6.0 Shirley Basin South, Wyoming, Disposal Site

6.1 Compliance Summary

The Shirley Basin South, Wyoming, Uranium Mill Tailings Radiation Control Act (UMTRCA) Title II Disposal Site was inspected on July 25, 2024. No significant changes were observed on the disposal cell or in associated drainage features. Inspectors identified routine maintenance needs but found no cause for a follow-up inspection.

Groundwater is monitored annually in accordance with the site-specific U.S. Department of Energy (DOE) Office of Legacy Management (LM) Long-Term Surveillance Plan (DOE 2004) (LTSP). The most recent sampling event occurred in June 2024. Alternate concentration limits (ACLs) continue to be exceeded in the point of compliance (POC) well 5-DC for selenium. Groundwater protection standards for sulfate and total dissolved solids (TDS) also continue to be exceeded in three wells near the disposal cell but no exceedances were measured in livestock well K.G.S. #3 or in any of the wells near the site boundary. No risks to human health and the environment were identified.

6.2 Compliance Requirements

Requirements for the long-term surveillance and maintenance of the site are specified in the site-specific LTSP (DOE 2004) 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 40.28 (10 CFR 40.28). Table 6-1 lists these requirements.

Table 6-1. License Requirements for the Shirley Basin South, Wyoming, Disposal Site

Requirement	LTSP	This Report	10 CFR 40.28
Annual Inspection and Report	Sections 3.3 and 3.4	Section 6.4	(b)(3)
Follow-Up Inspections	Section 3.5	Section 6.5	(b)(4)
Routine Maintenance and Emergency Measures	Section 3.6	Section 6.6	(b)(5)
Environmental Monitoring	Section 3.7	Section 6.7	(b)(3)

6.3 Institutional Controls

The 1527-acre site, identified by the property boundary shown in Figure 6-1, is owned by the United States and was accepted under the NRC general license in 2005. The LTSP disposal site description section states that the U.S. government owns 1512 acres (also known as Parcel 1), whereas Appendix A of the LTSP includes the deed that conveyed 1527 acres of Petrotomics Company (Petrotomics) land (Parcel 1 and Parcel 2). DOE is the licensee and, in accordance with the requirements for UMTRCA Title II sites, LM is responsible for the custody and long-term care of the site. Institutional controls (ICs) at the site include federal ownership of the property, administrative controls, and the following physical ICs that are inspected annually: disposal cell, entrance gate and sign, perimeter fence and signs, site marker, boundary monuments, and monitoring wellhead protectors.

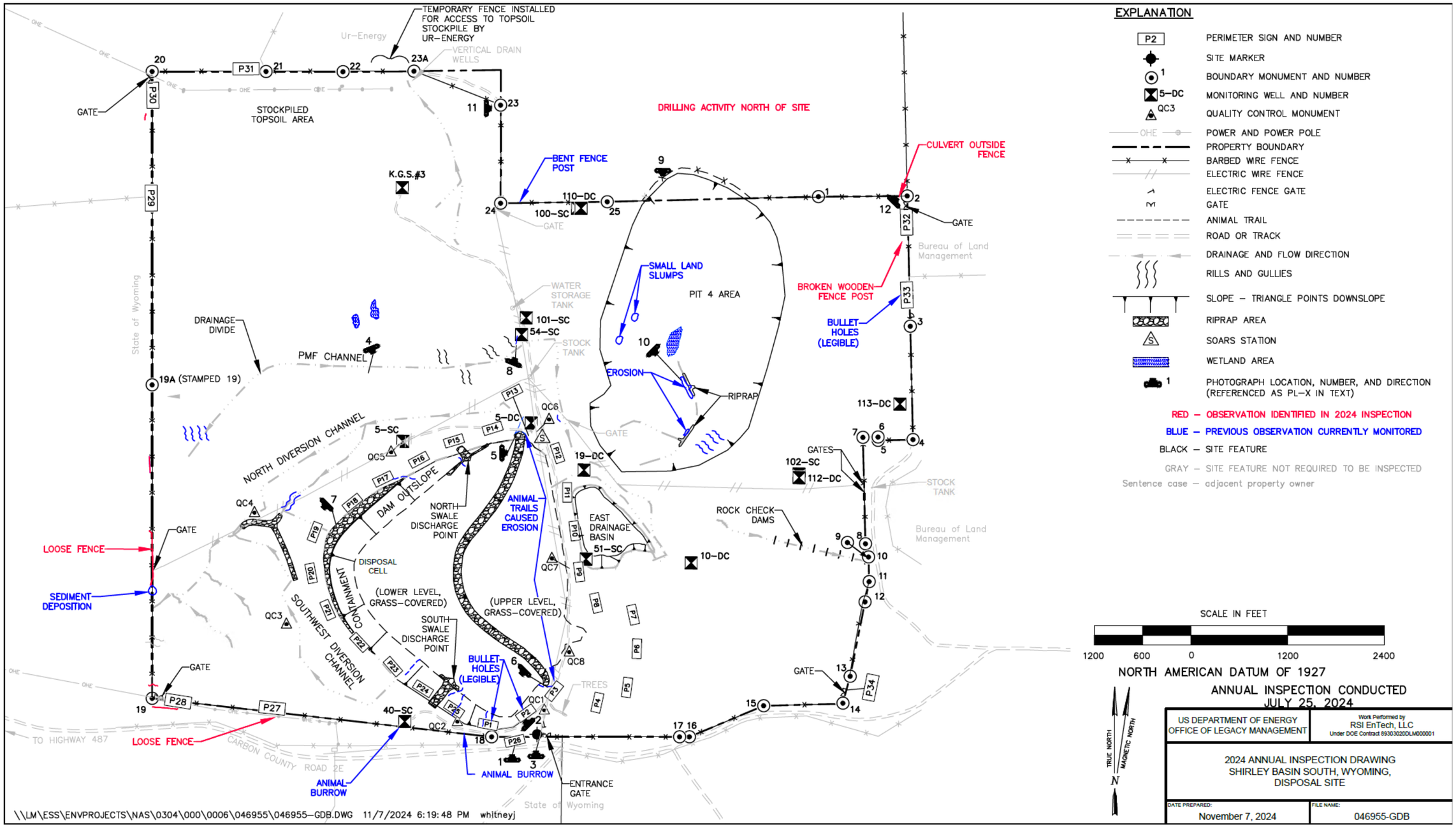


Figure 6-1. 2024 Annual Inspection Drawing for the Shirley Basin South, Wyoming, Disposal Site

6.4 Inspection Results

The site, approximately 60 miles south of Casper, Wyoming, was inspected by M. Guziak and T. Santonastaso of the Legacy Management Support (LMS) contractor. D. Richardson (LMS) and N. Keller (LM) 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.

6.4.1 Site Surveillance Features

Figure 6-1 shows the locations of site features, including site surveillance features and inspection areas, in black and gray font. Site features that are present but not required to be inspected are shown in gray font. Observations from previous inspections that are currently monitored are shown in blue, and new observations identified during the 2024 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 6-1 by photograph location (PL) numbers. The photographs and photograph log are presented in Section 6.9.

6.4.1.1 Site Access and Entrance Gate

Access to the site is immediately off Carbon County Road 2E. The entrance gate is a barbed-wire gate in the perimeter fence. The gate, along the southern portion of the perimeter fence, was secured by a locked chain. No maintenance needs were identified.

6.4.1.2 Perimeter Fence and Signs

A four-strand barbed-wire fence encloses the site. Sections along the north site boundary are secured with a temporary wire fence. Ur-Energy Inc. (Ur-Energy), the adjacent landowner, may use these sections to reach a topsoil stockpile area on the site.

In 2007, LM granted a grazing license to a local rancher that allows grazing of livestock in exchange for maintenance. An animal burrow is present under the fence near boundary monument BM-18. A post is bent near boundary monument BM-24. A post is broken near perimeter sign P32, and the fence has slacked near perimeter sign P27. Interior gates were not locked. These maintenance items are the responsibility of the rancher.

An arroyo formed beneath the fence on the southern portion of the west boundary in 2023. The arroyo formed in line with the fence, damaging several sections. Sediment from the erosional event was deposited below the slope break. The damaged fence was removed and the perimeter fence was realigned approximately 30 feet east and away from the arroyo in October 2023. The new fence has slacked and needs maintenance to stabilize. No other maintenance needs were identified.

The entrance sign identified as perimeter sign P26 (PL-1) is on the main site access road near the site marker. Nine perimeter signs (warning and no-trespassing signs) are posted along the site perimeter at potential points of access, and another 25 signs are positioned around the disposal

cell. Perimeter signs P1, P2 (PL-2), and P33 have bullet holes but remain legible. No maintenance needs were identified.

6.4.1.3 Site Marker

The site has one granite site marker (PL-3) near the entrance gate. No maintenance needs were identified.

6.4.1.4 Boundary Monuments

There are 27 boundary monuments delineating the site property boundary. All boundary monuments were inspected. No maintenance needs were identified.

6.4.1.5 Aerial Survey Quality Control Monuments

In July 2019, eight permanent aerial survey quality control monuments were installed at the site for an aerial survey of the disposal cell. The quality control monument locations are shown in Figure 6-1. Concrete is spalling around quality control monument QC-8, but it is still functioning as intended. No maintenance needs were identified.

6.4.1.6 Monitoring Wells

The site groundwater monitoring network consisted of eight monitoring wells when the site was transferred to LM. Six additional wells (100-SC, 101-SC, and 102-SC in the Upper Sand Aquifer and 110-DC, 112-DC, and 113-DC in the Main Sand Aquifer) were installed in 2008 to provide a better understanding of the characteristics and behavior of the affected aquifers at the site. The groundwater monitoring network now consists of 14 monitoring wells. The wellhead protectors were undamaged and locked. Monitoring well 40-SC has two animal burrows under the concrete slab but remains stable. No maintenance needs were identified.

6.4.2 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 cover of the disposal cell, (2) the containment dam and diversion channels, and (3) the site perimeter and balance of the site. Inspectors examined specific site surveillance features within each area and looked for evidence of erosion, settling, slumping, or other modifying processes that might affect conformance with LTSP requirements.

6.4.2.1 Cover of the Disposal Cell

The disposal cell, completed in 2000, occupies 142 acres. It has a soil cover and was revegetated primarily with rangeland and native grasses. The vegetation on the disposal cell and throughout the site is managed through the grazing license. The disposal cell surface is constructed at two elevations (the upper, eastern surface and the lower, western surface) that are separated by a riprap-armored slope (PL-4). There were no signs of erosion, settlement, or other modifying processes on the disposal cell cover or side slopes that might affect the integrity of the disposal cell.

Cattle have worn trails around the riprap-armored slopes, which has caused erosion on the north (PL-5) and south (PL-6) ends of the eastern riprap-armored slope. Grazing of the paddock containing the disposal cell was paused in 2022 to consider options for addressing the erosion. These trails are to be protected from cattle by the rancher to prevent degradation of the as-built riprap features before resuming grazing of the disposal cell paddock.

Gradual vegetation encroachment has been observed in the riprap on the slope that separates the two elevations and on the lower riprap slope (PL-7). The establishment of perennial vegetation enhances slope stability. Riparian vegetation has established at the toe of the slopes in areas that accumulate snowmelt runoff and summer precipitation.

The upper surface is contoured to drain into a basin east of the disposal cell and west over the riprap-protected slope to the lower surface. The lower surface is contoured to drain to a riprap-armored north swale discharge point and south swale discharge point. The riprap dissipation basins at the discharge points usually hold runoff water in spring and early summer. The north and south swale discharge points were dry during the inspection. Vegetation has established in both the north swale and south swale discharge points. No maintenance needs were identified.

6.4.2.2 Containment Dam and Diversion Channels

The tailings pile was reclaimed in place and contained behind a horseshoe-shaped earthen containment dam. The containment dam is predominantly grass covered, but the steeper portion (5:1 slope) of the dam outslope is protected by riprap. There were no signs of erosion, settlement, or other modifying processes that might affect the integrity of the dam. Encroaching vegetation on riprap surfaces enhances the stability of the slope.

The surface water diversion system consists of a combination of diversion channels, drainage basins, and contoured surfaces. Two primary diversion channels, the north and southwest diversion channels, keep runoff away from the disposal cell. Rock armor was placed on the steeper slopes and flow concentration points where design flow velocities could erode surfaces and impact the disposal cell. A probable maximum flood (PMF) channel was constructed north of the disposal cell along the side of the reclaimed mine overburden soil pile. Part of the PMF channel drains to the west and discharges to a small, closed basin, which was dry. The portion of the PMF channel that flows eastward and discharges into the east drainage basin captures stormwater from a larger drainage area. These drainage basins are large enough to accommodate PMF water volumes.

Discharge plumbing from the water storage tank has caused minor erosion near monitoring well 54-SC (PL-8) and the PMF channel. This discharge is not impacting site features currently, but headcutting erosion could occur toward the well and well pad, causing the well pad to become destabilized. Inspectors will continue to monitor this area. No maintenance needs were identified.

6.4.2.3 Site Perimeter and Balance of Site

A major site feature is the reclaimed Pit 4 area in the northeast portion of the site. Reclamation activities included rounding the side slopes, partially backfilling the pit to an elevation above the

projected surface of the uppermost aquifer, revegetating the surfaces, and protecting against potential erosion areas with riprap. Vegetation is well established, and a wetland area has formed at the bottom of the pit (PL-9). Some minor slumps and displacement features are present on the west and southeast side slopes of the pit, but they do not represent a significant slope stability concern. A riprap-armored drainage channel near the bottom of the pit, first reported to have eroded in 2016, has continued to erode (PL-10). Repair of the riprap armor is not necessary because potential erosion in that portion of the pit is not expected to impact the disposal cell.

The site is surrounded by public land administered by the U.S. Bureau of Land Management and the State of Wyoming, as well as private land. Land on three sides is used primarily for livestock grazing. Ur-Energy is the property owner north of the site and can access and use stockpiled topsoil on the site. This access is in accordance with an agreement originally established between Petrotomics, the former site licensee, and Pathfinder Mines Corporation (Pathfinder), which was acquired by Ur-Energy. LM is the successor to Petrotomics. The Wyoming Department of Environmental Quality (WDEQ) extended Pathfinder's mine area permit to include the soil stockpile area. In accordance with the permit, Ur-Energy will be required to reclaim the disturbed area, including replacing fences, when it has finished removing topsoil from the stockpile. No stockpiled topsoil has been removed.

Within the permit area, inspectors discovered two structures. The structures were determined to be vertical drain wells (named VD-2 and VD-3) installed by the former licensee before site transition.

Monitoring well K.G.S. #3 is completed in a deep formation (Lower Sand Aquifer). The grazing license allows the rancher to pump water from well K.G.S. #3 to water livestock and to operate solar-powered electric fences to manage livestock rotation.

The area 0.25 mile 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. Land use changes since the 2023 inspection include: new drilling activity north of the site on Ur-Energy property (PL-11) and associated road improvements including a culvert installation near the northeast corner (PL-12). No other changes were identified.

6.5 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.

6.6 Routine Maintenance and Emergency Measures

In accordance with the LTSP (DOE 2004), routine site maintenance will be performed by LM as needed. Unlocked interior gates will be locked, minor fence repairs will be conducted, and cattle trail erosion will be protected by the rancher. Repair of the western fence will be subcontracted by LM. No other maintenance needs were identified.

Emergency measures are corrective actions LM will take in response to unusual damage or disruption that threatens or compromises site health and safety, security, integrity, or compliance with 40 CFR 192. No emergency measures were identified.

6.7 Environmental Monitoring

In accordance with the LTSP (DOE 2004), annual groundwater monitoring is required at the site to verify that the ACLs are not exceeded at POC wells and to verify continued compliance with applicable groundwater protection standards. The monitoring network described in the LTSP comprises seven wells in the uppermost (Upper Sand and Main Sand) aquifers. The uppermost aquifers consist of two sand units in the Wind River Formation. A third aquifer, the Lower Sand Aquifer, is separated by approximately 50 feet of claystone, siltstone, and bedded sandstone from the overlying Main Sand unit (DOE 2011b). In consultation with NRC, LM installed six additional monitoring wells in fall 2008 to provide a better understanding of the groundwater chemistry and flow direction in the Upper Sand and Main Sand Aquifers.

The current monitoring network is described in Table 6-2 and shown in Figure 6-2. Although no monitoring wells are designated as points of exposure, groundwater chemistry at downgradient wells 100-SC, 102-SC, 110-DC, and 113-DC represents groundwater quality for groundwater flowing offsite in the Upper Sand and Main Sand Aquifers.

Table 6-2. Groundwater Monitoring Network at the Shirley Basin South, Wyoming, Disposal Site

Monitoring Well	Network Application
5-SC	POC well; Upper Sand Aquifer
40-SC	Upgradient well; Upper Sand Aquifer
51-SC	POC well; Upper Sand Aquifer
54-SC	Downgradient well; Upper Sand Aquifer
100-SC*	Downgradient well; Upper Sand Aquifer
101-SC*	Downgradient well; Upper Sand Aquifer
102-SC*	Downgradient well; Upper Sand Aquifer
5-DC	POC well; Main Sand Aquifer
10-DC	Downgradient well; Main Sand Aquifer
19-DC	POC well; Main Sand Aquifer
110-DC*	Downgradient well; Main Sand Aquifer
112-DC*	Downgradient well; Main Sand Aquifer
113-DC*	Downgradient well; Main Sand Aquifer
K.G.S. #3	Lower Sand Aquifer

Note:
* Installed by LM in 2008.

Monitoring well 54-SC is screened across the Upper Sand and Main Sand Aquifers. In 2010, DOE submitted a request to decommission the well, stating that it represented a conduit for potential contamination migration between the Upper Sand and Main Sand Aquifers. DOE withdrew this request in 2011 based on a determination that, although difficult to discern the exact unit the screen is located within, groundwater elevations and updated hydrogeological evaluations indicated that well 54-SC is most likely screened in the Upper Sand Aquifer (Surovchak 2011).

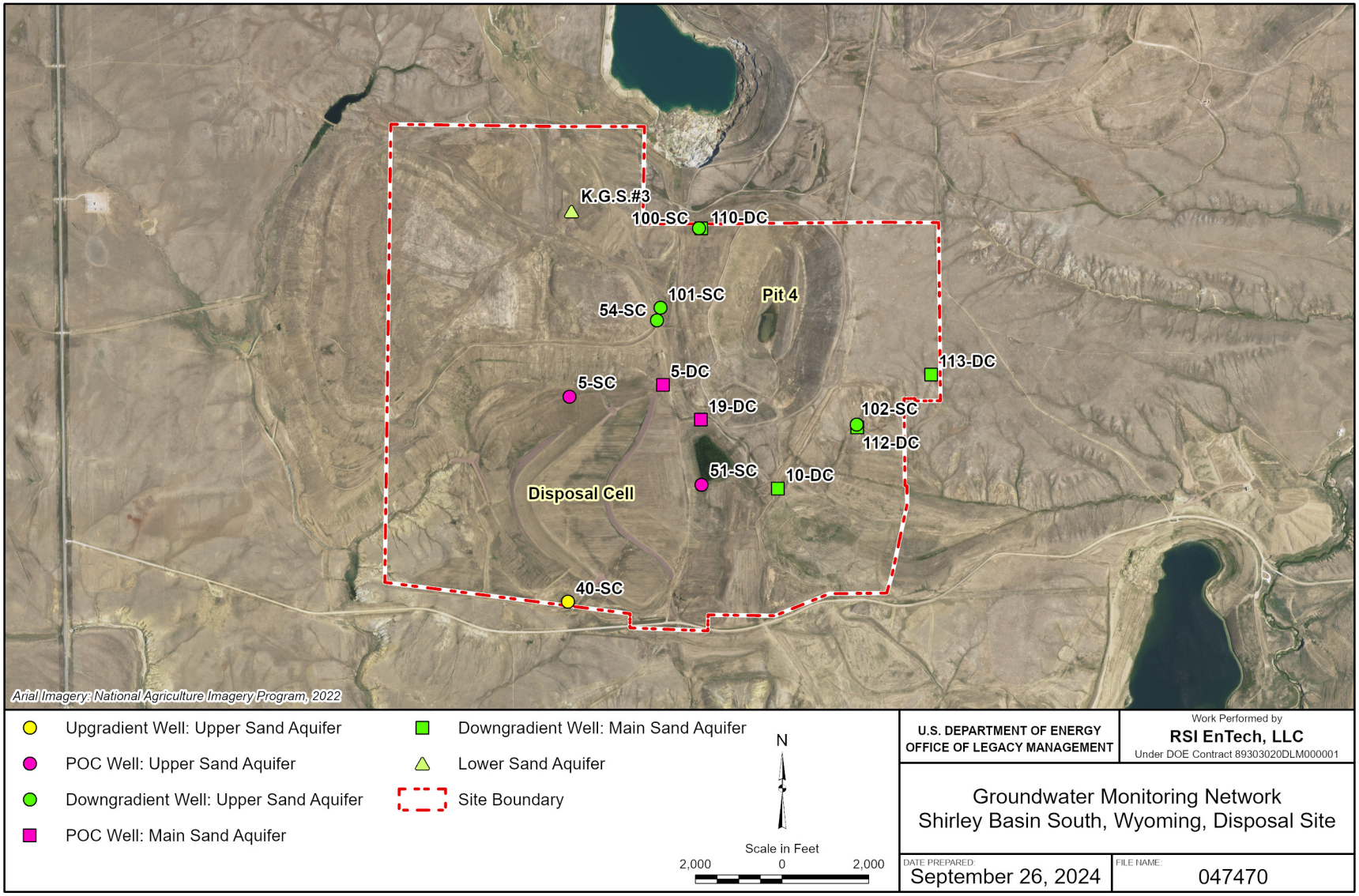


Figure 6-2. Groundwater Monitoring Network at Shirley Basin South, Wyoming, Disposal Site

Water level, pH, and specific conductance are measured at the time of sampling, and samples are analyzed for cadmium, chloride, chromium, lead, nickel, nitrate (+ nitrite as nitrogen [N]), radium-226 (^{226}Ra), radium-228 (^{228}Ra), selenium, sulfate, thorium-230 (^{230}Th), TDS, and uranium. Analytical results are compared to the ACLs and Wyoming Class III groundwater protection standards listed in Table 6-3. Water level elevations are measured at the monitoring wells to evaluate flow direction as the Upper Sand and Main Sand Aquifers recover from mining and reclamation activities.

Table 6-3. ACLs and Groundwater Protection Standards for the Shirley Basin South, Wyoming, Disposal Site

Analyte	ACL	Groundwater Protection Standard[a]
Cadmium	0.079 mg/L	0.05 mg/L
Chloride	NA	2000 mg/L
Chromium	1.83 mg/L	0.05 mg/L
Lead	0.05 mg/L	0.1 mg/L
Nickel	6.15 mg/L	NA
Nitrate (+ Nitrite as N)	NA	100 mg/L
^{226}Ra	91.3 pCi/L	5 pCi/L (combined total ^{226}Ra and ^{228}Ra)
^{228}Ra	25.7 pCi/L	
Selenium	0.12 mg/L	0.05 mg/L
Sulfate	NA	3000 mg/L
^{230}Th	2409 pCi/L	NA
TDS	NA	5000 mg/L
Uranium	9.2 mg/L	NA

Note:
[a] This column shows the current Wyoming Class III groundwater protection standard values for livestock use, which apply to groundwater flowing offsite and well K.G.S. #3 (*Wyoming Administrative Rules* Section 020.0011.8.06292018 [WAR 020.0011.8.06292018]).

Abbreviations:
mg/L = milligrams per liter
NA = not applicable
pCi/L = picocuries per liter

Groundwater flow direction in the Upper Sand and Main Sand Aquifers at the site has been influenced primarily by dewatering and recovery at Pathfinder Pit 33 north of the site boundary and at Pit 4 (Petrotomics 1996). The Upper Sand unit and Main Sand unit coalesced and formed the main ore body at Pit 4, which was partially backfilled with overburden materials during reclamation, raising the bottom of the pit to an elevation above the projected recovered phreatic surface of the Upper Sand aquifer. The backfill operation did not recreate the hydrogeologic characteristics of the original formation, and the aquifers are no longer confined at Pit 4.

The site map showing 2024 groundwater level elevations for the Upper Sand Aquifer wells is provided in Figure 6-3. Corresponding water elevations over time are plotted in Figure 6-4.

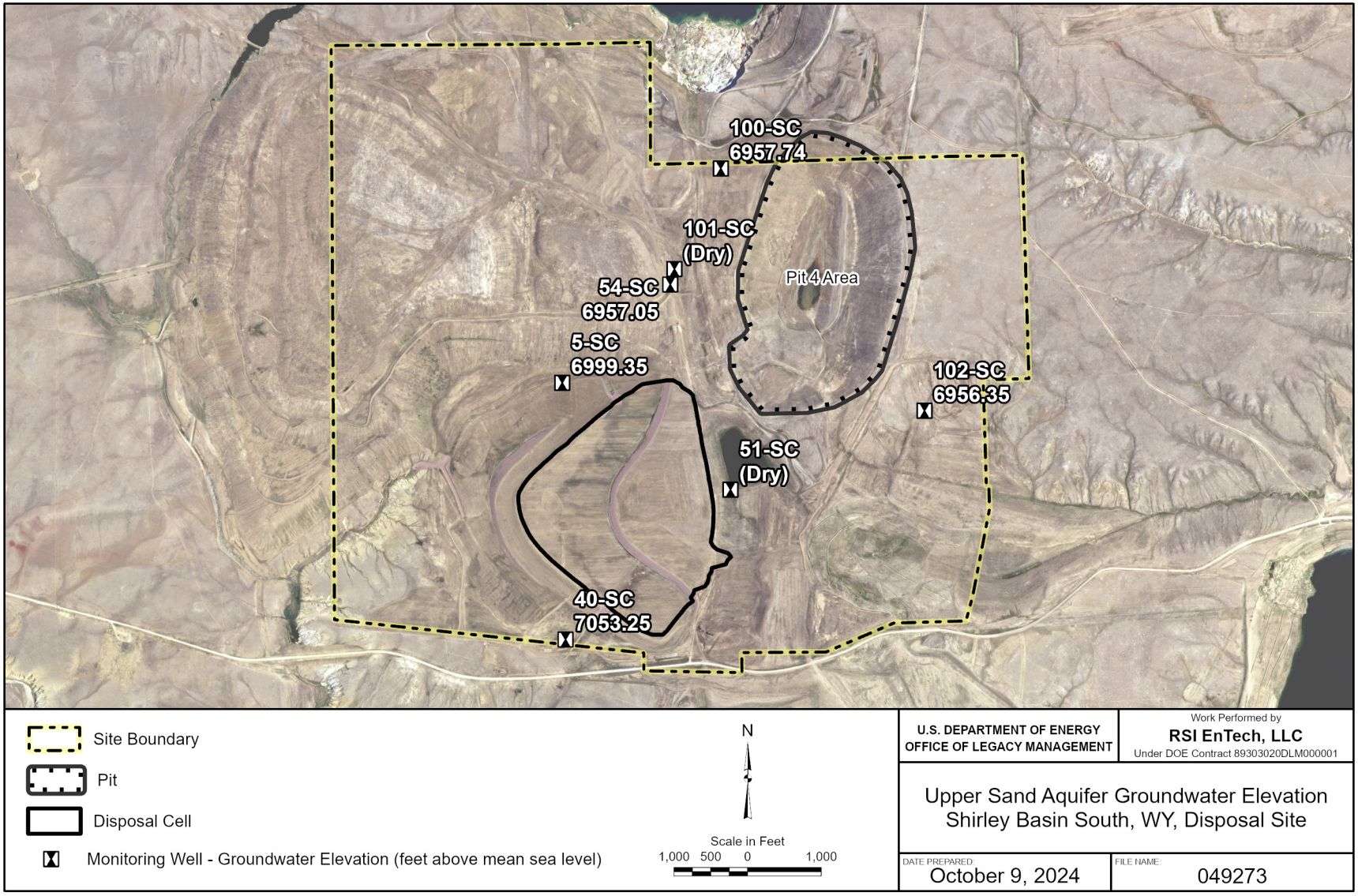
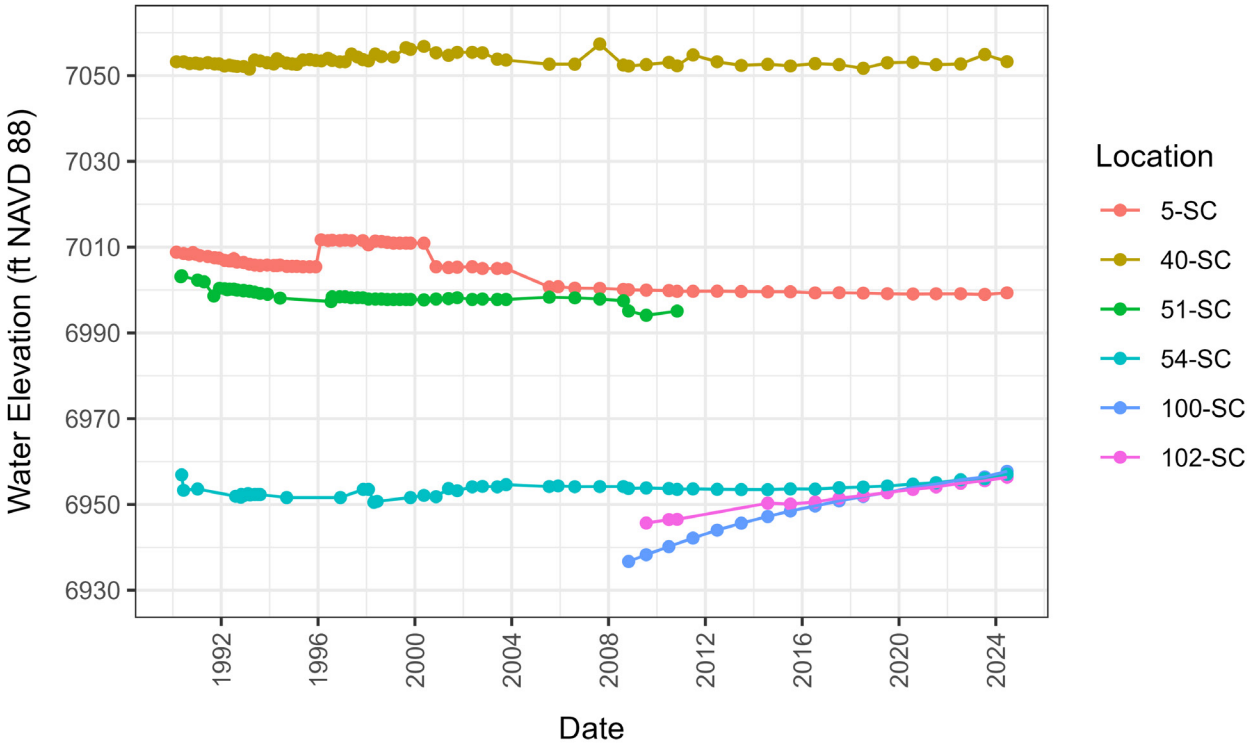


Figure 6-3. June 2024 Groundwater Elevations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site



Abbreviations: ft = feet, NAVD 88 = North American Vertical Datum of 1988

Figure 6-4. Hydrographs for Upper Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site, 1990–2024

The LTSP (DOE 2004) specifies the inclusion of groundwater contour maps with the annual inspection report. However, as concluded in annual reports since 2005, the well network does not provide a spatial distribution of data points necessary to generate contours without significant uncertainty. All references to flow directions discussed in this report are generalized.

The apparent groundwater flow direction within the Upper Sand Aquifer at the site is in the direction of structural dip and toward the eastern site boundary (Figure 6-3). Water levels are increasing in wells 100-SC and 102-SC but have been relatively constant in the remaining Upper Sand Aquifer wells (Figure 6-4). Well 51-SC was dry and has not recorded a water level since November 2010. Well 101-SC has been dry since its installation in 2008.

The map in Figure 6-5 shows the groundwater elevations measured in wells screened in the Main Sand Aquifer in 2024. Figure 6-6 plots corresponding groundwater elevations over time. Piezometric heads have been gradually rising at all wells since 2000, with an average rate of increase of approximately 0.8 foot per year since LM began monitoring water levels in 2005 (Figure 6-6). The rising levels indicate a gradual recovery of the aquifer. However, the altered conditions at Pit 4 might prevent a return to premining elevations of the water table because the Upper Sand and Main Sand units now coalesce at this location.

DOE will continue monitoring and evaluating groundwater elevations as recovery continues in the Main Sand Aquifer. Once groundwater conditions have stabilized, LM will evaluate the adequacy of the monitoring program.

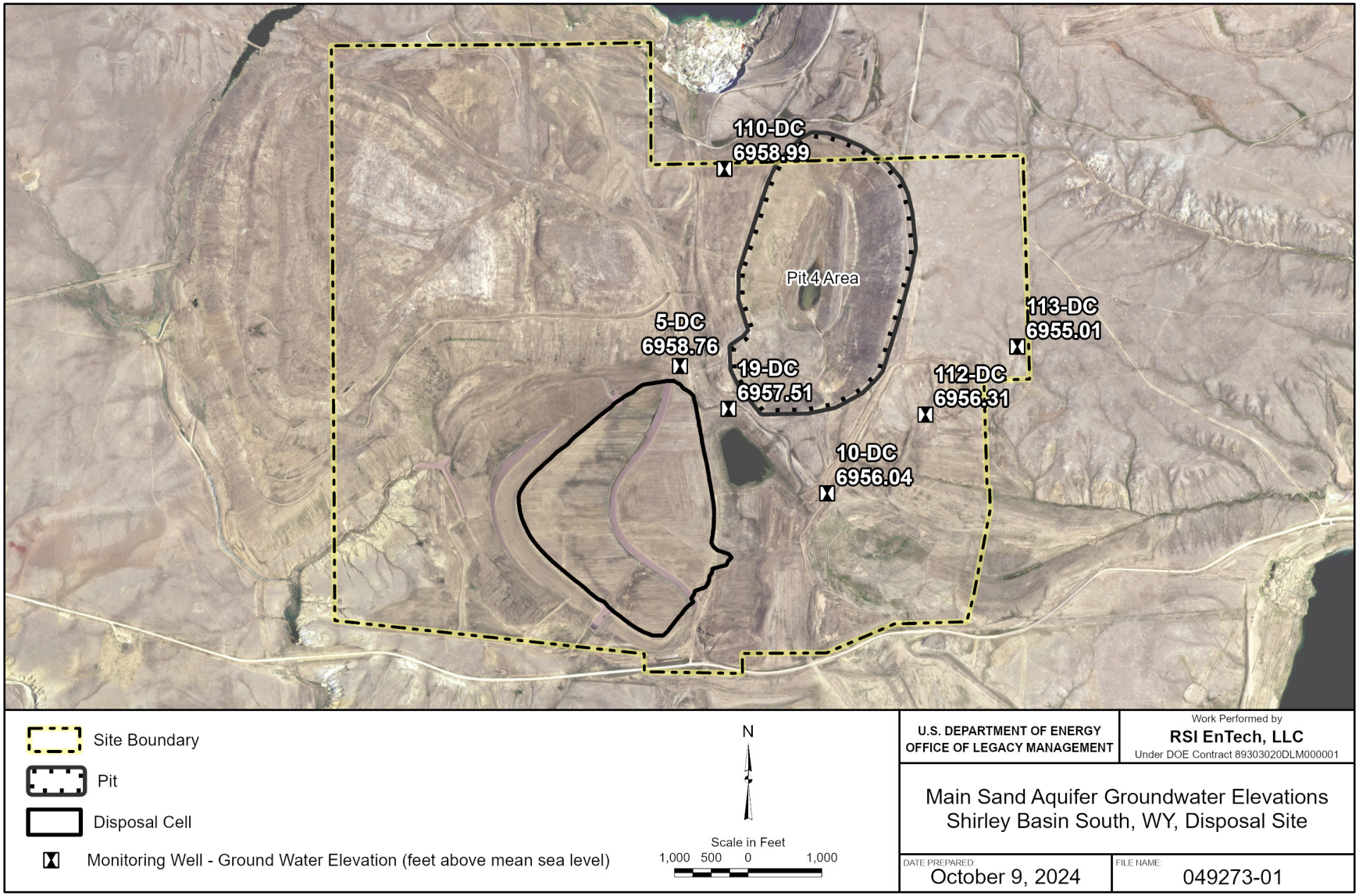
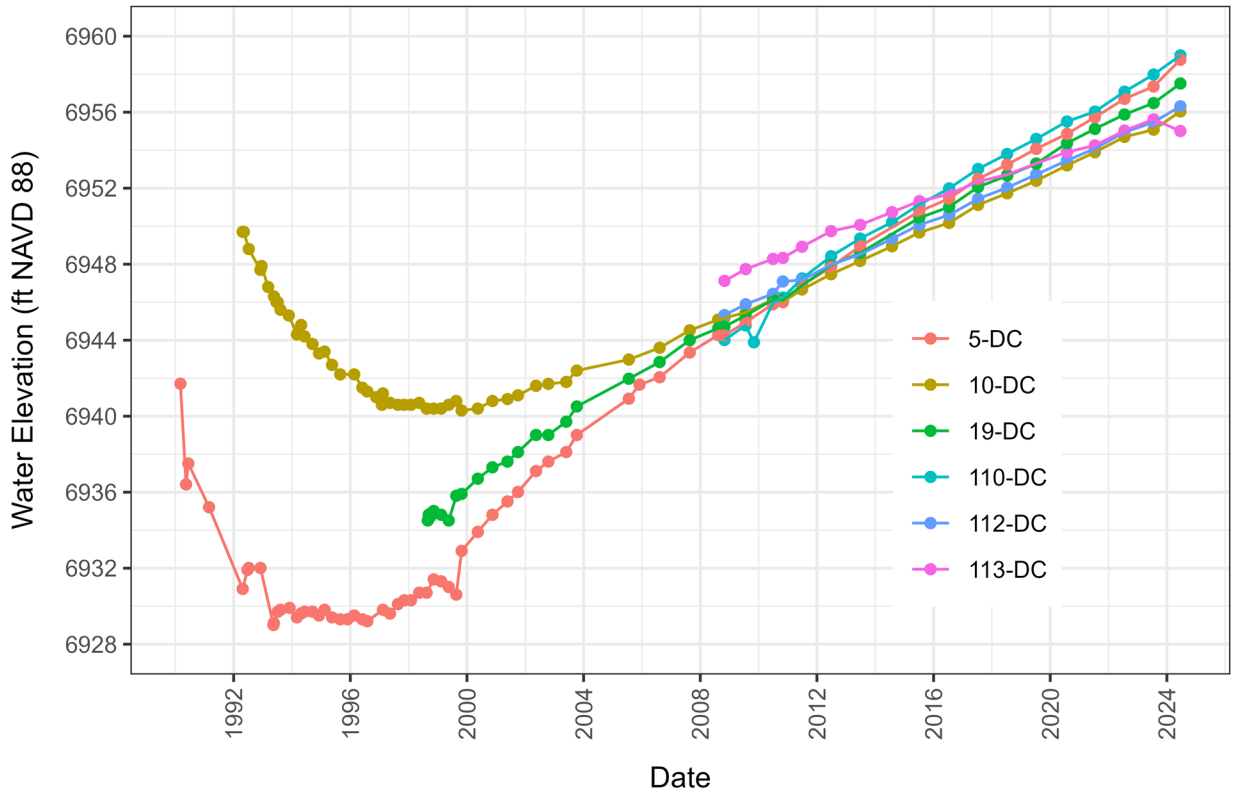


Figure 6-5. June 2024 Groundwater Elevations in the Main Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site



Abbreviations: ft = feet, NAVD 88 = North American Vertical Datum of 1988

Figure 6-6. Hydrographs for Main Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site, 1990–2024

To better understand the increasing water level trends in several of the onsite wells, LM will utilize water level data collected by Ur-Energy as part of an in situ recovery mine north of the site boundary when available. Historical static water level and water quality data addressed in this section are available at https://gems.lm.doe.gov/ through the Geospatial Environmental Mapping System (GEMS).

Analytical results from the June 2024 groundwater monitoring event are provided in Table 6-4 for the Upper Sand Aquifer, Table 6-5 for the Main Sand Aquifer, and Table 6-6 for well K.G.S. #3, which is screened in the Lower Sand Aquifer. Samples could not be collected from Upper Sand Aquifer wells 51-SC and 101-SC because they continue to be dry.

Figure 6-7 and Figure 6-8 provide matrices of time-concentration plots for each Shirley Basin South site monitoring well and analyte combination. Figure 6-7 shows time-concentration plots for all analytes with ACLs as listed in Table 6-3. Figure 6-8 shows time-concentration plots of the indicator parameters: chloride, nitrate, pH, sulfate, and TDS. In both figures, all data since 2000 are plotted, including data from Petrotomics for the period 2000–2004.

Table 6-4. 2024 Groundwater Monitoring Results in the Upper Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site

Analyte	Limit or Standard	Well[a]				
		5-SC (POC)	40-SC	54-SC	100-SC	102-SC
Cadmium	0.079 mg/L 0.05 mg/L[b]	0.028	ND	0.00043	ND	ND
Chloride	2000 mg/L[b]	309	6.52	362	154	35.7
Chromium	1.83 mg/L 0.05 mg/L[b]	***0.333***[c]	ND	***0.528***[c]	0.00124	ND
Lead	0.05 mg/L 0.1 mg/L[b]	ND	ND	ND	ND	ND
Nickel	6.15 mg/L	2.93	0.0128	1.3	0.00205	ND
Nitrate (as N)	100 mg/L[b]	0.118	1.07	0.11	ND	0.0551
^{226}Ra	91.3 pCi/L	1.26	ND	8.49	4.14	ND
^{228}Ra	25.7 pCi/L	5.44	ND	***85.7***[d]	5.35	2.09
Selenium	0.12 mg/L 0.05 mg/L[b]	***0.086***[c]	0.0071	***0.063***[c]	ND	ND
Sulfate	3000 mg/L[b]	***12,600***[c]	1110	***10,200***[c]	1170	538
^{230}Th	2409 pCi/L	480	ND	49.5	ND	ND
TDS	5000 mg/L[b]	***16,900***[c]	1820	***15,200***[c]	2030	1000
Uranium	9.2 mg/L	2.04	0.00008	0.0375	0.0015	0.00092

Notes:
[a] ***Bold italicized*** and shaded results exceed a standard or limit.
[b] Wyoming Class III groundwater protection standard (*Wyoming Administrative Rules* Section 020.0011.8.06292018 [WAR 020.0011.8.06292018]).
[c] Result exceeds the corresponding Wyoming Class III groundwater protection standard.
[d] Result exceeds an ACL.

Abbreviations:
mg/L = milligrams per liter
ND = not detected (below method detection limit)
pCi/L = picocuries per liter

Table 6-5. 2024 Groundwater Monitoring Results in the Main Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site

Analyte	Limit or Standard	Well[a]					
		5-DC (POC)	10-DC	19-DC (POC)	110-DC	112-DC	113-DC
Cadmium	0.079 mg/L 0.05 mg/L[b]	ND	ND	ND	ND	ND	ND
Chloride	2000 mg/L[b]	308	61.3	86.9	167	37.3	6.19
Chromium	1.83 mg/L 0.05 mg/L[b]	***0.248***[c]	ND	0.00243	0.00144	ND	ND
Lead	0.05 mg/L 0.1 mg/L[b]	ND	0.0062	ND	ND	ND	ND
Nickel	6.15 mg/L	2.46	ND	0.515	ND	ND	ND
Nitrate (as N)	100 mg/L[b]	0.203	0.0243	0.22	ND	ND	0.118
^{226}Ra	91.3 pCi/L	ND	15.7	7.57	***161***[d]	10.7	1.01
^{228}Ra	25.7 pCi/L	5.94	4.96	7.59	8.94	10.1	2.73
Selenium	0.12 mg/L 0.05 mg/L[b]	***0.145***[c,d]	ND	ND	ND	ND	ND
Sulfate	3000 mg/L[b]	***18,900***[c]	1010	2550	1880	1050	583
^{230}Th	2409 pCi/L	111	ND	ND	ND	ND	ND
TDS	5000 mg/L[b]	***25,400***[c]	1800	3770	3480	1710	1090
Uranium	9.2 mg/L	0.017	0.012	0.00011	0.014	0.013	0.00093

Notes:
[a] ***Bold italicized*** and shaded results exceed a standard or limit.
[b] Wyoming Class III groundwater protection standard (*Wyoming Administrative Rules* Section 020.0011.8.06292018 [WAR 020.0011.8.06292018]).
[c] Result exceeds the corresponding Wyoming Class III groundwater protection standard.
[d] Result exceeds an ACL.

Abbreviations:
mg/L = milligrams per liter
ND = not detected (below method detection limit)
pCi/L = picocuries per liter

Table 6-6. 2024 Groundwater Monitoring Results for Well K.G.S. #3 in the Lower Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

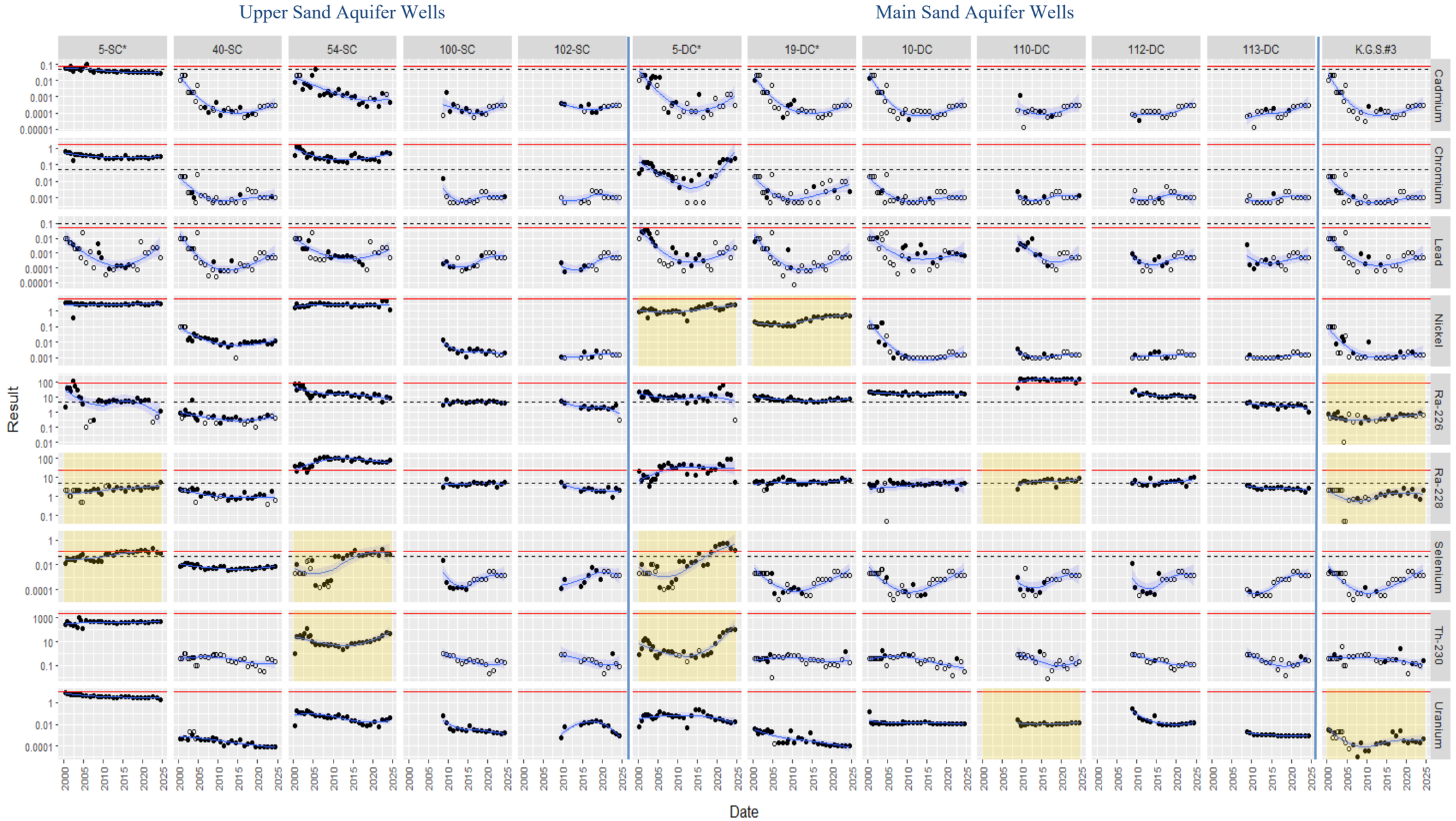
Analyte	Limit or Standard	K.G.S. #3 Result
Cadmium	0.079 mg/L 0.05 mg/L[a]	ND
Chloride	2000 mg/L[a]	3.76
Chromium	1.83 mg/L 0.05 mg/L	ND
Lead	0.05 mg/L 0.1 mg/L[a]	ND
Nickel	6.15 mg/L	ND
Nitrate (as N)	100 mg/L[a]	ND
^{226}Ra	91.3 pCi/L	ND
^{228}Ra	25.7 pCi/L	2.0
Selenium	0.12 mg/L 0.05 mg/L[a]	ND
Sulfate	3000 mg/L[a]	226
^{230}Th	2409 pCi/L	0.254
TDS	5000 mg/L[a]	481
Uranium	9.2 mg/L	0.00043

Note:
[a] Wyoming Class III groundwater protection standard (*Wyoming Administrative Rules* Section 020.0011.8.06292018 [WAR 020.0011.8.06292018]).

Abbreviations:
mg/L = milligrams per liter
ND = not detected (below method detection limit)
pCi/L = picocuries per liter

Mann-Kendall trend analysis was performed for the monitored constituents. Mann-Kendall trends were calculated from 2005, when the site was transferred to LM, to 2024. Mann-Kendall trend analyses characterize the direction of concentration trends using a 0.05 significance level, meaning a calculated p-value of less than 0.05 indicates the null hypothesis is rejected and a significant trend in the time series exists. Table 6-7 identifies the analyte-well combinations with statistically significant increasing (or decreasing) trends based on the detailed Mann-Kendall trend test summary. Trend analysis results are only listed for well-analyte combinations with a statistically significant trend.

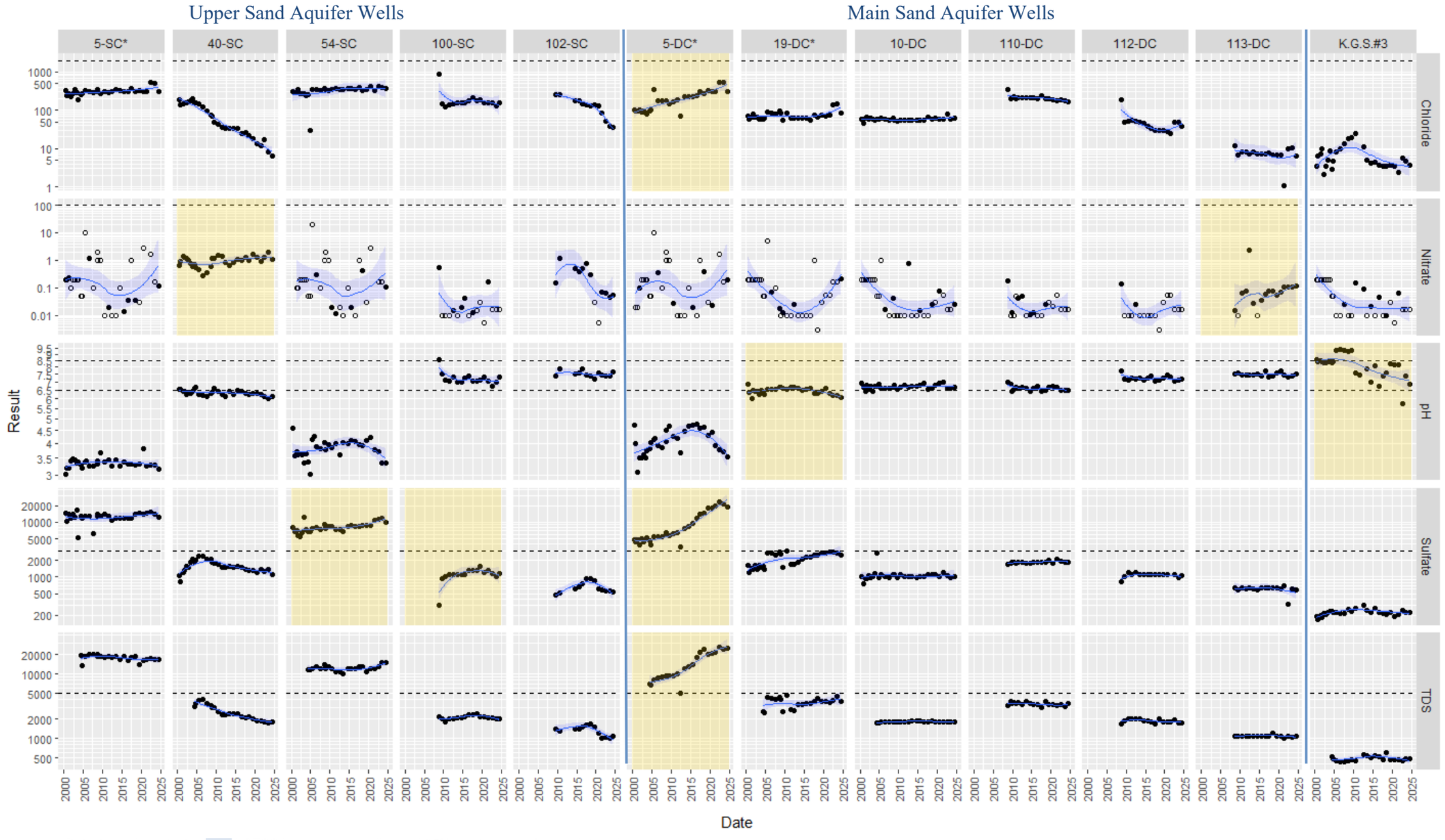
The Mann-Kendall trend analyses could be biased by varying method detection limits (MDLs) for some analytes. To assess whether this variation could account for some observed increasing concentration trends, for each well-parameter combination shown in Figure 6-7 and (for nitrate) Figure 6-8, LM evaluated the relationship between the MDLs and the corresponding analytical results. For most well-parameter combinations, the MDLs show a slightly increasing trend since 2005, but these increases are not likely to account for the increasing trends observed for some analytes (e.g., the increasing selenium concentration trends found for wells 5-SC, 54-SC, and 5-DC). Changes in the MDLs would most likely impact trend analysis results for the well-parameter combinations with a moderate to high percentage of nondetects, but no significant trend was found for any well-analyte combination with detection frequencies less than 50%.



● Detect ○ Nondetect; —— LOESS local regression line and 95% pointwise confidence interval
------ ACL from Table 6-3; - - - - Groundwater protection standard from Table 6-3; Shaded plots denote well-analyte combinations with statistically significant increasing concentration trends since 2005 (from Table 6-7).

Notes: Units are in milligrams per liter, except for Ra-226, Ra-228, and Th-230 (in picocuries per liter). Well names followed by an asterisk (*) denote POC wells (shown first for each aquifer). A semilogarithmic scale is used because of the wide range in analyte concentrations across site wells.
Abbreviation: LOESS = locally estimated scatterplot smoothing

Figure 6-7. Time-Concentration Plots of Analytes with ACLs in Monitoring Wells, Shirley Basin South, Wyoming, Disposal Site: 2000–2024



● Detect ○ Nondetect —— LOESS local regression line and 95% pointwise confidence interval
- - - Groundwater protection standard from Figure 6-3, except for pH which, although not an analyte addressed in the LTSP, is an important indicator parameter where the groundwater protection standard is a range (6.5–8.5 standard units).
Shaded plots denote well-analyte combinations with statistically significant increasing concentration trends since 2005, or—for pH—significant decreasing trends (Table 6-7).

Notes: Units are in milligrams per liter, except for pH (in standard units). Well names followed by an asterisk (*) denote POC wells (shown first for each aquifer). A semilogarithmic scale is used because of the wide range in analyte concentrations across site wells.
Abbreviation: LOESS = locally estimated scatterplot smoothing

Figure 6-8. Time-Concentration Plots of Indicator Parameters in Monitoring Wells, Shirley Basin South, Wyoming, Disposal Site: 2000–2024

Table 6-7. Mann-Kendall Trend Analysis Results for Shirley Basin South Site Monitoring Wells, 2005–2024[a,b]

Analyte	No. of Samples (No. of Nondetects)	Kendall's tau	Trend
Upper Sand Aquifer Wells			
5-SC (POC)			
Cadmium	22	−0.67	Decreasing
^{228}Ra	21 (1)	0.42	Increasing
Selenium	21	0.56	Increasing
TDS	21	−0.56	Decreasing
Uranium	21	−0.69	Decreasing
40-SC			
Chloride	21	−0.92	Decreasing
Nitrate	21	0.41	Increasing
Sulfate	21	−0.81	Decreasing
TDS	21	−0.87	Decreasing
Uranium	21	−0.65	Decreasing
54-SC			
Cadmium	21 (2)	−0.51	Decreasing
^{226}Ra	21	−0.45	Decreasing
^{228}Ra	22	−0.42	Decreasing
Selenium	21 (2)	0.69	Increasing
Sulfate	21	0.55	Increasing
^{230}Th	21	0.63	Increasing
Uranium	21	−0.51	Decreasing
100-SC			
Nickel	17 (3)	−0.54	Decreasing
Sulfate	17	0.45	Increasing
Uranium	17	−0.76	Decreasing
102-SC			
Cadmium	13 (6)	−0.41	Decreasing
Chloride	13	−0.91	Decreasing
Nitrate	13 (2)	−0.47	Decreasing
Main Sand Aquifer Wells			
5-DC (POC)			
Chloride	21	0.53	Increasing
Nickel	21	0.58	Increasing
Selenium	21 (2)	0.70	Increasing
Sulfate	21	0.82	Increasing
TDS	21	0.84	Increasing
^{230}Th	21 (4)	0.38	Increasing
Uranium	21	−0.46	Decreasing
19-DC (POC)			
Nickel	21	0.69	Increasing
Uranium	21 (1)	−0.47	Decreasing
pH	21	−0.53	Decreasing

Analyte	No. of Samples (No. of Nondetects)	Kendall's tau	Trend
Main Sand Aquifer Wells (continued)			
110-DC			
Chloride	19	−0.54	Decreasing
Lead	18 (9)	−0.52	Decreasing
^{228}Ra	18	0.46	Increasing
TDS	19	−0.35	Decreasing
Uranium	19	0.34	Increasing
112-DC			
Chloride	17	−0.55	Decreasing
^{226}Ra	17	−0.52	Decreasing
Uranium	17	−0.40	Decreasing
113-DC			
Nitrate	17 (2)	0.50	Increasing
^{226}Ra	17	−0.38	Decreasing
^{228}Ra	17	−0.48	Decreasing
Uranium	17	−0.74	Decreasing
Lower Sand Aquifer Well			
K.G.S. #3			
Chloride	19	−0.48	Decreasing
^{226}Ra	19 (6)	0.40	Increasing
^{228}Ra	19 (5)	0.50	Increasing
Uranium	19 (1)	0.53	Increasing
pH	19	−0.44	Decreasing

Notes:

[a] 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. Trend analyses were conducted at the 0.05 significance (or alpha) level using a two-sided test. 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.

[b] Trend analysis results are only listed for well-analyte combinations with a statistically significant trend ($p < 0.05$). With no significant trend for any analyte, well 10-DC is not listed above. Significant trends are also noted for pH, which, although not an analyte addressed in the LTSP, is an important indicator parameter.

As stipulated in the LTSP (DOE 2004), LM is required to notify NRC and WDEQ if an ACL is exceeded at a POC well, or if trends indicate that a groundwater protection standard may be exceeded at the point of exposure (i.e., the site boundary). Since DOE acquired the site in 2005, exceedances of ACLs have been limited to the following POC wells and parameters:

- Upper Sand Aquifer POC well 5-SC — cadmium (2005 only) and selenium (2019–2020, 2022)
- Main Sand Aquifer POC well 5-DC — ^{228}Ra (most years; exceptions [below ACL] in 2012, 2014, 2017–2018, and 2024]) and selenium (since 2019)

Based on the data shown in Figure 6-7 and Figure 6-8 and trend analysis results (Table 6-7), there is no indication that a groundwater protection standard will be exceeded at the site boundary or in well K.G.S. #3. Concentration trends for constituents with ACLs are discussed in the following paragraphs, along with an updated analysis of the statistically significant trends identified in Table 6-7.

Constituents with ACLs

In LM's initial July 2005 sampling, the results for cadmium in POC well 5-SC exceeded the respective ACL. When compared with historical results provided by the previous site licensee, the results for cadmium in well 5-SC were within the range of historical measurements. Cadmium concentrations in well 5-SC have since declined (significant trend) to below the ACL (most recent result of 0.028 milligrams per liter [mg/L]), and concentrations in most remaining wells have been below the detection limit (Figure 6-7). Along with well 5-SC, statistically significant decreasing trends in cadmium concentrations were also found for wells 54-SC and 102-SC (Table 6-7).

Nickel concentrations in Upper Sand Aquifer wells 5-SC and 54-SC have been below the ACL (Figure 6-7) and trends have been stable (non-trending). The most recent (2024) results were 2.93 and 1.3 mg/L, respectively (Table 6-4). Although statistically significant increasing trends were identified for Main Sand Aquifer wells 5-DC and 19-DC, nickel concentrations are below the ACL (most recent results of 2.46 and 0.515 mg/L, respectively).

Radium-226 concentrations in well 110-DC, installed in 2008 near the north site boundary, consistently exceeded the ACL between 2009 and 2022, and again in 2024 (Figure 6-7). LM evaluated the cause of these exceedances and determined that the elevated concentrations do not represent a contaminant plume migrating offsite; rather, they are attributed to natural conditions within the ore-bearing sand unit as aquifer recovery continues (DOE 2011a). In 2024, the ^{226}Ra concentration in this well was 161 picocuries per liter (pCi/L), consistent with most historical measurements. Although below the ACL, ^{226}Ra concentrations in most remaining wells (exceptions being 40-SC, 102-SC, 113-DC, and K.G.S. #3) typically exceed the 5 pCi/L groundwater protection standard for combined ^{226}Ra and ^{228}Ra.

Since 2005, ^{228}Ra concentrations have consistently exceeded the ACL in well 54-SC (significant decreasing trend) and, with some exceptions (2012, 2014, 2017–2018, and 2024), also in well 5-DC. When compared with historical results provided by the previous site licensee, the results for ^{228}Ra in both wells have been within the range of historical measurements. Mann-Kendall trend analysis (Table 6-7) indicates statistically significant increasing trends for ^{228}Ra in wells 5-SC (POC) and 110-DC and, for both ^{226}Ra and ^{228}Ra, in Lower Sand Aquifer K.G.S. #3.

Significant decreasing trends were identified for well 54-SC (^{228}Ra), well 112-DC (^{226}Ra), and 113-DC (^{226}Ra and ^{228}Ra). Radium-228 is a decay product of thorium-232 (^{232}Th), which is highly immobile. Petrotomics attributed elevated concentrations at the site to natural thorium in the uranium ore (Petrotomics 1996). Thorium-232 is very immobile, so the source of ^{228}Ra in groundwater must be close to the affected wells. Because the half-life of ^{228}Ra is relatively short, the data suggest the possible presence of ^{232}Th sources near monitoring wells 54-SC and 5-DC. Since 2019, ^{232}Th in well 54-SC has increased from 17.6 to 110 pCi/L (2024 result).

Radium-226 and ^{228}Ra concentrations in well K.G.S. #3 are below respective ACLs and are not expected to reach those ACLs in the near future. Under Class III groundwater protection standards, the threshold value of 5 pCi/L represents the sum of ^{226}Ra and ^{228}Ra concentrations (Table 6-3). The summed ^{226}Ra and ^{228}Ra concentrations in well K.G.S. #3 have historically been below the 5 pCi/L threshold and are not expected to exceed it in the near future. LM will continue to monitor this well to ensure that applicable standards are not exceeded and that the well continues to be safe for livestock use.

In response to groundwater concentrations of ^{226}Ra and ^{228}Ra that exceeded the approved ACLs for the site, LM evaluated the groundwater in 2013 (DOE 2013). NRC concluded that the current groundwater monitoring data do not conclusively demonstrate whether the tailings impoundment is leaking (Orlando 2014). However, NRC concluded that, until further notice, no additional evaluation of the cause of the elevated radium concentrations by LM is warranted because there is no risk to human health and the environment. NRC concluded that, for the present time, and until notified otherwise, DOE's ACL evaluation program should be suspended such that DOE does not need to conduct additional evaluations concerning ACL exceedances at the site. Instead, DOE should continue with the monitoring program as currently provided for in the LTSP (Orlando 2014). Groundwater at and in the vicinity of the site is not a source of drinking water due to limited yield and poor ambient conditions resulting from naturally occurring uranium mineralization and human activities related to uranium exploration and mining that occurred in the area from the late 1950s to the early 1990s. Livestock water at the site is drawn from a separate aquifer, the Lower Sand Aquifer, which is not hydraulically connected to the aquifers of concern and is not impacted by former milling operations (DOE 2004; DOE 2011b).

Selenium concentrations have exceeded the ACL and the groundwater protection standard in wells 5-SC, 54-SC, and 5-DC (Figure 6-7). Mann-Kendall trend analysis continues to indicate statistically significant increasing selenium trends in these wells (Table 6-7). LM previously noted that selenium is a relatively poor early indicator constituent for tailings seepage, as selenium concentrations measured in tailings water were relatively low and attenuated easily (DOE 2011b).

Thorium-230 concentrations have been below detection limits in most wells as shown in Figure 6-7. Exceptions are wells 5-SC, 54-SC, and 5-DC, but ^{230}Th levels have been below the corresponding ACL. Although a statistically significant increasing trend is indicated for wells 54-SC and 5-DC based on data since 2005, current levels are sufficiently low such that exceedances are not expected in the foreseeable future (most recent results of 49.5 and 111 pCi/L, respectively). The highest Th-230 activity has been measured in well 5-SC, with an average of approximately 500 pCi/L and a stable trend.

Uranium concentrations have been consistently below the 9.2 mg/L ACL in all wells (Figure 6-7), with statistically significant decreasing trends identified for most wells (Table 6-7). A statistically significant increasing trend was identified for uranium in wells 110-DC and K.G.S. #3. In both wells, uranium concentrations have been well below the ACL. Despite the statistically significant increasing trend, uranium concentrations in well K.G.S. #3 have remained generally stable since 2019 (0.0002–0.0004 mg/L) (Figure 6-7).

Indicator Parameters

In 2024, Wyoming Class III groundwater protection standards for indicator parameters (chloride, nitrate, sulfate, and TDS) were met at downgradient site boundary wells (100-SC, 102-SC, 110-DC, 112-DC, and 113-DC), but standards continue to be exceeded for sulfate and TDS in wells 5-SC, 54-SC, and 5-DC near the disposal cell. Statistically significant increasing trends were identified for several well-indicator parameter combinations as shown in Table 6-7, most notably well 5-DC, where chloride, sulfate, and TDS have also been significantly increasing since 2005 and pH has been decreasing since approximately 2015 (Figure 6-8).

Consistent with conclusions drawn in the groundwater monitoring evaluation report (DOE 2011b), water quality in well K.G.S. #3 is still considered unaffected by mill-related activity. This conclusion is supported by the lack of tailing-derived indicator contaminants, such as sulfate, chloride, nitrate, and TDS (Figure 6-8). Along with chloride, pH has decreased significantly in this well since 2005 (Table 6-7).

Additional Considerations

DOE will consider whether it would be appropriate to install an additional well at the southern site boundary to monitor potential seepage of contaminants from the tailings pile into the Main Sand Aquifer. Groundwater levels continue to increase in the Main Sand Aquifer throughout the site (Figure 6-6), indicating that the aquifer has not yet equilibrated from site-related activities. Once the aquifer reaches a quasi-steady state regarding groundwater elevations, that would be the optimal timing for a more comprehensive evaluation of flow directions.

The LTSP (DOE 2004) specifies that this report will include isoconcentration maps for uranium and sulfate in each aquifer; however, the monitoring well network LM inherits from the former licensee does not provide sufficient data points to interpolate a statistically defensible contaminant plume. Uranium concentrations from 2024 are shown in Figure 6-9 and Figure 6-10 for the Upper Sand and Main Sand Aquifers, respectively. Corresponding sulfate concentration data are plotted in Figure 6-11 and Figure 6-12. Uranium concentrations remain below the ACL; however, as stated above, sulfate concentrations exceeded the State of Wyoming groundwater protection standard in Upper Sand Aquifer wells 5-SC and 54-SC and Main Sand Aquifer well 5-DC but not in livestock well K.G.S. #3 or in wells near the boundary.

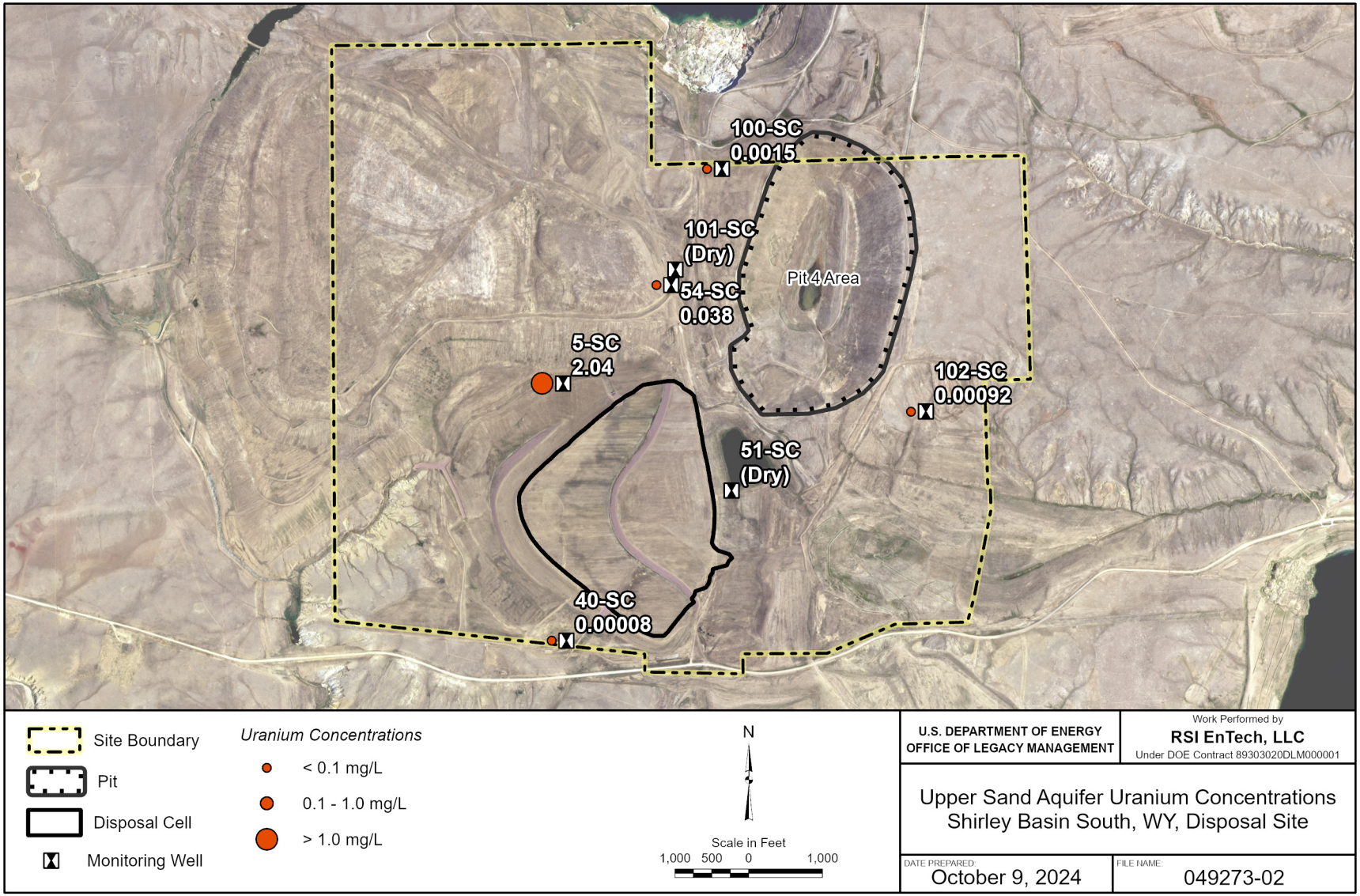


Figure 6-9. June 2024 Uranium Concentrations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

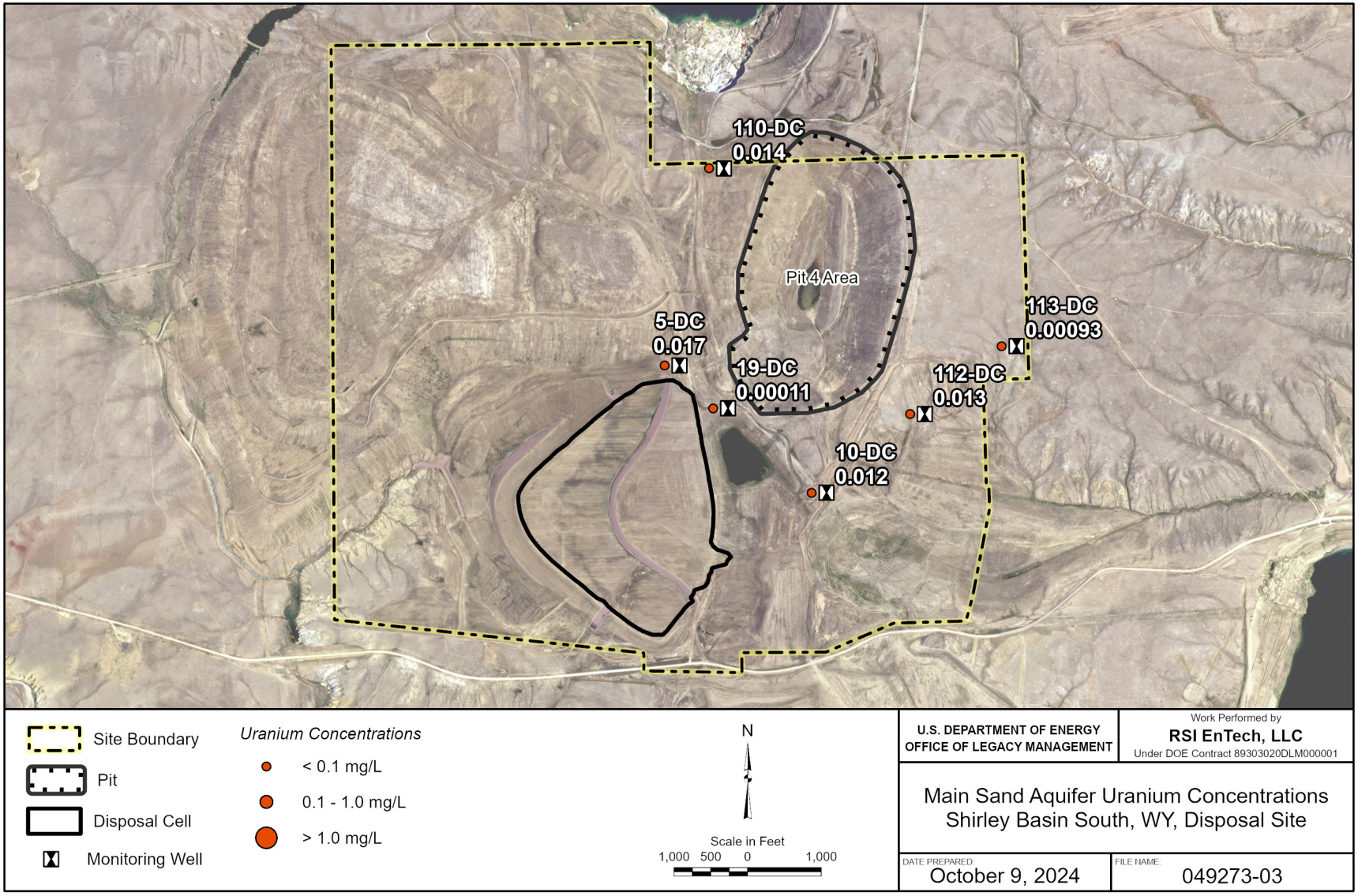


Figure 6-10. June 2024 Uranium Concentrations in the Main Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

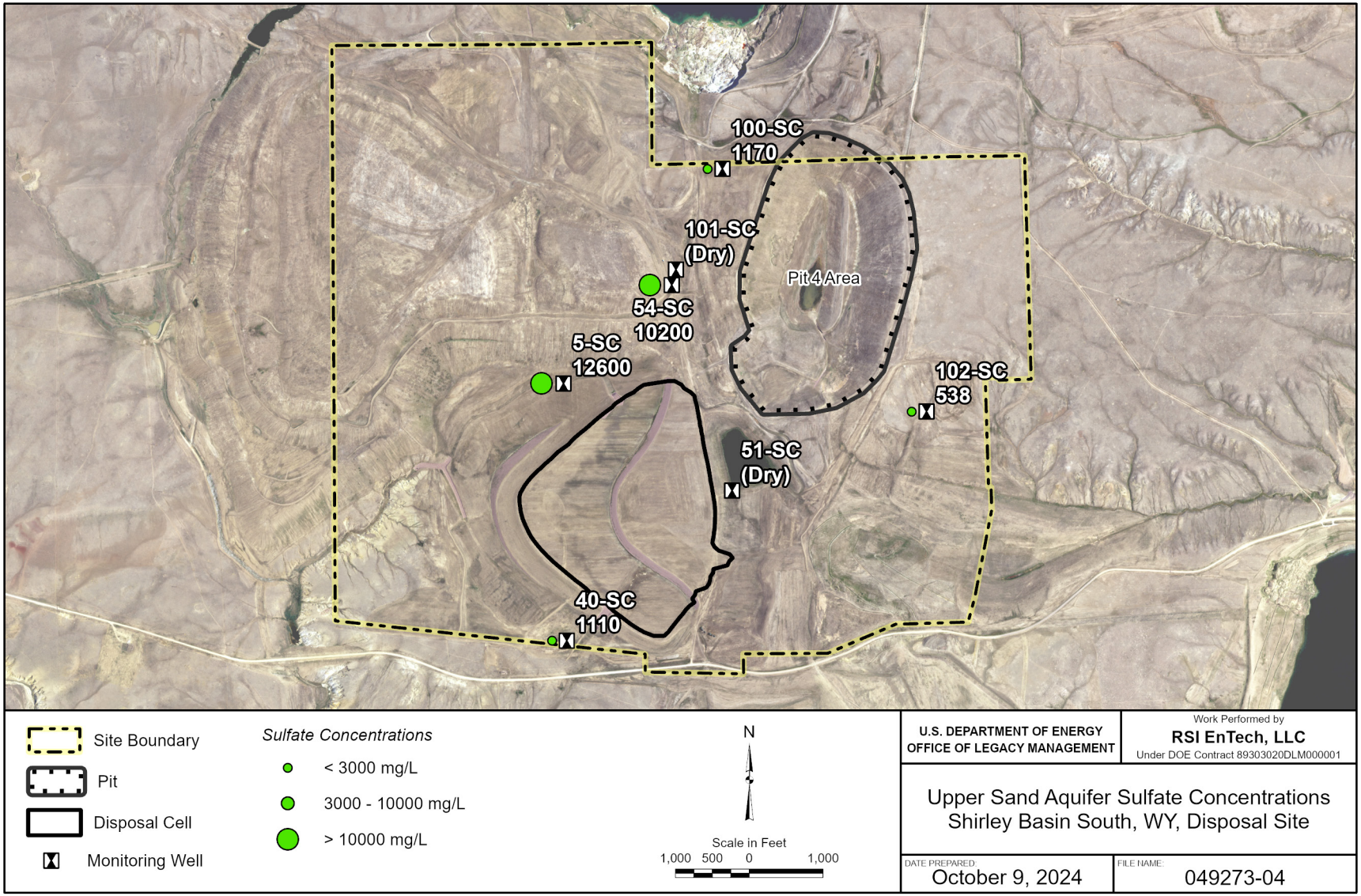


Figure 6-11. June 2024 Sulfate Concentrations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

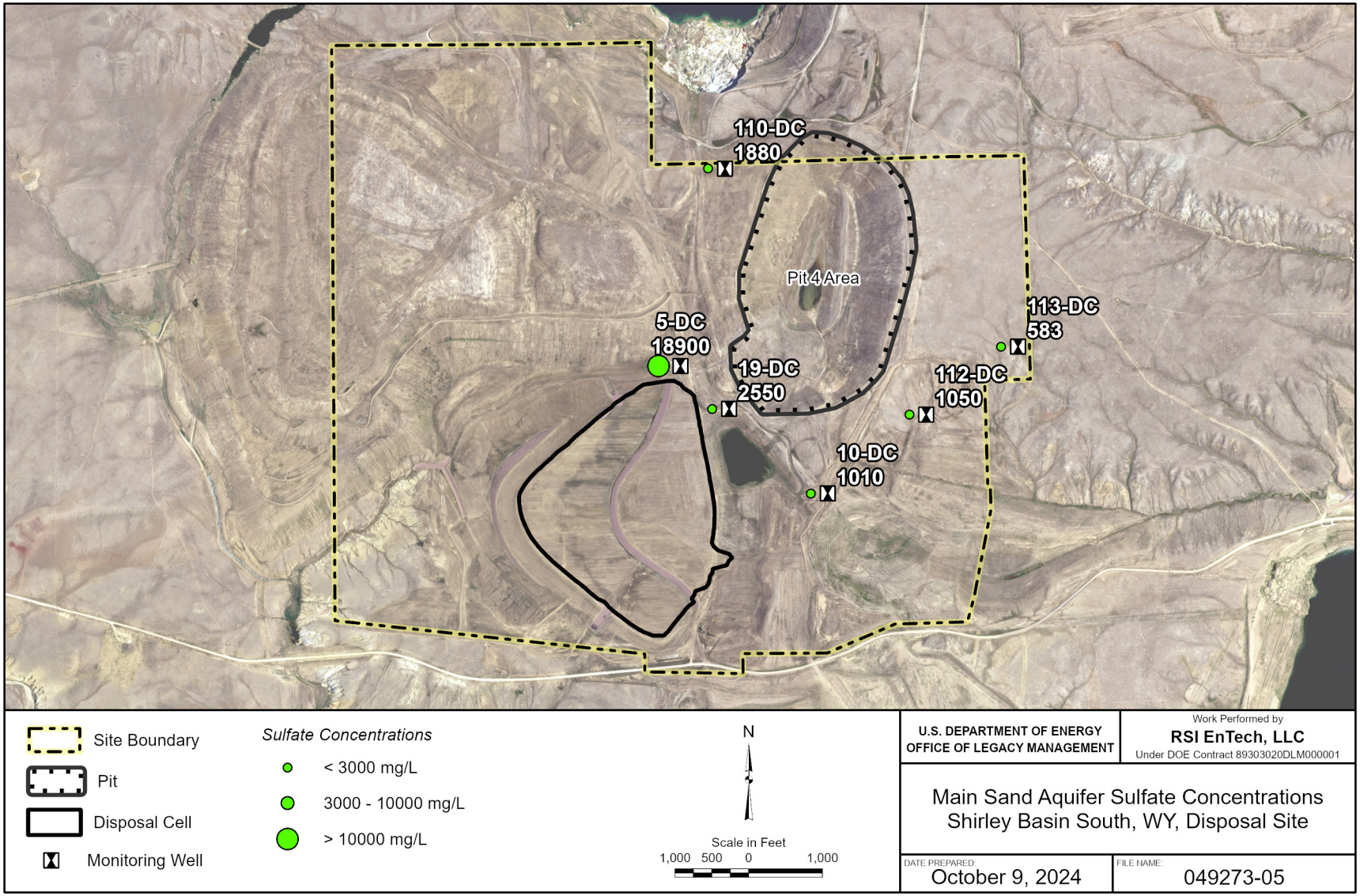


Figure 6-12. June 2024 Sulfate Concentrations in the Main Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

6.8 References

Note: Previous compliance reports and other key site-related documents are available on the LM public website at: https://lmpublicsearch.lm.doe.gov/SitePages/default.aspx?sitename=Shirley_Basin.

10 CFR 40.28. 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*.

DOE (U.S. Department of Energy), 2004. *Long-Term Surveillance Plan for the U.S. Department of Energy Shirley Basin South (UMTRCA Title II) Disposal Site, Carbon County, Wyoming*, DOE–LM/GJ766–2004, December.

DOE (U.S. Department of Energy), 2011a. *Evaluation of Elevated Radium-226 and Radium-228 Concentrations at the Shirley Basin South, Wyoming, UMTRCA Title II Disposal Site*, LMS/SBS/S07587, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2011b. *Groundwater Monitoring Evaluation for the Shirley Basin South, Wyoming, UMTRCA Title II Disposal Site*, LMS/SBS/S07784, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2013. *Groundwater Evaluation and Recommended Monitoring for the Shirley Basin South, Wyoming, UMTRCA Title II Disposal Site*, LMS/SBS/S10313, Office of Legacy Management, August.

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 October 28, 2024.

Orlando, D., 2014. D. Orlando, senior project manager, Special Projects Branch, Decommissioning and Uranium Recovery Licensing Directorate, Division of Waste Management and Environmental Protection, Office of Federal and State Materials and Environmental Management Programs, U.S. Nuclear Regulatory Commission, letter ([September 11, 2013] about U.S. Nuclear Regulatory Commission Staff Review of U.S. Department of Energy Report Titled "Groundwater Evaluation and Recommended Monitoring for the Shirley Basin South, Wyoming, UMTRCA Title II Disposal Site") to S. Surovchak, site manager, Office of Legacy Management, U.S. Department of Energy, March 25.

Petrotomics (Petrotomics Company), 1996. *Petrotomics Tailings Facility Application for Alternate Concentration Limits to Amend USNRC Source Material License SUA-551*, prepared by Shepherd Miller Inc., September.

Surovchak, S., 2011. S. Surovchak, site manager, Office of Legacy Management, U.S. Department of Energy, letter (about Actions Related to the Shirley Basin South, Wyoming, UMTRCA Title II Disposal Site) to deputy director, U.S. Nuclear Regulatory Commission, September 29.

WAR 020.0011.8.06292018. "Quality Standards for Wyoming Groundwaters," *Wyoming Administrative Rules*, https://rules.wyo.gov/, accessed October 28, 2024.

6.9 Photographs

Photograph Location Number	Azimuth	Photograph Description
PL-1	0	Entrance Sign
PL-2	315	Perimeter Sign P2 Showing Bullet Holes
PL-3	—–	Site Marker
PL-4	157	Disposal Cell Overview
PL-5	90	Erosion Caused by Animal Trail North of Upper Riprap Slope
PL-6	225	Erosion Caused by Animal Trail South of Upper Riprap Slope
PL-7	225	Vegetation Encroachment on Lower Riprap Slope
PL-8	22	Erosion Caused from Overflowing Water Storage Tank
PL-9	180	Pit 4 Overview and Wetland Area
PL-10	135	Pit 4 Lower Riprap-Armored Drainage Channel Erosion
PL-11	90	Drilling Activity North of Site Boundary
PL-12	45	Road Improvements Adjacent to Northeast Site Boundary

Note:
—– = Photograph taken vertically from above.

PL-1. Entrance Sign

PL-2. Perimeter Sign P2 Showing Bullet Holes

PL-3. Site Marker

PL-4. Disposal Cell Overview

PL-5. Erosion Caused by Animal Trail North of Upper Riprap Slope

PL-6. Erosion Caused by Animal Trail South of Upper Riprap Slope

PL-7. Vegetation Encroachment on Lower Riprap Slope

PL-8. Erosion Caused from Overflowing Water Storage Tank

PL-9. Pit 4 Overview and Wetland Area

PL-10. Pit 4 Lower Riprap-Armored Drainage Channel Erosion

PL-11. Drilling Activity North of Site Boundary

PL-12. Road Improvements Adjacent to Northeast Site Boundary