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2024 Verification Monitoring Report for the Slick Rock, Colorado, Processing Sites

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Abbreviations

ACL	alternate concentration limit
BTEX	benzene, toluene, ethylbenzene, and xylene
CDPHE	Colorado Department of Public Health and Environment
CFR	*Code of Federal Regulations*
COPC	constituent of potential concern
CSM	conceptual site model
EA	Environmental Assessment
ft	feet
GCAP	Groundwater Compliance Action Plan
GEMS	Geospatial Environmental Mapping System
IC	institutional control
LM	Office of Legacy Management
LOESS	locally estimated scatterplot smoothing
MCL	maximum concentration limit
mg/L	milligrams per liter
N	nitrogen
NAVD 88	North American Vertical Datum of 1988
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
^{226}Ra	radium-226
^{228}Ra	radium-228
SDWA	Safe Drinking Water Act
SOWP	Site Observational Work Plan
SRE	Slick Rock East
SRW	Slick Rock West
UMTRCA	Uranium Mill Tailings Radiation Control Act
VMR	Verification Monitoring Report

Executive Summary

The Slick Rock, Colorado, Processing Sites consist of two former uranium-ore processing facilities adjacent to the Dolores River in San Miguel County, Colorado: the Slick Rock East (SRE) site and the Slick Rock West (SRW) site. The sites are 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 are regulated by the U.S. Nuclear Regulatory Commission (NRC). This Verification Monitoring Report (VMR) summarizes groundwater and surface water monitoring data through calendar year 2024 and assesses the progress of aquifer restoration as it relates to the proposed compliance strategy of natural flushing combined with institutional controls (ICs) and compliance monitoring.

The compliance strategy for the SRE and SRW sites is documented in the 2003 *Preliminary Final Ground Water Compliance Action Plan for the Slick Rock, Colorado, UMTRA Sites*, also called the GCAP. Under this proposed strategy, both sites were anticipated to naturally flush to a condition in which groundwater cleanup objectives would be met within 100 years, the time frame permitted under UMTRCA regulations. The constituents of potential concern (COPCs) at the SRE site are uranium and selenium. COPCs at the SRW site include uranium, selenium, molybdenum, nitrate, and manganese. Several other COPCs—benzene, toluene, ethylbenzene, and xylene (collectively referred to as BTEX), radium-226 (^{226}Ra), and ^{228}Ra—are limited to a single SRW alluvial well (0319). As part of the compliance strategy for the SRW site, an alternate concentration limit (ACL) of 0.18 milligram per liter (mg/L) was proposed for selenium because initial flow and transport modeling predicted that concentrations would not naturally flush to levels below the corresponding UMTRCA maximum concentration limit (MCL) of 0.01 mg/L within 100 years.

The ICs proposed for the SRE and SRW sites are environmental covenants between the State of Colorado, represented by the Colorado Department of Public Health and Environment (CDPHE), and the landowner, Umetco Minerals Corporation. ICs are still pending for both sites; NRC will not concur with a proposed GCAP until ICs are established.

For both SRE and SRW sites, the discussion and interpretations documented in this report are generally consistent with conclusions drawn in the previous biennial VMR issued in July 2023. In September 2023, COPC concentrations increased in several wells, with some having the highest on record. Based on the 2024 sampling results, those concentrations have since declined to levels consistent with previous (pre-2023) results. With respect to the overall compliance strategy, the primary issues at both sites are the lack of attenuation found for several COPCs: most notably uranium, selenium (SRW only), and molybdenum.

At the SRE site, uranium concentrations remain above the 0.044 mg/L UMTRCA standard in most alluvial wells, with little to no attenuation since 2000 (the baseline period). Given increases in uranium concentrations in downgradient offsite wells to levels exceeding the standard, transport of milling-related uranium to locations across the Dolores River has likely occurred. In 2023, maximum uranium concentrations were measured in the majority of alluvial wells monitored at the site. Uranium concentrations in two wells have increased significantly in the last decade. These findings indicate that natural flushing has not been an effective groundwater remedy for uranium at the SRE site.

Selenium concentrations have exceeded the 0.01 mg/L MCL in only one SRE well (0305). Except for a recent spike of 0.13 mg/L measured in 2023, selenium concentrations in well 0305 have always been below the 0.05 mg/L U.S. Environmental Protection Agency Safe Drinking Water Act (SDWA) standard.

Uranium concentrations have routinely exceeded the 0.044 mg/L MCL in only two SRW site wells (0508 and 0510), screened in the alluvial aquifer in the area of the former tailings pile. Uranium concentrations in these wells have remained fairly stable at about 0.1 mg/L and in the last decade have shown no signs of attenuation.

Selenium and molybdenum concentrations within the alluvial aquifer at the SRW site indicate that natural flushing has not been an effective remedy for either COPC. Selenium concentrations have consistently exceeded the 0.18 mg/L ACL in five wells within or near the former tailings area (1.7–4.1 mg/L in 2024), and there has been little to no attenuation. Similarly, molybdenum concentrations in these five wells (0.91–2.1 mg/L in 2024) continue to exceed the corresponding 0.1 mg/L MCL, with no statistically significant reductions since 2000.

Although nitrate concentrations remain elevated relative to the 10 mg/L MCL in the same five tailings area wells noted above, concentrations have declined in these wells since 2000, in most cases significantly. These findings indicate that nitrate is flushing out of the alluvial aquifer at the SRW site, consistent with the current groundwater compliance strategy. Manganese concentrations in SRW wells are now all well within the range of background levels measured at SRE well 0300 and most are lower than the 3.5 mg/L benchmark.

All BTEX constituents continue to show significant decreasing concentration trends, suggesting that these analytes continue to be naturally flushed from the alluvial aquifer in the vicinity of well 0319. Currently, benzene is the only constituent that exceeds the corresponding SDWA maximum contaminant level in this well (0.69 mg/L in 2024). The ^{226}Ra and ^{228}Ra concentrations in well 0319 have decreased significantly since 2000 and have been below the corresponding 5 picocuries per liter UMTRCA MCL since 2008.

Based on annual surface water sampling conducted since 2000 and comparison of the results to corresponding surface water standards, there has been no apparent impact on the Dolores River water quality from historical milling activities at the Slick Rock former processing sites. Uranium concentrations at each surface water location continue to be below the lower bound chronic CDPHE water quality standard of 0.0168 mg/L and indistinguishable from background. COPC concentrations at SRW surface water locations have also been below the respective acute and chronic CDPHE water quality standards or, in the case of selenium, comparable to upstream (background) results.

1.0 Introduction

This Verification Monitoring Report (VMR) provides an update of natural flushing progress at the Slick Rock, Colorado, Processing Sites from the completion of surface remediation in 1996 to the present. The Slick Rock processing sites consist of two former uranium-ore processing facilities, referred to as the Slick Rock East (SRE) site (formerly the North Continent site) and the Slick Rock West (SRW) site (formerly the Union Carbide site). The processing sites are in a remote area along the Dolores River in San Miguel County, Colorado (Figure 1). The SRW site is approximately 1 mile downstream from the SRE site (Figure 2). The processing sites are owned by Umetco Minerals Corporation but managed by the U.S. Department of Energy Office of Legacy Management (LM) under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I program. Both sites are regulated by the U.S. Nuclear Regulatory Commission (NRC).

The proposed compliance strategy for the SRE and SRW sites is documented in the *Preliminary Final Ground Water Compliance Action Plan for the Slick Rock, Colorado, UMTRA Sites* (DOE 2003b), also called the GCAP. To achieve compliance with the maximum concentration limits (MCLs) established in Title 40 *Code of Federal Regulations* Section 192 (40 CFR 192), the proposed compliance strategy for the SRE and SRW sites is natural flushing in conjunction with institutional controls (ICs) and continued monitoring (DOE 2003b). Additionally, an alternate concentration limit (ACL) of 0.18 milligram per liter (mg/L) was proposed for selenium at the SRW site because initial flow and transport modeling predicted that selenium concentrations will not naturally flush to levels below the 0.01 mg/L MCL established under UMTRCA. ICs are pending for the Slick Rock sites until mineral rights issues are resolved. NRC will not concur with a proposed GCAP until ICs are established. The purpose of this VMR is to assess the progress of aquifer restoration as it relates to the current proposed compliance strategy of 100-year natural flushing and continued monitoring.

1.1 Background

From 1931 to 1942, the mill at the SRE site extracted vanadium from ore using a sulfuric acid leaching process. In 1942, the extraction techniques included an initial salt roast circuit with an acid-leach process to recover vanadium, uranium, and radium concentrates (Merritt 1971). Tailings and mill wastes were disposed of on the alluvial floodplain at the SRE site (Figure 3). The mill at the SRW site operated from 1957 to 1961 using a recirculated sulfuric acid solution, a sand-slime separation process, and ammonia neutralization to extract uranium from the ore. The finer fraction of upgraded material was sent to the mill at Rifle, Colorado, and tailings were disposed of on the alluvial floodplain at the SRW site (Figure 4).

Surface remediation at the Slick Rock sites began in 1995 and was completed in 1996. As part of the remediation process, uranium mill tailings and other residual radioactive materials associated with the former milling operations were relocated to the Slick Rock disposal cell (formerly called the Burro Canyon disposal cell), approximately 5 miles east of the Slick Rock processing sites (Figure 1). Approximately 134,000 cubic yards of material was relocated from the SRE site, and 671,000 cubic yards of material was relocated from the SRW site. The sites were regraded with onsite material, and subsequent revegetation efforts have been successful.

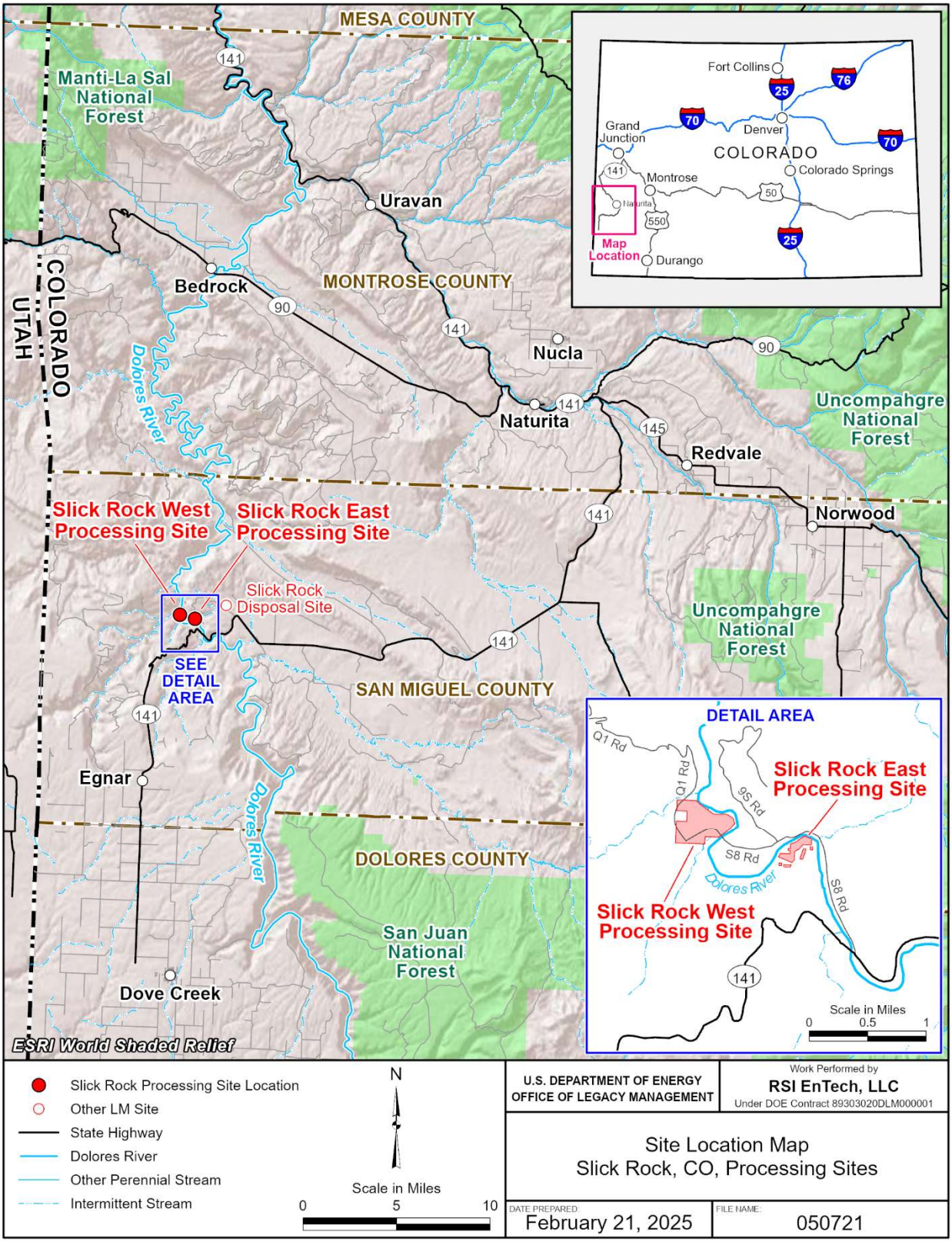


Figure 1. Slick Rock, Colorado, Processing Sites Location Map

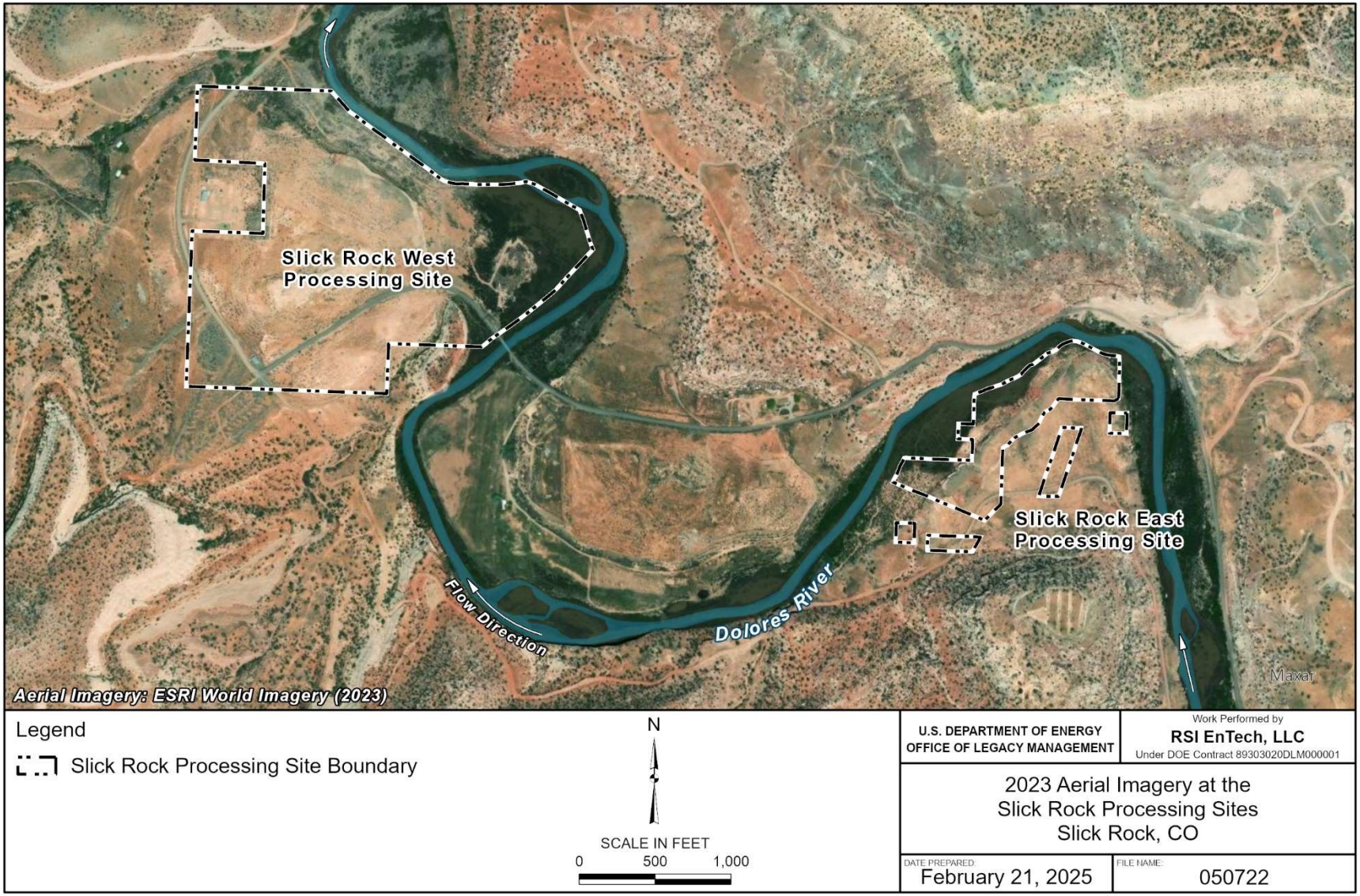


Figure 2. Aerial Photograph of the Slick Rock Processing Sites

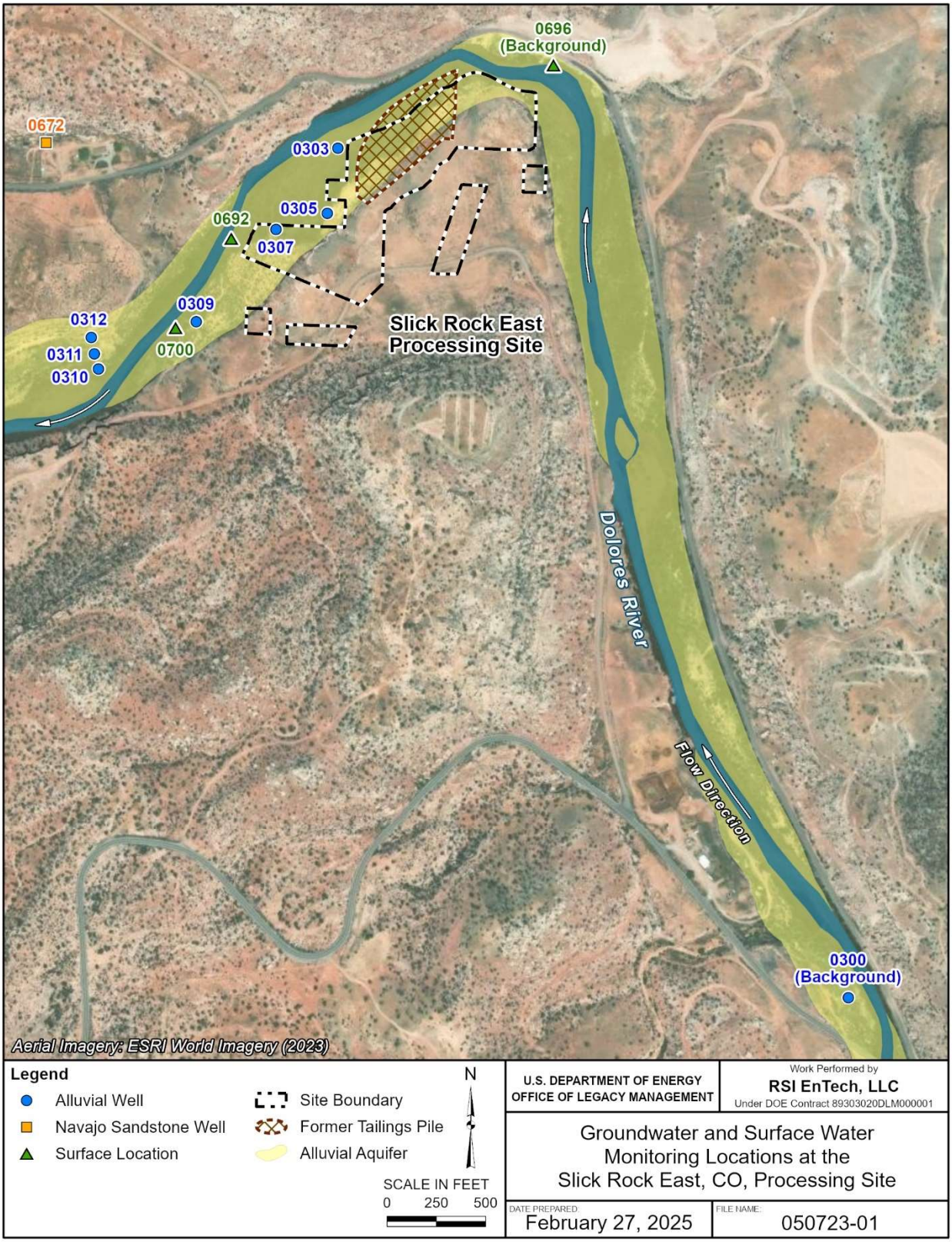


Figure 3. Groundwater and Surface Water Monitoring Locations at the SRE Site

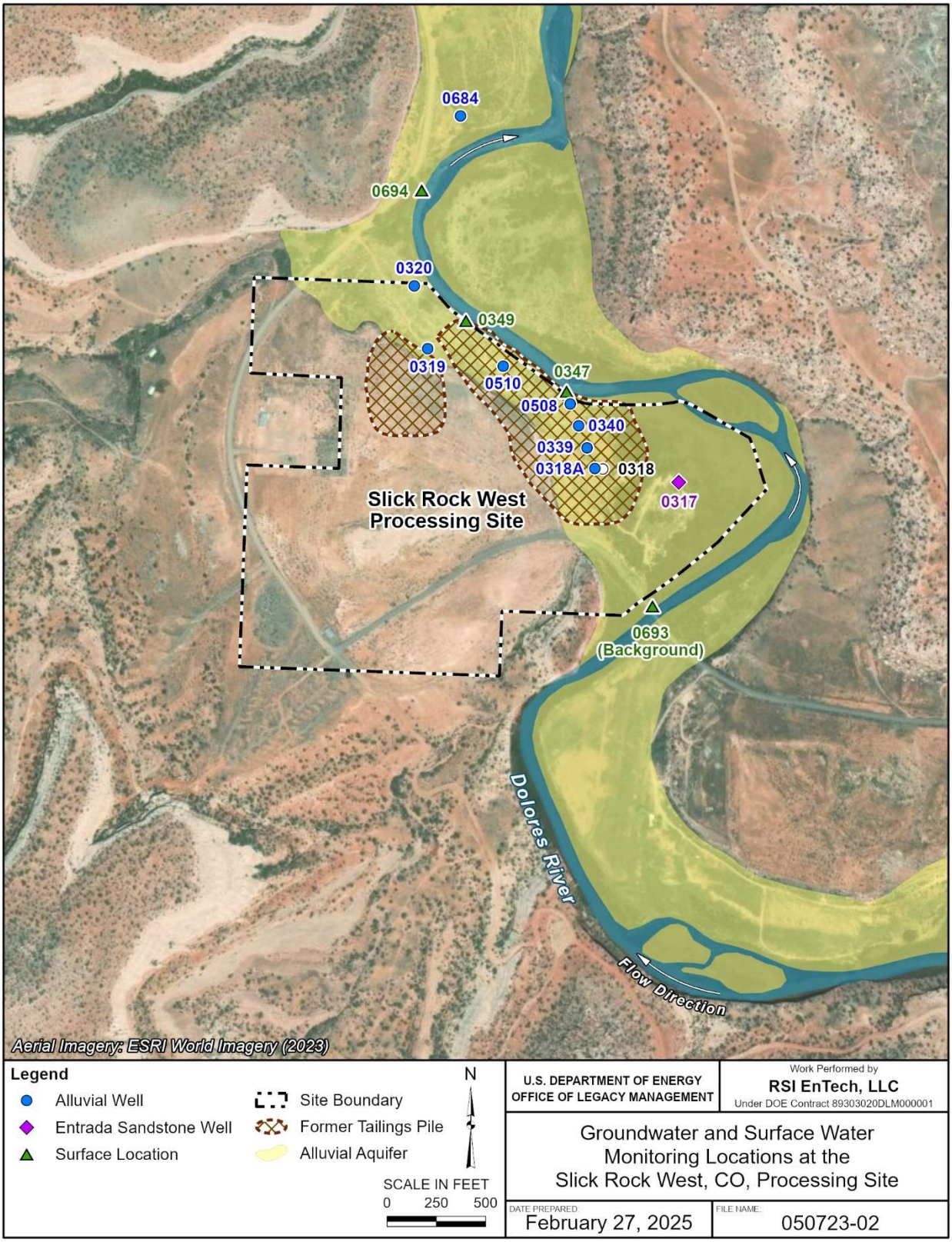


Figure 4. Groundwater and Surface Water Monitoring Locations at the SRW Site

Umetco Minerals Corporation currently owns the SRE and SRW sites; the land between the two sites is privately owned. Water for domestic or agricultural use in the area of the Slick Rock sites is primarily supplied by groundwater from the Navajo Sandstone. Historically, wells completed in the Navajo Sandstone provided water for the milling operations and for the mill community at the SRW site. There are no known uses of groundwater from either the alluvial aquifer or the underlying Entrada Sandstone beneath the former processing sites. More detailed historical information is provided in the following two reports: the *Site Observational Work Plan for the Slick Rock, Colorado, UMTRA Project Site*, also called the SOWP (DOE 2002), and the *Environmental Assessment of Ground Water Compliance at the Slick Rock, Colorado, UMTRA Project Sites* (DOE 2003a), also called the EA.[1]

1.2 Hydrologic Setting

To support this discussion, geologic diagrams and hydrologic cross sections for both the SRE and SRW sites are provided in Appendix A. The uppermost aquifer at both the SRE and SRW sites is the Dolores River alluvium, which ranges from 15 to 20 feet (ft) thick and is laterally restricted by the bedrock that forms the walls of the Dolores River Canyon (Figure A-1). The alluvial aquifer is discontinuous and pinches out in areas where the river meets the canyon wall. Alluvial deposits that also occur on the terraces adjacent to the river are typically unsaturated and hydrologically isolated from the Dolores River alluvial aquifer (DOE 2002). The alluvial aquifer consists primarily of silty sands and silty sandy gravels with an occasional interbedded clay lens (DOE 2002). Surface water inflow from the Dolores River provides the majority of recharge to the alluvial aquifer at both sites. Groundwater in the alluvial aquifer generally discharges back to the river.

The hydrostratigraphic units at the Slick Rock sites are, in descending stratigraphic order, the Dolores River alluvium, the Salt Wash Member of the Morrison Formation, the Summerville Formation, the Entrada Sandstone, and the Navajo Sandstone. The bedrock units dip approximately 6 degrees to the northeast in the Slick Rock area. The Salt Wash Member of the Morrison Formation is composed of intercalated fine-grained sandstone and mudstone layers. The Summerville Formation is composed of evenly-bedded mudstone, siltstone, and very fine- to fine-grained sandstone. Because of the fine-grained layers in these two formations, they are not major water-bearing units and were interpreted to have a relatively low permeability that limits vertical groundwater movement (DOE 2002). The Salt Wash Member and the Summerville Formation were not hydraulically characterized at the Slick Rock sites (DOE 2002).

The alluvial aquifer at the SRE site is bounded by the Dolores River to the east, north, and south. The alluvial aquifer is underlain by both the Salt Wash Member and the Summerville Formation at the site. Geologic cross sections indicate that the Entrada Sandstone is approximately 60 to 150 ft below the base of the alluvial aquifer at the SRE site (Figure A-2). No other relevant borehole data are available for the site within the SRE site boundaries. The Entrada Sandstone directly underlies the alluvial aquifer at the SRW site and is water-bearing (Figure A-3). The Entrada Sandstone ranges from 40 to 60 ft thick in the SRW site floodplain area and is unconfined when in connection with the alluvial aquifer. The Entrada Sandstone recharges from precipitation infiltration upgradient; the groundwater flow direction is generally to the east in the direction of the regional dip (DOE 2002).

[1] Key site-related documents are available on the LM public webpages at: https://lmpublicsearch.lm.doe.gov/SitePages/default.aspx?sitename=Slick_Rock_Processing.

Domestic groundwater use in the Slick Rock sites area is primarily supplied by the Navajo Sandstone, which underlies the Entrada Sandstone and is estimated to be 180 ft thick at the SRW site (DOE 2002). The Navajo Sandstone recharges from infiltration upgradient from the site where it outcrops. Upward vertical gradients were measured by comparing groundwater elevations in wells screened in the Navajo Sandstone to those screened in the Entrada Sandstone; these measurements indicate that groundwater in the Navajo Sandstone discharges upward into overlying units in the Slick Rock sites area (DOE 2002).

1.3 Site Compliance Strategy and Water Quality Monitoring

Steady state contaminant transport modeling conducted for the SOWP predicted that, based on a natural flushing remedy, concentrations of most constituents of potential concern (COPCs) would decrease to concentrations below the corresponding MCLs within the 100-year regulatory time frame established in 40 CFR 192 (DOE 2002). Based on these modeling efforts, the proposed compliance strategy for the SRE site is natural flushing in conjunction with ICs and continued monitoring (DOE 2003a; DOE 2003b). This compliance strategy was also proposed for the SRW site, along with an ACL of 0.18 mg/L for selenium. This ACL was proposed because initial flow and transport modeling predicted that selenium concentrations in SRW site alluvial wells would not naturally flush below the 0.01 mg/L UMTRCA MCL within 100 years.

The EA and the proposed draft GCAP state that public health will be protected during the natural flushing process through ICs that will restrict access to contaminated groundwater in the alluvial aquifer (DOE 2003a; DOE 2003b). The ICs proposed for the former Slick Rock processing sites are environmental covenants between the State of Colorado, represented by the Colorado Department of Public Health and Environment (CDPHE), and the landowner, Umetco Minerals Corporation. ICs are still pending for the Slick Rock sites because mineral rights issues between the State of Colorado and the U.S. Bureau of Land Management have not been resolved. NRC will not concur with a proposed GCAP until ICs are established.

1.3.1 COPCs and Remediation Goals

The primary COPCs at the Slick Rock sites are uranium and selenium. These COPCs are common to both the SRE and SRW sites. In addition to uranium and selenium, COPCs at the SRW site also include manganese, molybdenum, and nitrate (Table 1). Several other COPCs—benzene, toluene, ethylbenzene, and xylene (collectively referred to as BTEX), radium-226 (^{226}Ra), and ^{228}Ra—are monitored at just one location: SRW alluvial well 0319. To assess the status of compliance, COPC concentrations are compared to the groundwater compliance standards or alternate benchmarks listed in Table 1. Groundwater standards for molybdenum, nitrate as nitrogen (N), ^{226}Ra, ^{228}Ra, selenium (at the SRE site only), and uranium are the MCLs established under UMTRCA and codified in 40 CFR 192. At the SRW site, groundwater standards for BTEX are the maximum contaminant levels established under the U.S. Environmental Protection Agency's Safe Drinking Water Act (SDWA) (Title 42 *United States Code* Section 300f [42 USC 300f]). Given the lack of regulatory standards for manganese, the maximum upgradient concentration measured at the designated background location (SRE well 0300) (Figure 3) in 2000 was established as a benchmark (DOE 2002). As discussed above, a human health risk-based ACL of 0.18 mg/L was established for selenium and applied as an alternate benchmark for SRW wells (DOE 2003a; DOE 2003b).

Table 1. Groundwater Compliance Standards for COPCs at the SRE and SRW Sites

COPC	Compliance Standard or Benchmark	Basis[a]	Applicable Sites and Wells[b]
Uranium	0.044 mg/L	UMTRCA MCL	All wells except SRW wells 0317 and 0319
Selenium	SRE: 0.01 mg/L[c] SRW: 0.18 mg/L	SRE: UMTRCA MCL SRW: Proposed ACL (DOE 2002)	SRE wells 0300,[d] 0305, 0307, and 0672 All SRW wells
Manganese	3.5 mg/L[e]	Maximum concentration in background well 0300 in September 2000[e]	SRE wells 0300[d] and 0672 All SRW wells except 0317 and 0319
Molybdenum	0.10 mg/L	UMTRCA MCL	SRE wells 0300[d] and 0672 All SRW wells except 0319
Nitrate as N[f]	10 mg/L[f]	UMTRCA MCL	SRE well 0300[d] (background) All SRW wells except 0317 and 0319[c]
Benzene	0.005 mg/L	SDWA	SRW well 0319
Toluene	1 mg/L	SDWA	SRW well 0319
Ethylbenzene	0.7 mg/L	SDWA	SRW well 0319
Xylene	10 mg/L	SDWA	SRW well 0319
^{226}Ra and ^{228}Ra	5 pCi/L	UMTRCA MCL	SRE well 0300[d] (background, since 2014) SRW well 0319 (Analysis for radium in other SRW wells was discontinued after 2001 because concentrations were below 5 pCi/L)

Notes:

[a] All SDWA-based standards are the maximum contaminant levels established in 42 USC 300f.

[b] Wells listed in this column are based on monitoring recommendations made in the proposed draft GCAP (DOE 2003b); these recommendations are the same as those initially proposed in the EA (DOE 2003a) and the initial draft GCAP (DOE 2003b). The only exceptions are background well 0300 (monitored annually since 2014) and SRE Navajo Sandstone well 0672, which has been monitored as a best management practice for all analytes except nitrate, BTEX, and Ra since 2015.

[c] The UMTRCA MCL for selenium is less than the 0.05 mg/L SDWA maximum contaminant level.

[d] Although designated as an SRE site well for database purposes, well 0300 is considered representative of background alluvial groundwater quality for both the SRE and SRW sites (DOE 2002).

[e] Since 2001, manganese concentrations in background well 0300 (SRE) have exceeded 3.5 mg/L, the benchmark established in the SOWP (DOE 2002), four times. The maximum concentration in this well, 4.5 mg/L, was measured in September 2015.

[f] The UMTRCA-established MCL for nitrate at the sites is 10 mg/L as N, equivalent to 44.3 mg/L nitrate as NO_3. Between 2000 and 2004, samples were analyzed for nitrate as NO_3. For the purpose of this analysis, these results were converted to nitrate as N equivalents by applying a conversion factor of 0.2259.

Abbreviations:

pCi/L = picocuries per liter
USC = *United States Code*

1.3.2 Groundwater and Surface Water Monitoring Schedule and Locations

Groundwater and surface water samples are collected annually at the Slick Rock sites. At the SRE site, the current monitoring network consists of nine monitoring wells and three surface water locations (Figure 3). Table 2 lists each of these locations and describes the monitoring rationale and analytes measured. Except for the COPCs monitored in upgradient well 0300, uranium and selenium are the only COPCs currently monitored at the SRE site because concentrations of other COPCs have been below respective MCLs or compliance standards. Other tailings water indicator parameters, such as specific conductance and pH, are monitored at the SRE site in lieu of the full suite of COPCs. As noted in Table 1, although designated as an SRE site well for database purposes, well 0300 is considered representative of background alluvial groundwater quality for both the SRE and SRW sites (DOE 2002).

Table 2. SRE Site Water Quality Monitoring Locations

ID[a]	Location	Rationale[b]	Analytes
Groundwater			
0300[c]	Upgradient	Upgradient (background) monitoring location for both SRE and SRW sites (DOE 2002). For most analytes, sampled in 2000–2001, 2010, and 2014 to present.	Manganese, molybdenum, nitrate, ^{226}Ra, ^{228}Ra, selenium, and uranium
0303	Onsite	SRE uranium plume area.	Uranium
0305	Onsite	SRE uranium plume area; selenium also above the UMTRCA MCL.	Selenium and uranium
0307	Onsite	Uranium plume area; monitor selenium downgradient of well 0305.	
0309	Onsite	Farthest downgradient well onsite.	Uranium
0310[c]	Offsite (north bank of Dolores River)	Wells installed in August 2000 to assess potential uranium migration offsite and across the Dolores River.	
0311			
0312[c]			
0672[c]	Offsite, north of Dolores River	Completed in the Navajo Sandstone northwest of the SRE site; this domestic supply well has been monitored as a best management practice since 2015.	Selenium and uranium[d]
Surface Water			
0696	Upstream	Surface water background (inlet area).	Uranium
0692	Adjacent to site	Predicted location where the centroid of the uranium plume would intersect the river (DOE 2003b).	
0700[c]	Downstream	Location established in 2005, about 100 ft southwest of well 0309.	

Notes:
[a] Sampling locations are listed first in order of matrix and then by approximate flow direction (upgradient or upstream locations are listed first).
[b] Most rationales are from Table 3 of the proposed draft GCAP (DOE 2003b).
[c] Location added to the monitoring network after LM prepared the draft GCAP.
[d] Between 2015 and 2022, LM also monitored well 0672 annually for manganese and molybdenum (SRW COPCs). During that period, concentrations of these constituents were well below the standards or benchmarks listed in Table 1 (<0.01 and <0.0001 mg/L for manganese and molybdenum, respectively). Nitrate was also briefly monitored in this well (2021–2022 only); results were 0.4 mg/L, well below the 10 mg/L UMTRCA standard. Given these results, monitoring for SRW analytes was discontinued in 2023.

The monitoring network at the SRW site consists of nine monitoring wells and four surface water locations (Figure 4). Table 3 lists each location and describes the corresponding monitoring rationale and analytes measured.

Table 3. SRW Site Water Quality Monitoring Locations

ID[a]	Location	Rationale[b]	Analytes
Groundwater			
0317[c]	Onsite	Entrada Sandstone well where molybdenum concentrations have exceeded the UMTRCA MCL.	Molybdenum and (since 2010) selenium
0318, 0318A	Onsite	Area of highest measured concentrations for several COPCs. Due to a broken well screen, well 0318 was abandoned and replaced with well 0318A in September 2010.	Manganese, molybdenum, nitrate, selenium, and uranium
0339[d]	Onsite	Installed in September 2010 to better characterize the extent of elevated selenium in the eastern area of the former tailings pile.	
0340[d]	Onsite		
0508	Onsite	High selenium, nitrate, molybdenum, and uranium.	
0510	Onsite	Edge of former tailings pile; high COPC concentrations.	
0319	Onsite	Hot spot for BTEX and radium.	BTEX, ^{226}Ra, ^{228}Ra, and (since 2010) selenium
0320	Onsite	Farthest downgradient well onsite; monitor plume movement.	Manganese, molybdenum, nitrate, selenium, and uranium
0684	Offsite	Farthest downgradient well; verify contaminants are not migrating offsite.	
Surface Water			
0693	Upstream	Upstream SRW surface water location (but downstream of SRE).	Manganese, molybdenum, nitrate, selenium, and uranium
0347	Adjacent to site	Predicted location where the centroid of the selenium plume intersects the river (DOE 2003b).	
0349		Predicted location where the centroids of contaminant plumes intersect the river (DOE 2003b).	
0694	Downstream	Potential for contaminant plumes to discharge to the river at this location.	

Notes:

[a] Sampling locations are listed first in order of matrix then by approximate flow direction (upgradient or upstream locations are listed first).

[b] Rationales are from Table 4 of the proposed draft GCAP (DOE 2003b).

[c] The draft GCAP also recommends monitoring of Entrada Sandstone well 0324 for nitrate and selenium (DOE 2003b). Well 0324, colocated with alluvial well 0508 (see Figure 4-3 of the SOWP [DOE 2002]), has not been sampled since 2003.

[d] Denotes location added to the monitoring network after LM prepared the draft GCAP.

1.4 Evaluation Approach

To assess the effectiveness of the compliance strategy at the SRE and SRW sites, temporal trends in COPC concentrations in groundwater and surface water are evaluated relative to baseline conditions. Baseline conditions for the Slick Rock sites correspond to the earliest recorded sample in each well following the completion of surface remediation and establishment of the current monitoring network. Although surface remediation was completed in 1996, some wells were not installed until 2000. Therefore, for consistency, data from 2000 are used to characterize baseline conditions for both the SRE and SRW sites.

The assessment of natural flushing progress provided in this report is limited to the statistical evaluation of concentration trends because the current monitoring network at both sites does not allow for an evaluation of plume geometry over time or an evaluation of bulk plume metrics. For example, generation of defensible plume maps and contouring of concentration data is not possible for the SRE site because of the limited number of wells on either side of the discharge boundary (the Dolores River) and their configuration. Similarly, analysis of plume geometry is not possible for the SRW site because of the limited number of wells within the current monitoring network and their (mostly linear) configuration.

For chemical data, all time-concentration plots presented in this report were developed using a faceting approach, whereby data are partitioned into a matrix of panels, with each panel plotting data for a single well. In each facet, a nonparametric smoothing method—locally estimated scatterplot smoothing (LOESS)—is used, whereby the surrounding shaded area represents the 95% pointwise confidence interval. Because of the wide range in COPC concentrations /measured across SRE and SRW site wells, most data are plotted using a semilogarithmic scale. All temporal plots in this report were developed using R, version 4.4.2 (R Core Team 2024), and the *ggplot2* package, version 3.5.1 (Wickham 2016).

To facilitate interpretation of the analytical results and to assess the effectiveness of the proposed compliance strategies, Mann-Kendall trend analysis was performed for all monitoring well-COPC combinations. Only wells routinely monitored were included in these analyses. The Mann-Kendall nonparametric test is used to statistically assess if there is an upward or downward trend of the variable of interest over time. This test characterizes the direction of concentration trends using a 0.05 significance (or alpha) level, meaning there is a 5% chance of concluding that a trend exists that could simply be the result of random chance. Mann-Kendall trends were initially run for the period 2000–2024, representing measurements collected since comprehensive postremediation monitoring began. To account for more recent shifts in concentration trends, a second set of trend tests was run for the 2014–2024 time frame.

In accordance with LM's quality assurance procedures, field duplicates are routinely collected during semiannual sampling events. In interpreting and mapping the data for this VMR, and for consistency with the data used for trend analyses, only the original sample is used for reporting purposes (results of duplicate analyses are excluded). At times, the field duplicate results are higher than the corresponding initial sample, but these results are generally within the range of laboratory variation associated with the analytical method. Results labelled in all time-concentration plots and in the corresponding spatial distribution maps are rounded to two or three significant figures (depending on magnitude). Historical water quality and water level data for both SRE and SRW sites (including results of duplicate analyses) are reported and published on the LM Geospatial Environmental Mapping System (GEMS) website at https://gems.lm.doe.gov/.

2.0 SRE Compliance Remedy Performance

The proposed groundwater compliance strategy at the SRE site is natural flushing in conjunction with ICs and continued monitoring for uranium and selenium, the two COPCs at the site (DOE 2003a; DOE 2003b). This section begins with a discussion of groundwater elevation trends. Spatial distributions and temporal trends for uranium and selenium concentrations are then evaluated for monitoring wells at and downgradient of the SRE site.

2.1 Groundwater Levels

Groundwater elevations measured in SRE site alluvial wells during the 2024 sampling event are shown in Figure 5; corresponding temporal trends are shown in Figure 6. The vertical datum used in these and subsequent water elevation plots is North American Vertical Datum of 1988 (NAVD 88). Groundwater elevations generally decrease in the direction the river flows, as is expected and consistent with the groundwater flow direction evaluation in the SOWP (DOE 2002). Groundwater elevation data are not available for Navajo Sandstone well 0672 because it is an active domestic supply well, and, as such, its water levels are variable in response to pumping. Historically, groundwater levels in SRE site wells have typically fluctuated about 2–3 ft (Figure 6), consistent with observations in the SOWP (DOE 2002).

2.2 COPC Spatial Distributions and Temporal Trends

This section updates groundwater monitoring data collected at the SRE site and assesses the status of the natural flushing compliance strategy for groundwater cleanup. Apart from field parameters, uranium and selenium are the primary COPCs currently monitored at the SRE site, as levels of other constituents have been below respective groundwater standards. Background well 0300 is an exception, as this well also serves as the background location for the SRW site. Therefore, several SRW site COPCs are also monitored in this well, as indicated in Table 2. While uranium is monitored at each SRE well location, selenium is monitored at only four wells: 0300, 0305, 0307, and (as a best management practice) domestic supply well 0672. Figure 7 plots uranium and selenium concentrations in SRE site monitoring wells for baseline (2000) and current (2024) conditions. To facilitate comparisons, wells that were sampled during the baseline period that are no longer monitored are shown in red.

2.2.1 Uranium

Figure 7 indicates that uranium concentrations in onsite wells and wells downgradient of the historical tailings boundary (wells 0303, 0305, 0307, and 0309) are still elevated relative to the 0.044 mg/L MCL. In 2024, uranium concentrations exceeded this standard in all (non-background) SRE alluvial wells except well 0310, north of and adjacent to the Dolores River (0.035 mg/L in 2024). In 2023, however, the uranium result for well 0310 (0.060 mg/L) was the highest on record for this well, exceeding the UMTRCA standard for the first time (Figure 8). Maximum uranium concentrations were also recorded for five other SRE wells in 2023: well 0305 (2.4 mg/L, 0307 (1.6 mg/L), well 0309 (0.51 mg/L), well 0311 (0.21 mg/L), and upgradient location 0300 (0.047 mg/L) (Figure 8). During the September 2023 monitoring event, samplers noted evidence of floodwater at several locations, including well 0307. Relative to the start of measurements in June 2020, Dolores River elevations at the nearby gage peaked in May 2023 (https://waterdata.usgs.gov/monitoring-location/09168730), likely accounting for the 2023 rise in

groundwater elevations shown in Figure 6. The nature of the hydrologic connection between groundwater at the Slick Rock sites and the Dolores River and its influence on contaminant release to the dissolved phase has not been evaluated at either (SRE or SRW) site. This potential influence will be addressed in LM's future updates to the conceptual site model (CSM).

North of well 0310, uranium concentrations in well 0311 have consistently exceeded the 0.044 mg/L MCL, while those in well 0312 have periodically exceeded the standard (Figure 8). Uranium concentrations in Navajo Sandstone well 0672 (0.003 mg/L in 2024) have not changed since the baseline period (consistently 0.003 mg/L). The MCL has been exceeded twice in well 0300, once in 2014 (0.045 mg/L) and more recently in 2023 (0.045 mg/L).

Since 2000, Mann-Kendall trend analysis indicates no statistically significant trends in uranium concentrations in most SRE wells (Table 4). Uranium concentrations in SRE well 0303, downgradient of the former tailings pile, continue to be relatively stable at about 1 mg/L. Uranium concentrations in wells 0305 and 0307 are now similarly elevated. Since 2000, statistically significant trends were found for onsite well 0305 (decreasing) and offsite well 0311 (increasing) (Table 4). A statistically significant increasing trend was also found for far upgradient (background) well 0300 (increasing), a trend that will be further evaluated as part of LM's future updates to the CSM. Trend analysis conducted for the 2014–2024 time frame indicates significant increasing trends for wells 0307 and 0309; no significant trend was found for remaining wells.

Overall, these findings indicate that natural flushing has not been an effective attenuation mechanism for uranium at the SRE site. Uranium concentrations in wells 0303, 0305, and 0307 remain at levels about an order of magnitude greater than the steady-state modeling predictions documented in the SOWP, assuming 20 years of natural flushing (DOE 2002). Uranium concentrations in onsite well 0307 and offsite well 0309 have increased significantly in the last decade, while concentrations in far downgradient wells across the river (wells 0310, 0311, and 0312) continue to approach or exceed the 0.044 mg/L MCL.

2.2.2 Selenium

Because of historically low concentrations throughout the monitoring network (Figure 7), selenium is currently monitored in only four SRE site wells: 0300 (background), 0305, 0307, and 0672. Selenium concentrations have exceeded the 0.01 mg/L UMTRCA MCL in well 0305 only (typically 0.02–0.03 mg/L), below the 0.05 mg/L SDWA maximum contaminant level (Figure 9). The 2023 monitoring event was an exception, when, similar to the increases in uranium concentrations noted previously, selenium increased from 0.031 mg/L (in 2022) to 0.13 mg/L, a historical maximum for this well. That spike was not sustained; the most recent (2024) result was 0.012 mg/L, consistent with most historical measurements and essentially equal to the MCL.

Although a statistically significant decreasing trend was found for well 0305 using data since 2000, no significant trend was found for the 2014–2024 time frame (Table 4; Figure 9). For both analysis time frames, no significant trend was found for remaining SRE wells.

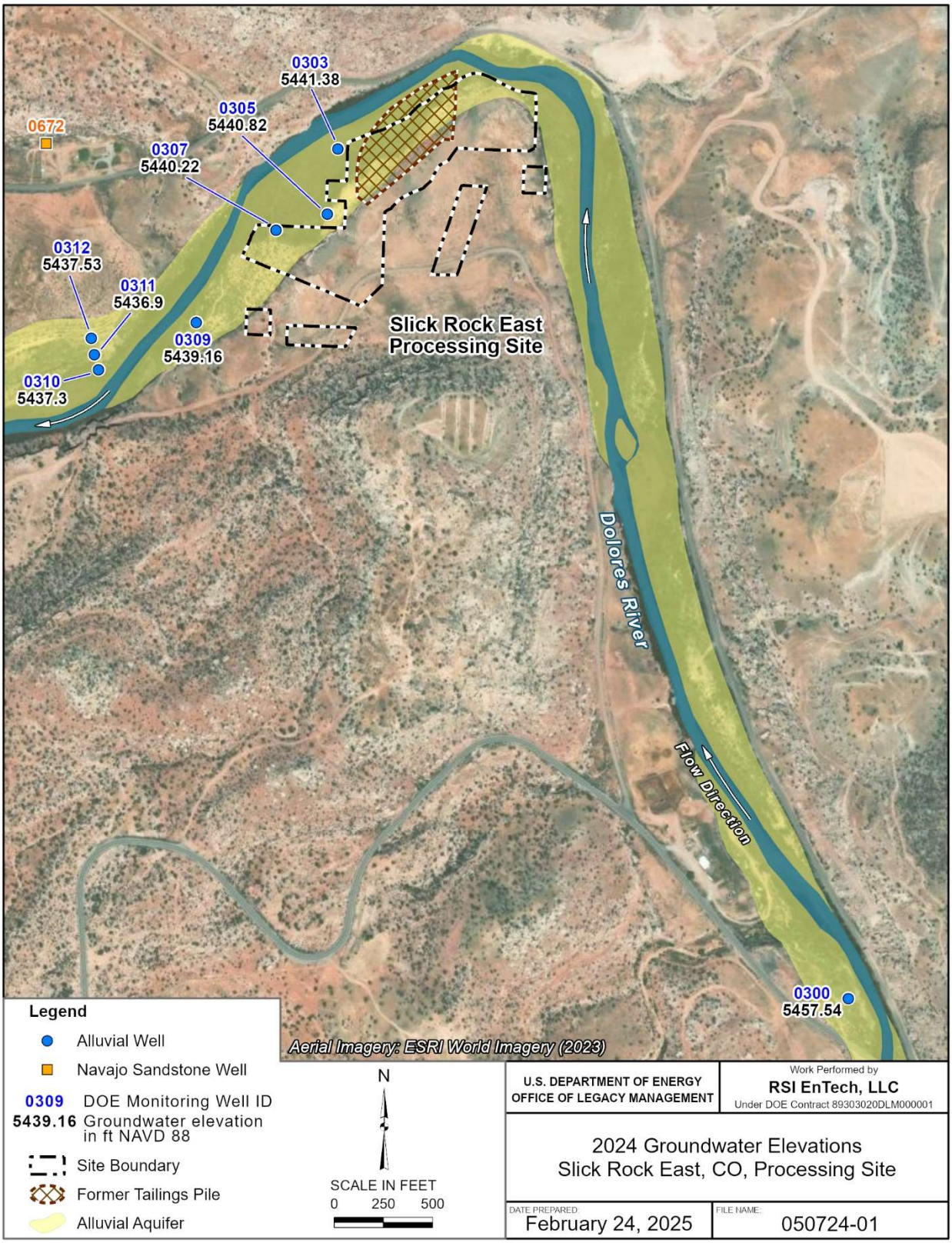
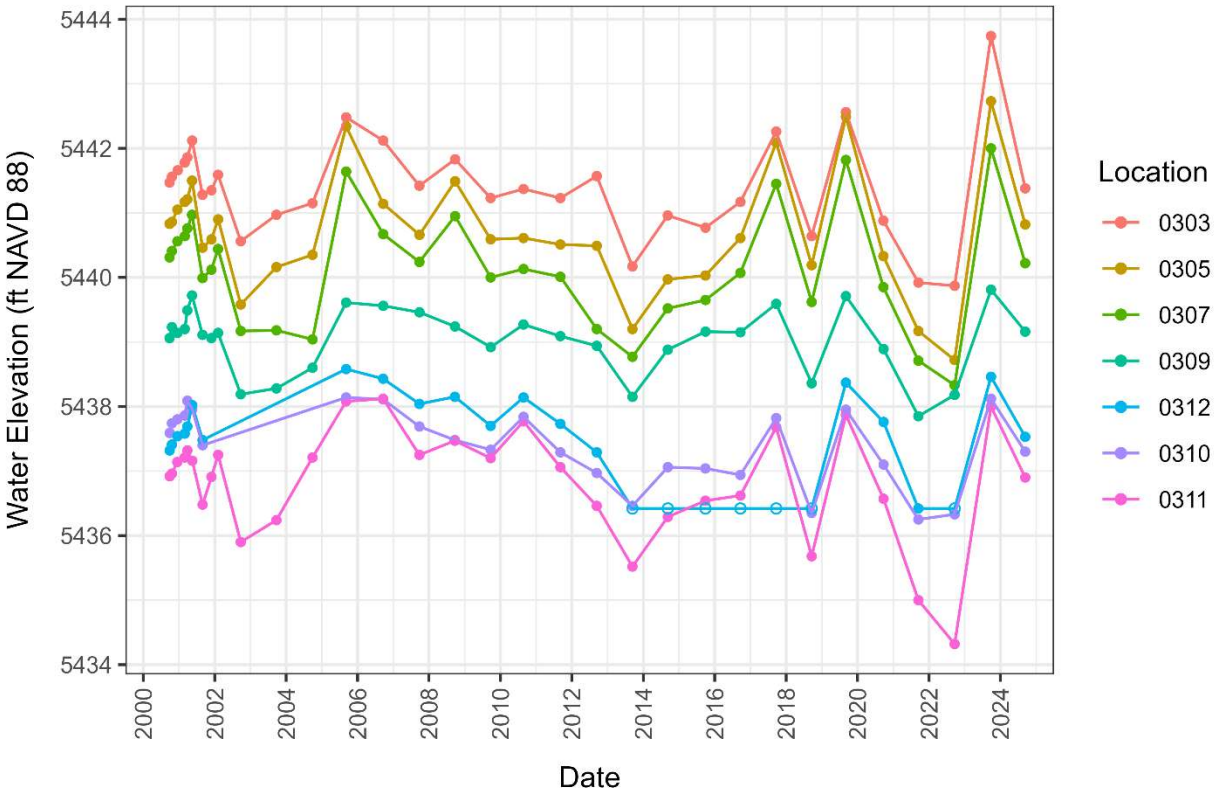
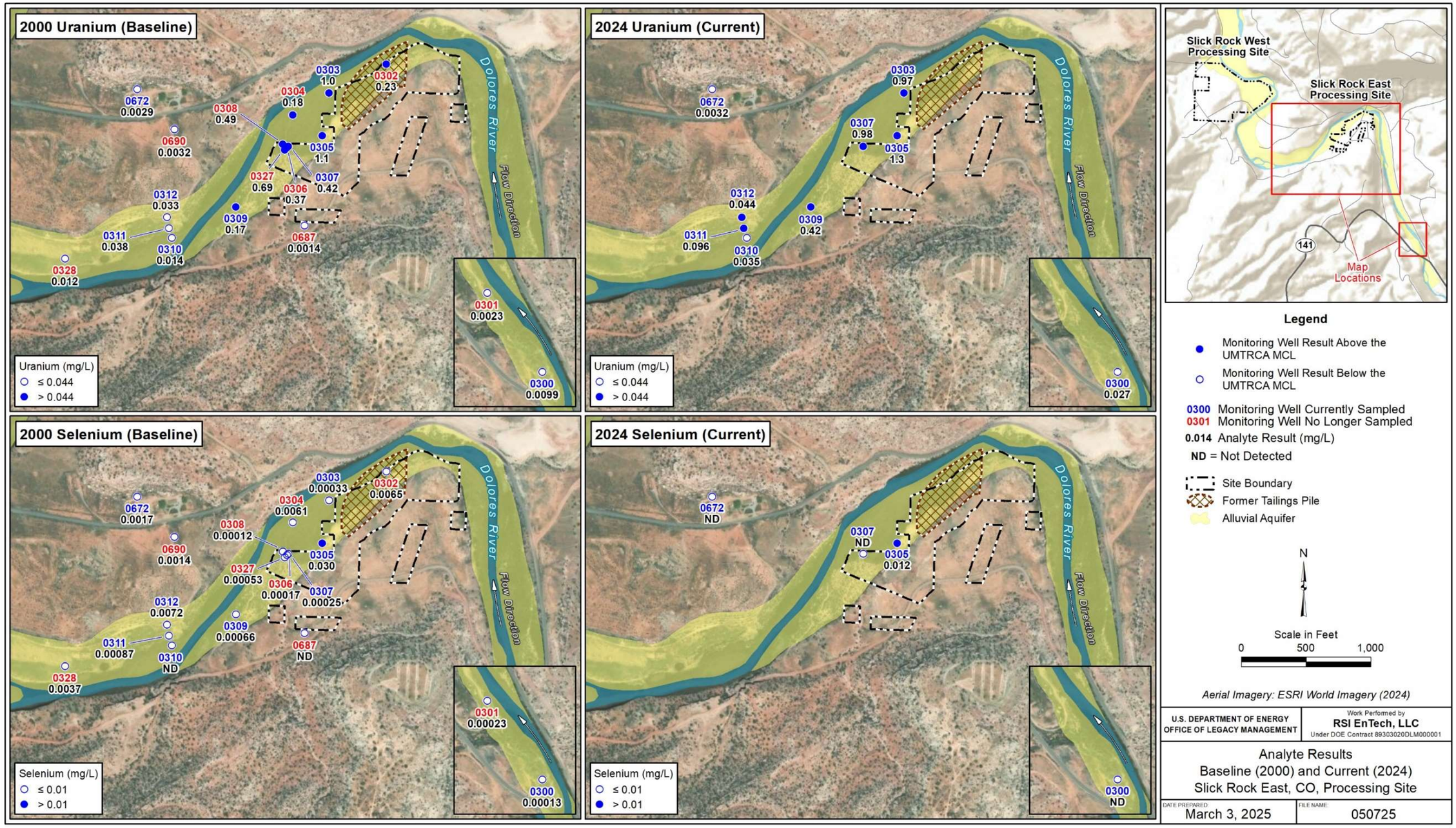


Figure 5. 2024 Groundwater Elevations in SRE Site Monitoring Wells



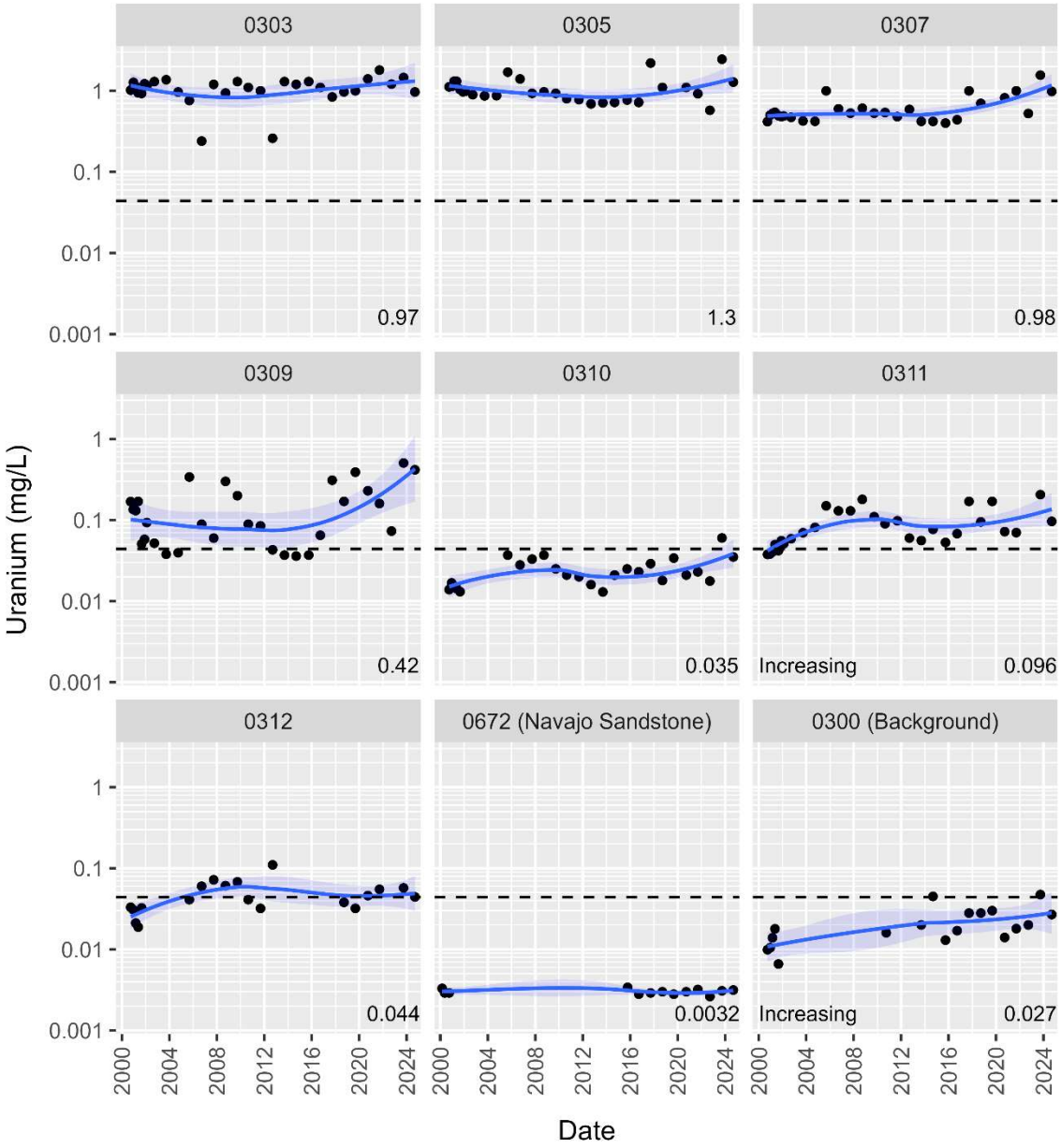
Notes:
In the legend, monitoring wells are listed in order of descending average groundwater elevation. Water elevations are not shown for background well 0300 because they are approximately 10–20 ft higher than those in wells on and downgradient of the SRE site (5455.5 to 5458.7 ft NAVD 88). Open symbols (○) for well 0312 denote that the well was dry at the time of measurement. For plotting purposes, these records are assigned values equal to the minimum recorded elevation.

Figure 6. Groundwater Elevation Trends in SRE Site Monitoring Wells, 2000–2024



Note: Baseline results are from September 2000; all results are rounded to two significant figures. Because the 2024 result for SRE well 0312 was 0.0443 mg/L, the filled symbol denotes an exceedance of the MCL.

Figure 7. Uranium and Selenium Concentrations in SRE Site Monitoring Wells, 2000 and 2024



Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results.
For wells with statistically significant trends for the 2000–2024 time frame (Table 4), the direction of the trend is indicated in the lower left corner of the plot. Because of the doubling of uranium concentrations in well 0311 between 2001 and 2004, sampling at wells 0310 and 0312 resumed in 2005 after a 4-year hiatus.

Figure 8. Time-Concentration Plots of Uranium in SRE Site Monitoring Wells, 2000–2024

Table 4. Mann-Kendall Trend Test Results for COPCs in SRE Site Wells, 2000–2024

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	Most Recent Result (mg/L)	2000–2024 Time Frame				2014–2024 Time Frame				
				No. of Samples (No. of Nondetects)[b]	Kendall's Tau[c]	*p* Value[d]	Trend	Initial Trend Analysis Date	No. of Samples (No. of Nondetects)[b]	Kendall's Tau[c]	*p* Value[d]	Trend
Uranium												
0303	9/26/2000	9/11/2024	0.97	30	0.12	0.35	None	09/08/2014	11	0.13	0.64	None
0305	9/26/2000	9/11/2024	1.3	29	−0.21	0.11	Decreasing	09/08/2014	10	0.29	0.28	None
0307	9/26/2000	9/11/2024	0.98	29	0.25	0.060	None	09/08/2014	10	0.53	0.039	Increasing
0309	9/26/2000	9/11/2024	0.42	30	0.13	0.31	None	09/08/2014	11	0.53	0.029	Increasing
0310	9/27/2000	9/11/2024	0.035	25	0.24	0.097	None	09/09/2014	11	0.20	0.43	None
0311	9/27/2000	9/11/2024	0.096	29	0.44	0.001	Increasing	09/09/2014	10	0.31	0.24	None
0312	9/27/2000	9/11/2024	0.044	19	0.28	0.11	None	09/19/2018	6	0.47	0.26	None
0672	2/25/2000	9/11/2024	0.0032	13	0.013	1	None	10/15/2015	10	0.11	0.72	None
0300	9/27/2000	9/11/2024	0.027	18	0.49	0.005	Increasing	09/08/2014	11	0.14	0.58	None
Selenium												
0305	9/26/2000	9/11/2024	0.012	30	−0.38	0.003	Decreasing	09/08/2014	11	0.04	0.94	None
0307	9/26/2000	9/11/2024	<0.0015	30 (19)	0.15	0.22	None	09/08/2014	11 (8)	0.04	0.93	None
0672	2/25/2000	9/11/2024	<0.0015	13 (4)	−0.10	0.65	None	10/15/2015	10 (4)	−0.18	0.49	None
0300	9/27/2000	9/11/2024	<0.0015	18 (10)	0.11	0.51	None	09/08/2014	11 (6)	−0.26	0.25	None

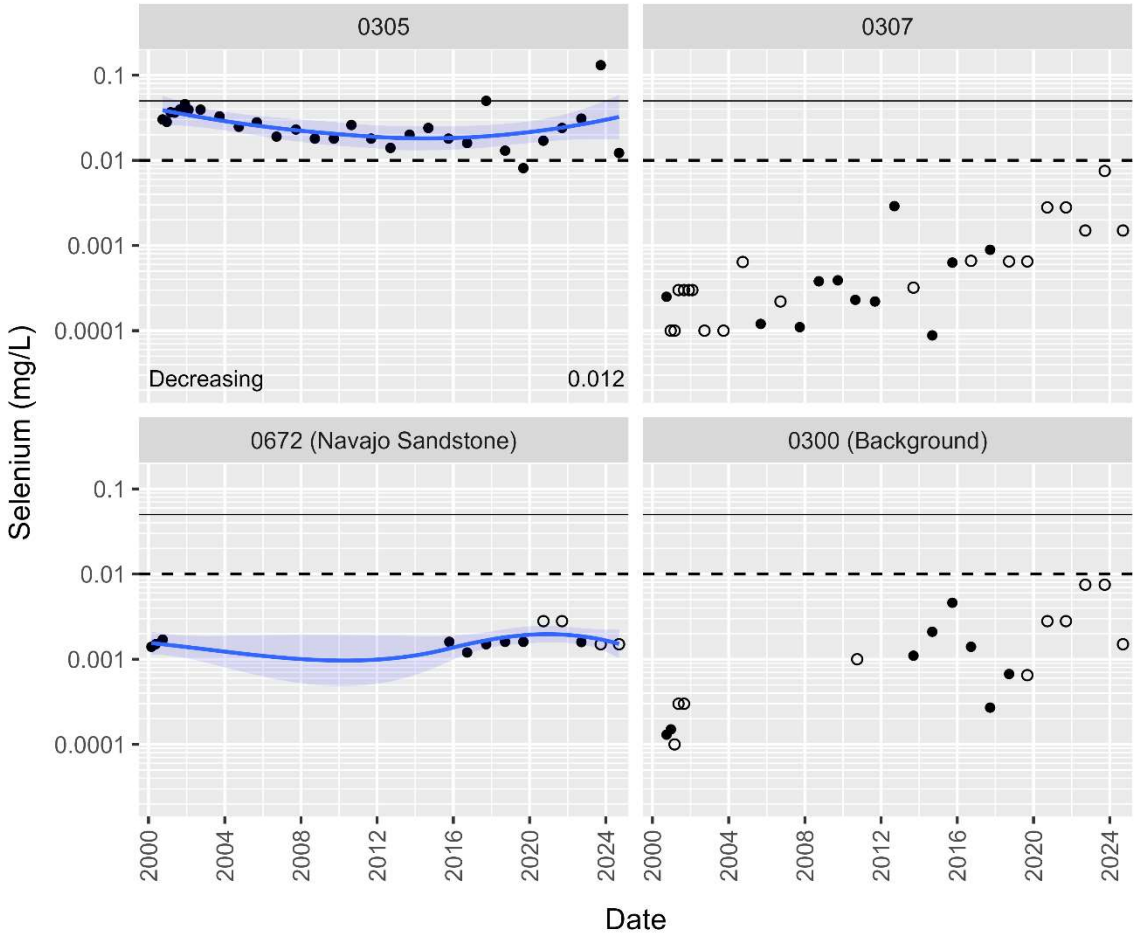
Notes:

[a] For each COPC, wells are listed in approximate order of increasing distance from the former SRE tailings area and flow direction. Mann-Kendall trend test results for background well 0300 are listed last.

[b] The number of nondetects is only indicated for well-parameter combinations with nondetect results. Detection frequencies for uranium were all 100%.

[c] Trend tests were performed using the NADA (Nondetects and Data Analysis for Environmental Data) package in R, version 1.6-1.1 (Lee 2025). 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. All trend tests were run using a 0.05 significance (or alpha) level. 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. A tau value of 1.0 corresponds to a perfect strong association between the time series, indicating a significant increasing trend. Conversely, a perfect association in the negative direction (for decreasing trends) will have a tau value of −1.0. Time series data with no statistically significant trend will have a tau value closer to 0.0.

[d] A calculated *p* value of <0.05 indicates that the null hypothesis is rejected and a significant trend in the time series exists.



Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results; only results above the detection limit are shown. For the well(s) with statistically significant trends for the 2000–2024 analysis time frame (Table 4), the direction of the trend is indicated on the plot. For all wells, no statistically significant trend was found for the 2014–2024 data subset (Table 4).

Figure 9. Time-Concentration Plots of Selenium in SRE Site Monitoring Wells, 2000–2024

3.0 SRW Compliance Remedy Performance

The proposed groundwater compliance strategy at the SRW site is natural flushing in conjunction with ICs and compliance monitoring (DOE 2003a; DOE 2003b). To assess the effectiveness of the compliance strategy at the SRW site, temporal trends in COPC concentrations in groundwater are compared to baseline (2000) conditions. This section begins with a discussion of groundwater elevation trends. Spatial distributions and temporal trends of COPC concentrations in SRW site monitoring wells are then evaluated for monitoring wells at and downgradient of the SRW site using the approach discussed in Section 1.4. Historical water quality and water level data for the site are reported and published on the LM GEMS website.

3.1 Groundwater Levels

Groundwater elevations measured in SRW site wells during the 2024 sampling event are shown in Figure 10; corresponding temporal trends are shown in Figure 11. Groundwater elevations in the alluvial aquifer generally decrease in the direction the river flows. Similar to the SRE site, groundwater elevations in SRW alluvial aquifer wells have typically fluctuated about 2–3 ft (Figure 11). Entrada Sandstone well 0317 historically showed upward vertical gradients with nearby abandoned alluvial aquifer wells of about −0.01 ft/ft (DOE 2002). Data from the SOWP also indicate that upward vertical gradients were greater (approximately 0.08 ft/ft) between wells screened in the Entrada and the Navajo Sandstones (DOE 2002). The upward vertical gradients suggest that groundwater has an upward flowing component from the Entrada Sandstone and the underlying Navajo Sandstone to the alluvial aquifer and the Dolores River. The upward vertical hydraulic gradient precludes downward migration of contamination into bedrock at the site.

3.2 COPC Spatial Distributions and Temporal Trends

This section updates groundwater monitoring data collected at the SRW site and assesses the status of the natural flushing compliance strategy for groundwater cleanup. In most time-series figures provided in this section (for analytes monitored in multiple wells), time-concentration plots for SRW wells are listed in approximate order of increasing distance from the former tailings area corresponding to the general direction of groundwater flow. Results for wells 0318/0318A, 0508, and 0510 are plotted first because these wells have been consistently monitored and, for most COPCs, have typically had the highest concentrations. Results for former (abandoned) well 0318 are color-coded to distinguish between results from the original well and results from the replacement well 0318A. Because of a broken well screen, well 0318 was abandoned and replaced with well 0318A in September 2010. Except for manganese, COPC results for the two wells (0318 and 0318A) were merged in the statistical trend analysis.

3.2.1 Uranium

Figure 12 shows the spatial distribution of uranium concentrations in SRW site monitoring wells for baseline (2000) and current (2022) conditions. To facilitate comparisons, wells that were sampled during the baseline period that are no longer monitored are shown in red in Figure 12. Corresponding time-concentration plots for wells that are currently routinely monitored are shown in Figure 13. Supporting Mann-Kendall trend analysis results for uranium and other SRW COPCs are documented in Table 5.

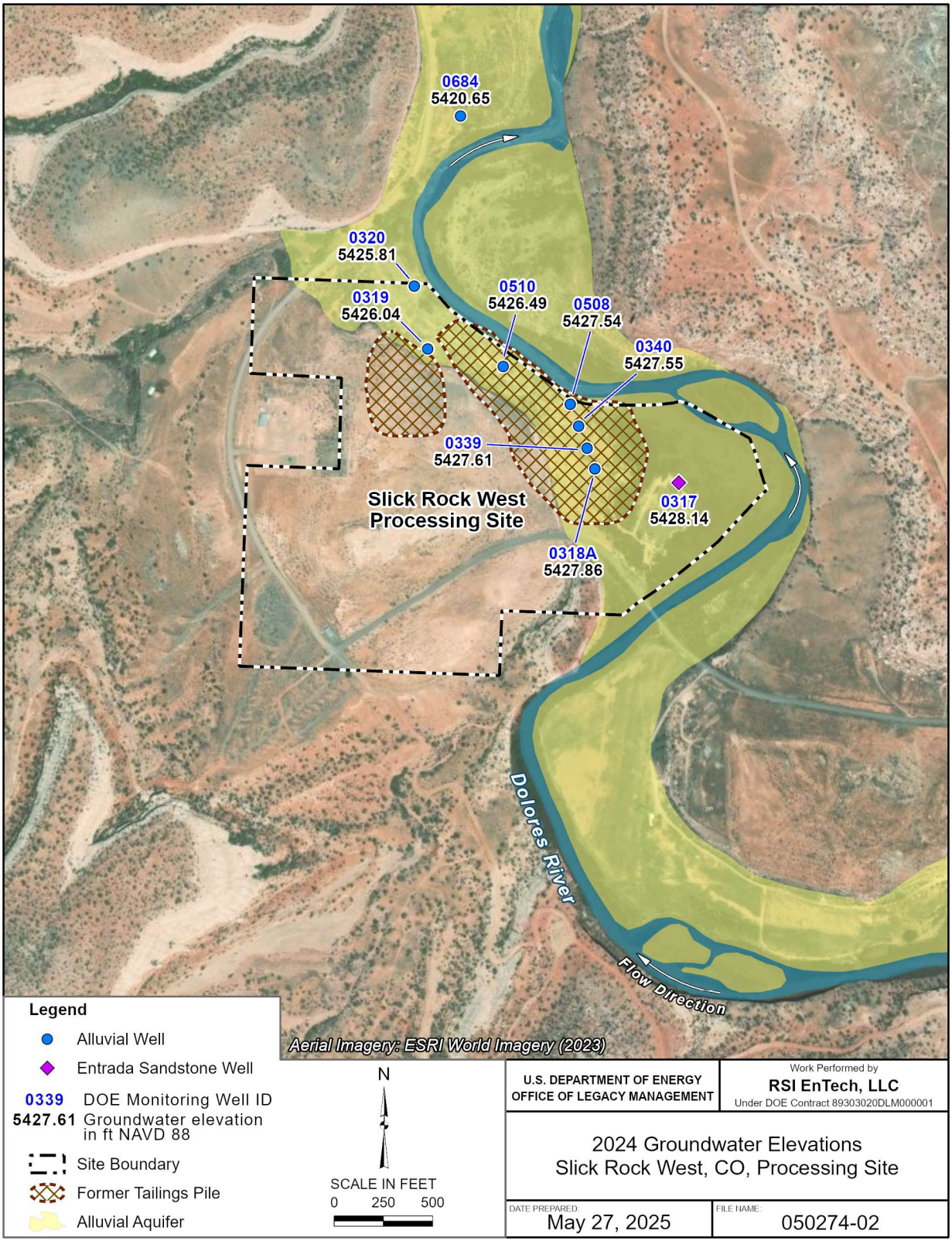
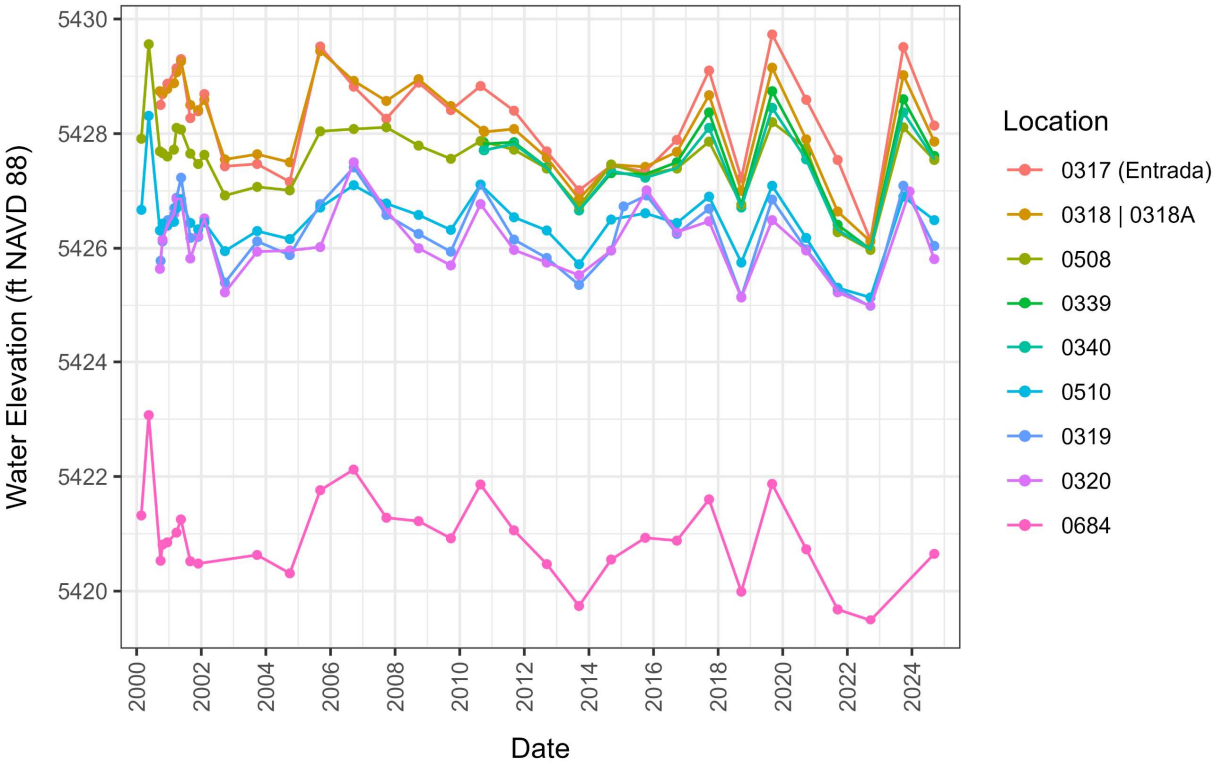
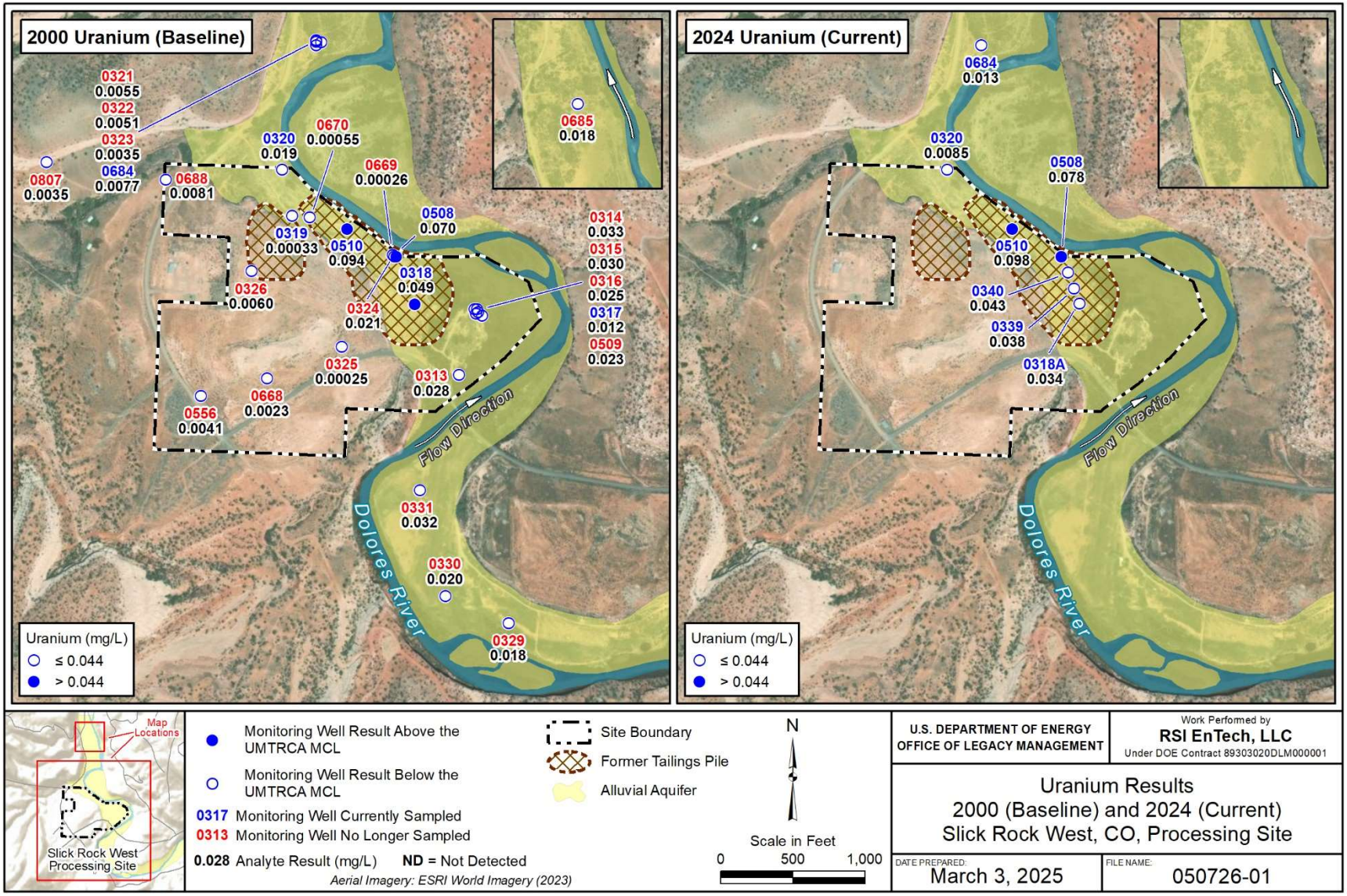


Figure 10. 2024 Groundwater Elevations in SRW Site Monitoring Wells



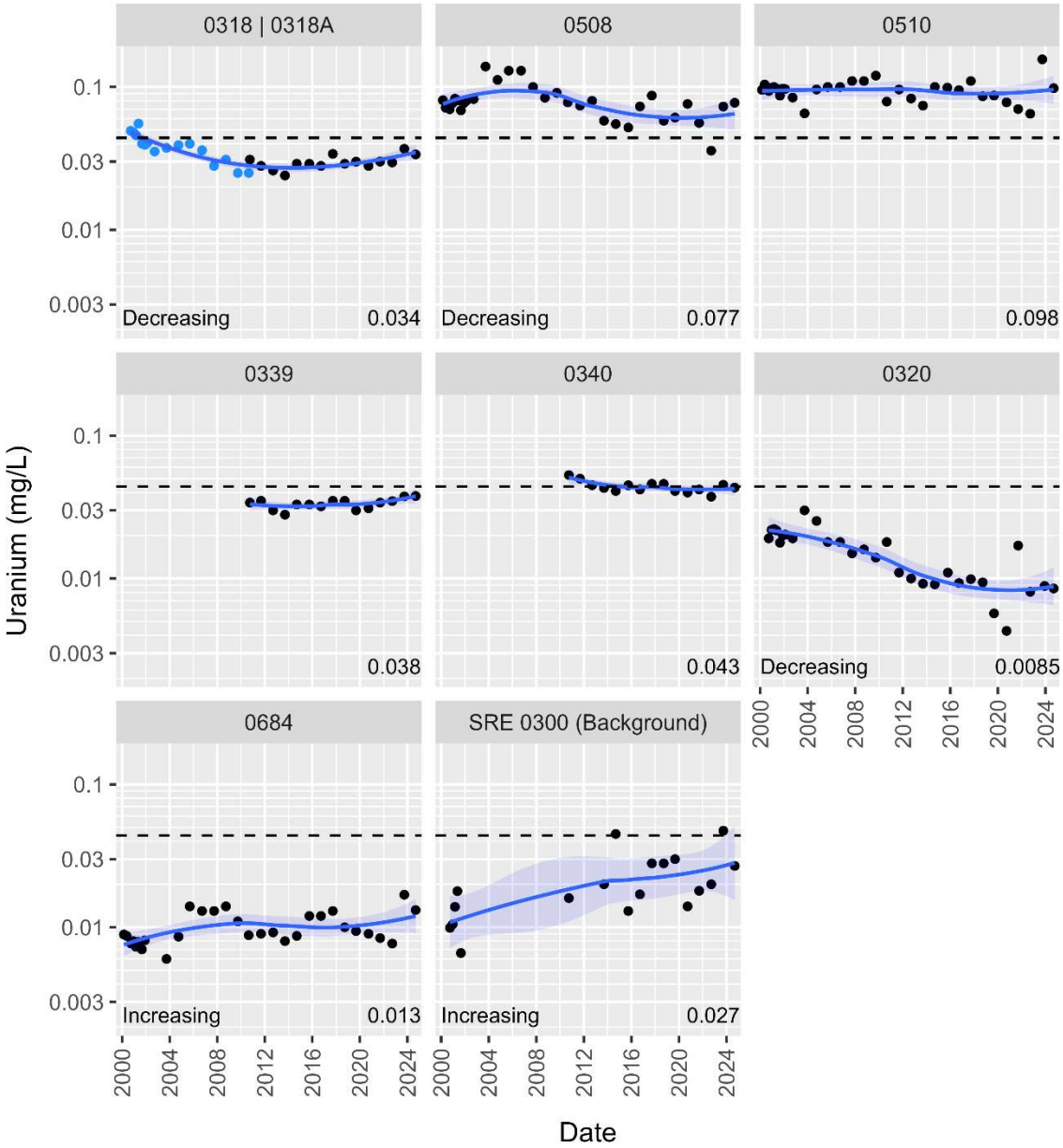
Notes:
In the legend, monitoring wells are listed in order of descending average groundwater elevation. Results for former well 0318 (abandoned in September 2010) and replacement well 0318A are merged to facilitate review. The August 2010 measurement from well 0318 just prior to abandonment is excluded from the plot; only the September 2010 measurement from well 0318A is shown.

Figure 11. Groundwater Elevation Trends in SRW Site Monitoring Wells, 2000–2024



Note: Baseline results are from September 2000; all results are rounded to two significant figures.

Figure 12. Uranium Concentrations in SRW Site Monitoring Wells, 2000 and 2024



Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 5), the direction of the trend is indicated in the lower left corner of the plot. Trend analysis conducted for the 2014–2024 time frame identified no statistically significant trends.

Figure 13. Time-Concentration Plots of Uranium in SRW Site Monitoring Wells, 2000–2024

Table 5. Mann-Kendall Trend Test Results for Primary COPCs in SRW Site Wells, 2000–2024

Well[a,b]	Initial Trend Analysis Date	Final Trend Analysis Date	Most Recent Result (mg/L)	2000–2024 Time Frame				2014–2024 Time Frame				
				No. of Samples (No. of Nondetects)[c]	Kendall's Tau[d]	*p* Value[e]	Trend	Initial Trend Analysis Date	No. of Samples (No. of Nondetects)[c]	Kendall's Tau[d]	*P* Value[e]	Trend
Uranium												
0318 | 0318A[a]	9/19/2000	9/10/2024	0.034	31	−0.46	<0.001	Decreasing	9/9/2014	11	0.36	0.13	None
0320	9/20/2000	9/10/2024	0.0085	30	−0.69	<0.001	Decreasing	9/9/2014	11	−0.24	0.35	None
0339	9/29/2010	9/10/2024	0.038	15	0.31	0.11	None	9/9/2014	11	0.38	0.12	None
0340	9/29/2010	9/10/2024	0.043	15	−0.35	0.073	None	9/9/2014	11	−0.07	0.81	None
0508	2/23/2000	9/10/2024	0.078	32	−0.26	0.039	Decreasing	9/9/2014	11	0.16	0.53	None
0510	2/24/2000	9/10/2024	0.098	32	−0.12	0.35	None	9/9/2014	11	−0.31	0.21	None
0684	2/23/2000	9/10/2024	0.013	30	0.26	0.042	Increasing	9/9/2014	11	−0.04	0.94	None
Selenium												
0317	9/28/2000	9/10/2024	0.0062	22	0.21	0.18	None	9/9/2014	11	0.26	0.31	None
0318 | 0318A[a]	9/19/2000	9/10/2024	1.7	31	0.11	0.42	None	9/9/2014	11	−0.44	0.07	None
0319	9/28/2000	9/10/2024	<0.0015	22 (5)	0.23	0.13	None	9/9/2014	11 (4)	−0.27	0.24	None
0320	9/20/2000	9/10/2024	<0.0015	30 (18)	0.13	0.30	None	9/9/2014	11 (7)	0	1	None
0339	9/29/2010	9/10/2024	1.8	15	−0.21	0.30	None	9/9/2014	11	−0.31	0.21	None
0340	9/29/2010	9/10/2024	4.1	15	0.13	0.52	None	9/9/2014	11	0.04	0.94	None
0508	2/23/2000	9/10/2024	3.6	32	0.19	0.12	None	9/9/2014	11	0.22	0.39	None
0510	2/24/2000	9/10/2024	2.0	32 (10)	0.41	<0.001	Increasing	9/9/2014	11	−0.04	0.94	None
0684	2/23/2000	9/10/2024	<0.0015	30	0.12	0.33	None	9/9/2014	11 (4)	−0.16	0.50	None
Molybdenum												
0317	9/28/2000	9/10/2024	0.15	28	−0.74	<0.001	Decreasing	9/9/2014	9	−0.22	0.45	None
0318 | 0318A[a]	9/19/2000	9/10/2024	1.4	31	−0.01	0.93	None	9/9/2014	11	0.02	1	None
0320	9/20/2000	9/10/2024	0.016	30	0.56	<0.001	Increasing	9/9/2014	11	0.64	0.008	Increasing
0339	9/29/2010	9/10/2024	1.1	15	−0.06	0.80	None	9/9/2014	11	0.16	0.53	None
0340	9/29/2010	9/10/2024	2.1	15	0.43	0.026	Increasing	9/9/2014	11	0.44	0.07	None
0508	2/23/2000	9/10/2024	1.8	32	0.12	0.34	None	9/9/2014	11	0.53	0.027	Increasing
0510	2/24/2000	9/10/2024	0.91	32	−0.06	0.65	None	9/9/2014	11	0.26	0.31	None
0684	2/23/2000	9/10/2024	0.0053	30 (2)	0.48	<0.001	Increasing	9/9/2014	11	−0.14	0.58	Decreasing
0300[b]	2/23/2000	9/11/2024	0.010	17 (2)	0.57	0.0014	Increasing	9/8/2014	11	0.54	0.024	Increasing
Nitrate as N												
0318 | 0318A[a]	9/19/2000	9/10/2024	32.1	30	−0.61	<0.001	Decreasing	9/9/2014	11	−0.27	0.28	None

Table 5. Mann-Kendall Trend Test Results for Primary COPCs in SRW Site Wells, 2000–2024 (continued)

Well[a,b]	Initial Trend Analysis Date	Final Trend Analysis Date	Most Recent Result (mg/L)	2000–2024 Time Frame				2014–2024 Time Frame				
				No. of Samples (No. of Nondetects)[c]	Kendall's Tau[d]	*p* Value[e]	Trend	Initial Trend Analysis Date	No. of Samples (No. of Nondetects)[c]	Kendall's Tau[d]	*P* Value[e]	Trend
Nitrate as N (continued)												
0320	9/20/2000	9/10/2024	<0.017	29 (13)	−0.20	0.13	None	9/9/2014	11 (7)	−0.07	0.80	None
0339	9/29/2010	9/10/2024	39.9	15	−0.11	0.59	None	9/9/2014	11	−0.20	0.44	None
0340	9/29/2010	9/10/2024	135	15	−0.65	<0.001	Decreasing	9/9/2014	11	−0.44	0.07	None
0508	2/23/2000	9/10/2024	134	31	−0.73	<0.001	Decreasing	9/9/2014	11	−0.27	0.27	None
0510	2/24/2000	9/10/2024	134	31	−0.69	<0.001	Decreasing	9/9/2014	11	−0.60	0.012	Decreasing
0684	2/23/2000	9/10/2024	<0.017	29 (11)	−0.39	0.002	Decreasing	9/9/2014	11 (7)	−0.06	0.86	None
0300[b]	9/27/2000	9/11/2024	<0.017	17 (6)	−0.22	0.21	None	9/8/2014	11 (5)	−0.16	0.48	None
Manganese												
0318[a]	9/19/2000	8/25/2010	0.0069	16	−0.82	<0.001	Decreasing	Not applicable				
0318A[a]	9/29/2010	9/10/2024	0.073	15	−0.71	<0.001	Decreasing	9/9/2014	11	−0.73	0.002	Decreasing
0320	9/20/2000	9/10/2024	0.66	30	−0.01	0.99	None	9/9/2014	11	0.36	0.14	None
0339	9/29/2010	9/10/2024	1.6	15	−0.23	0.25	None	9/9/2014	11	−0.24	0.35	None
0340	9/29/2010	9/10/2024	3.7	15	−0.63	0.0012	Decreasing	9/9/2014	11	−0.46	0.06	None
0508	2/23/2000	9/10/2024	3.2	32	−0.72	<0.001	Decreasing	9/9/2014	11	−0.16	0.53	None
0510	2/24/2000	9/10/2024	3.2	32	−0.61	<0.001	Decreasing	9/9/2014	11	−0.44	0.07	None
0684	2/23/2000	9/10/2024	0.63	30	0.29	0.027	Increasing	9/9/2014	11	0.24	0.35	None
0300[b]	9/27/2000	9/11/2024	2.4	17	−0.17	0.36	None	9/8/2014	11	−0.16	0.53	None

Notes:

[a] For most parameters, results for former well 0318 and colocated replacement well 0318A were merged in the statistical trend analyses. The final (August 25, 2010) result for well 0318 was excluded given temporal redundancy with the subsequent result from replacement well 0318 (first sampled on September 29, 2010). Manganese does not warrant this treatment because of the marked difference in results between the two wells and the anomalous result(s) in well 0318 before its abandonment.

[b] This table also includes Mann-Kendall trend analysis results for background well 0300. Although designated as an SRE site well, well 0300 is considered representative of background alluvial groundwater quality for both the SRE and SRW sites. Results for uranium and selenium are provided in Table 4.

[c] The number of nondetects is only indicated for well-parameter combinations with nondetect results. Detection frequencies for uranium were all 100%.

[d] Trend tests were performed using the Nondetects and Data Analysis for Environmental Data (NADA) package in R, version 1.6-1.1 (Lee 2025). 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. All trend tests were run using a 0.05 significance (or alpha) level. 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. A tau value of 1.0 corresponds to a perfect strong association between the time series, indicating a significant increasing trend. Conversely, a perfect association in the negative direction (for decreasing trends) will have a tau value of −1.0. Time series data with no statistically significant trend will have a tau value closer to 0.0.

[e] A calculated *p* value of <0.05 indicates that the null hypothesis is rejected and a significant trend in the time series exists.

Uranium concentrations have routinely exceeded the 0.044 mg/L MCL in only two SRW site wells: wells 0508 and 0510, screened in the alluvial aquifer in the area of the former tailings pile (Figure 12, Figure 13). In 2023, the uranium result for well 0510, 0.16 mg/L, was the highest on record since remediation was completed in 1996. The concentration then declined in 2024 to 0.098 mg/L, consistent with historical observations. The MCL has also been exceeded in former well 0318 (2000–2001 only) and periodically in well 0340 (just south of well 0508), where uranium concentrations have ranged from 0.04–0.05 mg/L.

Based on data since 2000, Mann-Kendall trend analysis indicates statistically significant decreasing trends in wells 0318/0318A, 0508, and 0320, and an increasing trend in offsite downgradient well 0684 (Table 5). As noted previously (Section 2.2.1), a significant increasing trend was also found for SRE well 0300, applied as the background well for both SRE and SRW sites. However, uranium concentration trends in all SRW wells have no statistically significant trend since 2014.

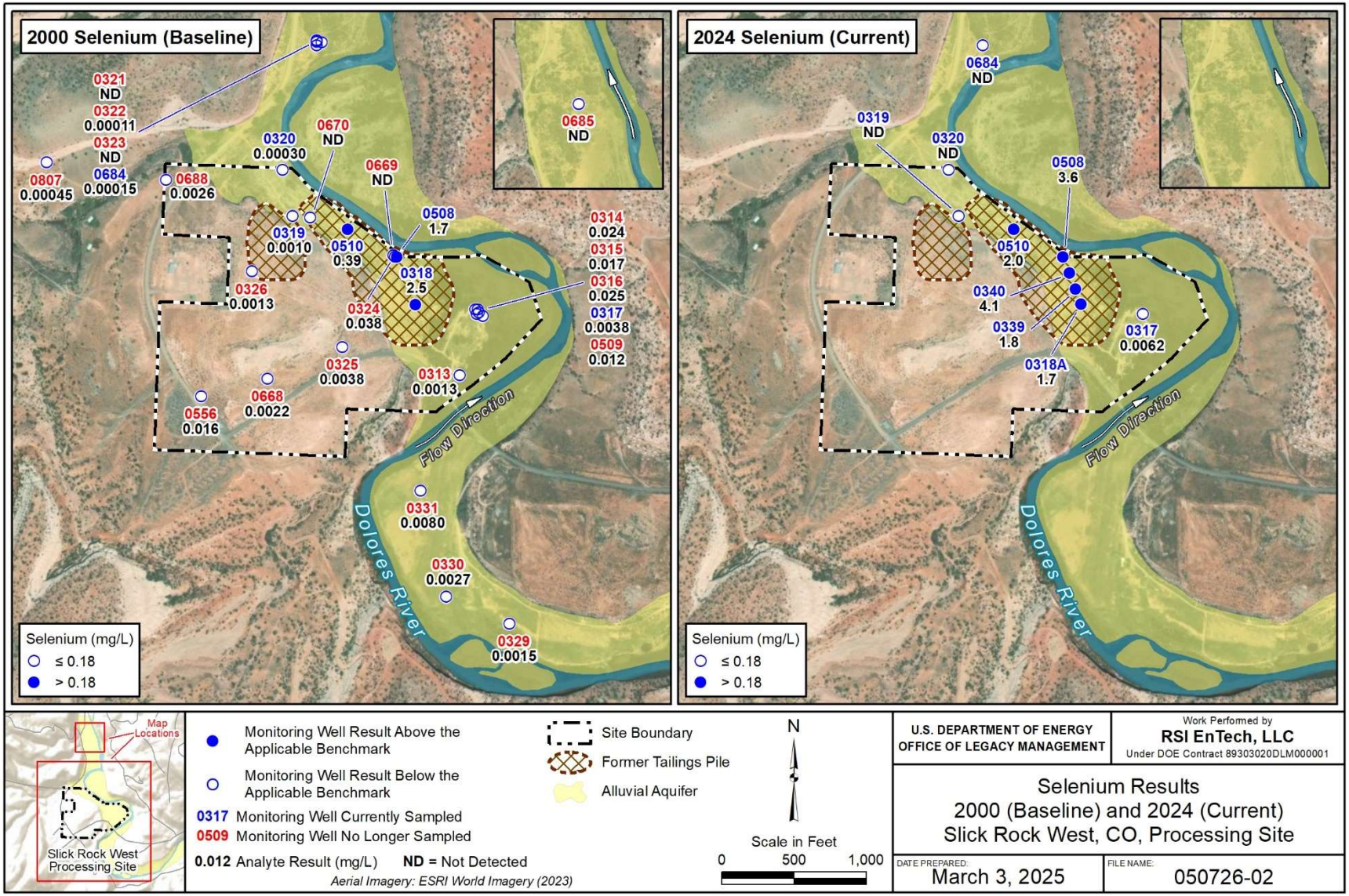
3.2.2 Selenium

Figure 14 shows the spatial distribution of selenium concentrations in SRW site monitoring wells for baseline (2000) and current (2024) conditions. Corresponding time-concentration plots are shown in Figure 15 for the wells that are currently monitored. Selenium has been historically elevated in five SRW wells screened in the alluvial aquifer within the area of the former tailings pile: 0318/0318A, 0508, 0510, 0339, and 0340. Selenium concentrations have consistently exceeded the 0.18 mg/L ACL in these wells and there has been little to no attenuation (Figure 15). Except for well 0510, with a statistically significant increasing trend since 2000, no significant trends were found for remaining wells for either the 2000–2024 or more recent 2014–2024 time frames (Table 5). These data trends suggest that selenium is not flushing out of the alluvial aquifer in this region of the site at a sufficient rate to remain below even the proposed ACL. Selenium concentrations in the remaining wells have been below both the ACL and the 0.01 mg/L MCL.

Selenium concentrations in downgradient wells 0320 and 0684 have been consistently below the 0.01 mg/L MCL. The most recent selenium results in both wells were below the detection limit of 0.0015 mg/L. Selenium concentrations in Entrada Sandstone well 0317 have also been consistently below the MCL (although at times approaching it); the most recent result was 0.0062 mg/L. In summary, SRW monitoring results and trend analysis indicate that natural flushing has not been an effective attenuation mechanism for selenium at the SRW site.

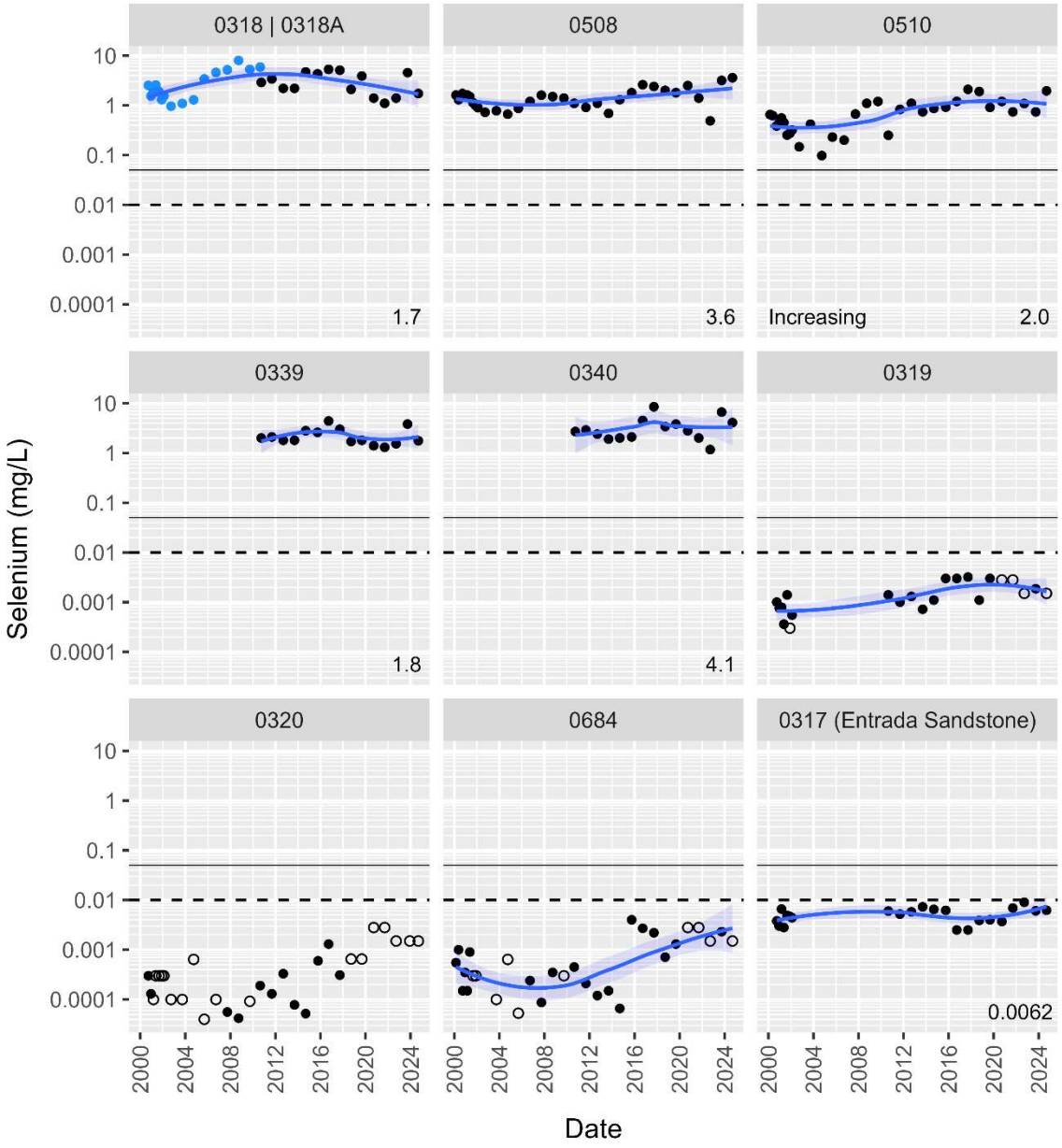
3.2.3 Molybdenum

Figure 16 shows the spatial distribution of molybdenum concentrations in SRW site monitoring wells for baseline (2000) and current (2024) conditions. Corresponding time-concentration plots are shown in Figure 17. Like selenium, molybdenum concentrations have been historically elevated in SRW alluvial wells 0318/0318A, 0508, 0510, 0339, and 0340. In these wells, molybdenum concentrations have typically ranged from 1 to 2 mg/L, an order of magnitude above the 0.1 mg/L UMTRCA MCL, and show little to no attenuation.



Note: Baseline results are from September 2000; all results are rounded to two significant figures.

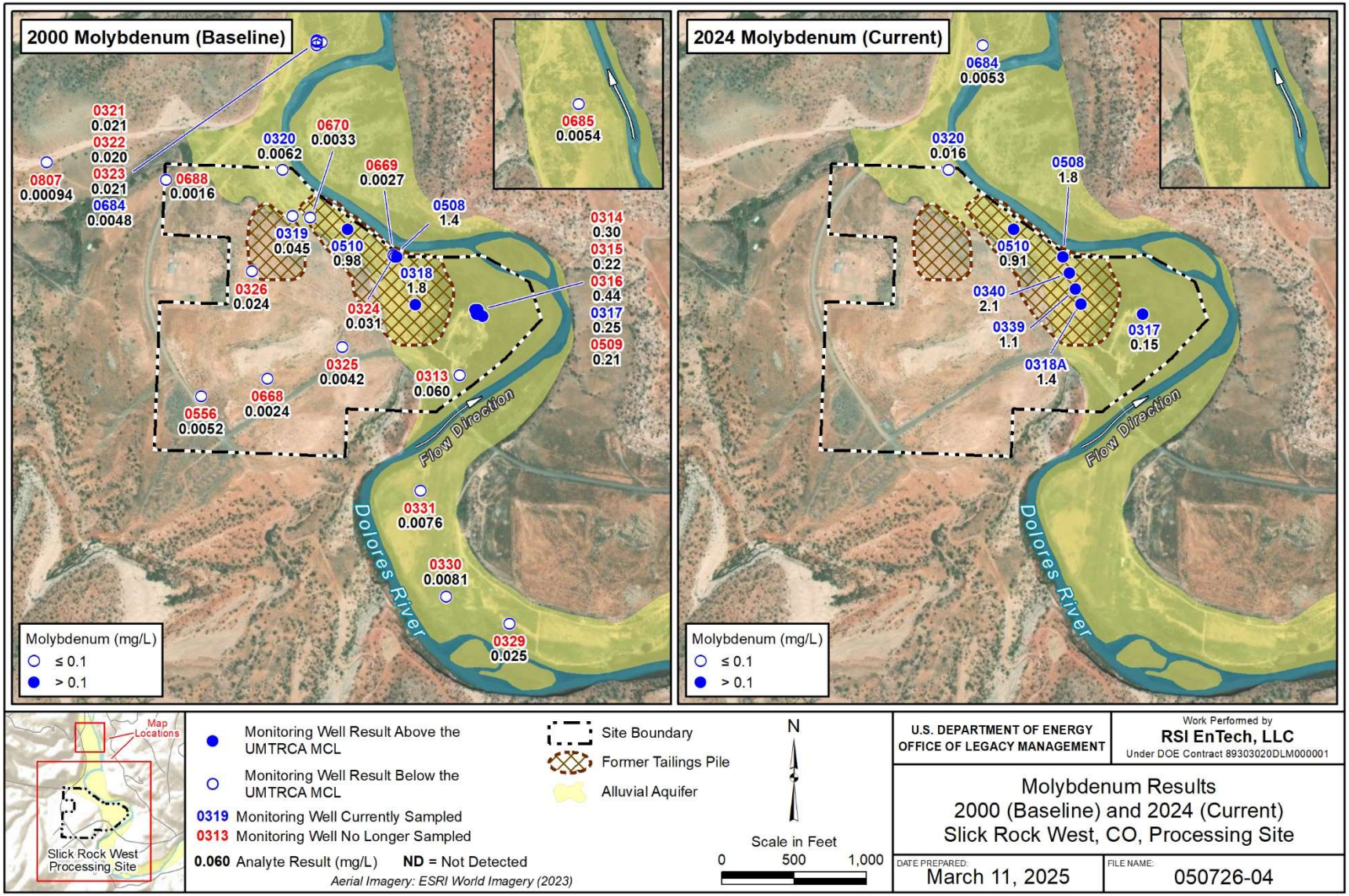
Figure 14. Selenium Concentrations in SRW Site Monitoring Wells, 2000 and 2024



● Detect ○ Nondetect
● Result for former well 0318
—— LOESS local regression line and 95% confidence interval (applied only to wells with ≥50% detection frequencies)
- - - 0.01 mg/L UMTRCA MCL
—— 0.18 mg/L ACL

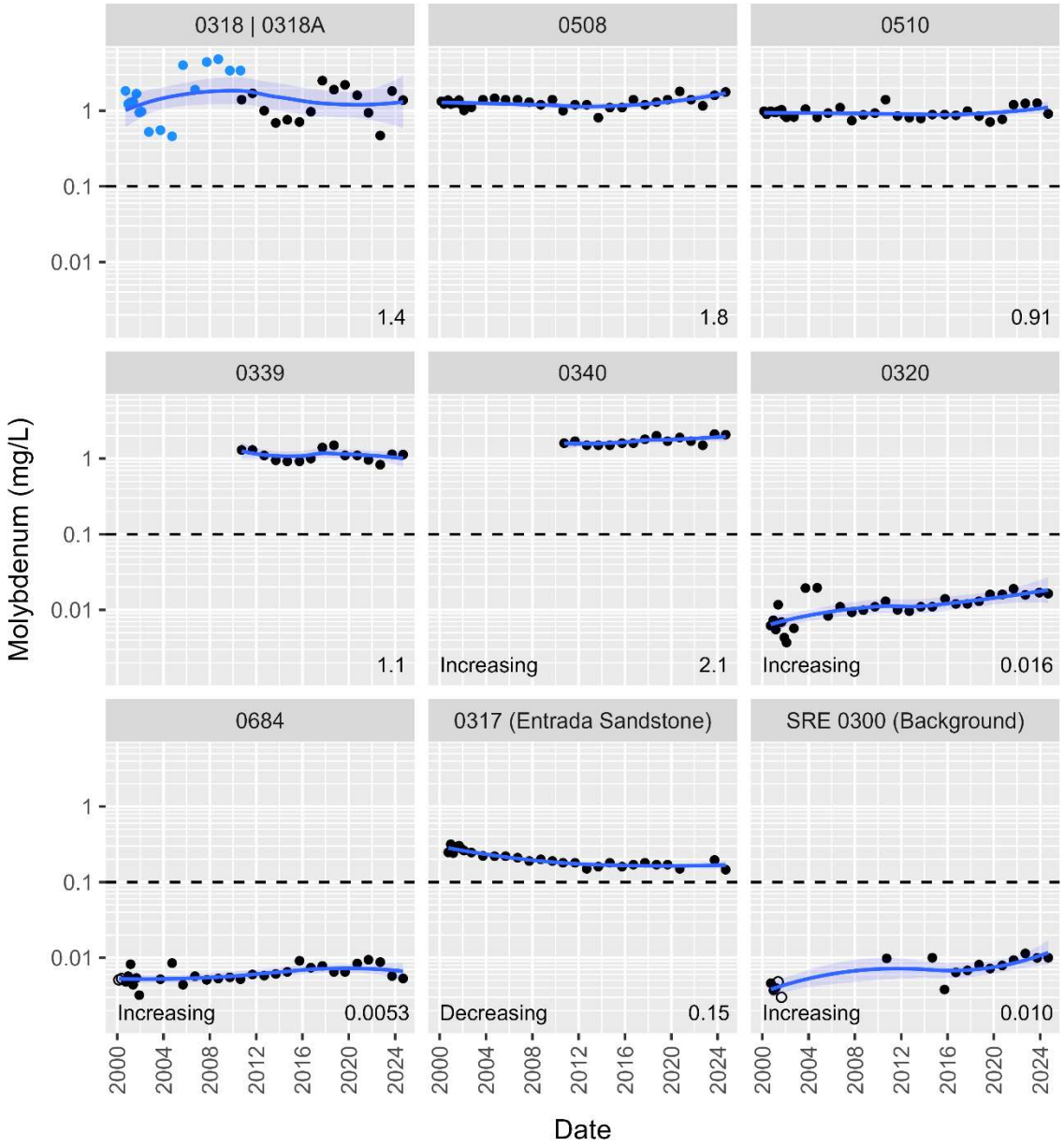
Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results (applied only to results above the detection limit). For wells with statistically significant trends for the 2000–2024 analysis time frame (Table 5), the direction of the trend is indicated on the plot. For all wells, no statistically significant trend was found for the 2014–2024 data subset. Data for background (SRE) well 0300 are not shown due to the high proportion of nondetects (Figure 9).

Figure 15. Time-Concentration Plots of Selenium in SRW Site Monitoring Wells, 2000–2024



Note: Baseline results are from September 2000; all results are rounded to two significant figures.

Figure 16. Molybdenum Concentrations in SRW Site Monitoring Wells, 2000 and 2024



Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 5), the direction of the trend is indicated in the lower left corner of the plot.

For the more recent (2014–2024) time frame, a significant increasing trend was found for well 0508 and significant increasing trends for wells 0320 and 0300 were sustained (Table 5). The trend direction shifted for well 0684 (now decreasing) and no significant trend was found for remaining wells.

Figure 17. Time-Concentration Plots of Molybdenum in SRW Site Monitoring Wells, 2000–2024

In 2024, molybdenum concentrations in this well subset ranged from 0.91 to 2.1 mg/L, with the highest levels measured in well 0340. Statistically significant increasing trends were found for well 0340 (2010–2024) and 0508 (2014–2024l) (Table 5). Significant increasing trends were also found for downgradient wells 0320 and 0684, where molybdenum concentrations are still below the 0.1 mg/L MCL (2024 results were 0.016 and 0.0053 mg/L, respectively) (Figure 17). Molybdenum concentrations in remaining SRW alluvial wells have been relatively stable, with no significant trend.

Molybdenum concentrations in Entrada Sandstone well 0317 have consistently exceeded the 0.1 mg/L standard, albeit slightly (historical maximum of 0.32 mg/L). Since 2000, molybdenum concentrations in this well have significantly decreased (Table 5); the most recent (2024) result of 0.15 mg/L is the lowest on record (Figure 17).

In summary, similar to observations for selenium at the SRW site, increasing or stable trends in molybdenum concentrations within the tailings pile area suggest that molybdenum is not flushing out of the alluvial aquifer in this region. Molybdenum concentrations in these wells continue to exceed the MCL with no statistically significant reductions since 2000.

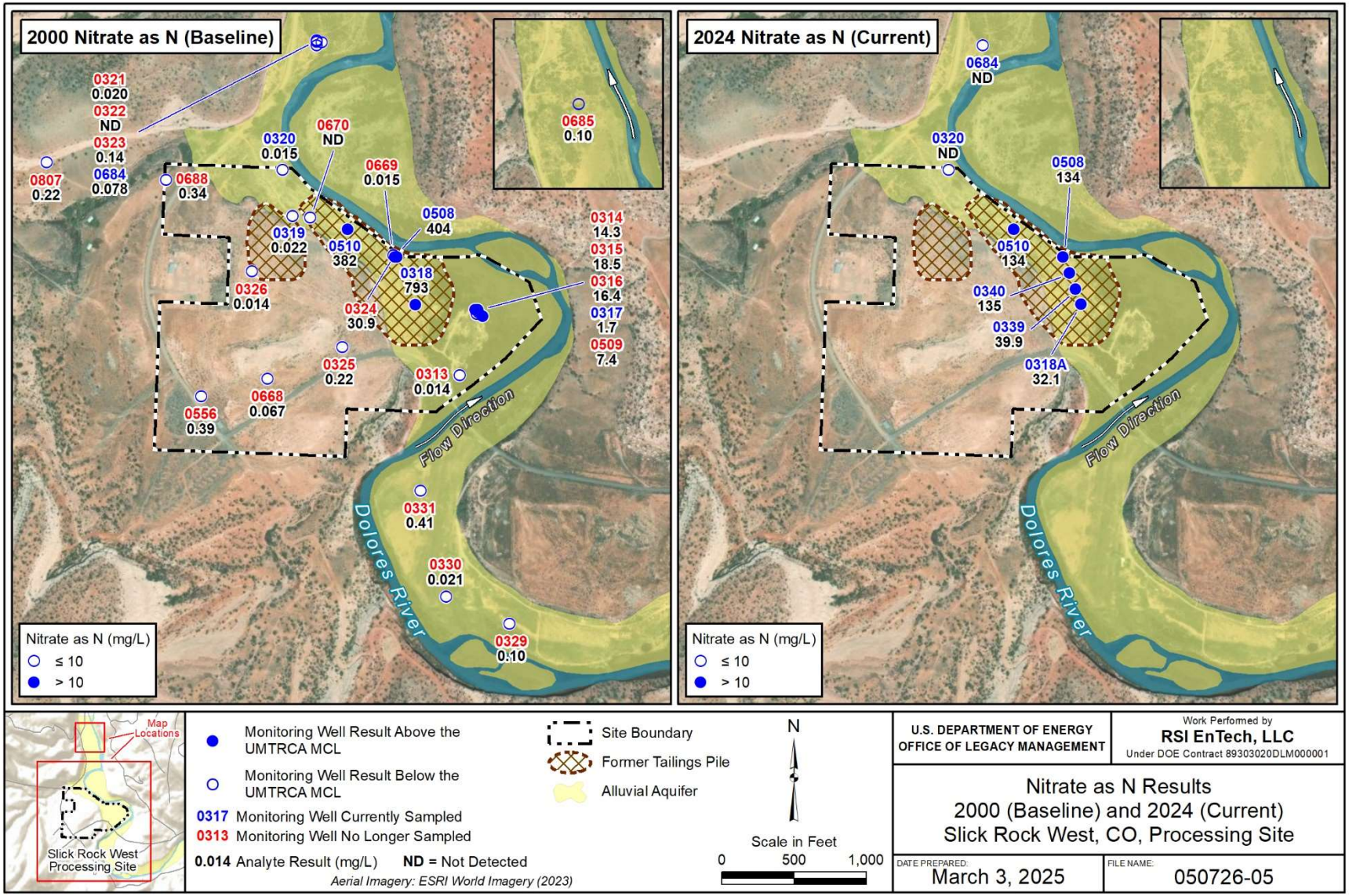
3.2.4 Nitrate as N

Figure 18 shows the distribution of nitrate (as N) concentrations in SRW site monitoring wells for baseline (2000) and current (2024) conditions. Corresponding time-concentration plots are shown in Figure 19. Nitrate concentrations still exceed the 10 mg/L MCL in SRW alluvial wells within or near the former tailings pile area, the same five wells with persistent molybdenum and selenium. Although nitrate concentrations have declined in these wells since 2000, in most cases significantly (Table 5), concentrations in several wells (0508, 0510, and 0340) are still an order of magnitude higher that the MCL (134–135 mg/L in 2024). Also, the rate of attenuation has slowed in the last decade. Except for well 0510, no statistically significant trend was found for the 2014–2024 time frame (Table 5).

However, for all SRW wells and analysis time frames, Kendall's tau values are negative, indicating a predominant decreasing trend in nitrate concentrations across the site. These findings indicate that nitrate is flushing out of the alluvial aquifer at the SRW site, to either the Dolores River or a location not captured by the current monitoring network.

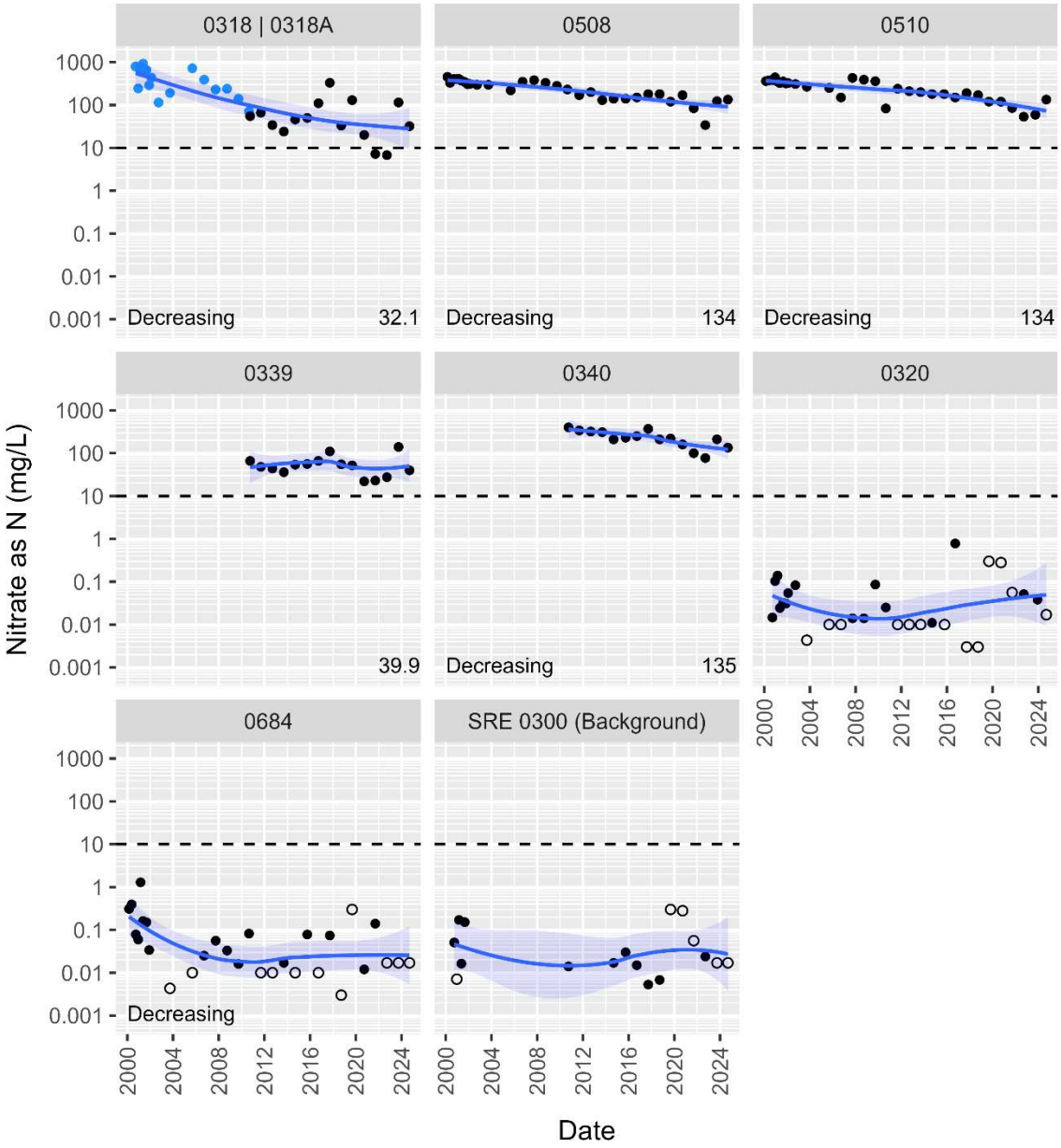
3.2.5 Manganese

In 2000 (baseline conditions), manganese concentrations were elevated in three wells within the former tailings area: well 0318 (12.8 mg/L) and wells 0508 and 0510 (6.6–6.9 mg/L) (Figure 20). In September 2024 (representing current conditions), manganese concentrations in SRW wells ranged from 0.0073 to 3.7 mg/L, well within the range of background levels measured at SRE well 0300 (1.8–4.5 mg/L). In all but one well (0340), manganese concentrations were also below the 3.5 mg/L compliance benchmark (Table 1). Although predominantly statistically significant trends were found for the 2000–2024 analysis time frame, manganese concentrations have stabilized in most wells since 2014, with no significant trend apart from a continued decreasing trend in well 0318A (Table 5) (Figure 21). In summary, manganese concentrations in SRW wells have stabilized to levels characteristic of background conditions.



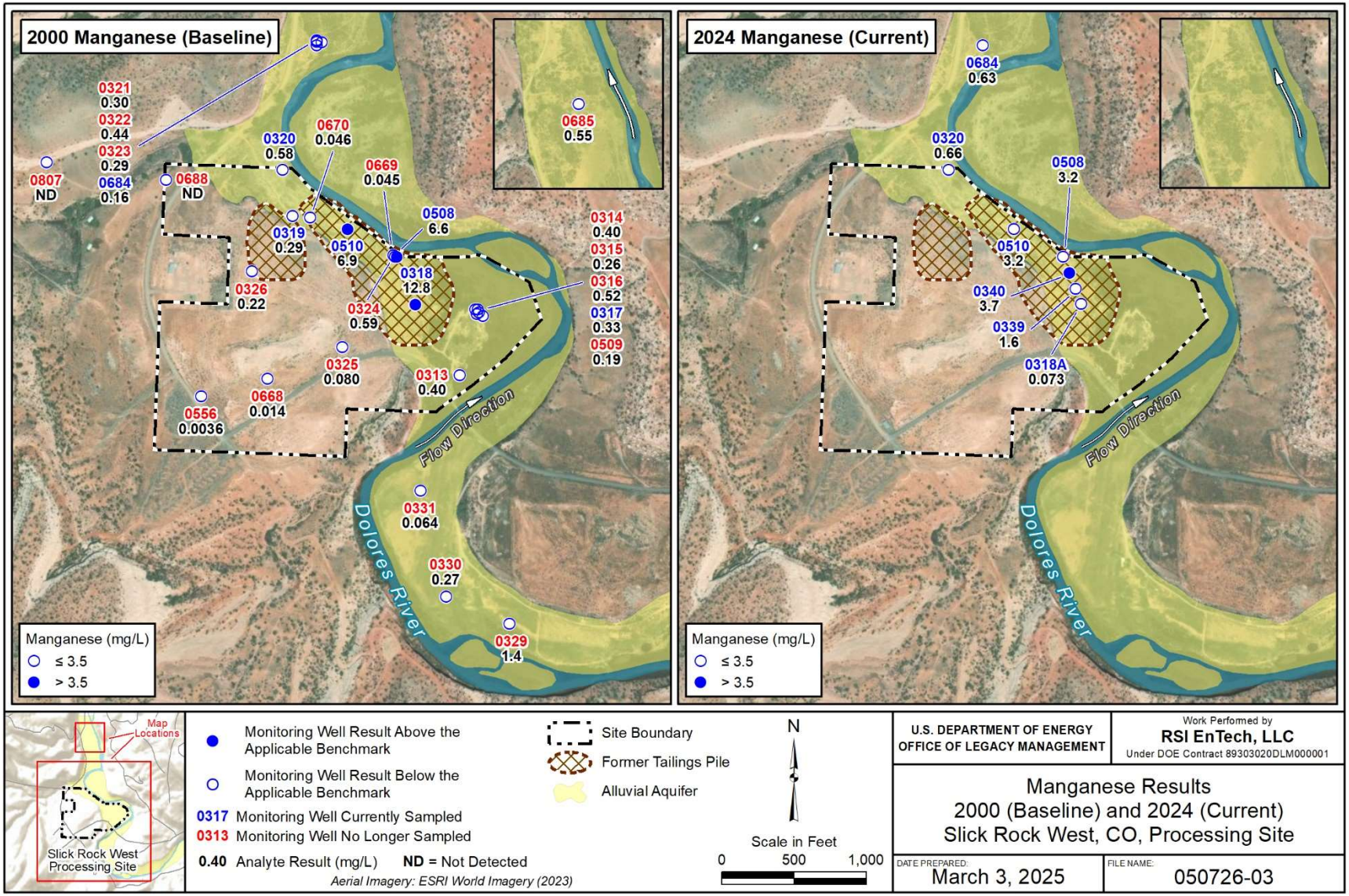
Note: Baseline results are from September 2000; results are rounded to two or three significant figures (depending on magnitude).

Figure 18. Nitrate (as N) Concentrations in SRW Site Monitoring Wells, 2000 and 2024



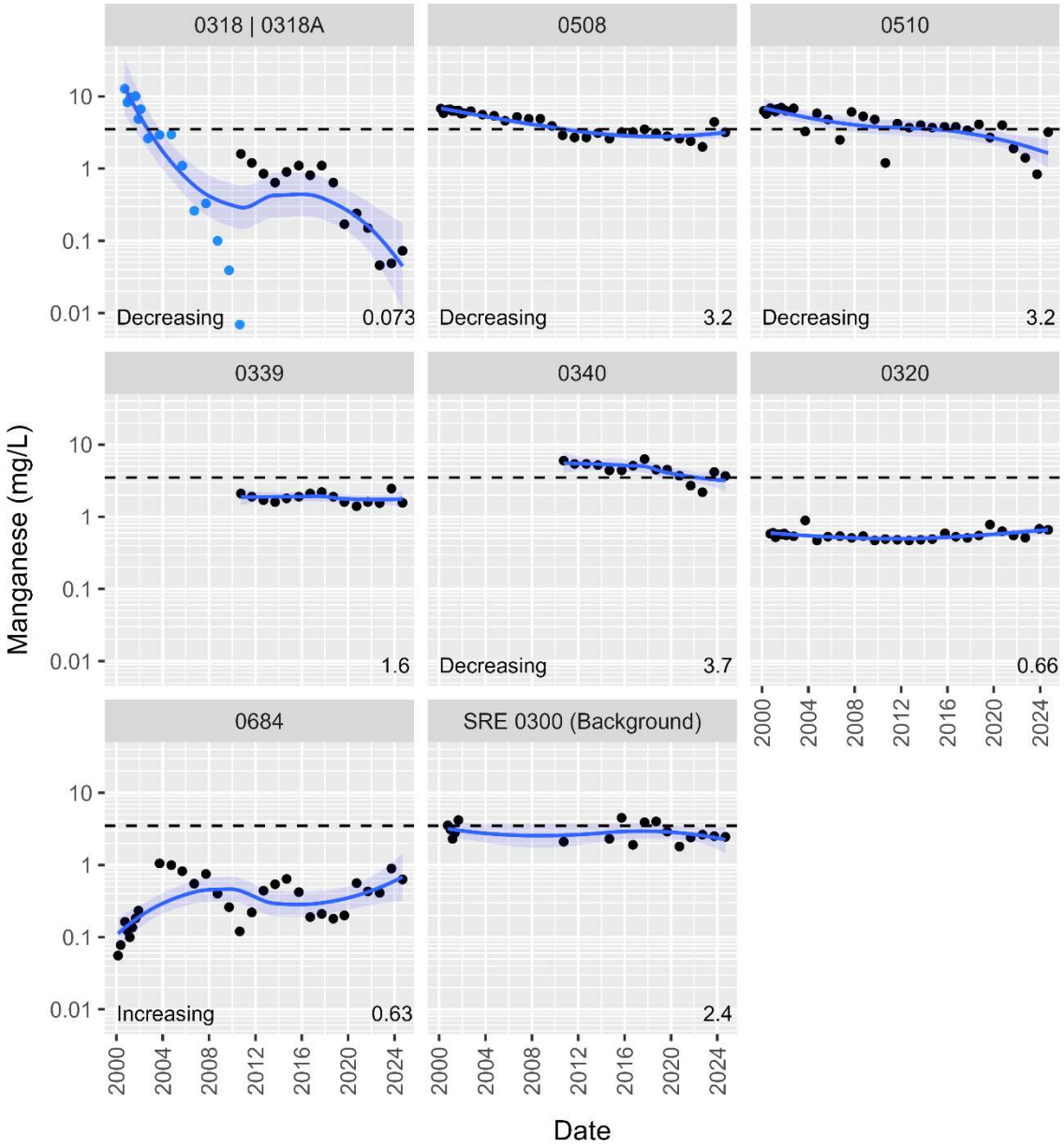
Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results (applied only to results above the detection limit). For wells with statistically significant trends for the 2000–2024 analysis time frame (Table 5), the direction of the trend is indicated on the plot. For all wells, no statistically significant trend was found for the 2014–2024 data subset. For the 2014–2024 data subset, no significant trend was found except for well 0510, with a continued significant decreasing trend.

Figure 19. Time-Concentration Plots of Nitrate as N in SRW Site Monitoring Wells, 2000–2024



Note: Baseline results are from September 2000; all results are rounded to two significant figures.

Figure 20. Manganese Concentrations in SRW Site Monitoring Wells, 2000 and 2024



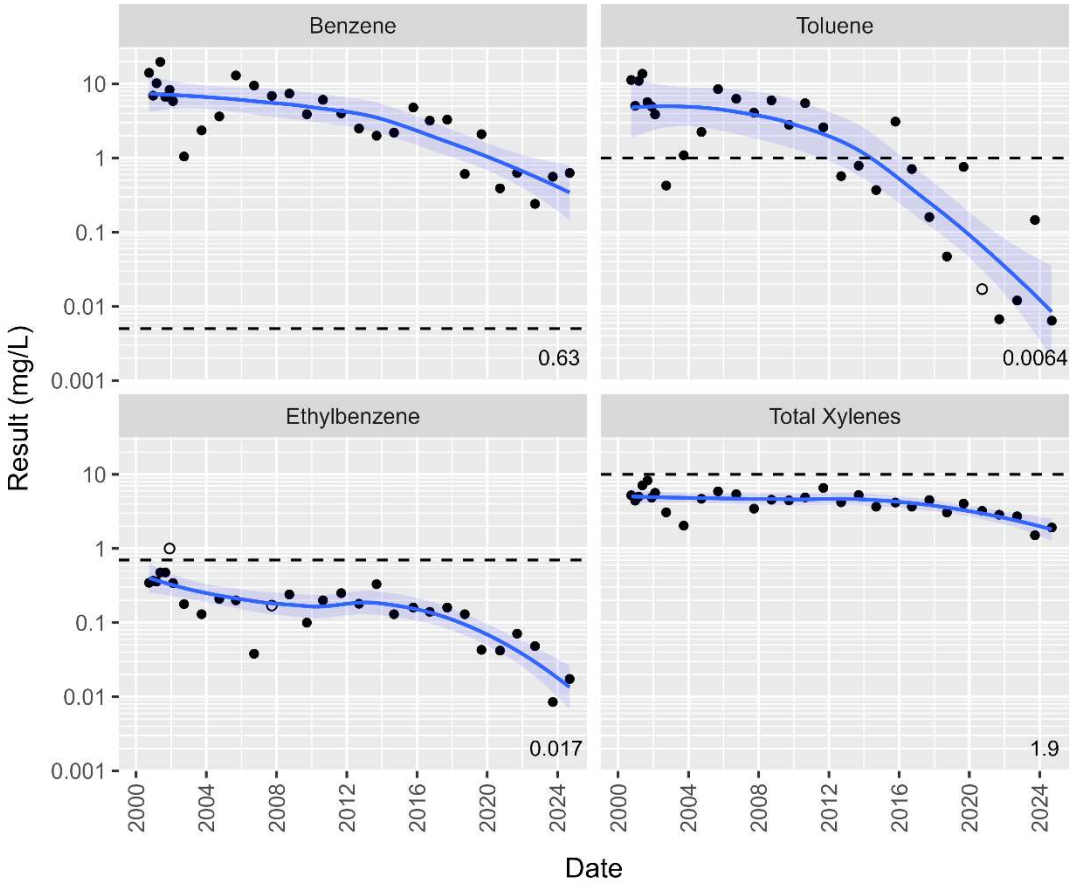
Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 5), the direction of the trend is indicated in the lower left corner of the plot. The trend direction shown for well 0318 | 0318A applies to both wells (and time frames); results were not merged in the analysis as discussed in Table 5, Note a). For remaining wells, no statistically significant trends were found for the 2014–2024 time frame.

Figure 21. Time-Concentration Plots of Manganese in SRW Site Monitoring Wells, 2000–2024

3.2.6 BTEX

During site characterization activities conducted for the SOWP (DOE 2002), a localized aromatic hydrocarbon plume was identified in the area of alluvial well 0319 (Figure 4). Since then, this well has been routinely monitored for BTEX. Field technicians have often noted a heavy petroleum odor while sampling the well. BTEX concentrations for well 0319 are shown in Figure 22 along with corresponding SDWA maximum contaminant levels. Based on Mann-Kendall trend analysis, a statistically significant decreasing trend was yielded for each BTEX constituent using data since 2000 and, for the culled dataset, since 2014.

Currently, benzene is the only constituent exceeding the corresponding SDWA maximum contaminant level. The most recent result, 0.63 mg/L, exceeds the 0.005 mg/L standard by about one order of magnitude. Toluene has been below the SDWA standard of 1.0 mg/L since 2016, and concentrations of both ethylbenzene and total xylenes have never exceeded the respective SDWA standards. These findings suggest that aromatic hydrocarbons continue to be naturally flushed out of the alluvial aquifer in the vicinity of well 0319.

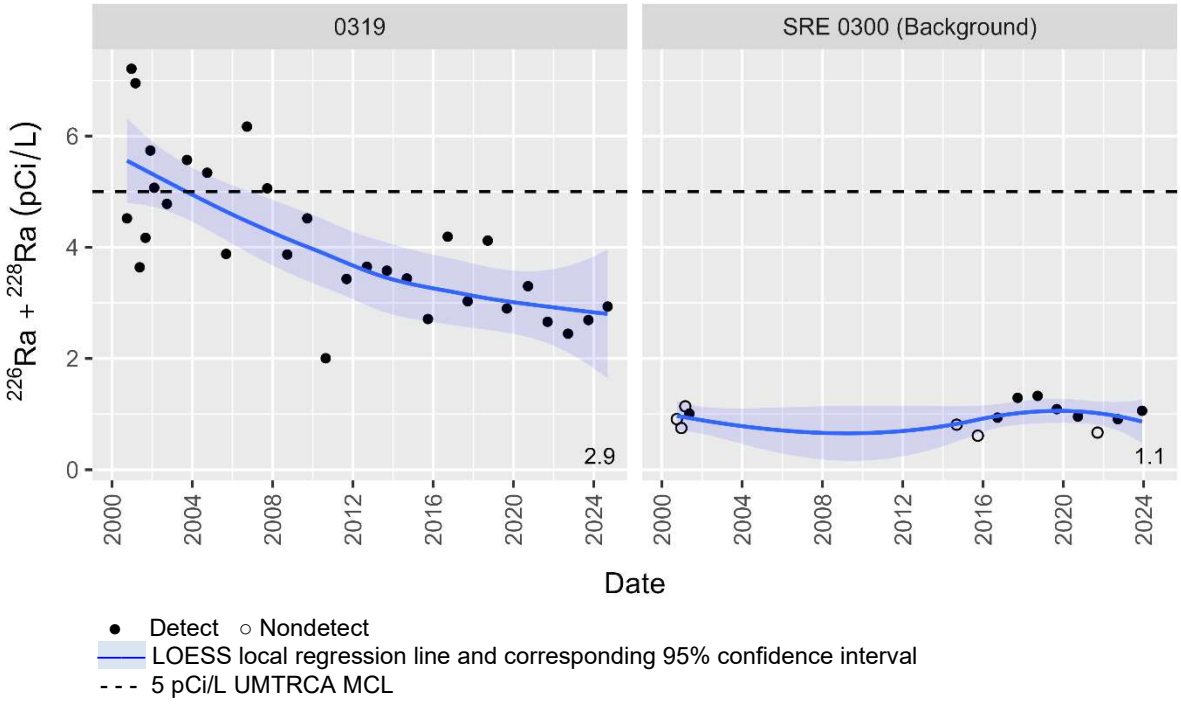


Notes:
Values shown in the lower right corner of individual graphs are the most recent (2024) results.
Mann-Kendall trend analysis indicates that concentration trends for all BTEX constituents are significantly decreasing for both 2000–2024 and 2014–2024 time frames.

Figure 22. Time-Concentration Plots of BTEX in SRW Well 0319, 2000–2024

3.2.7 Radium

Although ^{226}Ra and ^{228}Ra have been detected in other SRW site wells, their presence above the 5 picocuries per liter (pCi/L) UMTRCA MCL has historically been limited to well 0319. The sum of the measured ^{226}Ra and ^{228}Ra concentrations for the period 2000–2024 is plotted in Figure 23 along with results for background well 0300. Radium concentrations in SRW well 0319 have been below the 5 pCi/L UMTRCA MCL since 2008 (2.9 pCi/L in 2024) but still slightly exceed background levels. A statistically significant decreasing trend was found for well 0319 for both 2000–2024 and 2014–2024 time frames.



Notes:
Values shown in the lower right corner of individual graphs are the most recent (2023 or 2024) results. Open symbols (nondetect) indicate when both ^{226}Ra and ^{228}Ra were reported as below the method detection limit (plotted values are the sum of the method detection limits). In some cases, mostly applying to background well 0300, only one isotope (usually ^{228}Ra) was detected. Filled symbols are shown in these cases with values representing the sum of the detected result and (conservatively) the method detection limit for the other isotope.

Figure 23. Time-Concentration Plots of ^{226}Ra and ^{228}Ra (Combined), 2000–2024

4.0 COPC Concentration Trends in Dolores River Samples

Surface water is sampled in the Dolores River from three locations at the SRE site and four locations at the SRW site (Figure 3 and Figure 4). SRE locations are monitored for uranium only, while samples from SRW locations are analyzed for uranium, selenium, molybdenum, nitrate, and manganese. Historical uranium concentration trends for the SRE Dolores River locations are shown in Figure 24. For all parameters monitored in surface water (SRE and SRW sites), Table 6 lists the corresponding CDPHE water quality criteria along with a summary of the most recent (2024) results. At SRE monitoring locations, uranium concentrations continue to be well below both acute and chronic water quality standards for aquatic life. Results for downgradient locations 0692 and 0700 have also been below the lower bound CDPHE domestic water supply standard of 0.0168 mg/L and comparable to (and often lower than) background levels.

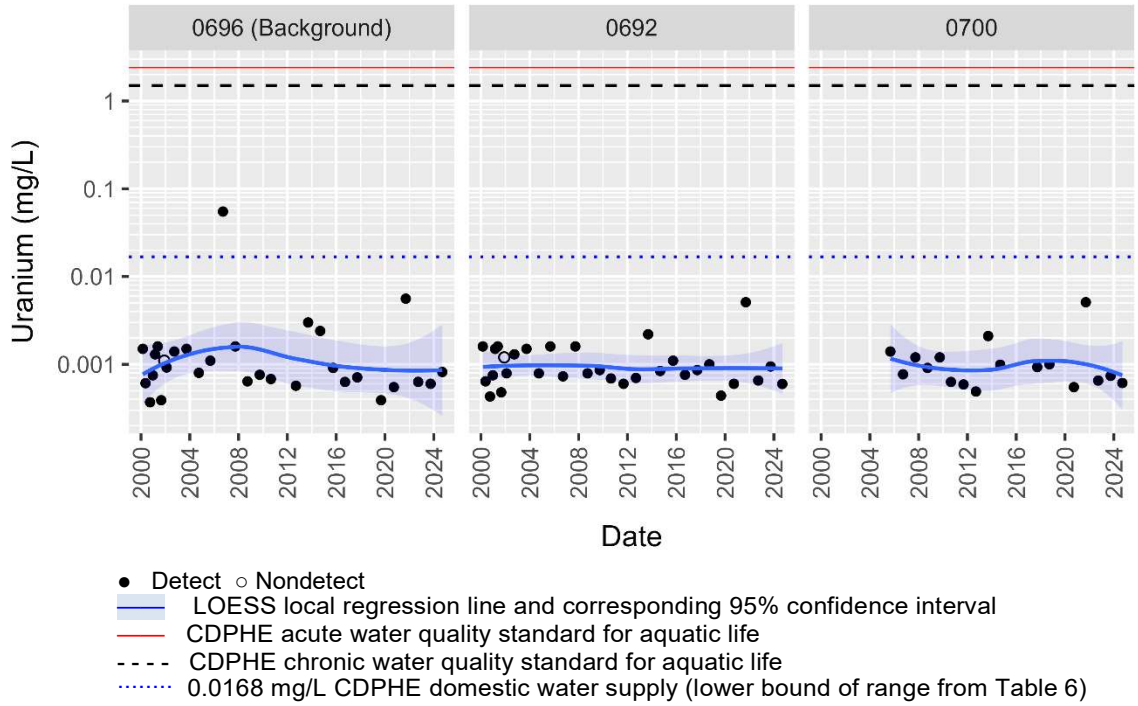


Figure 24. Uranium Concentrations in Dolores River Surface Water Monitoring Locations at the SRE Site, 2000–2024

Trends for COPCs in SRW locations from 2000–2024 are shown in Figure 25. Except for selenium, COPC concentrations in samples collected from SRW site Dolores River locations have been below the respective water quality standards listed in Table 6. Selenium concentrations at downgradient locations have occasionally exceeded aquatic life standards but in general have been comparable to background. In 2023–2023, COPC results for all locations were below CDPHE standards.

In summary, based on annual surface water sampling conducted since 2000 and comparison of the results to corresponding CDPHE water quality standards, there has been no apparent impact on the Dolores River water quality from historical milling activities at the Slick Rock former processing sites.

Table 6. Dolores River Water Quality Standards and 2024 Surface Water Sampling Results for the SRE and SRW Sites

Parameter	State of Colorado Surface Water Regulations (mg/L)[a]				Range of 2024 Results (mg/L)[b]
	Aquatic Life Acute	Aquatic Life Chronic	Agriculture (Chronic [T])	Domestic Water Supply	
Manganese	2.986[c] (TVS)	1.65[c] (TVS)	0.20	0.05[d]	0.0032–0.0050
Molybdenum	NA	0.15	0.30	0.53	ND–0.0011
Nitrate as N	10.0	NA	NA	NA	ND (all results <0.017)
Selenium	0.0184 (TVS)	0.0046 (TVS)	0.02	0.05	ND (all results <0.0015)
Uranium	2.402[c] (TVS)	1.501[c] (TVS)	NA	0.0168–0.03[e] (Chronic [T])	0.0005–0.0008 (maximum at SRE upgradient location 0696)

Notes:

[a] Sources: Volume 5 *Code of Colorado Regulations* (CCR) Sections 1002-31 and 1002-35. The applicable segment is the Lower Dolores River, Segment 2 (COGULD02): mainstem of the Dolores River from the Colorado Highway 141 road crossing near the Slick Rock sites to the Colorado-Utah border. This segment is designated as "Aquatic Life Warm 1" and is classified for agricultural, recreational, and water supply uses (5 CCR 1002-35). Corresponding table value standards (TVSs) can be found in Table III of 5 CCR 1002-31. For metals, most standards apply to the dissolved fraction.

[b] In contrast to previous VMRs (DOE 2023), SRE and SRW results are pooled because of the similarity in results across sites and locations and predominantly nondetect results for nitrate and selenium. Except for uranium and selenium (monitored at both SRE and SRW sites), all results correspond to the SRW site. Refer to Figure 24 and Figure 25 for more detailed results.

[c] For both uranium and manganese, acute and chronic TVS standards are dependent on (and directly related to) hardness (as $CaCO_3$), a parameter that has not been measured in site surface water samples. Hardness can be estimated using concentration values for calcium and magnesium, but these analytes have also not been analyzed in Slick Rock site surface water samples since 2000–2001. At that time, calcium and magnesium concentrations in samples from upgradient surface water locations (SRE 0696 and SRW 0693) ranged from 35.7–61.7 and 7.46–20.4 mg/L, respectively. Based on these results, estimated hardness concentrations range from 120 to 238 mg/L. TVS values for manganese and uranium listed above conservatively assume a hardness concentration of 100 mg/L and are based on the suggested values reported in Table IV of 5 CCR 1002-31.

[d] According to CDPHE regulations, for all surface waters with a "water supply" classification that are not in actual use as a water supply (a condition that applies to this segment of the Dolores River), no water supply standards are applied for iron, manganese, or sulfate unless the CDPHE Water Quality Control Commission determines, as the result of a site-specific rulemaking hearing, that such standards are appropriate (5 CCR 1002-35). As such, the most stringent water supply standard of 0.05 mg/L does not apply.

[e] The uranium standard is a range. The first number in the range (0.0168 mg/L) is a strictly health-based value, based on the CDPHE Water Quality Control Commission's established methodology for human-health-based standards. The second number in the range (0.03 mg/L) is the MCL defined in 5 CCR 1002-31.

Abbreviations:

$CaCO_3$ = calcium carbonate
CCR = *Code of Colorado Regulations*
NA = not applicable
ND = not detected
T = total recoverable
TVS = table value standard

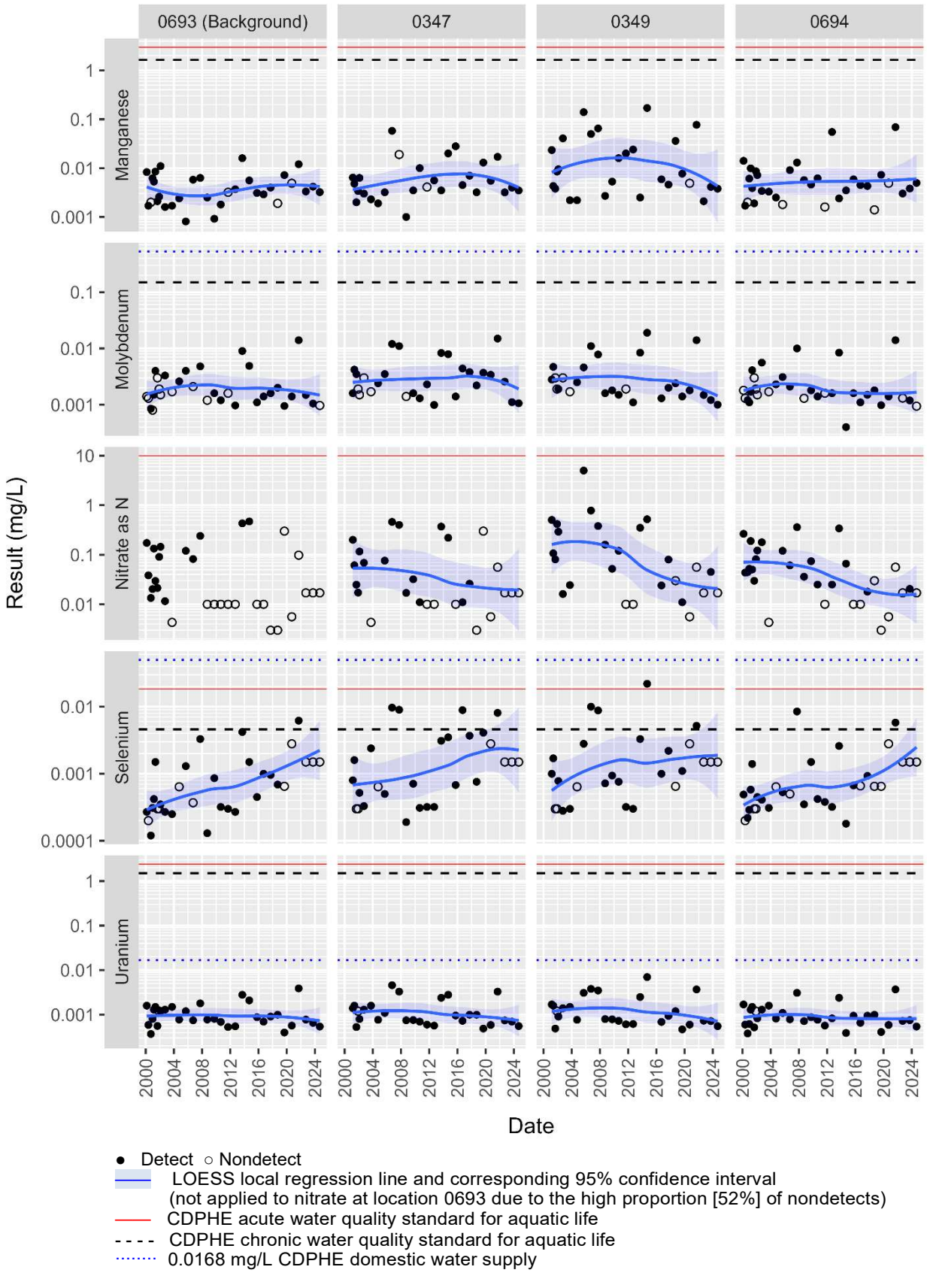


Figure 25. COPC Concentrations in Dolores River Surface Water Monitoring Locations at the SRW Site, 2000–2024

5.0 Compliance Remedy Performance Summary

For both SRE and SRW sites, the discussion and interpretations documented in this report are generally consistent with conclusions drawn in the previous biennial VMR issued in July 2023 (DOE 2023). Updated observations for the 2023–2024 reporting period are summarized here.

With respect to SRE site COPC concentrations:

- Uranium concentrations remain above the 0.044 mg/L UMTRCA standard in most SRE site alluvial wells, with little to no attenuation since 2000 (the baseline period). Given increases in uranium concentrations in downgradient offsite wells to levels exceeding the 0.044 mg/L standard, transport of milling-related uranium to locations across the Dolores River has likely occurred. These findings indicate that natural flushing has not been an effective groundwater remedy for uranium at the SRE site.
- As true historically, selenium concentrations have exceeded the 0.01 mg/L MCL in only one SRE site well (0305). Except for a recent spike of 0.13 mg/L measured in 2023, selenium concentrations in this well have been below the 0.05 mg/L SDWA standard.

With respect to SRW site data:

- Uranium concentrations have routinely exceeded the 0.044 mg/L MCL in only two SRW site wells (0508 and 0510). Uranium concentrations in these former tailings area wells have remained stable at about 0.1 mg/L and in the last decade have shown no signs of attenuation.
- Selenium and molybdenum concentrations within the alluvial aquifer indicate that natural flushing has not been an effective remedy for either constituent. For both constituents, concentrations have consistently exceeded corresponding compliance goals in five former tailings area wells, with no statistically significant reductions since 2000.
- Although nitrate concentrations remain elevated relative to the 10 mg/L MCL in five SRW wells, predominantly decreasing concentration trends indicate that nitrate is flushing out of the alluvial aquifer at the site, consistent with the current proposed groundwater compliance strategy.
- Manganese concentrations in SRW wells are now all *well* within the range of background levels measured at SRE well 0300 and most are lower than the 3.5 mg/L benchmark.
- Concentrations of BTEX constituents in well 0319 continue to decrease significantly relative to baseline conditions. Currently, benzene is the only constituent that exceeds the corresponding SDWA maximum contaminant level in this well.
- Radium-226 and ^{228}Ra concentrations in well 0319 have decreased significantly since 2000 and have been below the corresponding 5 pCi/L MCL since 2008.

Based on annual surface water sampling conducted since 2000 and comparison of the results to corresponding CDPHE surface water standards or upstream (background) results, there has been no apparent impact on the Dolores River water quality from historical milling activities at the Slick Rock former processing sites.

ICs are still pending for both SRE and SRW sites because mineral rights issues between the State of Colorado and the U.S. Bureau of Land Management have not been resolved. NRC will not concur with a proposed GCAP until ICs are established.

6.0 References

Note: Site-related documents are available on the LM public webpages at https://lmpublicsearch.lm.doe.gov/SitePages.

5 CCR 1002-31. "The Basic Standards and Methodologies for Surface Water," *Code of Colorado Regulations*, 5 CCR 1002-31.

5 CCR 1002-35. "Regulation No. 35 – Classifications and Numeric Standards for Gunnison and Lower Dolores River Basins," *Code of Colorado Regulations*, 5 CCR 1002-35.

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

42 USC 300f. "Definitions," *United States Code*, 42 USC 300f.

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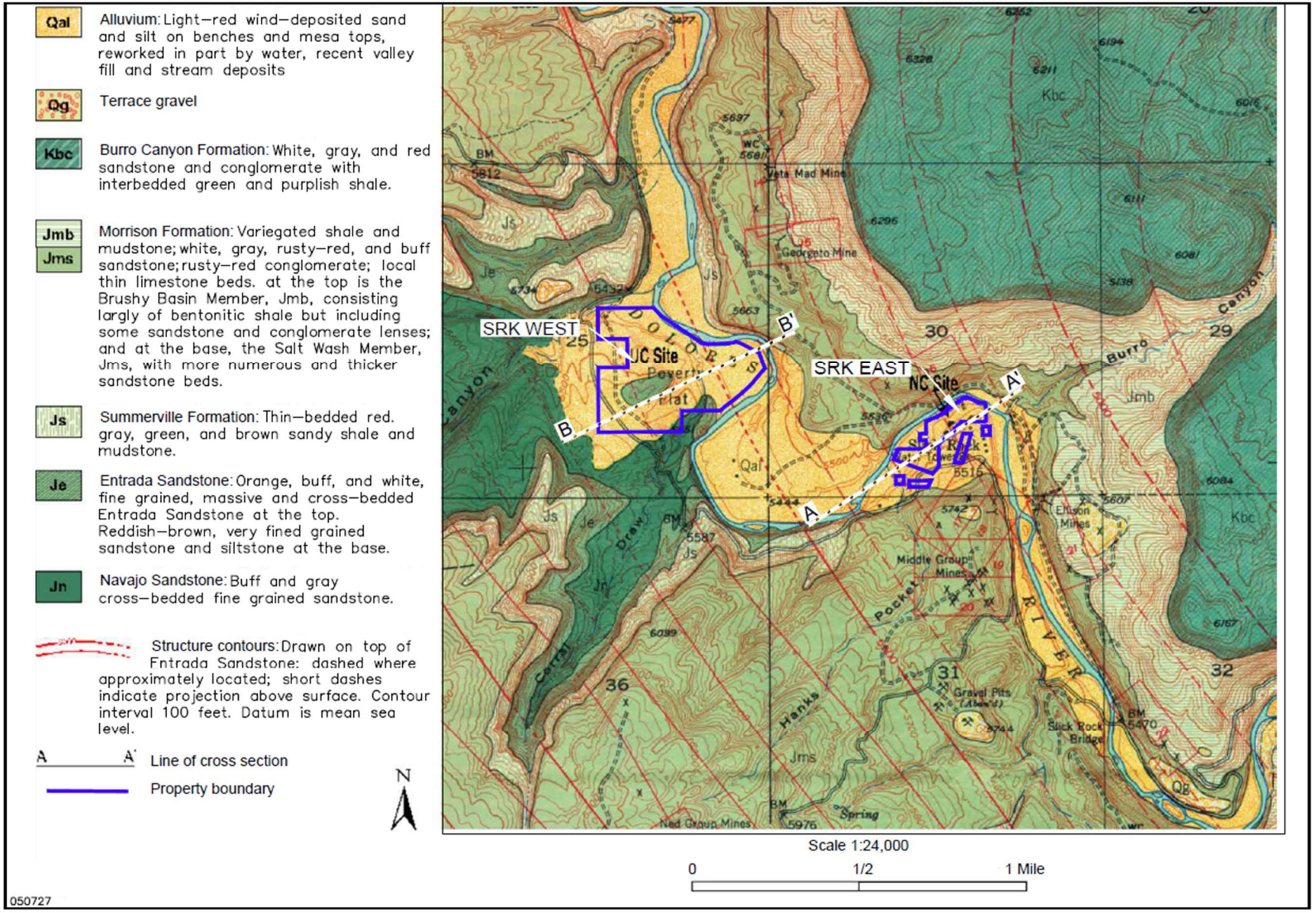
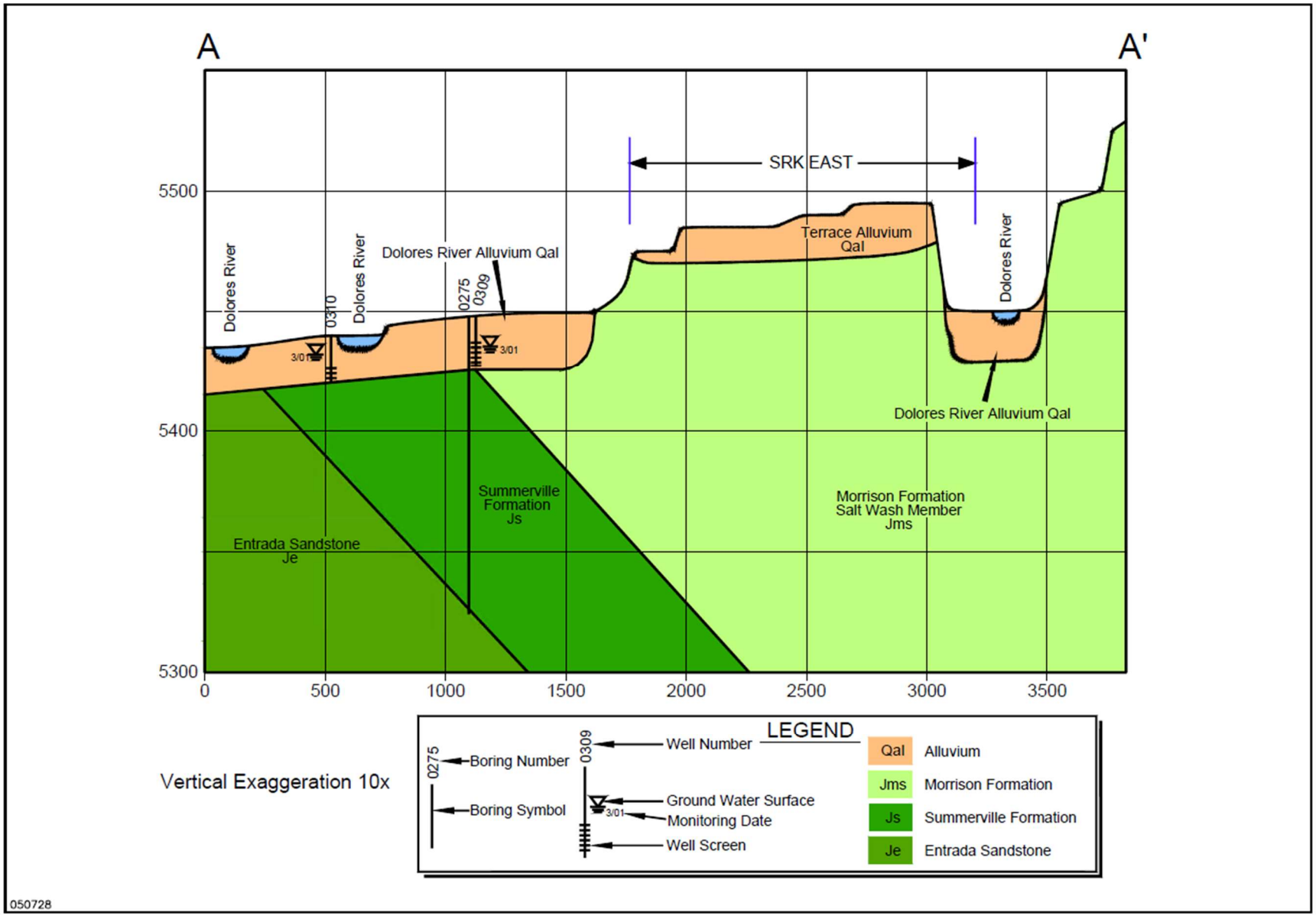
Appendix A

Geologic Diagram and Hydrologic Cross Sections



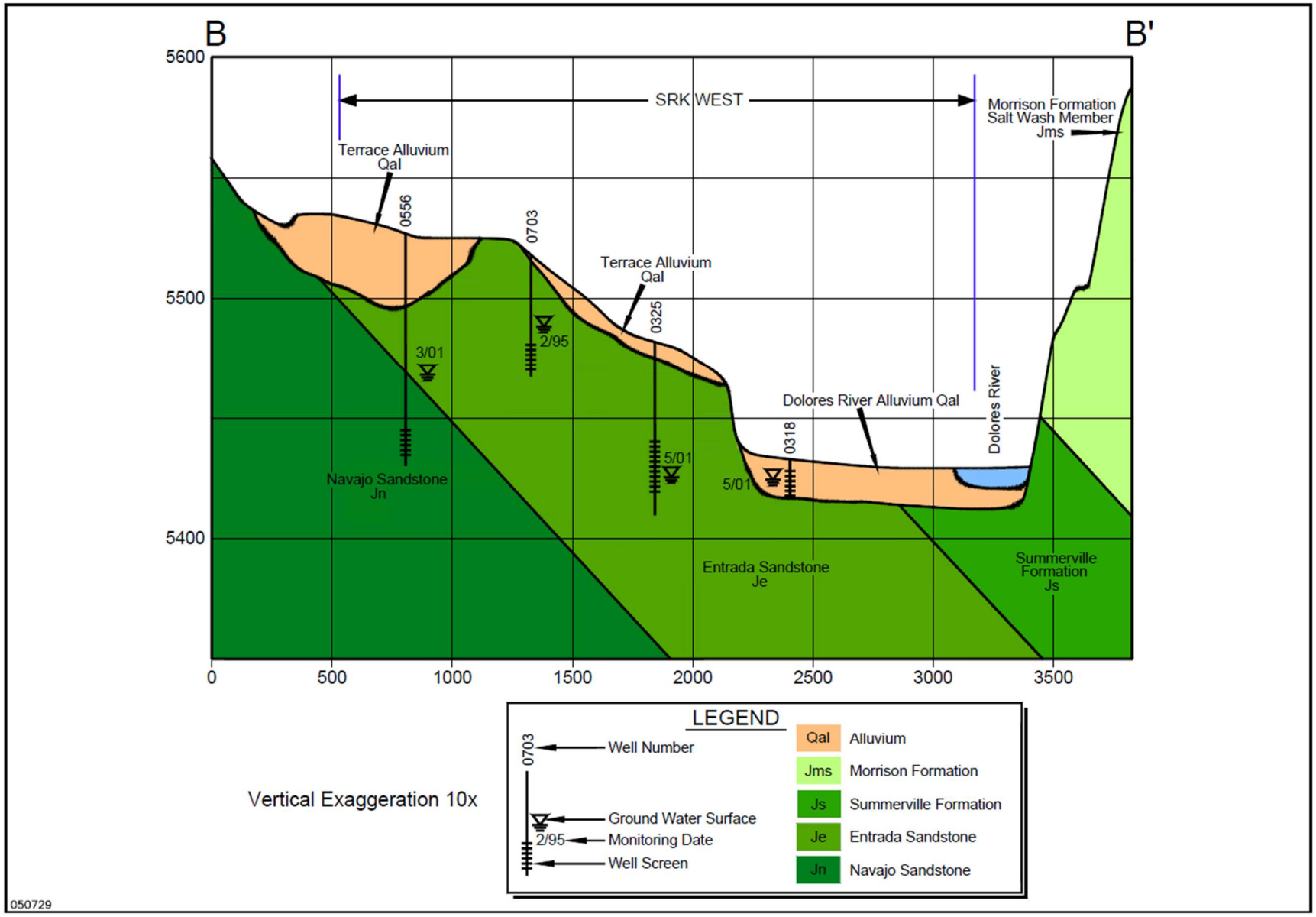
Abbreviation: SRK = Slick Rock

Figure A-1. Geologic Diagram of the Slick Rock Processing Sites



Abbreviation: SRK = Slick Rock

Figure A-2. Hydrologic Cross Section of the Slick Rock East Processing Site



Abbreviation: SRK = Slick Rock

Figure A-3. Hydrologic Cross Section of the Slick Rock West Processing Site