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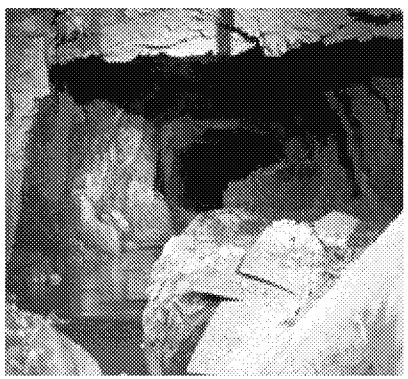
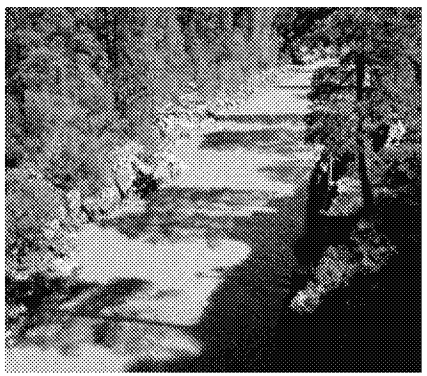
Illustration of a "Finger-printing" Method to Isolate Gold King Release Metals from Background Concentrations in the San Juan River

Kate Sullivan, Mike Cyterski, Chris Knightes, John Washington, Steve Kraemer, Lourdes Prieto, Brian Avant





Office of Research and Development
National Exposure Research Laboratory

June 20, 2017

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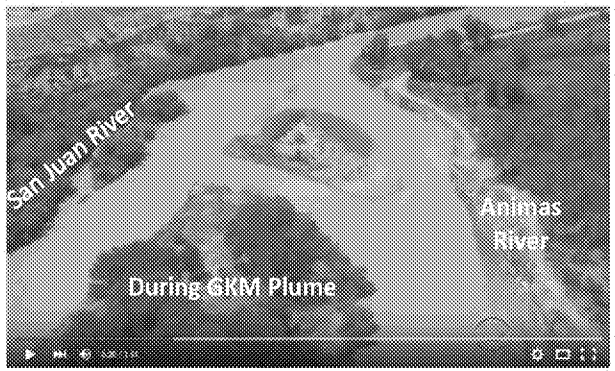
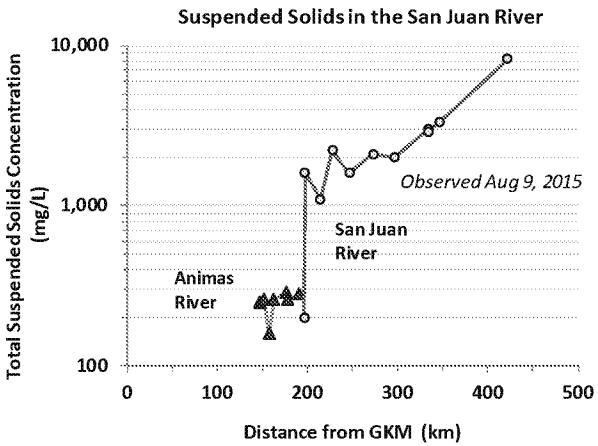
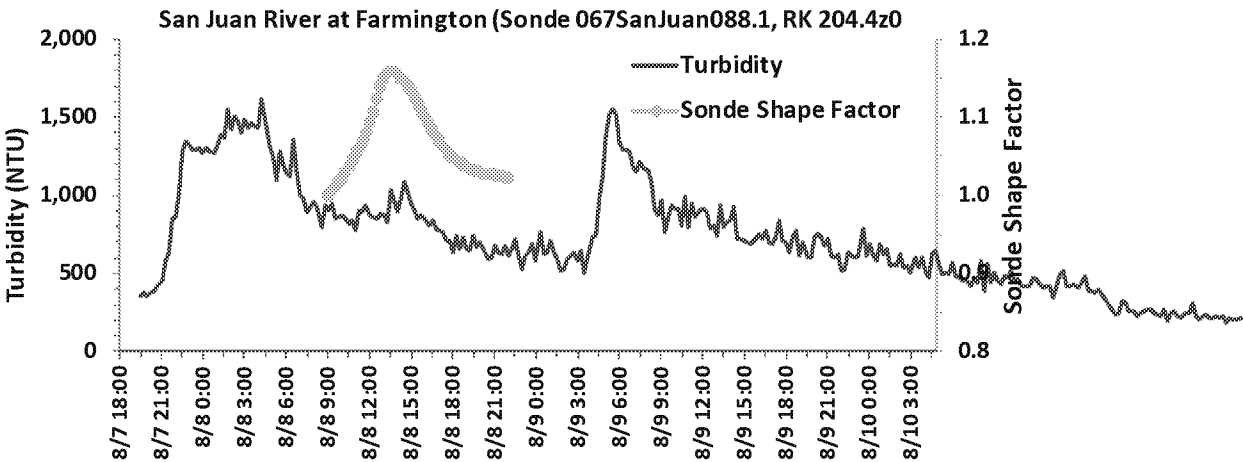
The challenge was to quantify the Gold King plume in the San Juan River given the high background sediment load

- Sediment has a suite of metals that occur in large or trace amounts, depending on metal
- During the GKM plume, the strong visual signal was lost due to sediment and its background content of metals that masked the GKM metals
- This prompted us to look for some means to detect the Gold King metals within the background sediment







Sediment loads were high and variable at the general time the GKM plume passed as indicated by turbidity

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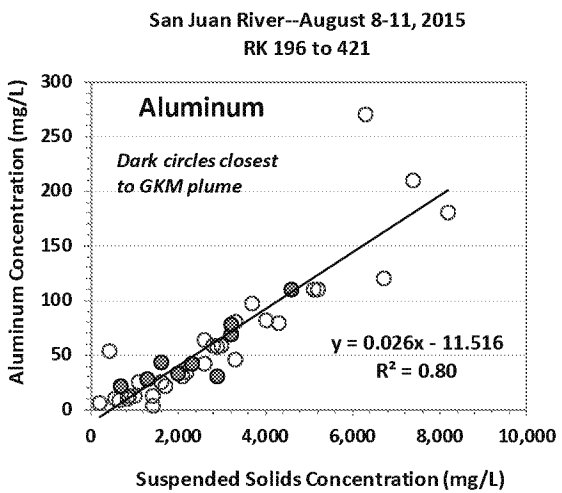
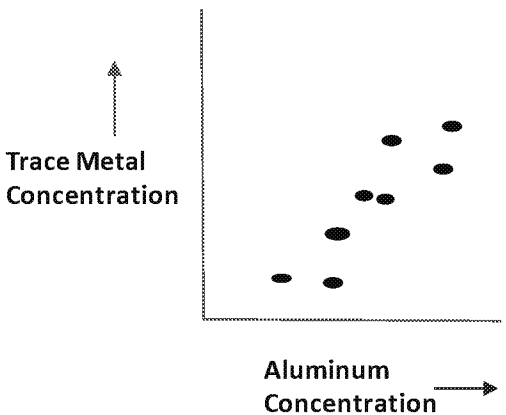
Rationale

- Only a limited number of direct measures of sediment were available during the GKM event and in the months afterward
- Must use an indicator from the standard set of metals in the samples (23)
- Aluminum (Al) and Iron (Fe) are abundant in rocks and soils and their concentrations should indicate general sediment levels
- The relative distribution of the major and trace metals in the water and sediments of the river should mimic the elemental composition of the dominant geologies of the watershed
- Therefore, trace metals should also have a relationship with Al or Fe that is constant, while their actual concentrations should vary with the sediment load





As sediment increases, the aluminum increases

As aluminum increases, other metals increase proportionately

A simple approach was adopted

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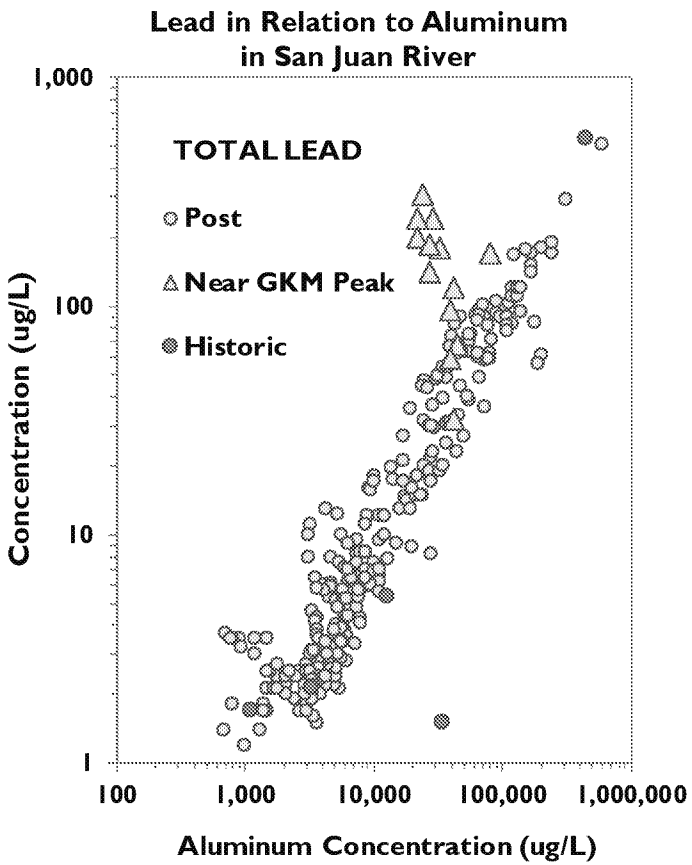
Graph the concentration of trace metals against the concentration of either Al or Fe, or calculate their ratio



All San Juan Samples Grouped

$$Trace\ Metal\ Ratio = \frac{Trace\ Concentration}{Aluminum\ Concentration}$$

- Using lead as an example, there is a strong central tendency in its relationship with aluminum over a wide range of concentration
- The relationship was remarkably consistent for the entire San Juan River
- Deviations from the baseline underlying relationship indicate a contaminant
- The technique was helpful for evaluating the Gold King Mine plume—it may have utility for other applications in this river system

(This works just as well with Fe)

Total Water Concentration—San Juan River during the GKM plume and through Fall 2015 shows strong correspondence of most trace metals to aluminum

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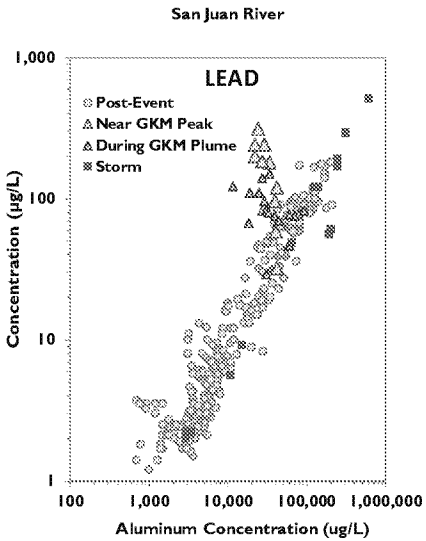

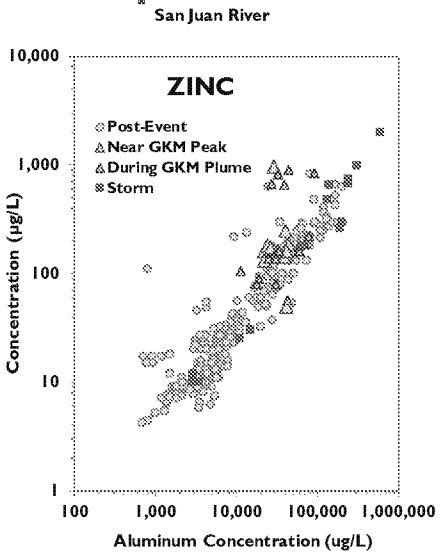

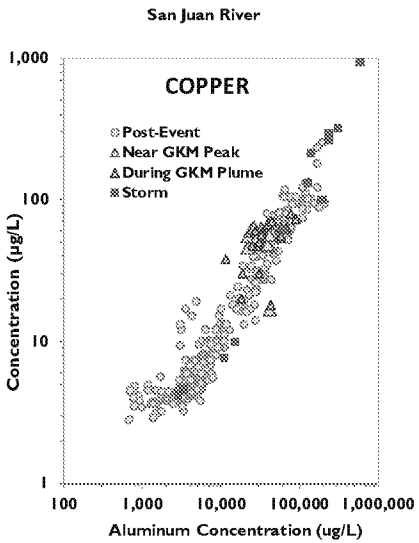

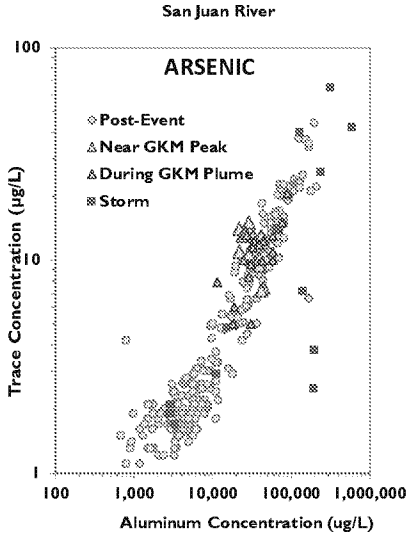

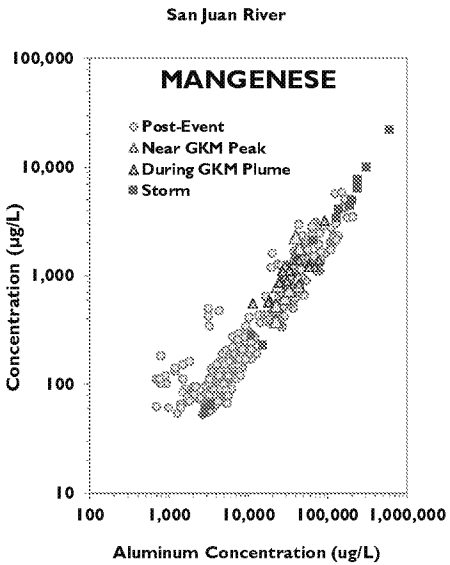

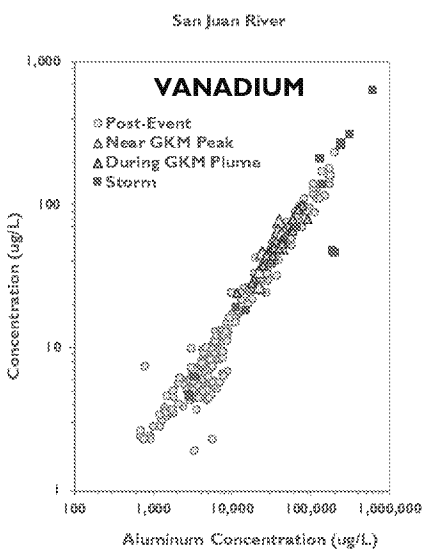

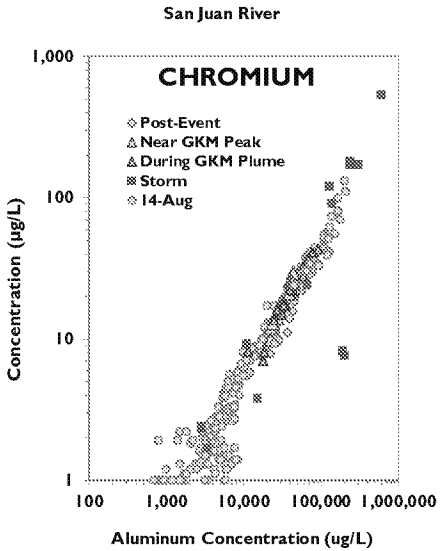

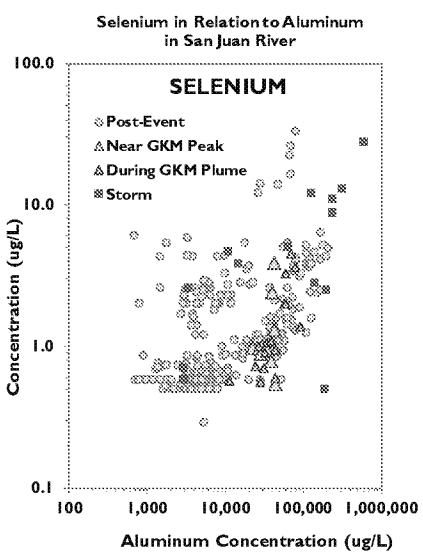

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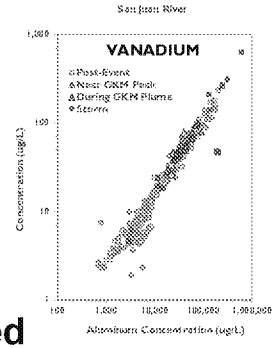
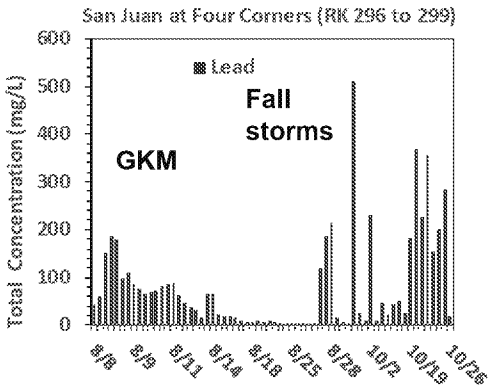
The trace *metal:Al* ratio is independent of concentration and should remain more or less constant over time

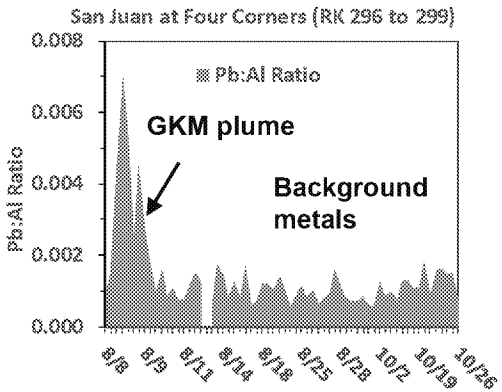


Metals concentrations increased and receded during a series of high flow events, one of which included the GKM release . . . .

. . .the Pb:Al ratio only increased significantly during the GKM period indicating external contaminants.

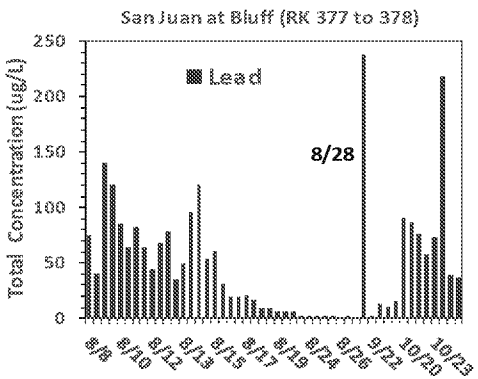
San Juan at Four Corners (RK 296)

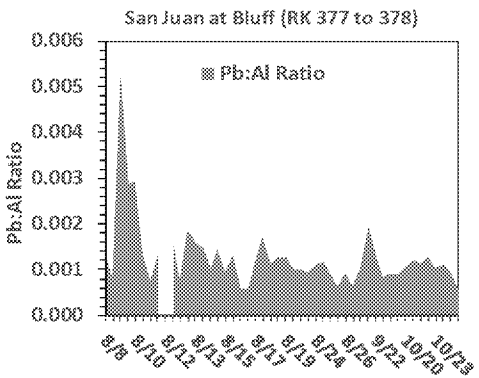




Most of the post GKM event samples in the San Juan River reflect background conditions

San Juan at Bluff RK 377)





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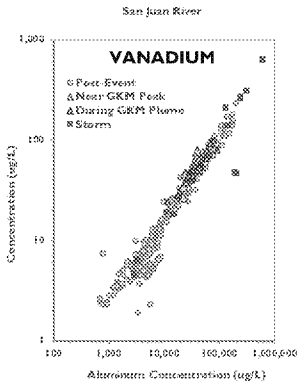
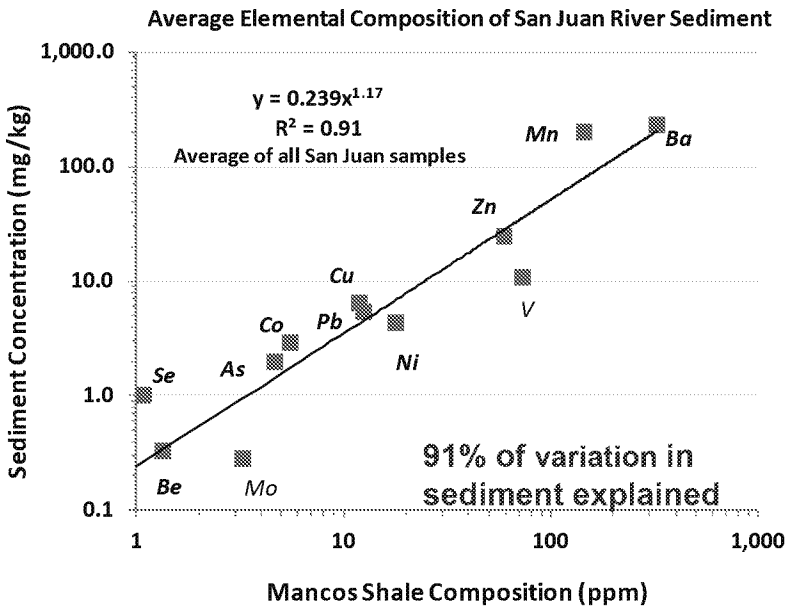
The elemental content of water and sediment in the San Juan River resembles that of the Mancos Shale, the prominent surficial geology in the area

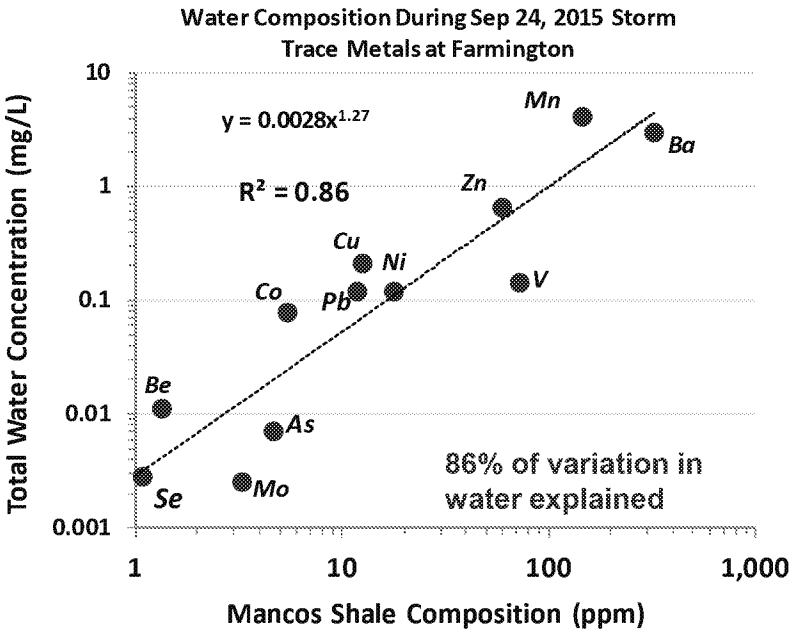


This controls the basic ratio between aluminum and the trace metals

Sediment



Water



Solid samples from pits (soil and shale extract)
Mancos composition from Tuttle et al., 2007)

Mancos Shale is 5.9% Aluminum

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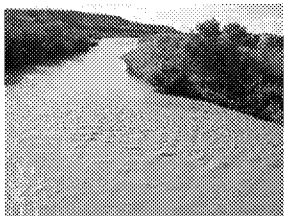
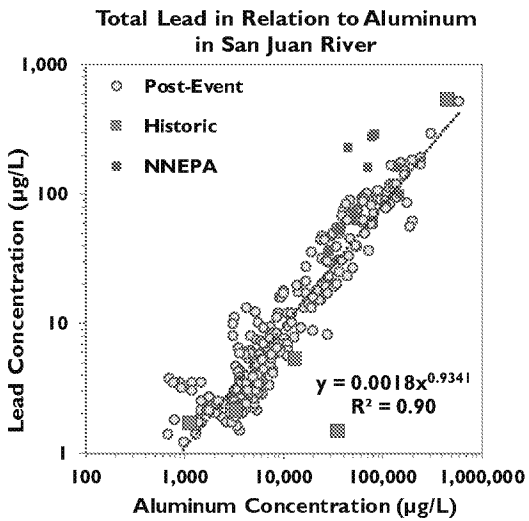
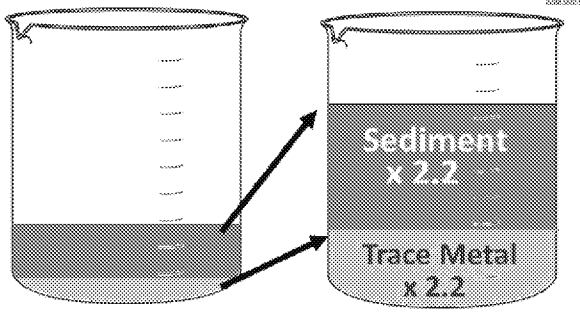
Using the fingerprinting technique to establish background exposures to metals

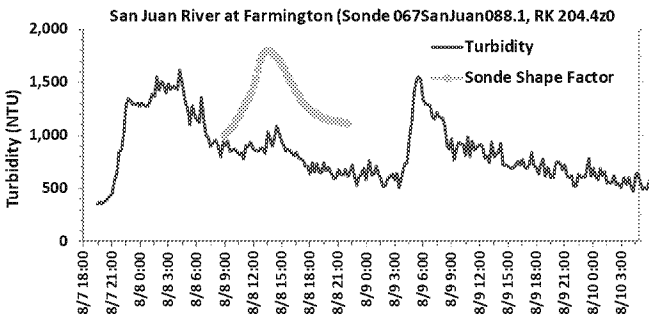


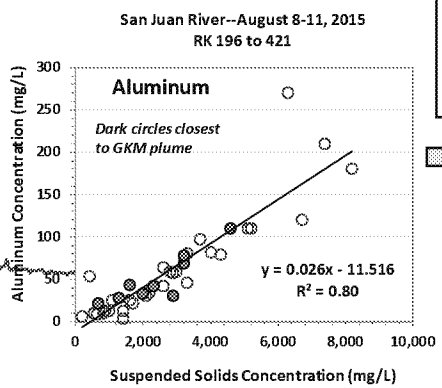




As sediment increases, the amount of each metal (concentration) rises proportionately

Continuous trace of streamflow or turbidity combined with estimates of metals could produce a continue trace of metal concentration





Allows quantification of RISK

(magnitude and duration)

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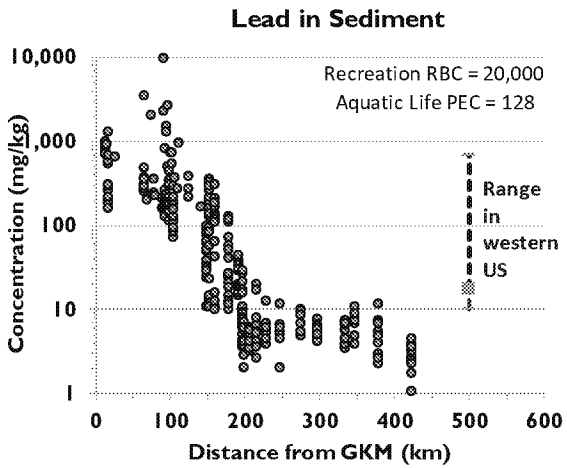
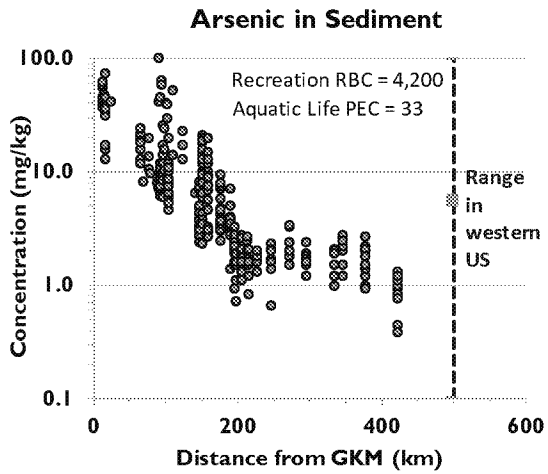
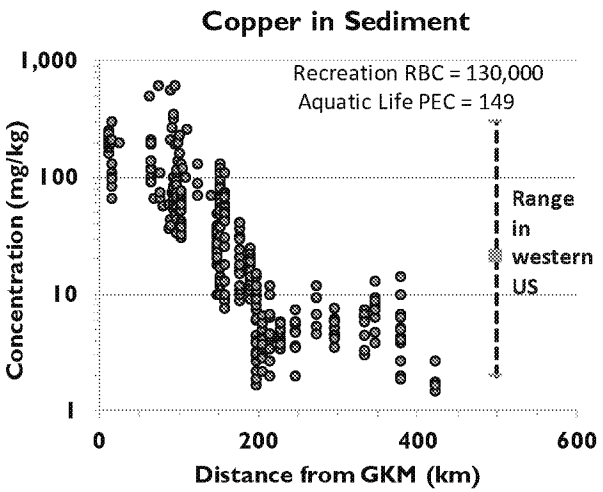
The San Juan River sediments have very low metals levels compared to much of the western US . . .

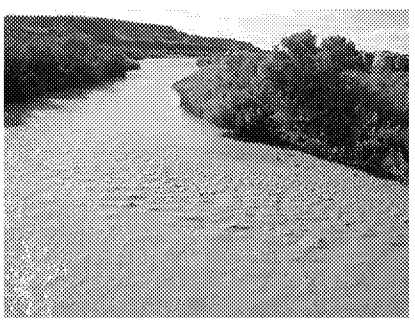






. . . but some of the highest sediment loads measured anywhere on earth.

This results in high metals concentrations in the rivers at times.



Regional values established in a national synoptic survey (Schacklette and Boerngen, 1982)

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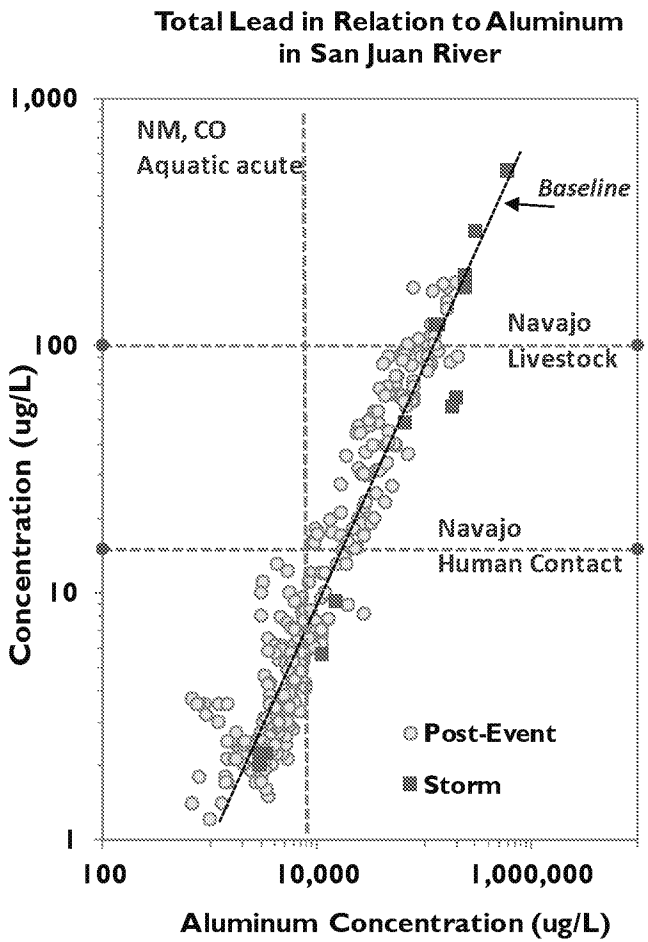
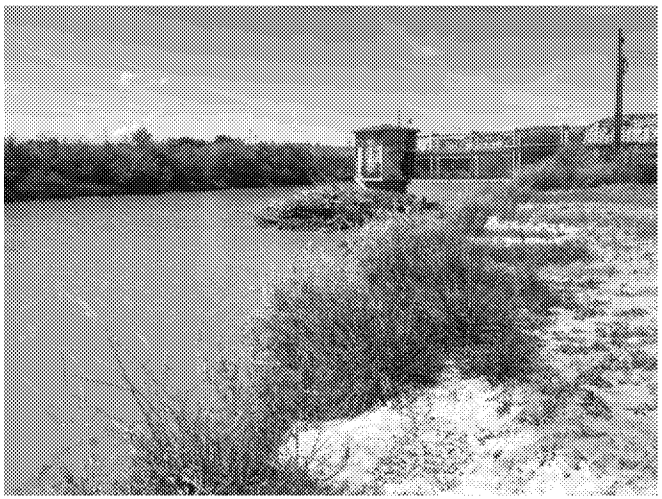
At higher but frequently observed sediment loads, the San Juan River metals exceed some water quality criteria





Many water quality criteria for one or more metals that are based on TOTAL concentrations:

- **All recreational criteria**
- **Tribal domestic water use**
- **Some agricultural**
- **Some livestock**
- **Aluminum criteria for aquatic acute**

Some are likely to be exceeded during high sediment events

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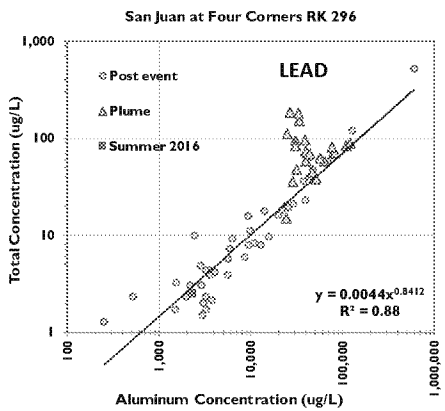
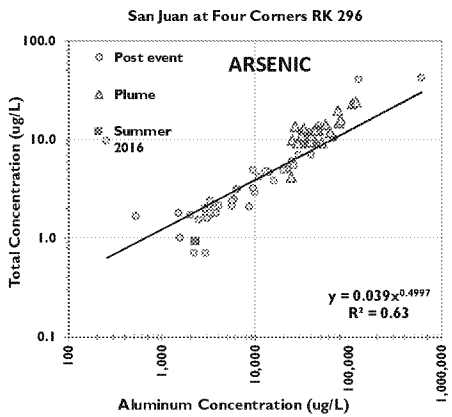
Initially, the Gold King Mine Release was a short-term influx of high quantities of metals that were diluted and deposited through the system

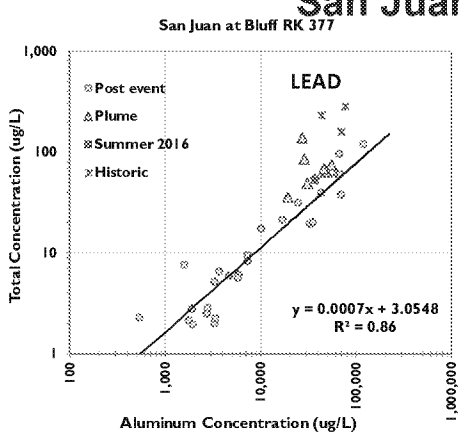
Short-term response was detectable for some metals in the upper San Juan, but the signal diminished in the lower SJ. Other metals were not detectable.

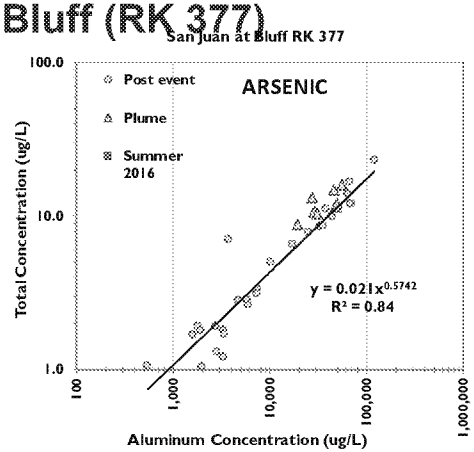
San Juan River at Four Corners (RK 296)





San Juan River at Bluff (RK 377)





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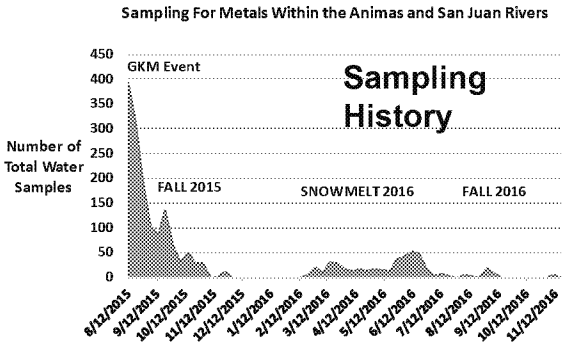
We believe the ratio is a strong signature of the Gold King release

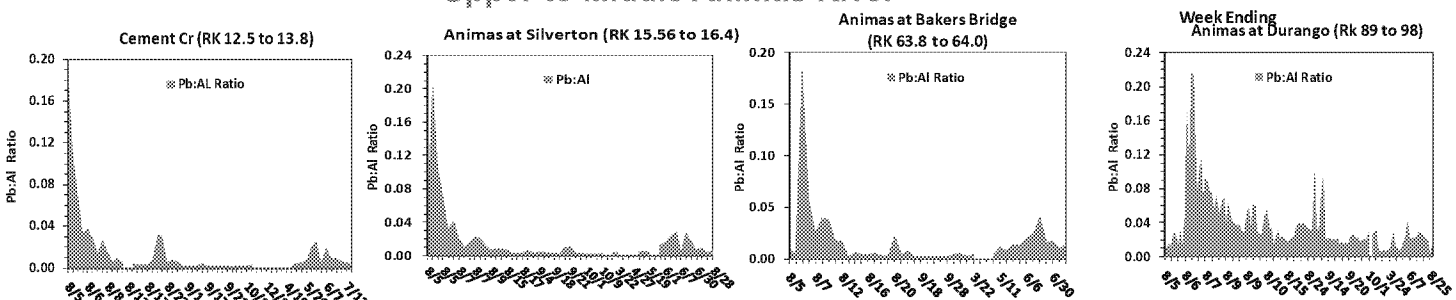
Pb:Al Ratio is plotted sequentially by date: PLOTS COMPRESS TIME



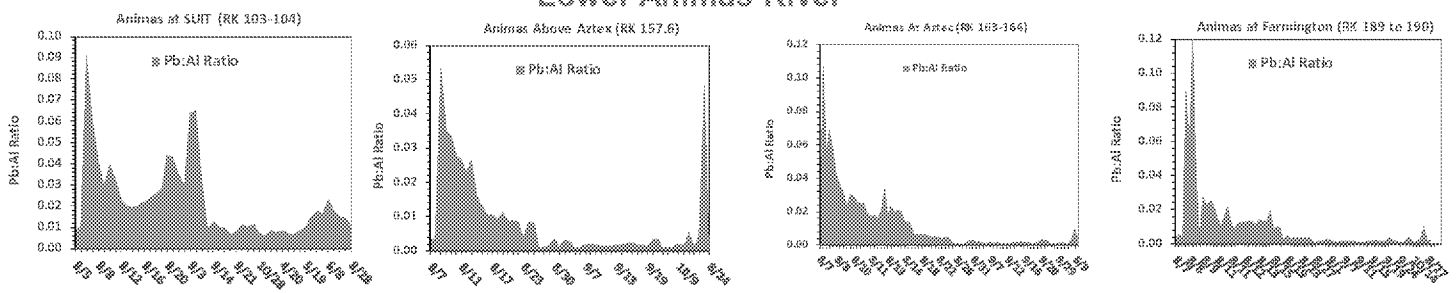
The ratio was very high during the GKM plume

(left side of the graphs)

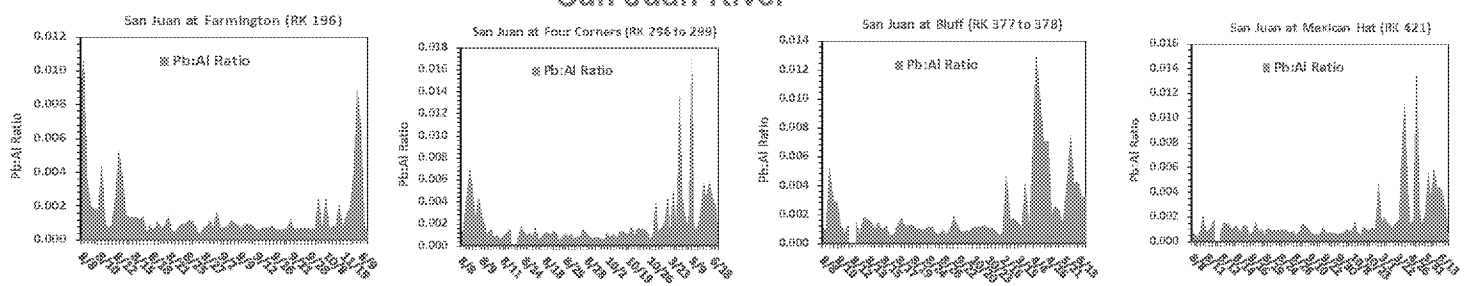
Upper to Middle Animas River



Lower Animas River



San Juan River



2015 | 2016 2015 | 2016 2015 | 2016 2015 | 2016

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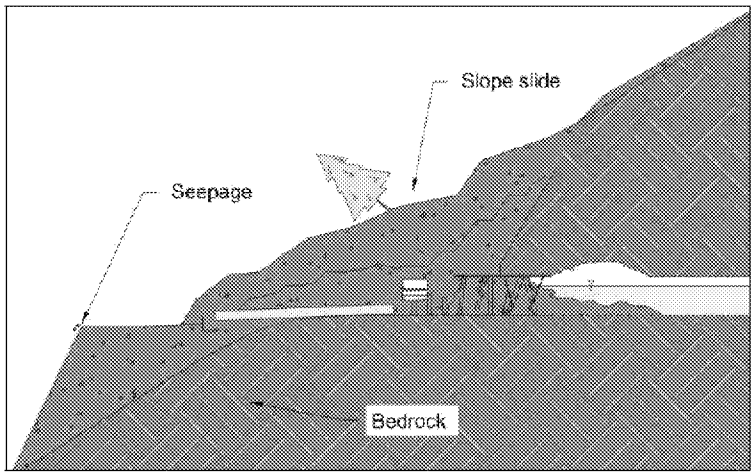
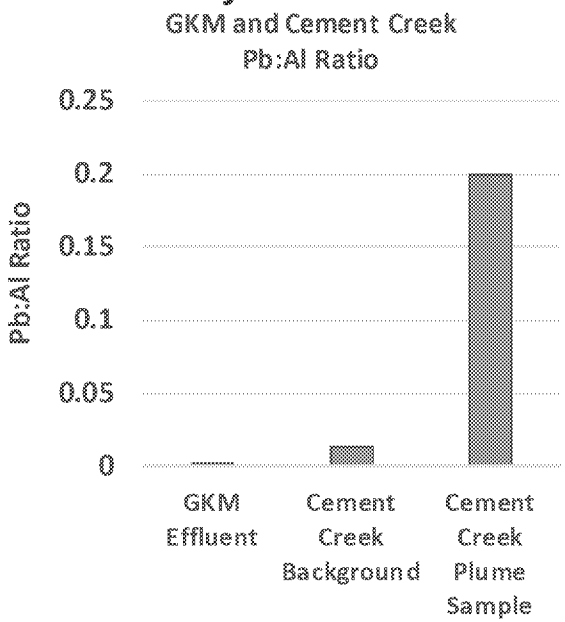
The metals content of the GKM release was unusual compared to what typically flows from the mine

The metals composition of the GKM release was more like the eroded waste pile than the pool within the mine



Mine waste dumps like the one outside of Gold King Mine have been called "the most polluted soils on earth"

The release was highly enriched with lead and many other metals



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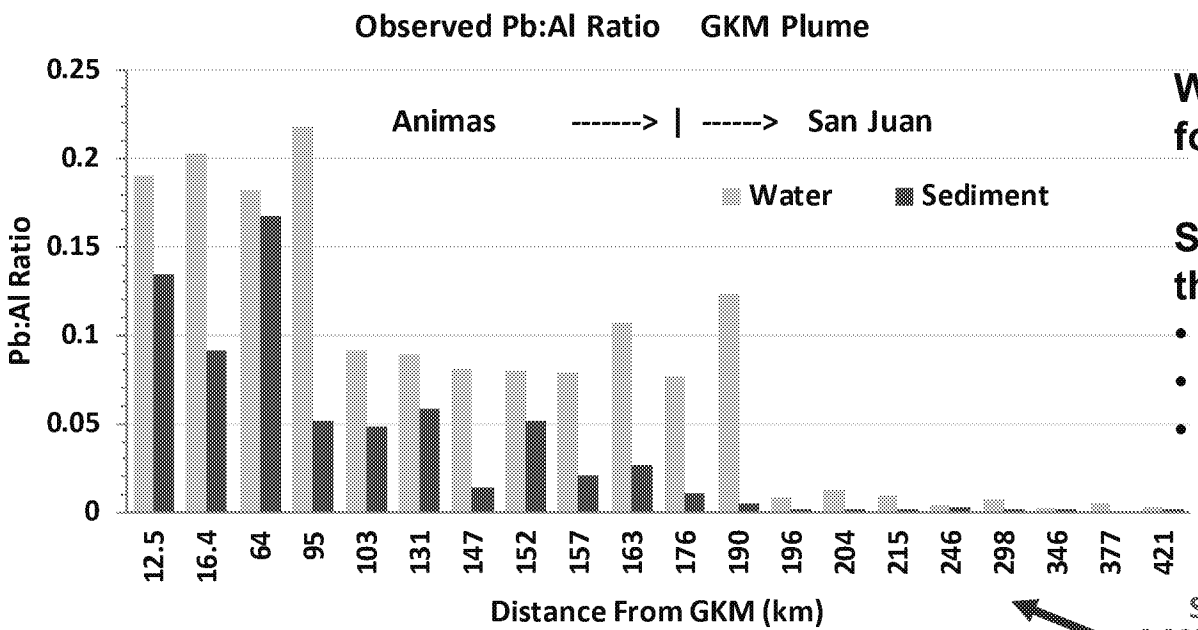
Summarizing the GKM Release Signature: Peak Pb:Al Ratio in Water and Sediment

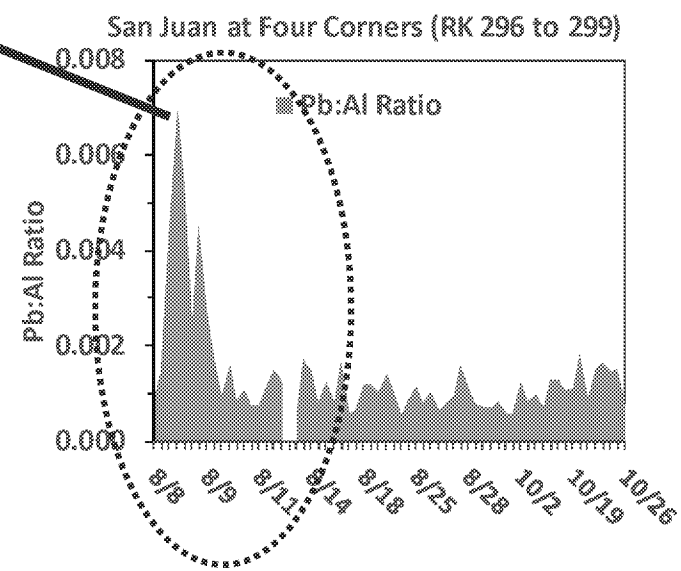


Water and sediment ratios followed similar patterns

Stepped profile with three distinct areas:

- **Upper Animas to Durango**
- **Lower Animas**
- **San Juan**

The GKM signature was distinctive at a location even when the ratio was small



Trace:Al Ratio From Aug 2015 to June 2016

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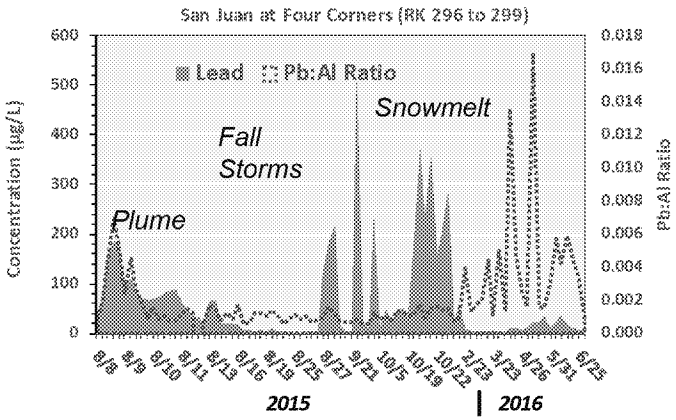
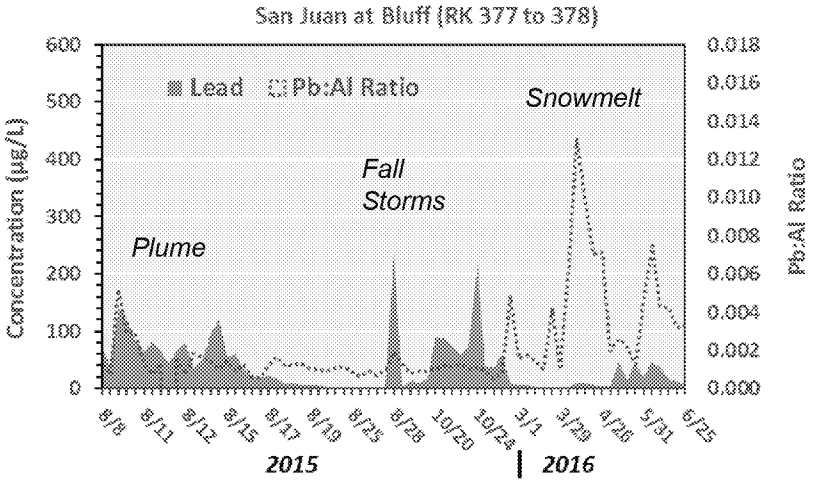
San Juan River: **Four Corners** **Bluff**

Lead





Metal concentrations increased during Fall storms, but the Pb:Al ratio did not indicating background metals

The trace:Al ratios for most metals spiked sharply during portions of the 2016 snowmelt, indicating movement of Gold King release deposits

Data is plotted sequentially in order—PLOTS COMPRESS TIME

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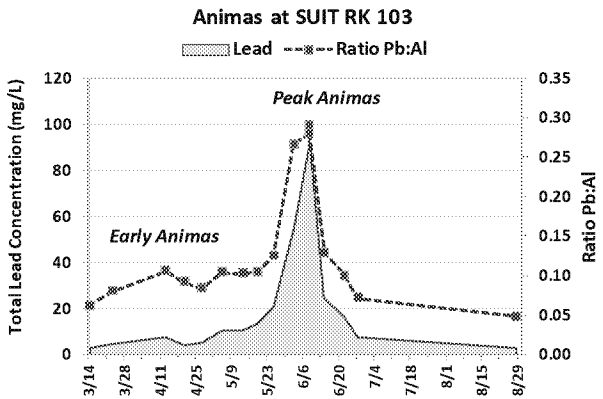
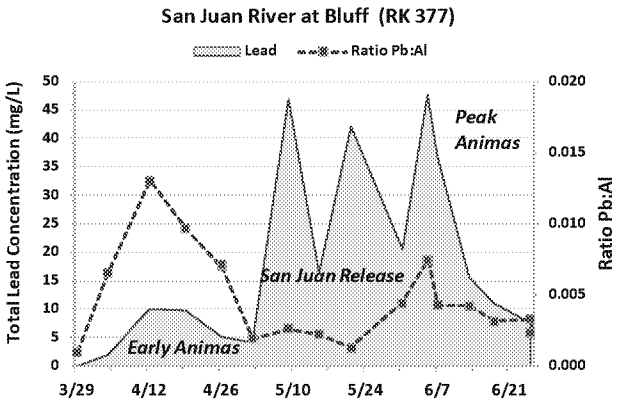
Looking more closely at sites in the Animas and San Juan Rivers during the 2016 snowmelt period

- There was a small rise in Pb:Al ratio in both the Animas and San Juan when flow increased in early spring
- The mass moved during this period accounted for the mass estimated to have deposited during the Gold King plume

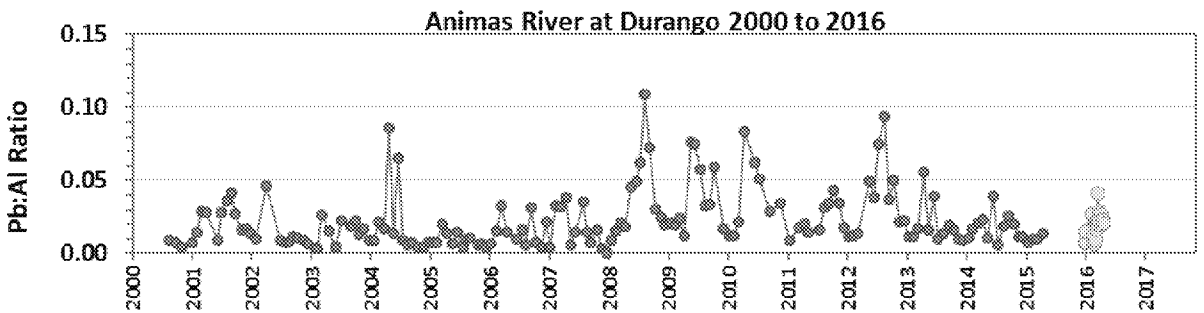
Animas at SUIT RK 103



San Juan at Bluff RK 377



Each year, there is a spike in metals and the Pb:Al ratio in the Upper/Middle Animas during spring snowmelt

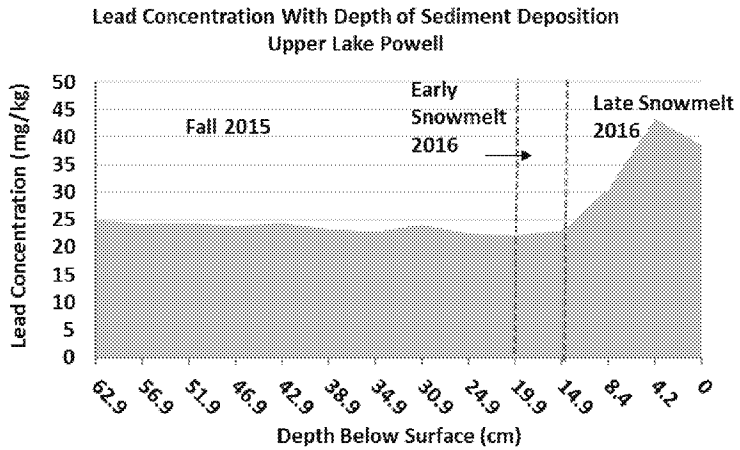


United States Environmental Protection Agency

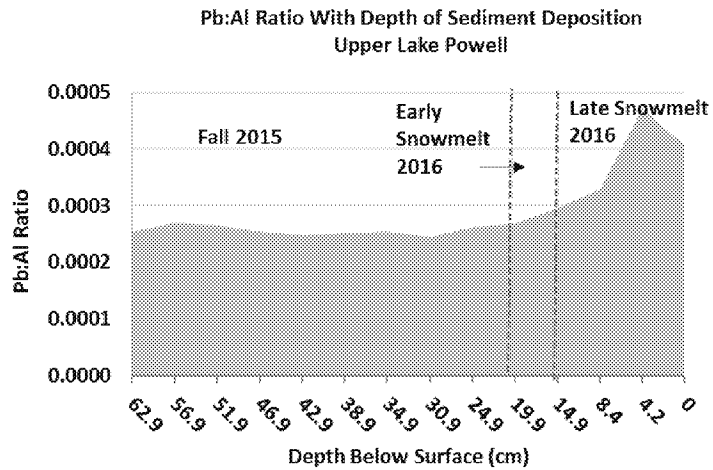
The USGS placed settling pans in Lake Powell after the plume through 2016 snowmelt to characterize effects of the Gold King release

This is preliminary data—USGS is still validating

Concentration



Pb:Al Ratio



- **Sediment pans are inverted to simulate timeline from Aug 23, 2015 to June 2016**
- **There appears to be a spike in lead and other metals during 2016 snowmelt when most of the GKM metals arrived**
- **Peaks were centered during the early snowmelt period for several metals**

United States Environmental Protection Agency

Summary

- The "fingerprinting" technique (ratio of trace metal to aluminum) was helpful for isolating Gold King release metals within the background concentrations of metals
- The signature was an indicator of the release—not Gold King Mine
- The ratio is not an indictor of risk when there is a spike—it only means that something is different
- The observed patterns of the ratio support the conclusion that the Gold King release was removed from the rivers in a series of events with most transported through the San Juan into Lake Powell during 2016 snowmelt
- EPA has sampled during 2017 snowmelt to help test that hypothesis
- The fingerprinting method puts all the data to use and may be useful for other applications in assessing metals contamination