Element 1. Public Drinking Water Protection

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SUMMARY

Most of the heavy metal contaminants released by the Gold King Mine (GKM) spill existed as suspended solids. Dissolved metal concentrations in surface water were generally much lower than suspended concentrations. Monitoring data collected since August 5, 2015 show that concentrations of total metals in the Animas San Juan Rivers increase to levels of concern during high stream flow events (Figure 1), and that a positive relationship exists between turbidity and total lead in untreated Animas River water (Figure 2). The increase of total metal concentrations in river water during high-flow events is not a violation of EPA National Primary Drinking Water Regulations, but is of concern to the public water systems that use rivers as a water source. These public water systems must ensure that their treatment infrastructure produces drinking water in compliance with the National Primary Drinking Water Regulations.

Goals: Determine if the GKM spill will have any impact on the water sources used by public water supply systems; ensure that public water systems deliver drinking water that complies with the National Primary Drinking Water Regulations; and monitor for accumulation of heavy metals in drinking water treatment infrastructure.

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Figure 1. Total Lead in Surface Water, Colorado, New Mexico and Utah.

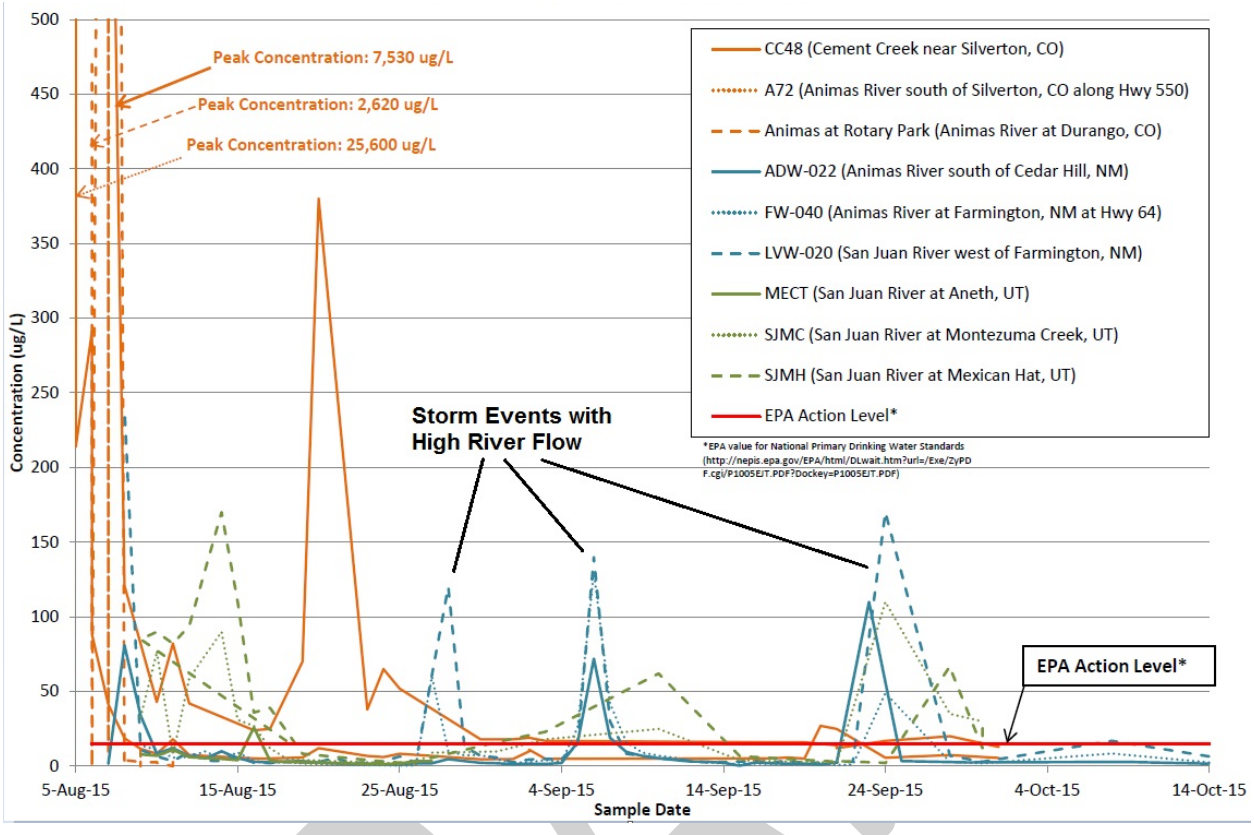
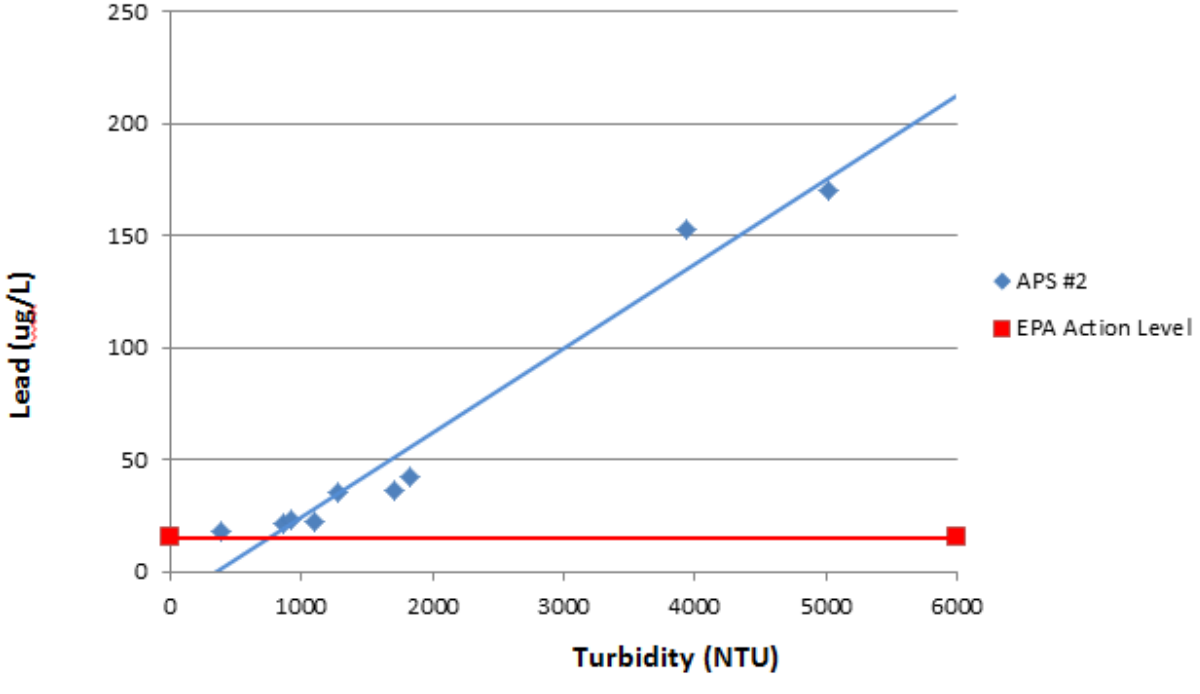


Figure 2. Turbidity and Total Lead, City of Farmington, Animas Pump Station #2, During High Flow.



New Mexico Environment Department (NMED) Actions:

- Continue to monitor entry points of public water supply in accordance with compliance monitoring schedules and laboratory analyses required by the Safe Drinking Water Act (SDWA). Increase sampling frequency, if appropriate, in response to any detection of increased heavy metal concentrations in treated water being served. Add source water monitoring, as needed if treatment is not treating raw water adequately and metals are being detected at the entry point.
- Provide outreach and education at public meetings on source water protection (SWP) planning and offer individual assistance to each public water system with a drinking water source of supply in the Animas River watershed. Provide information and education on potential regional planning activities, where multiple water systems protect sources of drinking water and plan for emergencies together.

City of Farmington (COF) Actions:

- Establish real time monitoring at COF source water intakes for turbidity, and take appropriate actions when turbidity increases to levels of concern to the COF.
- Monitor sedimentation basins for evidence of heavy metal buildup.

WORKPLAN

NMED:

Public drinking water systems will continue to be monitored using existing SDWA protocol. Any additional samples also will be collected in accordance with regulatory requirements. Public meetings will be conducted for systems in the Animas/San Juan River watersheds to educate on SWP planning and the potential benefits of regional planning. Individual SWP planning assistance will be provided to public water systems within the watersheds as requested.

City of Farmington:

Turbidity Monitoring – The City of Farmington (COF) has installed sondes at source-water intake locations. The sondes provide real-time measurements of pH, specific conductance, turbidity, dissolved oxygen, and ultraviolet absorbance.

The COF has established a relationship between turbidity and total lead in river water (Figure 2). A turbidity level of approximately 400 NTU corresponds to a total lead concentration of 0.015 mg/L, the EPA Action Level for treated drinking water. As a precautionary measure to further reduce the possibility that drinking water exceeding the action level of 0.015 mg/L for lead might be delivered to consumers, the COF is programming their SCADA system to close source water intakes when a turbidity level of 400 NTU is reached.

The COF will establish a communication system to provide email notice to other public water systems that divert water from the Animas River when turbidity levels in river water reach 400 NTU. The other water systems may take whatever action they feel is appropriate based on the information provided to them

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Sedimentation Basin Sediment Monitoring – The COF will collect representative samples at the Farmington Lake sedimentation basin. If an adequate thickness of core can be obtained, the cores will be divided into vertical segments for analyses of total metals and toxicity characteristic leaching procedure (TCLP) metals. The sampling data will be compared with regulatory standards. The vertical distribution and composition of metals also will be evaluated for possible differentiation between pre and post August 5, 2015 contaminants.

Sampling methodology developed by the COF may be applied to sedimentation basins for other public water systems that utilize water from the Animas River.

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BUDGET

NMED (2 years)

It is unknown if any additional source water samples will be required, so no budget for additional sampling is requested at this time. Additionally, the outreach and education activities will be conducted by NMED using existing funds provided by EPA pursuant to the federal Safe Drinking Water Act.

COF BUDGET (2 years)

Task	Total
Develop communication system with other public water systems that divert water from the Animas River to alert them when COF sondes detect high turbidity	**$50,000**
Collect soil core samples from the sedimentation basin at Farmington Lake for metals analyses	**$75,000**
2 Year TOTAL	**$125,000**

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Element 2. Surface Water Quality

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SUMMARY

Goals: Determine if surface-water quality has changed as a result of the Gold King Mine (GKM) spill, and evaluate any changes with respect to regulatory standards and criteria.

Actions:

U.S. Geological Survey (USGS) Actions

- Install field instrumentation at eleven USGS stream gaging stations in the Animas and San Juan Rivers to monitor for turbidity, pH, specific conductance, and temperature.
- Make real-time data for turbidity, pH, specific conductance, and temperature provisionally available on the USGS WaterQualityWatch website, along with flow rate which is already measured by USGS at the eleven gaging stations and available on the WaterWatch website.
- Make the real-time water-quality and flow data available for subscription e-mail and text alerts to public water systems and others through the USGS WaterAlert service, which will send automated messages when field measurements exceed specified levels.
- Install and manage nine ISCO auto-samplers and associated samples, co-located with gaging stations where water quality measurements are being collected.

San Juan Soil and Water Conservation District (SWCD) Actions

- Conduct baseflow sampling for surface water quality sampling for field parameters, total and dissolved solids, anions/cations, dissolved and total metals, suspended solids on filter paper for total metals, bacteria, Bacteroides, nitrogen, and phosphorus.

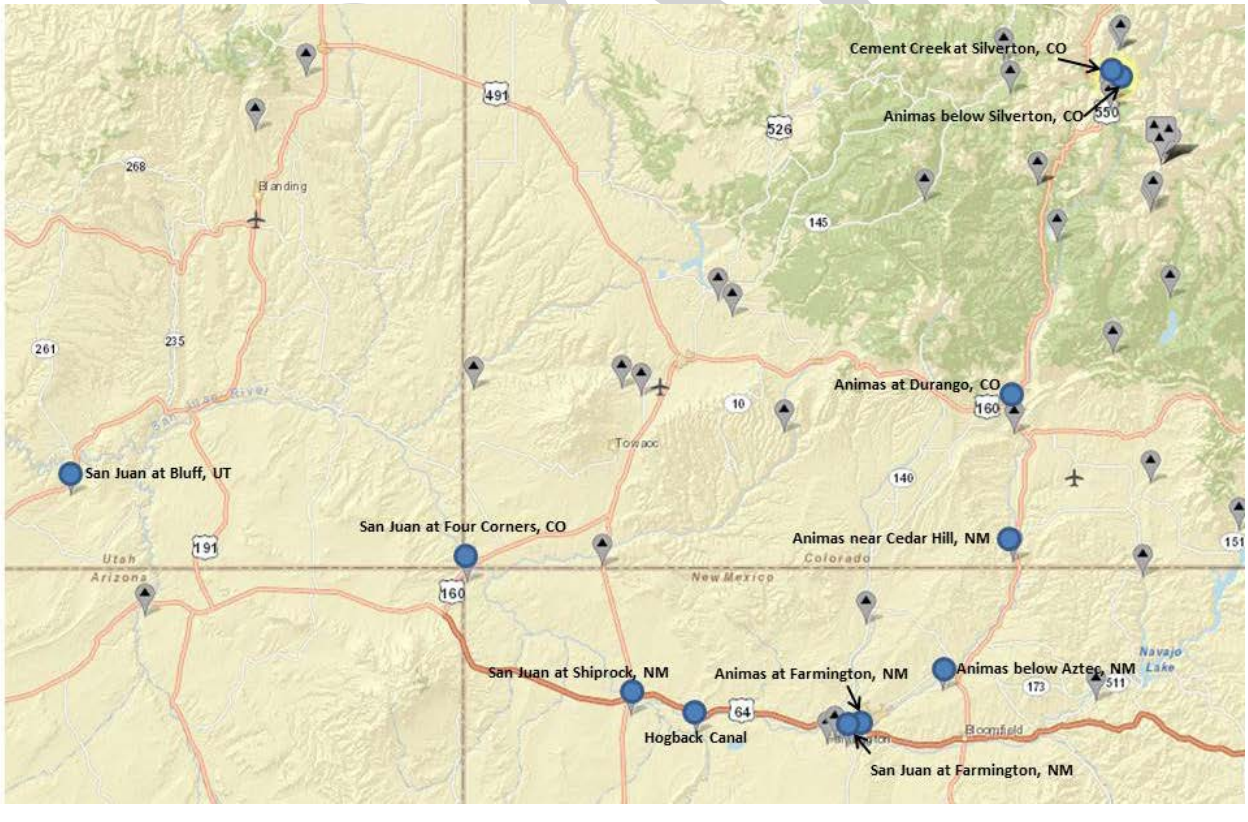
WORKPLAN

The primary objective of long-term surface water monitoring is to determine how surface water quality, including baseflow, snowmelt, and stormflow, has changed as a result of the GKM spill. Results will be evaluated to determine if these changes represent a risk to human health and the environment; this evaluation will be accomplished by comparing sampling results to both State Water Quality Standards set to protect human health, wildlife and aquatic life as well as to pre-event baseline, when it exists, to determine if pollutant levels have increased significantly.

Sampling Objective #1: USGS Surface Water Monitoring and Communication System

The USGS has established surface water gaging stations for the Animas and San Juan Rivers:

- Cement Creek at Silverton, CO (09358550)
- Animas River below Silverton, CO (09359020);
- Animas River at Durango, CO (09361500);
- Animas River near Cedar Hill, NM (09363500);
- Animas River below Aztec, NM (09364010);
- Animas River at Farmington, NM (09364500);
- San Juan River at Farmington, NM (09365000);
- Hogback Canal near Waterflow, NM (09367580);
- San Juan at Shiprock, NM (09368000);
- San Juan at Four Corners, CO (09371010); and
- San Juan near Bluff, UT (09379500).



The USGS presently measures stream flow and provides provisional real-time stream flow data on USGS websites. The USGS will install additional instrumentation at these eleven gaging

locations that will be capable of measuring and transmitting turbidity, pH, specific conductance, and temperature in real time. The USGS will also provide provisional real-time data for these parameters on the USGS WaterQualityWatch website. The USGS will provide the capability for public water systems and others to subscribe to the WaterAlert service to receive automated e-mail or text alerts when these field measurements exceed specified levels.

Sampling Objective #2: Collect seasonal baseflow water quality data

Seasonal (quarterly sampling) grab sample collection will be conducted by the SWCD at the ten USGS gaging station locations listed in Sampling Objective #1. Seasonal sampling will target pre-snowmelt conditions (~March), peak snowmelt (May/June), summer low flow (August), and post-monsoon (November). Samples will be analyzed for field parameters, total dissolved solids (TDS), SSC, major cations/anions, dissolved/total metals, total nutrients, and bacteria following New Mexico Environment Department (NMED) Surface Water Quality Bureau's (SWQB's) Quality Assurance Project Plan (QAPP) and standard operating procedures (SOPs) for data collection.

Results will be compared to Surface Water Quality Standards to determine if standards have been exceeded. Results will also be compared to historical water quality data collected by SWQB and the USGS to determine if pollutant concentrations have increased over pre-event baseline. For the purposes of this analysis a >10% increase would be considered significant.

Sampling Objective #3: Snowmelt sampling to determine if contaminated sediments are mobilized

Deploy ISCO auto-samplers to sample at nine of the eleven listed USGS gaging station locations. An ISCO auto-sampler will not be installed at two of the eleven gaging stations due to limited access during the winter caused by snow and ice: 1) the Cement Creek at Silverton, CO (09358550); and 2) the Animas River station below Silverton, CO (09359020). Sampling events will particularly focus on: (1) the first significant snowmelt event of the year that causes the river to rise above flow conditions that existed during the GKM release (~800 cfs); (2) peak snowmelt in the Cement Creek watershed; and (3) recession of the snowmelt hydrograph, which causes flow to dip below flow conditions that existed during the GKM release. Grab samples will be collected by the San Juan SWCD from the two gaging stations not equipped with ISCO auto-samplers.

Samples from the ISCO auto-samplers and grab samples will be analyzed for major ions, dissolved and total metals, and suspended sediment concentration.

Sampling Objective #4: Storm event sampling to determine if contaminated sediments are mobilized

Deploy ISCO auto-samplers to sample at nine of the eleven listed USGS gaging station locations. An ISCO auto-sampler will not be installed at two of the eleven gaging stations due to limited access during the winter caused by snow and ice: 1) the Cement Creek at Silverton, CO (09358550); and 2) the Animas River station below Silverton, CO (09359020). Sampling should capture pre-storm event baseline (if possible), during the storm (rising limb of hydrograph) and on the falling limb of the hydrograph for four storms. Grab samples will be collected by the San

Juan SWCD from the two gaging stations not equipped with ISCO auto-samplers. Samples will be analyzed for major ions, dissolved and total metals, and suspended sediment concentration.

Results will be compared to surface-water quality standards to determine if standards are exceeded. Suspended sediment results will be compared to U.S. Environmental Protection Agency (EPA) developed screening levels developed to protect human health. Because a snowmelt and storm water dataset for the Animas River does not exist for the period before the GKM release, a simple baseline comparison is not possible. As a proxy, the suspended sediment component will be compared to the results of the core samples taken by EPA on September 2 and 3, 2015 at seven locations in New Mexico to determine if the level of contaminants in the suspended sediment has increased as a result of the GKM release.

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BUDGET

BUDGET (2 years)

This budget includes the cost of equipment purchase, installation, operation and maintenance, sampling, laboratory analysis, data interpretation, and reporting for two years, as outlined above.

	Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
USGS	Years 1 and 2	$251,803	$431,800	$185,610	$37,414	$1,226,934
San Juan SWCD	Years 1 and 2	$43,000	$199,200	$9,956	$6,833	$318,000
					2 Year Total	$1,544,934

*Total includes fringe and overhead (12%).

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Element 3. Sediment

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SUMMARY

Goals:

- Determine if elevated heavy metal concentrations presently occur in stream and irrigation ditch sediment, and in soil that has been irrigated with water diverted from the Animas River; and
- Monitor the migration of contaminated surface water sediment from Colorado (CO) into New Mexico (NM), as it pertains to irrigated agriculture and the river-agricultural land interface.

Actions:

- Initial and periodic future sampling, especially after runoff/storm events, of surface water sediment and irrigated soils for heavy metals and evidence of increasing concentrations migrating into NM from CO.
- Facilitate coordination between ditch associations and public water systems to ensure that future ditch flushing does not adversely impact drinking water intakes.

WORKPLAN

Due to the extent of the area affected, soil scientists at New Mexico State University (NMSU) and Texas Tech University propose to use portable X-ray fluorescence (PXRF) spectrometry to measure metal concentrations in surface soil. The technology is sanctioned both by U.S. Environment Protection Agency (EPA) and National Resources Conservation Service (NRCS), and is much more cost effective than inductively coupled plasma (ICP) analysis, allowing for a much more extensive evaluation of the potential impact of the spill. Validation using ICP

spectroscopic analysis will be performed on selected sites covering representative soil types and contamination levels.

In doing so, multiple types of land were evaluated to include: irrigated lands (water taken from the Animas River), non-irrigated lands (Control), and riverbank sediment. Notably, the riverbank sediment was observed to be a mix of natural alluvial sediment and Gold King Mine (GKM) sludge

PXRF was highly effective at quickly collecting elemental data with results verified both by NIST certified standards and ICP analysis. The variance of PXRF data relative to certified values is ~5-10%.

Sample Locations: Working in collaboration with staff from the NM-NRCS, CO-NRCS, UT-NRCS and AZ-NRCS (includes Navajo Nation), sampling stations will be established at representative locations along rivers and ditches, and all agricultural lands irrigated with potentially contaminated water from the Animas or San Juan Rivers will be mapped. The scope of this monitoring is proposed to extend from Silverton, CO to Lake Powell. With regard to irrigated croplands, soil types, cropping history, and irrigation practices will be identified and a strategic subset of fields will be targeted for sampling over the whole region. Samples will be selected to provide a comprehensive cross section of agricultural resources and cropping systems. NMSU has a good working relationship with much of the constituency in the Four-Corners region. Dr. Kevin Lombard and his research and extension colleagues have met on many occasions over the past month with Navajo leadership and chapter houses and community forums to help answer questions. The list of potential collaborators including community leaders, growers, ranchers, and non-profit groups who respect and work with our faculty and staff from the NM Cooperative Extension Service—including the Federally Recognized Tribal Extension Program (FRTEP), the Agricultural Science Center at Farmington, San Juan College, and Fort Lewis College—will facilitate access to field sites throughout the region.

Sample Analyses: PXRF spectrometry is a novel, yet widely accepted means of rapid elemental assessment in soils and sediments. Reference methods for the technique have been developed both by the NRCS (Soil Survey Staff, 2014) and Environmental Protection Agency (EPA, 2007) (Method 6200) for use in soils and sediments. Essentially, the PXRF spectrometer is a handheld unit that uses low power x-rays eject inner shell electrons from various elements. As this occurs, outer shell electrons then cascade down to fill inner shell voids, but in doing so much relinquish energy, termed *fluorescence*. The fluorescence energy is precisely measured via an integrated silicon drift detector and used to both identify which elements are present as well as their abundance. The operational theory, optimized uses, limitations and applications are summarized by Weindorf et al. (2014). Traditional elemental soil analysis relies upon digestion with caustic acids (EPA 1996a, 1996b), filtration, and elemental quantification via inductively coupled plasma optical emission spectroscopy (ICP-OES) (Soltanpour et al., 1996). While the ICP-OES technique is highly accurate and will remain the analytical standard for the foreseeable future, it is laboratory-based equipment and requires extensive sample processing, consumables, etc. With regards to analytical accuracy, the PXRF reported elemental values are typically within 5-10% of the certified elemental concentrations (determined via ICP-OES), only the PXRF reported values can be obtained on-site in 60 sec. Both techniques allow for multi-elemental analysis; quite commonly ~20 elements are reported by each instrument.

For rapid analysis of elemental concentrations on-site, the monitoring team will use Delta Premium (DP-6000) PXRFs featuring a Rh X-ray tube operated at 10-40 keV with elemental quantification accomplished via integrated ultra-high resolution (<165 eV) silicon drift detector. Scanning will be conducted in a proprietary software configuration known as Geochem Mode which offers elemental quantification of the following elements: V, Cr, Fe, Co, Ni, Cu, Zn, W, Hg, As, Se, Pb, Bi, Rb, U, Sr, Y, Zr, Th, Mo, Ag, Cd, Sn, Sb, Ti, Mn, Mg, Al, Si, P, S, Cl, K, and Ca. Geochem mode consists of two beams; each will be set to scan for 30 sec, such that one complete sample scan is accomplished in 60 sec. General limits of detection for each element are provided as Fig. 3. However, the data generated by the PXRF while scanning provides both the elemental quantity on an element by element basis, as well as the error term for each measurement (e.g., Pb 250 mg kg^{-1}; ±5 mg kg^{-1}). Furthermore, the location of each soil scanned will be georeferenced with a handheld GPS unit to catalog the location of metals/elements detected. PXRF performance will be compared to a subset of samples by analyzed Dr. April Ulery's lab using inductively coupled plasma optical emission spectrometry (ICP-OES) technology and assessed via scanning of two NIST certified soil standards whereby PXRF elemental quantity will be compared to certified reference values with a recovery percentage calculated on an element by element basis.

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BUDGET

BUDGET (2 years)

This budget includes the cost of sampling, laboratory analysis, data interpretation, and reporting for two years.

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Years 1 and 2	$84,935	$40,000	$39,500	$10,000	**$250,541**
				2 Year Total	**$250,541**

***Total includes fringe and overhead (12%)**

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Element 4. Solids Characterization

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SUMMARY

Goals: Determine specific form of contaminants in the Gold King Mine (GKM) spill solids and assess likely release and re-release pathways. Provide characterization support for other tasks in the monitoring plan.

Actions:

- Review solid characterization data for GKM site and surrounding mines and mine waters to establish likely initial forms of solid contaminants.

- Directly characterize solids and associated metals from water and sediment along the flow path.
- Model the likely transformation and release of mixed metals in GKM spill solids in different depositional environments.

WORKPLAN

The complex mineralogy and geochemistry of solids contained in the GKM spill needs to be established in order to assess the relative role of the processes controlling transformations and release of contaminant metals into surrounding environments. In particular, the redox sensitivity of the metals and susceptibility to mobilization via chemical or biogeochemical transformations is an important consideration. Preliminary data released by EPA suggests that metals such as arsenic, lead, chromium, zinc and copper were present in particulate form in the Animas River after the spill. Samples will be taken using best practices to preserve the redox state of sediments. Advanced microscopy (e.g., transmission and scanning electron microscopy microprobe mapping) and spectroscopy (e.g. X-ray photoelectron spectroscopy and X-ray fluorescence) will be used to characterize the distribution, chemical composition, oxidation state, and structure of metal-bearing solid phases present in sediment samples. X-ray diffraction will be used to evaluate mineral composition and crystallinity. Additionally, controlled laboratory experiments will be performed to assess the release of metals when reacted under environmentally relevant conditions to determine the mobility of aqueous metal phases. Aqueous metal speciation of redox-active metals will be measured in surface and groundwaters using high performance liquid chromatography (HPLC) coupled to inductively coupled plasma-mass spectrometry (ICP-MS). Additional natural tracers such as stable isotopes (oxygen, deuterium, sulfur) and radiogenic isotopes will be determined in selected water and sediment samples to assess the possibility of other sources of metals and sulfate along the flowpath.

Specific parameters for sediment sampling:

- Grain size analysis
- Mineralogy and spectroscopy of iron, aluminum, manganese phases,
- Selective digestion and extraction tests
- Batch and column tests
- Leachate studies

Microscopy (XRD, scanning electron microscopy, SEM; transmission electron microscopy, TEM) and spectroscopy (X-ray photoelectron spectroscopy, XPS; X-ray fluorescence, XRF) available at UNM will be used to determine the chemical composition, structure, and morphology of metal-bearing phases. Controlled laboratory experiments will be performed to evaluate the release of metals under environmentally relevant pH and redox conditions. Batch and column experiments will be performed to assess the reactivity of sediments under pH and

alkalinity conditions similar to those observed in the river. We anticipate the bicarbonate will play an important role in competitive metal complexation from the sediments and could stimulate metal release. We will also perform experiments under different dissolved oxygen concentrations to evaluate the effect of both biotic and abiotic processes under relevant redox conditions. Influent and effluent metal concentrations will be monitored using ICP-OES and ICP-MS. We will also measure aqueous Fe speciation using the ferrozine method (for detection of Fe(II) and ICP to measure total iron. Additionally, we will use HPLC coupled with ICP-MS to measure aqueous speciation of Cu, Cr, Pb and As. Geochemical models and speciation codes for species distribution, sorption/desorption and complexation will be performed with available aqueous data from surface and groundwaters.

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BUDGET

BUDGET (2 years)

This budget includes one graduate student dedicated to the project, full-time for 24 months. The budget includes 12% overhead cost.

Year	Salary	Tuition/Health (student)	Analysis	Equipment/ Supplies	Travel	Total*
1	$59,983	$5,616	$15,000	$2,000	$5,000	$112,799
2	$44,983	$5,616	$15,000	$2,000	$5,000	$90,959
					2 year Total	**$203,758**

*Total includes application of 12% overhead cost and fringe.

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Element 5. Riverbed and Shallow Alluvium Interactions

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SUMMARY

Goals: The primary goal of this monitoring element is to evaluate the potential for transport, sequestration, and release of heavy metals in riverbed sediments and the shallow alluvium along the Animas and San Juan river corridor. Hydraulic and geochemical interactions between the river water column, riverbed sediments, and the shallow alluvial aquifer are quantified with (1) a detailed compilation and reanalysis of existing well and surface water quantity and quality data in areas affected by the event, (2) synoptic sampling campaigns, and (3) installation of high-frequency monitoring sites.

Actions:

- Sample surface water, near-river wells, stream sediment, rock coatings, and hyporheic zone sediment and pore fluid at thirteen sites from Cement Creek, CO, through NM, and into Halchita, UT, for general chemistry and trace metals.

Our sampling strategy aims at capturing the effects of hydrologic, geomorphic, and geochemical processes in surface and ground waters. To this end, we propose to develop:

(1) A detailed compilation and reanalysis of existing well and surface water quantity and quality data in areas affected by the event;
(2) Synoptic sampling campaigns; and
(3) Installation of high-frequency monitoring sites.

First, compiling and reanalyzing legacy data will allow us to establish a base-line scenario to evaluate recovery. Second, four synoptic campaigns will be performed every year. These campaigns interrogate the system during periods where important changes in the aquifer-river interactions occur: baseflow, snowmelt rise, beginning of irrigation season, and one monsoon event (see Figure 1). These campaigns will start near the release location in Cement Creek, a tributary of the Animas River in Colorado, and end in the San Juan River as it approaches Halchita in Utah (see Figure 2). Sampling locations will include (i) neutral, gaining, and losing reaches along this longitudinal transect, (ii) sections significantly impacted by pumping and irrigation, and (iii) locations with legacy data and/or existing wells. Leveraging existing well and surface water observations will be critical for these campaigns and the study as a whole.

At each sampling location, water samples will be collected for detailed chemical analyses and instantaneous measurements of basic geochemical parameters will be recorded (pH, redox potential, temperature, dissolved oxygen, and electrical conductivity). In addition to surface water sampling, soil pits or piezometers will sample pore-water and, when possible, measure hydraulic gradient within the channel and sediment core samples will be collected for grain size, sorption, and mineralogical analyses. Laboratory sequential extraction experiments will also be conducted to better understand metal release from selected sediment core samples under controlled pH and redox conditions. These localized samples will cover a variety of morphological features that induce exchange with sediments, allowing us to explore the role of geomorphic drivers in areas with similar levels of exposure. To complement the synoptic sampling and increase temporal resolution, water quality sondes (e.g., YSI sondes) and auto-samplers will be deployed in key locations along the transect. Data collected will be used to:

(1) Evaluate the rates of recovery and propose adequate conceptualizations and models to predict the long-term impact to the system;
(2) Propose critical zones with high risk of accumulation or release of contaminants; and
(3) Design improved sampling strategies and propose risk mediation measures for future events.

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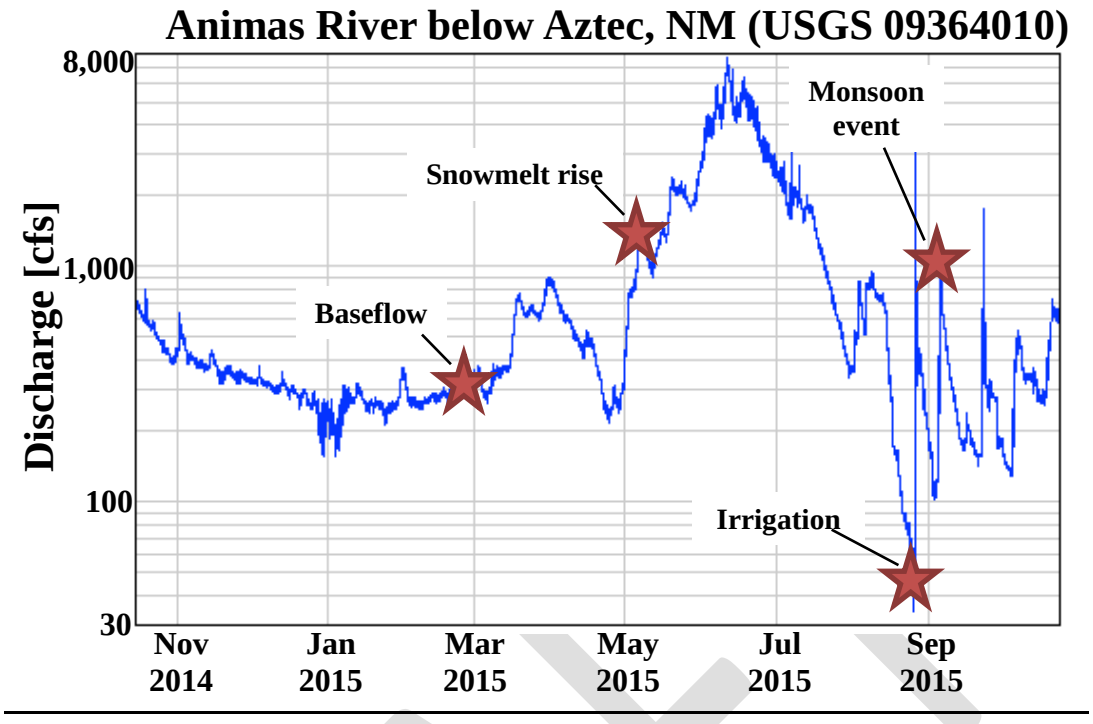

Figure 1. Typical hydrograph for the study area with approximated sampling times.

WORKPLAN

A) Groundwater-Surface water interactions—synoptic sampling

The levels of sampling and instrumentation for a synoptic sampling campaign in the Animas and San Juan rivers are described below. These campaigns will be seasonal (baseflow, snowmelt rise, irrigation) and event-based (one monsoonal event) (Figure 1). In the latter case, sampling campaigns will follow significant flood events in the watershed, capturing the dynamic nature of transport, accumulation and release of heavy metals. Each campaign will last five to six days and will require four people.

<u>Levels of sampling and instrumentation:</u>

- **Site Level 1**: one surface water sample, one hyporheic (or pore) water sample, and one sediment profile samples (2 water samples + sediment sample sequence from 1 soil pit + 1 erosion pin)
- **Site Level 2**: one surface water sample, two hyporheic (or pore) water samples, two sediment profile samples (3 water samples + sediment sample sequences from 1 soil pit + 2 erosion pins)
- **Site Level 3**: one surface water sample, three hyporheic (or pore) water samples, three sediment profile samples (4 water samples + sediment sample sequences from 2 soil pits + 3 erosion pins)

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General description:

- Each **water sample** includes:
  - 1 unfiltered 250 ml sample for general chemistry and alkalinity
  - 2 acidified 125 ml samples (one of them filtered with 0.45 um filter) for total metals and dissolved metals
  - 1 unfiltered 50 ml sample for stable isotopes of water
  - 1 filter of mesh size 0.45 um for solid analysis of colloids
  - 1 unfiltered 250 ml sample for metal isotopes
- Each sediment sample will be taken near the erosion pin from the soil pit used for pore water sampling. In each case, multiple depths of sediment will be sampled depending on the channel sediment size. For example, in coarse channels (cobble and boulder) we will collect a surface rock to analyze the sediment attached to its surface and then collect a sediment sample from the top 5 cm below the armoring layer and below ~20 cm where finer material (coarse sand matrix with gravel) is present. In the case of gravel or finer channels, sediment samples will be collected at 0-5 cm, 5-10 cm, 10-20 cm, and 20-50 cm. If the erosion pins show sediment accumulation, the profile will capture the new sediment as well as previously deposited materials. Sediment accumulation depths should be recorded. Accumulation of metals in sediment will be quantified using a sequential extraction procedure in the laboratory.
- An in-channel solute slug test will be used to infer gaining and losing conditions and discharge. When possible, direct measurements of discharge will be taken.
- Each location with a water sample will be analyzed with a multiparameter meter for DO, EC, pH, ORP, turbidity, and temperature.

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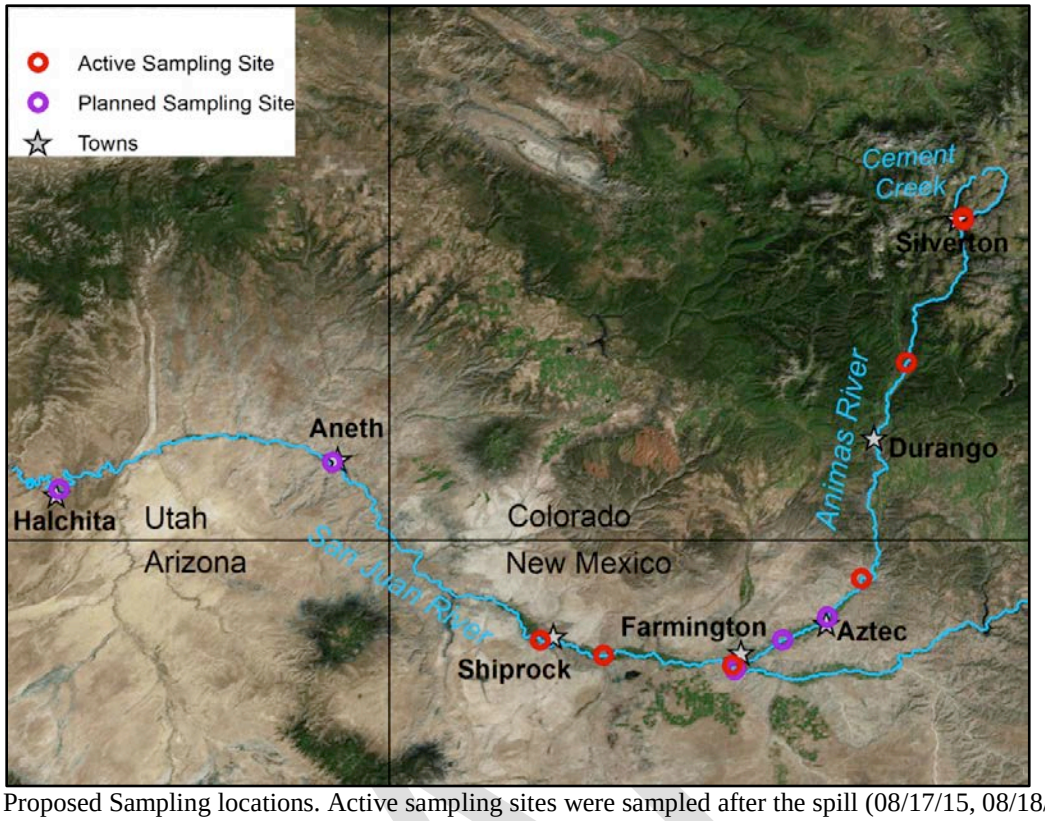

Figure 2. Proposed Sampling locations. Active sampling sites were sampled after the spill (08/17/15, 08/18/15, and 08/26/15). Planned sampling sites are complementary sites and will be sampled during this monitoring plan.

<u>Sampling sites (13 total, see Figure 2):</u>

- 1 in Cement Creek (Level 1)
- 1 in Silverton, CO (Animas downstream). We will match a site with the legacy data (Level 3)
- 1 in Hermosa, CO (Level 3)
- 1 in irrigated area upstream of Cedar Hill, NM (Level 2)
- 1 in agricultural land near Aztec, NM (Level 1)
- 1 in urban area near Farmington Lake (Level 1)
- 3 in Farmington, NM (Level 2: Animas, San Juan upstream, and San Juan downstream)
- 1 near the Hogback canal diversion (Level 2)
- 1 in Shiprock, NM (Level 2)
- 1 in Aneth, UT (Level 1)
- 1 in Halchita, UT (Level 1)

<u>Summary per campaign:</u>

- 5 of Level 1 (10 water samples + sediment sample sequences from 5 soil pits + 5 erosion pins)
- 6 of Level 2 (18 water samples + sediment sample sequences from 6 soil pits + 12 erosion pins)
- 2 of Level 3 (8 water samples + sediment sample sequences from 4 soil pits + 6 erosion pins)

Totals: water samples = 36; sediment sample sequences = 15; soil pits = 15; and erosion pins = 23

B) Groundwater-Surface water interactions—continuous sampling

Five sampling locations along the river transect will be instrumented with continuous and autonomous monitoring sensors for physical and chemical parameters. These sensors allow capture of the dynamic nature of GW-SW interactions and their geochemical implications.

- Isco automatic water sampler with event trigger. In this case, samples will be taken at the beginning, during, and after flood events.
- Two YSI multiparameter sondes. One in the channel and one in a well nearby.
- Two Solinst LTC sensors. One in the channel and one in a well nearby.

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BUDGET

BUDGET (2 years)

This budget includes the cost of sampling, laboratory analysis, data interpretation, and reporting for each year, as outlined above. Salary totals include the principle investigators, one graduate student (MS or PhD), and field assistants (typically undergraduate students). Each synoptic campaign includes one PI and the graduate student.

The budget assumed four sampling campaigns per year, three seasonal and one event-based. The equipment required for the synoptic campaigns will be purchased in the first year and used for both years of campaigns. Equipment budget includes a 12% overhead cost

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Year 1	$128,592	$61,536	$224,016	$21,440	**$464,574**
Year 2	$134,636	$63,957	***	$22,298	**$247,398**
				2 Year Total	**$711,972**

*Total includes fringe and overhead (12%)

DRAFT

Element 6. Regional Water Table Mapping

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DRAFT

SUMMARY

Goals: Provide seasonal data and interpretation of the hydrologic interactions between the river and the surrounding groundwater in the alluvial aquifer.

Actions:

- Collect manual water level measurements on a seasonal basis in up to 80 wells along the New Mexico section of the Animas River.
- Install instrumentation with continuous recorders in up to 25 wells to record temperature and water levels continuously.

At a regional scale the Animas River is a gaining reach along its length from the Colorado-New Mexico state line to Farmington, where it joins the San Juan River (New Mexico Bureau of Geology and Mineral Resources [NMBGMR], 2015, unpublished data). With regard to the contamination of the Animas River due to the August 5, 2015, Gold King Mine (GKM) spill, accumulation of contaminated sediments along the Animas River in Colorado and New Mexico, has created a heightened concern for water quality both in the river and in the surrounding groundwater.

Following the assumption that the Animas River is a gaining river along most of the length in New Mexico, concerns of contamination seeping into the groundwater are decreased. However, the amount of water flowing in this river varies seasonally. Under high flow conditions resulting from snowmelt or storm events, sections of the Animas may change from gaining to losing, which would allow infiltration of contamination into the groundwater. Additionally, with more turbulent flow related to periodic high flow rates, contaminated sediments will be re-distributed along the river and into the irrigation ditch network. Long-term monitoring of the dynamic interactions and potential changes to groundwater flow directions (either to the river or from the river) is an important aspect to consider for the region facing potential contamination issues as a result of the GKM spill. This proposed work will examine several sections of the Animas River in New Mexico, to address the possible changes in groundwater-surface water interactions related to seasonal changes in surface water flow. Timeline of this project is 2 years.

WORKPLAN

Task 1: Manual water level measurements

In order to address the groundwater flow conditions on a seasonal basis, we propose to manually measure groundwater levels in up to 80 wells along the New Mexico section of the Animas River, during key seasonal periods. Manual measurements are completed using a steel tape or an electric probe to record the depth-to water in the well. To insure the measurement represents the static water level that is not influenced by pumping, the pump is turned off and the well is allowed to recover for at least 2 hours before measuring the water level. Standard operating procedures for water level measurements will be followed. The periods of data collection are approximately:

- Winter (November – February), when river is likely under baseflow conditions;
- Spring snowmelt (March through June), when river discharge is likely being influenced by snowmelt in the mountains;
- Pre-monsoons (June-July), when river discharge is influenced by irrigation activities; and
- Post-monsoons (October-November).

Measuring groundwater levels when the river is under baseflow conditions will help to characterize the groundwater system under “natural” conditions and will provide a baseline that can be used to assess the effects

of irrigation and extreme runoff events on local and regional groundwater flow conditions and groundwater/surface water interactions.

Task 2: Instrumentation with continuous recorders

Additionally, we propose to instrument 25 wells with data loggers that record temperature and water level readings (pressure) continuously. (Note: some of these pressure transducers will also record conductivity, see project B below). Data loggers will provide information between manual measurements, with ambient fluctuations monitored by continuous water level measurements. These continuous monitoring devices will be set to record parameters at least 2 times daily, or in some locations as much as hourly. The instruments would remain in the well network for up to 5 years (or lifetime of the instrument) in order to continuously monitor groundwater changes. If this timeline is beyond the period of this proposed work, funding for data acquisition, processing and interpretation would need to be arranged.

DRAFT

BUDGET

BUDGET (2 years)

This budget includes the cost of manual water level measurements, instrumentation, and reporting for each year, as outlined above. Salary totals include the principle investigators, staff of NMBGMR, and student workers.

The budget assumes four data collection events per year and equipment will be purchased in the first year. The values below reflect 12% overhead.

Year	Salary	Equipment/ Supplies	Travel	Total*
Year 1	$56,823	$14,000	$5,000	**$84,922**
Year 2	$55,053	***	$5,000	**$64,952**
			2 Year Total	**$149,874**

*Total includes application of 12% overhead cost and fringe.

DRAFT

Element 7. Regional Groundwater Quality Monitoring

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SUMMARY

Goal: Determine if groundwater quality has been impacted by the Gold King Mine (GKM) spill.

Actions:

- Map and evaluate water quality data collected by the U.S. Environmental Protection Agency (EPA) in August 2015 from private domestic wells and sampled for laboratory analysis.

- Identify additional private water supply wells that may be influenced by recharge from irrigation ditches and sample for general chemistry and trace metals.
- If possible, identify indicator parameters that can be used to monitor groundwater for possible impacts from the spill. Select 30 wells for 4 times annual sampling of indicator parameters based upon hydraulic relationships to rivers and irrigation ditches.

As stated in Element 6, Regional Groundwater-Surface Water Hydraulics, there is general agreement that the Animas River is a gaining reach in New Mexico (New Mexico Bureau of Geology and Mineral Resources [NMBGMR], 2015, unpublished data). The August 5, 2015, GKM spill and accumulation of contaminated sediments along the Animas River in Colorado and New Mexico has created a heightened concern for water quality both in the river and in the surrounding groundwater. The goal of this project is to determine if there has been impact to groundwater quality as a result of the GKM spill. Timeline for this project is projected for two years.

WORKPLAN

Task 1: Data compilation

Private domestic wells can act as low-cost monitoring wells which provide an indication of possible groundwater contamination related to the GKM spill. Many of these wells were utilized by the EPA to examine groundwater quality immediately after the August 5 spill. This task will map and evaluate water quality data collected by the EPA in August 2015 from private domestic wells, where samples were submitted for laboratory analysis. This baseline information will be utilized in this effort, as available, to target key wells for follow up water quality sampling.

Task 2: Well selection

By collecting seasonal water quality samples, in conjunction with water level measurements discussed in Element 6, it will provide periodic snapshots of changes in water chemistry that may develop. Utilizing land ownership maps and existing well information, we will identify private domestic wells that may be influenced by recharge from the river or irrigation ditches. Target wells will be selected based upon several criteria including: 1) EPA samples of concern (from August 2015 results), 2) wells utilized for drinking water, and 3) wells located in close proximity to the river or irrigation ditches, especially ‘at risk’ drinking water wells at elevations lower than the floodplain.

Task 3: Water quality sampling

Seasonally (baseflow, snowmelt, pre-monsoon, post-monsoon) we will collect and analyze private domestic well water from up to 30 wells in the Animas alluvial aquifer in New Mexico. Ideally, these sample locations and timing will be paired with surface water and pore water sampling performed by collaborating researchers listed on this proposal (Elements 5 and 6, also at New Mexico Institute of Mining and Technology [NMT]). Depending upon long-term well owner participation, we will sample the same 30 wells each season to address changes over time. These well samples will be analyzed for major ions, with total and dissolved trace metals. While private well water quality is not formally regulated, it is important for the state of New Mexico, and well owners, to understand the water quality in and around these wells as an effect of the GKM spill. These water quality samples will not be used for regulatory purposes.*Task 4: Environmental tracers sampling*

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Additionally, in order to examine the rates of groundwater flow in the alluvial aquifer along the Animas River, we will utilize environmental tracers including stable isotopes of oxygen and hydrogen, carbon-14, and tritium. While these data may not specifically address water quality concerns, they can provide a timeline for when possible impacts to groundwater contamination may affect private domestic wells. We propose to examine up to 10 wells per year with these techniques.

Task 5: Water quality characterization

Within year 1, we will identify indicator parameters (if any exist) related to GKM spill that can be used to monitor groundwater quality for possible impacts from the spill. Utilizing the water quality results from various sampling campaigns, we will develop maps and charts to display possible changes in ion chemistry or trace metals.

Task 6: Instrumentation with continuous recorders

We propose utilizing continuous data recorders (Solinst LTC loggers) in up to 15 wells or surface water locations (river or irrigation ditches) to monitor pressure, temperature, and electrical conductivity fluctuations on a daily basis. These data would provide indicators of water quality changes that occur between field measurements, and possibly provide background information on hydrologic changes affecting the system (i.e. storm events, land use changes).

Task 7: Providing recommendations

Depending upon the results of this project, and if there are water quality impairments or concerns, we can provide recommendations or proposals for continued or expanded monitoring. If results of the environmental tracers study indicate very short groundwater residence times, the timeline of potential water quality impact on groundwater may pass quickly. If however, groundwater travels much slower in the Animas alluvial aquifer, recommendations can be made for further monitoring, ideally with identified “indictor parameters” discussed above.

DRAFT

BUDGET (2 years)

This budget includes the cost data compilation, water quality sampling, tracer sampling, and water quality characterization, as outlined above. Water quality testing and isotopes of Oxygen and Hydrogen will be analyzed at NMBGMR laboratories. Other environmental tracers will be analyzed off campus at commercial and research laboratories. Salary totals include the principle investigators, NMBGMR staff, and student workers.

The budget assumes four data collection events per year and equipment will be purchased in the first year. The values below reflect 12% overhead.

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Year 1	$54,579	$35,690	$22,500	$5,000	**$131,902**
Year 2	$55,053	$35,690	***	$5,000	**$107,232**
				2 year Total	**$239,134**

*Total includes application of 12% overhead cost and fringe.

DRAFT

Element 8. Ongoing and Potential Future Discharges in the Silverton, CO Mining Area

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SUMMARY

Goals: Identify and characterize ongoing and potential future discharges of mine waste into the Animas watershed.

Actions:

- Identify locations, volumes and chemical quality of water impounded in mine workings in the upper Animas watershed.
- Identify and chemically characterize ongoing mine water seeps and gauge flow rates.
- Identify locations of waste rock and mill tailings piles that have the potential to discharge into surface water.

WORKPLAN

The work shall be completed in three phases, with a written progress report to the NMED program on each phase, due at the end of each task. All water, sediment, and mineralogical testing will be done by the New Mexico Institute of Mining and Technology (NMT) and New Mexico Bureau of Geology and Mineral Resources (NMBGMR) laboratory. Whole rock geochemistry will be submitted to qualified labs outside of NMT/NMBGMR.

Task 1

- Compile existing data on history, inventory, and characterization of mine features in the watershed; including water impounded in mine workings, ongoing mine water seeps, waste rock and mill tailings piles.
- Establish a GIS database.
- From existing data, develop a list of high-risk features to examine, including preparation of maps.
- Field examination, characterization. Characterize each site, including field tests.
- Develop a sampling plan.

Task 2

- Field examination, characterization, and surface sampling of high-risk mine features in watershed; including sampling of water impounded in mine workings, ongoing mine water seeps, waste rock and mill tailings piles.
- Laboratory analyses.

- Establish monitoring stations.

Task 3

- Final report, including results of the analyses listed above and the following:
- Maps with locations of mines, tailings and water seeps
- Labeled digital photograph(s) of mine features
- Data sheets for each sites to be used in the database
- Hazard ranking of mine features that have a high risk of affecting the watershed
- Recommendations

DRAFT

BUDGET

BUDGET (2 years)

This budget includes the cost of sampling, laboratory analysis, data interpretation, and reporting, as outlined above. Salary and travel totals include the principle investigator, staff of NMBGMR, and a student worker.

Budget includes a 12% overhead cost.

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Years 1 and 2	$107,514	$27,500	$10,000	$15,025	**$179,244**

*Total includes application of 12% overhead cost and fringe.

DRAFT

Element 10.1. Aquatic and Riparian Habitat Assessment

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SUMMARY

Goals: Determine if GKM spill contaminants have adversely affected, or are being accumulated by, aquatic and riparian plants and animals.

Actions:
Monitor and, when effects are observed or expected, sample aquatic and riparian plants and animals.

WORKPLAN

Microbes, algae, and plants that reside in or around rivers and streams obtain essential nutrients from the water and sediments for growth. Water and sediments that are contaminated with heavy metals (e.g., lead and arsenic) are also taken up by these organisms. Aquatic insects consume contaminated plants and microbes for food and accumulate (fat-soluble) metals in their tissues because they cannot be excreted. Thus, metals bioaccumulate exponentially at each step of the food chain; for example, when fish consume contaminated invertebrates, concentrations of heavy metals can increase by several orders of magnitude in their tissues relative to microbes, plants, and aquatic insects. Likewise, when aquatic insect larvae hatch and move into riparian areas they are consumed by terrestrial predators like spiders and tiger beetles and thereby become available to terrestrial consumers like birds that also can exhibit exponential increases in metal concentrations. Our long-term monitoring plan will link up with other research in the system, especially on microbial processes at the surface and the hyporheic zone, to document the pathways by which metals are sequestered in plants, and then move and bioaccumulate through higher levels of the food chain and potentially become available to larger organisms, including humans.

We rely on two types of data to do this. First, heavy metal concentrations will be determined from tissues of riparian and aquatic plants and algae, aquatic and terrestrial arthropods, and fishes. There are two potential pathways for metals to be taken up by plants. If the predominate pathway is through groundwater into tree roots, we would expect riparian plants to be a potential

primary source of contamination. Otherwise, algae can take up contaminants through surface water and sediments. To differentiate these two potential pathways to consumers, we will use naturally-occurring stable isotopes of carbon, which are an excellent tracer for the source of food for higher levels in the food web in rivers and streams. For example, if an aquatic insect eats algae, its carbon isotopic signature will be very different than if it consumed leaves that have fallen in from the riparian zone. Likewise, stable isotopes of nitrogen are excellent tracers of position in the food chain (i.e., primary producer, primary consumer, secondary consumer, and so on). By simultaneously comparing metal concentrations and stable isotope ratios in consumers, we can identify how much metal is obtained through which pathway. This knowledge can help assess risks to aquatic and terrestrial wildlife of heavy metal effects due to consumption, and hopefully allow for more effective remediation of toxic metals.

This work plan and budget includes the analysis of metals and stable isotope ratios in tissues of aquatic algae, riparian plants, aquatic invertebrates, riparian (terrestrial) invertebrates, and fishes of the San Juan River. The goal is to identify how metals move through the riparian food web, from river sediments to the water column and surrounding riparian areas through incorporation of contaminants into sources of food (algae, riparian plants) and consumers (aquatic and terrestrial arthropods, fishes). Simultaneous analysis of stable isotopes (carbon and nitrogen) and metals allows us to identify the sources and biological pathways through which metals can move out of the stream and into surrounding wildlife. Long-term monitoring of the system will offer detailed understanding how metals are sequestered, retained via biological processes (primary production, consumption, and movement) in the system.

DRAFT

BUDGET

BUDGET (2 years)

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Year 1	$50,887	$13,500	$500	$3,000	**$90,274**
Year 2	$50,887	$13,500	$500	$3,000	**$90,275**
				2 Year Total	**$180,549**

*Total includes fringe and 12% overhead

DRAFT

Element 10.2 Benthic microbial community and functions

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SUMMARY

Goals: Determine how toxics contamination from the Gold King Mine spill has affected microbial communities downstream of the site, including inhibition of microbial activities.

Actions:

- Monitor microbial communities in pristine and impacted sites, with site selection coordinated with other projects.
- Conduct batch laboratory experiments to assess inhibition of nitrogen and carbon processing.

WORKPLAN

Short and long-term changes in benthic microbial community compositions and functions in Colorado and New Mexico watercourses

Little is known about how benthic microbial communities respond in the short and long term to an acute, acidic, metal-laden disturbance. These communities are known to be important for in-stream nutrient processing, such as nitrification/denitrification, and specialized bacteria are also known to use metals as electron acceptors and donors to transform their oxidation states. We will leverage existing EPA sampling efforts and sampling other project tasks to determine the short and long-term effects of the acute, acidic, metal-laden disturbance on microbial communities in downstream watercourses with widely varying characteristics.

We will determine whether the high metals contamination has affected the resident microbial communities composition and function, particularly with respect to nutrient cycling functions and metals biotransformations. In terms of community composition, we are, for example, interested in whether known metal-oxidizing (e.g. *Bacillus* and *Leptospirillum* spp.) and reducing bacteria (e.g. *Geobacter* and *Shewanella* spp.) are enriched, and/or nitrifiers and denitrifiers are reduced. Microbial communities in affected and pristine sources will be characterized by extracting DNA and analyzing 16S rRNA gene sequences with the Illumina platform, with data analysis using Qiime and Mothur to generate profiles of these complex microbial communities.

Statistical comparisons of the communities to each other and to environmental parameters will be made in the Vegan Package. By monitoring the sites over time and comparing contaminated and pristine sites, we should gain key insights to the fundamental effects of contamination on the communities in situ. We anticipate 6 sampling events per year, including one in each season and two more timed after significant rain events.

We will also assess the effects of the contaminants on key stream nutrient processing functions by batch testing the collected sediment samples. For example, nitrification and denitrification rates will be measured of the collected sediments (coordinated with Element 10.3), and inhibition of known nitrifiers and denitrifiers will be tested by batch testing of sediment and aqueous samples mixed with activated sludge from Albuquerque's Southside Water Reclamation Plant. These tests will determine the inhibitory of effects of the contamination, independent of changes in microbial communities.

DRAFT

BUDGET

This budget includes the cost of collecting sediment samples, laboratory analysis, data interpretation, and reporting for each year, as outlined above. Salary totals include the principle investigator and one graduate student.

BUDGET (2 years)

Year	Salary	Tuition/Health (student)	Sampling and Analysis	Equipment/ Supplies	Travel	Total*
1	$33,678	$17,905	$16,500	$5,000	$4,000	$84,945
2	$33,678	$18,954	$16,500	$5,000	$4,000	$86,037
					2 year Total	**$170,983**

*Total amount includes fringe and overhead (12%)

DRAFT

Element 10.3. Nutrient processing studies

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SUMMARY

Goals: Understand the fate of nutrients along the Animas river, as well as the capacity of biotic communities to take up nutrients in response to the Gold King Mine (GKM) spill.

Actions:

- Conduct microcosm experiments using native sediments collected from the Cement Creek – Animas River- San Juan River continuum.
- Use the results of the microcosm studies to quantify the effects of the GKM spill.

The fate of nutrients along a river continuum is controlled by transport dynamics and the capacity of biotic communities to take up nutrients in response to natural and anthropogenic disturbances (e.g., floods, nutrient loading from wastewater treatment plants and spills of contaminants such as heavy metals). Understanding in-stream nutrient processing along a river continuum is extremely complex due to physical, chemical and biological heterogeneity. However, recent methodological and theoretical advances provide an unprecedented opportunity to better understand the effects of disturbances in controlling nutrients export and water impairment across river continuums. These include recently developed theoretical and technical methods that substantially reduce the number of experiments needed to characterize nutrient processing, and recent advances in molecular biology techniques and sequencing technology that allow for rapid and large scale comparisons of the structure and function of microbial communities. We will apply a recently tested (in our lab), new generation of coupled field-laboratory experiments to investigate how in-stream nutrient processing is being affected by the Gold King Mine spill both spatially and temporally, from headwaters to large rivers.

WORKPLAN

Column experiments

We will run column experiments to characterize nutrient processing in the highly metabolically active benthic and hyporheic zones under standardized flow conditions. We will pack native sediments from the Cement Cr. –Animas River – San Juan River continuum (same twenty sites where aquifer-river interactions will be studied) in PVC columns (52 cm length and 7 cm inner diameter). Three replicates of each sampling site will be collected and brought to our UNM, Civil Engineering Ecohydrology laboratory in buckets with ice gels and river water. We will run filtered river water (from respective sampling sites) for about 2 hours and will then inject a short-

term pulse addition of NO_3 and PO_4 (to reach maximum concentrations C_{max}<5x background conditions), resazurin – a bioreactive tracer indicating metabolic activity – (C_{max} <100 µg/L) and NaCl – as conservative tracer for water movement– (Electrical Conductivity EC_{max} < 50 µS/cm + $EC_{ambient}$). We will use a constant tracer injection rate of ~7 mL/min for 90 min using a Masterflex (Cole-Parmer) peristaltic pump. This time for the tracer injection has been determined from preliminary tests as the time required to reach plateau (steady-state concentration) conditions. After the injection of the conservative and reactive tracers, we will flush the columns with river water until background concentrations are reached again. We will take samples at the end of the column from background concentrations before the tracer injections to background concentrations after the tracer injections. We will use these methods to perform tracer injections in column experiments using the recently developed Tracer Additions for Spiraling Curve Characterization (TASCC) method (Covino et al., 2010), which allows investigating in-stream nutrient processing kinetics from ambient to saturated conditions with single tracer experiments (Figure 1). The TASCC method is an efficient approach because uptake rates are calculated for each individual sample across the breakthrough curve of the solute, dramatically increasing the information content of each tracer experiment. TASCC requires an instantaneous pulse and the monitoring of the change in concentration of conservative (e.g., NaBr) and reactive tracers (e.g., NO_3). By comparing the ratio of reactive to conservative tracers for every independent sample across the breakthrough curves (e.g., $[NO_3/NaBr]_{breakthrough\text{-}curve}$) to the ratio of the enrichment solution (e.g., $[NO_3/NaBr]_{injection}$), nutrient uptake for each sample across the nutrient concentration gradient from ambient to peak concentrations can be determined. In addition to providing more information, TASCC is cost-effective because it requires only around 30 water samples from each column test to fully characterize nutrient uptake kinetics at a given site. We will run a total of 360 column

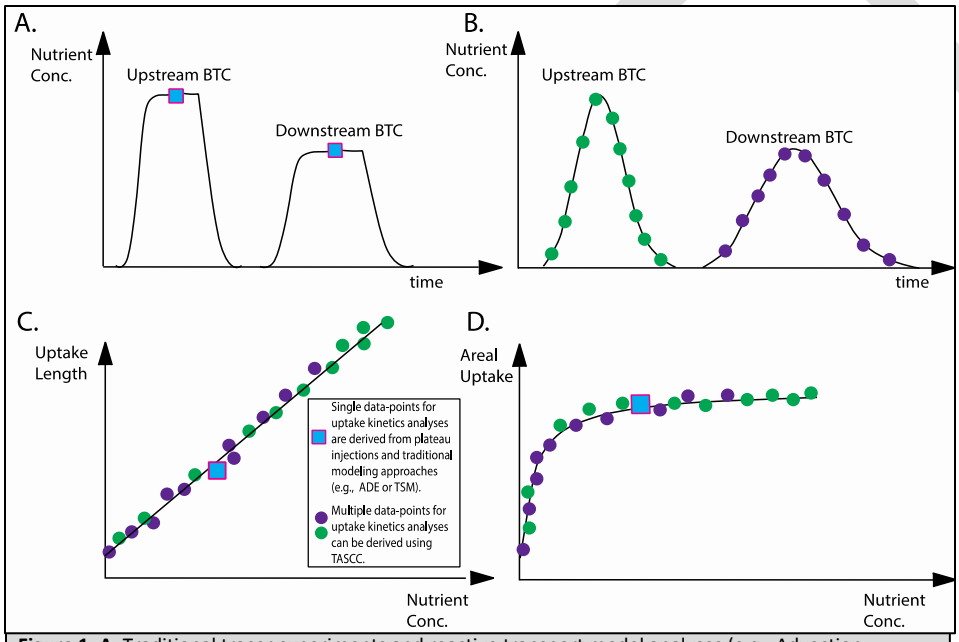

Figure 1. A. Traditional tracer experiments and reactive transport model analyses (e.g., Advection-dispersion equation -ADE- or transient storage model -TSM-) yield only one data point (per experiment) that can be used to analyze nutrient processing kinetics from tracer breakthrough curves (BTCs) (see **A, C** and **D**). **B.** The newly developed TASCC method is a better compromise between experimental affordability and increased information content for generating uptake kinetics analyses such as those shown in **C** and **D**. Note that TASCC increases the information content derived from each tracer experiment by a factor that is directly proportional to the number of samples taken across the solute breakthrough curve. Using TASCC, we will investigate how nutrient processing is affected by the spill of heavy metals, spatially and temporally, along a river continuum.

experiments in this study, i.e., 3 columns per site, 20 sites, and 2 seasons (summer and winter) per each of 3 years.

Microbial community characterization: Benthic and shallow hyporheic samples will be analyzed from each replicate from the column experiments. Direct cell counts will be used to determine bacterial abundance. Samples will be divided for dilution with 1X PBS, deposited onto PTFE-coated microscope slides, DAPI stained, and cells counted using an epifluorescence microscope with appropriate filters (Zeiss) at 1000X magnification. A minimum of 10 fields with at least 50 cells per field will be counted with appropriate adjustments to the counting procedure for low cell densities.

For DNA analysis, we will store samples in sucrose-lysis buffer at -80°C prior to extraction of DNA using the CTAB method (Mitchell and Takacs-Vesbach, 2008). The Illumina platform (Caporaso et al., 2011, 2012) will be used to sequence 16S rRNA amplicons (in triplicate reactions) by multiplexing our sample libraries and generating ~10,000 sequences per sample. This depth is more than adequate to uncover differences in community structure along the river continuum (Kuczynski et al., 2010). Raw sequence data will be demultiplexed, binned by sample, and quality screened as described by Caporaso et al. (2010). Community analysis of the sequences will be performed using Qiime (Caporaso, et al., 2010) and Mothur (Schloss et al., 2009), and statistical comparisons of the communities to each other and to environmental parameters will be made in the Vegan Package (Oksanen et al., 2007) in R (Team, 2012). Additionally, a recently developed bioinformatics approach (PICRUSt) will be used to infer metagenomes, and thus community function, from the 16S rRNA gene sequence data and a reference genome database (Langille et al., 2013).

Data synthesis

Our column experiments with standardized mass-transfer conditions and microbial analyses will help us quantify the effects of the Gold King Mine spill on the microbial communities' structure and function and how these effects alter in-stream nutrient processing across space (multiple sites across the river continuum) and time (summer and winter seasons). Variation in community composition and diversity as a result of changing inputs, substrate, temporal factors, and disturbance levels will allow us to directly link altered community structure to changes in nutrient retention. Information on uptake kinetic curves at the local-scale from multiple sites and seasons will help us understand the impact of metals on the biochemical cycles of nitrogen and phosphorous.

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BUDGET

BUDGET (2 years)

This budget includes the cost of collecting sediment samples, laboratory analysis, data interpretation, and reporting for each year, as outlined above. Salary totals include the principle investigator and one graduate student.

Budget includes a 12% overhead cost.

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Year 1	$48,471	$18,780	$6000	$3,000	**$85,401**
Year 2	$50,064	$18,780	$6000	$3,000	**$87,185**
				2 Year Total	**$172,586**

*Total includes 12% overhead and fringe

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Element 10.4. Fish and other Wildlife

Principle Investigator:
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SUMMARY

Goals: Determine if Gold King Mine (GKM) spill contaminants have adversely affected, or are being accumulated by, fish and other wildlife.

Actions:
Monitor and, when effects are observed or expected, sample fish and other wildlife.

WORKPLAN

New Mexico Department of Game and Fish (NMDGF) (2015) provides detailed information on wildlife and fish populations in the areas potentially affected by the GKM spill, and provides the basis for the following monitoring activities.

Aquatic Wildlife:

The Animas River supports several native and non-native fish species, with mayfly and caddis fly taxa representing the largest proportion of macro-invertebrates. Rainbow trout are stocked in a two-mile reach through Aztec. The San Juan River downstream of the Animas River is designated as critical habitat for federally endangered Colorado pikeminnow and razorback sucker. These species are stocked in the Animas and into the San Juan. The following monitoring activities will be conducted:

- Fish health and population monitoring in the Animas and San Juan Rivers including larval fish monitoring (long and short term)
- Macro-invertebrate monitoring (long and short term)
- Fish tissue testing for heavy metals (long term)
- Economic impact monitoring of angling opportunity loss (if affected, long term)

Terrestrial Wildlife:

Mule deer, elk, coyote, red fox, gray fox, raccoon, striped skunk, river otter, beaver, muskrat, porcupine, ground squirrels, rats, mice and bats inhabit the Animas and San Juan River corridors. The following monitoring activities will be conducted:

- Possible tissue/hair/fecal sampling of mule deer and elk if effects are expected (long term)
- Continue monitoring population demographics of mule deer and elk (long term)
- Possible tissue and hair sampling of non-ungulate mammals that are harvested by hunters and trappers, particularly of semi-aquatic species like beaver and muskrat, for toxicity testing (long term)
- Possible tissue and hair sampling of non-consumable mammal species (e.g., mice, rats) that use the riparian zone of the affected area for toxicity testing (long term)
- Monitoring of non-ungulate mammal populations through surveys of these species and communication with local resource managers and sportsmen (short and long term)

Amphibians and Reptiles:

Within the affected area, 8 amphibians, and 24 reptiles (1 turtle, 12 lizards, and 11 snakes) are found, and none are federally or state listed as endangered. The following monitoring activities will be conducted:

- Walking surveys for signs of sick or dead amphibians, particularly at the tadpole stage (short term)
- Dip-netting surveys for signs of sick or dead amphibians, particularly at the tadpole stage (short term)
- Tissue sampling of amphibians at various life history stages for signs of bioaccumulation (long term)
- Tissue sampling of garter snakes for signs of bioaccumulation (long term)

Birds:

The affected area is an important migratory stopover point for waterfowl and holds thousands of geese and hundreds of ducks through the winter. The area also has a resident breeding population of Canada geese and dabbling ducks. Great blue herons use both rivers, primarily during migration and winter. Both rivers also provide year-round habitat for several raptor and corvid species including horned owls, golden eagles, red-tailed hawks, turkey vultures, and common ravens. This is an important wintering area for bald eagles. The following monitoring activities will be conducted:

- Waterfowl tissue testing for heavy metals (short and long term)
- Avian influenza testing – recommended because heavy metal toxicity may mimic avian influenza symptoms (long term)

Reference Cited

New Mexico Department of Game and Fish, 2015, New Mexico Wildlife and Fisheries Resource Potentially Affected by the Gold King Toxic Liquid Release, https://www.env.nm.gov/riverwatersafety/documents/150815-RPT-GoldKingMineWhitePaper-NMDGF.pdf

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BUDGET

BUDGET (2 years)

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Budget is under-development (to be provided at later date)					

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Element 10.5. Agricultural Vegetation

Principal Investigators:
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SUMMARY

Goals:

- Determine if elevated heavy metal concentrations occur in agricultural crops that have been irrigated with water diverted from the Animas River;

Actions:

- Facilitate coordination between ditch associations, grower groups, farmers markets, farm boards, county, state and federal service providers and the general public to ensure food and agriculture safety.

WORKPLAN

Due to the extent of the area affected, soil and horticultural scientists at New Mexico State University (NMSU) propose to use inductively coupled plasma (ICP) spectroscopic analysis to measure metal concentrations in various irrigated crops. The technology is sanctioned by the U.S. Environmental Protection Agency (EPA).

Sample Locations: Working in collaboration with staff from the New Mexico (NM)-Natural Resource Conservation Service (NRCS), Colorado (CO)-NRCS, Utah-NRCS and Arizona-NRCS (includes Navajo Nation), sampling stations will be established at representative locations along irrigation ditches and all agricultural lands irrigated with potentially contaminated water from the Animas or San Juan Rivers will be mapped. The scope of this monitoring is proposed to extend from Silverton, CO to Lake Powell. With regard to irrigated croplands, soil types, cropping history, and irrigation practices will be identified and a strategic subset of fields will be targeted for sampling over the whole region. Samples will be selected to provide a comprehensive cross section of agricultural resources and cropping systems. NMSU has a good working relationship with much of the constituency in the Four-Corners region. Dr. Kevin

Lombard and his research and extension colleagues have met on many occasions over the past month with Navajo leadership and chapter houses and community forums to help answer questions. The list of potential collaborators including community leaders, growers, ranchers, and non-profit groups who respect and work with our faculty and staff from the NM Cooperative Extension Service—including the Federally Recognized Tribal Extension Program (FRTEP), the Agricultural Science Center at Farmington, San Juan College, and Fort Lewis College—will facilitate access to field sites throughout the region.

Sample Analyses: Plant samples from agricultural use vegetation will be collected in conjunction with soil monitoring activities involving Portable X-ray fluorescence (PXRF) spectrometry and outlined in proposal Element 3. Sediment. These will include forage crops (e.g. alfalfa and pasture grasses) and horticultural (e.g. vegetables and fruit). Samples will be collected in fields and may be purchased from local farmers markets or feed store. Plant samples will be transported on ice to the lab in Farmington (NMSU-ASC Farmington/San Juan College) for initial processing. Fresh plant matter will be washed in distilled water and then air dried for transport to Soil Science research labs. The original rinsate will be collected and analyzed according to EPA method 3015 (total metals in water) to determine if any heavy metals were attached to the plant surfaces. Dried biomass will be digested using EPA method 3052 (total metals in organically based matrices) and analyzed in Dr. April Ulery's lab using inductively coupled plasma optical emission spectrometry (ICP-OES) technology. NIST certified plant standards will be used between every 14 samples.

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BUDGET

BUDGET (2 years)

This budget includes the cost of sampling, laboratory analysis, data interpretation, and reporting for each year, as outlined above.

Year	Salary	Sampling & Analysis	Equipment/ Supplies	Travel	Total*
Years 1 and 2	$12,000	$10,000	$6,500	$5,000	**$45,315**
				2 Year Total	**$45,315**

*Total includes fringe and overhead (12%)

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Element 12.2 Informational Conference

Principal Organizer:
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SUMMARY

Goal: The goal of the conference is to disseminate information and results from monitoring and research efforts in the Animas San Juan watershed. The conference will support the activities outlined in the Long-Term Monitoring Plan: Evaluating the Effects of the Gold King Mine Wastewater Spill in Northern New Mexico, prepared by the State of New Mexico's Long-Term Impact Review Team (draft report, October 20, 2015). The conference will bring together academics, agencies, representatives, and community members and provide a forum for addressing concerns and questions over the Gold King Mine spill and the continuing monitoring efforts.

Actions:

- **Objective 1:** identify and invite participants who have an interest in the topic including researchers, technicians, and water providers
- **Objective 2**: identify and invite speakers with expertise in the theme and related topics
- **Objective 3**: issue a Call for Papers that encourages presentations in topics such as the geology, minerology, and ore bodies in the Animas and San Juan Watersheds; effects of acid mine drainage; corrective measures to control mine seepage and hydraulic consequences; monitoring effects of spills; remediation proposals for mining; remediation for the Animas River; spill impacts on agriculture; biological effects of acid rock drainage; groundwater quality impacts; spill effects on wildlife and humans.
- **Objective 4**: provide an opportunity for participants to take an educational tour of the watershed area near the Gold King Mine site.
- **Objective 5**: prepare a conference website that includes abstracts for each of the speaker's presentation; the website will include speaker slide presentations.

WORKPLAN

The New Mexico Water Resources Research Institute (NM WRRI) will host a three-day conference in May 2016 to facilitate the exchange of data and ideas among four states, three Environmental Protection Agency (EPA) regions, two Tribes, and numerous local and municipal agencies and public water systems. The conference will bring together an estimated 200 participants to gain a better understanding of the theme of the conference, Environmental Conditions of the Animas and San Juan Watersheds with Emphasis on Gold King Mine and other Mine Waste Issues. The NM WRRI will coordinate all aspects of the conference with the guidance of a planning committee comprised of representatives from some of the sponsoring entities. These sponsors include: NM WRRI, New Mexico Environment Department (NMED),

New Mexico State University (NMSU), University of New Mexico (UNM), New Mexico Tech (NM Tech), New Mexico Bureau of Geology (NM BOG), City of Farmington, San Juan County, City of Aztec, San Juan Soil & Water Conservation District, and the San Juan Watershed Group.

Environmental Conditions of the Animas and San Juan Watersheds
with Emphasis on Gold King Mine and other Mine Waste Issues

May 17-19, 2016
San Juan College, Farmington, NM

Preliminary Program

Day 1 A.M.:	Plenary session
Day 1 P.M.:	Concurrent sessions
Day 2 A.M.:	Concurrent sessions
Day 2 P.M.:	Plenary session
Day 3:	Tour of watershed

Estimated Timeline

Project Period: October 1, 2015 – May 31, 2016

November 2015	Meet with conference planning committee (ongoing) Choose venue and prepare budget estimates Begin to identify speakers Draft Call for Papers Prepare conference website (updated throughout project period)
December 2015	Call for Papers Issued with March 1 deadline for submissions Confirm venue Begin to invite plenary session speakers Distribute *Save the Date* announcements
January 2016	Confirm speakers and develop program for plenary sessions Confirm tour route and post details on website Website goes live and registration opened
February 2016	Continue to update website with speaker bios, abstracts, and program
March 2016	March 7 deadline for Call for Papers Planning committee reviews papers submitted and organizes sessions March 21 announcement of accepted papers; program updated
April 2016	Continue to update website with abstracts, bios, and program Work with speakers on presentation needs, e.g., AV/PP slides Confirm tour details

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May	Website updated with all presentation abstracts/slides, including final postings
May 17-19, 2016	Conference takes place in Farmington, NM

May	Website updated with all presentation abstracts/slides, including final postings
May 17-19, 2016	Conference takes place in Farmington, NM

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BUDGET

BUDGET (2 Years)

Year	Salary	Conference Facility	Food/Service Items and Supplies	Travel	Total*
Year 1	$31,543	$1,000	$8,508	$14,574	**$62,300**
Year 2	$32,489	$1,030	$8,863	$16,032	**$65,311**
				2 Year Total	**$127,611**

*****Total includes fringe on salary and 12% overhead. Salary, fringe, facility, food, and supplies have been increased by 3% in year 2**.**

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