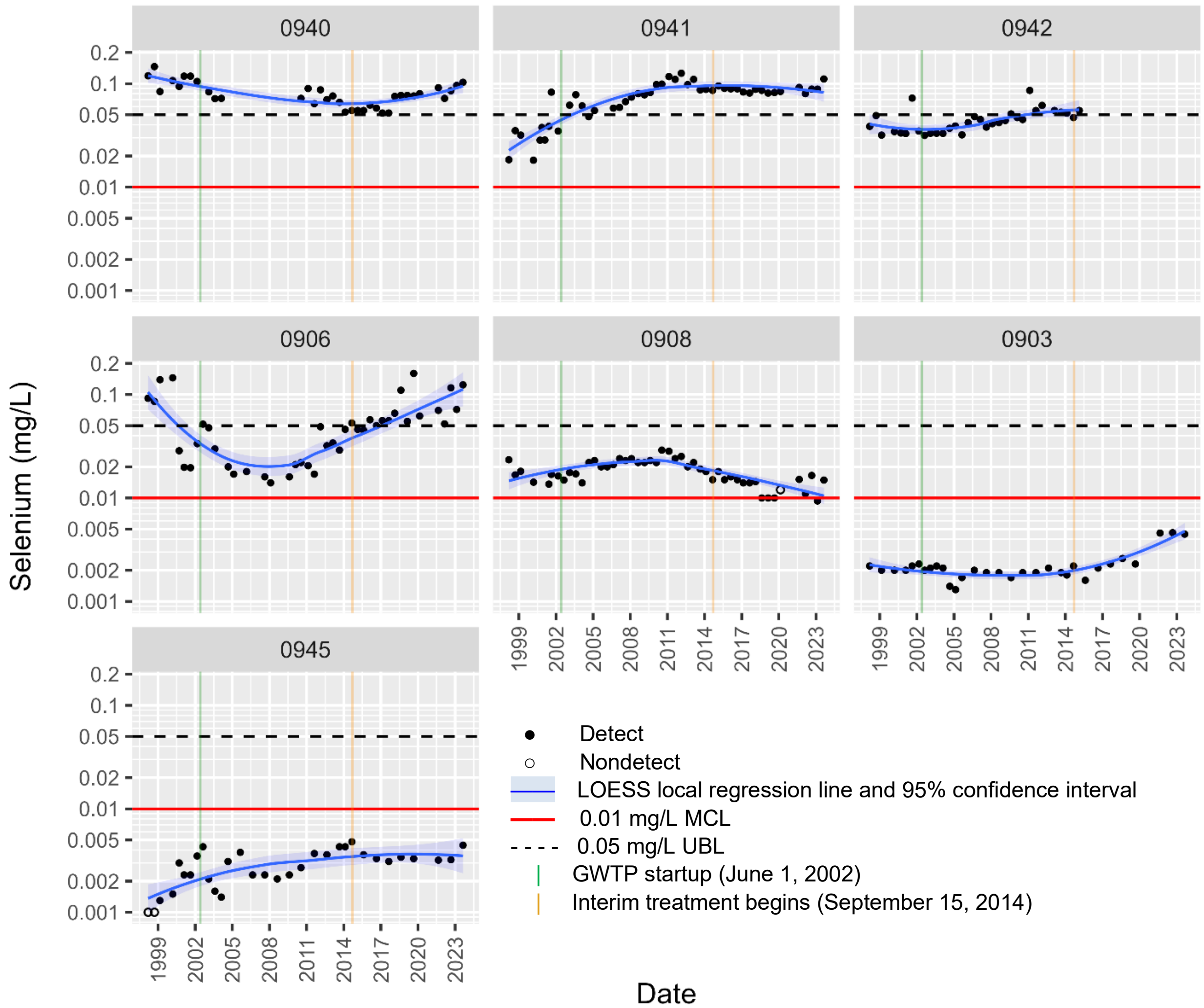
N = nitrogen



Note: Downgradient wells (from Table 19-2) are ordered in general direction of groundwater flow or distance from the disposal cell (Figure 19-2). Data for the upgradient background well are plotted last.
Abbreviation: LOESS = locally estimated scatterplot smoothing, N = nitrogen

Figure 19-4. Time-Concentration Plots of Nitrate (as N) in Groundwater at the Tuba City, Arizona, Disposal Site, 1998–2023

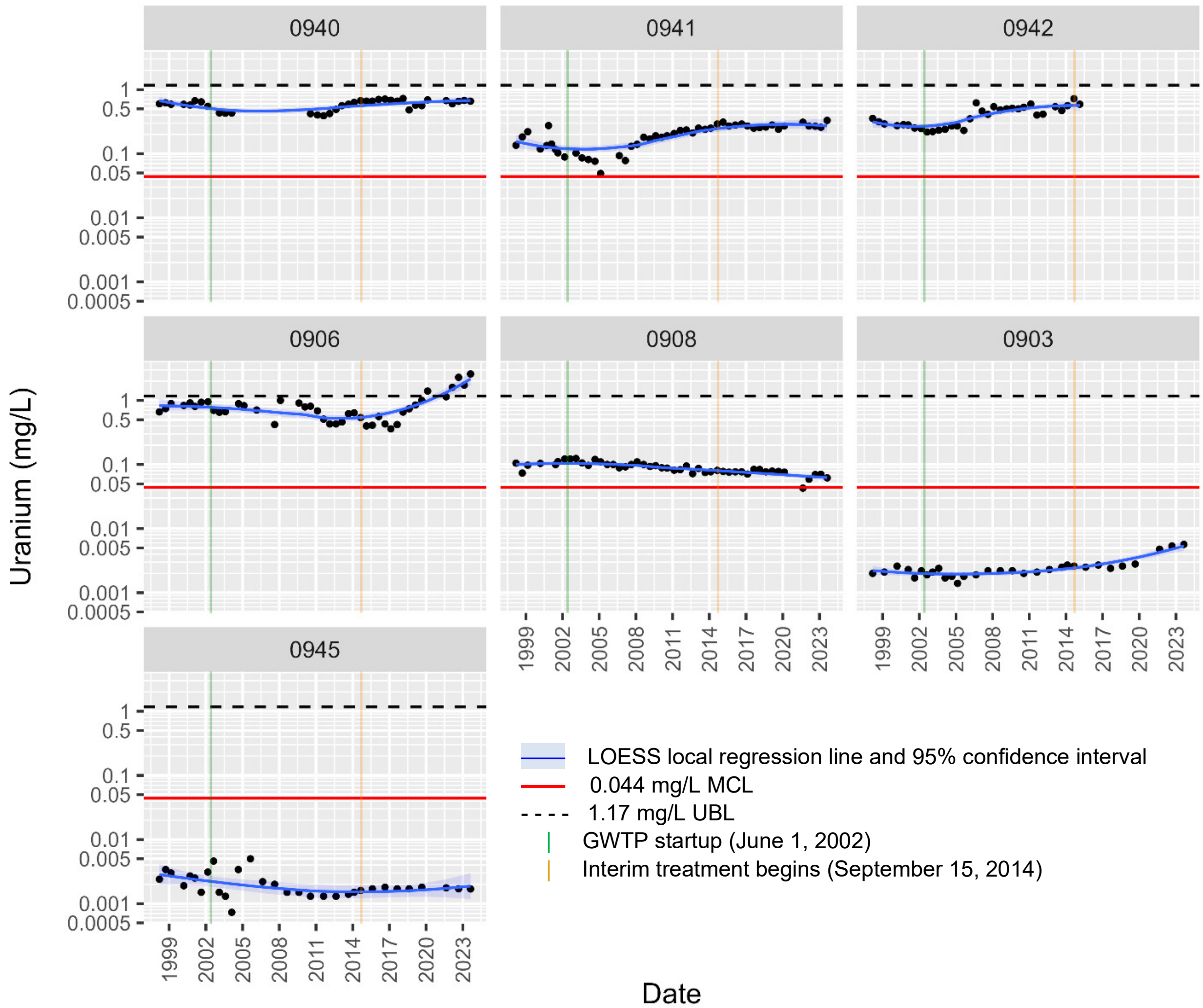
Nitrate (+ nitrite as nitrogen [N]) concentrations have historically exceeded the 10 mg/L MCL in all LTSP evaluative wells except background well 0945 (Figure 19-4). The 311 mg/L UBL has been exceeded in all downgradient evaluative monitoring wells except southernmost well 0903, approximately 1250 feet south of the site perimeter. Mann-Kendall trend analysis for 1998–2023 indicates statistically significant increasing nitrate concentration trends in four of the six wells currently monitored: wells 0903, 0908, 0941, and background well 0945 (Table 19-4). For the 2015–2023 period, however, trends remain statistically significant only for wells 0903 and 0908 (Table 19-5). The UBL has been exceeded fairly consistently in wells 0940 and 0906, but only recently (2018–2023) in wells 0941 and 0908. In 2023, the UBL was exceeded in wells 0906 (325 mg/L), 0908 (329 mg/L), and 0940 (505–565 mg/L). Nitrate concentrations in southernmost downgradient well 0903, although regularly exceeding the 10 mg/L MCL since 2004, have remained below the UBL. However, results have increased in the last several years, with the maximum result (30.1 mg/L) detected in August 2022. The most recent (August 2023) nitrate result for well 0903 is 29.3 mg/L.



Note: Downgradient wells (from Table 19-2) are ordered in general direction of groundwater flow or distance from the disposal cell (Figure 19-2). Data for the upgradient background well are plotted last.
Abbreviation: LOESS = locally estimated scatterplot smoothing

Figure 19-5. Time-Concentration Plots of Selenium in Groundwater at the Tuba City, Arizona, Disposal Site, 1998–2023

Selenium concentrations have historically exceeded the 0.01 mg/L MCL in all non-background evaluative monitoring wells except southernmost well 0903 (Figure 19-5). The 0.05 mg/L UBL has been exceeded consistently in wells 0940 and 0941, immediately downgradient of the disposal cell, since 1998 and 2005, respectively. Since 2018, the highest selenium concentrations have been measured in well 0906. After declining by an order of magnitude between 2000 and 2008 (from 0.15 to 0.014 mg/L), concentrations have since increased; the most recent result was 0.12 mg/L. This increase in selenium concentrations in well 0906 since 2009 correlates with the period when average annual cumulative extraction rates dropped from 80 to 35 gallons per minute (gpm) due to intermittent shutdowns of the GWTP (DOE 2020). Mann-Kendall trend analysis for 1998–2023 indicates statistically significant increasing trends in wells 0906 and 0941, but for the more recent period (2015–2023), two additional wells (0940 and 0903) show significant increasing trends (Table 19-4 and Table 19-5).



Note: Downgradient wells (from Table 19-2) are ordered in general direction of groundwater flow or distance from the disposal cell (Figure 19-2). Data for the upgradient background well are plotted last.
Abbreviation: LOESS = locally estimated scatterplot smoothing

Figure 19-6. Time-Concentration Plots of Uranium in Groundwater at the Tuba City, Arizona, Disposal Site, 1998–2023

Uranium concentrations have historically exceeded the 0.044 mg/L MCL in all downgradient compliance wells except for well 0903 and a single (August 2021) measurement in well 0908 (Figure 19-6). The 1.17 mg/L UBL has not been exceeded except for recent measurements in well 0906. Uranium concentrations in well 0906 exceeded the UBL for the first time in February 2020 and have since increased to 2.59 mg/L (a historical maximum) in August 2023. Mann-Kendall trend analysis for 1998–2023 indicates statistically significant increasing nitrate concentration trends in three of the six wells currently monitored: wells 0903, 0940, and 0941. For 2015–2023, the statistically significant increasing trend for downgradient well 0903 continues, and a significant increasing trend was also found for well 0906 (Table 19-5), in contrast to the previous stable trend (Figure 19-6). Although still below both the MCL and the UBL, the most recent (August 2023) uranium concentration in well 0903 is the highest result on record for this well at 0.0057 mg/L.

A detailed evaluation of the recent increasing concentration trends in these wells is provided in the 2019–2021 groundwater remedy performance update (DOE 2022). Well 0908 is the only well with a significant decreasing uranium concentration trend (Table 19-4, Table 19-5). The most recent result (0.062 mg/L) slightly exceeds the 0.044 mg/L MCL.

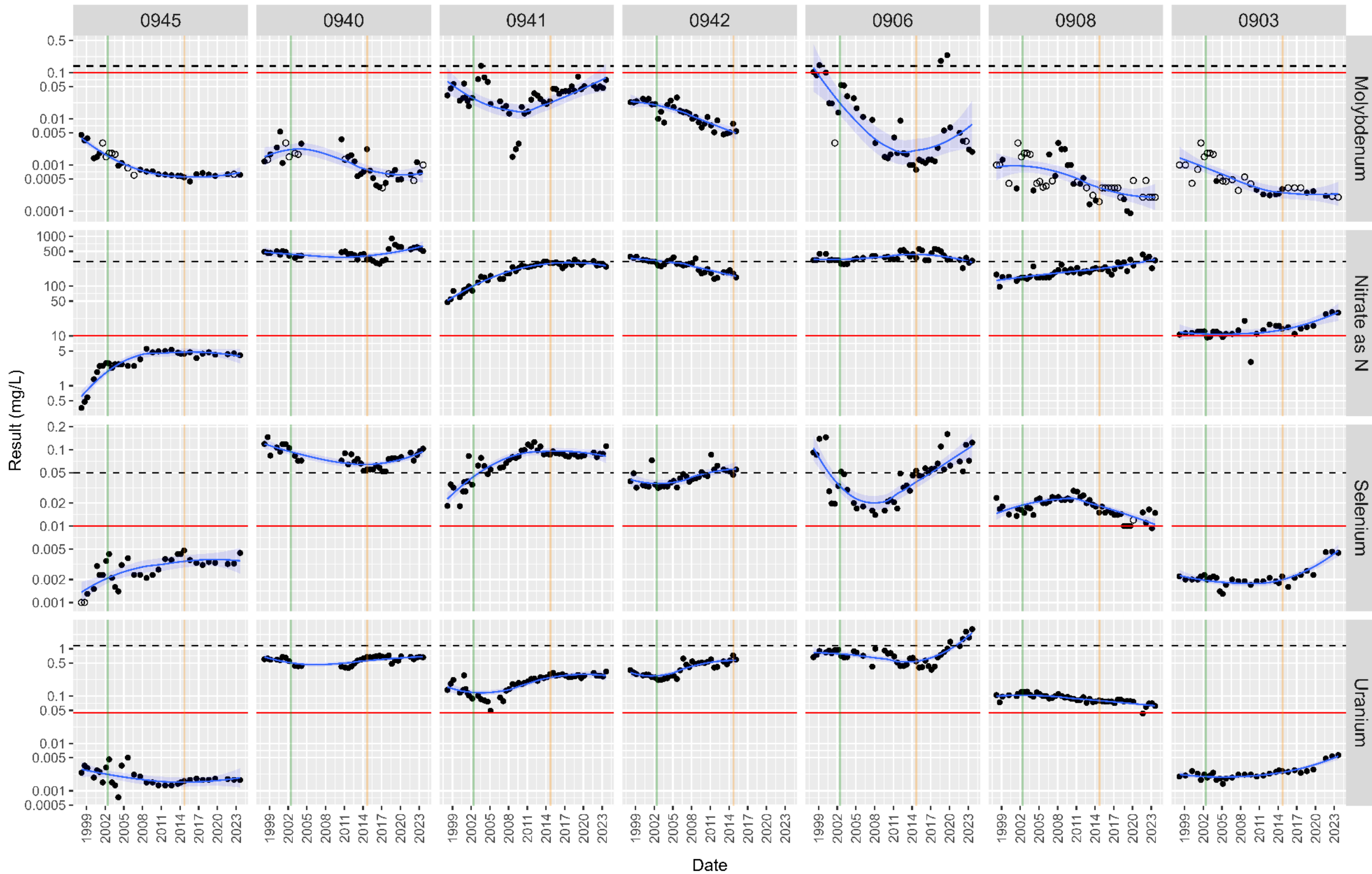
Similar to conclusions drawn in the previous annual report (DOE 2023a), analytical results from the 2023 evaluative monitoring effort indicate that groundwater quality in downgradient wells is still degraded relative to background concentrations in upgradient well 0945 (Figure 19-7). The only exceptions to the latter are molybdenum concentrations in wells 0908 and 0903, which are comparable to background. Since 2015 (when interim treatment began), contaminant concentrations are significantly increasing for the following well-analyte combinations (wells ordered in the general direction of groundwater flow or the distance from the disposal cell):

- Well 0940—selenium
- Well 0941—molybdenum
- Well 0906—selenium and uranium
- Well 0908—nitrate
- Well 0903—nitrate, selenium, and uranium

These increasing trends warrant continued monitoring, especially those in well 0903, the southernmost downgradient well. These increases correlate with the timing of the GWTP shutdown, after which the site began operating under interim treatment with an average annual cumulative extraction rate of 7 gpm. Analysis of water quality trending and progress of the groundwater remedy are reported in the site-specific remedy performance reports for the Tuba City site (DOE 2022; DOE 2023b).

19.8 Corrective Action

Corrective action is taken to correct out-of-compliance or hazardous conditions that create a potential health and safety problem or that may affect the integrity of the disposal cell or compliance with 40 CFR 192. No need for corrective action was identified.



● Detect ○ Nondetect —— LOESS local regression line and 95% confidence interval
Limits from Table 19-3: —— = MCL; - - - = UBL
| GWTP startup (June 1, 2002); | Interim treatment begins (September 15, 2014)
Note: Wells are ordered in general direction of groundwater flow or distance from the disposal cell (Figure 19-2); data for upgradient well 0945 are plotted first.
Abbreviation: LOESS = locally estimated scatterplot smoothing

Figure 19-7. Summary of Historical Evaluative Monitoring Results at the Tuba City, Arizona, Disposal Site (1998–2023)

19.9 References

10 CFR 40.27. U.S. Nuclear Regulatory Commission, "General License for Custody and Long-Term Care of Residual Radioactive Material Disposal Sites," *Code of Federal Regulations*.

40 CFR 192. U.S. Environmental Protection Agency, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations*.

40 CFR 192 Subpart A. U.S. Environmental Protection Agency, "Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites," *Code of Federal Regulations.*

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Lee, L., 2020. "NADA: Nondetects and Data Analysis for Environmental Data," R package, version 1.6-1.1, https://CRAN.R-project.org/package=NADA, accessed January 8, 2024.

19.10 Photographs

Photograph Location Number	Azimuth	Photograph Description
PL-1	270	Gap Under Fence near Perimeter Sign P9
PL-2	45	Gap Created by Animals Under Fence Between Perimeter Signs P21 and P22
PL-3	270	Sediment Deposition Gage Between Perimeter Signs P9 and P10
PL-4	270	Debris near Perimeter Sign P9
PL-5	270	Erosion Under Base of Perimeter Sign P10
PL-6	—	Site Marker SMK-2
PL-7	—	Quality Control Monument QC-2
PL-8	0	Evaporative Minerals on Top Slope of Disposal Cell
PL-9	130	Horizontal Lines on West Slope of Disposal Cell
PL-10	45	Vegetation on South Slope of Disposal Cell
PL-11	180	Erosion Gully and Soil Accumulation in Diversion Ditch North of Disposal Cell

Note:
— = Photograph taken vertically from above.

PL-1. Gap Under Fence near Perimeter Sign P9

PL-2. Gap Created by Animals Under Fence Between Perimeter Signs P21 and P22

PL-3. Sediment Deposition Gage Between Perimeter Signs P9 and P10

PL-4. Debris near Perimeter Sign P9

PL-5. Erosion Under Base of Perimeter Sign P10

PL-6. Site Marker SMK-2

PL-7. Quality Control Monument QC-2

PL-8. Evaporative Minerals on Top Slope of Disposal Cell

PL-9. Horizontal Lines on West Slope of Disposal Cell

PL-10. Vegetation on South Slope of Disposal Cell

PL-11. Erosion Gully and Soil Accumulation in Diversion Ditch North of Disposal Cell