Gold King Mine Acid Mine Drainage Release:

DRAFT Analysis of Fate & Transport of Metals in the Animas & San Juan Rivers

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Analysis Objectives

Characterize the release, transport and fate of approximately 3 million gallons of acid mine drainage (AMD) released from the Gold King Mine (GKM) on August 5, 2015.

- Focus on suite of metals such as cadmium, copper, lead, mercury, nickel, and zinc.

- Identify potential for water quality impacts, including municipal wells, and implications for future monitoring priorities

Key Definitions:

Plume – the section of river containing contaminants released from the Gold King Mine. The plume moves downstream over time.

Dissolved metals – metal ions that are part of the liquid solution.

Colloidal and particulate metals – small particles including metals, which are dispersed in a liquid solution, e.g. milk or paint.

Preliminary Key Findings

- Preliminary estimates indicate more than 400,000 kg of metals entered the Animas River from the Gold King Mine release. Less than 2% of the total was dissolved metals and the remainder were in a colloidal form.
- Much of this total metal load was picked up from Cement Creek as the 3 million gallons of AMD traveled from the GKM to the Animas River.
- We estimate that, by the time the plume reached the lower Animas River, the metal load in the plume was roughly equivalent to one day's worth of high spring runoff of AMD discharges into the Animas River from all existing AMD sources in the Animas River watershed.
- GKM monitoring suggest hot spots of metal contaminants in the lower Animas and San Juan Rivers unrelated to the GKM release that may warrant further investigation

Preliminary Key Findings

- The Animas River naturally diluted the plume as it travelled downstream. The mixing of the plume with more basic water lowered acidity (increased pH) and triggered chemical transformation of the dissolved metals to colloidal and particulate metals.
  - We estimate that 100% of the dissolved metals from the Gold King Mine were transformed to colloidal or particulate metals (the intense yellow color) by the time the plume reached the San Juan River.
  - Elevated dissolved metal concentrations in the Animas River returned to background levels within a day after the plume passed.
  - We estimate that the majority of the total metal load was deposited in the Animas River riverbed before joining the San Juan River. Some of the total metal load entered the San Juan River.
- EPA groundwater modeling suggests that municipal wells that located in the floodplain near the Animas River (within ~100 m) that were pumping have the potential to draw river water, possibly including dissolved metals associated with the plume passage.

Background Sources of Metals

- United States Geological Survey (USGS) studies of AMD in the Animas River in the 1990's found that increased colloidal & dissolved metal concentrations were common in the river following storms and spring snowmelt due to ongoing AMD contamination from the high density of abandoned inactive mines in the headwaters
  - Streambeds accumulate metals from AMD during periods of low flow and release accumulated loads of metals during periods of high flow
  - It may not be possible to isolate the specific effects of the GKM event from the ongoing cumulative effect of multiple sources of metals from past or future runoff

Methods

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

Methods

MODELING

- Purpose of modeling:
  - Establish timing of plume movement and transport of metals in surface and groundwater
  - Estimate possible magnitude of concentrations and chemical transformations not completely sampled during the fast-moving plume event
  - Identify & prioritize areas for further follow up and monitoring

- Applied established peer reviewed EPA models:
  - WASP (Water Quality Analysis Simulation Program): to analyze transport of metals through rivers;
  - WhAEM: to examine groundwater transport & connection of wells to the river;
  - EnviroAtlas: for data gathering and geospatial analysis

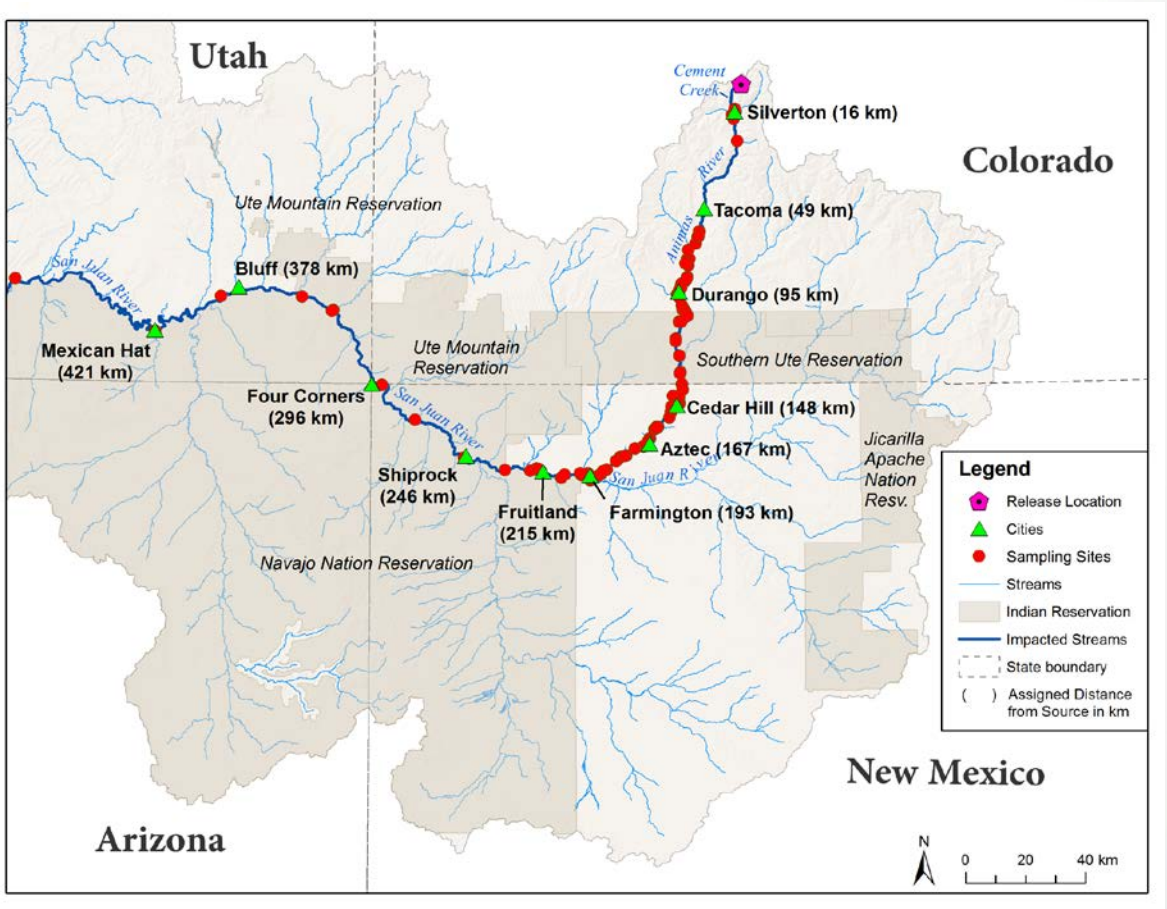
- Used USGS PHREEQ model to assist with geochemical analyses

Methods

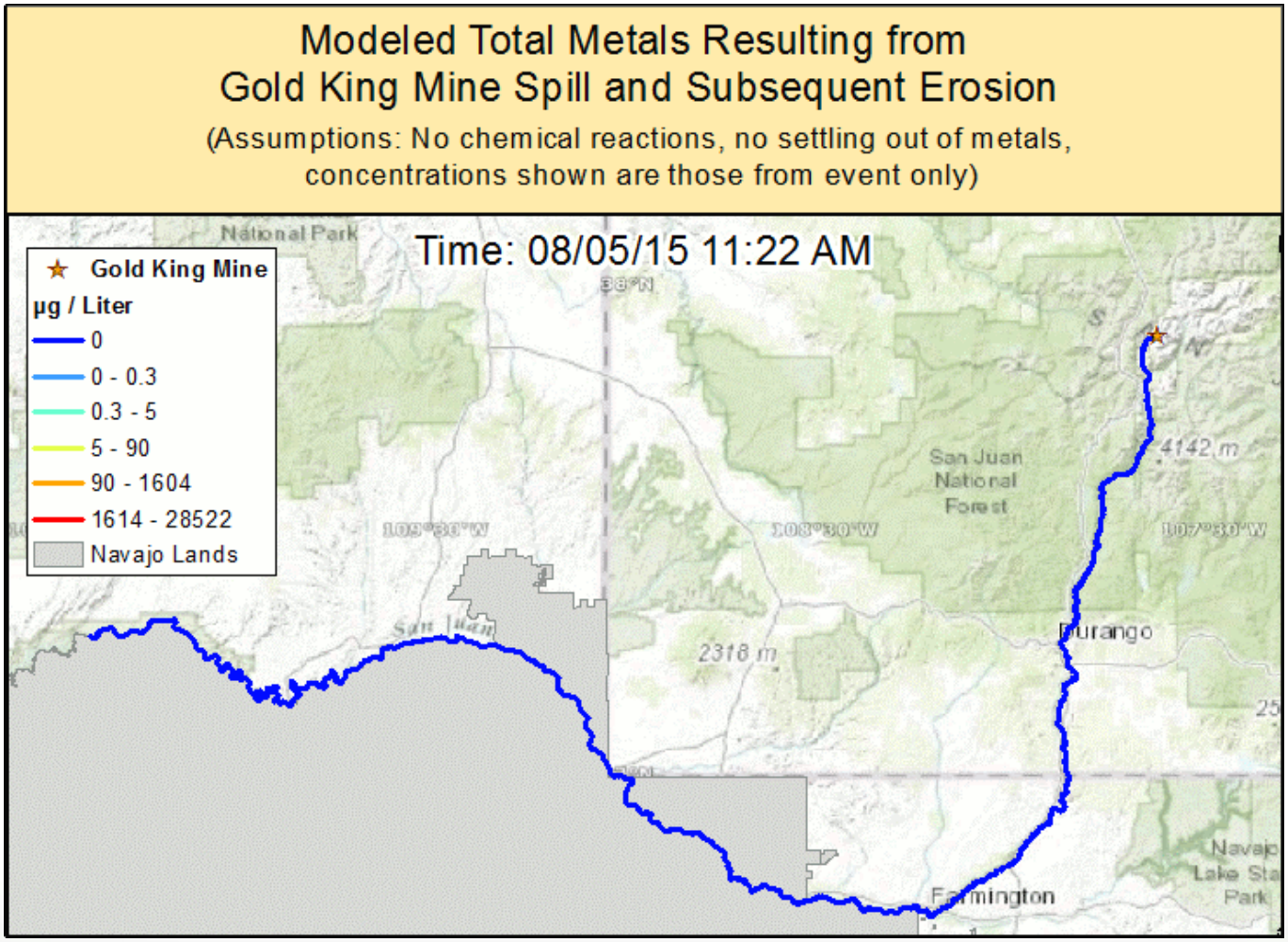
EPA and State monitoring response to the GKM release enabled understanding of the dynamics of water quality impacts on a large scale.

Used publicly available data accessed from agency websites

- **EPA Regions 8,6, and 9**
  - **Surface water and and sediments sampled before and during GKM plume and on a daily basis after**
  - **Over 600 surface water samples in first month**
  - **Drinking water well data**
- **Colorado DPHE**
  - **Water quality at mine source and headwaters of Animas**
  - **Well data from 5 municipal wells**
- **New Mexico Environment Dept water quality during plume**
- **USGS hydrology data**
- **USGS historical studies of AMD in the Animas River**

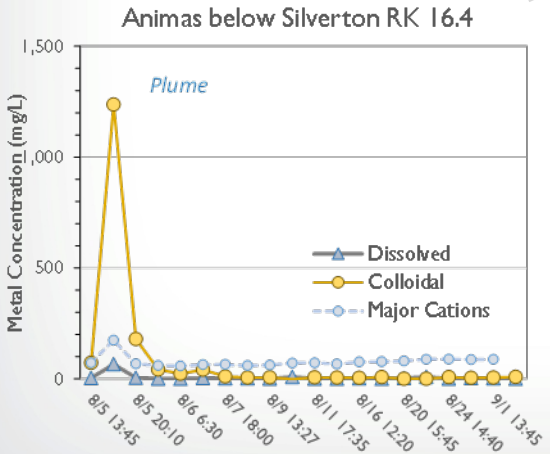


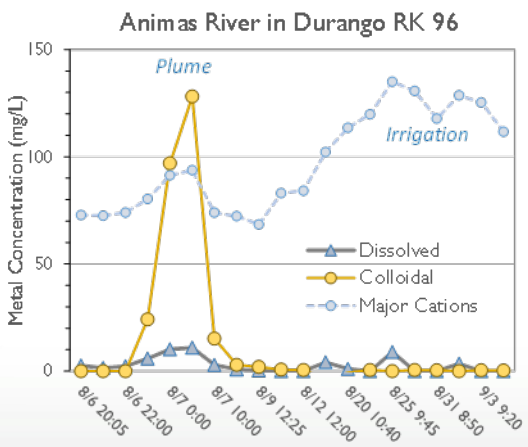
Plume Simulation

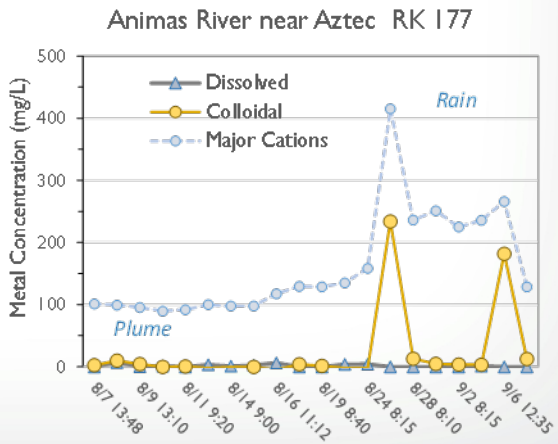


Characterize Transport and Fate of AMD – Animas River

- Monitored data showed significant decline in dissolved metal concentrations with increasing distance from mine.
  - There was consistency between modeling results and monitored data
  - GKM dissolved metals concentrations returned to background within hours after the plume passed at all sites

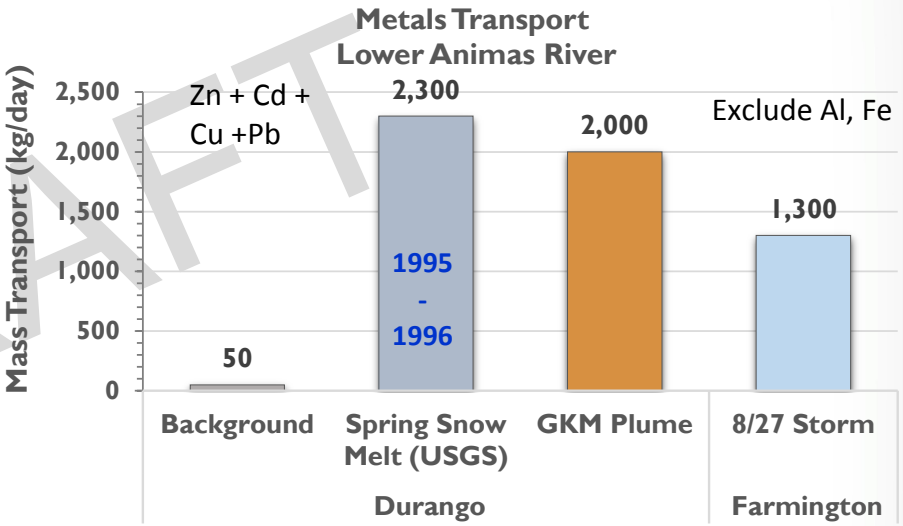






Implications for Monitoring Going Forward

- **USGS sampled metals in the Animas during spring runoff in 1995-96 finding that the Animas River carries large metal loads during high streamflow**
  - Mostly colloidal (85-99%)
  - Some dissolved (1 – 15%)
- **The GKM plume was similar to a day of high spring runoff for combined metals.**
- **Monitoring can expect high metal loads during rain and snowmelt and will need to account for the complexity of contributing sources in the watershed**
- **GKM contaminants may be difficult to isolate during future high runoff from existing and ongoing AMD contamination.**

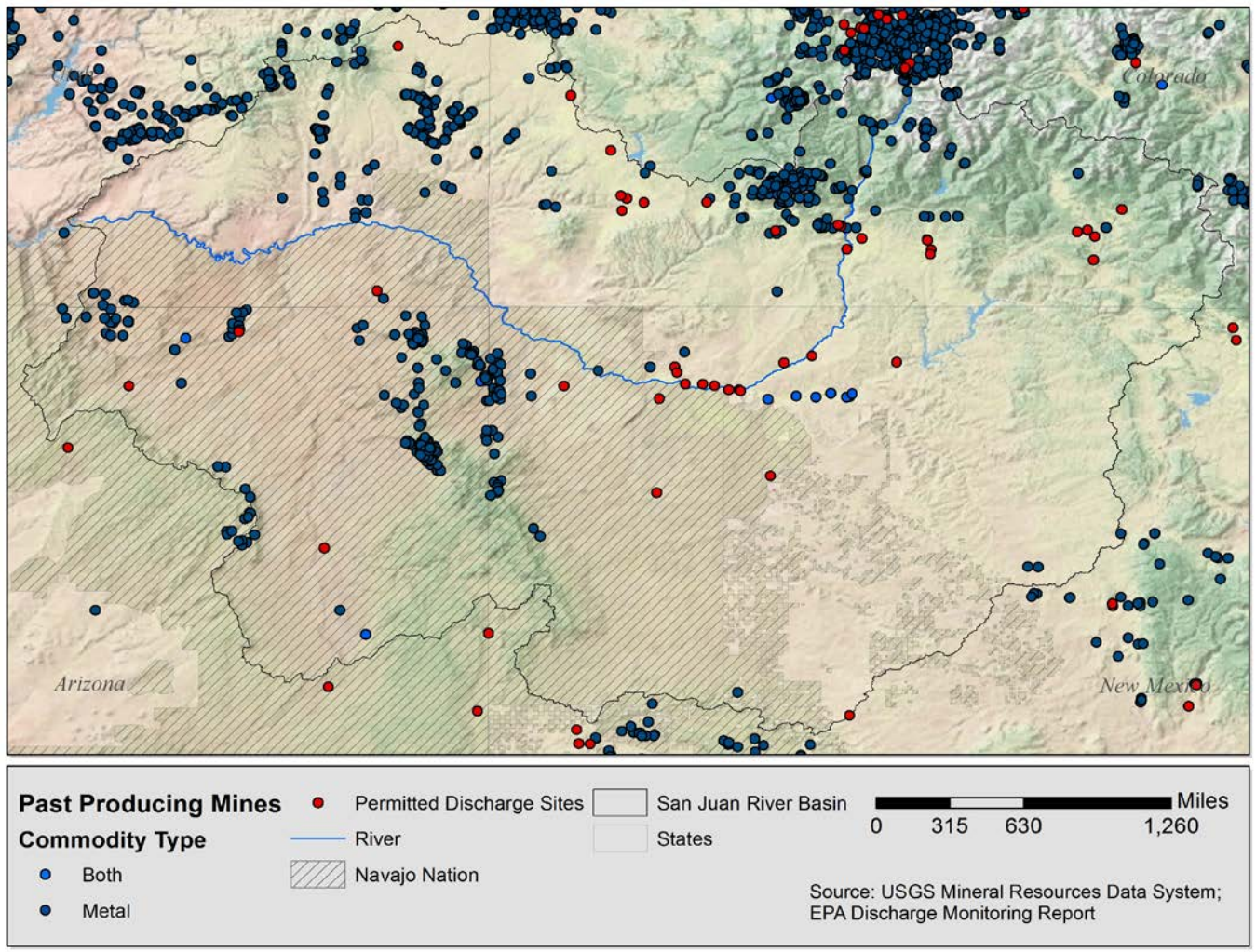


GKM metal load in the lower Animas was similar to one day of high spring runoff

Implications for Monitoring Going Forward

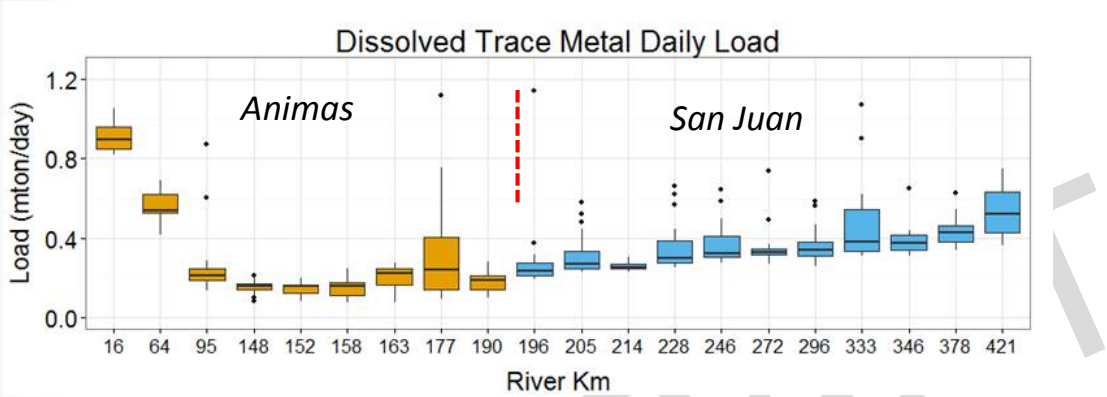
Possible contributers to metal loads in the lower Animas and San Juan during high runoff

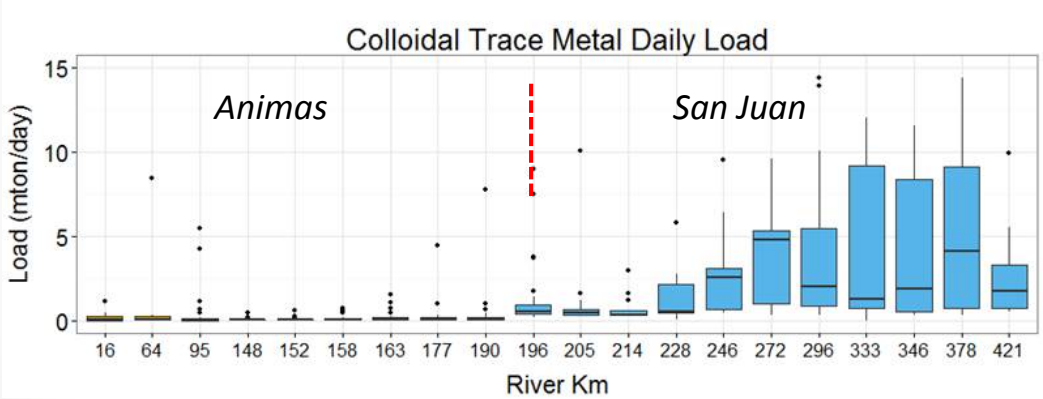
- **Natural differences in geology/sediments**
- **Permitted dischargers**
- **Historic ore processing facilities**
- **Ongoing AMD from hundreds of abandoned mines**



Characterize Transport and Fate of AMD

Trace Metals
Surface Water in the San Juan





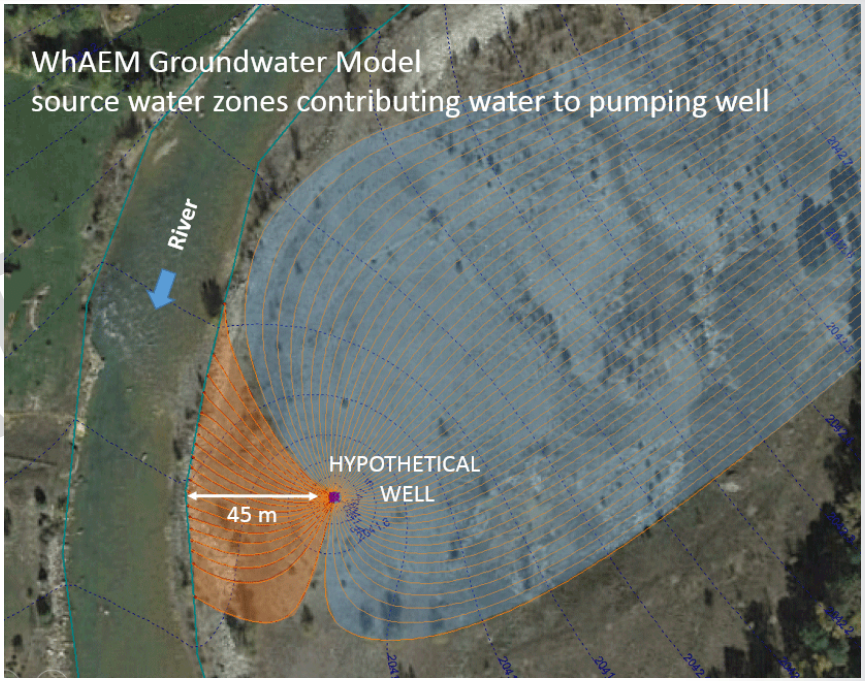
Boxplots show range of data and median and quartiles at each monitoring site collected during August

- Dissolved and colloidal trace metal loads increase within the San Juan River as it flows westward
  - During GKM plume
  - Late August storms
- Suggests other sources contribute to metal loads in San Juan
- Monitoring will need to be designed to improve understanding of sources

Potential Impacts on Wells

Which wells located in the Animas River floodplain have the potential to draw water from the river?

- **Rivers and groundwater in alluvial floodplains exchange water**
  - **most of the time, groundwater feeds rivers**
  - **pumping wells located in the floodplain can draw in river water**
- **WhAEM model used to inform:**
  - **capture zone of pumping wells**
  - **particle tracking representing solute movement from river to well**



Could those wells have acquired contaminated water from the river?

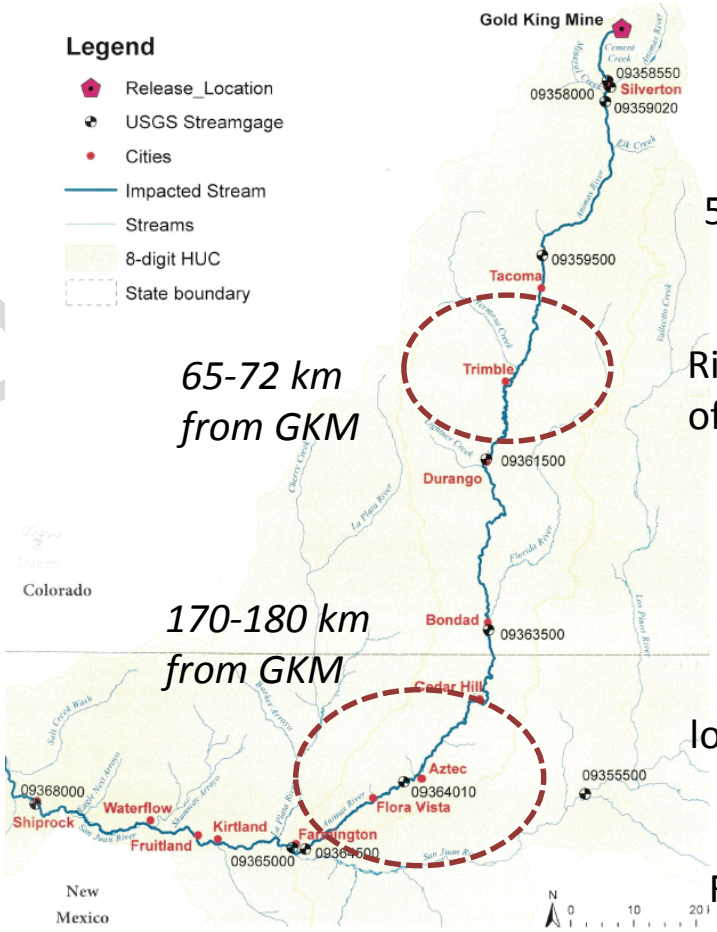
- **WhAEM model used to inform:**
  - **break-through from Animas River to well given pumping**
  - **likely time frame and strength of signal**

Influencing Factors:

- *Proximity to river*
- *Pumping volume (we tested for typical annual diversions and maximum rated yield)*
- *Pumping schedule (municipal wells pump more consistently than irrigation wells)*

Selecting Wells for Simulation Study

- **Selection Criteria**
  - **Municipal wells only**
  - **Within 1,000 m of Animas River**
  - **Located within the alluvial floodplain**
  - **Sufficient available data to calibrate the model**
    - **Pump tests**
    - **Drillers logs**
  - **Available water quality sampling post- plume (preferred)**
- **Identified Sites**
  - **5 wells located north of Durango, CO**
  - **5 wells north of Farmington NM near Flora Vista and Aztec**



5 wells in mid-Animas River north of Durango

5 wells in lower Animas River Aztec, Farmington area

Next Steps for Analysis

- The analysis and results presented here will be peer reviewed by an external review panel during the week of February 22, 2016
- The peer review report is expected to be complete by mid March
- We have a more detailed technical version of this presentation available and are happy to offer further briefings if requested