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 27, 2023. No major changes were observed on the disposal cell or in associated drainage features. Inspectors identified maintenance needs and 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 July 2023. The 2023 data indicate that alternate concentration limits (ACLs) continue to be exceeded in the point of compliance (POC) well 5-DC for radium-228 (^{228}Ra) and selenium. In contrast to previous years, the ACL for radium-226 (^{226}Ra) was not exceeded in any well in 2023. 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 United States government owns 1512 acres (also known as Parcel 1) whereas Appendix A of the LTSP includes the deed that conveyed 1527 acres of 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.

6.4 Inspection Results

The site, approximately 60 miles south of Casper, Wyoming, was inspected by J. Cario and M. Guziak of the Legacy Management Support (LMS) contractor. J. Hugo (LMS) participated in the inspection to evaluate the erosional features in Pit 4 and around the riprap of the disposal cell, both reported first in 2022, as well as the arroyo under the site boundary fence reported by the grazing licensee to LM in spring 2023. N. Keller (LM site manager), T. Santonastaso (LMS), S. Loose (Wyoming Department of Environmental Quality [WDEQ]), and S. Cameron (Florida International University DOE Fellow) 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. 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 6-1 by photograph location (PL) numbers. The photographs and photograph log are presented in Section 6.9.

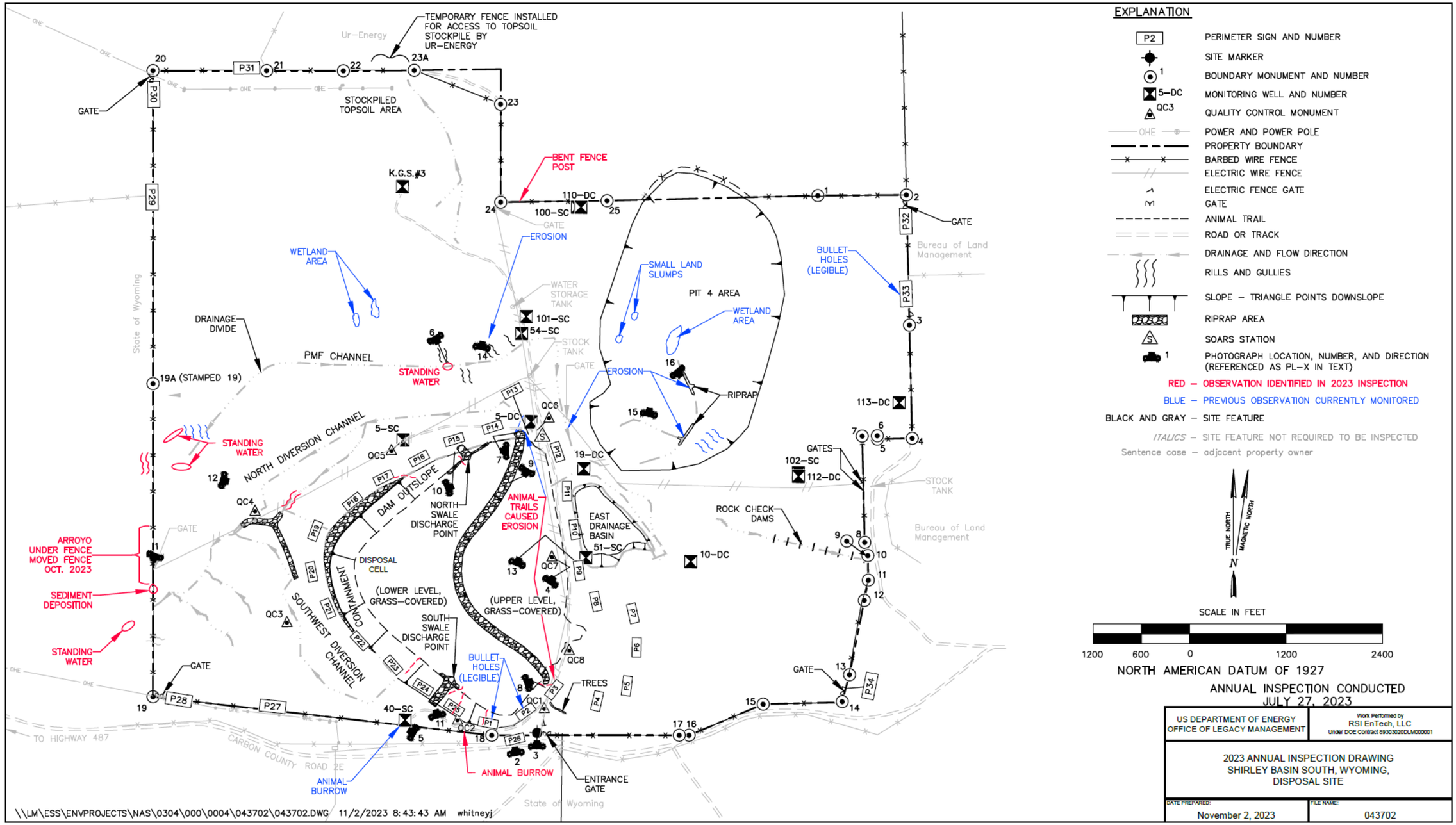
6.4.1.1 Site Access and Entrance Gate

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. The northeast gate accesses Wyoming state land and was not locked. The northwest gate accesses U.S. Bureau of Land Management (BLM) land and was not locked. The gates will be secured with standard LM locks by the 2024 inspection.

6.4.1.2 Perimeter Fence and Signs

A four-strand barbed-wire fence encloses the site. A grazing license LM granted to a local rancher allows him to graze livestock onsite in exchange for minor maintenance of the perimeter fence. An animal burrow is present under the fence near boundary monument BM-18, and a post is bent on the north side near boundary monument BM-24. These items are minor and will be addressed by the grazing licensee. A large erosional feature (arroyo) has formed underneath the fence on the southern portion of the west boundary (PL-1). The arroyo formed inline with the fence, damaging several sections. Sediment from the erosional event was deposited below the slope break. This section of the fence line was subsequently realigned approximately 30 feet inward (away from the arroyo) in October 2023. Another erosional feature is developing north of the arroyo but is not yet impacting the fence.

Nine perimeter signs (warning and no-trespassing signs) are posted along the site perimeter at potential points of access (PL-2), and another 25 signs are positioned around the disposal cell. Perimeter signs P1, P2, and P33 have bullet holes but remain legible. Several perimeter signs have exposed concrete at the base but remain stable. No maintenance needs were identified.



EXPLANATION

- P2 — PERIMETER SIGN AND NUMBER
- SITE MARKER
- 1 — BOUNDARY MONUMENT AND NUMBER
- 5-DC — MONITORING WELL AND NUMBER
- QC3 — QUALITY CONTROL MONUMENT
- OHE — POWER AND POWER POLE
- PROPERTY BOUNDARY
- BARBED WIRE FENCE
- ELECTRIC WIRE FENCE
- ELECTRIC FENCE GATE
- GATE
- ANIMAL TRAIL
- ROAD OR TRACK
- DRAINAGE AND FLOW DIRECTION
- RILLS AND GULLIES
- SLOPE – TRIANGLE POINTS DOWNSLOPE
- RIPRAP AREA
- S — SOARS STATION
- 1 — PHOTOGRAPH LOCATION, NUMBER, AND DIRECTION (REFERENCED AS PL-X IN TEXT)

RED – OBSERVATION IDENTIFIED IN 2023 INSPECTION

BLUE – PREVIOUS OBSERVATION CURRENTLY MONITORED

BLACK AND GRAY – SITE FEATURE

ITALICS – SITE FEATURE NOT REQUIRED TO BE INSPECTED

Sentence case – adjacent property owner

TRUE NORTH / MAGNETIC NORTH

SCALE IN FEET

1200 600 0 1200 2400

NORTH AMERICAN DATUM OF 1927

ANNUAL INSPECTION CONDUCTED JULY 27, 2023

US DEPARTMENT OF ENERGY OFFICE OF LEGACY MANAGEMENT	Work Performed by RSI EnTech, LLC Under DOE Contract 89303020DLM000001
2023 ANNUAL INSPECTION DRAWING SHIRLEY BASIN SOUTH, WYOMING, DISPOSAL SITE	
DATE PREPARED: November 2, 2023	FILE NAME: 043702

Figure 6-1. 2023 Annual Inspection Drawing for the Shirley Basin South, Wyoming, Disposal Site

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. Quality control monument QC-7 was covered by sediment, which was removed during the inspection (PL-4). T-posts were placed near all quality control monuments prior to the 2023 inspection to improve visibility. 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 small animal burrows under the concrete slab but remains stable (PL-5). 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-6).

Cattle have worn trails around the riprap-armored slopes, which has caused erosion on the north (PL-7) and south (PL-8) ends of the eastern riprap-armored slope. These trails may need to be repaired in the future to prevent degradation of the as-built feature. No settlement, or other

modifying processes on the disposal cell cover or side slopes that might affect the integrity of the disposal cell were observed.

Gradual vegetation encroachment has been observed in the riprap on the slope that separates the two elevations (PL-9). The establishment of perennial vegetation enhances slope stability. Riparian vegetation is establishing at the toe of the slope in areas that accumulate snowmelt runoff and summer precipitation.

The upper surface is contoured to drain into a basin east of the disposal cell A 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 (PL-10) and south swale discharge point (PL-11). The riprap dissipation basins at the discharge points usually hold runoff water in spring and early summer. Water was present in the north and south swale discharge points during the inspection. Vegetation is establishing in both the north swale and south swale discharge points. No maintenance needs were identified.

In August 2023, a remote telemetry meteorological station, also known as a System Operation and Analysis at Remote Sites (SOARS) station, was installed on the cover of the disposal cell to monitor local weather conditions at the site.

6.4.2.2 Containment Dam and Diversion Channels

The tailings pile was reclaimed in place and contained behind a horseshoe-shaped earthen dam, identified as the containment dam. The containment dam is predominantly grass covered, but the steeper portion (5:1 slope) of the dam out slope 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 (PL-12). Two primary diversion channels, the north, and the 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. Water was present during the inspection in this closed basin. The portion of the PMF channel that flows eastward and discharges into the East Drainage Basin (PL-13) captures stormwater from a larger drainage area. Water was present in the part of the PMF channel that drains to the east about 0.25 mile west of where it intersects the main road. 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-14) 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

The site is surrounded by public land administered by BLM, the State of Wyoming, and 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 through sections of secured temporary fence along the northern site boundary. This access is in accordance with an agreement originally established between Petrotomics Company, the former site licensee, and Pathfinder Mines Corporation (Pathfinder), which was acquired by Ur-Energy. LM is the successor to Petrotomics, and the terms of the agreement remain in effect. 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.

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 (the Upper Sand 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 where standing water from runoff is often present (PL-15). Some minor slumps and displacement features are present on the west side slope of the pit, but they do not represent a significant slope stability concern. Rilling and a minor land slump is also occurring on the southeast side slope of the pit but does not represent a significant slope instability concern. A rock-armored drainage channel near the bottom of the pit, first reported to have eroded in 2016, has continued to grow, and in the lower section, most of the riprap has been eroded (PL-16). Repair of the rock armor is not necessary because potential erosion in that portion of the pit is not expected to impact slope stability.

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 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. No such changes were observed. No maintenance needs 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. Realignment of the eroded disposal site fence was conducted in October of 2023. Unlocked gates will be secured during the 2024 inspection.

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 most recent sampling event was completed in July 2023. 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.

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.

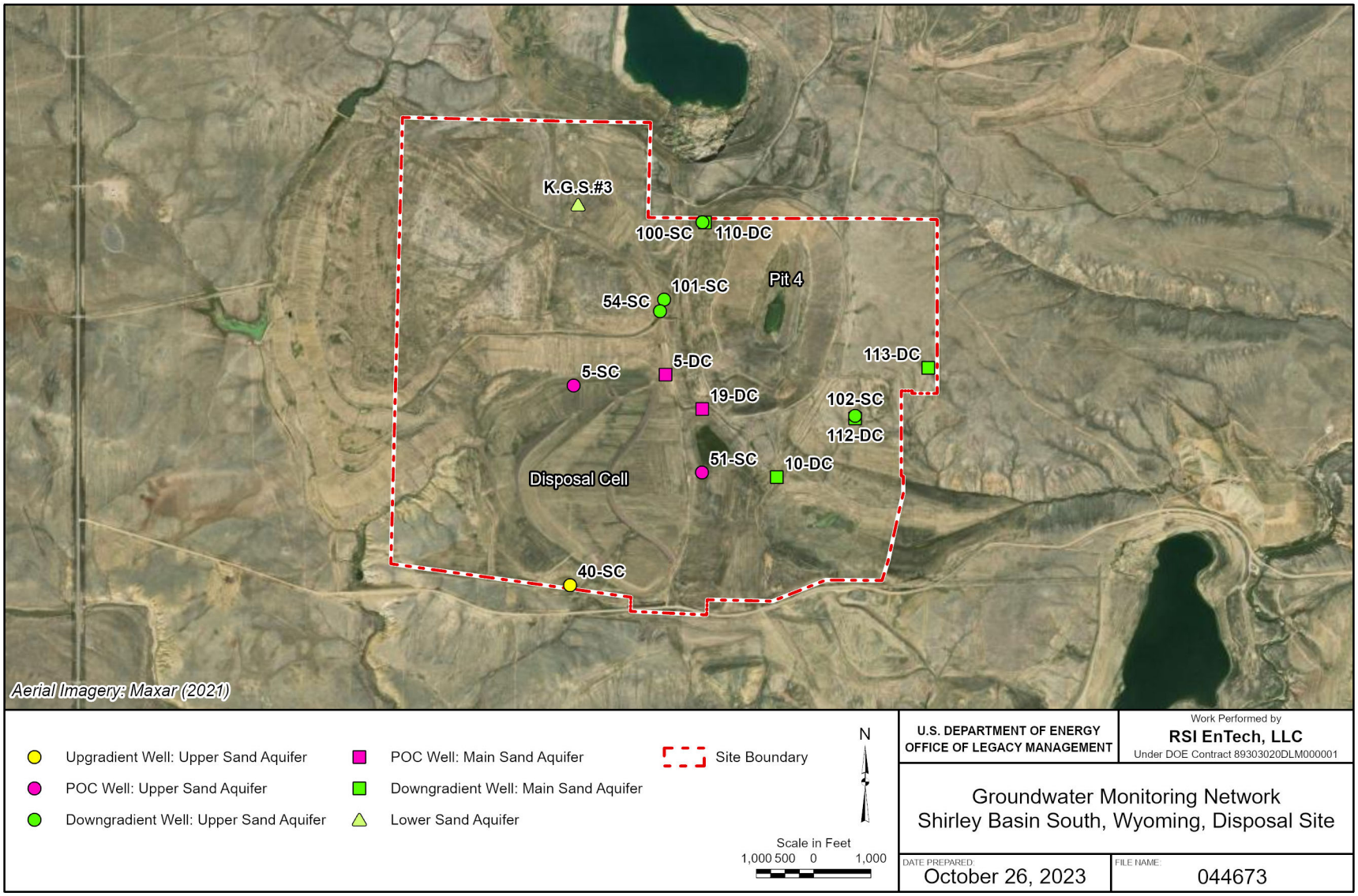


Figure 6-2. Groundwater Monitoring Network at Shirley Basin South, Wyoming, Disposal Site

Although no monitoring wells are designated as points of exposure, groundwater chemistry at downgradient wells 100-SC, 102-SC, 110-DC, and 113-DC are considered most representative of groundwater quality for groundwater flowing offsite in the Upper Sand and Main Sand Aquifers. Monitoring well 54-SC had been identified as screened across the Upper Sand and Main Sand Aquifers following review of boring logs and downhole video logs taken in 2008 (DOE 2009). 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). The reclassification of well 54-SC in this annual report represents a change relative to past annual reports (e.g., DOE 2022).

Water level, pH, and electrical conductivity are measured at the time of sampling, and samples are analyzed for cadmium, chloride, chromium, lead, nickel, nitrate + nitrite as nitrogen (N), ^{226}Ra, ^{228}Ra, selenium, sulfate, thorium-230 (^{230}Th), TDS, and uranium.[1] Analytical results are compared to the ACLs and Wyoming Class III groundwater protection standards listed in Table 6-3.

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[b]
Chloride	NA	2000 mg/L
Chromium	1.83 mg/L	0.05 mg/L[b]
Lead	0.05 mg/L	0.1 mg/L[b]
Nickel	6.15 mg/L	NA
Nitrate + Nitrite as N	NA	100 mg/L[b]
^{226}Ra	91.3 pCi/L	5 pCi/L[b,c] (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

Notes:
[a] This column shows the current Wyoming Class III groundwater protection standard values for livestock use, which apply to this site (WAR 020.0011.8.06292018).
[b] Standard has been updated since the LTSP was issued.
[c] The combined standard for radium (^{226}Ra + ^{228}Ra) is not used as a point of comparison in this chapter because the two isotopes are addressed separately in the LTSP.

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

[1] In 2023, additional constituents (including major ions, iron, and ferrous iron) were analyzed to help in LM's ongoing updated evaluation of the site conceptual model.

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. 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 July 2023 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.

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. For the same reasons (insufficient data), flow directions were not calculated using well triangles or any other numerical method; therefore, 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). Increasing water levels in wells 100-SC and 102-SC (Figure 6-4) are possibly due to groundwater recovery from Pit 4 dewatering activities. Water levels in the remaining Upper Sand Aquifer wells have been relatively constant (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 July 2023. Figure 6-6 plots corresponding groundwater elevations over time. Since 2010, water levels measured in the Main Sand Aquifer wells near the disposal cell indicate that the flow direction has shifted to the south-southeast. This shift in flow direction (e.g., based on 2023 head data) is different than reported flow directions reported in past hydrogeological evaluations (DOE 2011b; DOE 2013) and predicted by the former licensee's model (Petrotomics 1996).

Piezometric heads have been gradually rising at all Main Sand Aquifer 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.

In response to recent NRC comments on recent annual inspection reports (Orlando 2021; Bolz 2022), DOE will continue monitoring and evaluating groundwater elevations as recovery continues in the Main Sand Aquifer. Once groundwater conditions have stabilized, LM will determine if the monitoring program remains adequate. Groundwater elevations, apparent trends in flow directions, and water quality evaluations from existing Main Sand Aquifer wells will inform LM future actions to track potential offsite migration of site contaminants.

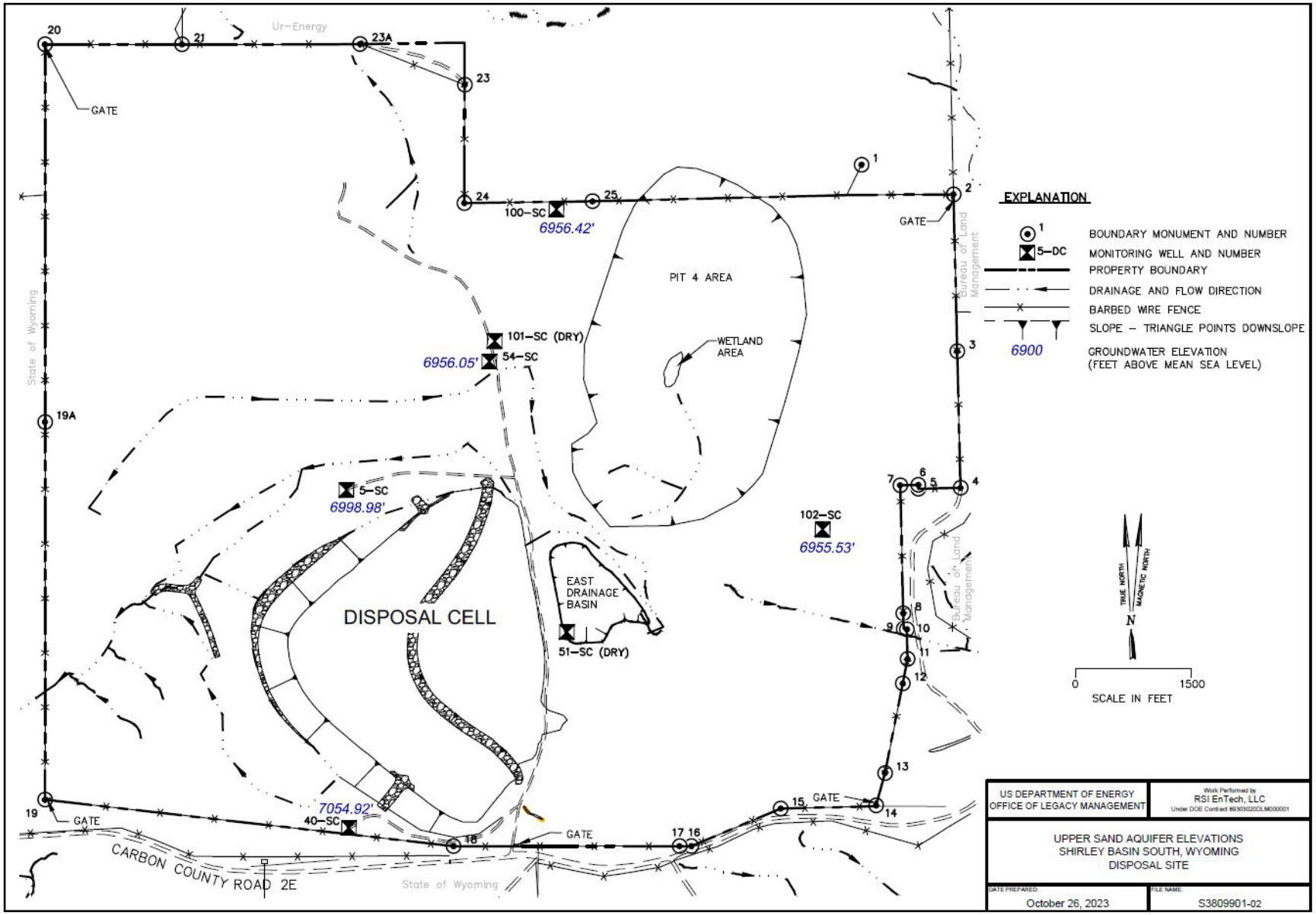
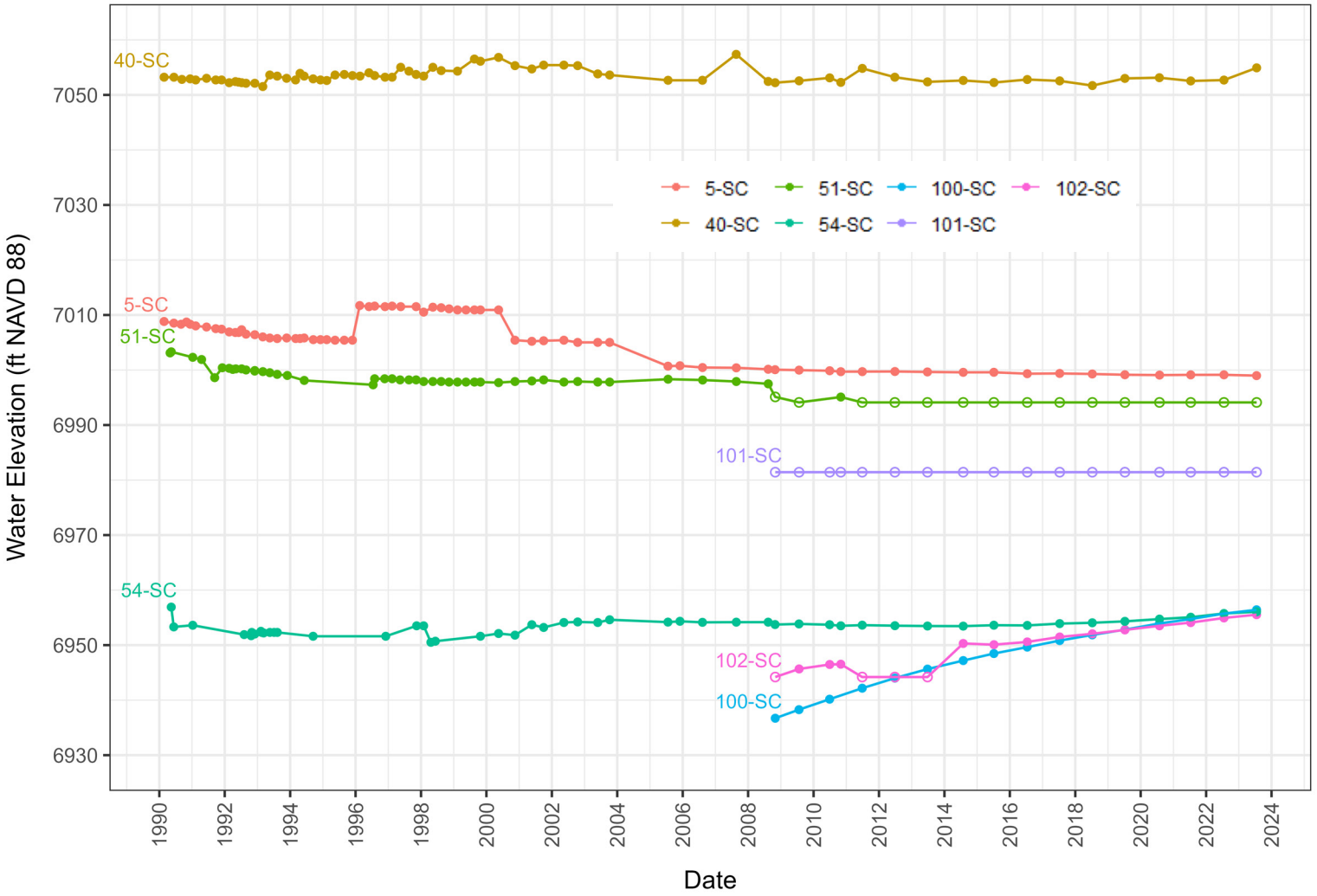


Figure 6-3. July 2023 Groundwater Elevations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site



Notes: Hollow symbols indicate that the well was dry or that the water level was below the pump. For these observations, plotted values are the corresponding bottom screen elevations or, for well 51-SC (with no available well construction information), the minimum recorded water elevation. POC well 51-SC has been dry since 2011, and well 101-SC has been dry since its installation in 2008.
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

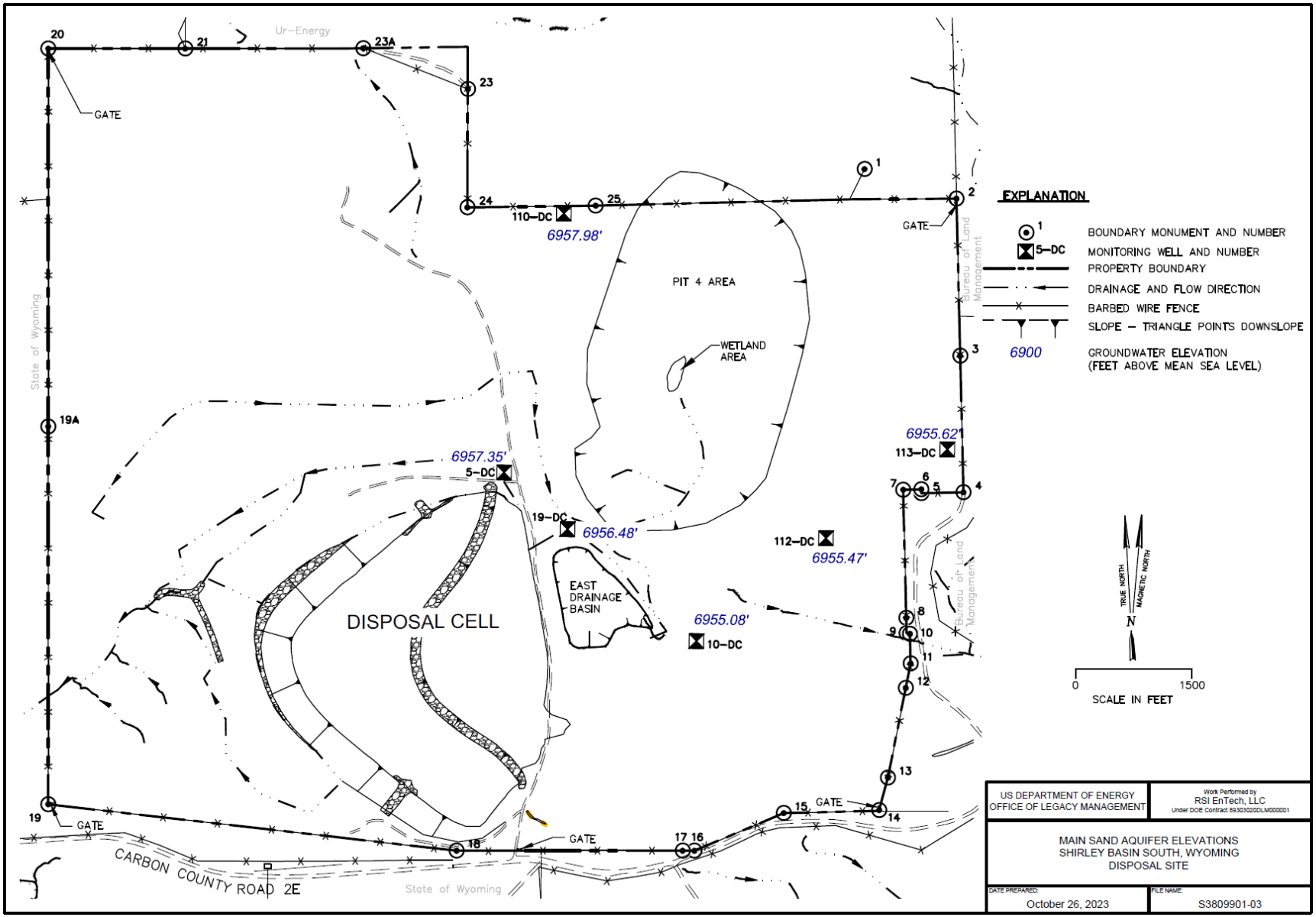
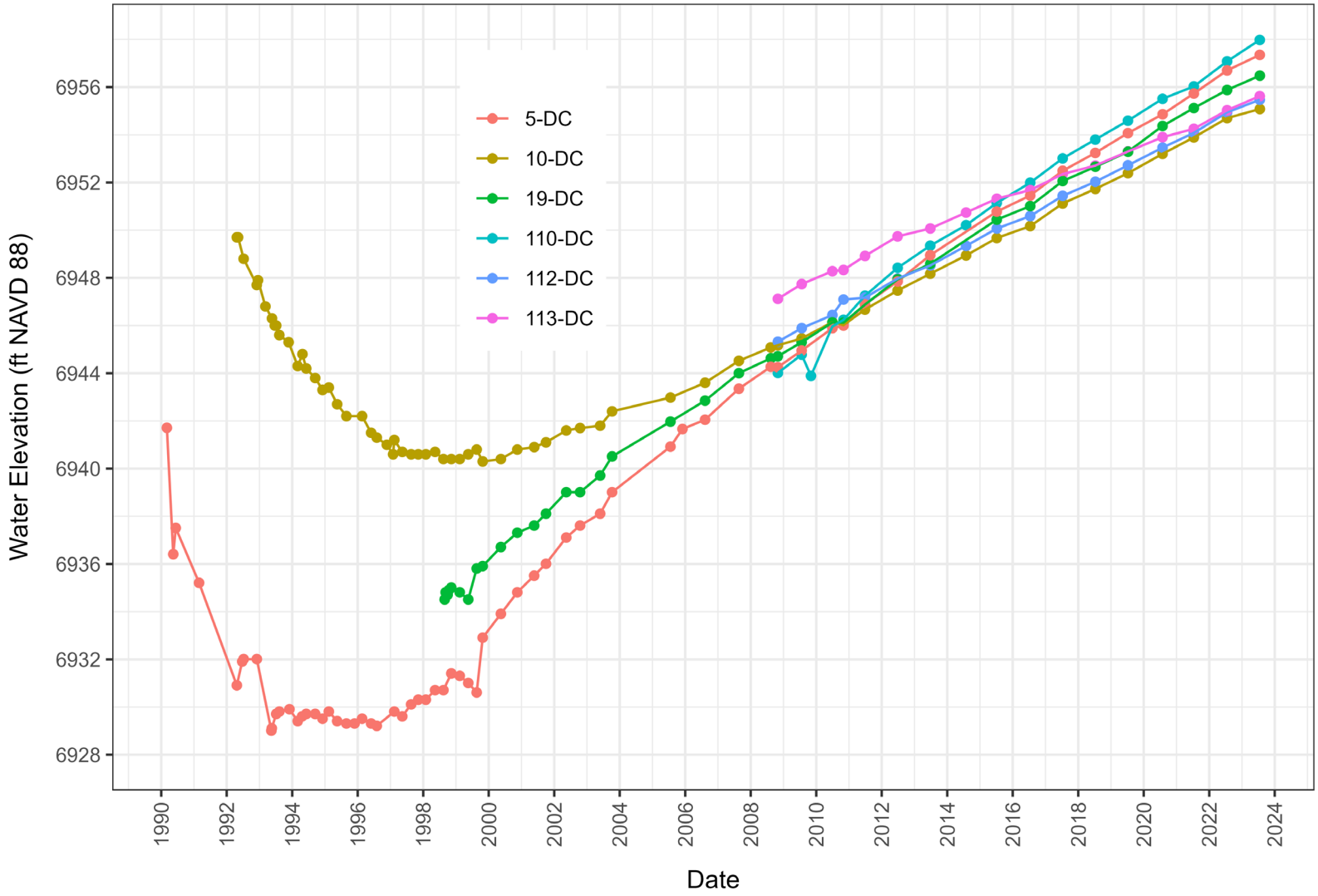


Figure 6-5. July 2023 Groundwater Elevations in the Main Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site



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

To better understand the increasing water level trends in several of the onsite wells, LM is planning to further evaluate potential regional impacts on water level trends in both the Upper Sand and Main Sand aquifers at the site. In particular, temporal water level data from the Ur-Energy pit lake and Ur-Energy groundwater wells north of the site boundary is a current, key data gap that would greatly inform water level trend uncertainties (e.g., time for water levels to equilibrate, or stabilize) at the Shirley Basin South site.

Analytical results from the July 2023 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. Recent exceedances of the ACLs or groundwater protection standards listed Table 6-3 are clearly noted in these tables.

Samples could not be collected from Upper Sand Aquifer wells 51-SC and 101-SC because they continue to be dry. POC well 51-SC has been dry since 2011 and well 101-SC has been dry since its installation in 2008 (Figure 6-4).

Table 6-4. 2023 Groundwater Monitoring Results in the Upper Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site

Analyte	Limit or Standard[b]	Well[a]				
		5-SC (POC)	40-SC	54-SC	100-SC	102-SC
Cadmium	0.079 mg/L 0.05 mg/L[c]	0.030	ND	ND	ND	ND
Chloride	2000 mg/L[c]	509	8.29	403	128	38.2
Chromium	1.83 mg/L 0.05 mg/L[c]	***0.325***[e]	0.0012	***0.61***[e]	ND	ND
Lead	0.05 mg/L 0.1 mg/L[c]	ND	ND	ND	ND	ND
Nickel	6.15 mg/L	3.22	0.008	4.42	ND	ND
Nitrate + Nitrite as N	100 mg/L[c]	ND	1.91	ND	ND	0.044
^{226}Ra	91.3 pCi/L	ND	ND	9.97	4.05	2.98
^{228}Ra	25.7 pCi/L	3.05	1.99	***64.2***[d]	4.53	2.66
Selenium	0.12 mg/L 0.05 mg/L[c]	***0.102***[e]	0.0065	***0.088***[e]	ND	ND
Sulfate	3000 mg/L[c]	***14,300***[e]	1400	***11,900***[e]	1000	560
^{230}Th	2409 pCi/L	465	ND	54.2	ND	ND
TDS	5000 mg/L[c]	***16,500***[e]	1740	***15,200***[e]	2030	1000
Uranium	9.2 mg/L	2.95	0.000087	0.028	0.0015	0.0013

Notes:
[a] ***Bold italicized*** results exceed a standard or limit. Well-analyte combinations with at least one exceedance in 2023 are shaded. Upper Sand Aquifer wells 51-SC and well 101-SC are not listed in this table because these wells have been dry for over a decade (refer to text above).
[b] ACL or groundwater protection standard from Table 6-3.
[c] Wyoming Class III groundwater protection standard (WAR 020.0011.8.06292018).
[d] Result exceeds an ACL.
[e] Result exceeds the corresponding Wyoming Class III groundwater protection standard.

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

Table 6-5. 2023 Groundwater Monitoring Results in the Main Sand Aquifer Wells at the Shirley Basin South, Wyoming, Disposal Site

Analyte	Limit or Standard[b]	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[c]	ND	ND	ND	ND	ND	ND
Chloride	2000 mg/L[c]	549	59	146	181	49.0	10.4
Chromium	1.83 mg/L 0.05 mg/L[c]	***0.18***[e]	ND	ND	ND	ND	ND
Lead	0.05 mg/L 0.1 mg/L[c]	ND	0.0007	ND	ND	ND	ND
Nickel	6.15 mg/L	2.57	ND	0.56	ND	ND	ND
Nitrate + Nitrite as N	100 mg/L[c]	ND	ND	ND	ND	ND	0.104
^{226}Ra	91.3 pCi/L	15.6	18.2	6.59	82.7	12.2	2.27
^{228}Ra	25.7 pCi/L	***93.8***[d]	4.16	7.57	6.17	9.33	1.73
Selenium	0.12 mg/L 0.05 mg/L[c]	***0.20***[d,e]	ND	ND	ND	ND	ND
Sulfate	3000 mg/L[c]	***22,100***[e]	995	2760	1870	972	620
^{230}Th	2409 pCi/L	109	ND	1.51	ND	ND	0.31
TDS	5000 mg/L[c]	***27,800***[e]	1800	4420	3070	1770	1040
Uranium	9.2 mg/L	0.015	0.012	0.0001	0.014	0.013	0.0009

Notes:

[a] ***Bold italicized*** results exceed a standard or limit. Analytes and wells with at least one exceedance in 2023 are shaded.

[b] ACL or groundwater protection standard from Table 6-3.

[c] Wyoming Class III groundwater protection standard (WAR 020.0011.8.06292018).

[d] Result exceeds an ACL.

[e] Result exceeds the corresponding Wyoming Class III groundwater protection standard.

Abbreviations:

mg/L = milligrams per liter

ND = not detected (below method detection limit)

pCi/L = picocuries per liter

Table 6-6. 2023 Groundwater Monitoring Results for Well K.G.S. #3 in the Lower Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

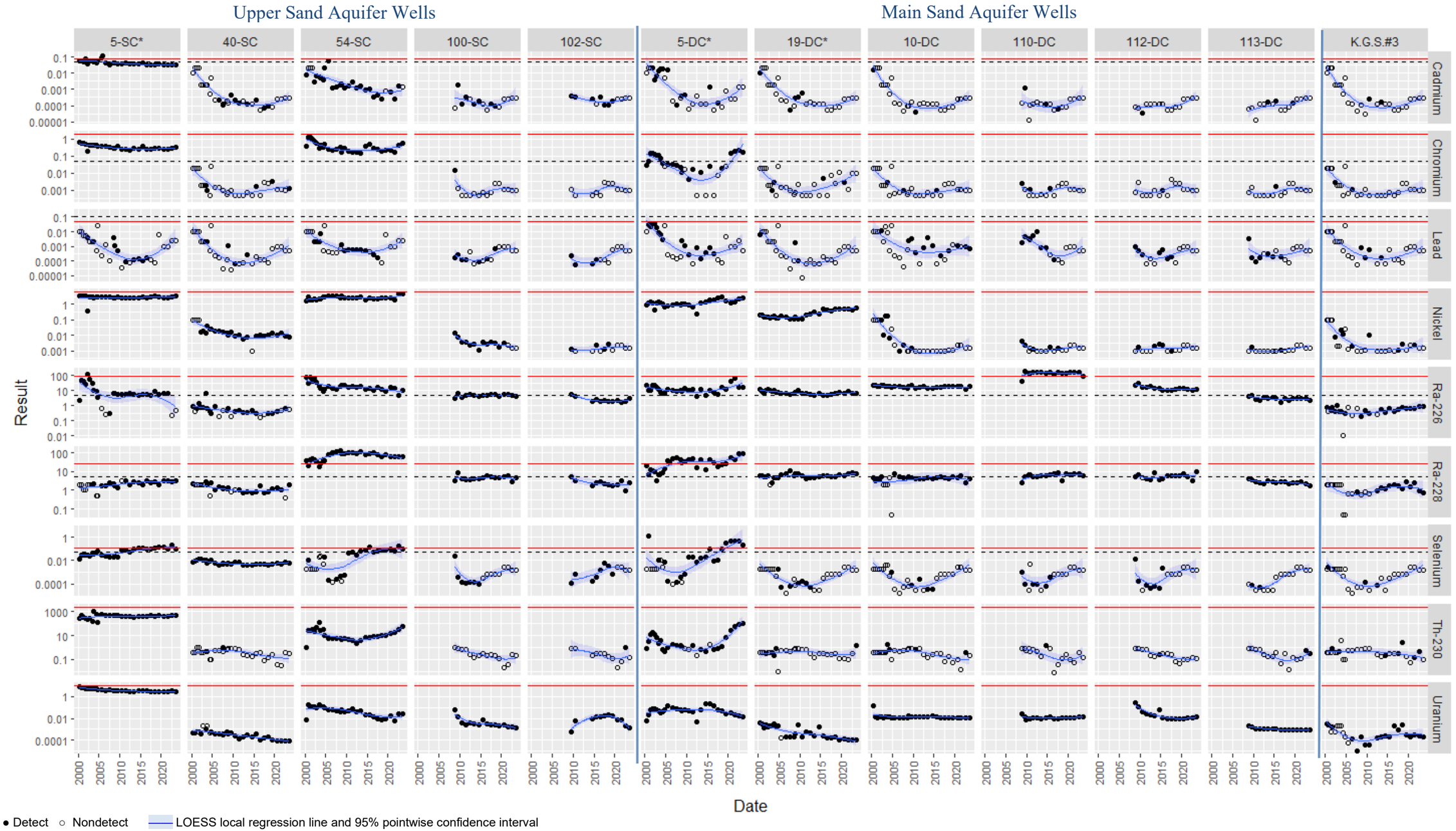
Analyte	Limit or Standard[a]	K.G.S. #3 Result
Cadmium	0.079 mg/L 0.05 mg/L[b]	ND
Chloride	2000 mg/L[b]	4.82
Chromium	1.83 mg/L 0.05 mg/L	ND
Lead	0.05 mg/L 0.1 mg/L[b]	ND
Nickel	6.15 mg/L	ND
Nitrate + Nitrite as N	100 mg/L[b]	ND
^{226}Ra	91.3 pCi/L	0.939
^{228}Ra	25.7 pCi/L	0.716
Selenium	0.12 mg/L 0.05 mg/L[b]	ND
Sulfate	3000 mg/L[b]	229
^{230}Th	2409 pCi/L	ND
TDS	5000 mg/L[b]	479
Uranium	9.2 mg/L	0.0002

Note:
[a] ACL or groundwater protection standard from Table 6-3.
[b] Wyoming Class III groundwater protection standard (WAR 020.0011.8.06292018).

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

As a prelude to the discussion of results that follows, Figure 6-7 and Figure 6-8 provide matrices of time-concentration plots for each Shirley Basin South site monitoring well and analyte combination. Because of the large number of plots (168 distinct well and analyte combinations are represented), these figures are broken out based on the categorization of analytes applied in Sections 6.1 and 6.2 of the 2011 groundwater monitoring evaluation report (DOE 2011b). Figure 6-7 shows time-concentration plots for the nine hazardous constituents, that is, 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.

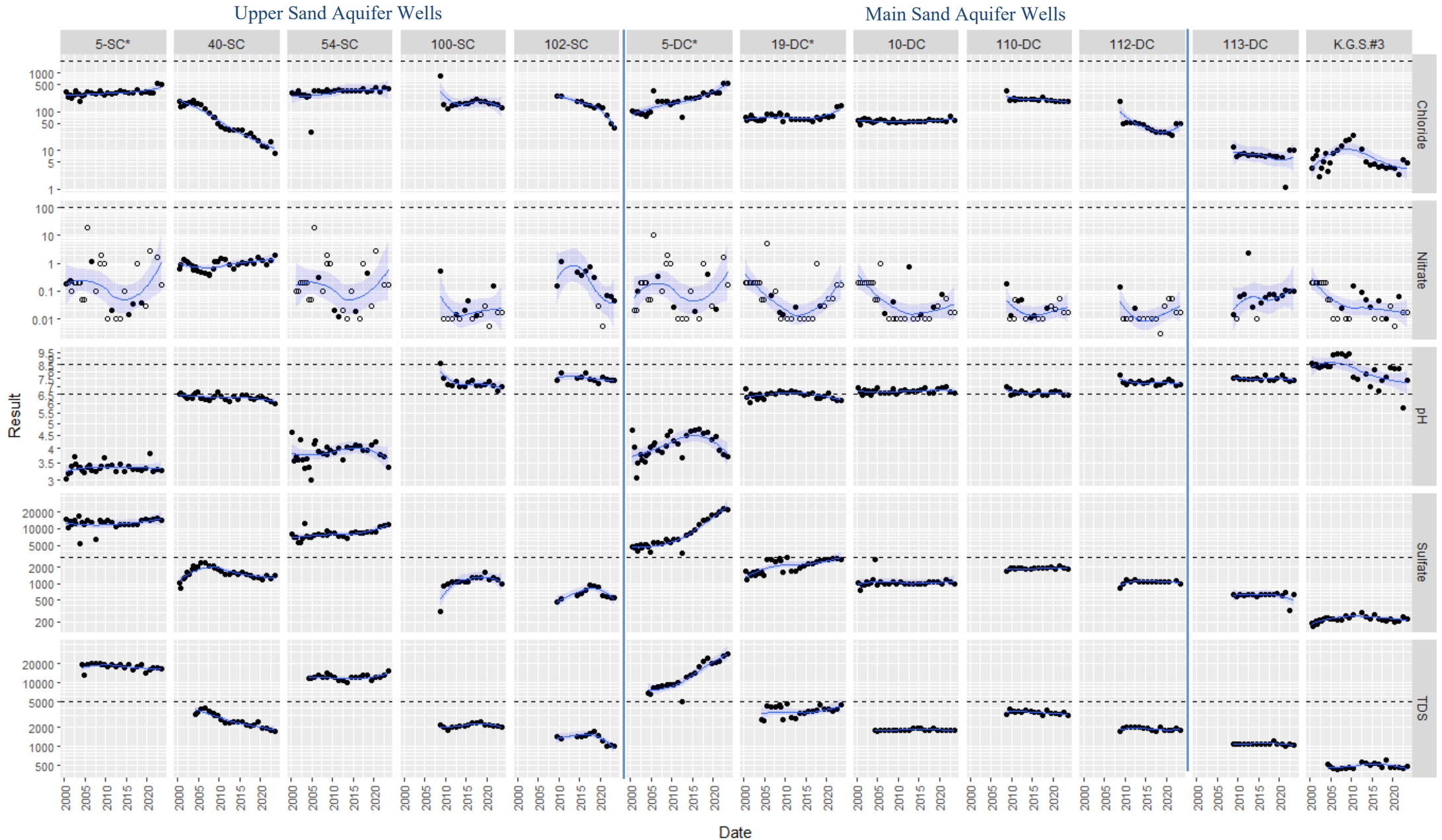
Consistent with the presentation in the previous annual report (DOE 2022), and in response to NRC's comments on the 2020 annual inspection report (Orlando 2021), Mann-Kendall trend analysis was performed for the monitored constituents. Mann-Kendall trends were calculated from 2005, when the site was transferred to LM and low-flow sampling of constituents was first recorded, to 2023. 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.



● Detect ○ Nondetect LOESS local regression line and 95% pointwise confidence interval
------ ACL from Table 6-3; - - - Groundwater protection standard from Table 6-3.

Notes: Units 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.

Figure 6-7. Time-Concentration Plots of Hazardous Constituents (Analytes with ACLs) in Monitoring Wells, Shirley Basin South, Wyoming, Disposal Site: 2000–2023



● 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).

Notes: Units 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.

Figure 6-8. Time-Concentration Plots of Indicator Parameters in Monitoring Wells, Shirley Basin South, Wyoming, Disposal Site: 2000–2023

Table 6-7. Mann-Kendall Trend Analysis Results for Shirley Basin South Site Monitoring Wells, 2005–2023

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	No. of Samples (No. of Nondetects)[b]	Most Recent Result[c]	Kendall's tau[d]	Trend[e]
Hazardous Constituents (Analytes with ACLs)						
Cadmium (mg/L)						
5-SC*	7/20/2005	7/18/2023	21	0.03	−0.633	Decreasing
54-SC	7/20/2005	7/18/2023	20 (2)	<0.0015	−0.500	Decreasing
102-SC	7/23/2009	7/18/2023	12 (5)	<0.0003	−0.439	Decreasing
Chromium (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	*0.325*	−0.205	No Trend
54-SC	7/20/2005	7/18/2023	20	*0.61*	0.089	No Trend
5-DC*	7/20/2005	7/18/2023	20 (6)	*0.182*	0.089	No Trend
Lead (mg/L)						
10-DC	7/20/2005	7/19/2023	20 (9)	0.0007	0.116	No Trend
110-DC	10/30/2008	7/18/2023	17 (8)	<0.0005	−0.529	Decreasing
Nickel (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	3.22	0.184	No Trend
40-SC	7/21/2005	7/19/2023	20 (1)	0.008	−0.263	No Trend
54-SC	7/20/2005	7/18/2023	20	4.42	−0.184	No Trend
100-SC	10/30/2008	7/18/2023	16 (3)	<0.0015	−0.55	Decreasing
5-DC*	7/20/2005	7/18/2023	20	2.57	0.563	Increasing
19-DC*	7/20/2005	7/19/2023	20	0.56	0.679	Increasing
^{226}Ra (pCi/L)						
5-SC*	7/20/2005	7/18/2023	20 (4)	<0.51	0.111	No Trend
40-SC	7/21/2005	7/19/2023	20 (7)	<0.58	−0.121	No Trend
54-SC	7/20/2005	7/18/2023	20	*9.97*	−0.416	Decreasing
100-SC	10/30/2008	7/18/2023	16	4.05	0.133	No Trend
102-SC	7/23/2009	7/18/2023	12	2.98	−0.303	No Trend
5-DC*	7/20/2005	7/18/2023	20	*15.6*	0.258	No Trend
10-DC	7/20/2005	7/19/2023	20	*18.2*	0.037	No Trend
19-DC*	7/20/2005	7/19/2023	20	*6.59*	0.021	No Trend
110-DC	10/30/2008	7/18/2023	18	*82.7*	−0.046	No Trend
112-DC	10/30/2008	7/18/2023	16	*12.2*	−0.5	Decreasing
11 3-DC	10/30/2008	7/18/2023	16	2.27	−0.292	No Trend
K.G.S. #3	7/21/2005	7/24/2023	18 (4)	0.94	0.601	Increasing
^{228}Ra (pCi/L)						
5-SC*	7/20/2005	7/18/2023	20 (1)	3.05	0.363	Increasing
40-SC	7/21/2005	7/19/2023	20 (3)	1.99	−0.079	No Trend
54-SC	7/20/2005	7/18/2023	21	*64.2*	−0.457	Decreasing
100-SC	10/30/2008	7/18/2023	16	4.53	0.183	No Trend
102-SC	7/23/2009	7/18/2023	12	2.66	−0.333	No Trend
5-DC*	7/20/2005	7/18/2023	21	*93.8*	0.067	No Trend
10-DC	7/20/2005	7/19/2023	20	4.16	−0.147	No Trend
19-DC*	7/20/2005	7/19/2023	20	*7.57*	−0.037	No Trend
110-DC	10/30/2008	7/18/2023	17	*6.17*	0.397	Increasing
112-DC	10/30/2008	7/18/2023	16 (1)	*9.33*	0.242	No Trend
113-DC	10/30/2008	7/18/2023	16	1.73	−0.55	Decreasing
K.G.S. #3	7/21/2005	7/24/2023	13	0.72	0.418	Increasing
Selenium						
5-SC*	7/20/2005	7/18/2023	20	0.102	0.626	Increasing
40-SC	7/21/2005	7/19/2023	20	0.0065	0.137	No Trend
54-SC	7/20/2005	7/18/2023	20 (2)	0.089	0.732	Increasing
102-SC	7/23/2009	7/18/2023	12 (4)	<0.0015	0.091	No Trend
5-DC*	7/20/2005	7/18/2023	20 (2)	*0.20*	0.716	Increasing

Table 6-7. Mann-Kendall Trend Analysis Results for Shirley Basin South Site Monitoring Wells, 2005–2023 (continued)

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	No. of Samples (No. of Nondetects)[b]	Most Recent Result[c]	Kendall's tau[d]	Trend[e]
^{230}Th (pCi/L)						
5-SC*	7/20/2005	7/18/2023	20	465	−0.168	No Trend
54-SC	7/20/2005	7/18/2023	20	54.2	0.605	Increasing
5-DC*	7/20/2005	7/18/2023	20 (4)	109	0.316	No Trend
Uranium (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	2.95	−0.653	Decreasing
40-SC	7/21/2005	7/19/2023	20	0.00009	−0.621	Decreasing
54-SC	7/20/2005	7/18/2023	20	0.028	−0.563	Decreasing
100-SC	10/30/2008	7/18/2023	16	0.0015	−0.75	Decreasing
102-SC	7/23/2009	7/18/2023	12	0.0013	−0.015	No Trend
5-DC*	7/20/2005	7/18/2023	20	0.015	−0.432	Decreasing
10-DC	7/20/2005	7/19/2023	20	0.012	−0.063	No Trend
19-DC*	7/20/2005	7/19/2023	20 (1)	0.0001	−0.437	Decreasing
110-DC	10/30/2008	7/18/2023	18	0.014	0.294	No Trend
112-DC	10/30/2008	7/18/2023	16	0.013	−0.45	Decreasing
113-DC	10/30/2008	7/18/2023	16	0.0009	−0.742	Decreasing
K.G.S. #3	7/21/2005	7/24/2023	18 (1)	0.0002	0.51	Increasing
Indicator Parameters						
Chloride (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	509	0.247	No Trend
40-SC	7/21/2005	7/19/2023	20	8.29	−0.916	Decreasing
54-SC	7/20/2005	7/18/2023	20	403	0.279	No Trend
100-SC	10/30/2008	7/18/2023	16	128	0.083	No Trend
102-SC	7/23/2009	7/18/2023	12	38.2	−0.894	Decreasing
5-DC*	7/20/2005	7/18/2023	20	549	0.568	Increasing
10-DC	7/20/2005	7/19/2023	20	59	0.258	No Trend
19-DC*	7/20/2005	7/19/2023	20	146	0.037	No Trend
110-DC	10/30/2008	7/18/2023	18	181	−0.484	Decreasing
112-DC	10/30/2008	7/18/2023	16	49	−0.592	Decreasing
113-DC	10/30/2008	7/18/2023	16	10.4	−0.283	No Trend
K.G.S. #3	7/21/2005	7/24/2023	18	4.82	−0.497	Decreasing
Nitrate (mg/L)						
40-SC	7/21/2005	7/19/2023	20	1.91	0.453	Increasing
102-SC	7/23/2009	7/18/2023	12 (2)	0.044	-0.47	Decreasing
113-DC	10/30/2008	7/18/2023	16 (2)	0.10	0.45	Increasing
Sulfate (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	*14,300*	0.311	No Trend
40-SC	7/21/2005	7/19/2023	20	1400	−0.795	Decreasing
54-SC	7/20/2005	7/18/2023	20	*11,900*	0.532	Increasing
100-SC	10/30/2008	7/18/2023	16	1000	0.475	Increasing
102-SC	7/23/2009	7/18/2023	12	560	0.015	No Trend
5-DC*	7/20/2005	7/18/2023	20	*22,100*	0.832	Increasing
10-DC	7/20/2005	7/19/2023	20	995	0.068	No Trend
19-DC*	7/20/2005	7/19/2023	20	2760	0.221	No Trend

Table 6-7. Mann-Kendall Trend Analysis Results for Shirley Basin South Site Monitoring Wells, 2005–2023 (continued)

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	No. of Samples (No. of Nondetects)[b]	Most Recent Result[c]	Kendall's tau[d]	Trend[e]
Sulfate (continued)						
110-DC	10/30/2008	7/18/2023	18	1870	0.32	No Trend
112-DC	10/30/2008	7/18/2023	15	972	0.038	No Trend
113-DC	10/30/2008	7/18/2023	16	620	0.083	No Trend
K.G.S. #3	7/21/2005	7/24/2023	18	229	−0.327	No Trend
TDS (mg/L)						
5-SC*	7/20/2005	7/18/2023	20	*16,500*	−0.553	Decreasing
40-SC	7/21/2005	7/19/2023	20	1740	−0.879	Decreasing
54-SC	7/20/2005	7/18/2023	20	*15,200*	0.089	No Trend
100-SC	10/30/2008	7/18/2023	16	2030	0.233	No Trend
102-SC	7/23/2009	7/18/2023	12	1000	−0.258	No Trend
5-DC*	7/20/2005	7/18/2023	20	*27,800*	0.853	Increasing
10-DC	7/20/2005	7/19/2023	20	1800	−0.005	No Trend
19-DC*	7/20/2005	7/19/2023	20	4420	0.037	No Trend
110-DC	10/30/2008	7/18/2023	18	3070	−0.412	Decreasing
112-DC	10/30/2008	7/18/2023	16	1770	−0.25	No Trend
113-DC	10/30/2008	7/18/2023	16	1040	−0.15	No Trend
K.G.S. #3	7/21/2005	7/24/2023	18	479	0.203	No Trend

Notes:
* POC well
64.2 Result exceeds corresponding ACL (and, for ^{228}Ra and selenium, corresponding groundwater protection standard).
0.61 Result exceeds corresponding groundwater protection standard from Table 6-3.

[a] Trend analysis results are only listed for well-analyte combinations with frequent (≥50%) detections. No statistically significant trend was found for the remaining 59 records with detection frequencies <50% (applying to cadmium, chromium, lead, nickel, nitrate, selenium, and ^{230}Th). For these well-analyte combinations, the majority (67%) had negative tau values, indicating decreasing (though not statistically significant) trends. Although results are not listed above, trend analysis was also applied to pH because it is an indicator parameter (DOE 2011b). Statistically significant decreasing trends were identified for three wells: 100-SC, 19-DC, and K.G.S. #3.

[b] The number of nondetects is only indicated for well-parameter combinations with nondetect results.

[c] The data in this column (most recent result) duplicates information included in Table 6-4 through Table 6-6 but is repeated here as a context for evaluating analyte-well combinations with increasing trends.

[d] 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.

[e] In their review of the 2022 annual compliance report (DOE 2022), NRC observed that the Mann-Kendall trend analyses could be biased by varying minimum detection limits for the contaminants of concern (Hayes 2023). In response to this comment, for each well-parameter combination shown Figure 6-7 and Figure 6-8 (excluding pH), LM also plotted the corresponding method detection limits and analyzed the relationship between those variations and the variation in corresponding analytical results. For most well-parameter combinations, the method detection limits (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 (as noted above), no significant trend was found for any well-analyte combination with detection frequencies less than 50%. Furthermore, as indicated in Note "d", the NADA package used to perform the trend analyses was developed to account for varying detection limits.

Abbreviations:
mg/L = milligrams per liter
pCi/L = picocuries per liter

As stipulated in the LTSP (DOE 2004), LM is required to notify NRC and WDEQ of any exceedances in constituent ACLs. Since DOE acquired the site in 2005, exceedances of ACLs have been limited to the following wells and parameters:

- Upper Sand Aquifer POC well 5-SC — cadmium (2005 only) and selenium (2019–2020, 2022)
- Upper Sand Aquifer well 54-SC — ^{228}Ra (consistent), selenium (2015 and 2022 only)
- Main Sand Aquifer POC well 5-DC — ^{228}Ra (consistent), selenium (since 2019)
- Main Sand Aquifer well 110-DC — ^{226}Ra only, 2009–2022 (no exceedance in 2023)

Recent or historical exceedances of State of Wyoming groundwater protection standards have been limited to the following wells and parameters:

- Upper Sand Aquifer POC well 5-SC — cadmium (2000–2005 only), selenium, sulfate, and TDS
- Upper Sand Aquifer well 54-SC — cadmium (2005 only), selenium, sulfate, and TDS
- Main Sand Aquifer POC well 5-DC — selenium, sulfate, and TDS

These exceedances are discussed in the following paragraphs, along with an updated analysis of the concentration trends identified in Table 6-7. The discussion focuses on parameters for which exceedances have been identified and those exhibiting statistically significant increasing concentration trends. As such, chromium and lead are not discussed (refer to Figure 6-7).

Hazardous Constituents

In LM's initial July 2005 sampling, the results for cadmium in POC well 5-SC exceeded the respective ACL of 0.079 milligrams per liter (mg/L). Cadmium concentrations in well 5-SC have since declined to below the ACL (most recent result of 0.03 mg/L) and concentrations in most remaining wells have been below the detection limit (Figure 6-7). For the three wells with detection frequencies greater than 50% (5-SC, 54-SC, and 102-SC), Mann-Kendall trend analysis identified statistically significant decreasing trends in cadmium concentrations (Table 6-7).

Nickel concentrations in Upper Sand Aquifer wells 5-SC and 54-SC have been just below the 6.15 mg/L ACL (Figure 6-7), but trends have been stable (non-trending). The most recent (2023) results were 3.22 and 4.42 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 2.57 and 0.56 mg/L, respectively).

Radium-226 concentrations in well 110-DC, installed in 2008, consistently exceeded the 91.3 picocuries per liter (pCi/L) ACL between 2009 and 2022 (Figure 6-7). In 2023, the ^{226}Ra concentration in this well was 82.7 pCi/L, versus approximately 150 pCi/L in 2021–2022. Well 110-DC was considered a downgradient well at the time of installation in 2008, when groundwater flow direction in the Main Sand Aquifer was generally to the north-northeast. However, due to the recent changes in flow direction noted previously, well 110-DC is currently hydraulically upgradient from well 5-DC near the disposal cell. Although below the ACL, ^{226}Ra concentrations in most remaining wells (54-SC, 5-DC, 19-DC, and 112-DC) have been elevated

relative to background (40-SC) and to the 5 pCi/L groundwater protection standard for combined ^{226}Ra and ^{228}Ra.

Since 2005, ^{228}Ra concentrations have consistently exceeded the 25.7 pCi/L ACL in well 54-SC and, with few exceptions (2012, 2014, and 2017–2018), also in well 5-DC. Mann-Kendall trend analysis (Table 6-7) indicates statistically significant increasing trends for ^{228}Ra in wells 5-DC and 54-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 (^{226}Ra and ^{228}Ra), well 112-DC (^{226}Ra), 113-DC (^{228}Ra).

Radium-228 is a decay product of thorium-232 (^{232}Th), which is highly immobile. 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. Elevated levels of ^{226}Ra and ^{228}Ra in wells 54-SC and 5-DC were previously attributed to mobilization of contaminants near the Pit 4 area where the Upper Sand and Main Sand units coalesce (DOE 2011a). Constituent mass loading from either naturally occurring mineralization or from tailings pile seepage into the groundwater has not been directly measured or quantified at the Shirley Basin South site.

Selenium concentrations have exceeded the 0.12 mg/L ACL (and the 0.05 mg/L groundwater protection standard) in wells 5-SC, 54-SC, and 5-DC (Figure 6-7). Consistent with findings presented in the previous annual report (DOE 2022), 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 levels were measured to be relatively low in tailings water 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 well below the corresponding 2409 pCi/L ACL. Although a statistically significant increasing trend is indicated for well 54-SC based on data since 2005, current levels are sufficiently low (most recent result of 54.2 pCi/L) such that exceedances are not expected in the foreseeable future.

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). Consistent with trend analysis findings for ^{226}Ra and ^{228}Ra, a statistically significant increasing trend was identified for uranium in well K.G.S. #3. However, the most recent uranium result (0.0002 mg/L) is well below the ACL. Radium-226 and ^{228}Ra concentrations are below corresponding ACLs and the combined ^{226}Ra plus ^{228}Ra groundwater protection standard of 5 pCi/L (most recent results of 0.94 and 0.72 pCi/L, respectively). As indicated in Table 6-4 through Table 6-7, concentrations of all monitored parameters in well K.G.S. #3 are below applicable standards, both the ACLs and groundwater protection standards for livestock listed in Table 6-3.

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, TDS, and pH (Figure 6-8). The increasing concentration trend observed for ^{226}Ra since 2013 is likely attributed to natural groundwater processes or reestablishment of groundwater

equilibrium from pumping influence. Although a statistically significant increasing trend was found for ^{228}Ra for the 2005–2023 monitoring period, concentrations have declined since 2019, from 2.87 pCi/L to 0.72 pCi/L (most recent result).

As indicated above, both ^{226}Ra and ^{228}Ra concentrations in well K.G.S. #3 are below respective ACLs of 91.3 pCi/L and 25.7 pCi/L, respectively, 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 summation of ^{226}Ra and ^{228}Ra concentrations (Table 6-3). However, this threshold value was updated after completion of the LTSP and is not used as a comparison because both analytes are addressed and classified independently in the LTSP (DOE 2004). Regardless, 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 watering purposes. Similarly, despite a statistically significant increasing trend for uranium, uranium concentrations have remained generally stable (<0.00033 mg/L) since 2019 (Table 6-7); the most recent (2023) result was 0.0002 mg/L.

Indicator Parameters

In 2023, 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 (Table 6-4, Table 6-5, and Figure 6-8). 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).

Well 5-SC is apparently downgradient from the disposal cell, but additional water level measurements in the Upper Sand Aquifer would be required to accurately determine flow directions in the vicinity of this well. Data for other potential seepage indicators do not support the potential mechanism of seepage from the tailings pile leaking into the Upper Sand Aquifer in the vicinity of well 5-SC. Regarding observed trends in well 5-DC, groundwater levels in Main Sand Aquifer wells indicate the apparent regional flow direction is to the south-southeast (Figure 6-5), which places well 5-DC upgradient from the disposal cell. However, as indicated previously, the current monitoring well network within the Main Sand Aquifer is insufficient for determining accurate flow directions in the vicinity of well 5-DC. As a result, the reasons for the increasing contaminant trends observed in well 5-DC (and decreasing pH) are still unknown.

Additional Considerations

The following concluding discussion reiterates information provided in recent previous annual reports (e.g., DOE 2022) because some of this information is still germane to LM's ongoing evaluations at the site.

In 2014, NRC staff concluded that the groundwater monitoring data do not demonstrate tailings impoundment leakage. Additionally, DOE's ACL evaluation program should be suspended so DOE will no longer conduct additional evaluations concerning ACL exceedances at the site

(Orlando 2014). NRC staff based this conclusion on three factors: (1) the source of radium in the site groundwater is uncertain, (2) the groundwater is not a current or potential near-term source of drinking water, and (3) livestock water at the site originates from an aquifer (the Lower Sand Aquifer) that is not impacted by former milling operations. For these reasons, there is no imminent threat to public health and safety, or the environment posed by site groundwater contamination.

In response to NRC 2020 annual inspection report comments (Orlando 2021), DOE considered 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. As discussed earlier in this section and concluded in the previous annual report (DOE 2022), 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. A more comprehensive evaluation of flow directions will be best conducted once the aquifer reaches a quasi-steady state regarding groundwater elevations.

The LTSP (DOE 2004) specifies that this report will include isoconcentration maps for uranium and sulfate in each aquifer; however, the monitoring well network does not provide sufficient data points to interpolate a statistically defensible contaminant plume for either aquifer. Uranium concentrations from 2023 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 of 3000 mg/L in Upper Sand Aquifer wells 5-SC and 54-SC and Main Sand Aquifer well 5-DC. Measured concentrations of all constituents remained below standards in well K.G.S. #3, which is screened in the Lower Sand Aquifer north of the tailings impoundment (Table 6-6).

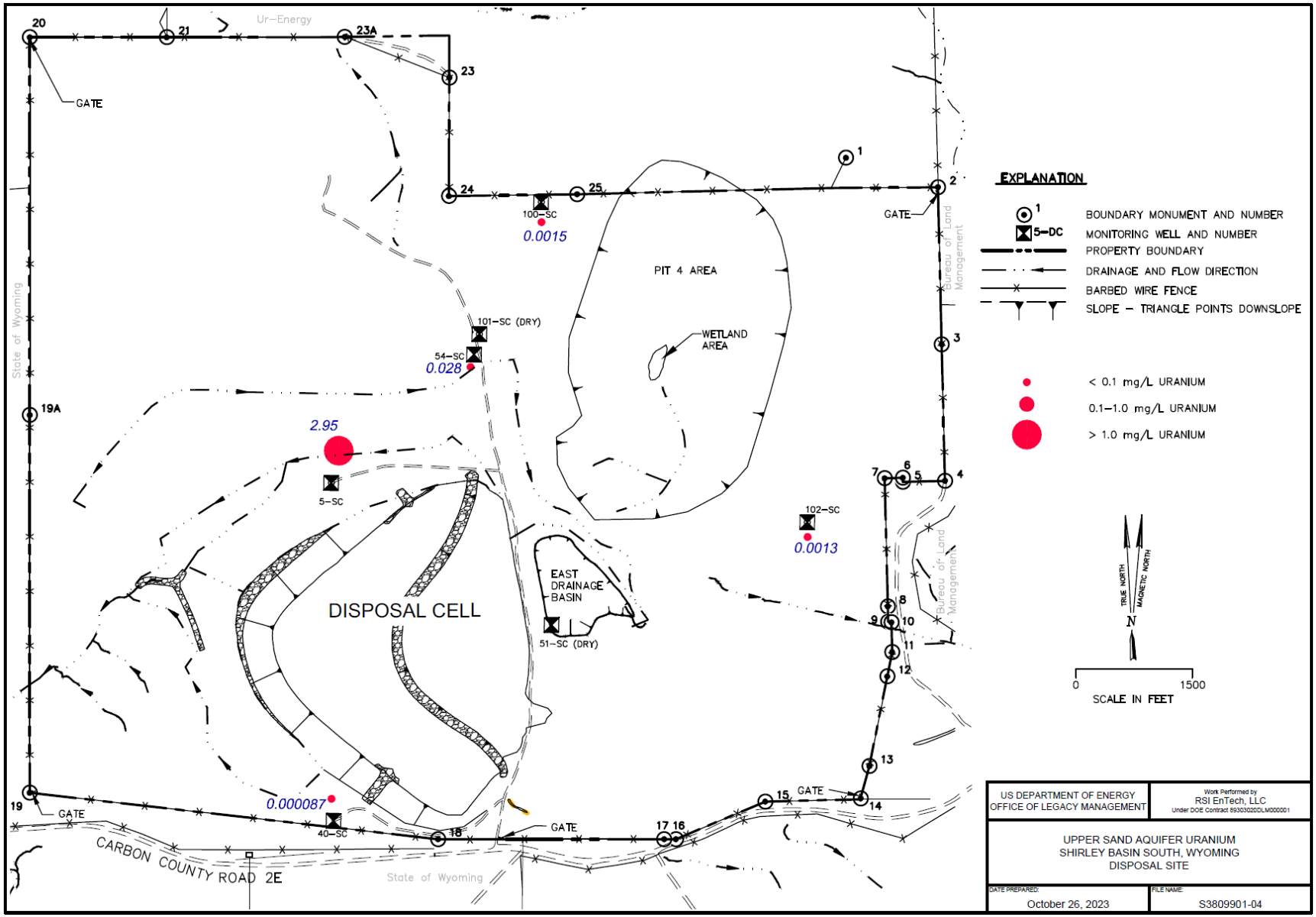


Figure 6-9. July 2023 Uranium Concentrations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

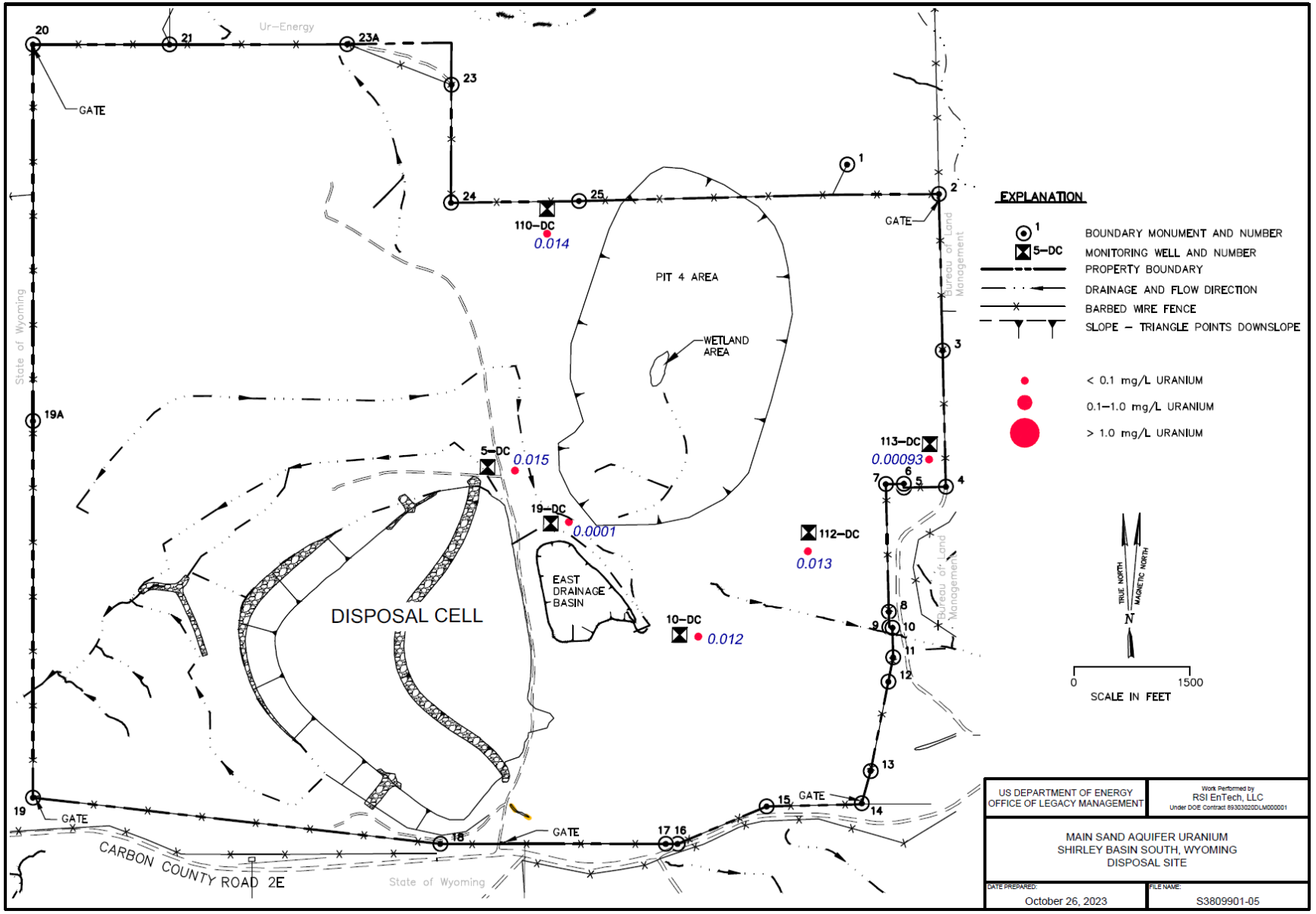


Figure 6-10. July 2023 Uranium Concentrations in the Main Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

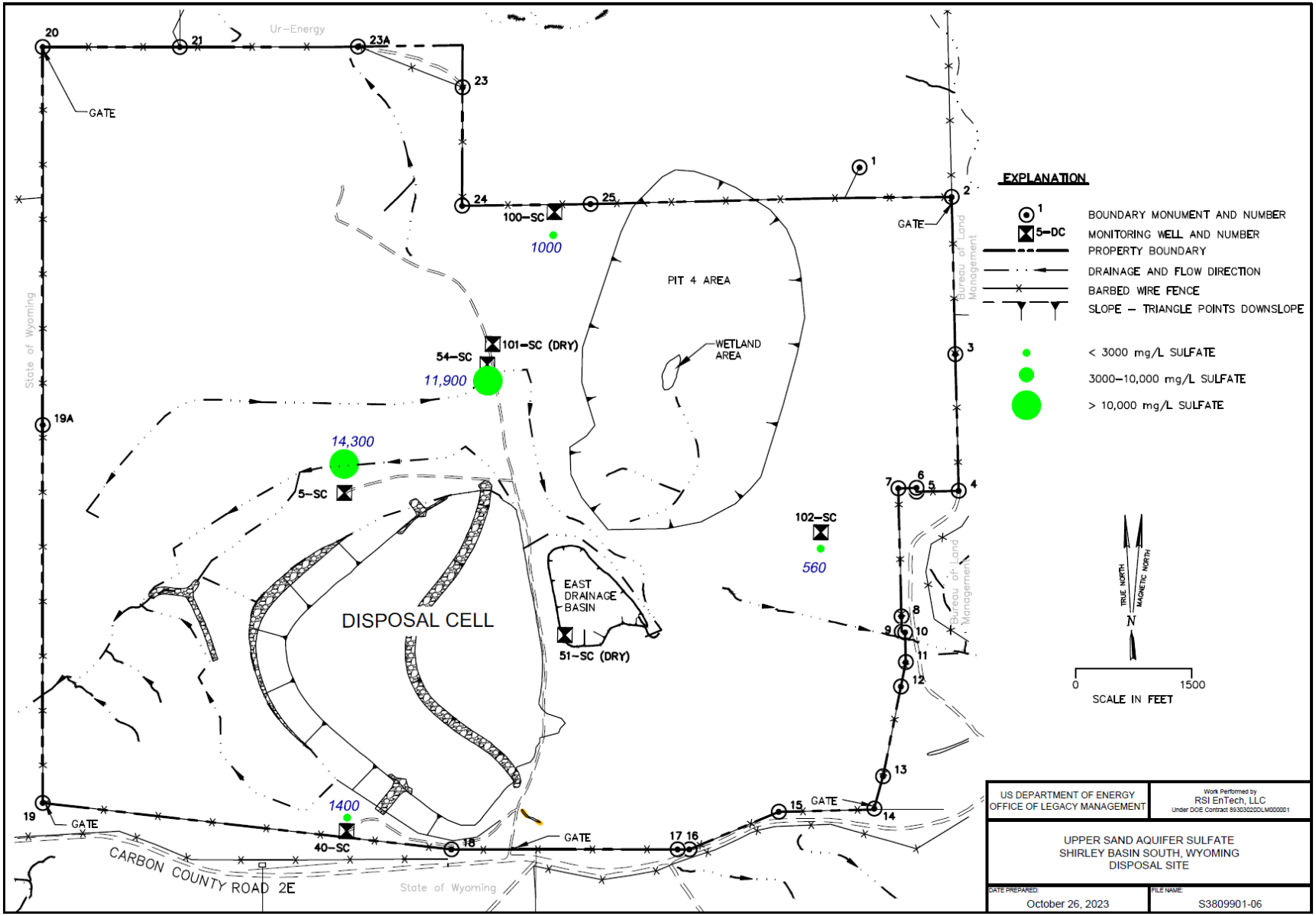


Figure 6-11. July 2023 Sulfate Concentrations in the Upper Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

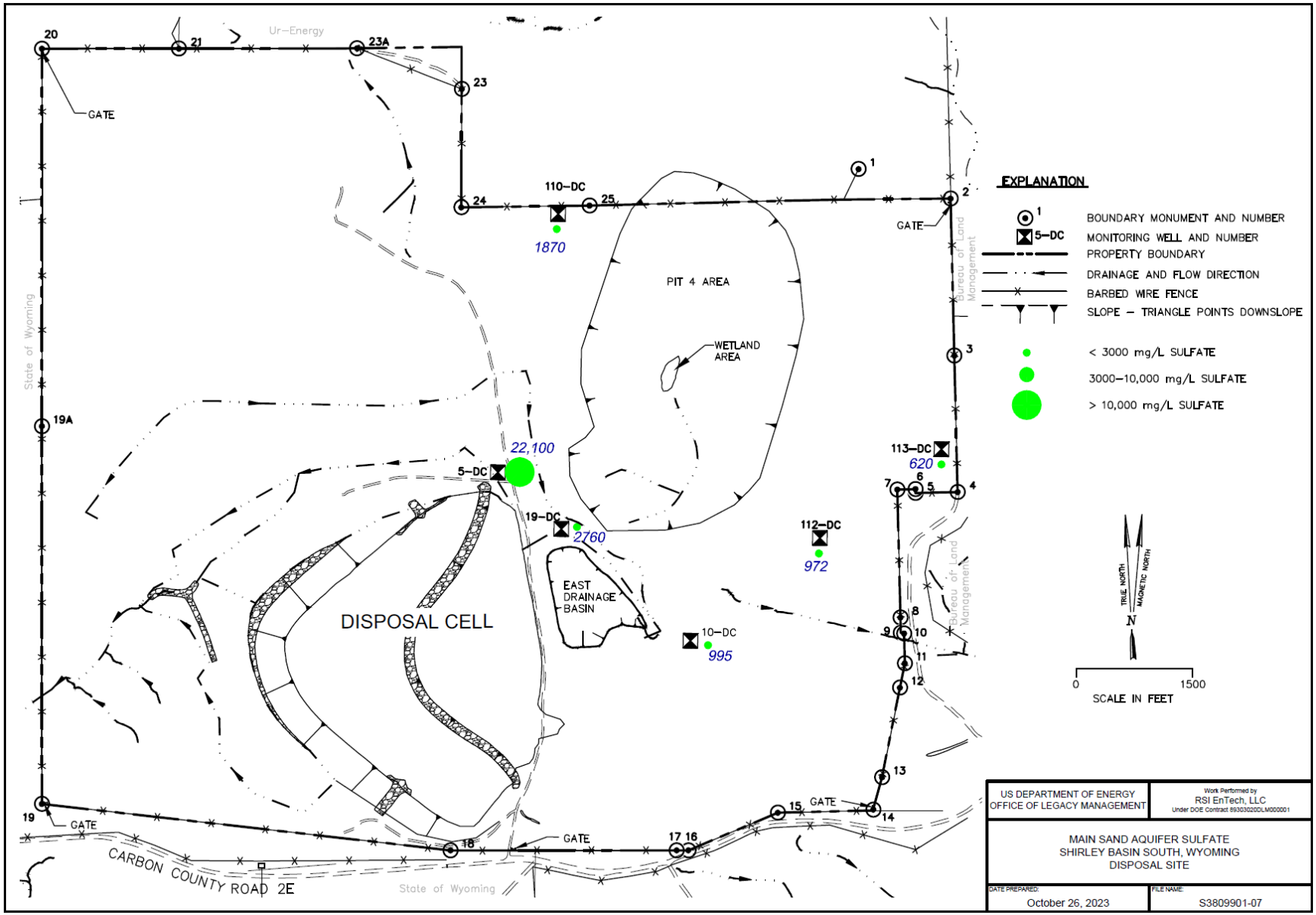


Figure 6-12. July 2023 Sulfate Concentrations in the Main Sand Aquifer at the Shirley Basin South, Wyoming, Disposal Site

6.8 References

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*.

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6.9 Photographs

Photograph Location Number	Azimuth	Photograph Description
PL-1	200	Arroyo Under Fence on Lower Reclaimed Slopes
PL-2	350	Perimeter Sign P26
PL-3	—	Site Marker at Entrance Gate
PL-4	35	Quality Control Monument QC-7
PL-5	300	Burrowing near Monitoring Well 40-SC
PL-6	150	Overview North Side of Disposal Cell and North Swale Discharge Point
PL-7	270	Erosion Caused by Animal Trail North of Upper Riprap Slope
PL-8	70	Erosion Caused by Animal Trail South of Upper Riprap Slope
PL-9	210	Vegetation Encroachment on Upper Riprap Slope
PL-10	70	North Swale Discharge Point
PL-11	345	South Swale Discharge Point
PL-12	105	Overview of Diversion Channels and Contoured Surfaces West of Disposal Cell
PL-13	20	East Drainage Basin
PL-14	10	Erosion Caused from Overflowing Water Storage Tank
PL-15	10	Pit 4 Overview and Wetland Area
PL-16	140	Pit 4 Lower Riprap Armored Drainage Channel Erosion

Note:
— = Photograph taken vertically from above.

PL-1. Arroyo Under Fence on Lower Reclaimed Slopes

PL-2. Perimeter Sign P26

PL-3. Site Marker at Entrance Gate

PL-4. Quality Control Monument QC-7

PL-5. Burrowing Near Monitoring Well 40-SC

PL-6. Overview North Side of Disposal Cell and North Swale Discharge Point

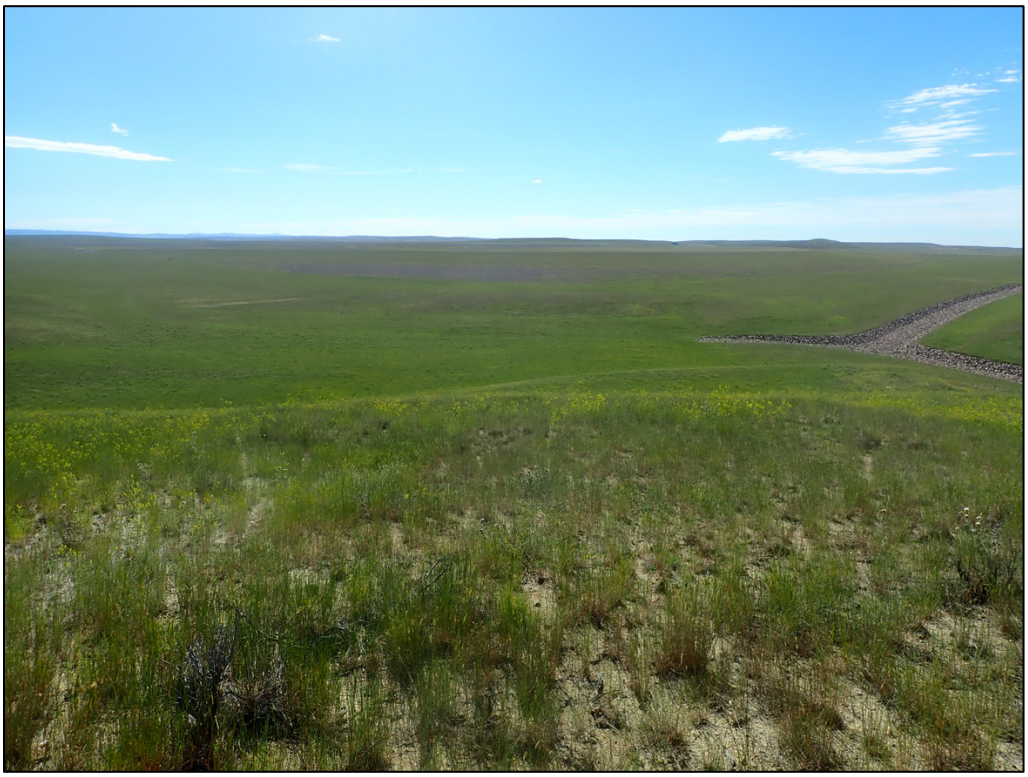
PL-7. Erosion Caused by Animal Trail North of Upper Riprap Slope

PL-8. Erosion Caused by Animal Trail South of Upper Riprap Slope

PL-9. Vegetation Encroachment on Upper Riprap Slope

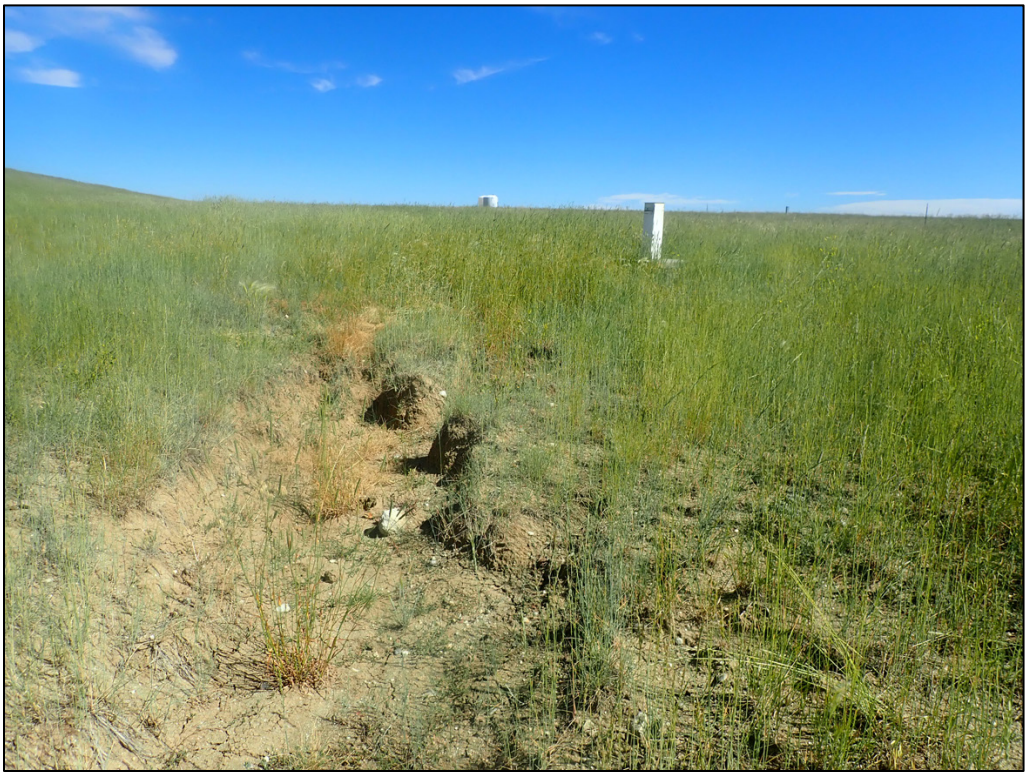
PL-10. North Swale Discharge Point

PL-11. South Swale Discharge Point



PL-12. Overview of Diversion Channels and Contoured Surfaces West of Disposal Cell

PL-13. East Drainage Basin



PL-14. Erosion Caused from Overflowing Water Storage Tank

PL-15. Pit 4 Overview and Wetland Area

PL-16. Pit 4 Lower Riprap Armored Drainage Channel Erosion