2017 Oral Abstracts

Ecological and Chemical Analysis of Heavy Metal Transduction in Salix exigua on the Animas and Florida Rivers

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Abstract 1

On August 5th, 2015, an accident at the Gold King Mine in Silverton, Colorado triggered the release of three million gallons of heavy metals into the Animas River. As heavy metals have toxic effects in high concentrations over time, it is extremely important to quantify the amounts of heavy metals in both the water itself, as well as surrounding riparian zones. This study inquired as to whether heavy metals were present in Salix exigua, or coyote willow, which makes up a large portion of the riparian biota. Samples were taken from three sites, at Oxbow Park and Preserve and Trimble Lane on the Animas River, as well as from a control site on the Florida River. Six metals, including aluminum, zinc, cadmium, manganese, barium, and iron, were quantified in root and leaf samples to account for the fate and transport of these metals from the water and sediment into the plants. As bioaccumulation of metals in ecosystems can have effects in many areas, assessing the concentrations in the flora surrounding the river is essential to accounting for all aspects of river health. Metals were found to be significantly higher in roots compared to shoots, across all sites. Furthermore, the Animas River had significantly higher concentrations of heavy metals than the control site. Specifically, Oxbow Park and Preserve had the highest levels due to the geomorphology of this river reach. This study was essential for the quantification of heavy metal concentrations in the Animas River, and will help gain insight to the ecological health. It also will serve as baseline data for future studies accounting for plant health in this area.

Application of Newly Identified Solar-atmospheric Connections Towards Improved Forecasts of the Animas River and Other Streams in the Western US

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Abstract 2

Considerations of connections between modern solar cycles, Hadley circulation patterns, variations in the tropopause, and streamflow characteristics of several mid latitude, high altitude watersheds have pointed to the potential for improved multi-annual to sub-decadal forecasting of streamflows in targeted locations. Such conditions appear to apply to watersheds of the Himalayas as well as to the southern Rocky Mountains of the western United States.

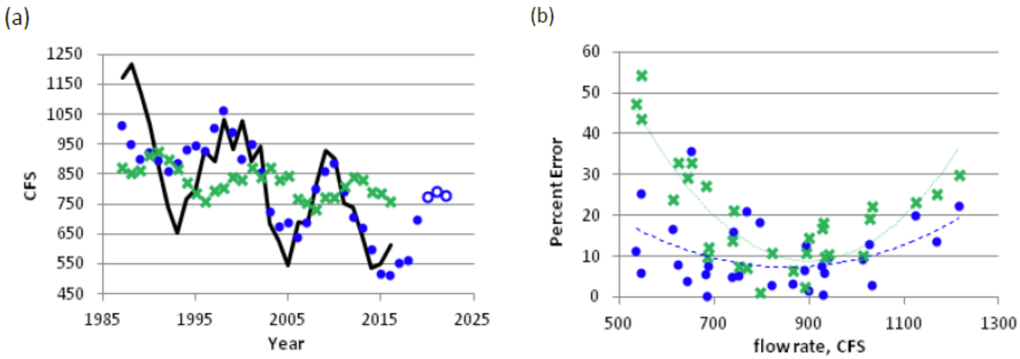
Following the development of a comprehensive conceptual model as a foundation to the study, correlations and linear regressions were developed for key sequential features. The resulting forecasting approach focused on streamflow time series for prime candidate streams of the Rocky Mountains, including the Animas and Pecos Rivers. A third stream, the Gila River in the Mogollon Mountains was included in the comparative study because of its marginal candidacy with respect to geopotential height and latitude, and also because of the opportunity to compare the new approach to a recently published forecasting study utilizing competing global circulation models (GCMs) which were applied to that river.

The forecasts based upon the new regression method were the most accurate of all featured methods, for the series considered under a 5 year trailing average. Through a sequence of solar and tropospheric regression exercises, forecasts for the Animas and Pecos Rivers were advanced as far as 6 years into the future. The forecasts under the new method were also found to be more accurate than the conventional autocorrelation and GCM methods under an annual average with

a 2 year lead forecast approach, although the fidelity of all results were diminished in comparison to the 5 year average set of forecasts.

Subsequent exploration of monthly correlations suggest that for appropriate locations, including the Animas River, advances of hydroclimate forecasting accuracy with monthly resolution yet multi-annual lead times may also be possible through the new technique.

Animas River Forecast Performance Charts. (a) Time Series Comparisons Q4, 5 yr average, 3 yr lead, cfs (b) Percent error of Q4, 5 yr average, 3 yr lead



Legend

- **Observed**
- **Solar Component**
- **New Approach**
- **Conventional Autocorrelation Approach**

The Gold King Mine Spill in the Context of Historical Water Quality Impacts to Utah's San Juan River and Lake Powell

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Abstract 3

In early August 2015, the release of metals-laden, mining-adit discharge from the Gold King Mine (GKM) near Silverton, CO, caused the downstream transport of a bright orange plume that captured international headlines. The Gold King Mine discharges to Cement Creek, a tributary of the Animas River, which contributes to the San Juan River and ultimately flows into Lake Powell. While the impact of this single event has raised large-scale public health and ecological concerns and resulted in the restitution of nearly $30M, it further identifies the need for better understanding of long-term metals source contributions, fate, and transport to the San Juan River and the Lake Powell sediment repository. This presentation will describe the GKM spill, the observed effects of the spill on Utah's waters, evaluate how the spill compares to long-term transport conditions, and describe current and future multi-jurisdictional, multi-agency activities to better understand metals-source impacts on the San Juan River and Lake Powell.

The Colorado Data Sharing Network: A useful tool for visualizing water quality data in the Animas watershed

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Abstract 5

The Colorado Data Sharing Network (CDSN) is a publicly accessible website, coloradowaterdata.org, which has been set up to "enhance Colorado's watersheds and water quality by providing CDSN's data partners and Colorado's citizens with an accessible and affordable tool kit for data management, data analysis, and data sharing." The CDSN is set up via the nationwide Ambient Water Quality Management System (AWQMS), and also includes additional Web GIS functions.

As an organization that works in the interstate-watershed of the Animas River, the San Juan Watershed Group (via the San Juan Soil & Water Conservation District) got permission to be added as the CDSN's first data partner in New Mexico. SJWG has since uploaded E.coli, nutrient, and ambient water quality data from two of its most recent water quality studies in New Mexico. Data added by the Animas Watershed Partnership on the Colorado side of the Animas gives an even more complete picture of nutrient and bacteria trends in the Animas River.

This interactive presentation will demonstrate several of the many useful tools in the CDSN that can be used to explore the nutrient and bacteria data, as well as many other parameters collected by diverse entities. The presentation will focus on ways the general public can search and filter data of interest via the "CDSN Google-Map." A parameter of interest, like lead, can be selected and highlighted based on water quality benchmarks or concentrations of concern. The user can then see at which sites this water quality parameter was measured, when the measurements took place, and whether any exceedances occurred. It will also touch on the more complicated analyses available for data partners via AWQMS.

Quality data is critical for decision making and research in all fields, and when freely shared can improve the work of others. Access to data can make the difference in determining if a single measurement is an outlier or part of a long-term trend, and can help to identify "known unknowns" and thus free up resources to ask new questions.

Mine Spills and Antibiotic Resistance – What is the Connection?

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Abstract 7

Antibiotic resistant bacteria are found in most environments, especially in waters that have been impacted by severe pollution. Many researchers have confirmed a direct correlation between pollution (including industrial pollution and mine drainage) and the spread and persistence of antibiotic resistant bacteria and antibiotic resistance genes within the resident bacterial communities in water and sediments. Although the threat posed to human health by the presence of resistant bacteria and antibiotic resistance genes in natural, non-pathogenic bacteria in these environments is minimal, health risks are enhanced by the potential for horizontal transfer of resistance genes to human pathogens.

Increases in bacterial antibiotic resistance and resistance genes have been reported in environments impacted by acid mine drainage. These increases are generally coupled with contamination by heavy metals, which have been shown to induce the development of resistance mechanisms in bacteria.

Several studies have shown increased presence of multiple-antibiotic resistant bacteria, or "superbugs" in water and sediments exposed to acid mine drainage.

This presentation will cover the state-of-the-art of the research on antibiotic resistance, heavy metals, acid mine drainage, and their connection in the environment. The talk will review the spread and the persistence of heavy metals, and how their presence in acid mine drainage influences the selective survival of antibiotic resistant bacteria. Finally, the author will propose a monitoring system to assess human health risk posed by exposure to antibiotic resistant bacteria to populations impacted by the August 2015 Gold King Mine Spill.

Surface Water Geochemistry During Snowmelt and Monsoons in the Animas and San Juan Rivers

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Abstract 8

Surface water samples collected in the Animas and San Juan Rivers during 2016 snowmelt and in the Animas River in three 2016 monsoonal storms were evaluated for dissolved (<0.45 μm) and total concentrations of metals such as aluminum, iron, lead, manganese, and arsenic.

Dissolved concentrations of aluminum, iron, and lead range between 0.70 % and 14% of the total concentrations; manganese and arsenic have higher dissolved concentrations compared to total concentrations (1.2%-75%). Concentrations of total aluminum, iron, lead, manganese, and arsenic increase during the rising limb of all hydrographs, suggesting a relationship with sediment concentrations, which increase with increasing streamflow. Aluminum and iron have the highest total concentrations, 63,400 μg/L and 82,500 μg/L, respectively. Metals such as lead and arsenic are known to adsorb to iron, aluminum or manganese, which are present in the total water analyses. A National Uranium Resource Evaluation study of this area from the 1970s found that aluminum and iron have the highest concentrations of all elements found in streambed sediments, which suggests that the sediment in these rivers is partially composed of aluminum and iron. For the total surface water chemistry, in snowmelt samples, the relations of aluminum and iron to lead and arsenic are positive and linear, while in monsoonal samples, the relations are polynomial. Further evaluation of the chemistry of the watershed sediments, the stream bed sediments, and suspended sediments will help to understand the geochemical processes in the Animas and San Juan Rivers.

Potential Surrogate Methods for Monitoring Concentration of Metals in Real-time, Animas and San Juan Rivers, Northeastern New Mexico

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Abstract 9

Availability of real-time metal concentrations in the Animas and San Juan Rivers could inform water users (municipalities, irrigators, etc.) when metal concentrations in the river are elevated to levels of concern. Elemental analysis of physical, surface-water samples do not occur on a time scale sufficient to support operators in making immediate timely decisions. However, there is some evidence of positive relationships between sediment concentration or turbidity and metals concentration in the Animas and San Juan Rivers. Surrogate technologies (active hydroacoustics, laser diffraction, turbidity, optical backscatter, and densimetric) have been successful at quantifying suspended-sediment concentrations in real time. Stream-water pH and sediment chemistry in the Animas and San Juan Rivers cause metals to remain associated with the solid phase in the water column. It is likely that these solid-phase metals correlate with surrogate measurements previously used to estimate suspended-sediment concentration, such that suspended-sediment concentration could be used as a surrogate for metal concentrations.

However, these surrogates have site specific limitations: turbidity (and optical backscatter) correlations have high uncertainties in sand channels; active hydroacoustics can be overwhelmed with high levels of suspended-sediment; laser diffraction sensors are prone to fouling due to biofilms; and densimetric measurements require suspended-sediment concentrations above 20,000 mg/L. In the Animas and San Juan Rivers, it is likely that the most promising surrogate measurements to estimate real-time metal concentrations would be active hydroacoustics and turbidity.

AML Project: Inventory and Characterization of Inactive/Abandoned Mine (AML) Features in New Mexico

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Abstract 13 – Both Oral and Poster

New Mexico's mineral wealth is among the richest of any state in the U.S. In 2015, New Mexico ranked 10th in coal production, 2nd in copper production, and 20th in total nonfuel minerals production (McLemore, 2017). Most of the state's production comes from oil, gas, coal, copper, potash, industrial minerals (potash, perlite, cement, zeolites, etc.) and aggregates. Other important commodities include molybdenum, gold, uranium, and silver. However, legacy issues of past mining activities forms negative public perceptions of mining, and inhibits future minerals production in the state. Some legacy mines have the potential to contaminate the environment; the Gold King uncontrolled release into the Animas River is a recent example. At the time the General Mining Law of 1872 was written, there was no recognition of the environmental consequences of discharge of mine and mill wastes or the impact on drinking water, and riparian and aquatic habitats. Miners operating on federal lands had little or no requirement for environmental protection until the 1960s-1970s, although the dumping of mine wastes and mill tailings directly into rivers was halted by an Executive Order in 1935. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break, but legacy issues still exist.

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has been examining the environmental effects of mine waste rock piles and tailings throughout New Mexico since the early 1990s (http://geoinfo.nmt.edu/staff/mclemore/projects/environment/home.html). There are tens of thousands of inactive or abandoned mine features in 274 mining districts in New Mexico (McLemore, 2017; including coal, uranium, metals, and industrial minerals districts), however many of them have not been inventoried or prioritized for reclamation. The New Mexico Abandoned Mine Lands (AML) Bureau of the New Mexico Mining and Minerals Division (NMMMD) estimates that there are more than 15,000 abandoned mine features in the state (http://www.emnrd.state.nm.us/MMD/AML/amlmain.html). The New Mexico AML Program has safeguarded over 2,300 mine openings since inception in 1981 in about 250 separate construction projects (some of which were focused on coal gob reclamation and not safeguarding). The U.S. Bureau of Land Management (BLM) recently estimated that more than 10,000 mine features are on BLM lands in New Mexico and only 705 sites have been reclaimed (http://www.blm.gov/wo/st/en/prog/more/ Abandoned_Mine_Lands/ abandoned_mine_site.html).

The NMBGMR has collected published and unpublished data on the districts, mines, deposits, occurrences, and mills since it was created in 1927 and is slowly converting historical data into a relational database, the New Mexico Mines Database (McLemore et al., 2005a, b). More than 8,000 mines are recorded in the New Mexico Mines Database and more than 7,000 are inactive or abandoned. These mines often include two or more actual mine features.

Most of these mine features do not pose any physical or environmental hazard and many more, pose only a physical hazard, which is easily but costly to remediate. But a complete inventory of these features is needed. Some of these inactive or abandoned mine features can pose serious health, safety and/or environmental hazards, such as open shafts and adits (some concealed by deterioration or vegetative growth), tunnels and

drifts that contain deadly gases, highwalls, encounters with wild animals, radon and metal-laden waters. Other sites have the potential to contaminate surface water, groundwater and air quality. Heavy metals in mine waste piles, tailings and acid mine drainage can potentially impact water quality and human health.

Many state and federal agencies and mining companies have mitigated many of the physical safety hazards by closing some of these mine features, but very few of these reclamation efforts have examined the long-term environmental effects. There is still potential for environmental effects long after remediation of the physical hazards, as found in several areas in New Mexico (for example Terrero, Jackpile and Questa mines). Some of these observations only come from detailed geochemical and electron microprobe studies that are not part of a remediation effort.

The NMBGMR in cooperation with the Mineral Engineering Department at New Mexico Tech and the AML program is conducting research on legacy mine features in New Mexico. The objective of our research is to develop a better procedure to inventory and characterize legacy, inactive or abandoned mine features in New Mexico. This project will inventory, characterize, and prioritize for remediation the mine features in three mining districts in New Mexico: the Jicarilla Mountains district in Lincoln County and the North Magdalena and Rosedale districts in Socorro County for the New Mexico AML Program. Additional mining districts in Socorro County are being examined as well. The project involves field examination of the mines features and collecting data on the mine features (Bureau of Land Management, 2014). Samples are collected to determine total whole rock geochemistry, mineralogical, physical, and engineering properties, acid-base accounting, hydrologic conditions, particle size analyses, soil classification, shear strength testing for stability analysis, and prioritization for remediation, including hazard ranking. Not only will samples be collected for geochemical and geotechnical characterization, but the mine features will be mapped, evaluated for future mineral-resource potential, and evaluated for slope stability.

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Continued Monitoring of the Animas River Valley Groundwater Level After the Gold King Mine Mine-water Release of 2015

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Abstract 15

Following the August 5, 2015 bulkhead breach of the Gold King Mine roughly 3 million gallons of mine waste water and tailings were introduced to a tributary of the Animas River, turning the water a vivid orange. While the river has since returned to its normal color there is still concern that the toxic metals left on the streambed may begin to seep into the shallow alluvial aquifers and impact the communities in the surrounding area. In August 2015, in collaboration with other agencies (USGS, NM OSE, and NMED), groundwater level measurements were collected at over 100 locations along the Animas River. Using the network of wells established in 2015, we developed a groundwater level monitoring program in the Animas River valley utilizing private domestic wells.

This well network has been manually measured now for nearly 2 years, helping us to understand the seasonal fluctuations of the water table and how it affects the groundwater/ surface water interactions in the area. The four annual measurement campaigns are carried out at specific intervals to capture water levels during hydrologic events that likely influence the regional hydrology. Not all wells in the monitoring network are measured during each sampling visit due to scheduling conflicts and well owners opting out the network. A winter measurement is recorded when the river is under base-flow conditions. The spring measurement occurs just as the agricultural season begins and irrigation ditches are filled. An early June measurement captures water levels as the main snowmelt pulse moves through the area and the Animas River stage is at its highest. Finally, a fall measurement is recorded near the end of the monsoon and agriculture season. Repeat water level measurements are important to understand the seasonal fluctuations in of a groundwater system, particularly one that is hydraulically connected to surface water features, such as rivers or irrigation ditches.

In addition to collecting manual water level measurements, a network of 24 wells have been instrumented with continuous data loggers. Four of the instruments have at least a year of data, while the other 20 were installed in fall 2016. The data loggers collect water level and temperature every 12 hours. From a continuous record of groundwater level, we can see brief temporal scale fluctuations in water levels that help us understand what factors have an influence on the water table in the area. These continuous records also allow us to better distinguish annual highs and lows of the water table that are otherwise missed by the quarterly measurements. In most wells, the resulting hydrographs show a pronounced connection with the ditches and river. Intermittent spikes in river stage can be seen in some wells as small pressure changes in the water levels record. When the ditches were shut off many of the wells rapidly decline. Twelve of the data loggers also measure specific conductivity, allowing us to see temporal fluctuations related to the groundwater chemistry.

A water table map has been delineated for each seasonal measurement collection. Each water table is constructed using the manually collected water level measurements, paired with a high-resolution LiDAR digital elevation model. The river stage elevation is constrained by 3 USGS streamflow gauges, as well as several river stage measurements that were manually surveyed during at the end of monsoon season and winter base-flow conditions. For the most part, the water table map shows the river is a gaining system,

where groundwater from the surrounding valley flows down-gradient and discharges into the river. With the implementation of high resolution elevation and river stage datasets, several vulnerable locations along the river were identified. The winter and spring water table map showed that in close proximity to the river, the water table contours were almost perpendicular to the river, and even slightly inverted in places, indicating neutral or losing conditions, respectively. With a neutral water table, fluctuations in the river stage can quickly turn a slightly gaining reach to a slightly losing reach. Regions that showed the greatest vulnerability to surface water infiltration were located along the reach between Cedar Hill and Aztec. Specifically, the wells in close proximity to the river at Inca were most susceptible to surface water influence. The water table east of Cedar Hill also demonstrated the potential for surface water impact, as well as a small stretch just north of Aztec. The degree to which the river is losing is so slight (less than 1 ft) that it is not detected by coarse resolution, regional water table maps. In areas with dense enough sampling, we refined the contouring to 5 ft intervals.

While this does not mean that these wells are in immediate danger of drawing water from the river, it does however, show that there are reaches of the river that are slightly losing. This means that metals that are resting on the streambed have the potential to move into the groundwater. The water levels indicate that losing reaches are more prevalent during the winter months, when the water table is lowest, most notably in close proximity to the river, along the reach between Aztec and Cedar Hill.

Geologic Setting and History of Mining in the Animas River Watershed, Southern Colorado

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Abstract 16

On August 5, 2015, EPA contract personnel caused the release of wastewater at the Gold King mine, Colorado into the Animas River. Approximately 3 million gallons of acid mine water containing metals and iron oxyhydroxide sediments were released. The aftermath of this uncontrolled rapid release of mine waters has resulted in re-evaluation of ongoing environmental impacts from of legacy mines throughout the U.S. and examination of potential consequences along the Animas River. The Bonita Creek mining district, which includes the Gold King mine and 45 other mines in the Animas River watershed is now a superfund site. The purposes of this presentation are to provide geologic and historical background of mining in the Animas River watershed, and to begin to address the path forward in preventing similar spills. Most of the information presented is from previous work, including Church et al. (2007), Church (2014), Gobla et al. (2015), and Yager et al. (2016) among other references and the Animas River Stakeholders Group website (http://animasriverstakeholdersgroup.org/blog/).

The Animas River Watershed is in the northernmost headwaters of the Animas River in San Juan County, Colorado. It includes the drainage basins of the Animas River upstream from Silverton and its two main tributaries, Cement and Mineral Creeks (Church et al., 2007). Elevations are extreme; Silverton is at 9,305 ft and some of the mountain peaks in the headwaters rise to more than 13,800 ft. The Animas River Watershed encompasses an area of approximately 150 sq miles. The Bonita Peak mining district (declared a superfund site in 2016) is within this area (https://semspub.epa.gov/ work/08/1570792.pdf).

A Late Oligocene volcanic center erupted many cubic miles of lava and volcanic tuff and formed the Silverton caldera at approximately 22-25 million years ago. Volcanism was followed by multiple episodes of hydrothermal activity along faults that produced widespread areas of pyrite alteration and quartz-pyrite-metals veins. Most of the host rock is very fractured and permeable, which results in complex, interconnecting groundwater flow paths. Subsequent weathering of hydrothermally mineralized veins and altered rocks, particularly the acid sulfate and the quartz-pyrite-sericite alteration that is extensive in the watershed, results in the generation of natural acid drainage and mobilizes metals from the host rocks (Church et al. 2007; Yager et al., 2016, among other studies). Thus, not all elevated concentrations of metals and low-pH conditions found in streams are the result of historical mining. The sources for these heavy metals are both man-made (i.e., mining related) and naturally occurring. In 1874, it was noted that water in both Cement and Mineral Creeks contained iron sulfate, making the water undrinkable (Rhonda, 1876). Weathering of the mine wastes is another major source of metals and acidity.

Early mining was by the Spanish. An arrastra, used to recover gold and silver, was found in the district. The district was rediscovered about 1860. Development began in 1871 with the Little Giant mine. However, extensive mineral exploration did not begin until after the signing of the Bernot Treaty with the Ute Tribe in 1873. Gold and silver production increased once the railroad to Silverton was built in July 1882. Once milled, most sulfide concentrates were shipped to Durango, Colorado for smelting. Production occurred during four

periods: (1) the Smelting Era 1871–1889, (2) the Gravity Milling Era 1890–1913, (3) the Early Flotation Era 1914–1935, and (4) the Modern Flotation Era 1936–1991. The production from the watershed amounted to more than $529 million, including >2.2 million oz Au, >51 million oz Ag, >112 million lbs Cu, >765 million lbs Pb and >604 million pound Zn from more than 300 mines (Church et al., 2007).

More than 5,000 prospects, mines and mills are found in the Animas River Watershed, many of which contain waste rock, tailings piles and/or are discharging mine drainage (Church et al., 2007). Of the 18.1 million short tons of ore produced in the Animas River Watershed from 373 mines and mills, an estimated 8.6 million short tons of mill waste (about 48%) was discharged directly into surface streams or adjacent land prior to about 1935. EPA estimates that there are approximately 248,000 cubic yards of waste rock and water discharging out of mining adits is at the cumulative rate of 3,740 gallons per minute (5.4 million gallons per day) (https://semspub.epa.gov/work/08/1570792.pdf).

At the time the General Mining Law of 1872 was passed by the U.S. Congress, there was no recognition of the environmental consequences of direct discharge of mine and mill wastes into the nation's rivers and streams or the impact of this activity on the availability of drinking water supplies, and riparian and aquatic habitats. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s and 1970s, although the dumping of mine wastes and mill tailings directly into the nation's rivers was halted by an Executive Order in 1935. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break and most miners were utilizing acceptable standard mining practices at that time. However during the 1970s and 1980s, operating mines were required to perform some remediation efforts. Water treatment plants were operated by mining companies in the area, but closed when the mines closed. By 2007, more than

$20,000,000 had been spent on remediation, largely on removal of mill tailings deposited in the riparian zone of the Animas River (Church et al., 2007). Both private and public (EPA, USFS, State of Colorado, BLM) funds have been used for these remediation efforts.

Some of the challenges for reclamation efforts in the Animas River Watershed include (Church et al., 2007; Church, 2014; Gobla et al., 2015):

- Complex land ownership (USFS, BLM, orphaned properties held by San Juan County for delinquent taxes, private property)
- Rugged mountain geography and climate (access is difficult during winter months)
- Issues of financial liability
- Technical approaches needed to mitigate acid mine drainage without resorting to costly treatment facilities
- The need for adequate space to build new repositories to move those mine wastes that cannot be mitigated in place
- Effect of reclamation on tourism in a historical mining district Silverton.

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An Overview of the Gold King Mine Release and its Transport and Fate in the Animas and San Juan Rivers

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Abstract 17 – Both Oral and Poster

On August 5, 2015, a large acidic mine pool trapped behind a collapsed mine structure and rock debris in the Gold King Mine (GKM) was accidently breached releasing approximately 11.3 million liters (3 million gallons) of low pH (~3) metal contaminated mine drainage into a small tributary in the headwaters of the Animas River in southwestern Colorado. The release introduced approximately 490,000 kg of dissolved and particulate metals over a 12-hour period into the Animas River at Silverton, CO, located 13 km downstream from the mine. The mine effluent contained 2,900 kg of dissolved metals. Most of the released metals were eroded from the old waste pile outside the mine entrance and within Cement Creek by the rushing water. The release introduced large quantities of particulate aluminum, iron, manganese, lead, copper, arsenic and zinc to the Animas River, of which 15,000 kg was in dissolved form.

The release traveled as a coherent plume of metals through 550 kilometers (342 miles) of the Animas and San Juan Rivers over an 8- day period before ultimately reaching Lake Powell in Utah. As part of emergency response measures, EPA, States, Tribes and non- governmental organizations initiated extensive monitoring of water and sediments, collecting over 1,400 water quality and 800 sediment samples the rivers from August 2015 to November 2016. These data were extensively analyzed and augmented with modeling to quantify the source, transport, and fate of metals released from the Gold King Mine. Metal mass estimates were based on empirical reconstruction of water samples and flow measured at USGS gages, supported by a process-based water quality model (Water Quality Analysis Simulation Program --WASP) that simulated the contaminant transport as the plume flowed through the rivers.

When the acidic plume entered the larger and more alkaline Animas River at Silverton, CO, both dissolved and colloidal/particulate metals concentrations declined rapidly, as chemical reactions and hydraulic processes diluted, transformed and deposited material. Only 5% of the metal mass released from Gold King Mine arrived at Lake Powell with the plume. Most of the entrained particulates and the iron and aluminum oxides that formed within the plume were deposited in the river bed and along channel margins, primiarly in the upper reaches of the Animas River between Silverton (16.4 km from source) and Durango, Colorado (100 km) (Figure 1). This material remained in place until it was mobilized during snowmelt in 2016. Another 6% of the release mass (49,000 kg) was deposited in the lower Animas and San Juan Rivers during the plume. These deposits were remobilized and delivered to Lake Powell during a monsoonal storm that occurred on August 27, 2015, 20 days after the release event. Bed sediment samples confirmed that deposits had been removed by the storm.

Snowmelt mobilized the large mass of Gold King release deposits in the Upper Animas River starting in early April 2016 when increasing streamflow exceeded the levels observed during the GKM release. During this

period, water samples collected throughout the Animas and San Juan Rivers matched the metal composition of Gold King deposits transporting 433,000 kg that could be attributed to the GKM release. The sum of estimated Gold King Mine release mass delivered to Lake Powell in the three events was 506,000 kg (Fig. 2). The cumulative sum was very close to the initial estimate of 490,000 kg released to the Animas River.

Movement of the GKM release mass through the San Juan River in each of the three stages was accompanied by significant amounts of sediment that also naturally contain the same metals as the Gold King release, but in different mineral form and abundance. The elemental composition of metals in sediment was similar to that of the Mancos Shale that produce them. The Gold King release mass delivered to Lake Powell in the three events was mixed with 15,000,000 kg of sediment associated metals (Fig. 2B).

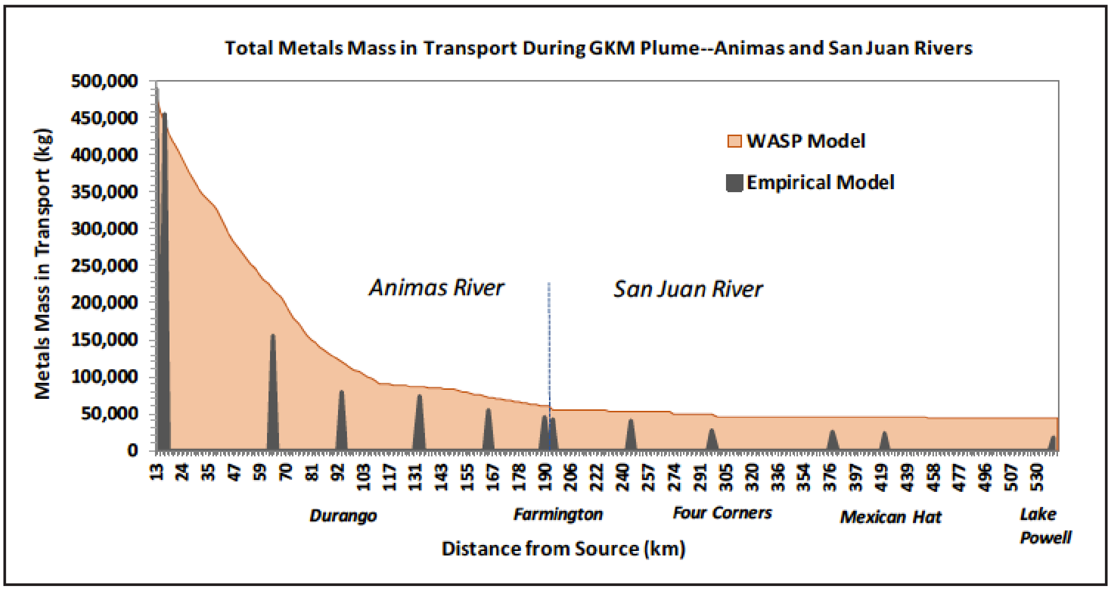

Figure 1. The total metals mass transported at locations in the Animas and San Juan Rivers during the Gold King Mine (GKM) plume, as simulated by the Water Quality Analysis Simulation Program (WASP) and empirical analysis of water sample data.

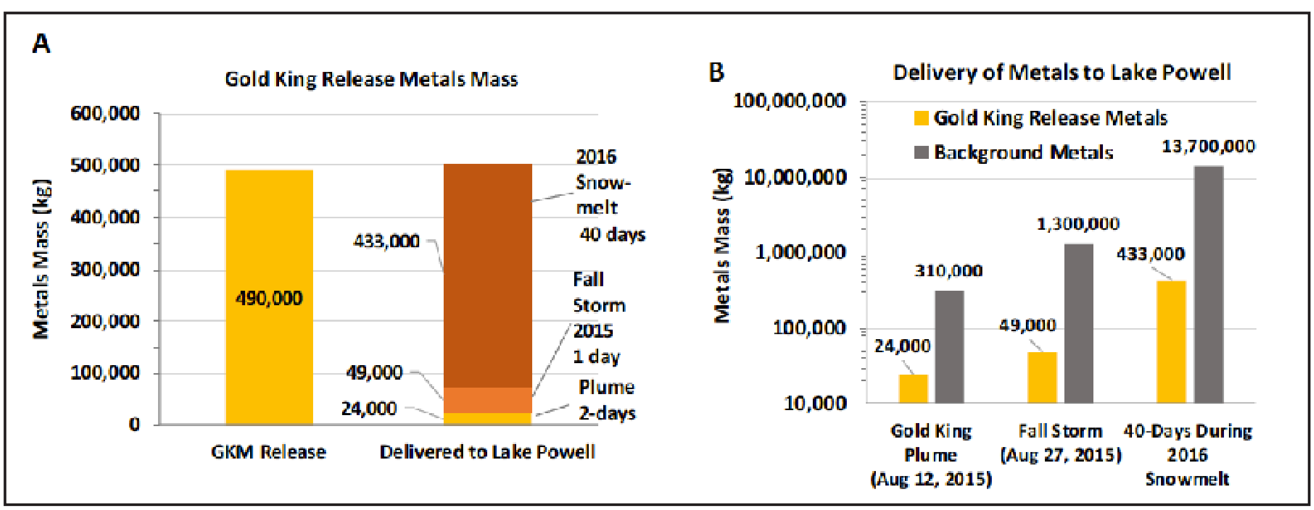

Figure 2. Summary of delivery of Gold King Mine (GKM) released metals mass to Lake Powell (kg) in three events: A) Estimated release mass and timing of delivery to Lake Powell; B) Mass of GKM compared to background metals in each event.

Illustration of a Fingerprinting Method to Isolate Gold King Release Metals from Background Concentrations in the San Juan River

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Abstract 18 – Both Oral and Poster

Detecting the Gold King Mine metals as the release plume passed was difficult once it entered the San Juan River on August 8, 2015. Plume metals concentrations were relatively low after 200 km of travel and deposition in the Animas River while background concentrations of the same metals were high due to high sediment load in the San Juan River. A metal fingerprinting technique was used to isolate metals in the Gold King release from background using the measured concentrations of the 23 TAL metals (Metal/Cynaide Target Analyte List) available with most water samples. The method associates the concentration of trace metals to that of aluminum or iron as representative of the dominant metals in the geologic substrate. Metal concentrations can be plotted together, as in Figure 1A, or the ratio can be computed for each sample for use as a value, such as plotted in time in Figure 1B. The correlation technique allowed maximum use of typically available water sample data to isolate Gold King metals as contaminants within the varying background concentrations associated with the natural sediments of the San Juan River.

The rationale for the approach was that aluminum and iron are abundant crustal elements and exist in relatively-consistent proportions in the rocks, soil, and sediments that weather from them.Because aluminum and iron are abundant metals, their concentrations in water should be proportionate to the sediment mass and readily measurable. In turn, the trace metals should be present in proportion to aluminum or iron. Higher concentrations of all the metals would be expected when sediment loads are higher and samples collected over a range of flows should routinely reflect the range of sediment in the water.

Figure 1A provides an example of the correlation ratio of lead to aluminum concentrations in samples collected from the San Juan River. Data include historic samples and those collected during and after the Gold King release including during several large fall storms. Concentrations vary over 3 orders of magnitude and demonstrate a consistent relationship between lead and aluminum. All of the trace metals show a strong relationship of this kind, except for selenium. For some metals, such as vanadium, the relationship explains up to 95% of the variability among samples in the San Juan River. In addition, the relative abundance of trace metals in the Mancos shale explains as much as 80% of the variability of the trace metals in water.

The technique was effective in identifying the GKM release metals within background concentrations during the plume and in post-event samples from the San Juan River. For example, the correlation technique indicated that some trace metals sampled at the times thought to coincide with passage of the Gold King plume were elevated relative to expected given the concentration of aluminum, such as illustrated for lead in Figure 1. Metals that were notably elevated in the San Juan River during the Gold King plume included lead and to a lesser extent zinc. After the plume passed, ratios fell back into their normal pattern. Other metals were comparable to background metals during the GKM plume, and concentrations did not differ from their basic concentration relationship. Although metals concentrations were much higher during the fall storms (highest values in Figure 1A) there was no indication that lead concentrations were elevated above expected after August 10 2015 (Figure 1B) suggesting no GKM influence.

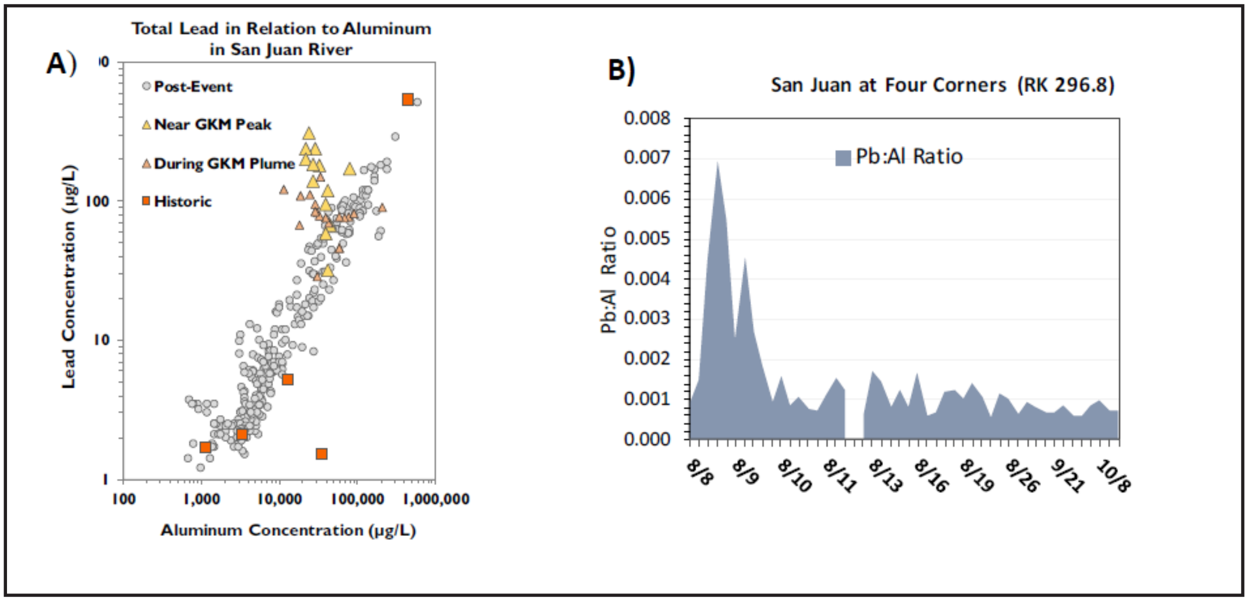

Figure 1. Examples of comparison of trace metals to aluminum concentration. A) all samples collected from the San Juan River identified by time periods relevant to GKM analysis; B) Ratio of lead to aluminum concentrations for samples collected from the San Juan River at Four Corners plotted in temporal sequence from the GKM plume August to October 2015.

The San Juan River received far more Gold King metals mass (433,000 kg) during the 2016 snowmelt period than it did during the actual release in August 2015 (24,000 kg). The correlation method indicated that the concentrations of a many metals were elevated above their expected relationships during April at all locations in the San Juan River, suggesting that GKM deposits were mobile. Metal concentrations were low but while relatively elevated the mass of metals transported was similar to the estimated mass of GKM deposits in the Animas River. Relationships returned to expected levels for the remainder of the snowmelt period.

The relationship of metals concentrations to background sediments in the San Juan River and the application and utility of the technique for isolating metal sources including the Gold King release metals in the San Juan River is discussed, and the potential for using the technique to identify other metals contaminant sources in this watershed is explored.

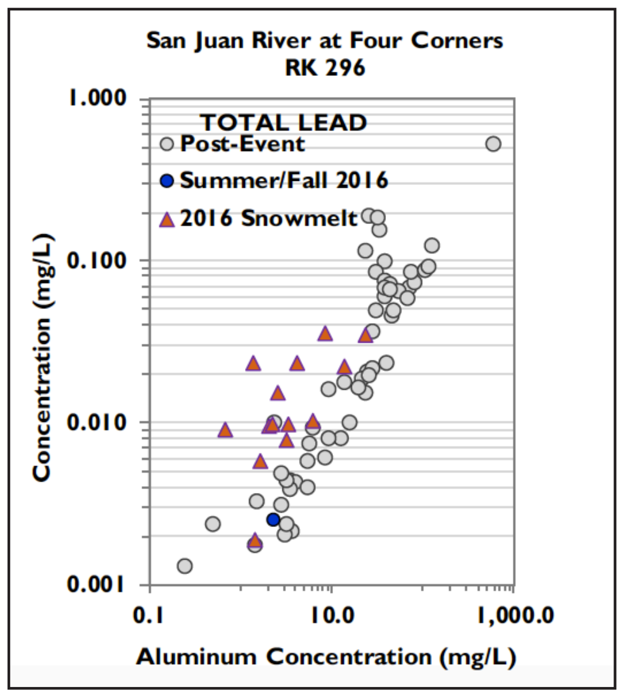

Figure 2. Total water concentration of lead in relation to aluminum during and after the Gold King Release in the San Juan River at Four Corners, emphasizing samples collected during the 2016 snowmelt period.

Characteristics of Metals Concentrations in the Animas and San Juan Rivers During Passage of the Gold King Mine Release Plume

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Abstract 19 – Both Oral and Poster

The accidental release of 11.3 million liters (~ 3,000,000 gallons) of acidic mine water from the Gold King Mine (GKM) in southwestern Colorado on August 5, 2015, created high concentrations of dissolved and particulate metals into the Animas River over about a 12-hour period. The release traveled as a coherent plume through 550 km (342 miles) of the Animas and San Juan Rivers over an 8-day period before ultimately reaching Lake Powell, Utah. Extensive monitoring of water and sediments by EPA, States, Tribes and others was augmented by water quality modeling to characterize the release.

The release initiated in Cement Creek, a headwater tributary of the Animas River 13km upstream of Silverton, CO. Reconstructed metal concentrations from samples collected within the mine after the release suggest that the acidic mine effluent (pH 2.9) contained approximately 700 mg/L of dissolved metals dominated by iron, aluminum, manganese, copper and zinc with small concentrations of lead, arsenic, and cadmium (virtually no mercury). This concentration of metals was significantly augmented as the low pH effluent eroded the mine waste pile outside the GKM entrance and reworked sediments as it flowed through Cement Creek. By the time the plume reached the Animas River, the peak concentration of total metals was estimated at be approximately 41,000 mg/L (excluding major cations Ca, K, Mg, Na), of which 90% was particulate and 10% was dissolved. Concentrations of several metals such as lead and arsenic increased dramatically. Lead was the signature metal that allowed tracking the release within the naturally occurring concentrations and variability of metals within the river system.

The concentrated core of the plume carried most of the metal mass past most locations in approximately a 12 to 14-hour period that remained remarkably consistent without significant dispersion. Although many water samples were collected as the plume traveled over the lengthy distance, the short duration of the plume's core explains why sampling of peak concentrations was so difficult despite intensive monitoring efforts. When the acidic plume entered the larger and more alkaline Animas River, both dissolved and colloidal/particulate metals concentrations declined rapidly as chemical reactions and hydraulic processes diluted, transformed, and deposited material. Metals concentrations were reduced to 13% of original strength by the time the plume traveled 5 kmthrough the upper Animas where multiple headwater tributaries converge. Dilution reduced concentrations to less than 1% as the plume reached Durango 95 km downstream of the GKM.

When the plume flowed into the more alkaline waters of the Animas River, geochemical reactions were triggered that produced a vivid yellow color. Increasing pH triggered formation of iron and aluminum oxides and other incipient minerals within the plume that created a mixture of particulate and colloidal materials that scavenged dissolved trace metals into their structures and removed themfrom solution. Data from deployed sondes suggests that the interior of the 12-hour core of the plumewas like a chemical reactor

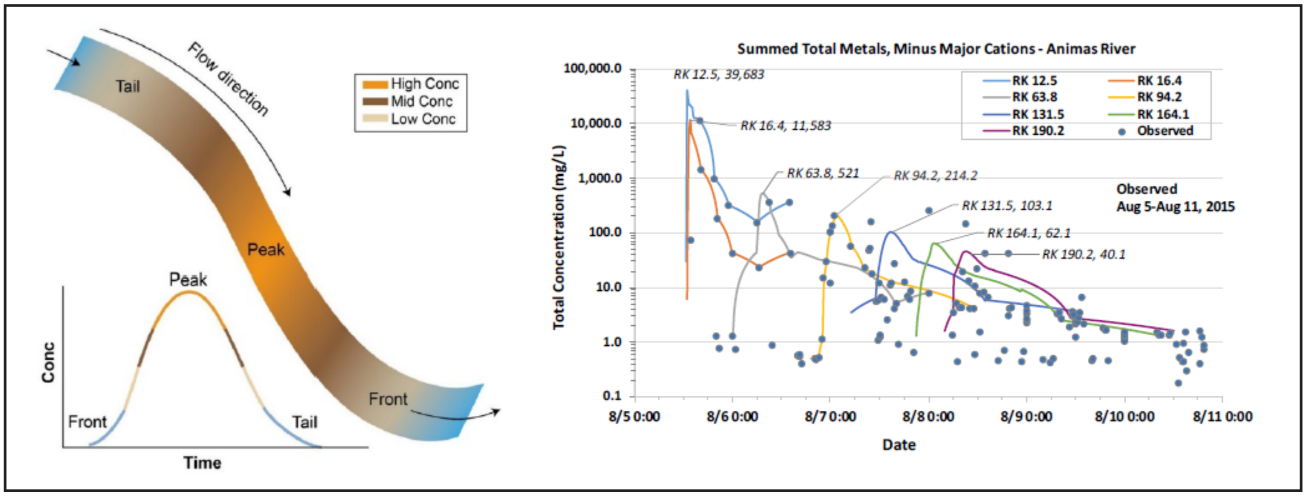

Figure 1. A) Conceptual drawing of what the Gold King plume was; B) Observed total metals concentrations (excluding Ca, K, Mg, Na) and reconstructed plumes in the Animas River.

that was stratified into a series of "fronts." The front of the plume was characterized by dissolved metals, the center by a lower pH interior, and followed by a trail of colloidal/particulate material. This pattern was observed through the length of the Animas River, although most of the chemical reactions appeared to be completed in the first 125 km of the plume'stravel, after which the acidity was largely exhausted. Dissolved metals were at background by 190 km downstream of the GKM.

The particulates and colloids that formed within the GKM plume were deposited throughout the length of affected rivers as the plume moved. Only 5% of the GKM plume mass reached the receiving waters of Lake Powell during the initial release, with 89% left in the Animas River, and 6% was deposited in the San Juan River. Although a large amount of GKM material was deposited in the upper Animas downstream of Silverton, the metal deposits were not different in content or significant in mass relative to metals already in that river bed which has been impacted by a legacy of mining and ongoing acidic mine contamination for over 100 years. GKM metal concentrations inthe sediments of the lower Animas River in New Mexico (river km 145 southward) were much lower but more distinguishable since this area has not been as impacted by previous mining effects. Metal concentrations declined towards pre-release conditions within hours of the plume passing, buta complete return to summer baseline conditions required days to weeks.

States and tribes have adopted water quality criteria that establish concentrations of constituents, including metals, that protect designated beneficial uses from harmful effects. Most of the metals in the GKM release have criteria for one or more beneficial uses that vary by State and Tribal jurisdictions. Despite the unusual metal concentrations, the large number of measured metals and thevariety of beneficial use criteria, there were relatively few exceedances of water quality criteria as the plume passed. However, criteria for several metals were exceeded for a few hours up to the duration of the plume (24 hours). State domestic supply and irrigation criteria for lead and manganese were exceeded in the Animas River. Aquatic acute criteria for aluminum were exceeded for a few hours in the Animas and San Juan Rivers. Tribal criteria for lead in drinking water were exceeded for the duration of the plume in the San Juan River.

Let's Not Wait for Catastrophic Spills to Happen: Holistic, Long-Term, Multi-Jurisdictional Monitoring in Legacy Mining Areas

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Abstract 20

Catastrophic releases of mining-related waste at three sites in the region over a period of decades led to increased awareness of mining contamination and intensified monitoring. All three sites — the Churchrock, NM uranium mill (1979), the Terrero Mine near Pecos, NM (1991), and the Gold King Mine near Silverton, CO (2015) — had been impacted by decades of mining operations. These catastrophic releases led to long-needed corrective actions at each site, but their long-term impacts remain uncertain. Increasing groundwater uranium levels in eastern Arizona, for example, are believed to result in part from historical mining discharges in Churchrock, some 70 miles upstream. Impacts to public health from the Churchrock spill and decades of mine dewatering have not studied. These cases illustrate the need for holistic, long- term, multi-jurisdictional monitoring in legacy mining areas, coupled with broad community engagement that addresses local needs and involves citizens in monitoring and health research.

The Churchrock uranium mill tailings spill occurred on July 16, 1979, releasing 1,100 tons of solids and 94 million gallons of acidic (pH = 1.5), saline and radioactive liquid — the largest release of radioactive wastes, by volume, in U.S. history. While most of the solid material was contained by an emergency catchment at the base of the breach point in the 40-foot-high starter dam, most of the liquid entered the North Fork of the Puerco River, flowed through Gallup, New Mexico and into Arizona where evaporation and seepage into the stream bed caused the surface flow to cease near Chambers, AZ. After the

Sheep, goats and cattle sampled along the Puerco River had higher concentrations of isotopic uranium in muscle, bone, liver and kidney compared with control animals, a result of drinking mine water from the river. Based in part on these findings, the state recommended the Puerco River not be used for human consumption, livestock watering, or irrigation. Despite documented human exposure to the spill, mine water and mining wastes, no health studies were conducted in the Puerco River Valley during this period. Human biomonitoring conducted by state and academic groups between 2003 and 2010 found average urine-uranium concentrations were significantly higher in New Mexicans than among people in the rest of the US, and even higher for people who lived in the Grants uranium area. Uranium has recently increased to levels greater than the drinking water standard in public, school and livestock wells in eastern Arizona.

Early spring rainfall runoff from the Terrero Mine in 1991 caused a massive fish kill in the Pecos River and in a hatchery along the river. More than 90,000 trout died at the hatchery, alone. The site had been monitored by state and federal agencies, and had a long history of previous fish kills, but the devastating 1991 event brought increased attention to the unaddressed contamination from the mine and nearby El Molino mill. Elevated concentrations of metals were discovered in fish and small mammals. The recreational-based economy of the Village of Pecos was severely impacted. The mining company and state signed an

Administrative Order on Consent (AOC) on December 2, 1992 containing many provisions parallel to the Superfund process to be executed under state authority with Federal oversight. Pursuant to the AOC, source control and site restoration actions were conducted. No fish kills attributable to the mine have occurred since the mid-1990s, contaminant levels in surface water and stream sediment have decreased, and stream impairments for several parameters have been lifted. The recreational economy of the Village of Pecos and the Upper Pecos River remains intact following cleanup.

The Gold King Mine (GKM) spill occurred on August 5, 2015. More than 3 million gallons of acidic mine water containing sediment and heavy metals were released into Cement Creek, which flows into the Animas River and then into New Mexico where the river joins the San Juan River before flowing into the Navajo Nation and Utah. Surface and groundwater, sediment, benthic macroinvertebrates, fish, agricultural produce, livestock and human urine and blood are being tested for heavy metals by one or more federal, state, tribal, and local agencies and academic institutions. Differences in the media tested and in test methods used by the various jurisdictions reflect differing priorities, standard practices, and availability of funding. The watersheds affected by the GKM spill also had received contaminants from natural geologic sources and from more than a century of mining and milling activity. While surface water quality rapidly returned to pre-spill conditions during low-flow conditions, monsoon events and spring runoff can create turbidity that causes untreated river water to contain metals at concentrations greater than drinking water standards. River water continues to meet New Mexico standards for irrigation and livestock watering. Test results of agricultural produce so far show low to non- detectable concentrations of heavy metals. There is no evidence thus far that the GKM spill affected any water supply wells in New Mexico. Fish tissue testing in Colorado and New Mexico has not detected elevated metals attributable to the GKM spill. The GKM is within the Bonita Peak Mining District, listed as a Superfund site by EPA in 2016.

Holistic, long-term, multi-jurisdictional monitoring in legacy mining areas would lead to identification and elimination of conditions that could potentially cause catastrophic contaminant releases, and could guide and justify funding for source control and site restoration. Monitoring programs, conducted in collaboration with trained community members with broad community acceptance, should include definition of several elements, depending on site conditions:

- background contamination;
- river, hyporheic zone and groundwater hydraulics and interactions;
    - extent and magnitude of contamination in sediment/soil, ground and surface water, airborne dust and the food web, including crops, livestock and wildlife;
    - contaminant fate and transport;
    - human exposure pathways and biomonitoring; and
    - impacts to the cultural and spiritual values of water and other affected media.

Source Identification for Metals in the San Juan River System

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Abstract 21

The accidental release of 3 million gallons of contaminated water into the Animas River on August 5th 2015 turned national and state attention towards mining sourced metal loading in the Animas and San Juan River systems. While extensive sampling was completed during and after the spill to understand the mass, fate, and transport of metals released from the Gold King Mine (GKM), little is known about the ongoing and historical metal loading from both anthropogenic sources (i.e. Bonita Mining District) and natural sources present in the tributaries of the San Juan Watershed. Particle-associated metals have been deposited in Lake Powell since its construction in 1963 but no known signatures exist to differentiate metals deposited in sediment sourced from mining and natural sources. Because mining contaminated sediments are distributed throughout the reach of the San Juan River, distinction of natural versus mining- induced loads can be performed by contrasting contaminant loads in mined versus unmined tributaries. The San Juan tributaries for McElmo Creek and Chinle Wash represent natural loading of metals from Mancos Shale and Chinle Sandstone dominated geology, respectively, whereas the tributaries of the Animas and the San Juan River downstream of Farmington, NM, represent mining impacted tributaries. In order to establish baseline signatures, ratios of total metal concentration per mass of sediment were calculated from surface water samples collected by Environmental Protection Agency (EPA), Utah Division of Environmental Quality (UDEQ), and the New Mexico Environmental Department (NMED). These values were converted into loads using discharge data from USGS stream gauges. Analysis of results is ongoing. Once elemental ratios are established, isotopic signatures (e.g. Pb, U, Sr, and S) will be used to strengthen the fingerprints of the various tributaries. Knowledge gained from source identification in the particle bound metals of the San Juan Watershed can be used to understand current and historical loading in Lake Powell (cores and sediment traps collected by USGS) to aid in management and potential mitigation.

Geochemical Characterization of Shallow Groundwater Near the Animas River, Northwestern New Mexico

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Abstract 22

With funding from the U.S. EPA, through the New Mexico Environment Department (NMED), the New Mexico Bureau of Geology (NMBG) is working to assess potential impacts from the Gold King Mine (GKM) spill to the shallow aquifer adjacent to the Animas River in northwestern New Mexico. Initial sampling of over 250 domestic and irrigation wells by the NMED and U.S. EPA in August 2015 provides important baseline information about geochemical conditions in the shallow groundwater immediately after the GKM spill occurred. Since then, as part of a long-term monitoring plan, NMBG researchers have sampled between 15 and 26 wells at regular time intervals that correlate to flow conditions on the river: base flow (January), initial snowmelt input (March), peak snowmelt input (June), and monsoon influenced/ post-irrigation flows (October). Water samples were analyzed for major cations (total and dissolved) and anions, trace metals (total and dissolved) and stable isotopes of hydrogen and oxygen. Sample locations were chosen to provide a relatively uniform coverage between the New Mexico – Colorado border and the confluence of the Animas River and the San Juan River near Farmington, NM. Most wells sampled are in close proximity to the river. Many wells have been sampled repeatedly so that changes in water chemistry with time can be observed. In January 2017, several wells were instrumented with dataloggers that record specific conductance at hourly intervals.

Before an assessment of groundwater quality impacts due to the GKM spill can be done, it is necessary to have an understanding of the overall hydrogeologic system. Because this reach of the Animas is mostly a gaining stream, where groundwater discharges into the river, it unlikely that significant amounts of mining related contaminants have entered the shallow aquifer. However, groundwater level monitoring efforts by NMBG have identified localized areas where groundwater levels may occasionally be below the stage of the river, allowing river water leak into the shallow aquifer. Irrigation in this region is from river water distribution through ditches throughout the Animas River valley, and is a mechanism by which intermittently (i.e. storm events) contaminated surface water can infiltrate into the aquifer system. In combination with water level data, these geochemical data are being used to characterize the shallow groundwater system by assessing groundwater flow directions, water/mineral interactions, and groundwater/surface water interactions.

Total dissolved solids (TDS) in groundwater ranges from 315 to 2380 mg/L, with calcium as the dominant cation in all groundwater samples. Sulfate and bicarbonate are the dominant anions, with slightly higher sulfate concentrations observed south of Aztec. Mass and charge balance analyses show that the major ion concentrations are primarily controlled by the dissolution of limestone, and gypsum, with some cation exchange, which slightly increases sodium to chloride molar ratios. Sulfate concentrations correlate significantly with and can be used as a proxy for TDS values. The general chemistry in most wells has not changed significantly the last two years of monitoring. In relation to the river, groundwater appears to have higher specific conductance values.

Preliminary results from stable isotopes of oxygen and hydrogen show a clear difference in water sources for the river and groundwater during peak snowmelt inputs in June 2016. During this time, water in the river was dominantly derived from snowmelt at higher elevations near the head waters in Colorado. The stable isotopic composition of this river water plots to the left of the global meteoric water line (GMWL) along an apparent evaporation line showing progressive evaporation of winter precipitation in the downstream direction. The isotopic compositions of river water during other sampling times cluster closer to the GMWL along with most groundwater samples, indicative of mixing of groundwater and river water due to groundwater discharging into the river and/or irrigation return flow.

In general, groundwater exhibits very low trace metal concentrations. However, in localized areas north of Aztec, where low or reversed gradients between the river and groundwater occur, we found high groundwater concentrations of aluminum, iron and manganese, above the secondary MCL values. Additional expected data, including environmental tracer concentrations, will help to further characterize the hydrogeologic system and groundwater/ surface water interactions so that we can better assess the possible groundwater quality impacts from the GKM spill.

Metal Concentrations in Soil and Sediments after Gold King Mine Spill

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Abstract 25 – Both Oral and Poster

Even two years after the August 2015 Gold King Mine Spill, the question “Is it safe to use the water?” is unanswered. The heavy metal contaminated yellow plume of water that flowed into the Animas River is still a concern for public health and agricultural practices. Immediately after the spill, most irrigation ditches were closed for several weeks and contaminated water was excluded from agricultural fields. However, there was disagreement about whether the metals were flushed out of the river or not and if surface water contamination may have spread through the watershed. Our goal is to evaluate the potential impact of the 2015 Gold King Mine Spill discharges and legacy mining/milling wastes on sediment, soil, and crop health. To accomplish this goal, the NMSU team is monitoring the presence of heavy metals in irrigation water diverted from the Animas River, irrigation ditch sediments and irrigated field soils. This presentation will focus on irrigation ditch sediments and agricultural fields.

We are monitoring the total concentration of aluminum, arsenic, calcium, chromium, copper, iron, lead, manganese and zinc in 10 different irrigation ditches fed by the Animas River. Collection sites range from Twin Rocks, near the Colorado-New Mexico border to Indian Village in Shiprock to represent a comprehensive image of agricultural resources and potential impacts. Sediment samples from the dry ditches are collected before and after the irrigated growing season, while water samples are collected at three different times: before the growing season while energizing the ditches (April); mid-growing season (July); and post-growing season (October-November). Soil samples from crop fields were collected before and after the growing season.

Soil and sediment metal concentrations are measured in-situ using portable X-Ray fluorescence (PXRF) and will be compared to samples digested in acid and analyzed by inductively coupled plasma-optical emission spectrometry (ICP-OES) following USEPA methods. The PXRF readings were made under two beams in Soil mode and Geochem mode (for aluminum) for 60 seconds. The concentration of metals in soil will be compared to the residential screening level (RSL) recommended by USEPA (for example lead RSL is 400 ppm, arsenic is 3.5 ppm, etc.).

On examining the concentration of metals in dry irrigation ditches sampled in March 2017, the average value of arsenic (4.8 mg/kg), iron (14,382 mg/kg) and manganese (540.2 mg/kg) were higher than the EPA RSL. However, copper (24.2 mg/kg), lead (43.4), zinc (176.4) and aluminum (5,758 mg/kg)) are below the RSL values. Calcium concentration is in the range of 2,189.5 to 11,219.5 mg/kg and is found as white patches in some areas with higher concentrations. The average value of chromium across the region was 44.8 mg/ kg.

Tó'Łítso, the Water is Yellow: Water Quality Results of the San Juan River on the Navajo Nation One Year After the Gold King Mine Spill

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Abstract 26

On August 5, 2015, 3 million gallons of acid mine drainage was accidently released from the Gold King Mine spill, eventually reaching the San Juan River – the lifeblood of the Navajo Nation. Many Native American communities have subsistence livelihoods and strong cultural practices and spiritual beliefs that are deeply connected to the natural environment. As a result, environmental contamination from catastrophic mine spills severely impacts indigenous people to the core of their spiritual and physical livelihoods and there is potential for unique exposure pathways and greater health risks. Building on established partnerships with the Navajo Nation, we collected environmental samples in November 2015, March and June 2016 and household samples in August 2016. We also held community focus groups in May and June 2016. In this talk, we will present water quality results of water samples collected along the San Juan River on the Navajo Nation. The next steps are to complete the analysis of the household samples and report our results back to study participants and the community in the Fall of 2017. The results of this investigation will be used in the future to develop a community-based intervention, designed to: a) prevent potentially harmful exposures based on actual measured risk, and/or b) effectively communicate long-term risks from the Gold King mine.

Communicating River Data to the Public: the Animas River Community Forum Monitoring Gaps Analysis Committee

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Abstract 27

In response to the Gold King Mine spill incident, the Animas River Community Forum came together for the purpose of promoting communication, coordination and collaborative action; fostering public confidence; supporting resiliency in our communities; and enhancing planning, improved public safety and health for the future; all while honoring the institutional authorities and decision making of government and community organizations. The Forum brings together local county and municipal governments and agencies, local conservation organizations and watershed groups, river recreation businesses, economic development and environmental health partner, some of which had previously had very little interaction regarding the river.

One of the common interests that the partners identified early on was to conduct an assessment of the gaps that exist with regard to river monitoring. In response to this interest, the partners formed a committee called the Monitoring Gaps Analysis Team (MGAT). The team began meeting in December 2015 and quickly identified their purpose and agreed on a strategy to guide their work. The goal of the committee is to lead "a collaborative process to identify and make available timely, useful, accessible information for decision makers and the public – to tell accurate stories about our resources and community." The committee's data objective is to compile baseline information to address questions related to public health, public concerns, and ecosystem resilience of the Animas River including tributaries.

To date, the committee has prepared and conducted a survey to identify top concerns of the public. These concerns were sought in order to define questions for monitoring that are most pertinent to the people's concerns. Based on this survey the committee hosted a monitoring exchange to identify existing monitoring efforts. The Exchange was attended by 18 partners who conduct monitoring within the watershed. The committee is currently working to develop an information piece aimed at delivering existing data on nine monitoring questions to the public and at fostering conversation and deliberation about the resilience of the Animas and its ability to continue to safely support quality of life, economy and natural values.

Water Quality and Sediment Monitoring of the San Juan River, Three Major Tributaries, and Two Irrigation Canals within the Navajo Nation

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Abstract 30

The Navajo Nation was conducting ambient water quality monitoring along the San Juan River and its tributaries prior to the Gold King Mine spill in August of 2015. Four rounds of monitoring were scheduled for the river at five locations between the Hogback in New Mexico and Bluff, Utah, during the summer of 2015. Additionally, the three major tributaries with access near their mouths were selected to determine how they may affect water quality in the San Juan. These were the Chaco and Mancos Rivers in New Mexico and McElmo Creek in Utah.

Two rounds of monitoring were completed at each site in July 2015. Immediately after the spill and into early October of 2015 we began monitoring five additional sites on the San Juan River and dropped the Chaco and Mancos Rivers. We also began monitoring metals in the sediment at each location. After receiving supplemental funding from US EPA, we began monitoring water and sediment at fifteen locations in October 2016. These include the ten San Juan River locations from Farmington, NM, to Mexican Hat, UT; the Chaco River, Mancos River, and McElmo Creek; and the Fruitland and Hogback Canals in New Mexico. The goal is to complete fifteen rounds at each location by July 2017. Assessment of the results to date with particular emphasis on livestock and agricultural uses will be presented. How the tributaries and storm events affect San Juan River water quality will also be discussed.