GOLD METAL **WATERS**

THE ANIMAS RIVER AND THE GOLD KING MINE SPILL

EDITED BY

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INTRODUCTION

From Gold *Medal* to Gold *Metal* Waters

BRAD T. CLARK

More than 500,000 abandoned hardrock mines are scattered across the American West, a legacy of the boom-and-bust cycle of resource development. Estimates for comprehensive cleanup range from $36 million to $72 billion (Moyer 2016). At many mine sites, acidic mixes of heavy metals have drained unchecked for decades from the myriad shafts, tunnels, and portals (or so-called adits).[1] Degraded water quality and damage to aquatic environments have resulted across many regional watersheds. According to the US Environmental Protection Agency (EPA), abandoned hardrock mines affect 40 percent of headwaters in the western United States; an additional 180,000 acres of lakes and reservoirs are estimated to have been impacted (Limerick et al. 2005). Since many of these affected waters are sourced from or flow across public lands, the lost revenue for communities with economies heavily dependent on any array of outdoor activities (e.g., angling, hiking, boating) is substantial.[2]

From a national perspective, millions of dollars are lost each year from the paucity of royalties paid by private enterprises on the wealth they've

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extracted from beneath the public domain. Ever since manifest destiny lured explorers and fortune seekers west, profits from hardrock mining have been privatized while environmental impacts remained socialized—culminating in what Pulitzer Prize–winning historian Vernon L. Parrington (1930) referred to as "the Great Barbecue" of the American West.

In Colorado alone, the Colorado Division of Reclamation, Mining, and Safety (CDRMS) estimates that there are *at least* 23,000 abandoned hardrock mine lands—classified as lands where mines operated prior to 1975, when the state began to establish limited forms of mining and reclamation standards. Today, these hardrock mine lands impact water quality in approximately 1,645 miles of streams and rivers.[3]

Remediation efforts have been mixed, often stymied by a combination of outdated laws, funding woes, and ill-enforced regulations. Local politics, persistent NIMBY-ism, and liability concerns have further frustrated policy development and comprehensive restoration efforts—including National Priorities List (NPL) designation under the 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), henceforth referred to as Superfund. All the while, acid mine drainage (AMD) from many of these "ticking time bombs" has contaminated watersheds and river basins on which tens of millions of westerners increasingly depend.

> Whether it's 100,000 or 500,000 [abandoned mines], that's hundreds of thousands too many . . . the Animas River spill has alerted the nation to the much more broad problem that many people were not paying attention to before.
>
> —*Ty Churchwell, backcountry coordinator, Trout Unlimited, cited in Quiñones 2015*

THE GOLD KING MINE (GKM) SPILL

On August 5, 2015, the issue of AMD was thrust into the public and political spotlight with the unintended release of 3+ million gallons of subterranean mine water, carrying 880,000 pounds of heavy metals from the entrance of the abandoned Gold King Mine (GKM) into Cement Creek, a tributary to the Animas River in southwest Colorado. Just upstream from its confluence with the mainstem Animas, Cement Creek flows through Silverton, Colorado, the administrative seat of San Juan County. The Silverton area thus became the primary source associated with the spill, where an estimated 120-plus historic mine sites have contributed to AMD for decades (CDRMS 2015). Even prior to the arrival of hardrock mining in the area (circa 1870s), naturally occurring acid rock drainage (ARD) from the underlying geology had degraded water quality for millennia.[4]

Soon after the spill, the entire Animas turned an unusually bright, yellowish-orange color below its confluence with Cement Creek, prompting local officials to restrict public access and suspend multiple municipal intakes and agricultural diversions in Colorado and New Mexico.[5] It took roughly 36 hours for the toxic plume to reach the regional hub of Durango, Colorado, where the Animas has long since been designated a "Gold Medal" fishery by the Colorado Wildlife Commission; it is one of thirteen similarly listed fishing areas across the state's 9,000+ river miles ("Gold Medal Streams" 2018). After crossing into New Mexico, the Animas delivered its discolored plume to the San Juan River, which eventually joins the mainstem Colorado beneath the stagnant waters of Lake Powell (figure 0.1).[6] Throughout the river basin, local communities, Native American reservations, irrigated agriculture, and recreational and wildlife areas were inundated. States of emergency were declared in Colorado, New Mexico, and Utah, as well as by the Navajo Nation Commission on Emergency Management.

Nine days after the initial spill, the toxic plume reached Lake Powell in southeast Utah. All the while, local, national, and international media outlets capitalized on the highly visible, sensational event. The seemingly pristine river in the scenic and diverse corner of the Southwest had turned into a dayglow-orange conduit for acidic, heavy metal–laden water on an inexorable path to the nation's second largest reservoir.

Calls for a strong political response and policy reforms quickly materialized, prompting many to reconsider Superfund listing(s) and anticipate additional changes to existing policies—notably the 1972 Clean Water Act (CWA) and the 1872 General Mining Law. By drawing insights from multiple disciplinary perspectives, this volume adds rich understanding of and context to the dramatic events following the 2015 GKM spill and the ongoing saga of AMD and abandoned mine reclamation across the American West.

As luck would have it, the federal agency in charge of implementing and enforcing many of the nation's most prolific environmental laws accidentally triggered the GKM blowout. The EPA had contracted with a third party

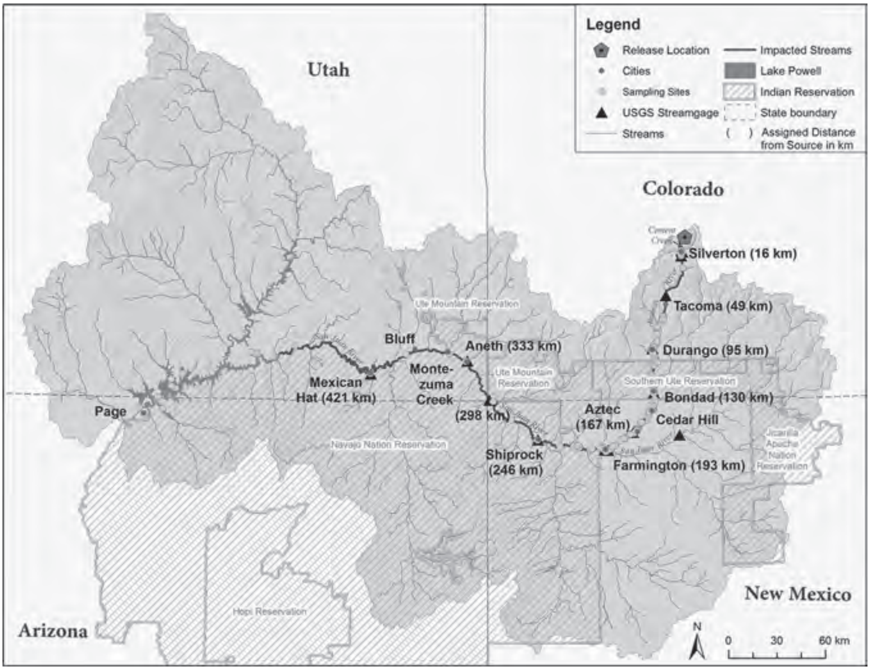

FIGURE 0.1. Path of the GKM Plume along the Animas and San Juan Rivers. *Courtesy*, "One Year After the Gold King Mine Incident: A Retrospective of EPA's Efforts to Restore and Protect Impacted Communities," US Environmental Protection Agency, last updated August 1, 2016.

(Pennsylvania-based Weston Solutions, Inc.) to perform exploratory excavation work to investigate conditions at GKM and assess its ongoing AMD releases. The EPA was quick to assume full responsibility for the spill, and Administrator Gina McCarthy made multiple visits to affected areas, extending apologies for her agency's failed actions.

In a region where local distrust of the EPA is common and opposition to federally led cleanup of abandoned mines has been long-standing, McCarthy's regret for her agency's actions was met with mixed reactions. Some longtime area residents even suggested that the EPA's actions were deliberate and intended to *force* federal cleanup on the Upper Animas River watershed, effectively ending any future mining operations in the region. According to one longtime Silverton resident, "I'm afraid of the EPA. They're too powerful. There's suspicion on my part that now the EPA is sitting judge and jury to decide the outcome of a fate that is a result of their negligence" (Olivarius-Mcallister 2018).

IN THE SPILL'S AFTERMATH: RAPID AND FUNDAMENTAL POLICY CHANGE

A classic view of policymaking in American government described the process as "muddling through," to characterize the behavior of elected officials and public administrators as slow, cautious, and deliberate (Lindbloom 1959). The result is an iterative process, whereby policymaking is (and should be) wholly incremental. Rapid policy development or reversal is considered the exception, not the norm. Hence, analysis of the policymaking process involved "the science of muddling through" (Lindbloom 1959).

Another adage, commonly used in the social sciences, is that *all politics are local*—in the sense that a community-level understanding of issues, events, and problems is essential for understanding policy developments at the national scale. The GKM spill is a case in point; it occurred in the relatively small and isolated Upper Animas watershed yet spawned a national and international media sensation and ensuing debates about the dangers of abandoned mines and AMD.

The strong local opposition to federally led cleanup efforts that had persisted for decades in the Silverton area quickly changed following the spill's visibly disturbing aftermath. After 25-plus years of opposition, it took less than 4 months (or 110 days) for local leaders to vote unanimously to direct city staff members to pursue a Superfund listing with the EPA and the Colorado Department of Public Health and the Environment (CDPHE). Around four months (or 136 days) later, the EPA officially proposed Superfund listing in the *Federal Register* for what would soon become the Bonita Peak Mining District (BPMD). This significant policy development was formalized on September 6, 2016, when the EPA announced the official designation of the BPMD on the NPL—only 137 days after the initial proposal. The time that elapsed between BPMD's proposed and formal listings represents the shortest involved for all of Colorado's nineteen, currently listed, nonfederal NPL facilities; the average time interval is more than 14 months.[7] Anecdotal evidence suggests that this time frame—between proposed and official listing—is a function of the extent and tone of public comments opposing NPL listing (i.e., fewer opposing comments correlates with a shorter time frame).[8] Roughly 60 percent of the public comments submitted by mostly local and regional interests supported the EPA's proposed listing of the BPMD in April 2016.[9]

More broadly, the complete time frame between the initial 2015 spill and formal site listing—a mere 383 days, is remarkable given the decades-long opposition by local leaders and area residents. Such a swift and complete reversal of policy preference is uncommon in American politics, where deliberation and incrementalism (i.e., muddling through) are the norm.

CONTENT AND OUTLINE OF THE WORK

As an editor and author of multiple chapters in this volume, my academic background is in political science and policy analysis. Throughout my undergraduate and postgraduate training, as well as my professional career, I have focused largely on environmental issues, particularly water policy and natural resource management. This has required me to incorporate and expand into my teaching and research aspects from an array of other disciplines—ranging from ecology and geology to history and law. All contributing authors to this work share similar multidisciplinary interests and skillsets, and the majority currently serve as affiliate faculty in the multidisciplinary Environment and Sustainability Department at Fort Lewis College (FLC) in Durango, Colorado. The result of our collaborative efforts is this volume, a uniquely inter- and trans-disciplinary examination into the 2015 GKM spill. Each chapter reflects the professional and personal experiences of its author(s); this allows for a singular event to be surveyed and interpreted from multiple, diverse perspectives.

Our intended audience is similarly broad and diverse; chapters were written with both academic and nonacademic readerships in mind. While all chapters were robustly researched and composed via various academic traditions, deliberate efforts were taken to minimize technical and discipline-specific jargon. The volume is thus relevant for readers broadly interested in hardrock mining in the American West and the legacies of AMD. Chapters should also appeal to readers with more specific interests in any number of other substantive areas, including the history of mining and mining communities in the San Juan Mountains; the region's unique geography, geology, and ecology; environmental law and policy; demographics, socioeconomics, and politics in the Upper and Lower Animas River watersheds; post-spill psychological, economic, and legal impacts; implications for Native American communities, including environmental justice concerns; intergovernmental response to disaster; environmental reclamation strategies; and the potential of future policy developments following the 2015 spill.

The heart of this volume consists of ten chapters written by FLC faculty from eight academic programs, as well as a scientist from a not-for-profit information center based in southwest Colorado. In two chapters (6 and 8), the lead authors recruited as coauthors select FLC students, community activists and educators, and faculty from the University of Arizona's College of Agriculture and Life Sciences. Three of these coauthors are members of the Navajo (Diné) Tribe and thus added valuable perspectives and knowledge to the narrative.

Chapter 1 presents a broad overview of the region's geography, human and hardrock mining histories, and past and present demographic profiles. It was written by a political scientist (Dr. Brad Clark). Chapter 2 discusses the aquatic ecology of the Animas River in both pre- and post-spill contexts. It was written by the water programs director for the Mountain Studies Institute (Scott Roberts).[10] Chapter 3 discusses details of the actual spill and those in the immediate aftermath. Of particular interest is the role of the GKM spill as a powerful focusing event (i.e., an unexpected and dramatic occurrence) and how this prompted profound and unusually fast-paced policy change regarding abandoned mine reclamation in the Upper Animas watershed—official Superfund listing was set in motion a mere 110 days after the GKM event when Silverton officials *unanimously* approved pursuing the federal designation in November 2015. It was written by a political scientist (Dr. Brad Clark). Chapter 4 addresses a host of hydrogeologic and ecological dimensions of the Animas River watershed from the perspective of the natural and physical sciences. It was coauthored by a biologist (Dr. Cynthia Dott) and two geologists (Drs. Gary Gianniny and David Gonzales).

Chapters 5–8 were written from perspectives within the social and behavioral sciences. Chapter 5 places the GKM spill in the context of other major, historic events in the watershed and discusses the central role the Animas River has played in the development of Durango's landscape and sense of place. It was written by a geographer (Dr. Pete McCormick). Chapter 6 examines a range of economic impacts associated with the 2015 spill. It was authored by a professor of management in the School of Business Administration at FLC (Dr. Lorraine Taylor) and her student (Keith Winchester). Chapter 7 discusses the psychological reactions to the GKM spill. It was written by a team of psychologists (Drs. Brian Burke, Alane Brown, Betty Dorr, and Megan Wrona). Chapter 8 examines a host of social and cultural impacts from the spill on communities in the Animas and San Juan River basins. It was written by a group led by a sociologist (Dr. Becky Clausen), along with a hydrologist and environmental engineer (Dr. Karletta Chief), community activists and educators (Teresa Montoya, Janene Yazzie, Jack Turner, Lisa Marie Jacobs, and Ashley Merchant), and a recent FLC graduate (Steven Chischilly).

The next two chapters return to the realm of environmental policy and regulation of hardrock mining. They assess the ongoing development of so-called Good Samaritan legislation, intended to relieve nongovernmental citizen groups from liabilities when initiating AMD remediation projects. Chapter 9 expands on this through a critical examination into the problems associated with court litigation as a means to ensure implementation and enforcement of federal environmental laws. It was written by a political scientist (Dr. Michael Dichio). Chapter 10 examines the primary actors behind the two competing perspectives regarding AMD remediation in San Juan County—both prior to and immediately following the 2015 GKM spill. It was written by a political scientist (Dr. Brad Clark). Finally, in the afterword, historian Dr. Andrew Gulliford employs the saying *we all live downstream* to highlight the many lessons to be learned from the 2015 GKM spill.

REMAINDER OF THE INTRODUCTION

This chapter concludes with a brief history of gold and silver mining in Colorado and, specifically, historical activities in the Cement Creek drainage. The AMD problem is then defined and its geologic and *anthropogenic* (i.e., human-induced) causes are discussed. The chapter ends with a brief chronology of events before and immediately after the spill. An update on the most recent developments (circa August 2018) in the unending GKM story is included.

TABLE 0.1. Time line of significant GKM-related events

Year	*Event*	*Description*
1860	Baker Party arrives in Upper Animas watershed.	Discovery of gold and silver deposits in Baker's Park area near present-day Silverton.
1860–1861	Animas City established.	Becomes first trading hub in the lower Animas River Valley.
1873	Brunot Agreement.	United States assumes control of 4 million acres from Utes.
1874	First mining rush; Sunnyside Mine patented.	An estimated 2,000 prospectors establish 1,000 mining claims in Baker's Park area.
1876	Colorado statehood; Town of Silverton incorporated.	Silverton poised to become mining hub of San Juan County.
1877	Animas Canyon Toll Road completed, linking Silverton to lower Animas Valley.	Increased delivery of supplies and materials to miners in Silverton area; transport of ores to Animas City (eventually Durango).
1880	Durango incorporated.	Durango will subsume Animas City by 1940s.
1881	Denver & Rio Grande Railroad reaches present-day Durango.	Animas City (later Durango) established as regional hub.
1882	Railroad reaches Silverton.	Rail linkage provides foundation for growth.
1887	Gold King Mine (GKM) established.	Olaf Nelson stakes claim; never becomes rich; dies of pneumonia 4 years later.
1890–1920	Primary production era at GKM.	665,000 tons of ore (silver, gold, lead, copper) produced.
1894	GKM sold for $15,000.	First of many changes in ownership.
Early 1940s	Uranium processing in Durango.	Uranium milled for Manhattan Project, atomic weapons.
1963	Uranium processing ends.	Nearby lands and Animas severely contaminated.
1975	Mine tailings spill in Silverton.	Roughly 50,000 metric tons spilled into Animas River.
1985	Lake Emma disaster.	Lake above Sunnyside Mine collapses into mine tunnels; 500 million gallons flood mine, AMD blowout.
1985–1991	Superfund cleanup (Durango).	Site remediation and relocation of radioactive wastes.
1994	Animas River Stakeholders Group (ARSG) forms.	ARSG starts local AMD remediation projects, becomes outlet for opposition to Superfund.
1996–2002	American Tunnel bulkheads installed.	AMD from Sunnyside decreases; AMD from GKM and others in Cement Creek drainage increases significantly.
2009	Annual AMD from GKM at 200,000 lbs. of heavy metals.	GKM labeled one of the worst AMD sources in Cement Creek by Colorado Division of Reclamation, Mining, and Safety.

continued on next page

TABLE 0.1—*continued*

Year	*Event*	*Description*
2014	Sunnyside Gold Corporation permanent treatment plant.	$10 million offer has stipulation that if accepted, potential Superfund listing in Cement Creek permanently stopped.
2015	GKM blowout, 10:30 a.m. on August 5.	3 million gallons of AMD released into Cement Creek.
2015	36 hours later, plume hits Durango.	Animas River turns orange in color; river and all intakes closed; intense media coverage.
2015	Silverton, San Juan County pursue Superfund listing.	Unanimous approval by vote on November 23.
2016	Colorado governor requests BPMD listing.	Governor Hickenlooper requests adding BPMD to NPL on February 29.
2016	EPA proposes Superfund listing.	EPA proposes BPMD listing on April 7
2016	Final Superfund listing by EPA.	BPMD announced on September 9 in the Federal Register.
2016	First of multiple lawsuits on May 23.	New Mexico sues EPA, mine owners; New Mexico sues Colorado on June 30; Navajo Nation sues EPA, mine owners on August 17.
2018	EPA outlines cleanup plan (June).	26 sites to be restored via "Interim Remedial Action Plan."

Hardrock Mining in Colorado

Following the California Gold Rush, gold fever came to Colorado in June 1858, when prospectors began sluicing sand and gravel at the confluence of Cherry Creek and the South Platte River near the present-day location of downtown Denver. Soon thereafter, 100,000 prospectors followed, and by the early 1860s, many had found their way south and west to the Upper Animas River watershed in the state's rugged San Juan Mountains. The area, which would become San Juan County following Colorado's 1876 statehood, quickly became one of the most important hardrock mining regions in the Rocky Mountain West (US DOI 2015).[11]

Cement Creek and the Gold King Mine

The Upper Animas watershed draws from three main sources—the Animas headwaters, Cement Creek, and Mineral Creek—all of which have historically been impacted by AMD. In the Cement Creek drainage, a cluster of abandoned sites at and above the historic mining ghost town of Gladstone has been the primary source of metals loading. Along with the GKM, these mine sites include the American Tunnel, the Red and Bonita Mine, and the Mogul Mines.

At an elevation of approximately 11,400 ft., the GKM was established in 1887, when Olaf Nelson first staked a claim high in Cement Creek's north fork on the slopes of Bonita Peak. Following multiple changes in ownership, the mine continued to operate until late 1922 and has remained largely out of operation since 1923. During its time, GKM produced 711,144 tons of gold and silver ore from seven separate levels, spanning 760 vertical feet ("Gold King Mine" 2015). At the time of the 2015 blowout, GKM was owned by Todd Hennis of the Golden, Colorado–based San Juan Corporation. Hennis also owns the neighboring Mogul Mine in the Cement Creek drainage.

GKM is located within an extensive volcanic field in the Upper Animas watershed, in what is commonly referred to as the collapsed Silverton caldera. The area represents the southern terminus of the Colorado Mineral Belt, which runs diagonally across the state from Durango to Boulder. Because of its volcanic origins and underlying geology, the Upper Animas watershed is naturally a highly mineralized region, which has experienced several heat-induced mineralizing events over the previous 25 million to 35 million years. These processes deposited valuable metals at GKM and altered surrounding rocks ("Gold King Mine" 2015). As a result, Cement Creek and surrounding waterways receive acid drainage that is naturally formed, albeit less concentrated and more dispersed. Indeed, select tributaries to the Animas—including Cement Creek—were practically devoid of life (i.e., biologically dead) prior to the onset of mining activities.[12]

During the heyday of hardrock mine production (circa 1890–1920), an estimated 4.3 million tons of tailings were discharged directly into Silverton-area streams via the many large gold and silver mills, such as the one formerly located at the Gladstone townsite (Church et al. 2007). By the early 1900s, downstream conditions in Durango had deteriorated to the point that the city was forced to switch its municipal supply from the Animas to the Florida River watershed, an area with a far less extensive history of hardrock mining. In Silverton, drinking water has long since been sourced from an Animas tributary well above Cement Creek.

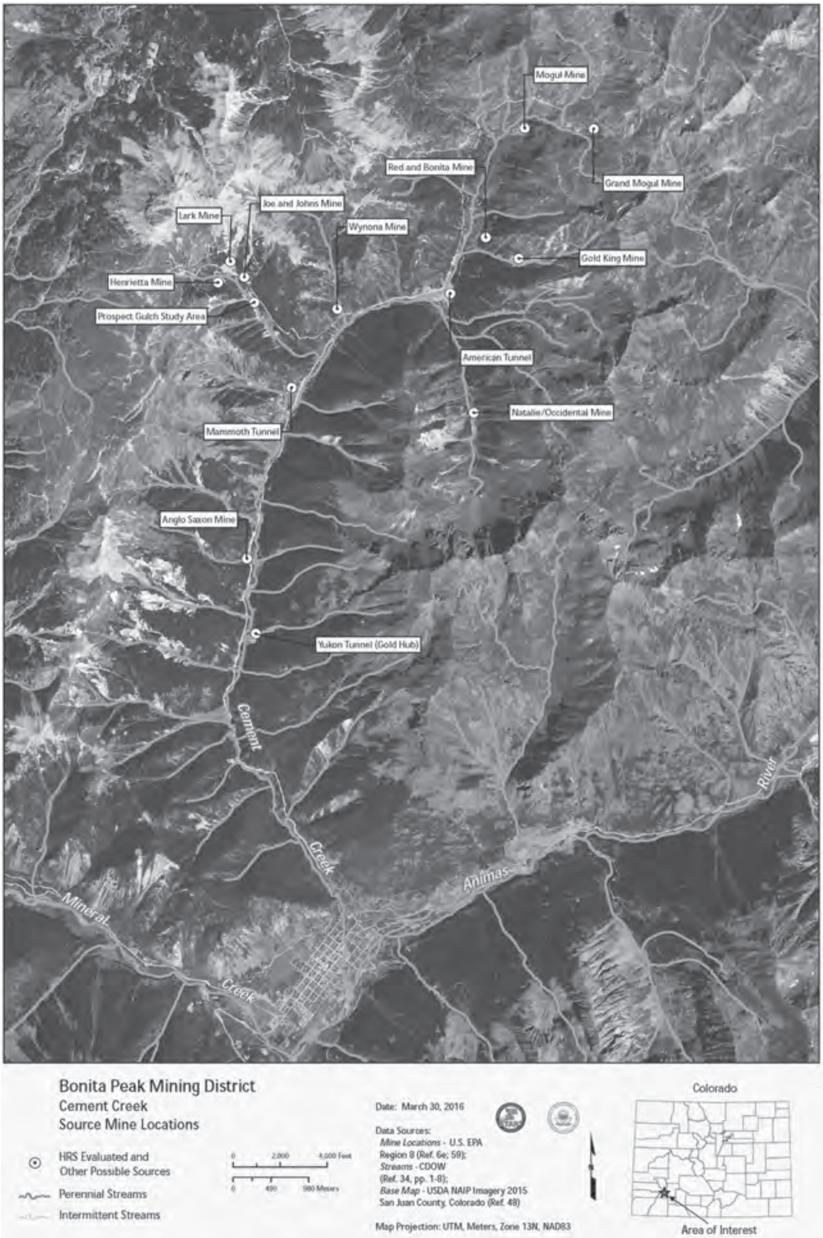

FIGURE 0.2. Mines in the Cement Creek drainage. *Courtesy*, "Gold King Mine Release—Analysis of Fate and Transport in the Animas and San Juan Rivers," US Environmental Protection Agency, last updated June 21, 2016.

It wasn't until the mid-1970s that laws were passed to protect the environment from the impacts of hardrock mining. Without regulation or the required posting of bonds to ensure reclamation of mined sites, prospectors could freely disturb the landscape and impact waterways; when mining activities ended, they could simply and *legally* walk away.

With thousands of mines having been sunk into mountainsides, precipitation and discharge from natural springs perpetually accumulate in the many miles of subterranean tunnels and shafts.[13] The waters react with naturally occurring iron sulfide minerals (e.g., pyrite) and oxygen, which produces sulfuric acid. These acidic waters dissolve the area's naturally occurring heavy metals, including zinc, arsenic, lead, cadmium, copper, aluminum, thallium, and selenium. After periods of accumulation, metal-laden waters inevitably discharge from the hundreds of mine adits (or openings).[14]

In addition, pyrite is the most common material in the area's piles of mine tailings. When exposed to oxygen and precipitation at the surface, tailings further contribute to the production of acidity and sulfides. Quite simply, AMD is produced virtually whenever and wherever pyrite is exposed to oxygen and water. Along with mine adits, this makes tailings and waste piles primary culprits of anthropogenic AMD. In total, since mining began in the watershed, an estimated 8.6 million tons of tailings ended up in the Upper Animas River environment ("Technical Evaluation" 2015).

In Cement Creek, AMD has caused its pH value to fall to around 3.5, which is similar to that of store-bought vinegar. In such acidic water, heavy metals are soluble (or easily dissolved). After being diluted with less acidic waters (e.g., the mainstem Animas), pH levels rise; as this happens, metals begin to (re)solidify in the water column and eventually settle as contaminated sediments. The orange-ish color of the impacted waters is the result of these heavy metals (e.g., copper and zinc) becoming attached to iron particles. Together, these processes have had tremendous impacts on aquatic ecosystems in nearby waters. For example, no fish have been found to survive in the Animas for approximately 2 miles after it is joined by Cement Creek, and precipitous declines in fish populations have been reported as far as 20 miles downstream from this confluence (US EPA 2016). For communities serviced with drinking water from contaminated rivers and streams, the bioaccumulation of metals is a public health concern.

Before the 2015 GKM incident, there were two significant AMD releases in the Upper Animas watershed. In June 1974, a tailings dam breached at Sunnyside Mine's mill in Silverton and an estimated 116,000 tons of acidic tailings were released into the Animas. As a result, the cities of Durango, Colorado, and Farmington, New Mexico, were forced to close municipal water intakes for a period of seven days and fish kills were reported near Durango, 40 miles away from the spill (Bird 1986). A second release occurred in June 1978, when a portion of Sunnyside Mine located beneath Lake Emma collapsed, releasing 500 million gallons of sediment-laden water into the mine's tunnels. Contaminated waters soon burst via the mine's American Tunnel, launching wrecked mine equipment, timbers, and sulfide rock tailings into the Animas (Bird 1986).[15]

Large-scale mining in the area ended in 1991, when the Sunnyside Mine and its American Tunnel were closed due to a combination of declining ore reserves, falling gold and silver prices, and mounting concerns over water quality in Cement Creek.[16] In fact, a year prior to Sunnyside's closing, the State of Colorado's Water Quality Control Division (CWQCD) had begun a program to establish water quality standards in the Upper Animas watershed. Preliminary analysis indicated that the majority of heavy metals were coming from around eighty abandoned mine sites across the Upper Animas watershed. A number of these were initially targeted for reclamation to minimize drainage and restore impacted surface lands. In general, the projects involved installation of hydraulic bulkheads (i.e., concrete plugs) at mine openings—to stem AMD that had accumulated deep within the mines, as well as construction of settling ponds and basic treatment plants—to remediate residual seepage and increase pH levels through the addition of lime.[17] GKM was not included in these initial cleanup efforts, as other sites received priority.

Releases of contaminated water decreased notably at many of the sites where bulkheads were installed and treatment facilities constructed. However, impounded waters at many of these sites simply migrated to neighboring subterranean voids or fissures and steadily accumulated in neighboring mines. By most accounts, GKM was chief among these in the Cement Creek drainage; shortly after the first Sunnyside Mine bulkhead was completed in 1996, seepage from GKM increased as discharge from Sunnyside *dropped* from 1,700 to 100 gallons per minute (gpm).

Two additional bulkheads were completed at the Sunnyside Mine and American Tunnel between 2001 and 2002; and in 2003, bulkheads were added to the Mogul Mine. Again, significant increases in discharge were detected from GKM and other neighboring mines. These waters were initially stored and remediated at a treatment plant near Gladstone, which by 2004 was closed due to a host of technical, financial, and legal troubles. All the while, additional waters pooled via drainage from tunnels behind Sunnyside's bulkheads, and discharges from GKM and others steadily rose.[18] By 2006, peak discharges from GKM had risen to over 300 gpm. Three years later, GKM was found to be releasing nearly 200,000 pounds of metals into the watershed each year; this led to its ranking as "arguably one of the worst high quantity, poor water quality draining mines in the State of Colorado" by the CDRMS (Thompson 2015). Also in 2009, the CDRMS closed all of the adits at GKM by backfilling their portals with various fill materials; they were not bulkheaded. Subsequent to the backfilling, AMD averaged 200 gpm from GKM's lowermost Level-7 adit.

By 2010, significant declines in brook trout populations in the Animas River below Silverton had been reported by the Colorado Department of Wildlife. Between 2010 and 2014, AMD discharge from GKM averaged 153 gpm. In part, this prompted the EPA to initiate additional data gathering on water quality as an initial step in the process of determining whether Cement Creek was eligible for federally led reclamation under Superfund. The EPA also began petitioning Silverton's elected officials and area residents to consider supporting Superfund designation.

As the Superfund option gained traction over the next few years, Hennis and the Sunnyside Gold Corporation (SGC) made repeated offers to fund construction of a permanent water treatment facility for the Cement Creek drainage as the Sunnyside Mine and American Tunnel continued to discharge AMD at the rate of 100 gpm, despite the multiple sealed bulkheads. In exchange for its $10 million overture, SGC asked for total exemption from any potential liabilities for future restoration efforts in Cement Creek. Such an offer was hardly surprising, given that SGC is among the largest *potentially responsible parties* (PRP) under Superfund financially liable for comprehensive AMD remediation in the Upper Animas watershed. In addition, the offer was backed by SGC's parent company—the Kinross Gold Corporation, an international, publicly traded mining conglomerate based in Canada.[19]

Nothing ever materialized, as the $10 million offer was left on the table until the GKM blowout occurred.

In 2014, the EPA returned to the GKM site at CDRMS's request that it reopen and stabilize the Level-7 adit that had previously collapsed. The drainage system and backfilling at the entrance had reportedly not been maintained or routinely monitored since 2009 ("Technical Evaluation" 2015). The EPA quickly determined that additional time and resources would be necessary to complete GKM's reopening, and work stopped after a few hours of excavation. The remaining work was postponed until the following year, when bulkhead construction was completed by early summer 2015 at the nearby Red and Bonita Mine. Its valve, however, was left open out of concern that closing it could increase water levels at GKM.

By late July 2015, EPA contractors had returned and resumed work by reconstructing the access road to GKM. On the morning of August 4, an EPA on-scene coordinator and an official from the CDRMS arrived at GKM. Per their instructions, EPA's Emergency and Rapid Response Services contractor began to excavate an area at the mine's collapsed Level-7 adit. The drainage from GKM was measured at 69 gpm. After less than 4 hours of work, a set of collapsed timbers was uncovered at GKM's presumed opening. Excavation stopped, and workers left the site altogether to allow time for overnight consideration of future activities. And then it happened . . .[20]

On the morning of August 5, 2015, it was determined that excavation should continue at the Level-7 adit. At 10:51 a.m.—roughly 80 minutes after work began—a small leak of water appeared 15 feet to 20 feet above the adit's floor. The EPA's contractor had allegedly miscalculated the depth and pressure of water accumulated behind the bulkhead (US House Committee on Natural Resources 2016). Within minutes, a portion of bedrock fell away from the mine's opening and a greater volume shot upward 1.5–2-feet; the breached opening later measured 10 feet in width and 15 feet high. Initially, the discharging water was clear but soon changed to a reddish-orange color. The excavator's operator reported that he had hit a "spring" and quickly removed the machine.

The access road was soon destroyed by the burst of water, and the EPA's vehicle was rendered undriveable. It took approximately an hour for the peak flow to subside, after which discharge decreased to a fairly constant 500–700 gpm. The pH was measured (by a handheld paper test) at 4.5—a strongly acidic level similar to that of black coffee.

The onsite workers had no cell phone or satellite connections; nearly an hour elapsed before they were able to establish radio contact with offsite personnel, who subsequently issued initial notifications of the spill to the EPA's on-scene coordinator and the CDRMS. It took almost another hour for the state's main regulatory agency with direct jurisdiction over the accident—the CDPHE—to complete notifications to the City of Durango, the San Juan Basin Health Department, and other operators of water intakes.

Initial water quality samples were not taken until roughly 6:00 p.m.; after two days, results indicated elevated levels of copper, lead, manganese, and zinc. By August 8, GKM's discharge flow rate had steadied to an approximate average of 587 gpm and its pH had fallen to 3—similar to that of orange or grapefruit juice.[21] A week after the initial spill, CDPHE reported that metals loading in the Animas had returned to pre-spill levels, while levels of cadmium, copper, and zinc remained above historic standards in Cement Creek.

ISSUES AND DEVELOPMENTS FOLLOWING THE SPILL

By May 2019, almost four years after the spill, a number of notable issues and important developments had impacted the course of the ongoing GKM story. For context and a brief update, the following warrant retention.

Water Treatment

After official Superfund listing of the BPMD, a $1.5 million temporary water treatment plant was constructed on Cement Creek near the historic mining hub of Gladstone, roughly 8 miles north of Silverton. It became operational in October 2015. At the plant, lime is added to the AMD to raise overall pH levels in Cement Creek. This causes dissolved metals to solidify in the water column and settle in retaining ponds. The practice is generally effective, yet a tremendous amount of sludge is generated in the process—an estimated 4,600 cubic yards per year from the average 450 gpm of discharge from GKM. Further, it will likely be necessary for the treatment plant to be operated *in perpetuity*.

On the evening of March 14, 2019, a period of unusually heavy snowfall caused a power outage at the treatment plant as well as an avalanche that temporarily blocked access to the plant. After a period of less than 48 hours, the EPA brought the plant back online, and it resumed normal operations on the afternoon of March 16. During shutdown, an estimated 264 gallons per minute of untreated AMD drained into Cement Creek and the Animas River. As a precautionary measure, the water intake facilities for the Cities of Aztec and Farmington, New Mexico, were temporarily closed. The EPA conducted water quality samples from four locations along the Animas River, from its confluence with Cement downriver to sites above and in Durango. A considerable elevation of heavy metals, especially copper, was detected at the confluence and lower concentrations in the Animas roughly 1 mile downriver of Silverton. The two sampling locations in Durango yielded heavy metal concentrations within the range of those measured when the water treatment plant was operational.

Sludge Storage, Transport, and Safety

When the treatment plant went online in October 2015, the sludge was stored onsite along Cement Creek at an area known as Gladstone. According to the EPA, the amount of available storage space was to be entirely filled by August 2018. For months previous, the EPA had unsuccessfully searched for additional storage space in the Upper Animas watershed. The massive tailings ponds north of Silverton, operated by SGC (GKM's current owner), were identified as suitable locations, yet the company was listed in 2018 as a PRP for EPA's cleanup and the two sides were unable to agree on acceptable uses for the ponds. As the one remaining viable option, it was decided that all future sludge would be transported by truck more than 70 miles and over two mountain passes to a landfill south of Durango, near the New Mexico border. Elected officials and the majority of residents in both San Juan and La Plata Counties opposed the plan on financial, public safety, and environmental grounds—particularly the carbon footprint that would result from the estimated 700 annual trips spanning an unknown number of years.

With time running out on the search for an alternative plan, the EPA reached an agreement for onsite storage at the historic Kittimac tailings pile, a 10–15 mile one-way drive from the Gladstone treatment site. Thus the short-term problem of sludge storage has been addressed, but what remains is the larger, more complex issue—what to do with the massive amounts of sludge that will result from long-term AMD treatment under Superfund.

Meanwhile, in the near term, safety concerns over sludge transport across *any* distance remain valid. A few days into the trucking of sludge to the Kittimac site, a vehicle driven by an EPA contractor crashed into Cement Creek, releasing roughly 9 cubic yards of sludge material into the waterway. The driver was not seriously injured, yet such an inauspicious start hardly inspires much confidence.

Mine Spill versus Forest Fire: Comparing the Impacts Following Disaster

Roughly 3 years after the GKM spill, the Animas River Basin played host to another catastrophic event—massive wildfires. On June 1, 2018, the 416 Fire started 10 miles north of Durango; a week later the Burro Fire ignited a short distance to the northwest. Together, the officially named 416 and Burro Complex Fire would burn more than 54,000 acres, making it the sixth largest and most destructive fire in Colorado history.

The fire prompted the first-ever official closing of the nearly 1.9 million acre San Juan National Forest, which included an extended suspension of operations of both the Purgatory Resort and the Durango & Silverton Narrow Gauge Railway, which normally carries up to 193,000 tourists per day during the summer months and injects $190–$200 million annually into the two tourist towns (Best 2018). With the tourist train suspended, the economy in San Juan County was particularly decimated.

In contrast, the economies of Durango and La Plata and San Juan Counties showed minor and only temporary negative impacts following the GKM spill. Despite a reliance of up to 20 percent on tourism, many economic sectors across the area—including lodging, retail, and food and beverage—actually posted higher than average sales for August 2015. In Durango proper, sales tax revenues for August 2015 were up 2.5 percent.

The fire's ecological footprint was similarly enormous, with longtime impacts far in excess of those following the 2015 GKM spill. In particular, flash floods and debris flows from the 416 burn scar led to massive fish kills in the Animas River and its tributary, Hermosa Creek. These were attributed primarily to suffocation that resulted from high ash concentrations and low dissolved oxygen levels in the waterways. Fish surveys by the CDPW found fish populations (both brown and rainbow trout) in multiple river and creek segments that were more than ten times below historical levels.

Concentrations of heavy metals were also much higher following the 2018 fires than those detected during the flow of GKM's toxic plume through Durango. While no evidence of any die-offs of aquatic life was linked to the GKM's AMD, heavy metal concentrations caused a near-total fish kill in the Animas after the 2018 fire season. Specifically, concentrations of aluminum were measured at fifty times higher than those associated with GKM's plume; iron levels were six times higher; manganese was twenty times higher; levels of mercury were three times higher than those registered at the peak of the GKM event (Romero 2018). Granted that the fires of 2018 were slow-moving disasters lasting more than two months and the GKM plume discolored the Animas for roughly a week, the degree, magnitude, and duration of media coverage regarding the former far exceeded that of the latter. Yet the political attention and policy change directly following the GKM spill were much more intense and substantive than those resulting from the 416 and Burro Fire Complex.

Initial Remediation Plans

Also in June 2018, the EPA released its proposed Interim Remedial Actions Plan (IRAP)—informally referred to as the "quick-action cleanup plan," for inaugural restoration work at twenty-six abandoned mining sites in the BPMD outside of Silverton (Romero 2018). In particular, the EPA created five types or sources of potential AMD-related pollution (officially termed "contaminant migration issues" [CMI]) at the twenty-six sites. The first involves mine portal discharges, of which there are twenty. The second targets eleven sites where stormwater and mining-related materials commingle. The third focuses on contaminated sediments held in mine portal settling ponds. The fourth centers on two sites where mine wastes are entirely within or located on both banks of a waterway. The final type of contaminant migration issue targets two mining-impacted recreation areas (e.g., dispersed campsites) where tailings piles or contaminated soils levels of arsenic and lead are in excess of human-health thresholds (Romero 2018).

According to the EPA, the CMI-related work will occur simultaneously with the formulation of the more comprehensive long-term plan known as the "Site-Wide Remedial Investigation and Feasibility Study," which will address restoration at all forty-eight mine sites within the BPMD, including

GKM and others in the Cement Creek drainage. Specific to the GKM site, the EPA plans to transition the temporary water treatment plant at Gladstone to some form of a permanent facility by January 2022.

The majority of public comments submitted in response to this proposed "quick-action" plan were critical; many commenters cited their disapproval of the EPA's focus on remediation activities at a large number of relatively minor sites of AMD-related pollution as opposed to focusing on a smaller number of major sites of AMD contamination—specifically, those high in the Cement Creek drainage such as the GKM, the Red and Bonita Mine, the American Tunnel, and the Mogul Mine complex.[22]

In addition, many commenters expressed ongoing skepticism toward and distrust of the EPA's takeover of AMD remediation in the Upper Animas watershed. For example, Peter Butler, then-co-coordinator of the now-defunct ARSG, reacted to the proposed interim plan by stating that the plan "seems to have been developed for the political purpose of showing that something is being done as opposed to developing an overall cost-effective strategy for improving water quality" (quoted in Romero 2018). Reflecting a similar sentiment, Bill Simon, former coordinator emeritus of the ARSG, stated that "if one was serious about 'draining the swamp' I would suggest saving most of the over $8M and 10 years of fiddling around and instead attack the real cause of the problem. That alone will go further than a bunch of high visibility 'feel good' projects primarily designed for PR purposes" (quoted in Romero 2018).

In response, the interim project manager for the BPMD stated that the extreme complexity of the mine network in Cement Creek justified the proposed activities and that years of investigation are necessary for development of a long-term solution for large sources of AMD such as GKM. Specifically, it was stated that the proposed plan deals with "immediate steps that are relatively straightforward and simple" across the entire headwaters of the Animas River (Romero 2018).

In May 2019, the EPA released its final Interim Record of Decision (IROD); it included minor changes to the 2018 IRAP, based primarily on consideration of public comments and ongoing feasibility studies. Specifically, the IROD reduces the number of targets to twenty-three (including the two dispersed campsites) and retains the five CMIs—which were renamed Interim Remedial Actions (IRAs). Together, implementation of the five IRAs at the

TABLE 0.2. Interim Record of Decision (IROD)—Costs and locations (US EPA 2019)

IRA	*Cost (millions)*	*Location(s)*	*Target(s)*
Mine portal Discharge for "mine influenced water" (MIW)	≈ $2.5	18 mining-related sources of AMD	13 mines and 5 tunnels
Mining-related source/ stormwater interactions	≈ $2.0	10 mining-related sources of AMD	9 mines and 1 tunnel
Mine portal pond sediments	≈ $3.7	8 mining-related sources of AMD	5 mines and 3 tunnels
In-stream mine wastes	≈ $0.50	1 mining-related source of AMD	1 mine
Mining-impacted recreation areas	≈ $1.7	5 mining-related sources of AMD	2 mines, 1 tunnel, and 2 campgrounds
Total	≈ $10.4		

Note: The total number of locations listed in the IROD is twenty-three. Many locations and targets are listed multiple times for different IRAs.

twenty-three sites will cost nearly $10.4 million in total, which includes initial construction activities as well as operation and maintenance costs over a 15-year period (US EPA 2019). For a cost breakdown of the IRAs, see table 0.2.

NOTES

1. An adit is a horizontal or near-horizontal opening to an underground mine used for entrance, ore removal, drainage, and ventilation.

2. Anglers are especially affected by AMD and have become a potent force in calling for restoration of abandoned sites. Their main lobbying organization, Trout Unlimited, continues to devote significant resources to heighten awareness and promote legislation intended to facilitate cleanups.

3. The pace of policy development increased in 1976, when the Colorado Mined Land Reclamation Division was created to regulate non-coal mining operations. That same year, the Colorado General Assembly passed the Colorado Mined Land Reclamation Act, which created the Mined Land Reclamation Board to serve in administrative and adjudicatory capacities over non-coal mines.

4. AMD and ARD are formed when pyrite (an iron sulfide, or FeS_2) is exposed to and reacts with oxygen and water to form sulfuric acid (H_2SO_4) and dissolved iron (Fe). Some or all of this iron precipitates to form the red, orange, or yellow sediments in the bottom of streams containing AMD and/or ARD. The acid runoff further dissolves heavy metals such as copper, lead, and mercury into surface water and groundwaters.

5. AMD has caused the pH value in Cement Creek to fall to around 3.5, which is similar to that of store-bought vinegar. In such acidic water, heavy metals are soluble (or easily dissolved). After being diluted with less acidic waters (e.g., from the mainstem Animas), pH levels rise; as this happens, metals begin to (re)solidify in the water column and eventually settle as contaminated sediments. The orange-ish color of the impacted waters is the result of these heavy metals (e.g., copper and zinc) becoming attached to iron particles.

6. The distance from the GKM site on Cement Creek's north fork to the New Mexico state line is 83 miles. The Animas continues an additional 30-odd miles to its confluence with the San Juan River. Since the completion of Glen Canyon Dam in 1963, the San Juan joins the Colorado at Lake Powell.

7. The shortest time between the proposal and official NPL listing in Colorado was 130 days, for the Air Force Plant PJKS (Peter J. Kiewit and Sons) federal site. Cleanup and construction activities were completed by February 2014; the site is currently owned and operated by Lockheed Martin Astronautics Operation. The 464 acre plant is located 25 miles southwest of Denver and is surrounded by another 4,700 acres of Lockheed Martin property. Operations at PJKS included testing Titan rockets, as well as design and manufacture of technical systems for space and defense.

8. For information about stages of NPL listing, see https://www.epa.gov/superfund/superfund-cleanup-process.

9. See public comments made in response to EPA's proposed NPL listing at https://semspub.epa.gov/work/08/1570791.pdf.

10. The Mountain Studies Institute (MSI) is an independent 501(c)3 not-for-profit center of knowledge established in 2002 in Silverton, Colorado. MSI's currently stated mission is "to empower communities, managers, and scientists to innovate solutions through mountain research, education, and practice." For more information, see http://www.mountainstudies.org/mission-vision.

11. In August 2015, the Colorado Division of Reclamation, Mining, and Safety classified 120 Silverton-area mine sites as the following: 18 mines had active water treatment, 18 mines were under investigation, 66 mines had no active treatment, and 18 nonpoint sources (i.e., waste piles of ore) had no active treatment. These AMD sources were classified as "actively" or "likely impacting" water quality. See http://mining.state.co.us/Programs/Abandoned/Documents/LegacyMineWork.pdf.

12. Coincidentally, the naturally acidic waters of Cement Creek support one of the few areas on the planet where iron fens are located. Iron fens are a type of unique wetland that has highly acidic water (a 4.5 pH or less), which results in a diverse array of plant life. Most iron fen plant species (e.g., Sphagnum mosses) are

found only in the boreal forests of Canada and Alaska, more than 1,200 miles away. Currently, there are only thirteen iron fens globally; four of these are located in San Juan County. "Appendix D Wild and Scenic Rivers Suitability, last modified September 2013," https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5435197.pdf.

13. GKM is in an alpine environment and experiences significant precipitation, mostly in the form of snow from late fall to spring. Snow accumulations average roughly 15 feet.

14. An adit is a horizontal or near-horizontal entrance to an underground mine, by which the mine can be entered, drained, and ventilated and minerals extracted.

15. The event happened on a Sunday, when operations at the Sunnyside Mine were down. Had it occurred on a workday, a crew of 125 miners would have likely perished from the sudden inrush of water into the mine and the subsequent blowout into the Animas. See Bird (1986, 16).

16. The American Tunnel is often mistaken for an actual independent mine. In actuality, it is the lower level of the Gold King Mine at Gladstone, Colorado. In 1959, the American Tunnel was extended more than a mile to intersect Sunnyside Mine, 600 feet below the original mine workings. As such, the American Tunnel is Sunnyside's lowest transportation and ore-haulage level. See Rosemeyer (2017).

17. An alternative to the practice of bulkhead placement at mine openings in order to block AMD has been referred to as "source control," whereby hydraulic controls (e.g., rock plumbing) are installed above mine adits to prevent precipitation and other surface flows from infiltrating the inner workings of abandoned mines. The goal is to minimize or prevent water from contacting mineralized deposits. Such a source control approach has been implemented to remediate zinc pollution at the Idarado Mine in neighboring Ouray County. See Fiscor (2015).

18. Discharge from the Red and Bonita Mine contains extremely high levels of zinc, while drainage from GKM is much more acidic. See US DOI (2015).

19. For 2017, Kinross posted a net profit of $445.40 million.

20. This chronology of events was derived from two sources: US EPA (2015); EPA Region 8 (2015).

21. The pH scale runs from levels 1–14, with lower values indicating higher acidity. Each whole number up or down in the scale is equivalent to 10 times the concentration of the previous step. Neutral water has a pH of 7, but a pH of 6–8 is generally considered normal. Depending on the species, the recommended pH for fish is between 6.0 and 9.0.

22. The 30-day public comment period lasted from June 14 through July 16, 2018.

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