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2024 Verification Monitoring Report for the Durango, Colorado, Processing Site

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Abbreviations

ACL	alternate concentration limit
CFR	*Code of Federal Regulations*
COC	contaminant of concern
ft	feet
IC	institutional control
LOESS	locally estimated scatterplot smoothing
mg/L	milligrams per liter
^{222}Rn	radon-222
SOWP	Site Observational Work Plan
^{234}U	uranium-234
^{238}U	uranium-238
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey
VMR	Verification Monitoring Report

Executive Summary

This Verification Monitoring Report for the Durango, Colorado, Processing Site summarizes monitoring data through calendar year 2024 and assesses the progress of the current compliance strategy. To assess the progress of natural flushing at the mill tailings area for uranium, cadmium, selenium, and molybdenum, temporal trends in groundwater levels and flow directions, contaminant of concern concentrations in groundwater and surface water, and bulk uranium plume metrics are compared relative to baseline conditions. Evaluation of manganese and sulfate are reported in comparison with the risk-based goal and average background level. While no further remediation is required at the raffinate ponds area, continued monitoring is conducted as a best management practice. Temporal trends in uranium and selenium concentrations for groundwater and surface water at the raffinate ponds area were compared relative to baseline conditions.

Concentrations of cadmium, manganese, molybdenum, and selenium in groundwater at the mill tailings area are currently below their respective compliance or risk-based goals, with the exception of well 0612 (cadmium and manganese). Cadmium concentrations at well 0612 have remained consistent, whereas manganese concentrations show a slightly increasing trend (tau value = 0.30). As reported in the 2014 VMR, cadmium and manganese concentrations in groundwater at well 0612 are likely associated with thick slag deposits (non-Uranium Mill Tailings Radiation Control Act material), resulting from the lead smelter operation before the vanadium and uranium milling.

Analysis of sulfate at the mill tailings area indicates that concentrations could reach the average background goal of 1276 milligrams per liter by 2072 at most locations, except for wells 0633, 0634, and 0635, where concentrations are presently above the average background goal with increasing trends. Water levels in wells 0633 and 0634 are typically within the Mancos Shale where naturally occurring concentrations of sulfate are high.

Uranium concentrations in groundwater are declining or stable across the mill tailings area at most locations, except for wells 0630 and 0635, which have increasing trends. Five out of the eight monitoring wells are currently above the groundwater compliance standard for uranium. Although monitoring well 0633 has an overall decreasing trend, recent concentrations have exceeded the historical range and are currently being investigated alongside the highly variable groundwater elevation at well 0633. Based on an analysis of attenuation rates for individual wells and average concentration from bulk plume metrics, natural flushing of uranium will occur at a slower rate than it was during the previous review period.

However, the lower 95% confidence interval for the average plume concentration trend suggests that the compliance goal of 0.044 milligram per liter could still be achieved within the allotted 100-year time period. It is important to consider that natural variability in groundwater elevations and uranium concentrations over the last 5 years make it difficult to predict natural flushing timelines.

In the raffinate ponds area, where supplemental standards apply, monitoring takes place as a best management practice. No significant changes in concentrations have occurred in the previous 5 years for all monitoring wells for both selenium and uranium.

Surface water concentrations of the Animas River along the mill tailings and raffinate ponds areas are consistent with background location 0652. Samples from the ephemeral South Creek location 0588 at the raffinate ponds area are higher in concentrations of selenium and uranium than those from the Animas River locations.

1.0 Introduction

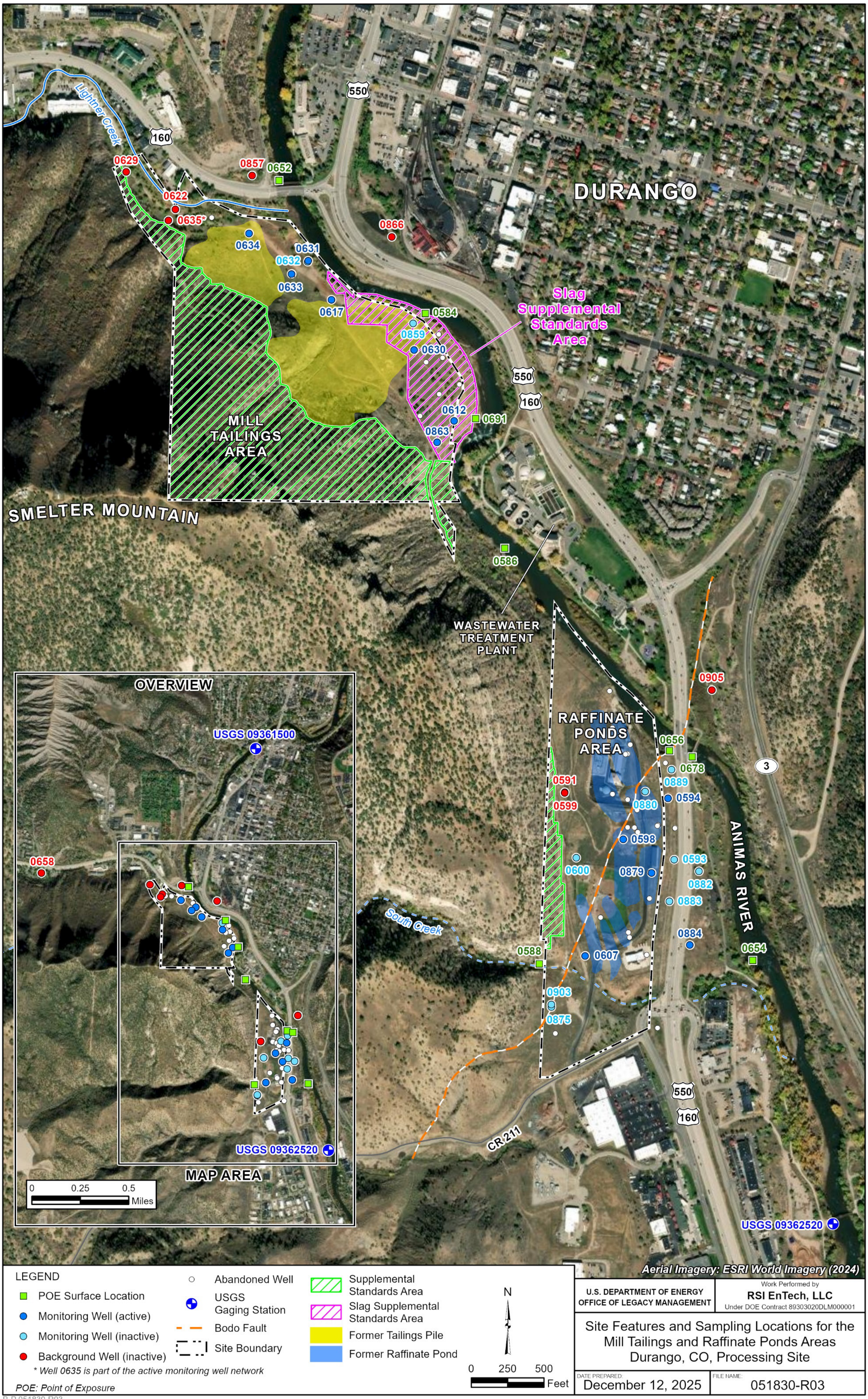
This Verification Monitoring Report (VMR) provides an update of natural flushing progress at the Durango, Colorado, Processing Site from completion of characterization activities following surface remediation in 1991 to the present. The Durango processing site, consisting of mill tailings and raffinate ponds areas, is in the city of Durango, Colorado (Figure 1). This site is managed by the U.S. Department of Energy Office of Legacy Management under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I program and is regulated by the U.S. Nuclear Regulatory Commission.

The mill tailings and raffinate ponds areas are each managed under separate compliance strategies, monitoring plans, and institutional controls (ICs). The focus of the VMR is to assess the progress of natural flushing as it relates to the mill tailings area's compliance strategy of 100-year natural flushing with ICs, as permitted by Title 40 *Code of Federal Regulations* Section 192 (40 CFR 192), preventing use of the groundwater in the shallow aquifer (DOE 2008). The compliance strategy for the raffinate ponds area groundwater is supplemental standards or no further remediation, and, as such, there is no requirement for assessing natural flushing (40 CFR 192; DOE 2008), monitoring is only conducted for reporting as a best management practice. Information related to site history, compliance strategies, hydrogeology, and remedial activities is provided as summaries. Details related to the Durango processing site can be found in the documents referenced throughout the report.

1.1 Site History

The Durango processing site location has an extended history of ore smelting and processing. From 1880 to 1930, smelting operations at the site produced gold, silver, lead, and copper. In 1941, a vanadium processing mill was constructed to provide strategic metals for the war effort. The same processing mill was used between 1943 and 1946 to recover uranium from the vanadium tailings, again to support the war effort. After a 3-year hiatus, the mill was restarted and processed uranium ore between 1949 and 1963 before closing for the final time.

UMTRCA surface cleanup activities began in 1986 and were completed in 1991, during which 2.5 million cubic yards of radioactive contaminated material was removed from the Durango processing site and vicinity properties and transported to the Durango, Colorado, Disposal Site. Groundwater and surface water characterization activities were conducted during and following surface remediation activities and were completed in 2002. Based on data from characterization activities, natural flushing with a 100-year duration and ICs corresponding to the site boundary was selected for the mill tailings area as the compliance strategy. Because of poor ambient groundwater quality, supplemental standards were selected as the compliance strategy for the raffinate ponds area. The mill tailings area is currently used as a public park. The U.S. Bureau of Reclamation currently operates a pumping plant associated with the Animas-La Plata Project on the northern portion of the raffinate ponds area.



Note: Inactive wells are available for sampling but are not included in the monitoring network.
Abbreviation: USGS = U.S. Geological Survey

Figure 1. Site Features and Sampling Locations for the Mill Tailings and Raffinate Ponds Areas at the Durango, Colorado, Processing Site

1.2 Hydrologic Setting

The Durango processing site consists of two separate areas having different hydrogeologic regimes (Figure 1). The mill tailings area is bound to the north by Lightner Creek, to the northeast by the Animas River, and to the southwest by Smelter Mountain and consists of relatively permeable alluvium near the Animas River and less permeable colluvium near Smelter Mountain (DOE 2002). Both unconsolidated deposits are underlain by relatively impermeable Mancos Shale (DOE 2002). Most of the mill tailings area wells are screened within the alluvium, but several wells have screens that extend into the Mancos Shale. At the southeastern end of the site along the Animas River, a slag layer from the former lead and silver smelting operation sits on top of the alluvium or soil in most locations and can reach thicknesses up to 30 feet (ft) and predates milling (DOE 2014). Surface water inflow from Lightner Creek and portions of the adjacent Animas River provide the majority of recharge to the alluvial aquifer (DOE 2002). Precipitation infiltration occurs across the entire mill tailings area, but recharge contributions are less than from surface water (DOE 2002). Alluvial groundwater discharges to both Lightner Creek and the Animas River (DOE 2002).

Different than the mill tailings area, alluvium is largely absent from the raffinate ponds area, leaving the underlying low permeability Point Lookout Sandstone and Menefee Formation to convey groundwater to the Animas River northeast of the site (DOE 2002). The Menefee Formation is relatively permeable where fractures or coal beds are present and is comparable to the hydraulic conductivity of the Bodo Fault (DOE 2002). The Bodo Fault, which trends diagonally across the raffinate ponds area, is thought to preferentially convey groundwater at the site (DOE 2002). Recharge to groundwater occurs as lateral inflow from Smelter Mountain; infiltration from ephemeral South Creek, which bisects the site; and precipitation infiltration (DOE 2002).

1.3 Site Remediation, Compliance Strategy, and Water Quality Monitoring

Groundwater and surface water quality characterization performed in the 1990s and early 2000s identified contaminants of concern (COCs) at the Durango processing site (DOE 2002; DOE 2008). Based on evaluations of COC migration and attenuation potentials, risk assessment, groundwater flow and transport modeling, and COC trend evaluations, compliance strategies for the mill tailings and raffinate ponds areas were developed. Natural flushing with a 100-year duration for uranium, cadmium, selenium, and molybdenum, with ICs corresponding to the site boundary, was selected as the compliance strategy for the mill tailings area (DOE 2008). Under this approach, the COCs manganese and sulfate are evaluated against the risk-based goal and average background concentration, respectively, as they are not regulated under 40 CFR 192 (DOE 2008). Selenium is evaluated with respect to its alternate concentration limit (ACL) due to naturally occurring sources (DOE 2008). Because of poor ambient water quality, supplemental standards were selected as the compliance strategy for the raffinate ponds area (DOE 2008). Groundwater and surface water quality sampling is routinely performed at the Durango processing site to assess COC concentration trends and remedy performance at the mill tailings area.

1.3.1 Contaminants of Concern and Remediation Goals

Surface water and groundwater sampling conducted during characterization activities identified cadmium, manganese, molybdenum, selenium, sulfate, and uranium as mill tailings area COCs (DOE 2008). Table 1 lists the compliance goals for these constituents in groundwater at the mill tailings area. Because the compliance strategy for the raffinate ponds area is supplemental standards based on poor ambient groundwater quality, there are no compliance goals for that portion of the Durango processing site. However, selenium and uranium trends in groundwater and surface water at the raffinate ponds area are reported as a best management practice.

Table 1. Contaminants of Concern and Groundwater Compliance Goals for the Mill Tailings Area

COC	Groundwater Compliance Goals (mg/L)	Source
Cadmium	0.01	40 CFR 192 MCL
Manganese	NA	1.7 mg/L risk-based goal (DOE 2008)
Molybdenum	0.1	40 CFR 192 MCL
Selenium	0.05	ACL (DOE 2003)
Sulfate	NA	1276 mg/L average background (DOE 2002)
Uranium	0.044	40 CFR 192 MCL (activity based)

Note:
To evaluate the progress of natural flushing, the risk-based goal for ecological receptors was applied to manganese and the average background concentration was applied to sulfate.

Abbreviations:
MCL = maximum concentration limit
mg/L = milligrams per liter
NA = Not applied as a compliance standard

1.3.2 Groundwater and Surface Water Monitoring Schedule and Locations

The Durango processing site groundwater and surface water samples are typically collected in May or June from the monitoring wells and surface water sampling locations listed in Table 2 and Table 3 for the mill tailings and raffinate ponds areas, respectively. Figure 2 and Figure 3 show the monitoring well and surface water sampling locations for the mill tailings and raffinate ponds areas, respectively.

Table 2. Durango Processing Site Water Quality Monitoring Locations in the Mill Tailings Area

Sample Location	Sample Type	Aquifer/Formation or Surface Water Feature Monitored	Location	Analytes
0617	Groundwater	Slag/Alluvium/Colluvium	Onsite	Manganese Molybdenum Selenium Sulfate Uranium
0630		Alluvium/Mancos Shale		
0631		Alluvium/Mancos Shale		
0633		Alluvium/Mancos Shale		
0634		Alluvium/Mancos Shale		
0635		Alluvium		
0863		Colluvium	Onsite, Downgradient	Cadmium Manganese Molybdenum Selenium Sulfate Uranium
0612		Alluvium		
0652	Surface Water	Animas River	Background	Cadmium Molybdenum Selenium Uranium
0584			Offsite, Downgradient	
0586				
0691				

Source: DOE 2008

Table 3. Durango Processing Site Water Quality Monitoring Locations in the Raffinate Ponds Area

Sample Location	Sample Type	Aquifer/Formation or Surface Water Feature Monitored	Location	Analytes
0594 (replaces 0880)	Groundwater	Menefee	Onsite	Selenium Uranium
0598		Menefee/Point Lookout Sandstone (Bodo Fault)		
0607		Alluvium/Menefee		
0879*		Menefee		
0884		Menefee	Offsite, Downgradient	
0588	Surface Water	South Creek	Offsite, Upgradient	
0654		Animas River	Offsite, Downgradient	
0656/0678		Animas River		

Source: DOE 2008

Note:

* Well 0879 water levels are measured annually, and sampling occurs every 5 years in preparation for the VMR (DOE 2021).

1.4 Source Area

The primary source of uranium and other COCs at the 40-acre mill tailings area is related to the two former tailings piles (Figure 2). Non-mill-related slag from the smelter operation was deposited at the southeast corner of the site along the edge of the Animas River and may be the source of metals detected in groundwater, such as cadmium, manganese, and molybdenum (DOE 2014). Overflow water from the stored alkaline leach tailings and slurried acid-leached tailings were mixed into settling ponds on top of the tailings impoundments before infiltrating the subsurface. Liquid waste from acid-leach tailings was pumped to a tank above the mill and discharged into a 3000 ft long unlined ditch that carried the waste to a series of ponds on the 20-acre raffinate ponds area, approximately 1500 ft south of the mill tailings area (Figure 1 and Figure 3). At the raffinate ponds area, an additional 3000 ft of ditch carried raffinate through the series of ponds. The raffinate evaporated and percolated into the underlying alluvium, colluvium, and sandstone bedrock (DOE 2002).

The ponds and tailings were removed during surface remedial action completed in 1991 and placed into the disposal cell located at the Durango disposal site (DOE 1991; DOE 2002). Supplemental standards for soils were applied to contamination left in place in (1) the banks of the Animas River, (2) the erosion-protective riprap covering a small lens of uranium precipitate believed to be from a spill that leached through layers of lead slag at the mill tailings area along the Animas River, (3) the unreachable areas of windblown contamination on the slope of Smelter Mountain, and (4) the soils contaminated with thorium-230 in the raffinate ponds area (Figure 1) (DOE 1995; DOE 2002).

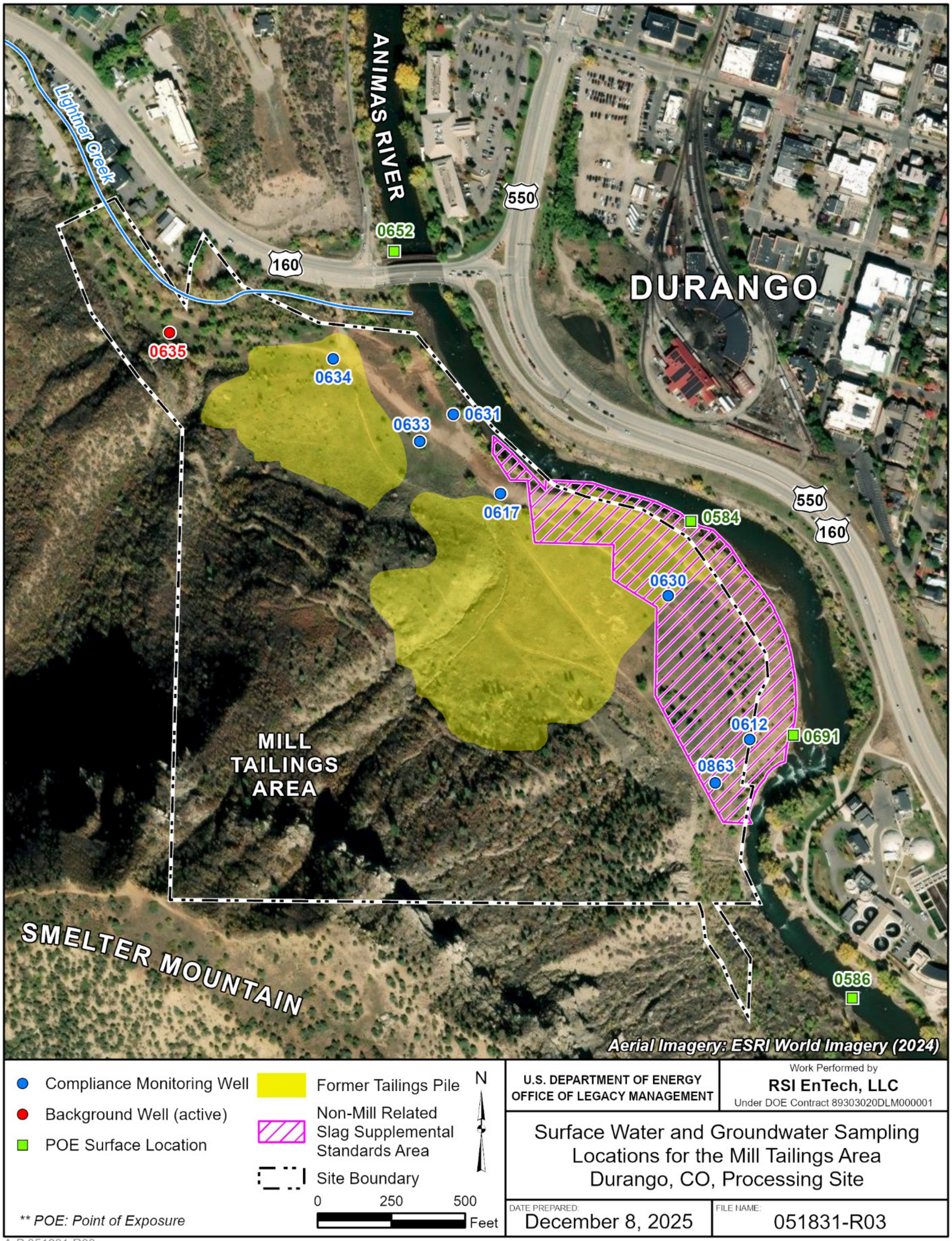


Figure 2. Surface Water and Groundwater Sampling Locations for the Mill Tailings Area

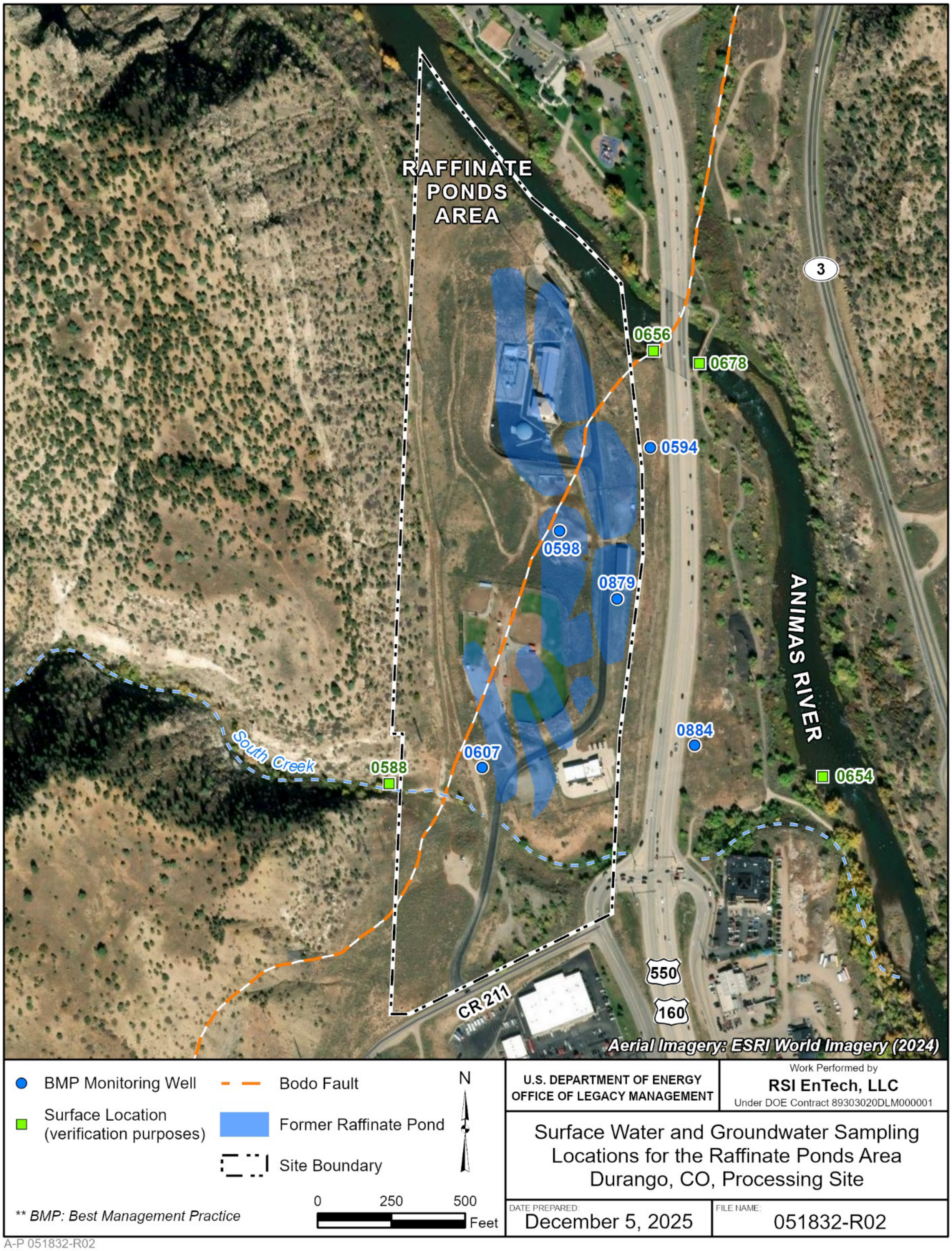


Figure 3. Surface Water and Groundwater Sampling Locations for the Raffinate Ponds Area

2.0 Compliance Remedy Performance

The current compliance strategies at the Durango processing site are natural flushing with a 100-year duration with ICs corresponding to the site boundary for the mill tailings area and no further action for the raffinate ponds area. To assess the effectiveness of the compliance strategy at the mill tailings area, temporal trends in groundwater levels and flow directions, COC concentrations in groundwater and surface water, and bulk uranium plume metrics are compared relative to baseline conditions. For the raffinate ponds area, temporal trends in uranium and selenium concentrations for groundwater and surface water are reported. Baseline conditions for the Durango processing site correspond to 1992 following the completion of surface remediation and establishment of the current monitoring network.

2.1 Mill Tailings and Raffinate Ponds Areas Groundwater Levels

Groundwater elevations within the mill tailings area have been generally stable for wells screened in the alluvium and wells screened across the alluvium and Mancos Shale. Since 2019, groundwater elevations have steadily declined in well 0634 and have become increasingly variable in well 0633 (Figure 4). During the sampling event in 2018, staff noted that a water level could not be collected from well 0633 due to a mat of roots observed within the casing, suggesting that further investigation into the integrity of that well is required.

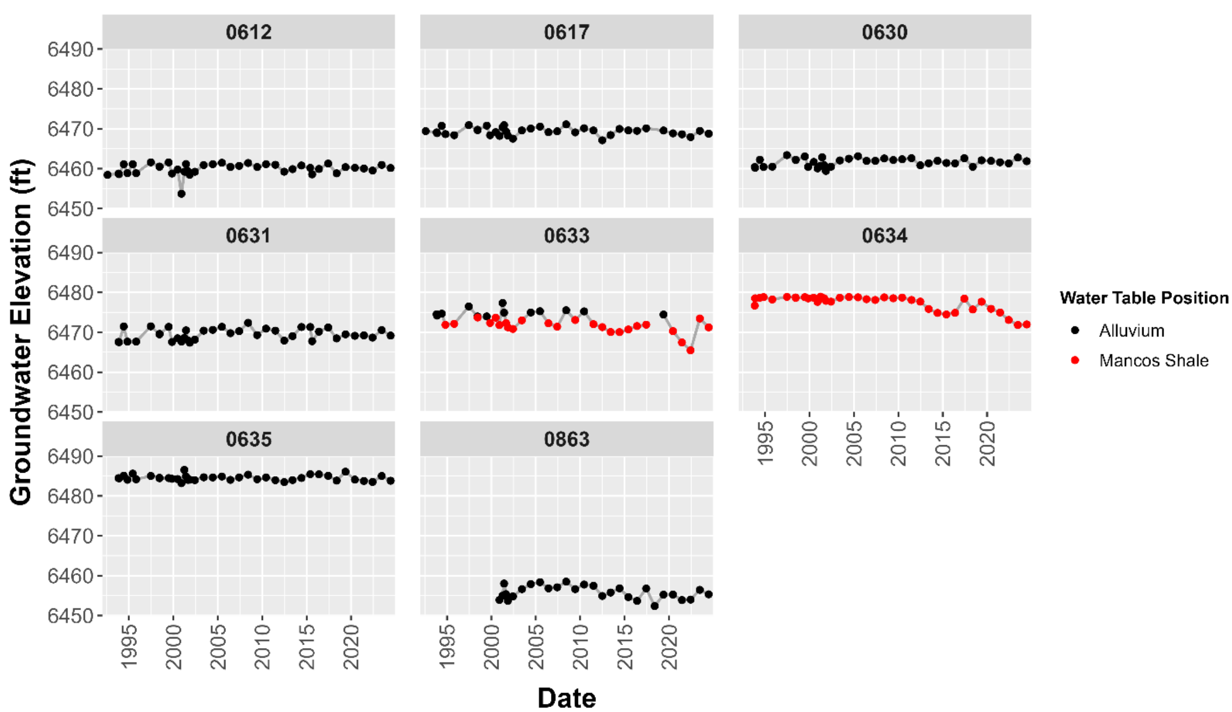


Figure 4. Groundwater Elevations from Mill Tailings Area Wells Between 1992 and 2024

The 2024 water table is shown in Figure 5 for the alluvial aquifer in the mill tailings area. To better define the water table, control points were necessary to represent the interpolated Animas River stage between the U.S. Geological Survey (USGS) gaging locations (09361500 and 09362520 in Figure 1). Stage elevations from both USGS stations were converted to the local site datum as part of the interpolation process. The water table elevation is primarily controlled by the stage of the Animas River, and flow conditions remain relatively stable except for short duration reversals of flow direction adjacent to the river in response to spring runoff conditions. Groundwater within the alluvium discharges to Lightner Creek at the northern portion of the mill tailings area, consistent with the conceptual site model presented in the Site Observational Work Plan (SOWP) (DOE 2002). North of well 0617, groundwater flows to the east before discharging to the Animas River. South of well 0617 to well 0630, groundwater flow is generally parallel to the Animas River and transitions from an easterly direction to a south-southeast direction (Figure 5). This finding is also supported by the conceptual site model where Animas River water recharges the alluvial aquifer in this portion of the site (DOE 2002).

A complimentary method of examining groundwater flow direction and hydraulic gradient independent of the Animas River stage was performed using three-point estimators (McKenna and Wahi 2006). Three-point estimators can provide quantitative, local information on the hydraulic gradient by approximating the water table as a plane using three monitoring wells as vertices of a triangle. Three-point estimator analyses were limited to dates when the water table was within the alluvium, with the exception of well 0634, where all groundwater elevations were within the Mancos Shale. Groundwater elevations at well 0633 have remained within the Mancos Shale since 2020, and thus three-point estimators using well 0633 as a vertex only represent site conditions from 2001–2019 when groundwater elevations were measured in the alluvium. Three-point estimators were also evaluated to ensure that hydraulic gradient estimates were reliable based on published criteria for the head drop (Devlin and McElwee 2007) and geometry of each estimator (McKenna and Wahi 2006). Results presented here use the following wells as triangle vertices:

- Wells 0629, 0622, and 0635
- Wells 0631, 0633, and 0617
- Wells 0634, 0633, and 0631
- Wells 0635, 0634, and 0633

Plots and summary tables comparing flow direction and hydraulic gradient with mean groundwater elevation and time are presented in Appendix A. These plots show that groundwater flow conditions are relatively stable at the site.

Results of the three-point estimators representing flow directions between 1993 and 2024 are shown in Figure 5 as rose diagrams at the center of each triangle. North of well 0617 in the mill tailings area, both three-point estimators and the interpolated water table map consistently show alluvial groundwater flowing eastward toward the Animas River (Figure 5). Data from the three-point estimators south of well 0617 were excluded because they either did not meet the geometric requirements for reliability or indicated a possible survey error.

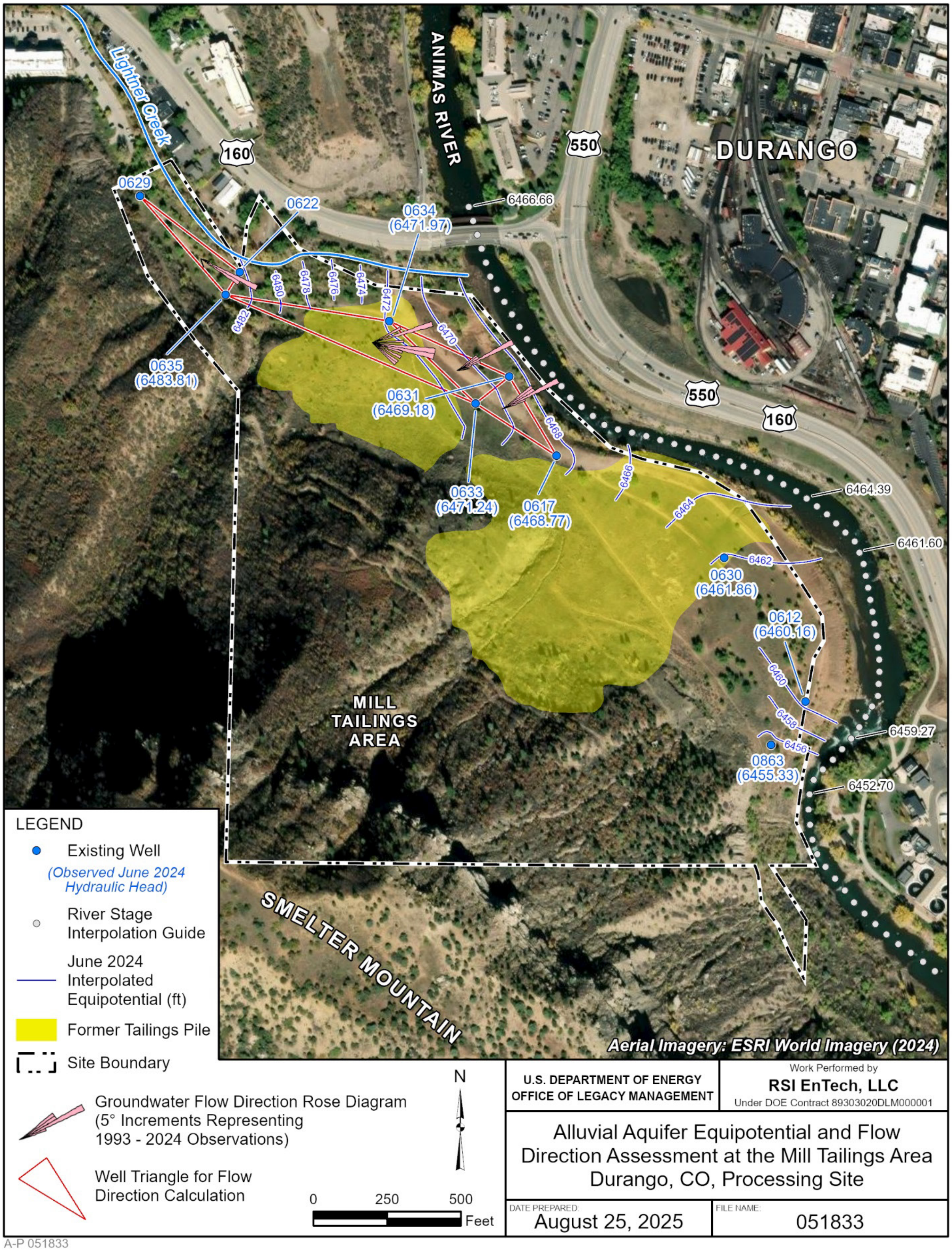


Figure 5. Alluvial Aquifer Equipotential and Flow Direction Assessment at the Mill Tailings Area

At the raffinate ponds area, temporal groundwater elevations generally display greater variability relative to those observed at the mill tailings area. Well 0607, located farthest west and upgradient of the Animas River, exhibited the least amount of groundwater elevation variability relative to other wells at the raffinate ponds area (Figure 6). Due to limited water level data collected for the raffinate ponds area, a water table map could not be generated. Groundwater flow direction and hydraulic gradient magnitude were evaluated using three-point estimators for wells screened in the Menefee Formation and to the east of the Bodo Fault to limit interfering effects. The results presented here use the following wells as triangle vertices:

- Wells 0607, 0594, and 0884
- Wells 0607, 0879, and 0884

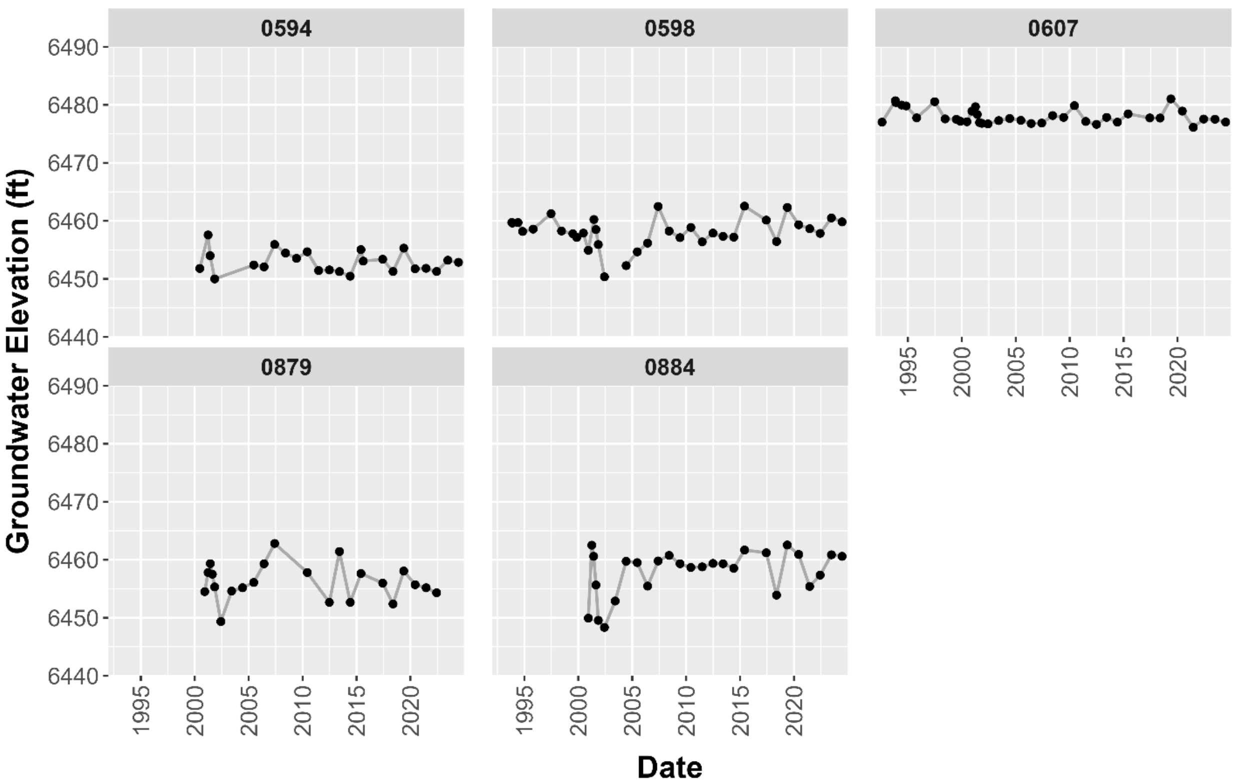


Figure 6. Groundwater Elevations form Raffinate Ponds Area Wells Between 1992 and 2024

Plots and summary tables comparing flow direction and hydraulic gradient with mean groundwater elevation and time are presented in Appendix A. Results indicate that in the raffinate ponds area to the east of the Bodo Fault and north of South Creek, groundwater flow is predominantly to the east and northeast toward the Animas River (Figure 7 and Appendix A). This conclusion is consistent with the water table map presented in the SOWP (DOE 2002).

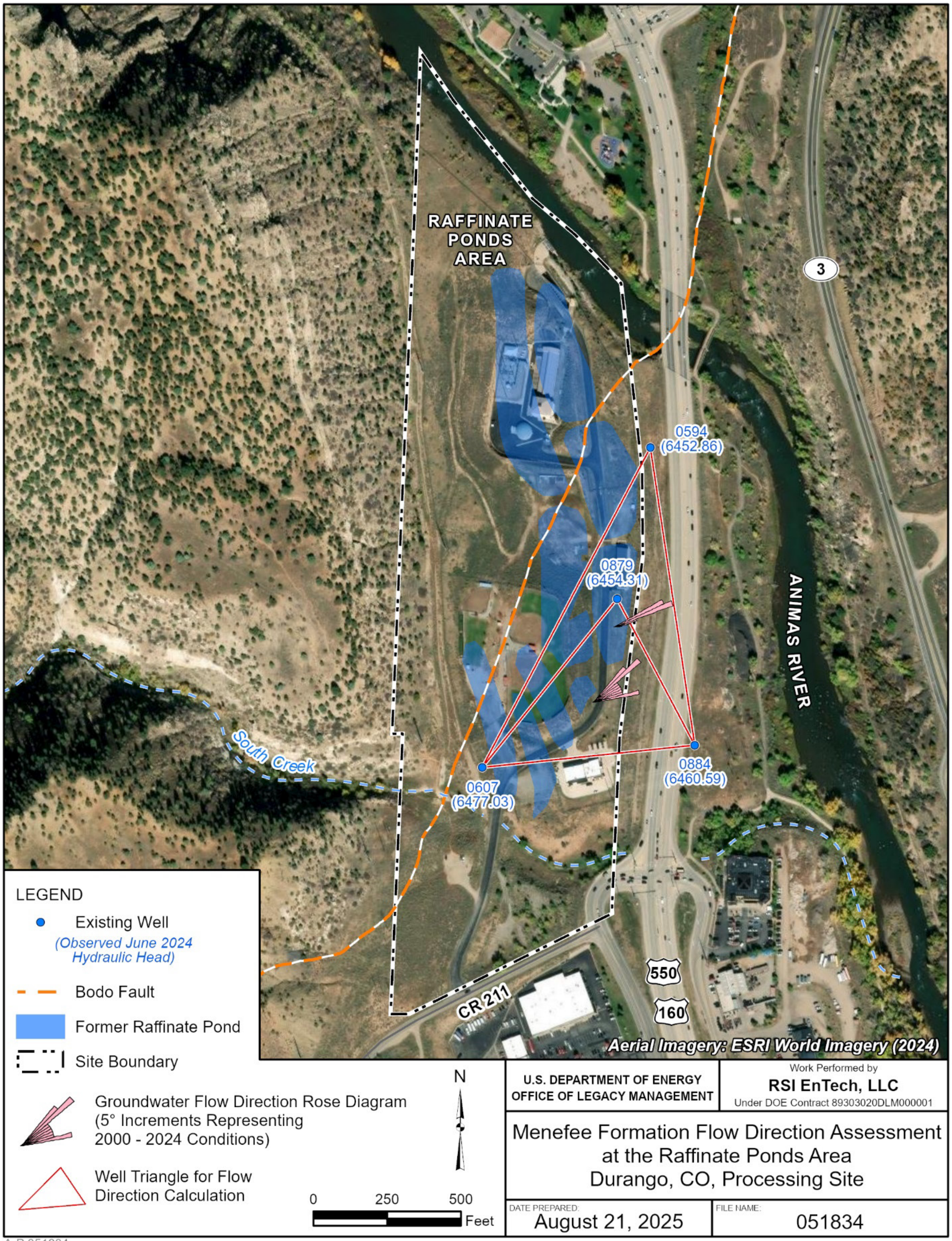


Figure 7. Menefee Formation Flow Direction Assessment at the Raffinate Ponds Area

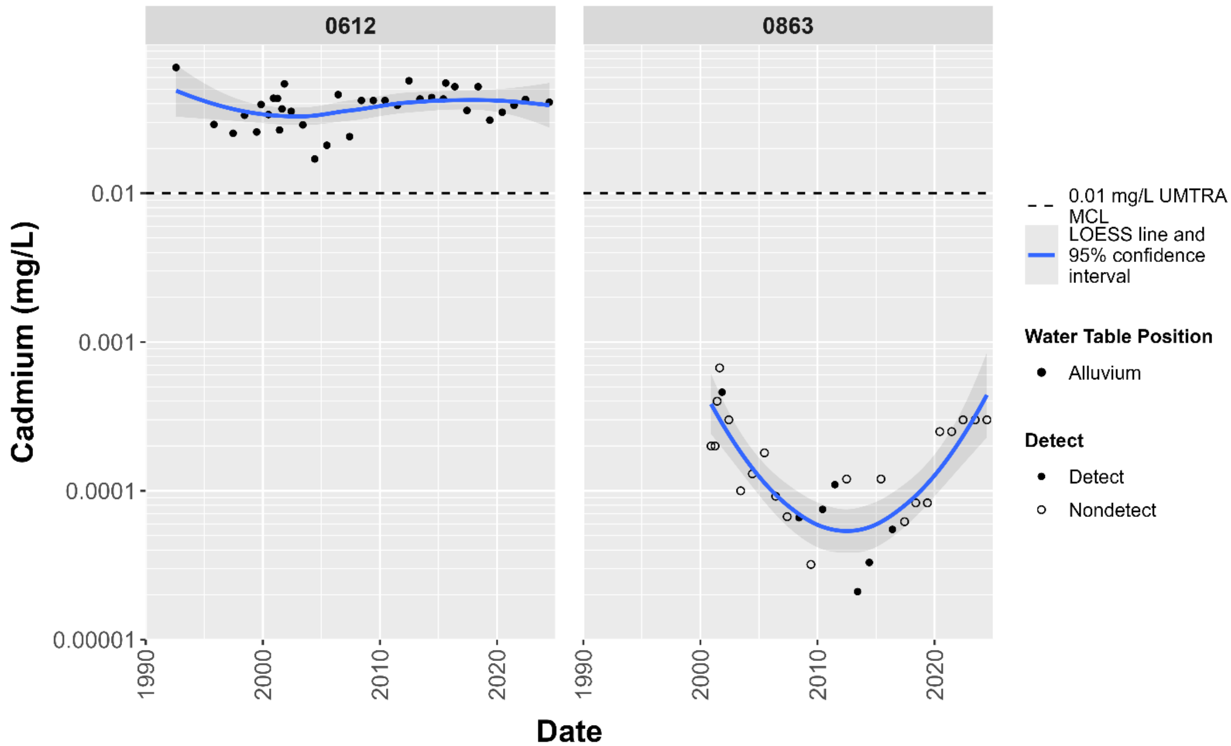
2.2 Monitoring Well COC Trends

COC concentration trends (Figure 8 through Figure 15) for wells listed in Table 2 and Table 3 were evaluated to (1) determine natural flushing progress at the mill tailings area and (2) be monitored as a best management practice at the raffinate ponds area following surface remediation (1992) to present. Since many of the wells at the mill tailings area are screened across the Mancos Shale and the alluvium, trend plots are color-coded to indicate the position of the water table at the time each sample was collected. In each of the plots in Figure 8 through Figure 15, the blue line represents the locally estimated scatterplot smoothing (LOESS) line with a 95% confidence interval shaded around the LOESS line. The dashed line represents the respective compliance goal for each constituent in milligrams per liter (mg/L). Mann-Kendall trend analysis with a 0.05 significance level was used to characterize the direction of concentration trends (Table 4 through Table 9). The starting year for the Mann-Kendall analysis was adjusted from 1992 to 2000 for wells with a relatively high number of nondetects for cadmium, molybdenum, and selenium to prevent a false trend from being identified due to changing detection limits. For wells in the mill tailings area that were identified as having a decreasing concentration trend, linear regression of the log-transformed concentration data was performed to determine the best fit, 95% upper and lower attenuation half-lives, and range of years when concentrations, assuming continuing trends, are predicted to reach the COC standards. Based on current data, it is impossible to predict when, if at all, wells with stable or increasing concentration trends might reach COC standards at the mill tailings area. It is important to note that wells having stable or increasing concentration trends may develop, with time, downward concentration trends and ultimately reach COC standards. Linear regression analyses are not required for the raffinate ponds area, having no compliance goals associated with that portion of the site. A discussion of the COC concentration trends for the mill tailings and raffinate ponds areas are presented in the following sections.

2.2.1 Mill Tailings Area

2.2.1.1 Cadmium

Cadmium is currently monitored in wells 0863 and 0612, and the results are presented in Figure 8. Cadmium concentrations in well 0863 remain below the compliance goal of 0.01 mg/L. Concentrations of cadmium in well 0612 remain above the compliance goal with no discernible trend, indicating that natural flushing within the 100-year time frame may not be attainable unless a consistent downward trend develops (Table 4). The persistent cadmium concentrations for well 0612 are hypothesized to be caused by slag material, a non-UMTRCA material, present in the vicinity of the well (Figure 2) (DOE 2014). Without a discernible trend in cadmium concentrations in well 0612 in the 16 years of monitoring following the Groundwater Compliance Action Plan, the monitoring strategy has been reevaluated, with sampling for cadmium to continue only for surface water locations to ensure that the compliance strategy remains protective at the point of exposure, the Animas River (DOE 2008).



Abbreviations: MCL = maximum concentration limit, UMTRA = Uranium Mill Tailings Remedial Action

Figure 8. Cadmium Concentration Trends from 1992 to 2024

Table 4. Mill Tailings Area Monitoring Well Cadmium Concentration Trends and Year Compliance Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Compliance Goal (0.01 mg/L) of Cadmium Concentration in Groundwater Reached		
					Concen-tration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/6/1992	6/18/2024	35	0.041	None	0.18	Not applicable, no trend					
0863	11/29/2000	6/18/2024	28	Nondetect	Insufficient Detections		Not applicable, concentration less than compliance goal					

Abbreviation:
CI = confidence interval

2.2.1.2 *Manganese*

Manganese concentrations in groundwater are currently below the risk-based goal of 1.7 mg/L in seven of the eight monitoring wells (Figure 9). Manganese concentrations in well 0612 have been consistently above 1.7 mg/L with an increasing trend (Figure 9 and Table 5), making it difficult to predict when concentrations will meet this risk-based goal. Manganese concentrations in well 0617 are currently below the risk-based goal with an increasing concentration trend since 1992; however, concentrations have declined from the maximum value of 2.0 mg/L observed in 2013 (Figure 9 and Table 5).

Well 0612 is screened primarily in the alluvium below approximately 18 ft of slag, and well 0617 is partially screened within a 12 ft slag layer. Similar to cadmium, the persistence of manganese has been argued to be related to sources other than milling, possibly slag from historical lead smelter operations (DOE 2014). An analysis of solid-phase manganese concentrations in the slag layer relative to soils in background and non-slag mill tailings areas may be needed to help pinpoint the source and interpret the observed increasing trends.

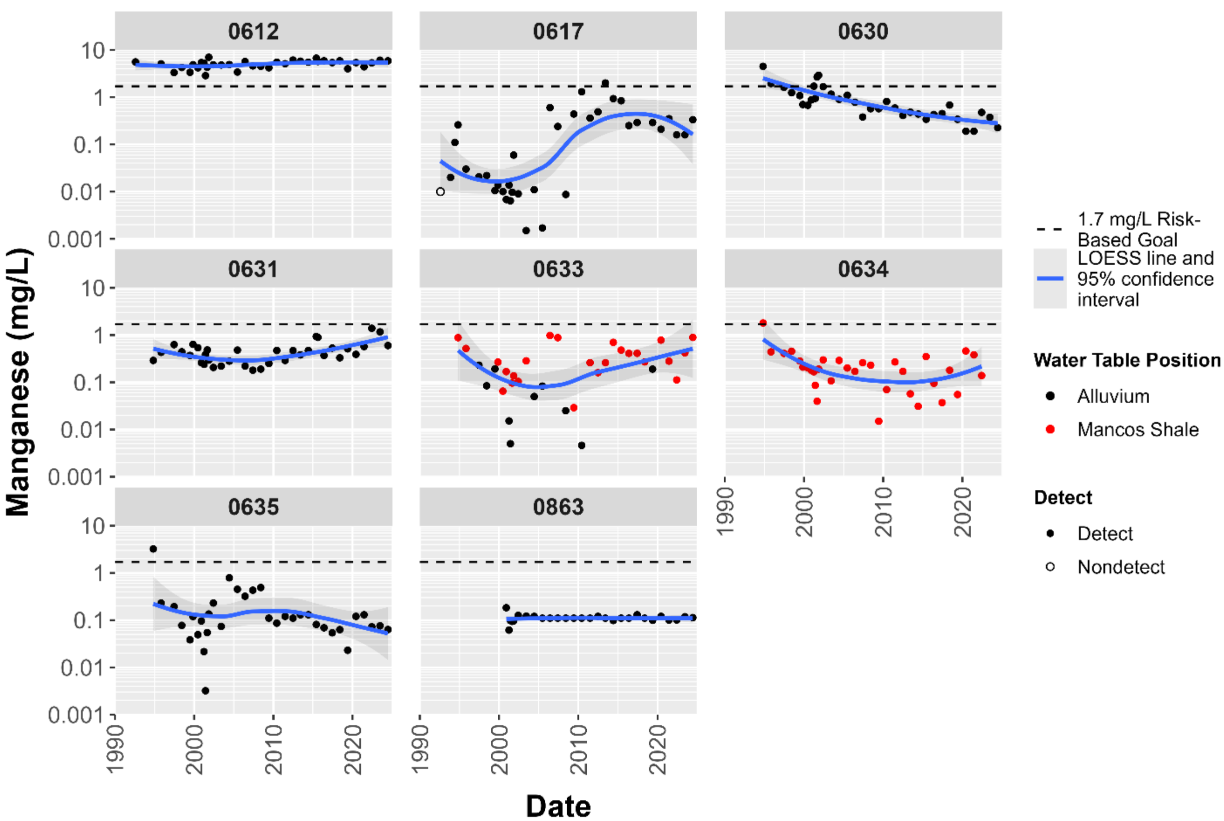


Figure 9. Manganese Concentration Trends from 1992 to 2024

Table 5. Mill Tailings Area Monitoring Well Manganese Concentration Trends and Year Risk-Based Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concen-tration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Risk-Based Goal (1.7 mg/L) of Manganese Concentration in Groundwater Reached		
					Concen-tration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/6/1992	6/18/2024	36	5.9	Increasing	0.30	Not applicable, increasing trend					
0617	8/7/1992	6/18/2024	37	0.33	Increasing	0.29	Not applicable, concentration less than risk-based goal					
0630	10/31/1994	6/18/2024	35	0.23	Decreasing	−0.65	Not applicable, concentration less than risk-based goal					
0631	11/1/1994	6/18/2024	36	0.60	None	0.23	Not applicable, concentration less than risk-based goal					
0633	10/31/1994	6/18/2024	35	0.89	None	0.17	Not applicable, concentration less than risk-based goal					
0634	11/2/1994	6/7/2022	33	0.14	Decreasing	−0.28	Not applicable, concentration less than risk-based goal					
0635	11/2/1994	6/18/2024	35	0.063	None	−0.15	Not applicable, concentration less than risk-based goal					
0863	11/29/2000	6/18/2024	28	0.11	None	0.05	Not applicable, concentration less than risk-based goal					

Abbreviation:
CI = confidence interval

2.2.1.3 Molybdenum

Molybdenum concentrations in groundwater remain below the compliance standard of 0.1 mg/L (DOE 2008) for all locations since June 2012 (Figure 10) (DOE 2014). Mann-Kendall trend analysis indicates that concentrations continue to decrease in three of the eight wells (Table 6). Molybdenum trends in wells 0633 and 0634 are currently increasing; however, the concentrations are approximately 2 orders of magnitude below the compliance standard (Figure 10 and Table 6). Given the low concentrations relative to the compliance standard combined with decreasing or no concentration trends in six of the eight wells, sampling for this analyte at a reduced frequency could be considered (e.g., once every 3 to 5 years).

Abbreviations: MCL = maximum concentration limit, UMTRA = Uranium Mill Tailings Remedial Action

Figure 10. Molybdenum Concentration Trends from 1992 to 2024

Table 6. Mill Tailings Area Monitoring Well Molybdenum Concentration Trends and Year Compliance Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concen-tration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Compliance Goal (0.1 mg/L) of Molybdenum Concentration in Groundwater Reached		
					Concen-tration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/6/1992	6/18/2024	36	0.057	Decreasing	−0.78	Not applicable, concentration less than compliance goal					
0617	6/27/2000	6/18/2024	28	0.0017	None	0.16	Not applicable, concentration less than compliance goal					
0630	10/31/1994	6/18/2024	35	0.0028	Decreasing	−0.43	Not applicable, concentration less than compliance goal					
0631	11/1/1994	6/18/2024	36	0.0036	Decreasing	−0.58	Not applicable, concentration less than compliance goal					
0633	10/31/1994	6/18/2024	35	0.0010	Increasing	0.29	Not applicable, concentration less than compliance goal					
0634	6/22/2000	6/7/2022	27	0.0010	Increasing	0.27	Not applicable, concentration less than compliance goal					
0635	6/22/2000	6/18/2024	29	0.0013	None	−0.13	Not applicable, concentration less than compliance goal					
0863	11/29/2000	6/18/2024	28	0.00068	Insufficient detections		Not applicable, concentration less than compliance goal					

Abbreviation:
CI = confidence interval

2.2.1.4 Selenium

Selenium concentrations in groundwater are currently below the ACL of 0.05 mg/L (DOE 2008) in all eight monitoring wells (Figure 11 and Table 7). Selenium concentrations that exceed the ACL from well 0633 mostly occur when the water table is within the alluvium, apart from the June 2023 sample where the concentration exceeded the ACL when the water table was within the Mancos Shale. Selenium concentrations are generally below the ACL when the water table is within the Mancos Shale, suggesting a continuing alluvium selenium source in the vicinity of the well 0633. Selenium concentrations in well 0630 have been increasing since 1992; however, concentrations within the last 5 years have remained stable at approximately 0.035 mg/L.

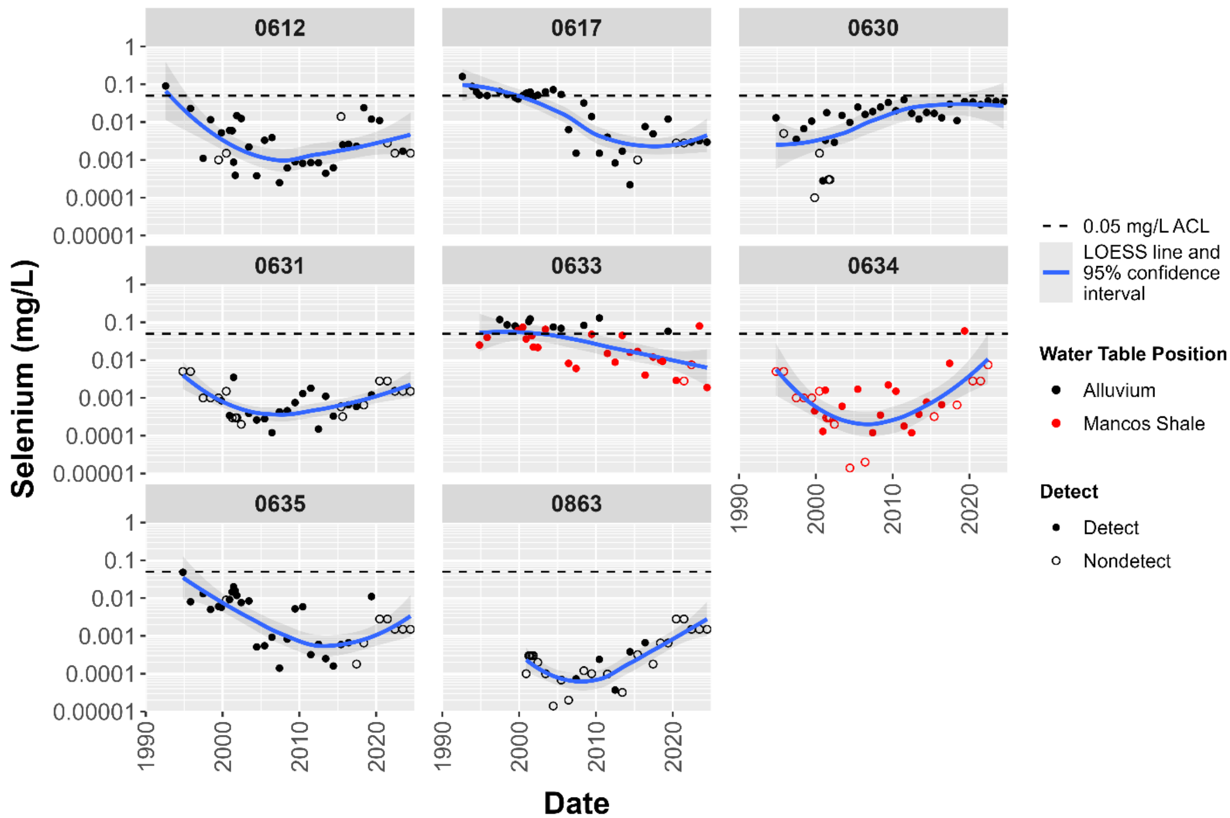


Figure 11. Selenium Concentration Trends from 1992 to 2024

Table 7. Mill Tailings Area Monitoring Well Selenium Concentration Trends and Year Compliance Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Compliance Goal (0.05 mg/L) of Selenium Concentration in Groundwater Reached		
					Concentration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/6/1992	6/18/2024	36	Nondetect	None	−0.15	Not applicable, concentration less than compliance goal					
0617	8/7/1992	6/18/2024	37	0.0030	Decreasing	−0.57	Not applicable, concentration less than compliance goal					
0630	10/31/1994	6/18/2024	35	0.035	Increasing	0.54	Not applicable, concentration less than compliance goal					
0631	11/1/1994	6/18/2024	36	Nondetect	None	0.06	Not applicable, concentration less than compliance goal					
0633	10/31/1994	6/18/2024	35	0.0019	Decreasing	−0.41	Not applicable, concentration less than compliance goal					
0634	6/22/2000	6/7/2022	27	Nondetect	None	0.15	Not applicable, concentration less than compliance goal					
0635	11/2/1994	6/18/2024	35	Nondetect	Decreasing	−0.46	Not applicable, concentration less than compliance goal					
0863	11/29/2000	6/18/2024	28	Nondetect	Insufficient detections		Not applicable, concentration less than compliance goal					

Abbreviation:
CI = confidence interval

2.2.1.5 Sulfate

Sulfate concentrations in groundwater are currently above the average background concentration of 1276 mg/L at six of the eight monitoring wells (Figure 12). Sulfate concentrations at wells 0612, 0617, and 0630 have a significant decreasing trend and are expected to reach average background levels sometime between 2028 and 2072 (Table 8), which is consistent with the findings of the 2019 VMR (DOE 2020). Significantly increasing sulfate concentration trends for wells 0633, 0634, and 0635 currently exceed the 1276 mg/L average background concentration goal (Table 8). Based on current data, it is difficult to predict when wells with stable or increasing concentration trends will meet background levels. It is important to note that wells having stable or increasing concentration trends may develop downward concentration trends and ultimately reach the average background sulfate concentration goal.

Wells 0633 and 0634 have greater than 70% of their respective screened intervals within the Mancos Shale (DOE 2014), and their water table elevations are frequently within the Mancos Shale (Figure 12). Sulfate is a predominant, naturally occurring anion in Mancos Shale groundwater that strongly correlates with specific conductance at the site (DOE 2011; DOE 2018). Previous study of vertical concentration profiles through well screens that span across the alluvium and Mancos Shale interface frequently show increasing sulfate concentration with depth, even in upgradient well 0622 and established background wells 0629, 0857, and 0866 (DOE 2018). Of these upgradient and background wells, only well 0629 was shown to exceed the goal of 1276 mg/L in the Mancos Shale (DOE 2018). Nevertheless, there is potential for the Mancos Shale to naturally contribute concentrations that exceed 1276 mg/L (DOE 2018). However, the significantly decreasing sulfate concentration trends at wells 0612, 0617, and 0630 suggest a mill-related source rather than background-derived concentrations, which would be expected to have stable trends. Similarly, wells 0633 and 0634, in the vicinity of the former mill tailings piles, have increasing sulfate concentration trends indicating a mill-related source rather than purely background-derived concentrations. This finding is supported with isotopic activity ratios (uranium-234 [$^{234}U]/^{238}U$) below 1.00 for both wells 0633 and 0634 (DOE 2014); however, variability in concentrations outside of the historical range has occurred since 2018 for well 0633.

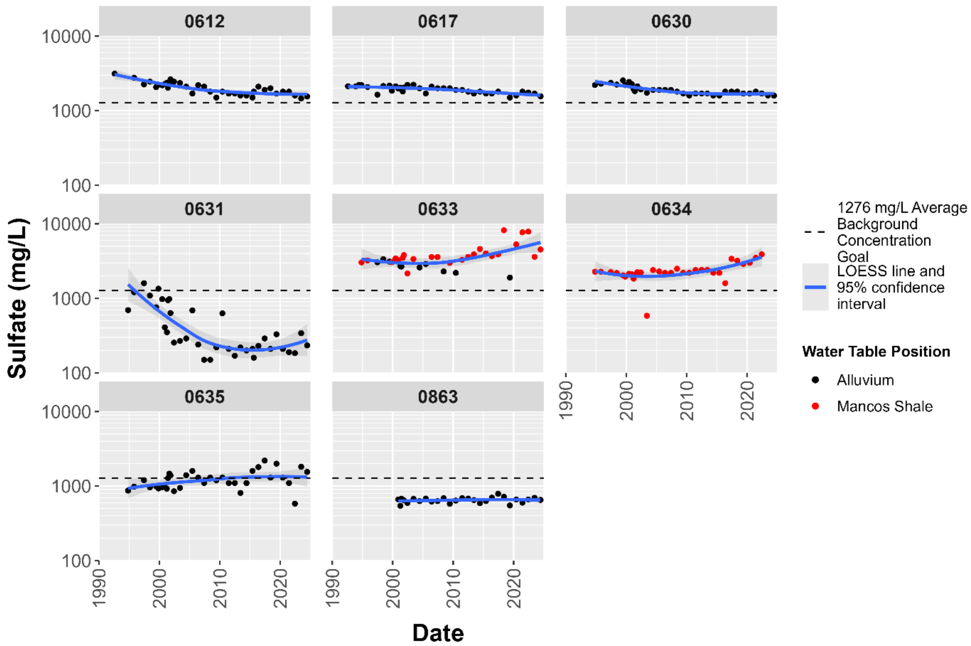


Figure 12. Sulfate Concentration Trends from 1992 to 2024

Table 8. Mill Tailings Area Monitoring Well Sulfate Concentration Trends and Year Compliance Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Average Background (1276 mg/L) of Sulfate Concentration in Groundwater Reached		
					Concentration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/6/1992	6/18/2024	36	1550	Decreasing	−0.57	40.5	32.1	54.7	2034	2028	2043
0617	8/7/1992	6/18/2024	37	1560	Decreasing	−0.55	78.5	60.2	112.8	2052	2041	2072
0630	10/31/1994	6/18/2024	35	1590	Decreasing	−0.67	56.7	44.9	77.2	2040	2033	2052
0631	11/1/1994	6/18/2024	36	234	Decreasing	−0.51	Not applicable, concentration less than average background concentration					
0633	10/31/1994	6/18/2024	35	4530	Increasing	0.40	Not applicable, increasing trend					
0634	11/2/1994	6/7/2022	33	3900	Increasing	0.40	Not applicable, increasing trend					
0635	11/2/1994	6/18/2024	35	1550	Increasing	0.31	Not applicable, increasing trend					
0863	11/29/2000	6/18/2024	28	653	None	0.13	Not applicable, concentration less than average background concentration					

Abbreviation:
CI = confidence interval

2.2.1.6 Uranium

Uranium concentrations in groundwater are currently above the established groundwater compliance standard of 0.044 mg/L (DOE 2008) in five of the eight monitoring wells (Figure 13). Mann-Kendall trend analysis shows a significant decreasing trend for wells 0612, 0617, 0631, and 0633. Estimates for the attenuation year in individual wells range from as early as 2025 (lower 95% confidence interval at well 0631) to as late as 2190 (upper 95% confidence interval at well 0612) (Table 9). Taking the trend line average of wells with statistically identified decreasing trends and predicted compliance goals suggests that the compliance standard may be met by approximately 2084. The overall mean attenuation year is similar to those estimated with the same wells from previous VMRs (2072 from DOE 2014 and 2075 from DOE 2020).

Uranium concentrations within well 0633 have exhibited a statistically significant decreasing Mann-Kendall trend since 1994; however, a 5 order of magnitude increase in p-value since 2019 prohibits projecting a time frame to reach the compliance goal using linear regression. Elevated uranium concentrations in 2020 and 2021 (1.6 and 2.9 mg/L, respectively) are greater than historically observed concentrations in well 0633 and are coincident with the observed increased variability in observed groundwater elevations (Figure 4). The increased variability in groundwater elevations in well 0633 is not currently understood and is being investigated. As noted in Section 2.2.1.5, a previous uranium isotopic activity ratio ($^{234}U/^{238}U$) of 0.96 was found in a groundwater sample collected from well 0633 in 2001, consistent with a mill-tailings origin (DOE 2014).

Well 0634 is characterized as having no statistical trend, and the time frame to reach the compliance standard cannot be estimated with linear regression. While groundwater elevations in well 0634 are within the Mancos Shale (Figure 13), the isotopic activity ratio ($^{234}U/^{238}U$) reported for well 0634 is 0.93 (DOE 2014), which is consistent with uranium in groundwater having a mill-tailings origin as opposed to a Mancos Shale origin. This is further supported by the observation that uranium concentration variations in the well screen increased with elevation by a factor of 2 (DOE 2018).

Concentration trends for uranium in groundwater were found to be increasing at wells 0630 and 0635. Well 0630 is on the southeastern edge of the former mill tailings boundary (Figure 2), and increasing concentrations may be related to the southeast component of groundwater flow (Figure 5), consistent with transport and natural flushing from the southern tailings pile. A similar observation was discussed in the 2019 VMR where increasing trends at well 0630 could be a result of an upgradient pulse of uranium migrating through the system (DOE 2020). While the uranium concentration in well 0635 is currently below the compliance standard, given the high tau value of 0.65 and a probability value of effectively 0, it is possible that concentrations of uranium will exceed 0.044 mg/L in the future (Table 9). The isotopic activity ratio ($^{234}U/^{238}U$) of 1.56 for a sample collected in 2001 for well 0635 suggests a mixed source of mill-tailings and non-mill origin for the uranium at that time (DOE 2014). Combined with the increasing concentration of sulfate above 1276 mg/L at well 0635 since 1992 (Table 8), additional isotopic sampling of uranium would provide evidence to indicate if a change in mill-related composition groundwater has occurred and if the well is considered representative of background conditions as suggested in the 2014 VMR (DOE 2014).

Abbreviations: MCL =maximum concentration limit, UMTRA = Uranium Mill Tailings Remedial Action

Figure 13. Uranium Concentration Trends from 1992 to 2024

Table 9. Mill Tailings Area Monitoring Well Uranium Concentration Trends and Year Compliance Goal Is Reached

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall		Half-Life, years			Year Compliance Goal (0.044 mg/L) of Uranium Concentration in Groundwater Reached		
					Concentration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
0612	8/7/1992	6/18/2024	36	1.1	Decreasing	−0.56	25.98	20.53	35.38	2142	2114	2190
0617	8/7/1992	6/18/2024	37	0.12	Decreasing	−0.52	35.15	25.78	55.21	2080	2060	2123
0630	10/31/1994	6/18/2024	35	0.30	Increasing	0.67	Not applicable, increasing trend					
0631	11/1/1994	6/18/2024	36	0.076	Decreasing	−0.75	10.35	8.71	12.75	2029	2025	2034
0633	10/31/1994	6/18/2024	35	1.2	Decreasing	−0.24	Not applicable, no trend					
0634	11/2/1994	6/7/2022	33	0.014	None	0.08	Not applicable, no trend					
0635	11/2/1994	6/18/2024	35	0.021	Increasing	0.65	Not applicable, concentration less than compliance goal					
0863	11/29/2000	6/18/2024	28	0.00021	None	0.05	Not applicable, concentration less than compliance goal					

Abbreviation:
CI = confidence interval

2.2.2 Raffinate Ponds Area

The compliance strategy for the raffinate ponds area is no further remediation (DOE 2008). The raffinate ponds area is a limited-use aquifer subject to supplemental standards, and monitoring of selenium and uranium is conducted as a best management practice. However, in reporting temporal concentration changes, Mann-Kendall trend analysis was conducted, and time-concentration plots were created for wells 0594, 0598, 0607, 0879, and 0884 (Figure 3). Results for the trend analysis for selenium and uranium are shown in Table 10 and Table 11, with temporal concentrations shown in Figure 14 and Figure 15, respectively. The blue line in each plot in Figure 14 and Figure 15 represents the LOESS line with a 95% confidence interval shaded around the LOESS line. The only significant trends for selenium indicate decreasing concentrations for onsite well 0879,well 0594, and offsite downgradient well 0884 (Table 10 and Figure 14). A decreasing trend was also calculated for uranium for onsite wells 0598 and 0879, but a significantly increasing trend was calculated for offsite downgradient well 0884 (Table 11 and Figure 15). A significant increasing trend in uranium for well 0884 is expected since radon-222 (^{222}Rn) profiling indicates that the well is screened within a zone of high groundwater flux (DOE 2018) that could control transport. The decreasing trend in selenium and corresponding increasing trend in uranium for well 0884 may be indicative of the preferential sorption of selenium since selenium distribution coefficients in the Menefee Formation were experimentally shown to be 10 to 25 times greater than uranium (DOE 2002).

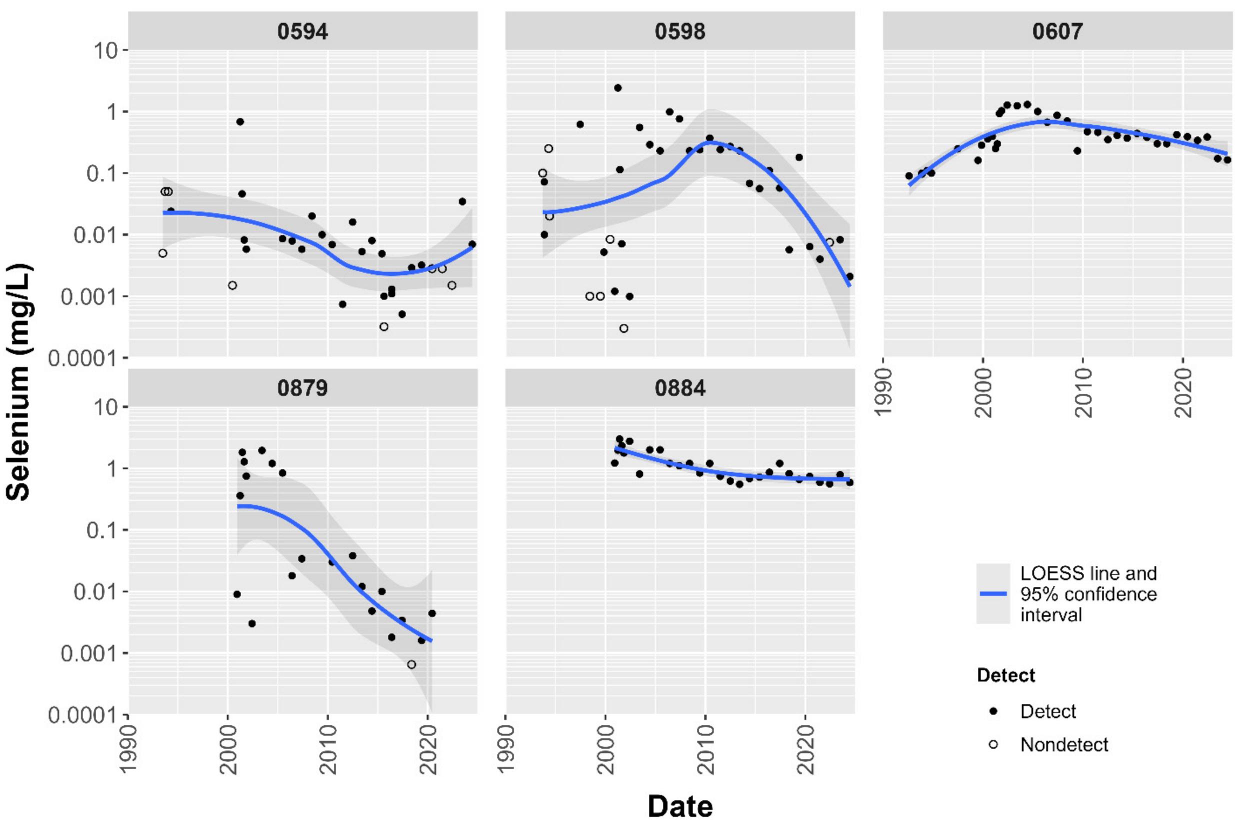


Figure 14. Selenium Concentration Trends from 1992 to 2024

Table 10. Raffinate Ponds Monitoring Well Selenium Concentration Trends

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall	
					Concentration Trend	Tau Value
0594	6/29/1993	6/17/2024	30	0.00697	Decreasing	−0.26
0598	9/24/1993	6/17/2024	37	0.00209	None	−0.02
0607	8/6/1992	6/17/2024	36	0.164	None	0.09
0879	12/5/2000	6/10/2020	21	0.0044	Decreasing	−0.54
0884	12/6/2000	6/17/2024	28	0.589	Decreasing	−0.59

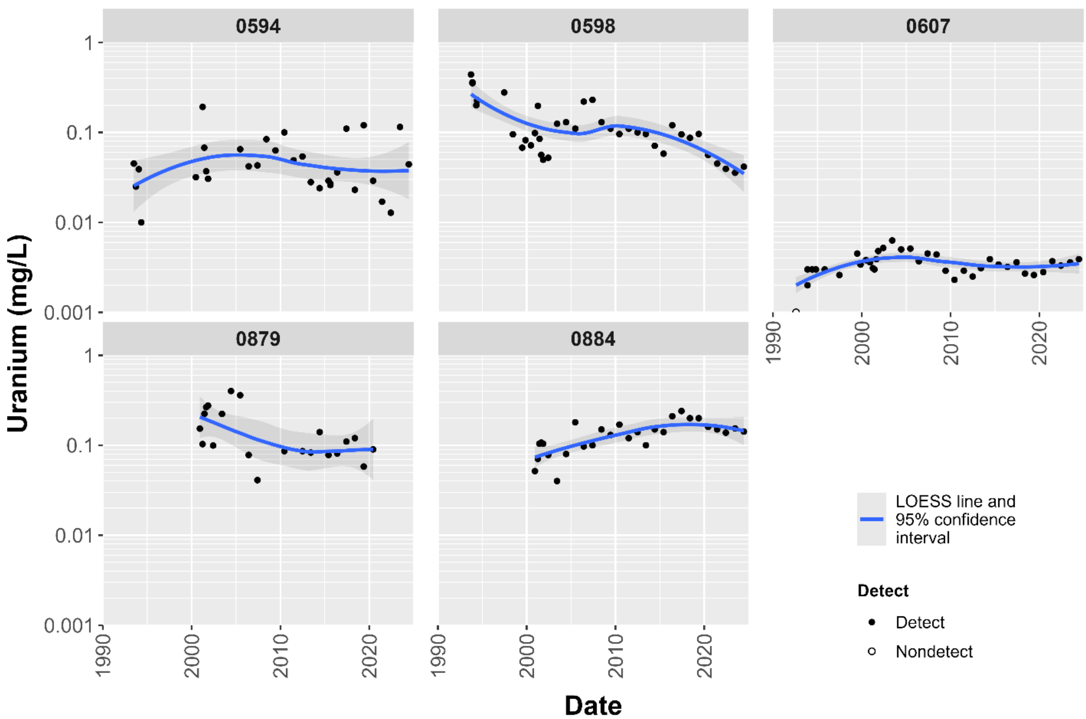


Figure 15. Uranium Concentration Trends from 1992 to 2024

Table 11. Raffinate Ponds Area Monitoring Well Uranium Concentration Trends

Well	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Last Concentration Sampled (mg/L)	Mann-Kendall	
					Concentration Trend	Tau Value
0594	6/29/1993	6/17/2024	30	0.0441	None	−0.06
0598	9/24/1993	6/17/2024	37	0.0416	Decreasing	−0.42
0607	8/7/1992	6/17/2024	37	0.0039	None	0.03
0879	12/5/2000	6/10/2020	21	0.09	Decreasing	−0.31
0884	12/6/2000	6/17/2024	28	0.142	Increasing	0.48

2.3 Mill Tailings Area COC Plume Geometry and Concentrations

Spatial variations in groundwater concentration for the June 2024 sampling event are shown in Figure 16 for cadmium, manganese, molybdenum, and selenium with respect to each COC's compliance or ecological risk-based goal at the mill tailings area. Given the number of monitored wells and limited exceedances for these COCs, interpolated plume maps were not created. Cadmium and manganese exceedances are limited to the vicinity of well 0612. There are no locations with current exceedances of selenium or molybdenum.

Plume concentration maps for sulfate and uranium in alluvial groundwater were generated using June 2001 (representing baseline conditions) and June 2024 (most recent sampling event) data for a temporal comparison of concentrations at the mill tailings area (Figure 17 and Figure 18, respectively). The extent of the sulfate plume is defined by regions exceeding the average background concentration of 1276 mg/L, and the extent of the uranium plume is defined by regions exceeding the 0.044 mg/L compliance goal. Data from 2001 were selected for baseline conditions because they represented the most complete and earliest dataset that could be used with the current monitoring network. The area selected for contouring was limited to the extent of the saturated alluvial aquifer (including well 0863) that was mapped laterally in the SOWP (DOE 2002, Figure 5-1) and confirmed after review of available boring logs. The natural neighbor method was used to interpolate the water table on the given dates while kriging was used to interpolate concentrations. Concentrations for wells where the water table was in the Mancos Shale (the alluvium was dry) are reported in the figures but not used in the interpolation as they are not representative of the alluvial aquifer. An outcome of applying this interpolation scheme is the alluvial aquifer plume footprint appears reduced from 2001 to 2024 as a result of more of the alluvial aquifer being dry in 2024 compared to 2001. It is possible that future plume depictions will have increased footprints if more of the alluvium becomes saturated.

Concentrations of sulfate in groundwater are shown in Figure 17. June 2001 interpolated concentrations indicate that the sulfate plume is bounded to the east by the Animas River and wells 0631 and 0859, to the south by colluvium well 0863, and to the north by well 0635 and Lightner Creek. The plume is not characterized west of wells 0617, 0630, and 0633, creating uncertainty in the plume extent, but, given the footprint of the former tailings piles, it is possible the plume extends westward to where the alluvial aquifer pinches out. Background well 0629 indicates concentrations greater than 1276 mg/L, but the groundwater elevation is within the Mancos Shale. Background well 0857, to the north of Lightner Creek, also had sulfate concentrations greater than 1276 mg/L.

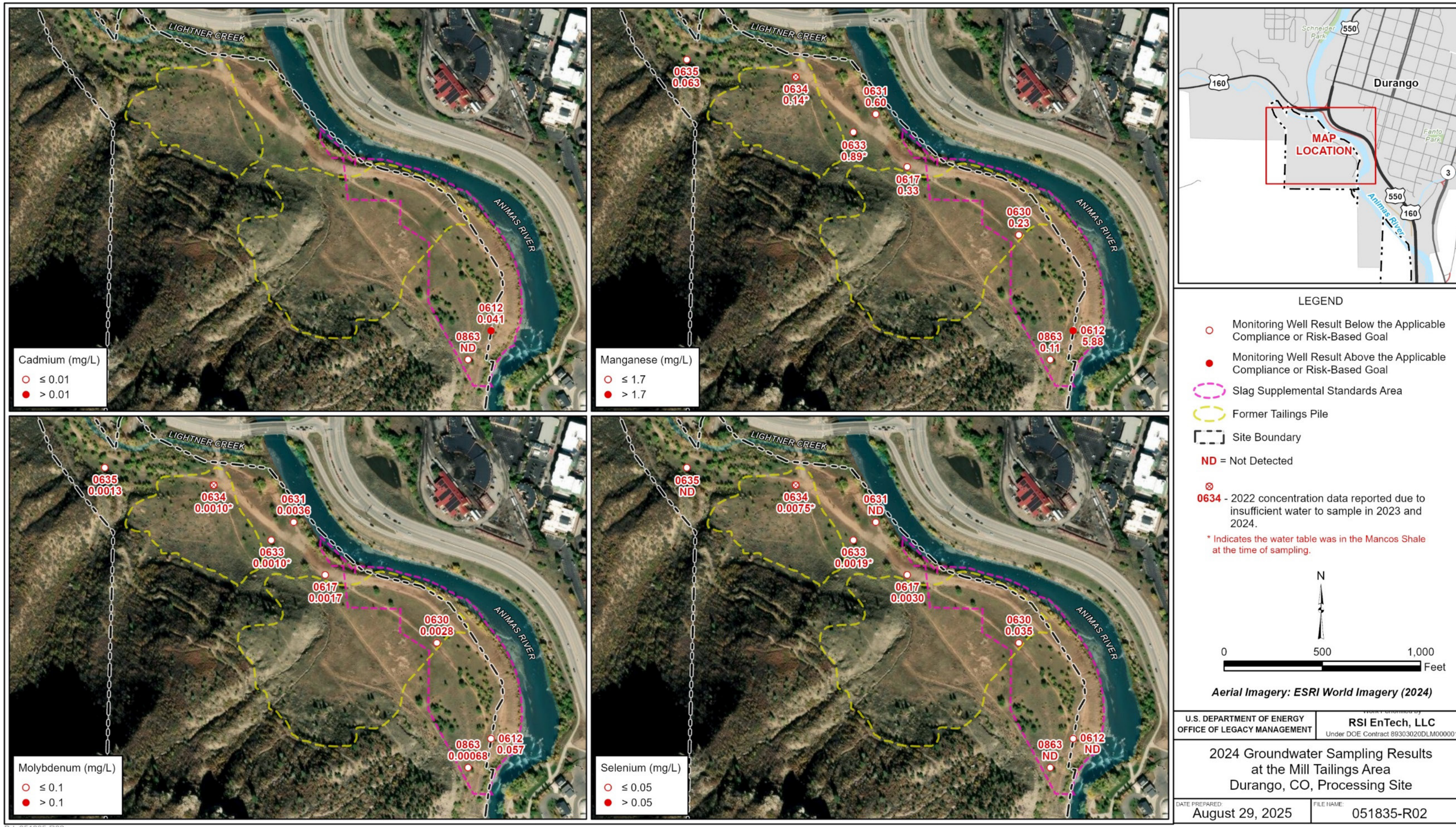


Figure 16. 2024 Groundwater Sampling Results for Cadmium, Manganese, Molybdenum, and Selenium at the Mill Tailings Area

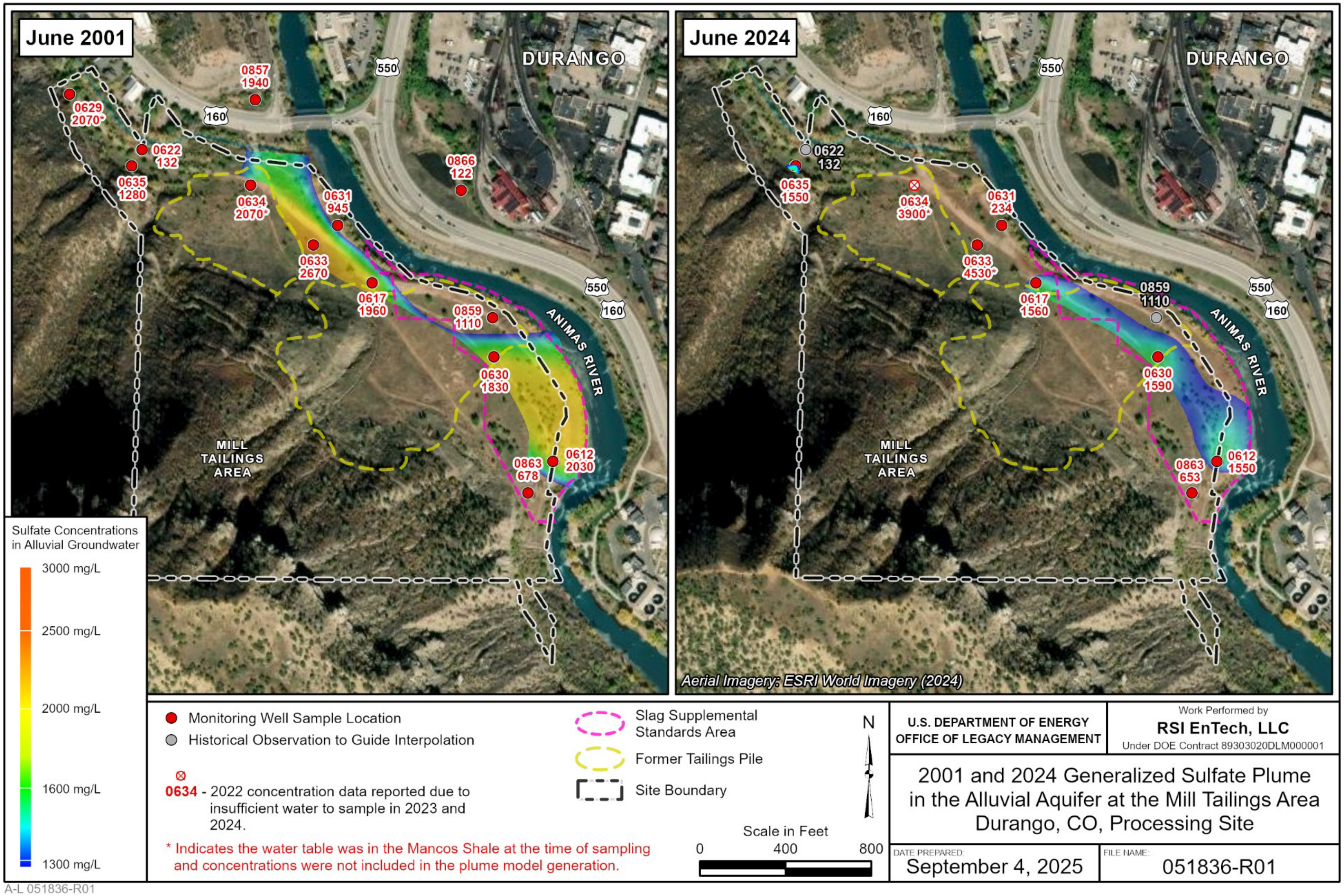


Figure 17. 2001 and 2024 Concentrations of Sulfate in Groundwater at the Mill Tailings Area

In June 2024, the maximum concentration of sulfate was 4530 mg/L from well 0633. However, this result was not used for interpolating the plume within alluvial groundwater in Figure 17 as the water level was observed to be within the Mancos Shale. The highest sulfate concentration in the alluvium was 1590 mg/L in well 0630, a decrease from 1830 mg/L in June 2001. The southern portion of the plume is monitored by wells 0630 and 0612, where well 0612 also decreased in concentration from 2030 g/L to 1550 mg/L between 2001 and 2024. A small, isolated plume exists in the northern region of the mill tailings area at well 0635 with a sulfate concentration of 1550 mg/L, a decrease from 2000 mg/L in 2019. Historic concentrations from well 0622 are used to guide plume interpolation in the northern region of the mill tailings area due to well 0622 never exhibiting sulfate levels above background throughout the entirety of the well's sampling period (1982–2014). Historical concentrations from well 0859 were also used to bound the eastern extent of the plume; however, the true extent of the plume to the east was more uncertain in June 2024 without continued monitoring from well 0859.

Concentrations of uranium in alluvial groundwater are shown in Figure 18. In June 2001, the uranium plume was bounded to the east by the Animas River, to the south by the colluvium well 0863, and to the north by well 0635 and Lightner Creek. The plume was not characterized west of wells 0617, 0630 and 0633, creating uncertainty in the plume extent, but, given the footprint of the former tailings piles, it is possible the plume extended westward to where the alluvial aquifer pinched out. The maximum uranium concentration in June 2001 was 1.56 mg/L from well 0612.

By June 2024, the maximum concentration of uranium was 1.23 mg/L at well 0633, but since water levels in well 0633 were in the Mancos Shale at the time of sampling, well 0633 data were not used for plume interpolation. The highest uranium concentration within the alluvium was 1.11 mg/L in well 0612, a decrease from 1.56 mg/L in 2001. Notable concentration decreases are also apparent to the north in wells 0617 and 0631. The eastern extent of the plume in June 2001 reaches well 0859, where the concentration was nearly the compliance goal of 0.044 mg/L. Sampling of well 0859 was discontinued after four consecutive sampling events between June 2001 and June 2002 yielded concentrations below the uranium standard of 0.044 mg/L. Historical uranium concentrations from well 0859 were used to bound the eastern extent of the plume; however, the true extent of the plume to the east was more uncertain in June 2024 (Figure 18) without continued monitoring from well 0859.

Both uranium and sulfate plume distributions (Figure 17 and Figure 18) support the previous evaluation that colluvium well 0863 is not on a flow path (cross gradient) from the former southern mill tailings pile to the Animas River (DOE 2014).

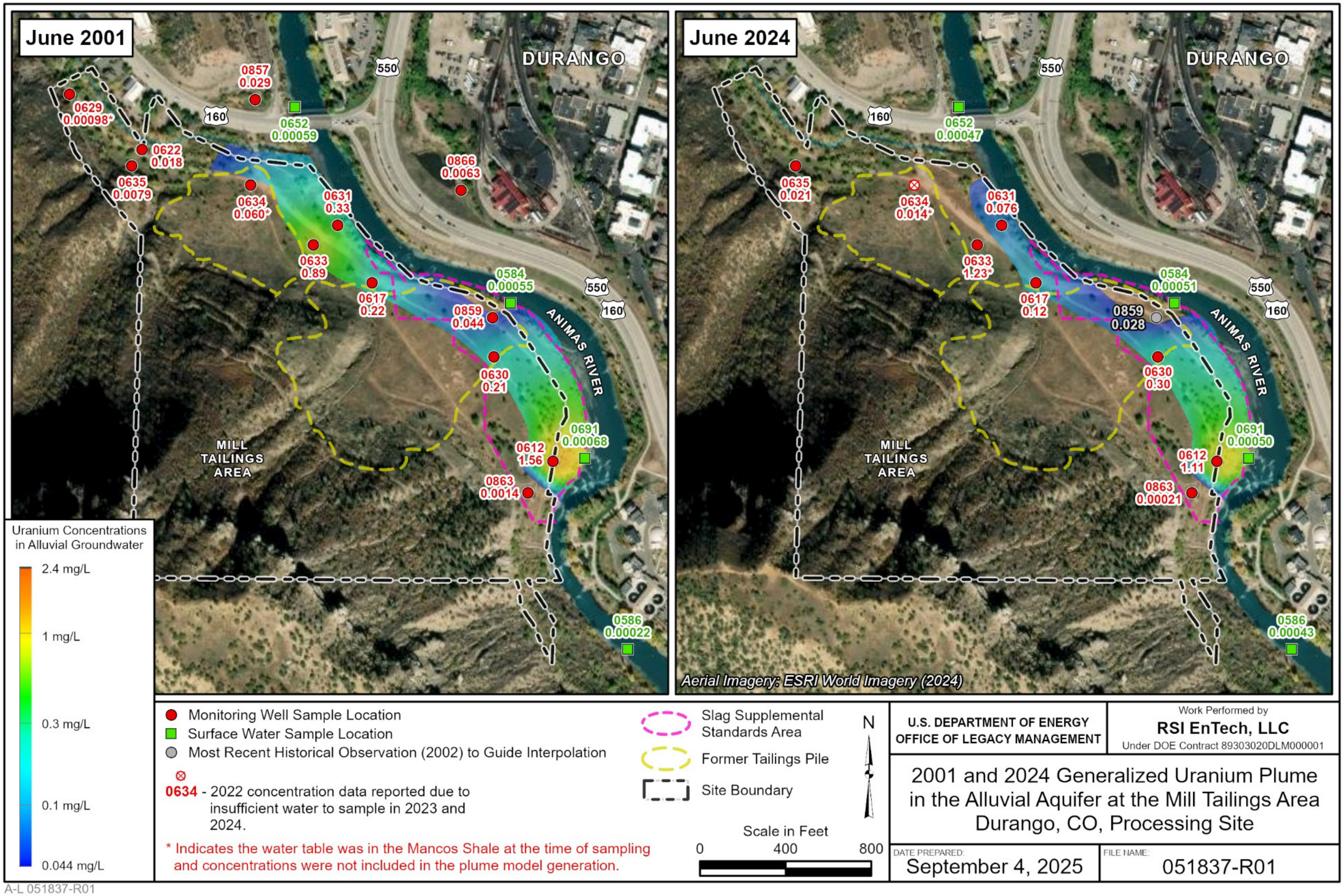


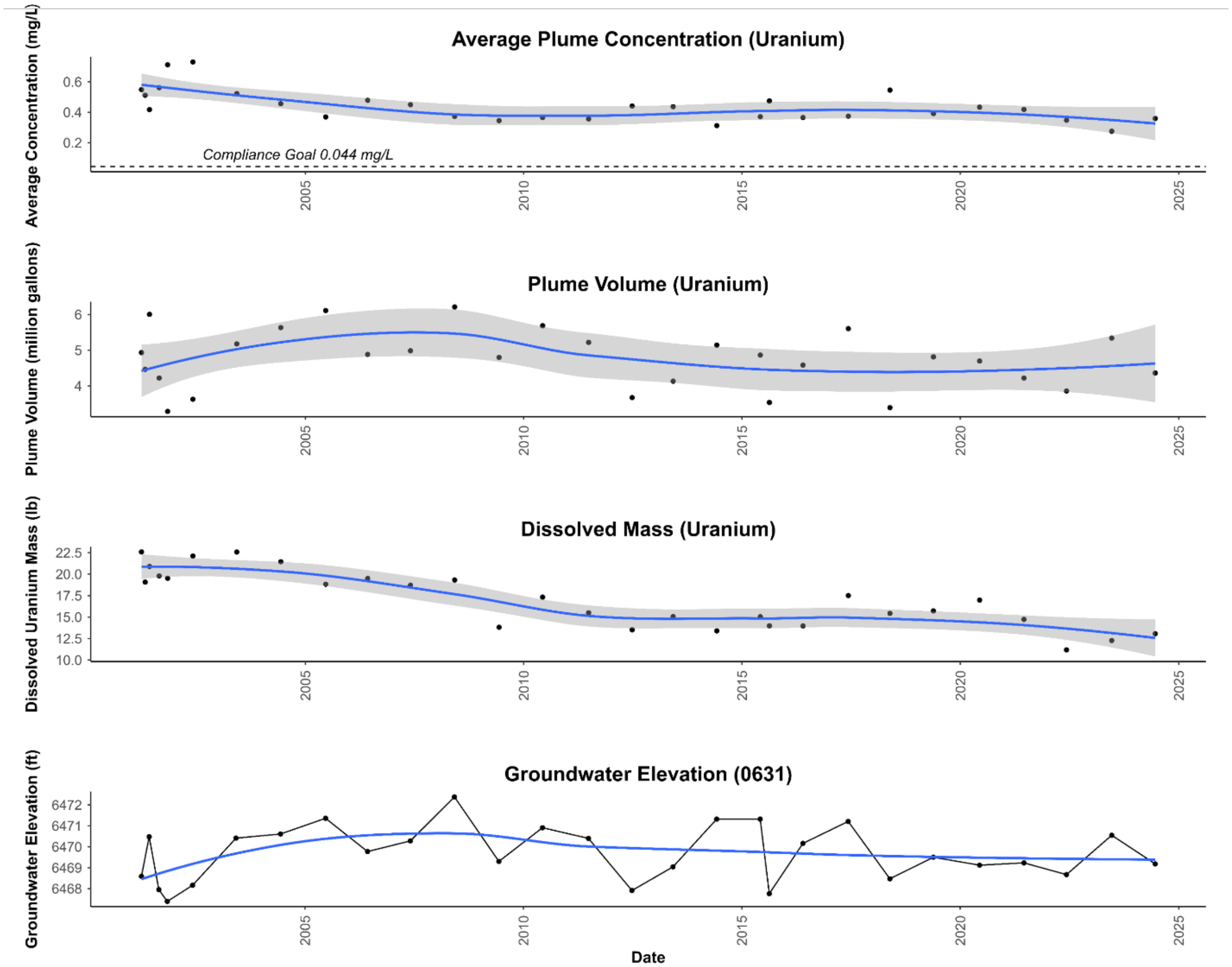
Figure 18. 2001 and 2024 Concentrations of Uranium in Groundwater and Surface Water at the Mill Tailings Area

2.4 Mill Tailings Area Bulk COC Plume Metrics

Bulk plume metrics for the mill tailings area were calculated for uranium using Earth Volumetric Studio version 2024.9.1. The calculation is performed using a three-dimensional interpolation (when a sufficient number of wells were sampled) and extrapolation of groundwater concentration data with kriging for sampling events since March 2001. The interpolated plume volume is bound on the bottom by the top of the Mancos Shale (interpolated from site boring logs) where relatively little groundwater flow occurs (DOE 2002; DOE 2018). The interpolated plume is bound on the top by the interpolated groundwater elevations recorded for each sampling event. Since wells are often screened across the Mancos Shale/alluvium interface, concentrations pertaining to water table elevations within the Mancos Shale were not included in the interpolation. A porosity of 0.25 was assumed for plume volume and plume mass calculations.

Bulk uranium plume metrics characterizing plume volume, dissolved plume mass, and average plume concentration provide an assessment of natural flushing progress (Figure 19). The blue line in each plot represents the LOESS line, and the surrounding gray represents the 95% confidence interval around the LOESS line. The average plume concentration has significantly decreased ($p < 0.05$) from 2001 to 2024 (Figure 19 and Table 12). Linear regression of the log-transformed average plume concentration indicates the average plume concentration reaching the compliance standard of 0.044 mg/L at approximately the year 2138, which is similar to predictions presented in Table 9. These results differ slightly from the previous VMR, where the projected time frame was 2101, with the lower 95% confidence interval at 2068 and the upper 95% confidence interval at 2213 (DOE 2020). The estimate presented in this report has a high degree of uncertainty with the lower and upper 95% confidence intervals between the years of 2094 and 2275, respectively (Table 12). Estimated times to reach the compliance standard presented in Table 9 and Table 12 are most sensitive to the decreasing trend at well 0612, where the concentration of uranium in the alluvial aquifer is the greatest.

Variations in plume mass are related to both changes in plume volume and average plume concentration. Plume volume has fluctuated from 3.3 to 6.2 million gallons between 2001 and 2024. Uranium plume volume is correlated with groundwater elevations, as illustrated by a comparison of plume volume with the hydrograph for well 0631 in Figure 19. Well 0631 was selected for comparison because (1) groundwater elevations are always within the alluvial aquifer; (2) hydraulic conductivity was reported to be 27 ft per day, which is typical of values from the alluvial aquifer (DOE 2002); and (3) ^{222}Rn profile data in well 0631 indicate a relatively high flux zone within the alluvium that corresponds with the profile trend in the dissolved uranium concentration (DOE 2018). Fluctuations in well 0631 are related to changes in Animas River stage and precipitation recharge. Plume mass has shown a similar pattern in fluctuation as plume volume and has ranged from 11.2 to 22.6 pounds between 2001 and 2024 (Figure 19). The decrease in average plume concentration and plume mass between 2001 and 2012 suggests that uranium was being flushed from the system at a rate greater than the loading rate into the aquifer. Visual examination of trends between 2012 and 2024 indicates a dynamic equilibrium in plume mass and average concentration may have been achieved (i.e., the uranium loading rate has generally decreased and is approaching the flushing rate). Bulk plume metrics and groundwater elevation data from Figure 19 are presented as tables in Appendix B.



Abbreviation: lb = pounds

Figure 19. Temporal Variations in Dissolved Uranium Bulk Plume Metrics and Alluvium Groundwater Fluctuations

Table 12. Mill Tailings Area Average Uranium Concentration Trends and Year Compliance Goal Is Reached

Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples	Mann-Kendall		Half-Life, years			Year 0.044 mg/L Concentration in Groundwater Reached		
			Concentration Trend	Tau Value	Trend Line	Lower 95% CI	Upper 95% CI	Trend Line	Lower 95% CI	Upper 95% CI
4/1/2001	6/18/2024	29	Decreasing	−0.41	38.61	25.37	80.75	2138	2094	2275

Abbreviation:
CI = confidence interval

2.5 Surface Water COC Concentration Trends

Surface water was sampled from six locations in the Animas River adjacent to both the mill tailings and raffinate ponds areas in 2024 and analyzed for cadmium, molybdenum, selenium, and uranium (Figure 1, Table 2, and Table 3). At the raffinate ponds area, Animas River location 0678 replaced location 0656 in 2013 (DOE 2014). Results from 1992 to 2024 are presented in Figure 20 and Figure 21 for the mill tailings and raffinate ponds areas, respectively.

Concentrations of constituents at all locations along the Animas River remain indistinguishable from background levels (Figure 20). The colored lines in each plot represent the LOESS lines with a 95% confidence interval shaded around the LOESS lines. The most recent surface water concentrations across the mill tailings area for uranium are also shown in Figure 20. Samples were also collected from South Creek (location 0588), upgradient from the raffinate ponds area, to assess the quality of water entering the site from the west. South Creek location 0588 is in the lower end of the arroyo that extends from the raffinate ponds area to the Durango disposal site. South Creek is typically dry except following heavy rainfall events or wet periods or when treated water is released from the toe drain collection pond at the base of the disposal cell (DOE 2002). Samples from South Creek in 2024 had concentrations of selenium (0.0019 mg/L) and uranium (0.107 mg/L) that are within observed historical ranges for this location (Figure 21). Concentrations of selenium and uranium observed in South Creek are generally higher than those from other surface water locations (Figure 21).

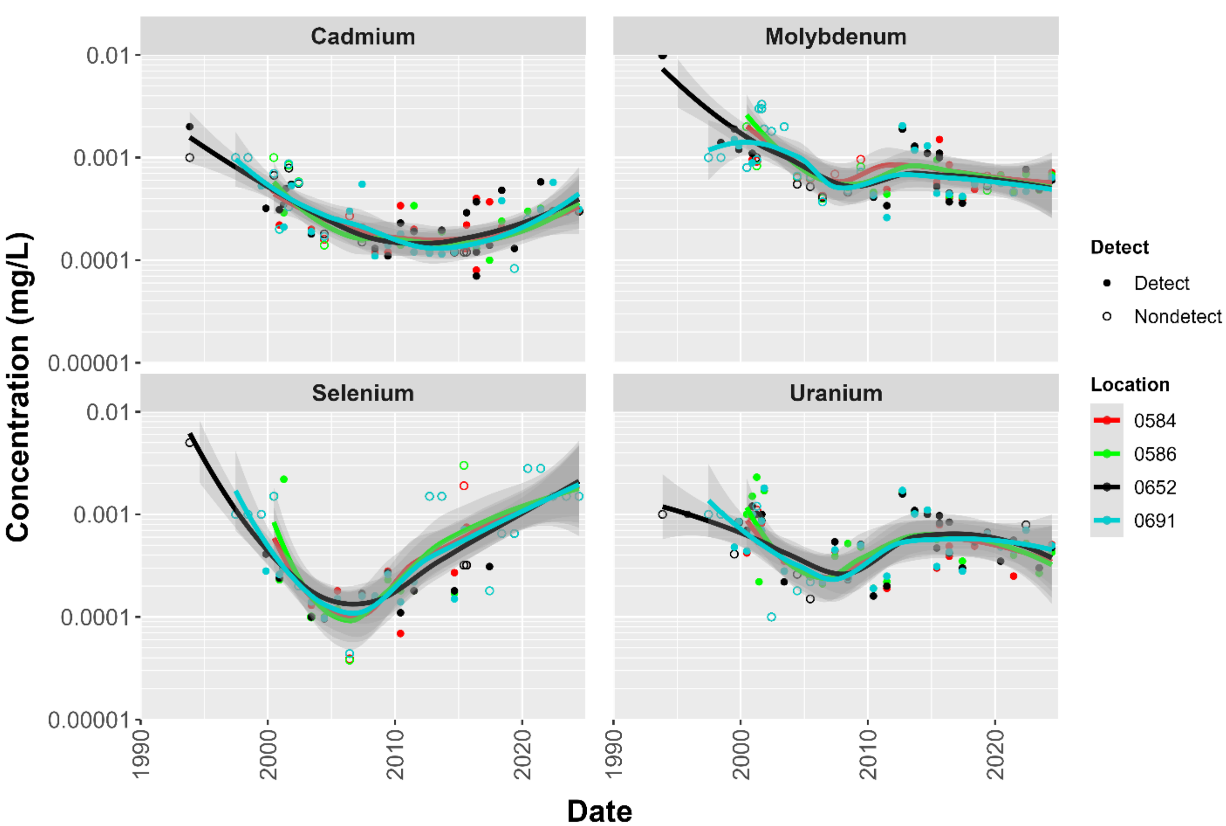


Figure 20. Temporal Concentrations of Cadmium, Molybdenum, Selenium, and Uranium in Surface Water Along the Mill Tailings Area

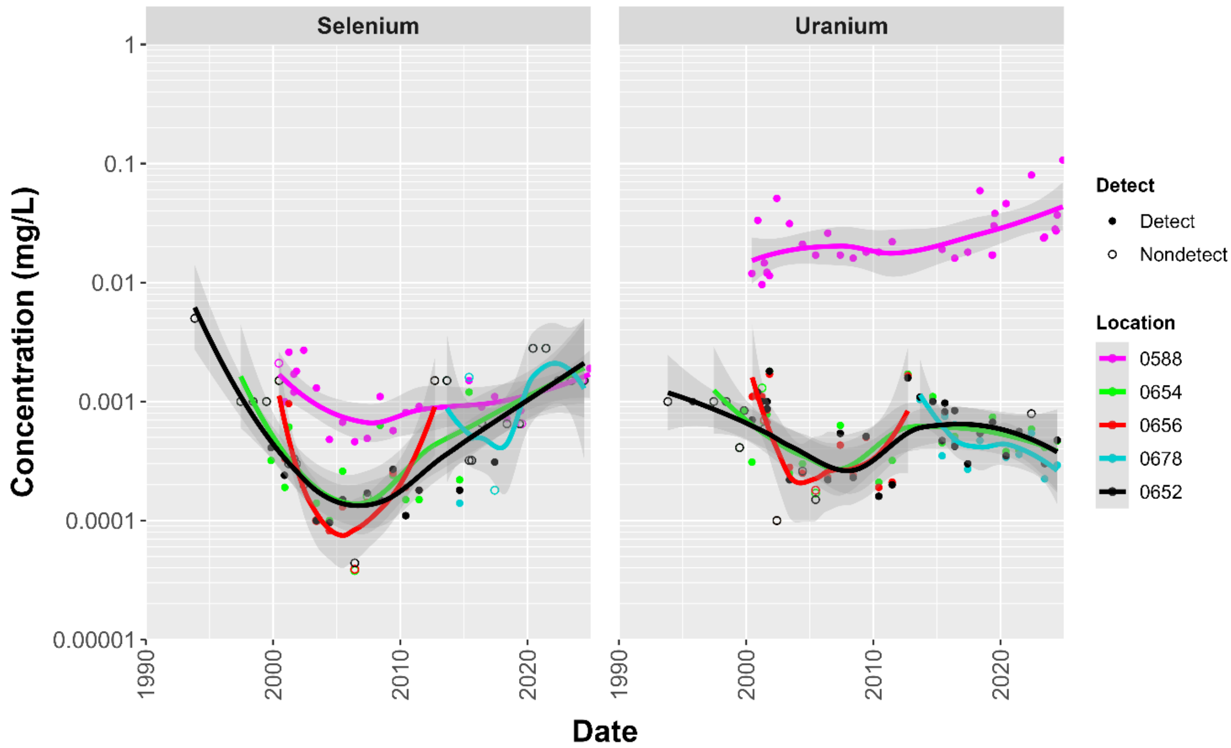


Figure 21. Temporal Concentrations of Selenium and Uranium in Surface Water Along the Raffinate Ponds Area

3.0 Compliance Remedy Performance Summary

Based on the evaluation included in this report, the following observations were made on the discrete areas of the site:

Mill Tailings Area:

- Estimated groundwater flow directions are consistent with the conceptual site model presented in the SOWP (DOE 2002). Because of the uncertainty in the vertical elevation datum of monitoring wells, comparisons between Animas River stage and groundwater elevations are difficult. A resurvey of the monitoring wells has been performed, and the data will be available for future reports.
- Concentrations of cadmium, manganese, molybdenum, and selenium in groundwater at the mill tailings area are currently below their respective compliance or risk-based (manganese) goals with the following exceptions:
  - — Cadmium and manganese have been persistently above their respective compliance and risk-based goals, respectively, at well 0612. These COCs are likely related to sources other than milling. Cadmium concentrations at well 0612 have remained consistent, and based on a review of the concentration trend and source of cadmium, the monitoring strategy has been reevaluated and sampling for cadmium will occur only at surface water locations to ensure that the compliance strategy remains protective at the point of exposure. Concentrations of manganese are not expected to fall below the risk-based

goal within 100 years at well 0612, and annual monitoring will continue given the increasing trend.

- Selenium has recently exceeded the ACL at wells 0633 and 0634. Groundwater elevations in these wells are frequently within the Mancos Shale, where elevated, naturally occurring concentrations of selenium have been reported in groundwater samples across the Colorado Plateau (DOE 2011). However, until recently, well 0633 selenium concentrations above the standard mostly occur when the water table is within the alluvium. Selenium concentrations are generally below the standard when the water table is within the Mancos Shale, indicating an ongoing selenium source in the alluvium near the well. Analysis of sulfate at the mill tailings area indicates that concentrations could decrease to below the average background concentration goal of 1276 mg/L within 100 years at five of the eight locations. The remaining three locations are wells 0633, 0634, and 0635, where concentrations are currently above the average background goal with increasing trends. Groundwater elevations are frequently within the Mancos Shale at wells 0633 and 0634, where elevated sulfate is naturally occurring. Significant decreasing trends in sulfate concentration at wells 0612, 0617, 0630, and 0631 suggest a mill-related source given the proximity of wells 0633 and 0634 to the former mill tailings piles.
- Natural flushing of uranium appears to be proceeding in a manner consistent with previous VMRs in the mill tailings area (DOE 2012; DOE 2014; DOE 2020). However, recent concentration trends suggest that natural flushing may occur at a slower rate than estimated in previous VMRs for uranium in the mill tailings area (DOE 2012; DOE 2014; DOE 2020). Given the variability of groundwater elevations and concentrations at well 0633, it is possible that trends will shift and the rate of natural flushing could change. Attenuation rates for monitoring wells with significantly decreasing trends (wells 0612, 0617, and 0631) suggest that natural flushing at those locations could occur within the 100-year time frame. COC concentrations in well 0630 remain above the compliance standard with statistically significant increasing concentration trends; therefore, the time frame to achieve natural flushing cannot be estimated at this location. Although well 0633 exhibits a statistically significant decreasing trend for uranium, elevated concentrations since 2020 prevent estimating a time frame to reach the compliance goals with linear regression. Overall, Mann-Kendall analysis of average uranium plume concentration data indicates a statistically significant decreasing concentration trend. Though highly uncertain, linear regression analysis estimates that average uranium plume concentrations could be below the compliance goal around year 2138 with the 95% lower and upper confidence limits between the years 2094 and 2275, respectively.
- Since the previous VMR (DOE 2020), variability in concentrations of uranium and sulfate and groundwater elevations from well 0633 do not align with the range of historic observations. Additional data will assist with the interpretation of the observed variability.

Raffinate Ponds Area:

- The aquifer beneath the raffinate ponds area is subject to supplemental standards, designated as limited use, and monitored as a best management practice. Concentration trends of selenium have either been decreasing or exhibiting no trend, and uranium concentration trends are only increasing at downgradient well 0884. The increase in concentrations at well 0884 are expected as uranium continues to migrate downgradient.

Surface Water at Mill Tailings and Raffinate Ponds Areas:

- Surface water COC concentrations along the Animas River adjacent to the mill tailings and raffinate ponds areas are consistent with the concentrations at background location 0652. Samples from the ephemeral South Creek location 0588 at the raffinate ponds area are higher in concentrations of selenium and uranium than those from the Animas River locations.

4.0 References

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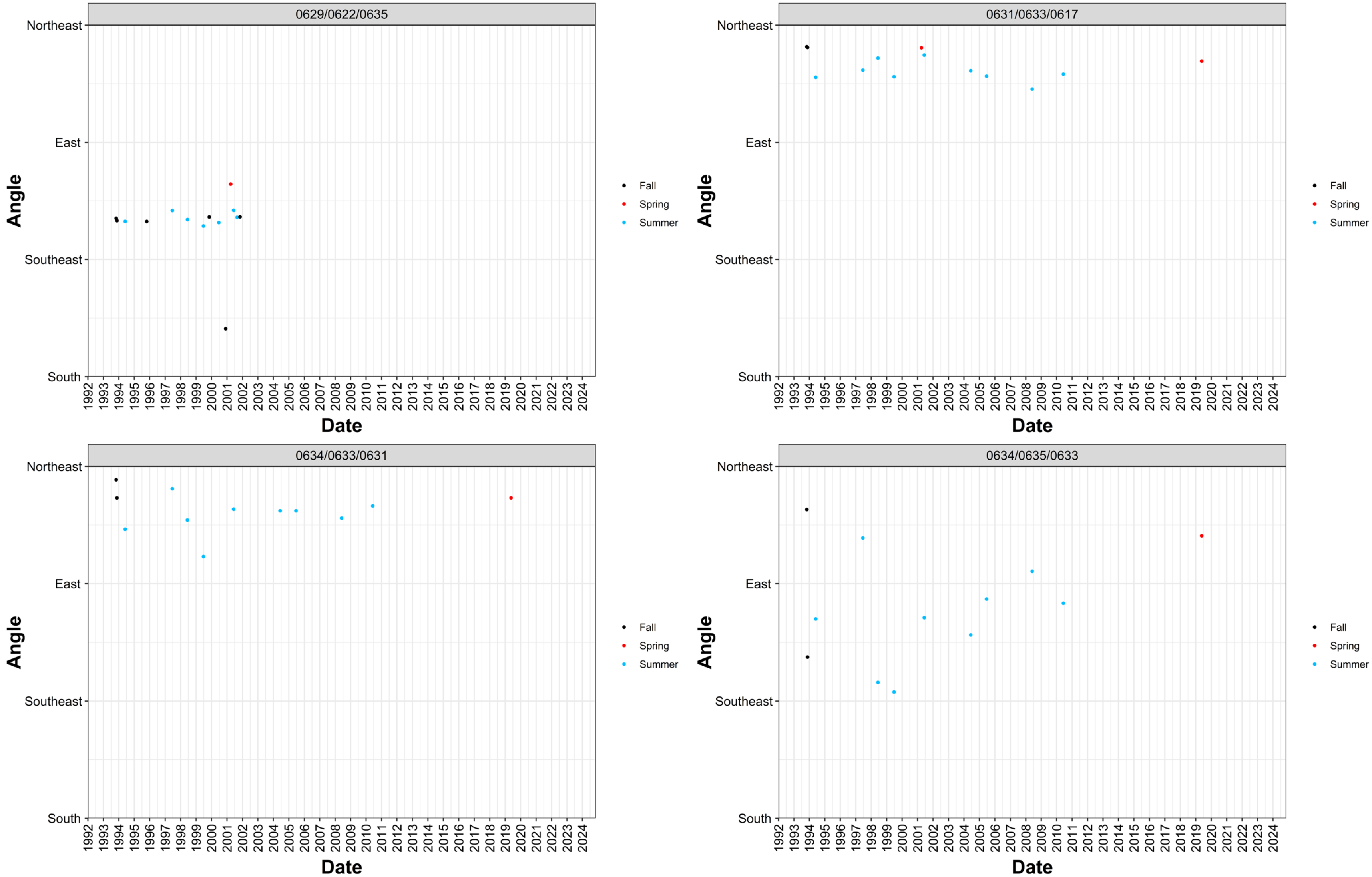
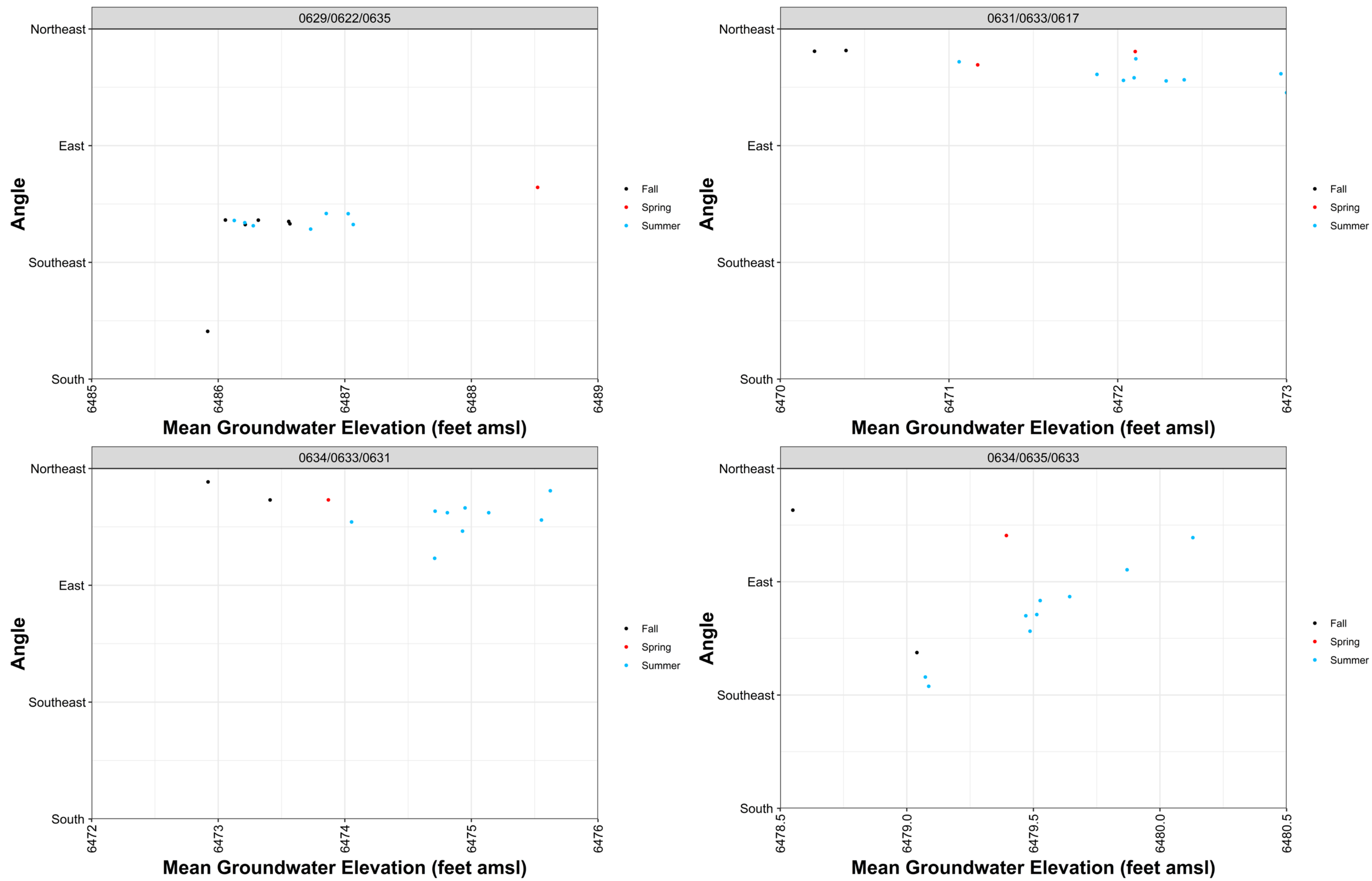
McKenna, S.A., and A. Wahi, 2006. "Local Hydraulic Gradient Estimator Analysis of Long-Term Monitoring Networks," *Groundwater* 44(5):723–731.

Appendix A

Three-Point Estimator Results

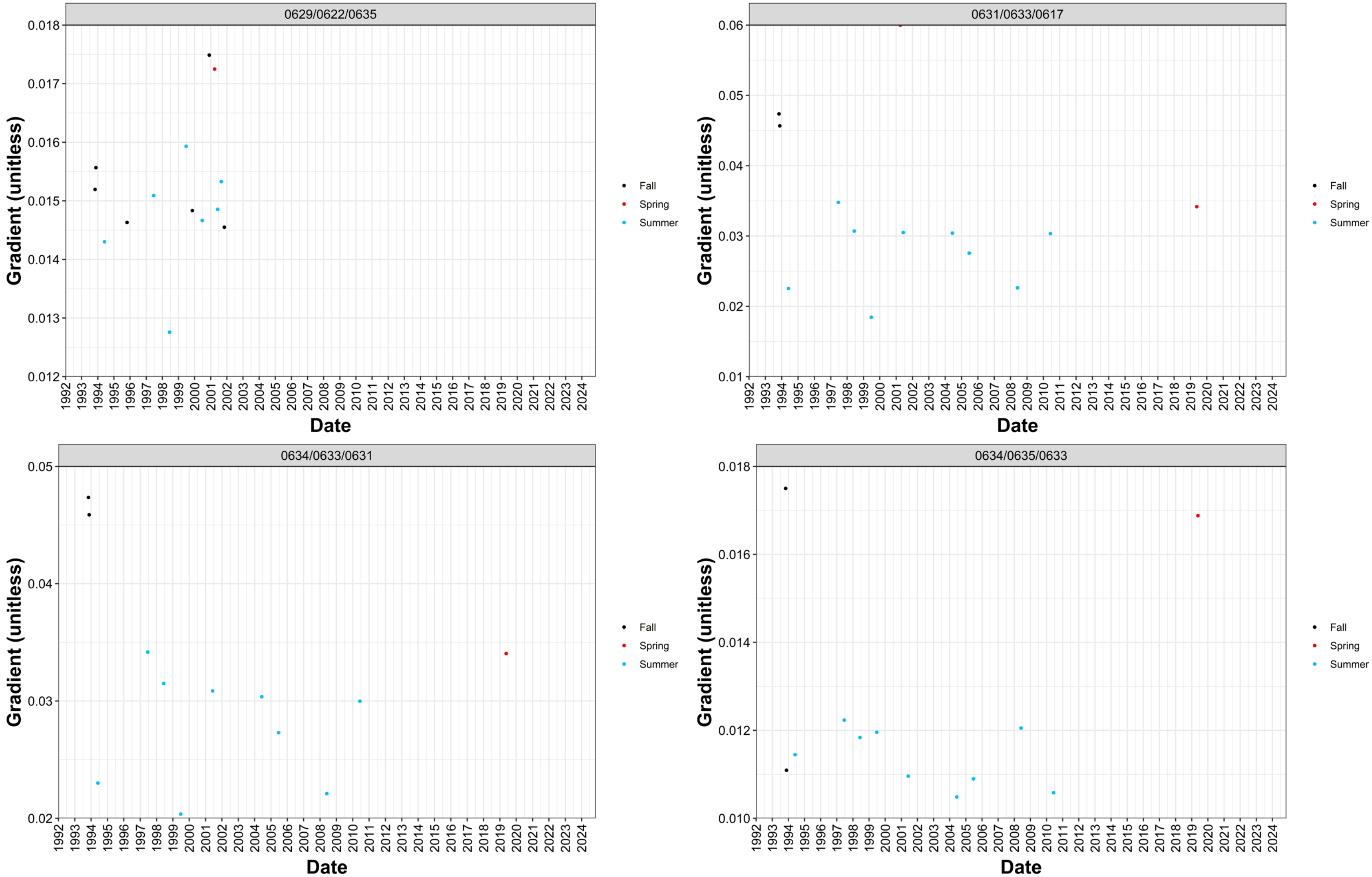


Figures A-1 through A-4. Mill Tailings Area Direction of Groundwater Flow Versus Time for Wells 0629, 0622, and 0635; 0631, 0633, and 0617; 0634, 0633, and 0631; and 0634, 0635, and 0633 (left to right)

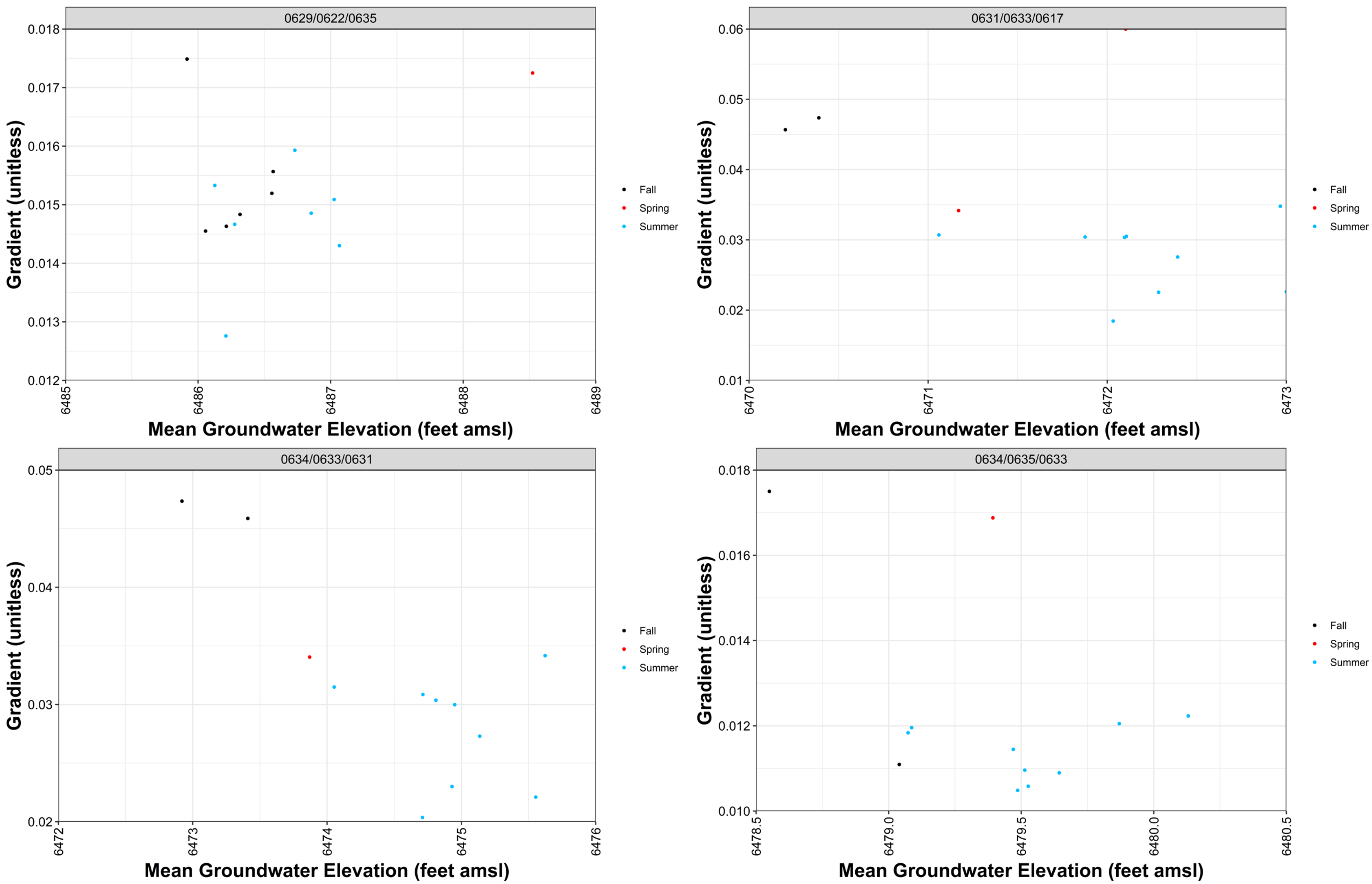


Abbreviation: amsl = above mean sea level

Figures A-5 through A-8. Mill Tailings Area Direction of Groundwater Flow Versus Mean Groundwater Elevation for Wells 0629, 0622, and 0635; 0631, 0633, and 0617; 0634, 0633, and 0631; and 0634, 0635, and 0633 (left to right)

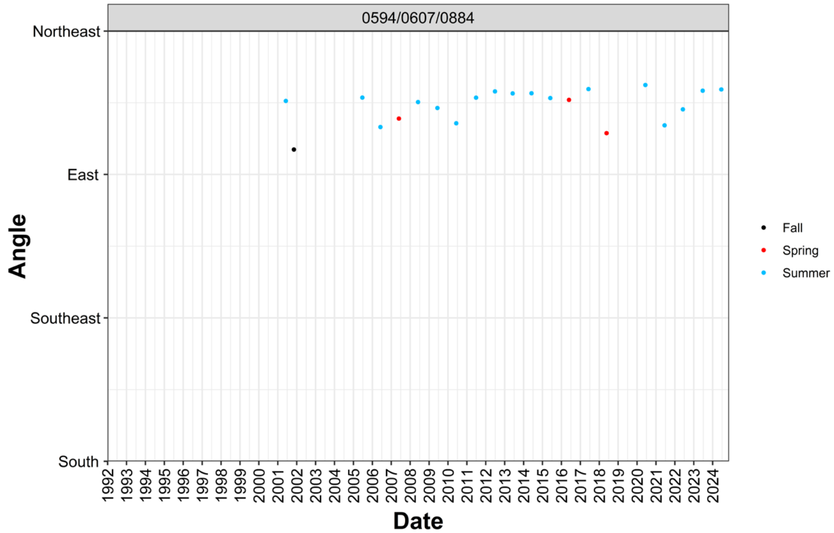


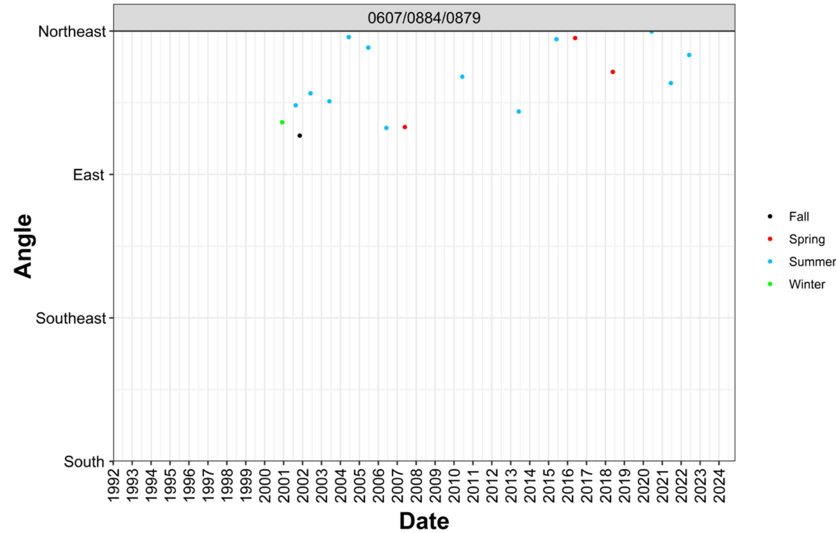
Figures A-9 through A-12. Mill Tailings Area Hydraulic Gradient Versus Time for Wells 0629, 0622, and 0635; 0631, 0633, and 0617; 0634, 0633, and 0631; and 0634, 0635, and 0633 (left to right)



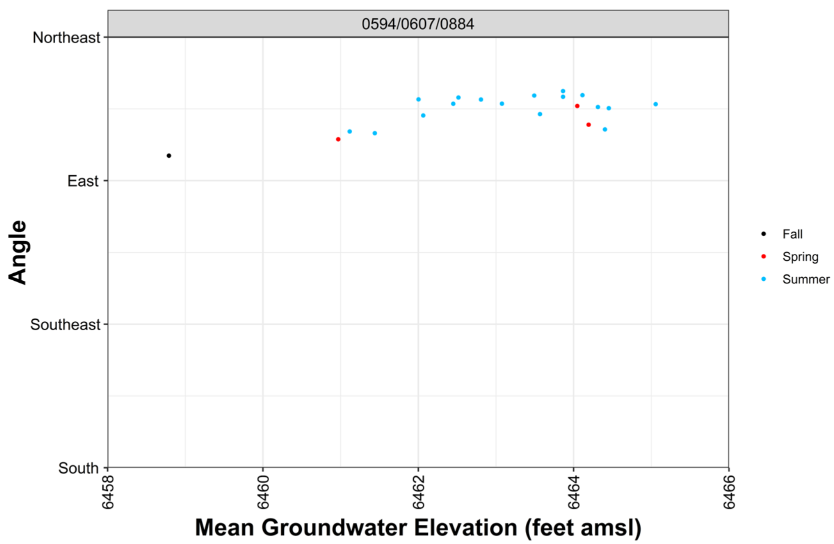
Abbreviation: amsl = above mean sea level

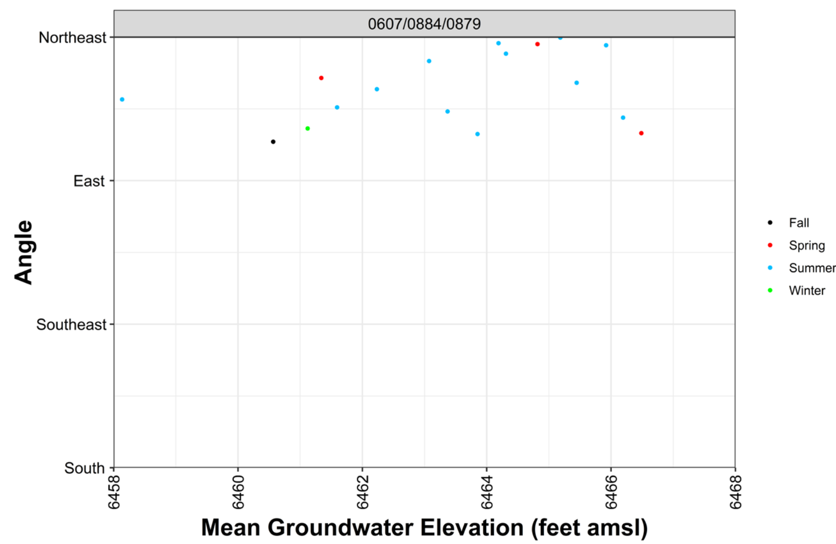
Figures A-13 through A-16. Mill Tailings Area Hydraulic Gradient Versus Groundwater Elevation for Wells 0629, 0622, and 0635; 0631, 0633, and 0617; 0634, 0633, and 0631; and 0634, 0635, and 0633 (left to right)





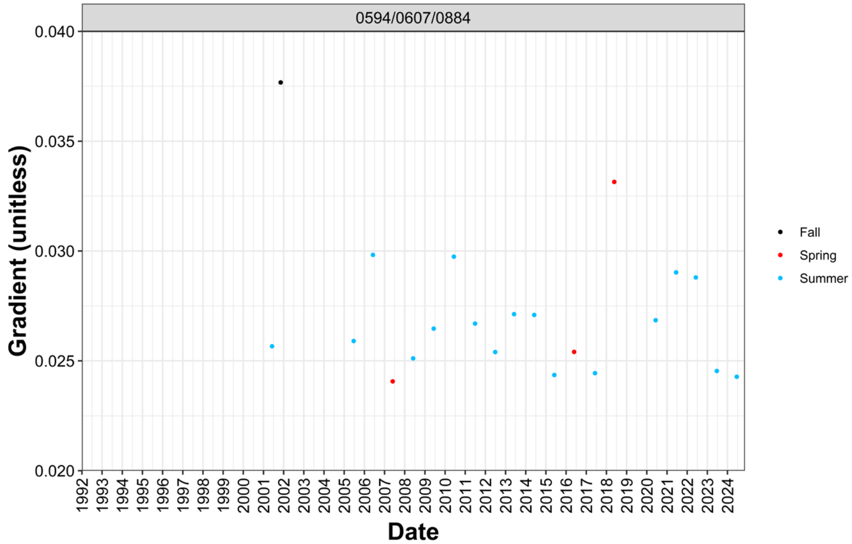
Figures A-17 and A-18. Raffinate Ponds Area Direction of Groundwater Flow Versus Time for Wells 0594, 0607, and 0884 and 0607, 0884, and 0879

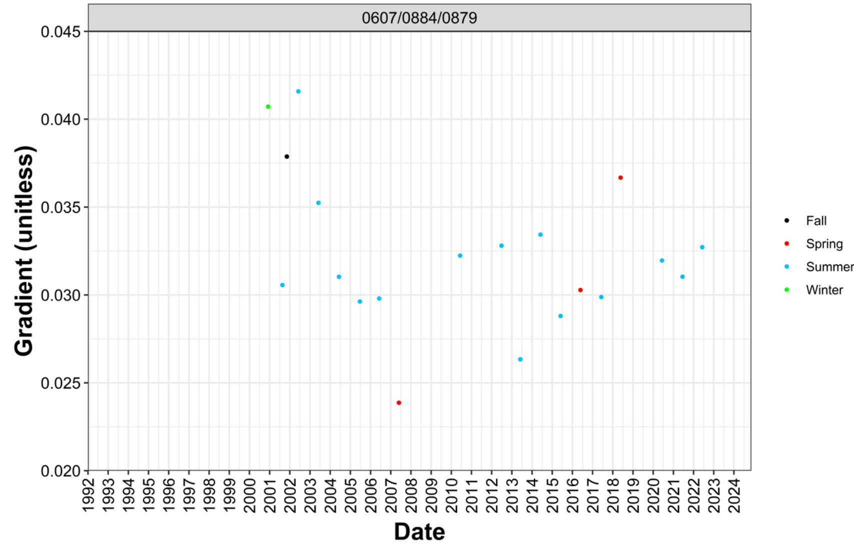




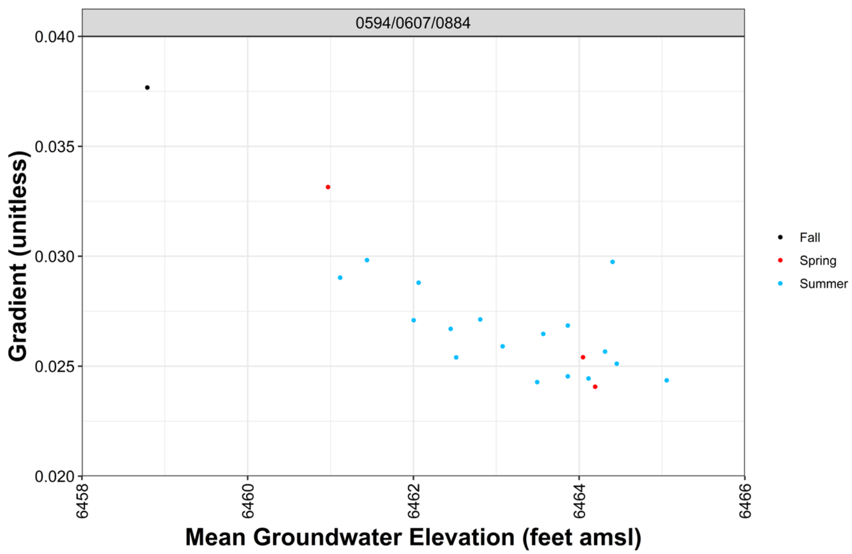
Abbreviation: amsl = above mean sea level

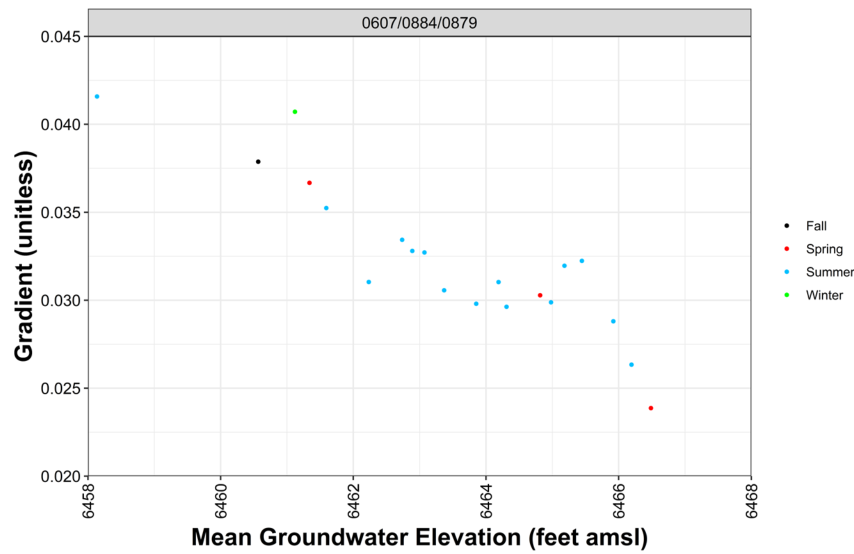
Figures A-19 and A-20. Raffinate Ponds Area Direction of Groundwater Flow Versus Mean Groundwater Elevation for Wells 0594, 0607, and 0884 and 0607, 0884, and 0879





Figures A-21 and A-22. Raffinate Ponds Area Hydraulic Gradient Versus Time for Wells 0594, 0607, and 0884 and 0607, 0884, and 0879





Abbreviation: amsl = above mean sea level

Figures A-23 and A-24. Raffinate Ponds Area Hydraulic Gradient Versus Mean Groundwater Elevation for Wells 0594, 0607, and 0884 and 0607, 0884, and 0879

Table A-1. Three-Point Estimator Results Summary for the Durango Processing Site Raffinate Ponds Area

Well Triangle	Min Base to Height Ratio	Max Base to Height Ratio	Date	Well 1 Water Level (ft)	Well 2 Water Level (ft)	Well 3 Water Level (ft)	Mean Water Level (ft)	Head Drop (ft)	Gradient	Angle (degree)
0629/0622/ 0635	0.21	5.14	11/1/1993	6490.8	6484.4	6484.5	6486.6	6.4	0.015	119
			11/19/1993	6490.9	6484.4	6484.4	6486.6	6.6	0.016	120
			6/1/1994	6491.1	6485.0	6485.1	6487.1	6.0	0.014	120
			10/25/1995	6490.3	6484.1	6484.2	6486.2	6.2	0.015	120
			6/18/1997	6491.2	6484.9	6485.0	6487.0	6.3	0.015	116
			6/13/1998	6489.8	6484.4	6484.5	6486.2	5.4	0.013	120
			6/24/1999	6491.2	6484.5	6484.5	6486.7	6.8	0.016	122
			11/9/1999	6490.5	6484.2	6484.3	6486.3	6.2	0.015	119
			6/22/2000	6490.4	6484.2	6484.2	6486.3	6.2	0.015	121
			11/29/2000	6490.4	6484.2	6483.2	6485.9	7.2	0.017	162
			3/29/2001	6492.9	6486.1	6486.5	6488.5	6.8	0.017	106
			6/6/2001	6490.9	6484.7	6484.9	6486.9	6.2	0.015	116
			8/27/2001	6490.4	6484.0	6484.0	6486.1	6.4	0.015	119
			11/5/2001	6490.1	6484.0	6484.1	6486.1	6.1	0.015	119
0631/0633/ 0617	0.47	2.35	11/1/1993	6467.6	6474.5	6469.1	6470.4	6.9	0.047	53
			11/19/1993	6467.5	6474.2	6468.9	6470.2	6.7	0.046	54
			6/1/1994	6471.5	6474.7	6470.7	6472.3	3.9	0.023	65
			6/18/1997	6471.5	6476.5	6470.9	6473.0	5.6	0.035	62
			6/10/1998	6469.5	6474.0	6469.7	6471.1	4.5	0.031	58
			6/24/1999	6471.4	6474.0	6470.8	6472.0	3.2	0.018	65
			4/3/2001	6468.6	6477.4	6470.4	6472.1	8.8	0.060	54
			6/6/2001	6470.5	6474.9	6470.9	6472.1	4.4	0.031	57
			6/9/2004	6470.6	6475.0	6470.1	6471.9	4.9	0.030	63
			6/20/2005	6471.4	6475.3	6470.5	6472.4	4.7	0.028	65
			6/2/2008	6472.4	6475.5	6471.1	6473.0	4.4	0.023	70
			6/8/2010	6470.9	6475.2	6470.1	6472.1	5.1	0.030	64
			5/21/2019	6469.5	6474.5	6469.6	6471.2	4.9	0.034	59
0634/0633/ 0631	0.36	3.43	11/1/1993	6476.7	6474.5	6467.6	6472.9	9.1	0.047	50
			11/19/1993	6478.5	6474.2	6467.5	6473.4	11.0	0.046	57
			6/1/1994	6478.7	6474.7	6471.5	6474.9	7.2	0.023	69
			6/18/1997	6478.9	6476.5	6471.5	6475.6	7.4	0.034	54
			6/10/1998	6478.7	6474.0	6469.5	6474.1	9.2	0.031	66
			6/24/1999	6478.8	6474.0	6471.4	6474.7	7.5	0.020	80
			6/6/2001	6478.7	6474.9	6470.5	6474.7	8.3	0.031	61
			6/9/2004	6478.9	6475.0	6470.6	6474.8	8.2	0.030	62
			6/20/2005	6478.8	6475.3	6471.4	6475.1	7.4	0.027	62
			6/2/2008	6478.8	6475.5	6472.4	6475.6	6.4	0.022	65
			6/8/2010	6478.7	6475.2	6470.9	6475.0	7.8	0.030	60
			5/21/2019	6477.7	6474.5	6469.5	6473.9	8.2	0.034	57

Table A-1. Three-Point Estimator Results Summary for the Durango Processing Site Raffinate Ponds Area (continued)

Well Triangle	Min Base to Height Ratio	Max Base to Height Ratio	Date	Well 1 Water Level (ft)	Well 2 Water Level (ft)	Well 3 Water Level (ft)	Mean Water Level (ft)	Head Drop (ft)	Gradient	Angle (degree)
0634/0635/ 0633	1.27	6.63	11/1/1993	6476.7	6484.5	6474.5	6478.6	10.0	0.017	62
			11/19/1993	6478.5	6484.4	6474.2	6479.0	10.2	0.011	118
			6/1/1994	6478.7	6485.1	6474.7	6479.5	10.4	0.011	104
			6/18/1997	6478.9	6485.0	6476.5	6480.1	8.5	0.012	72
			6/10/1998	6478.7	6484.6	6474.0	6479.1	10.6	0.012	128
			6/24/1999	6478.8	6484.5	6474.0	6479.1	10.5	0.012	132
			6/6/2001	6478.7	6484.9	6474.9	6479.5	10.0	0.011	103
			6/9/2004	6478.9	6484.6	6475.0	6479.5	9.7	0.010	110
			6/20/2005	6478.8	6484.9	6475.3	6479.6	9.6	0.011	96
			6/2/2008	6478.8	6485.3	6475.5	6479.9	9.8	0.012	85
			6/8/2010	6478.7	6484.6	6475.2	6479.5	9.4	0.011	97
			5/21/2019	6477.7	6486.1	6474.5	6479.4	11.6	0.017	72
0594/0607/ 0884	0.71	2.03	6/5/2001	6454.0	6478.4	6460.6	6464.3	24.4	0.026	67
			11/8/2001	6450.0	6476.8	6449.6	6458.8	27.3	0.038	82
			6/22/2005	6452.4	6477.3	6459.5	6463.1	24.9	0.026	66
			6/6/2006	6452.1	6476.8	6455.5	6461.4	24.7	0.030	75
			5/29/2007	6455.9	6476.9	6459.8	6464.2	20.9	0.024	72
			6/3/2008	6454.5	6478.2	6460.8	6464.5	23.7	0.025	67
			6/10/2009	6453.5	6477.8	6459.3	6463.6	24.3	0.026	69
			6/10/2010	6454.7	6479.9	6458.7	6464.4	25.2	0.030	74
			6/28/2011	6451.4	6477.1	6458.8	6462.5	25.7	0.027	66
			6/27/2012	6451.5	6476.6	6459.4	6462.5	25.1	0.025	64
			6/3/2013	6451.3	6477.8	6459.3	6462.8	26.6	0.027	65
			6/3/2014	6450.5	6477.0	6458.5	6462.0	26.6	0.027	65
			6/1/2015	6455.0	6478.5	6461.7	6465.1	23.4	0.024	66
			5/26/2016	6453.8	6478.0	6460.4	6464.0	24.2	0.025	67
			6/7/2017	6453.4	6477.8	6461.2	6464.1	24.4	0.024	63
			5/22/2018	6451.3	6477.7	6453.9	6461.0	26.5	0.033	77
			6/10/2020	6451.7	6478.9	6460.9	6463.9	27.2	0.027	62
			6/16/2021	6451.8	6476.1	6455.4	6461.1	24.3	0.029	75
			6/6/2022	6451.3	6477.6	6457.4	6462.1	26.3	0.029	70
			6/22/2023	6453.2	6477.5	6460.9	6463.9	24.3	0.025	64
			6/17/2024	6452.9	6477.0	6460.6	6463.5	24.2	0.024	63

Table A-1. Three-Point Estimator Results Summary for the Durango Processing Site Raffinate Ponds Area (continued)

Well Triangle	Min Base to Height Ratio	Max Base to Height Ratio	Date	Well 1 Water Level (ft)	Well 2 Water Level (ft)	Well 3 Water Level (ft)	Mean Water Level (ft)	Head Drop (ft)	Gradient	Angle (degree)
0607/0884/0879	0.83	1.42	12/5/2000	6478.9	6449.9	6454.5	6461.1	29.0	0.041	74
			8/21/2001	6477.0	6455.7	6457.5	6463.4	21.3	0.031	68
			11/8/2001	6476.8	6449.6	6455.3	6460.6	27.3	0.038	78
			6/4/2002	6476.7	6448.3	6449.4	6458.1	28.4	0.042	65
			6/3/2003	6477.3	6452.9	6454.6	6461.6	24.4	0.035	67
			6/9/2004	6477.7	6459.7	6455.2	6464.2	22.5	0.031	47
			6/22/2005	6477.3	6459.5	6456.1	6464.3	21.2	0.030	50
			6/6/2006	6476.8	6455.5	6459.3	6463.9	21.3	0.030	75
			5/29/2007	6476.9	6459.8	6462.8	6466.5	17.1	0.024	75
			6/10/2010	6479.9	6458.7	6457.8	6465.4	22.1	0.032	59
			6/27/2012	6476.6	6459.4	6452.7	6462.9	24.0	0.033	41
			6/3/2013	6477.8	6459.3	6461.4	6466.2	18.5	0.026	70
			6/3/2014	6477.0	6458.5	6452.7	6462.7	24.4	0.033	44
			6/1/2015	6478.5	6461.7	6457.6	6465.9	20.8	0.029	48
			5/26/2016	6478.0	6460.4	6456.1	6464.8	21.9	0.030	47
			6/7/2017	6477.8	6461.2	6456.0	6465.0	21.8	0.030	44
			5/22/2018	6477.7	6453.9	6452.4	6461.3	25.3	0.037	58
			6/10/2020	6478.9	6460.9	6455.7	6465.2	23.2	0.032	45
			6/16/2021	6476.1	6455.4	6455.2	6462.2	21.0	0.031	61
			6/6/2022	6477.6	6457.4	6454.3	6463.1	23.2	0.033	53

Notes:
Well 1, Well 2, and Well 3 identify the individual wells that make the vertices of the three-point estimator well triangle.
The angle is measured clockwise from north (0 degrees).

Appendix B

Bulk Plume Metrics Results

Table B-1. Bulk Plume Metrics and Groundwater Elevation Data Presented in Figure 19 for the Durango Processing Site Mill Tailings Area

Date	Average Plume Concentration (mg/L)	Uranium Mass (lb)	Plume Volume (million gallons)
4/1/2001	0.55	22.59	4.9
6/7/2001	0.42	20.90	6.0
8/27/2001	0.56	19.79	4.2
11/6/2001	0.71	19.52	3.3
6/5/2002	0.73	22.11	3.6
6/7/2003	0.52	22.58	5.2
6/9/2004	0.46	21.45	5.6
6/20/2005	0.37	18.83	6.1
6/6/2006	0.48	19.50	4.9
5/30/2007	0.45	18.72	5.0
6/2/2008	0.37	19.32	6.2
6/9/2009	0.34	13.82	4.8
6/8/2010	0.37	17.33	5.7
6/28/2011	0.36	15.51	5.2
6/26/2012	0.44	13.52	3.7
6/4/2013	0.44	15.06	4.1
6/4/2014	0.31	13.40	5.1
6/3/2015	0.37	15.04	4.9
8/18/2015	0.47	13.99	3.5
5/25/2016	0.37	13.97	4.6
6/8/2017	0.37	17.51	5.6
5/22/2018	0.55	15.43	3.4
5/21/2019	0.39	15.71	4.8
6/10/2020	0.43	16.98	4.7
6/16/2021	0.42	14.74	4.2
6/7/2022	0.35	11.19	3.9
6/20/2023	0.28	12.28	5.3
6/18/2024	0.36	13.07	4.4

Date	Groundwater Elevation at Well 0631 (ft amsl)
4/4/2001	6468.59
6/7/2001	6470.48
8/27/2001	6467.95
11/6/2001	6467.39
6/5/2002	6468.16
6/3/2003	6470.41
6/10/2004	6470.61
6/21/2005	6471.36
6/7/2006	6469.77
5/31/2007	6470.28
6/3/2008	6472.38
6/9/2009	6469.3
6/9/2010	6470.91
6/28/2011	6470.4
6/26/2012	6467.91
6/4/2013	6469.04
6/4/2014	6471.32
6/3/2015	6471.32
8/18/2015	6467.76
5/25/2016	6470.16
6/8/2017	6471.21
5/22/2018	6468.47
5/21/2019	6469.5
6/10/2020	6469.12
6/16/2021	6469.23
6/7/2022	6468.67
6/20/2023	6470.55
6/18/2024	6469.18

Abbreviations:
amsl = above mean sea level
lb = pounds