Gold King Mine Water Spill

Long-Term Monitoring Plan

May 5, 2017

Prepared by the New Mexico Long-Term Impact Team

Message from New Mexico Environment Secretary Butch Tongate

Shortly after the August 5, 2015 Gold King Mine (GKM) spill, Governor Susana Martinez appointed a team to monitor and assess the Long-Term impacts of the spill. The state-led team includes top science and engineering experts from executive agencies and other organizations in New Mexico. During 2016, the team conducted extensive testing of river water, sediment, well water, treated drinking water, fish tissue, and crop tissue. Seasonal water-level surveys were conducted to identify areas where river water may be seeping into alluvial groundwater. Sondes were installed in the Animas River to continuously monitor water quality, and to inform decisions by public water systems on closing water intakes during times of high flow and potential contamination.

A Citizens' Advisory Committee (CAC) was seated to provide community oversight and input on the Long-Term monitoring and response to the spill. New Mexico spearheaded efforts to develop a 2016 Spring Runoff Preparedness Plan bringing three states, three tribes, and numerous county and municipal agencies on board for collaborative success throughout the watershed. An Exposure and Risk Dashboard was developed to clearly and briefly convey contamination conditions, contaminant exposure pathways, and risks to the general public. Numerous technical papers and presentations were the highlights of a well-attended two-day conference on water quality conditions in the Animas and San Juan Rivers held in Farmington.

To keep the responsible parties accountable, the State of New Mexico filed lawsuits against the U.S. Environmental Protection Agency (EPA), several mining companies and the State of Colorado. While New Mexico supports EPA's inclusion of the Bonita Peak Mining District (which includes the GKM) in the National Priorities List as a Superfund site, we also demand that EPA use sound science, be honest with the public, and treat residents downstream from Colorado as stakeholders in the Superfund process. Unfortunately, EPA's recent decision to reject all GKM damage claims contradicts their earlier enthusiastic distribution of claims forms and assertions that affected parties would be made whole through the claims process. These inconsistent actions provide little hope that EPA, a responsible party for the spill, will hold itself to the same standards that it has long required of private citizens.

We look forward to continue working together with our New Mexico stakeholders to protect our unique environment.

Yours truly,

Butch Tongate
Secretary- New Mexico Environment Department

Introduction

The Gold King Mine (GKM) is located in the upper Animas watershed near the town of Silverton in the San Juan Mountains of southwestern Colorado, and was in operation from approximately 1887 until 1922. The GKM is one of some 400 abandoned or inactive mines in the San Juan Mountains. Acid rock drainage (ARD) forms when geologic minerals undergo oxidation and release sulfuric acid and dissolved metals into water. For the purpose of this Long-Term Monitoring Plan, ARD is meant to include drainage from both undisturbed naturally occurring minerals and ore bodies as well as drainage from mine workings. ARD from the ore bodies and from some of the mine workings impacted water quality in the Animas River and in many of its tributaries. The GKM, however, was not a source of ARD when mining operations ceased in 1922. Seepage of ARD from the GKM began after bulkheads were installed at other mine workings in the area, in the late 1990s to early 2000s, in an effort to control ARD. The bulkheads caused groundwater to become impounded and rise into previously unsaturated natural geologic fractures and mine workings, such as adits. Adits are horizontal, or nearly horizontal, passages from the surface by which a mine is entered, and can be used to dewater and ventilate mine workings. Flooded mine workings, including adits at the GKM, became sources of ARD seepage that did not exist prior to installation of the bulkheads. The U.S. Environmental Protection Agency (EPA) and the State of Colorado took actions to investigate and alleviate these newly created seeps of ARD.

On August 5, 2015, an EPA work crew digging into the GKM Level 7 adit triggered a blowout and continuous discharge of impounded mine water. The EPA afterwards reported that more than 3 million gallons of acidic mine water containing sediment, heavy metals, and other chemicals discharged into Cement Creek, an Animas River tributary near Silverton, Colorado. The plume flowed down the Animas River, and into New Mexico where the Animas River joins the San Juan River which flows into the Navajo Nation and Utah.

The New Mexico Environment Department (NMED), the New Mexico Office of the State Engineer (OSE), the New Mexico Department of Health (NMDOH), the New Mexico Department of Agriculture (NMDA), the New Mexico Department of Game and Fish (NMDGF), the New Mexico Department of Emergency Management and Homeland Security, and San Juan County coordinated an emergency response to ensure that public health and safety were protected. Governor Susana Martinez declared an emergency, authorizing the use of up to $750,000 in emergency funds as part of emergency response and follow-up actions.

Response actions provided benefits for impacted communities in New Mexico by immediately addressed impacts from the GKM spill. The State of New Mexico (State) is continuing GKM related support efforts through the Governor-appointed multi-agency Long-Term Impact Review Team (LTIRT or Team) to implement long-term monitoring and control of contaminated water and sediment, to communicate risk and to mitigate effects of hazardous waste migrating from the Superfund site.

The Governor-appointed multi-agency LTIRT includes New Mexico state agencies responsible for the Environment, Health, Game & Fish, Agriculture, Homeland Security and Office of the State Engineer. This team provides inter-disciplinary expertise and technical support in the Animas and San Juan River basins on a watershed scale level. The Team recruited top science and engineering experts from state universities, the N.M. Bureau of Geology and from the U.S. Geological Survey, along with experts from local governments to serve on the GKM Long-Term Monitoring Technical Consortium (GKM LTMTC), a working sub-group of the LTIRT led by NMED. NMED also coordinates with the GKM LTMTC and adjacent states affected by the GKM spill to enhance data collection (i.e., monitoring), to leverage analyses and strengthen results.

The GKM LTMTC held a series of conference calls, meetings and extensive outreach activities including public meetings to collaboratively identify key issues and develop the Long-Term Monitoring Plan (LTMP 2016) as the first step towards consolidating and prioritizing the State's Phase II post-GKM blowout efforts. The LTMP 2016 was prepared by the executive agencies on the Long-Term Impact Team in collaboration with New Mexico State University (NMSU), the New Mexico Water Resources Research Institute (WRRI) , New Mexico Tech, the New Mexico Bureau of Geology and Mineral Resources, the University of New Mexico (UNM), San Juan County, the City of Farmington, and the San Juan Soil and Water Conservation District. The draft LTMP 2016 was released for public comment during October 20 through November 20, 2015, and finalized on April 4, 2016. The LTMP 2016 is a dynamic document focusing on water quality, sediment, agriculture, human health and wildlife, and is subject to data-driven modifications as observations and test results become available. The NMED coordinated with the GKM LTMTC to complete updates to the elements as presented in this LTMP 2017.

Activities related to the LTMP accomplished during 2016 are described below. Funding has been awarded that supports, in part, five elements from the LTMP 2016: Element #6 Water Table Mapping; Element #7 Groundwater Quality Monitoring; Element #10.1 Aquatic and Riparian Habitat Assessment; Element #12.2 Informational Conference and Element #13 Community Outreach and Involvement.

2016 LTMP Accomplishments

Long-Term Monitoring

1. NMED signed a Joint Funding Agreement with the U.S. Geological Survey to install four sondes in the Animas and San Juan Rivers to provide continuous water-quality measurements. Real time data from the sondes are available from the USGS website (https://waterwatch.usgs.gov/).

2. The City of Farmington installed and maintains two sondes in the Animas River at the location of each of their drinking water supply intakes.

3. The NM Bureau of Geology, pursuant to a Memorandum of Agreement with NMED, conducted three seasonal surveys of groundwater elevations and groundwater chemistry. Localized areas where the river water appears to be seeping into groundwater, at least on a seasonal basis, were discovered in some areas north of Aztec. These areas will be targeted for more intensive sampling. To date, however, testing of private domestic water wells has not detected any contamination attributable to the GKM spill.

4. NMED spearheaded efforts to develop a Spring Runoff Preparedness Plan that was signed by three states, three tribes, and numerous county and municipal agencies. NMED also conduct preparedness training that was attended by first responders from New Mexico, the Navajo Nation, and Colorado.

5. UNM conducted mineralogical testing of solids that were released during the GKM spill and published a paper of test results in the Journal of Environmental Science and Technology. The mineral jarosite, which formed inside the GKM and was released during the spill, plays a significant role in transporting and releasing heavy metals in the river system. (Rodriguez-Freire, et al, 2016c).

6. NMDOH conducted biomonitoring sampling in San Juan County involving testing the well water and urine of county residents for heavy metals.

7. NMED purchased a portable X-ray fluorescence spectrometer (XRF) and conducted an initial survey of heavy metals in sediment along Cement Creek, and the Animas and San Juan Rivers.

8. NMSU began testing crop tissue for heavy metals. Preliminary test results do not show high concentrations of metals.

9. NMDGF completed two surveys of edible fish tissue showing that heavy metals are within guidelines for human consumption.

10. The City of Aztec discovered a layer of lead-contaminated alluvial aquifer sediment that appears to reflect river seepage into groundwater. Additional investigation is planned, and will include more intensive testing of water wells and crops in this area. See also Figure 6 on page 12.

<u>Public Involvement and Other Activities</u>

11. NMED appointed a Citizens' Advisory Committee (CAC) to provide community oversight and input on monitoring and other activities. The CAC established its leadership, operating rules, and conducted monthly meetings during 2016.

12. NMED developed an Exposure and Risk Dashboard to communicate contamination conditions, potential contaminant exposure pathways, and associated risks to the public. https://www.env.nm.gov/wp-content/uploads/2016/01/Animas-San-Juan-Risk-Dashboard.pdf

13. WRRI, with assistance from the entire team, planned and conducted a two-day conference on water quality conditions in the Animas and San Juan Rivers. The conference was well attended with numerous technical papers and presentations.

Implementing New Mexico's Long-Term Monitoring Plan for GKM Spill Activities

Conceptual Model

The geology, ore deposits, and ARD in the watershed surrounding Silverton, Colorado area are discussed in great detail by the papers contained in Church et al. (2007). The discussion provided in this paragraph draws heavily from the work of those authors, particularly Stanton et al. (2007), Vincent et al. (2007), and von Gerard et al. (2007). The mountains surrounding the Silverton, Colorado area include two volcanic calderas that were intruded by hydrothermal fluids that created sulfur-rich, base-metal ore bodies enriched in copper, lead, silver, molybdenum, and zinc. Pyrite and other sulfide minerals in this region have undergone various degrees of bio-geochemical oxidation by natural geologic processes, resulting in the release of sulfuric acid and metals (ARD) into groundwater and surface water. Over the past 9,000 years, iron, aluminum, manganese, and other metals concentrated in ARD have precipitated and cemented near- surface sediments forming ferricrete. Cement Creek (Figure 1) was named after the widespread naturally occurring deposits of ferricrete in this watershed. These geologic deposits of ferricrete demonstrate that ARD has been occurring in this mineralized area long before mining began in the late 19th century.

The bio-geochemistry and mineralogy of the GKM is a dynamic system that is sensitive to physicochemical changes that took place during and after mining. Reactive solid phases precipitate from the oxidation and dissolution of sulfide minerals, including pyrite and chalcopyrite at the GKM. These phases commonly include ferric (oxy)hydroxide, gypsum, jarosite, and schwertzmannite, which react with mine water producing an acidic metal-sulfate-rich solution. Acid rock drainage has high concentrations of dissolved and total calcium, magnesium, sodium, sulfate, iron, aluminum, manganese, and other metals that influence surface-water quality in the region. The mineral jarosite (Figure 2), which formed inside the GKM and was released during the spill, plays a significant role in transporting and releasing heavy metals in the river system (Rodriguez-Freire, 2016 c).

Figure 1. Ferricrete deposit in Cement Creek, CO. (From U.S. Geological Survey photo gallery)
Excavation of mine tunnels drained groundwater from the mountain and allowed air to enter the ore zone, providing greater opportunity for the oxidation of sulfide minerals and production acidic mine water. There is no doubt that mining activity increased the amount of ARD entering the Animas watershed.

In the late 1990s and early 2000s, after mining operations had ceased, bulkheads were installed in the American Tunnel (Figure 3) and in other excavations in lower levels of the mine workings to control ARD seepage. After the bulkheads were installed, the water table in the mountain rose and flooded mine workings, such as GKM level 7, located at higher elevations, and created ARD seeps that did not exist prior to installation of the bulkheads (Sorenson and Brown, 2015).

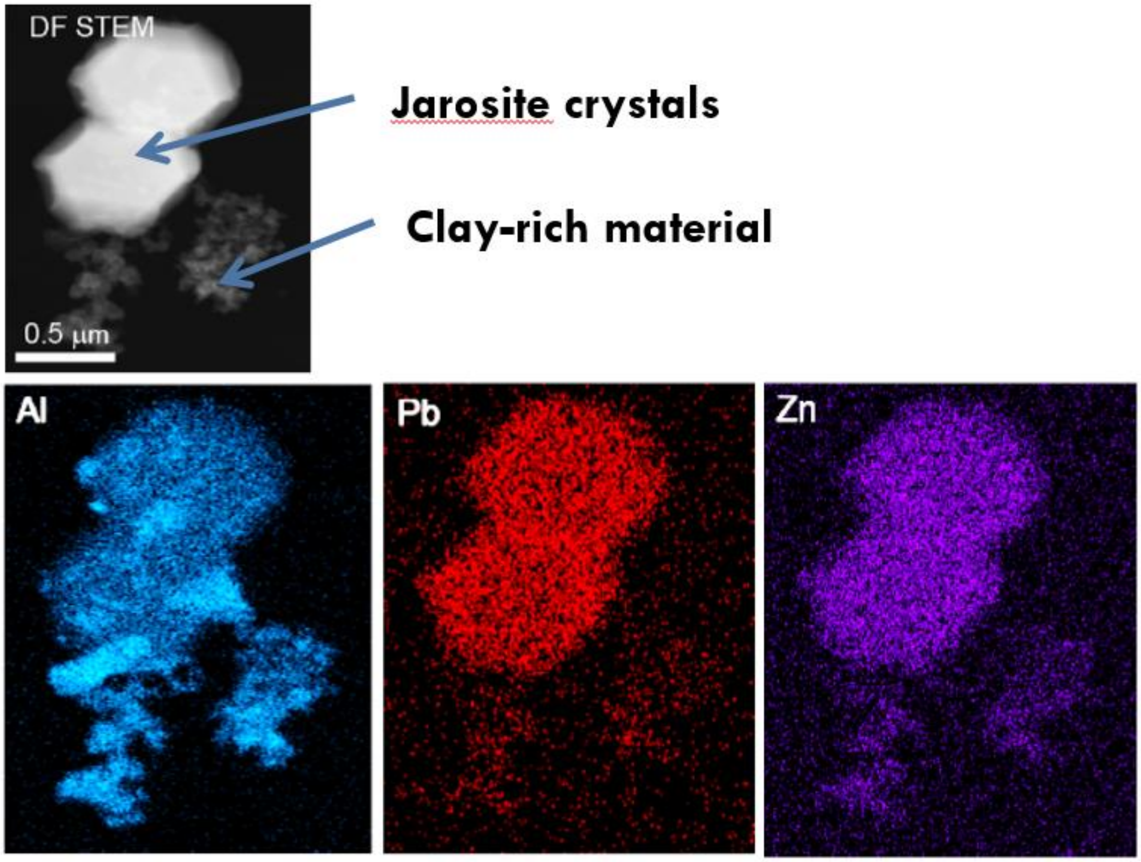

Figure 2. Jarosite grains containing aluminum, lead, zinc, and other metals that can be released as jarosite becomes unstable at higher pH.

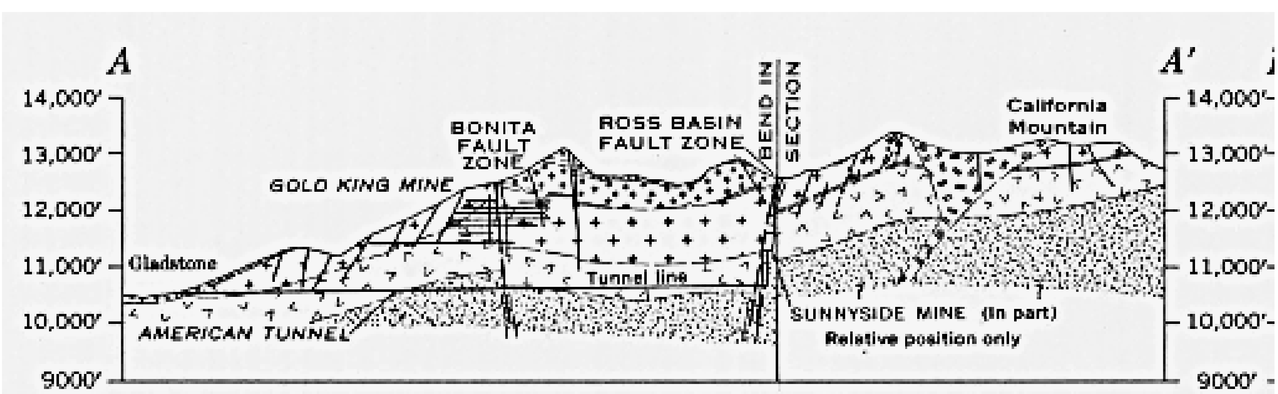

Figure 3. Geologic Cross Section Through the Gold King Mine and American Tunnel. (From Burbank and Leudke, 1969, Plate 6)

Metals and other chemicals concentrated in Animas River water are transported in both the dissolved and suspended phases with the majority of the contaminant mass occurring in the suspended fraction. Adsorption, precipitation, and co-precipitation are the dominant processes controlling the chemistry and mineralogy of the suspended fraction. The ability of the Animas River to transport large volumes of suspended sediment is related to the steepness of the gradient, which directly controls flow velocity that decreases south of Silverton. The riverbed area downstream of where the gradient decreases is characterized by low-energy flow environments where mine-waste sediment and associated heavy metals may have deposited and accumulated for decades. Accumulation of contaminated sediments most likely presents significant long-term potential sources of heavy metal migration into New Mexico, especially during storm events and snowmelt where re-suspension of sediment occurs. Post-spill monitoring conducted by the City of Farmington has established a relationship between turbidity and total lead during high flow in the Animas River (Figure 4).

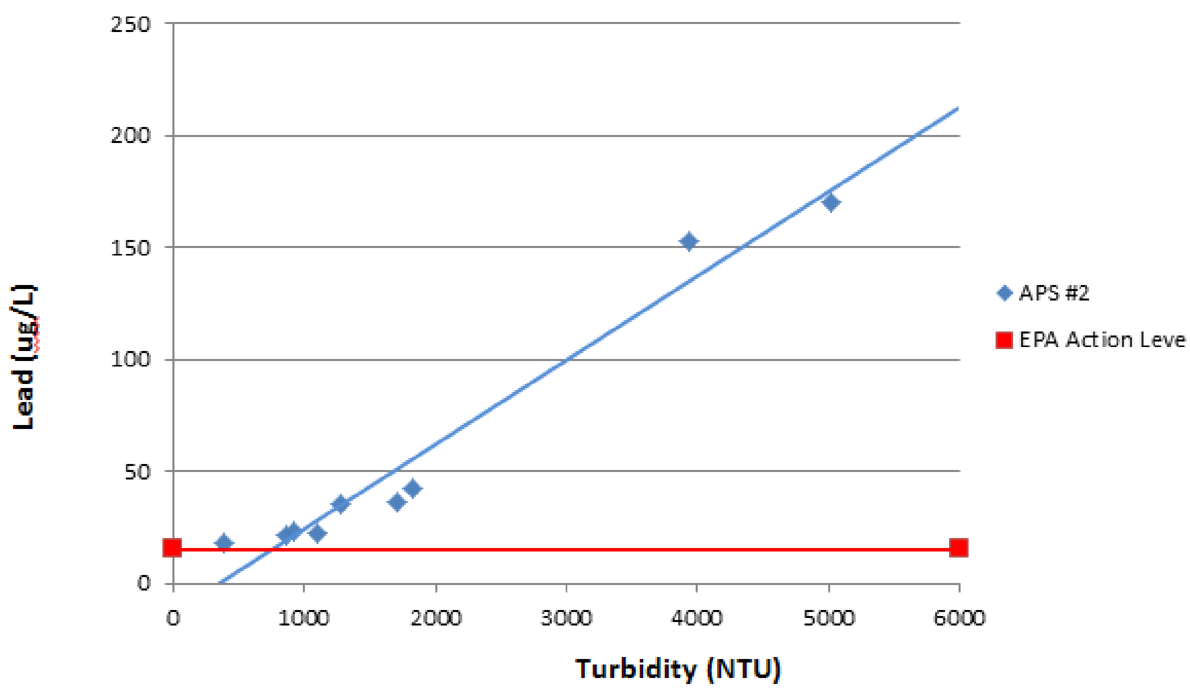

Figure 4. Turbidity and Total Lead, City of Farmington, Animas Pump Station #2, During High Flow.

Some homeowners who are not served by a public water system, especially those that do not have indoor plumbing or a private domestic well, haul water from the Animas or San Juan Rivers or from irrigation canals for domestic supply. This water likely undergoes minimal treatment; the NMED has previously issued advisories for at-home chlorination of water to disinfect. Without appropriate treatment, users of hauled surface water may be exposed to dissolved and suspended metals in their drinking water.

A review of historical monitoring data for public water systems that divert water from the Animas River provides no evidence that Primary Drinking Water Standards for metals have ever been exceeded in the drinking water delivered to consumers (N.M. Department of Public Health, 1967; Garcia and Olaechea, 1974; Garcia and Pierce, 1980). All of these public water supply systems utilize a sedimentation basin or reservoir, as well as a treatment system to further decrease suspended solids concentrations. Sedimentation and treatment provide significant protection for the subject drinking water against any suspended-phase heavy metals that may migrate from the Silverton mining area.

A conceptual illustration of the Animas River hydrologic system is shown in Figure 5. The Animas River valley alluvial aquifer in Colorado receives base flow from groundwater (Von Gerard et al., 2007). Seasonal surveys of groundwater elevations and groundwater chemistry since the GKM spill indicate that the Animas River also is primarily a gaining stream from the Colorado-New Mexico state line down to Farmington, NM where the Animas River joins the San Juan River (Timmons et al., 2016). Flow of circumneutral pH groundwater into the river provides a source of dilution of Long-Term ARD, and of historical mining waste spills that have occurred in the past.

While the Animas River is predominantly a gaining stream, river water diverted into irrigation ditches has the potential to recharge the alluvial aquifer in irrigated croplands and along the length of the ditches. Additionally, localized areas where river water appears to be seeping into groundwater, at least on a seasonal basis, were discovered in some areas near and north of Aztec (Timmons et al., 2016). A layer of lead-contaminated alluvial aquifer sediment that appears to reflect river seepage into groundwater was discovered along the east bank of the river near Aztec (Figure 6). Additional investigation of the origin, composition, and extent of this mineralized layer is needed.

Areas in the vicinity of this mineralized layer will be targeted for additional testing of well water and crops. To date, however, testing of private domestic water wells has not detected any contamination attributable to the GKM spill (Flynn et al., 2016; Timmons et al., 2016).

Alluvial groundwater typically contains a substantially higher concentration of total dissolved solids (TDS) compared to Animas River water. Potential sources of elevated groundwater TDS may include cation exchange, dissolution of soluble sulfate minerals present in the alluvium, evaporation of groundwater in waterlogged valley areas (as evidenced by “white alkali” accumulation, Figure 7), upwelling of mineralized groundwater from bedrock units underlying the alluvium, and discharges from onsite wastewater systems especially those that receive waste from salt-based water softeners.

Elevated concentrations of dissolved manganese and iron occur in some alluvial aquifer wells, and nitrate concentrations are typically low (less than 1 mg/L), indicating reducing conditions in those areas. Possible causes of these reducing conditions include oxidation of naturally occurring organic matter and/or sulfide minerals deposited in the alluvium, oxidation of thermogenic and biogenic natural gas that occurs in some areas of the alluvial aquifer (Chafin, 1994), and oxidation of reactive organic matter discharged by onsite wastewater systems.

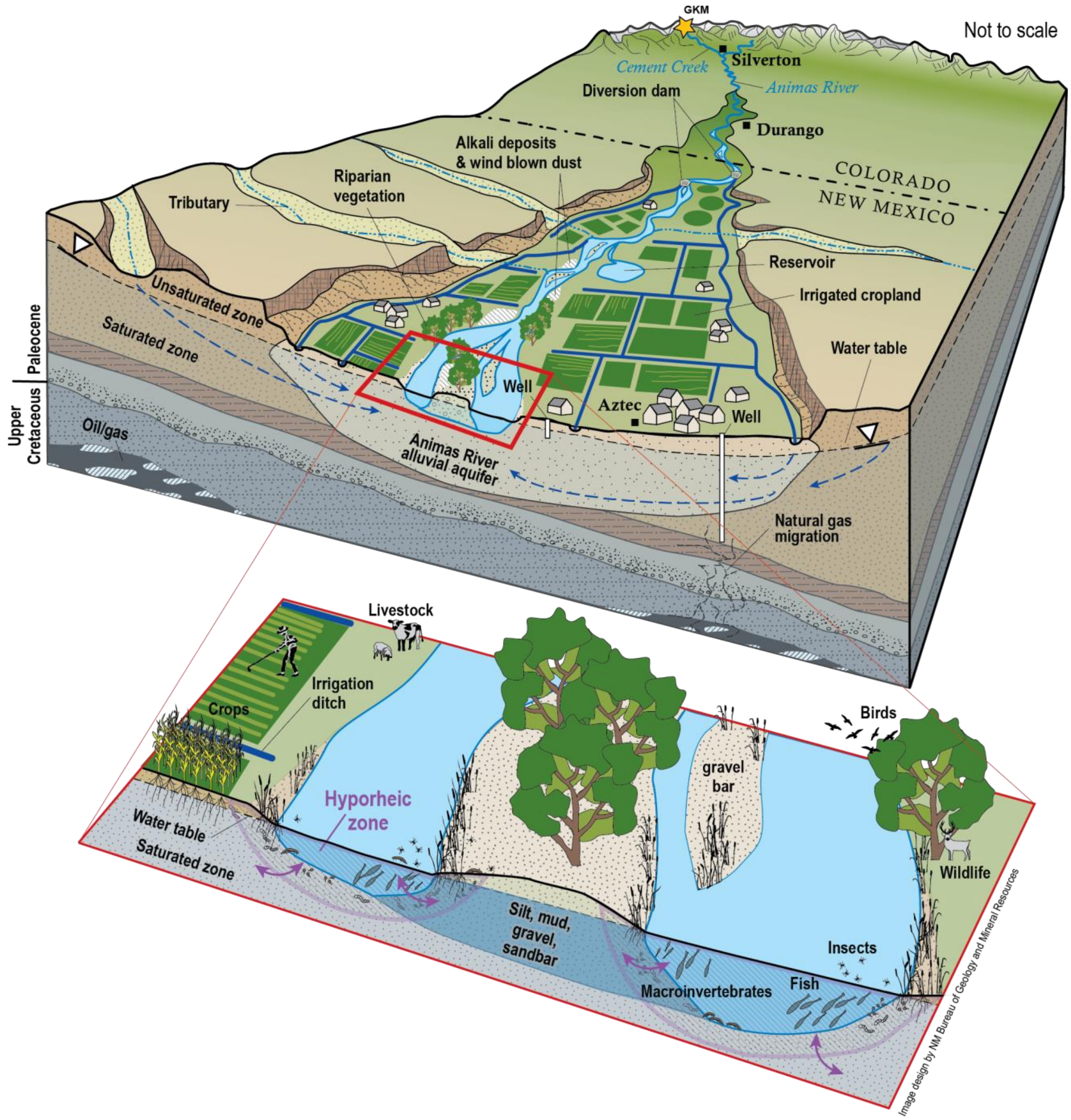

Figure 5. Conceptual illustration of the Animas River Hydrologic System. Many of the potential pathways for contaminant migration discussed in this Long-Term Monitoring Plan are identified on this image. (Timmons et al., 2016).

Figure 6. Lead-Contaminated Mineral Layer Along the Water Table of the Alluvial Aquifer Near Aztec (March 2016).

Figure 7. “White alkali” in Flora Vista, NM (August 2015).

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 aquatic insects, 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.

The uptake of contaminants into the food web was documented in a detailed study of the migration and fate of radioactive contaminants discharged into the Animas River from the former uranium mill in Durango (Tsivoglou et al., 1960). Elevated levels of gross alpha, gross beta, and radium were detected in algae and in aquatic insects downstream from the mill.

Data Gaps

- Historical and ongoing contaminant loadings to the Animas and San Juan watersheds
- Background-baseline contaminant concentrations in sediment and water caused by natural geologic sources and historical mining and milling
- Distribution and mass balance of contaminants in sediment and water
- Characterization of ground and surface water quality (metal speciation, stable isotopes, microorganisms)
- Aquifer-river-irrigation ditch hydraulics
- Origin, composition, and extent of alluvial water-table mineralized zone near Aztec
- Identify areas river water seeps into groundwater and near wells.
- Uptake of contaminants by plants, livestock, macro-invertebrates, fish, and wildlife
- Toxicological and ecological risk assessment
- Evaluate impacts of storm events on sediment, and ground and surface water quality
- Patterns of potential contaminant consumption by residents for human exposure pathways (discussed above)

LTMP Outline

The overarching goals of the LTMP are to:

1. Identify the impacts of the August 5, 2015 spill on water quality and the environment in New Mexico and, to the extent possible, differentiate this from previous spills, historical acid mine drainage, and naturally occurring acid rock drainage over geological time; and

2. Generate the data needed to perform an assessment of potential exposure pathways and risks to public health, public and private drinking water sources, water-based recreation, livestock, irrigated agriculture, and fish and other wildlife.

To achieve these goals, specific monitoring elements are summarized below. The monitoring elements include work that the Long-Term Impact Review Team has determined needs to be performed. Detailed technical work plans have been developed for each of the technical monitoring elements and are summarized below. While some work plan projects have been funded, additional funding and resources are needed, to fully perform all of the monitoring proposed. The LTMP is dynamic and subject to data-driven modifications as observations and test results become available.

For the purpose of this monitoring plan, and based upon information presented in the previous sections, the following metals are of concern with regard to acid rock and mine drainage and to the GKM spill: aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc.

LTMP Elements

1. <u>Public Drinking Water Systems</u>

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.

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). If appropriate, increase sampling frequency in response to any detection of increased heavy metal concentrations in treated water being served. As needed, add source water monitoring, if raw water treatment is not adequate and metals detections at entry points do not comply with SDWA requirements or National Primary Drinking Water Regulations.

- 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.

- Continue real time monitoring at the City of Farmington (COF) source water intakes for turbidity, and take appropriate actions when turbidity increases to levels of concern to the COF.

- Develop and support a communication system that provides email notice to public water systems that divert water from the Animas River when turbidity levels in river water reach 200 NTU.

- Monitor sedimentation basins for evidence of heavy metal buildup.

2. Surface Water Quality

Goals: Determine if surface-water quality has changed as a result of the GKM spill, and evaluate any changes with regulatory standards and criteria.

Actions:

- Maintain field instrumentation installed at nine USGS stream gaging stations in the Animas and San Juan Rivers to monitor for turbidity, pH, specific conductance, and temperature.

- Continue making real-time data for turbidity, pH, specific conductance, and temperature provisionally available on the USGS Water Quality Watch website, along with flow rate which is already measured by USGS at the nine gaging stations and available on the WaterWatch website: https://waterwatch.usgs.gov/

- Maintain the real-time water-quality and flow data available through subscription e-mail and text alerts to public water systems and others who participate in the USGS Water Alert service, which sends automated messages when field measurements exceed specified levels.

- Manage nine ISCO auto-samplers and associated samples co-located with USGS gaging stations where water quality measurements are being collected.

- Support baseflow sampling correlated to 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.

- Maintain a reverse-911 system to communicate alerts and relevant information on surface water quality to area irrigators and farmers. Triggers for alerts and information are based on analysis of data collected from the Animas and San Juan Rivers, including data collected at the USGS sondes locations.

- Maintain USGS sondes installed for high flow spring runoff events and support post-GKM spill event updates to USGS stream gaging stations in the Animas and San Juan Rivers (i.e., added monitoring for turbidity, pH, specific conductance and temperature). These locations are currently operational and the data can be accessed on the USGS WaterQualityWatch website mentioned above.

3. Sediment and Agricultural Sampling (Streams, Irrigation Ditches, Irrigated Croplands and Crops)

Goals:

- Determine if elevated heavy metal concentrations presently occur in irrigation water and irrigation ditch sediment, and in soil and crops that have been irrigated with water diverted from the Animas River; and,

- Monitor the migration of contaminated surface water sediment from Colorado into New Mexico, as it pertains to irrigated agriculture and the river-agricultural land interface.

- Monitor and sample agricultural crops, and analyze for GKM heavy metals contaminants; compare to risk screening levels.

Actions:

- Initial and periodic future sampling, especially after runoff/storm events, of surface water sediment and irrigated soils and crops for heavy metals and evidence of increasing trends of metals concentrations migrating into New Mexico from Colorado.

- Facilitate coordination between ditch associations and public water systems to ensure that future irrigation ditch flushing does not adversely impact drinking water intakes.

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

4. Annual X-Ray Fluorescence (XRF) River Sediment and Soil Survey

Goal: Characterize the nature and extent of GKM-metals contaminated river sediment and soils. These data will supplement and enhance the existing dataset from the EPA, USGS, NMSU, Navajo Nation, Utah Department of Environmental Quality, Colorado Department of Health and the Environment and other stakeholders collected within the watershed historically and as part of the GKM spill response.

Actions:

- Collect soil and sediment samples along the length of the watershed from Cement Creek to the San Juan River on Navajo Nation.

- Conduct on-site (portable XRF) and off-site analysis on samples collected.

- Record sample site locations (i.e., GPS coordinates) and levels of GKM and mining-related metals in soil and sediment samples.

5. Solids Characterization

Goals: Determine specific form of contaminants in GKM spill solids and assess likely release and re-release pathways to support other tasks in the monitoring plan. Characterize the nature and extent of metals-contaminated sediment.

Actions:

- Directly characterize solids and associated metals from water and sediment along the flow path of the GKM spill.
- Review solid characterization data for GKM site, surrounding mines, and mine waters to establish likely initial forms of solid contaminants.
- Assess the mobility, likely transformation and release of metals in GKM spill solids in different depositional environments.

Scientists on the GKM Long-Term Monitoring Technical Consortium (GKM LTMTC) published a peer-reviewed scientific paper on this topic (Rodriguez-Freire, et al. 2016c).

6. Riverbed and Shallow Alluvium Interactions

Goals: 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 twenty sites from Cement Creek, CO, through NM, and into Bluff, UT for general chemistry and trace metals.
- Compilation and reanalysis of legacy data to establish a base-line to evaluate recovery.

7. Regional Groundwater Table Mapping and Groundwater Quality Monitoring [1, 2]

Goal: Monitor groundwater quality conditions and levels over time to assess groundwater contamination resulting from the GKM spill.

Actions:

- Map and evaluate water quality and groundwater level data collected by EPA and other cooperators to support long-term groundwater quality monitoring decisions, including well selection and sampling schedule.
- Track groundwater to surface water interactions and flow path changes using a network of up to 25 data loggers that measure parameters at regular time intervals.
- Collect groundwater quality samples from up to 80 selected wells two times a year.
- Analyze data to assess spatial and temporal trends in groundwater quality, and to assess impacts from the GKM spill.

8. Ongoing and Potential Future Discharges in the Mining Area

Goal: 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.

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[1] Preliminary work for Element 7 was completed under Elements 6 and 7 of the LTMP 2016 and funded by EPA through June 30, 2017. Equipment purchased will be utilized for continued Long-Term regional groundwater monitoring of contamination resulting from the GKM spill.

[2] Scientists on the GKM Long-Term Monitoring Technical Consortium (GKM LTMTC) published a peer-reviewed scientific paper on preliminary work relative to Elements 6 and 7: Timmons, S., et al. 2016, *Groundwater Monitoring along the Animas River, New Mexico: Summary of Groundwater Hydraulics and Chemistry from August 2015 to June 2016*. New Mexico Bureau of Geology and Mining Resources Aquifer Mapping Program Publication Final Technical Report September 2016. This paper is available online at: https://geoinfo.nmt.edu/resources/water/amp/brochures/FTR_Animas_River_Sept_2016_LR.pdf

- Identify locations of waste rock and mill tailings piles that have the potential to discharge into surface water.

9. Airborne Dust

Goal: Determine if the GKM spill has created potentially unhealthy contaminant concentrations in airborne dust.

Actions: The Long-Term Impact Review Team will review the sediment data and make a decision on what monitoring, if any, is necessary for airborne dust.

10. Plants and Animals

10.1 Aquatic and Riparian Habitat Assessment

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

Actions:

- Determine heavy metal concentrations from tissues of riparian and aquatic plants and algae, aquatic and terrestrial arthropods, and fishes.

- Evaluate two potential pathways of primary sources of contamination, riparian plants (groundwater into roots) and algae (through surface water and sediments) through use of naturally-occurring stable isotopes of carbon, or stable isotopes of nitrogen, as tracers for the source of food for higher levels in the food web, in rivers and streams.

- Analysis of metal concentrations and stable isotopes (carbon and nitrogen) ratios to characterize metals pathways.

- Document how metals move through the food web, from surrounding riparian areas and river sediments into the water column, to sources of food (algae, riparian plants) and consumers (aquatic and terrestrial arthropods, fishes).

10.2 Benthic Microbial Community and Functions

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 non-impacted and impacted sites.

- Assess inhibition of microbial nitrogen and carbon processing in laboratory experiments.

10.3 Nutrient Processing Studies

Goal: Document the fate of nutrients along the Animas river, as well as the capacity of biotic communities to take up nutrients in response to the GKM spill.

Actions:

- Conduct microcosm experiments to understand microbial nutrient processing using native sediments collected from the Cement Creek – Animas River-San Juan River continuum. investigate how in-stream nutrient processing is being affected by the Gold King Mine spill both spatially and temporally, from headwaters to large rivers.

- Use the results of the microcosm studies to quantify the effects of the GKM spill on benthic and hyporheic microorganisms.

10.4 Fish and Other Wildlife

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

Actions:
Monitor populations and health, and when effects are observed or expected, sample fish and other wildlife for heavy metals toxicity.

- Aquatic Wildlife (fish and macroinvertebrates)
- Terrestrial Wildlife (mule deer, elk, beaver or muskrat, and mice or rats)
- Amphibians and Reptiles (turtles, lizards and snakes)
- Birds (waterfowl)

11. Informational Conference

Goal: Disseminate information and results from the monitoring and research efforts outlined in this LTMP. Bring together academics, agencies, representatives and community members and provide a forum for addressing concerns and questions over the GKM spill and the continuing monitoring efforts.

Actions: Coordinate an informational conference during the Summer of 2017, in Farmington, New Mexico. The Second Annual Conference on Environmental Conditions of the Animas and San Juan Watersheds with Emphasis on Gold King Mine and Other Mine Issues is scheduled for June 20-22, 2017, at San Juan College in Farmington, New Mexico.
https://animas.nmwrri.nmsu.edu/2017/

This element is funded by an EPA Clean Water Act Section 106 grant through June 2017.

12. <u>Community Outreach and Involvement</u>

Goal: Keep the public informed of the results from the monitoring and research efforts outlined in this Plan. Provide opportunities for public comment on the progress and direction of monitoring activities.

Actions: Distribute written informational material to the public, host periodic public meetings, create and support a Citizens' Advisory Committee to work with the technical Long-Term Impact ReviewTeam to ensure that citizen and stakeholder concerns continue to be carried forward.

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