Gold King Mine Release – Analysis of Fate and Transport in the Animas and San Juan Rivers

Session 1

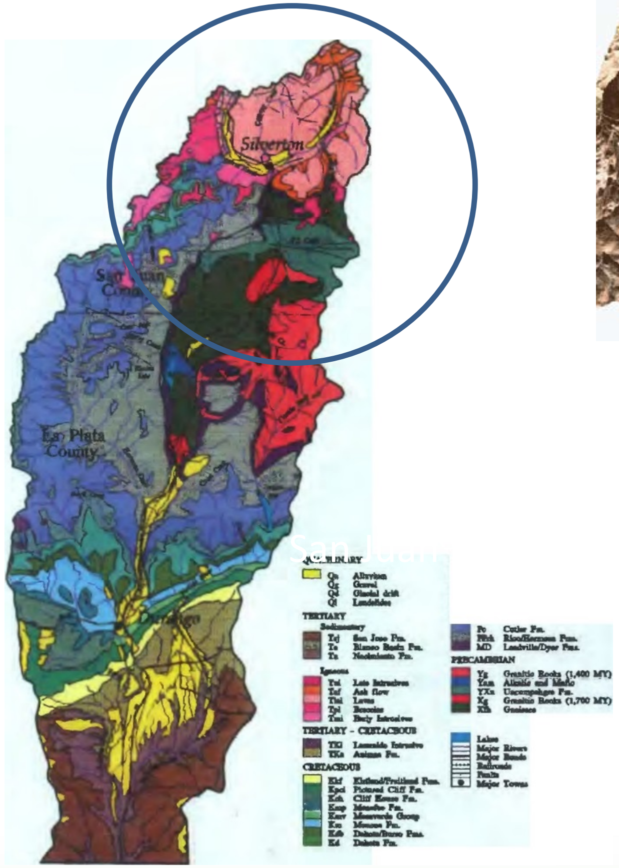
Gold King Mine Team
National Exposure Research Lab/ORD

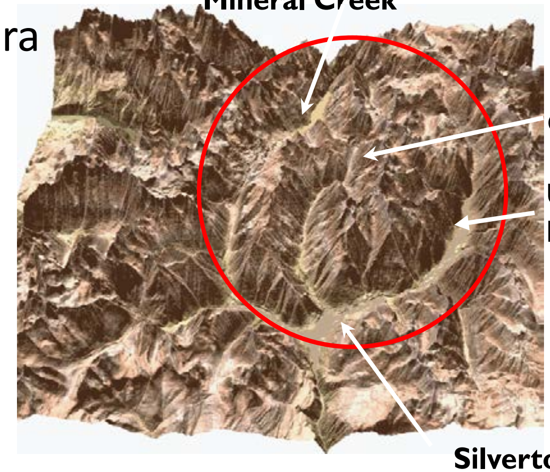
June 21, 2016

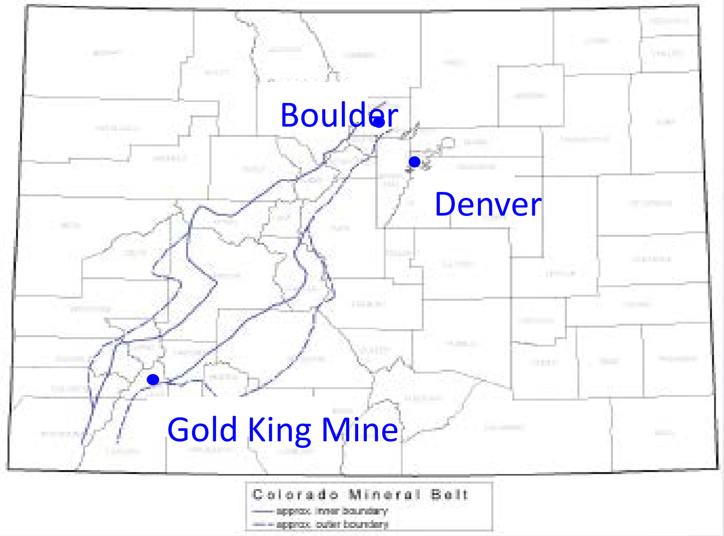
Metals Mining in Colorado

- **Mineral belt of Colorado originated during mountain-building in the Paleogene age**
- **A volcanic caldera intruded into Precambrian rock and sedimentary carbonates near Silverton**
- **Extensively hydrothermally altered sulfide ores within the caldera produced economically extractable metal ores**
- **Gold mining began in 1871 with 1,000 to 1,500 mining claims staked in the area over the next century**
- **Actively mined until about 1990**

Silverton Caldera



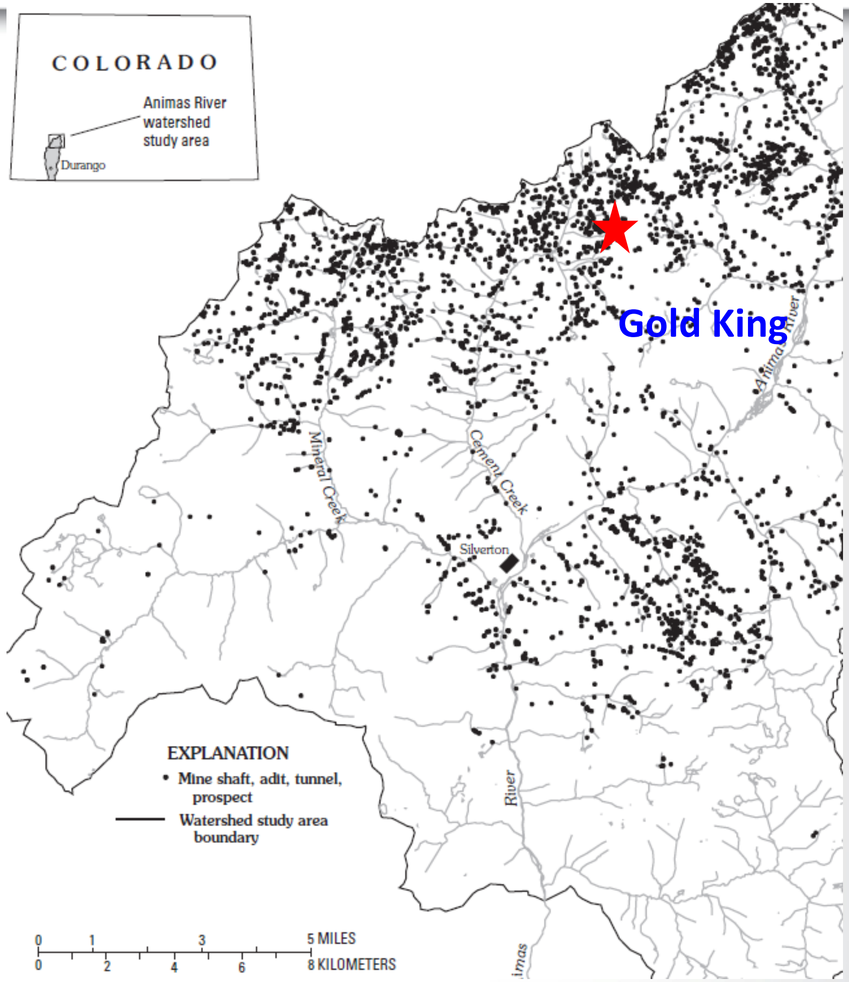




Gold King Mine Background

- **Numerous old mines leak acid mine drainage (AMD) into the tributaries of the headwaters of the Animas River and elsewhere in the river basin**
- **Gold King and associated mine complex has been described as one of the highest AMD producers among the Animas River basin by the CO Dept. of Mines**
  - **Recent estimates suggest GKM leaks 480 gpm**
  - **690,000 gpd; 250 million gals/yr**
  - **The 8/5/2015 release was equivalent to 4 days of normal AMD leakage from this mine**

Cement Creek routinely colors the Animas River in Silverton with "yellow boy" iron and aluminum oxides that form with neutralization of acidity in the higher pH river water



What made the GKM release unique was the sudden release of a large volume of AMD that visibly and measurably impacted the river for a long distance downstream

GKM plume moved downriver from August 5 to August 13, 2015

Upper Animas River in San Juan National Forest

Near Durango, CO 100 km from GKM

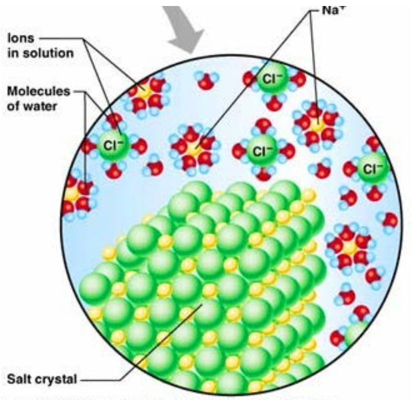
At Farmington joining San Juan 200 km from GKM

What is the risk associated with AMD?

- **Acid Mine Drainage Characteristics**
  - **Very low pH (2.9 in GKM)**
  - **High concentrations of dissolved or "ionic" metals**
- **"Heavy" metals can be toxic to humans, livestock, wildlife, and aquatic life**
- **EPA, states, and tribes have established water quality criteria identifying unsafe concentrations for short or long-term exposure**
  - **Most criteria target the "dissolved" form of metals**
  - **Colloidal/particulate forms are generally thought to have low toxicity to aquatic life**

Lead, Copper, Zinc, Arsenic, Nickel, Cadmium Mercury, Beryllium, Barium, Vanadium, Selenium etc.

Metal ions highly reactive and seek to bind with any charged surface

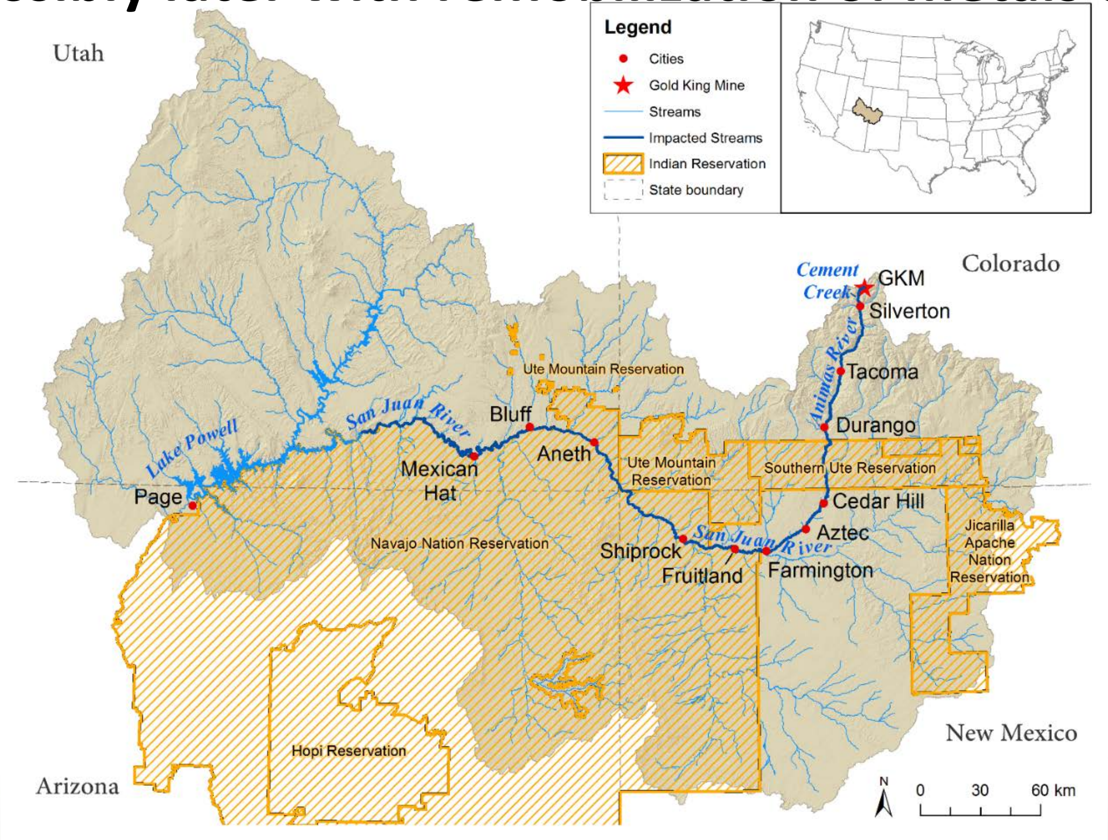


Once sorbed into more stable lattices or onto surfaces, the metals are much less biologically available

Potentially Affected Water Users

- **States**
  - Colorado
  - New Mexico
  - Utah
  - Arizona
- **Tribes**
  - Southern Ute Indian Tribe
  - Ute Moutain Ute Tribe
  - Navajo Nation
- **Many municipalities and counties**
- **EPA**
  - Region 8
  - Region 6
  - Region 9

The GKM release created potential for exposure to high concentrations of metals during the "plume" movement and possibly later with remobilization of metals transferred to the bed



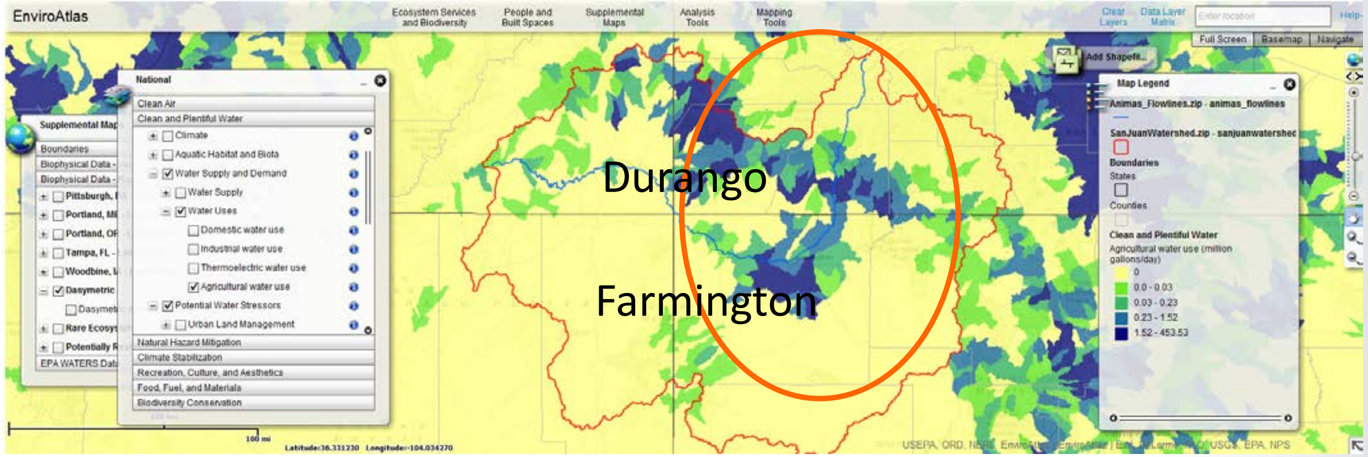
The release triggered EPA emergency response to protect downstream water users by curtailing use with cooperation of states, tribes, municipalities and public in the days following the event

Exposure Potential

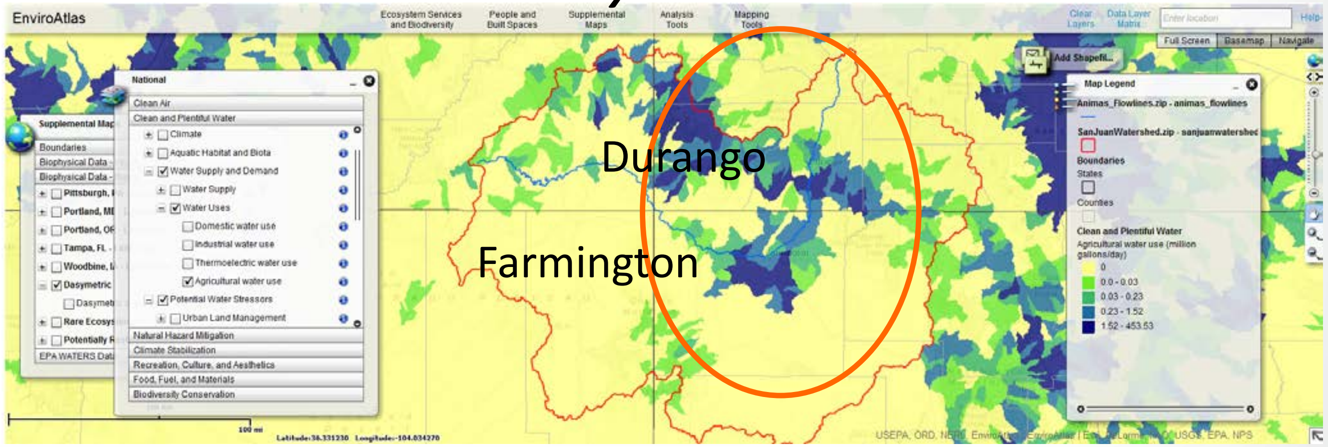
Domestic water supplies

- Population centers from Durango, CO to Farmington, NM
- Groundwater wells

- Contamination of irrigation ditches and livestock watering



Domestic Use Density

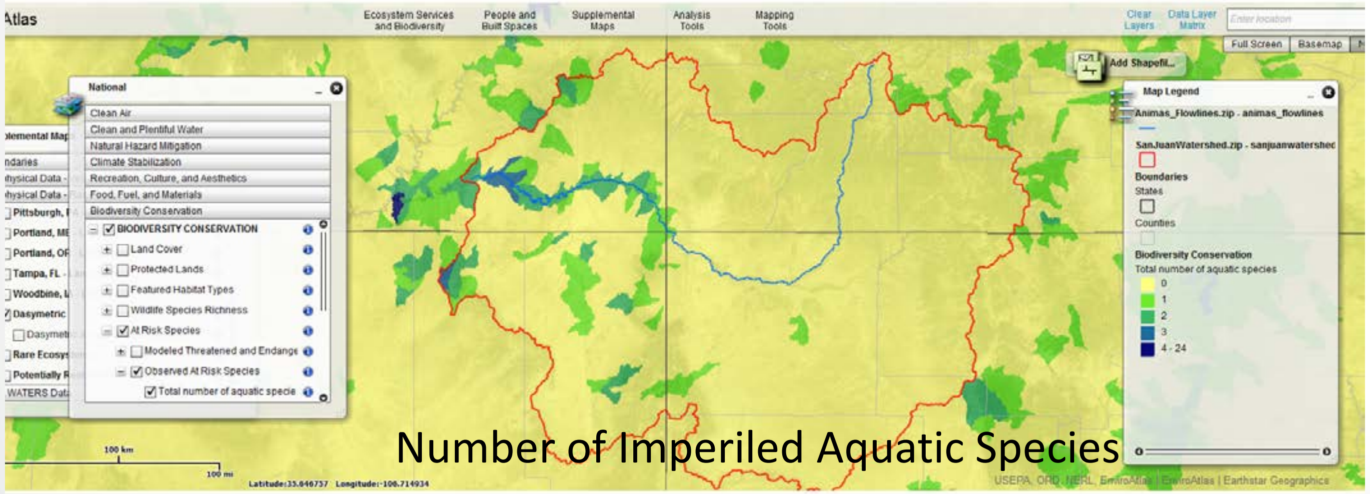


Agricultural Use Density

Exposure Potential

- **Animas River has recreational fisheries**
  - **Rainbow trout**
  - **Brown trout**
- **San Juan River also has species identified in ESA as endangered or at risk**

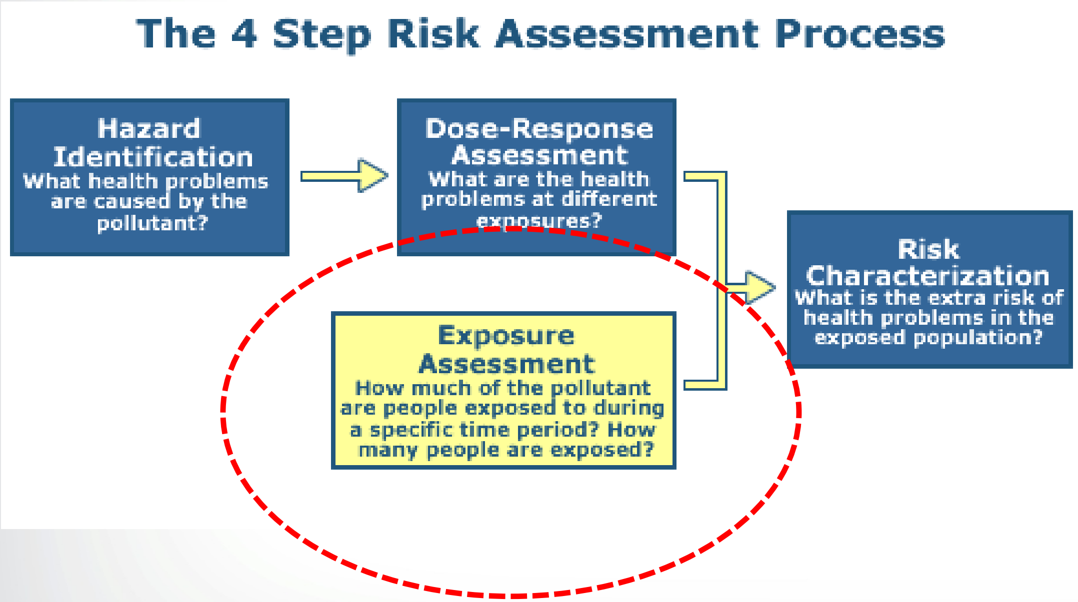
Recreational river use



Number of Imperiled Aquatic Species

Research Objectives

The general objectives of this research was to assess potential exposure to metals released from the Gold King Mine (GKM) site on August 5, 2015 as the plume of acid mine drainage (AMD) traveled through the Animas and San Juan Rivers



Specific research objectives:

Quantify the release from the Gold King Mine
- Contaminants
- Volume and timing

Characterize transport and fate of AMD in Animas and San Juan Rivers
- Surface water
- Sediments

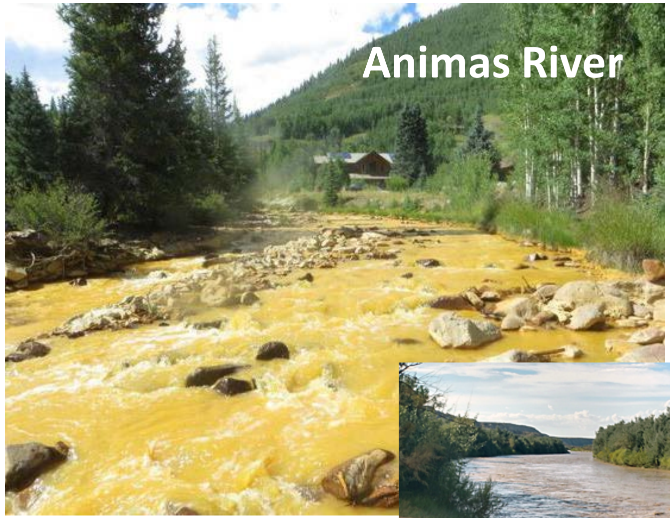
Quantify water quality impacts
- Near term
- Longer term

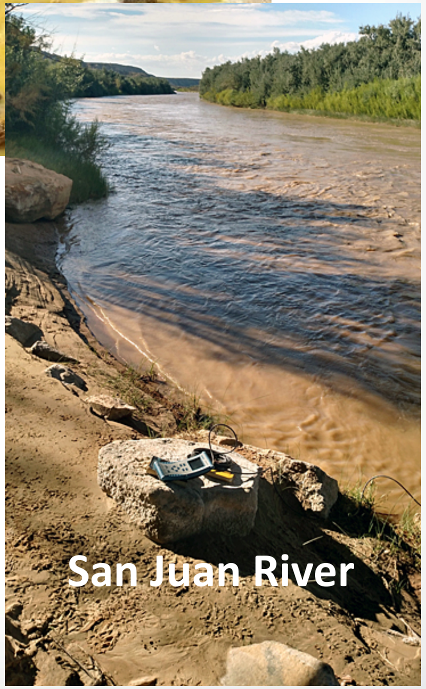
Characterize potential exposure to AMD for various water users, including municipal wells

Advise future monitoring priorities

Analysis Questions

- **Primary Questions**
  - **How much was released and what was its composition?**
  - **Where did the material in the release volume go?**
  - **How was water quality affected?**
  - **What was the potential for water user exposure to metals?**
  - **Did any of the material stay in the river system, sequester to the streambed?**
  - **If so, will that material be released into the river and will it have secondary impacts after the initial spill?**
  - **Were groundwater drinking water or irrigation sources potentially impacted?**
  - **Have metal concentrations in the water and sediment returned to pre-event levels?**





ORD Project Team

Team of ORD scientists with multidisciplinary expertise in geochemistry, surface and groundwater hydrology, environmental engineering, water quality modeling, fish biology and bioaccumulation, statistics, and geographical information tools

Asked by ORD Assistant Administrator to analyze fate and transport of GKM release

ORD/NERL Subject Experts Working on the Project

- **John Washington, Geochemistry**
- **Chris Knightes, WASP, water quality**
- **Mike Cyterski, Data analysis, statistics**
- **Kate Sullivan, Hydrology, project lead**
- **Craig Barber, Fish effects**
- **Steve Kraemer, Groundwater**
- **Anne Neale, Megan Mehaffey, EnviroAtlas**
- **Lourdes Prieto, GIS and data acquisition**

Review Outline

- **Session 1:**
  - Introduction
  - Data and research approach
  - Release volume and characteristics of AMD from Gold King Mine
- **Session 2:**
  - GKM plume characteristics and travel time in the Animas and San Juan Rivers
  - Geochemical transformations
  - Water quality during plume travel
  - Exposure potential
- **Session 3:**
  - Accounting for metals mass in the Animas and San Juan Rivers
  - Post-GKM event trends in water and sediment quality
  - Potential mobilization of deposited materials during storms and snowmelt
- **Session 4:**
  - Groundwater modeling of potential for contamination of wells in river alluvium
  - Wrap-up and summary
  - Discussion/questions

Each session will include time for discussion/questions

EPA/ORD Research Path

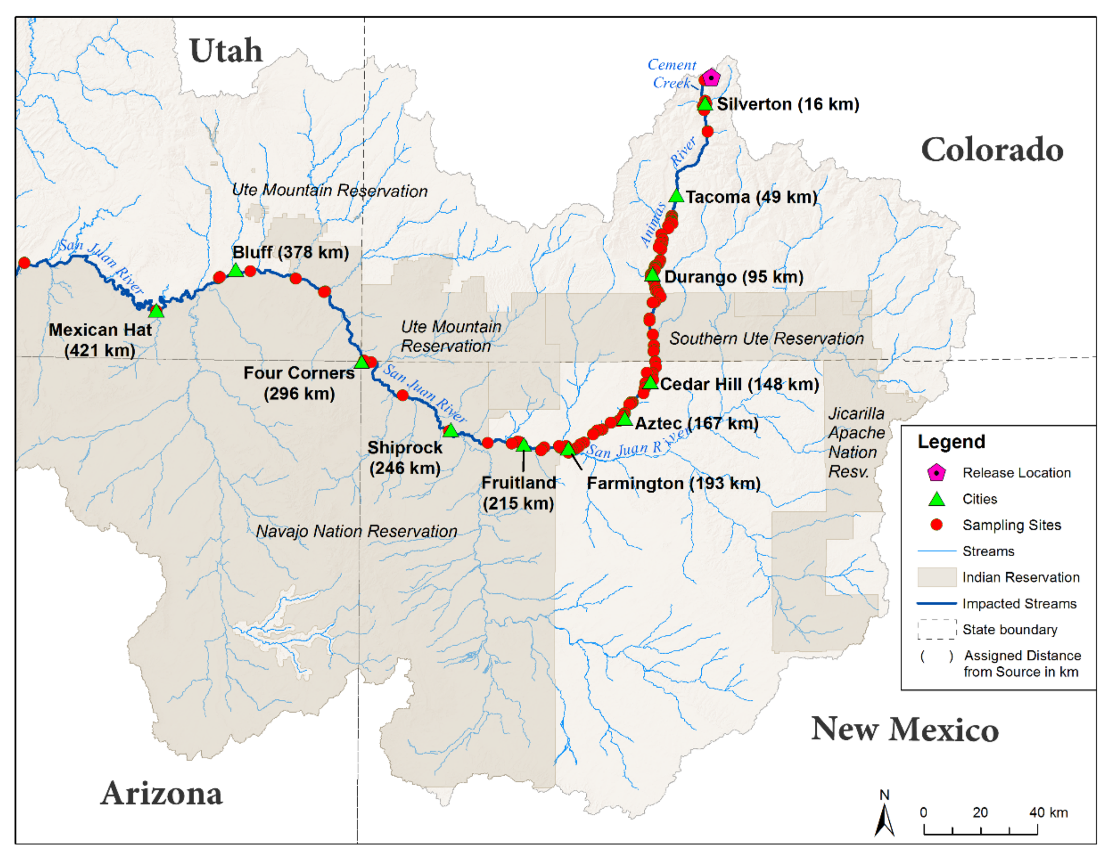
Methods

- We used publicly available data obtained from multiple sources to characterize the GKM release, transport, and fate
- We empirically analyzed water quality & hydrologic data collected during and after the GKM release to estimate metal concentrations and loadings downstream as the plume passed.
- We applied existing, peer-reviewed software-based process analytical models to assist understanding of transport and fate in the 600-km river system, river alluvium groundwater, and bioaccumulation.
- We reviewed USGS studies of AMD in the Animas River in the 1990's to gain insight into system behavior and expected conditions.
- We consulted with EPA regions and program staff with detailed knowledge of the event to cross check and validate results.

Reporting

- Independent peer review pre-report held Feb 22-25: reviewers traveled to Athens, GA for 3 days of presentations focused primarily on methods. Recommendations have been incorporated into current results and presentations.
- Technical review with states, tribes, others
- Report in progress (will receive independent peer review)

Data Overview



- The combined efforts of EPA, states and tribes provided an extensive database of metals concentration in water and sediments along 600 km of river
- Some historic data also available from the same groups and USGS
- 12 USGS gages within the reach

- We used publicly available data downloaded from agency websites
- Merged data from multiple sources
- We report sites as distance from Gold King Mine

Data Sources--Overview

		Metals					
		Surface Water			Sediment		
		GKM Plume Event (Aug 5-20)	Post-Event (Aug 21-Oct)	Pre-Event/ Historic	GKM Plume Event (Aug 5-20)	Post-Event (Aug 21-Oct)	Pre-Event/ Historic
Federal	EPA Region 8	X	X	SADIE	X	X	X
	EPA Region 6	X	X		X	X	
	EPA Region 9	X	X		X	X	
	U.S. Geological Survey	3 samples		X			X
States	Colorado DPHE	X			X		
	New Mexico ED	X					
	Utah DEQ	X			X		
Tribes	Southern Ute Indian Tribe	X					
	Ute Mountain Tribe			X			
	Navajo Nation NNEPA	X	X	X			

Supplemental material has additional info on data sources and methods

Metals -- Total Fraction

24 metals

Not all metals measured at all sites in every sampling event

SURFACE WATER TOTAL Recoverable	Federal Agencies				States			Tribes		
	EPA Region 8	EPA Region 6	EPA Region 9	U.S. Geological Survey	Colorado DPHE	New Mexico ED	Utah DEQ	Southern Ute Indian Tribe	Ute Mountain Tribe	Navajo Nation NNEPA
Metals										
Aluminum	X	X	X	X	X	X	X	X	X	X
Antimony	X	X	X	X		X	X	X	X	X
Arsenic	X	X	X	X	X	X	X	X	X	X
Barium	X	X	X	X	X	X	X	X		
Beryllium	X	X	X	X	X	X	X	X		
Cadmium	X	X	X	X	X	X	X	X	X	X
Calcium	X	X	X		X	X	X	X	X	X
Chromium	X	X	X	X	X	X	X	X	X	X
Cobalt	X	X	X	X	X	X	X	X		X
Copper	X	X	X	X	X	X	X	X	X	X
Iron	X	X	X	X	X		X	X	X	
Lead	X	X	X	X	X	X	X	X	X	X
Magnesium	X	X	X		X	X	X	X		X
Manganese	X	X	X	X	X	X	X	X	X	X
Mercury	X	X	X	X	X	X	X	X	X	X
Molybdenum	X	X	X	X	X	X	X	X	X	X
Nickel	X	X	X	X	X	X	X	X	X	X
Potassium	X	X	X		X		X	X	X	X
Selenium	X	X	X	X	X	X	X	X	X	
Silver	X	X	X	X	X	X	X	X	X	X
Sodium	X	X	X		X		X	X	X	X
Thallium	X	X	X	X		X	X	X	X	X
Vanadium	X	X	X	X	X	X	X	X	X	X
Zinc	X	X	X	X	X	X	X	X	X	X

- **Mostly similar testing by various agencies but differences exist—see supplemental material**

Metals -- Dissolved Fraction

<0.45 micron filtered

24 metals

Surface Water Dissolved	Federal Agencies				States			Tribes		
	EPA Region 8	EPA Region 6	EPA Region 9	U.S. Geological Survey	Colorado DPHE	New Mexico ED	Utah DEQ	Southern Ute Indian Tribe	Ute Mountain Tribe	Navajo Nation NNEPA
Aluminum	X	X	X	X	X	X	X	X	X	X
Antimony	X	X	X	X		X	X	X		X
Arsenic	X	X	X	X	X	X	X	X	X	X
Barium	X	X	X	X	X	X	X	X		
Beryllium	X	X	X	X	X	X	X	X		
Cadmium	X	X	X	X	X	X	X	X	X	X
Calcium	X	X	X	X	X	X	X	X	X	X
Chromium	X	X	X	X	X	X	X	X	X	X
Cobalt	X	X	X	X	X	X	X	X		X
Copper	X	X	X	X	X	X	X	X	X	X
Iron	X	X	X	X	X		X	X	X	
Lead	X	X	X	X	X	X	X	X	X	X
Magnesium	X	X	X	X	X	X	X	X	X	X
Manganese	X	X	X	X	X	X	X	X	X	X
Mercury	X	X	X	X	X	X	X	X		X
Molybdenum	X	X	X	X	X	X	X	X	X	X
Nickel	X	X	X	X	X	X	X	X		X
Potassium	X	X	X	X	X		X	X	X	X
Selenium	X	X	X	X	X	X	X	X	X	
Silver	X	X	X	X	X	X	X	X	X	X
Sodium	X	X	X	X	X		X	X	X	X
Thallium	X	X	X	X		X	X	X		X
Vanadium	X	X	X	X	X	X	X	X	X	X
Zinc	X	X	X	X	X	X	X	X	X	X
Other Consitutents										
Boron					X	X			X	
Uranium-234/235/238					X	X			X	
Mercury	X	X	X		X	X	X	X		X
Silica				X					X	
Silicon					X				X	
Titanium					X					
Strontium					X					
Hardness, Dissolved (as CaCO3)						X	X	X		

Other water quality constituents

Relatively few geochemistry-relevant parameters measured during plume movement—

--lack of data limited geochemical analyses

Other Chemicals and Constituents	Federal Agencies				States			Tribes		
	EPA Region 8	EPA Region 6	EPA Region 9	U.S. Geological Survey	Colorado DPHE	New Mexico ED	Utah DEQ	Southern Ute Indian Tribe	Ute Mountain Tribe	Navajo Nation NNEPA
Alkalinity (as CaCO3)							X			
Alkalinity, Phenolphthalein (total hydroxide+1/2 carbonate)										X
Alkalinity, total				X		X	X	X	X	X
Bicarbonate (as $CaC0_3$)				X		X	X	X	X	X
Boron					X	X				X
Bromate					X					
Bromide					X	X				
Carbonate						X	X		X	X
Chloride				X		X	X			X
Conductivity	X	X	X				X			
Cyanide						X				X
Cyanides amenable to chlorination (HCN & CN)										X
Dissolved oxygen	X	X	X	X	X	X				X
DOL						X				
Fluoride				X	X	X				X
Gross alpha radioactivity, (Americium-241 ref std)										X
Hardness (as $CaCO_3$)				X			X	X		
Hydroxide (as $CaCO_3$)								X	X	X
Nitrate/Nitrite (as N)					X		X			
Phosphorus									X	
Phosphate-phosphorus									X	
Orthophosphate	X	X	X							
pH	X	X	X	X	X	X	X			X
Residue Filterable								X		
Residue Non-Filterable								X		
Salinity						X				X
Silica										
Silicon					X					
Specific conductance	X	X	X	X		X				X
Strontium					X					
Sulfate				X	X	X	X			X
Temperature, water	X	X	X	X	X	X			X	X
Titanium					X					
Total dissolved solids				X		X	X	X		X
Total suspended solids						X	X	X		X
Turbidity						X				
Uranium-234/235/238				X	X	X				
CO_2				X						

Other constituents -- SONDES

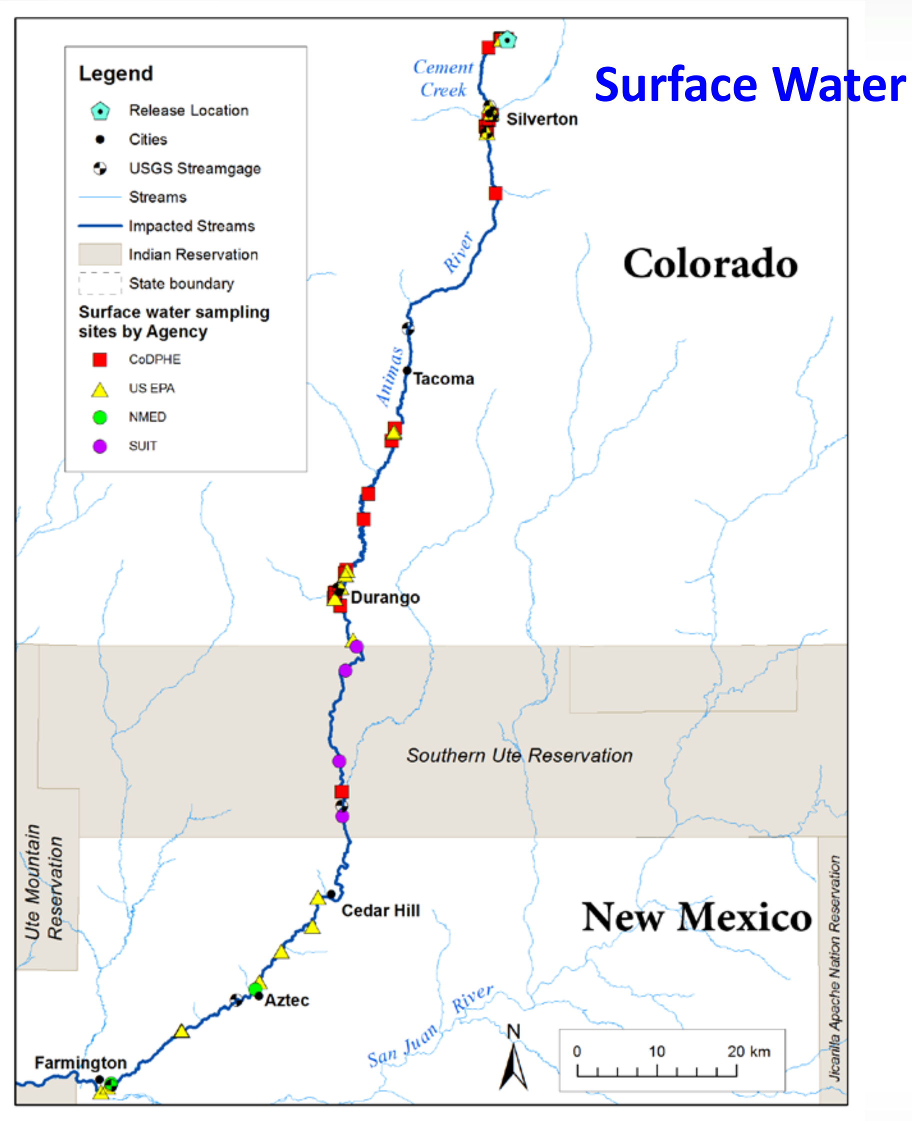
Continuous Sondes	Federal Agencies				States			Tribes		
	EPA Region 8	EPA Region 6	EPA Region 9	U.S. Geological Survey	Colorado DPHE	New Mexico ED	Utah DEQ	Southern Ute Indian Tribe	Ute Mountain Tribe	Navajo Nation NNEPA
pH						X		X		
Specific Conductance						X		X		
Temperatre						X		X		
Turbidity						X				
ODOSat						X		X		
ODO Conc						X		X		
Total Dissolved Solids								X		
Streamflow				X						

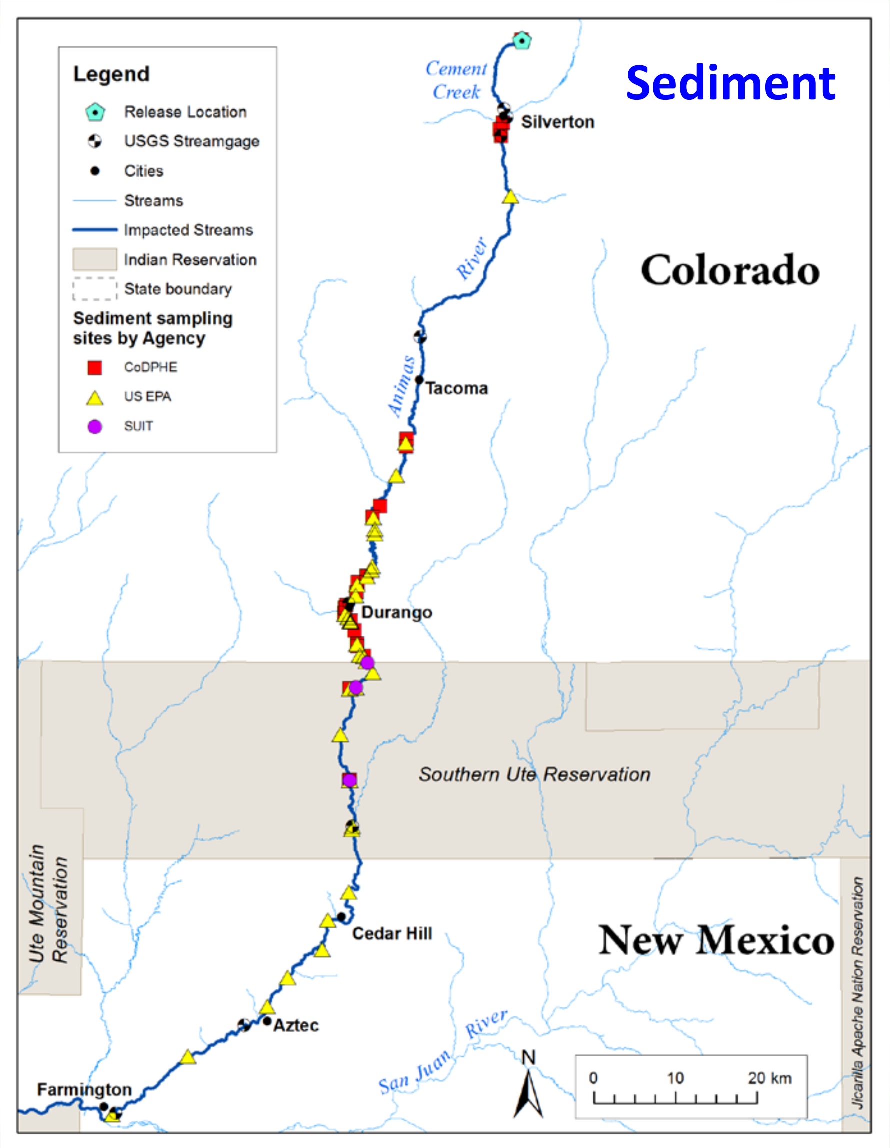
Sondes were helpful in establishing timing of plume movement

Uncertainties in Data

- The distinction between dissolved and "solid" phases of metals (we term colloidal/particulate) is determined by sample filtering
  - All GKM samples separated by 0.45 micron filter
  - Fine AMD colloids can be smaller in size than 0.45 micron filter—can introduce systematic errors in fraction partitioning
- Acid treatment for preserving samples could affect metal phase—difficult to screen data for this
- Uncertainties due to differences in field sampling protocols are unknown, but not thought to be significant problem
- Samples below testing detection limits
  - All agencies provide sufficient info in data sets for qa qualifiers and detection limits
  - Agencies vary in how non-detects are reported as results
  - We generally focus on the metals with reasonable number of "detects"
  - Confident in plume related results because concentrations were high—detection limits mostly affect interpretation of "return to background"
- Differences in sampling timing and what was tested forces us to narrow data used for some summarizing analyses

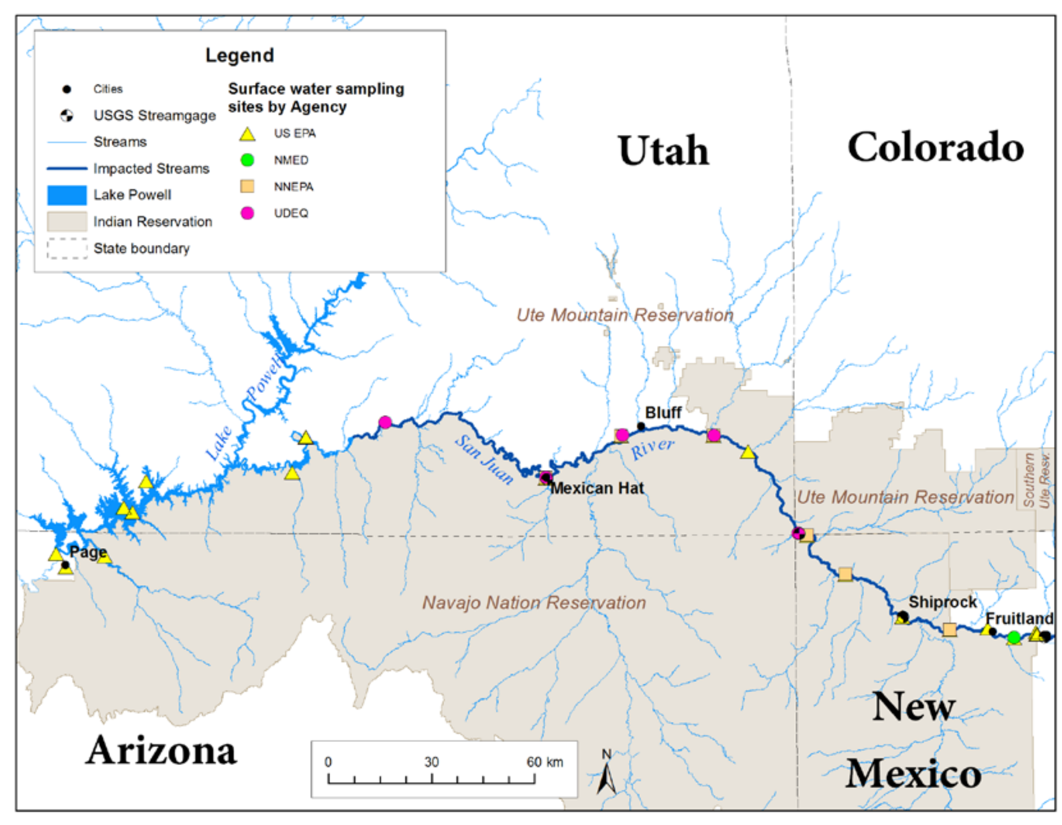
Animas River Sampling Sites



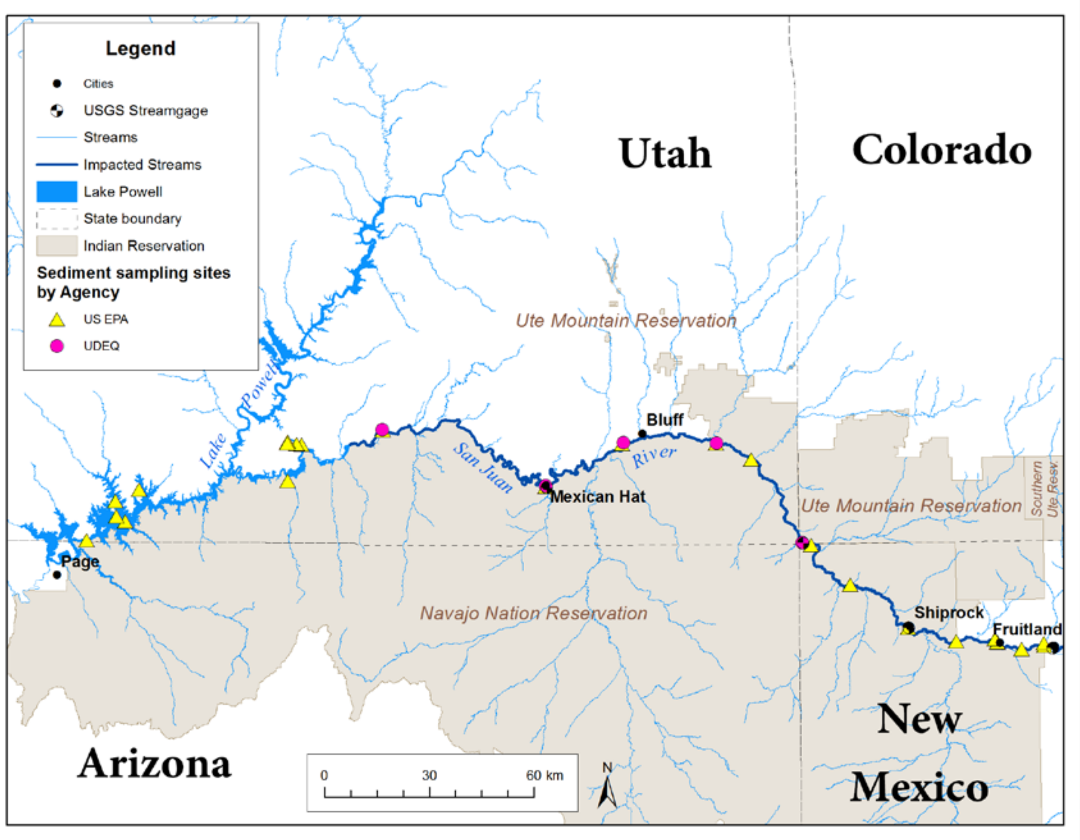


San Juan River Sampling Sites

Surface Water



Sediment



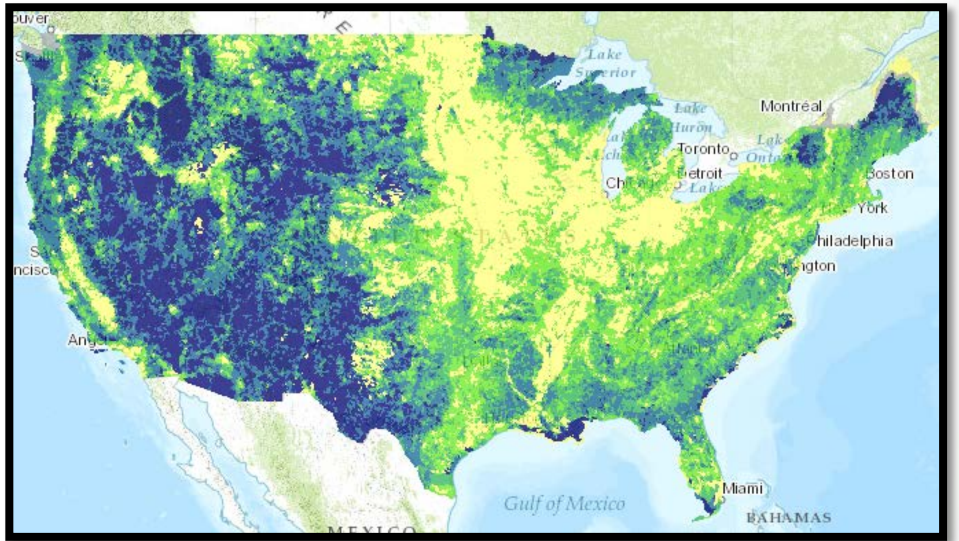
Used Data and Technology from EnviroAtlas

EnviroAtlas is:

- An online decision support tool giving users the ability to view, analyze, and download geospatial data and other resources
- Designed to inform decision-making, education, and additional research
- Freely available to anyone with internet access

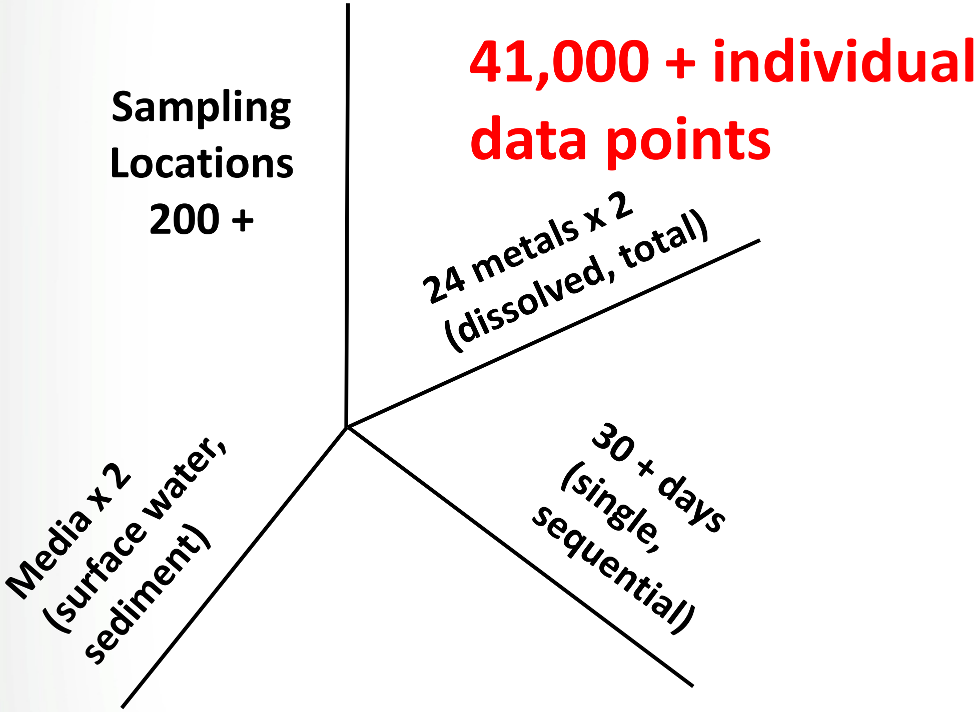
EnviroAtlas includes:

- Geospatial indicators of natural resources, benefits provided, and drivers of change
- Supplemental data (e.g., boundaries, land cover, soils, hydrography, impaired water bodies, wetlands, demographics)
- Analytic and interpretive tools



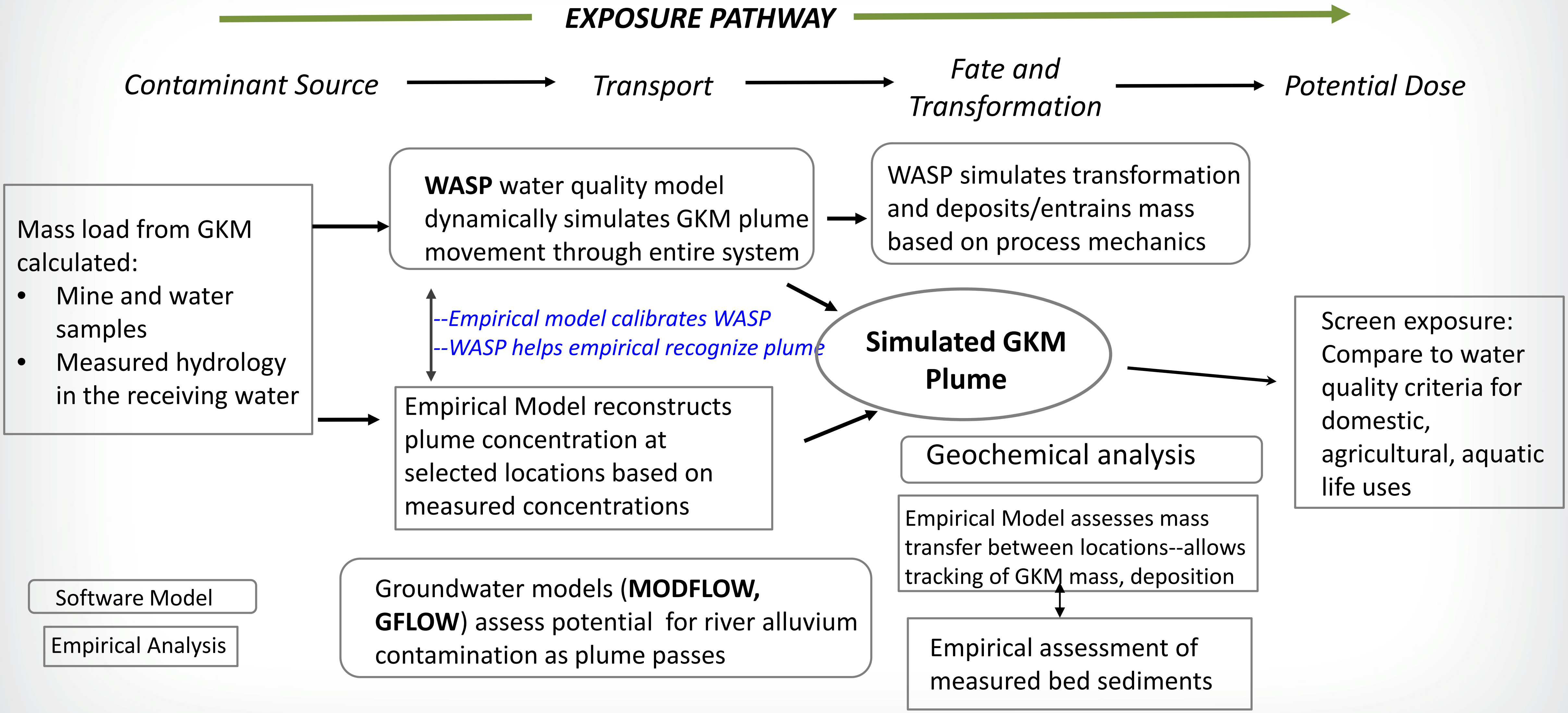
Developed through cooperative effort amongst multiple Federal agencies and other organizations.

Data Integration



- EPA/ORD team took opportunistic approach—used everything we could
- Overall, we think the data composited from all sources allow for a robust look at the GKM event and reasonably good comparison to historic conditions
- Ability to synthesize overall understanding of event outweighs methodological uncertainties
- Distilling data for consistent and understandable analyses was challenging
  - Large number of sites, metals, samples, media
  - Concentrations ranged over 4 orders of magnitude

GKM Analysis Road Map



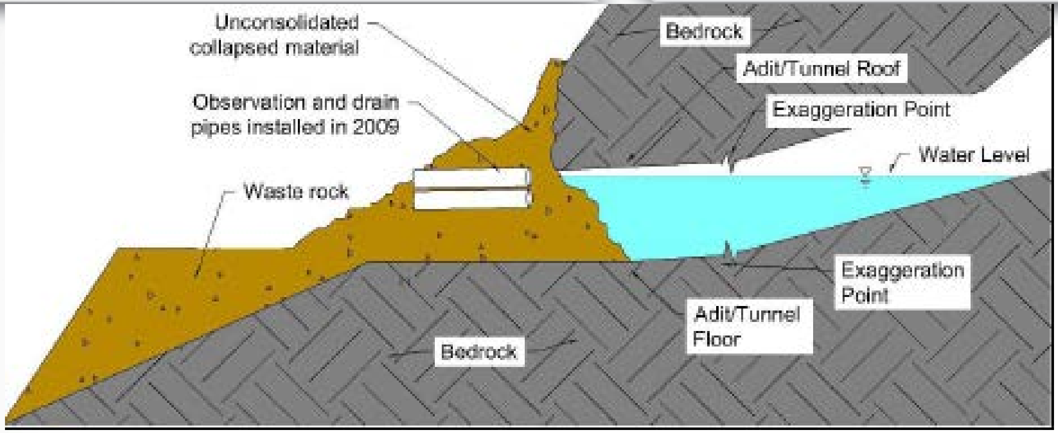
RESULTS

Release From Gold King Mine

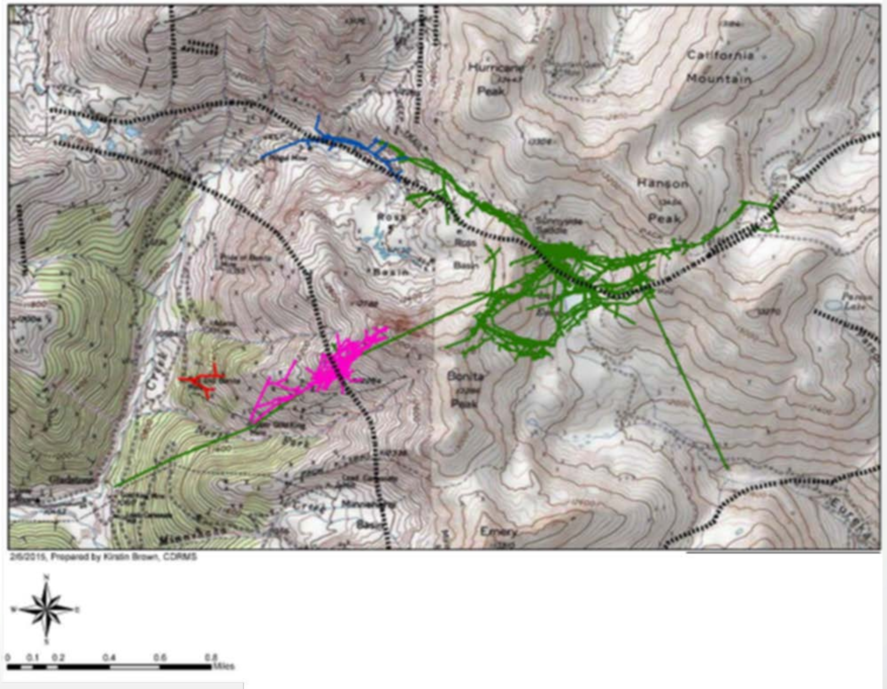
How much?

What was in it?

Gold King Mine Situation

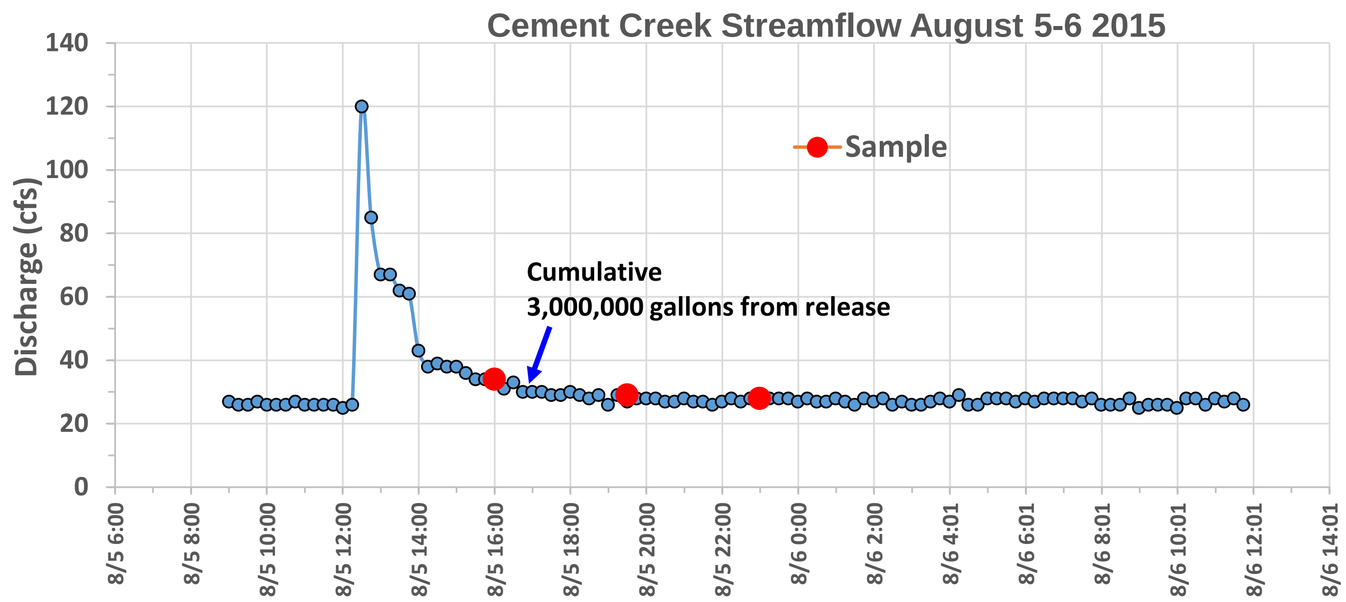


See Bureau of Reclamation Report (October 2015)

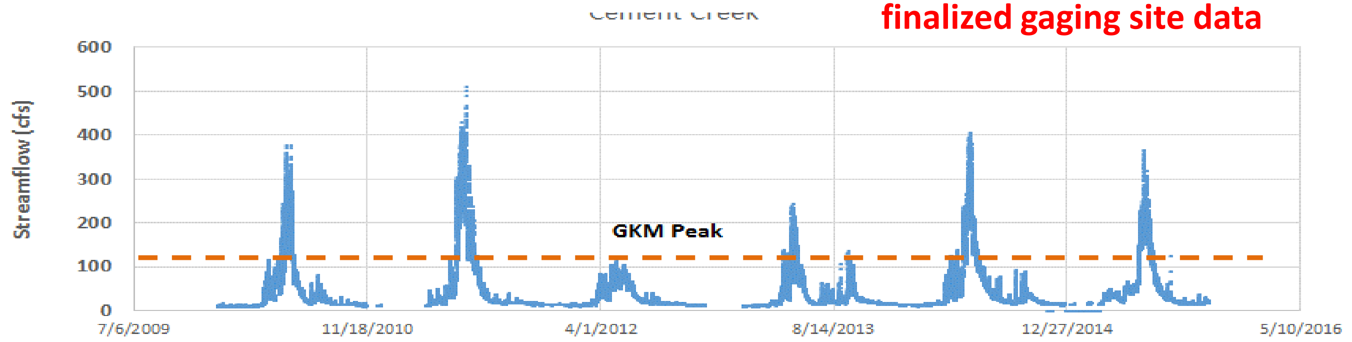


- **On August 5, 2015, EPA and its contractors were working at the collapsed entrance of the Gold King Mine**
- **Due to subsurface hydrologic connection among 4 mines on the hillslope, the pond inside the lowermost Gold King mine was "pressurized"**
- **Disturbance to the plugged entrance created a small leak that quickly turned into a flood carrying a slurry of acidic water laden with dissolved metals to Cement Creek**
- **Rushing water eroded additional contaminants from the mountainside and probably from within Cement Creek carrying it into the headwaters of the Animas River**

Volume Released From GKM

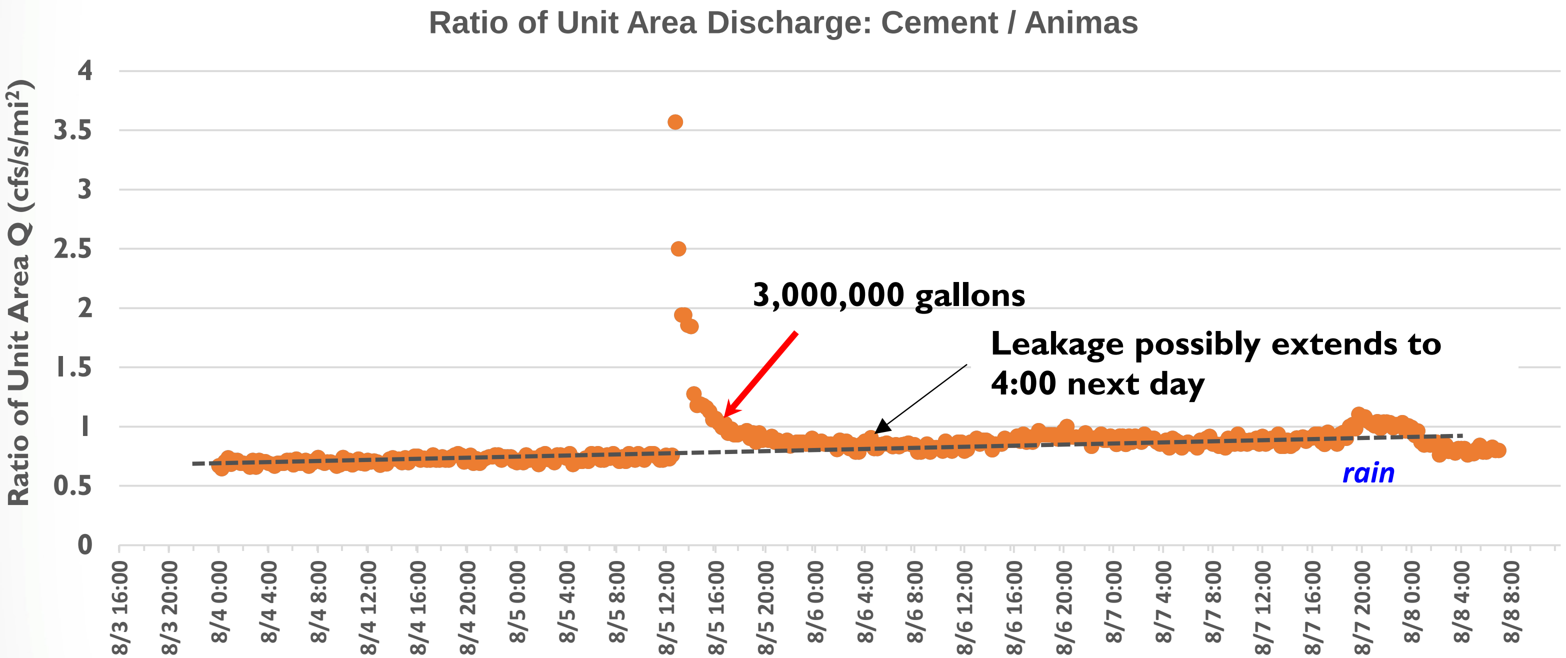


** Final volume 2,919,000 after USGS finalized gaging site data



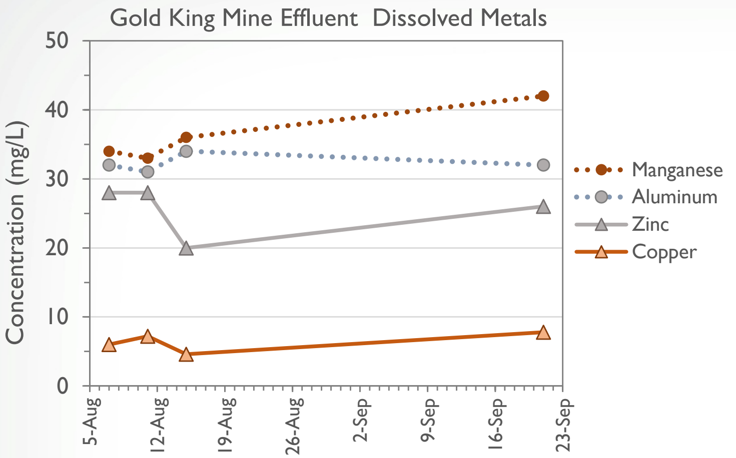
- 3,000,000** gallons (11.42 million liters) of acidic water pH 2.9
- Release begins at 11:00 AM
- Most of the release volume observed between12:45 and 17:45 at Cement Cr gage 12.5 km downstream
- Peak of release flood similar to flow during snowmelt

Volume Released From GKM

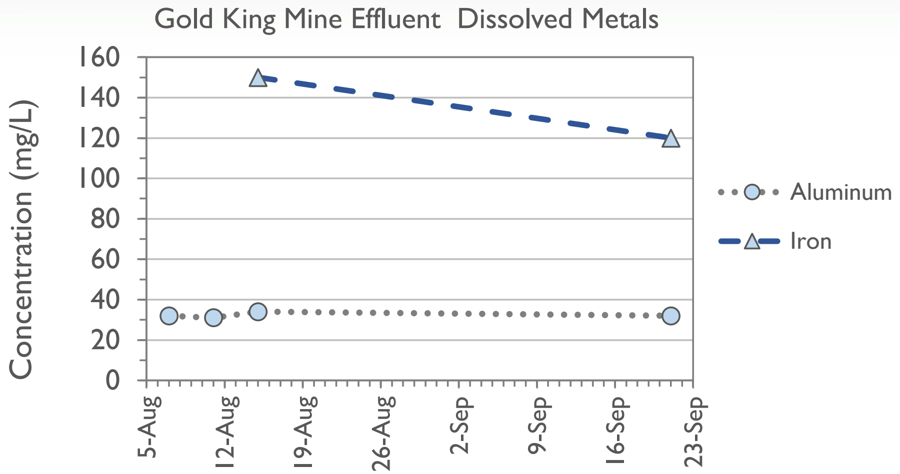


- Comparing flow in Cement Creek relative to Animas above Cement suggest some leakage possibly continues until the next morning
- Other factors also could be disrupting the relative relationship in flow between the two sites
- We accept USGS estimate of 3,000,000 gallons where release ends at about 17:45

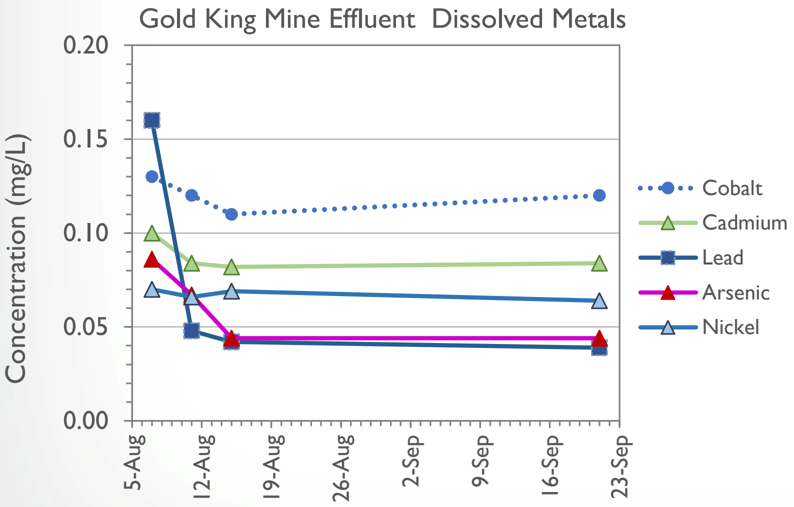
GKM Effluent Chemistry



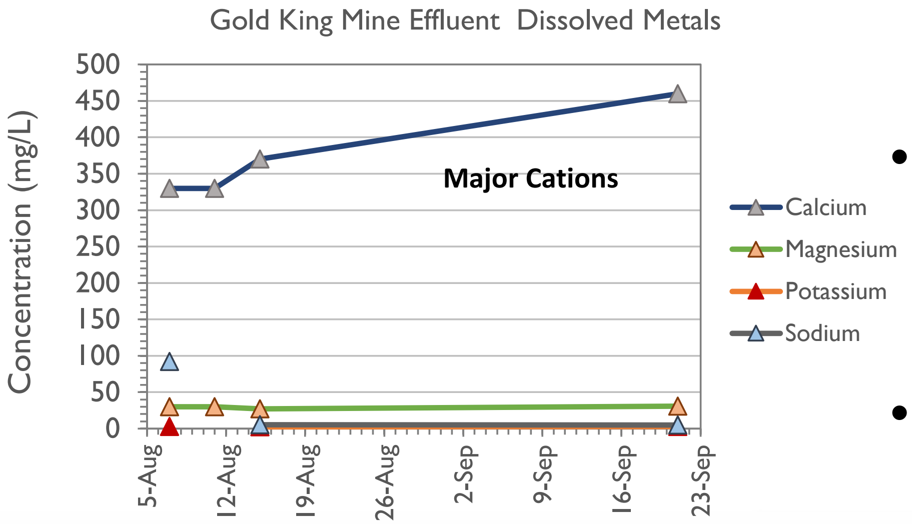
Colorado DPHE: Aug 7, 11 EPA Aug 15, Sep 21



Colorado DPHE: Aug 7, 11 EPA Aug 15, Sep 21



Colorado DPHE: Aug 7, 11 EPA Aug 15, Sep 21



Colorado DPHE: Aug 7, 11 EPA Aug 15, Sep 21

- **Concentrations of metals in the mine after the event could have increased or decreased relative to that during the release as new water filling mine voids reached equilibrium**
- **GKM effluent measured 4 times after release**
  - EPA: Aug 15, Sep 21
  - CODPHE: Aug 7, 11
- **Some initial adjustments for many metals, but not a lot of change**
- **Aug 15 EPA sample used to represent release for most metals**

GKM Effluent Release Concentration

mg/L	CODPHE	CODPHE	EPA CC06	EPA CC06		Dissolved	
Metal	7-Aug	11-Aug	15-Aug	21-Sep	Average of Samples	Selected Value	
Aluminum	32	31	34	32	32.25	34	15-Aug
Antimony			0.004	0.006	0.005	0.0037	15-Aug
Arsenic	0.086	0.067	0.044	0.044	0.06025	0.060	15-Aug
Barium	0.021		0.009	0.002	0.010	0.0086	15-Aug
Beryllium	0.003	0.006	0.011	0.013	0.0082	0.011	15-Aug
Cadmium	0.100	0.084	0.082	0.08	0.09	0.082	15-Aug
Calcium	330	330	370	460	372.5	370	15-Aug
Chromium	0.015		0.006	0.016	0.012	0.015	15-Aug
Cobalt	0.13	0.12	0.11	0.12	0.12	0.11	15-Aug
Copper	6.0	7.2	4.6	7.8	6.4	7.0	
Iron			150	120	135	150	15-Aug
Lead	0.160	0.048	0.042	0.039	0.0723	0.042	15-Aug
Magnesium	30	30	27	31	29.5	27	15-Aug
Manganese	34	33	36	42	36.25	36	15-Aug
Mercury	0	0	0	0	0	0.00000	15-Aug
Molybdenum			0.004	0.005	0.005	0.0042	15-Aug
Nickel	0.070	0.066	0.069	0.064	0.067	0.069	15-Aug
Potassium	2.8		2.4	3.0	2.7	2.4	15-Aug
Selenium	0.002	0.001	0.005	0.010	0.004	0.0047	15-Aug
Silver			0.0001	0.0006	0.0004	0.0001	15-Aug
Sodium	92		5	4.8	34	5.3	15-Aug
Thallium			0.0003	0.060	0.030	0.03	15-Aug
Vanadium			0.038	0.033	0.036	0.038	15-Aug
Zinc	28	28	20	26	25.5	26.0	21-Sep
Sum All, mg/l			650	727	675	658	

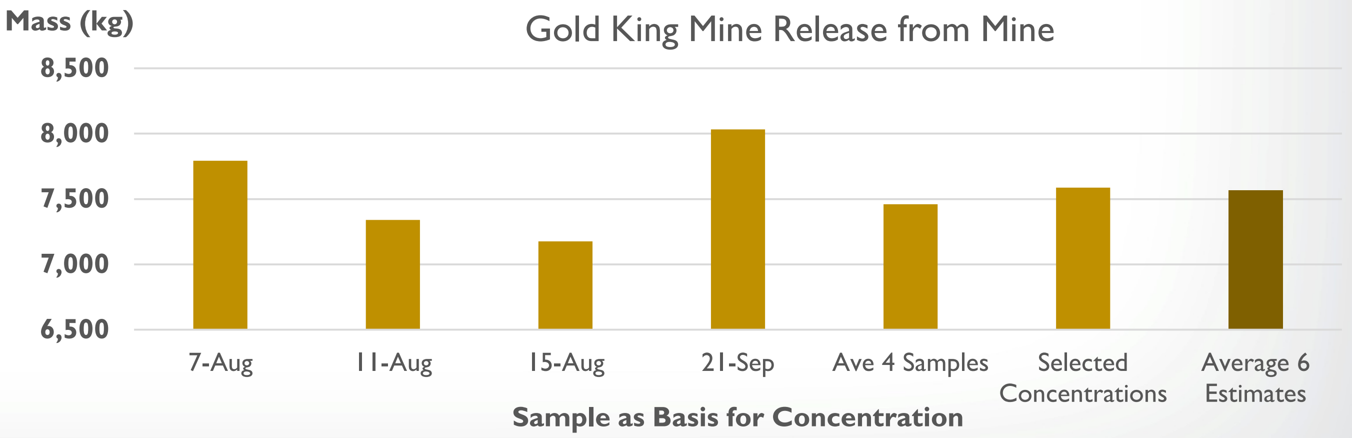
Effluent Mass (kg)= Concentration (mg/l) x Volume (l)÷10^6

Volume = 11,046,485 liters

Using selected concentrations based primarily on Aug 15 sample:

Total estimated metal mass released from GKM = 7,600 kg

6 mass estimates using each concentration column to the left ranged from 7,200 to 8,000 kg, with a mean of 7,565 kg (SE 127 kg)

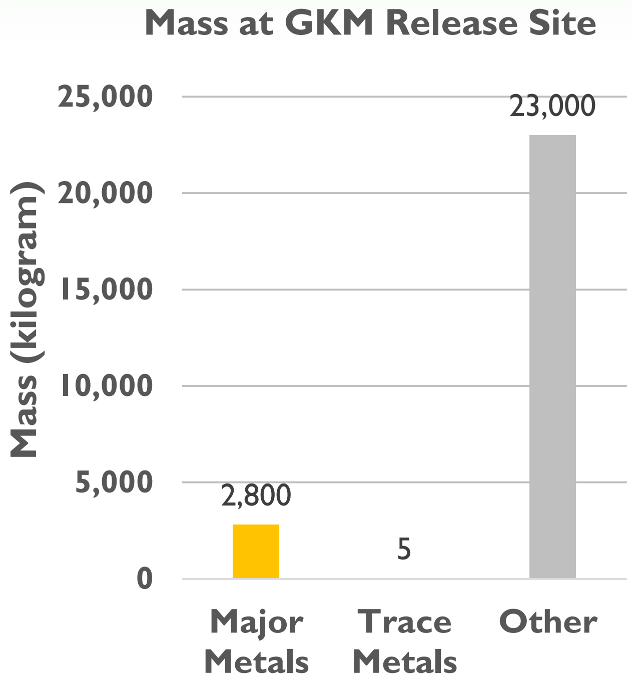


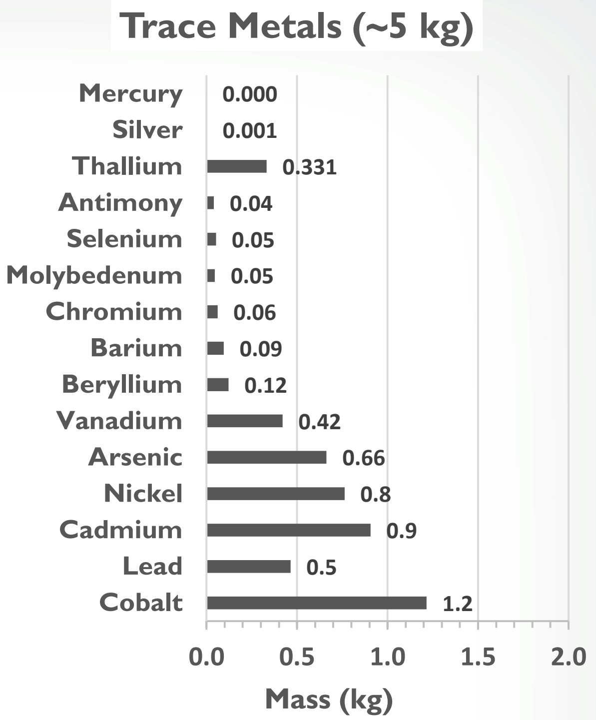
GKM Effluent Release Chemical Makeup

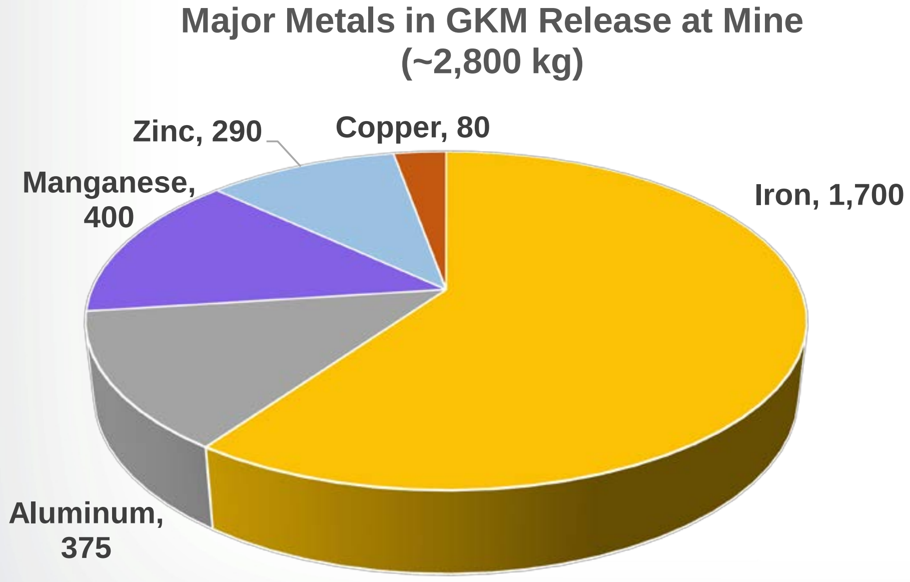
Total Release=26,000 kg

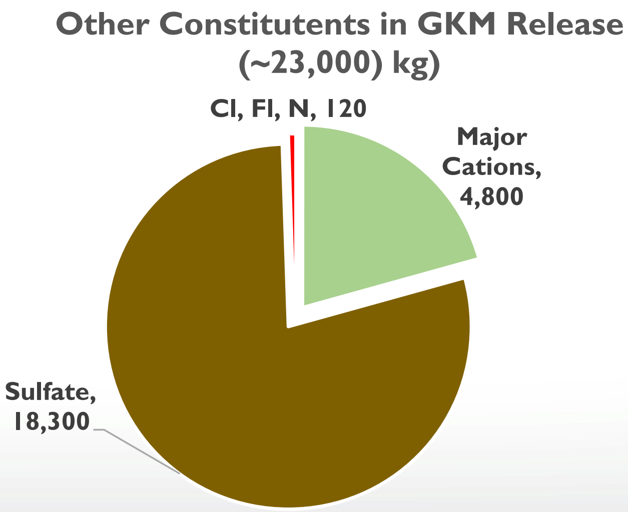
Major Metals : 2,800 kg

Almost all dissolved









GKM Release Event

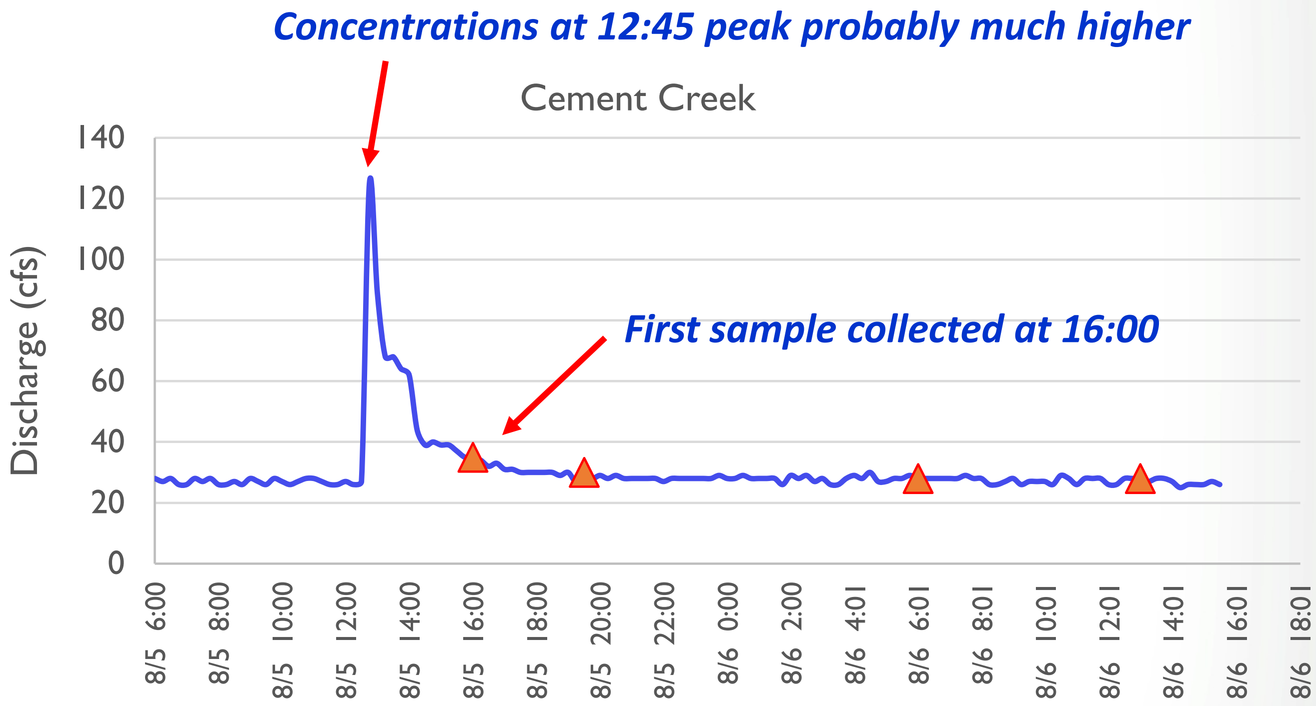
- **Not just an AMD release but also an erosion event**
- **Most of water released within about a 2-hour period**
- **Fast moving flood traveled through Cement Creek at 1.5 to 2 m/s providing the power to entrain and transport metals + sediments**

Significantly increased metals loads between the mine entrance and Cement Creek entry into Animas River

Potential Metal Sources: mine waste outside entrance, hillslope saturated with leakage, streambed

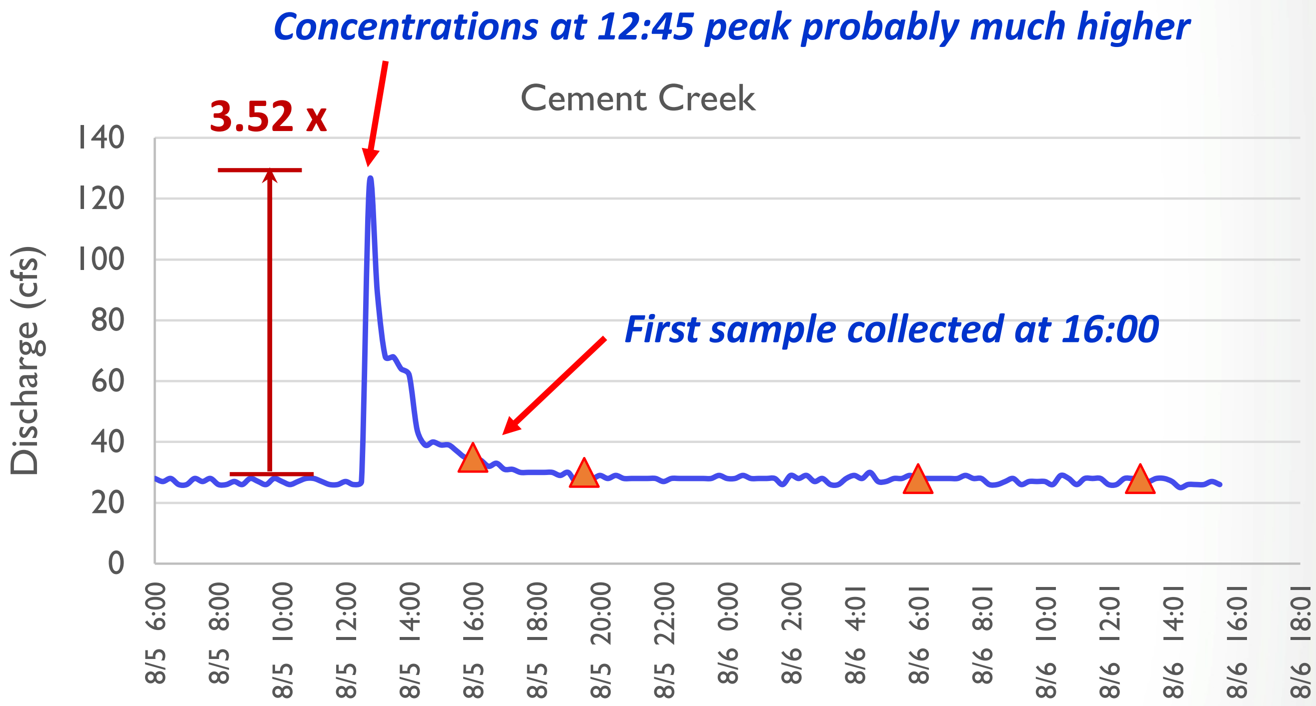
GKM Release to Animas River

- **First sample in Cement Creek during release was collected at 16:00**
- **This sample did not likely represent peak concentrations at 12:45**
- **Approach to estimating total and dissolved peak concentrations was carefully reviewed by the independent peer review panel who provided suggestions**



GKM Release to Animas River

- **First sample in Cement Creek during release was collected at 16:00**
- **Does not likely represent peak concentrations at 12:45**
- **Factor to increase total recoverable concentration at 12:45 computed as proportion of streamflow at 16:00 $Q_{peak}/Q_{16:00}$ = 3.53**



EPA/ORD team and Peer Reviewers agreed:
Estimates very uncertain, concentrations could have been higher or lower

Estimating Peak Concentrations in Cement Creek—DISSOLVED FRACTION

Algorithm to estimate dissolved metal concentrations at release peak:

- **Step 1: Estimate background concentration of metals in Cement Creek above GKM; done from samples collected by EPA and CODPHE in August 2015**
- **Step 2: Use 16:00 Cement Creek sample and background concentrations from Step 1 to solve for GKM concentration**

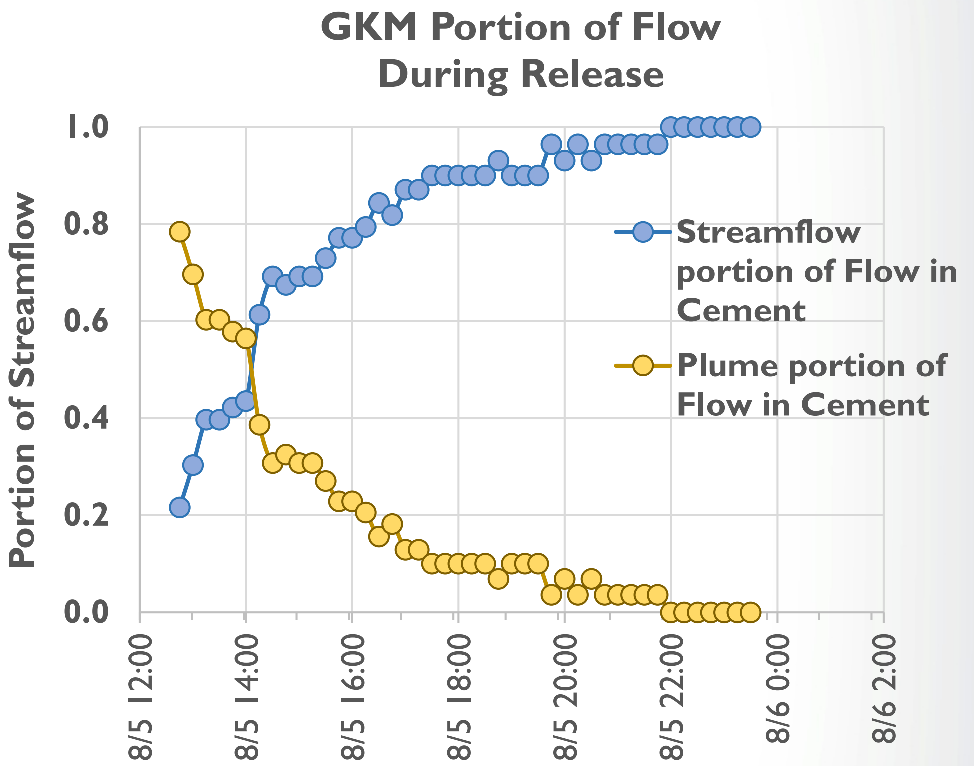
  [Cement Conc$_{16:00}$]=[GKM Conc] x (GKM q Portion$_{16:00}$) + [Background Conc] x (Background q Portion$_{16:00}$)

- **Step 3: Use Step 2 result and data from plot to the right in a mixing model at other time steps:**

  [Cement Conc$_t$]=[GKM Conc] x (GKM q Portion$_t$) + [Background Conc] x (Background q Portion$_t$)

- **Step 4: Account for salt surge from entrained materials**

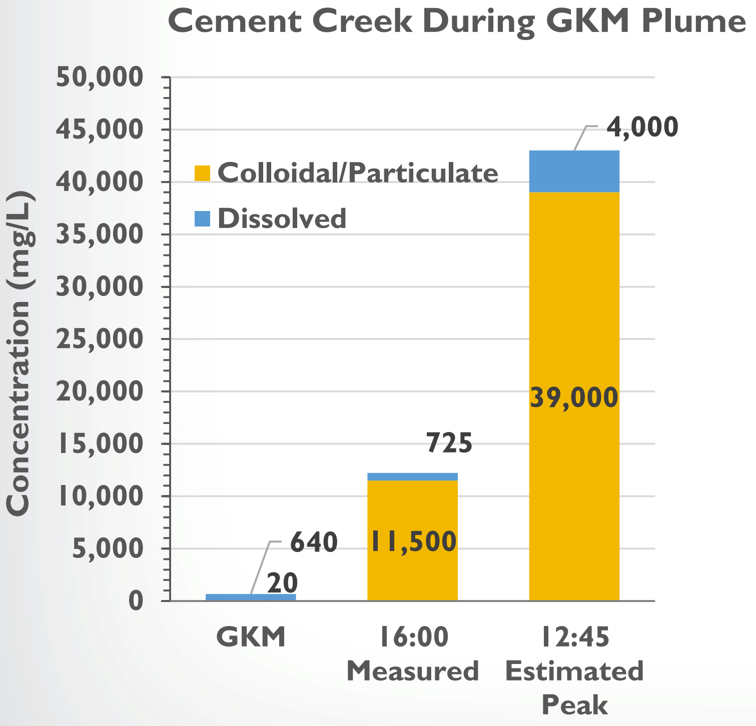
  First 30 minutes (2 time steps) increase estimated concentration by 2x



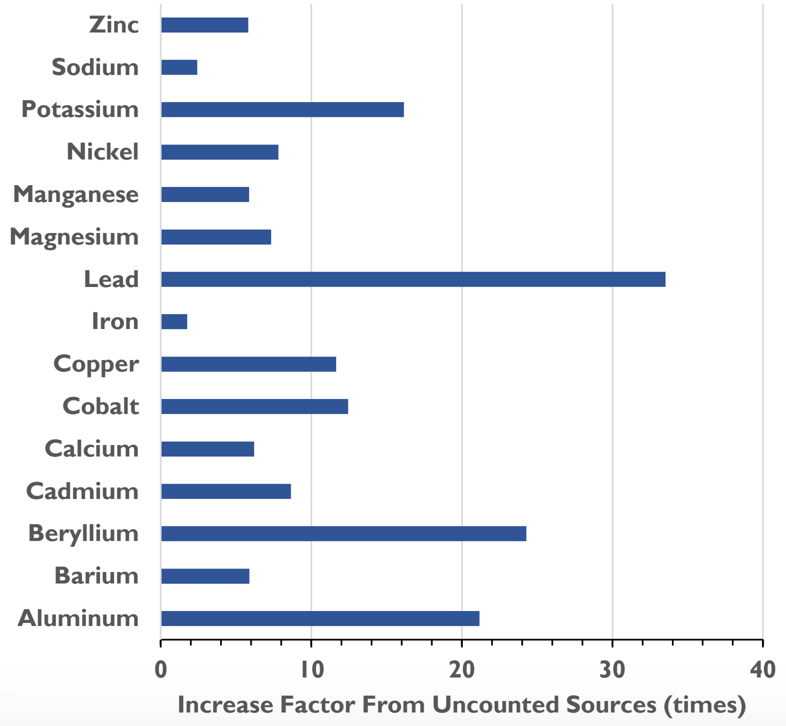
GKM Release to the Animas River

A considerable mass of additional metals was entrained between the mine entrance and the Animas River

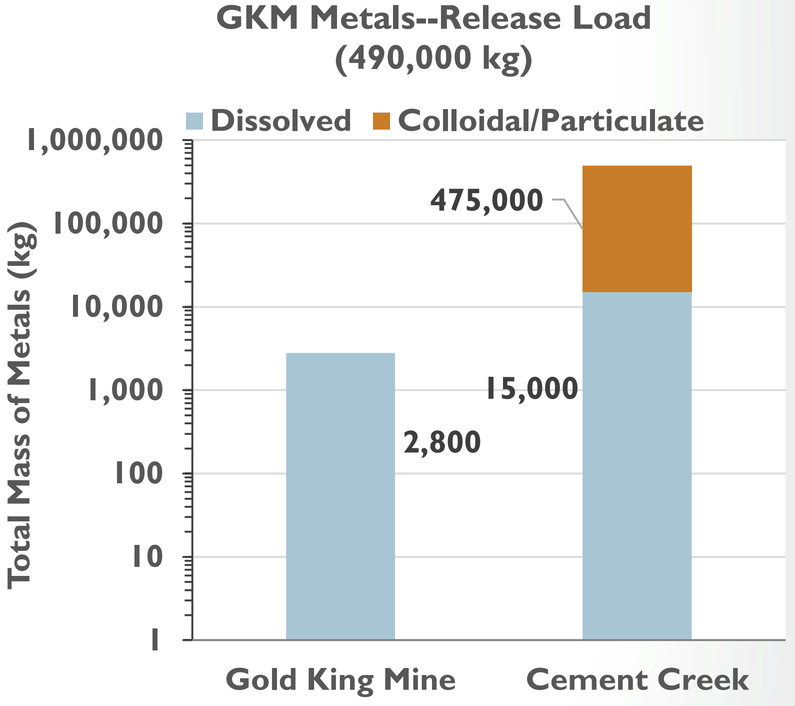
Resulting Concentrations in Cement Creek at Peak



Relative Increase in Dissolved Concentration in Cement Creek From Sources Other than GKM Release Volume

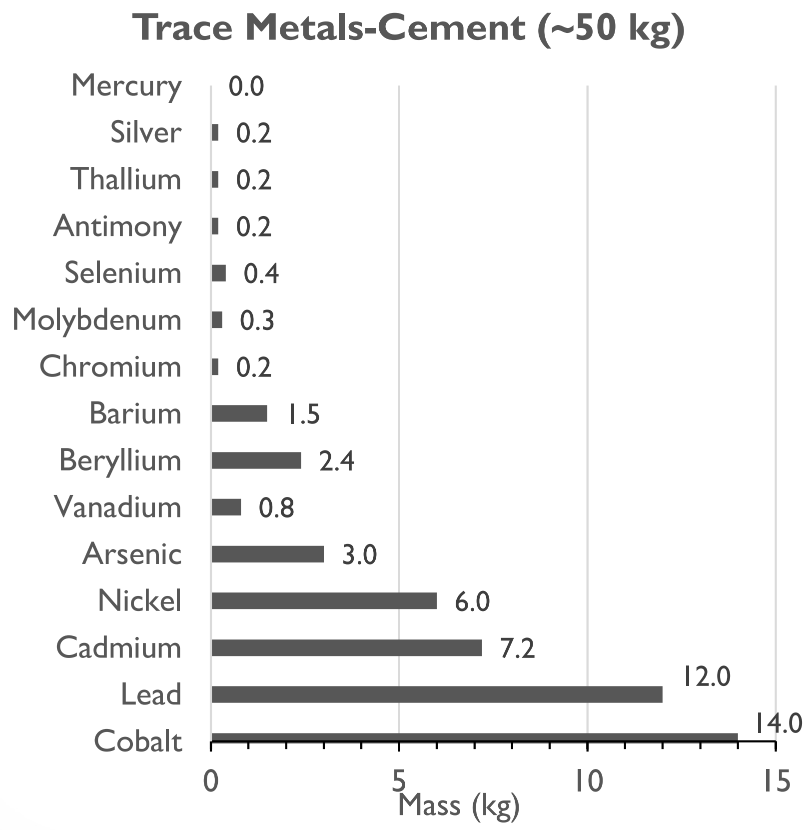


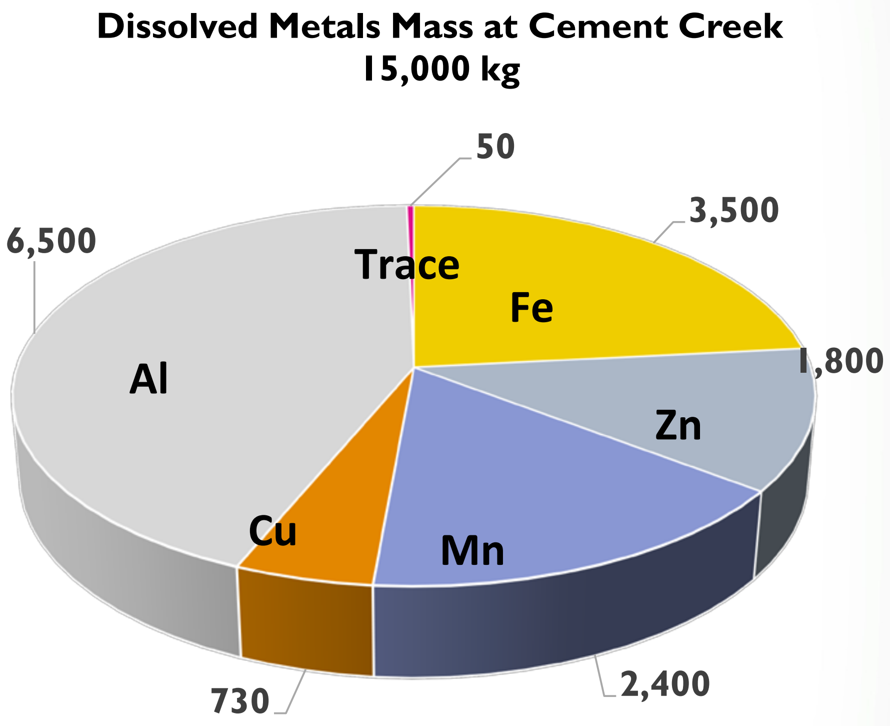
Metals mass from release delivered to Animas River



(Excludes sulfate, major cations)

Dissolved Metal Mass in Cement Creek





Risk Perspective on GKM Metal Load

Water Quality Screening Thresholds—Various Uses, Metals, Agencies

Surface Water in mg/L

Surface Water	Screening Criteria		Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
Drinking Water Related	Drinking water MCL	EPA (DWA)		0.006	0.010	2.000	0.004	0.005				1.300		0.015			0.002				0.050			0.002		
	Secondary Drinking	EPA (DWA)	0.050									1.000	0.300			0.050						0.100	30.000			5.000
	Child Health Advisory 1-Day	EPA (DWA)		0.010		0.700	30.000	0.040								1.000	0.002	0.080	1.000			0.200		0.007		6.000
	Domestic Supply	Colorado			0.01	1.0		0.005		0.05				0.05			0.002					0.1				
	Domestic Supply	New Mexico		0.006	0.010	2.000	0.004	0.005		0.100		1.300		0.015					0.700		0.050			0.002		10.500
	Domestic Source	Utah			0.010	1.000	0.004	0.010		0.05				0.015			0.002				0.050	0.050				
	Health Based Ingestion	Utah	5.25	6.75	31.25							7.75	11.75	37.25		7.0								40.5		
Recreation	Recreational	Region 8	170.000	0.067	0.050	33.000	0.330	0.083		220	0.050	6.700	120.000	0.200		7.800	0.050	0.830	3.300		0.830			0.002	0.830	50.000
Agricultural (Irrigation, livestock)	Irrigation	Region 6		5.000				0.010		0.100	1.000	0.200		5.000		0.200			0.200		0.130				0.100	2.000
	Irrigation	New Mexico	5.000		0.100			10.000		0.100	0.050	0.200		5.000				1.000			0.130				0.100	2.000
	Irrigation (short-term)	Utah	20.000		2.000			0.050		1.000	5.000	5.000	20.000	10.000		10.000		0.050			0.020				1.000	10.000
	Agriculture	Colorado			0.100							0.200	1.000													
	Agricultural Supply	Navajo Nation	5.000		0.100			0.010		0.100	0.050	0.200		5.000				0.010			0.130				0.100	2.000
	Revised Irrigation	Region 9	5.000		2.000			0.050		1.000	0.050	0.200		10.000				1.000			0.020				0.100	10.000
	Livestock	Region 6					0.100	0.050		1.000		0.500		0.100			0.010		1.000		0.250				0.100	25.000
	Livestock updated	Region 9			0.200			0.050		1.000	1.000	0.500		0.100							0.050				0.100	25.000
	Livestock	New Mexico			0.200			0.050		1.000	1.000	0.500		0.100							0.050				0.100	25.000
	Livestock	Utah	5.000		0.200			0.050	500.0	1.000	1.000	0.500		0.100	250.0		0.010				0.050		1000.0		0.100	25.000
	Livestock and Wildlife Watering	Navajo Nation	0.500		0.020	10.000		0.050		1.000	1.000	0.500		0.100			0.01				0.002				0.100	25.000
Aquatic Life	Water + Fish	Colorado		0.006	0.00002					100.000		1.300							0.610		0.170			0.00024		7.400
	Aquatic Acute	Navajo Nation	0.750	0.088	0.340		0.065	0.004		0.012		0.021		0.038			0.0024		0.761		0.002	0.007		0.700		0.176
	Aquatic Acute	Region 6		8.358	0.340			0.003		0.972		0.025		0.130		3.710	0.001		0.813		0.020	0.010				0.290
	Aquatic Acute	Region 9	8.358				0.340	0.003		0.972		0.025		0.130		3.710	0.104		0.813		0.020	0.010				0.290
	Aquatic Acute	Colorado	7.650		0.340			0.003		0.016		0.024		0.136		3.697			0.806		0.0184	0.007				0.2860
	Aquatic Acute	New Mexico	7.650		0.340			0.003		0.004		0.0250		0.026		3.882		7.92	0.900		0.020	0.008				0.288
	Aquatic Acute	Utah	0.750		0.340			0.002		0.570		0.0130	1.000	0.065					0.468		0.0184	0.0016				0.120
	Warm Water Fish 1-hr	Utah	0.750		0.340			0.002		0.570		0.0130	1.000	0.065					0.468		0.0184	0.0016				0.120
	Warm Water Fish 4-day	Utah	0.087		0.150			0.0003		0.074		0.0090	1.000	0.0025					0.052		0.0046					0.120
	Aquatic Chronic	Utah	0.087					0.0003		0.074		0.0090	1.000	0.0025			0.00001		0.052		0.0046					0.120
	Aquatic Chronic	Region 6		3.348	0.150			0.00072		0.126	0.050	0.016		0.005		2.050	0.001		0.090		0.005					0.219
	Aquatic Chronic	Region 9	3.348				0.150	0.001		0.126		0.016		0.005		2.050	0.001		0.090		0.005					0.219
	Aquatic Chronic	Colorado	1.262		0.150			0.0007		0.011		0.0162	1.000	0.0053		2.042	0.00001	0.160	0.090		0.0046	0.00023		0.015		0.228
	Aquatic Chronic	Navajo Nation	0.087	0.030	0.150		0.005	0.0004		0.070		0.0138		0.039			0.000012		0.085		0.002			0.150		0.183
	Aquatic Chronic	New Mexico	3.065		0.150			0.0010		0.069		0.016		0.003		2.145	0.001	1.895	0.100		0.005					0.230

Blue shading is dissolved

Yellow shading is total

Hardness-based criteria calculated at 180 mg/l

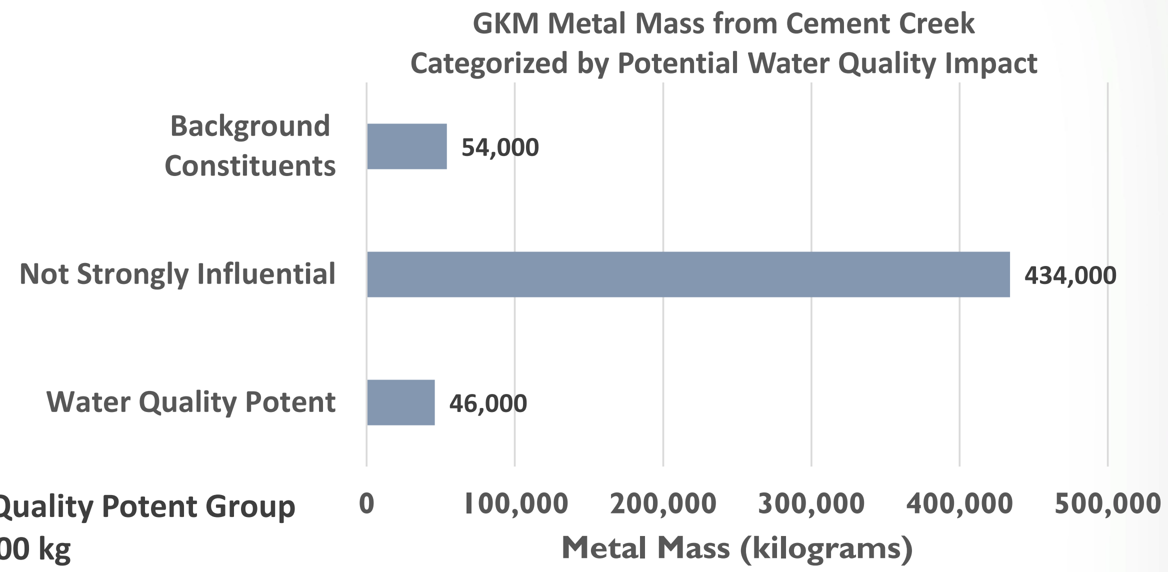
Risk Perspective on GKM Load

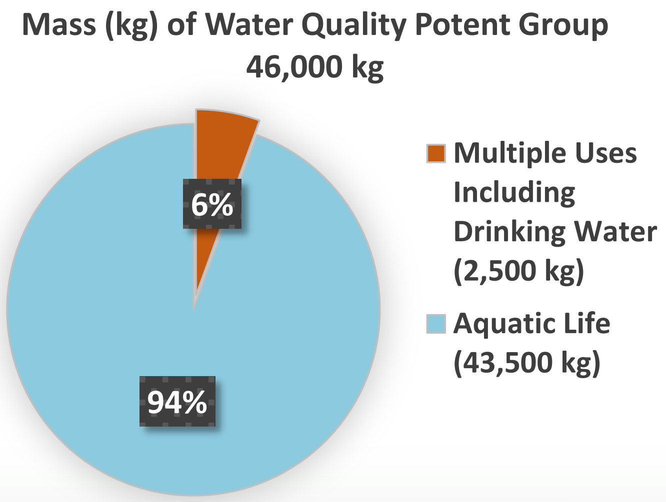
Rationale for Grouping Metals Relative to Potential Effects

Water Quality Potent	Dissolved metals with criteria for most Uses: Drinking water, Recreation, Agriculture, Livestock, Aquatic Life (acute and chronic)	Dissolved Arsenic, Cadmium, Copper, Lead, Mercury, Nickel, Zinc, Manganese
	Dissolved Metals with Criteria Primarily for Aquatic Life	Manganese
	Metals Primarily Targeted for Aquatic Life with Both Fractions	Total and Dissolved Aluminum and Selenium
Not Strongly Influential	Low Toxicity Risk (Do not have many criteria or criteria too high to screen in here)	All forms of Antimony, Barium, Beryllium, Chromium, Cobalt, IRON, Molybedenum, Silver, Thallium, Vanadium. All colloidal/particulate forms for top category
Background Constituents	Major Anions and Cations (dominant background consituents, no criteria)	All forms of Calcium, Potassium, Magnesium, Sodium, Sulfates, NO_x, Chlorides

Risk Perspective on GKM Load

- **Approximately 46,000 kg of metals with highest potential for adverse effects**
  - **2,500 kg potentially affecting drinking water, irrigation, agriculture**
  - **43,500 affecting aquatic life**





Session Summary Key Findings

- **Nearly 500,000 kg of metals were delivered to the Animas River from the Gold King Mine release. About 15,000 kg of the total mass was dissolved metals and the remainder was in a colloidal/particulate form.**
- **Much of the metal mass was entrained as the flood of mine water travelled downslope from the mine entrance and through Cement Creek.**

Supplemental Material

- Data Sources
- Site List of Compiled Data
- Laboratory Methods

Gold King Mine Event-Related Water and Sediment Quality Data Sources

Data source	Information Obtained	Use in study
US EPA **http://www2.epa.gov/goldkingmine**	- sediment and/or surface water quality data collected in Colorado (CO), New Mexico (NM), Arizona (AZ), and Utah (UT) during and post GKM event. - interactive map with GKM release location, river mile markers, and location of surface water and sediment sampling sites - geographic coordinates of sampling sites and GKM release location	- empirical graphing and analysis for release characterization, WASP model calibration - reference, establish distance from GKM source, obtain the coordinates of the GKM release location for mapping purposes - reference, analysis, and cartography
US EPA Region 6 Scribe database **https://www.epaosc.org/site/SCRIBE** **(requires password permission)**	- list and location of public water systems (PWS) sampled by Region 6 - water quality data for those PWS collected after GKM event	- GW analysis: site selection and analysis
US EPA Region 8	- Data for well in Colorado	- GW analysis
Colorado Department of Public Health and Environment (CDPHE) **https://www.colorado.gov/pacific/cdphe/animas-river-water-quality-sampling-and-data**	- surface water and sediment quality data collected in CO after the GKM plume's arrival - drinking water quality data collected in CO after the GKM plume's arrival - fish tissue sample data collected after the arrival of the GKM's plume - geographic coordinates of sampling sites	- empirical graphing and analysis for release characterization - hypothesis testing of groundwater connection to public wells - corroboration of BASS simulation for arsenic - reference, analysis, and cartography
New Mexico Department of Environment **https://www.env.nm.gov/riverwatersafety/GoldKingData.html**	- surface water quality data collected in NM during GKM event - sonde data collected in NM during GKM event - well water quality collected in NM during GKM event - geographic coordinates of sampling sites	- empirical graphing and analysis for release characterization -GKM plume timing - GW analysis - reference, analysis, and cartography
Utah Department of Environmental Quality **http://www.deq.utah.gov/Topics/Water/goldkingmine/data.htm**	- surface water and sediment quality data collected in San Juan River, Utah during the GKM event - geographic coordinates of sampling sites	- empirical graphing and analysis for release characterization - reference, analysis, and cartography
Southern Ute Indian Tribe **Personal communication** **ftp://ftp.southernute-nsn.gov**	- surface water and/or sediment quality data collected during GKM event - sonde data collected on SUIT Reservation during GKM event - geographic coordinates of sampling sites	- empirical graphing and analysis for release characterization - GKM plume timing - reference, analysis, and cartography
National Water Quality Monitoring **http://waterqualitydata.us/portal/**	- Navajo Nation water quality data collected in New Mexico and Utah during the GKM event and pre-event - geographic coordinates of sampling sites	- GKM fate and transport analysis - reference, analysis, and cartography

Pre-event and historic water and sediment quality data sources used in Gold King Mine analyses

Data source	Information Obtained	Use in study
US EPA Superfund Analytic Data Integrator & Explorer (SADIE) https://r8.ercloud.org/sadie (requires password permission)	- surface water and sediment quality data collected pre-GKM release	- pre-event water quality characterization
US EPA STORET Central Warehouse (https://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange)	- surface water quality data collected pre-GKM release	- pre-event water quality characterization
USGS Gold King Mine Release Database http://water.usgs.gov/owq/gkm/wq.html	- surface water and sediment quality data collected pre-GKM release	- pre-event water quality characterization
USGS Professional Paper 1651 database http://pubs.usgs.gov/pp/1651/ (http://pubs.usgs.gov/pp/1651/downloads/	- surface water and sediment quality data collected pre-GKM release	- pre-event water quality characterization
USGS Open-File Report 97-151 appendices data https://pubs.er.usgs.gov/publication/ofr97151	- surface water and sediment quality data collected pre-GKM release	- pre-event water quality characterization
National Water Quality Monitoring http://waterqualitydata.us/portal/	- Navajo Nation water quality data collected in New Mexico and Utah during the GKM event and pre-event - geographic coordinates of sampling sites	- pre-event water quality characterization - reference, analysis, and cartography
Ute Mountain Tribe Personal communication	- surface water quality data collected pre-GKM release - macroinvertebrate screening data pre-GKM release	- pre-event water quality characterization
USGS National Water Information System (NWIS) Surface Water Data http://waterdata.usgs.gov/nwis	- water quality data for a reference gage in the San Juan River	-WASP GKM plume modeling

Surface Water and Sediment Sample Sites—Upper Animas River

Agency	SiteID	Description	Distance from GKM source (miles)	Distance from GKM source (km)	Media	Site Type	Watershed Location	Latitude	Longitude
EPA	**CC06**	source	0	**0.00**	SW	Source	Cement Creek	37.894583	-107.638358
CO (CDPHE)	**CO_GKM_0**	Gold King Mine Adit	0	**0.00**	SW, SED	Source	Cement Creek	37.89455	-107.63827
CO (CDPHE)	**CO_GKM_1**	Gold King Mine Effluent	0.49	**0.79**	SW	Main	Source?	37.895200	-107.6468
CO (CDPHE)	**CO_GKM_2**	Influent Prior to Treatment	0.50	**0.80**	SW	Main	Source?	37.895200	-107.647000
CO (CDPHE)	**CO_RI_R1**	Cement Cr abv Gold King Mine	0.51	**0.82**	SW	Reference	Cement Creek	37.89605	-107.64696
CO (CDPHE)	**CO_RI_R2**	Cement Creek above Gold King	0.51	**0.82**	SW	Reference	Cement Creek	37.896192	-107.64682
CO (CDPHE)	**CO_GKM_3**	(Gold King Mine) Treatment Effluent	0.51	**0.82**	SW	Source	Cement Creek	37.89572	-107.64714
CO (CDPHE)	**CO_RI_R3**	Cement Creek Upstream of GKM Treatment	0.51	**0.82**	SW	Source	Cement Creek	37.89545	-107.6475
CO (CDPHE)	**CO_RI_M1**	Cement Cr blw Gold King Mine	0.54	**0.87**	SW	Main	Cement Creek	37.89468	-107.64737
EPA	**GKM13**		0.54	**0.87**	SW	Main	Cement Creek	37.894692	-107.647253
CO (CDPHE)	**CO_RI_M2**	Cement Creek (below mine)	0.56	**0.90**	SW	Main	Cement Creek	37.89456	-107.64774
CO (CDPHE)	**CO_RI_M3**	Cement Creek below Gold King	0.6	**0.97**	SW	Main	Cement Creek	37.893968	-107.647855
CO (CDPHE)	**CO_RI_M4**	Treatment	0.61	**0.98**	SW	Main	Cement Creek	37.8938	-107.64762
CO (CDPHE)	**CO_RI_M4.1**	Animas River	1.9	**3.06**	SW	Main	Cement Creek	37.8848	-107.66526
EPA	**CC48**		7.79	**12.54**	SW	Main	Cement Creek	37.819984	-107.663275
EPA	**CC 14th St Bridge**		8.36	**13.45**	SW	Main	Cement Creek	37.812475	-107.661401
CO (CDPHE)	**CO_RI_M5**	Cement Creek above Animas River	8.56	**13.78**	SW	Main	Cement Creek	37.809993	-107.6606917
CO (CDPHE)	**CO_RI_M6**	Cement Creek (above Animas River)	8.59	**13.82**	SW	Main	Cement Creek	37.80972	-107.66065
EPA	**A68**	reference	8.64	**13.90**	SW	Reference	Upper Animas	37.811202	-107.659167
CO (CDPHE)	**CO_RI_R5**	Animas River (above Cement Creek)	8.64	**13.90**	SW	Reference	Upper Animas	37.81109	-107.65932
CO (CDPHE)	**CO_RI_R6**	Animas River above Cement Creek	8.64	**13.90**	SW	Reference	Upper Animas	37.811355	-107.6591967
CO (CDPHE)	**CO_RI_R9**	Animas River above Cement Creek	8.64	**13.90**	SW	Reference	Upper Animas	37.811065	-107.659232
CO (CDPHE)	**CO_RI_R7**	Animas River above Cement Creek	8.64	**13.90**	SW, SED	Reference	Upper Animas	37.810892	-107.659445
CO (CDPHE)	**CO_RI_M7**	Mineral Creek)	9.06	**14.58**	SW	Main	Upper Animas	37.804035	-107.6645183
CO (CDPHE)	**CO_RI_M8**	Animas River above Mineral Creek	9.09	**14.63**	SW, SED	Main	Upper Animas	37.804023	-107.664772
CO (CDPHE)	**CO_RI_R8**	Mineral Creek above Animas River	9.41	**15.14**	SW	Reference	Upper Animas	37.80282	-107.6728217
CO (CDPHE)	**CO_RI_M9**	Animas River near Silverton	9.67	**15.56**	SW, SED	Main	Upper Animas	37.797001	-107.6693973
CO (CDPHE)	**CO_RI_M11**	(below Cement Creek) (blw Mineral Cr Conf)	9.73	**15.66**	SW	Main	Upper Animas	37.79625	-107.66942
CO (CDPHE)	**CO_RI_M12**	Creek)	10.15	**16.33**	SW	Main	Upper Animas	37.79039	-107.667385
EPA	**A72**		10.16	**16.35**	SW	Main	Upper Animas	37.79027	-107.667578
CO (CDPHE)	**CO_RI_M13**	at gage - just upstream of railroad bridge	10.2	**16.42**	SW, SED	Main	Upper Animas	37.789767	-107.6675452
CO (CDPHE)	**CO_RI_M44**	Animas River in canyon 3 above Elk Creek	15.24	**24.53**	SW	Main	Upper Animas	37.721807	-107.654554

Green shading indicates location where plume is reconstructed, mass is calculated with the empirical model and WASP is calibrated

Surface Water and Sediment Sample Sites—Middle Animas River

Agency	SiteID	Description	Distance from GKM source (miles)	Distance from GKM source (km)	Media	Site Type	Watershed Location	Latitude	Longitude
CO (CDPHE)	**CO_RI_M14**	Animas River at Bakers Bridge	39.46	**63.50**	SW, SED	Main	Middle Animas	37.45844	-107.7997567
CO (CDPHE)	**CO_RI_M15**	Animas River at Bakers Bridge	39.47	**63.52**	SW	Main	Middle Animas	37.458517	-107.7996933
EPA	**GKM02**		39.66	**63.83**	SW	Main	Middle Animas	37.455639	-107.800945
EPA	**Bakers Bridge**		39.78	**64.02**	SW	Main	Middle Animas	37.454134	-107.801601
CO (CDPHE)	**CO_RI_M16.1**	above James Ditch at headgate pre-flush	40.51	**65.19**	SW	Main	Middle Animas	37.444217	-107.8039933
CO (CDPHE)	**CO_DI_4**	James Ditch - 2nd flush	40.56	**65.27**	SW	Ditch	Middle Animas	37.443588	-107.804965
CO (CDPHE)	**CO_DI_5**	James Ditch - 1st flush	40.57	**65.29**	SW	Ditch	Middle Animas	37.443595	-107.8049267
CO (CDPHE)	**CO_DI_6**	James Ditch pre-flush	40.58	**65.31**	SW	Ditch	Middle Animas	37.443623	-107.8049783
CO (CDPHE)	**CO_DI_7**	James Ditch - post flush	40.59	**65.32**	SW	Ditch	Middle Animas	37.443517	-107.8050133
EPA	**GKM17**	off river pond	40.73	**65.55**	SW	pond	Middle Animas	37.441355	-107.805058
EPA	**GKM16**	off river pond	40.84	**65.73**	SW	pond	Middle Animas	37.439878	-107.804945
EPA	**GKM18**	off river pond	40.92	**65.85**	SW	pond	Middle Animas	37.438755	-107.805358
CO (CDPHE)	**CO_DI_8**	James Creek at James Ranch	41.71	**67.13**	SW	Ditch	Middle Animas	37.426782	-107.8150233
CO (CDPHE)	**CO_RI_M18**	Animas River at Trimble Bridge	45.93	**73.92**	SW	Main	Middle Animas	37.384737	-107.8374767
CO (CDPHE)	**CO_RI_M20**	north of Durango	49.31	**79.36**	SW	Main	Middle Animas	37.35618	-107.84412
EPA	**32nd St Bridge**		57.02	**91.76**	SW	Main	Middle Animas	37.299991	-107.868199
CO (CDPHE)	**CO_RI_M45**	Animas River at 32nd Street - post flush	57.02	**91.76**	SW	Main	Middle Animas	37.30009	-107.86886
CO (CDPHE)	**CO_RI_M46**	Animas River at 29th Street - post flush	57.31	**92.23**	SW	Main	Middle Animas	37.295592	-107.870735
EPA	**GKM04**		57.4	**92.38**	SW	Main	Middle Animas	37.294799	-107.870034
EPA	**NIMAS-ROTARY PARK**		58.56	**94.24**	SW	Main	Middle Animas	37.280718	-107.876927
CO (CDPHE)	**CO_RI_M27**	Animas River at 9th Street	59.51	**95.77**	SW	Main	Middle Animas	37.274563	-107.8842733
CO (CDPHE)	**CO_RI_M29**	Animas River at Durango - 9th St bridge	59.59	**95.90**	SW, SED	Main	Middle Animas	37.273659	-107.8854425
CO (CDPHE)	**CO_RI_M31**	at Durango - 9th St bridge - post flush	59.62	**95.95**	SW	Main	Middle Animas	37.273482	-107.8856213
EPA	**GKM05**		59.95	**96.48**	SW	Main	Middle Animas	37.268704	-107.885857
CO (CDPHE)	**CO_RI_M32**	Animas River at Lightner Creek	59.96	**96.50**	SW, SED	Main	Middle Animas	37.268357	-107.8861043
CO (CDPHE)	**CO_RI_M33**	Animas River at Lightner Creek	59.97	**96.51**	SW	Main	Middle Animas	37.268254	-107.8861295
CO (CDPHE)	**CO_RI_M35**	below (Durrango) WWTP	60.81	**97.86**	SW	Main	Middle Animas	37.259523	-107.8778555
CO (CDPHE)	**CO_RI_M36**	below Durango WWTF	60.82	**97.88**	SW	Main	Middle Animas	37.25933	-107.877775
EPA	**GKM01**		64.1	**103.16**	SW	Main	Middle Animas	37.221542	-107.859455
SUIT	**AR 19-3**	Southern Ute Tribe AR19-3	64.73	**104.17**	SW, SED	Main	Middle Animas	37.213842	-107.854161
SUIT	**AR 16-0**	Southern Ute Tribe AR16-0	67.7	**108.95**	SW, SED	Main	Middle Animas	37.18703	-107.86993
SUIT	**Basin Creek**		68.52	**110.27**	SW	Main	Middle Animas	37.18541	-107.878744
SUIT	**AR 7-2**	Southern Ute Tribe AR7-2	76.48	**123.08**	SW, SED	Main	Middle Animas	37.08499	-107.87838
CO (CDPHE)	**CO_RI_M41**	Animas River at Bondad Bridge	79.42	**127.81**	SW	Main	Middle Animas	37.050973	-107.875217
CO (CDPHE)	**CO_RI_M42**	Animas River at Bondad Bridge	79.43	**127.83**	SW	Main	Middle Animas	37.051025	-107.875025
CO (CDPHE)	**CO_RI_M43**	Bondad Bridge	79.43	**127.83**	SW	Main	Middle Animas	37.050948	-107.875088
SUIT	**NAR 6**		81.7	**131.48**	SW	Main	Middle Animas	37.02342	-107.87387

Green shading indicates location where plume is reconstructed, mass is calculated with the empirical model and WASP is calibrated

Surface Water and Sediment Sample Sites—Lower Animas River

Agency	SiteID	Description	Distance from GKM source (miles)	Distance from GKM source (km)	Media	Site Type	Watershed Location	Latitude	Longitude
EPA	**ADWS-IT2**	Intake Sampling Location	91.68	**147.54**	SW	Main	Lower Animas	36.9333	-107.90907
EPA	**ADW-022**	Intake Sampling Location	91.68	**147.54**	SW, SED	Main	Lower Animas	36.9333	-107.90907
EPA	**ISW-020 (NSW-AR**	Intake Sampling Location	94.19	**151.58**	SW, SED	Main	Lower Animas	36.900898	-107.917122
EPA	**DW-021 (ADWS-IT**	Intake Sampling Location	97.9	**157.55**	SW	Main	Lower Animas	36.872802	-107.96084
EPA	**/-010 (Also ADWS-**	Intake Sampling Location	101.2	**162.87**	SW	Main	Lower Animas	36.838545	-107.992183
EPA	**AWI-R8R6**	Intake Sampling Location	101.21	**162.88**	SW	Ditch	Lower Animas	36.838447	-107.992417
NMED	**66Animas029.2**	Aztec drinking water intake	101.28	**162.99**	SW	Ditch	Lower Animas	36.837463	-107.991684
NMED	**66Animas028.1**	Animas River above Estes Arroyo, near Aztec	101.96	**164.09**	SW	Main	Lower Animas	36.82949	-107.997663
EPA	**FWI-R8R6**	Intake Sampling Locations	109.71	**176.56**	SW	Main	Lower Animas	36.783476	-108.102056
EPA	**FWS-ARP2**	Farmington water system	109.71	**176.56**	SW	Main	Lower Animas	36.78357	-108.10214
EPA	**FW-012**	Intake Sampling Location	109.71	**176.56**	SW, SED	Main	Lower Animas	36.783635	-108.10211
EPA	**MWSS-ARI**	Intake	111.03	**178.69**	SW	off river pond	Lower Animas	36.77134	-108.11893
EPA	**MW-020**	ARI	111.03	**178.69**	SW, SED	Pond	Lower Animas	36.771913	-108.118596
NMED	**66Animas001.7**	Animas River at Boyd Park in Farmington	117.68	**189.39**	SW	Main	Lower Animas	36.72303	-108.201611
EPA	**FW-040**	Intake Sampling Location	118.16	**190.16**	SW, SED	Main	Lower Animas	36.719664	-108.207125
EPA	**FWS-FDPS**	Intake Sampling Location	118.85	**191.27**	SW	Main	Lower Animas	36.71455	-108.21644

Green shading indicates location where plume is reconstructed, mass is calculated with the empirical model and WASP is calibrated

Surface Water and Sediment Sample Sites—San Juan River

Agency	SiteID	Description	Distance from GKM source (miles)	Distance from GKM source (km)	Media	Site Type	Watershed Location	Latitude	Longitude
EPA	LVW-WPI	Water intake	121.82	196.05	SW	Main	San Juan	36.73139	-108.249
EPA	LVW-020	Intake Sampling Location	121.82	196.05	SW, SED	Main	San Juan	36.730556	-108.251046
EPA	SJLP		122.33	196.87	SW, SED	Main	San Juan	36.735887	-108.2539868
EPA	LVW-FD	Intake Sampling Location	126.35	203.34	SW	Ditch	San Juan	36.73156	-108.31426
NMED	67SanJua088.1	San Juan River at Lions Park near Kirtland	127.03	204.43	SW	Main	San Juan	36.722136	-108.325619
EPA	LVW-030	Intake Sampling Location	127.06	204.48	SW, SED	Main	San Juan	36.721812	-108.325933
EPA	SJFP		133.24	214.43	SW, SED	Main	San Juan	36.748156	-108.4120157
NNEPA	10SANJUANR25	@ bottom of Hogback fish passage	141.44	227.63	SW	Main	San Juan	36.745463	-108.5378488
EPA	SJHB		141.46	227.66	SW, SED	Main	San Juan	36.745192	-108.5377578
EPA	SJSR		153.07	246.34	SW, SED	Main	San Juan	36.781624	-108.6927838
NNEPA	10SANJUANR26	San Juan River near Canal Creek	169.31	272.48	SW	Main	San Juan	36.893252	-108.8785948
EPA	SJDS		169.31	272.48	SW, SED	Main	San Juan	36.893312	-108.8786415
NNEPA	02SANJUANR06	near NM/CO border at the Four Corners	183.82	295.83	SW	Main	San Juan	36.996201	-109.0046225
EPA	SJ4C		183.82	295.83	SW, SED	Main	San Juan	36.996216	-109.0046838
UDEQ	4954000	San Juan R at US160 Xing in CO	185.63	298.74	SW, SED	Main	San Juan	37.001755	-109.032726
EPA	MECT	reference	206.85	332.89	SW, SED	Reference	San Juan	37.218462	-109.190811
EPA	SJME		207.05	333.21	SW, SED	Main	San Juan	37.216811	-109.19615
UDEQ	4953990		214.82	345.72	SW, SED	Main	San Juan	37.257788	-109.30975
NNEPA	02SANJUANR07	near bridge at Montezuma Creek	214.87	345.80	SW	Main	San Juan	37.258277	-109.310476
EPA	SJMC		214.87	345.80	SW, SED	Main	San Juan	37.258226	-109.3106036
UDEQ	4953400	SAN JUAN R AT SWINGING FOOTBRIDGE	226.65	364.76	SW	Main	San Juan	37.280001	-109.4928962
UDEQ	4953250	SAN JUAN R AT SAND ISLAND	234.29	377.05	SW, SED	Main	San Juan	37.260279	-109.6137343
NNEPA	02SANJUANR08	at US 191 bridge near Bluff	234.62	377.58	SW	Main	San Juan	37.257673	-109.61849
EPA	SJBB		234.64	377.62	SW, SED	Main	San Juan	37.25737	-109.6185856
EPA	SJMH		261.8	421.33	SW, SED	Main	San Juan	37.149993	-109.8662835
NNEPA	29SANJUANR05	Immediately upstream from the mouth of McElmo Creek	261.84	421.39	SW	Main	San Juan	37.150388	-109.866814
UDEQ	4953000	SAN JUAN R AT MEXICAN HAT US163 XING	261.9	421.49	SW, SED	Main	San Juan	37.150758	-109.867672
UDEQ	4952942	San Juan River at Clay Hills boat ramp	317.36	510.74	SW, SED	Main	San Juan	37.293008	-110.399621
EPA	LPCH		337.87	543.75	SW, SED	Main	San Juan	37.25567	-110.66414
EPA	SJIN		337.93	543.85	SW	Main	San Juan	37.2536	-110.6632
EPA	LPPW		350.46	564.01	SW, SED	Lake	Lake Powell	37.16278	-110.7085
EPA	LPRC		390.2	627.97	SW, SED	Lake	Lake Powell	37.13642	-111.19226
EPA	LPGB		394.15	634.32	SW, SED	Lake	Lake Powell	37.05487	-111.23475
EPA	LPPC		396.12	637.49	SW, SED	Lake	Lake Powell	37.06631	-111.26525
EPA	LPNC	Lake Powell	402.32	647.47	SW	Lake	Lake Powell	36.939	-111.32459
EPA	LPDAM	Lake Powell at Dam	412.31	663.55	SW	Lake	Lake Powell	36.94436	-111.48691
EPA	PAGE	Lake Powell	414.15	666.51	SW	PWS	Lake Powell	36.908472	-111.4535528

Test Methods for Metals Employed by Data Contributors

Surface Water

Aluminum -Chromium

ICP-AES – Inductively Coupled Plasma-Atomic Emission Spectroscopy		
ICP/MS – Inductively Couple Plasma/Mass Spectrometry		
cICP–MS - Collision/reaction cell Inductively Coupled Plasma-Mass Spectrometry		

	Analytical Method									
Analyte	USEPA Region 6	USEPA Region 8	USEPA Region 9	Colorado DPHE	Southern Ute Indian Tribe	Navajo Nation	New Mexico ED	Utah DEQ	SADIE	USGS GKM database
Aluminum (Al)	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.7, 200.7/6010, EPA 200.8 ICP-AES and ICP/MS	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES USGS I-2477-92 D ICP/MS Unknown D EPA 200.7 TR ICP-AES USGS I-4471-97 TR ICP-AES USGS I-4471-97 TR ICP/MS Unknown TR
Antimony (Sb)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	NA	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-2477-92 D ICP/MS Unknown D USGS I-4471-97 T ICP/MS
Arsenic (As)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8, 200.8/6020 ICP/MS	USGS I-2020-05 D cICP–MS USGS I-2063-98 D GFAAS USGS I-2477-92 D ICP/MS Unknown D USGS I-4020-05 T cICP–MS USGS I-4063-98 T GFAAS
Barium (Ba)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES USGS I-2477-92 D ICP/MS Unknown D EPA 200.7 TR ICP-AES USGS I-4471-97 TR ICP/MS
Beryllium (Be)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7, 200.7/6010 ICP-AES	USGS I-2477-92 D ICP/MS Unknown D USGS I-4471-97 TR ICP/MS
Boron (B)	NA	NA	NA	EPA 200.7 ICP-AES	NA	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	NA	NA	NA
Cadmium (Cd)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8, 200.8/6020 ICP/MS	EPA 200.7 D ICP-AES USGS I-2138-89 D GF-AAS USGS I-2477-92 D ICP/MS Unknown D EPA 200.7 T ICP-AES USGS I-4471-97 T ICP/MS Unknown T
Calcium (Ca)	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7, 200.7/6010, EPA 200.8 ICP-AES and ICP/MS	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES Unknown D
Chromium (Cr)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7/6010, EPA 200.8 ICP-AES and ICP/MS	EPA 200.7 D ICP-AES USGS I-1233-93 D GFAAS USGS I-2020-05 D cICP–MS USGS I-2477-92 D ICP/MS Unknown D EPA 200.7 TR ICP-AES USGS I-3233-93 TR GFAAS USGS I-4020-05 TR cICP–MS Unknown TR
Chromium(III)	NA	NA	NA	NA	NA	SM 3500-CR(D)	NA	NA	NA	NA
Chromium(VI)	NA	NA	NA	NA	NA	SM 3500-CR(D)	NA	NA	NA	NA

Test Methods for Metals Employed by Data Contributors

Surface Water

Cobalt -Molybedenum

ICP-AES – Inductively Coupled Plasma-Atomic Emission Spectroscopy	
ICP/MS – Inductively Couple Plasma/Mass Spectrometry	
cICP–MS - Collision/reaction cell Inductively Coupled Plasma-Mass Spectrometry	

	Analytical Method									
Analyte	USEPA Region 6	USEPA Region 8	USEPA Region 9	Colorado DPHE	Southern Ute Indian Tribe	Navajo Nation	New Mexico ED	Utah DEQ	SADIE	USGS GKM database
Cobalt (Co)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-2020-05 D cICP–MS USGS I-2477-92 D ICP/MS Unknown D USGS I-4020-05 TR
Copper (Cu	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8, 200.8/6020 ICP/MS	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES
Iron (Fe)	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	NA	EPA 200.7 ICP-AES	EPA 200.7, 200.7/6010 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES Unknown D EPA 200.7 TR ICP-AES
Lead (Pb)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8, 200.8/6020 ICP/MS	EPA 200.7 D ICP-AES USGS I-2403-89 D GFAAS USGS I-2477-92 D ICP/MS Unknown D
Magnesium	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES
Manganese	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES
Mercury (H	EPA 245.1 CVAA	EPA 245.1 CVAA	EPA 245.1 CVAA	EPA 200.8, EPA 245.1 ICP/MS and CVAA	EPA 7470A CVAA	EPA 1631E	EPA 245.1 CVAA	EPA 245.1 CVAA	NA	USGS I-2462-85 D CVAAS USGS I-2464-01 D CV-AFS USGS I-3462-85 TR CVAAS USGS I-4464-01 TR CV-AFS Unknown TR
Molybdenu	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 D ICP-AES USGS I-2477-92 D ICP/MS Unknown D EPA 200.7 TR ICP-

Test Methods for Metals Employed by Data Contributors

Surface Water

Nickel -Zinc

ICP-AES – Inductively Coupled Plasma-Atomic Emission Spectroscopy
ICP/MS – Inductively Couple Plasma/Mass Spectrometry
cICP–MS - Collision/reaction cell Inductively Coupled Plasma-Mass Spectrometry

Analyte	Analytical Method									
	USEPA Region 6	USEPA Region 8	USEPA Region 9	Colorado DPHE	Southern Ute Indian Tribe	Navajo Nation	New Mexico ED	Utah DEQ	SADIE	USGS GKM database
Nickel (Ni)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES USGS I-2020-05 D cICP–MS
Potassium (	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	NA	EPA 200.7 ICP-AES	EPA 200.7/6010 ICP-AES	SM 3120 ICP D ICP-OES USGS I-1630-85 D AAS Unknown D
Selenium (S	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-2020-05 D cICP–MS USGS I-2477-92 D ICP/MS USGS I-2668-98 D GFAAS Unknown D
Silver (Ag)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8, 200.8/6020 ICP/MS	USGS I-2477-92 D ICP/MS USGS I-2724-89 D GFAAS USGS I-2725-93 D GFAAS Unknown D
Sodium (Na	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	EPA 200.7 ICP-AES	NA	EPA 200.7 ICP-AES	EPA 200.7, 200.7/6010 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES Unknown D
Thallium (Tl	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	NA	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-2477-92 D ICP/MS USGS I-4471-97 T ICP/MS
Uranium	NA	NA	NA	EPA 200.8 ICP/MS	NA	EPA 200.8 ICP/MS	NA	NA	NA	NA
U-234/235,	NA	NA	NA	NA	NA	NA	EPA 200.8 ICP/MS	NA	NA	NA
Vanadium (	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES USGS I-2020-05 D cICP–MS
Zinc (Zn)	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.7 ICP-AES	EPA 200.8 ICP/MS	EPA 200.8 ICP/MS	EPA 200.7, 200.7/6010, EPA 200.8 ICP-AES	USGS I-1472-85 D ICP-AES USGS I-1472-87 D ICP-AES USGS I-1472-95 D ICP-AES USGS I-2020-05 D cICP–MS

(green)	Horizontal green shading indicates the method used to determine the analyte in question is the same.
NA	Means "Not applicable" because the analyte was not measured by that entity.

ICP-AES – Inductively Coupled Plasma-Atomic Emission Spectroscopy
ICP/MS – Inductively Couple Plasma/Mass Spectrometry
cICP–MS - Collision/reaction cell Inductively Coupled Plasma-Mass Spectrometry