

# Verification Monitoring Report and Analytical Update for the Durango, Colorado, Processing Site

August 2014



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## Abbreviations

ACL	alternate concentration limit
AR	activity ratio
BLRA	Baseline Risk Assessment
CCR	<i>Code of Colorado Regulations</i>
CDPHE	Colorado Department of Public Health and Environment
CFR	<i>Code of Federal Regulations</i>
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
ft <sup>3</sup> /day	cubic feet per day
GCAP	Groundwater Compliance Action Plan
MCL	maximum concentration limit
µg/L	micrograms per liter
mg/L	milligrams per liter
NRC	U.S. Nuclear Regulatory Commission
POC	point of compliance
RAP	Remedial Action Plan
SOWP	Site Observational Work Plan
TDS	total dissolved solids
U	uranium
UMTRCA	Uranium Mill Tailings Radiation Control Act
UPL	upper prediction limit
VMR	Verification Monitoring Report



## Executive Summary

This Verification Monitoring Report (VMR) for the Durango, Colorado, Processing Site summarizes monitoring data for calendar year 2013 and assesses remedy performance. The report also contains a data evaluation that takes a more in-depth look at historical information and site monitoring data than were presented in past VMRs. The primary objectives of the data evaluation were to identify opportunities for improving the groundwater compliance approach and the long-term monitoring plan at the site.

Different wells have been used as a measure of background groundwater quality in different reports for the mill tailings area. Generally, background water quality in the vicinity of the site is poor—consistent with that for the greater Durango area. Background concentrations are elevated for several constituents—most notably sulfate, but also iron, manganese, and chloride. A comparison of background and onsite groundwater indicates that the most reliable indicator of milling-related contamination is uranium. An evaluation of uranium isotope data indicates that most uranium in site groundwater is milling-related rather than derived from Mancos Shale. On the other hand, sulfate in site groundwater appears to be predominantly from nonmilling sources. While sulfate concentrations have declined significantly at well locations most affected by milling, concentrations remain high and constant where other sulfate sources are present. Onsite sulfate concentrations are within prediction limits computed for site background wells. Several wells that are screened partially across Mancos Shale exhibit significantly elevated concentrations of sulfate that do not decrease over time, suggesting a continuing source.

One well at the site (0612) contains elevated concentrations of several metals, including cadmium, manganese, molybdenum, and zinc, some of which exceed concentrations observed in tailings fluids. Concentrations do not appear to be declining so a continuing source is likely present. The well is constructed through a slag layer that is a remnant of a historical zinc and silver smelting operation at the site. The metals observed in groundwater at this location are consistent with those that are commonly found in byproduct materials from smelting operations. The collective influence of nonmilling-related contaminants at the site indicates that groundwater at the site may qualify for supplemental standards based on limited use.

Studies of potential impacts of contaminated groundwater on receptors in the Animas River (human and ecological) has indicated that post-surface remediation site conditions are protective of human health and the environment. A statistical comparison of post-remediation groundwater with more recent groundwater conditions indicates that groundwater quality at the site is generally improving over time and can be considered stable. Recent concentrations of all site constituents have remained within prediction limits based on post-remediation data. These results suggest that, based on site protectiveness, alternate concentration limits may be applied to mill tailings groundwater (particularly uranium) in lieu of more stringent standards (e.g., maximum concentration limits).

Uranium in mill tailings area groundwater is declining, on average, across the site. An analysis of attenuation rates for individual wells and site average indicate that at the average observed rates, natural flushing of uranium may still achieve maximum concentration limits (the current remediation goal) within the allotted 100-year time period. However, the uncertainty associated with such predictions is high. In addition, the compliance goal for sulfate is unrealistically low given the contributions by background and Mancos Shale. Improvements to the current compliance strategy, as discussed above, may be appropriate to consider.

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## **1.0 Introduction and Purpose**

This Verification Monitoring Report (VMR) presents monitoring data for the Durango, Colorado, Processing Site. The Verification Monitoring Report (VMR) typically assesses the progress of the groundwater remedy in achieving cleanup goals at a site. VMRs have been prepared for the Durango processing site since 2003. Previous VMRs for the site have focused on the mill tailings area and generally comparing current concentrations to modeled concentrations to determine if natural flushing was progressing within the modeled 100-year time frame. While that historical aspect of a VMR is still included as Groundwater and Surface Water Quality Data, Appendix A, this 2013 VMR includes a comprehensive analytical update.

Following this introduction, Section 2.0 presents site background information and includes pertinent information on site history, hydrology, and monitoring wells. Section 3.0 provides an additional data evaluation including:

- Background conditions at the mill site (Section 3.1.1).
- The potential impacts of milling and nonmilling sources on site water quality (Sections 3.1.2 through 3.1.5).
- Improvements to the current compliance strategy and potential alternatives (interspersed throughout Sections 3.1.1 to 3.1.7 and summarized in Section 3.1.8).
- Potential ways to optimize the monitoring approach (interspersed throughout Sections 3.1.1 to 3.1.7 and summarized in Section 3.1.8).
- Additional evaluation of the raffinate ponds area (Section 3.2).

Observations/Conclusions are provided in Section 4.0 that include recommended changes in the monitoring approach and information that impacts the site compliance strategy. Section 5.0 presents the references.



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## 2.0 Site Background Information

The Durango processing site is located in La Plata County approximately 0.25 mile southwest of the central business district of Durango (Figure 1). The site consists of two areas: (1) the mill tailings area, which is the setting of former uranium-ore milling and storage of mill tailings, as well as a lead smelter plant that operated before the uranium mill; and (2) a raffinate ponds area where liquid process wastes were impounded during milling operations. The former mill tailings area encompasses about 40 acres on a bedrock-supported river terrace between Smelter Mountain to the west, the Animas River to the east, and Lightner Creek to the north (Figure 1). The raffinate ponds area occupies about 20 acres on a separate river terrace located 1,500 feet (ft) south (downstream) of the mill tailings area (Figure 1).

### 2.1 Site Operations/Surface Remediation

#### 2.1.1 Mill Tailings Area

Before being used for processing mill tailings, the site was the location of a large lead and silver smelting operation, giving Durango the nickname of “Smelter City” (<https://www.durangoutdoors.com/trails/smelter-mountain-trail.htm>). Smelting at the site began in about 1880, and the operation was Durango’s largest employer until 1930, when the operation was shut down due to the Great Depression. It reopened in the 1940s for the purpose of processing uranium ore. During smelting operations, the facility produced gold, silver, lead, and copper. By the end of 1893, the plant was treating 300 tons of ore per day and employed 300 fulltime employees (HAER 1988). Wastes from the smelting operations in the form of slag were disposed of on part of the property. The slag, along with manmade fill, served as the base for disposal of one of the uranium mill tailings piles onsite. The Remedial Action Plan (RAP) (DOE 1991) for the site notes that the slag heaps were leveled to provide the site foundation and that up to 25 feet of slag overlies natural alluvial materials. This is an indication that, at least in some areas, the slag is not a solid layer, but can transmit water. Tailings were reportedly slurried into place against the base of Smelter Mountain (DOE 1991) and upon the slag foundation; tailings consisted of interlayered sands and slimes.

The U.S. Department of Energy (DOE) began surface cleanup of the mill tailings and raffinate ponds areas in November 1986 to meet the U.S. Environmental Protection Agency (EPA) standards for radium in soil. A total of 2.5 million cubic yards of contaminated material was relocated to the Durango disposal cell in Bodo Canyon several miles southwest of the processing site. Supplemental cleanup standards were applied to tailings that remained on the steep slopes of Smelter Mountain (Figure 1) and along the banks of the Animas River (DOE 1991). In addition, a thin lens of “uranium precipitate” was left in place at the mill tailings area below layers of slag along portions of the river.

A description in the supplemental standards application (DOE 1991, Attachment 6) describes the uranium lens as a “seam” of crystallized uranium salts located at the base of the slag material. This “deposit” was hypothesized to have formed as a result of an old spill on the slag that slowly leached through the slag layer, which is described as being vitreous and fractured. The same document refers to problems with excavating and drilling through the slag. It is unclear whether supplemental standards were formally applied to the uranium deposit beneath the slag, which had uranium concentrations averaging 94 picocuries per gram. It was further hypothesized that the

precipitate layer would eventually be washed away during spring runoff. It is not clear if the supposed precipitate layer washed away as expected or persisted for some time.

Figure 1 shows the approximate extent of the slag layer where supplemental standards were proposed based on information provided in the RAP. The boundary of the supplemental standards area appears to not coincide exactly with the extent of the slag. The well log for well 0617 (Figure 2) indicates that slag is present at that location; however, 0617 is located outside the designated supplemental standards area (Figure 3). The quitclaim deed places similar restrictions on the slag area, the river bank, and the windblown areas of Smelter Mountain (see Section 2.3).

To restore the site, approximately 230,000 cubic yards of uncontaminated soil was backfilled, contoured, and seeded. Riprap was placed in some sensitive areas along the Animas River to prevent erosion. Remedial action was completed in May 1991.

### **2.1.2 Raffinate Ponds Area**

Raffinates from the second stage of processing were pumped to a tank above the mill, which discharged into a 3,000 ft long ditch that carried the waste to the raffinate ponds area. An additional 3,000 ft of ditch carried the raffinate through a series of ponds on the terraced slope of the raffinate ponds area. The raffinate evaporated and percolated into the underlying alluvium, colluvium, and sandstone bedrock. The ponds and tailings were removed during surface remedial action completed in 1991. Unlike the mill tailings area, there is no indication that the raffinate ponds area was used for anything but mill-related processes.

## **2.2 Hydrogeology**

### **2.2.1 Mill Tailings Area**

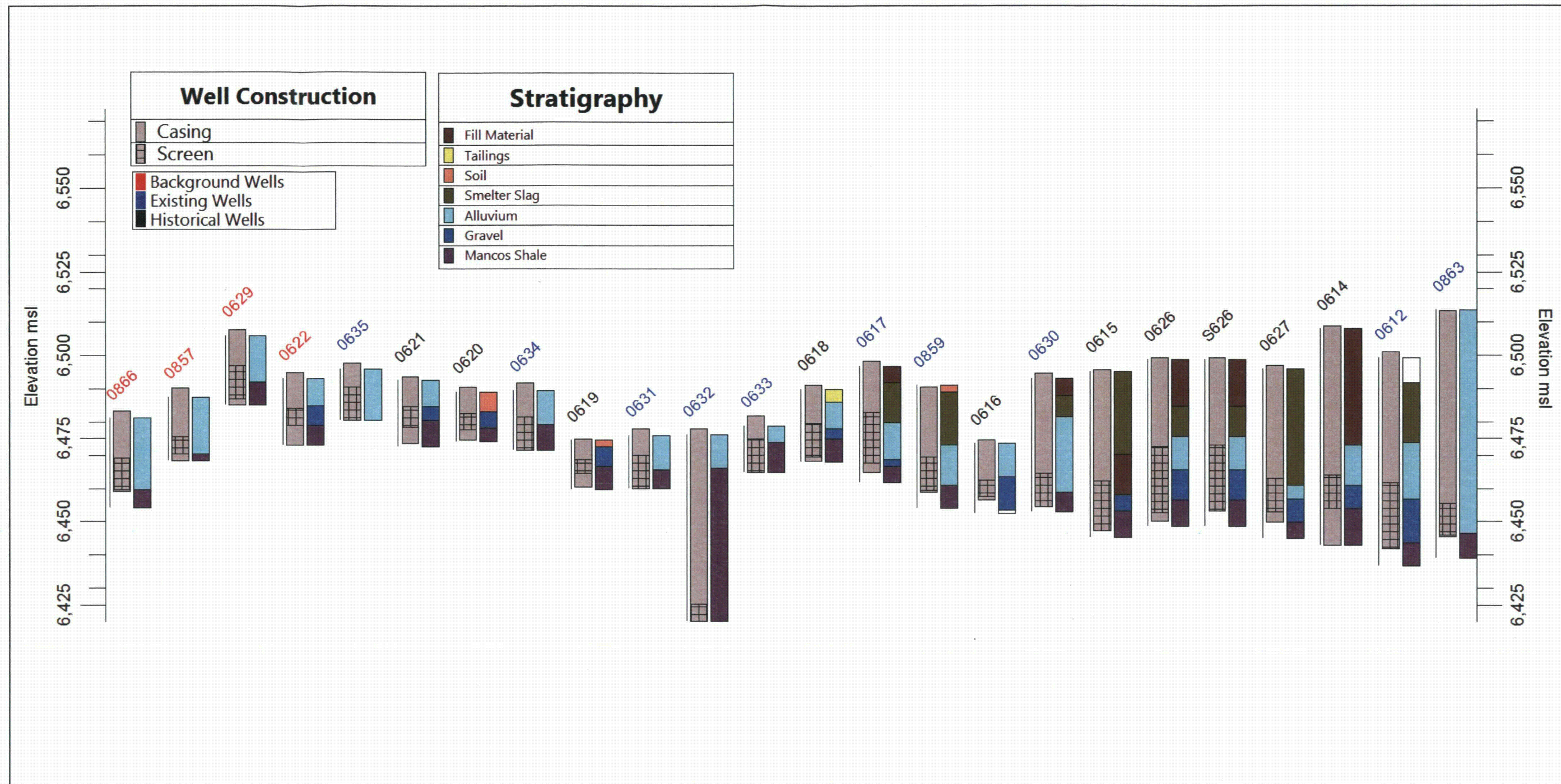
The uppermost aquifer at the mill tailings area is shallow and consists mostly of poorly sorted colluvium derived from Smelter Mountain, which rises steeply to the southwest. A portion of the shallow aquifer also comprises alluvial deposits associated with the Animas River and Lightner Creek. The colluvium and alluvium are underlain by the low-permeability Mancos Shale bedrock, which essentially acts as a hydraulic barrier that prevents downward migration of contaminants from the shallow groundwater system. Approximately 70 ft of colluvium overlies bedrock along the base of Smelter Mountain. These deposits thin eastward to about 15 ft in thickness close to the Animas River. Depth to groundwater increases from about 5 ft on the river terrace to about 60 ft near the mountain front. The saturated zone is thin (less than 10 ft thick), unconfined, of limited extent, and of low yield. Groundwater flow is generally to the southeast, parallel to the Animas River, at an average gradient of approximately 0.02 ft/ft. Hydraulic conductivity of the colluvium and alluvium ranges from 10 to 70 ft/day.





Figure 1. Durango Processing Site Features and Sampling Locations





Note: No log data available for historical well 0604 and background well 0658

Figure 2. Well Construction and Stratigraphic Logs for Existing and Historical Wells



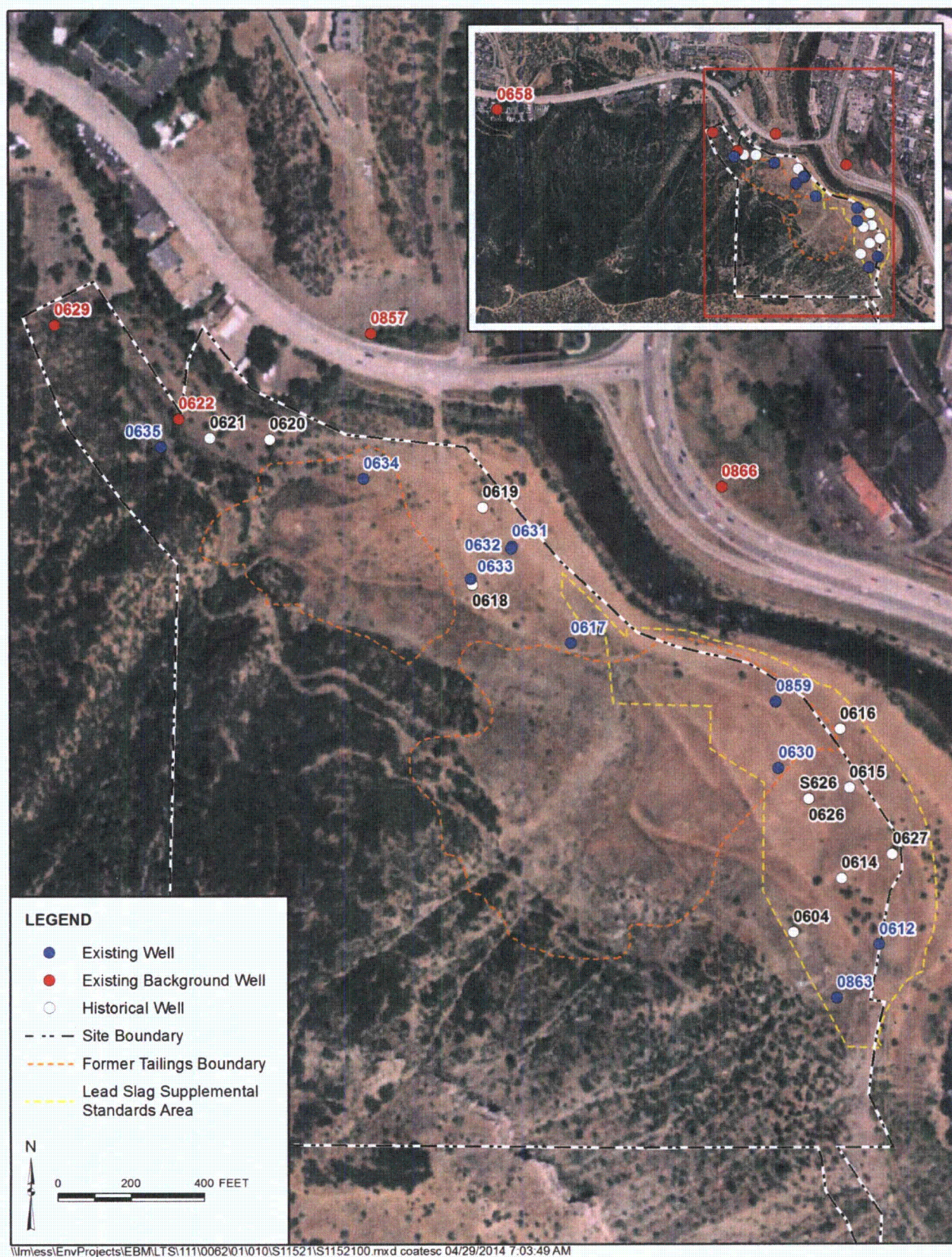


Figure 3. Mill Tailings Area Existing and Historical Wells



The colluvium is recharged primarily by runoff from Smelter Mountain and infiltrating precipitation, and the river alluvium receives inflow from Lightner Creek and from river loss along the upstream reach of a prominent river meander that defines the middle third of the mill tailings area's east boundary. Groundwater discharges to the Animas River along the upper and lower thirds of the river reach adjacent to the mill tailings area. Under average conditions, the estimated volume of groundwater discharge from the mill tailings area is 1,480 cubic feet per day ( $\text{ft}^3/\text{day}$ ); approximately 840  $\text{ft}^3/\text{day}$  of this total enters the Animas River near the mouth of Lightner Creek, and the remaining 640  $\text{ft}^3/\text{day}$  enters the Animas River east and southeast of the footprint of a former tailings pile (DOE 2002a). The alluvium and colluvium pinch out against bedrock cliffs near the southeast corner of the site, at which point groundwater discharge to the river is complete (DOE 2002a).

### **2.2.2 Raffinate Ponds Area**

Groundwater in the raffinate ponds area occurs in two bedrock units, both formations of the Mesa Verde Group, that are separated by the northeast-trending Bodo Fault (Figure 1). The Point Lookout Sandstone, the basal formation of the Mesa Verde Group, lies south of the fault and is divided into two members: a lower transitional member consisting of interbedded lenticular sandstones and shales, and an upper massive sandstone member. The Menefee Formation, north of the fault, consists of massive sandstone and shale along with beds of carbonaceous shale and coal. The Bodo Fault, a normal fault, dips to the southeast at approximately 55 degrees. The Point Lookout Sandstone is downthrown approximately 200 ft along the fault.

Groundwater in the raffinate ponds area is assumed to be unconfined. It is recharged by infiltration of precipitation and runoff from the Smelter Mountain area and the ephemeral South Creek. Eastward-flowing subsurface water also enters the groundwater system near the intersection of Bodo Fault and South Creek (Figure 1). Hydraulic conductivity data indicate that the Point Lookout Sandstone is the least conductive of the various bedrock units underlying the raffinate ponds area. The lower member (predominantly shale and siltstone) of the Point Lookout Sandstone is considered an aquitard. The Menefee Formation consists of mostly low-conductivity sandstone but is relatively permeable where fractures or lenticular coal beds are present. The largest hydraulic conductivities appear to occur near Bodo Fault and in the coal beds within the Menefee.

## **2.3 Land/Water Use and Institutional Controls**

The primary water source for the city of Durango is the Florida River upstream of its confluence with the Animas River. Additional water is withdrawn from the Animas River during high-demand periods (usually during the summer) from a location approximately 2 miles upstream of the mill tailings area. The portion of the Animas River bordering the mill tailings area of the Durango site is popular for seasonal boating and fishing. Development plans for both the mill tailings area and the raffinate ponds area do not include residential use (DOE 2002a). The quitclaim deed requires that land is used for public purposes and that ownership is restricted to a government entity within the state.

As part of the compliance strategy, public health will be protected at the mill tailings area through an environmental covenant between the State of Colorado and the City of Durango (landowner) that restricts access to contaminated alluvial groundwater. Additionally, deed restrictions (which serve as a notice to the public) for the mill tailings area prohibit access to

groundwater without written permission from DOE and the Colorado Department of Public Health and Environment (CDPHE). Groundwater use in the raffinate ponds area is restricted in perpetuity through a deed restriction that also requires DOE's permission before use of groundwater for any purpose. In addition, DOE must approve any construction plans, designs, or specifications before such activities may take place. Any habitable structures are required to employ a radon ventilation system or other mitigation measures. The State of Colorado is currently in the process of trying to obtain a signed environmental covenant agreement for the raffinate ponds area.

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### 3.0 Data Evaluation

Surface remediation and source removal was completed in 1991, and more than 2 decades of monitoring data have been collected since that time. The purpose of this data evaluation is to take a more in-depth look at the monitoring data than was presented in previous VMRs. Data used includes all historical data for the site as well as the data collected for calendar year 2013 since the last VMR was completed. A discussion of the 2013 monitoring data is included in Appendix A.

This analytical update includes an evaluation of background data, an evaluation of potential contaminant sources, and a look at spatial and temporal patterns observed for onsite wells. This analysis also includes a discussion of potential causes for observed trends and distributions of constituents in groundwater. The majority of this discussion pertains to the mill tailings area, though it also briefly reviews data for the raffinate ponds area. This VMR also provides suggestions for optimizing the monitoring approach for both portions of the site based on results of the data evaluation.

The key questions this analysis focuses on are summarized as follows:

1. Is groundwater contamination present in excess of maximum concentration limits or background levels?
2. Does contaminated groundwater meet the criteria for supplemental standards based on limited use groundwater?
3. Does contaminated groundwater qualify for alternate concentration limits (ACLs) based on acceptable human health and environmental risks and other factors?
4. Will natural flushing result in compliance with maximum concentration limits, background levels, or alternate concentration limits within 100 years?

This analysis addresses each of these questions in an effort to optimize the current compliance approach. Section 3.1.1 discusses background water quality for the site. Sections 3.1.2 through 3.1.5 describe potential sources of contamination at the site (milling and nonmilling) and the behavior of constituents identified in site groundwater over time. These sections combined can be used to answer questions 1 and 2. Section 3.1.6 evaluates the protectiveness of groundwater at the site since completion of surface remediation and addresses question 3. Section 3.1.7 provides a statistical evaluation of the progress of natural flushing to address question 4. Section 3.1.8 summarizes the potentially applicable compliance improvements.

#### 3.1 Mill Tailings Area

The uppermost aquifer is comprised of primarily an alluvial/colluvial system on top of Mancos Shale (aquitard). Various deposits have been recognized (including gravels, fill), but essentially the site consists of shallow unconsolidated materials on top of bedrock. According to the Baseline Risk Assessment (BLRA) for the site (DOE 1995), the colluvium covers the half of the site that borders Smelter Mountain; alluvium is present on the half of the site adjacent to the Animas River. Reportedly the colluvium yields little water, which may explain the lack of wells on that half of the site. Most of the mill site wells are screened predominantly in alluvial material. However, several have screens that extend at least partially into the Mancos Shale

(Figure 2). Well 0632, which was sampled only once due to a lack of water, is screened completely in the Mancos.

At the southeastern end of the site along the Animas River, there is a layer of slag from the former lead/silver smelting operation, as discussed in Section 2.1.1. Where present, the slag sits on top of alluvium or soil and in most locations is either present at the land surface or is covered with fill. The slag is up to 30 ft thick and predates the milling operation. Based on the descriptions of the slag, it does not appear to be a solid impermeable layer but is capable of transmitting water. The above-described uranium “deposit” (Section 2.1.1) reportedly formed due to fluids migrating through the slag layer and precipitating at its base. Some portions of the slag layer may be more solid than others. One reason that the slag was not removed during surface remediation (other than the fact that it was determined to not be residual radioactive material) was reportedly due to difficulties in excavation and drilling of the material (DOE 1991, Attachment 6). As shown in Figure 2, the wells in the slag area are completed below this layer and are screened below or partially in the slag layer. No wells are screened exclusively in the slag.

### **3.1.1 Background Water Quality**

Different wells have been designated as background for the mill tailings area in different reports. Background wells for the mill tailings area that were used in the Site Observational Work Plan (SOWP, DOE 2002a) included 0629, 0857, and 0866. It appears that well 0622 was determined to be a background well during development of monitoring requirements for the Groundwater Compliance Action Plan (GCAP; DOE 2003), and sampling of that well was subsequently discontinued. Well 0658 is located upgradient of the site along Lightner Creek (Figure 3), and groundwater in 0658 is unaffected by site-related activities.

The primary source of recharge (according to the SOWP; DOE 2002a) for the mill tailings area is Lightner Creek. Wells 0629, 0622, and 0635, located upgradient of the tailings piles and adjacent to the creek, are likely most representative of recharge from this source. Well 0658 also is likely to receive recharge from this source. Background wells 0857 and 0866, while unaffected by site-related activities, may not be representative of the bulk of background groundwater entering the mill site, as they are hydrogeologically separated from the mill site area (Figure 3). Water from these wells may be more similar to the Animas River recharge component. A combination of all of these background areas may be more representative of water entering the site than any one well.

This evaluation examines the likelihood that samples from wells 0635 and 0622 are representative of background water quality and whether data from those wells can be pooled with the data from other accepted background wells to form a larger, more representative data set. Uranium and sulfate, which have been considered to be the best indicators of site-related contamination, are the focus of this evaluation. Figure 4 and Figure 5 show uranium and sulfate time-concentrations plots for wells 0622 and 0635 along with the other recognized background wells.

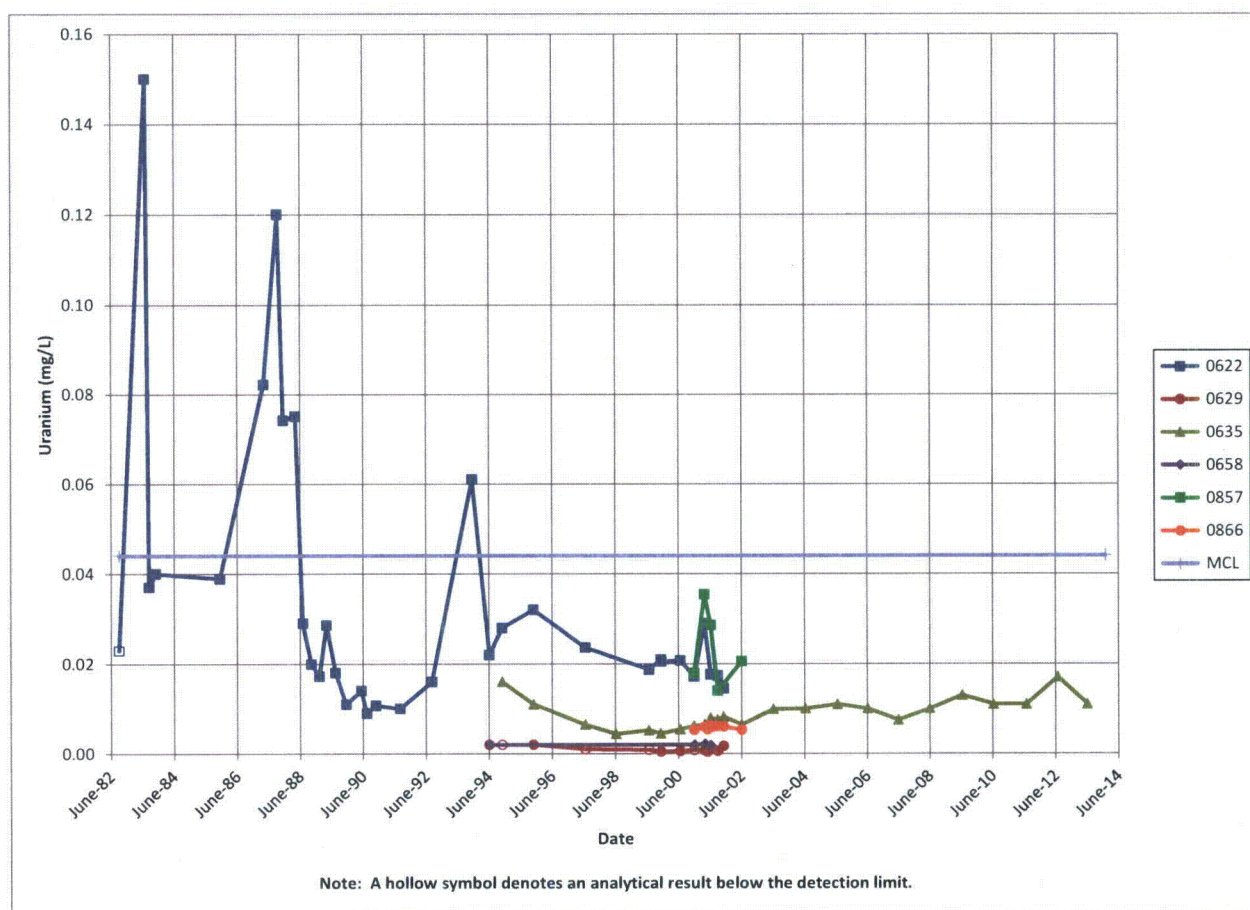


Figure 4. Uranium Concentrations in Background Wells

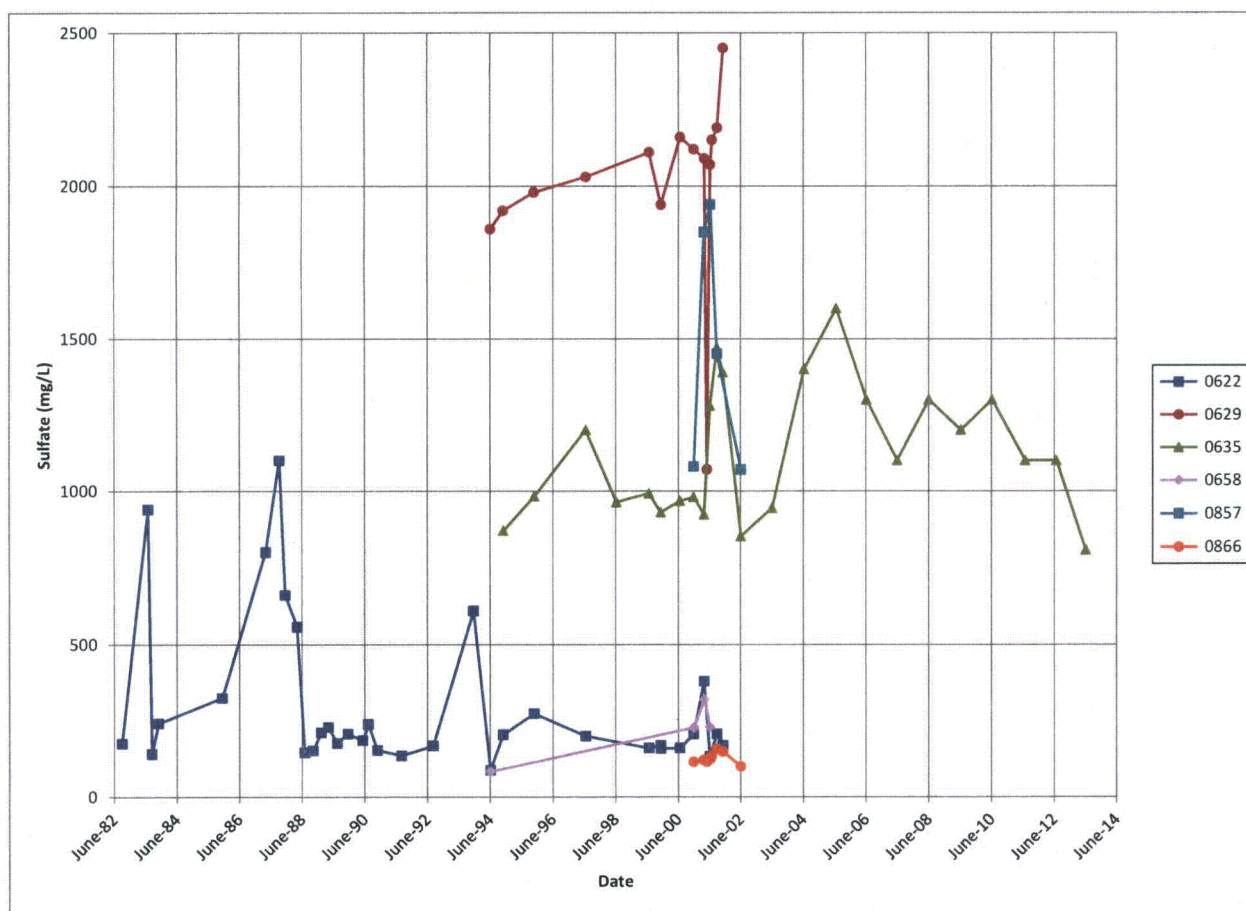


Figure 5. Sulfate Concentrations in Background Wells

Well 0622 does have elevated uranium concentrations compared to most of the other wells, with a couple of spikes occurring during surface remediation. However, only a single sample collected from well 0622 since the completion of surface remediation exceeded the maximum concentration observed in background well 0857. Although the RAP does not mention groundwater mounding associated with tailings, the BLRA (DOE 1995) attributed pre-surface remediation uranium at well 0622 to tailings seepage. That report also concluded that all site-related contamination had been “completely flushed” by the time that document was completed in 1995.

The most recent uranium data available for well 0622 overlaps with that from well 0857 (Figure 4), which is not affected by site-related contamination (being physically and hydrologically separate from the mill tailings area). These two wells display the highest background concentrations. Lowest uranium concentrations are observed in wells 0629 and 0658, which are also unaffected by site-related contamination. Wells 0635 and 0866 have concentrations between the two extremes. Data from well 0635 show an apparent downward trend followed by an upward one. It is not clear if these trends are meaningful or if they reflect the natural variability of the groundwater system. The short monitoring history for some wells that may be unequivocally considered to be background may not accurately capture the natural variability of the alluvial system. The uranium fluctuations observed in well 0857 illustrate this point.

Figure 5 shows sulfate concentrations for the same wells discussed above. As with uranium, well 0857 has among the highest sulfate concentrations observed. In contrast, well 0629, with very low uranium, displays the highest observed sulfate concentrations. As shown in Figure 2, well 0629 is screened partially across Mancos Shale, while the other background wells are completed mostly in alluvial material. Well 0622 has sulfate concentrations comparable to those in wells 0866 and 0658, which are unaffected by site-related contamination. Sulfate concentrations from well 0635, as with uranium, tend to be intermediate between the observed highs and lows for background.

Data for wells 0622 and 0635 for other known site-related constituents (e.g., vanadium, molybdenum, cadmium) are low and indistinguishable from other established background locations. Therefore, for the remainder of this report, it is assumed that since the completion of surface remediation, wells 0622 and 0635 are representative of background (i.e., nonmilling groundwater quality) for the mill tailings area. Background statistics are computed using the entire record of data for well 0635 and data collected since 1994 for well 0622 along with all data for wells 0629, 0658, 0857, and 0866.

Regionally, shallow groundwater for the Durango area is considered to be poor (DOE 1995). Hardness is high and concentrations of iron and manganese are elevated. Site-specific background analyses support this assessment. Wells have high levels of total dissolved solids (TDS), sulfate, manganese, and iron that exceed secondary drinking water standards. Different wells are high in different constituents, though all are elevated in TDS compared to the secondary drinking water standard of 500 milligrams per liter (mg/L). Table 1 provides a summary of background data reported in the SOWP; standards provided in the table are only for comparison to indicate that ambient groundwater is generally poor. State standards are provided where available, as these are most relevant for the purposes of aquifer classification. However, the UMTRCA maximum concentration limits (MCLs) from Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192) are most relevant from a compliance standpoint.

Table 2 provides updated background statistics for the wells discussed above. EPA's ProUCL software, Version 4.1.00, was used to compute these statistics (EPA 2010). In addition to standard summary statistics, a 95 percent upper prediction limit (UPL 95) was calculated for each constituent. A prediction interval (specified by upper and lower prediction limits) is an estimate of an interval in which future individual observations will fall, given what has already been observed. For data sets with greater variability, prediction intervals are generally wider. Upper prediction limits, usually a UPL 95, are often used to define an upper threshold value for a background data set in a detection monitoring program (EPA 2009). As long as observed concentrations remain below the UPL 95, it is concluded that groundwater quality is consistent with background. Results from the ProUCL statistical analysis are included in Appendix B. Note that background wells used in the SOWP were last sampled in 2002.



Table 1. Summary of Background Water Quality for the Mill Tailings Area (from SOWP; DOE 2002a)<sup>e</sup>

Constituent	FOD	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard
Arsenic	0/20	<0.0013	na	na	0.01 <sup>a</sup> /0.05 <sup>f</sup>
Cadmium	0/20	<0.007	na	na	0.005 <sup>a</sup> /0.01 <sup>f</sup>
Chloride	20/20	9.90	265	64.2	250 <sup>a</sup>
Sulfate	20/20	114	2190	1255	250 <sup>a</sup>
Iron	15/18	0.12	14.7	3.38	0.3 <sup>a</sup> /5 <sup>b</sup>
Manganese	20/20	0.073	1.05	0.601	0.05 <sup>a</sup> /0.2 <sup>b</sup>
Molybdenum	0/20	<0.0057	na	na	0.21 <sup>a</sup> /0.1 <sup>f</sup>
Selenium	8/20	<0.011	0.0148	0.014	0.05 <sup>a</sup> /0.01 <sup>f</sup>
TDS	20/20	623	3860	2528	500 <sup>d</sup>
Uranium	11/20	0.005	0.035	0.012	0.0168 to 0.03 <sup>c</sup> /0.044 <sup>f</sup>
Vanadium	0/20	<0.0020	na	na	0.1 <sup>b</sup>

<sup>a</sup> Domestic water supply—drinking water standard (Volume 5 Code of Colorado Regulations 1002-41 [5 CCR 1002-41])

<sup>b</sup> Agricultural Standard (5 CCR 1002-41)

<sup>c</sup> Domestic water supply—human health standards (5 CCR 1002-41)

<sup>d</sup> Federal Secondary Drinking Water Regulations

<sup>e</sup> Data from wells 0629, 0857, 0866; June 1999 through August 2001

<sup>f</sup> 40 CFR 192 groundwater standards; standard for uranium assumes secular equilibrium between U-234 and U-238

na = not applicable

FOD = frequency of detection

Table 2. Updated Background Statistics for Selected Constituents (1994+)

Constituent	Number of Samples	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	UPL 95 <sup>a</sup>
Chloride	54	1.45	265	33.66	264
Iron	39	0.0047	14.7	1.576	17.18
Manganese	70	0.0023	3.22	0.347	2.486
Sulfate	63	42	2,450	1,044	4,234
Uranium	60	0.0003	0.034	0.00996	0.0464

<sup>a</sup> Nonparametric Chebyshev UPL was used; wells 0622, 0629, 0635, 0857, 0866

For the Durango processing site, the background UPL 95 for a number of constituents exceeds water quality standards. Most of the exceeded standards are only secondary standards that are not compliance related. However, these exceedances are consistent with the observation that regional groundwater quality in the Durango area is generally poor. As with the raffinate ponds area, this suggests that ambient contamination, unrelated to uranium milling, is present in the uppermost aquifer in the mill tailings area.

### 3.1.2 Milling-Related Contamination

To determine the potential effects of uranium milling on groundwater quality at the site, it is important to determine which constituents were attributed to the milling process. This section provides a summary of information on milling-related contamination. Most milling-related data were collected during preparation of the RAP to help characterize mill-related contaminants; data from this time frame are limited. Samples of tailings-related fluids were collected from the tailings piles before the start of surface remediation using suction lysimeters. According to the RAP, sample volume “was sufficient” for analysis of major anions and cations, radium-226 and radium-228, and uranium. The description of the lysimeter sampling appeared to indicate that excessive amounts of fluids were not present. Radium-226 in tailings fluids was reported to range from 1.3 to 33 picocuries per liter and uranium from 0.047 to 2.89 mg/L. No other constituent results were reported in the RAP.

After relocation of tailings to Bodo Canyon, monitoring wells were installed within the tailings, and a more complete suite of analyses were performed from collected samples. Table 3 presents a summary of these results. It is assumed that these results are representative of tailings leachate compositions that could have affected site groundwater. Based on these data, it appears that tailings fluids were elevated in nearly all constituents except chloride relative to the standards. Iron in tailings fluids was higher than the domestic standard but less than the agricultural standard. In a comparison of Table 2 and Table 3, tailings concentrations of chloride, iron, and sulfate are not different from concentrations expected in background groundwater. However, uranium concentrations are markedly higher than background levels.

Table 3. Tailings Pore Water Samples (from DOE 1991)

Contaminant	Number of Samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard
Arsenic	15	0.09	0.57	0.19	0.01 <sup>a</sup> /0.05 <sup>e</sup>
Cadmium	15	0.014	0.063	0.037	0.005 <sup>a</sup> /0.01 <sup>e</sup>
Chloride	15	59	210	75	250 <sup>a</sup>
Iron	15	0.09	0.63	0.14	250 <sup>a</sup>
Manganese	15	3.03	8.63	6.01	0.3 <sup>a</sup> /5 <sup>b</sup>
Molybdenum	15	0.81	3.9	1.73	0.05 <sup>a</sup> /0.2 <sup>b</sup>
Selenium	15	0.045	0.408	0.132	0.21 <sup>a</sup> /0.1 <sup>e</sup>
Sulfate	15	1540	2800	1710	0.05 <sup>a</sup> /0.01 <sup>e</sup>
TDS	15	2790	5080	3250	500 <sup>d</sup>
Uranium	15	1.47	21.6	4.54	0.0168 to 0.03 <sup>c</sup> /0.044 <sup>e</sup>
Vanadium	5	5.7	14.4	11.1	0.1 <sup>b</sup>

<sup>a</sup> Domestic water supply—drinking water standard (Volume 5 *Code of Colorado Regulations* 1002-41 [5 CCR 1002-41])

<sup>b</sup> Agricultural Standard (5 CCR 1002-41)

<sup>c</sup> Domestic water supply—human health standards (5 CCR 1002-41)

<sup>d</sup> Federal Secondary Drinking Water Regulations

<sup>e</sup> 40 CFR 192 groundwater standards; standard for uranium assumes secular equilibrium between U-234 and U-238

Groundwater samples were collected from the mill tailings area shortly after the completion of surface remediation in the vicinity of the tailings piles; those results are summarized in Table 4. These samples likely represent the most highly contaminated groundwater that was historically present at the site; natural attenuation processes have reduced milling-related concentrations since that time. Maximum values for uranium, manganese, cadmium, selenium, arsenic, TDS, and chloride were all elevated above background. However, minimum and median values for these constituents suggest that only uranium has had a significant impact on site groundwater, with more than half the samples exceeding applicable standards.

*Table 4. Groundwater Data for Former Tailings Area Alluvial Wells—1987 to 1991 (from DOE 1991)*

Contaminant	Number of Samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard
Arsenic	37	<0.006	0.05	<0.006	0.01 <sup>a</sup> /0.05 <sup>e</sup>
Cadmium	37	<0.001	0.061	0.002	0.005 <sup>a</sup> /0.01 <sup>e</sup>
Chloride	37	2.1	795	52.2	250 <sup>a</sup>
Iron	37	<0.03	0.15	0.07	250 <sup>a</sup>
Manganese	37	<0.01	6.44	0.03	0.3 <sup>a</sup> /5 <sup>b</sup>
Molybdenum	37	<0.01	0.42	0.03	0.05 <sup>a</sup> /0.2 <sup>b</sup>
Selenium	37	<0.005	0.226	0.036	0.21 <sup>a</sup> /0.1 <sup>e</sup>
Sulfate	37	134	3,360	1,990	0.05 <sup>a</sup> /0.01 <sup>e</sup>
TDS	37	468	6,560	3,440	500 <sup>d</sup>
Uranium	37	<0.001	4.67	0.201	0.0168 to 0.03 <sup>c</sup> /0.044 <sup>e</sup>
Vanadium	20	<0.01	0.61	0.01	0.1 <sup>b</sup>

<sup>a</sup> Domestic water supply—drinking water standard (Volume 5 *Code of Colorado Regulations* 1002-41 [5 CCR 1002-41])

<sup>b</sup> Agricultural Standard (5 CCR 1002-41)

<sup>c</sup> Domestic water supply—human health standards (5 CCR 1002-41)

<sup>d</sup> Federal Secondary Drinking Water Regulations

<sup>e</sup> 40 CFR 192 groundwater standards; standard for uranium assumes secular equilibrium between U-234 and U-238

### 3.1.3 Spatial and Temporal Variation in Onsite Water Quality

This section examines the spatial and temporal variation in water quality at the mill tailings site to determine if any patterns emerge that enhance the understanding of the site. This discussion builds on the data presented in the background and milling-related contamination sections (Sections 3.1.1 and 3.1.2). Background wells located on the mill site (wells 0629, 0622, and 0635; Figure 3) are included on a number of figures for comparison. The first part of this section focuses on uranium and sulfate and provides a discussion of time-concentration plots and statistical trend analysis. The end of this section looks at data for other constituents observed at the site to examine the possibility that sources other than mill tailings may be adversely affecting groundwater quality in some portions of the site. Two such sources of contamination are considered—the Mancos Shale (Section 3.1.4) and the slag layer (Section 3.1.5).

Based on the discussion in Section 3.1.2, uranium is the most likely milling-related constituent at the site. Figure 6 through Figure 8 show time-concentration plots for uranium in onsite wells. Concentrations in wells 612 and 0633 are an order of magnitude higher than concentrations in all

other wells. These locations are the closest downgradient wells from each of the former tailings piles and likely received the most highly concentrated mill-related fluids. Data for historical site wells indicate that locations upgradient of well 0612 had concentrations of uranium as high as 6 mg/L. Concentrations in well 0633 have declined by approximately 1 mg/L since monitoring began at this location. Concentrations at location 0612 have declined approximately 3 mg/L since their peak.

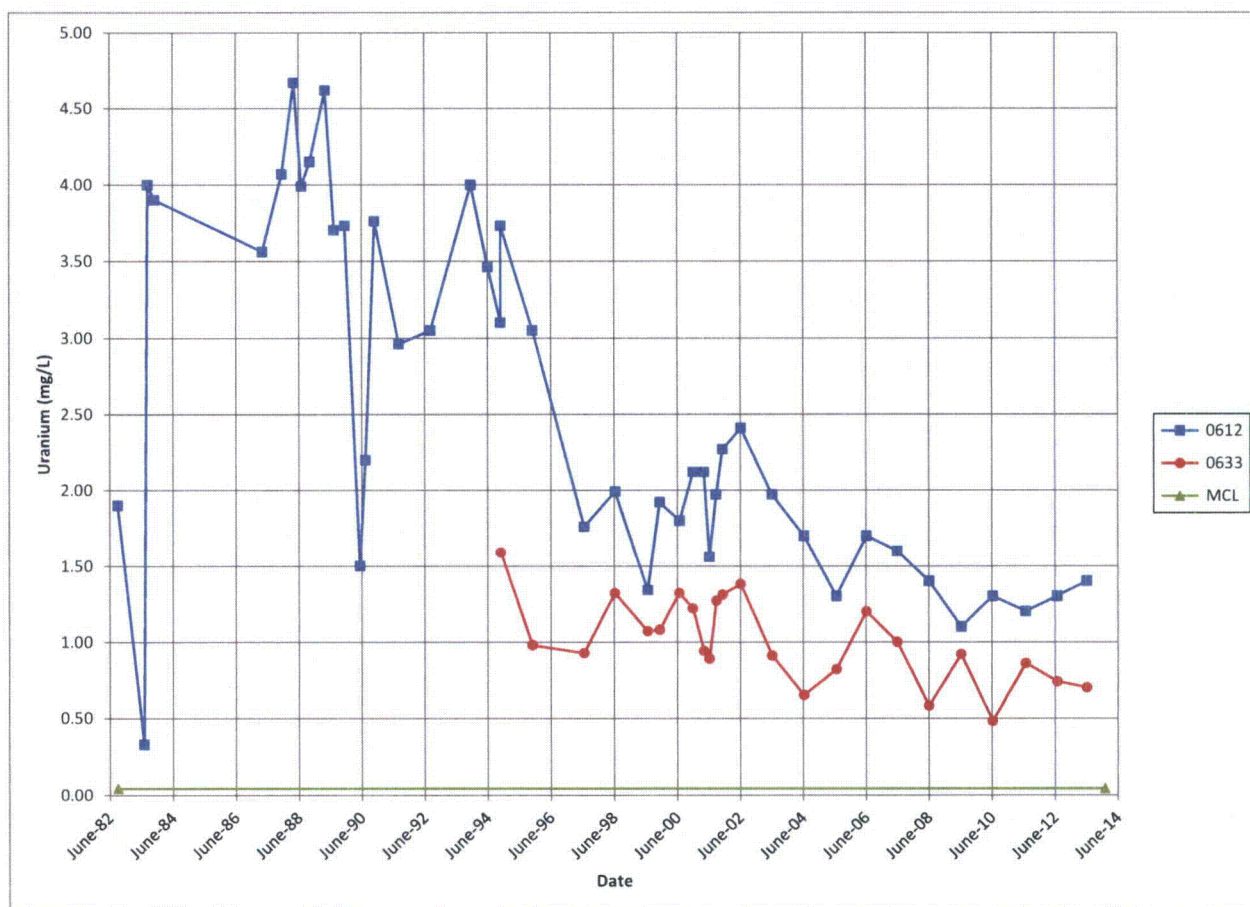


Figure 6. Uranium Concentrations Wells 0612 and 0633



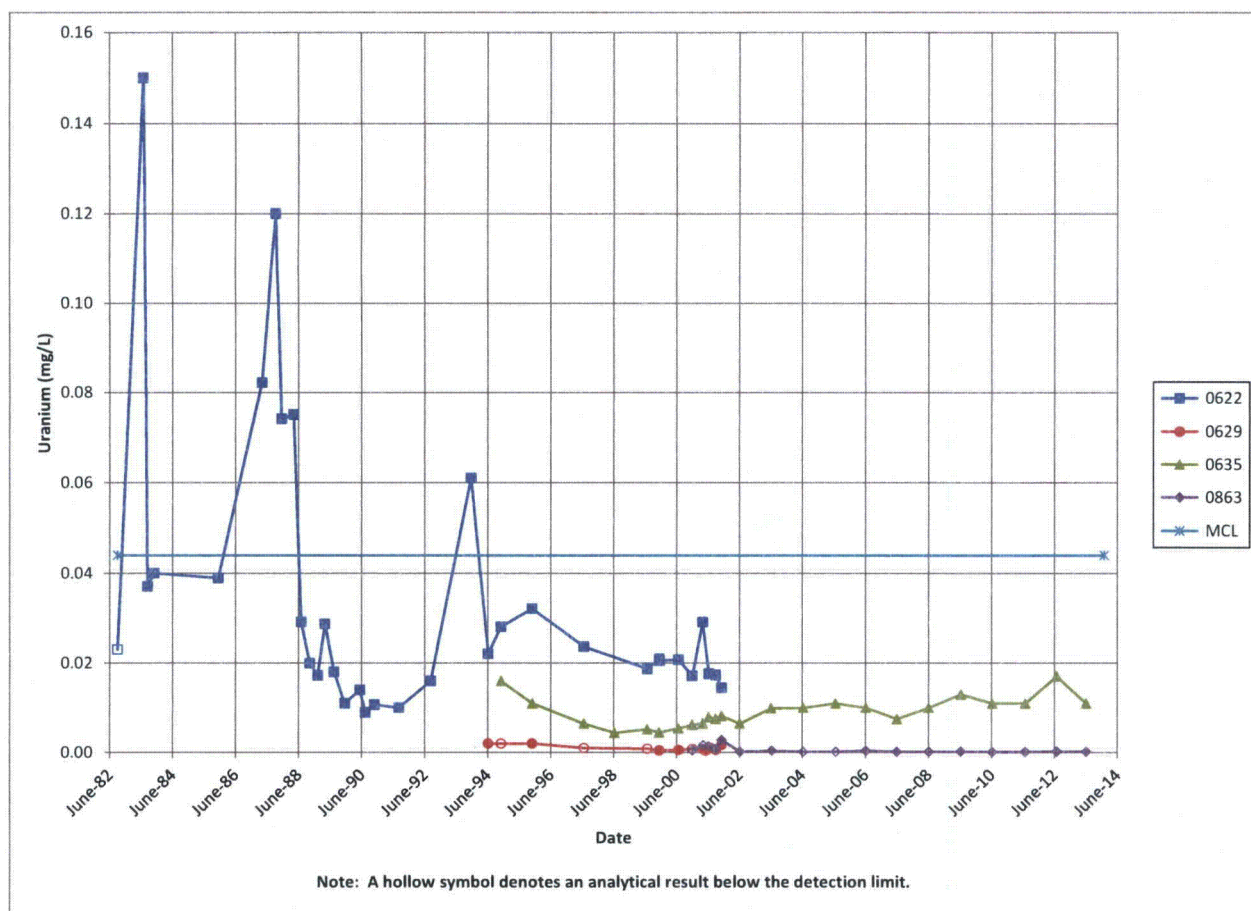


Figure 7. Uranium Concentrations Wells 0622, 0629, 0635, and 0863



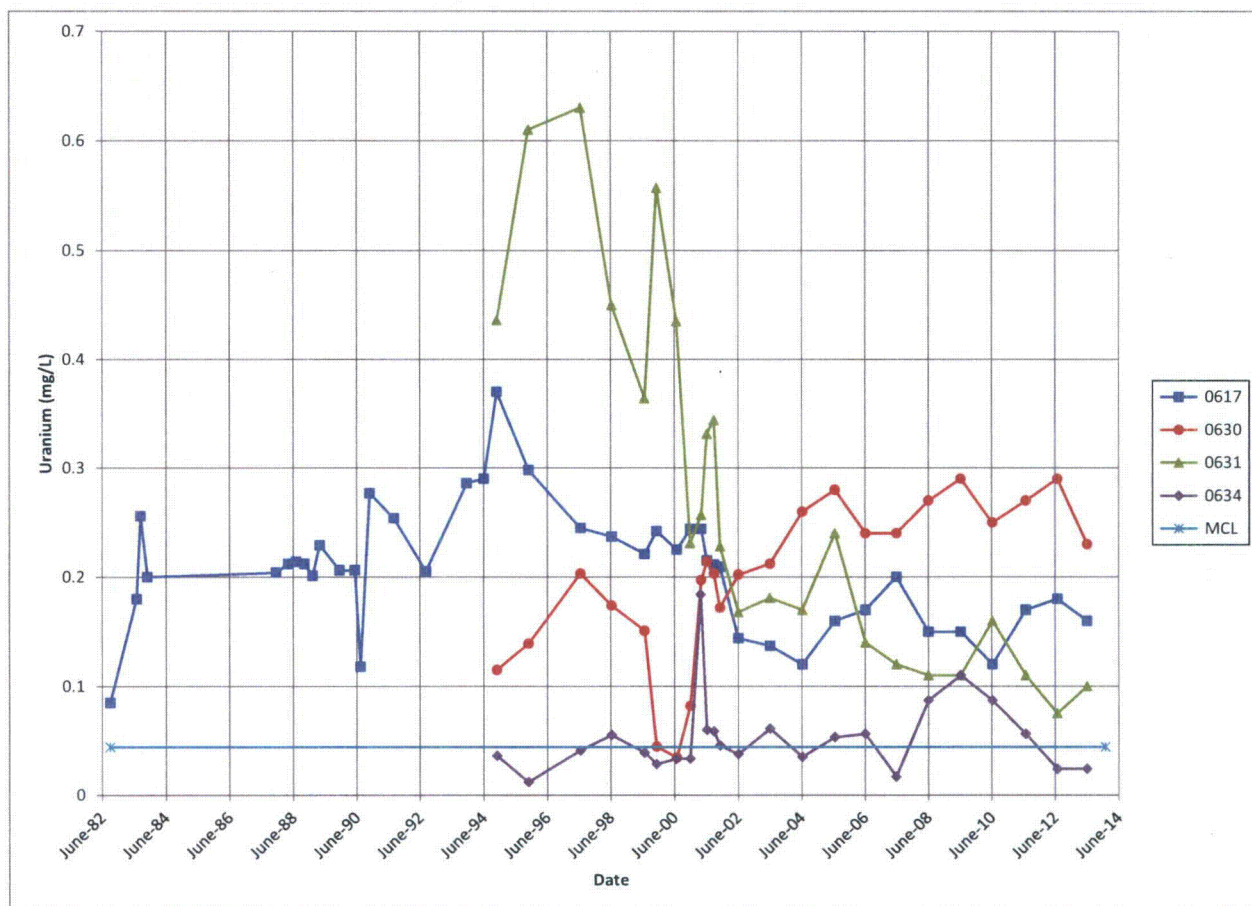


Figure 8. Uranium Concentrations Wells 0617, 0630, 0631, and 0634

The lowest uranium concentrations on the site are from wells 0629, 0635, and 0863. All of these wells have been below the uranium standard of 0.044 mg/L throughout their monitoring histories. Concentrations in well 0622 have also been relatively low and below the standard since about 1994.

Wells 0617, 0630, and 0634 have had concentrations regularly elevated above the UMTRCA groundwater standard. Uranium concentration in well 0617 appeared to be increasing prior to 1994 and declining after that time. Well 0630 appears to display an increasing trend, and uranium in well 0634 fluctuates around a concentration of about 0.05 mg/L. Note how wells 0617 and 0631 show opposite and crossing trends compared to well 0630 since the late 1990s. This is possibly due to a slug of uranium moving downgradient from the vicinity of wells 0631 and 0617 toward location 0630. While some water likely discharges to the river in the northern part of the site, movement parallel to the river from location 0617 to 0630 is consistent with the flowlines in the groundwater model (DOE 2002a). If uranium behavior at location 0630 parallels that of 0617 and 0631, uranium in 0630 should start declining in the near future.

Along with uranium, sulfate has historically been thought of as an indicator of site-related contamination in the mill tailings area. Figure 9 through Figure 11 show sulfate concentrations for highest to lowest concentration wells. Highest sulfate wells are 0612 and 0633, which have been in the 3,000 to 3,500 mg/L range. Medium concentration wells include onsite wells 0617,

0630, and 0634 and background well 0629, with concentrations in the 2,000 mg/L range. Lowest wells include background wells 0622 and 0635 along with onsite wells 0631 and 0863; these wells have concentrations that are generally below 1,500 mg/L.

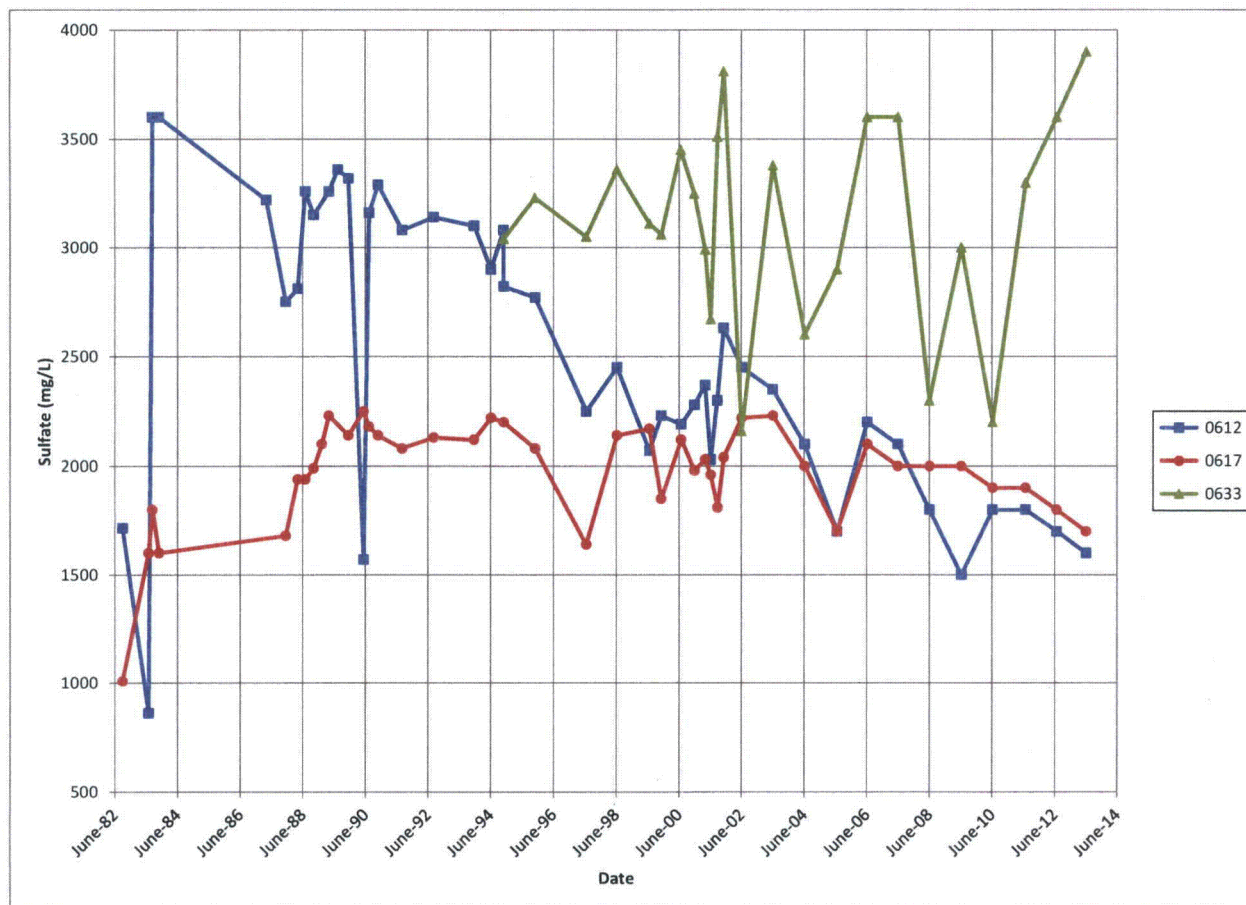


Figure 9. Sulfate Concentrations Wells 0612, 0617, and 0633

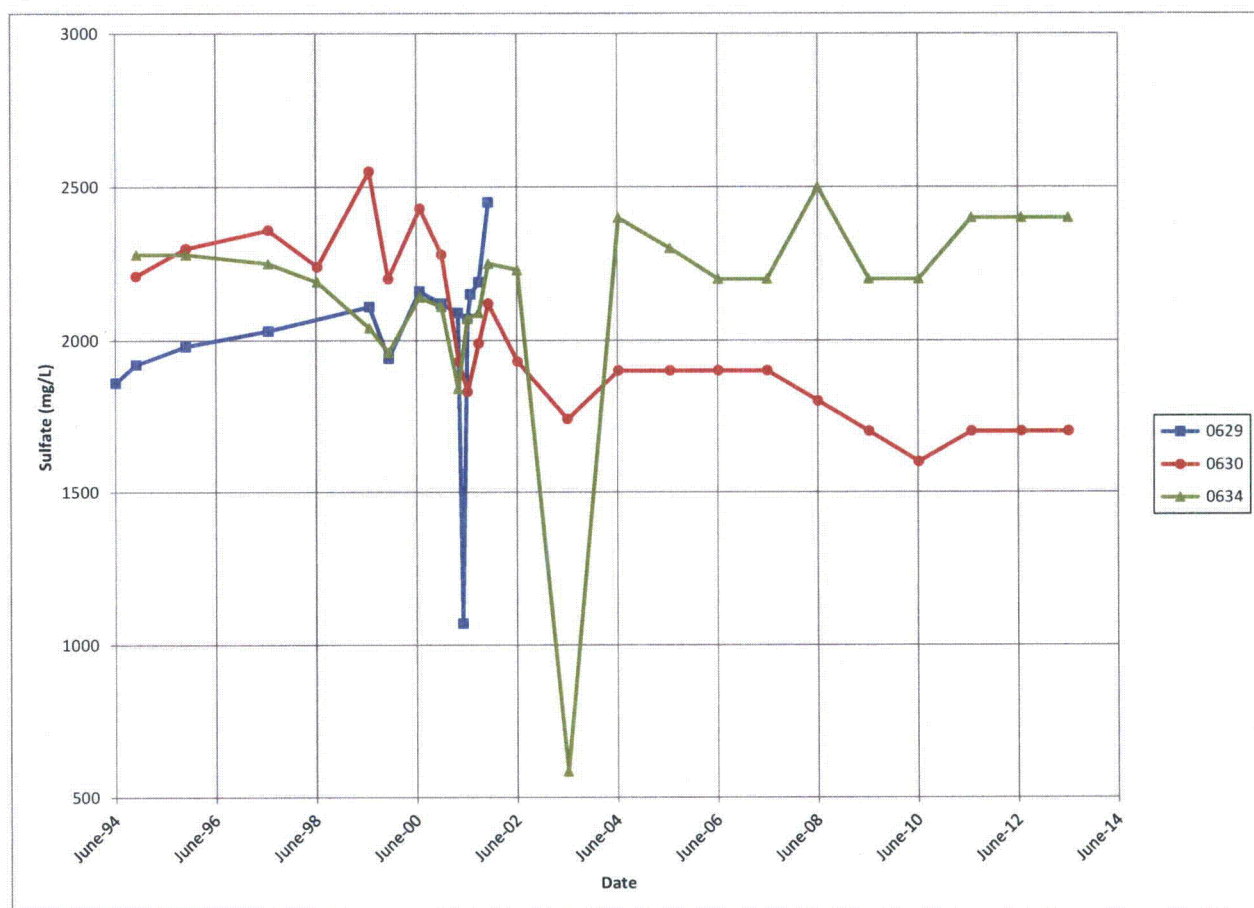


Figure 10. Sulfate Concentrations Wells 0629, 0630, and 0634



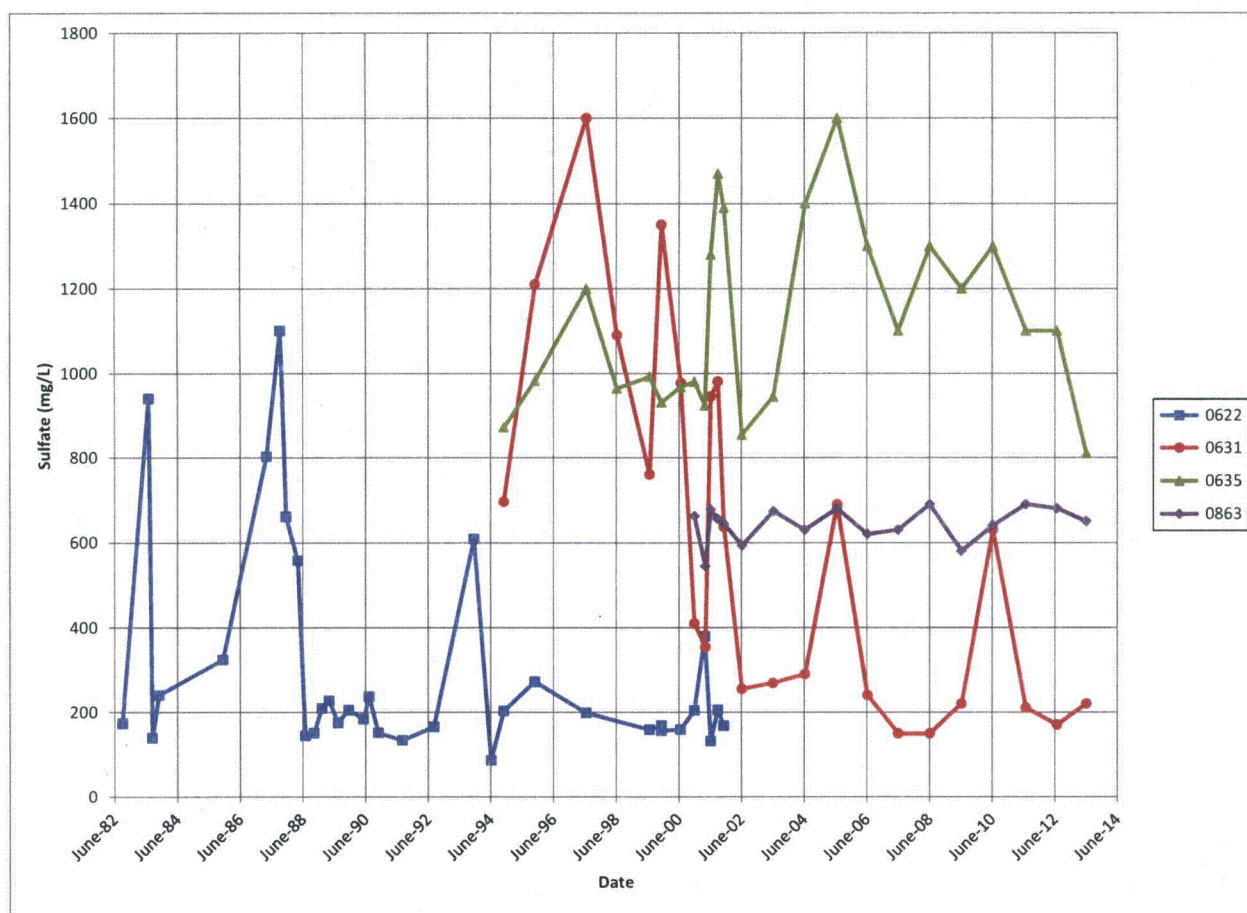


Figure 11. Sulfate Concentrations Wells 0622, 0631, 0635, 0863

Wells 0612, 0630, and 0631 have discernible downward trends on the time-concentration plots. For other wells, concentrations appear to fluctuate (quite markedly in some instances) about a somewhat constant level. For example, well 0617 appears to fluctuate above and below a concentration of around 2,000 mg/L; well 0633 has a wider fluctuation range about a concentration of around 3,000 mg/L. As with uranium, 0612 and 0633 have highest concentrations, but while 0612 displays a declining trend in sulfate, 0633 does not.

The discussion regarding background levels of sulfate indicated that fairly high levels of sulfate are attributed to background sources. All onsite samples have sulfate concentrations below the UPL 95 for background. Only wells 0612 and 0633 display concentrations that exceed the maximum observed in background wells of approximately 2,500 mg/L. As concentrations in well 0612 have declined to within the background range, it is likely that the excess sulfate observed at that location was derived from tailings fluids. In contrast, sulfate at location 0633 seems anomalous and distinct from that in the remainder of onsite wells. Historical wells 0626 and 0618 had concentrations comparable to those in 0633 (>3,000 mg/L). All of these wells are screened across the Mancos Shale. Wells 0629, 0630, and 0634 (Figure 10) are also partially screened across the Mancos. Well 0631 is also screened across the Mancos Shale, but recent results for sulfate are among the lowest observed at the site. This well is located immediately adjacent to the Animas River, and it is likely that surface water interaction with groundwater affects water quality at this location.

Although well 0863 is located closest to well 0612, it has sulfate concentrations that are more comparable to the lowest background wells. While sulfate at well 0612 has declined significantly over time, the low and steady concentrations observed in well 0863 suggest that site-related groundwater may be bypassing this well and flowing eastward to the river from location 0612. Well 0863 may be considered more of a background location than a downgradient one with respect to site-related contamination.

Statistical trend testing was performed in an attempt to quantify the apparent trends for uranium and sulfate observed and discussed above. The Mann-Kendall test for trend was used to determine if individual wells showed increasing or decreasing trends and at what level of significance. According to Gilbert (1987), this test “can be viewed as a nonparametric test for zero slope of the linear regression of time-ordered data versus time.” As the confidence level approaches 50 percent, the slope approaches zero. EPA’s ProUCL software, Version 4.1.00 (EPA 2010), was used to perform the Mann-Kendall statistical method. Initially, the entire data set of uranium for each well was used for the evaluation, including some data collected prior to the completion of surface remediation. Because time-concentration plots suggested that trends could be biased based on very high concentrations observed before source (i.e., tailings) removal, another evaluation was completed for both uranium (U) and sulfate (SO<sub>4</sub>) data collected a number of years after the completion of surface remediation (2001 onward). Results are reported in Table 5. Appendix B Section B.3 provides the ProUCL output from the evaluation.

*Table 5. Mann-Kendall Results for Mill Tailings Area Wells*

<b>Well Designation</b>	<b>Uranium Trend based on entire record (Confidence Level)</b>	<b>U Trend based on 2001+ Data (Confidence Level)</b>	<b>Sulfate Trend based on 2001+ Data (Confidence Level)</b>
0622	decreasing (95%)	na	decreasing (95%)
0635	increasing (95%)	increasing (95%)	increasing (85%)
0634	increasing (80%)	decreasing (80%)	increasing (95%)
0633	decreasing (95%)	decreasing (95%)	increasing (70%)
0631	decreasing (95%)	decreasing (95%)	decreasing (95%)
0617	decreasing (95%)	decreasing (90%)	decreasing (95%)
0630	increasing (95%)	increasing (95%)	decreasing (95%)
0612	decreasing (95%)	decreasing (95%)	decreasing (95%)
0863	na	decreasing (95%)	increasing (75%)
Average onsite wells	na	decreasing (95%)	decreasing (90%)

**Notes:** na = not applicable; only 1 year of data are available for well 0622 from 2001+; only 1 year of data available for well 0863 prior to 2001; average excludes well 0622 (assumed to be background).



Mann-Kendall trend results are generally the same for both pre- and post-remediation uranium data sets, with the exception of well 0634. The wells with highest uranium concentrations (e.g., 0612 and 0633) show strongly decreasing trends. Well 0622 also shows a strongly decreasing trend, supporting the hypothesis that milling-related uranium affected that location but has subsequently been flushing from the system. Well 0630 shows increasing uranium for both data sets; as noted above, this could be the result of an upgradient pulse of uranium moving through the groundwater system, consistent with natural flushing. While test results indicate a strongly increasing trend in uranium for well 0635, concentrations in this well are low and within the range of background; it is unclear if this trend is meaningful. A strongly decreasing trend for the average of onsite wells for uranium indicates that from a sitewide standpoint, natural flushing appears to be occurring.

As with time-concentration plots, Mann-Kendall results for sulfate are less clear than they are for uranium. Trend results confirm that wells 0612, 0630, and 0631 display downward trends in sulfate at a high level of confidence. On average for the site, sulfate appears to be decreasing, but with a slightly lower level of confidence than uranium. Well 0635, as with uranium, shows an increasing trend. Wells 0633 and 0863 also display increasing trends.

Figure 12 and Figure 13 show pre-remediation and post-remediation plume maps for both uranium and sulfate. To provide the most coverage, the maps were constructed using data collected over multiple years. The pre-remediation maps plot maximum concentrations obtained between 1983 and 1994 for any wells at the site. This should provide a “worst-case” picture of the groundwater before source removal was complete. The post-remediation plume maps plot the most recent result obtained for any site wells from the period 2001 to 2013. These maps show the result of natural flushing on groundwater quality. Different sets of wells were used for plume interpretation for the historical and recent maps. Fewer wells were available to construct the post-remediation map because a number of historical wells were abandoned. The southwestern half of the plume cannot be viewed with any confidence because it is based only on extrapolation from existing data using the kriging routine in the software package (no wells are located in this area). However, as noted above, this portion of the site is dominated by colluvium, which yields little water. Therefore, the figures are most useful for observing concentration changes in the alluvium.

Figure 12 seems to indicate that uranium is declining on a sitewide basis. Concentrations in the vicinity of the northern tailings pile that were on the order of 1 to 2 mg/L have declined by an order of magnitude or more in some cases. Likewise, concentrations in the downgradient portion of the site (based on well 0612) have declined by several milligrams per liter. The apparent flushing in the vicinity of well 0863 is probably not real because data for this well was not available for the pre-remediation map. It is more likely that the pre-remediation plume in this area was similar to the post-remediation plume and that milling-affected groundwater bypassed this area.

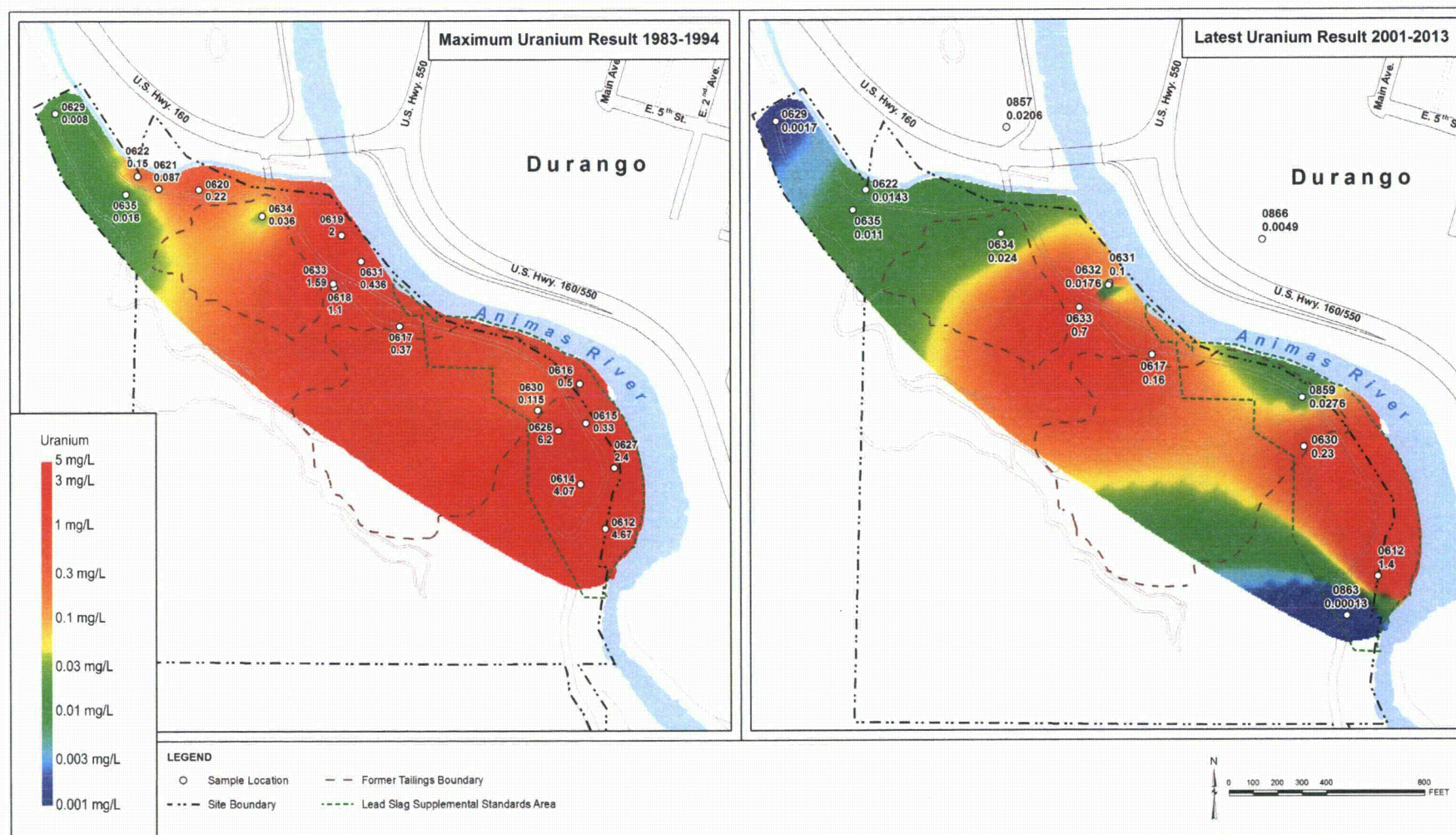


Figure 12. Uranium Plume Maps Pre-Remediation (1983–1994) and Post-Remediation (2001–2013)



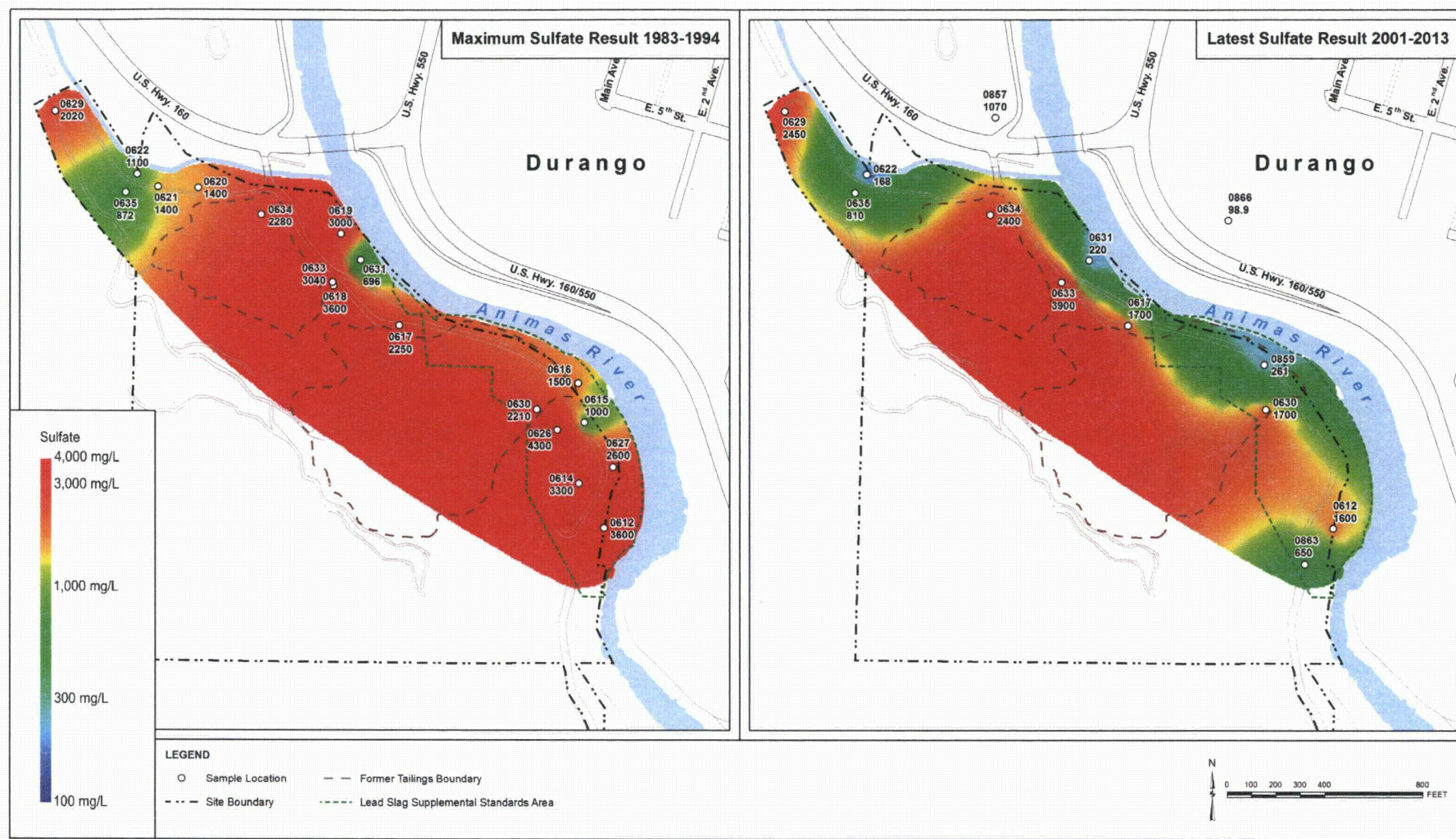


Figure 13. Generalized Sulfate Plume Maps Pre-Remediation (1983–1994) and Post-Remediation (2001–2013)

In contrast to uranium, sulfate concentrations in the vicinity of the northern tailings pile are not significantly different for pre- and post-remediation time frames. This reflects the relative constancy of most sulfate time-concentration plots for wells in this area. Based again on well 0612, sulfate concentrations have decreased in the downgradient portion of the site and in wells adjacent to the river. Again, the apparent flushing in the vicinity of well 0863 is likely not real. A comparison of the sulfate plume maps with the well logs in Figure 2 indicates that the highest concentration locations generally correspond to wells that are screened into the Mancos Shale. In particular, wells 0629, 0633, and 0634 have shown little change. The overall behavior of sulfate at the site suggests that while some sulfate may be milling-related and declining over time, a separate more constant source is needed to maintain the concentrations observed in the upgradient portion of the site.

Figure 14 through Figure 21 are time-concentration plots for a number of other constituents. These figures show all onsite wells and are intended for use in observing overall patterns, not in comparing trends on a well-by-well basis. For a number of constituents, the familiar pattern seen in well 0612 for uranium and sulfate is also apparent—initially high concentrations followed by a discernible decline over time. This pattern is observed for chloride, magnesium, selenium, nitrate, and molybdenum and is consistent with natural flushing of mill-related contamination. However, other observations are inconsistent with this interpretation. Cadmium and manganese concentrations in well 0612 have been higher than concentrations in other wells. Although, unlike most other constituents, these two do not display any well-defined trends, but rather seem to fluctuate within a fairly steady range. This suggests some other ongoing and constant source may be present. Well 0633, as with sulfate, shows anomalously high concentrations of magnesium. Selenium concentrations in well 0633 have also been among the highest observed in any wells and have fluctuated significantly over time. Nitrate levels in wells 0633 and 0617 have been elevated at times over those of other wells at the site. Well 0617 has displayed the highest concentration of selenium at the site, has had detectable levels of cadmium, and has had among the highest levels of molybdenum and manganese.

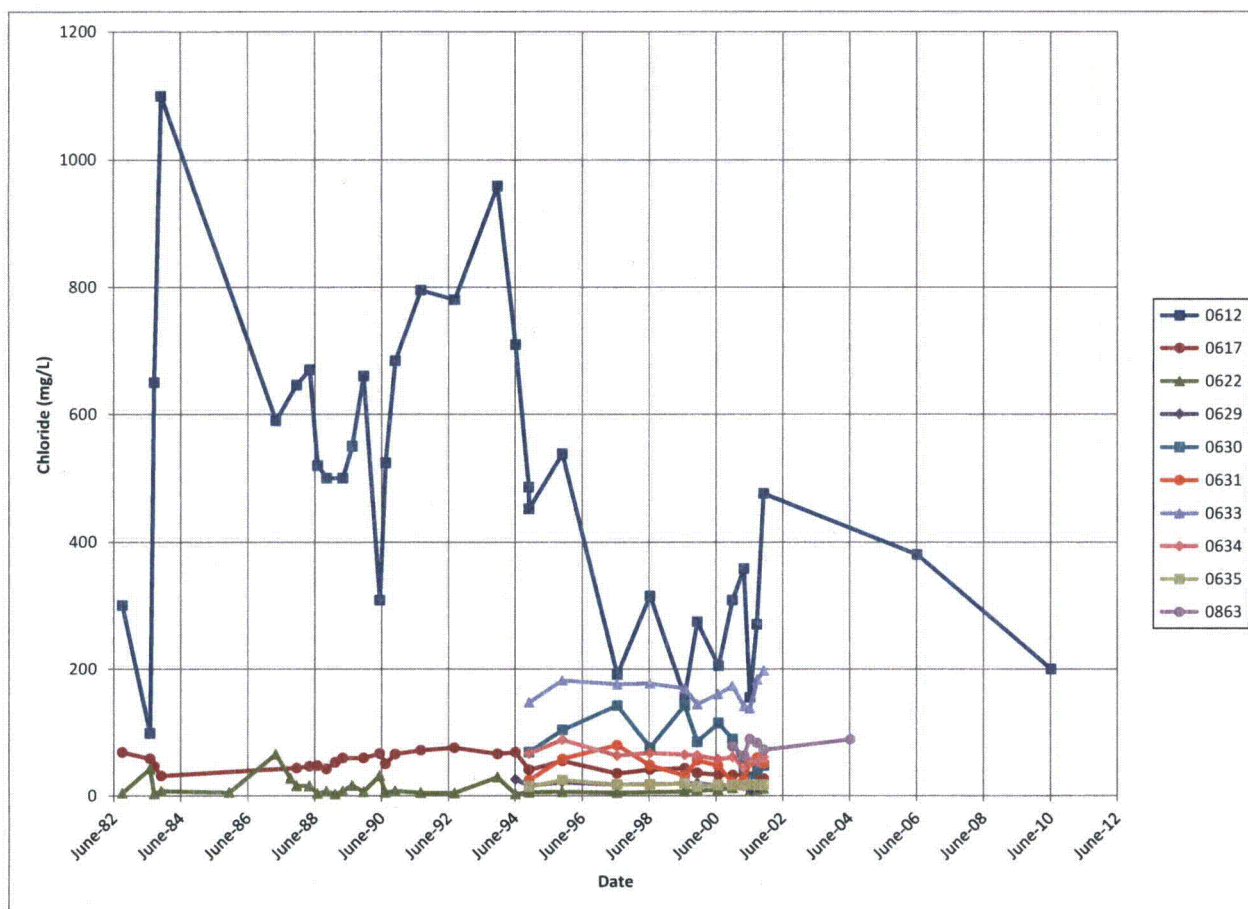


Figure 14. Chloride Concentrations



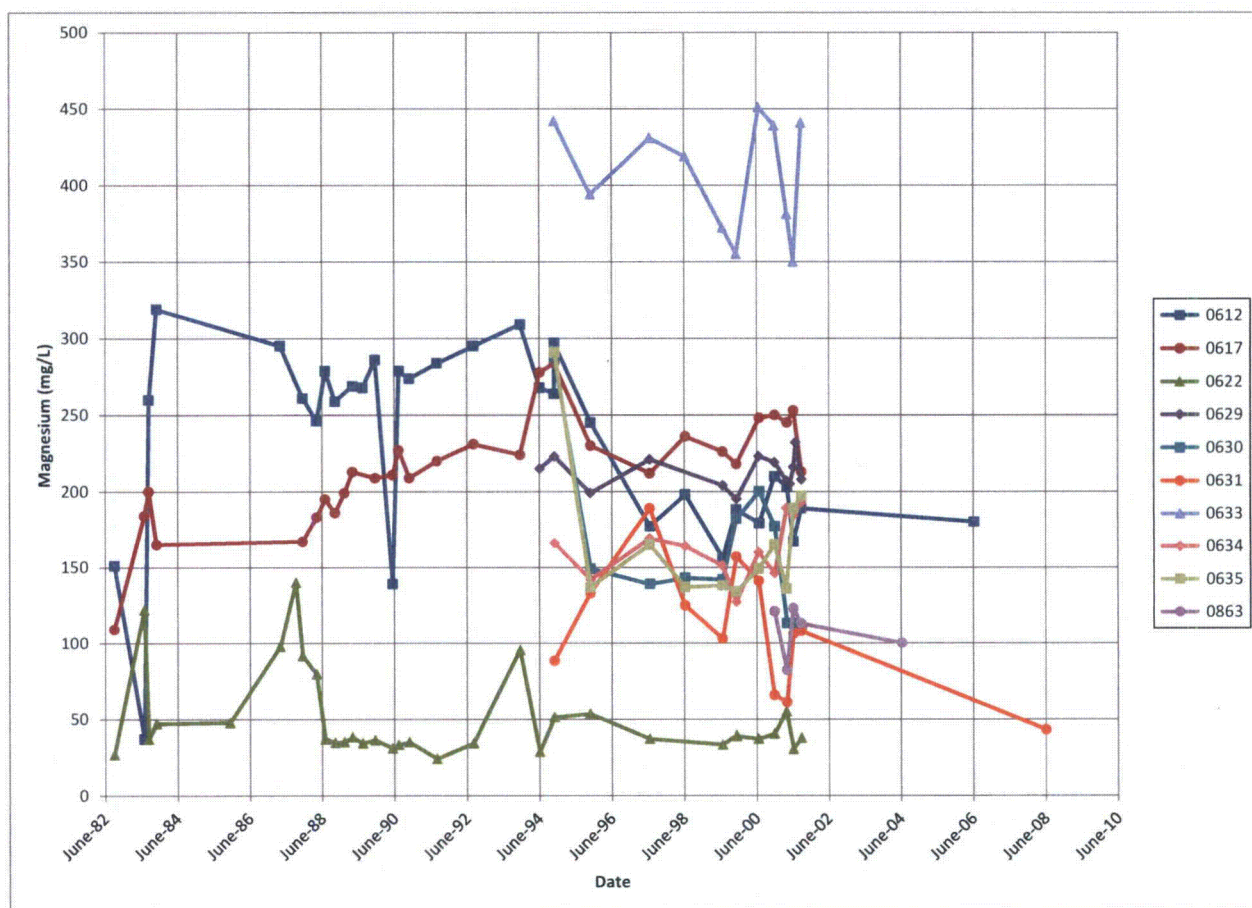


Figure 15. Magnesium Concentrations

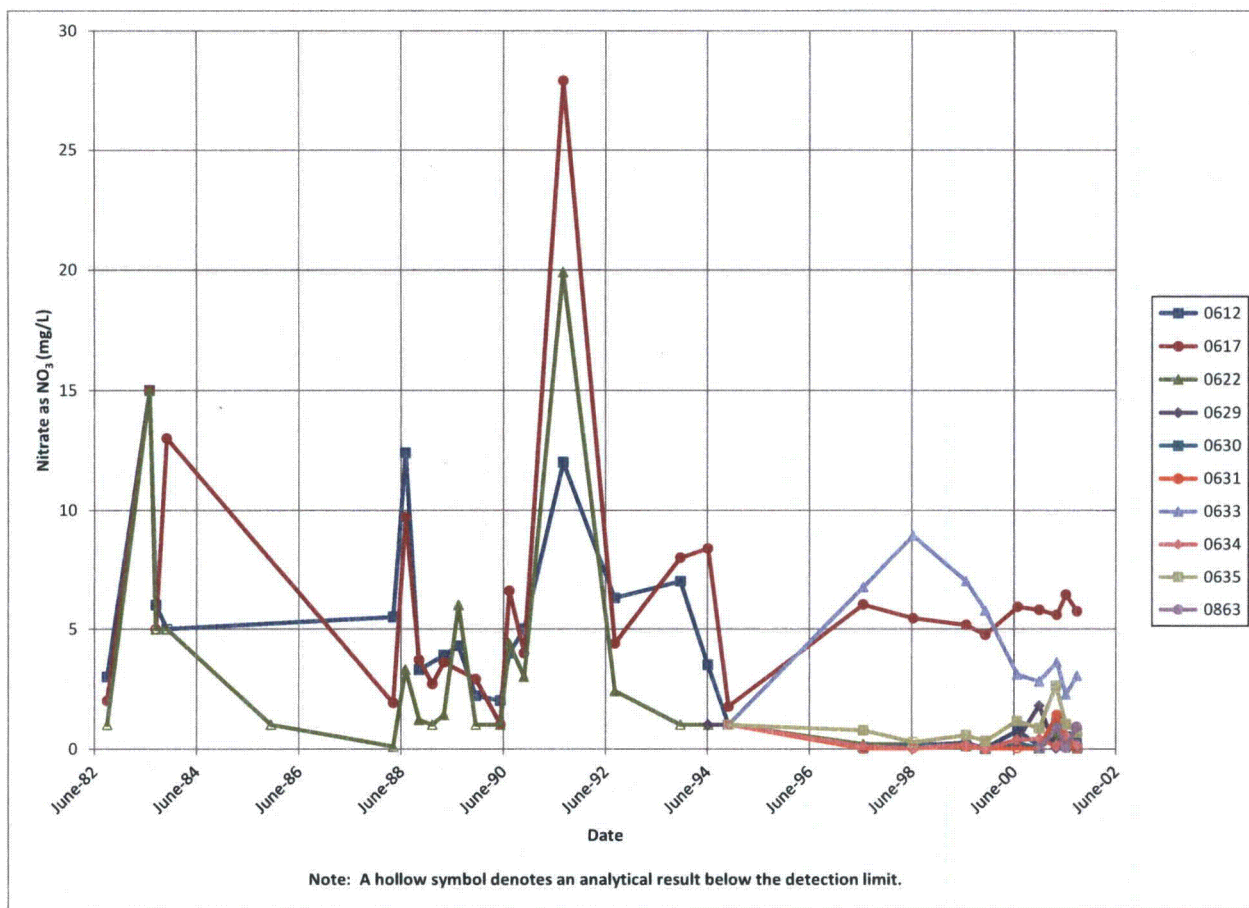


Figure 16. Nitrate as  $\text{NO}_3$  Concentrations

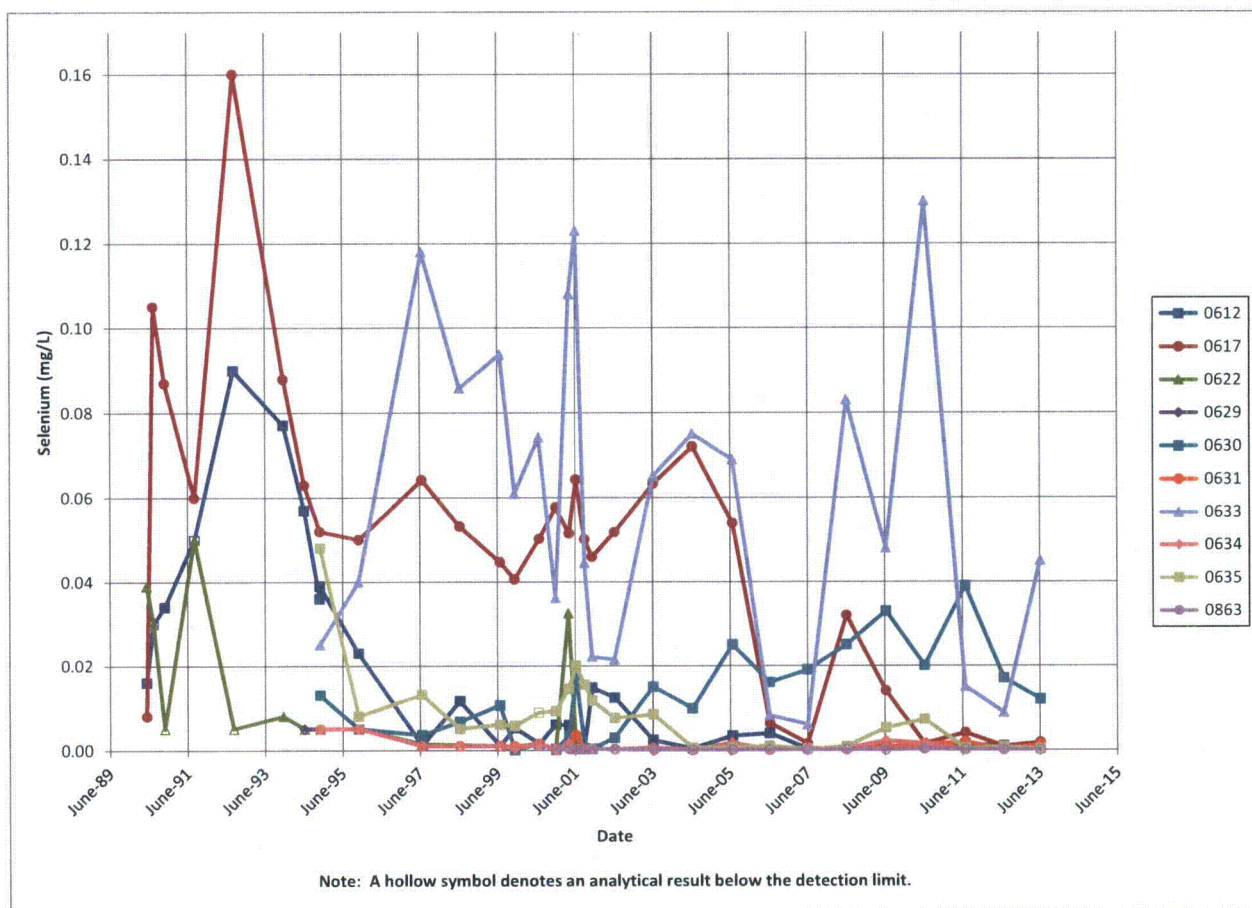


Figure 17. Selenium Concentrations

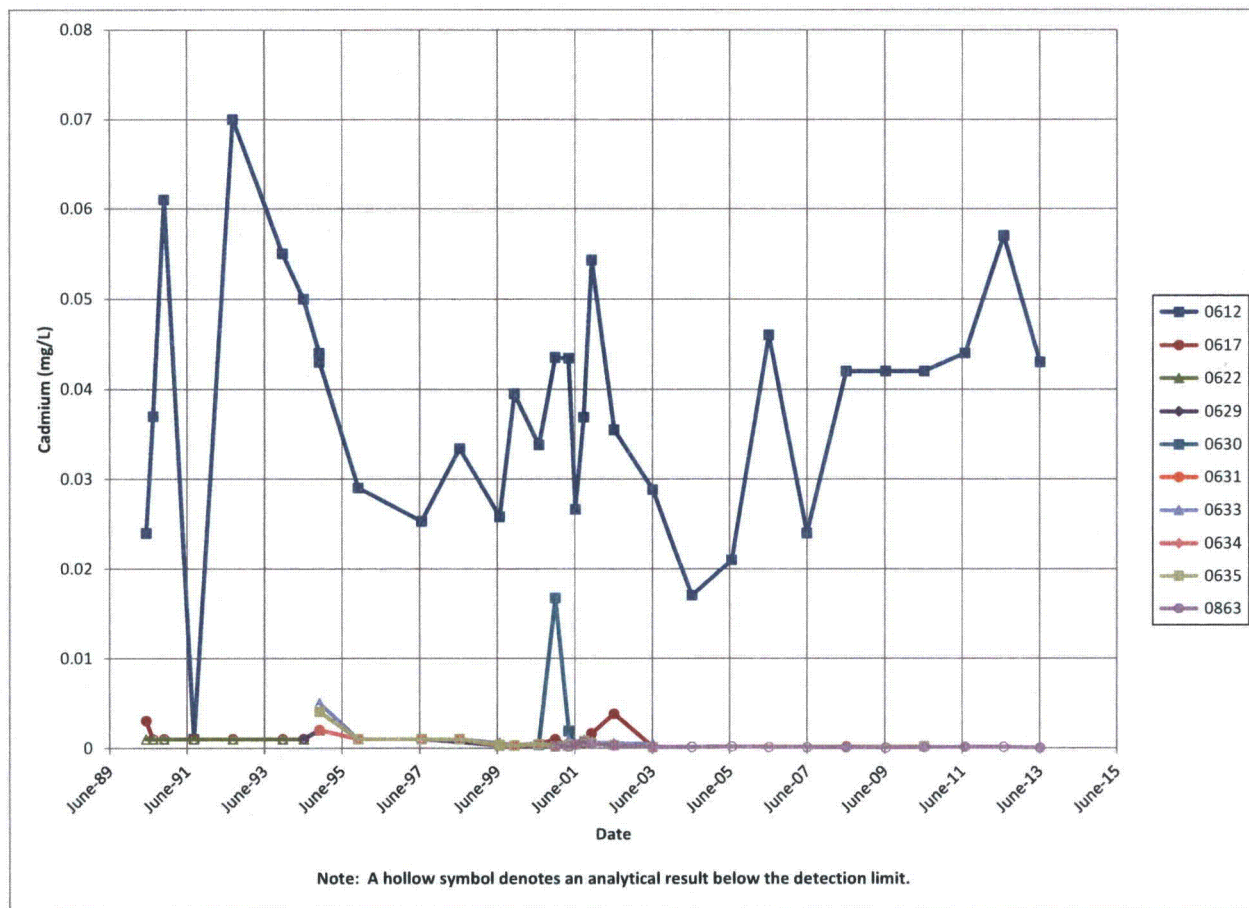


Figure 18. Cadmium Concentrations



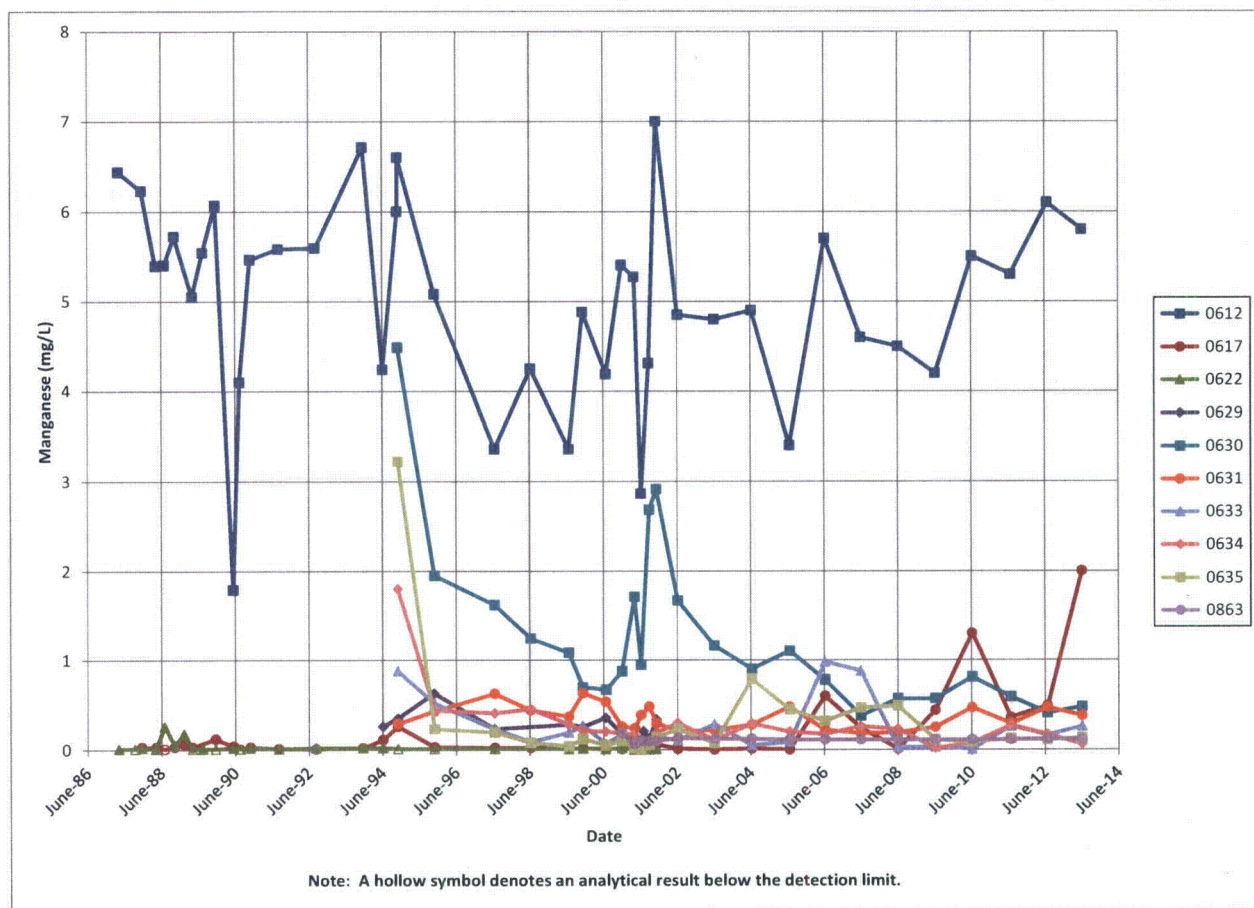


Figure 19. Manganese Concentrations

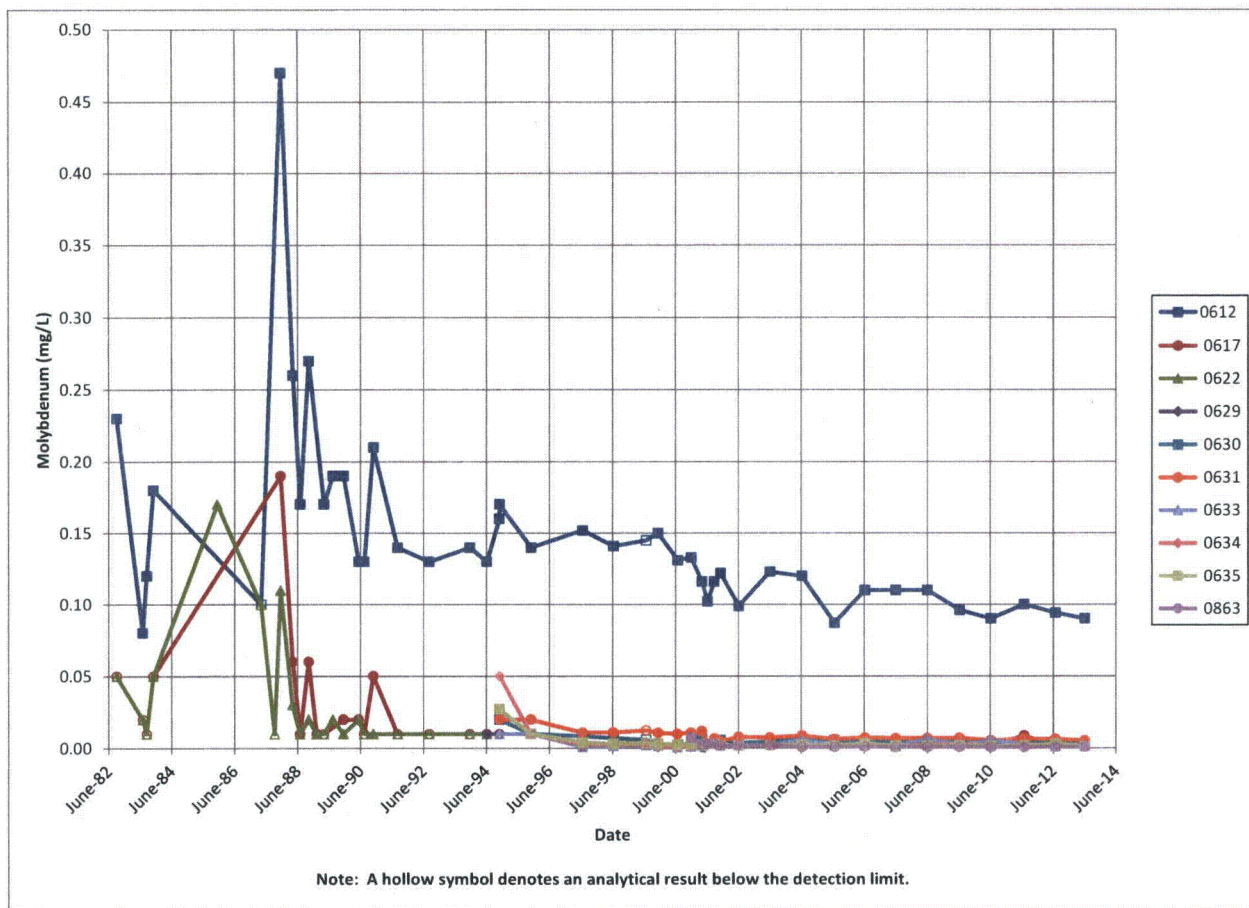


Figure 20. Molybdenum Concentrations

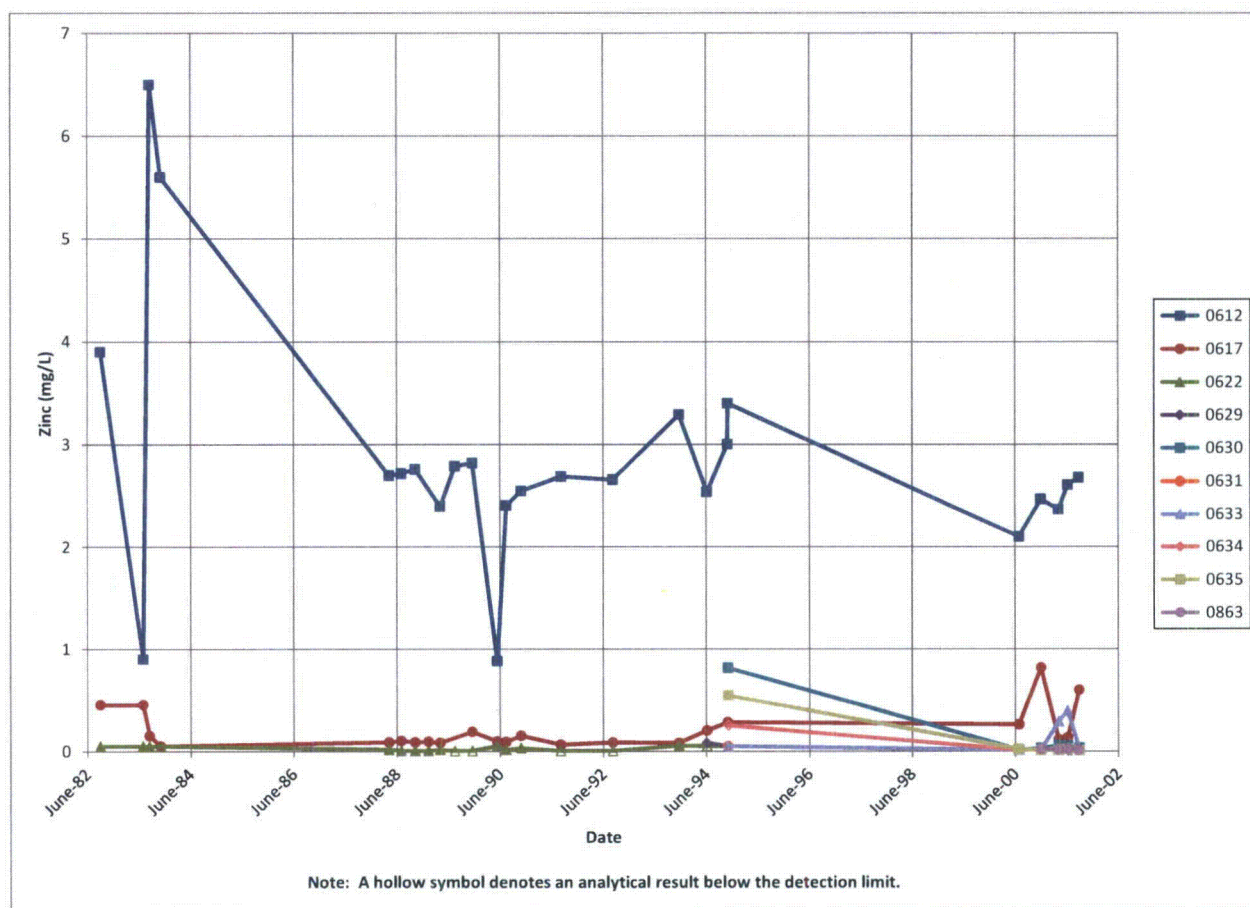


Figure 21. Zinc Concentrations

To explain the somewhat anomalous behaviors observed for some constituents in some wells, somewhat localized nonmilling sources are needed. As discussed previously, the alluvium/colluvium at the mill tailings site is underlain by Mancos Shale, and a number of site wells are screened across the Mancos. Mostly notably, well 0633 is screened almost entirely in Mancos Shale (Figure 2). Well 0629, which is the highest sulfate background well, is also partially screened in the Mancos. Mancos Shale also crops out along the western border of the site; water recharging the site could be interacting with Mancos before entering the site. Groundwater samples derived from the Mancos Shale have been associated with elevated levels of uranium, nitrate, selenium, sulfate, and magnesium, among other constituents (DOE 2011). Well 0633 shows elevated levels of all of these constituents. It is possible that the Mancos Shale may affect groundwater quality at the site to varying degrees. The potential for Mancos as an influence on site contamination is further explored in Section 3.1.4.

As discussed in Section 2.1.1, a slag layer that remains from a historical smelting operation underlies much of the southeastern portion of the mill site. It has been hypothesized in the past that the slag layer is a potential source for cadmium and possibly other constituents that have been observed in well 0612, which is screened below the slag layer. The possible influence of the slag layer on groundwater quality at the mill site (particularly at well 0612) is discussed further in Section 3.1.5.

### 3.1.4 Potential Mancos Shale Influence

The Mancos Shale underlies the alluvial and colluvial deposits in the mill tailings area and crops out on portions of the site. It has been hypothesized that naturally occurring constituents in the Mancos Shale could have affected groundwater quality at the Mill Tailings area. This hypothesis is in concert with analytical results of samples from numerous groundwater seeps in Mancos Shale throughout the Colorado Plateau. Many of the sample results showed uranium concentrations of about 150 micrograms per liter ( $\mu\text{g/L}$ ) and sulfate concentrations of more than 10,000 mg/L (DOE 2011). This section provides a brief evaluation of the possibility that the Mancos Shale could be affecting shallow groundwater in the mill tailings area.

A suite of groundwater samples was collected in 2001 from the mill tailings area and analyzed for uranium-234 and uranium-238 as well as total uranium. The U-234/U-238 activity ratio (AR) has been used in the past to distinguish groundwaters that contain milling-related uranium from those that contain naturally occurring uranium. Mill tailings fluids typically have uranium AR values near the secular equilibrium value of 1, while natural waters tend to have AR values exceeding unity (1), with typical values up to 3 (Zielinski et al. 1997).

All of the mill tailings area wells that were sampled for uranium isotopes except 0632 have well screens that contact the alluvium; however, in most wells, the well screen also contacts a portion of the underlying Mancos Shale (Figure 2). Because the alluvium typically transmits water much more readily than Mancos Shale, it is likely that most of the water sampled in site wells is from alluvium. Table 6 provides results for uranium isotopes, AR values, and total uranium.

Duplicate samples were collected from three locations during the initial 2001 sampling event; additional samples were collected from wells 0866 and 0629 2 months after the initial sampling event. AR values obtained for location 0866 were 1.20 and 1.32 for the first sample and duplicate and 1.14 for the sample collected later. Duplicate samples for location 0631 produced ARs of 0.97 and 1.03; ARs for location 0633 were 0.96 and 0.99. AR values for well 0629 for first and second sampling events were 1.88 and 3.26, respectively. This is an indication that analytical or sampling variability can have a fairly significant impact on ARs for samples that are low in total uranium.

Figure 22 shows the 2001 uranium concentrations and  $^{234}\text{U}/^{238}\text{U}$  ARs. For this diagram, wells were interpreted to be in one of three groups: background, offsite, and onsite. Wells designated backgrounds include the three onsite wells included as background in this VMR—0622, 0629, and 0635. Offsite wells include the background wells that are unaffected by site-related contamination—0857, 0866, and 0658. The remaining wells on the mill site are designated as onsite wells.



Table 6. ARs and Total Uranium for Mill Tailings Area Wells

Location	U-234 (pCi/L)	U-238 (pCi/L)	U234/U238	Total U (µg/L)
0612	732	766	0.96	2,120
0617	90	163	0.55	244
0622	10	12.4	0.81	29
0629	0.62	0.33	1.88	1
0629	0.62	0.19	3.26	0
0630	75.4	74.7	1.01	197
0631	88.2	90.6	0.97	252
0631	92.5	89.9	1.03	257
0632	15.6	7.8	2.00	18
0633	316	328	0.96	851
0633	356	360	0.99	942
0634	58.5	63	0.93	184
0635	3.9	2.5	1.56	7
0658	0.92	0.86	1.07	2
0857	14.1	14.2	0.99	35
0859	18.8	22.9	0.82	55
0863	1.4	0.54	2.59	2
0866	3	2.5	1.20	6
0866	3.3	2.5	1.32	6
0866	2.4	2.1	1.14	5

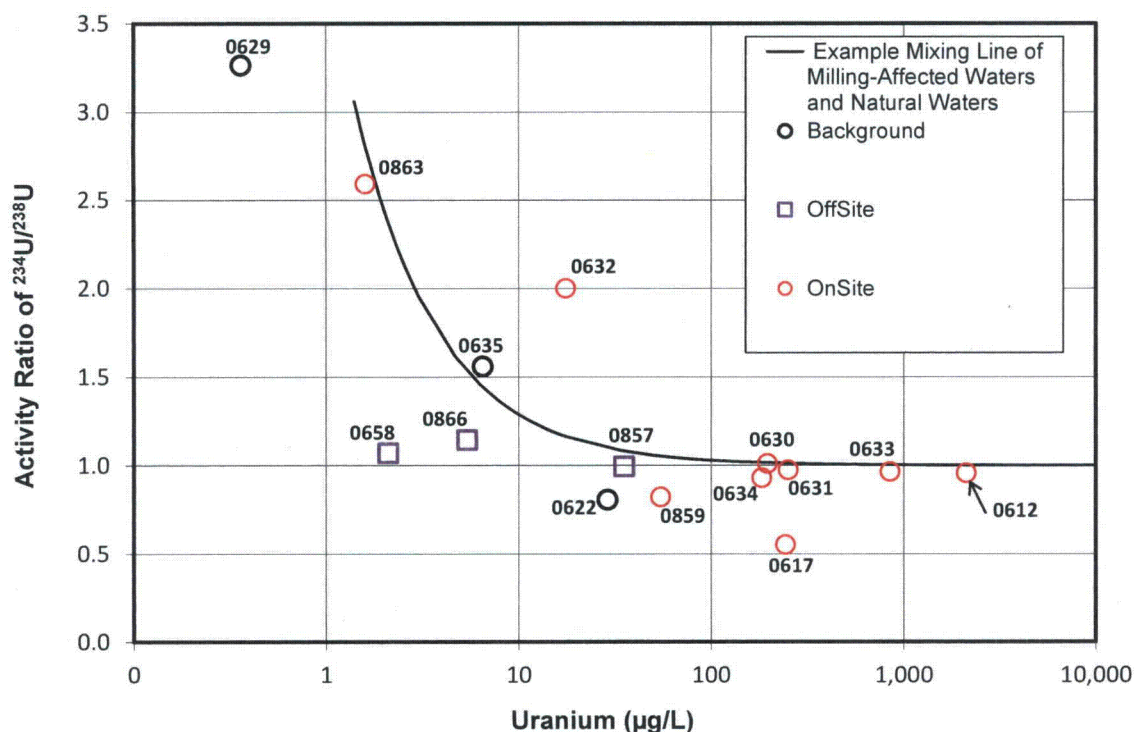


Figure 22. Uranium Concentrations and  $^{234}\text{U}/^{238}\text{U}$  Activity Ratios in Groundwater Samples Collected at the Durango Mill Site in 2001

An obvious relationship shown by Figure 22 is that wells with higher concentrations of uranium (i.e., those exceeding the standard), which are the majority of onsite wells, have AR values close to one. This is an indication that most of the uranium in onsite wells is likely tailings derived. The onsite wells that have ARs significantly higher than 1 include 0632 and 0863. Well 0632 has a short well screen that is entirely within the Mancos Shale. This well has only been sampled once (the 2001 sampling) because it is normally dry. Well 0632 had a uranium concentration of 0.0176 mg/L and a relatively high AR value—signatures that are consistent with Mancos Shale. Well 0863 is predominantly screened in alluvium, but as discussed in Section 3.1.3, the water quality in this well is more similar to that in background wells than to water in wells with site-related contamination. The isotopic results support the hypothesis that site-related contamination bypasses this location and discharges to the river. Because of this, well 0863 is not useful for monitoring site-related contamination.

Offsite wells 0657-8, 0858, and 0866 are not affected by site-related contamination. Uranium ARs in wells 0858 and 0866 are above 1, but uranium has an AR of essentially 1 in well 0857. This is an indication that mill-related contamination cannot be identified solely on the basis of AR values. The high AR value observed for well 0629, however, does support its designation as a background well, with an AR signature quite distinct from those of onsite wells. Well 0635, with an AR of around 1.5, would also appear to be a candidate for background; however, it could also represent a mixture of background and site-related uranium. Figure 22 shows an example mixing line indicating that a range of ARs could be generated through mixing of high AR natural

waters with low AR milling-affected waters. This curve could shift to the left or right depending on the total concentration of uranium in the natural waters. Both background wells 0635 and 0622 plot loosely along this mixing curve between the two extremes. This may be an indication that they represent mixtures of true background (perhaps represented by well 0629) and mill-related waters (represented by well 0612). Conversely, with the variety of ARs exhibited by locations that are known to be unaffected by milling, their ARs could also reflect natural background conditions.

Wells 0622, 0859, and 0617 all display ARs less than 1. ARs slightly below 1 are not unusual. Because wells 0622 and 0859 have fairly low uranium, analytical uncertainty could be responsible for these low values. However, uranium concentrations for well 0617 are high, so the low AR value is likely real. While AR values as low as that observed in well 0617 are not unheard of, they are unusual (Osmond and Cowart 1976). Well 0617 is the only current monitoring well that is screened partially across the slag layer. (Note that there is a discrepancy between the well log for well 0617 and the coordinate data describing the supplemental standards area. While the log indicates that the well is screened across the slag, coordinate data indicates that well 0617 is outside the supplemental standards boundary.) Well 0617 has occasionally shown elevated (relative to most other wells) concentrations of a number of metals including selenium, cadmium, zinc, manganese, and molybdenum and has also exhibited elevated nitrate (Figure 16 through Figure 21). It is possible that whatever is responsible for these characteristics is also responsible for the low AR for well 0617. Well 0617 is constructed through the slag layer and appears to be located close to the area where the uranium “seam” was observed beneath the slag (Attachment 6 of the RAP [DOE 1991]). Dissolution of this material or the slag itself could account for some of the unusual characteristics exhibited in monitoring results for this well. The potential contribution of the slag layer to water quality is discussed further in Section 3.1.5.

Generally, AR values in the onsite groundwater are close to secular equilibrium and are consistent with a mill tailings origin as opposed to a Mancos Shale origin. Although elevated uranium concentrations were found in Mancos Shale seeps at locations throughout the Colorado Plateau, the uranium concentrations in these seeps were seldom more than 150 µg/L—even in groundwater with TDS up to 30,000 mg/L (DOE 2011). Many of the historical uranium concentrations in groundwater collected from the Durango mill site were much higher than the Mancos seep values, suggesting a non-Mancos source.

Sampling and analysis for uranium isotopes at Durango was part of a larger effort that involved sampling at a number of other UMTRCA Title I sites. Figure 23 shows the Durango samples on a plot with data from the Rifle, Grand Junction, Tuba City, and Slick Rock UMTRCA sites. The Mancos Shale is not an influence at any of these sites. Samples from the Durango site generally overlap with those collected from other Title I sites. The three samples that plot outside the range at the low uranium end are for wells 0629 and 0863—further indication that these are background and are not affected by mill-tailings fluids.

Total uranium in the highest concentration samples from the Durango site (wells 0612 and 0633) was higher than observed for other Title I sites included in Figure 23. Thus, although well 0633 is screened mostly in the Mancos, the high uranium concentrations contributed by tailings fluids essentially obliterate any Mancos influence. For example, based on the data in Table 6, if equal portions of water with compositions of wells 0612 and 0893 (representing opposite ends of the spectrum) were combined, the AR value would essentially be the same as that for well 0612.



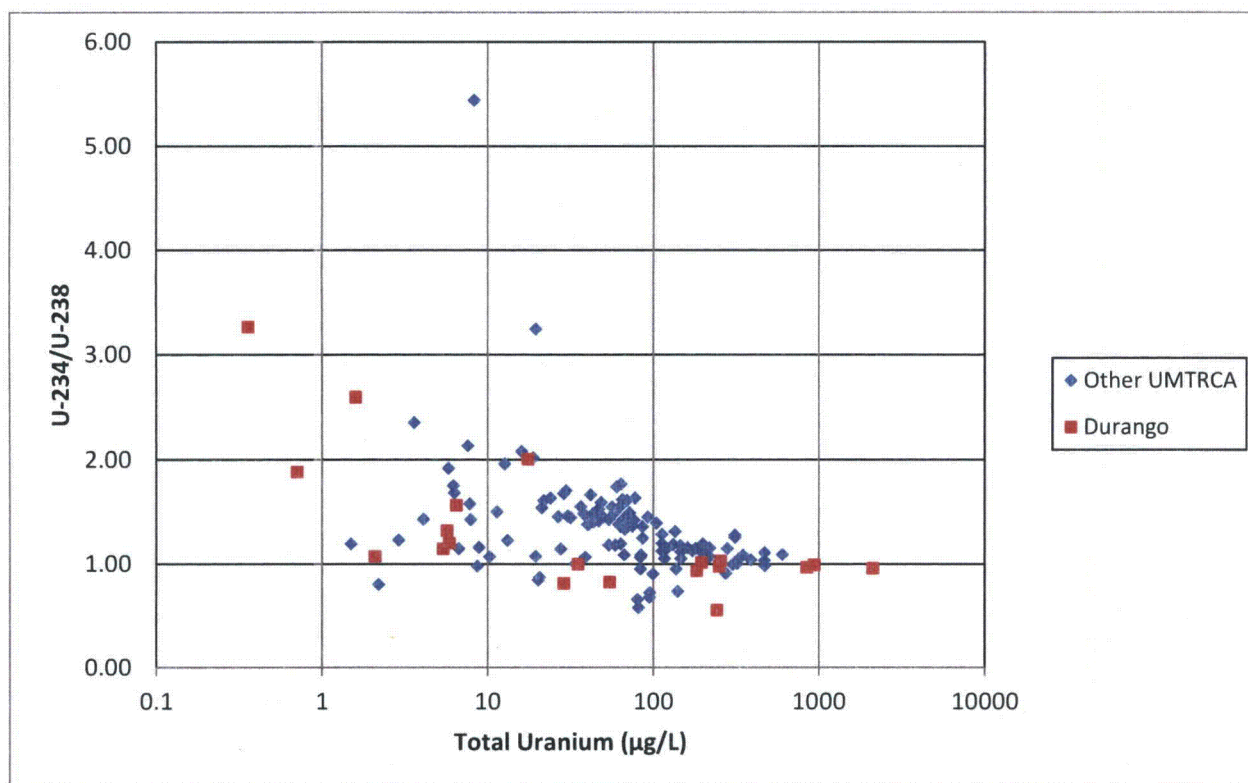


Figure 23. Uranium Activity Ratios at Durango and Other UMTRCA Sites

Figure 24 and Figure 25 compare the Durango samples to those collected at the terrace and floodplain areas, respectively, of the Shiprock Title I site. The terrace at the Shiprock site is situated directly on Mancos Shale, and groundwater in terrace wells is probably a combination of Mancos-derived and mill-derived chemistries. The floodplain area of the Shiprock site has received fluids from Mancos, milling, and other background sources. There is almost no overlap between the Durango samples and the Shiprock samples from the terrace. There is slightly more overlap between the Durango and floodplain samples, though all of the Shiprock samples tend to have higher AR values for comparable concentrations of total uranium.

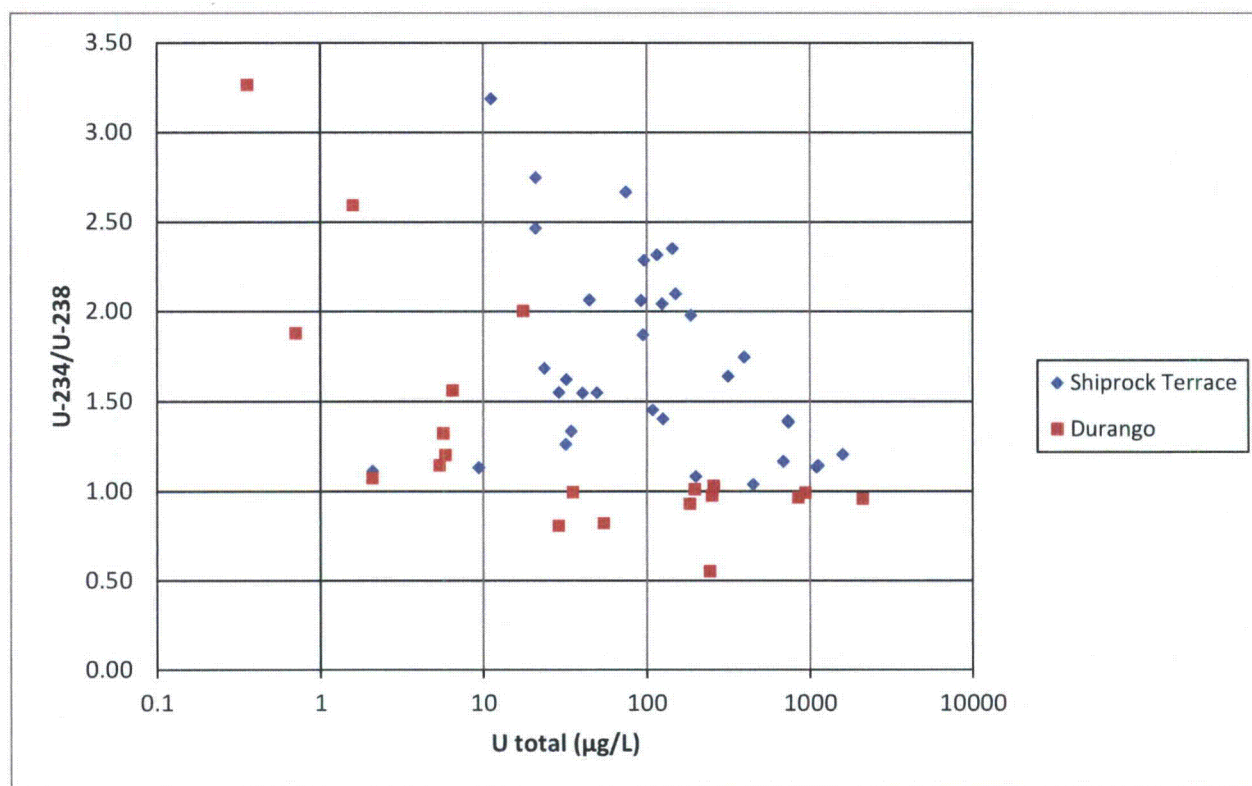


Figure 24. Uranium Activity Ratios: Shiprock Terrace and Durango

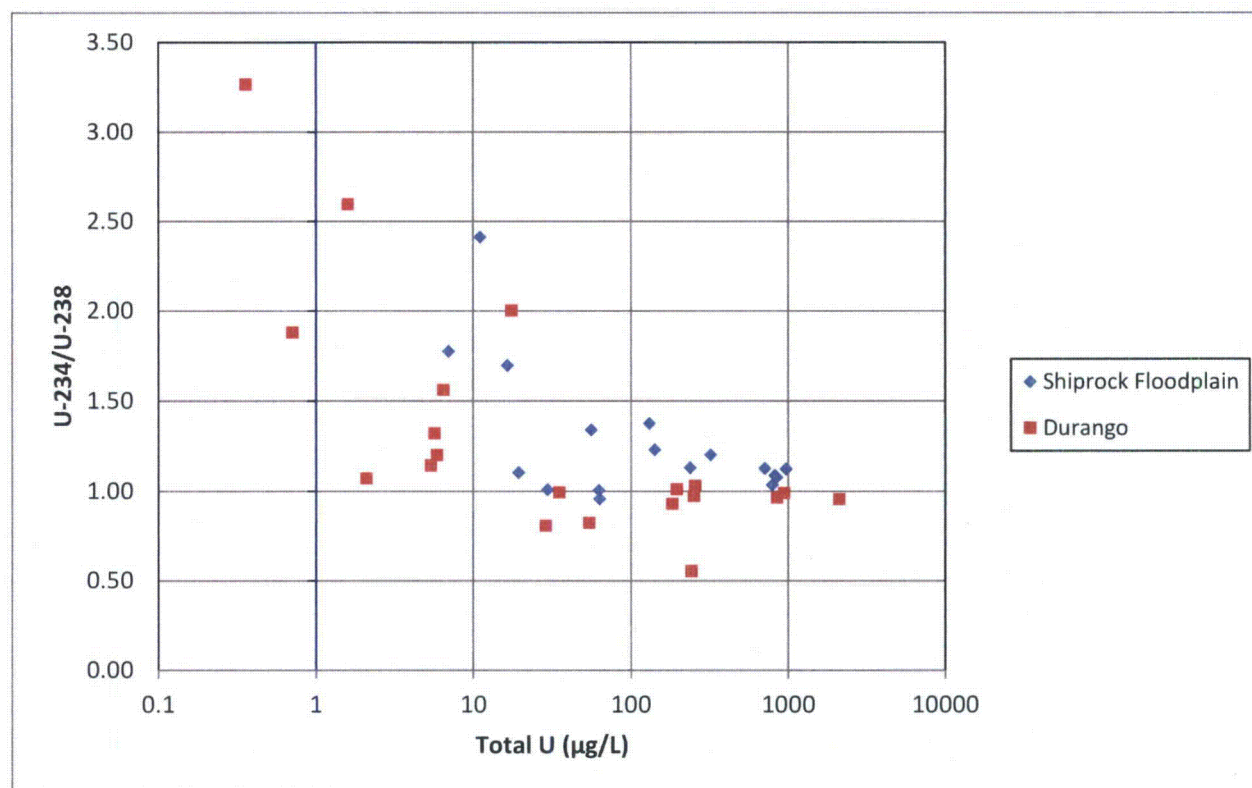


Figure 25. Uranium Activity Ratios: Shiprock Floodplain and Durango

It can be concluded that the Mancos shale is not a significant contributor to uranium at the site. However, it is possible that the presence of Mancos Shale in the region contributes to the elevated sulfate observed in background groundwaters as well as groundwater in onsite wells. Background well 0629 is screened partially across the Mancos and has elevated sulfate concentrations compared to background wells screened in the alluvium alone. Onsite well 0633 has the highest sulfate of any well at the site; concentrations appear to be level or increasing. This same well, which is screened predominantly in the Mancos, also has elevated concentrations of constituents such as magnesium and selenium, which are also derived from Mancos Shale. Sulfate in water from the Mancos Shale can have sulfate concentrations of 10,000 mg/L or more (DOE 2011). Therefore, although contributions of uranium from Mancos are obscured by uranium from tailings fluids, contributions of sulfate from the Mancos could have an influence at the site in addition to mill-related sulfate.

Figure 26 shows a plot of sulfate concentration versus the percent that a well is screened across the Mancos Shale. Wells that do not intersect the Mancos at all range from lowest to highest observed sulfate concentrations, indicating that wells do not need to intersect Mancos to have a high sulfate concentration. However, all the wells in which more than 40 percent of the screened length is in the Mancos had relatively high sulfate concentrations. Sulfate at all of these locations exceed the compliance goal identified in past VMRs of 1,276 mg/L, indicating that Mancos-related influences make that goal unrealistic.

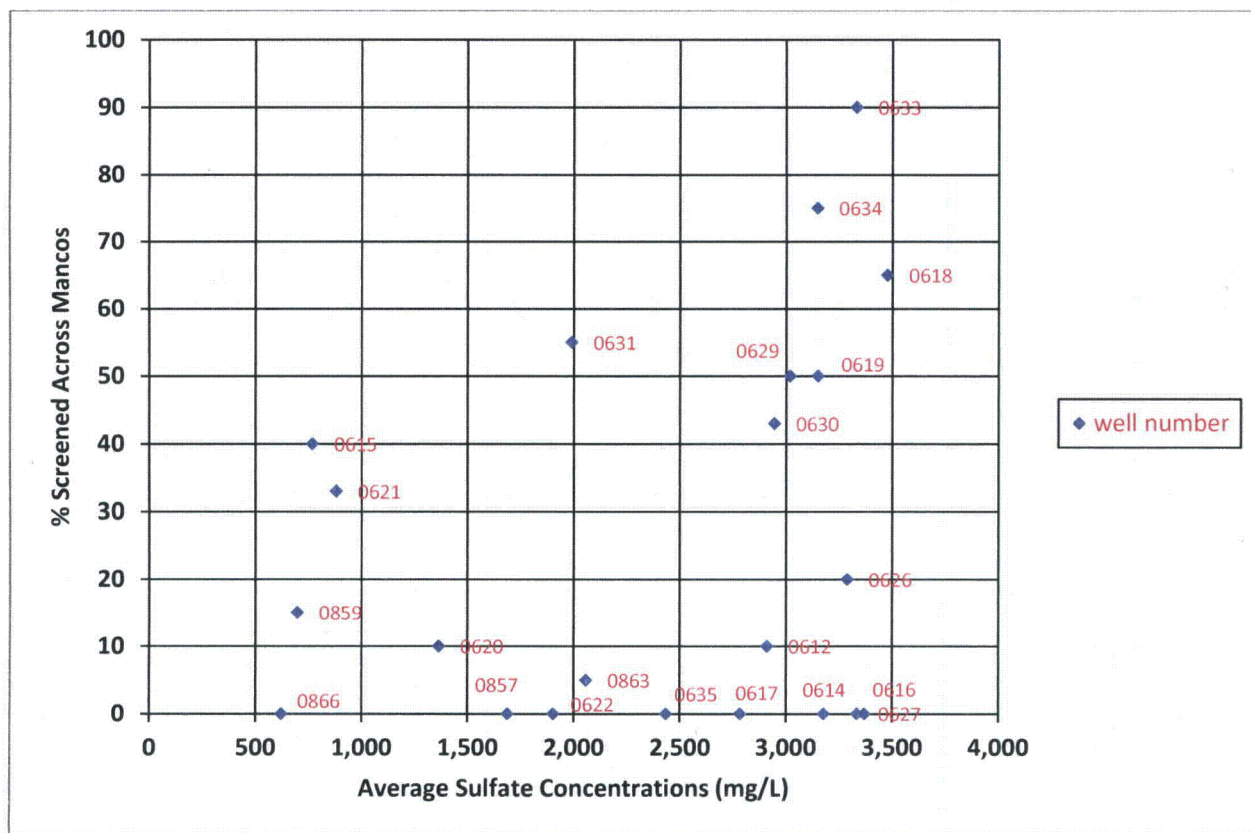


Figure 26. Average Sulfate Concentrations Versus Percent Screened Across Mancos



### 3.1.5 Potential Effects of the Slag Layer

Cadmium concentrations have been elevated in well 0612 since monitoring of that well began. Modeling of cadmium described in the SOWP indicated that it might not naturally flush in the allotted time frame. Previous monitoring reports have attributed the presence of cadmium at location 0612 to the slag layer. Figure 27 shows the distribution of cadmium and manganese, both historically (2000) and currently. Monitoring of cadmium in all wells except 0612 and 0863 was discontinued in about 2003 because concentrations were consistently below the detection limit. Concentrations of both cadmium and manganese have been elevated in well 0612 and have fluctuated over time. While the Mann-Kendall nonparametric method indicates a decreasing trend for both at a 70 percent confidence level, time-concentration plots for the two constituents show no apparent trend (Figure 28 and Figure 29). Very low  $R^2$  values indicate a poor level of explained variability. Therefore any apparent trend is inconclusive.

Cadmium is primarily found in zinc, lead, and copper ores and is extracted as a byproduct during the production of these metals (ATSDR 2012). Slag from processing of lead and zinc ores contains many metals, including cadmium, manganese, and molybdenum, among others (DOE 2002b). It therefore seems plausible that the slag could serve as a source for elevated cadmium and manganese. In addition to cadmium and manganese, historical information shows that samples from well 0612 were also elevated in zinc (up to 3.3 mg/L; Figure 21), which could also be associated with the slag. Well 0612 is constructed through the slag, though it is screened completely below the slag. Well 0617 is screened partially across the slag layer. While cadmium has been present at detectable levels in a few samples from well 0617, concentrations have remained an order of magnitude lower than in samples from well 0612. Elevated zinc was found in samples from two other wells that penetrated the slag—0626 and 0627. No cadmium data were available for these wells.

Most constituents observed in samples from well 0612 are site-related. They were elevated in the early days of groundwater monitoring at the site during or immediately after surface remediation. Since that time they have declined. Conversely, concentrations of other constituents—most notably cadmium, manganese, and zinc—have remained fairly constant over the monitoring period. Significant post-source-removal attenuation has not occurred. The presence and behavior of these constituents suggests a continuing source. Because these constituents are commonly found in association with lead smelting operations, the slag is a plausible source of this contamination. As the slag is unrelated to milling and is a potential ongoing source of contamination at the site.

### 3.1.6 Protectiveness of Post-Surface-Remediation Groundwater Quality

The data presented in previous sections indicate that milling-related contamination exists at the mill tailings site today. Concentrations at a number of site locations have attenuated, but elevated concentrations persist. Other potential sources of contamination have been identified that are not milling-related. Natural background water quality is poor and exceeds several secondary drinking water standards. It has been suggested that supplemental standards could apply at the mill tailings site based on a classification of limited use groundwater, as defined in 40 CFR 192.11(e). ACLs could also be justified for the site if it can be demonstrated that current and future groundwater quality is protective of human health and the environment. The purpose of this section is to present information regarding the current and likely future protectiveness of the groundwater. A statistical analysis of post-surface-remediation groundwater data is

conducted to provide a basis for establishing ACLs, should that option for groundwater compliance be considered.

The behavior of cadmium and manganese at well 0612 is in contrast to that of uranium. While uranium concentrations at well 0612 are also high, they show a steadily decreasing trend, consistent with a mill-related source that has been attenuating since source removal (Figure 30). Cadmium concentrations in well 0612 are consistently higher than those observed in tailings fluids and historical alluvial groundwater (Table 3 and Table 4), making the former upgradient tailings piles an unlikely source. As discussed in Section 3.1.5, zinc has also been elevated in well 0612. Molybdenum is also elevated compared to other wells; while it showed initial declines in concentration, consistent with natural flushing, molybdenum appears to have leveled off in response to a continuing source.

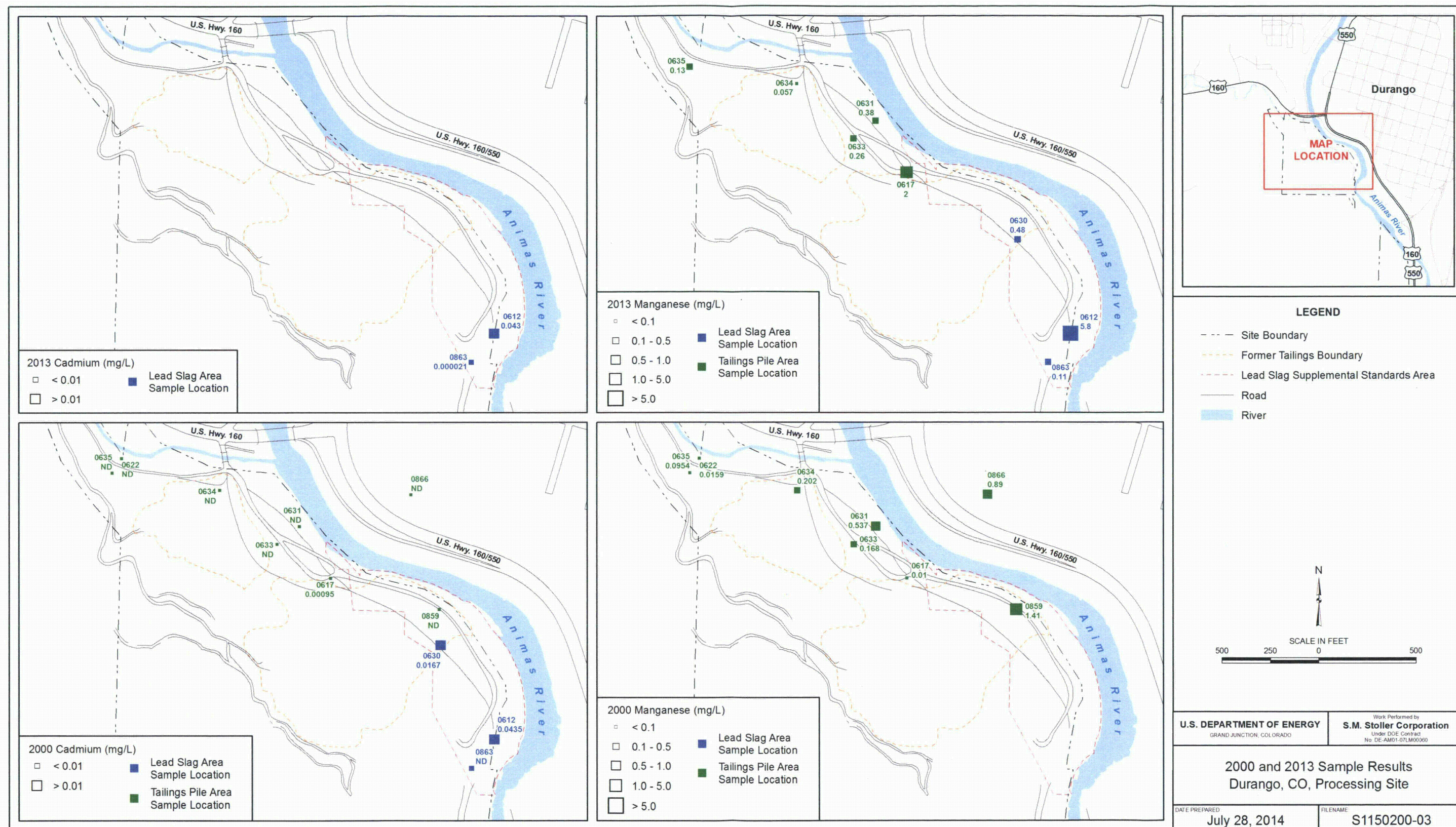
As noted previously, source removal at the mill tailings area began in 1986 and was completed in 1991. These activities eliminated most pathways to site-related contamination and resulted in significant improvements in groundwater quality for milling-related constituents (most notably uranium) during and immediately following remedial activities. After completion of surface remediation and implementation of institutional controls, the main complete pathway for exposure to groundwater contamination is where groundwater discharges to the Animas River.

A BLRA was completed for the site in 1995 (using data collected through January 1994). The evaluation focused primarily on risks associated with groundwater discharge to the Animas River. Human health risks associated with recreational use evaluated along with potential risks to ecological receptors in the river. EPA undertook another study not long after the completion of surface remediation (EPA 1998) that also focused on the Animas River; the emphasis of this study was on evaluating sediment quality and potential bioaccumulation of contaminants in fish. Both studies concluded that potential impacts to the river were very low. No contaminants of concern were detected in fish samples from EPA's study. Risks to human health were similar to background. Both of these studies demonstrated that conditions that prevailed at the site following surface remediation, including groundwater quality, are protective at the most likely points of exposure (i.e., along the Animas River). Annual surface water sampling at the mill tailings area was recently changed from the spring to the fall, when river flows are generally lower. Fall sampling results for site-related constituents have generally been comparable to, and often lower than, those for the spring.

The trend analysis in Section 3.1.3 demonstrated that average uranium concentration in mill tailings area groundwater has continued to decline since completion of surface remediation. Therefore, at least for uranium, it can be concluded that the site has remained protective since the time the BLRA and EPA study were conducted because concentrations discharging to the river have decreased over time. As long as concentrations continue to decline or to remain stable at post-remediation levels, continued protectiveness of the site will be assured.

To test the stability of uranium in groundwater following surface remediation, a new "baseline" condition was determined for each well using data collected between 1994 and 2004, as represented by the UPL 95 for uranium concentrations observed at each well. This provides a measure against which future monitoring data can be compared. This approach is consistent with that described in EPA (2009). Table 7 presents the 1994 to 2004 statistics for each onsite well for uranium. Statistics also include the site average, exclusive of background.





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Figure 27. Historical and Current Cadmium and Manganese Results



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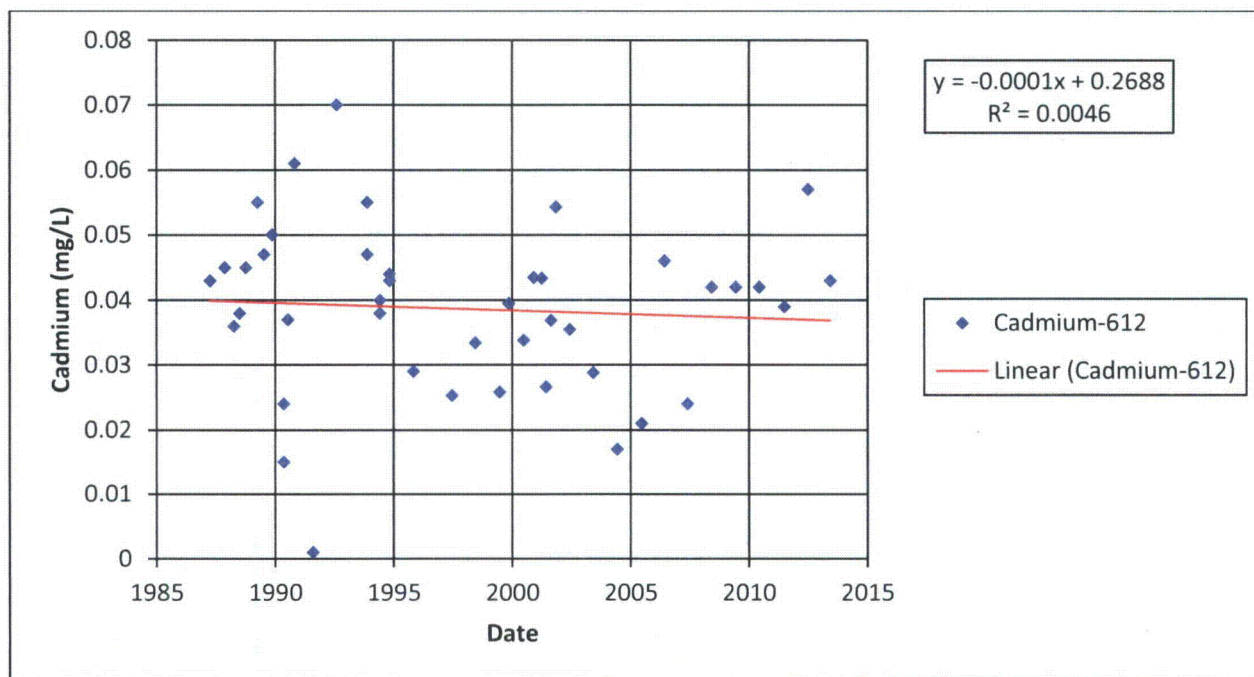


Figure 28. Cadmium Time-Concentration Plot for Well 0612

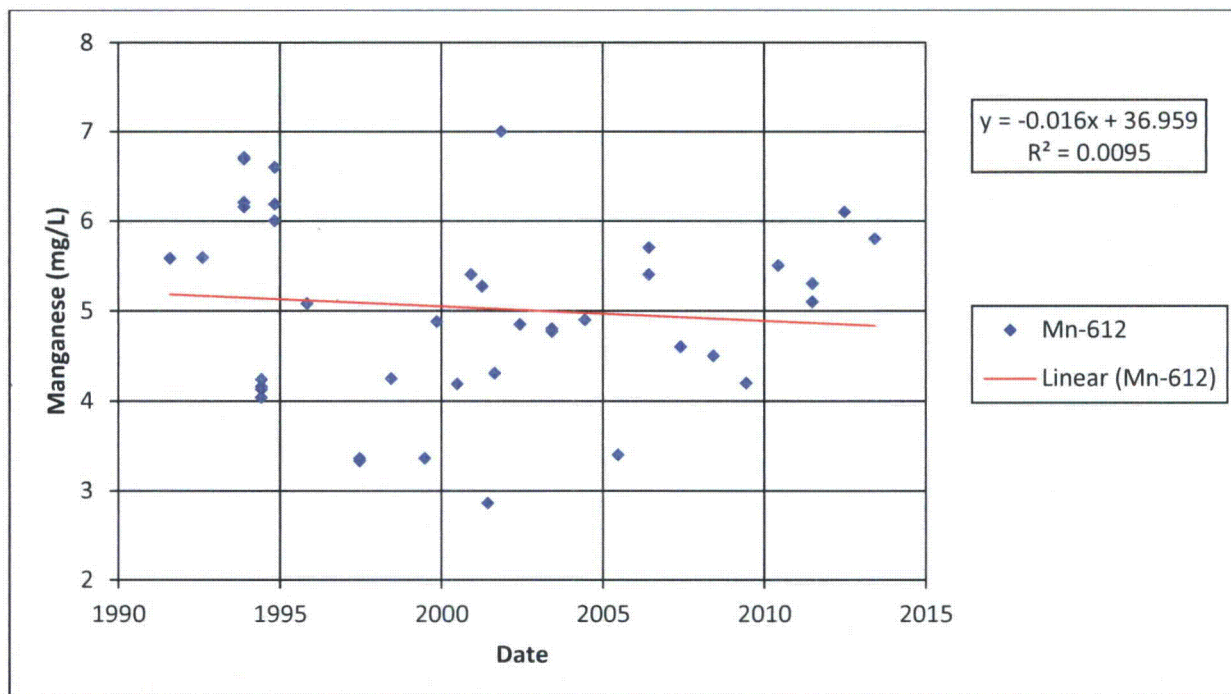


Figure 29. Manganese Time-Concentration Plot for Well 0612

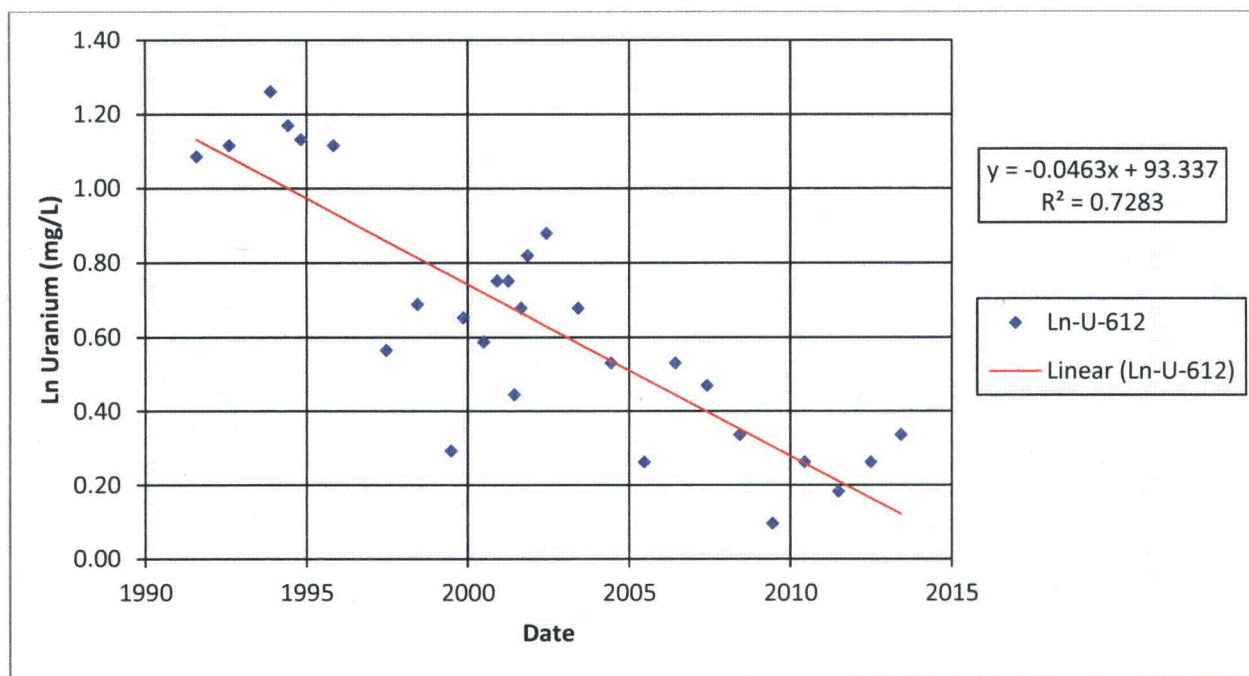


Figure 30. Uranium Time-Concentration Plot for Well 0612

Table 7. Uranium (mg/L) Statistics for Mill Tailings Area (1994 Through 2004)

Well Number	Number of Samples	Minimum	Maximum	Mean	UPL 95 <sup>a</sup>	Max since 2004
0612	16	1.34	3.22	2.14	4.62	1.7
0617	16	0.12	0.33	0.225	0.477	0.20
0630	15	0.0344	0.26	0.159	0.459	0.29
0631	15	0.168	0.63	0.357	1.06	0.24
0633	15	0.65	1.38	1.076	2.062	1.20
0634	15	0.012	0.184	0.0506	0.227	0.11
Average	15	0.421	0.729	0.563	0.965	0.584

<sup>a</sup> Nonparametric Chebyshev UPL was used

Data collected after baseline sampling are compared to UPL 95 values. Post-2004 uranium data for mill tailings wells were evaluated; maximum concentrations for each well are also provided in Table 6. Monitoring results for uranium have been within predicted limits for all onsite wells since 2004. This is an indication that groundwater quality is now stable and that site conditions remain protective of human health and the environment. On this basis, the application of ACLs for site groundwater, in lieu of more restrictive MCLs, could be justified.

This analysis could serve as the basis for establishing ACLs for the site. The approach for establishing ACLs varies from site to site—no single approach is considered “correct.” For some sites, ACLs are established on a well-by-well basis. At others, a single sitewide value is established for each constituent—usually based on the wells with highest concentrations. Future monitoring results for individual wells are then compared with the ACL values. At yet other



sites, ACLs and compliance monitoring are based on sitewide average concentrations. Because well 0612 has had the highest observed concentrations of site-related constituents, ACLs based on data from this well could serve as a basis for development of numerical values for ACLs.

### 3.1.7 Evaluation of Natural Flushing

For the mill tailings area, the current compliance strategy is natural flushing. Modeling presented in the SOWP indicated that mill-related uranium contamination should naturally attenuate at the site and meet the UMTRCA groundwater MCL of 0.044 mg/L within the 100-year period allotted for natural flushing. As discussed in Section 3.1.3 of this report, overall uranium concentrations in groundwater at the site are declining. This quantifies attenuation rates and discusses the likelihood that the compliance goals can be met within the established 100-year time frame.

EPA has developed guidance for evaluating the progress of natural attenuation (i.e., natural flushing) in groundwater (EPA 2011). For the first phase of analysis, trends are evaluated to estimate when cleanup goals are expected to be reached. The analysis assumes that the attenuation process follows a first-order rate law. This assumption is based on a review of contaminant trends at hundreds of hazardous waste sites, which showed that a first-order rate law is almost always a better fit than a zero rate law (EPA 2011). Natural-log-transformed concentration data that follow a first-order rate law should plot along a straight line.

Linear regression results for the log-transformed data can be used to predict when cleanup goals should be reached. The slope of the regression lines represents the attenuation rate constant. The uncertainty in the rate constant is described as a confidence interval on the rate constant (EPA 1999). EPA describes a procedure for estimating the slower, one-tailed 90 percent confidence interval on the rate constant (EPA 2011), providing an upper bound on attenuation estimates. The procedures from EPA (2011) were used, along with the data analysis package provided in Microsoft Excel, to estimate when uranium could be expected to reach the UMTRCA groundwater standard (0.044 mg/L). Calculations were also performed using the slower 90 percent confidence interval (Appendix C). Figure 31 shows an example time-concentration plot of log-transformed average uranium data for site monitoring wells. (The log-transformed standard of 0.044 mg/L is  $-3.12$ .) Results of the linear regression are also included on the figure. Plots and regression data for individual wells are included in Appendix C. Table 8 reports the results of the attenuation analysis compared to the numerical modeling predictions that were conducted for the SOWP and run again for the 2010 VMR (DOE 2010).

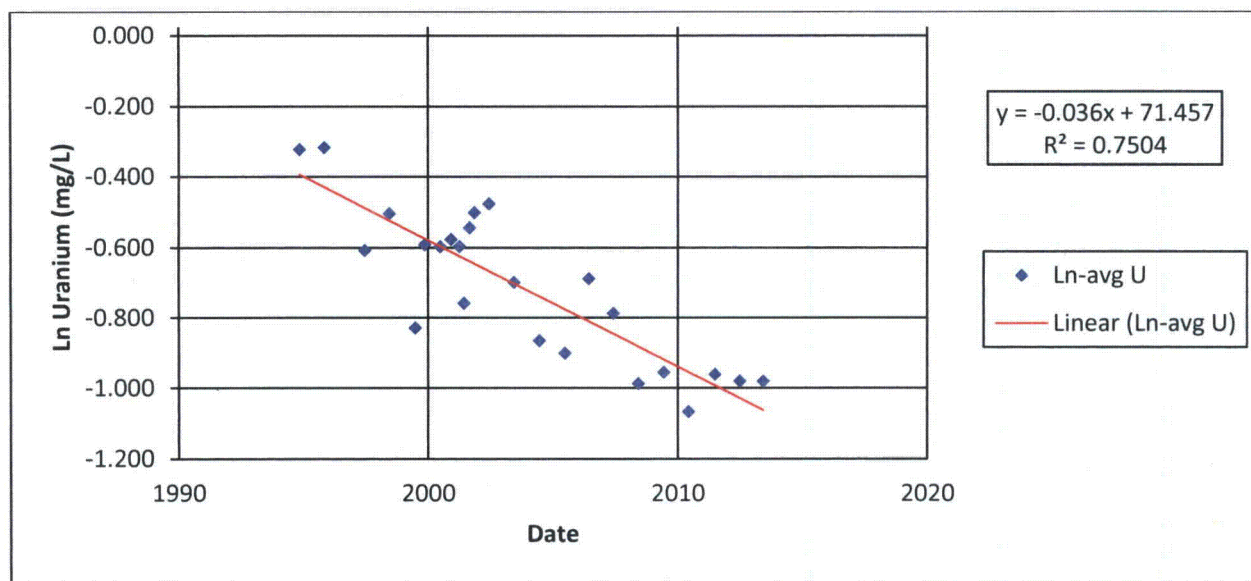


Figure 31. Regression Results for Average U (Natural-Log-Transformed Data)

Table 8. Uranium Attenuation Analysis Results

Well Designation	Estimated Uranium Attenuation Year (1991+ data)	Estimated Uranium Attenuation Year (2001+ data)	Estimated Uranium Attenuation Year Based on Modeling <sup>a</sup>
0612	2083	2088	2036
0617	2048	2083	2036
0631	2018	2020	2033
0633	2108	2080	2039
0634	n/a—increasing	2009	2009
Average	2072	2067	—

<sup>a</sup> Modeling uses 2002 as the baseline for predictions

Analyses were performed for two data sets—one from 1991 forward and the other from 2001 forward. This was done to evaluate whether attenuation rates have been declining and leveling off in more recent years. Steep declines are noted at many UMTRCA sites immediately following source removal; attenuation rates then commonly decline less rapidly and often level off completely. EPA notes that a natural attenuation evaluation should be restricted to time periods either before the start of active remediation or after the benefits of active remediation have been realized (EPA 2011). The coefficient of determination (i.e.,  $R^2$ ), which is included on the regression figures in Appendix C, represents the degree to which natural flushing (represented by time) explains the variation in the data. This statistic reflects the goodness of fit of the regression model. Rate constants obtained from regressions with lower values of  $R^2$  are less reliable predictors of future concentrations than ones with  $R^2$  closer to 1. Therefore estimated attenuation years should be viewed with more skepticism for regressions with lower  $R^2$ . Use of the slower one-tailed 90 percent confidence limit on the rate constant is a way of quantifying the uncertainty in attenuation times (EPA 1999).

Results of the linear regression analysis for wells showing a decreasing trend in uranium show that the uranium standard could be expected to be reached in a reasonable time frame (less than 100 years) based on the average estimated rate constants. However, using the slower one-tailed 90 percent confidence interval on the rate constants to estimate the longest durations required for flushing, estimated attenuation times were extended for tens to hundreds of years (Appendix C). This simply illustrates the great uncertainty associated with trying to make predictions over the time frame allotted for natural flushing (i.e., 100 years). Estimated time frames to meet the uranium standard are extended slightly for most locations using average rate constants for just the 2001+ data. One exception to this is for well 0633, for which estimates are reduced by more than 20 years. All wells in which uranium concentrations are declining are estimated to achieve the standard within 100 years based on the average attenuation rate.

Predictions based on the regression analysis indicate longer time frames for natural flushing for wells 0612, 0617, and 0633 compared with the modeled values. The regression prediction for well 0631 is shorter than the modeling prediction by more than a decade. Both the regression (2001+ data) and the model predicted that the standard should be met for well 0634 by the year 2009. In reality, concentrations in this well have been fluctuating above and below the standard throughout the monitoring period. Given the uncertainties associated with both methods of prediction (modeling and statistical), results are generally consistent with one another in that both indicate that flushing may achieve the uranium standard within the 100-year time frame allotted by 40 CFR 192.

### **3.1.8 Summary of Mill Tailings Area**

Based on the analysis provided above, several different groundwater compliance options appear to be justifiable for the mill tailings area, including the current compliance strategy of natural flushing. It was demonstrated in Section 3.1.1 that background water quality for the area is poor and is naturally elevated in a number of constituents. Information presented in Sections 3.1.3 through 3.1.5 suggests that additional sources other than milling can adversely impact groundwater quality at the site. These include impacts from Mancos Shale and the slag layer from past smelter operations. All of these factors together suggest that groundwater at the site may qualify for supplemental standards based on limited use, similar to the raffinate ponds area.

Data presented in Section 3.1.3 for the best milling-related indicator—uranium—indicate that natural flushing is occurring at the site and that overall uranium concentrations are trending downward. The current compliance strategy may still be appropriate provided that flushing can meet compliance objectives within a 100-year period. This evaluation has demonstrated that the current compliance objective for sulfate is unrealistically low considering site background and other sources of sulfate contamination. The current strategy assumes that the MCL is the appropriate compliance standard for uranium.

Studies summarized in Section 3.1.6 demonstrated that the site was protective after source removal was completed; no adverse impacts were found for the only complete pathway to groundwater contamination—the Animas River. Data presented in Section 3.1.6 indicate that groundwater quality at the site is stable or improving over time and will be protective into the future. Based on protectiveness of human health and the environment, the use of ACLs could also be justified in lieu of stricter groundwater standards. Several different approaches could be used to establish numerical values for ACLs.



Results presented in Section 3.1.7 indicate that natural flushing could meet the MCL for uranium in the allotted 100-year time frame. Based on average attenuation rate constants for individual wells and the average of on-site wells, compliance could be achieved in about 75 years. However, uncertainties in these predictions are high—actual time frames could extend for decades if not hundreds of years.

In terms of appropriateness of the site monitoring approach, this evaluation indicated that sulfate is not a good indicator of milling-related contamination. Similarly, elevated cadmium and manganese observed at well 0612 are likely derived from a nonmilling source—possibly the slag layer. Therefore, those constituents also are not useful for monitoring milling-related contamination. Wells 0622 and 0635 may have had some minor mill-related contamination at one time, but monitoring results for more than a decade demonstrate that they now represent background water quality. Monitoring data for the southernmost well in the monitoring network—well 0863—demonstrate that it is not in the flow path of site-related contamination. It is also representative of background. If the background data set for the site is found to be sufficient, monitoring of background wells could be discontinued. The evaluation has demonstrated that groundwater quality at the mill tailings area is protective at the point of exposure in the Animas River. It is also stable or improving and has remained within predicted limits over the last several years. Sampling of the river even at low flow times of the year results in surface water quality indistinguishable from background. A reduction in the frequency of monitoring could be justified on this basis.

## **3.2 Raffinate Ponds Area**

The uppermost aquifer in the raffinate ponds consists of the Menefee Formation and Point Lookout Sandstone Formation bedrock units. These units are juxtaposed along the north-northeast trending Bodo Fault (Figure 1). It is assumed that these units function as a single aquifer and that water flows from near the base of Smelter Mountain toward the Animas River. Therefore, water originating in the Point Lookout Sandstone (on the west side of the fault) will flow across the fault and mix with water in the Menefee Formation.

### **3.2.1 Background**

Well 0599 is completed in the Point Lookout Sandstone Formation and is located upgradient from the former raffinate ponds (Figure 1); it is considered to be background for the site (DOE 2002a). Generally, as with the mill tailings area, background water quality is poor. Based on data in the SOWP, background groundwater concentrations of nitrate, sulfate, iron, manganese, selenium, and TDS exceeded water quality standards. On the basis of high background levels of selenium, it was determined that supplemental standards applied to groundwater at the raffinate ponds area and that no further action was needed. Monitoring has been conducted as a best management practice only. A limited data evaluation was completed for the raffinate ponds area data; this focused on uranium, the best site-related indicator constituent.

### **3.2.2 Trends**

The compliance strategy for the raffinate ponds area is not contingent upon natural flushing or other processes to reduce concentrations. However, to evaluate the stability of the groundwater

system, a Mann-Kendall analysis was completed for site wells using uranium data. For wells with longer monitoring histories (e.g., 0598, 0607), the trend test was applied to different monitoring periods. Results are presented in Table 9. The wells located within the footprint of the former raffinate ponds (wells 0598, 0607, 0879; Figure 1) all show decreasing trends for complete data sets. Based on only the most recent data, concentrations in well 0598 appear to have stabilized; concentrations in well 0607 continue to decline. In contrast, the two wells downgradient of the raffinate ponds—wells 0594 and 0884—display increasing trends in uranium. This suggests that site-related contamination is migrating downgradient over time as would be expected based on natural processes.

*Table 9. Mann-Kendall Results for Uranium in the Raffinate Ponds Area*

Well Designation	Years	Trend	Confidence Level
0594	1991+	increasing	85%
0598	1991+	decreasing	95%
0598	2001+	none	NA
0607	1980+	decreasing	80%
0607	1990+	decreasing	90%
0607	2000+	decreasing	95%
0879	2000+	decreasing	90%
0884	2000+	increasing	95%

### 3.2.3 Post-Surface-Remediation Water Quality

As with the data from the mill tailings area, uranium data were used to develop baseline statistics for the raffinate ponds area (Table 10). In order to have an adequate sample size to compute the statistics (8 to 10 analyses recommended), a longer time period was used than for the mill tailings area. Statistics were computed from available data between 1995 and 2009. These were compared to monitoring results obtained after 2009. As with the mill tailings area, uranium results for all wells since 2009 were below their respective UPL 95. This is an indication that the groundwater system is relatively stable. Results are consistent with predictions based on past observations. Even though the Mann-Kendall test indicated that a couple of wells displayed increasing trends, results have still remained within expected limits.

Table 10. Uranium Statistics for the Raffinate Ponds Area (Data Collected 1995 Through 2009)

Well Number	Number of Samples	Minimum	Maximum	Mean	UPL 95 <sup>a</sup>	Max since 2009
0594	10	0.0305	0.192	0.0656	0.284	0.10
0598	17	0.0497	0.278	0.121	0.43	0.11
0879	11	0.041	0.36	0.202	0.738	0.086
0607	18	0.0026	0.0063	0.00404	0.0085	0.0031
0884	13	0.04	0.18	0.0994	0.273	0.14

<sup>a</sup> Nonparametric Chebyshev UPL was used

### 3.2.4 Summary of Raffinate Pond Area

Monitoring at the raffinate ponds area is being conducted as a best management practice. For supplemental standards sites, groundwater monitoring is not required; all monitoring could be discontinued for this site. A trend evaluation for the raffinate ponds area indicates that site-related contamination is still moving past two downgradient site wells—0594 and 0884. All other wells have decreasing trends. If it is desirable to reduce, but not eliminate, monitoring at this site, the two downgradient wells would provide the most useful information. Monitoring of just these two wells for uranium would likely be adequate for monitoring behavior of milling-related contamination. A reduction in monitoring frequency could be considered.



## 4.0 Conclusions and Recommendations

Based on the evaluation included in this report, the following observations can be made:

- A more detailed evaluation of background water quality for the mill tailings area indicates that natural groundwater quality is poor and elevated in a number of constituents that exceed secondary drinking water standards. Among these are sulfate, iron, manganese, and chloride. Other potential sources of nonmilling contamination have been identified that are likely to affect water quality at the site. These include Mancos Shale and a layer of smelter slag that predates the uranium milling operations. The presence of elevated background concentrations and nonmilling sources of contamination suggest that supplemental standards may be applicable based on limited use groundwater. Uranium appears to be the only good indicator of milling-related contamination at the mill tailings area. Natural flushing appears to be proceeding as expected for uranium at the mill tailings area. Overall, concentrations are trending downward. Average attenuation rates suggest flushing could occur within the allotted 100-year time frame. However, uncertainties associated with these predictions indicate standards may not be attainable within a reasonable period of time. Uranium isotope data indicate that the majority of uranium at the site is milling-related and not derived from natural sources. Background levels of uranium are not elevated above applicable standards.
- Historical data for the site indicate that sulfate was associated with the milling processes. However, current concentrations at the site are consistent with those observed in background groundwater and groundwater associated with Mancos Shale. These sources of sulfate likely obscure any remaining mill-related sulfate. Sulfate is therefore not a good indicator of milling-related contaminant behavior. The sulfate compliance goal identified in the GCAP is unrealistically stringent. All sulfate concentrations at the site are below the UPL 95 based on background. Sulfate could be eliminated as a contaminant of concern for the site.
- While some milling-related contamination may have affected well locations 0622 and 0635 in the past, concentrations of constituents in these wells have been consistent with background levels for the last decade. Southernmost well 0863 does not appear to be in the flow path of site-related contamination. Groundwater in this well is more similar to background groundwater. If the background data set is considered to be adequate, these wells could be eliminated from future monitoring.
- Past studies conducted at the site have demonstrated that post-remediation groundwater quality was protective of human health and the environment. Since that time frame, groundwater quality has remained stable at the site and continues to be protective. On the basis of protectiveness, ACLs could be established for the site. Molybdenum and selenium have met their respective standards in all mill tailings area wells for the last three sampling rounds. These analytes can be eliminated from future monitoring, as stated in the GCAP.
- Elevated levels of cadmium and manganese observed at well 0612 are likely derived from a source other than milling—possibly the slag layer. The concentrations and behaviors of these constituents are inconsistent with those that were derived from milling-related activities. Monitoring of these constituents is not useful for tracking the behavior of milling-related contamination.
- Monitoring in the raffinate ponds area is being conducted as a best management practice. Because data are not required for compliance purposes, it may be possible to eliminate or reduce the frequency of monitoring in this area (e.g., once every 5 years). The monitoring

network could be reduced to the two downgradient wells at the site—all others have shown stable or declining concentrations. Increasing trends in uranium at the two downgradient wells suggest that the maximum concentrations in the groundwater plume have not yet passed these locations.

- Surface water monitoring could be discontinued at both areas, as results are consistently below levels that are protective of surface water even during low flow.

## 5.0 References

5 CCR 1002-41. Colorado Department of Public Health and Environment, "The Basic Standards for Ground Water," *Code of Colorado Regulations*.

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

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## **Appendix A**

### **Groundwater and Surface Water Quality Data**

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## Results of 2013 Monitoring

The annual groundwater and surface water monitoring approach for the Durango processing site was established in the GCAP (DOE 2003). The GCAP specifies that monitoring will continue for the first 5 years following U.S. Nuclear Regulatory Commission (NRC) concurrence with the GCAP. Monitoring for cadmium at the mill tailings area will continue annually for the first 10 years following concurrence because of the greater uncertainty about whether this constituent will flush naturally within the allotted 100-year period established in 40 CFR 192. Monitoring data obtained through the initial 5-year period will measure the progress of natural flushing of the constituents listed in Table A-2. The GCAP specifies that after the 5-year annual monitoring period, the scope of subsequent monitoring will be addressed in a long-term management plan. Although NRC has not yet approved the GCAP, DOE has adopted the monitoring approach recommended in that document. However, the time frames mentioned above will not begin until after the GCAP is approved.

At the mill tailings area, monitoring wells 0612, 0617, 0630, 0631, 0633, 0634, 0635, and 0863 have been established as point-of-compliance (POC) wells that are used to monitor the progress of natural flushing in groundwater in the alluvial aquifer (Figure A-1). In accordance with provisions of the GCAP, natural flushing for a given analyte is complete when its concentration meets the compliance goal at all POC wells for three consecutive annual sampling events. Monitoring for that constituent may then be discontinued.

Surface water locations 0652, 0584, 0691, and 0586, located along the Animas River (Figure A-1), are sampled to verify continued protection of the aquatic environment. Table A-1 summarizes the rationale and requirements for compliance monitoring in the mill tailings area.

Groundwater and surface water of the raffinate ponds area are monitored only as a best management practice, and no POC wells have been established. Table A-2 summarizes the monitoring practices.

At the request of CDPHE, surface water sampling was conducted in September 2012 and again in September 2013 to determine if there is a seasonal low-flow effect on concentrations entering the Animas River.

### A.1 General Water Quality

Table A-3 compares the maximum concentrations of the site contaminants detected in June 2013 to the corresponding compliance goals established in the GCAP for the mill tailings area. The compliance goals for cadmium, molybdenum, and uranium are 40 CFR 192 MCLs. The compliance goal for selenium (0.05 mg/L) is adopted from the EPA Safe Drinking Water Act as an ACL (the 40 CFR 192 MCL is 0.01 mg/L). An ACL was established for selenium because selenium occurs naturally in groundwater beneath the site at levels above the 40 CFR 192 MCL. There are no MCLs for manganese and sulfate. The compliance goal for manganese is the EPA drinking water equivalent level. This is a lifetime exposure concentration that is protective of adverse, noncancer health effects; it assumes that all of the exposure to a contaminant is from drinking water (EPA 2004). The sulfate goal is equivalent to its average background concentration in local groundwater.

*Table A-1. Annual Groundwater and Surface Water Compliance Monitoring Requirements for the Mill Tailings Area*

Sampling Location	Monitoring Purpose	Analytes	Location
<b>Groundwater Monitoring</b>			
0617, 0630, 0631, 0633, 0634, 0635	POC/verify natural flushing	Manganese Molybdenum Selenium Sulfate Uranium	Onsite
0612, 0863	POC/verify natural flushing; verify cadmium flushing	Cadmium Manganese Molybdenum Selenium Sulfate Uranium	Onsite downgradient
<b>Surface Water Monitoring</b>			
0652	Surface water background	Cadmium Molybdenum Selenium Uranium	Offsite upstream
0584, 0691	Verify no site-related increase above background		Offsite; site groundwater discharge area
0586	Verify no site-related increase above background		Offsite; downstream of site groundwater discharge

*Table A-2. Summary of Monitoring Practices at the Raffinate Ponds Area*

Sampling Location	Monitoring Purpose	Analytes	Location
0879, 0594 (replaced 0880)	Monitor concentrations in groundwater in the shallow bedrock.	Selenium Uranium	Onsite
0598	Monitor concentrations in groundwater in the deep bedrock and Bodo Fault zone.	Selenium Uranium	Onsite
0607	Monitor concentrations in groundwater entering the site.	Selenium Uranium	Onsite
0884	Monitor offsite downgradient concentrations and migration.	Selenium Uranium	Offsite downgradient
0588	Surface water quality entering the site.	Selenium Uranium	Offsite upgradient
0654, 0656	Downgradient surface water concentrations.	Selenium Uranium	Offsite downgradient

*Table A-3. Current Groundwater Contaminants and Compliance Goals for the Mill Tailings Area*

Contaminant of Concern	Compliance Goal (mg/L)	Compliance Goal Source	Maximum Concentration Observed in June 2013 (mg/L)
Cadmium	0.01	40 CFR 192 MCL	0.043
Manganese	1.6	Drinking Water Equivalent Level (EPA 2004)	5.8
Molybdenum	0.1	40 CFR 192 MCL	0.090
Selenium	0.05	ACL (DOE 2003)	0.045
Sulfate	1,276.0	Average Background (DOE 2002a)	3,900.0
Uranium	0.044	40 CFR 192 MCL (activity based)	1.4





Figure A-1. Durango Processing Site Features and Sampling Locations



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Bedrock groundwater at the raffinate ponds area qualifies for supplemental standards on the basis of limited use groundwater as defined in 40 CFR 192. Because supplemental standards apply to groundwater in the raffinate ponds area, no numerical compliance goals have been established for that portion of the site.

Current monitoring of the Animas River verifies previous findings in the BLRA (DOE 1995) that past milling operations have negligible effect on surface water quality. Based on seasonal sampling results provided in the 2012 verification monitoring report, it was determined that September river flows were lower and surface water concentrations higher than in June. Surface water sampling in 2013 was therefore conducted in September to capture low-flow chemistry. Table A-4 provides surface water sampling results for selected constituents. Complete monitoring results for the mill tailings area are included in Attachment A-1.

*Table A-4. 2013 Sampling Results for Selected Constituents in the Animas River*

Area	Location	Cadmium (mg/L)	Molybdenum (mg/L)	Selenium (mg/L)	Uranium (mg/L)
Background	0652	0.0001	0.0012	<0.0015	0.0010
Mill Tailings	0584	0.0001	0.0012	<0.0015	0.0010
Mill Tailings	0586	0.0001	0.0012	<0.0015	0.0010
Mill Tailings	0691	0.0001	0.0011	<0.0015	0.0010
Raffinate Ponds	0654	0.0001	0.0012	<0.0015	0.0010
Raffinate Ponds	0678	0.0001	0.0012	<0.0015	0.0010

## **A.2 Groundwater**

### **A.2.1 Mill Tailings Area**

Groundwater was sampled from the eight POC locations (Figure A-1) and analyzed for the constituents shown in Table A-1. Sampling results for 2013 are provided in Attachment A-1 and are discussed below by constituent.

#### **A.2.1.1 Cadmium**

Figure A-2 contains a map view of the site showing the concentration of cadmium in groundwater at the compliance wells in June 2013. Consistent with past years, concentrations are elevated only in well 0612. As discussed above, based on historical information on tailings fluid composition and lack of trending, a source other than mill tailings is assumed for cadmium at this location. The slag layer represents a plausible source.

#### **A.2.1.2 Manganese**

Figure A-2 illustrates the distribution of manganese concentrations in groundwater in June 2013. As with cadmium, and consistent with past years, concentrations are elevated only in well 0612. A localized, persistent source is hypothesized as with cadmium. The slag layer is suggested as a plausible source.

#### ***A.2.1.3 Molybdenum***

Molybdenum concentrations in June 2013 remained below the compliance goal of 0.1 mg/L at all locations. Because all locations have been below the standard for at least three consecutive sampling rounds, monitoring for this analyte can be discontinued as specified in the GCAP.

#### ***A.2.1.4 Selenium***

Selenium concentrations in June 2013 remained below the compliance goal (0.05 mg/L) at all well locations. Because all locations have been below the standard for at least three consecutive sampling rounds, monitoring for this analyte can be discontinued as specified in the GCAP.

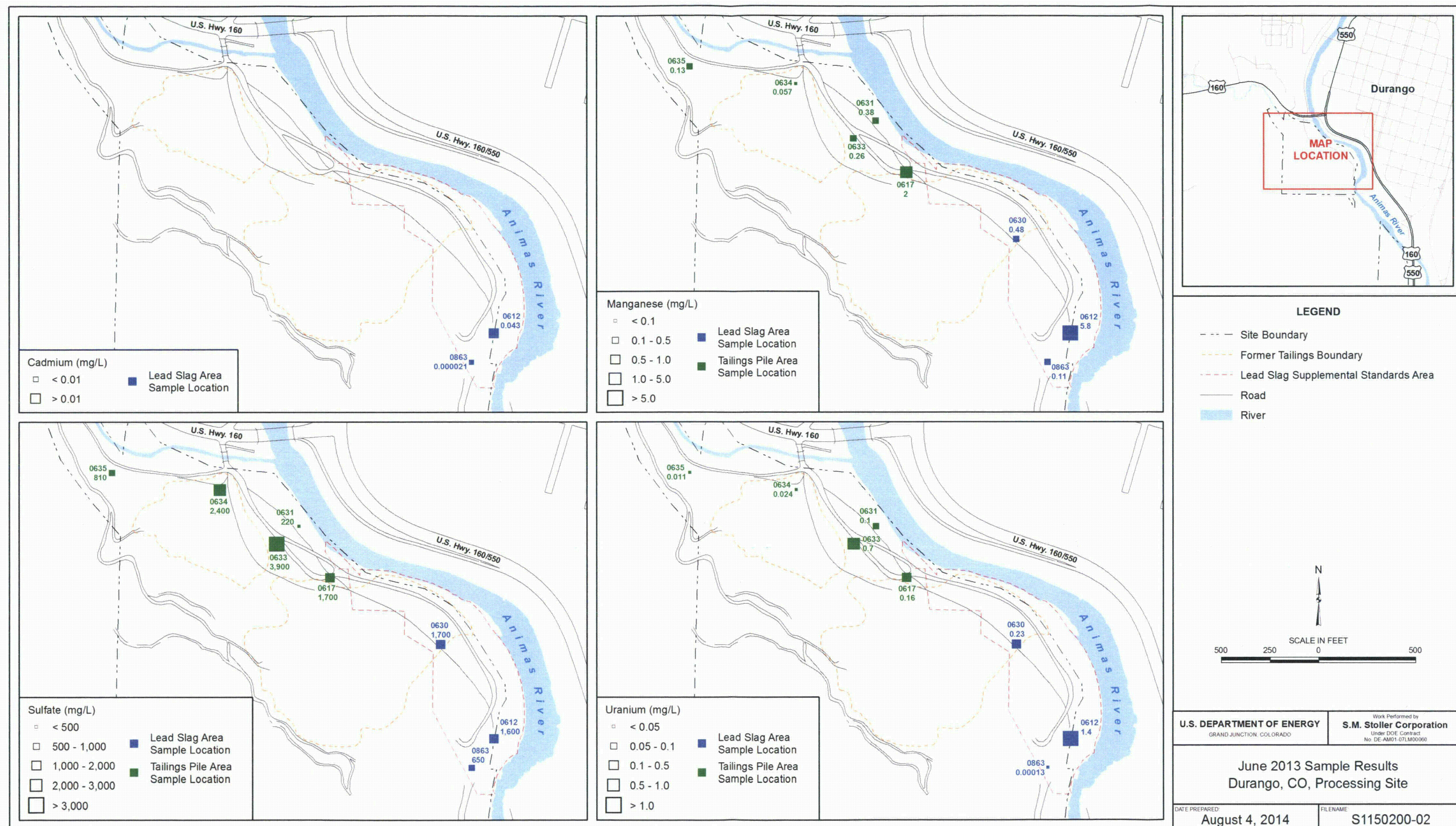
#### ***A.2.1.5 Sulfate***

Figure A-2 shows sulfate concentrations for 2013. The highest concentrations observed in 2013 were at location 0633. As discussed above, concentrations in the well have been trending upward over time. Because this well is screened predominantly in the Mancos Shale, a Mancos-derived source is hypothesized. Other wells at the site that are screened across Mancos tend to have higher levels of sulfate, including background well 0629. Because background concentrations of sulfate are relatively high and because Mancos Shale represents another likely sulfate source, monitoring of sulfate is not very meaningful for evaluating natural flushing of site-related contamination. The current compliance goal of 1,276 mg/L is unrealistically low. The UPL 95 computed for sulfate in background wells was 4,234 mg/L (Table 2 main report). A UPL 95 for background data is commonly used as a “not-to-exceed” value for groundwater compliance monitoring (EPA 2009) and is probably a more reasonable compliance goal than that established in the GCAP. Sulfate in onsite wells has never exceeded the UPL 95 value.

#### ***A.2.1.6 Uranium***

Uranium concentrations exceeded the compliance goal at all locations except wells 0634, 0635, and 0863 in June 2013 (Figure A-2). The evaluation in this report has demonstrated that uranium in mill tailings area groundwater is mostly milling-related. Concentrations continue to decline as mill-related contamination is naturally flushed from the system.





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Figure A-2. June 2013 Sample Results

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### A.2.2 Raffinate Ponds Area

Groundwater in the raffinate ponds area is being monitored as a best management practice. Bedrock groundwater at the raffinate ponds area qualifies for supplemental standards on the basis of limited use groundwater due to widespread elevated concentrations of naturally occurring selenium. Because naturally occurring sources of both selenium and uranium are present in the area, groundwater concentrations of these constituents are not expected to flush to compliance goals. Therefore, no modeling was done for the raffinate ponds area.

Groundwater was sampled from five wells in the monitoring network in 2013 and analyzed for uranium and selenium. Complete monitoring results for the raffinate ponds area for 2013 are provided in Attachment A-2. Table A-5 summarizes the monitoring results for selenium and uranium.

*Table A-5. 2013 Uranium and Selenium Results for Raffinate Ponds Area*

Well Location	Selenium (mg/L)	Uranium (mg/L)
0594	0.0053	0.028
0598	0.230	0.096
0607	0.410	0.0031
0879	0.012	0.083
0884	0.550	0.100

### A.3 Surface Water

Surface water was sampled from six locations in the Animas River (Figure A-1) adjacent to both the mill tailings and raffinate ponds areas during September 2013 and analyzed for cadmium, molybdenum, selenium, and uranium. Sampling results indicate that locations adjacent to the sites are indistinguishable from background (Table A-4).



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**Attachment A-1**

**Mill Tailings Processing Site (DUR01)**

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GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR01, Durango Mill Tailings Process Site  
 REPORT DATE: 5/5/2014 8:45 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Alkalinity, Total (As CaCO3)	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	393	F #	-	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	431	F #	-	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	294	F #	-	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	366	F #	-	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	638	FQ #	-	-
	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	402	FQ #	-	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	453	F #	-	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	479	F #	-	-
Cadmium	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	0.043	F #	0.00058	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	0.00002	B F #	1.2E-05	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	0.00001	B F #	1.2E-05	-
Manganese	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	5.800	F #	0.00011	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	2.000	F #	0.00011	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	0.480	F #	0.00011	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	0.380	F #	0.00011	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	0.260	FQ #	0.00011	-
	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	0.057	FQ #	0.00011	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	0.130	F #	0.00011	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	0.110	F #	0.00011	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	0.110	F #	0.00011	-
Molybdenum	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	0.090	F #	0.0016	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	0.002	F #	0.00032	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	0.0026	F #	0.00032	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	0.0053	F #	0.00032	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	0.001	B FQ #	0.00032	-

GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR01, Durango Mill Tailings Process Site  
 REPORT DATE: 5/5/2014 8:45 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN- CERTAINTY
Molybdenum	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	0.0016	FQ #	3.2E-05	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	0.0012	F #	3.2E-05	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	0.00061	F #	3.2E-05	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	0.00064	F #	3.2E-05	-
Oxidation Reduction Potential	mV	0612	WL	06/04/2013	N001	37.41 - 57.41	42.6	F #	-	-
	mV	0617	WL	06/04/2013	N001	14.00 - 29.00	-132.5	F #	-	-
	mV	0630	WL	06/04/2013	N001	28.30 - 38.30	5.7	F #	-	-
	mV	0631	WL	06/04/2013	N001	6.00 - 16.00	-73.8	F #	-	-
	mV	0633	WL	06/04/2013	N001	4.00 - 14.00	-138.4	FQ #	-	-
	mV	0634	WL	06/04/2013	N001	8.00 - 18.00	48.5	FQ #	-	-
	mV	0635	WL	06/04/2013	N001	5.50 - 15.50	-64.1	F #	-	-
	mV	0863	WL	06/04/2013	N001	58.00 - 67.50	34.2	F #	-	-
pH	s.u.	0612	WL	06/04/2013	N001	37.41 - 57.41	6.63	F #	-	-
	s.u.	0617	WL	06/04/2013	N001	14.00 - 29.00	6.83	F #	-	-
	s.u.	0630	WL	06/04/2013	N001	28.30 - 38.30	6.73	F #	-	-
	s.u.	0631	WL	06/04/2013	N001	6.00 - 16.00	7.25	F #	-	-
	s.u.	0633	WL	06/04/2013	N001	4.00 - 14.00	6.72	FQ #	-	-
	s.u.	0634	WL	06/04/2013	N001	8.00 - 18.00	6.99	FQ #	-	-
	s.u.	0635	WL	06/04/2013	N001	5.50 - 15.50	6.85	F #	-	-
	s.u.	0863	WL	06/04/2013	N001	58.00 - 67.50	6.96	F #	-	-
Selenium	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	0.00044	FJ #	3.2E-05	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	0.0017	F #	3.2E-05	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	0.012	F #	0.00032	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	0.0011	F #	3.2E-05	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	0.045	FQ #	0.00032	-

GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR01, Durango Mill Tailings Process Site  
 REPORT DATE: 5/5/2014 8:45 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Selenium	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	0.00037	FQJ #	3.2E-05	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	0.00025	FJ #	3.2E-05	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	0.00003 U	F #	3.2E-05	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	0.00003 U	F #	3.2E-05	-
Specific Conductance	umhos/cm	0612	WL	06/04/2013	N001	37.41 - 57.41	3823	F #	-	-
	umhos/cm	0617	WL	06/04/2013	N001	14.00 - 29.00	3152	F #	-	-
	umhos/cm	0630	WL	06/04/2013	N001	28.30 - 38.30	3064	F #	-	-
	umhos/cm	0631	WL	06/04/2013	N001	6.00 - 16.00	1433	F #	-	-
	umhos/cm	0633	WL	06/04/2013	N001	4.00 - 14.00	7708	FQ #	-	-
	umhos/cm	0634	WL	06/04/2013	N001	8.00 - 18.00	4636	FQ #	-	-
	umhos/cm	0635	WL	06/04/2013	N001	5.50 - 15.50	2192	F #	-	-
	umhos/cm	0863	WL	06/04/2013	N001	58.00 - 67.50	2146	F #	-	-
Sulfate	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	1600	F #	25	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	1700	F #	25	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	1700	F #	25	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	220	F #	5	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	3900	FQ #	50	-
	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	2400	FQ #	50	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	810	F #	10	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	650	F #	10	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	650	F #	10	-
Temperature	C	0612	WL	06/04/2013	N001	37.41 - 57.41	12.53	F #	-	-
	C	0617	WL	06/04/2013	N001	14.00 - 29.00	12.59	F #	-	-
	C	0630	WL	06/04/2013	N001	28.30 - 38.30	19.96	F #	-	-
	C	0631	WL	06/04/2013	N001	6.00 - 16.00	14.23	F #	-	-



GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR01, Durango Mill Tailings Process Site  
REPORT DATE: 5/5/2014 8:45 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Temperature	C	0633	WL	06/04/2013	N001	4.00 - 14.00	14.71	FQ #	-	-
	C	0634	WL	06/04/2013	N001	8.00 - 18.00	13.37	FQ #	-	-
	C	0635	WL	06/04/2013	N001	5.50 - 15.50	13.56	F #	-	-
	C	0863	WL	06/04/2013	N001	58.00 - 67.50	12.41	F #	-	-
Turbidity	NTU	0612	WL	06/04/2013	N001	37.41 - 57.41	1.56	F #	-	-
	NTU	0617	WL	06/04/2013	N001	14.00 - 29.00	9.7	F #	-	-
	NTU	0630	WL	06/04/2013	N001	28.30 - 38.30	9.17	F #	-	-
	NTU	0631	WL	06/04/2013	N001	6.00 - 16.00	1.69	F #	-	-
	NTU	0633	WL	06/04/2013	N001	4.00 - 14.00	9.26	FQ #	-	-
	NTU	0634	WL	06/04/2013	N001	8.00 - 18.00	3.94	FQ #	-	-
	NTU	0635	WL	06/04/2013	N001	5.50 - 15.50	3.69	F #	-	-
	NTU	0863	WL	06/04/2013	N001	58.00 - 67.50	2.62	F #	-	-
Uranium	mg/L	0612	WL	06/04/2013	N001	37.41 - 57.41	1.400	F #	0.00015	-
	mg/L	0617	WL	06/04/2013	N001	14.00 - 29.00	0.160	F #	2.9E-05	-
	mg/L	0630	WL	06/04/2013	N001	28.30 - 38.30	0.230	F #	2.9E-05	-
	mg/L	0631	WL	06/04/2013	N001	6.00 - 16.00	0.100	F #	2.9E-05	-
	mg/L	0633	WL	06/04/2013	N001	4.00 - 14.00	0.700	FQ #	2.9E-05	-
	mg/L	0634	WL	06/04/2013	N001	8.00 - 18.00	0.024	FQ #	2.9E-06	-
	mg/L	0635	WL	06/04/2013	N001	5.50 - 15.50	0.011	F #	2.9E-06	-
	mg/L	0863	WL	06/04/2013	N001	58.00 - 67.50	0.00013 *	FJ #	2.9E-06	-
	mg/L	0863	WL	06/04/2013	N002	58.00 - 67.50	0.0001	F #	2.9E-06	-

## GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR01, Durango Mill Tailings Process Site

REPORT DATE: 5/5/2014 8:45 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
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RECORDS: SELECTED FROM USEE200 WHERE site\_code='DUR01' AND (data\_validation\_qualifiers IS NULL OR data\_validation\_qualifiers NOT LIKE '%R%' AND data\_validation\_qualifiers NOT LIKE '%X%' ) AND DATE\_SAMPLED between #1/1/2013# and #12/31/2013#

SAMPLE ID CODES: 000X = Filtered sample. N00X = Unfiltered sample. X = replicate number.

LOCATION TYPES: WL WELL

## LAB QUALIFIERS:

- \* Replicate analysis not within control limits.
- + Correlation coefficient for MSA < 0.995.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic & Radiochemistry: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- M GFAA duplicate injection precision not met.
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- S Result determined by method of standard addition (MSA).
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Y Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Z Laboratory defined (USEPA CLP organic) qualifier, see case narrative.

## DATA QUALIFIERS:

- |  |  |  |
|--|--|--|
| F Low flow sampling method used.                     | G Possible grout contamination, pH > 9.  | J Estimated value.                             |
| L Less than 3 bore volumes purged prior to sampling. | N Presumptive evidence that analyte is present. The analyte is "tentatively identified". | Q Qualitative result due to sampling technique |
| R Unusable result.                                   | U Parameter analyzed for but was not detected.   | X Location is undefined.                       |

QA QUALIFIER: # = validated according to Quality Assurance guidelines.

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SURFACE WATER QUALITY DATA BY PARAMETER (USEE800) FOR SITE DUR01, Durango Mill Tailings Process Site  
 REPORT DATE: 5/5/2014 8:47 am

PARAMETER	UNITS	LOCATION CODE	SAMPLE: DATE	ID	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Alkalinity, Total (As CaCO3)	mg/L	0584	09/04/2013	N001	111		#	-
	mg/L	0586	09/04/2013	N001	113		#	-
	mg/L	0652	09/04/2013	N001	106		#	-
	mg/L	0691	09/04/2013	N001	101		#	-
Cadmium	mg/L	0584	09/04/2013	N001	0.0001	B	#	0.00011
	mg/L	0586	09/04/2013	N001	0.0001	B	#	0.00011
	mg/L	0586	09/04/2013	N002	0.0001	B	#	0.00011
	mg/L	0652	09/04/2013	N001	0.0001	B	#	0.00011
	mg/L	0691	09/04/2013	N001	0.0001	B	#	0.00011
Molybdenum	mg/L	0584	09/04/2013	N001	0.0012	B	#	0.00017
	mg/L	0586	09/04/2013	N001	0.0011	B	#	0.00017
	mg/L	0586	09/04/2013	N002	0.0012	B	#	0.00017
	mg/L	0652	09/04/2013	N001	0.0012	B	#	0.00017
	mg/L	0691	09/04/2013	N001	0.0011	B	#	0.00017
Oxidation Reduction Potential	mV	0584	09/04/2013	N001	126.0		#	-
	mV	0586	09/04/2013	N001	100.4		#	-
	mV	0652	09/04/2013	N001	131.7		#	-
	mV	0691	09/04/2013	N001	129.0		#	-
pH	s.u.	0584	09/04/2013	N001	8.06		#	-
	s.u.	0586	09/04/2013	N001	7.96		#	-
	s.u.	0652	09/04/2013	N001	8.17		#	-
	s.u.	0691	09/04/2013	N001	8.14		#	-
Selenium	mg/L	0584	09/04/2013	N001	0.0015	U	#	0.0015
	mg/L	0586	09/04/2013	N001	0.0015	U	#	0.0015
	mg/L	0586	09/04/2013	N002	0.0015	U	#	0.0015
	mg/L	0652	09/04/2013	N001	0.0015	U	#	0.0015
	mg/L	0691	09/04/2013	N001	0.0015	U	#	0.0015
Specific Conductance	umhos/cm	0584	09/04/2013	N001	522		#	-
	umhos/cm	0586	09/04/2013	N001	523		#	-
	umhos/cm	0652	09/04/2013	N001	487		#	-
	umhos/cm	0691	09/04/2013	N001	521		#	-
Temperature	C	0584	09/04/2013	N001	22.99		#	-
	C	0586	09/04/2013	N001	18.09		#	-
	C	0652	09/04/2013	N001	21.91		#	-
	C	0691	09/04/2013	N001	23.37		#	-

SURFACE WATER QUALITY DATA BY PARAMETER (USEE800) FOR SITE DUR01, Durango Mill Tailings Process Site  
REPORT DATE: 5/5/2014 8:47 am

PARAMETER	UNITS	LOCATION CODE	SAMPLE: DATE	ID	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Turbidity	NTU	0584	09/04/2013	N001	4.62		#	-
	NTU	0586	09/04/2013	N001	6.15		#	-
	NTU	0652	09/04/2013	N001	7.55		#	-
	NTU	0691	09/04/2013	N001	4.56		#	-
Uranium	mg/L	0584	09/04/2013	N001	0.0010		#	6.7E-05
	mg/L	0586	09/04/2013	N001	0.0010		#	6.7E-05
	mg/L	0586	09/04/2013	N002	0.0010		#	6.7E-05
	mg/L	0652	09/04/2013	N001	0.0010		#	6.7E-05
	mg/L	0691	09/04/2013	N001	0.0010		#	6.7E-05

RECORDS: SELECTED FROM USEE800 WHERE site\_code='DUR01' AND (data\_validation\_qualifiers IS NULL OR data\_validation\_qualifiers NOT LIKE '%R%' AND data\_validation\_qualifiers NOT LIKE '%X%' ) AND DATE\_SAMPLED between #1/1/2013# and #12/31/2013#

SAMPLE ID CODES: 000X = Filtered sample. N00X = Unfiltered sample. X = replicate number.

LAB QUALIFIERS:

- \* Replicate analysis not within control limits.
- + Correlation coefficient for MSA < 0.995.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic & Radiochemistry: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- M GFAA duplicate injection precision not met.
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- S Result determined by method of standard addition (MSA).
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Y Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Z Laboratory defined (USEPA CLP organic) qualifier, see case narrative.

DATA QUALIFIERS:

- F Low flow sampling method used.
- J Estimated value.
- N Presumptive evidence that analyte is present. The analyte is "tentatively identified".
- R Unusable result.
- X Location is undefined.
- G Possible grout contamination, pH > 9.
- L Less than 3 bore volumes purged prior to sampling.
- Q Qualitative result due to sampling technique
- U Parameter analyzed for but was not detected.

QA QUALIFIER: # = validated according to Quality Assurance guidelines.

**Attachment A-2**

**Raffinate Pond Processing Site (DUR02)**



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GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR02, Durango Raffinate Pond Process Site  
REPORT DATE: 5/5/2014 8:50 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Alkalinity, Total (As CaCO3)	mg/L	0594	WL	06/04/2013	N001	8.50 - 38.50	438	F #	-	-
	mg/L	0607	WL	06/03/2013	0001	35.00 - 55.00	329	FQ #	-	-
	mg/L	0879	WL	06/04/2013	N001	27.00 - 36.90	423	#	-	-
	mg/L	0884	WL	06/04/2013	N001	36.50 - 46.50	317	F #	-	-
Oxidation Reduction Potential	mV	0594	WL	06/04/2013	N001	8.50 - 38.50	120.5	F #	-	-
	mV	0598	WL	06/04/2013	N001	66.20 - 96.20	-10.7	F #	-	-
	mV	0607	WL	06/03/2013	N001	35.00 - 55.00	157.1	FQ #	-	-
	mV	0879	WL	06/04/2013	N001	27.00 - 36.90	3.6	#	-	-
	mV	0884	WL	06/04/2013	N001	36.50 - 46.50	50.0	F #	-	-
pH	s.u.	0594	WL	06/04/2013	N001	8.50 - 38.50	7.00	F #	-	-
	s.u.	0598	WL	06/04/2013	N001	66.20 - 96.20	6.86	F #	-	-
	s.u.	0607	WL	06/03/2013	N001	35.00 - 55.00	7.48	FQ #	-	-
	s.u.	0879	WL	06/04/2013	N001	27.00 - 36.90	6.79	#	-	-
	s.u.	0884	WL	06/04/2013	N001	36.50 - 46.50	7.00	F #	-	-
Selenium	mg/L	0594	WL	06/04/2013	N001	8.50 - 38.50	0.0053	F #	0.00032	-
	mg/L	0598	WL	06/04/2013	N001	66.20 - 96.20	0.230	F #	0.00032	-
	mg/L	0607	WL	06/03/2013	0001	35.00 - 55.00	0.410	FQ #	0.00032	-
	mg/L	0879	WL	06/04/2013	N001	27.00 - 36.90	0.012	#	0.00032	-
	mg/L	0884	WL	06/04/2013	N001	36.50 - 46.50	0.550	F #	0.00032	-
Specific Conductance	umhos/cm	0598	WL	06/04/2013	N001	66.20 - 96.20	7554	F #	-	-
	umhos/cm	0607	WL	06/03/2013	N001	35.00 - 55.00	2184	FQ #	-	-
	umhos/cm	0879	WL	06/04/2013	N001	27.00 - 36.90	7932	#	-	-
	umhos/cm	0884	WL	06/04/2013	N001	36.50 - 46.50	3749	F #	-	-
Temperature	C	0594	WL	06/04/2013	N001	8.50 - 38.50	20.98	F #	-	-

GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR02, Durango Raffinate Pond Process Site  
 REPORT DATE: 5/5/2014 8:50 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Temperature	C	0598	WL	06/04/2013	N001	66.20 - 96.20	18.21	F #	-	-
	C	0607	WL	06/03/2013	N001	35.00 - 55.00	17.26	FQ #	-	-
	C	0879	WL	06/04/2013	N001	27.00 - 36.90	14.75	#	-	-
	C	0884	WL	06/04/2013	N001	36.50 - 46.50	15.11	F #	-	-
Turbidity	NTU	0594	WL	06/04/2013	N001	8.50 - 38.50	4.29	F #	-	-
	NTU	0598	WL	06/04/2013	N001	66.20 - 96.20	7.83	F #	-	-
	NTU	0607	WL	06/03/2013	N001	35.00 - 55.00	15.4	FQ #	-	-
	NTU	0879	WL	06/04/2013	N001	27.00 - 36.90	1.62	#	-	-
	NTU	0884	WL	06/04/2013	N001	36.50 - 46.50	2.05	F #	-	-
Uranium	mg/L	0594	WL	06/04/2013	N001	8.50 - 38.50	0.028	F #	2.9E-05	-
	mg/L	0598	WL	06/04/2013	N001	66.20 - 96.20	0.096	F #	2.9E-05	-
	mg/L	0607	WL	06/03/2013	0001	35.00 - 55.00	0.0031	FQ #	2.9E-05	-
	mg/L	0879	WL	06/04/2013	N001	27.00 - 36.90	0.083	#	2.9E-05	-
	mg/L	0884	WL	06/04/2013	N001	36.50 - 46.50	0.100	F #	2.9E-05	-



GROUNDWATER QUALITY DATA BY PARAMETER WITH DEPTH (USEE200) FOR SITE DUR02, Durango Raffinate Pond Process Site  
 REPORT DATE: 5/5/2014 8:50 am

PARAMETER	UNITS	LOCATION CODE	LOCATION TYPE	SAMPLE: DATE	ID	DEPTH RANGE (FT BLS)	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN- CERTAINTY
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RECORDS: SELECTED FROM USEE200 WHERE site\_code='DUR02' AND (data\_validation\_qualifiers IS NULL OR data\_validation\_qualifiers NOT LIKE '%R%' AND data\_validation\_qualifiers NOT LIKE '%X%') AND DATE\_SAMPLED between #1/1/2013# and #12/31/2013#

SAMPLE ID CODES: 000X = Filtered sample. N00X = Unfiltered sample. X = replicate number.

LOCATION TYPES: WL WELL

LAB QUALIFIERS:

- \* Replicate analysis not within control limits.
- + Correlation coefficient for MSA < 0.995.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic & Radiochemistry: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- M GFAA duplicate injection precision not met.
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- S Result determined by method of standard addition (MSA).
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Y Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Z Laboratory defined (USEPA CLP organic) qualifier, see case narrative.

DATA QUALIFIERS:

- |  |  |  |
|--|--|--|
| F Low flow sampling method used.                     | G Possible grout contamination, pH > 9.  | J Estimated value.                             |
| L Less than 3 bore volumes purged prior to sampling. | N Presumptive evidence that analyte is present. The analyte is "tentatively identified". | Q Qualitative result due to sampling technique |
| R Unusable result.                                   | U Parameter analyzed for but was not detected.   | X Location is undefined.                       |

QA QUALIFIER: # = validated according to Quality Assurance guidelines.

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SURFACE WATER QUALITY DATA BY PARAMETER (USEE800) FOR SITE DUR02, Durango Raffinate Pond Process Site  
 REPORT DATE: 5/5/2014 8:51 am

PARAMETER	UNITS	LOCATION CODE	SAMPLE: DATE	ID	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN-CERTAINTY
Alkalinity, Total (As CaCO3)	mg/L	0654	09/04/2013	N001	96		#	-
	mg/L	0678	09/04/2013	N001	109		#	-
Cadmium	mg/L	0654	09/04/2013	N001	0.0001	B	# 0.00011	-
	mg/L	0678	09/04/2013	N001	0.0001	B	# 0.00011	-
Molybdenum	mg/L	0654	09/04/2013	N001	0.0012	B	# 0.00017	-
	mg/L	0678	09/04/2013	N001	0.0012	B	# 0.00017	-
Oxidation Reduction Potential	mV	0654	09/04/2013	N001	100.2		#	-
	mV	0678	09/04/2013	N001	108.2		#	-
pH	s.u.	0654	09/04/2013	N001	8.26		#	-
	s.u.	0678	09/04/2013	N001	8.00		#	-
Selenium	mg/L	0654	09/04/2013	N001	0.0015	U	# 0.0015	-
	mg/L	0678	09/04/2013	N001	0.0015	U	# 0.0015	-
Specific Conductance	umhos/cm	0654	09/04/2013	N001	518		#	-
	umhos/cm	0678	09/04/2013	N001	527		#	-
Temperature	C	0654	09/04/2013	N001	23.31		#	-
	C	0678	09/04/2013	N001	26.84		#	-
Turbidity	NTU	0654	09/04/2013	N001	5.25		#	-
	NTU	0678	09/04/2013	N001	8.77		#	-
Uranium	mg/L	0654	09/04/2013	N001	0.0010		# 6.7E-05	-
	mg/L	0678	09/04/2013	N001	0.0010		# 6.7E-05	-

SURFACE WATER QUALITY DATA BY PARAMETER (USEE800) FOR SITE DUR02, Durango Raffinate Pond Process Site  
 REPORT DATE: 5/5/2014 8:51 am

PARAMETER	UNITS	LOCATION CODE	SAMPLE: DATE	ID	RESULT	QUALIFIERS: LAB DATA QA	DETECTION LIMIT	UN- CERTAINTY
-----------	-------	------------------	-----------------	----	--------	----------------------------	--------------------	------------------

RECORDS: SELECTED FROM USEE800 WHERE site\_code='DUR02' AND (data\_validation\_qualifiers IS NULL OR data\_validation\_qualifiers NOT LIKE '%R%' AND data\_validation\_qualifiers NOT LIKE '%X%') AND DATE\_SAMPLED between #1/1/2013# and #12/31/2013#

SAMPLE ID CODES: 000X = Filtered sample. N00X = Unfiltered sample. X = replicate number.

LAB QUALIFIERS:

- \* Replicate analysis not within control limits.
- + Correlation coefficient for MSA < 0.995.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic & Radiochemistry: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- M GFAA duplicate injection precision not met.
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- S Result determined by method of standard addition (MSA).
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Y Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Z Laboratory defined (USEPA CLP organic) qualifier, see case narrative.

DATA QUALIFIERS:

- |  |  |
|--|--|
| F Low flow sampling method used.   | G Possible grout contamination, pH > 9.              |
| J Estimated value.   | L Less than 3 bore volumes purged prior to sampling. |
| N Presumptive evidence that analyte is present. The analyte is "tentatively identified". | Q Qualitative result due to sampling technique       |
| R Unusable result.   | U Parameter analyzed for but was not detected.       |
| X Location is undefined.   |  |

QA QUALIFIER: # = validated according to Quality Assurance guidelines.



**Appendix B**  
**ProUCL Output**

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**B-1. Statistics for Background Wells—Mill Tailings Area**

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General Background Statistics for Full Data Sets			
User Selected Options			
From File	WorkSheet.wst		
Full Precision	OFF		
Confidence Coefficient	95%		
Coverage	90%		
Different or Future K Values	1		
Number of Bootstrap Operations	2000		
uranium			
General Statistics			
Total Number of Observations	60	Number of Distinct Observations	48
Tolerance Factor	1.604		
Raw Statistics		Log-Transformed Statistics	
Minimum	3.60E-04	Minimum	-7.929
Maximum	0.0354	Maximum	-3.341
Second Largest	0.029	Second Largest	-3.54
First Quartile	0.0048	First Quartile	-5.34
Median	0.0069	Median	-4.978
Third Quartile	0.015	Third Quartile	-4.204
Mean	0.00996	Mean	-5.1
Geometric Mean	0.00609	SD	1.186
SD	0.00828		
Coefficient of Variation	0.832		
Skewness	1.027		
Background Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.162	Lilliefors Test Statistic	0.18
Lilliefors Critical Value	0.114	Lilliefors Critical Value	0.114
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% UTL with 90% Coverage	0.0232	95% UTL with 90% Coverage	0.0408
95% UPL (t)	0.0239	95% UPL (t)	0.045
90% Percentile (z)	0.0206	90% Percentile (z)	0.0279
95% Percentile (z)	0.0236	95% Percentile (z)	0.0429
99% Percentile (z)	0.0292	99% Percentile (z)	0.0962
Gamma Distribution Test		Data Distribution Test	
k star	1.11	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	0.00897		
MLE of Mean	0.00996		
MLE of Standard Deviation	0.00945		
nu star	133.2		
A-D Test Statistic	0.829	Nonparametric Statistics	
5% A-D Critical Value	0.776	90% Percentile	0.021
K-S Test Statistic	0.114	95% Percentile	0.0252
5% K-S Critical Value	0.118	99% Percentile	0.0316
Data follow Appx. Gamma Distribution at 5% Significance Level			
Assuming Gamma Distribution		95% UTL with 90% Coverage	0.025
90% Percentile	0.0223	95% Percentile Bootstrap UTL with 90% Coverage	0.0254
95% Percentile	0.0288	95% BCA Bootstrap UTL with 90% Coverage	0.0254
99% Percentile	0.0435	95% UPL	0.0284
		95% Chebyshev UPL	0.0464
95% WH Approx. Gamma UPL	0.029	Upper Threshold Limit Based upon IQR	0.0302
95% HW Approx. Gamma UPL	0.031		
95% WH Approx. Gamma UTL with 90% Coverage	0.0275		
95% HW Approx. Gamma UTL with 90% Coverage	0.0292		

sulfate

General Statistics

Total Number of Observations	63	Number of Distinct Observations	53
Tolerance Factor	1.595		

Raw Statistics

Minimum	42	Log-Transformed Statistics	
Maximum	2450	Minimum	3.738
Second Largest	2190	Maximum	7.804
First Quartile	203.5	Second Largest	7.692
Median	1070	First Quartile	5.316
Third Quartile	1535	Median	6.975
Mean	1044	Third Quartile	7.335
Geometric Mean	682.8	Mean	6.526
SD	726.1	SD	1.099
Coefficient of Variation	0.695		
Skewness	0.141		

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.162	Lilliefors Test Statistic	0.247
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	2203	Assuming Lognormal Distribution	
95% UPL (t)	2266	95% UTL with 90% Coverage	3944
90% Percentile (z)	1975	95% UPL (t)	4343
95% Percentile (z)	2239	90% Percentile (z)	2793
99% Percentile (z)	2733	95% Percentile (z)	4165
		99% Percentile (z)	8809

Gamma Distribution Test

k star	1.267	Data Distribution Test	
Theta Star	824.5	Data do not follow a Discernable Distribution (0.05)	
MLE of Mean	1044		
MLE of Standard Deviation	927.9		
nu star	159.6		

A-D Test Statistic

5% A-D Critical Value	3.144	Nonparametric Statistics	
K-S Test Statistic	0.773	90% Percentile	2086
5% K-S Critical Value	0.198	95% Percentile	2147
Data not Gamma Distributed at 5% Significance Level	0.115	99% Percentile	2289

Assuming Gamma Distribution

90% Percentile	2268	95% UTL with 90% Coverage	2150
95% Percentile	2881	95% Percentile Bootstrap UTL with 90% Coverage	2150
99% Percentile	4280	95% BCA Bootstrap UTL with 90% Coverage	2150
		95% UPL	2158
		95% Chebyshev UPL	4234
95% WH Approx. Gamma UPL	2925	Upper Threshold Limit Based upon IQR	3532
95% HW Approx. Gamma UPL	3131		
95% WH Approx. Gamma UTL with 90% Coverage	2770		
95% HW Approx. Gamma UTL with 90% Coverage	2944		

chloride

General Statistics

Total Number of Observations	54	Number of Distinct Observations	51
Tolerance Factor	1.624		

Raw Statistics

Minimum	1.45	Log-Transformed Statistics	
Maximum	265	Minimum	0.372
Second Largest	260	Maximum	5.58
First Quartile	10.6	Second Largest	5.561
Median	16.3	First Quartile	2.361
Third Quartile	25.28	Median	2.791
Mean	33.66	Third Quartile	3.23
Geometric Mean	18.47	Mean	2.916
SD	52.35	SD	1.02
Coefficient of Variation	1.555		
Skewness	3.469		

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.32	Lilliefors Test Statistic	0.174
Lilliefors Critical Value	0.121	Lilliefors Critical Value	0.121
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	118.7	Assuming Lognormal Distribution	
95% UPL (t)	122.1	95% UTL with 90% Coverage	96.76
90% Percentile (z)	100.8	95% UPL (t)	103.4
95% Percentile (z)	119.8	90% Percentile (z)	68.22
99% Percentile (z)	155.5	95% Percentile (z)	98.81
		99% Percentile (z)	198

Gamma Distribution Test

k star	0.924	Data Distribution Test	
Theta Star	36.41	Data do not follow a Discernable Distribution (0.05)	
MLE of Mean	33.66		
MLE of Standard Deviation	35.01		
nu star	99.84		

A-D Test Statistic

5% A-D Critical Value	3.353	Nonparametric Statistics	
K-S Test Statistic	0.781	90% Percentile	66.43
5% K-S Critical Value	0.248	95% Percentile	106.9
Data not Gamma Distributed at 5% Significance Level	0.125	99% Percentile	262.4

Assuming Gamma Distribution

90% Percentile	79.01	95% UTL with 90% Coverage	148
95% Percentile	103.7	95% Percentile Bootstrap UTL with 90% Coverage	129
99% Percentile	161.3	95% BCA Bootstrap UTL with 90% Coverage	129
		95% UPL	176
		95% Chebyshev UPL	264
95% WH Approx. Gamma UPL	98.85	Upper Threshold Limit Based upon IQR	47.29
95% HW Approx. Gamma UPL	98.04		
95% WH Approx. Gamma UTL with 90% Coverage	94.42		
95% HW Approx. Gamma UTL with 90% Coverage	93.3		

iron

General Statistics

Total Number of Observations	39	Number of Distinct Observations	35
Tolerance Factor	1.696		

Raw Statistics

Minimum	0.0047	Log-Transformed Statistics	
Maximum	14.7	Minimum	-5.36
Second Largest	11.8	Maximum	2.688
First Quartile	0.03	Second Largest	2.468
Median	0.25	First Quartile	-3.507
Third Quartile	0.444	Median	-1.386
Mean	1.576	Third Quartile	-0.823
Geometric Mean	0.193	Mean	-1.646
SD	3.536	SD	2.152
Coefficient of Variation	2.243		
Skewness	2.68		

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.501	Shapiro Wilk Test Statistic	0.942
Shapiro Wilk Critical Value	0.939	Shapiro Wilk Critical Value	0.939
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	7.573	Assuming Lognormal Distribution	
95% UPL (t)	7.613	95% UTL with 90% Coverage	7.418
90% Percentile (z)	6.108	95% UPL (t)	7.603
95% Percentile (z)	7.392	90% Percentile (z)	3.041
99% Percentile (z)	9.802	95% Percentile (z)	6.645
		99% Percentile (z)	28.8

Gamma Distribution Test

k star	0.316	Data Distribution Test	
Theta Star	4.984	Data appear Lognormal at 5% Significance Level	
MLE of Mean	1.576		
MLE of Standard Deviation	2.803		
nu star	24.67		

A-D Test Statistic

5% A-D Critical Value	2.737	Nonparametric Statistics	
K-S Test Statistic	0.852	90% Percentile	5.196
5% K-S Critical Value	0.264	95% Percentile	10.54
Data not Gamma Distributed at 5% Significance Level	0.153	99% Percentile	13.6

Assuming Gamma Distribution

90% Percentile	4.618	95% UTL with 90% Coverage	11.8
95% Percentile	7.089	95% Percentile Bootstrap UTL with 90% Coverage	11.26
99% Percentile	13.47	95% BCA Bootstrap UTL with 90% Coverage	11.8
		95% UPL	11.8
		95% Chebyshev UPL	17.18
95% WH Approx. Gamma UPL	5.749	Upper Threshold Limit Based upon IQR	1.065
95% HW Approx. Gamma UPL	5.687		
95% WH Approx. Gamma UTL with 90% Coverage	5.682		
95% HW Approx. Gamma UTL with 90% Coverage	5.611		



manganese

General Statistics

Total Number of Observations	70	Number of Distinct Observations	61
Tolerance Factor	1.577		

Raw Statistics

Minimum	0.0023	Log-Transformed Statistics Minimum	-6.075
Maximum	3.22	Maximum	1.169
Second Largest	1.05	Second Largest	0.0488
First Quartile	0.0257	First Quartile	-3.695
Median	0.149	Median	-1.91
Third Quartile	0.48	Third Quartile	-0.735
Mean	0.347	Mean	-2.149
Geometric Mean	0.117	SD	1.796
SD	0.487		
Coefficient of Variation	1.403		
Skewness	3.284		

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.239	Lilliefors Test Statistic	0.101
Lilliefors Critical Value	0.106	Lilliefors Critical Value	0.106
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	1.116	Assuming Lognormal Distribution 95% UTL with 90% Coverage	1.981
95% UPL (t)	1.166	95% UPL (t)	2.378
90% Percentile (z)	0.972	90% Percentile (z)	1.165
95% Percentile (z)	1.149	95% Percentile (z)	2.236
99% Percentile (z)	1.481	99% Percentile (z)	7.604

Gamma Distribution Test

k star	0.555	Data Distribution Test Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.625		
MLE of Mean	0.347		
MLE of Standard Deviation	0.466		
nu star	77.76		

A-D Test Statistic

5% A-D Critical Value	0.749	Nonparametric Statistics 90% Percentile	0.927
K-S Test Statistic	0.81	95% Percentile	0.99
5% K-S Critical Value	0.0925	99% Percentile	1.723
Data appear Gamma Distributed at 5% Significance Level	0.112		

Assuming Gamma Distribution

90% Percentile	0.919	95% UTL with 90% Coverage	0.978
95% Percentile	1.285	95% Percentile Bootstrap UTL with 90% Coverage	0.98
99% Percentile	2.177	95% BCA Bootstrap UTL with 90% Coverage	1
		95% UPL	1.009
		95% Chebyshev UPL	2.486
95% WH Approx. Gamma UPL	1.227	Upper Threshold Limit Based upon IQR	1.161
95% HW Approx. Gamma UPL	1.326		
95% WH Approx. Gamma UTL with 90% Coverage	1.125		
95% HW Approx. Gamma UTL with 90% Coverage	1.2		

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**B-2. Mann-Kendall Test results—Uranium for Mill Tailings  
Area Wells (1991+ data)**

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User Selected Options

Date/Time of Computation 4/17/2014 9:21

From File WorkSheet.wst

Full Precision OFF

Confidence Coefficient 0.95

Level of Significance 0.05

**U-612**

General Statistics

Number of Values 28

Minimum 1.1

Maximum 3.53

Mean 2.005

Geometric Mean 1.898

Median 1.86

Standard Deviation 0.698

SEM 0.132

Mann-Kendall Test

Test Value (S) -224

Critical Value (0.05) -1.645

Standard Deviation of S 50.53

Standardized Value of S -4.413

Approximate p-value 5.09E-06

Statistically significant evidence of a decreasing trend at the specified level of significance.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation 4/17/2014 9:21

From File WorkSheet.wst

Full Precision OFF

Confidence Coefficient 0.95

Level of Significance 0.05

**U-617****General Statistics**

Number of Values	28
Minimum	0.12
Maximum	0.33
Mean	0.207
Geometric Mean	0.2
Median	0.21
Standard Deviation	0.0547
SEM	0.0103

**Mann-Kendall Test**

Test Value (S)	-226
Critical Value (0.05)	-1.645
Standard Deviation of S	50.58
Standardized Value of S	-4.449
Approximate p-value	4.32E-06

Statistically significant evidence of a decreasing trend at the specified level of significance.

**Mann-Kendall Trend Test Analysis****User Selected Options**

Date/Time of Computation	4/17/2014 9:22
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-630

### General Statistics

Number of Values	24
Minimum	0.0344
Maximum	0.29
Mean	0.197
Geometric Mean	0.176
Median	0.208
Standard Deviation	0.0732
SEM	0.0149

### Mann-Kendall Test

Test Value (S)	175
Critical Value (0.05)	1.645
Standard Deviation of S	40.25
Standardized Value of S	4.323
Approximate p-value	7.71E-06

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:22
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-631

### General Statistics

Number of Values	24
Minimum	0.075
Maximum	0.63
Mean	0.272
Geometric Mean	0.226
Median	0.23
Standard Deviation	0.168
SEM	0.0343

### Mann-Kendall Test

Test Value (S)	-219
Critical Value (0.05)	-1.645
Standard Deviation of S	40.27
Standardized Value of S	-5.413
Approximate p-value	3.09E-08

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:23
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05



## U-633

### General Statistics

Number of Values	24
Minimum	0.48
Maximum	1.38
Mean	0.977
Geometric Mean	0.944
Median	0.931
Standard Deviation	0.251
SEM	0.0512

### Mann-Kendall Test

Test Value (S)	-105
Critical Value (0.05)	-1.645
Standard Deviation of S	40.3
Standardized Value of S	-2.58
Approximate p-value	0.00493

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:25
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.8
Level of Significance	0.2

## U-634

### General Statistics

Number of Values	24
Minimum	0.012
Maximum	0.184
Mean	0.053
Geometric Mean	0.0445
Median	0.0431
Standard Deviation	0.0362
SEM	0.00739

### Mann-Kendall Test

Test Value (S)	41
Critical Value (0.2)	0.842
Standard Deviation of S	40.28
Standardized Value of S	0.993
Approximate p-value	0.16

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:26
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-635

### General Statistics

Number of Values	24
Minimum	0.0044
Maximum	0.017
Mean	0.00863
Geometric Mean	0.00814
Median	0.00805
Standard Deviation	0.00303
SEM	6.19E-04

### Mann-Kendall Test

Test Value (S)	174
Critical Value (0.05)	1.645
Standard Deviation of S	40.02
Standardized Value of S	4.323
Approximate p-value	7.69E-06

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:27
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-622

### General Statistics

Number of Values	32
Minimum	0.009
Maximum	0.15
Mean	0.0344
Geometric Mean	0.0258
Median	0.0215
Standard Deviation	0.0324
SEM	0.00573

### Mann-Kendall Test

Test Value (S)	-176
Critical Value (0.05)	-1.645
Standard Deviation of S	61.65
Standardized Value of S	-2.839
Approximate p-value	0.00227

Statistically significant evidence of a decreasing trend at the specified level of significance.



**B-3. Mann-Kendall Test Results—Uranium for Mill Tailings  
Area Wells (2001+ data)**

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User Selected Options

Date/Time of Computation	4/17/2014 8:12
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

**U-0863**

General Statistics

Number of Values	16
Minimum	8.50E-05
Maximum	0.0028
Mean	5.23E-04
Geometric Mean	2.58E-04
Median	1.55E-04
Standard Deviation	7.65E-04
SEM	1.91E-04

Mann-Kendall Test

Test Value (S)	-55
Tabulated p-value	0.008
Standard Deviation of S	22.19
Standardized Value of S	-2.434
Approximate p-value	0.00747

Statistically significant evidence of a decreasing trend at the specified level of significance.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	4/17/2014 8:35
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-612

### General Statistics

Number of Values	16
Minimum	1.1
Maximum	2.41
Mean	1.644
Geometric Mean	1.6
Median	1.58
Standard Deviation	0.4
SEM	0.1

### Mann-Kendall Test

Test Value (S)	-66
Tabulated p-value	0.001
Standard Deviation of S	22.06
Standardized Value of S	-2.946
Approximate p-value	0.00161

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:38
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.9
Level of Significance	0.1

## U-617

### General Statistics

Number of Values	16
Minimum	0.12
Maximum	0.244
Mean	0.171
Geometric Mean	0.168
Median	0.165
Standard Deviation	0.036
SEM	0.009

### Mann-Kendall Test

Test Value (S)	-36
Tabulated p-value	0.058
Standard Deviation of S	22.12
Standardized Value of S	-1.582
Approximate p-value	0.0568

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:39
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05



## U-630

### General Statistics

Number of Values	16
Minimum	0.172
Maximum	0.29
Mean	0.238
Geometric Mean	0.235
Median	0.24
Standard Deviation	0.0351
SEM	0.00877

### Mann-Kendall Test

Test Value (S)	66
Tabulated p-value	0.001
Standard Deviation of S	22.12
Standardized Value of S	2.938
Approximate p-value	0.00165

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:40
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-631

### General Statistics

Number of Values	16
Minimum	0.075
Maximum	0.344
Mean	0.177
Geometric Mean	0.162
Median	0.164
Standard Deviation	0.0811
SEM	0.0203

### Mann-Kendall Test

Test Value (S)	-89
Tabulated p-value	0
Standard Deviation of S	22.13
Standardized Value of S	-3.977
Approximate p-value	3.49E-05

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:40
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-633

### General Statistics

Number of Values	16
Minimum	0.48
Maximum	1.38
Mean	0.91
Geometric Mean	0.874
Median	0.875
Standard Deviation	0.265
SEM	0.0662

### Mann-Kendall Test

Test Value (S)	-40
Tabulated p-value	0.039
Standard Deviation of S	22.21
Standardized Value of S	-1.756
Approximate p-value	0.0396

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:41
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.8
Level of Significance	0.2

## U-634

### General Statistics

Number of Values	16
Minimum	0.017
Maximum	0.184
Mean	0.0622
Geometric Mean	0.0523
Median	0.056
Standard Deviation	0.0409
SEM	0.0102

### Mann-Kendall Test

Test Value (S)	-25
Tabulated p-value	0.153
Standard Deviation of S	22.14
Standardized Value of S	-1.084
Approximate p-value	0.139

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:28
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## U-635

### General Statistics

Number of Values	24
Minimum	0.0044
Maximum	0.017
Mean	0.00863
Geometric Mean	0.00814
Median	0.00805
Standard Deviation	0.00303
SEM	6.19E-04

### Mann-Kendall Test

Test Value (S)	174
Critical Value (0.05)	1.645
Standard Deviation of S	40.02
Standardized Value of S	4.323
Approximate p-value	7.69E-06

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 8:43
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.8
Level of Significance	0.2



## average U

### General Statistics

Number of Values	16
Minimum	0.344
Maximum	0.621
Mean	0.459
Geometric Mean	0.451
Median	0.438
Standard Deviation	0.0913
SEM	0.0228

### Mann-Kendall Test

Test Value (S)	-73
Tabulated p-value	0
Standard Deviation of S	22.19
Standardized Value of S	-3.245
Approximate p-value	5.87E-04

Statistically significant evidence of a decreasing trend at the specified level of significance.

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**B-4. Mann-Kendall Test Results—Sulfate for Mill Tailings  
Area Wells (2001+ data)**

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User Selected Options

Date/Time of Computation	4/17/2014 9:31
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

**SO4-622**

General Statistics

Number of Values	32
Minimum	42
Maximum	1100
Mean	287.6
Geometric Mean	225.8
Median	200.5
Standard Deviation	249.2
SEM	44.05

Mann-Kendall Test

Test Value (S)	-117
Critical Value (0.05)	-1.645
Standard Deviation of S	61.64
Standardized Value of S	-1.882
Approximate p-value	0.0299

Statistically significant evidence of a decreasing trend at the specified level of significance.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	4/17/2014 9:31
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05



**SO4-612****General Statistics**

Number of Values	24
Minimum	1500
Maximum	3080
Mean	2152
Geometric Mean	2119
Median	2195
Standard Deviation	385.1
SEM	78.61

**Mann-Kendall Test**

Test Value (S)	-154
Critical Value (0.05)	-1.645
Standard Deviation of S	40.23
Standardized Value of S	-3.803
Approximate p-value	7.15E-05

Statistically significant evidence of a decreasing trend at the specified level of significance.

**Mann-Kendall Trend Test Analysis****User Selected Options**

Date/Time of Computation	4/17/2014 9:32
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## SO4-617

### General Statistics

Number of Values	24
Minimum	1640
Maximum	2230
Mean	1982
Geometric Mean	1975
Median	2000
Standard Deviation	167.5
SEM	34.2

### Mann-Kendall Test

Test Value (S)	-82
Critical Value (0.05)	-1.645
Standard Deviation of S	40.18
Standardized Value of S	-2.016
Approximate p-value	0.0219

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:33
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

## SO4-630

### General Statistics

Number of Values	24
Minimum	1600
Maximum	2550
Mean	1996
Geometric Mean	1979
Median	1915
Standard Deviation	267.6
SEM	54.63

### Mann-Kendall Test

Test Value (S)	-195
Critical Value (0.05)	-1.645
Standard Deviation of S	40.09
Standardized Value of S	-4.839
Approximate p-value	6.51E-07

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:34
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

**SO4-631****General Statistics**

Number of Values	24
Minimum	150
Maximum	1600
Mean	604.2
Geometric Mean	464.3
Median	519.5
Standard Deviation	427.8
SEM	87.32

**Mann-Kendall Test**

Test Value (S)	-172
Critical Value (0.05)	-1.645
Standard Deviation of S	40.29
Standardized Value of S	-4.244
Approximate p-value	1.10E-05

Statistically significant evidence of a decreasing trend at the specified level of significance.

**Mann-Kendall Trend Test Analysis****User Selected Options**

Date/Time of Computation	4/17/2014 9:34
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.7
Level of Significance	0.3

## SO4-633

### General Statistics

Number of Values	24
Minimum	2160
Maximum	3900
Mean	3116
Geometric Mean	3078
Median	3170
Standard Deviation	483.7
SEM	98.74

### Mann-Kendall Test

Test Value (S)	27
Critical Value (0.3)	0.524
Standard Deviation of S	40.27
Standardized Value of S	0.646
Approximate p-value	0.259

Statistically significant evidence of an increasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:35
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05



**SO4-634****General Statistics**

Number of Values	24
Minimum	585
Maximum	2500
Mean	2146
Geometric Mean	2090
Median	2200
Standard Deviation	365.4
SEM	74.6

**Mann-Kendall Test**

Test Value (S)	70
Critical Value (0.05)	1.645
Standard Deviation of S	40.07
Standardized Value of S	1.722
Approximate p-value	0.0426

Statistically significant evidence of an increasing trend at the specified level of significance.

**Mann-Kendall Trend Test Analysis****User Selected Options**

Date/Time of Computation	4/17/2014 9:36
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.85
Level of Significance	0.15

**SO4-635****General Statistics**

Number of Values	24
Minimum	810
Maximum	1600
Mean	1123
Geometric Mean	1104
Median	1100
Standard Deviation	216.3
SEM	44.15

**Mann-Kendall Test**

Test Value (S)	45
Critical Value (0.15)	1.036
Standard Deviation of S	40.21
Standardized Value of S	1.094
Approximate p-value	0.137

Statistically significant evidence of an increasing trend at the specified level of significance.

**Mann-Kendall Trend Test Analysis****User Selected Options**

Date/Time of Computation	4/17/2014 14:10
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	0.9
Level of Significance	0.1

## avg sulfate

### General Statistics

Number of Values	17
Minimum	1522
Maximum	1940
Mean	1664
Geometric Mean	1660
Median	1644
Standard Deviation	113.5
SEM	27.54

### Mann-Kendall Test

Test Value (S)	-34
Tabulated p-value	0.088
Standard Deviation of S	24.28
Standardized Value of S	-1.359
Approximate p-value	8.70E-02

Statistically significant evidence of a decreasing trend at the specified level of significance.

### Mann-Kendall Trend Test Analysis

#### User Selected Options

Date/Time of Computation	4/17/2014 9:38
From File	WorkSheet_a.wst
Full Precision	OFF
Confidence Coefficient	0.75
Level of Significance	0.25

## SO4-863

### General Statistics

Number of Values	17
Minimum	544
Maximum	690
Mean	643.6
Geometric Mean	642.4
Median	650
Standard Deviation	41.13
SEM	9.975

### Mann-Kendall Test

Test Value (S)	19
Tabulated p-value	0.245
Standard Deviation of S	24.21
Standardized Value of S	0.743
Approximate p-value	0.229

Statistically significant evidence of an increasing trend at the specified level of significance.

**B-5. Post-Remediation Uranium Baseline Statistics—Mill  
Tailings Area Wells**



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Nonparametric Background Statistics for Full Data Sets--Data from 1994 to 2004--Uranium in onsite mill tailings area wells

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Coverage	90%
Number of Bootstrap Operations	2000

U-612

Some Non-Parametric Statistics

Number of Valid Observations	16
Number of Distinct Observations	14
Minimum	1.34
Maximum	3.22
Second Largest	3.1
Mean	2.144
Geometric Mean	2.082
First Quartile	1.79
Median	1.98
Third Quartile	2.305
SD	0.552
Variance	0.304
Coefficient of Variation	0.257
Skewness	0.889
Mean of Log-Transformed data	0.733
SD of Log-Transformed data	0.246

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics

90% Percentile	3.075
95% Percentile	3.13
99% Percentile	3.202

95% UTL with 90% Coverage

Order Statistic	16
Achieved CC	1
UTL	3.22

95% BCA Bootstrap UTL with 90% Coverage

95% Percentile Bootstrap UTL with 90% Coverage 3.22

95% UPL

95% Chebyshev UPL 4.622

Upper Limit Based upon IQR 3.078

U-617

Some Non-Parametric Statistics	
Number of Valid Observations	16
Number of Distinct Observations	16
Minimum	0.12
Maximum	0.33
Second Largest	0.298
Mean	0.225
Geometric Mean	0.218
First Quartile	0.211
Median	0.231
Third Quartile	0.244
SD	0.056
Variance	0.00314
Coefficient of Variation	0.249
Skewness	-0.264
Mean of Log-Transformed data	-1.524
SD of Log-Transformed data	0.276

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics	
90% Percentile	0.291
95% Percentile	0.306
99% Percentile	0.325
95% UTL with 90% Coverage	
Order Statistic	16
Achieved CC	1
UTL	0.33
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	0.33
95% UPL	
95% Chebyshev UPL	0.477
Upper Limit Based upon IQR	0.295

U-630

Some Non-Parametric Statistics	
Number of Valid Observations	15
Number of Distinct Observations	14
Minimum	0.0344
Maximum	0.26
Second Largest	0.214
Mean	0.159
Geometric Mean	0.14
First Quartile	0.12
Median	0.174
Third Quartile	0.203
SD	0.0666
Variance	0.00444
Coefficient of Variation	0.419
Skewness	-0.694
Mean of Log-Transformed data	-1.968
SD of Log-Transformed data	0.601

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics	
90% Percentile	0.213
95% Percentile	0.228
99% Percentile	0.254
95% UTL with 90% Coverage	
Order Statistic	15
Achieved CC	1
UTL	0.26
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	0.26
95% UPL	
95% Chebyshev UPL	0.459
Upper Limit Based upon IQR	0.328

U-631

Some Non-Parametric Statistics	
Number of Valid Observations	15
Number of Distinct Observations	15
Minimum	0.168
Maximum	0.63
Second Largest	0.61
Mean	0.357
Geometric Mean	0.325
First Quartile	0.23
Median	0.344
Third Quartile	0.443
SD	0.156
Variance	0.0244
Coefficient of Variation	0.438
Skewness	0.479
Mean of Log-Transformed data	-1.124
SD of Log-Transformed data	0.454

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics	
90% Percentile	0.589
95% Percentile	0.616
99% Percentile	0.627
95% UTL with 90% Coverage	
Order Statistic	15
Achieved CC	1
UTL	0.63
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	0.63
95% UPL	
95% Chebyshev UPL	1.06
Upper Limit Based upon IQR	0.762

U-633

Some Non-Parametric Statistics	
Number of Valid Observations	15
Number of Distinct Observations	14
Minimum	0.65
Maximum	1.38
Second Largest	1.32
Mean	1.076
Geometric Mean	1.054
First Quartile	0.919
Median	1.08
Third Quartile	1.29
SD	0.219
Variance	0.0479
Coefficient of Variation	0.203
Skewness	-0.211
Mean of Log-Transformed data	0.0528
SD of Log-Transformed data	0.215

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics	
90% Percentile	1.32
95% Percentile	1.338
99% Percentile	1.372
95% UTL with 90% Coverage	
Order Statistic	15
Achieved CC	1
UTL	1.38
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	1.38
95% UPL	
95% Chebyshev UPL	2.062
Upper Limit Based upon IQR	1.847

U-634

Some Non-Parametric Statistics	
Number of Valid Observations	15
Number of Distinct Observations	15
Minimum	0.012
Maximum	0.184
Second Largest	0.0608
Mean	0.0506
Geometric Mean	0.0426
First Quartile	0.0342
Median	0.0388
Third Quartile	0.0568
SD	0.0392
Variance	0.00154
Coefficient of Variation	0.776
Skewness	3.126
Mean of Log-Transformed data	-3.156
SD of Log-Transformed data	0.569

Data do not follow a Discernable Distribution (0.05)

Non-Parametric Background Statistics	
90% Percentile	0.0604
95% Percentile	0.0978
99% Percentile	0.167
95% UTL with 90% Coverage	
Order Statistic	15
Achieved CC	1
UTL	0.184
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	0.184
95% UPL	
95% Chebyshev UPL	0.227
Upper Limit Based upon IQR	0.0906

U-635

Some Non-Parametric Statistics	
Number of Valid Observations	15
Number of Distinct Observations	13
Minimum	0.0044
Maximum	0.011
Second Largest	0.01
Mean	0.00705
Geometric Mean	0.0068
First Quartile	0.0057
Median	0.0065
Third Quartile	0.00805
SD	0.00202
Variance	4.08E-06
Coefficient of Variation	0.287
Skewness	0.638
Mean of Log-Transformed data	-4.991
SD of Log-Transformed data	0.281

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics	
90% Percentile	0.00996
95% Percentile	0.0103
99% Percentile	0.0109
95% UTL with 90% Coverage	
Order Statistic	15
Achieved CC	1
UTL	0.011
95% BCA Bootstrap UTL with 90% Coverage	
95% Percentile Bootstrap UTL with 90% Coverage	0.011
95% UPL	
95% Chebyshev UPL	0.0162
Upper Limit Based upon IQR	0.0116



U-avg

Some Non-Parametric Statistics		
Number of Valid Observations	15	
Number of Distinct Observations	15	
Minimum	0.421	
Maximum	0.729	
Second Largest	0.725	
Mean	0.563	
Geometric Mean	0.557	
First Quartile	0.521	
Median	0.554	
Third Quartile	0.605	
SD	0.0892	
Variance	0.00796	
Coefficient of Variation	0.158	
Skewness	0.348	
Mean of Log-Transformed data	-0.586	
SD of Log-Transformed data	0.158	

Data appear Normal at 5% Significance Level

Non-Parametric Background Statistics		
90% Percentile	0.683	
95% Percentile	0.726	
99% Percentile	0.728	
95% UTL with 90% Coverage		
Order Statistic	15	
Achieved CC	1	
UTL	0.729	
95% BCA Bootstrap UTL with 90% Coverage		
95% Percentile Bootstrap UTL with 90% Coverage	0.729	
95% UPL		
95% Chebyshev UPL	0.965	
Upper Limit Based upon IQR	0.731	

Statistics of avg. on-site wells without background

Background Statistics		
Normal Distribution Test		Lognormal Distribution Test
Shapiro Wilk Test Statistic	0.943	Shapiro Wilk Test Statistic 0.952
Shapiro Wilk Critical Value	0.881	Shapiro Wilk Critical Value 0.881
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level
Assuming Normal Distribution		
95% UTL with 90% Coverage	0.871	Assuming Lognormal Distribution 95% UTL with 90% Coverage 0.9
95% UPL (t)	0.845	95% UPL (t) 0.865
90% Percentile (z)	0.789	90% Percentile (z) 0.794
95% Percentile (z)	0.827	95% Percentile (z) 0.842
99% Percentile (z)	0.898	99% Percentile (z) 0.938
Gamma Distribution Test		
k star		Data Distribution Test
Theta Star	0.0191	Data appear Normal at 5% Significance Level
MLE of Mean	0.656	
MLE of Standard Deviation	0.112	
nu star	1029	
A-D Test Statistic		
5% A-D Critical Value	0.347	Nonparametric Statistics
K-S Test Statistic	0.735	90% Percentile 0.796
5% K-S Critical Value	0.166	95% Percentile 0.845
Data appear Gamma Distributed at 5% Significance Level	0.221	99% Percentile 0.847
Assuming Gamma Distribution		
95% UTL with 90% Coverage	0.803	95% UTL with 90% Coverage 0.848
90% Percentile	0.85	95% Percentile Bootstrap UTL with 90% Coverage 0.848
95% Percentile	0.944	95% BCA Bootstrap UTL with 90% Coverage 0.848
99% Percentile		95% UPL 0.848
		95% Chebyshev UPL 1.124
95% WH Approx. Gamma UPL	0.857	Upper Threshold Limit Based upon IQR 0.854
95% HW Approx. Gamma UPL	0.859	
95% WH Approx. Gamma UTL with 90% Coverage	0.888	
95% HW Approx. Gamma UTL with 90% Coverage	0.891	

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**B-6.      Post-Remediation Uranium Baseline Statistics—  
             Raffinate Ponds Area Wells**

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General Background Statistics for Full Data Sets--Uranium data from post-1994 through 2009--Raffinate area onsite wells		
User Selected Options		
From File	WorkSheet_a.wst	
Full Precision	OFF	
Confidence Coefficient	95%	
Coverage	90%	
Different or Future K Values	1	
Number of Bootstrap Operations	2000	

U-594

General Statistics

Total Number of Observations	10	Number of Distinct Observations	10
Tolerance Factor	2.355		

Raw Statistics

Minimum	0.0305
Maximum	0.192
Second Largest	0.084
First Quartile	0.0383
Median	0.053
Third Quartile	0.067
Mean	0.0656
Geometric Mean	0.0557
SD	0.0478
Coefficient of Variation	0.729
Skewness	2.408

Log-Transformed Statistics

Minimum	-3.49
Maximum	-1.65
Second Largest	-2.477
First Quartile	-3.265
Median	-2.956
Third Quartile	-2.704
Mean	-2.887
SD	0.555

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.7	Shapiro Wilk Test Statistic	0.894
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	0.178	95% UTL with 90% Coverage	0.206
95% UPL (t)	0.158	95% UPL (t)	0.162
90% Percentile (z)	0.127	90% Percentile (z)	0.113
95% Percentile (z)	0.144	95% Percentile (z)	0.139
99% Percentile (z)	0.177	99% Percentile (z)	0.202

Gamma Distribution Test

k star	2.327	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.0282		
MLE of Mean	0.0656		
MLE of Standard Deviation	0.043		
nu star	46.54		

A-D Test Statistic

5% A-D Critical Value	0.732	90% Percentile	0.0948
K-S Test Statistic	0.205	95% Percentile	0.143
5% K-S Critical Value	0.268	99% Percentile	0.182
Data appear Gamma Distributed at 5% Significance Level			

Assuming Gamma Distribution

90% Percentile	0.123	95% UTL with 90% Coverage	0.192
95% Percentile	0.148	95% Percentile Bootstrap UTL with 90% Coverage	0.192
99% Percentile	0.204	95% BCA Bootstrap UTL with 90% Coverage	0.192
		95% UPL	0.192
		95% Chebyshev UPL	0.284
95% WH Approx. Gamma UPL	0.157	Upper Threshold Limit Based upon IQR	0.11
95% HW Approx. Gamma UPL	0.158		
95% WH Approx. Gamma UTL with 90% Coverage	0.189		
95% HW Approx. Gamma UTL with 90% Coverage	0.192		



U-598

General Statistics			
Total Number of Observations	17	Number of Distinct Observations	16
Tolerance Factor	2.002		
Raw Statistics			
Minimum	0.0497	Log-Transformed Statistics Minimum	-3.002
Maximum	0.278	Maximum	-1.28
Second Largest	0.23	Second Largest	-1.47
First Quartile	0.0718	First Quartile	-2.634
Median	0.0983	Median	-2.32
Third Quartile	0.13	Third Quartile	-2.04
Mean	0.121	Mean	-2.248
Geometric Mean	0.106	SD	0.529
SD	0.0688		
Coefficient of Variation	0.568		
Skewness	1.13		
Background Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.858	Shapiro Wilk Test Statistic	0.948
Shapiro Wilk Critical Value	0.892	Shapiro Wilk Critical Value	0.892
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution			
95% UTL with 90% Coverage	0.259	95% UTL with 90% Coverage	0.305
95% UPL (t)	0.245	95% UPL (t)	0.273
90% Percentile (z)	0.209	90% Percentile (z)	0.208
95% Percentile (z)	0.234	95% Percentile (z)	0.252
99% Percentile (z)	0.281	99% Percentile (z)	0.362
Gamma Distribution Test			
k star	3.18	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.0381		
MLE of Mean	0.121		
MLE of Standard Deviation	0.0679		
nu star	108.1		
A-D Test Statistic			
5% A-D Critical Value	0.506	Nonparametric Statistics	
K-S Test Statistic	0.743	90% Percentile	0.224
5% K-S Critical Value	0.152	95% Percentile	0.24
	0.21	99% Percentile	0.27
Data appear Gamma Distributed at 5% Significance Level			
Assuming Gamma Distribution			
		95% UTL with 90% Coverage	0.278
90% Percentile	0.212	95% Percentile Bootstrap UTL with 90% Coverage	0.278
95% Percentile	0.25	95% BCA Bootstrap UTL with 90% Coverage	0.278
99% Percentile	0.332	95% UPL	0.278
		95% Chebyshev UPL	0.43
95% WH Approx. Gamma UPL	0.258	Upper Threshold Limit Based upon IQR	0.217
95% HW Approx. Gamma UPL	0.261		
95% WH Approx. Gamma UTL with 90% Coverage	0.28		
95% HW Approx. Gamma UTL with 90% Coverage	0.285		

U-879

General Statistics

Total Number of Observations	11	Number of Distinct Observations	11
Tolerance Factor	2.275		

Raw Statistics

Minimum	0.041	Log-Transformed Statistics	
Maximum	0.4	Minimum	-3.194
Second Largest	0.36	Maximum	-0.916
First Quartile	0.101	Second Largest	-1.022
Median	0.223	First Quartile	-2.291
Third Quartile	0.271	Median	-1.501
Mean	0.202	Third Quartile	-1.308
Geometric Mean	0.166	Mean	-1.796
SD	0.118	SD	0.711
Coefficient of Variation	0.583		
Skewness	0.309		

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.949	Shapiro Wilk Test Statistic	0.937
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	0.47	Assuming Lognormal Distribution	
95% UPL (t)	0.425	95% UTL with 90% Coverage	0.836
90% Percentile (z)	0.353	95% UPL (t)	0.637
95% Percentile (z)	0.396	90% Percentile (z)	0.413
99% Percentile (z)	0.476	95% Percentile (z)	0.534
		99% Percentile (z)	0.867

Gamma Distribution Test

k star	2.024	Data Distribution Test	
Theta Star	0.0998	Data appear Normal at 5% Significance Level	
MLE of Mean	0.202		
MLE of Standard Deviation	0.142		
nu star	44.52		

A-D Test Statistic

5% A-D Critical Value	0.276	Nonparametric Statistics	
K-S Test Statistic	0.735	90% Percentile	0.36
5% K-S Critical Value	0.189	95% Percentile	0.38
Data appear Gamma Distributed at 5% Significance Level	0.257	99% Percentile	0.396

Assuming Gamma Distribution

90% Percentile	0.392	95% UTL with 90% Coverage	0.4
95% Percentile	0.477	95% Percentile Bootstrap UTL with 90% Coverage	0.4
99% Percentile	0.667	95% BCA Bootstrap UTL with 90% Coverage	0.4
		95% UPL	0.4
		95% Chebyshev UPL	0.738
95% WH Approx. Gamma UPL	0.511	Upper Threshold Limit Based upon IQR	0.524
95% HW Approx. Gamma UPL	0.533		
95% WH Approx. Gamma UTL with 90% Coverage	0.608		
95% HW Approx. Gamma UTL with 90% Coverage	0.645		

U-607

General Statistics

Total Number of Observations	18	Number of Distinct Observations	16
Tolerance Factor	1.974		

Raw Statistics

Log-Transformed Statistics

Minimum	0.0026	Minimum	-5.952
Maximum	0.0063	Maximum	-5.067
Second Largest	0.0052	Second Largest	-5.259
First Quartile	0.00318	First Quartile	-5.753
Median	0.00385	Median	-5.56
Third Quartile	0.00473	Third Quartile	-5.355
Mean	0.00404	Mean	-5.539
Geometric Mean	0.00393	SD	0.244
SD	9.95E-04		
Coefficient of Variation	0.246		
Skewness	0.516		

Background Statistics

Lognormal Distribution Test

Normal Distribution Test			
Shapiro Wilk Test Statistic	0.955	Shapiro Wilk Test Statistic	0.969
Shapiro Wilk Critical Value	0.897	Shapiro Wilk Critical Value	0.897
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

Assuming Lognormal Distribution

95% UTL with 90% Coverage	0.00601	95% UTL with 90% Coverage	0.00637
95% UPL (t)	0.00582	95% UPL (t)	0.00609
90% Percentile (z)	0.00532	90% Percentile (z)	0.00538
95% Percentile (z)	0.00568	95% Percentile (z)	0.00588
99% Percentile (z)	0.00636	99% Percentile (z)	0.00694

Gamma Distribution Test

Data Distribution Test

k star	14.94	Data appear Normal at 5% Significance Level	
Theta Star	2.71E-04		
MLE of Mean	0.00404		
MLE of Standard Deviation	0.00105		
nu star	537.7		

A-D Test Statistic

0.278 Nonparametric Statistics

5% A-D Critical Value	0.739	90% Percentile	0.00513
K-S Test Statistic	0.118	95% Percentile	0.00537
5% K-S Critical Value	0.203	99% Percentile	0.00611
Data appear Gamma Distributed at 5% Significance Level			

Assuming Gamma Distribution

95% UTL with 90% Coverage

90% Percentile	0.00543	95% Percentile Bootstrap UTL with 90% Coverage	0.0063
95% Percentile	0.00591	95% BCA Bootstrap UTL with 90% Coverage	0.0063
99% Percentile	0.00687	95% UPL	0.0063
		95% Chebyshev UPL	0.0085
95% WH Approx. Gamma UPL	0.00597	Upper Threshold Limit Based upon IQR	0.00705
95% HW Approx. Gamma UPL	0.006		
95% WH Approx. Gamma UTL with 90% Coverage	0.00621		
95% HW Approx. Gamma UTL with 90% Coverage	0.00625		

U-884

General Statistics

Total Number of Observations	13	Number of Distinct Observations	12
Tolerance Factor	2.155		

Raw Statistics

Minimum	0.04	Minimum	-3.219
Maximum	0.18	Maximum	-1.715
Second Largest	0.15	Second Largest	-1.897
First Quartile	0.078	First Quartile	-2.551
Median	0.1	Median	-2.303
Third Quartile	0.107	Third Quartile	-2.235
Mean	0.0994	Mean	-2.382
Geometric Mean	0.0924	SD	0.41
SD	0.0383		
Coefficient of Variation	0.385		
Skewness	0.567		

Log-Transformed Statistics

Background Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.962	Shapiro Wilk Test Statistic	0.965
Shapiro Wilk Critical Value	0.866	Shapiro Wilk Critical Value	0.866
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

95% UTL with 90% Coverage	0.182	95% UTL with 90% Coverage	0.224
95% UPL (t)	0.17	95% UPL (t)	0.197
90% Percentile (z)	0.148	90% Percentile (z)	0.156
95% Percentile (z)	0.162	95% Percentile (z)	0.181
99% Percentile (z)	0.188	99% Percentile (z)	0.24

Assuming Lognormal Distribution

Gamma Distribution Test

k star	5.447	Data appear Normal at 5% Significance Level	
Theta Star	0.0182		
MLE of Mean	0.0994		
MLE of Standard Deviation	0.0426		
nu star	141.6		

Data Distribution Test

A-D Test Statistic	0.23	Nonparametric Statistics	
5% A-D Critical Value	0.735	90% Percentile	0.146
K-S Test Statistic	0.142	95% Percentile	0.162
5% K-S Critical Value	0.237	99% Percentile	0.176
Data appear Gamma Distributed at 5% Significance Level			

Assuming Gamma Distribution

90% Percentile	0.156	95% UTL with 90% Coverage	0.18
95% Percentile	0.178	95% Percentile Bootstrap UTL with 90% Coverage	0.18
99% Percentile	0.224	95% BCA Bootstrap UTL with 90% Coverage	0.174
		95% UPL	0.18
		95% Chebyshev UPL	0.273
95% WH Approx. Gamma UPL	0.183	Upper Threshold Limit Based upon IQR	0.151
95% HW Approx. Gamma UPL	0.186		
95% WH Approx. Gamma UTL with 90% Coverage	0.202		
95% HW Approx. Gamma UTL with 90% Coverage	0.206		



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## **Appendix C**

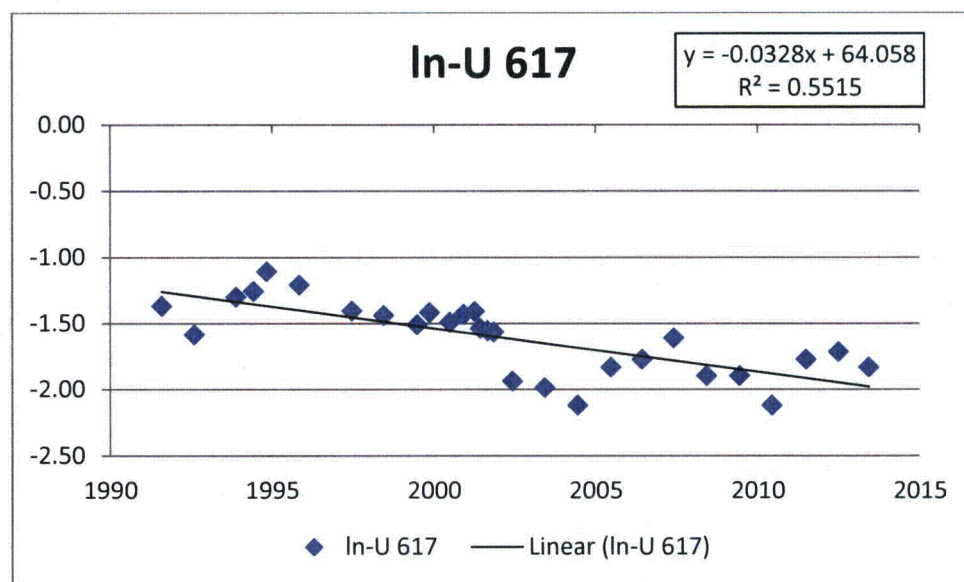
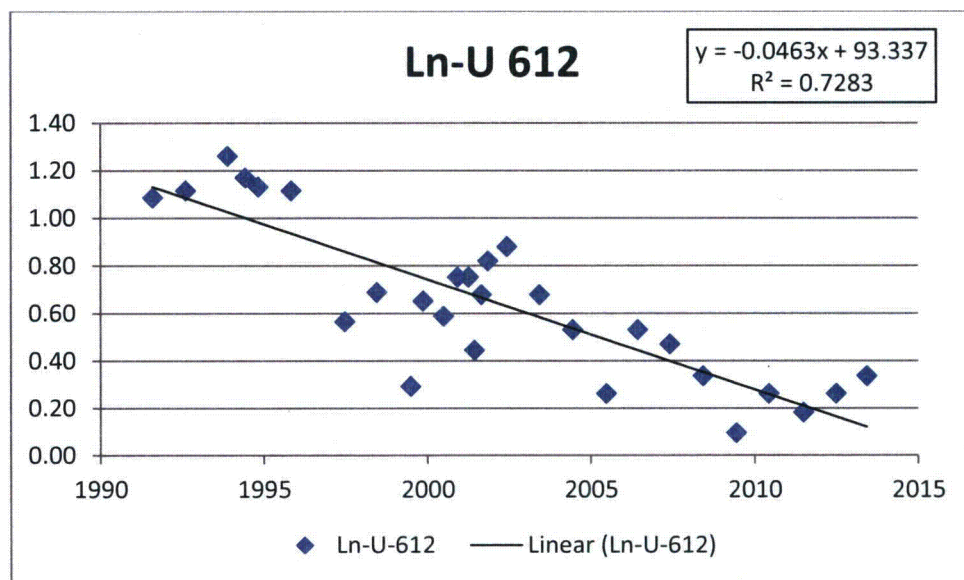
### **Regression Output from Excel**

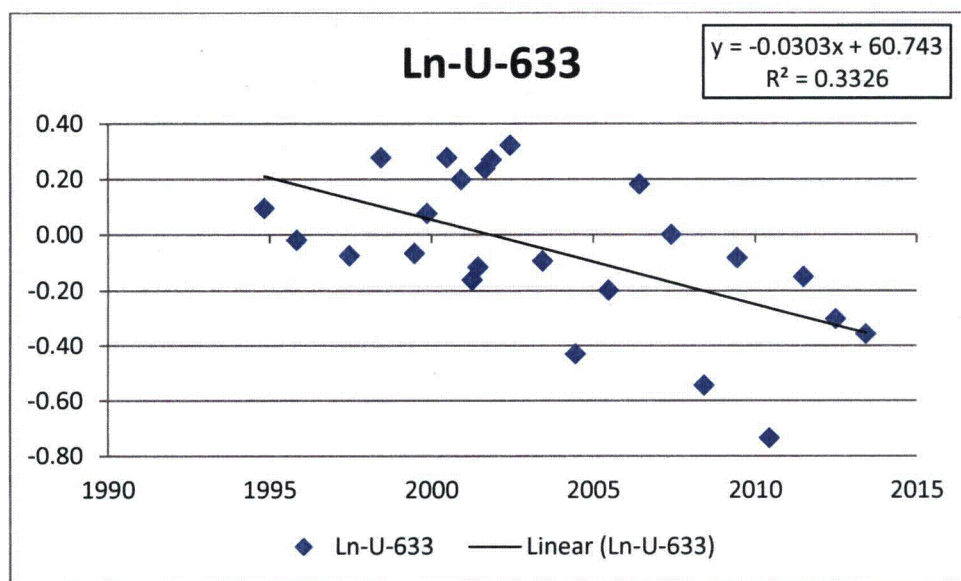
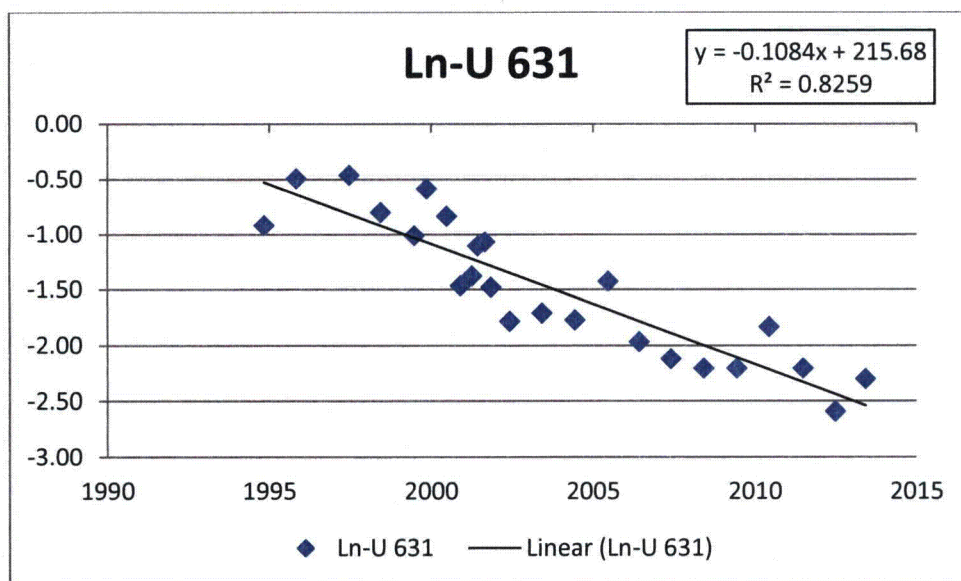


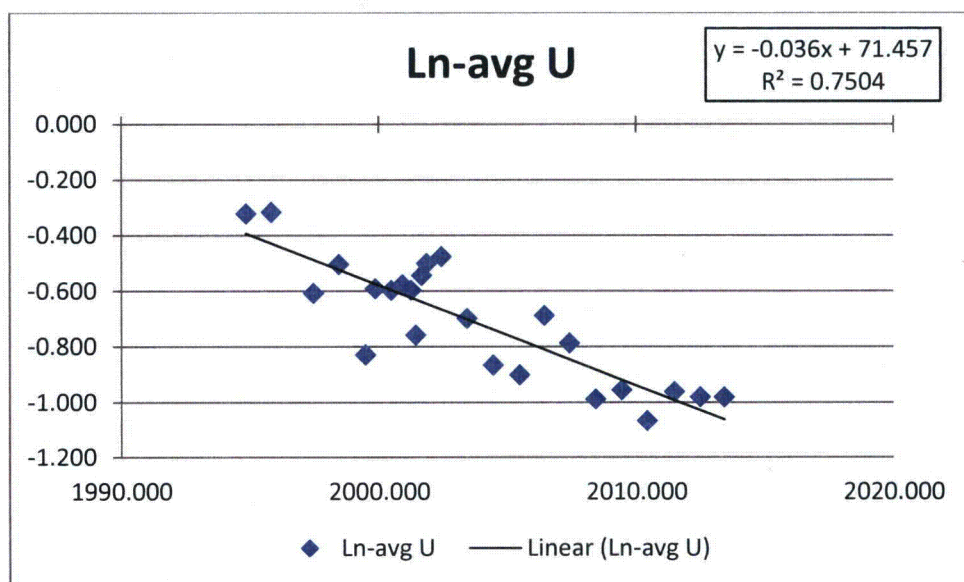
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## Regression backup for appendix

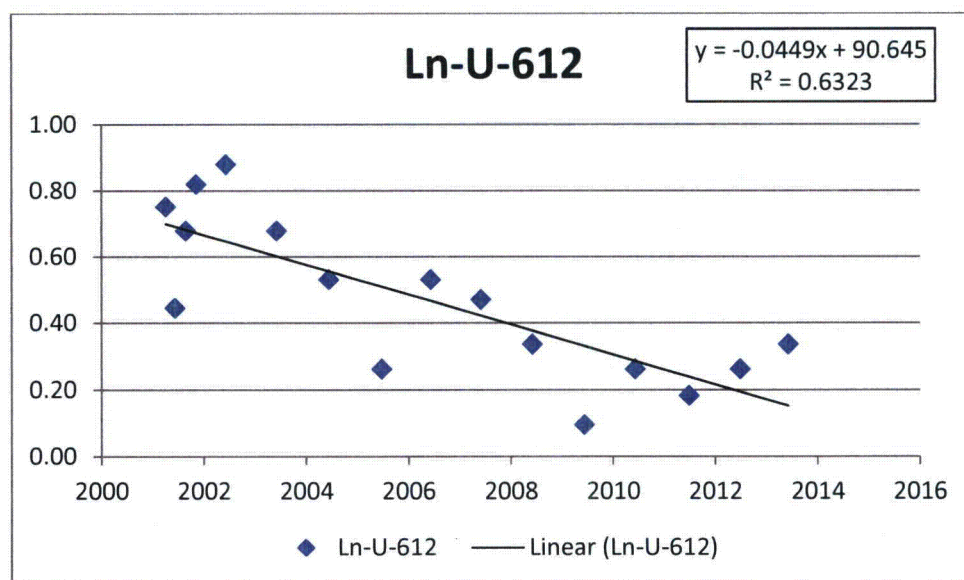
Plots for wells in Mill Tailings Area 1991+

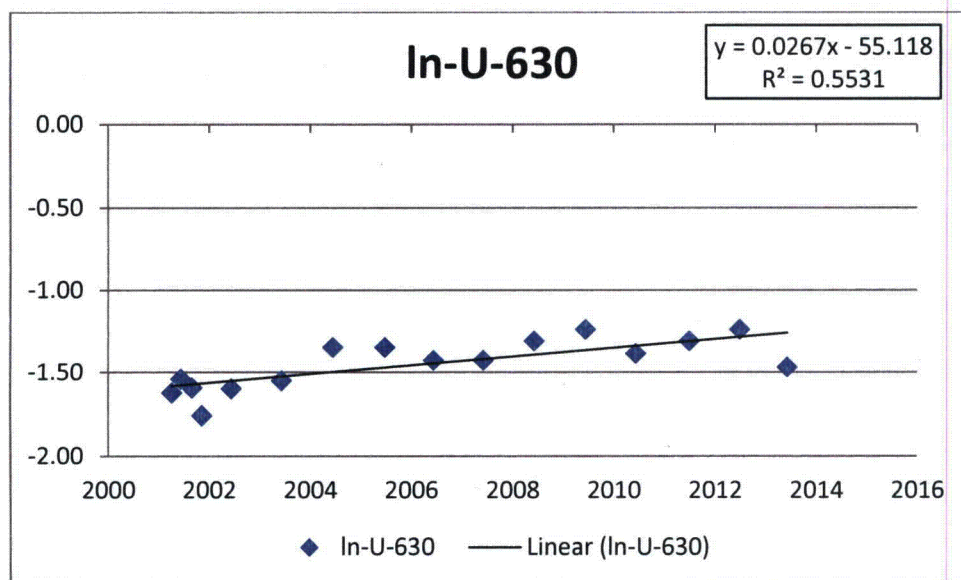
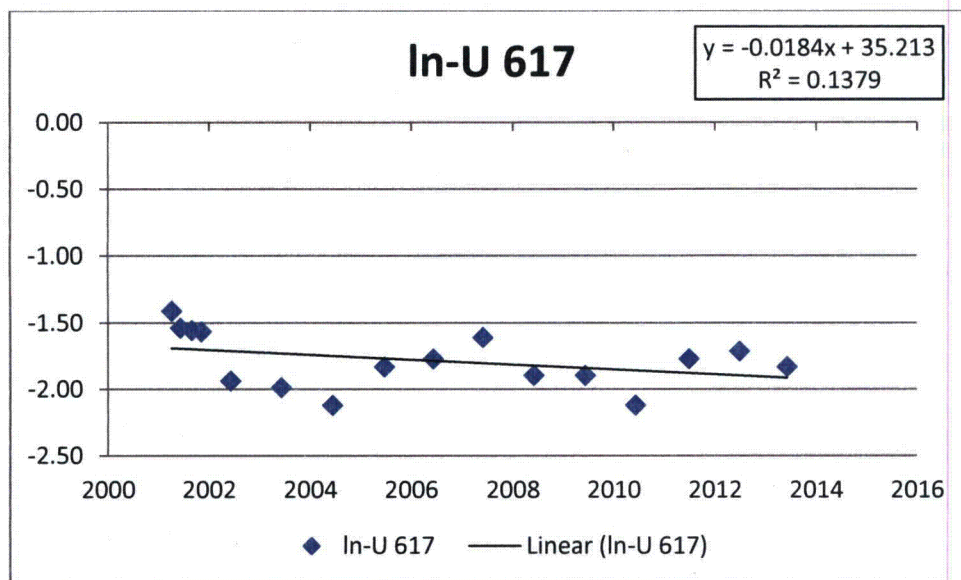


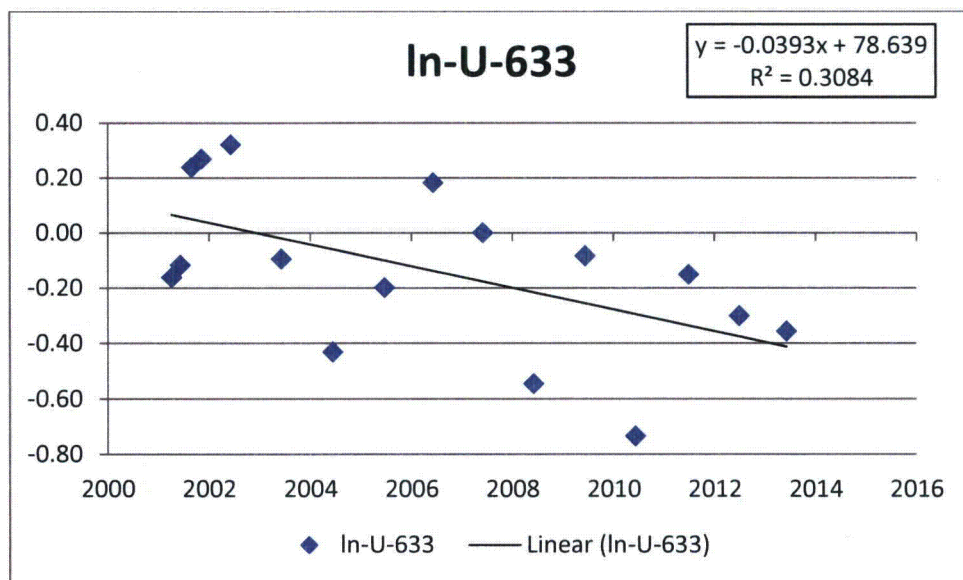
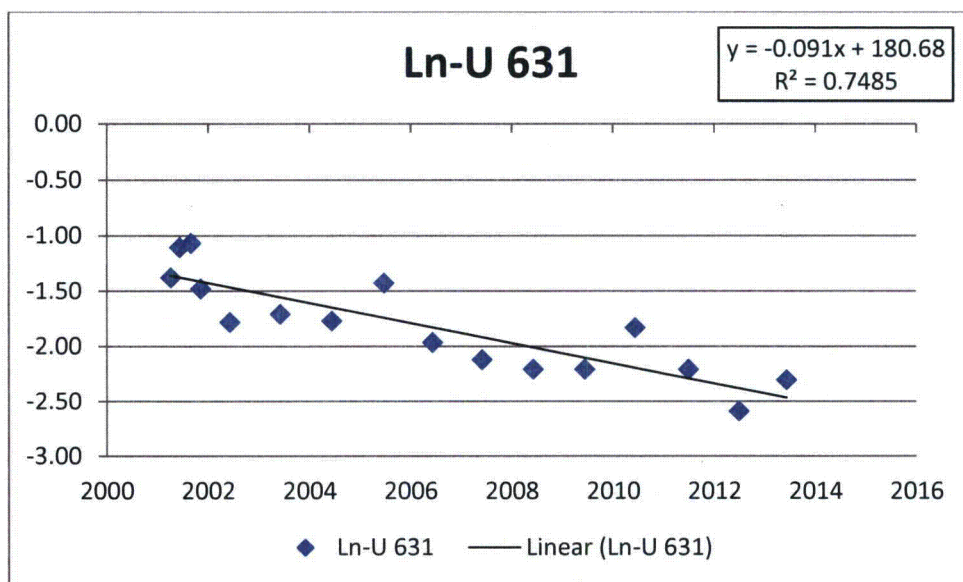




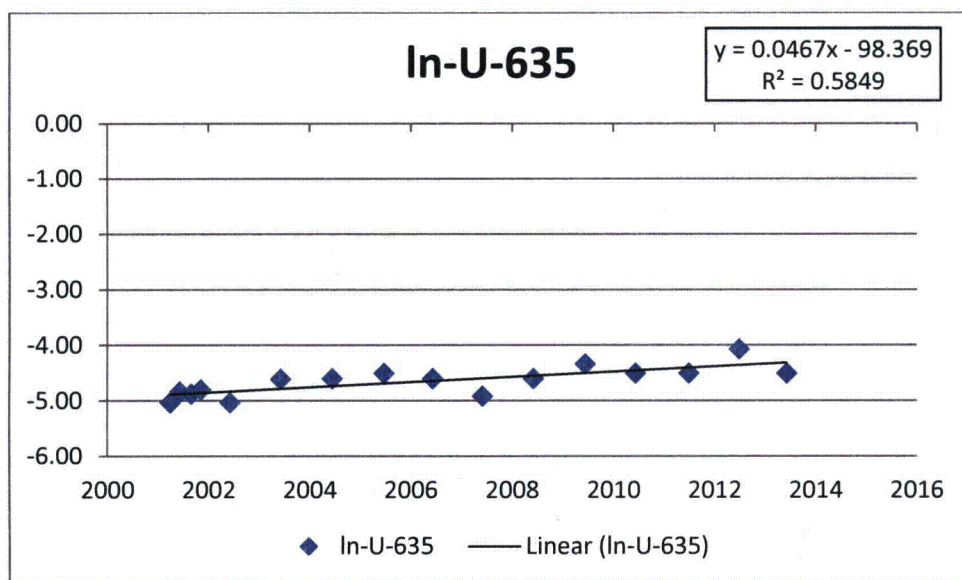
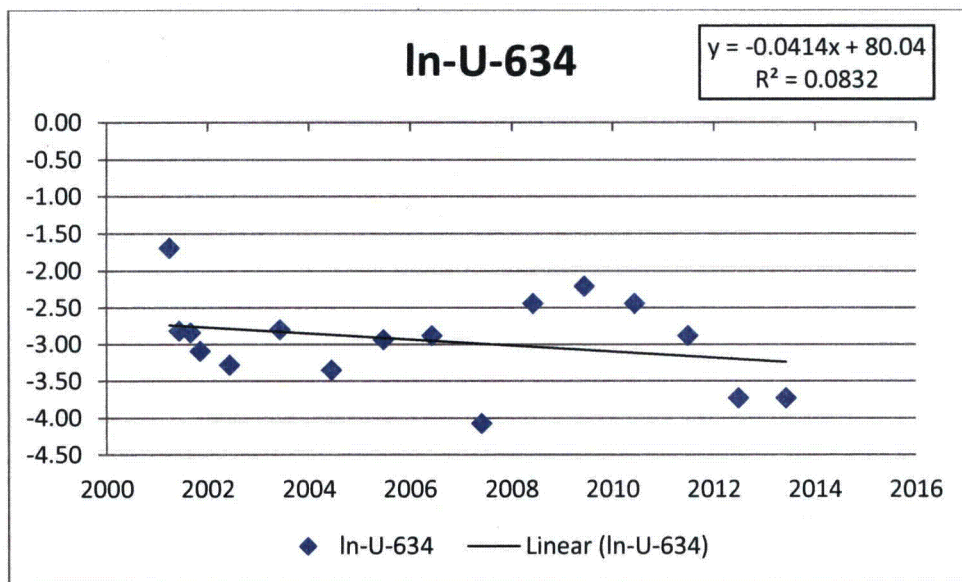
Plots for wells in Mill Tailings Area 2001+

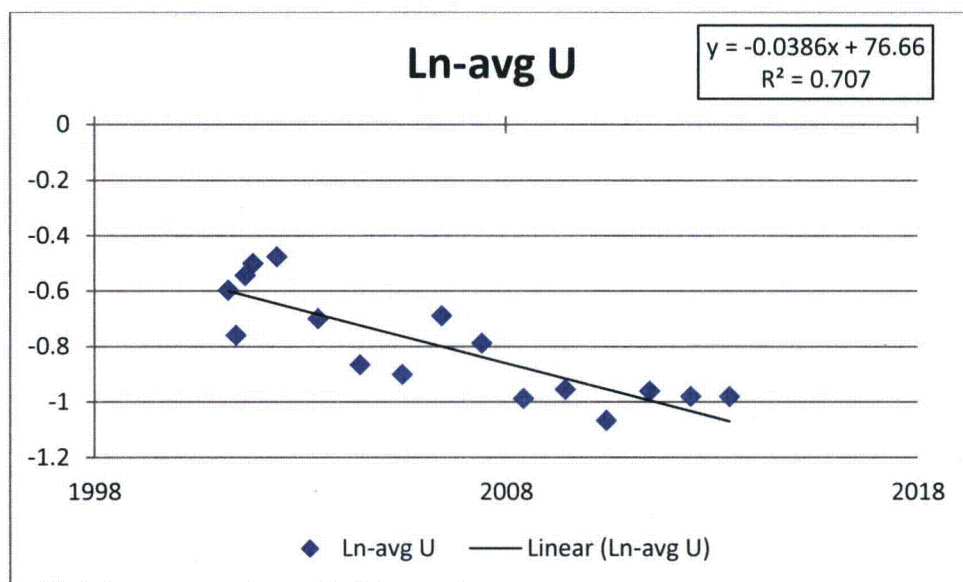












## SUMMARY OUTPUT for Well 0612--Uranium

Regression Statistics	
Multiple R	0.85337921
R Square	0.728256075
Adjusted R Square	0.717804386
Standard Error	0.177531083
Observations	28

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.196071249	2.196071	69.67831193	7.90E-09
Residual	26	0.819449423	0.031517		
Total	27	3.015520672			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 80.0%	Upper 80.0%
Intercept	93.33669996	11.10490423	8.404998	6.92E-09	70.51024241	116.1631575	78.73406335	107.9393366
Decimal date	-0.046297361	0.005546352	-8.34735	7.90E-09	-0.05769805	-0.03489667	-0.053590657	-0.039004064

## SUMMARY OUTPUT for Well 0617 - Uranium

Regression Statistics	
Multiple R	0.742606833
R Square	0.551464908
Adjusted R Square	0.534213558
Standard Error	0.18567794
Observations	28

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	1.102085837	1.102086	31.96648	6.04E-06
Residual	26	0.896383732	0.034476		
Total	27	1.998469569			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 80.0%	Upper 80.0%
Intercept	64.05759203	11.61473632	5.5152	8.68E-06	40.18315961	87.93202445	48.78454056	79.3306435
date	-0.032798138	0.005800986	-5.65389	6.04E-06	-0.044722235	-0.02087404	-0.040426271	-0.025170005

## SUMMARY OUTPUT - Well 0631--Uranium

Regression Statistics	
Multiple R	0.908814
R Square	0.825944
Adjusted R Square	0.818032
Standard Error	0.267576
Observations	24

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	7.474408	7.474408	104.3959	8.15E-10
Residual	22	1.575129	0.071597		
Total	23	9.049536			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 80.0%	Upper 80.0%
Intercept	215.6787	21.25463	10.14737	9.24E-10	171.599257	259.7580638	187.5962632	243.7610576
Date	-0.10838	0.010608	-10.2174	8.15E-10	-0.130381845	-0.08638401	-0.122398142	-0.09436771

## SUMMARY OUTPUT - Well 0633--Uranium

Regression Statistics	
Multiple R	0.576678
R Square	0.332558
Adjusted R Square	0.302219
Standard Error	0.231189
Observations	24

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.585881	0.585881	10.96165	0.003179252
Residual	22	1.175862	0.053448		
Total	23	1.761744			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	60.74255	18.3642	3.30766	0.003203	22.65752427	98.82758426	22.65752427	98.82758426
Dec. date	-0.03034	0.009165	-3.31084	0.003179	-0.049351477	-0.01133692	-0.049351477	-0.01133692

## SUMMARY OUTPUT Average Uranium

Regression Statistics	
Multiple R	0.866281
R Square	0.750442
Adjusted R Square	0.739099
Standard Error	0.111697
Observations	24

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.825379938	0.82538	66.15589008	4.48E-08
Residual	22	0.274478336	0.012476		
Total	23	1.099858275			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 80.0%	Upper 80.0%
Intercept	71.4566	8.872930016	8.053326	5.29E-08	53.05526804	89.8579292	59.7333575	83.17983978
date	-0.03602	0.004428257	-8.13363	4.48E-08	-0.045201438	-0.0268342	-0.041868571	-0.030167018

### Calculation of Estimated Date for Attenuation to Standard

Regression Equation:  $Y = mX + b$

Rearranged to solve for X:  $X = (Y - b)/a$

$Y = \ln \text{ uranium standard } (0.044) = -3.12$

#### For data from 1991+

Well	Y	b	a	X	
	612	-3.12	93.337	-0.0463	2083
	617	-3.12	64.058	-0.0328	2048
	631	-3.12	215.68	-0.1084	2018
	633	-3.12	60.743	-0.0303	2108
avg U		-3.12	71.47	-0.036	2072

#### For data from 2001+

Well	Y	b	a	X	
	612	-3.12	90.645	-0.0449	2088
	617	-3.12	35.213	-0.0184	2083
	631	-3.12	180.68	-0.091	2020
	633	-3.12	78.639	-0.0393	2080
	634	-3.12	80.04	-0.0414	2009
avg U		-3.12	76.66	-0.0386	2067

#### For 90% upper confidence estimate of slowest attenuation rate