



UTAH DEPARTMENT of  
ENVIRONMENTAL QUALITY  
**WATER  
QUALITY**

# *Utah's Long-term Monitoring and Assessment Plan for the San Juan River and Lake Powell, Utah*

**March 21, 2016**

***Prepared by:***

Utah Department of Environmental Quality, Division of Water Quality

Utah Department of Environmental Quality, Division of Drinking Water

***Reviewed by:***

Utah Department of Health, Environmental Epidemiology Program

Utah Department of Natural Resources, Division of Wildlife Resources

Utah Department of Agriculture and Food

***Contacts:***

Erica Gaddis, Assistant Director, Utah Division of Water Quality, [egaddis@utah.gov](mailto:egaddis@utah.gov)

Jodi Gardberg, Standards and Technical Services Section Manager, Utah Division of Water Quality, [jgardberg@utah.gov](mailto:jgardberg@utah.gov)

Jim Harris, Monitoring and Reporting Section Manager, Utah Division of Water Quality, [jamesharris@utah.gov](mailto:jamesharris@utah.gov)

Carl Adams, Watershed Protection Manager, Utah Division of Water Quality, [carladams@utah.gov](mailto:carladams@utah.gov)

Ying-Ying McCauley, Engineering Section Manager, Utah Division of Drinking Water, [ymacauley@utah.gov](mailto:ymacauley@utah.gov)

## Table of Contents

<b>1. Introduction</b>	<b>1</b>
<b>2. Analyses and Background</b>	<b>2</b>
Available Historical Water Quality Data	2
Assessment and Screening of Water Quality Data	4
Comparison to Utah’s Water Quality Standards for Class 1C Domestic Source Water	6
Comparison of Data from Drinking Water Systems with Drinking Water Standards	6
Screening of Total Metals Data with Recreational Exposure Water Screening Values	6
Comparison with Water Quality Criteria for Class 3B Aquatic Life Use	6
Comparison with Screening Values for Agricultural Uses	7
Evaluation of EPA Water Quality Data for Dissolved Metals	7
Water Quality Trends	8
Storm Influence on Water Quality	11
Assessment of San Juan River Sediment Data	13
Sediment in Lake Powell	18
Cumulative Load Estimates	19
<b>3. Long-Term Monitoring and Assessment Plan</b>	<b>21</b>
Study Objectives	21
Water Quality Monitoring to Protect Uses of the San Juan River	22
Task 1. Surface Water Quality Monitoring	23
Task 2. Real-Time Reporting of Water Quality Conditions	24
Drinking Water Monitoring	25
Task 3. Public Drinking Water Systems Monitoring	25
Task 4. Private Well Monitoring	26
Metals Load Analysis and Source Characterization	27
Task 5. Total Metal Load Analysis, including Utah Tributaries	27
Task 6. Inventory of Mining Sources in San Juan River Watershed	29
Accumulation of Metals in the San Juan River and Lake Powell Sediments	31
Task 7. Sediment Sampling in San Juan River and Tributaries	31
Task 8. Current Metal Concentrations in Lake Powell Sediments	32
Task 9. Historic Metal Concentrations in Lake Powell Sediments	32
Assess Impacts of Metal Contaminants on San Juan River and Lake Powell Uses	32
Task 10. Ecological Risk Assessment	33
Task 11. Human Health Risk Assessment	33
Coordination and Outreach	34
Task 12. Interagency Partnership and Collaboration	34
Task 13. Public Information and Stakeholder Outreach	35
<b>4. Budget</b>	<b>36</b>
<b>5. References</b>	<b>40</b>

## Appendices

- Appendix A.** Summary of Historic UDEQ Data for San Juan River
- Appendix B.** Summary of Historic USGS Data for San Juan River
- Appendix C.** Screening Tables for UDEQ Data in San Juan River following GKM Release
- Appendix D.** Statement of Evaluation
- Appendix E.** Summary of Water Quality Exceedances Observed in USEPA Data in San Juan River following GKM Release
- Appendix F.** Time-Series Plots of UDEQ and EPA Data Collected in San Juan River
- Appendix G.** Correlation Plots between Total and Dissolved Metals and River Discharge
- Appendix H.** Correlation Plots between Total and Dissolved Metals and Total Suspended Solids

## Tables

<b>Table 1.</b> UDEQ Sampling Locations at Selected San Juan River and Tributary Sites.....	2
<b>Table 2.</b> Summary of Water Quality Benchmarks used to Screen Water Quality Data for the San Juan River.....	5
<b>Table 3.</b> Human Health–Based Screening Values for Soils .....	15
<b>Table 4.</b> Summary of Sediment Data in the San Juan River and Comparison to Health-Based Screening Values.....	16
<b>Table 5.</b> Summary of Proposed 2016 Water Quality Monitoring in San Juan River Watershed in Utah .....	24
<b>Table 6.</b> Budget .....	36

## Figures

<b>Figure 1.</b> Map of historic and current UDEQ and USGS sampling locations in the San Juan River and Lake Powell. ....	3
<b>Figure 2.</b> Dissolved lead and zinc concentrations from August 8 through October 27, 2015, in the San Juan River.....	9
<b>Figure 3.</b> Total lead and zinc concentrations from August 8 through October 27, 2015, in the San Juan River (top two panels) and the corresponding hydrograph from the San Juan at Four Corners gauging station (bottom panel). ....	11
<b>Figure 4.</b> Total lead and nickel concentrations and daily discharge from USGS gauging stations from August 8 through October 27, 2015. ....	12
<b>Figure 5.</b> Total lead and nickel against TSS from August 8 through 28, 2015. ....	13
<b>Figure 6.</b> TSS and corresponding daily discharge from USGS gauges on the San Juan River from August 8 through 28, 2015. ....	13
<b>Figure 7.</b> Sediment metal concentrations in the San Juan River before and after the GKM plume entered Utah. ....	17
<b>Figure 8.</b> Trace metal concentrations in sediment cores collected by the USGS in the San Juan River delta of Lake Powell.....	19
<b>Figure 9.</b> Estimated historic releases of Gold King Mine drainage. ....	20

# 1. Introduction

The Gold King Mine (GKM) spill and release to Cement Creek, a tributary to the Animas River in Colorado, began on August 5, 2015, as a result of efforts to install a pipeline to treat mine waste. An estimated 3 million gallons of contaminated water was released, some of which traveled downstream to the San Juan River and ultimately into Lake Powell in southeastern Utah. The Utah Department of Environmental Quality (UDEQ) deployed monitoring crews and began sampling efforts on the San Juan River at four locations on August 8, 2015, in an effort to detect the plume of mine waste as it entered Utah. This was later expanded to five sampling locations. Monitoring, cleanup, and remediation activities to-date have been undertaken by state and federal agencies.

It is expected that many of the dissolved metals released from the GKM and other mines in the Bonita Peak Mining District are rapidly transformed to colloidal forms and become adsorbed or otherwise deposited in the stream channel. The U.S. Environmental Protection Agency (EPA) estimates that 80% of the metals released during the GKM incident remain in Animas River sediments and will eventually be transported downstream (EPA 2016a). Monitoring and reporting to stakeholders and the public about the effects of metals transport on river uses during the 2016 spring runoff event will require timely and frequent collection and analysis of water quality samples. In addition, UDEQ is interested in understanding the potential long-term impacts of accumulation of material deposited in the sediments of the San Juan River and Lake Powell.

Herein, UDEQ summarizes the findings from historical and incident response water quality sampling (Section 2). These findings provide the rationale for 13 tasks that make up Utah's long-term monitoring plan for the San Juan River and Lake Powell (Section 3). This plan is adaptive, and changes to specific tasks will depend on further findings. The activities described in this plan are contingent on funding. UDEQ has not yet secured sufficient funds to conduct all of the activities identified in the plan. If sufficient funds can not be secured, the scope of this plan will need to be modified.

## 2. Analyses and Background

### *Available Historical Water Quality Data*

UDEQ has been sampling sites in the target reaches of the San Juan River and its major Utah tributaries since 1978 (Table 1; Appendix A; Figure 1). Of these, the most recent and data-rich sites on the San Juan River are the San Juan River at Mexican Hat and the San Juan River above Lake Powell. Because some sites have not been sampled in 15 years, UDEQ augmented the historical data with samples collected by other agencies. The U.S. Geological Survey (USGS) also collects water quality samples (Appendix B); however, UDEQ was only able to locate one site (San Juan River near Bluff) with an appreciable number of metals results. Cooperative monitoring with the Bureau of Reclamation on Lake Powell was also compiled. For a complete summary of available parameters and summary statistics of UDEQ's data, see Appendix A.

**Table 1.** UDEQ Sampling Locations at Selected San Juan River and Tributary Sites

MLID	UDEQ Location Name	Abbreviated Name	Latitude	Longitude	Min. Sample Date	Max. Sample Date	No. of Metals Samples
4954000	SAN JUAN R AT US160 XING IN CO	SJR at Four Corners	37.002775	-109.031765	3/6/1978	8/10/1988	29
4953250	SAN JUAN R AT SAND ISLAND	SJR at Bluff	37.260279	-109.613734	3/6/1978	8/10/1988	26
4953400	SAN JUAN R AT SWINGING FOOTBRIDGE	N/A	37.280001	-109.492896	8/8/1978	2/19/1981	21
4953800	SAN JUAN R BL CONFLUENCE W/ W FK ALLEN CANYON	N/A	37.253332	-109.267054	3/6/1978	2/19/1981	26
4953900	SAN JUAN RIVER AB ANETH	N/A	37.213334	-109.186505	9/15/1988	6/23/1998	27
4953950	SAN JUAN R AT MARBLE WASH	N/A	37.145294	-109.114296	8/8/1978	4/10/1979	6
4953880	MC ELMO CK AT HIWAY U262 XING	McElmo Creek	37.218048	-109.190111	7/2/1985	6/23/1998	48
4953560	MONTEZUMA CK AT U163 XING	Montezuma Creek	37.272086	-109.327694	2/22/1989	4/30/2008	5
4952940	SAN JUAN R AB LAKE POWELL	SJR above Lake Powell	37.294158	-110.406798	6/7/1997	8/2/2014	50
4953000	SAN JUAN R AT MEXICAN HAT US163 XING	SJR at Mexican Hat	37.146948	-109.853672	3/6/1978	7/15/2009	74

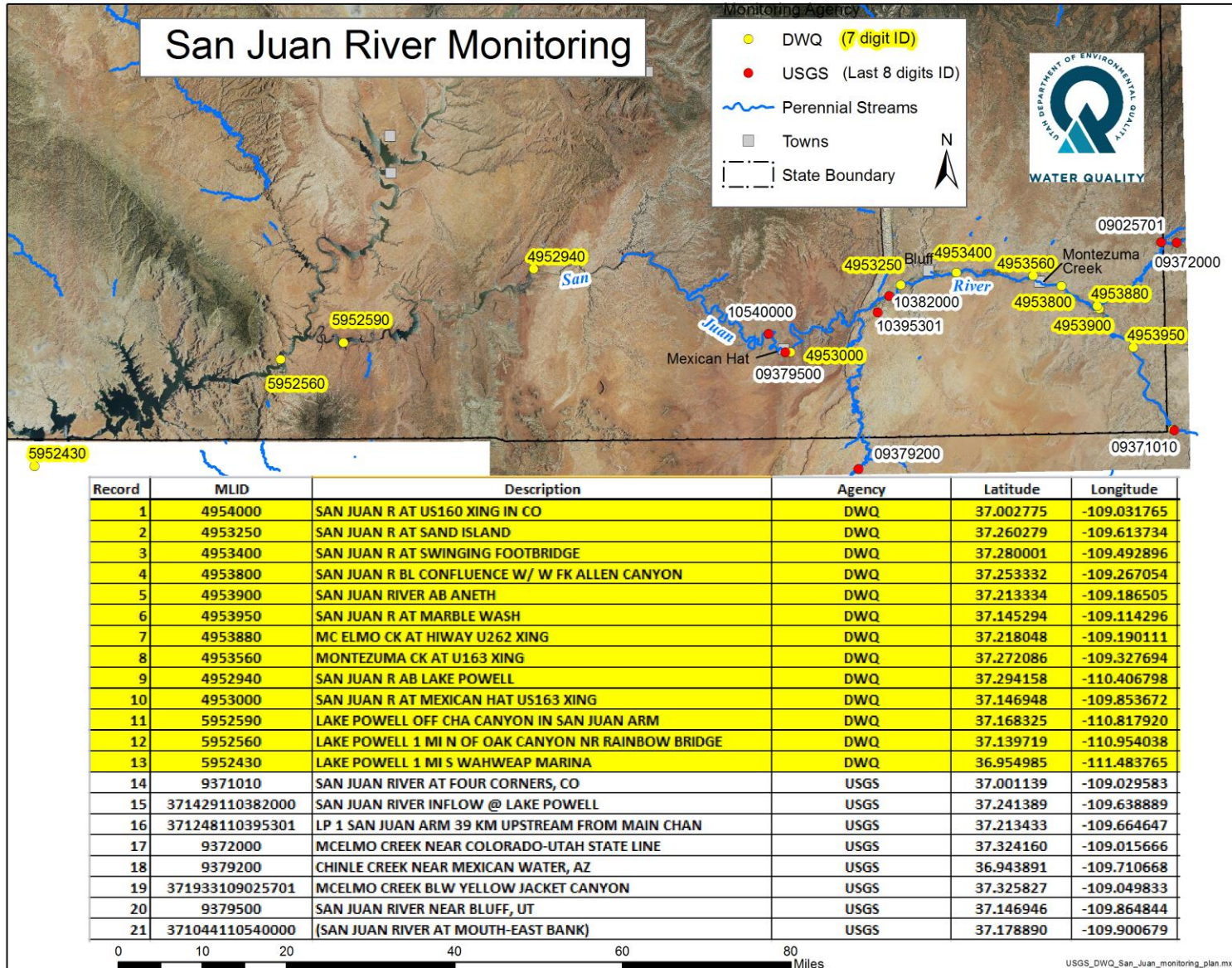


Figure 1. Map of historic and current UDEQ and USGS sampling locations in the San Juan River and Lake Powell.

### ***Assessment and Screening of Water Quality Data***

UDEQ intensively collected water samples during the first 3 weeks of August 2015, after the GKM release, at five different locations on the San Juan River. When water data indicated that the initial pulse of contamination had passed, UDEQ instituted a less intensive monitoring scheme in September through October. In October, UDEQ's contractor deployed sampling equipment to collect river samples during storm events. These samples indicated that total metal concentrations in the river were elevated during the monsoonal storms in late fall 2015. However, none of the data exceeded health screening values for recreational exposures, as developed by the Utah Department of Health (UDOH) (Table 2). Because of the episodic nature of storms and the limitations of the field equipment used to sample these events, only total metals data were available for these storm events, which precluded an evaluation of water quality benchmarks that are based on dissolved metals (see Table 2). UDEQ also collected a full suite of metals, water column, and macroinvertebrate samples on September 22 and October 26, 2015.

Table 2 summarizes applicable water quality standards for the San Juan River (Utah Administrative Code [UAC] [R317-2-14](#)), Utah's drinking water standards (UAC [R309-200-5](#)), as well as screening values for recreational and agricultural uses. Recreational screening values were developed by the UDOH's [Environmental Epidemiology Program](#). Agricultural screening values are derived from National Academy of Science (NAS) *Water Quality Criteria, 1972* (NAS 1972). Those guidelines are reprinted in [EPA's 2004 Guidelines Water Reuse](#) (EPA 2004). Dissolved metal values were used for the assessment of agricultural use waters. Estimated values below the laboratory's reporting limit are evaluated in this analysis. These results generally show low-level concentrations and do not significantly affect the analysis outcome.

**Table 2.** Summary of Water Quality Benchmarks used to Screen Water Quality Data for the San Juan River

Analyte	CAS No.	Units*	Utah Water Quality Standards (Numeric Criteria) (UAC R317-2-14) for San Juan River Uses [dissolved metals]				Utah Primary Drinking Water Standards (UAC R309-200-5) [total metals]		Recreational Screening Values [total metals]	Agricultural Screening Values [dissolved metals]		
			1C (domestic)	3B (warm water fish) [1-hour]	3B (warm water fish) [4-day]	4 (agriculture)	Maximum Contaminant Level	Action Level		Livestock Water (µg/L)	Long-Term Irrigation Waters (µg/L) <sup>†</sup>	Short-Term Irrigation Waters (µg/L) <sup>†</sup>
Hardness	–	mg/L								180		
Aluminum	7429-90-5	µg/L		750	87			620,767		5,000	5,000	20,000
Antimony	7440-36-0	µg/L					6	248				
Arsenic	7440-38-2	µg/L	10	340	150	100	10	186		200	100	2,000
Barium	7440-39-3	µg/L	1,000				2,000	124,159				
Beryllium	7440-41-7	µg/L	<4				4	1,242				
Cadmium	7440-43-9	µg/L	10	2	0.25	10	5	62		50	10	50
Calcium	7440-70-2	µg/L								500,000		
Chromium	7440-47-3	µg/L	50	16 (VI); 570 (III)	11 (VI); 74 (III)	100	100	410		1,000	100	1,000
Cobalt	7440-48-4	µg/L						7,931		1,000	50	5,000
Copper	7440-50-8	µg/L		13	9	200		6,208	1,300	500	200	5,000
Iron	7439-89-6	µg/L		1,000	1,000			851,582			5,000	20,000
Lead	7439-92-1	µg/L	15	65	2.5	100		910	15	100	5,000	10,000
Magnesium	7439-95-4	µg/L								250,000		
Manganese	7439-96-5	µg/L						31,040			200	10,000
Mercury	7439-97-6	µg/L	2		0.012		2	1,242		10		
Molybdenum	7439-98-7	µg/L						3,104			10	50
Nickel	7440-02-0	µg/L		468	52			17,480			200	2,000
Potassium	7440-22-4	µg/L										
Selenium	7782-49-2	µg/L	50	18.4	4.6	50	50	3,104		50	20	20
Silver	7440-22-4	µg/L	50	1.6				3,630				
Sodium	7440-23-5	µg/L								1,000,000		
Thallium	7440-28-0	µg/L					2	25				
Vanadium	7440-62-2	µg/L						6,208		100	100	1,000
Zinc	7440-66-6	µg/L		120	120			217,786		25,000	2,000	10,000
TDS		mg/L				1,200						500,000–1,000,000
pH					6.5–9.0	6.5–9.0						

mg/L = milligrams per liter; µg/L = micrograms per liter; CAS = Chemical Abstract Service.  
<sup>†</sup> Data from NAS (1972).



### Comparison to Utah's Water Quality Standards for Class 1C Domestic Source Water

Concentrations of dissolved metals were compared to Utah's water quality standards for Class 1C use (protected for domestic purposes with prior treatment in UAC R317-2-14) as required by the Utah Division of Drinking Water. Of the 100 samples evaluated for the metals listed in Table 2, the only exceedance that was observed was for lead in a sample collected at the SJR at Four Corners site on August 28, 2015 (Appendix C).

### Comparison of Data from Drinking Water Systems with Drinking Water Standards

None of the public water systems regulated by the State of Utah have surface water intake directly from the San Juan River. The consumer's exposure to elevated levels of these metals through public drinking water supply is expected to be minimal. Nonetheless, the Utah Division of Drinking Water reviewed recent total metals data collected in two community water systems located near the San Juan River (Mexican Hat Special Services District and Bluff Water Works Service District). The data of the finished water delivered to consumers were examined for exceedances of drinking water maximum contaminant levels or action levels (UAC R309-200-5). The data do not indicate that the drinking water quality in these water systems has been affected by the GKM spill. It is noted that the copper results within Mexican Hat's distribution system are above the action level. Most often, plumbing piping (not the source water) is the cause of copper contamination. It is suspected that Mexican Hat's high copper results in its distribution system may be a result of the slightly corrosive nature of the treated water from its water treatment plant. The past samples taken at the well sources did not show elevated copper levels. It is unlikely the elevated copper levels are caused by the well sources or the GKM release.

### Screening of Total Metals Data with Recreational Exposure Water Screening Values

The Environmental Epidemiology Program has generated site-specific recreational screening values for metal exposures to the San Juan River waters (see Table 2). These values reflect the water contaminant concentrations that would exceed established ATSDR minimal risk levels, or EPA reference doses if an appropriate minimal risk level does not exist, for the most susceptible population: children under the age of 5 years.

These recreational screening values assume an exposure duration of 60 days, with 2 hours per day spent in the water. The accidental ingestion rate accounts for 50 milliliters (mL) of river water per hour, and total body contact with the water for that 2-hour period. An exceedance of these values does not necessarily indicate that adverse health effects will occur; rather, it is used as guidance for health professionals to further determine the likelihood that adverse health effects may occur due to the exposure.

No metals exceeded a recreational screening value. Recreational exposures to San Juan River water and sediment are not expected to harm people's health. See Appendix D for exposure calculation assumptions.

### Comparison with Water Quality Criteria for Class 3B Aquatic Life Use

The water concentrations of metals were compared to Utah's chronic and acute water quality standards for the Class 3B aquatic life use. In the UAC R317-2-14, the chronic standard refers to the 4-day average concentration, and the acute standard refers to the 1-hour average concentration. All of Utah's aquatic life criteria are based on dissolved fractions, with the exception of aluminum, which is based on the total recoverable fraction. The acute aluminum standard was exceeded at all sampling locations and on all dates. The highest total aluminum concentrations exceeded 100,000 micrograms per liter ( $\mu\text{g/L}$ ) at the SJR at Four Corners site on August 27 and 28, October 2, and October 19, 20, 21, and 23; at the SJR at Montezuma site on August 28 and October 23; at the SJR at Bluff on August 28 and October 24; at the SJR at Mexican Hat site on August 11, August 28, and October 24; and at the SJR above Lake Powell site on August 15 and October 27. Some of these exceedances appear to correlate with an increase in discharge on August 26 through 27, 2015, related to precipitation.

The chronic aquatic life standards for iron and mercury were exceeded at the SJR at Four Corners site on August 11 and August 28. The cadmium and copper chronic standards were also exceeded on August 28. Mercury concentrations exceeded the chronic standard at McElmo Creek on September 23, the only day a sample was collected from this location. The analytical method used for mercury has relatively low sensitivity, and the detection limit is higher than the standard. Therefore, all detected concentrations are above the standard, and non-detect concentrations are too high to determine if the water concentrations comply with the standard. This remains a significant uncertainty. Zinc concentrations exceeded the acute and chronic standards on August 28 at Montezuma. No other exceedances of the zinc standards were observed (see Appendix C).

### Comparison with Screening Values for Agricultural Uses

Concentrations of dissolved metals were compared to screening values, including Utah's water quality standards for the Class 4 use (protected for agricultural uses including irrigation of crops and stock watering). These comparisons show exceedances of the screening values for dissolved aluminum, iron, and manganese on August 28, 2015, and only at the sampling location upstream of the Utah state line. Results from the Utah sites are below the screening values for metals. The Utah agricultural water quality standard for total dissolved solids was exceeded on 1 day at the SJR at Mexican Hat site and 2 days at the SJR above Lake Powell site. Total dissolved solids are concluded to be unrelated to the release of GKM wastes because the concentrations are lower at the sampling location upstream of the Utah state line. The Utah Department of Agriculture and Food (UDAF) has analyzed the data and compared them to current toxicology knowledge and scientific data concerning animal and plant life safety. UDAF found no long-term exposure potential risks from the use of water for livestock or crop irrigation.

### *Evaluation of EPA Water Quality Data for Dissolved Metals*

UDEQ evaluated EPA data collected in August, September, and October 2015, with review from the UDOH, UDAF, and the Utah Department of Natural Resources (Division of Wildlife Resources). The EPA data were not validated by UDEQ, and with the exception of removing what appeared to be duplicate entries, the data were used as presented. The data were compared against Utah's water quality criteria for domestic source water, aquatic life, and agriculture. The data were also compared to screening values for irrigation and livestock.

The EPA data for total metals appear to be similar to the UDEQ results, posted separately, in August and September 2015. EPA analyzed more samples for dissolved metals in September and early October 2015 than UDEQ; therefore, it is difficult to compare that portion of the EPA data to UDEQ data. UDEQ split water quality samples with EPA on October 26, 2015; however, EPA has not yet released data from this date. Once EPA releases data from late October, a more robust comparison of the two datasets will be conducted. The EPA data indicate high concentrations of several dissolved metals that exceed Utah's water quality criteria for all uses in fall 2015 (Appendix E). Most, but not all, of these exceedances appear to be coincident with storms in the upper watershed (Colorado and New Mexico). UDEQ is exploring the relationship of water quality exceedances with storm activity and river turbidity. This will be an integral component of UDEQ's long-term monitoring plan. Table 1 in Appendix E summarizes the number of days that EPA data exceed Utah's water quality criteria and agricultural screening values. Other tables show the data values by metal and date that exceed Utah's water quality criteria for domestic source water (Table 2 in Appendix E), aquatic life (Tables 3 and 4 in Appendix E), agricultural uses (Table 5 in Appendix E), and agricultural screening values (Tables 6 and 7 in Appendix E).

The dissolved metals and metalloids concentrations were compared to Utah's water quality criteria for Class 1C use. The EPA data indicate exceedances on three separate occasions in the San Juan River at the SJR at Four Corners, McElmo Creek, and SJR at Mexican Hat sites. Exceedances were measured for arsenic, barium, beryllium, chromium, and lead on September 24 and 28, 2015. These exceedances

appear to correlate with an increase in river flow on September 24 and 25, 2015, related to precipitation, although by September 28, the river had returned to pre-storm flows. The EPA dataset also indicates one exceedance of the domestic source water criteria for lead on August 11, 2015, at McElmo Creek. A similar exceedance was not recorded in UDEQ's data, although there was one exceedance of the lead criteria in UDEQ's data on August 28, 2015. None of the public water systems regulated by the State of Utah have surface water intake directly from the San Juan River.

The dissolved metals and metalloids concentrations were also compared to agricultural screening values, including Utah's water quality criteria for Class 4 agricultural use. Water concentrations exceeded Utah's agricultural water quality criteria for chromium, copper, and lead at the SJR at Four Corners site on September 24, 2015. Aluminum, lead, and vanadium screening values for stock watering uses were exceeded on 9 days at the SJR at Four Corners, SJR at Montezuma Creek, SJR at McElmo Creek, SJR at Bluff, and SJR at Mexican Hat sites. The short-term screening values for irrigation use were exceeded on 2 days at the SJR at Four Corners and SJR at Mexican Hat sites. UDAF has analyzed the data and compared them to current toxicology knowledge and scientific data concerning animal and plant life safety. UDAF found no long-term exposure potential risks from use of the water for livestock or crop irrigation.

Crop irrigation with waters that may contain elevations of specific metallic elements (e.g., iron and sulfates) could lead to accumulation in the soils over time and therefore potentially be taken up by plants to then be ingested by livestock. Although these concentrations may be lower than the toxic criteria levels, they could have an accumulating effect to be considered in long-term use, especially when elevated water levels of these same elements may also be in the diet of consuming livestock drinking from this same water source. It may take multiple growing seasons to evaluate and determine the effects of these accumulated elements in the agricultural lands and crops harvested from them.

The dissolved metals and metalloids concentrations were also compared to Utah's water quality criteria for the Class 3B warm water aquatic life use. EPA did not report hardness; therefore, hardness was calculated based on calcium and magnesium concentrations for the hardness-dependent criteria. Exceedances of the acute aquatic life criteria for aluminum, copper, iron, and zinc were measured at the SJR at Four Corners, SJR at Montezuma Creek, SJR at McElmo Creek, SJR at Bluff, and SJR at Mexican Hat sites. Exceedances of the chronic criteria for aluminum, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, and zinc were measured at the same locations.

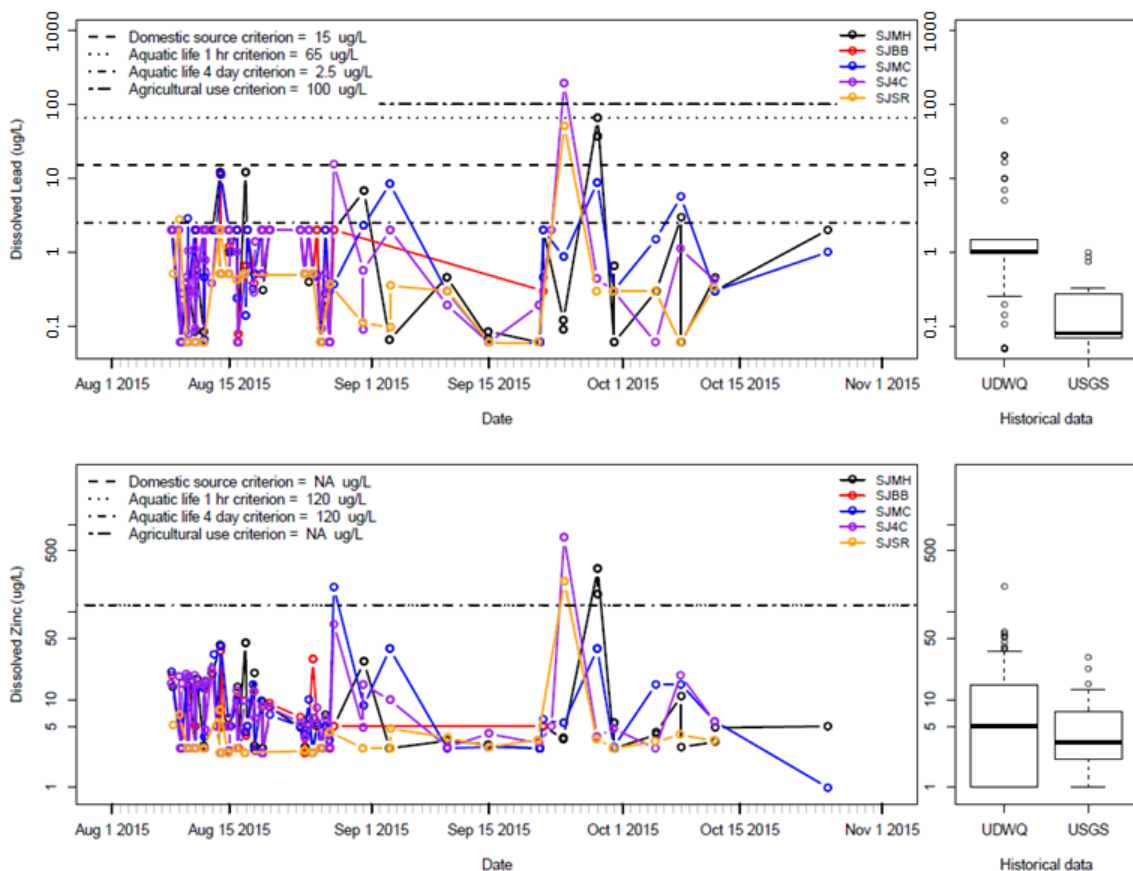
### ***Water Quality Trends***

UDEQ tracked and analyzed temporal variation in total and dissolved metal concentrations in the San Juan River from August 8, 2015, to October 27, 2015, using data collected by both UDEQ and EPA. This analysis focused on samples collected at five sites on the San Juan River: 1) SJR at Mexican Hat, Utah (EPA site SJMH); 2) SJR at Bluff (EPA site SJBB); 3) SJR at Montezuma (EPA site SJMC); 4) SJR at Four Corners (EPA site SJ4C); and 5) SJR at Shiprock, New Mexico (EPA site SJSR). Total and dissolved concentrations of all metals were plotted through time at these five sites. UDEQ's analyses focused on six metals of concern known to be associated with the GKM release: cadmium, copper, lead, mercury, nickel, and zinc. These concentrations were compared to applicable water quality standards and to historical data collected by UDEQ and USGS where available. However, historical observations were collected opportunistically and may or may not adequately reflect background variability in metal concentrations. Additional time series plots for all metals are available in Appendix F.

Initial analyses by UDEQ estimated plume arrival at the Utah border in the evening of Sunday, August 9. UDEQ water quality data support this estimate based on peak metal concentrations. However, a more recent simulation by EPA (EPA 2016b, *Draft Analysis of Fate and Transport of Metals in the Animas and*

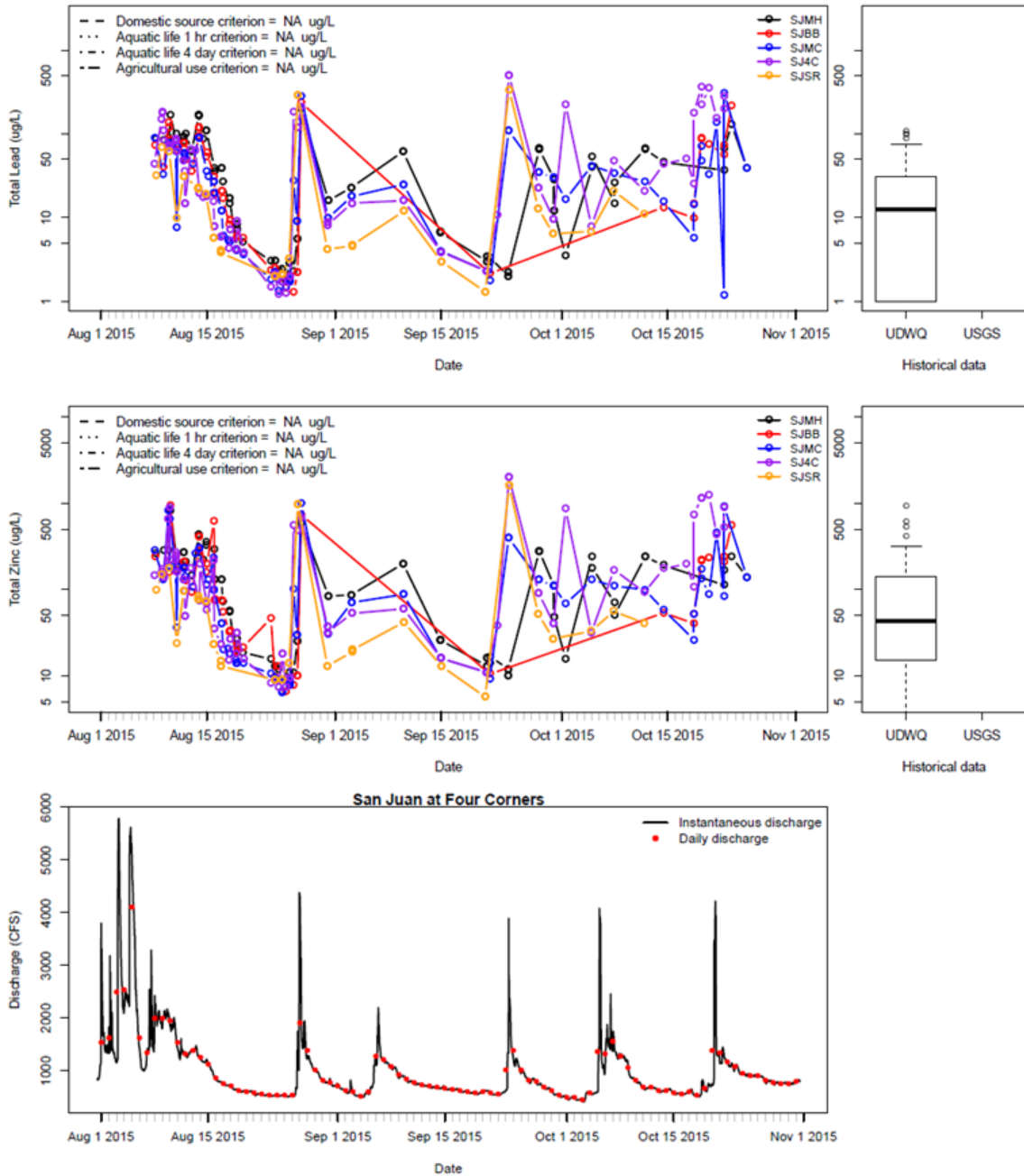
*San Juan Rivers*) estimates plume arrival in Utah as early as August 7, with the highest concentrations estimated to have occurred on August 8 and 9.

Immediately following the release, UDEQ identified several dissolved metals that appeared to show the arrival and passing of the plume. However, the addition of data from EPA, the lengthening of the time scale through October, and the detection limits for some dissolved metals somewhat obscure these initial observations. Several of the same metals show generally elevated dissolved concentrations immediately following the GKM release and subsequent spikes in concentrations in September and October (Figure 2). In many cases, the September and October spikes exceeded both concentrations observed following the release and the range of historical observations. Note that the data showing spikes in dissolved metals concentration were collected by EPA. UDEQ did not collect dissolved metals data in September or October, and therefore these data could not be independently verified. EPA also estimates that 100% of the dissolved metals associated with the GKM release were adsorbed to colloidal materials before the plume's arrival in the San Juan River. Nonetheless, UDEQ observed elevated concentrations of dissolved metals during the week following the release. Some of the metal pollution may have either remained in dissolved form or was transformed back to dissolved form when it arrived in Utah. Additional analysis is needed to understand the disparity between EPA's assertion that metals were all in colloidal form with the peaks in dissolved metals concentration observed in the San Juan River in Utah coincident with when the plume was estimated to arrive in Utah.



**Figure 2.** Dissolved lead and zinc concentrations from August 8 through October 27, 2015, in the San Juan River. Available historical observations are box plotted on the right. Applicable water quality criteria are shown as dashed lines and specified in the legend in the top left. Sites are identified in the legend at the top right. Graphs for additional metals are available in Appendix F.

Total metal concentrations during initial sampling (August 8–28) for several total metal concentrations, including copper, lead, nickel, and zinc, also follow a pattern consistent with estimated plume arrival and travel through Utah (Figure 3). Concentrations of total cadmium and mercury also partially follow this pattern, but are less distinct. These patterns suggest that UDEQ began sampling during the plume on August 8 and that the initial plume largely passed through UDEQ's sampling locations by about August 26. As with dissolved metal concentrations, observed total metal concentrations were largely within, but occasionally exceeded, the range of historic observations in the San Juan River. Following the presumed receding limb of the plume, longer-term sampling (August 27–October 26) showed additional subsequent elevated total metal concentrations. These samples showed increases in total metal concentrations beyond ranges observed during the plume and beyond the range of historical observations, with significant spikes in total concentrations of several metals including lead, nickel, and zinc on August 27–28 and September 21–23. Visually, these peaks appear to correspond with high discharge events at the Four Corners and Bluff gauging stations (see Figure 3). The peaks in total metal concentrations observed in UDEQ's data are fairly consistent with EPA's estimate of plume arrival and peak timing in Utah. However, UDEQ's data suggest the possibility of a longer tail in the passing of the plume and the potential for lingering impacts and resuspension of previously deposited sediment and metal contaminants associated with the GKM release and historic mining inputs to the San Juan River. A full analysis of the presence of abandoned mine sites within the watershed and their potential contributions of metal contaminants to the San Juan River would be necessary to confidently distinguish between the impacts of the August 5 GKM release and historical releases from GKM or other abandoned mine sites.



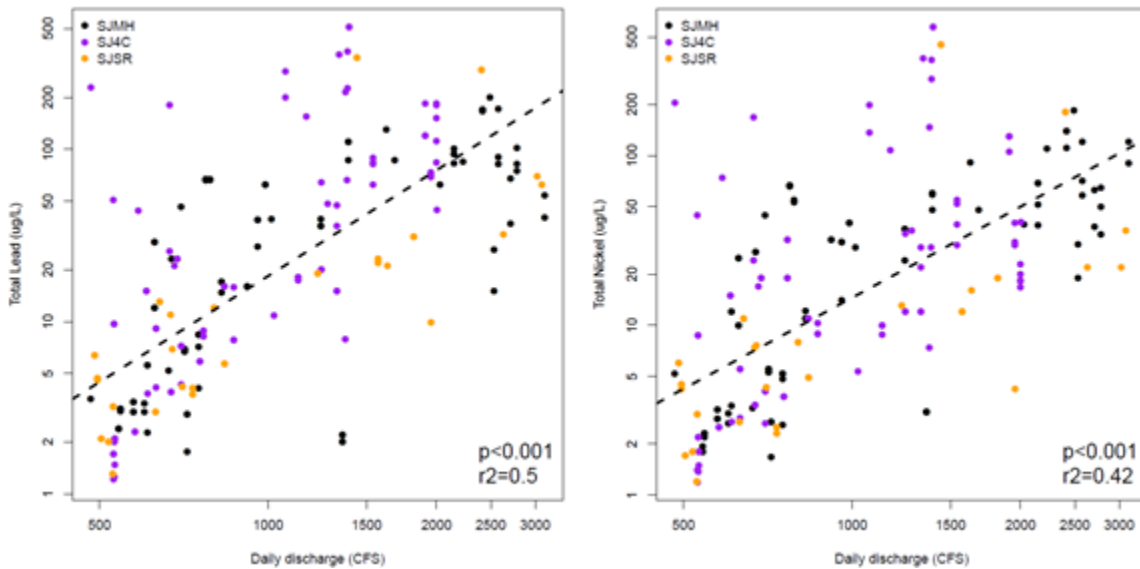
**Figure 3.** Total lead and zinc concentrations from August 8 through October 27, 2015, in the San Juan River (top two panels) and the corresponding hydrograph from the San Juan at Four Corners gauging station (bottom panel).

Available historical observations are box plotted on the right. Sites are identified in the legend at the top right. Graphs for additional metals and hydrographs from other sites are available in Appendix F.

### ***Storm Influence on Water Quality***

Analyses of water quality trends were further complicated by storm runoff events and subsequent increases in discharge in the San Juan River. The high discharges associated with these storm events likely increased the rate of transport of metal contaminants and diluted concentrations of total and dissolved metals. Together, these factors would cause a reduction in metal concentrations, particularly the dissolved component. However, runoff from these events may also have contributed additional loads of

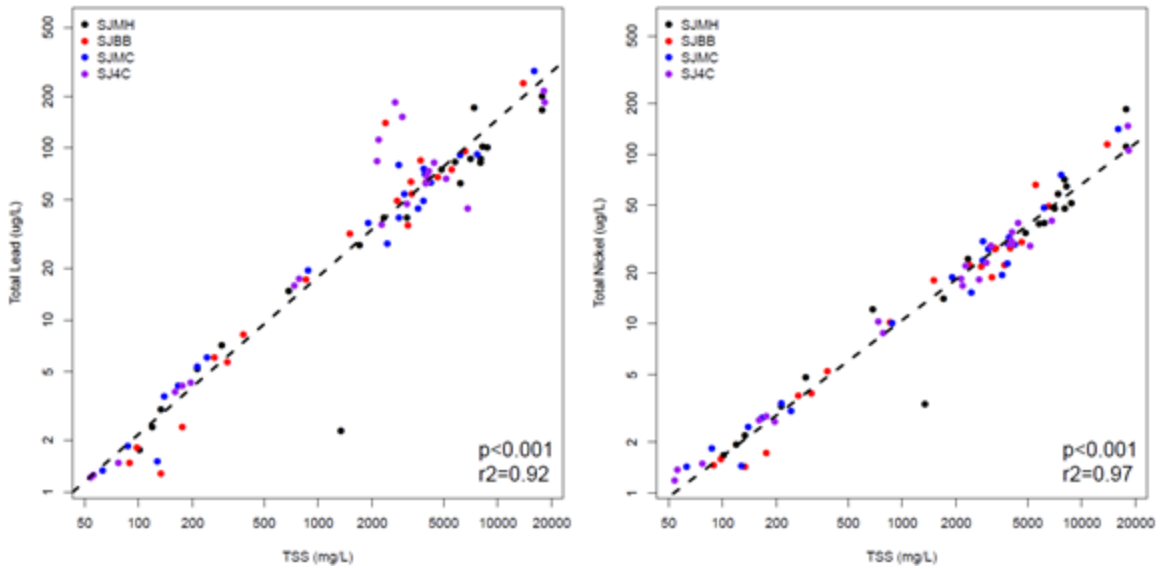
metal contamination to the San Juan River from other sources within the watershed, including the GKM. The relative contribution of metal contamination from the GKM release versus other possible sources is currently unknown. UDEQ analyzed the relationship between total and dissolved metal concentrations through the sampling period and daily stream discharge measurements collected at nearby USGS gauging stations at Four Corners, Colorado; Shiprock, New Mexico; and Bluff, Utah. Total concentrations of most metals were positively associated with daily discharge (Figure 4). These relationships could be further developed to target sampling during storms and spring runoff and to assess the risk of metal concentrations exceeding screening values. Dissolved concentrations of several metals also tended to be positively related to discharge, but were much weaker than relationships observed with total concentrations (Appendix G).



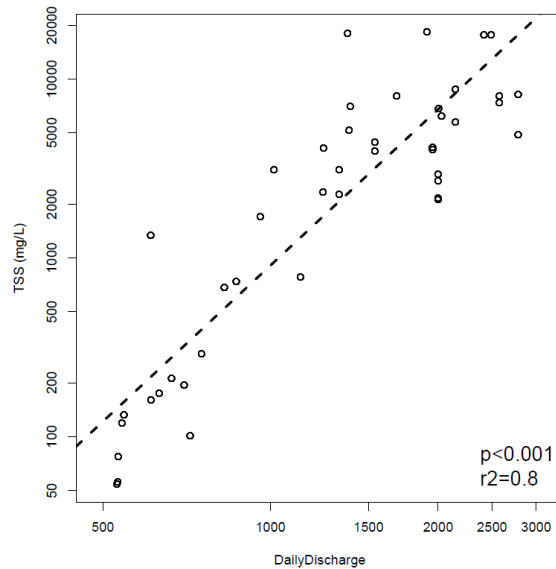
**Figure 4.** Total lead and nickel concentrations and daily discharge from USGS gauging stations from August 8 through October 27, 2015.

Additional plots of total metal concentrations and daily discharge are available in Appendix G.

UDEQ also analyzed the relationship between total and dissolved metal concentrations and turbidity, as measured by total suspended solids (TSS), immediately following the GKM release (August 8–28). With the exceptions of mercury, silver, and thallium, all total metal concentrations were strongly and positively related to TSS with  $r^2$  ranging from 0.5 to 0.97 (Appendix H; Figure 5). In particular, the six metals of primary concern (cadmium, copper, lead, mercury, nickel, and zinc) were all strongly associated with TSS, suggesting TSS may be a useful surrogate measure for total metal concentrations associated with the GKM release. If a similar relationship can be established between turbidity and metal concentrations, then metals can be estimated in real time using a turbidity meter at USGS gaging stations. However, the relationships between total metal concentrations and TSS or turbidity may break down through time as sediments associated with the GKM release continue to flush through the San Juan. Relationships between dissolved metal concentrations and TSS were mixed, with several showing weak positive associations, a few weak negative associations, and several with no relationship (Appendix H). Finally, TSS was strongly and positively related to discharge following the GKM release (Figure 6).



**Figure 5.** Total lead and nickel against TSS from August 8 through 28, 2015. Additional total metal and TSS plots available as Appendix H.



**Figure 6.** TSS and corresponding daily discharge from USGS gauges on the San Juan River from August 8 through 28, 2015.

### ***Assessment of San Juan River Sediment Data***

UDEQ collected sediment samples from up to five sites on at least 4 different days between August and October, 2015, on the San Juan River plus one sample collected at McElmo Creek on 1 day. The sampling sites were selected in the field to be representative of depositional environments in the river. The first round of sediment samples was collected before the predicted arrival of the GKM spill to Utah. The second sampling round was collected after the contaminated water had started crossing into Utah.

The colloidal portion of the contamination from the GKM was expected to travel slower and more dispersed than the dissolved water contamination due to settling and re-entrainment in upstream sections of the San Juan River system, including in the Animas River, during transport downstream to Utah.



At each site, ten (10) sub-samples of the top (approximately) 1 centimeter of sediment were collected and combined for laboratory analyses at each sampling site. Sediments were analyzed for metals and are reported in dry weight concentrations. Table 3 compares the sediment concentrations to human health-based screening values for soil because sediment-specific screening values are unavailable. The screening-level analyses show that sediment concentrations were lower than the health-based screening values for soil, which indicate that health effects to people from exposure to these pollutants in sediment are unlikely (Table 4). UDAF also reviewed the sediment data and found it difficult to predict adverse effects to the health of livestock and use of irrigation waters. Storm events or natural spring runoff waters may vary the amount of elements found in waters. Continual monitoring and data collection will be necessary for long-term planning, evaluation, and continued use of the San Juan River for agricultural purposes.

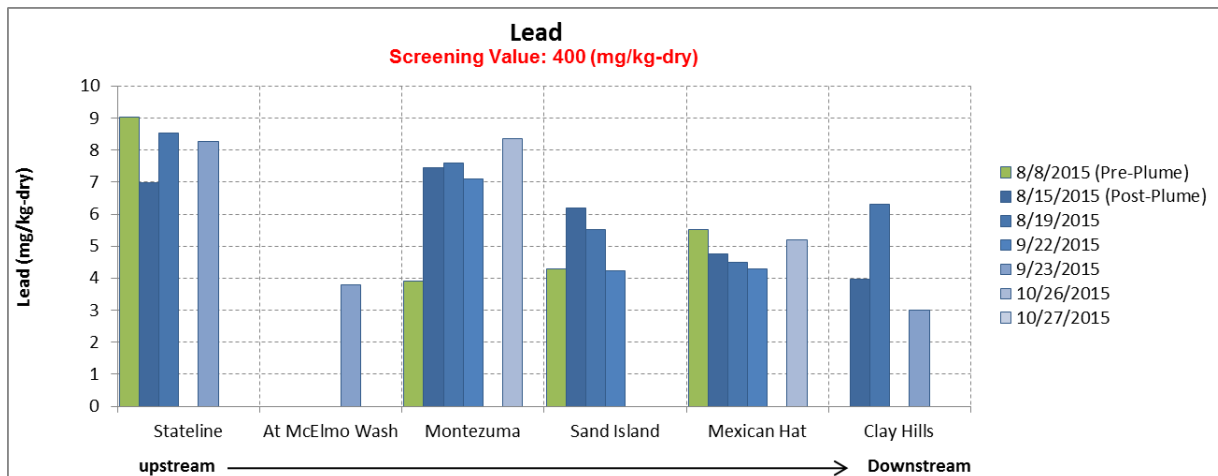
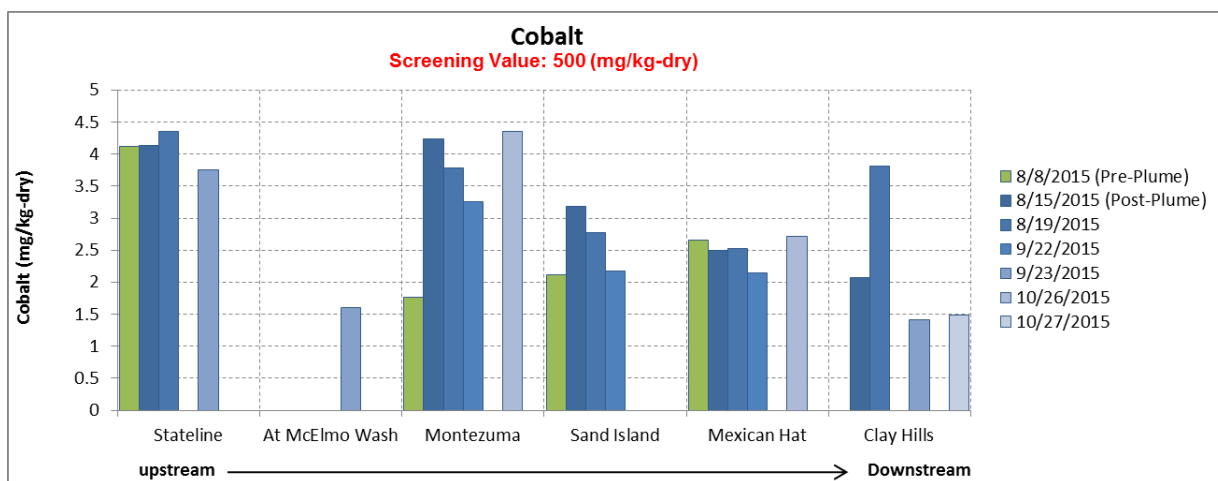
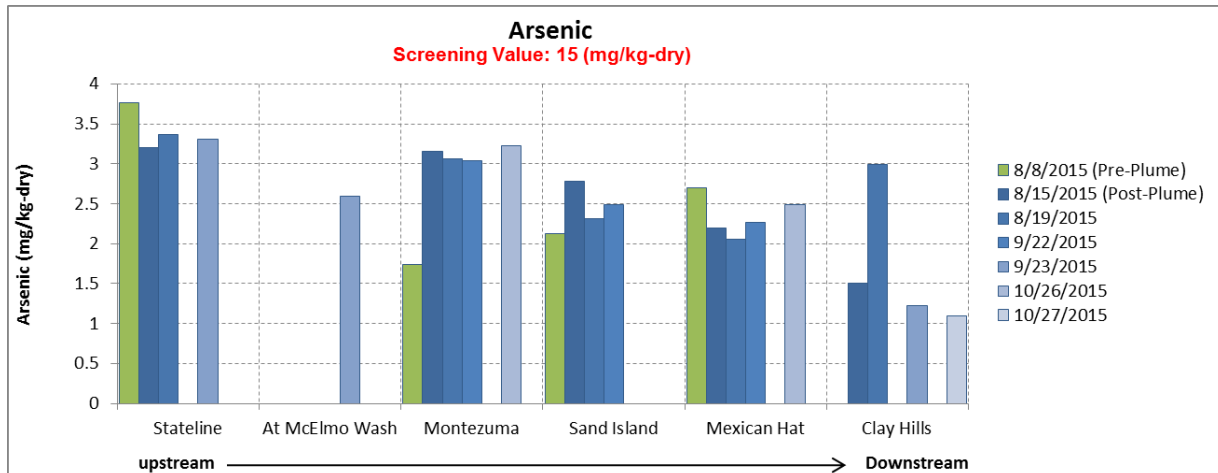
Although some patterns observed in pollutant concentrations in the UDEQ sediments appear to be related to the GKM spill, additional analyses are necessary. At the SJR at Four Corners site, sediment concentrations were generally similar between the pre- and post-plume arrival samples, with the exception of mercury, which increased over an order of magnitude before decreasing to pre-plume concentrations by the last sampling event (Figure 7; Appendix C). The concentrations in sediment at Montezuma Creek and Bluff of aluminum, arsenic, beryllium, cobalt, copper, cadmium, chromium, iron, lead, manganese, vanadium, and zinc all increase by approximately a factor of two after the pollutant plume was predicted to arrive in Utah. The sediment concentrations then consistently decreased for the next sampling round approximately 1 month later. However, these same patterns were not consistently exhibited in the sediment samples from the downstream locations of SJR at Mexican Hat and SJR above Lake Powell. Metal concentrations in sediment at these locations did not always increase after the predicted plume arrival. For instance, beryllium concentrations were lower post-plume at the SJR at Four Corners site, increased at the SJR at Montezuma and SJR at Bluff sites, and were lower post-plume at the SJR at Mexican Hat site. In addition, no pre-plume sediment sample is available for the SJR above Lake Powell site to conduct a pre-plume comparison. The lack of consistent patterns of contamination at the lower San Juan sites (SJR at Mexican Hat and SJR above Lake Powell) may be an indication that the contaminated sediments from the GKM release have not been transported to these locations yet.

Table 3. Human Health–Based Screening Values for Soils

Analyte	CAS #	Units	Soil CV (ppm)/(mg/kg)	
			Health-Based Comparison Value for Water Ingestion (CV) [Total Metals]	CV Type and Source
Aluminum	7429-90-5	mg/kg	50,000	Child Chronic EMEG
Antimony	7440-36-0	mg/kg	20	Child RMEG
Arsenic	7440-38-2	mg/kg	15	Child Chronic EMEG
Barium	7440-39-3	mg/kg	10,000	Child Chronic EMEG
Beryllium	7440-41-7	mg/kg	100	Child Chronic EMEG
Cadmium	7440-43-9	mg/kg	25	Child Intermediate EMEG
Calcium	7440-70-2	mg/kg	-	No CVs available
Chromium	7440-47-3	mg/kg	250	Child Intermediate EMEG Cr(VI)
Cobalt	7440-48-4	mg/kg	500	Child Intermediate EMEG
Copper	7440-50-8	mg/kg	500	Child Intermediate EMEG
Iron	7439-89-6	mg/kg	55,000	Child RSL
Lead	7439-92-1	mg/kg	400	Child RSL
Magnesium	7439-95-4	mg/kg	-	No Screening Level Available
Manganese	7439-96-5	mg/kg	2,500	Child RMEG
Molybdenum	7439-98-7	mg/kg	250	Child RMEG
Nickel	7440-02-0	mg/kg	1,000	Child RMEG
Nitrate+Nitrite	HZ2100-10-T	mg/kg	-	No Screening Level Available
Nitrite	14797-65-0	mg/kg	5,000	Child RMEG
Potassium	7440-22-4	mg/kg	-	No Screening Level Available
Selenium	7782-49-2	mg/kg	250	Child Chronic EMEG
Silver	7440-22-4	mg/kg	250	Child RMEG
Sodium	7440-23-5	mg/kg	-	No Screening Level Available
Sulfate		mg/kg	-	No Screening Level Available
Thallium	7440-28-0	mg/kg	0.78	Child RSL
Vanadium	7440-62-2	mg/kg	500	Child Intermediate EMEG
Zinc	7440-66-6	mg/kg	15,000	Child Intermediate EMEG
Mercury	7439-97-6	mg/kg	9.4	Child RSL
		<b>RMEG: ATSDR Reference Dose Media Evaluation Guide</b>		
		<b>EMEG: ATSDR Environmental Media Evaluation Guide</b>		
		<b>RSL: EPA Regional Screening Level</b>		

**Table 4.** Summary of Sediment Data in the San Juan River and Comparison to Health-Based Screening Values

		No Exceedence	Above Screening Level					Prior to Plume Arrival					Estimated Plume Arrival					Post Plume Arrival									
			Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc	
		Screening Level Value for Sediment	50000	20	15	10000	100	25		250	500	55000	400		2500	9.4	250	1000		250		0.78	500	15000			
Monitoring Location	Site Description	Collection Date	Collection Time	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		
4954000	Stateline	8/8/2015	1:23:00 PM	16600	ND	3.76	200	0.675	0.309	21900	14.2	4.12	8.65	11400	9.03	7060	280	0.00182	ND	8.11	4870	ND	0.044	722	0.181	29.4	40.1
		8/15/2015	9:43:00 AM	12900	ND	3.2	217	0.541	0.203	9140	12.1	4.14	8.26	11900	6.99	3300	240	0.00535	ND	6.4	2660	ND	0.034	344	0.14	25.3	32
		8/19/2015	8:15:00 AM	16200	ND	3.37	147	0.627	0.237	10600	11.6	4.36	9.9	11800	8.52	4350	246	0.0228	0.496	7.07	3810	ND	0.05	373	0.172	26.4	34.3
		9/23/2015	6:30:00 PM	12600	ND	3.31	313	0.535	0.254	9530	12.1	3.76	6.63	10900	8.27	3490	251	0.00345	0.507	6.25	3180	ND	0.045	413	0.165	28.1	28.8
GK06	McElmo Was	9/23/2015	10:52:00 AM	4920	ND	2.59	280	0.249	0.127	18000	3.82	1.61	2.27	5210	3.78	1780	461	0.00473	1.41	2.23	1810	ND	ND	197	0.08	10.1	13.6
4953990	Montezuma	8/8/2015	2:54:00 PM	6140	ND	1.74	279	0.291	0.122	8470	5.02	1.76	3.43	5530	3.9	1900	156	ND	ND	2.8	1690	ND	ND	145	0.068	13.5	18.5
		8/15/2015	10:30:00 AM	14600	ND	3.16	199	0.566	0.239	11100	13.9	4.23	7.94	12100	7.46	3810	241	0.00569	ND	6.67	3140	ND	0.032	393	0.171	26.7	33.1
		8/19/2015	9:30:00 AM	14100	ND	3.06	198	0.551	0.185	8620	10.4	3.79	6.59	10700	7.6	3390	212	0.00761	0.422	6.22	3180	ND	0.03	440	0.126	23.1	30.6
		9/22/2015	5:55:00 PM	10400	ND	3.04	161	0.437	0.173	20300	8.65	3.26	5.34	8070	7.09	2820	223	0.006	0.355	5.07	5080	ND	0.029	517	0.126	19.7	25.6
		10/26/2015	2:00:00 PM	10400	ND	3.23	175	0.54	0.242	19900	10.4	4.35	7.69	11800	8.36	5550	267	0.00757	0.578	7.98	2790	ND	0.037	400	0.144	21.4	26.7
4953250	Sand Island	8/8/2015	4:19:00 PM	7140	ND	2.13	232	0.321	0.127	7250	5.79	2.12	3.73	6340	4.28	1740	198	ND	ND	2.85	1810	ND	0.055	157	0.096	15.2	18.9
		8/15/2015	11:31:00 AM	10600	ND	2.78	297	0.451	0.17	10500	9.53	3.19	6.35	9630	6.2	3120	223	0.00284	ND	4.96	2540	ND	0.024	277	0.131	22.9	26.7
		8/19/2015	12:33:00 PM	10000	ND	2.31	228	0.381	0.146	7780	6.76	2.77	4.74	8270	5.51	2640	191	0.00565	ND	4.19	2500	ND	0.038	256	0.096	17	23.7
		9/22/2015	1:59:00 PM	4250	ND	2.49	518	0.226	0.0796	4610	2.32	2.18	2.53	7750	4.24	1980	198	0.00301	ND	2.15	535	ND	ND	126	0.064	7.43	20.6
4953000	Mexican Hat	8/8/2015	5:40:00 PM	8780	ND	2.7	271	0.423	0.165	6980	7.72	2.65	5.01	7630	5.52	2190	218	ND	0.43	4.09	2280	ND	0.068	291	0.13	18.9	26.1
		8/15/2015	12:04:00 PM	7480	ND	2.2	213	0.374	0.145	13300	8.76	2.49	3.76	7210	4.75	3340	192	ND	ND	4.5	2120	ND	0.046	201	0.069	16.9	24.5
		8/19/2015	1:03:00 PM	6470	ND	2.06	564	0.289	0.111	7940	5.13	2.53	3.45	7200	4.48	2000	182	0.00368	ND	3.6	1730	ND	ND	190	0.05	16.2	18.7
		9/22/2015	9:56:00 AM	6350	ND	2.26	411	0.272	0.112	8150	5.61	2.15	3.11	5900	4.3	1970	169	0.0019	ND	3.44	1300	ND	ND	193	0.074	14.6	18.4
4952940	Clay Hills	10/26/2015	4:15:00 PM	5300	ND	2.49	171	0.327	0.166	17300	5.23	2.71	4.4	7790	5.19	4120	207	0.00375	ND	4.87	1590	ND	ND	269	0.084	12.7	17.6
		8/15/2015	2:30:00 PM	6160	ND	1.5	251	0.309	0.146	16900	6.31	2.07	2.83	6040	3.96	3550	176	0.00334	ND	3.68	1790	ND	ND	218	0.065	13.7	16.5
		8/19/2015	3:09:00 PM	14400	ND	2.99	181	0.552	0.201	27400	12.4	3.81	5.56	10400	6.31	6580	262	0.00655	ND	8.02	4220	ND	ND	298	0.114	22	25.1
		9/23/2015	1:50:00 PM	2770	ND	1.22	215	0.162	0.0648	9870	3.24	1.41	ND	3760	2.99	1790	171	ND	ND	ND	1130	ND	ND	180	0.056	8.18	11.5
		10/27/2015	2:45:00 PM	2720	ND	1.1	163	0.178	0.087	13300	3.09	1.48	1.85	5190	ND	2780	138	0.00211	ND	2.52	787	ND	ND	113	0.033	6.74	10.4



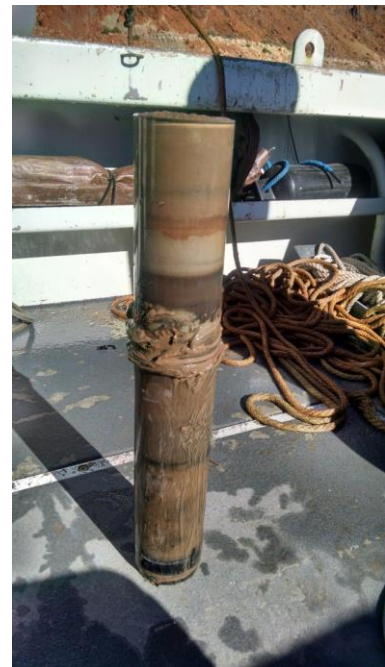
**Figure 7.** Sediment metal concentrations in the San Juan River before and after the GKM plume entered Utah.  
 Note: Sand Island is SJR at Bluff, and Clay Hills is SJR above Lake Powell.

### ***Sediment in Lake Powell***

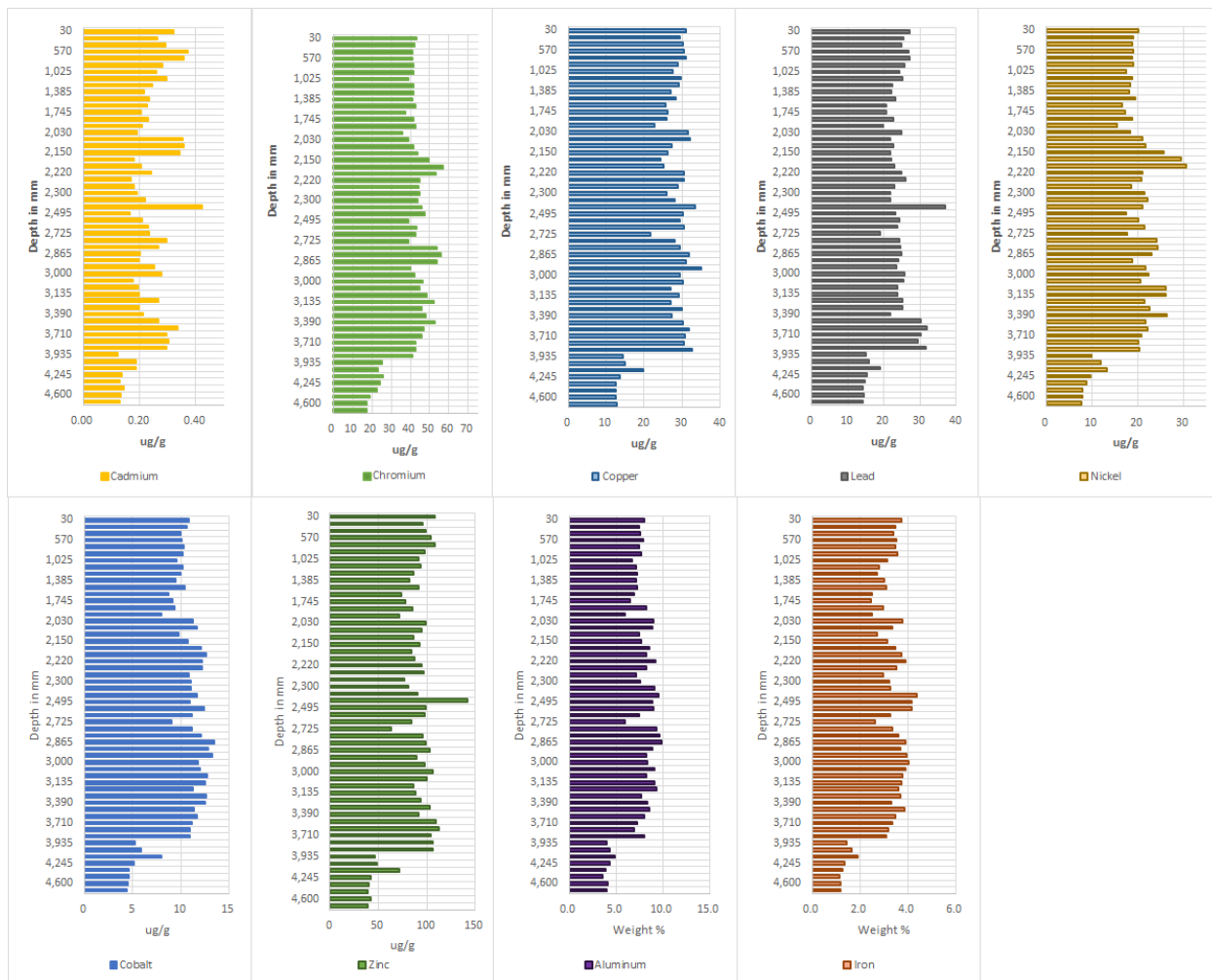
The ultimate fate of sediment transported downstream from the San Juan River watershed in which the GKM spill occurred is Lake Powell, a reservoir in southeastern Utah that has been accumulating sediment from the watershed since its formation in 1963 behind Glen Canyon Dam. Following the spill, sediment traps were deployed by USGS in August 2015 at the terminus of the San Juan River in Lake Powell to assess recent and ongoing deposition and sediment metal concentrations. The traps are designed to capture sediment as it falls to the bottom of the reservoir. At the time of retrieval in November 2015, the 1.5-foot-tall trap was completely full and showed extensive layering, which could signal different storm events in the watershed. Sediment from the traps is currently being analyzed for 42 metals. Additional sediment traps should be re-deployed in this area to capture sediments transported downstream during the spring 2016 runoff period.

Because of concerns from resource managers about the potential health impacts to humans and aquatic wildlife from contaminated sediment transported to Lake Powell, the USGS collected and analyzed sediment cores in 2010 and 2011 in the San Juan and Escalante River deltas of Lake Powell to assess the presence of trace elements and organic compounds. Sediment cores were collected from three locations in the San Juan River in 2010. Out of the 57 major and trace elements analyzed, most were detected at concentrations greater than minimum reporting levels in the sediment core subsamples and composited samples, with the exception of organochlorine pesticides and polychlorinated biphenyls, which were not detected in any samples (Hornewer 2014).

UDEQ also examined the metal concentrations measured in three cores from the San Juan arm of Lake Powell collected in 2010 (Hornewer 2014). Two of the three cores show a marked increase in metals concentration at depth (e.g., approximately 3.9 meters deep at Core 3; Figure 8). USGS estimates that the sediment deposition in the San Juan arm of Lake Powell is at least 0.5 meter per year (Hornewer 2014). Based on the almost 0.5 meter of deposition in the sediment trap collected after only 4 months in 2015, deposition rates can be substantially higher. Assuming a deposition rate of 0.5 to 1.0 meter, the 4.5-meter core in the San Juan arm of Lake Powell may represent 5 to 10 years of sediment deposition. Concentrations of metals (e.g., aluminum, cobalt, chromium, copper, iron, lead, manganese, vanadium, and zinc) in the USGS cores were generally higher than the surficial sediment samples collected in August and October 2015, from the San Juan River but still within the same order of magnitude. The differences between the concentrations measured in the USGS cores and UDEQ sediments cannot be interpreted with any confidence due to the small sample size and lack of age dating. Additional, age-dated sediment cores are needed to assess sediment pollutant concentrations over time.



**Sediment trap deployed in San Juan River Delta, August–September, 2015.**



**Figure 8.** Trace metal concentrations in sediment cores collected by the USGS in the San Juan River delta of Lake Powell in 2010. Graphs were created by UDEQ based on data provided by the USGS in Open File Report 2014-1096 (Hornewer 2014).

### ***Cumulative Load Estimates***

The GKM release represents a small fraction of the total estimated releases from the 48 abandoned mines in the Bonita Peak Mining District in Colorado over the past 100 years. The Department of the Interior (DOI) estimated that 8.6 million tons of tailings have made their way to the riverine environment over the life of the mines (DOI 2015). Releases from GKM itself are also significant over the past decade. Figure 9 shows an estimate of monthly releases from GKM based on discharge values reported by EPA in the [Summary Report: EPA Internal Review of the August 5, 2015 Gold King Mine Blowout](#) (EPA 2015a). Based on these flow estimates, the total cumulative load of releases from GKM exceeds 750 million gallons since 2005 and does not account for releases from adjacent mines. In a recent letter to the State of Colorado in which EPA proposes to add the Bonita Peak Mining District to the National Priorities List for the U.S. Comprehensive Environmental Response, Compensation & Liability Act, EPA estimates that the collective ongoing discharge from the Bonita Peak Mining District averages 5.5 million gallons per day (EPA 2016c, [Letter from EPA to Colorado regarding Proposed Listing of the “Bonita Peak Mining District” site on EPA’s Superfund National Priorities List](#)). Recognizing that the final resting place of metals since the mid-1960s is in the sediments of Lake Powell, UDEQ is very interested in understanding the historic releases of metals from the Bonita Peak Mining District and assessing the effect of legacy metals contamination on Utah’s waters.

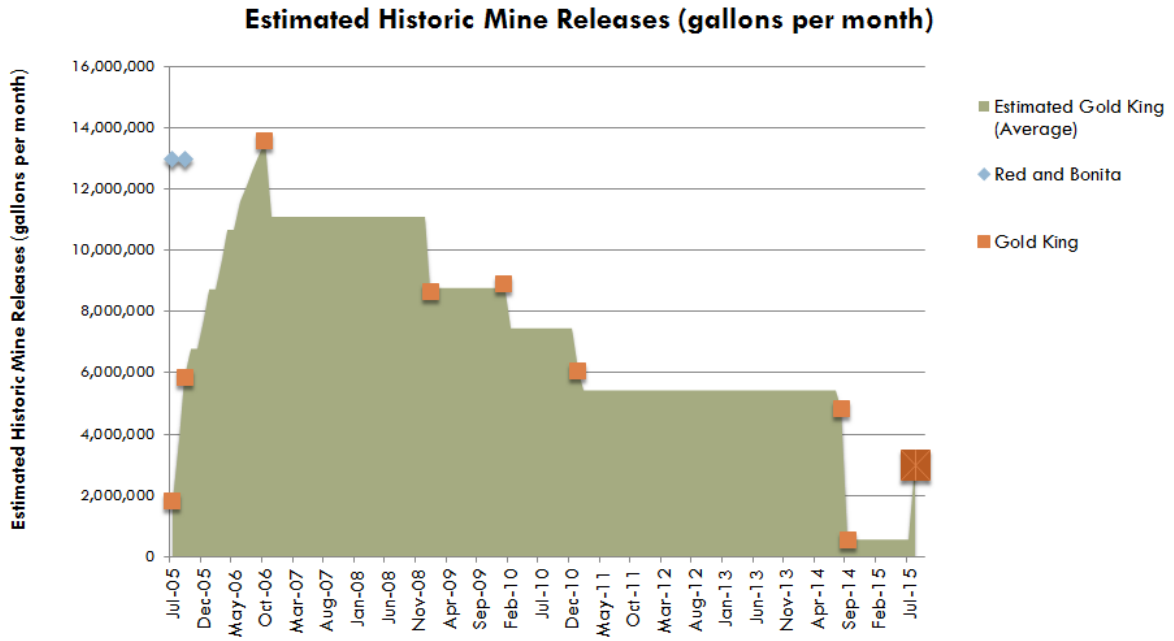


Figure 9. Estimated historic releases of Gold King Mine drainage.

### 3. Long-Term Monitoring and Assessment Plan

Utah’s long-term monitoring and assessment plan for the San Juan River and Lake Powell is framed by the following study objectives and formalized in 13 tasks described in more detail in the sections to follow. The analysis presented in the first section of this document provides the rationale and justification for the proposed monitoring tasks.

#### ***Study Objectives***

1. Do metal concentrations pose a risk to the uses (drinking water, recreation, aquatic life, and agriculture) in the San Juan River during spring runoff, storms, and summer baseflow conditions (Task 1 and Task 3)?
2. Can turbidity or flow be used as surrogates for high dissolved and/or total metals concentration in the San Juan River (Task 2)?
3. What is the historical and ongoing contaminant loading from the mines in the upper San Juan River watershed during the period from Lake Powell construction (mid-1960s) to present, with an emphasis on changes in mine treatment efforts? (Task 6)
4. What is the distribution and concentration of contaminants in the sediments of active depositional areas along the San Juan River (Task 7)?
5. Do the patterns of metal concentrations in the USGS core data reflect changes in treatment/management in the Silverton area (Task 9 and Task 6)?
6. Do observed metal loads pose a risk to plants, livestock, aquatic life, and/or humans (Task 10 and 11)?
7. What are the total loads of metals in the San Juan River as it enters Utah and as it enters Lake Powell (Task 5)? How much of this load is accounted for by tributary loading in Utah? What are other important potential sources of metals in the San Juan River watershed (Task 6)?
8. How does flow, including high flow events, affect sediment, groundwater, and surface water quality (Task 1, Task 2, Task 4, and Task 7)?
9. How do metals loads from the GKM compare to loads from other mines in the San Juan River watershed, especially the Silverton area (Task 6)?
10. Are the recent spikes in metal concentrations in the San Juan River—that exceeded screening criteria for recreation, human health, and aquatic life, among others—associated with resuspension from the recent spill or from chronic, and potentially ongoing mine inputs (Task 5 and Task 6)?

Thirteen tasks are proposed as part of Utah’s long-term monitoring plan. These tasks are intended to help facilitate the development of sustainable methods for identifying and communicating risk to stakeholders. The tasks are listed below and aim to address the study objectives listed above:

- Task 1. Surface water quality monitoring
- Task 2. Real-time reporting of water quality conditions
- Task 3. Public drinking water systems monitoring
- Task 4. Private well monitoring
- Task 5. Total metals load analysis, including Utah tributaries
- Task 6. Inventory of mining sources in San Juan River watershed
- Task 7. Sediment sampling in San Juan River and tributaries



- Task 8. Current metal concentrations in Lake Power sediments
- Task 9. Historic metal concentrations in Lake Powell sediments
- Task 10. Ecological risk assessment
- Task 11. Human health risk assessment
- Task 12. Interagency partnership and collaboration
- Task 13. Public information and stakeholder outreach

### ***Water Quality Monitoring to Protect Uses of the San Juan River***

Water quality data—collected before and after the GKM spill—reveal episodic events where metal concentrations in the San Juan River are sufficiently high to threaten uses associated with human health (recreation or culinary), aquatic life, and agriculture (livestock watering or irrigation). The relative risk that these events pose to these uses is dependent on both the concentration of metals (magnitude of exceedance above water quality benchmarks) and the duration of exposure. A more careful review of periods when the San Juan River has high metal concentrations suggests an association with periods of elevated discharge (see Figures 3 and 4). In this river, these high flow events occur during spring runoff, or immediately following upstream precipitation events. The duration of potential exposure to metals differs between these different high flow conditions, lasting much longer during spring runoff (typically late April through May) than events that follow storms. Although the characterization of metal contaminants during either of these high flow conditions is currently weak, the fact that relationships between metals and TSS are generally much greater than the relationship between metals and flow suggests that these two types of events may have different effects on river pollutants (see Figures 4–6). Addressing ongoing water quality concerns in the San Juan River will require a much more thorough characterization of both high flow conditions.

The episodic nature of these high metal events also has several important ramifications with respect to the ongoing need to communicate water quality conditions to stakeholders. The episodic nature of high metal concentrations suggests that the risk to uses is relatively low for much of the year. However, this does not negate the need to communicate potential risks when metal concentrations are high. Yet, timely communication of risk is complicated by monitoring and sample processing logistics, particularly with respect to storm-related events, where high flows—and potentially high metal concentrations—are intrinsically transitory. Collecting water samples during short-duration events is always challenging, and this is particularly true in remote locations such as the San Juan River. Once samples are collected, data are often unavailable for several days to a week, which means that an event may be over before any risks can be quantified and communicated to the public. UDEQ aims to minimize these complications by conducting frequent data collections, rushing sample processing, using turn-key analytical tools that help streamline data interpretation, and using a well-developed approach for communicating these risks to the public. However, these methods are resource intensive. Fortunately, the strong relationships between TSS and metal concentrations (see Figure 5) suggest that high-frequency, real-time turbidity sensors could be used to communicate risk in a more timely and efficient manner over the long term. However, the use of a turbidity surrogate will require a more thorough understanding of the relationship between TSS, turbidity, and total and dissolved metals under different hydrologic conditions.

The tasks outlined in this section are intended to start filling this data gap during the 2016 Spring Runoff season. UDEQ has determined that assessment of the risks associated with spring runoff and other high flow events requires real-time turbidity monitoring and regular water quality sampling to ensure that the river is safe for all uses. This determination was made based on the following:

- Approximately 3 million gallons of acidic mine water containing more than 400,000 kg of heavy metals was released from Gold King Mine into Cement Creek, which flows into the Animas River before flowing into the San Juan River (USEPA 2016a);

- Much of the material released during the Gold King Mine release has settled into the sediments and shoreline of Cement Creek and the Animas River in Colorado and these metals will be remobilized into the water column in both dissolved and colloidal forms during periods of high flow (USGS 2016a; Church et al. 1997);
- Flow in the Animas River at Durango (USGS gage 09361500) in the weeks and months following the Gold King Mine release are an order of magnitude lower than typical spring runoff flows (200 – 400 cfs versus 2,000 – 7,000 cfs); and
- EPA monitoring data collected during monsoonal storm events in September 2015 show elevated concentrations of dissolved and total metals in the Animas and San Juan Rivers including levels that exceed state water quality criteria and pose a threat to public drinking water systems

Some of the work described in Tasks 1 and 2 are also incorporated into a multi-jurisdiction *Spring Runoff Preparedness Plan*.

## Task 1. Surface Water Quality Monitoring

### Goals:

- Communicate potential risks associated with metal concentrations in the San Juan River to the public and other agencies to provide a basis for ongoing management decisions, especially during the 2016 spring runoff season and summer monsoonal storms.
- Provide data for use in developing statistical relationships between total and dissolved metals and continuously monitored parameters such as flow, turbidity, and/or conductivity to inform future monitoring strategies.
- Use established relationships with high-frequency data to provide data for more detailed analysis of metals loading and patterns during different high flow events to better define sources and fate of metals in the river.
- Contribute to the long-term record of metal concentrations for the San Juan River and its tributaries.

### Actions:

UDEQ will collect water quality samples (total and dissolve metals and major anions and cations) weekly during spring runoff and monthly during non-storm periods at the following San Juan River sampling locations (Table 5):

- MLID 4953000: the San Juan River at Mexican Hat, Utah (SJR at Mexican Hat)
- MLID 4953250: the San Juan River at Sand Island located near the town of Bluff, Utah (SJR at Bluff)
- MLID 4953390: the San Juan River in Montezuma, Utah (SJR at Montezuma)
- MLID 4954000: the San Juan River at Highway 160 bridge crossing, Colorado (SJR at Four Corners)
- MLID 4953880 McElmo Creek at U262 Crossing (McElmo Creek)
- MLID 4953560 Montezuma Creek at U162 Crossing (Montezuma Creek)

Before sampling, the long-term flow record in the San Juan River will be analyzed to identify flows that can be used to define the likely beginning and end of spring runoff conditions.

Water samples will be analyzed by a qualified laboratory within 3 to 4 days after each sampling event. Water quality results will be evaluated against established water quality benchmarks, including Utah’s water quality criteria and other screening values (see Table 2), on an ongoing basis. UDEQ will coordinate data analysis and interpretations among sister agencies (e.g., UDOH, UDAF, and Utah Department of Natural Resources), and disseminate these data interpretations to stakeholders.

UDEQ will contract with the USGS to install and maintain real-time turbidity and conductivity sondes at four existing USGS gaging stations in the San Juan River watershed:

- USGS 09379500 SAN JUAN RIVER NEAR BLUFF, UT
- USGS 09371010 SAN JUAN RIVER AT FOUR CORNERS, CO
- USGS 09372000 MCELMO CREEK NEAR COLORADO-UTAH STATE LINE
- USGS 09379200 CHINLE CREEK NEAR MEXICAN WATER, AZ

The contract will include regular maintenance and calibration of the deployed turbidity meters. In addition, UDEQ crews will collect independent instantaneous turbidity readings when grab samples are collected so that recorded turbidity data can be adjusted for any drift that is observed.

USGS will also be contracted to collect four cross-sectional, integrated water samples at each of the gaging stations. The samples will be spread across varying hydrologic conditions (dry, storm flow, and spring runoff) and will provide an understanding of the representativeness of UDEQ’s grab and ISCO water quality samples.

To evaluate the influence of storms on the San Juan River system, event-based ISCO samplers will be deployed at the four USGS gages and at UDEQ sites on the San Juan River (Table 5). Four separate storms will be sampled at each site with three samples collected per storm. Samples will be timed to represent the rising and the falling limbs of the hydrograph.

**Table 5.** Summary of Proposed 2016 Water Quality Monitoring in San Juan River Watershed in Utah

Location	UDEQ			USGS		
	Monthly Grab Samples	Spring Runoff Grab Samples	Storm ISCO Samplers	Turbidity and Conductivity Probes	Cross-Sectional Integrated Grab Samples	Storm ISCO Samplers
SJR at Four Corners	8	10	–	USGS 09371010	4	12
SJR at Montezuma	8	10	12	–	–	–
SJR at Bluff	8	10	12	–	–	–
SJR at Mexican Hat	8	10	–	USGS 09379500	4	12
McElmo Creek	8	10	–	USGS 09372000	4	12
Montezuma Creek	8	10	12	–	–	–
Chinle Creek	–	–	–	USGS 09379200	4	12

\* Assumes three samples collected during four storm events.

## Task 2. Real-Time Reporting of Water Quality Conditions

### Goals:

- Identify if flow, turbidity, and/or specific conductance thresholds indicate a probability of high metal concentrations in the San Juan River. This would allow timely advisories to be made and could be used as triggers for more in-depth water quality monitoring in the future.

- More accurately calculate total and dissolved metal loads coming into Utah via the San Juan River (McElmo and Montezuma Creeks).
- Calculate total and dissolved metal loads being delivered to Lake Powell.

**Actions:**

Statistical relationships among flow, turbidity, and metal concentrations will be developed for the four instrumented locations in the San Juan River (see Table 5). For each metal and designated use, UDEQ scientists will do the following:

- Quantify the magnitude of any observed excursions over water quality benchmarks (see Table 2).
- Use Receiver Operator Characteristic Curves to determine the turbidity concentration that best predicts—based on minimizing both Type I and II errors—excursions of benchmarks that are observed (McLaughlin 2012, 2014).
- Make recommendations about the future use of real-time turbidity readings to convey risks of metal contamination to potentially affected stakeholders.

This analysis will include a comparison of similarities and differences in metal, anion, or cation concentrations among the four storm-related events. If differences occur, upstream storm data will be evaluated to see if these differences can be ascribed to different storm locations or storm characteristics. For each storm-related event, UDEQ will evaluate the relationship between total and dissolved concentrations and summarize any spatial and temporal trends that are observed and the relative strength of the relationships. Depending on the outputs, event-based collections (e.g., ISCO samples) may be used to estimate the relative risk of water quality benchmarks based on dissolved metal constituents.

**Drinking Water Monitoring**

**Task 3. Public Drinking Water Systems Monitoring**

**Goals:**

- Determine whether the GKM spill will impact the water sources of the public drinking water systems regulated by the State of Utah.
- Ensure that Utah’s public water systems deliver drinking water that complies with the drinking water maximum contaminant levels and action levels.

**Actions:**

- Identify the public drinking water systems regulated by the State of Utah that are located near the San Juan River and identify their active water sources. These are as follows:
  - Mexican Hat (Water System #19008): two wells (North Well WSo01 and Pitless Adaptor Well WSo03)
  - Bluff Water Works (Water System #19002): four wells (1-94 Well WSo04, 1-96 Well WSo05, 2-96 Well WSo06, and Corral Well WSo07)
  - Sand Island (Water System #19071): one well (Sand Island Well WSo01)
- Monitor metal concentrations from the seven identified public drinking water wells in 2016 following a surface water runoff event to the San Juan River, as follows:
  - Take one sample for metals analyses from each well in 2016, preferably following a significant surface runoff event that is anticipated to disturb the river bed sediments.

- Deliver the water samples to a certified laboratory in Salt Lake City for complete metals analysis.
- Compare the 2016 metals results with available historical “new source metals” results.
- Continue to coordinate with these public water systems in regard to compliance source monitoring of the active sources, as a part of ongoing routine requirements by Utah Division of Drinking Water.

#### Task 4. Private Well Monitoring

##### **Goals:**

- Determine whether the GKM spill will impact the private water wells located in the areas regulated by the State of Utah.
- Evaluate whether these private wells deliver the water that complies with the drinking water maximum contaminant levels and action levels.

##### **Actions:**

- Identify the active private drinking water wells in the areas regulated by the State of Utah that are located near the San Juan River, as follows:
  - In all, 60 water rights are identified to be associated with private drinking water wells (based on the available records in the Utah Division of Water Rights’ database).
  - Based on the points of diversion of these 60 water rights, seven private drinking water wells in total are selected to be monitored because of their proximity to the San Juan River:
    - One in Aneth
    - Two in Montezuma Creek
    - Two in Bluff
    - Two in Mexican Hat
  - The selection of these seven private wells is solely based on a database search. The accessibility of these private wells has not been confirmed. Additional private water wells are also identified as backup sampling locations in case the selected private wells are not accessible.
  - UDEQ will coordinate with the San Juan County Health Department and the owners of the selected private wells for permission to monitor the selected wells.
- Establish the “baseline” metals data from the seven selected private wells in early 2016 (before a surface water runoff event affecting San Juan River):
  - Take one sample for metals analyses from each of the selected private wells in early 2016, preferably without a prior significant surface runoff event.
  - Deliver these samples to a certified laboratory in Salt Lake City for complete metals analysis.
- Monitor the “after-storm” metal concentrations from each of the selected private wells in 2016 (following a surface water runoff event affecting San Juan River):

- Take one sample for metals analyses from each selected private wells in 2016, following a significant surface runoff event that is anticipated to disturb the river bottom sediments.
- Deliver these samples to a certified laboratory in Salt Lake City for complete metals analysis.
- Compare the “baseline” dataset with the “after-storm” dataset.

### ***Metals Load Analysis and Source Characterization***

The San Juan River and its major tributaries, the Navajo, Piedra, Los Pinos, Animas, and La Plata Rivers, all have headwaters in the San Juan Mountains. Other tributaries that have large drainage areas are Canyon Largo, Chaco River, Chinle Wash, Montezuma Creek, and McElmo Creek. Metals and other chemicals concentrated in surface water are transported in both the dissolved and suspended phases, with the majority of the contaminant mass occurring in the suspended fraction. Adsorption, precipitation, and co-precipitation are the dominant processes controlling the chemistry and mineralogy of the suspended fraction. The San Juan River transports large volumes of suspended sediment, and the riverbed area is characterized by low-energy environments where mine-waste sediment and associated heavy metals may have deposited and accumulated for decades. Accumulation of contaminated sediments represents long-term potential sources of heavy metal loading into Lake Powell, especially during storm events and snowmelt when resuspension of sediment occurs.

Loading and delivery of metals in the San Juan River are influenced by a number of factors, including elevated background metal concentrations, the presence of mining-related sources in the watershed, natural geologic sources, and the role of hydrology on sedimentation and mobilization of metals. During the initial mine spill response, concentrations of several key metals were elevated in samples collected before the arrival of the mine plume, suggesting that natural geologic, mining, or other sources previously delivered metals to the San Juan River. A short-duration spike in metals was also observed following the mine spill. Task 6 will further investigate other mining-related sources, historic and current, that contribute to metals loading in the watershed.

The hydrologic regime of the San Juan River watershed is the largest contributing factor to how metal loads are delivered to and transported throughout the river. Flow in the San Juan River is largely influenced by spring snowmelt, summer monsoon rain events, and reservoir release from Navajo Lake, each of which affects the magnitude and duration of discharge and results in different metal concentrations and loading characteristics. Much of the metal loading to the San Juan River occurs episodically during high flow events. The proposed monitoring throughout this plan and the tasks outlined in this section will be used to develop a more accurate characterization of metal loads.

#### **Task 5. Total Metal Load Analysis, including Utah Tributaries**

##### ***Goal:***

- Calculate total metal loads entering Utah through the San Juan River and entering Lake Powell.
- Estimate contribution of total metal loads from major tributaries entering the San Juan River in Utah.
- Determine the relative importance of loading during spring runoff, storm events, and baseflow conditions.

### **Actions:**

Characterize metal loading in the main stem of the San Juan River and three tributaries during at least three different flow regimes (spring runoff, storm events, and baseflow conditions) through the following subtasks:

- **Data compilation:** Discharge, total metals, and dissolved metals will be compiled from a variety of data sources (e.g., UDEQ, EPA, USGS, New Mexico, Arizona, Colorado, and USGS) for locations where water quality data can be paired with daily discharge. Data collection for this task will occur as described in Tasks 1 and 2. Collection will occur at seven sites—four on the main stem of the San Juan River (SJR at Four Corners, Montezuma, Bluff, and Mexican Hat) and three at major tributaries in Utah (Montezuma Creek, McElmo Creek, and Chinle Creek)—at varying frequency. Data collection will include a combination of targeted storm and snowmelt runoff sampling, monthly grab sampling, ISCO storm event sampling, integrated cross-section samples, and long-term sonde deployments. Outputs of this subtask will include the following:
  - Compilation of USGS continuous flow record at Four Corners, Bluff, McElmo Creek, Chinle Creek, and two upstream gages with paired flow and water quality records.
  - Compilation of total and dissolved metals from paired water quality stations.
  - Compilation of historical water quality data for total and dissolved metals for Bluff, Four Corners, McElmo Creek, Chinle Creek, and selected upstream locations.
  - Compilation of regional weather observation data to characterize precipitation events in the San Juan River Basin.
- **Characterize hydrologic events:** The flow duration curve methodology will be used to characterize flow regimes that represent high flow, low flow, and mid-range flow conditions for each selected long-term USGS discharge locations. The hydrographs will also be paired with regional weather observations to determine timing of storm and other hydrologic events. The flow duration method allows for comparison of water quality at each flow regime to help determine the magnitude, duration, and timing of significant loading events. If necessary, separate flow duration curves will be developed for spring runoff. The outputs that form this subtask will be as follows:
  - Identification of major flow regime groups representing low flow, mid-range, storm, and runoff events.
  - Identification of event-driven loading episodes associated with spring snowmelt, rain-on-snow events, and summer monsoon events.
  - Determination of the subbasin origin of these events and differentiation from events occurring in Utah, New Mexico, and Colorado subwatersheds.
- **Characterize metals loading in the San Juan River:** Metals delivery to the San Juan River likely occurs from a variety of sources, including those upstream of the Four Corners, tributary inputs, and sediment resuspension. The load duration curve methodology will be employed to summarize the magnitude, duration, and timing of each source for a variety of hydrologic conditions related to snowmelt and precipitation events. Loading will also be summarized on a monthly and annual basis. This analysis will be used to compare loading between the SJR at Four Corners site with the expected load delivered from the San Juan River at sites further upstream of the Utah state line. An additional comparison between the SJR at Four Corners and SJR at Mexican Hat sites (paired with USGS gages at those locations) will help characterize changes in magnitude, loading from tributary influences, and the timing of loads for each identified flow regime. The products of this subtask include the following:

- Metals loading estimates for identified flow regimes and event-driven episodes.
  - A comparison of loading at the Four Corners to calculated upstream loading from the San Juan River.
  - A characterization of transport and delivery of metals load between the Four Corners and Bluff USGS gaging stations and corresponding UDEQ monitoring sites.
  - A characterization of tributary loading inputs from Chinle Creek and McElmo Creek for each flow regime.
  - Inventory of major contributing sources of metals to the Utah segment of the San Juan River.
- Investigate results of turbidity/metals relationships developed in Task 1 to determine potential real-time metal loading predictions.
  - Characterize changes in metal concentrations over both the rising and fall limb of spring runoff flows. Summarize any trends in metal concentrations observed. Use any temporal trends that are observed to stratify the data into distinct phases of spring runoff. Within each stratum, compare each metal concentration against water quality benchmarks (see Table 2) to define metal-specific periods of greatest risk. For each metal, calculate the magnitude of any observed excursions over each water quality benchmark, and rank each metal among all spring runoff samples and among samples within any temporal strata that are identified.
  - Develop quantitative estimates of the magnitude and duration of metal concentration during storm-related events. Evaluate and summarize spatial and temporal trends that are observed. For each event, identify and rank metals of concern by comparing metal concentrations against water quality benchmarks for each protected use (see Table 2). Evaluate and summarize any spatial or temporal trends that are observed with respect to the magnitude that each metal exceeds any water quality benchmark.
  - Compare and contrast differences in metal concentrations between spring runoff and storm-related high flow events. Identify time periods where metal concentrations are of greatest concern by comparing observed concentrations against water quality benchmarks.

#### Task 6. Inventory of Mining Sources in San Juan River Watershed

##### **Goal:**

- Identify and characterize mines and mine discharges of pollutants into the San Juan River.
- Identify distinct elemental ratios, mineral assemblages, and shape that can be used to trace mining sources from GKM and other mines in Bonita Peak Mining District.

##### **Actions:**

UDEQ supports efforts to develop a comprehensive historic accounting of metals loading from mining sources in the Silverton area, as well as other significant mining sources in the San Juan River watershed. UDEQ has determined that the USGS is the most qualified agency to conduct an updated comprehensive study of metals loading. Alternatively, such an analysis could be completed by qualified experts in Utah, New Mexico, and Colorado. UDEQ is discussing this task with New Mexico Environment Department (NMED). A placeholder budget has been allocated by EPA for comprehensive synthesis, and the costs have been proposed to be shared between NMED and other states and tribes. The study should not be limited to the GKM. The outputs that UDEQ would be most interested in from such a study are as follows:



- Ongoing metals loading (by individual metal), based on current flow rates and water quality data, cumulatively from mines in the Silverton area. Such loading estimates should be reported as annual averages and maximums.
- Estimates of metals loading since 2000 (by individual metal) cumulatively from mines in the Silverton area. These estimates could be based on representative flow data or modeled values and contemporary water quality data.
- Historic accounting of total metals load from the Silverton area with demarcation in the 1960s when Lake Powell was constructed.
- Compilation of timeline for all mines in the Silverton area detailing changes in mine discharge and treatment.
- Survey tailings locations and tributaries to Animas/San Juan system. Measure via sequential leaching the elemental makeup of the particle surfaces (quad ICP-MS). Measure the mineralogy of suspendable particles (QEMscan). Measure specific isotopes depending on predominant elements (MC-ICP-MS). Measure particle size distribution and shape in suspendable size range (laser diffraction/optical). Perform these measurements for all tailings sources in the same tributary as GKM, for sediment at tributaries to Animas and San Juan rivers, and for sediment cores in Lake Powell.

UDEQ recognizes that the Silverton area is not the only source of mine discharge in the San Juan River watershed. Utah aims to work collaboratively with other states and tribes in the watershed to compile a comprehensive inventory of abandoned mines that are discharging. To this end, Utah has budgeted to account for abandoned mines in Utah through the following tasks:

- 1) Inventory all mines in the Utah portion of the San Juan River watershed that are sources of metals to the San Juan River:
  - a. Compile existing data on history, inventory, and characterization of mine features in the watershed, including water impounded in mine workings, ongoing mine water seeps, waste rock, and mill tailings piles.
  - b. Establish a GIS database.
  - c. From existing data, develop a list of high-risk features to examine, including preparation of maps.
  - d. Field-examine each site, including field tests.
- 2) Quantify mine waste flow from major mines in the San Juan River:
  - a. Develop a sampling plan.
  - b. Establish monitoring stations.
  - c. Field-examine, characterize, and surface-sample high-risk mine features in the San Juan River watershed, including sampling water impounded in mine workings, ongoing mine water seeps, waste rock, and mill tailings piles.
  - d. Conduct laboratory analyses.
  - e. Create final report, including results of the analyses listed above and the following:
    - Maps with locations of mines, tailings, and water seeps.
    - Labeled digital photograph(s) of mine features.

- Data sheets for each site to be used in the database.
- 3) Determine metals signature from mine waste (e.g., add strontium and anions) and clarify whether other metals detected in the San Juan River can be attributed to a different source (e.g., barium):
  - a. Identify other potential sources of metals contamination.
  - b. Determine risk of sources other than mines that have a high potential of affecting the water quality of the San Juan River and Lake Powell.

### ***Accumulation of Metals in the San Juan River and Lake Powell Sediments***

Sediment sampling for metal pollutants is necessary to meet several study objectives related to accumulation and long-term storage of metals in the Utah section of the San Juan River and Lake Powell. Pollutant metals may be present in either a solid or dissolved state and in small-diameter solids (e.g., silt and clay size) that can be suspended in the water column. Dissolved metals can also precipitate to a solid form. Water samples can be used to quantify the dissolved and suspended solids of the metals. Sediment sampling is necessary to characterize the portions of the metals pollutants from the GKM and other mine releases that are partitioned to the solids that settle as sediment. In locations that are conducive to long-term deposition of sediments, sediment cores can be used to characterize historical loadings of metals pollutants. Beginning with the completion of Glen Canyon Dam in 1963, the sediment from the San Juan River has been accumulating in Lake Powell and will continue to accumulate for the foreseeable future. Sediment concentrations can be used to characterize temporal and spatial distribution of pollutants (nature and extent) within the lake.

#### **Task 7. Sediment Sampling in San Juan River and Tributaries**

##### **Goal:**

Measure and characterize pollutant concentrations in sediment to assess accumulation and long-term storage of metals in the San Juan River and Lake Powell.

##### **Actions:**

- Identify three sediment collection sites in depositional areas within the active channel (between bankfull margins) of the river near the following sites along the San Juan River and tributaries:
  - MLID 4953000: the San Juan River at Mexican Hat, Utah (SJR at Mexican Hat)
  - MLID 4953250: the San Juan River at Sand Island, Utah (SJR at Bluff)
  - MLID 4953390: the San Juan River in Montezuma, Utah (SJR at Montezuma)
  - MLID 4954000: the San Juan River at the Highway 160 bridge crossing in Colorado (SJR at Four Corners)
  - MLID 4953880 McElmo Creek at U262 Crossing (McElmo Creek)
  - MLID 4953560 Montezuma Creek at U162 Crossing (Montezuma Creek)
- Identify three areas at each of these sites where sediment samples can be collected from the active floodplain (above bankfull channel).
- Collect three composite samples of recently deposited sediment (< 6 inches) following existing UDEQ standard operating procedures immediately following the end of spring runoff and in late autumn for a total of 60 sediment samples (5 sites × 3 replicates × 2 locations (floodplain and active channel) × 2 seasons). Incorporate the resulting data as parameters in the ecological risk assessment analyses.

- Analyze grain size from each sediment sample to investigate the potential inverse correlation between metal concentrations and grain size due to increased sorption surface area with smaller grain sizes.
- Analyze metal concentrations from each sediment sample.

#### Task 8. Current Metal Concentrations in Lake Powell Sediments

##### **Goal:**

To evaluate the current pollutant loading via sediment transport to Lake Powell, sediment traps will be placed in the San Juan River delta of Lake Powell. Sediment traps were deployed soon after the GKM release, and these sediments will be analyzed for metals. The traps will be redeployed in 2016, and sediments will be collected and analyzed. The metal concentrations will be used in conjunction with the core concentrations to estimate potential health risks to ecological receptors. In addition, a survey of particle size will help demonstrate if metals are preferentially depositing in specific areas of Lake Powell and the San Juan River system. Smaller-sized particles will carry the majority of toxic element mass, such that the major inputs of toxic elements to Lake Powell will coincide with mobilization of fine particles.

##### **Actions:**

- Analyze USGS sediment traps from Lake Powell for metals.
- Redeploy three sediment traps in 2016 in three locations in the San Juan River delta of Lake Powell.
- Survey slack water deposits upstream of Lake Powell. Measure suspended particle sizes (filtration and laser diffraction), suspended particle concentration in water (gravimetric), and trace element concentrations on suspended particles as a function of particle size (quad ICP-MS).

#### Task 9. Historic Metal Concentrations in Lake Powell Sediments

##### **Goal:**

To evaluate historic loading via sediment to Lake Powell and current concentrations in surficial sediments for the ecological risk assessment, USGS will repeat the 2010–2011 study of sediment deposition in the San Juan delta and add core sampling sites in the Colorado River delta of Lake Powell.

##### **Actions:**

- Three cores will be taken close to the previous core locations in the San Juan River delta.
- Signature from mine wastes will be evaluated in the cores using stable isotope analyses.
- Evaluate pore water in Lake Powell cores if possible to determine if reducing conditions are driving solubilization of metals.

#### ***Assess Impacts of Metal Contaminants on San Juan River and Lake Powell Uses***

The San Juan River and Lake Powell have the designated uses of Class 1C, culinary water with prior treatment; Class 2A, frequent primary and secondary contact recreation; Class 3B, warm water aquatic life; and Class 4, agricultural uses. Each of these uses has associated numeric water quality criteria intended to protect the uses related to people, ecological receptors, livestock, and crops. When water concentrations exceed these criteria, the water quality is designated as not supporting the designated use and is therefore impaired. Water quality can be designated as impaired for exceedances of numeric criteria or the UAC R-317-2-7 [Narrative Standards](#). Pollutant concentrations with no numeric criteria are compared to the Narrative Standards to evaluate use support. In addition to comparisons to applicable

numeric criteria, UDEQ will evaluate the impacts of the metals contaminants using EPA protocols for ecological and human health risk assessments. The risk assessments will be used to determine compliance with the Narrative Standards and to provide additional risk characterization for pollutants that exceed their numeric criteria.

#### Task 10. Ecological Risk Assessment

##### **Goals:**

- The ecological risk assessment will be used to identify if remediation, administrative controls, engineering controls, or no further action is warranted by evaluating the potential for adverse effects to ecological receptors from pollutants in the San Juan River and Lake Powell.
- Outputs from these analyses and biological sampling being conducted by EPA and other states and tribes will be used to inform whether additional future actions such as biological monitoring are warranted for the San Juan River and Lake Powell in Utah.

##### **Actions:**

An ecological risk assessment is an established EPA process for “evaluating how likely it is that the environment may be impacted as a result of exposure to one or more environmental stressors” (EPA 2015b). UDEQ will contract with qualified environmental consultants to conduct a screening-level ecological risk assessment following EPA risk assessment guidelines.

Ecological receptors for the San Juan River are expected to include plants, sediment and water invertebrates, fish, and the terrestrial receptors of waterfowl, birds, and mammals. The sediment data collected under Tasks 7, 8, and 9 will be used for the assessments. Dissolved metal water quality data (Task 1 and historic) will be used to assess the potential for adverse effects to fish and aquatic invertebrates. The resulting analysis will do the following:

- Assess the potential for adverse effects to birds and mammals from exposure via food items using pollutant concentrations measured in invertebrates.
- Assess the potential for adverse effects to plants, invertebrates, and fish from direct exposure to pollutants in water.
- Assess the potential for adverse effects to birds and mammals from pollutant exposure in drinking water by comparison to livestock assessments (total recoverable metal concentrations) or toxicity reference values for birds and mammals.
- Evaluate whether elevated pollutant concentrations in the San Juan River are resulting in higher concentrations in macroinvertebrates or fish when compared to similar systems (three reference locations, unimpacted tributaries to San Juan River or Lake Powell).
- Assess the potential for adverse effects to invertebrates from exposure to pollutants using sediment concentrations in the San Juan River delta of Lake Powell using data collected from USGS sediment cores and sediment traps.

#### Task 11. Human Health Risk Assessment

##### **Goals:**

- The human health risk assessment will be used to identify if remediation, administrative controls, engineering controls, or no further action is warranted by evaluating the potential for adverse effects to humans from pollutants in the San Juan River and Lake Powell.

### **Actions:**

As defined by EPA, a human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future.

Humans can be exposed to pollutants in the San Juan River water when using the river as a source of culinary water. Humans can also be exposed to waterborne pollutants when recreating (wading, boating, swimming). Humans may also be exposed to pollutants from fish consumption. Water from the San Juan River is also used for irrigating crops and watering livestock, and pollutants may cause adverse effects such as reduced yields or illnesses in the livestock. It is UDEQ's and UDOH's opinion that a comprehensive assessment of all human exposure scenarios (residential, recreational, occupational, food-chain, etc.) to the river and its sediments will provide valuable information to better guide considerations of the future uses of this resource. UDEQ will contract with qualified environmental consultants to conduct a human health risk assessment following EPA risk assessment guidelines.

In addition to potential exposures to pollutants in the water, humans may also be incidentally exposed to pollutants in the sediment when working on the irrigation conveyances or recreating on the river. Using the turbid water for irrigation may also result in pollutant loading on fields used for crops. A human health risk assessment will do the following:

- Assess the potential human health risk presented by use of the San Juan River as a culinary water source using dissolved water concentrations of pollutants.
- Assess the potential for adverse health effects to humans from incidental exposure during recreational or agricultural activities using sediment concentrations.
- Assess the potential for adverse health effects to humans from incidental exposure to pollutants during recreational activities using total pollutant concentrations in water.
- Assess the potential for changes in risk with changing metal concentrations driven by flow. Use the human health risk assessment to evaluate whether risks vary enough to warrant different recommendations under different flow regimes.

## **Coordination and Outreach**

### **Task 12. Interagency Partnership and Collaboration**

#### **Goal:**

Continue to collaborate with partner state agencies to ensure that UDEQ decisions and actions support the needs of other agencies and reduce duplication of sampling where possible.

#### **Actions:**

- Distribute information to UDOH, Utah Division of Wildlife Resources, Utah Division of Drinking Water, UDAF, and Utah Division of Oil, Gas and Mining via email for review before materials are released to the public.
- Partner with Navajo Nation Environmental Protection Agency to improve monitoring efficiency and data sharing in areas of the San Juan River that are jointly managed by UDEQ and the Navajo Nation Environmental Protection Agency.
- Attend and participate in conferences and meetings regarding the GKM spill proposed by New Mexico, Colorado, and EPA.

## Task 13. Public Information and Stakeholder Outreach

### **Goal:**

Keep the public informed of the results from the monitoring and research efforts outlined in this plan. Provide opportunities for public input on the progress and direction of monitoring activities.

### **Actions:**

- Public information:
  - Distribute information to the public via the Utah Division of Water Quality website, Facebook, and Twitter to ensure that citizens and stakeholders are informed and their concerns are addressed.
  - Hold two local update meetings within the San Juan River Basin to present information and solicit public input.
  - Publish press releases, as deemed appropriate by UDEQ public information officer, in consultation with public information officers from other agencies.
- Technical stakeholder information:
  - Use the Lake Powell Stakeholder and Technical Advisory Committees to bring together academics, agencies, representatives, and community members to provide a forum for addressing questions and concerns over the GKM spill and the continuing monitoring efforts.

## 4. Budget

**Table 6.** Budget

Task	UDEQ Costs	Laboratory Costs	Contracted Costs	Total
Task 1. Surface water quality monitoring	\$131,357	\$146,016	\$50,300	\$327,673
Task 2. Real-time reporting of water quality conditions	\$8,699	\$0	\$91,720	\$100,419
Task 3. Public drinking water systems monitoring	\$1,236	\$3,500	\$0	\$4,736
Task 4. Private well monitoring	\$3,800	\$7,000	\$0	\$10,800
Task 5. Total metals load analysis, including Utah tributaries	\$29,383	\$0	\$0	\$29,383
Task 6. Inventory of mining sources in San Juan River watershed	\$13,255	\$11,056	\$125,000	\$149,311
Task 7. Sediment sampling in San Jan River and tributaries	\$7,574	\$10,008	\$0	\$17,582
Task 8. Current metal concentrations in Lake Powell sediments	\$3,364	\$0	\$23,100	\$26,464
Task 9. Historic metal concentrations in Lake Powell sediments	\$3,364	\$0	\$375,000	\$378,364
Task 10. Ecological risk assessment	\$3,438	\$3,336	\$44,000	\$50,774
Task 11. Human health risk assessment	\$3,438	\$0	\$44,000	\$47,438
Task 12. Interagency partnership and collaboration	\$19,671	\$0	\$0	\$19,671
Task 13. Public information and stakeholder outreach	\$12,963	\$0	\$0	\$12,963
Project management	\$53,776	\$0	\$0	\$53,776
<b>Total</b>	<b>\$295,318</b>	<b>\$180,916</b>	<b>\$763,120</b>	<b>\$1,229,354</b>

### **Cost Assumptions**

#### **Task 1. Surface Water Quality Monitoring**

- 22 UDEQ-led sampling events that will include six sites each: 10 collection events for spring runoff and monthly samples outside of the spring runoff period for a total of 22 sampling events runs.
- Each monitoring run will depart from Salt Lake City and will require 80 hours of staff time (includes travel time, preparation, and post-run activities).
- Each monitoring run will require 2 nights lodging and 3 days of per diem for two members of the monitoring staff.
- Ambient water chemistry samples will include 60 dissolved metals and 60 total metals with major anions and cations.
- An additional 15 quality assurance/quality control samples will be used for filtered metals and total metal duplicates.
- UDEQ staff will conduct monitoring, but this may change if a local contractor can be engaged.
- UDEQ staff will conduct data analysis and review.
- American West Analytical Laboratories (AWAL) will conduct all analyses.
- 24-hour sample turn around will not be required for more than 15 samples.
- UDEQ will purchase seven ISCO samplers to be used by USGS (4 samplers) and UDEQ (3 samplers) during four storm sampling events.

- All samples collected with ISCO samplers will be sent to AWAL or to the Utah Public Health Laboratory.

#### Task 2. Monthly Surface Water Monitoring

- USGS will deploy and maintain for 1 year four turbidity probes in the San Juan River system (two in the main stem and two in the tributaries).
- UDEQ staff will develop statistical relationships between continuous parameters (turbidity, conductance, and flow) and total and dissolved metals.

#### Task 3. Public Drinking Water Systems Monitoring

- One water sample will be collected from each of the seven active public drinking water wells following a surface water runoff event.
- Sample costs will include analytical costs at a commercial laboratory and labor and transportation costs for sample collection.
- Complete metals analysis will consist of 23 metals:
  - By inductively coupled plasma (ICP) (EPA Method 200.7): aluminum, barium, beryllium, boron, calcium, chromium, copper, iron, magnesium, manganese, nickel, potassium, sodium, silica, and zinc.
  - By ICP/mass spectrometry (MS) (EPA Method 200.8): antimony, arsenic, cadmium, lead, mercury, selenium, silver, and thallium.

#### Task 4. Private Well Monitoring

- Two water samples (“baseline” sampling and “after-storm” sampling) will be collected from each of the seven selected active private drinking water wells located near the San Juan River in 2016.
- Sample costs will include analytical costs at a commercial laboratory and labor and transportation costs for sample collection.
- Because of the extensive work in local coordination, identifying viable private well sampling sites, and obtaining permission to access these sites from well owners, the Task 4 UDEQ cost includes the costs associated with both UDEQ staff and San Juan County Health Department staff.
- Complete metals analysis will consist of 23 metals:
  - By ICP (EPA Method 200.7): aluminum, barium, beryllium, boron, calcium, chromium, copper, iron, magnesium, manganese, nickel, potassium, sodium, silica, and zinc.
  - By ICP/MS (EPA Method 200.8): antimony, arsenic, cadmium, lead, mercury, selenium, silver, and thallium.

#### Task 5. Total Metal Load Analysis, including Utah tributaries

- Analytical work will be completed by UDEQ staff.

#### Task 6. Inventory of Mining Sources in San Juan River Watershed

- Work will be completed by UDEQ staff.
- Two UDEQ employees will conduct site assessments for 6 to 8 mine sites (120 hours of labor).
- Sixteen samples (two per site) will be sent for laboratory analysis.
- Budget will be combined with New Mexico Environment Department task ongoing release inventory.



#### Task 7. Sediment sampling in San Juan River and Tributaries

- If collecting deep samples (< 6 inches), six access locations with five samples at each location. Five locations from the SJR at Bluff to SJR at Four Corners site and one in the SJR above Lake Powell site. Gradient in between the SJR at Bluff and SJR above Lake Powell sites suggests low deposition potential and access difficult.
- Sediment sample monthly or same frequency as water sampling, 5 samples/location × 5 locations × 12 months = 300 samples, plus 10% quality control = 330 samples.
- Note: monitoring staff time is imbedded in Task 1.
- Analysis of sediment data will be completed by UDEQ staff.

#### Task 8. Current Metal Concentrations in Lake Powell Sediments

- Analysis of sediment for pollutants in existing samples is already covered in Task 1.
- Sediment traps will be deployed at three locations in the San Juan arm of Lake Powell.
- Sediments samples will be analyzed for metal contaminants.
- Replication of USGS sediment core study in the San Juan arm of Lake Powell in 2016.
- University or agency partner will conduct stable isotope analyses on cores to determine if signature from Bonita Peak Mining District can be identified.

#### Task 9. Historic Metal Concentrations in Lake Powell Sediments

- Three locations will be sampled in the San Juan River Delta (additional sites may be samples in Colorado River delta using other funds).

#### Task 10. Ecological Risk Assessment

- Additional water or sediment data collection analyses data not needed.
- 10 + 2 quality control macroinvertebrates samples (six San Juan, four reference) analyzed for pollutants.
- 400 contractor hours assumed.
- Data already validated and compiled.
- Construct/update conceptual site model.
- Evaluate potential fate and transport of pollutants.
- Compare water concentrations to aquatic life criteria from six locations during storm and baseline conditions.
- Compare Lake Powell surficial sediment concentrations measured by USGS to toxicological benchmarks.
- Compare San Juan River sediment concentrations from each location (6) to toxicological benchmarks.
- Evaluate exposures to higher organisms via food web using invertebrate concentrations at six locations.
- Use livestock evaluation to compare to mammalian wildlife.
- Compare invertebrate concentrations in San Juan River and San Juan River delta of Lake Powell to three reference sites (unimpacted tributaries to San Juan or Lake Powell) (one-time reference site sampling).

#### Task 11. Human Health Risk Assessment

- Additional water or sediment data collection specific to human health data not needed.
- Two scenarios will be evaluated: high flow and base flow.
- Estimate 400 hours, including agricultural assessment.

#### Task 12 Interagency Partnership and Collaboration

- Four trips to New Mexico or Colorado for UDEQ staff to coordinate with other jurisdictions.
- Five trips to Bluff, Utah, to coordinate with local authorities and Navajo Nation.

#### Task 13. Community Outreach and Involvement

- Three UDEQ staff will attend conference hosted by NMED.
- Updates will be made to webpage monthly and four times during spring runoff.
- Two public meetings will be hosted in the San Juan River area (e.g., Bluff, Utah).
- The Lake Powell Stakeholder Group/Technical Advisory Committee will participate in one.
- Presentations will be made to stakeholder groups in Utah, including Utah Environmental Health Association, Water and Environment Association of Utah, and American Water Resources Association (Utah Chapter).

## 5. References

- Church, S.E., et al., 1997. Source, Transport, and Partitioning of Metals between Water, Colloids, and Bed Sediments of the Animas River, Colorado, USGS Open-File Report 97-151
- Hornever, N.J., 2014. *Sediment and Water Chemistry of the San Juan River and Escalante River Deltas of Lake Powell, Utah, 2010–2011*. U.S. Geological Survey Open-File Report 2014-1096, 7 p. Available at: <http://dx.doi.org/10.3133/ofr20141096>. Accessed March 16, 2016.
- McLaughlin, D.B. 2012. Assessing the predictive performance of risk-based water quality criteria using decision error estimates from receiver operating characteristics (ROC) analysis. *Integrated Environmental Assessment and Management* 8(4):674–684.
- . 2014. Maximizing the accuracy of field-derived numeric nutrient criteria in water quality regulations. *Integrated Environmental Assessment and Management* 10(1):133–137.
- National Academy of Science (NAS). 1972. *Water Quality Criteria, 1972*. A Report of the Committee on Water Quality Criteria. Washington, D.C.: Environmental Studies Board, National Academy of Science and National Academy of Engineering.
- U.S. Department of Interior (DOI). 2015. *Technical Evaluation of the Gold King Mine Incident San Juan County, Colorado*. Available at: <http://www.usbr.gov/docs/goldkingminereport.pdf>. Accessed March 16, 2016.
- U.S. Environmental Protection Agency (EPA). 2004. *2004 Guidelines for Water Reuse*. EPA/625/R-04/108. Available at: <http://nepis.epa.gov/Adobe/PDF/30006MKD.pdf>. Accessed March 16, 2016.
- . 2015a. *Summary Report: EPA Internal Review of the August 5, 2015 Gold King Mine Blowout*. Available at: [https://www.epa.gov/sites/production/files/2015-08/documents/new\\_epa\\_nmt\\_gold\\_king\\_internal\\_review\\_report\\_aug\\_24\\_2015fnldated\\_redacted.pdf](https://www.epa.gov/sites/production/files/2015-08/documents/new_epa_nmt_gold_king_internal_review_report_aug_24_2015fnldated_redacted.pdf). Accessed March 16, 2016.
- . 2015b. Ecological Risk Assessment. Available at: <https://www.epa.gov/risk/ecological-risk-assessment>. Accessed March 16, 2016.
- . 2016a. Presentation on February 5, 2016 to States, Tribes, and Local Health Officials in Denver. <https://www.epa.gov/sites/production/files/2016-02/documents/analysisfatetransportmetals.pdf>. Accessed March 16, 2016.
- . 2016b. Gold King Mine Acid Mine Drainage Release: DRAFT Analysis of Fate & Transport of Metals in the Animas & San Juan Rivers. Presentation presented to the Animas River Team, National Exposure Research Lab/EPA, February 5, 2016.
- . 2016c. Letter from EPA to Colorado regarding Proposed Listing of the “Bonita Peak Mining District” site on EPA’s Superfund National Priorities List. Available at: <https://www.epa.gov/sites/production/files/2016-02/documents/letterfromgovhickenlooperrebonitapeaksuperfunddesignation29feb2016.pdf>. Accessed March 16, 2016.