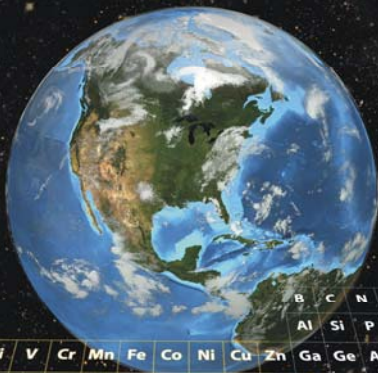


Environmental Sciences Laboratory

Assessment of Potential Gold King Mine Release Impacts to Durango, Colorado and Shiprock, New Mexico LM UMTRCA Sites

April 2017



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Abbreviations

AMD	acid mine drainage
AS&T	Applied Studies and Technology
ASPECT	Airborne Spectral Photometric Environmental Collection Technology
BDL	below detection limit
BOR	U.S. Bureau of Reclamation
CCR	<i>Code of Colorado Regulations</i>
CDPHE	Colorado Department of Public Health and Environment
CFR	<i>Code of Federal Regulations</i>
cfs	cubic feet per second
COCs	contaminants of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GCAP	Groundwater Compliance Action Plan
GEMS	Geospatial Environmental Mapping System
GKM	Gold King Mine
gpm	gallons per minute
kg	kilogram(s)
LM	Office of Legacy Management
MCL	(EPA) maximum contaminant level
mg/L	milligrams per liter
MSI	Mountain Studies Institute
NNEPA	Navajo Nation Environmental Protection Agency
River Watch	The Rivers of Colorado Water Watch Network
SC	specific conductance
SOWP	Site Observational Work Plan
s.u.	standard units
TAL	target analyte list (metal)
TTP	Technical Task Plan
UDEQ	Utah Department of Environmental Quality
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey

Executive Summary

On August 5, 2015, a U.S. Environmental Protection Agency (EPA) field team investigating the Gold King Mine (GKM) above Silverton, Colorado, inadvertently triggered the release of an estimated 3 million gallons of acidic, mine-impacted water to a tributary of the Animas River. The release contained elevated concentrations of iron, manganese, aluminum, copper, zinc, and lead. The iron imparted a yellow-orange color to the river; this discoloration was used to monitor the movement of the plume using aerial photography. Over an approximate 9-day period, the plume from the release flowed down the Animas River, past Durango, Colorado, joined the San Juan River at the confluence in Farmington, New Mexico, and ultimately reached the Colorado River at Lake Powell in Utah.

The GKM plume had potential to impact groundwater at two former uranium mill sites that are managed by the U.S. Department of Energy Office of Legacy Management (LM). The sites, located at Durango, Colorado, and Shiprock, New Mexico, are about 60 and 150 river miles downstream of GKM, respectively. The Durango site is adjacent to the Animas River, and the Shiprock site is adjacent to the San Juan River. Groundwater at both sites is hydraulically connected to the rivers. Aerial surveys, sampling, and assessment of flows conducted by EPA and other agencies indicated that the river plume reached the Durango site at about 10 p.m. on August 6 and the Shiprock site between late August 8 and early August 9, 2015. This report documents the results of a project conducted by LM to evaluate the potential for impact of the GKM release on the groundwater at these two sites. The work was funded by LM's Applied Studies and Technology (AS&T) program.

To assess potential impacts of the GKM plume on groundwater at the Durango and Shiprock sites, LM mobilized a nonroutine sampling effort on August 18, 2015, about 2 weeks after the GKM release. At the outset, LM recognized that there would likely be little overlap between LM contaminants of concern (namely uranium) and metals constituents typically associated with acid mine drainage. In fact, many of these elements have not been included in LM's analytical program since the 1980s and 1990s. Therefore, LM relied heavily on data from other agencies, primarily EPA, the U.S. Geological Survey, the Mountain Studies Institute, and The Rivers of Colorado Water Watch Network.

Although surface water in the Animas River near the Durango site was impacted by the release, as demonstrated by other agency data, LM's analysis indicates there was no apparent incursion of the river-borne GKM contaminants to the groundwater.

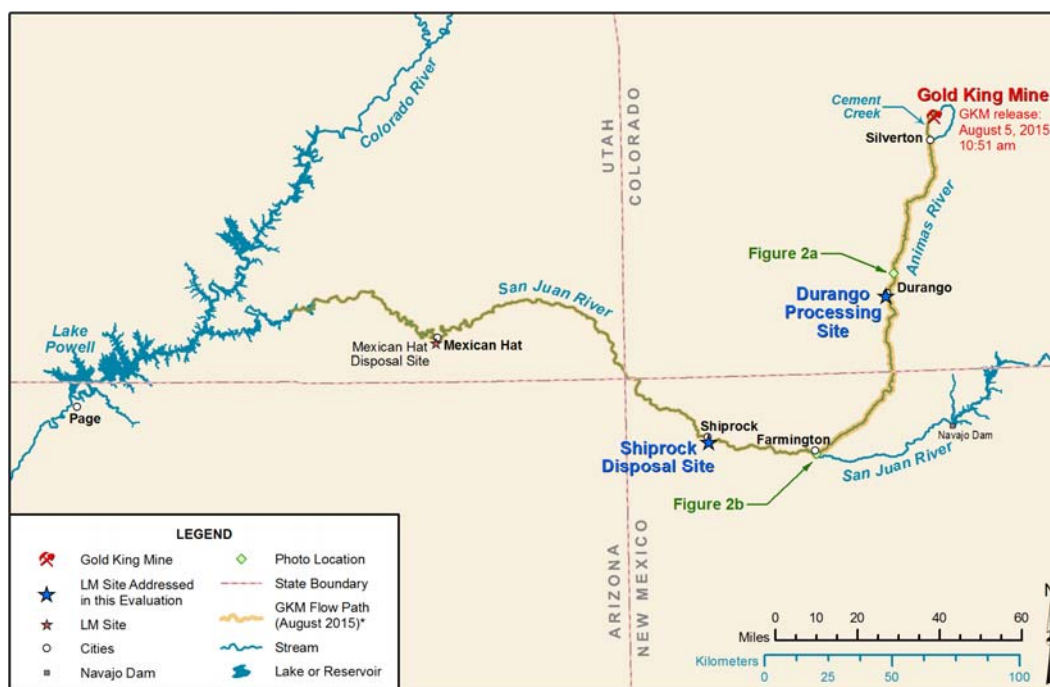
Analysis of GKM plume-related impacts to the Shiprock site was complicated by the distance of the site from the GKM release, the inability to detect a discernible plume in the river near the site, increased water flows from the Navajo Dam near Archuleta, New Mexico, and rain events. Although review of other agency data indicated slight increases in metals concentrations when comparing pre- vs. post-plume arrival sample results, these were of low magnitude and not sustained. As found for the Durango site, LM's evaluation of pre- and post-release groundwater data for the Shiprock site indicated no discernable change in concentration of any GKM plume-related metals.

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1.0 Introduction

On August 5, 2015, at approximately 11 a.m., a U.S. Environmental Protection Agency (EPA) field team investigating the Gold King Mine (GKM) above Silverton, Colorado, inadvertently triggered the release of an estimated 3 million gallons of acidic, mine-impacted waters to nearby Cement Creek, a tributary of the Animas River (EPA 2016b). Over an approximate 9-day period, the initially orange-tinted plume from the release flowed down the Animas River, past Durango, Colorado, joined the San Juan River at the confluence in Farmington, New Mexico, and ultimately reached the Colorado River at Lake Powell in Utah (Figure 1 and Figure 2). Along the Animas and San Juan River drainages lie two former uranium-ore processing sites managed by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I program: the Durango, Colorado, Processing Site and the Shiprock, New Mexico, Disposal Site, situated approximately 60 and 150 river miles downgradient of GKM, respectively.

At both of these sites, underlying groundwater contains milling-related constituents (primarily uranium) and there is a hydraulic connection with the adjacent rivers. At another LM site located near the San Juan River—the Mexican Hat, Utah, Disposal Site (Figure 1)—there is no such hydraulic connection (the site is 1 mile south of the river). This report documents LM’s evaluation of potential GKM plume-related impacts to the groundwater monitoring networks at the Durango and Shiprock sites. This work included a special (nonroutine) sampling event following the release, a review of GKM plume-related data and information compiled by EPA and other agencies, and a comparison of those results with monitoring data collected by LM. This work was performed under LM’s Applied Studies and Technology (AS&T) program in accordance with the Technical Task Plan (TTP) dated August 2015 (DOE 2015a).



* The reference to the GKM flow path in the map and legend above is consistent with EPA’s presentation in Figure 2-3 of the GKM Transport and Fate Study (EPA 2017).

Figure 1. Location of LM UMTRCA Title I Sites Relative to Gold King Mine Impacted Drainages



(a) Flyover view of Animas River segment approximately 10 miles north of Durango processing site, August 6, 2015 (view to south). *Source:* EPA 2017, Figure 4-13B (Bruce Gordon EcoFlight).



(b) Animas River and San Juan River confluence at Farmington, NM, August 8, 2015 (view to east). *Photo courtesy of The (Farmington, N.M.) Daily Times.*

*Figure 2. Photographs of Gold King Mine Plume in Animas River
(a) North of Durango and (b) at Animas River–San Juan River Confluence*

1.1 Purpose and Objectives

The purpose of this report is to assess what, if any, short- or long-term impacts the GKM release may have had at the Durango and Shiprock sites, in particular on the groundwater monitoring network. In accordance with Goal 1 of LM's Strategic Plan (DOE 2016a), LM performs long-term monitoring of groundwater and surface water at both sites to ensure protection of human health and the environment. There has been no evidence of adverse impacts to adjacent rivers as a result of former milling activities since cleanup was completed at the Durango and Shiprock sites (in 1991 and 1986, respectively). As part of the LM objective to ensure protection of human health and the environment, regular (annual or semiannual) groundwater monitoring has been ongoing at both sites for over a decade. The proximity of the Durango and Shiprock sites to the Animas and San Juan rivers, and the hydraulic connection between those site groundwater systems and rivers, warranted this investigation.

1.2 Background

To provide a context for this evaluation, this section provides background information regarding the GKM history, the August 2015 release event, and an overview of the Durango and Shiprock sites. Church et al. (2007) undertook a detailed investigation of historical mining and resulting environmental effects in the Animas River watershed. Others (e.g., BOR 2015, EPA 2017) provide additional information regarding historical mining impacts and the GKM release; only a brief overview is provided here.

1.2.1 Gold King Mine History

Historical Mining in the Animas River Watershed

The Gold King Mine is one of many mines located in a highly mineralized region of the San Juan Mountains known as the Silverton caldera. It is one of 48 mines that comprise the Bonita Peak Mining District,¹ where releases from historical and ongoing mining operations—referred to herein as acid mine drainage (AMD)—have occurred for over a century and impacted three drainages in the region: Mineral Creek, Cement Creek, and the Upper Animas River. The Colorado Division of Reclamation, Mining and Safety began reclamation work at GKM in 2008 and—due to the poor water quality and high outflow rates observed there, about 300–480 gallons per minute—initiated a comprehensive treatment project in 2014 in conjunction with EPA (EPA 2016a, EPA 2017).

GKM Release

On August 5, 2015, an EPA field team was investigating the upper Gold King Mine, GKM Level 7, to assess ongoing AMD releases and the feasibility of further mine remediation. While attempting to excavate loose material that had collapsed into the mine entrance (adit), the material gave way, opening the adit, and pressurized water began leaking above the adit, which quickly grew into a flood that spilled into nearby Cement Creek, 8 miles north of the Animas River. The incident occurred at about 11 a.m.; over the next 9 hours, an estimated 3 million gallons of mine-impacted waters were released, scouring the surrounding hillside

¹ On September 9, 2016, the Bonita Peak Mining District was added to EPA's National Priorities List. (See <https://cumulis.epa.gov/supercpad/cursites/csinfo.cfm?id=0802497>) A map of the mines in this region can be found at <https://semspub.epa.gov/work/08/1777520.pdf>.

and the Cement Creek streambed. The primary environmental concern from the release was the short-term surge of AMD-containing sediment and heavy metals—estimated to be approximately 490,000 kilograms (kg), or 540 tons—which presented a potential threat to the downstream portions of the Animas River, the San Juan River, and Lake Powell (EPA 2016b, 2017). This metal load was dominated by several components, including iron and aluminum, which resulted in the characteristic yellow-orange color of the plume shown in Figure 2. EPA estimated that the bulk (99%) of the total metal load had been scoured from a waste pile outside the mine and the Cement Creek streambed, while only 1% originated from inside the mine. EPA characterized the volume of the release as being equivalent to 4–7 days of ongoing GKM acid mine drainage and the total metal mass that entered the Animas River as being comparable to that carried in 1–2 days of high spring runoff (EPA 2017).

Shortly after the incident, the U.S. Bureau of Reclamation (BOR) prepared a technical evaluation of the GKM incident (BOR 2015). In its report, BOR attributed the GKM release to a series of events, including the extension of the American Tunnel to the Sunnyside Mine, and the subsequent plugging of the American Tunnel, which lies just below GKM Level 7. BOR concluded that the ultimate cause of the GKM “mine blowout” was an inadequately designed closure of the mine adit in 2009, combined with a misinterpretation of groundwater conditions during attempts to reopen the adit in 2014 and 2015.

1.2.2 LM Site Overview

The Durango processing site and the Shiprock disposal site are 2 of 22 inactive uranium ore-processing sites managed by LM under the UMTRCA Title I program. Although these two sites differ in their respective milling history and compliance strategies, at both sites underlying groundwater contains elevated levels of constituents related to the former processing activities (uranium and sulfate are the primary contaminants). As such, both sites are subject to the groundwater quality and monitoring requirements established under UMTRCA—namely, the Title 40 *Code of Federal Regulations* Section 192 (40 CFR 192) groundwater quality standards. To assess compliance with these standards, LM performs routine water quality monitoring annually (usually in June) at the Durango site and semiannually (March and September) at the Shiprock site. The GKM release was the catalyst for a nonroutine sampling event undertaken at both sites on August 18, 2015, as well as the shutdown of the Shiprock site floodplain remediation (groundwater extraction) system. Additional information regarding the Durango and Shiprock sites is provided in Sections 4.0 and 5.0, respectively.

As a prelude to this report, Table 1 presents a chronology of the GKM release and subsequent events potentially relevant to this evaluation, including LM sampling efforts or actions in response to the release. This chronology was compiled based on information provided by EPA, the Mountain Studies Institute (MSI), the Utah Department of Environmental Quality (UDEQ), and BOR.

Table 1. Chronology of Events Potentially Relevant to This Evaluation

Date	Description	Data Source or Comment
August 5, 2015	Gold King Mine release occurs (10:51 a.m. MDT); EPA issues first press release at 11:26 p.m.	EPA 2015
August 6, 2015	The Animas River is closed to recreational users. The plume reaches Rotary Park in Durango at approximately 10 p.m., when the Mountain Studies Institute reported that the river became visibly turbid. A “substantial” spike of GKM-related metals and concomitant sharp decrease in pH occurred at this same time.	MSI 2016a, 2016b
August 7, 2015	EPA begins extensive sampling of surface water and sediment in Animas and San Juan rivers at locations shown in Figure 3. EPA initiates ASPECT (Airborne Spectral Photometric Environmental Collection Technology) flyovers to detect the leading edge of the plume. At 2:16 p.m., the leading edge of the plume was just south of the New Mexico border. To help dilute spill-related contaminants in the San Juan River, the U.S. Bureau of Reclamation increased water releases from Navajo Dam from 650 to 1300 cubic feet per second.	https://www.epa.gov/goldkingmine/emergency-response-monitoring-data-gold-king-mine-incident#map https://www.epa.gov/sites/production/files/2016-01/documents/action_memo_gkm_release.pdf http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=49968 Refer also to Figure 25
August 8, 2015	Plume reaches confluence of Animas and San Juan rivers in Farmington, NM, at 9 a.m. and reaches Kirtland, NM—approximately 20 miles east of Shiprock—around 4:00 p.m. UDEQ characterized the plume as being visually diluted, with the leading edge far less defined. Animas River water was reported as being “muddy with an orange tinge.” The plume in the San Juan River was moving at approximately 2.5–4 miles per hour. Based on these estimates, the plume probably reached the Shiprock site late evening August 8 or the dark of the morning on August 9.	EPA 2016a (figure titled “Gold King Mine Release Path,” showing results of ASPECT flyovers) https://www.epa.gov/sites/production/files/2016-01/documents/action_memo_gkm_release.pdf UDEQ http://www.deq.utah.gov/Topics/Water/goldkingmine/
August 9, 2015	The leading edge of the plume is no longer discernible from aircraft. From Farmington to the north, the Animas River is visibly clearing.	Shaun McGrath (EPA Region 8 Administrator), Animas River/Gold King Mine EPA Public Meeting, Durango, Colorado, August 9, 2015
August 11, 2015	Pumping wells and treatment system (wells 1089 and 1104, and Trench 1) on Shiprock floodplain turned off in response to restrictions issued by the Navajo Nation.	The pump at Trench 2 had been shut off for some time, since June 18 (DOE 2015b). Pumps were left off until November 17, 2015.
August 18, 2015	LM sampling of surface water and near-river monitoring wells at Durango and Shiprock sites for AMD-related constituents.	This was a nonroutine sampling event, organized in response to the GKM release
September 2, 2015	EPA reports that metals concentrations in samples from Animas and San Juan rivers were “back to and maintaining pre-event levels.”	https://www.epa.gov/goldkingmine/emergency-response-monitoring-data-gold-king-mine-incident
September 22–24, 2015	Semiannual sampling performed at the Shiprock site.	Results of this sampling effort are documented in the 2015–2016 Annual Performance Report (DOE 2016b)
October 22, 2015	The Navajo Nation lifts use restrictions on water within the San Juan River system.	Memorandum from Russell Begaye, Navajo Nation (2015)

1.3 Scope of This Evaluation

In accordance with the AS&T Technical Task Plan that documents the scope of work (DOE 2015a), this report focuses on evaluating potential impacts of the GKM release to groundwater, and the associated monitoring or pumping networks, at the Durango and Shiprock sites. To do that—i.e., to understand what GKM plume-related metals might have entered the groundwater system—it was necessary to first examine potential impacts to surface water in the adjacent rivers.

At the Durango and Shiprock sites, LM regularly monitors for contaminants of concern (COCs) associated with former uranium milling, including uranium and sulfate. However, the evaluation in this report focuses primarily on constituents associated with AMD (e.g., aluminum, iron, lead, and zinc), and in particular on the metals comprising the bulk of the GKM effluent. At the outset (while developing the TTP), LM recognized that there would likely be little overlap between LM COCs and AMD-related constituents. For example, many of the elements likely associated with the GKM release have not been included in LM’s analytical program since the post-remediation site characterization work performed in the 1980s and 1990s (e.g., DOE 2000, DOE 2002b). Therefore, LM relied heavily on data from other agencies—primarily EPA, MSI, and The Rivers of Colorado Water Watch Network (River Watch)—especially when characterizing post-GKM plume impacts to surface water.

Results or trends for uranium milling-related constituents normally monitored by LM that do not overlap with GKM-related metals are not addressed here, as they are documented at length in routine data validation and monitoring reports that are readily accessible.²

Other endpoints evaluated by EPA and other agencies or organizations—for example, GKM release impacts to sediments or biota—are not addressed, except by way of summary. Although sediment samples were collected by EPA and other agencies following the GKM release, apart from work conducted during early site characterization efforts, this medium has not been sampled by LM. Additionally, in terms of assessing impacts to LM sites, there is probably not enough data to distinguish between GKM plume-related sediment impacts and the cumulative load resulting from historical mine drainage, especially in the Animas River watershed.

²Information regarding LM sites, as well as the UMTRCA program, can be found at <https://energy.gov/lm/sites/lm-sites>.

2.0 Methods

This section describes LM’s approach to evaluating potential GKM release impacts at the Durango and Shiprock sites. Section 2.1 describes LM’s sampling effort mobilized shortly after the release, Section 2.2 describes the overall technical approach used in evaluating the data, and Section 2.3 identifies the data gaps and uncertainties associated with this evaluation.

2.1 August 18, 2015, Special Sampling Event

Within 2 weeks of the GKM release—on August 18, 2015—LM performed a nonroutine sampling event at the Durango and Shiprock sites. Surface water and groundwater samples were collected at near-river locations considered most likely to be impacted by the GKM release. At the Durango site, three surface water locations and five monitoring wells were sampled (Section 4.0, Figure 11). The sampling scope was slightly greater on the Shiprock site floodplain because of the groundwater remediation (pumping) network in place there and (given historical known flow dynamics) the greater likelihood of surface water contaminants entering the groundwater system. At that site, four San Juan River locations and seven near-river shallow alluvial monitoring wells were sampled (Section 5.0, Figure 23).

In addition to the suite of COCs normally monitored (Table 2), samples were analyzed for AMD constituents considered most toxic to aquatic species: arsenic, cadmium, copper, lead, mercury, silver, and zinc (DOE 2015a). Total and dissolved constituent concentrations were measured in each sample. Sampling and analysis were conducted in accordance with LM’s *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351).³ Corresponding data review and validation reports are provided in Appendixes A and B for the Durango and Shiprock site sampling efforts, respectively.

2.2 Technical Approach

2.2.1 Analytes Evaluated

Table 2 provides a comparison of AMD-related constituents and LM site COCs and illustrates the general lack of overlap between metals dominating the GKM plume and the analytes routinely monitored at the Durango and Shiprock sites. In the summary of LM site COCs below, only manganese (shaded) is common to the major analytes comprising the GKM plume. Although the GKM effluent contained sulfate, a COC common to both sites, this analyte was not measured in most samples collected during the passage of the plume (EPA 2017).

Groundwater COCs at the Durango and Shiprock Sites

<u>Durango Mill Tailings Area</u>	<u>Durango Raffinate Ponds Area</u>	<u>Shiprock Floodplain</u>
<ul style="list-style-type: none">• Cadmium• Manganese• Molybdenum• Selenium• Sulfate• Uranium	<ul style="list-style-type: none">• Selenium• Uranium	<ul style="list-style-type: none">• Ammonia (as N)• Manganese• Nitrate (as N)• Selenium• Strontium• Sulfate• Uranium

³ <https://energy.gov/lm/downloads/sampling-and-analysis-plan-us-department-energy-office-legacy-management-sites>.

Table 2. Analytes Associated with Acid Mine Drainage and LM Site Contaminants of Concern

Constituent	GKM Primary	Analyte Common to EPA and LM Sampling	Durango Processing Site	Shiprock Disposal Site Floodplain	Comment
Aluminum	•				Not analyzed historically, nor in post-GKM water quality samples collected by LM. For this parameter, LM used data from other agencies.
Ammonia				•	Ammonia has been analyzed in Shiprock site samples only and is not addressed herein.
Arsenic		•			Limited historical data for LM sites; analyzed in 8/18/2015 and subsequent LM samples.
Cadmium		•	•		Cadmium is a COC at the Durango mill tailings area only, given the presence of a former smelting operation that preceded the mill.
Copper	•	•			
Iron	•				Iron was not analyzed in post-GKM water quality samples collected by LM.
Lead	•				
Manganese	•	•	•	•	Of the primary GKM-related parameters, manganese is the only constituent that overlaps with Durango and Shiprock site COCs. As such, it is probably the best tracer of GKM-related contamination.
Mercury		•			Although analyzed in LM samples collected during the 8/18/2015 nonroutine sampling, there were no measurable quantities of mercury released from the GKM spill (EPA 2017).
Molybdenum		•	•		
Nitrate				•	
Selenium		•	•	•	As illustrated later (e.g., Figure 8), selenium did not appear to be a good tracer of the GKM plume; many results were reported as BDL.
Silver		•			Until the August 2015 nonroutine sampling event, silver had not been analyzed at the Durango or Shiprock sites.
Strontium				•	Strontium is not associated with AMD, was not analyzed in EPA samples, and therefore is not evaluated here.
Sulfate	•		•	•	Although sulfate comprised a major proportion of the effluent mass (18,000 kg; EPA 2017), it was not analyzed in most surface water samples collected by EPA and other agencies.
Uranium			•	•	Uranium is the primary COC at both the Durango and Shiprock sites. It is not associated with AMD and, therefore, was not analyzed in most non-LM agency samples.
Zinc	•	•			

• Primary contaminant associated with the GKM discharge.

• Other constituent potentially associated with acid mine drainage analyzed in LM samples collected on August 18, 2015, and also included as a target analyte in EPA's GKM monitoring program.

• Durango processing site COC

• Shiprock disposal site (floodplain) COC

Abbreviation: BDL = below detection limits

To evaluate plume impacts, this report focuses first on the primary metals comprising the GKM effluent, listed here in order of relative mass as reported by EPA (2017): iron, manganese, aluminum, zinc, and copper (column 1 of Table 2). In terms of evaluating impacts to LM sites, manganese is considered the best “tracer” of potential GKM impacts, as (unlike other GKM metals) there are historical data for comparison. The nonmetal analyte sulfate would also be a good candidate in this regard, but it was analyzed in only a small fraction of samples collected by other agencies, precluding any meaningful evaluation of impacts. Less focus is given to the metals comprising a smaller portion of the effluent—e.g., arsenic and lead—but still elevated in media during the peak of the plume. Little to no focus is given to remaining Durango or Shiprock site COCs.

Uranium, the COC most common to LM UMTRCA sites, is not typically associated with historical acid mine drainage. Although not analyzed by EPA, uranium results reported by the Colorado Department of Public Health and Environment (CDPHE) for samples collected in the Animas River were all low: <0.0001 to 0.012 milligrams per liter (mg/L), less than both CDHPE’s 0.0168 mg/L health-based standard (Volume 5 *Code of Colorado Regulations* Regulation 1002-35 [5 CCR 1002-35]) and EPA’s Safe Drinking Water Act MCL (0.03 mg/L). Also, initial mapping of these data indicated no apparent spatial distribution. Uranium concentrations measured by CDPHE near the confluence of Animas River and Lightner Creek, closest to the Durango site, were 0.0006 and 0.0005 mg/L for total and dissolved fractions, respectively.

2.2.2 Data Sources Used

Because of the lack of overlap between GKM constituents and UMTRCA site COCs, and to frame this evaluation, LM relied heavily on data from other agencies, most notably the U.S. Geological Survey (USGS) (for river flow and elevation data), EPA, MSI, River Watch, and CDPHE. Although LM did not use data collected by UDEQ (its sampling focused on points downstream of the Shiprock site), the information posted on its website regarding conditions in the San Juan River and approximate arrival times of the GKM plume was helpful (e.g., see August 8, 2015, entry in Table 1).

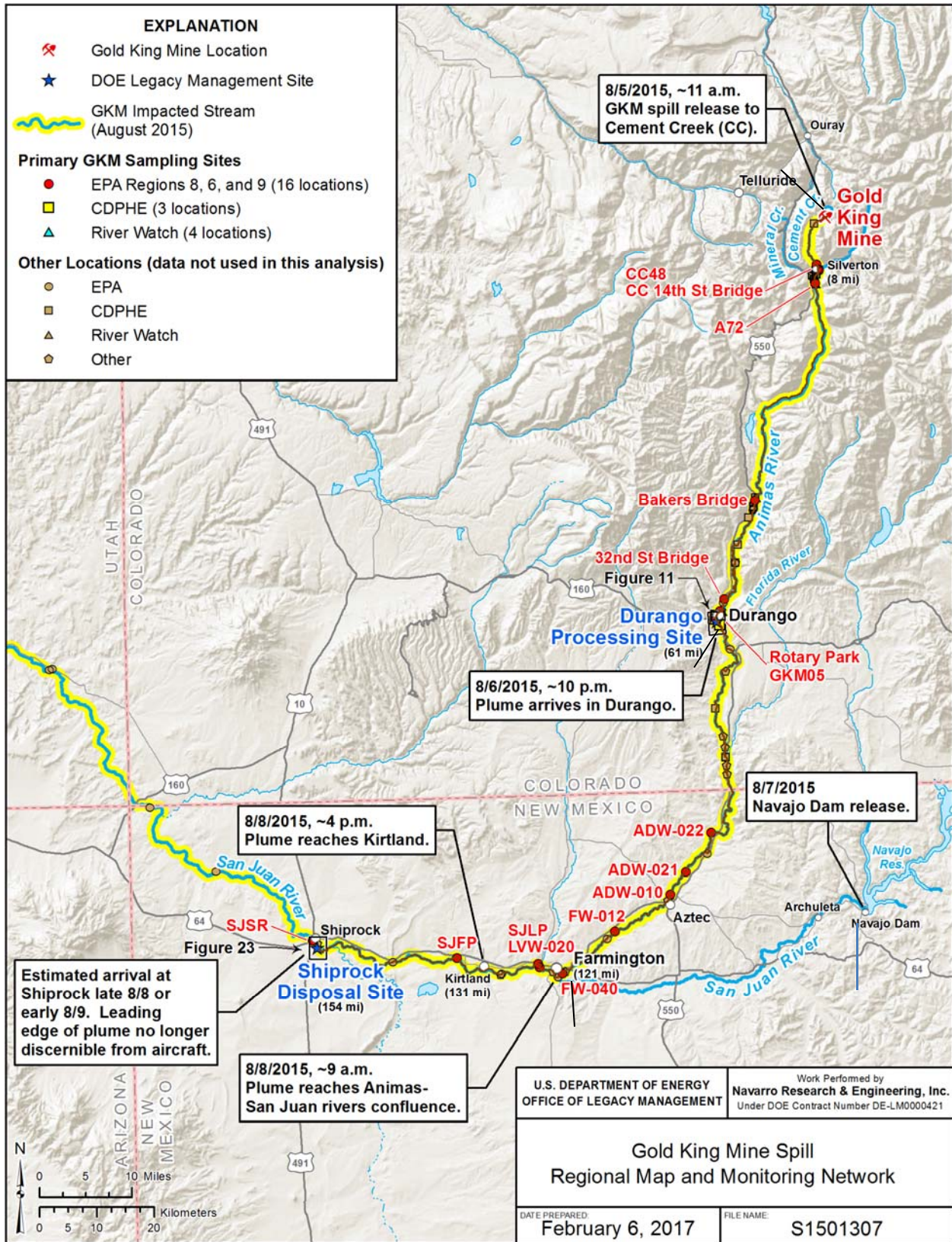
Table 3 documents the primary data sources used in this evaluation. Corresponding sample locations are shown in Figure 3. Although hundreds of locations of multiple environmental media (surface water, sediments, and groundwater) were sampled by various agencies, this evaluation used only the surface water sampling results. This allowed LM to better assess surface water impacts adjacent to the Durango and Shiprock sites, given the lag between the GKM release and LM’s (8/18/2015) special sampling event. Of the close to 35 sample locations monitored by EPA between the GKM and Shiprock as part of its emergency response sampling, data from only 16 locations were used (denoted by larger red symbols in Figure 3). The criteria for choosing these 16 locations were: (1) sufficient number of samples for evaluation of temporal trends (e.g., ≥ 10); (2) proximity to the Durango or Shiprock sites; (3) descriptive information provided in EPA’s Conceptual Monitoring Plan (EPA 2016c); or (4) the availability of late 2015 and 2016 EPA follow-up data. EPA’s analytical data, which comprised the majority of the data set, were supplemented by data from CDPHE, MSI, and River Watch. Data from the latter two agencies were instrumental in assessing pre- vs. post-GKM plume river characteristics.

Table 3. Data Sources Used in This Evaluation

Agency and Related Information	File Description	Comments, Hyperlink
EPA Emergency Response Data^a		
EPA Region 8 (Colorado and Utah) "Region 8 Surface Water Cumulative Table"	16 stations between GKM and just south of Durango	https://www.epa.gov/sites/production/files/2015-10/r8_surfacewater_cumulative_10282015.xlsx 8/5/2015 (13:45) through 10/1/2015
EPA Region 6 (New Mexico) "Region 6 Surface Water Cumulative Table"	12 locations between CO–NM border and just west of the Animas–San Juan rivers confluence	https://www.epa.gov/sites/production/files/2015-10/r6_surfacewater_cumulative_10282015.xlsx Data from 12 locations, south of CO–UT border to just downgradient of Animas–San Juan rivers confluence: 8/6/2015 (17:50) through 10/14/15
EPA Region 9 (Arizona and Navajo Nation) "Region 9 Surface Water Cumulative Table"	32 stations, only 4 of which are potentially relevant to this study	https://www.epa.gov/sites/production/files/2015-10/r9_surfacewater_cumulative_10282015.xlsx SJSR station (near Shiprock) is most relevant; three stations between Farmington and Shiprock potentially relevant; remaining stations (to Lake Powell) are beyond Shiprock 8/7/2015 (11:30) through 9/30/2015
EPA Follow-Up Data^b		
EPA (fall 2015 data)	27 locations	Fall 2015 Follow Up Monitoring Data (XLSX)
EPA (March 2016 data)	30 locations	March 2016 Follow Up Monitoring Data (XLSX)
EPA (June 2016 data)	31 locations	June 2016 Follow Up Monitoring Data (XLSX)
USGS Data		
USGS station 09361500 Animas River at Durango, CO	15-minute flow data	Summary of station data found at: http://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=09361500&agency_cd=USGS pH, specific conductivity, and turbidity data were not collected until April 2016
USGS station 09368000 San Juan River at Shiprock, NM	15-minute flow data; historical water quality data	Summary of station data found at: http://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=09368000&agency_cd=USGS and https://water.usgs.gov/owq/gkm/wq.html
Other Data		
The Rivers of Colorado Water Watch Network (River Watch)	Four locations (Cement Creek, A72, Bakers Bridge, Hatchery near Durango)	These data were instrumental in evaluating pre-GKM release water quality at select locations (River Watch 2016)
Mountain Studies Institute	Durango Rotary Park water quality data	2015 data provided by Scott Roberts; 2016 data downloaded from MSI website http://www.mountainstudies.org/goldkingspill/
CDPHE	Post-GKM release data for select Animas River locations	https://www.colorado.gov/pacific/cdphe/animas-river-water-quality-sampling-and-data Only data for stations near Durango were evaluated in this analysis. Additional information provided in CDPHE 2016.

^a <https://www.epa.gov/goldkingmine/emergency-response-monitoring-data-gold-king-mine-incident#samplingdataresults>.

^b <https://www.epa.gov/goldkingmine/follow-monitoring-data-gold-king-mine-incident>.



Note: Due to the density of sample locations in or near Silverton and Durango, CDPHE and River Watch locations are not apparent in this figure. The A72 and Bakers Bridge locations were sampled by both EPA and River Watch (only EPA symbols are shown here). Figure 11 and Figure 23 provide more detail for the Durango and Shiprock sites, respectively.

Figure 3. Gold King Mine Release Regional Map and Surface Water Monitoring Network

2.2.3 Data Evaluation and Presentation Approach

The following numbered items outline the overall approach used to assess potential GKM-related impacts to the Durango and Shiprock LM sites.

1. First, it was important to characterize the composition of the GKM release: what constituents comprised the spill effluent? Initially, this information was not readily available, and EPA did not publish its findings until early 2017, after this report was prepared (LM relied instead on interim fate and transport data posted on EPA's GKM website). This step allowed LM to focus the analysis on those constituents most likely to be indicative of plume impacts.
2. Second, to frame the evaluation and to characterize GKM plume impacts at various points along the Animas and San Juan river drainages, LM evaluated the progression of the plume using data from the 16 primary EPA sampling locations, denoted by red symbols in Figure 3. To help establish baseline (pre-release) conditions between GKM and Durango, historical data provided by River Watch were also utilized.
3. Third, when did the GKM plume arrive at the Durango and Shiprock sites? This was assessed by evaluating different agency websites, EPA's memoranda regarding the release (EPA 2016a), and Airborne Spectral Photometric Environmental Collection Technology (ASPECT) flyover results (Table 1 and Figure 3).
4. Fourth, what did the river hydrology data indicate in the Animas and San Juan river systems before (for historical context), during, and after the release? For example, what were the flow rates, or rates of discharge, in the rivers at various points in time?
5. To characterize potential GKM plume impacts to surface water adjacent to the Durango and Shiprock sites, LM then evaluated corresponding non-LM agency data (Figure 3), including those from Rotary Park and location GKM05 in Durango (Figure 11), and the SJSR station just west of the Shiprock site (Figure 23). This step was necessary because LM's nonroutine (August 18, 2015) sampling event took place 13 days after the GKM release: about 12 and 9 days after the plume's estimated arrival at the Durango and Shiprock sites, respectively.
6. Evaluate LM surface water sampling results, comparing results from the August 2015 nonroutine sampling with historical data (where available) and subsequent results from routine (semiannual or annual) monitoring events. Limited conclusions could be drawn based on these comparisons because of the general lack of overlap between site COCs and GKM-related parameters (necessitating steps 2 and 5).
7. Assess surface water-groundwater interaction at the time of plume arrival—was the river losing or gaining to the aquifer? For the Durango site, LM relied on generalized historical comparisons of river and groundwater levels. At the Shiprock site, LM was better able to assess these interactions using data from a nearby USGS gage and elevation data from a near-river well where groundwater levels are continuously monitored.
8. Evaluate LM groundwater sampling results, comparing historical results to the August 2015 and subsequent routine sampling results. As was the case for surface water, for some metals, there were large gaps between historical sampling events, precluding any statistical comparison of pre- versus post-GKM plume data.

To provide a context for evaluating the data, Animas and San Juan river sample results were compared to the surface water quality standards listed in Table 4 and LM's groundwater analytical results were compared to corresponding 40 CFR 192 groundwater quality standards developed under the UMTRCA program (Table 5).

Data plots and related graphics were developed using R version 3.3.2 (R Core Team 2016) and the ggplot2 package, version 2.2.0 (Wickham 2009). Because of the wide range in metals concentrations reflected in many of the figures herein, in most cases data are plotted using a logarithmic scale. In some cases, this plotting approach may mask relative magnitudes when making spatial or temporal comparisons.

2.3 Data Gaps and Uncertainties

The general lack of overlap between the COCs typically monitored by LM and GKM plume-related constituents limited LM's ability to draw definitive conclusions regarding GKM impacts. Because of this lack of overlap, LM relied on data from other agencies, most notably EPA's emergency response sampling. Compiling a data set that was comprehensive and easily reproducible was challenging, as agency databases differ in their structure, terminology, and reporting (e.g., handling of below detection limit results). Although LM reviewed thousands of records from EPA and the other organizations listed in Table 3, given the broad interagency scope of post-GKM sampling, it is possible that some relevant data were overlooked.

The assessment of plume impacts—as evidenced by increases in metals concentrations at various locations—was further complicated by the overall lack of pre-GKM release river water chemical data. For example, the EPA sampling station closest to Durango, GKM05 (shown in Figure 3 and Figure 11), was not sampled until 36 hours after the plume had passed. The varying plume arrival times also affected comparisons of data across locations, progressing downriver in the Animas and San Juan river drainages.

Although the TTP prescribed an assessment of statistical “significance” regarding both short- and long-term spill-related impacts, this was not possible because of the data gaps mentioned above. This evaluation focuses mostly on short-term impacts—i.e., what were the findings during or after the peak of the plume? Prediction of the fate of GKM-contaminated sediments within the Animas and San Juan river drainages is beyond the scope of this report. However, in its one-year summary report, EPA acknowledges that any GKM metals deposited in the sediment and remobilized during spring runoff or heavy rains may be difficult to (statistically) distinguish from historical and ongoing contamination (EPA 2016b).

Table 4. Surface Water Quality Standards and Background Reference Values for Metals and Sulfate (all units in mg/L unless otherwise noted)

Constituent	CDPHE Water Quality Standard ^a	NNEPA Agricultural Water Supply Standard ^b	Maximum Detected at LM Durango Site Background Location 0652 ^c	Maximum Detected at LM Shiprock Site Background Locations 0898/0967 ^c	EPA Recreation Risk-Based Screening Level (RSL) ^d
Aluminum	No standards other than for aquatic life, which vary based on hardness. For context, in some plots, a hardness of 185 mg/L is used, corresponding to acute and chronic criteria of 7.9 and 1.1 mg/L, respectively ^e	5.0 (D)	NA	NA	170 (D)
Arsenic	0.1 agriculture (30-day) 0.14 aquatic life chronic 0.34 aquatic life acute	2.0	0.001 (Jun 1999)	0.002 (Jul 2000)	0.05 (D)
Cadmium	0.01 agriculture (30-day)	0.05	0.002 (Nov 1993)	0.003 (Jul 2000)	0.083
Copper	0.2 agriculture (30-day)	0.2 (D)	0.0055 (Nov 2000)	<0.0034	6.7
Iron	1.0 (T) aquatic life chronic	not listed	0.436 (Aug 2001)	0.353 (Jul 2000)	120
Lead	0.1 agriculture (30-day)	10.0	0.02 (Nov 1993)	0.003 (Jul 2000)	0.2
Manganese	0.2 agriculture (30-day)	not listed	0.21 (Nov 2000)	6.2 (Sep 2011)	7.8
Mercury	0.01 µg/L (fish)	NCNS	0.005 (Nov 1993)	NA	0.05
Molybdenum	0.3 agriculture (30-day)	1.0 (D)	0.01 (Nov 1993)	0.009 (Jul 2000)	0.83
Selenium	0.005 aquatic life chronic 0.018 aquatic life acute 0.02 agriculture (30-day)	0.02	0.005 (Nov 1993)	0.013 (Sep 2011)	0.83
Silver	Varies based on hardness	NCNS	NA	NA	0.837
Sulfate	--	not listed	144 (Nov 1993)	240 (Sep 2011)	--
Zinc	2.0 agriculture (30-day)	10.0	0.12 (Nov 1993)	0.015 (Jul 2000)	50

Notes:

^a CDPHE Water Quality Control Commission Regulation No. 31, The Basic Standards and Methodologies for Surface Water (5 CCR 1002-31), Table III (Metal Parameters). For metal parameters, most CDPHE acute and chronic standards for aquatic life vary on the basis of hardness. These are not listed here—only nonvarying (e.g., agricultural) standards are listed here. Also, only CDPHE’s agriculture and aquatic life standards are cited here. See http://ft.dphe.state.co.us/wqc/wqcc/Current%20Water%20Q...BasicStandards_SurfaceWater_Effective_06-30-2016.pdf.

^b Navajo Nation Environmental Protection Agency (NNEPA), 2008. NCNS = no current numerical standard. See <http://www.navajonationepa.org/Pdf%20files/Navaj...Water%20Quality%20Standards%202007.pdf>.

^c Background (upgradient) surface water locations are shown in Figure 11 and Figure 23 for the Durango and Shiprock sites, respectively. Because Shiprock location 0967 has only been sampled by LM since 2014, data from the previous background location, 0898, were also used (Section 5.2.3).

^d EPA risk-based screening level (RSL) for recreational exposure (from Appendix C, Table 2 of EPA’s Post-GKM Conceptual Monitoring Plan (EPA 2016c). These RSLs represent levels that are not expected to cause adverse effects based on a continuous 64-day (2 liters/day) exposure for recreational users. See <https://www.epa.gov/goldkingmine/epa-releases-additional-data-and-public-records-gold-king-mine-response>.

^e This assumption is consistent with that used by EPA in Table 7-1 of its fate and transport analysis (EPA 2017).

Abbreviations: -- = no standard; D = dissolved; NA = not analyzed historically at either the Durango or Shiprock sites; NCNS = no current numerical standard; RSL= risk-based screening level; T = total

Table 5. Groundwater Quality Standards for GKM Metals and Sulfate and LM Site COCs

Contaminant	40 CFR 192 Standard (mg/L)	EPA MCL or SMCL (mg/L)	Alternate LM Standard (mg/L)	Durango or Shiprock Site COC?	Standard Basis or Comments
Aluminum	--	0.05–0.2 ^a	--	No	EPA standard is based on aesthetic qualities (e.g., colored water).
Arsenic	0.05	0.01	--	No	
Cadmium	0.01	0.005	--	Durango mill tailings site only	
Copper	--	1.0 ^a	--	No	EPA secondary drinking water standard.
Iron	--	0.3 ^a	--	No	EPA secondary drinking water standard.
Lead	0.05	0.015	--	No	Although the mill tailings area coincides with the location of a former lead smelter, lead results for 132 groundwater samples collected between 1995 and 2002 were all <0.01 mg/L. Monitoring for this constituent was discontinued after June 2002.
Manganese	--	0.05 ^a	Shiprock background range: 0.016–7.2	Both sites	EPA secondary drinking water standard.
Mercury	0.002	0.002	--	No	Mercury is not a COC at either the Durango or Shiprock sites (Table 2).
Molybdenum	0.1	--	--	Durango mill tailings site only	Molybdenum is a COC for the Durango site only.
Selenium	0.01	0.05	0.0001–0.02	Yes (both sites)	The 0.05 mg/L cleanup goal is the EPA Safe Drinking Water Act maximum contaminant level.
Silver	0.05	0.1 ^a		No	Silver is not a COC at either LM site.
Sulfate	--	250 ^a	2000 (Shiprock)	Yes (both sites)	Sulfate is elevated in an onsite artesian well unaffected by former milling processes (DOE 2002a).
Zinc	--	5 ^a		No	

Notes:

^a EPA secondary drinking water standard or range (most based on aesthetic qualities).

-- Not applicable (no corresponding standard).

Groundwater quality standards were obtained from Ground-Water Protection Standards for Inactive Uranium Tailings Sites (40 CFR 192). EPA MCLs are also provided, as there are no UMTRCA standards for some of the metals listed above.

Abbreviations:

MCL = Maximum Contaminant Level (EPA drinking water standard)

SMCL = Secondary MCL

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3.0 Overview of GKM Plume Impacts

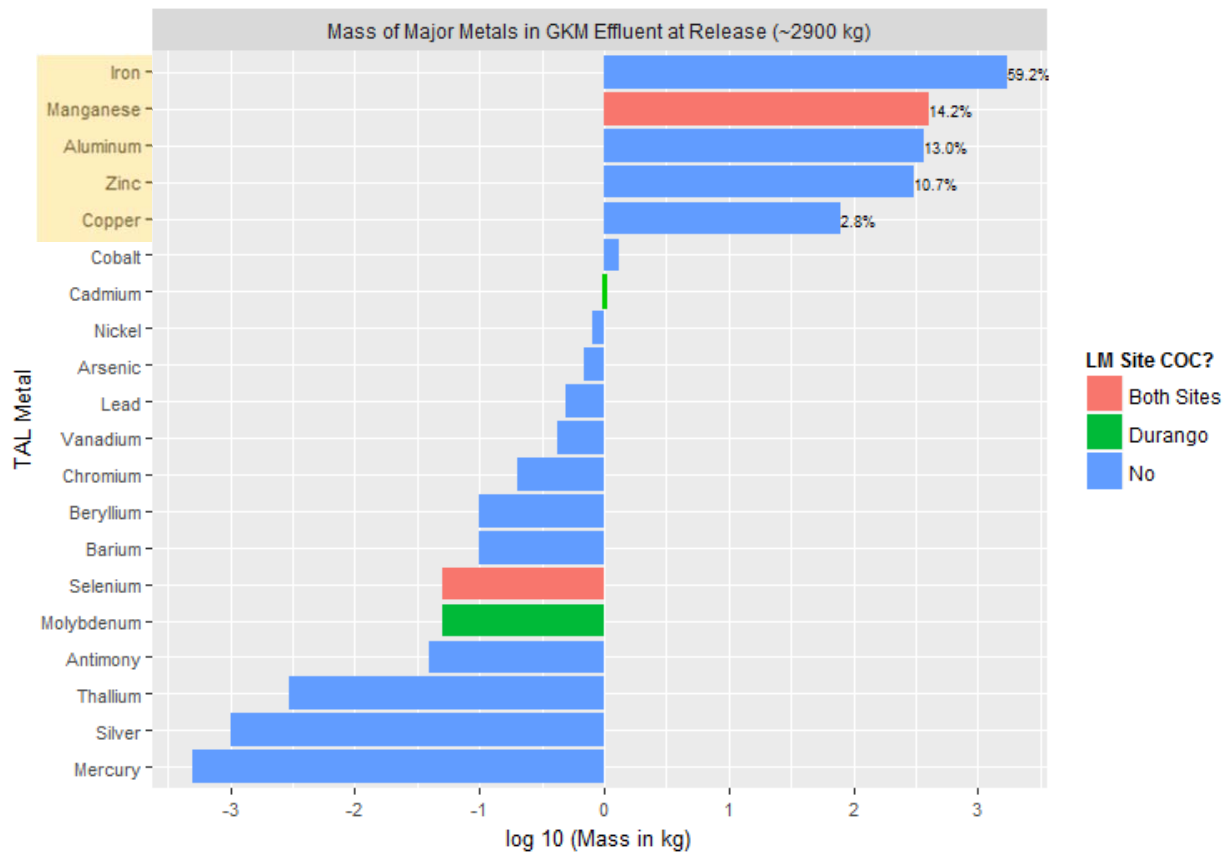
To frame this evaluation, this section provides an overview of the GKM plume. First, drawing upon data provided by EPA, the relative mass of metals in the mine pool or GKM effluent at the time of release is evaluated. After the release, the characteristic yellow-orange color of the affected drainages (later attributed to aluminum and iron) was evidence of the GKM plume front, but the magnitude or relative composition of the total metals load in those waters was not known. As an overview, data from select sampling points along the Animas and San Juan river drainages (Figure 3) are plotted for the August 2015 period following the release. To characterize the historical impacts of naturally occurring mineralization and mining in the Animas River watershed, this section concludes with a summary of pH and metals data that were helpful in assessing pre-GKM release, or baseline, water quality conditions. The bulk of this report, including all supporting data plots and analyses, was prepared before EPA issued the January 2017 GKM transport and fate analysis (EPA 2017). Therefore, some of the overview material presented in this section might overlap with EPA's published results.

3.1 Metals Composition of GKM Release

According to EPA's estimates, a total of 2900 kg of dissolved target analyte list (TAL) metals was released from the Gold King Mine (EPA 2017).⁴ The major TAL metals comprising the GKM effluent were, in order of relative proportion: iron (59%), manganese (14%), aluminum (13%), zinc (11%), and copper (3%) (Figure 4), referred to herein as "primary" GKM metals. Other TAL metals—including cobalt, cadmium, nickel, arsenic, and lead—were present in much smaller proportions. In Figure 4, the bars represent the mass of each TAL metal and are color-coded to denote commonality (or not) with COCs monitored at the Durango and Shiprock sites. Of the primary GKM metals, manganese is the only constituent that is monitored at both the Durango and Shiprock sites. Cadmium and molybdenum, comprising much smaller portions of the effluent, are monitored in select wells at the Durango site only.

While the metals contribution in Figure 4 is based on mass (in kilograms), that shown in Figure 5 is based on total and dissolved concentrations (in mg/L) measured in surface water collected from Cement Creek (14th Street Bridge location in Silverton). This was the first surface water sample EPA collected from Cement Creek after the GKM release. TAL metals concentrations in this sample were higher than those in any other surface water sample collected by EPA in the days following the release. Although Figure 4 and Figure 5 are not directly comparable (one shows mass in effluent and the other concentrations in water), they both indicate that iron, manganese, aluminum, zinc, and copper were major components of the plume. Based on TAL metals concentrations measured in the Cement Creek sample (Figure 5), total arsenic and lead were also prominent. Relative metals concentrations in the Cement Creek and Animas River samples (e.g., the higher proportion of lead) might differ from the composition of the GKM effluent because the release caused scouring of the surrounding hillside and Cement Creek, remobilizing AMD constituents historically deposited in the Cement Creek bed.

⁴ EPA calculated the metals mass in the mine pool, or effluent, by multiplying the volume of effluent (11.33 million liters, or 3 million gallons) by the concentrations of metals and other constituents measured in the effluent. This discussion, along with the supporting figure (Figure 4), is based on EPA's characterization of the GKM effluent provided in Section 3.3.3 of the January 2017 transport and fate analysis report (EPA 2017).



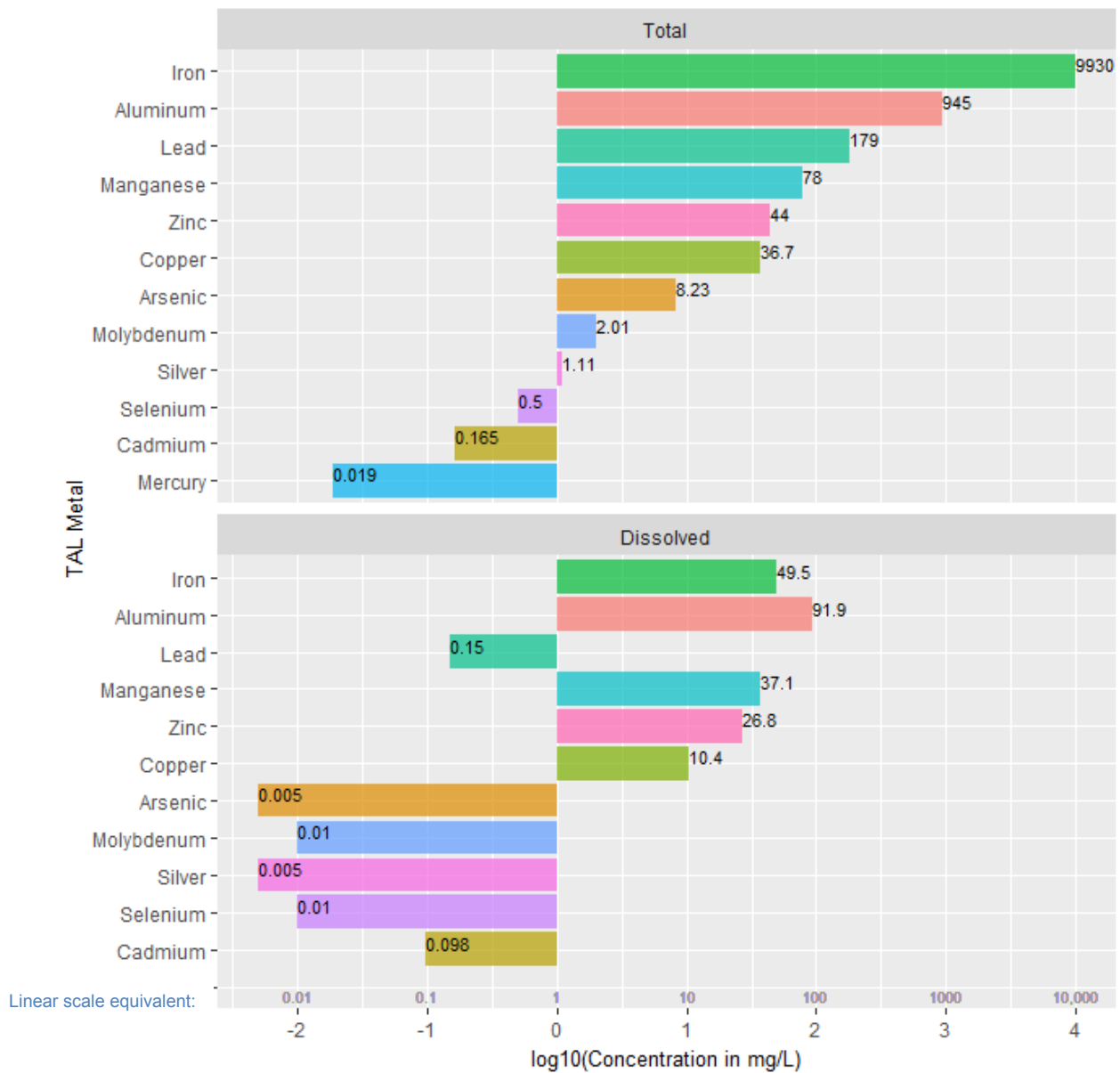
Notes:

In this figure, metals are listed in order of descending contribution to the total mass load based on the chemical makeup measured at the mine. A log scale is used to better show relative contributions of trace metals.

Gold shading denotes those constituents comprising the bulk of the majority of the total metals mass (>99%) in the GKM effluent, referred to as primary GKM metals herein

Data source: EPA 2017, Section 3.3.3, Figure 3-12: “Mass of total metals in effluent released from the Gold King Mine,” Figures 3-12c and 3-12d.

Figure 4. Masses of Major and Trace Metals in GKM Effluent Release



Notes:

In both (upper and lower) plots, metals are listed in order of descending contribution based on the total fraction (uppermost plot). This relative contribution is somewhat different for the dissolved fraction, as shown in the lower plot. Data from: https://www.epa.gov/sites/production/files/2015-10/r8_surfacewater_cumulative_10282015.xlsx, Cement Creek 14th St. Bridge location, Silverton, Colorado, sample collected 8/5/2015, 16:00, approximately 5 hours after the GKM release.

Figure 5. Metals Concentrations in August 5, 2015, Cement Creek 14th St. Bridge Surface Water Sample

3.2 Overview of GKM Impacts in Animas and San Juan River Watersheds

Figure 6 plots concentrations of the major GKM metals—iron, manganese, aluminum, zinc, and copper—measured in select Animas and San Juan river samples in August 2015, collected by EPA as part of its emergency response monitoring. Locations coinciding with the Durango (GKM05) and Shiprock (SJSR) sites are highlighted, and data are color-coded to reflect the number of days since the GKM release. This presentation is useful in only a general sense, because the plume arrived at each location at different times (refer to Table 1 and Figure 3). For locations closest to the mine, this arrival time is fairly well known. But farther down the drainage, especially in the San Juan River, the arrival time was not as clear. On the basis of EPA’s ASPECT flyovers, the plume front was no longer decipherable on August 9, the estimated day of arrival at the Shiprock site (Table 1).

Apart from the higher-magnitude metals concentrations measured at stations closest to GKM, no clear spatial or temporal trend is apparent. However, this figure does convey the magnitude of EPA’s sampling effort and the relative number of samples collected at each station (Rotary Park in Durango was sampled most frequently).

The progressive decrease in GKM metals in the uppermost portions of the Animas River drainage is more apparent in Figure 7, which plots metals concentrations over time (in August 2015) for select locations at or north of Durango that were most frequently sampled by EPA. Based on these data, GKM release impacts are most evident in samples from A72 (below Silverton) and Bakers Bridge, about 10 and 40 miles downstream of GKM, respectively. This is because at least one sample was collected before the plume passed. At these locations, within a day of the GKM release, primary GKM metals concentrations increased by 1 to nearly 3 orders of magnitude and then gradually declined. For example, at Bakers Bridge, total iron concentrations increased from 0.4 mg/L (8/5/2015) to about 330 mg/L (8/6/2015). (There were negligible differences in pre- vs. post-GKM-plume results for the dissolved iron fraction, however.) At this same location, manganese concentrations also increased, but to a smaller degree: only 1 order of magnitude in both total and dissolved fractions. The aforementioned spikes are not evident in the Cement Creek or the GKM05 samples, as the plume had already passed by the time EPA sampling began at those locations. What is apparent for all primary GKM metals is the progressive decline in both total and dissolved concentrations with increasing river distance from GKM, a finding that may reflect historical AMD impacts at locations upstream of Durango.

Figure 8 plots the remaining GKM metals that, on the basis of the effluent composition in Figure 4, comprised a smaller proportion of the metals load released to the Animas River (these are loosely referred to as “secondary” GKM metals in this report). In this figure, elevated levels of arsenic, cadmium, and lead indicative of GKM plume impacts are evident at a number of upstream locations in the Animas River watershed (CC48 to Rotary Park), in particular for the total (vs. dissolved) fraction. Downstream of Rotary Park, however, there are no discernible changes or patterns in the data distributions, using this plotting approach.⁵ Although LM analyzed post-GKM samples for mercury, selenium, and silver, Figure 8 illustrates the relative lack of impacts found for these constituents; most results were of low magnitude or not detected.

⁵ Again, in both Figure 6 and Figure 8, temporal patterns are not obvious due to different plume arrival times depending on location. As such, as stated in the introduction to this section, they are useful in only a general sense.



Notes:

: Vertical dotted line denotes change in drainage, from the Animas to the San Juan River (SJR).

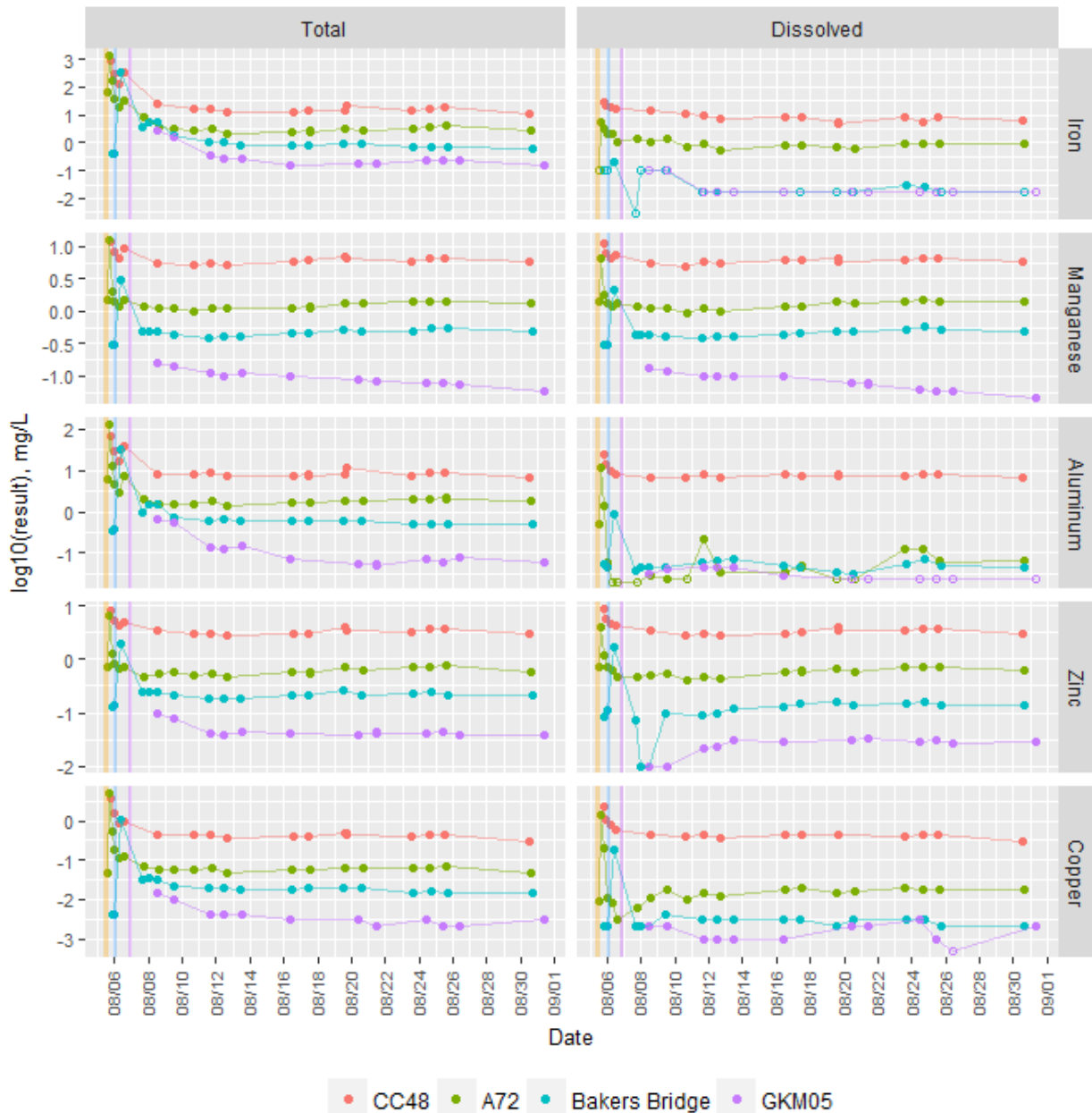
● Detected result. ○ Analytical result below the detection limit. The color of each point represents the time in days since the GKM release: the darker the point, the earlier in the month (see scale below).

Number of days since the August 5, 2015, 11:00 a.m. GKM release

Shaded locations coincide with the locations of LM sites—GKM05 coinciding with the Durango site and SJSR coinciding with the Shiprock site.

Metals are listed in order of relative proportion in GKM effluent (Figure 4). In some cases, results overlap, masking the number of data points collected. For example, although 35 samples were collected at Rotary Park in August 2015, iron was not detected in the dissolved fraction (all results were reported as <0.1 or <0.017 mg/L).

Figure 6. Major GKM Metals in Animas and San Juan River Surface Water Samples, August 2015



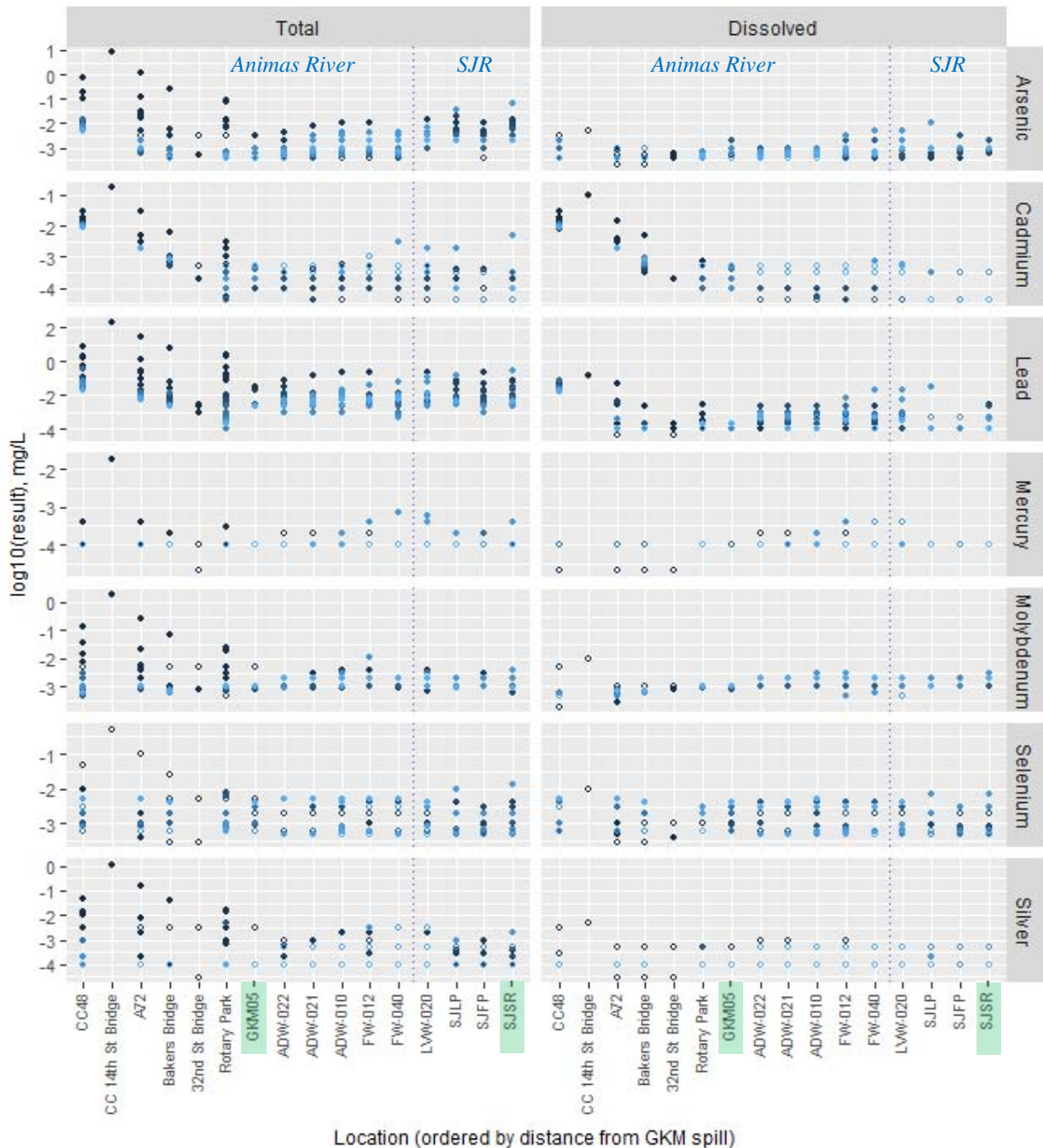
Notes:

In the legend, locations are listed in order of distance, or river miles (mi), downstream of GKM (Figure 3): CC48, Cement Creek (8 mi); A72 below Silverton (10 mi); Bakers Bridge (40 mi); and GKM05 in Durango (~60 mi).
 | First vertical line denotes August 5, 2015, ~11:00 a.m. GKM release; plume arrived at A72 by ~1:00 p.m.
 | Second vertical line denotes estimated plume arrival time at Bakers Bridge, ~2 a.m. on August 6, 2015 (EPA 2017).
 | Third vertical line denotes plume arrival time at Rotary Park in Durango, ~10 p.m. on August 6, 2015, as observed by MSI (MSI 2016a, 2016b).

This figure includes data for the most frequently sampled stations at or north of Durango based on EPA's Region 8 Emergency Response Monitoring Data (MSI's data for Rotary Park are not plotted here), https://www.epa.gov/sites/production/files/2015-10/r8_surfacewater_cumulative_10282015.xlsx.

Metals are listed in general order of relative proportion in GKM effluent (Figure 4).

Figure 7. Concentrations of Primary GKM Metals in Surface Water at Select Animas River Locations, August 2015

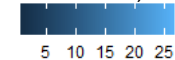


Notes:

: Vertical dotted line denotes change in corresponding drainage, from the Animas to the San Juan River (SJR).

● Detected result. ○ Analytical result below the detection limit.

The color of each point represents the number of days since the August 5, 2015, 11:00 a.m. GKM release (see scale below).



Shaded locations coincide with the locations of LM sites—GKM05 coinciding with Durango and SJSR with Shiprock.

As noted for Figure 6, in some cases results overlap, masking the number of data points collected. For example, except for locations closest to the GKM site, most results for mercury were reported as below the detection limit.

Figure 8. Secondary GKM Metals in Animas and San Juan River Water Samples, August 2015

To help characterize pre-GKM release, or baseline, water quality conditions in the Animas River watershed (at some locations reflective of historical AMD impacts), this section concludes with a summary of pH and metals data obtained from River Watch.

As discussed in Section 2.2.1, pH—a historical indicator of AMD—was not measured in samples collected during EPA’s emergency response monitoring. To evaluate the differences in water quality found in the region, we relied on data from MSI and River Watch (details provided in Table 3). Figure 9 plots pH for the period 2009–2016 for four locations that have been regularly monitored by these organizations: Cement Creek, A72 below Silverton, Bakers Bridge (about 40 miles south of GKM), and the Hatchery, just north of Rotary Park in Durango (Figure 3). Although this plot is not useful for identifying changes in pH during the release (River Watch collects samples monthly), it does illustrate the degraded water quality, with pH averaging about 3.5–4, that characterizes the Cement Creek drainage, reflecting natural acid rock drainage that has been exacerbated by mining. The variable pH found at location A72 is influenced by changes in flows (e.g., spring runoff) and mixing from Cement Creek, the upper Animas River, and Mineral Creek (with Cement Creek being the most acidic). Closer to Durango, at Bakers Bridge and the Hatchery, the pH is about 8.0, typical of non-AMD impacted stream conditions.

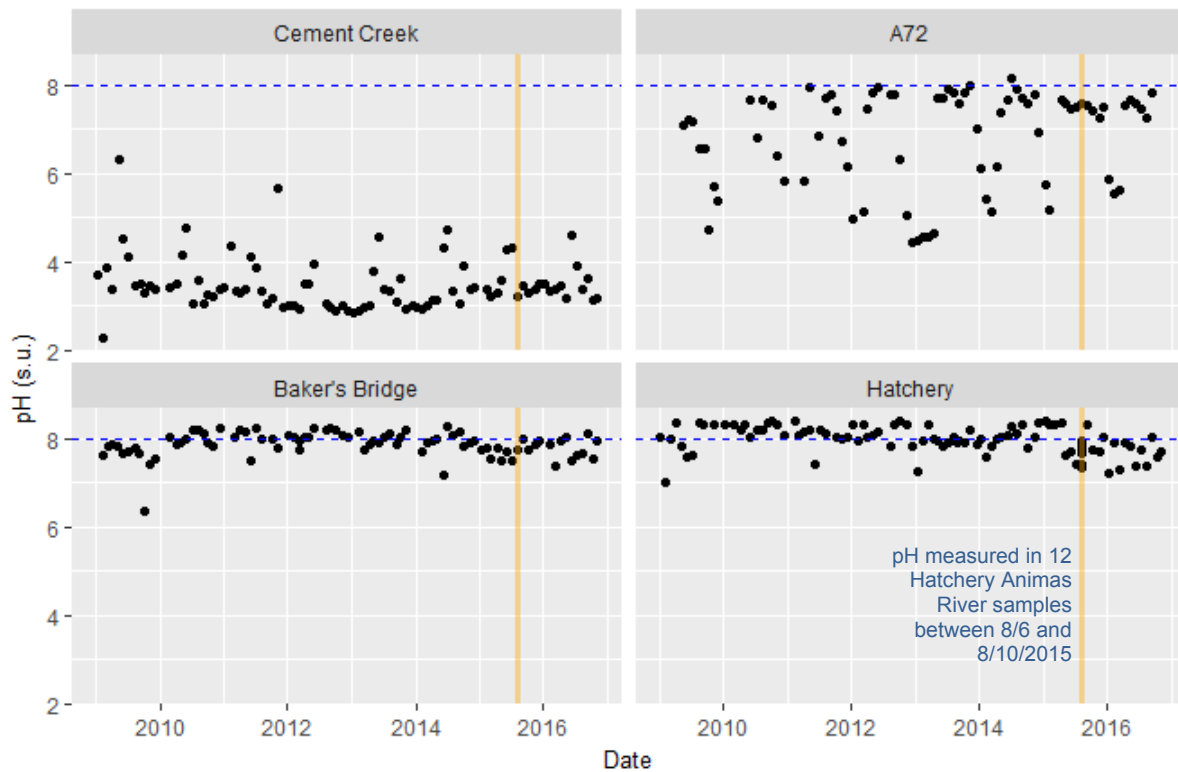
Figure 10 plots historical concentrations of major GKM metals at these same locations, again for the 2009–2016 period. In this figure, GKM plume-related spikes of short duration are evident for all metals. Also apparent in this figure is the relationship between the dissolved and particulate fractions. For example, most metals tend to stay dissolved under low pH conditions (e.g., in Cement Creek).

The primary conclusion to be drawn based on the data shown in Figure 9 and Figure 10 is that although short-term GKM plume impacts in the watershed are apparent (as evidenced by spikes coinciding with the release), water quality is degraded in the headwaters in this region, likely the combined effect of historical mining and naturally occurring mineralization.

3.3 Summary

EPA’s characterization of the GKM effluent (Section 3.1), combined with an evaluation of peak-plume impacts based on a sample data from Cement Creek, helped focus this analysis on the metals most likely to be indicative of plume impacts. The material presented in Section 3.2, although not directly relevant to LM’s evaluation of GKM impacts to the Durango and Shiprock site groundwater networks, was useful in assessing impacts to drainages adjacent to LM sites.

To assess impacts to groundwater, it was important to characterize impacts, if any, to the river system. Because of the approximate 2-week time gap between the GKM release and LM’s nonroutine sampling, LM relied on data from other agencies. On the basis of the data evaluated in this section, the following conclusions can be drawn: (1) GKM plume migration is evident at stations between the GKM and Durango, but less evident downstream, especially in the San Juan River; (2) GKM impacts appear to be short-term; and (3) the available data illustrate the longstanding impacts of acid mine drainage in the Cement Creek and Animas River drainages, most prominent in upstream reaches below the mine, declining gradually with decreasing distance to Durango.

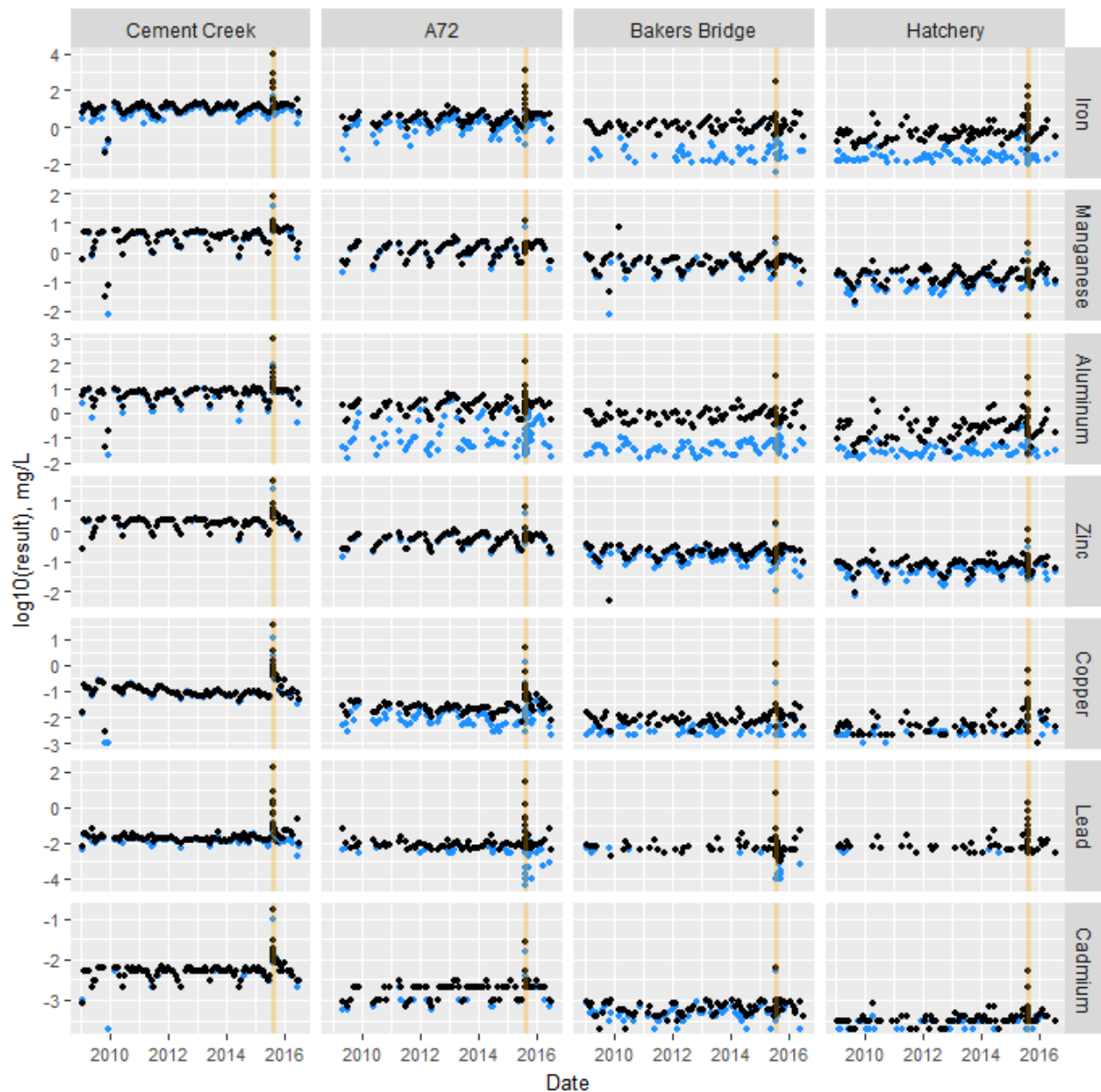


Source: River Watch (2016).

Notes:

--- Denotes average pH (8.0 s.u.) for nonimpacted river system. The 2009–2016 time period plotted here is consistent with the period of record (2009–present) used in EPA’s Conceptual Monitoring Plan (EPA 2016c).

Figure 9. pH in Cement Creek and Animas River at Select Locations, 2009–2016



Notes:

Fraction: ● total ● dissolved

Vertical line denotes August 5, 2015, GKM release.

In cases where total concentrations are similar or equal to corresponding dissolved results, the dissolved (●) result may be obscured by the total result in this figure.

Data set comprised mostly of River Watch data, supplemented by EPA and MSI data for GKM plume and post-plume period. River Watch data courtesy of Barb Horn (sent via email on 11/18/2016). Below detection limit (BDL) results were not included in this database (River Watch 2016).

Metals are listed in general order of relative proportion in GKM effluent (Figure 4). After the 8/5/2015 GKM release, data plotted for Cement Creek include EPA results for the 14th St. Bridge and CC48 locations.

Figure 10. Historical Concentrations of Major GKM Metals in Cement Creek and Select Animas River Locations, 2009–2016

4.0 Assessment of Potential GKM-Related Impacts at the Durango Processing Site

The Durango processing site is a former uranium-ore processing facility located approximately 0.25 mile southwest of the central business district of Durango. The site consists of two separate areas: (1) the mill tailings area, the setting of former uranium-ore milling and storage of mill tailings, as well as a lead smelter plant that operated before the uranium mill; and (2) a raffinate ponds area where liquid process wastes were impounded during milling operations (Figure 11). Both areas are located on the west bank of the Animas River.

Within 2 weeks of the GKM release—on August 18, 2015—LM sampled the following Durango site locations for AMD-related metals and site-related COCs (Table 2): three surface water locations (0652, 0584, and 0678), and five near-river groundwater monitoring wells (0857, 0866, 0631, 0612, and 0594). Wells 0857 and 0866, considered background wells for the mill tailings area (DOE 2014), were selected for this nonroutine sampling effort because of their proximity to the river (Figure 11). Following a brief overview of the site, this section evaluates relevant data collected from EPA and other agencies and then assesses LM’s post-spill sampling results.

4.1 Site Background

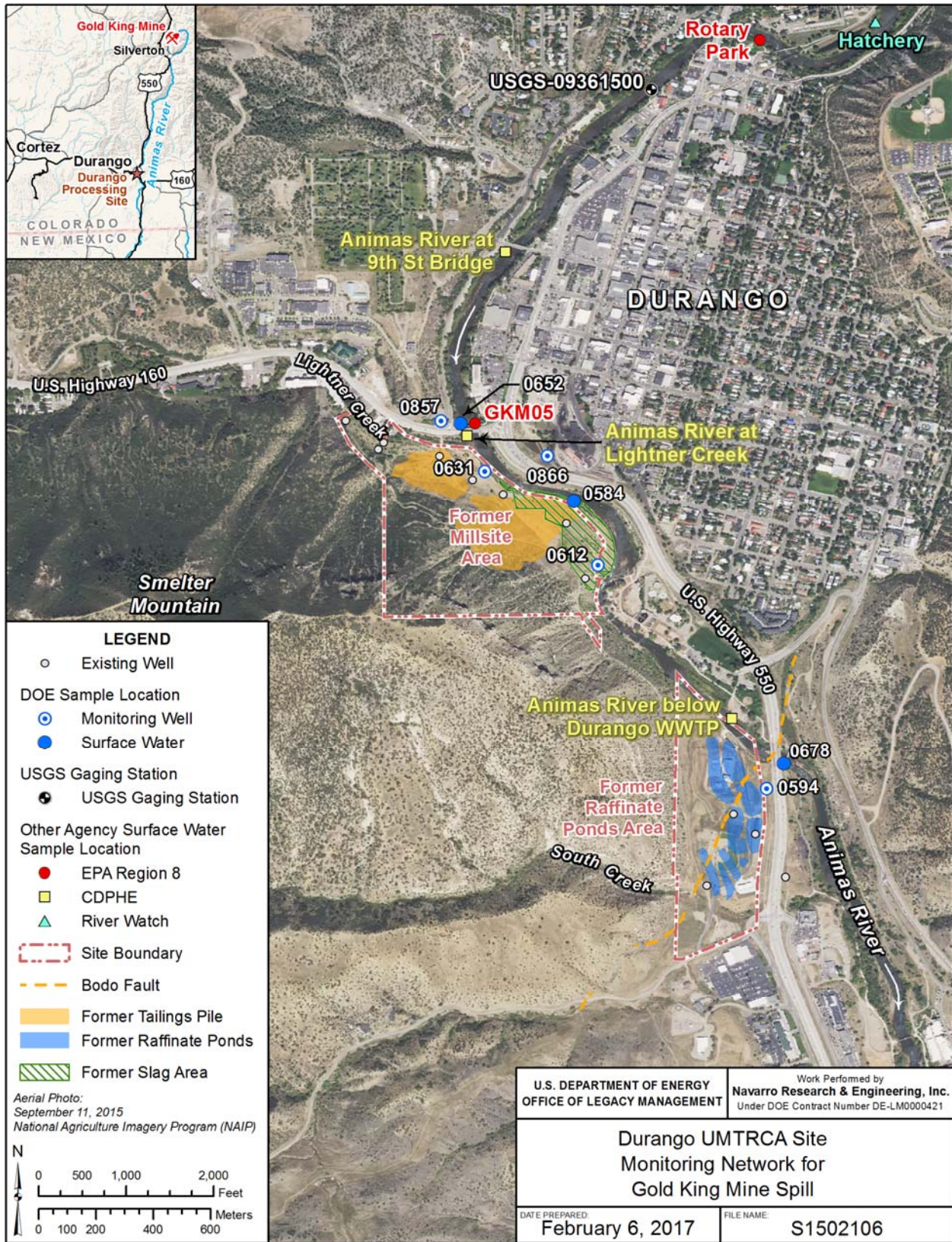
Because this report focuses on assessing potential impacts of the GKM release, only a brief overview of the site is provided here. Numerous reports documenting the site’s history, characterization, and monitoring efforts can be accessed via LM’s website.⁶ Primary historical site documents include the Site Observational Work Plan (SOWP), a comprehensive assessment of post-remediation site conditions and characteristics (DOE 2002b); the Groundwater Compliance Action Plan (GCAP), which documents LM’s strategy for groundwater cleanup at the site (DOE 2008); and Verification Monitoring Reports, which assess the progress of the groundwater remedy in achieving cleanup goals at the site (e.g., DOE 2014). Site data and sample location information, including well construction logs, can be found on LM’s Geospatial Environmental Mapping System (GEMS) website (<http://gems.lm.doe.gov/#site=DUP>).

Between 1949 and 1963, the former mill processed uranium ore for U.S. government defense programs. Surface cleanup of the site entailing the removal of approximately 2.5 million cubic yards of contaminated material took place between 1986 and 1991. Alluvial groundwater beneath the mill tailings area is contaminated as a result of constituents leaching from the tailings piles. Cadmium, molybdenum, uranium, and selenium are the primary COCs in the mill tailings area groundwater. Uranium and selenium are COCs at the raffinate pond area, but elevated selenium concentrations are not mill related and derive from natural geologic sources in the area.

The only metals regularly monitored by LM at the site that overlap with those measured in the GKM effluent are cadmium (remnant of a former smelting operation) and manganese. LM has been conducting annual (May–June) monitoring for site contaminants of concern (COCs)⁷ in groundwater and surface water at the site for well over a decade.

⁶ See <https://www.lm.doe.gov/Durango/Processing/Sites.aspx>.

⁷ Although the GCAP for the Durango site (DOE 2002b) uses the term “contaminants of potential concern” (COPC), the term COC is used here for consistency with terminology used throughout this report.



Note: In the weeks following the GKM release, CDPHE locations shown here were only sampled a few times, precluding any analysis of trends at those stations. Therefore, only the Lightner Creek location is used in this analysis. The Hatchery (River Watch) and Rotary Park (MSI) locations had much more data.

Figure 11. Durango UMRCA Site Monitoring Network, August 2015 Nonroutine Sampling

4.2 Relevant Data from Other Agencies

Using the general approach outlined in Section 2.2.3, this section presents relevant data from the USGS (river gage data) and other agencies to provide a context for subsequent analysis of LM sampling data. According to MSI, the GKM plume reached Rotary Park in Durango—about 1 mile upstream from the mill site—at approximately 10 p.m. the evening of August 6, 2015. This was evidenced by orange coloration of the water and spikes in concentrations of metals in the samples collected by MSI at that time (MSI 2016a, 2016b).

4.2.1 USGS Data: Animas River Flows Near Durango

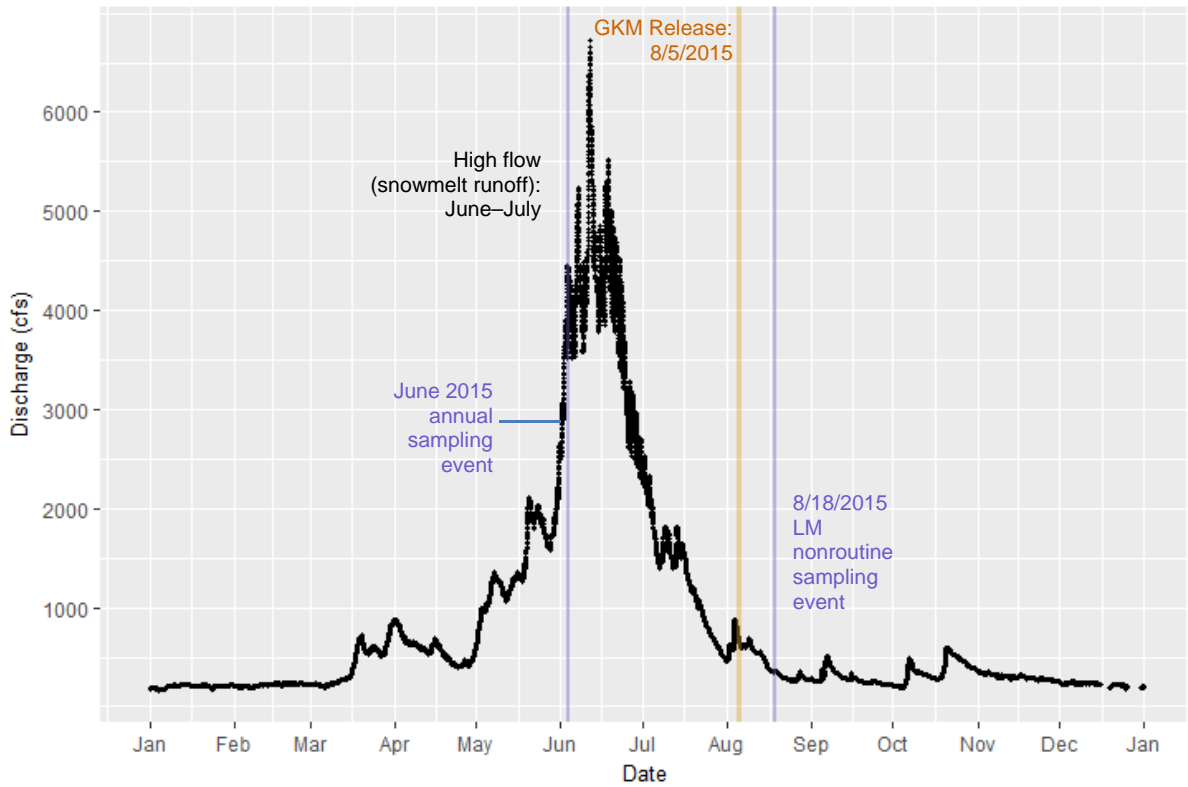
Figure 12 shows the discharge (flow rates) measured at the Durango Animas River gage in 2015. The uppermost plot (Figure 12a) shows the wide range in flows that occur in a given year. The high-flow period associated with snowmelt runoff in June–July is evident, when flows approached 7000 cubic feet per second (cfs). The smaller peaks likely reflect storm events, for example, the small monsoonal storms that typically occur in late summer. The lower plot (Figure 12b) zooms in on the August 1–20 period coinciding with the release event, when Animas River flows averaged about 600 cfs. The very slight 40 cfs increment between August 6 and midnight August 7 coincides with the plume period reported by MSI.⁸ However, this change in flows could just reflect normal variation. Overall, the GKM release occurred during relatively low flow conditions, as did LM’s subsequent sampling.

4.2.2 EPA, River Watch, and MSI Sample Results

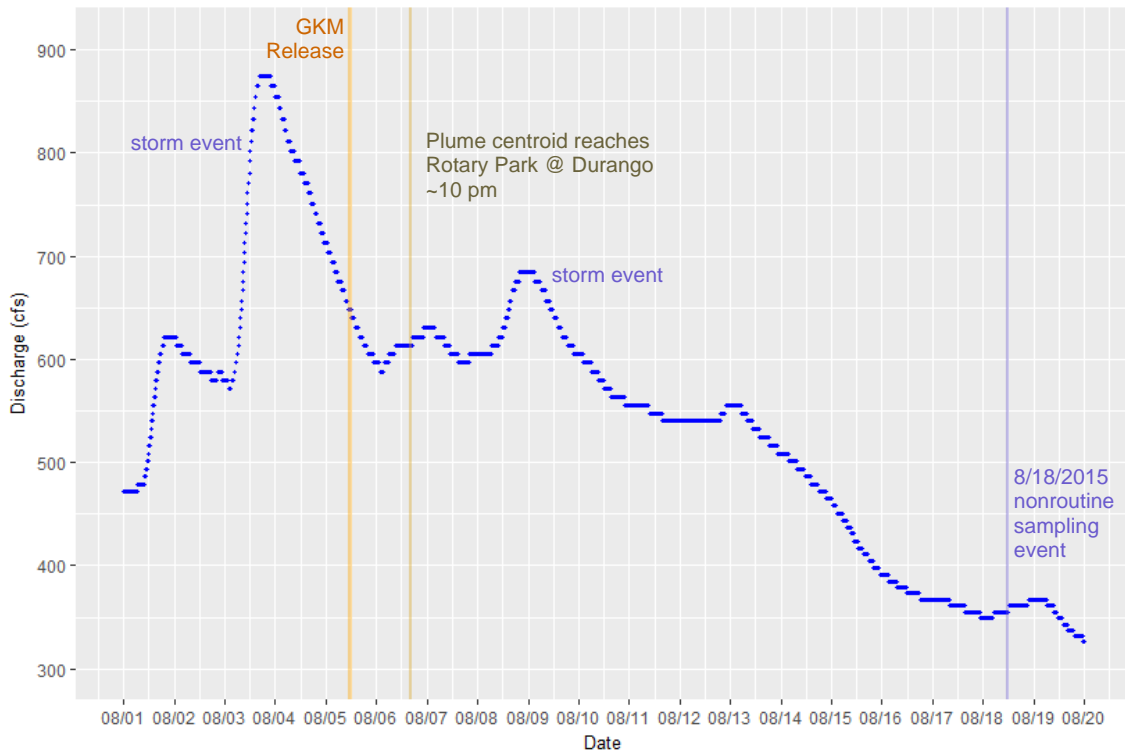
Figure 13 plots concentrations of GKM metals concentrations measured in surface water samples collected from four locations north of or within the Durango city limits: (1) Bakers Bridge, sampled by EPA and River Watch (20 miles north of Durango); (2) the Hatchery, sampled by River Watch only for several days after the release (northernmost point in Durango, 60 miles south of the GKM); (3) Rotary Park, extensively sampled by both MSI and EPA; and (4) GKM05, sampled by EPA and closest to the Durango site.

Although data from EPA location GKM05 would be most representative of metals in surface water potentially impacting the Durango site, Figure 13 also includes sampling results from more northerly locations to better illustrate the extent of impacts due to the release. EPA did not sample GKM05 until late morning August 8, 2015, about 36 hours after the plume front had passed. Although baseline conditions are not reflected here (refer to Figure 10), the impacts of the GKM plume are apparent. Concentrations of the major GKM metals—iron, manganese, aluminum, iron, and copper—were several orders of magnitude higher than those noted several days after the release. This is more the case for the total (suspended) fraction, as dissolved concentrations are notably lower. Data plots for location GKM05 are overlain with data from LM’s sampling and CDPHE’s sampling of the Lightner Creek location, showing close agreement between different agency results. Figure 14 includes the same data, but extends the time period to include follow-up data collected through 2016. In this figure, increases in total metals concentrations are evident due to spring runoff, but this trend is less discernible for the dissolved fraction that would most likely impact groundwater.

⁸ In its reports, MSI refers to the 26-hour time period from 10 p.m. on August 6, 2015, to midnight on August 7 as “the plume” and the August 8–9 period as the “initial recovery” (MSI 2016a, 2016b).

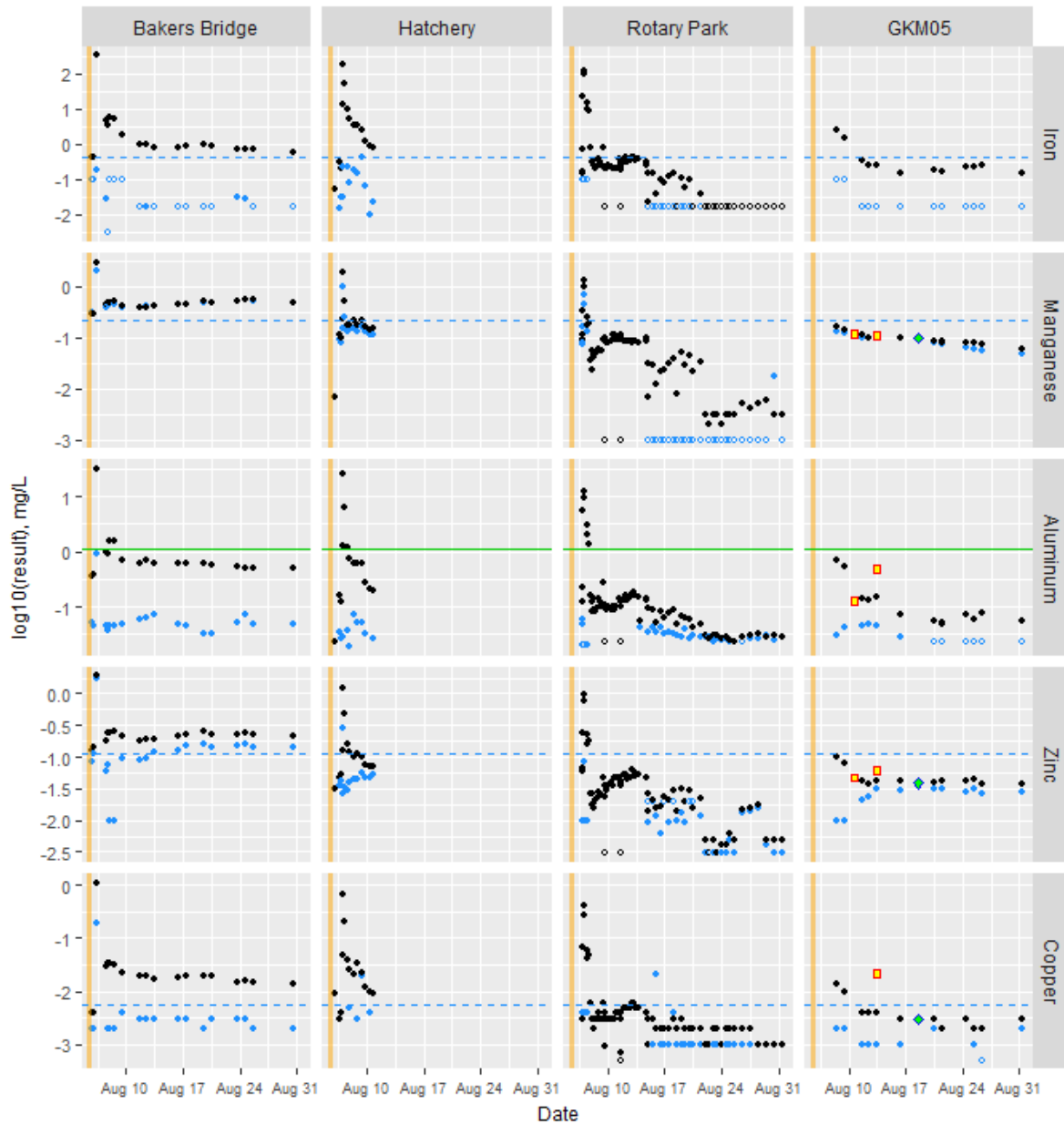


(a) Animas River Discharge at Durango During 2015



(b) Zoom View of Discharge, August 1–20, 2015

Figure 12. Animas River Discharge at Durango USGS Station 09361500, Year 2015



Notes:

Fraction: ● total ● dissolved

○ Analytical result below the detection limit

| Vertical line denotes August 5, 2015, GKM release

■ CDPHE Lightner Creek sample result ◆ LM 8/18/2015 sample result

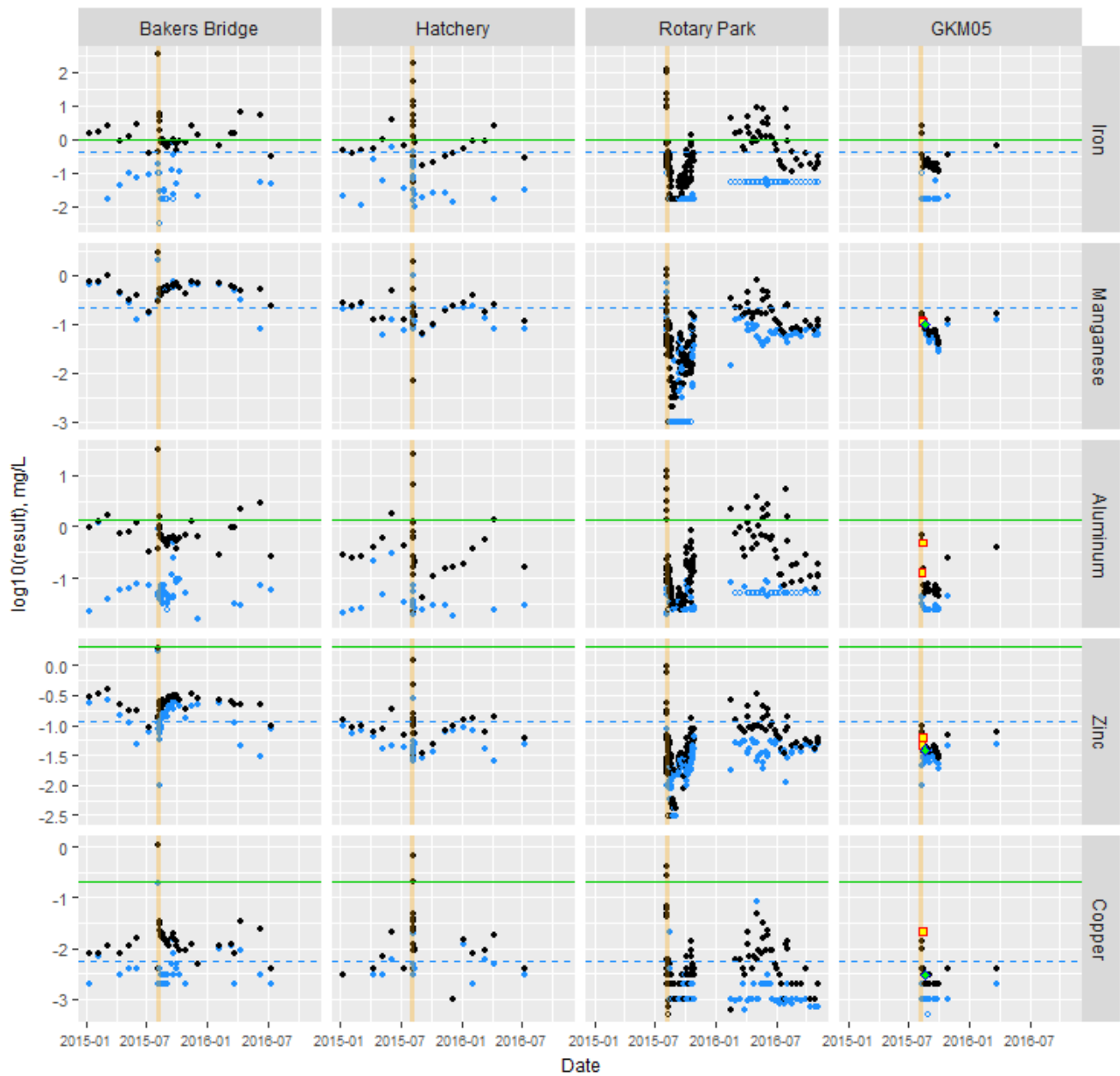
— Chronic standard for aluminum from Table 4

- - - Maximum concentration measured in Durango site background location 0652 (Table 4 and Figure 15)

Plots for Bakers Bridge and Rotary Park locations combine data from River Watch (2016) and EPA (Table 3).

Hatchery data are from River Watch (only). Data plotted for GKM05 are from EPA (only).

Figure 13. Concentrations of Major GKM Metals at Key EPA and Other Agency Durango Locations, August 2015



Notes:

Fraction: ● total ● dissolved

○ Analytical result below the detection limit

Vertical line denotes August 5, 2015, GKM release

--- Maximum concentration measured historically at Durango background location 0652

— Colorado standard (Table 4)

Plots for Bakers Bridge and Rotary Park locations combine data from River Watch (2016) and EPA (Table 3).

Hatchery data are from River Watch (only). Data plotted for GKM05 are from EPA (only).

Figure 14. Concentrations of Major GKM Metals at Key EPA and Other Agency Durango Locations, 2015–2016

The purpose of the preceding evaluation of non-LM agency data, and that of the following sections (Sections 4.3 and 4.4.1), is to provide a context for evaluating impacts to groundwater at the site. For example, if adjacent surface water is minimally impacted from the GKM release in terms of magnitude or duration, then the probability of significant plume-related contamination entering the groundwater system is likely low, especially if flow conditions are not conducive to surface-groundwater interactions (i.e., if the aquifer is losing to the river).

4.3 LM Surface Water Sampling Results

Figure 15 plots historical total and dissolved metals concentrations in the subset of Durango site surface water locations sampled on August 18, 2015. This figure illustrates the relative lack of data for most GKM metals: data for zinc, copper, arsenic, lead, silver, and mercury are very limited. However, in most cases results are consistent with historical observations. Because of the date scale in Figure 15 (necessary to capture all available data for comparison), the time frame encompassing the most recent measurements appears compressed. Note that the last three sampling dates plotted here are June 2–3, 2015; August 18, 2015; and May 25–26, 2016.

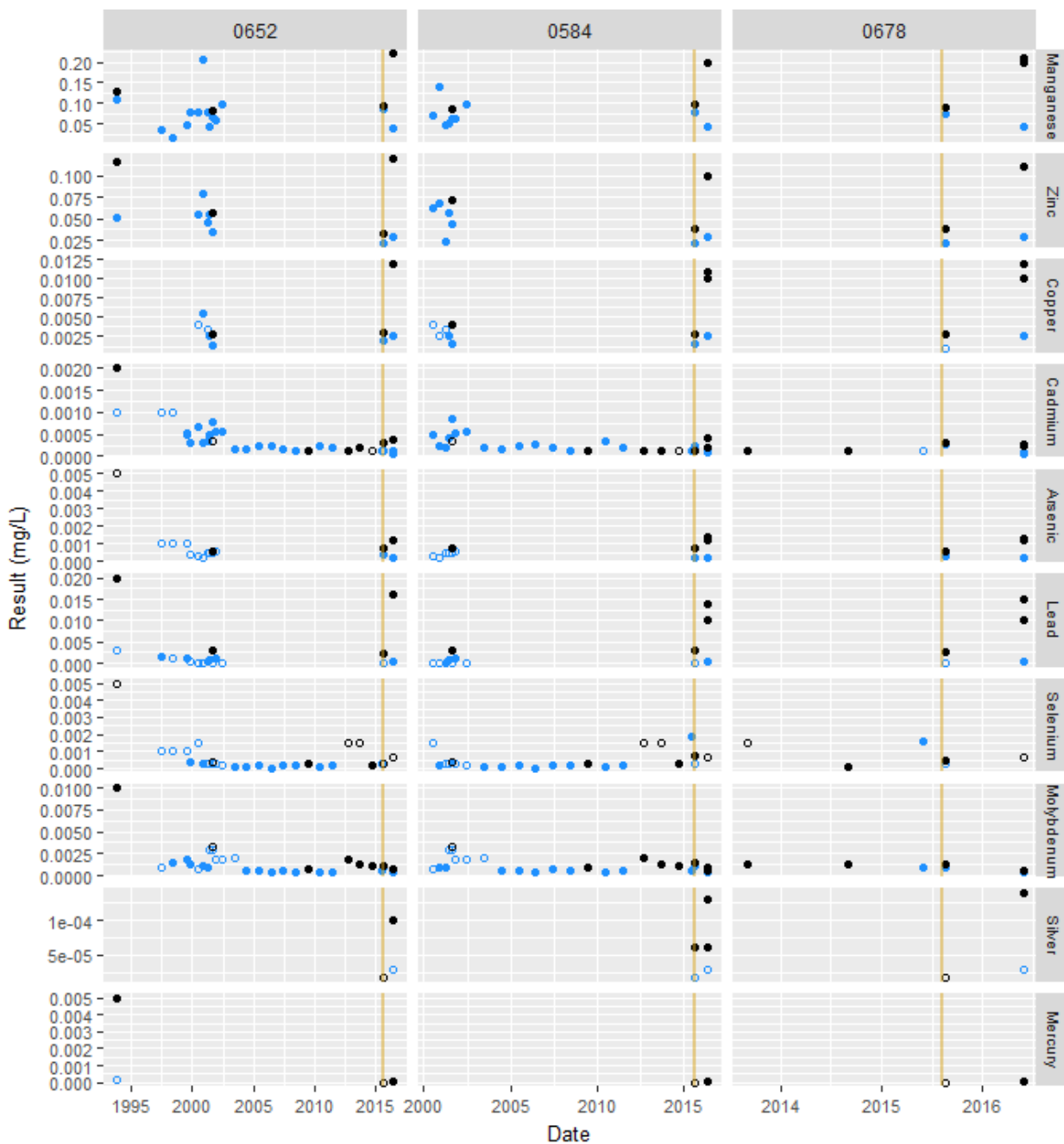
Pre- and post-GKM release comparisons are more easily made for manganese, cadmium, selenium, and molybdenum, which have had more continuous monitoring. GKM-related impacts are not apparent based on the results of the August 2015 nonroutine sampling—for all metals, results are consistent with historical measurements. However, some spikes in the data based on the subsequent annual sampling event, in May 2016, are apparent. This is likely due in part to the fact that that time period coincided with spring runoff (note flow rates and river elevations in Figure 16), but it could reflect the resuspension of sediments deposited as a result of the GKM release. In all cases, however, the concentrations are at (manganese only) or below (remaining metals) corresponding CDPHE agricultural and chronic aquatic life standards listed in Table 4.

Levels of sulfate and field parameters (pH, specific conductance [SC], and turbidity) measured in Durango site surface water samples collected in August 2015 and May 2016 are consistent with historical observations (Figure 17). Figure 17 only includes data for the 0652 (background) and 0584 (mill tailings area) locations; the southernmost river location (0678, in the raffinate ponds area) is excluded because sulfate and field parameters have not been routinely monitored there.

4.4 Assessment of GKM Spill-Related Impacts to Groundwater

4.4.1 Overview of Site Hydrogeology

Comprehensive characterizations of site hydrogeology can be found in site historical documents (DOE 2002b, DOE 2014); this discussion is limited to just a generalized overview of flow dynamics. The former mill tailings area encompasses about 40 acres on a bedrock-supported river terrace between Smelter Mountain to the west, the Animas River to the east, and Lightner Creek to the north. The raffinate ponds area occupies about 20 acres on a separate river terrace located 1500 feet (ft) south (downstream) of the mill tailings area. These areas are geologically and hydrologically different.



Notes:

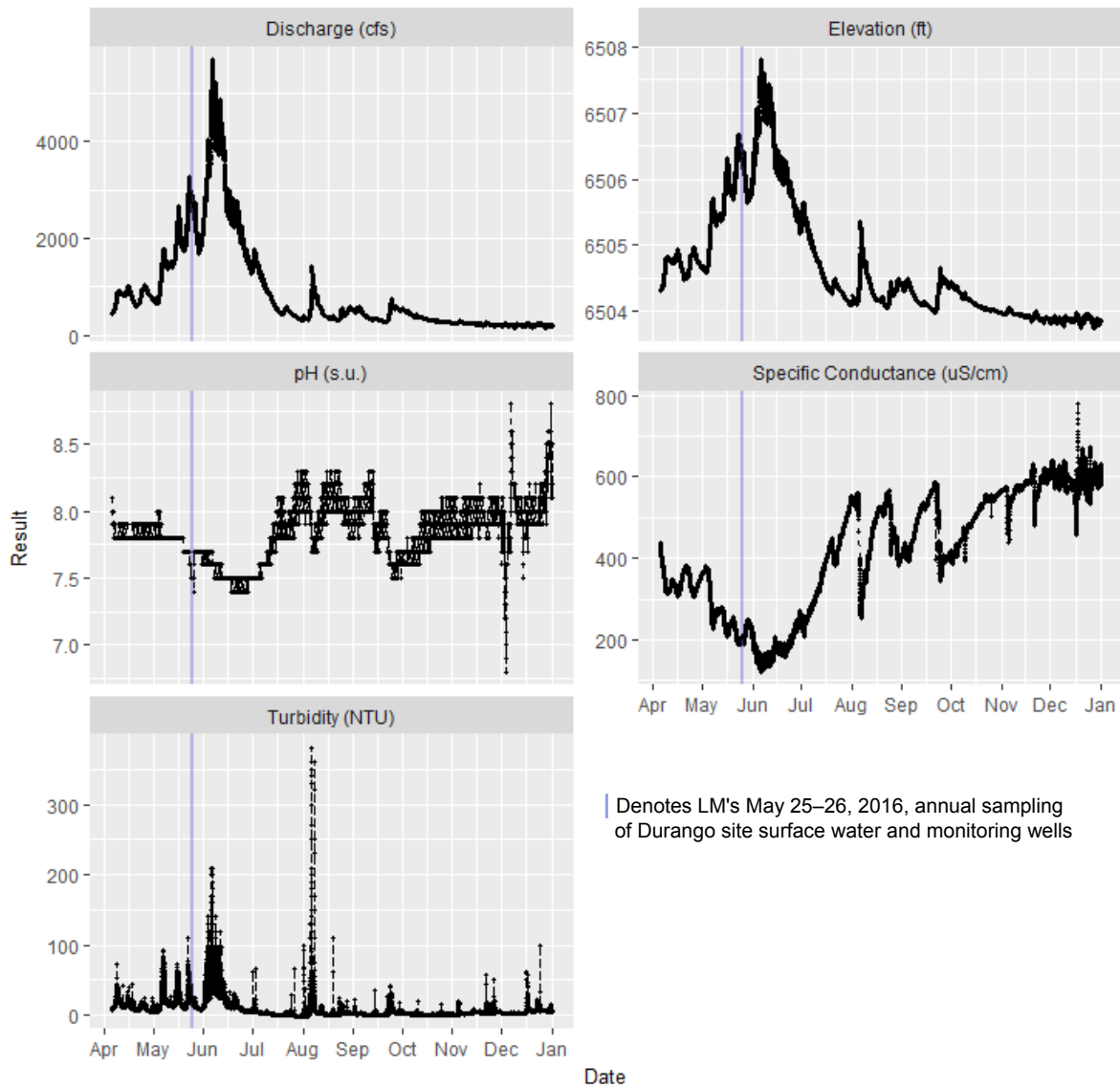
Fraction: ● total ● dissolved (only dissolved fraction measured for most historical samples)
 ○ Analytical result below the detection limit

Vertical line denotes August 5, 2015, GKM release. Two sampling events have taken place since then: the August 18, 2015, nonroutine event, and the most recent annual sampling (May 25–26, 2016).

Locations are listed in order of upstream to downstream; 0652 is a designated background location (DOE 2014). Metals are listed in order of relative proportion based on EPA’s description of the GKM effluent release chemical makeup (Figure 4).

CDPHE water quality standards (from Table 4) are not overlain on these plots because in most cases they are much higher than LM’s historical results. For reference, corresponding agricultural or chronic aquatic life standards are, in mg/L: manganese (0.2), zinc (2), copper (0.2), cadmium (0.01), arsenic (0.1), lead (0.1), selenium (0.005), and molybdenum (0.3).

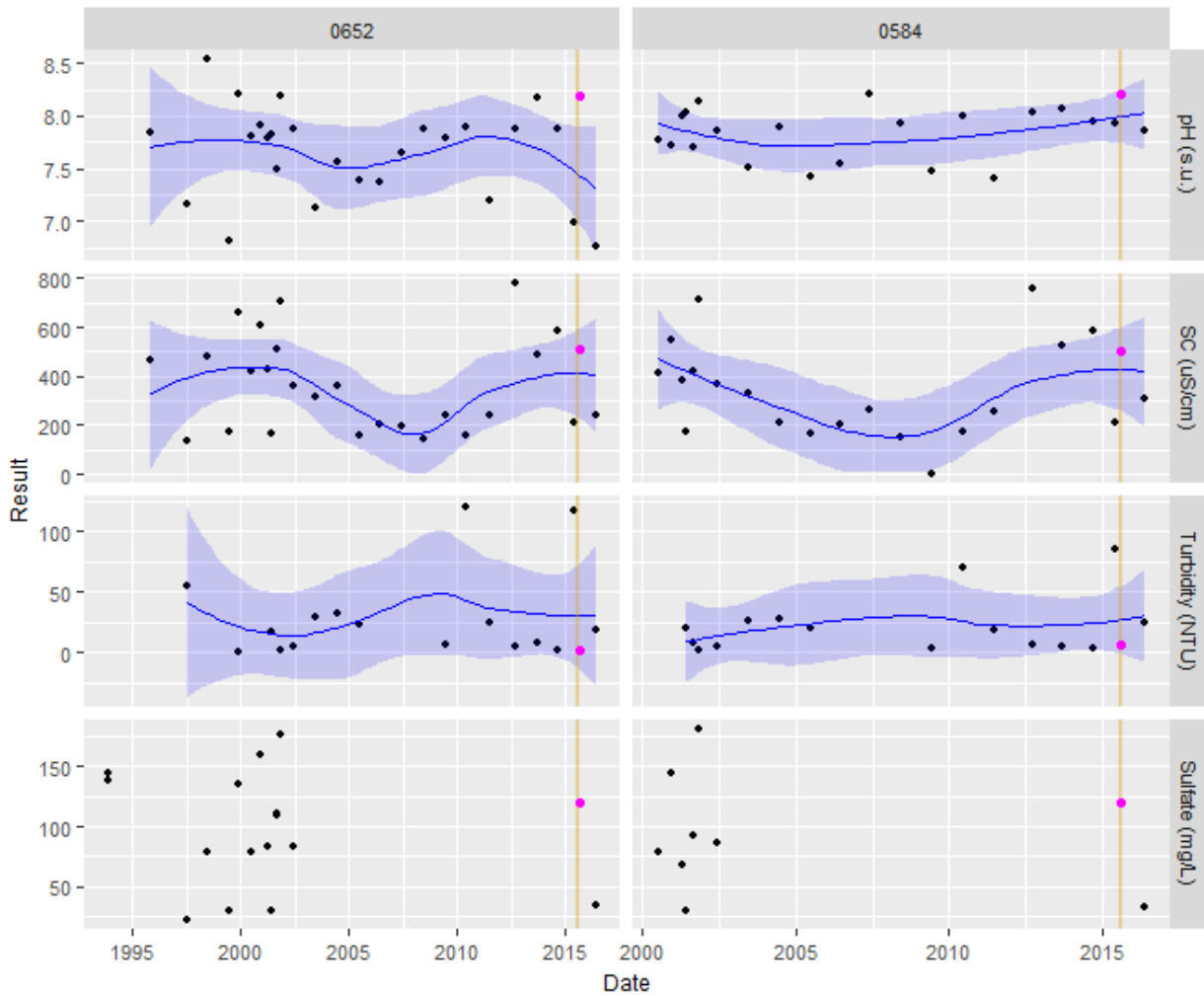
Figure 15. Historical Metals Concentrations in Durango Site Surface Water Samples



Notes:

This figure plots all data for the Durango USGS gage since instantaneous measurements of pH, specific conductance (SC), and turbidity began on April 5, 2016. Corresponding data for discharge and elevation are also shown (these parameters have been measured since 2007).

Figure 16. 15-Minute Measurements of River Flows, Elevation, and Field Parameters at Durango USGS Gage 09361500: April 5, 2016, through December 31, 2016



Notes:

Fraction: ● historical or recent measurement ● August 18, 2015, nonroutine sampling (post-GKM) result
 | Vertical line denotes August 5, 2015, GKM release
 — Blue line is LOESS local regression line (omitted for wells with limited data or large gaps in sampling);
 shaded area is the corresponding 95% pointwise confidence interval.

Data for the southernmost 0678 surface location (Figure 11) are not shown because these parameters have not been routinely monitored at this location.

Figure 17. Historical Field Measurements and Sulfate Concentrations in Durango Site Surface Water Samples

The uppermost aquifer at the mill tailings area is shallow and consists mostly of poorly sorted colluvium derived from Smelter Mountain (Figure 11). A portion of the shallow aquifer also comprises alluvial deposits associated with the Animas River and Lightner Creek. Depth to groundwater increases from about 5 ft on the river terrace to about 60 ft near the mountain front due to the increasing surface elevation with distance from the river. The saturated zone is less than 10 ft thick, unconfined, of limited aerial extent, and of low yield. On the basis of the site conceptual model developed in the late 1990s (DOE 2002b), groundwater in this area of the site generally flows towards the Animas River, as shown in Figure 18.

The colluvium in the mill tailings area is recharged primarily by runoff from Smelter Mountain and infiltrating precipitation, and the alluvial aquifer receives inflow from Lightner Creek and from river loss along the upstream reach of a prominent river meander that defines the middle third of the mill tailings area's east boundary. Groundwater discharges to the Animas River along the upper and lower thirds of the river reach adjacent to the mill tailings area. The alluvium and colluvium pinch out against bedrock cliffs near the southeast corner of the site, at which point groundwater discharge to the river is complete (DOE 2002b).

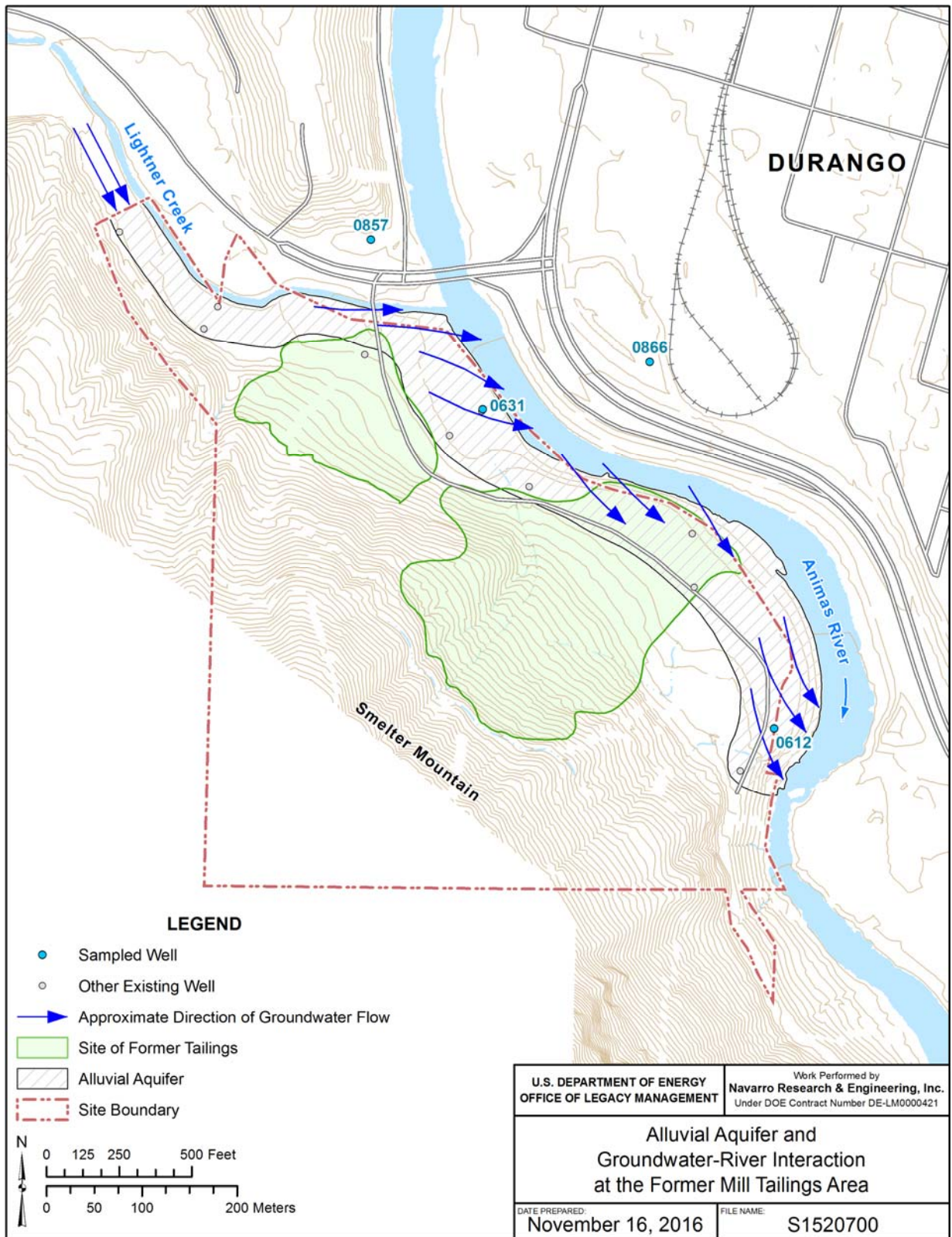
In contrast, groundwater in the raffinate ponds area is unconfined and occurs in two bedrock units that are separated by the northeast-trending fault (DOE 2002b). Like the mill tailings area, groundwater in this area of the site also generally flows towards the Animas River (Figure 19). It is recharged by infiltration of precipitation and runoff from the Smelter Mountain area and the ephemeral South Creek. As shown in the conceptual flow diagram, groundwater generally discharges along the entire reach (DOE 2002b).

4.4.2 Groundwater Sampling Results

On August 18, 2015, five near-river monitoring wells were sampled for analysis of Durango site COCs (Table 2) and the suite of metals initially thought to be most representative of AMD (DOE 2015a): arsenic, cadmium (also a site COC), copper, lead, mercury, silver, and zinc. The five wells, shown in Figure 11 are:

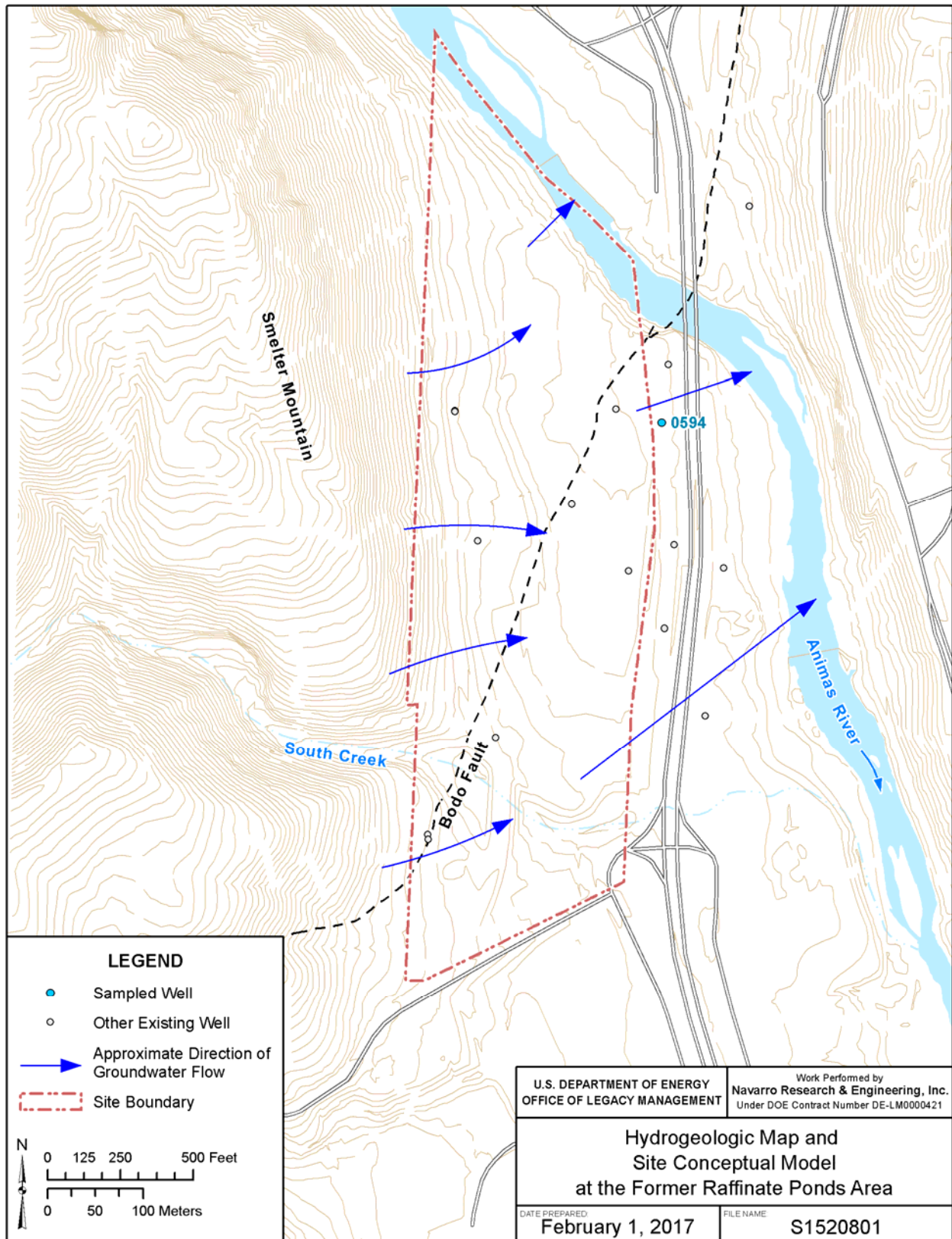
- Mill tailings area background alluvial wells 0857 and 0866
- Mill tailings area alluvial well 0631
- Mill tailings area alluvial well 0612, coinciding with the slag area (Figure 11)
- Raffinate ponds area well 0594, screened in bedrock in the Cretaceous Menefee formation

The evaluation of historical analytical results for these wells focuses on the well sampled with the largest historical database for GKM-related metals: well 0612, located in the southeastern portion of the mill tailings area (Figure 11). This alluvial well is constructed through a slag layer, a remnant of the former zinc and silver smelting operation at the site. Data are plotted on a separate figure for well 0612 for two reasons. First, it is the only well that has been sampled fairly routinely for most metals (mercury and silver are exceptions). Second, due to residual impacts from the former smelting operations, metals concentrations are higher in this well relative to those measured in the others listed above.



Adapted from Figure 5-1 of the SOWP Conceptual Site Model (DOE 2002b)

Figure 18. Durango Mill Tailings Area: Conceptual Animas River–Groundwater Interaction



Adapted from Figure 5-3 of the SOWP Conceptual Site Model (DOE 2002b)

Figure 19. Raffinate Ponds Area Site: Conceptual Animas River–Groundwater Interaction

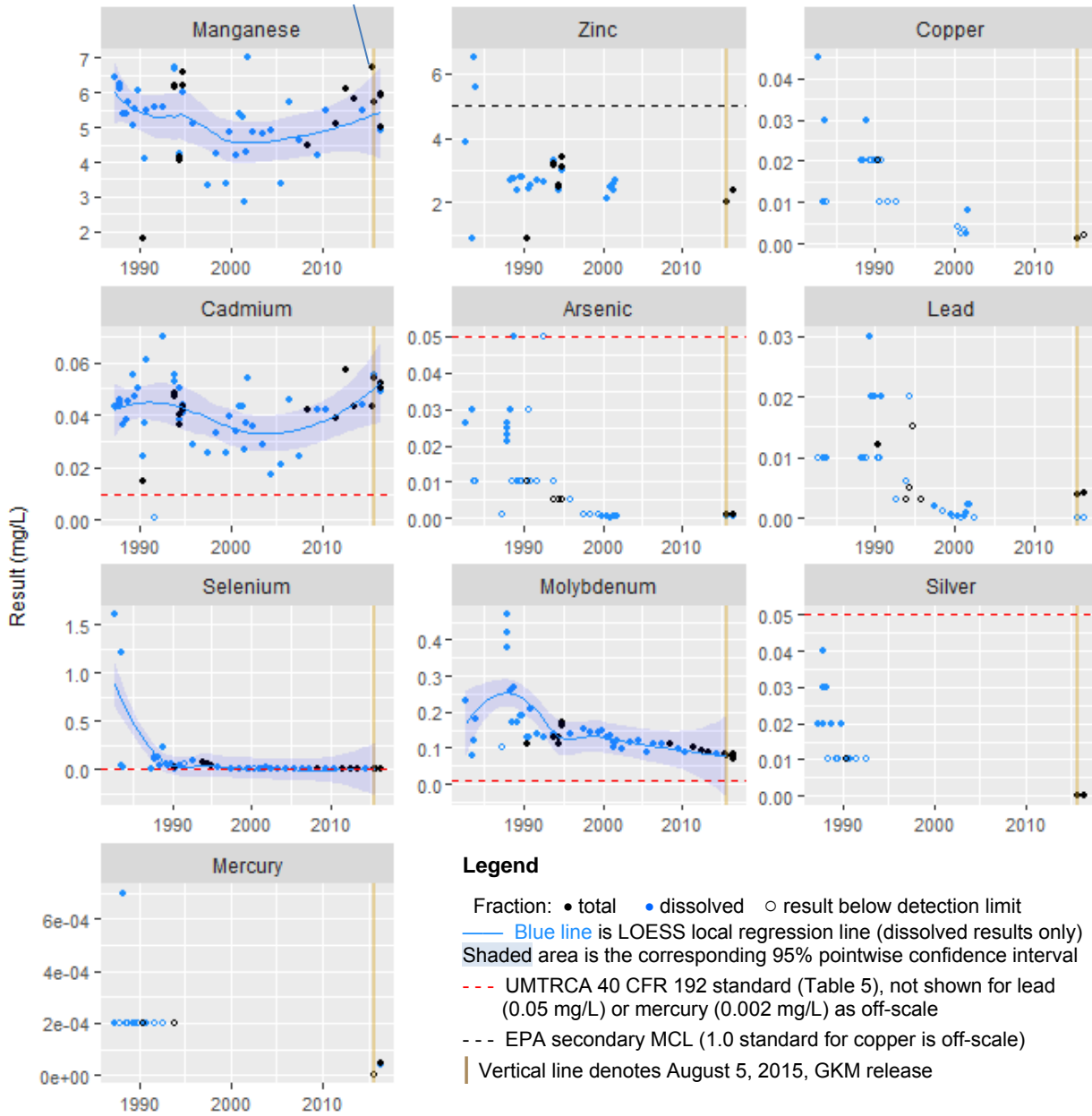
Figure 20 plots historical results for the suite of metals analyzed for the August 2015 nonroutine sampling event in well 0612. Corresponding UMTRCA groundwater standards are also shown or noted for comparison. No deviation in concentration trends is apparent for the post-GKM (August 2015) and subsequent (June 2016) annual sampling event. For manganese, the constituent most likely to be indicative of GKM plume impacts, the only recent apparent deviation corresponded to the June 2015 sampling event, a high runoff period that preceded the release.

Figure 21, which plots historical results for remaining Durango site wells, illustrates how infrequently some of the wells have been sampled for metals, in particular, background wells 0857 and 0866. Additionally, there is an inconsistency in the frequency of total and dissolved measurements: LM analyzed only the dissolved fraction in early (pre-2005) samples, in contrast to later years when total fraction analyses predominated. Acknowledging these limitations, for most metals (including, zinc, copper, and lead), there are no apparent impacts from the GKM release. Figure 22, which plots historical pH and sulfate measurements for onsite (nonbackground) wells, also indicates no deviations in trends that could be associated with the GKM release.

4.5 Summary

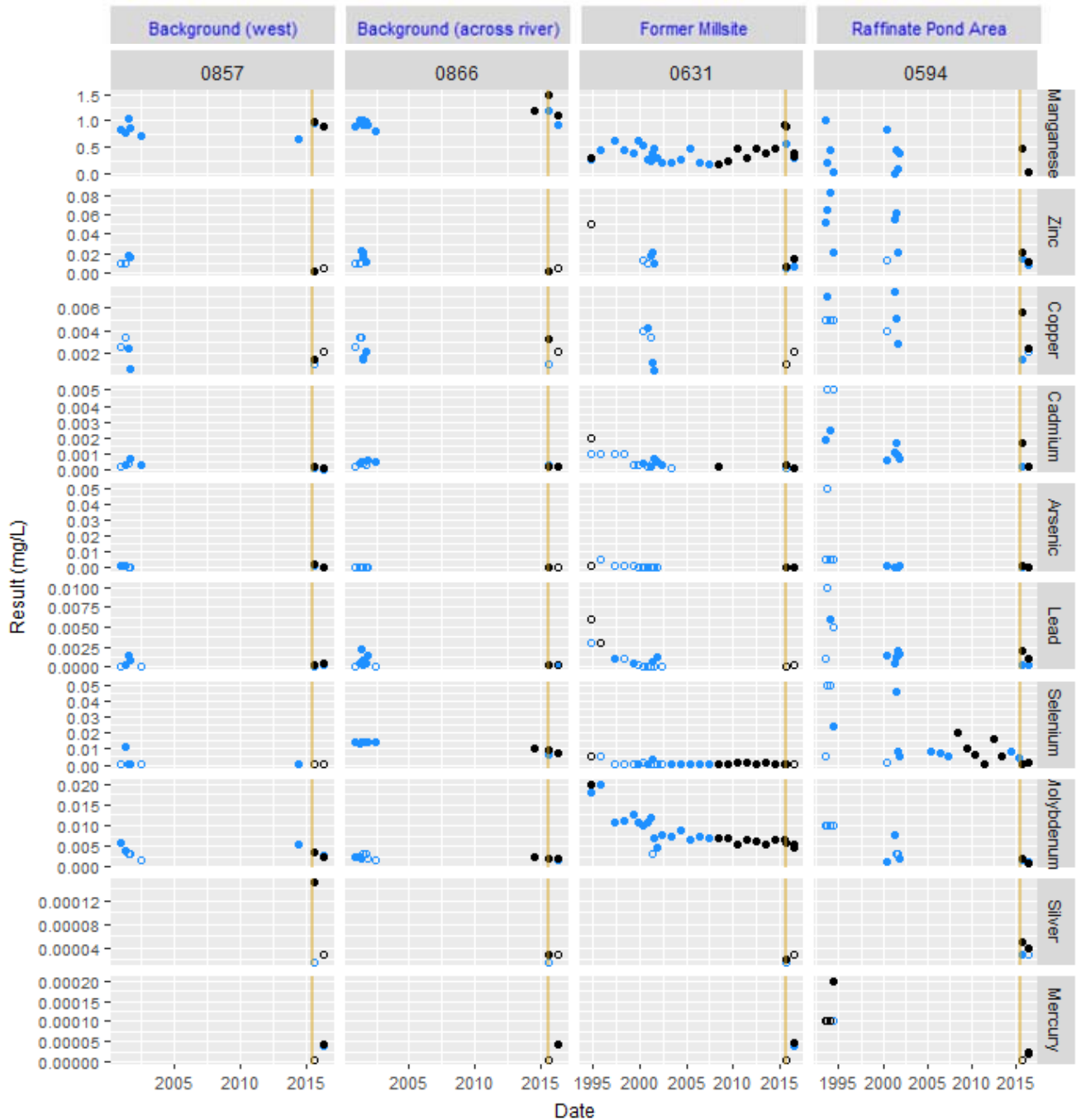
Short-term impacts to surface water in the Animas River in Durango resulting from the GKM plume, as evidenced by spikes in metals concentrations, have been well documented by EPA, MSI, and other organizations. However, following these spikes, levels of metals quickly declined. Data collected by MSI at Rotary Park showed some rebound corresponding to high spring runoff (for total, not dissolved fractions), after which levels declined. No plume-related impacts to surface water were apparent based on LM's data set alone. Acknowledging that historical groundwater data are very limited for most GKM-related metals (note caveats in Section 2.3), there are no apparent impacts to the site groundwater monitoring network resulting from the release. This conclusion is supported by the short-term impacts found in surface water combined with flow conditions (aquifer generally losing to the river) that would preclude incursion of surface water contaminants.

June 2015 (high-flow period)
sample result



Note:
Smoothing (regression) line only applied to those well-parameter combinations where there are sufficient data for trending.

Figure 20. Historical Metals Concentrations in Durango Mill Tailings Site Well 0612



Notes:

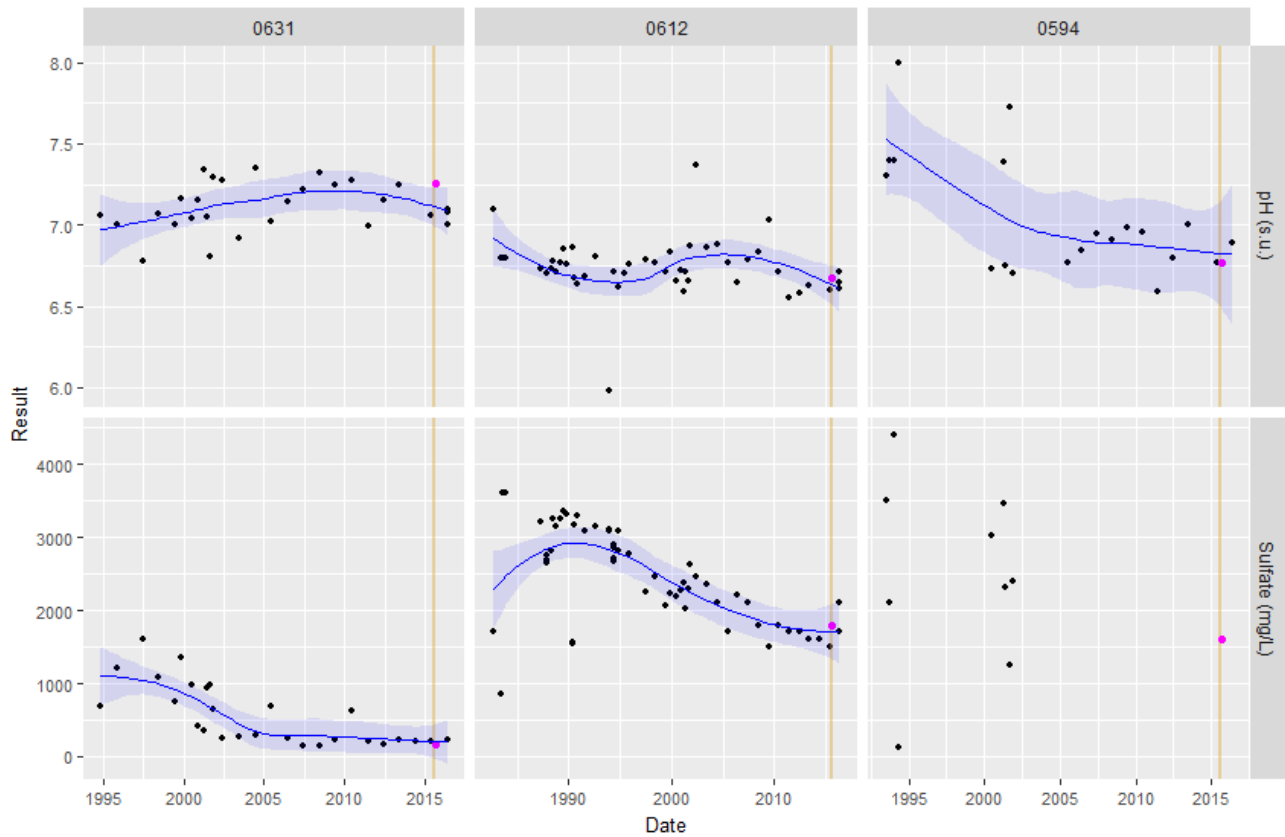
Fraction: ● total ● dissolved

○ Analytical result below the detection limit

| Vertical line denotes August 5, 2015, GKM release

Except for selenium and molybdenum, all concentrations are well below corresponding MCLs (Table 5). As shown above, silver and mercury have not been historically analyzed in groundwater samples.

Figure 21. Historical Metals Concentrations in Durango Site Monitoring Wells 0857, 0866, 0631, and 0594



Notes:

Data for offsite background locations 0857 and 0866 are not plotted here due to insufficient data.

● August 18, 2015, post-GKM release measurement

| Vertical line denotes August 5, 2015, GKM release

Figure 22. Historical pH and Sulfate Levels in Durango Site Groundwater Samples

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5.0 Potential Impacts to Water Quality at the Shiprock Site

The Shiprock site is a former uranium- and vanadium-ore processing facility located near the town of Shiprock, New Mexico, approximately 30 miles west of Farmington and 150 miles downriver from GKM (Figure 3). The uranium mill tailings disposal cell is located on a physiographic terrace elevated 60 ft above a floodplain of the San Juan River and separated from it by a steep escarpment (Figure 23). On the floodplain—the focus of this analysis given its proximity to the river—LM has been conducting groundwater remediation and associated semiannual monitoring of surface and groundwater since 2003. The floodplain remediation system consists mainly of two near-river groundwater extraction wells (1089 and 1104) and two collection trenches, Trench 1 and Trench 2.

On August 18, 2015, about 9 days after the GKM plume was estimated to have arrived at Shiprock, LM collected river and groundwater samples for analysis of site COCs (Table 2) and the suite of metals initially thought to be most representative of AMD (DOE 2015a): arsenic, cadmium, copper, lead, mercury, silver, and zinc. Four surface water locations (0967, 1203, 0899, and 0940) and seven near-river alluvial monitoring wells (0735, 1117 and 1130 [Trench 2 wells], 0612, 1142, 1136, and 1137) were sampled (Figure 23). To supplement the analysis, LM also used data from the nearby USGS river gage (09368000) and one EPA sampling location (SJSR) about 0.5 mile downstream of the well 1089/1104 remediation area. Following a brief overview of the site, this section presents relevant data from USGS and EPA and then evaluates LM's post-GKM release sampling results.

5.1 Site Background

Because this report focuses on assessing potential impacts of the GKM release, only a brief overview of the Shiprock site is provided here. Numerous reports documenting the site's history, characterization, and monitoring efforts can be accessed via LM's website.⁹ Primary historical site documents include the SOWP (DOE 2000), the GCAP (DOE 2002a), and Annual Performance Reports, which evaluate the performance of the groundwater remediation system at the site (e.g., DOE 2016b). Site data, sample location information, and well construction logs can be found on LM's GEMS website (<http://gems.lm.doe.gov/#site=SHP>).

The Shiprock mill operated from 1954 to 1968 on property leased from the Navajo Nation. Remediation of surface contamination, including the stabilization of mill tailings in an engineered disposal cell, was completed in 1986. During mill operations, uranium, nitrate, sulfate, and other milling-related constituents leached into underlying sediments and contaminated groundwater in the area of the mill site. In March 2003, DOE initiated active remediation of groundwater at the site using extraction wells and interceptor drains.

5.2 Assessment of Potential GKM-Related Impacts to Surface Water

Using the general approach outlined in Section 2.2.3, this section presents relevant data from the USGS and EPA's emergency response sampling at location SJSR to provide a context for subsequent analysis of LM sampling data.

⁹ See <http://www.lm.doe.gov/shiprock/Sites.aspx>.

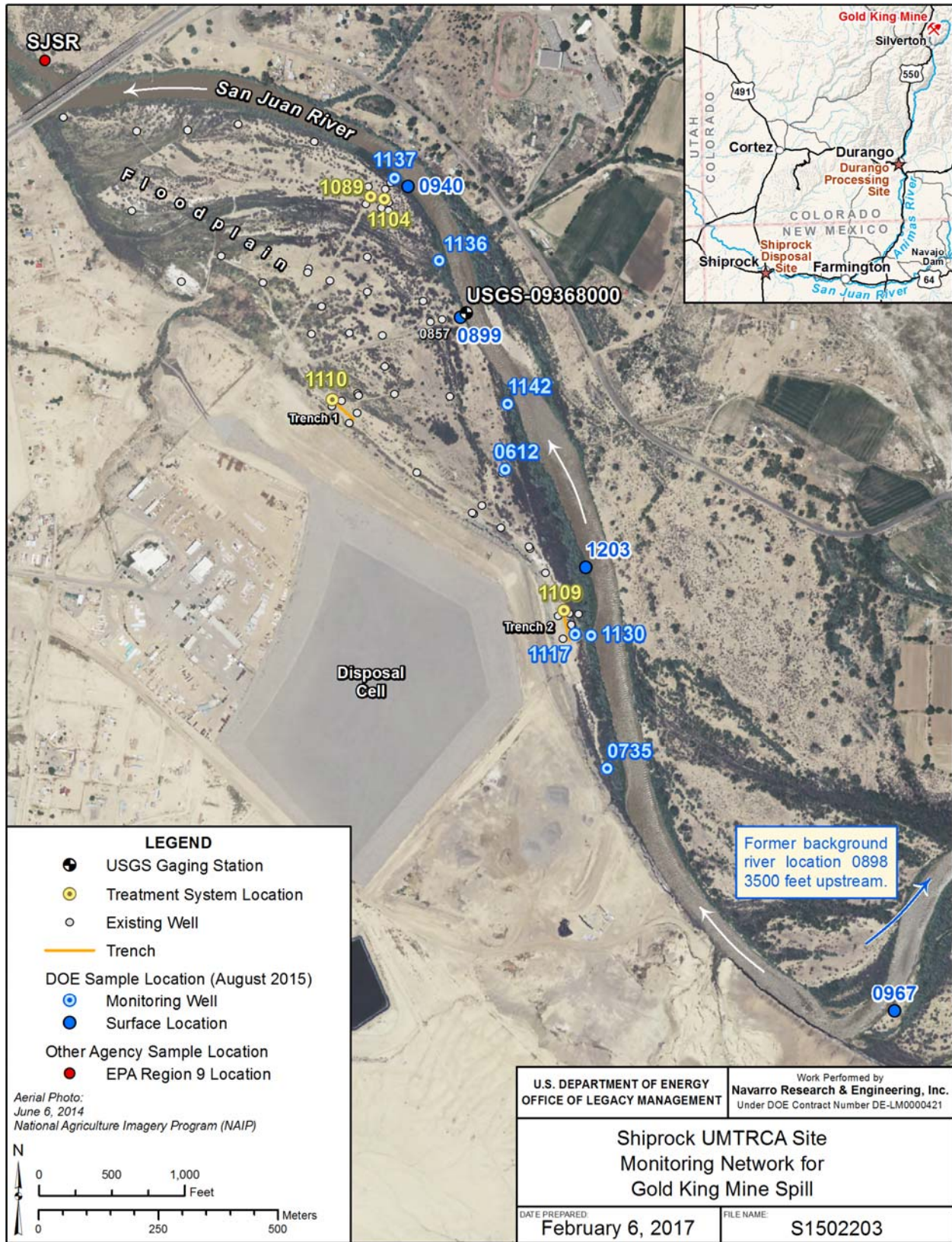
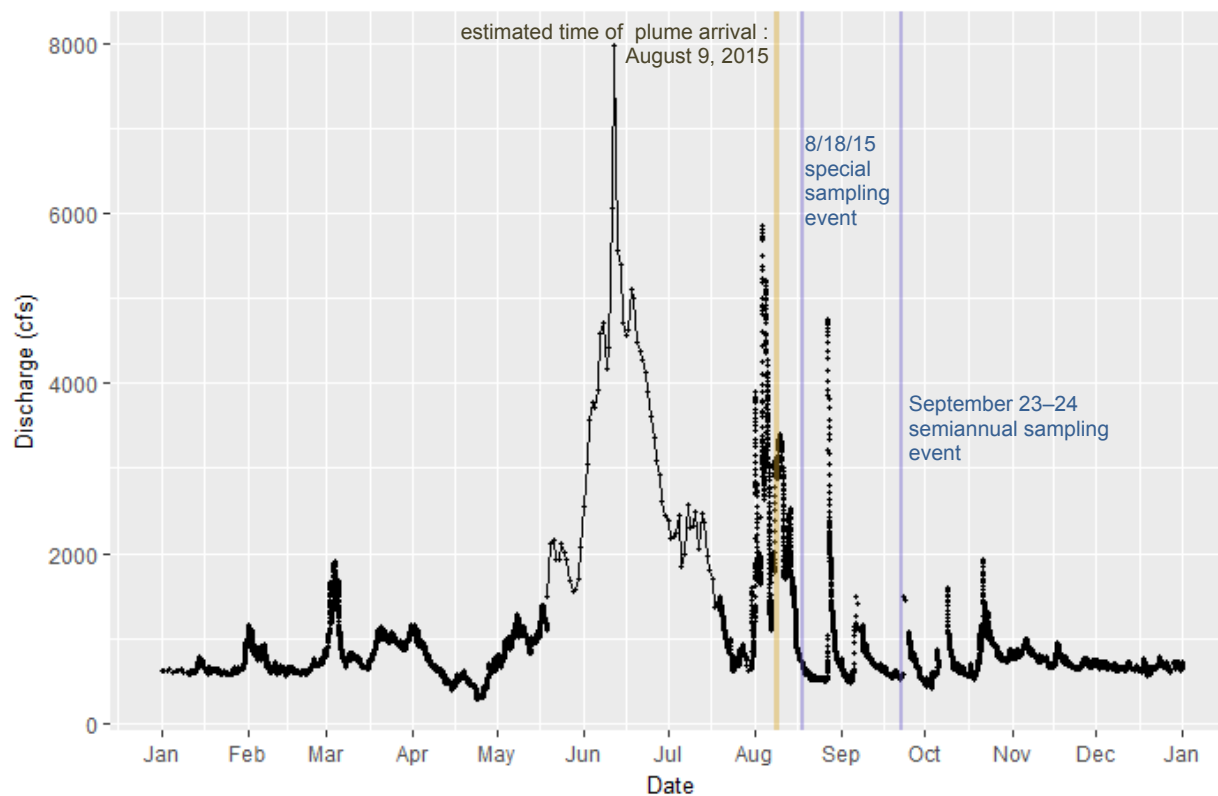


Figure 23. Shiprock UMTRCA Site Monitoring Network, August 2015 Nonroutine Sampling

5.2.1 San Juan River Flows

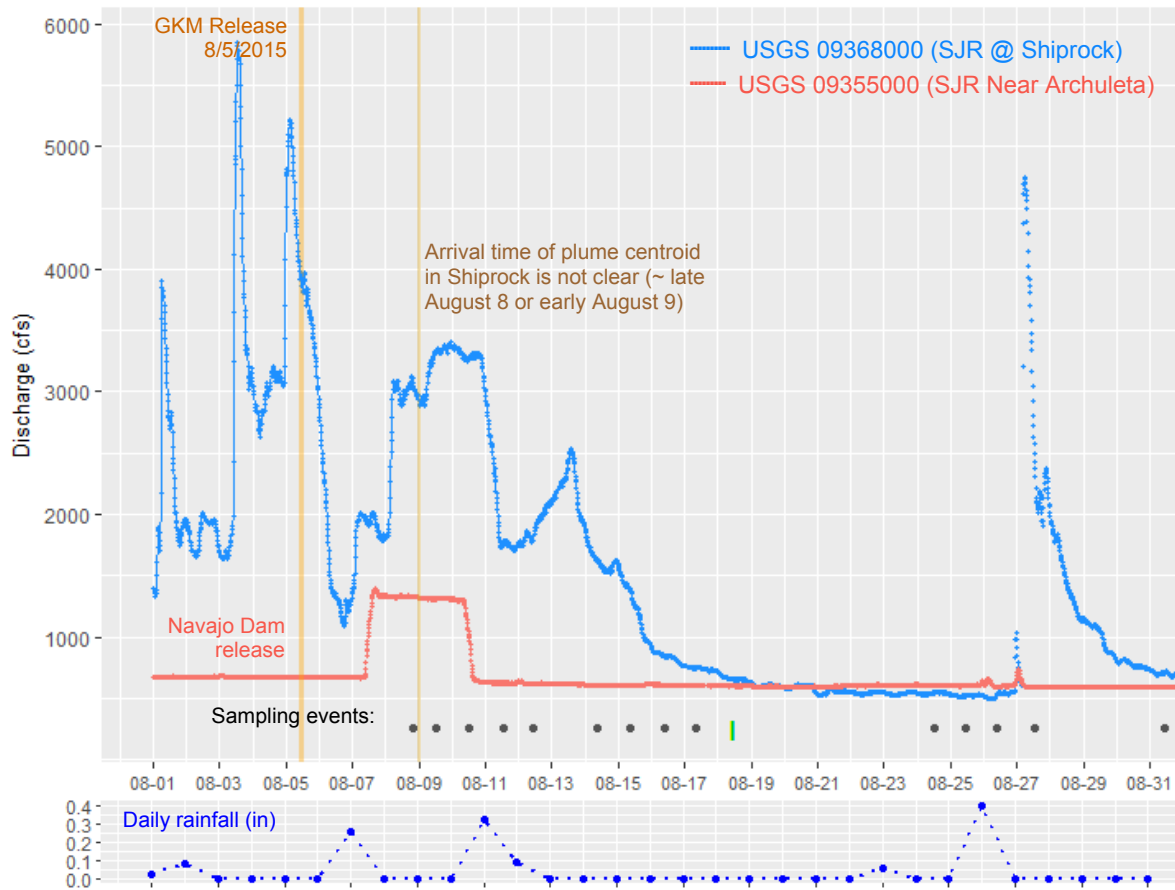
Figure 24 shows the discharge measured at the Shiprock (09368000) river gage in 2015. Similar to what was shown for Animas River flows at Durango (Figure 12), this figure illustrates the wide range in flows that occur in a given year. During the high-flow period associated with snowmelt runoff in June–July, San Juan River discharge approached 8000 cfs. Subsequent peaks likely reflect monsoonal storms characteristic of this region, which typically occur in the late summer or fall.



Vertical line denotes estimated time of GKM plume arrival at Shiprock (early a.m., August 9, 2015)
Denotes LM sampling events: the August 18, 2015, post-GKM nonroutine sampling, and September 2015 semiannual routine monitoring

Figure 24. Streamflows in San Juan River at Shiprock USGS Gage 09368000, Year 2015

Figure 25 shows a zoom view of San Juan River flows during the month of August 2015, coinciding with the GKM release. When LM began this analysis, given the uncertainties concerning GKM plume arrival time in the San Juan River downgradient from Kirtland (Figure 3), river flows were examined to ascertain whether or not the plume front could be detected based on the discharge. It was soon revealed that this analysis was complicated by several factors: (1) BOR’s deliberate release of water from the Navajo Dam near Archuleta, New Mexico, to help dilute the plume (Table 1); and (2) rain events, which also led to increases in river flows. At around the time the plume arrived at Shiprock (August 9, 0:00), the San Juan River was flowing at about 3000 cfs. It is not clear whether the subsequent (~500 cfs) increase in discharge is attributable to the Navajo Dam release, rain events, the GKM plume, or a combination of these factors.



Notes:

SJR = San Juan River

| Denotes date/time of August 5, 2015, GKM release and estimated plume arrival at Shiprock (early a.m. August 9, 2015)

● EPA Region 9 sampling of station SJSR

| August 18, 2015, LM nonroutine sampling for AMD constituents

In response to the GKM release, on August 7, 2015, the U.S. Bureau of Reclamation increased its water releases from Navajo Dam from 650 to 1300 cfs (dam location shown in Figure 3). The intent was to help dilute spill-related contaminants in the San Juan River (<http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=49968>).

According to Utah DEQ (8/9/2015 entry), the San Juan River was very turbid due to rains and was red-colored (<http://www.deq.utah.gov/Topics/Water/goldkingmine/>).

Rainfall data are from LM's SOARS (System Operation and Analysis at Remote Sites) (cliffRouterMET) meteorological station.

*Figure 25. San Juan River Discharges and Daily Rainfall, August 2015
Data from USGS Gages 09368000 (Shiprock) and 09355000 (SJR Near Archuleta)*

5.2.2 Evaluation of EPA Emergency Response and USGS Data

Unlike the Durango site, where numerous stations were sampled by other agencies, only one known EPA sampling location, SJSR, is near the Shiprock site (Figure 23). Between August 8 and September 30, 2015, EPA sampled this location 24 times, 16 times in August (denoted by the “•” symbol in Figure 25) and another 8 times in September 2015. The initial August 8, 2015 (19:34), sample was probably the only one representative of pre-GKM plume arrival conditions. Based on data provided by EPA and UDEQ, including flyover results and San Juan River flow rates upgradient of Shiprock (Table 1), LM estimated that the plume arrived at the Shiprock site either late August 8 or early the morning of August 9, 2015. These initial estimates were later supported by EPA based on its plume simulations, which indicated a modeled GKM plume peak at Shiprock, New Mexico, on August 9, 2015 at 0:00 (EPA 2017, Figure 4-26).

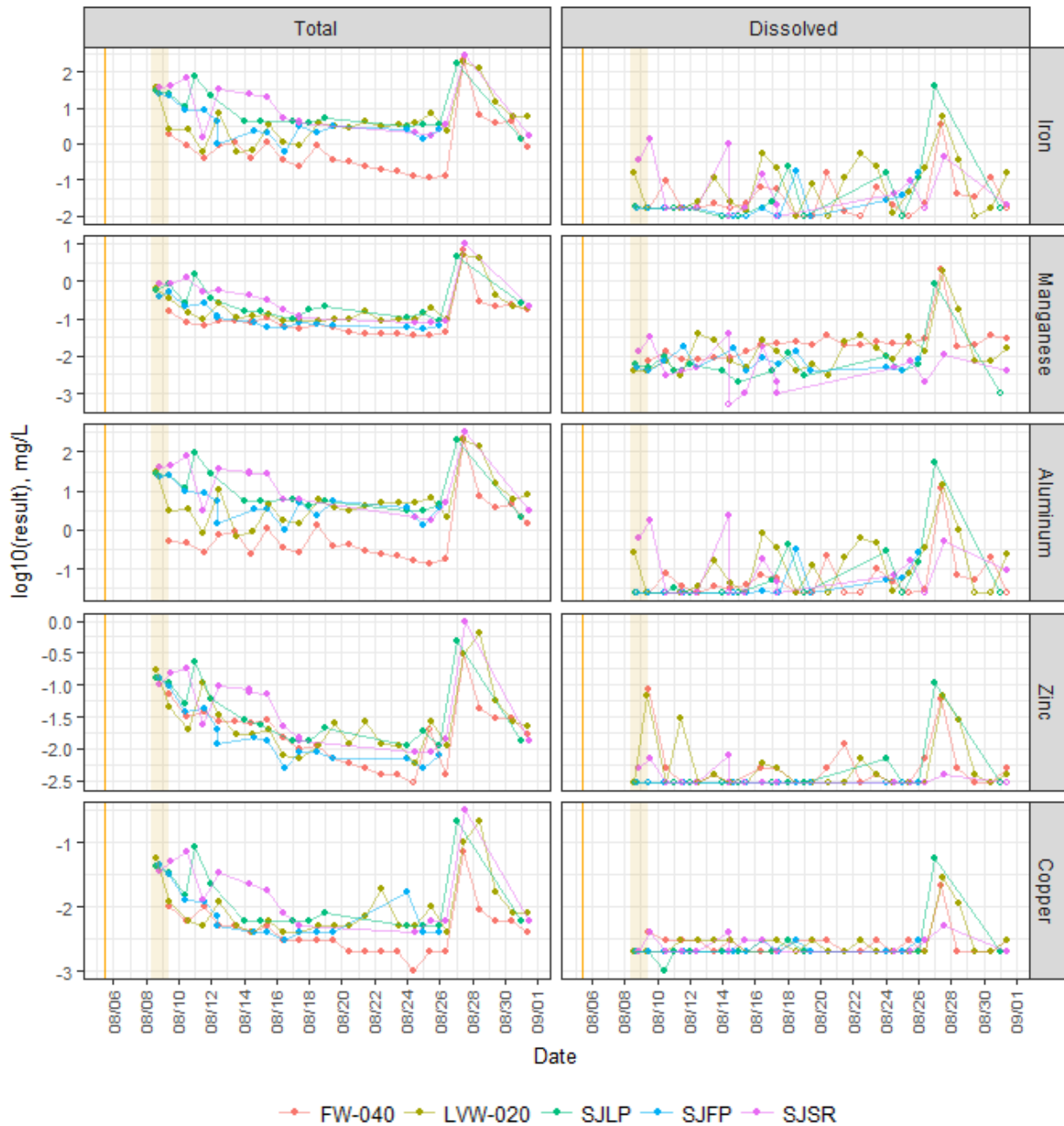
As a first step in framing the analysis of potential GKM impacts at the Shiprock site, LM first reviewed EPA's emergency sampling data for the five locations listed below. Because relative locations of the first three stations near the Animas–San Juan rivers confluence are not readily apparent in Figure 3, the associated graphic (inset below) provides greater detail.

- FW-040, Animas River north of the San Juan River confluence (see inset)
- LVW-020, San Juan River downstream of confluence¹⁰
- SJLP, about 30 miles upriver from Shiprock
- SJFP, San Juan River near Kirtland (Figure 3)¹⁰
- SJSR, San Juan River near Shiprock (Figure 23)



Figure 26 plots GKM metals concentrations measured at these locations in August 2015. The initial objective of this figure was to evaluate whether there were any differences in temporal trends of GKM metals at these different locations. For example, are any differences apparent between the Animas River location (FW-040) and those downstream of the confluence?

¹⁰ In EPA's online database, and as published in its Conceptual Monitoring Plan (EPA 2016c), the coordinates for LVW-020 are given as 36.730556° (latitude) and -108.25106° (longitude). In this plan, EPA describes LVW-020 as “Animas River upstream of the San Juan River,” which is not consistent with where this point is mapped. Also, although EPA describes the SFJP location as “San Juan River near Farmington, NM” (EPA 2016c), this location is actually closer to Kirtland (Figure 3).



| Denotes date/time of August 5, 2015 GKM.

Shaded area denotes approximate time of GKM plume arrival at these locations (specific arrival time would vary according to downstream distance from GKM); arrival at Shiprock estimated as early a.m. August 9, 2015.

Figure 26. GKM Primary Metals Measured in Surface Water Near the Animas–San Juan Rivers Confluence and at Shiprock (SJSR), August 2015

In contrast to the marked differences in GKM metal magnitude shown in Figure 7 for locations in or north of Durango, temporal patterns and concentration magnitudes are very similar for the subset of samples shown in Figure 26. The most notable trend apparent in this figure is the concomitant spike in total and dissolved concentrations on August 27, coinciding with a rain event (Figure 25). This was also noted by BOR in its assessment of San Juan River quality before, during, and after the GKM release (BOR 2016).

Another observation regarding these data is that, except for the late-August peak, total aluminum and iron concentrations in the Animas River FW-040 sample are notably lower than those in the San Juan River samples. This is consistent with EPA's estimations regarding the metal mass during GKM plume passage, where both iron and aluminum concentrations were much higher in the San Juan River above its confluence with the Animas River (EPA 2017, Figure 6-5).

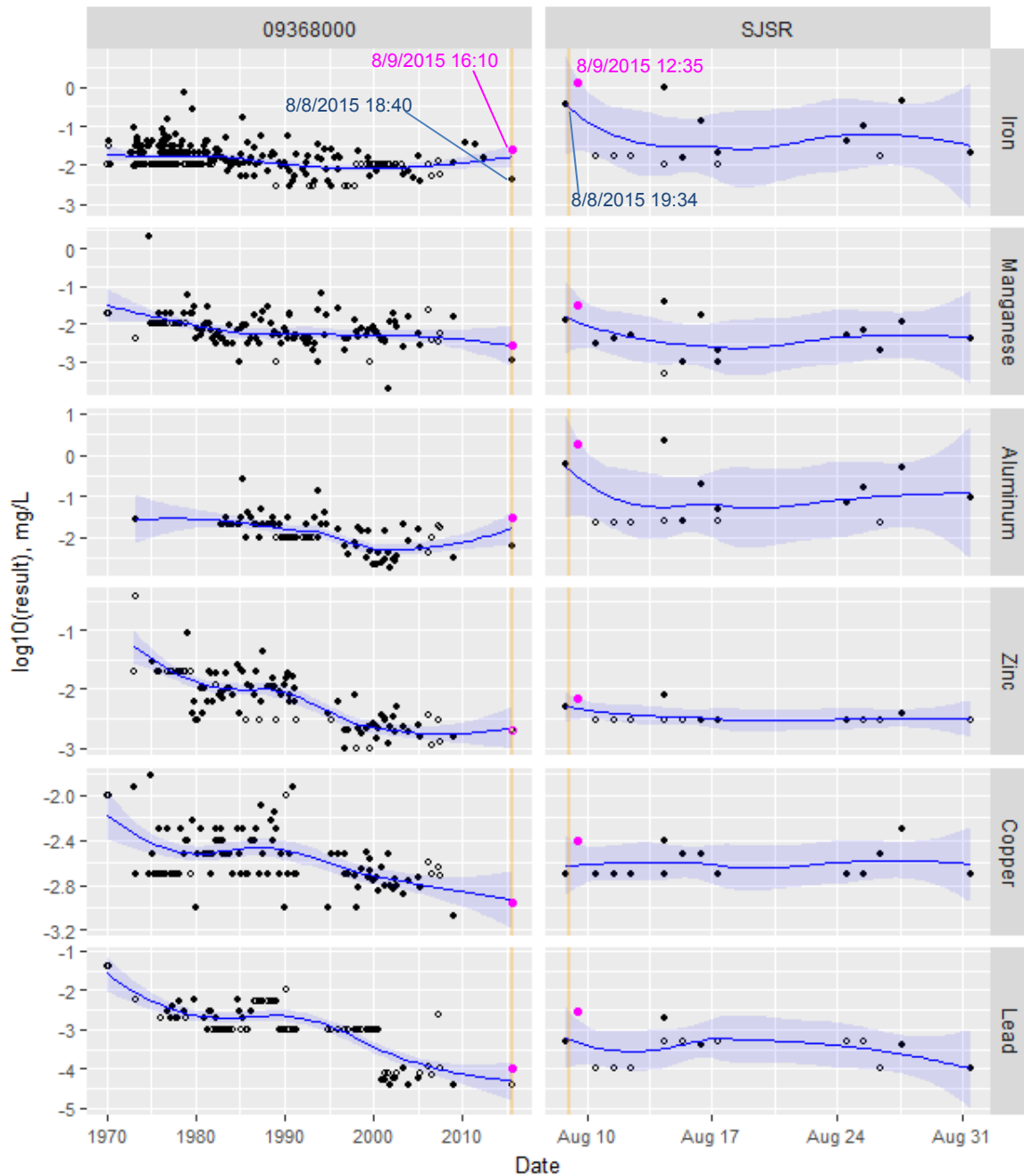
In an attempt to understand baseline concentrations of GKM-related metals in the San Juan River near Shiprock, USGS historical results for the river gage (years 1970–2015) are compared with EPA emergency response results for SJSR for the August 2015 period (Figure 27).¹¹ Both agencies collected samples on August 8 (likely before plume arrival), and August 9, 2015 (estimated day of plume arrival). For both agencies and all metals plotted in this figure, a slight increase is evident when comparing the pre-plume (August 8) data with the August 9, 2015 results. Although these increases might signal the plume arrival, results for aluminum, copper, lead, and zinc are below corresponding Navajo Nation Environmental Protection Agency (NNEPA) agricultural water supply standards listed in Table 4.

For the August 8–9, 2015, time period, EPA's reported results are higher than those of USGS for all metals listed. Although dissolved concentrations of metals measured by EPA might appear to be somewhat higher than those reported by USGS, this difference could reflect the difference in location (the USGS gage is closer to the site) or it could be an artifact of sampling technique or preservation.

Summary

Based on this analysis of USGS and EPA data—unlike for the Durango site, where short-term GKM plume impacts to the Animas River were well documented—there is no clear evidence of GKM release impacts to the San Juan River near the Shiprock site. As discussed above, identification of such impacts was complicated by the distance of the site from GKM, the inability to detect a discernible plume in the river near the site, increased water flows from the Navajo Dam, rain events, and the lack of pre-GKM release data. In fact, metals concentrations uniformly spiked at locations from the Animas–San Juan confluence downstream to Shiprock in late August 2015 following a rain event (Figure 26). These levels were much higher than those measured at the time of estimated plume arrival (August 8–9, 2015, depending on downstream distance from GKM). EPA and USGS data do indicate slight unsustained increases in some metals concentrations following the estimated GKM plume arrival at Shiprock (Figure 27). However, the magnitudes were low relative to corresponding water quality standards (Table 4).

¹¹ Because there were inconsistencies in how USGS reported results for the total metal fractions, only dissolved results are plotted in Figure 27. To ensure the reproducibility of this plot, LM used only data that met the criterion of "PARM_USGS_EPA_EQUIV_TX" (USGS/EPA equivalency) = "Yes" for the dissolved fraction.



Notes:

Vertical line denotes time of estimated plume arrival at Shiprock of August 9, 2015 (early a.m.)

● Detected result. ○ Analytical result below the detection limit.

● August 9, 2015, sample result

Metals listed in order or proportion in GKM effluent (Figure 4).

EPA data from EPA Region 9, from https://www.epa.gov/sites/...surfacewater_cumulative_10282015.xlsx.

USGS data extracted from USGS Gold King Mine Release Database (25 MB ZIP file), from <https://water.usgs.gov/owq/gkm/wq.html>.

Results for aluminum, copper, lead, and zinc are below corresponding NNEPA agricultural water supply standards listed in Table 4 (5, 0.2, 10, and 10 mg/L, respectively).

Figure 27. Dissolved Metals in USGS 09368000 (Historical) and EPA Region 9 SJSR Samples

5.2.3 LM Sampling of San Juan River Near Shiprock

Figure 28 plots historical metals concentrations for the four San Juan River locations sampled on August 18, 2015: 0967 (upgradient or background), 1203, 0899, and 0940. Because location 0967 has only been sampled by LM since 2014, data from the previous upgradient location, 0898—3500 ft upstream of 0967 (Figure 23)—for the period 2000–2014 are combined with 0967 data in these plots. Because the date scale in this figure spans 16 years, it may be difficult to distinguish between August 2015 and September 2015 (semiannual sampling event) results. For this reason, the August 18, 2015 sampling results are color-coded (●). Metals are listed in general order of assumed proportion in the GKM effluent as discussed in Section 3.1.

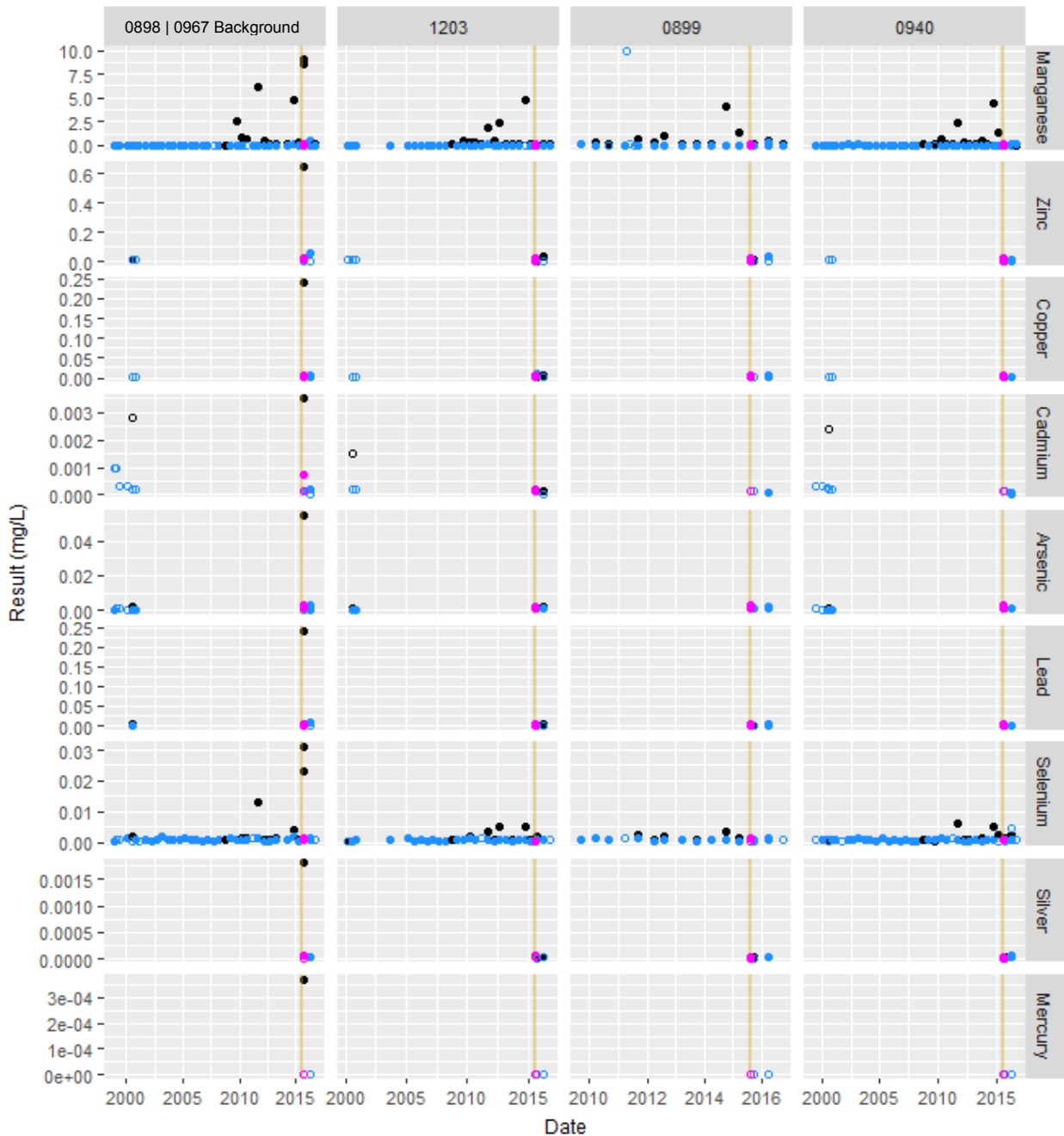
Data for zinc, copper, cadmium, arsenic, lead, silver, and (in particular) mercury are very limited. Except for the background (0898/0967) location, recent sampling results—including those for the August 2015 nonroutine sampling—are consistent with historical (circa 2000) results. This is also the case for manganese and selenium, which are routinely analyzed in LM samples at this site.

At the background location, although results for the August 2015 nonroutine sampling event are consistent with historical results, this was not the case for the subsequent September 2015 semiannual sampling results, when maximum concentrations of total metals were measured. These concentrations are also higher than those measured at any downstream location. The most likely explanation for these results is that the upgradient location was sampled 2 days later than the remaining locations, after a storm event (Figure 29).

Although the spikes seen in the upgradient location could be attributable to the resuspension of GKM-plume containing sediments, there is no conclusive evidence that that is the case. The San Juan River is characteristically sediment-rich (EPA 2017), and spikes of this nature are not uncommon. For example, data indicate that storm events result in total metals concentrations that exceed those measured during the peak plume concentrations following the GKM release (Figure 26, BOR 2016).

Because manganese is probably the best indicator of potential GKM plume impacts, to provide better resolution of the data in Figure 28, data were replotted using unique scales for each location (Figure 30). Apart from September 2015 spikes at the background location discussed above, recent results are within the range of historical results at all locations, suggesting no apparent impact from the GKM plume. Sulfate and field parameters (pH, SC, and turbidity) measured in surface water samples collected in August 2015 and during subsequent semiannual sampling events are also consistent with historical results (Figure 31). Occasional high turbidity associated with spring runoff or rain events is also apparent in this figure.

On the basis of this analysis of LM's sampling of the San Juan River, combined with the preceding assessment of other agency data, there are no apparent impacts to surface water adjacent to the Shiprock site that can be solely attributed to the GKM plume.



Notes:

| Vertical line denotes August 5, 2015, GKM release

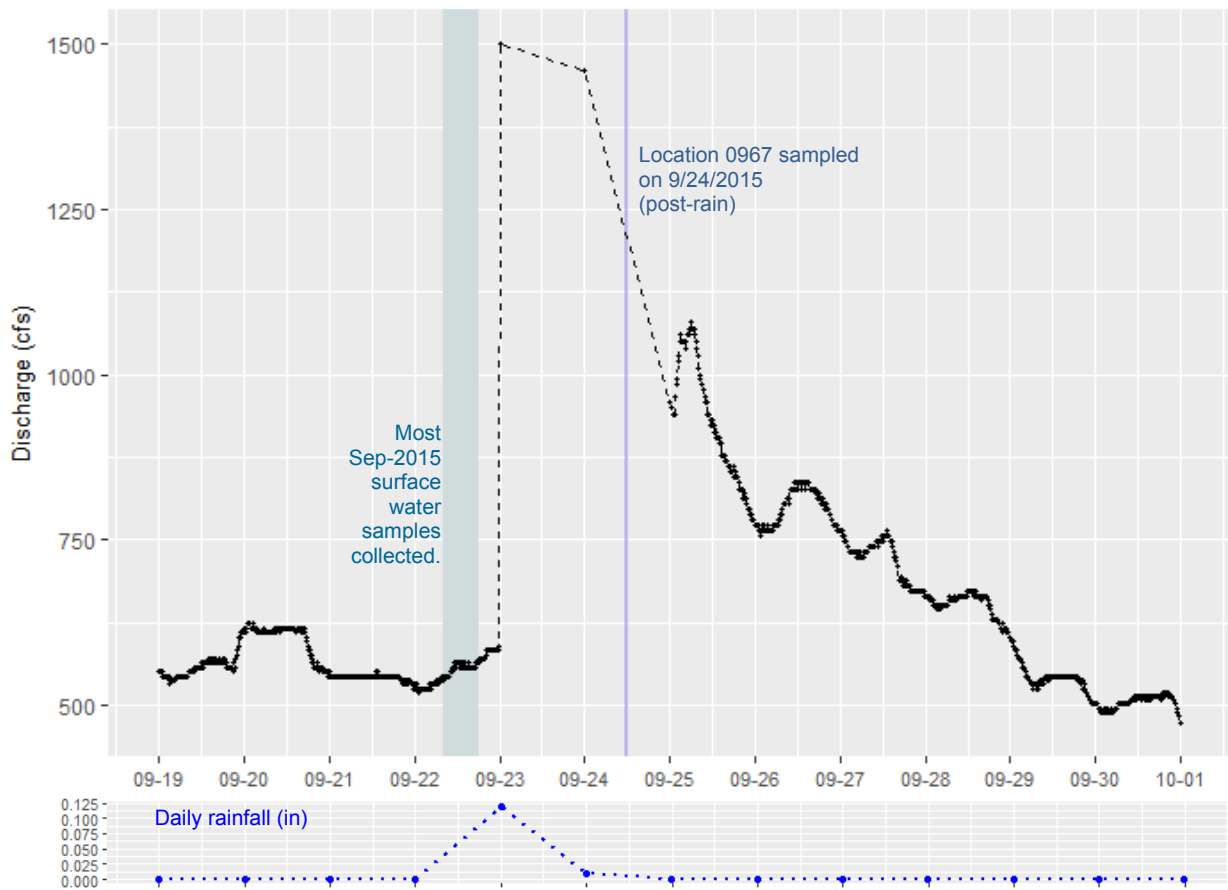
Fraction: ● total ● dissolved

○ Analytical result below the detection limit

● or ○ August 18, 2015, nonroutine sampling event (total vs. dissolved fractions not discernible in this plot)

Results for arsenic, cadmium, copper (dissolved), lead, and zinc are below corresponding NNEPA agricultural water supply standards listed in Table 4 (2, 0.05, 0.2, 10, and 10 mg/L, respectively).

Figure 28. Historical Metals Concentrations in Shiprock Site Surface Water Samples

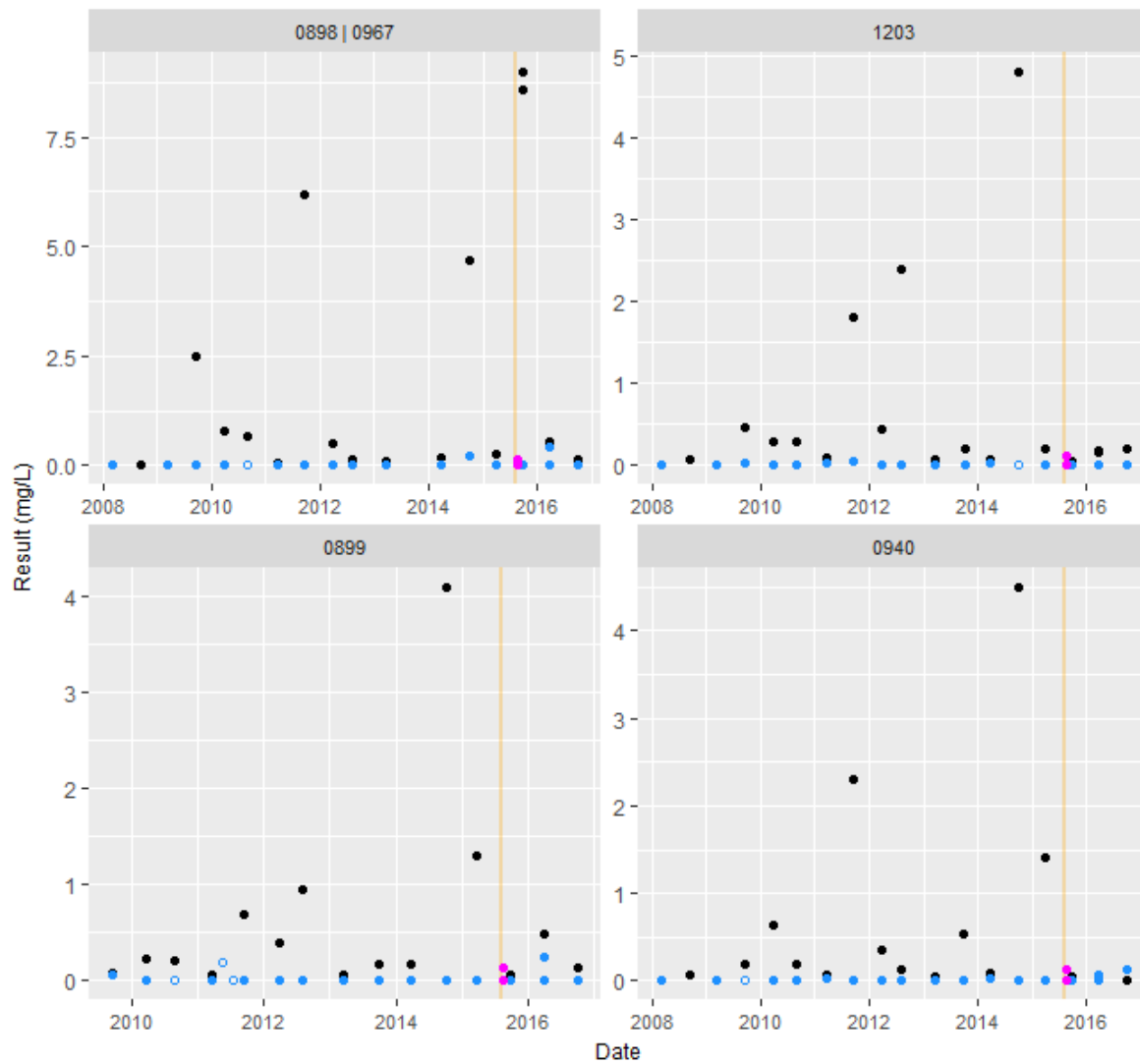


Notes:

- Denotes when all nonbackground samples were collected (9/22/2015)
- | Vertical line denotes 9/24/2015 sampling of upgradient (background) surface location 0967; see results plotted in Figure 28 for context.

Most of the data plotted in this figure are USGS 15-minute data. Because no records were posted for the period 9/23/2015, 00:00 through 9/24/2015, 23:45, USGS's daily estimated data for this period were used.

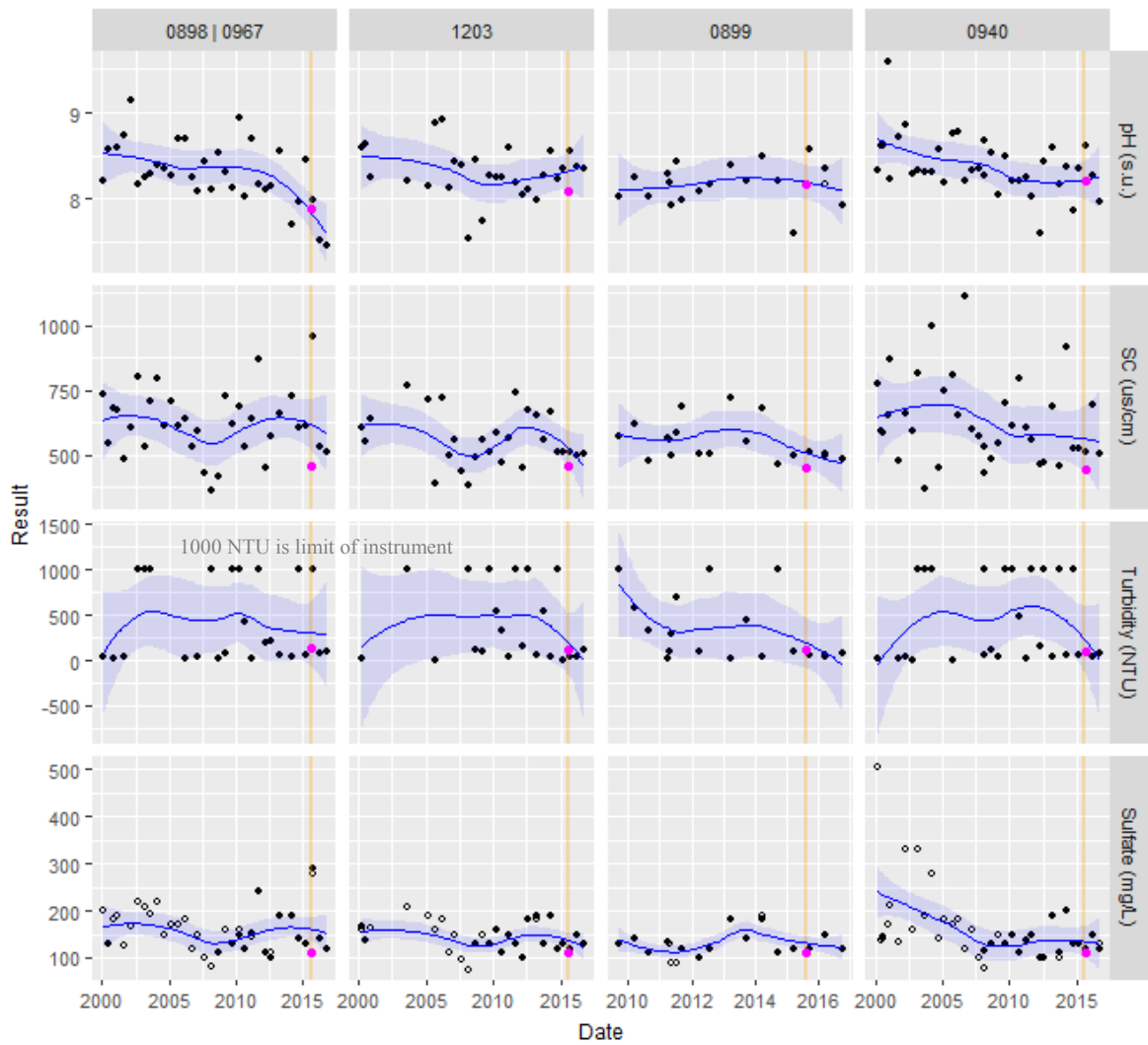
Figure 29. Shiprock Site Flows Corresponding to September 2015 Annual Sampling Event



Notes:

- Fraction: ● total ● dissolved
- Analytical result below the detection limit
- | Vertical line denotes August 5, 2015, GKM release
- August 18, 2015, nonroutine sampling event

Figure 30. Manganese Concentrations in Shiprock Site Surface Water Samples, 2008–2016



Notes:

| Vertical line denotes August 5, 2015, GKM release

Sample Type: ● Unfiltered ○ Filtered

● August 18, 2015, nonroutine sampling event (total vs. dissolved fractions not discernible in this plot)

NTU = nephelometric turbidity units

Figure 31. Historical Shiprock Site Surface Water Field Parameters and Sulfate

5.3 Assessment of Potential GKM Spill-Related Impacts to Groundwater

This section provides an overview of the Shiprock site floodplain hydrogeology, describes the groundwater extraction system on the floodplain, evaluates data regarding groundwater–river interactions at the time of the GKM release, and culminates in the analysis of groundwater sampling results for the major metals.

5.3.1 Overview of Site Floodplain Hydrogeology

The floodplain alluvial aquifer (floodplain aquifer) occurs in unconsolidated medium- to coarse-grained sand, gravel, and cobbles that were deposited in former channels of the San Juan River above the Mancos Shale that forms the bedrock underlying the entire site. The floodplain aquifer is hydraulically connected to the San Juan River. The river is a source of groundwater recharge to the floodplain aquifer in some areas, and it receives groundwater discharge in other areas. The floodplain aquifer also receives some inflow from groundwater in the terrace area. The floodplain alluvium is up to 20 ft thick and overlies Mancos Shale, which is typically soft and weathered for the first several feet below the alluvium (DOE 2002a).

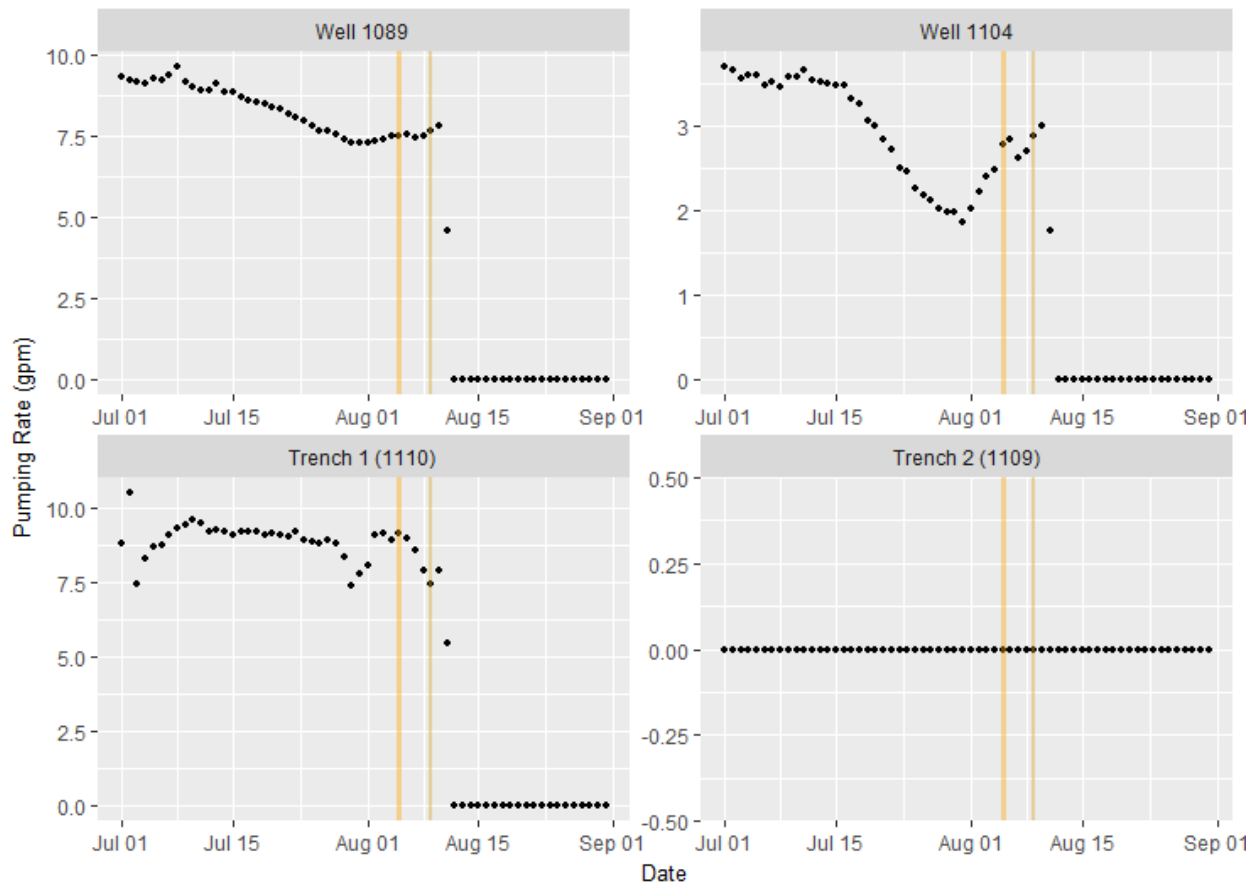
5.3.2 Groundwater Extraction System

At the Shiprock site, a plume of mill-derived groundwater that has been the focus of active remediation by LM for several years underlies the floodplain. As shown in Figure 23, the floodplain remediation system includes two groundwater extraction wells (1089 and 1104) and two collection trenches, Trench 1 (1110) and Trench 2 (1109). All extracted groundwater is pumped into a lined evaporation pond on the terrace, south of the disposal cell. Remedial pumping from these wells and trenches on the floodplain has been effective in reducing contaminant (uranium, sulfate, and nitrate) concentrations in the aquifer (DOE 2016b).

For the last several years, the remediation system has been shut down periodically for maintenance and repairs and to maintain evaporation pond water levels. Following the GKM release, all groundwater extraction on the floodplain at Shiprock was halted in response to Navajo Nation water use restrictions along the San Juan River. As shown in Figure 32, groundwater was being pumped from the three locations of 1089, 1104, and Trench 1 (farthest from the river) at the time of the GKM release. However, pumping was shut down shortly thereafter. Floodplain extraction wells remained off until after restrictions were lifted October 22, 2015; pumping was not resumed until November 17, 2015.

5.3.3 Floodplain Alluvial Aquifer–San Juan River Interactions

Groundwater extraction from the floodplain aquifer alters the natural groundwater flow direction in the vicinity of the pumping wells, deflecting groundwater flow towards the pumping wells. Despite the effect of pumping, the San Juan River has sections where water flows from the river into the floodplain aquifer and where water flows out of the floodplain aquifer into the river (DOE 2016c). There is one area, however—in the region of well 0612, installed adjacent to the upstream end of a riffle in the San Juan River—which is susceptible to inflow of river water under all flow conditions (DOE 2016c). That is, it is an area on the floodplain where the river generally loses to the aquifer.



Notes:

The first vertical line denotes the August 5, 2015, GKM release event. The second line denotes the estimated time of plume arrival at the Shiprock site (August 9, 2015, 0:00).

The pump at Trench 2 had been shut off since June 18, 2015, for site maintenance. Pumps for remaining locations (extraction wells 1089 and 1104 and Trench 1) were turned off on August 11, 2015, in response to Navajo Nation (NN) restrictions. Pumping did not resume until November 17, 2015, following NN lifting of the water use restrictions.

Figure 32. Flow Rates at Shiprock Floodplain Extraction Wells and Trenches, July–August 2015

To assess whether the river was losing or gaining at the time of the release, Figure 33 plots elevation of the San Juan River (based on USGS gage results) and the groundwater elevation in the floodplain aquifer measured at near-river well 0857 (Figure 23). Data are plotted for the entire year (2015) to provide historical context. This figure indicates that there is an approximate 2 ft gradient from the river to the floodplain during peak (June–July) flows. But throughout the rest of year, small gradients periodically shift from inflow to outflow. This figure shows that the aquifer was gaining at the time of the GKM release and days thereafter.

At the time of estimated plume arrival at Shiprock, there was an approximate 1 ft gradient from the river to the floodplain in the region of well 0857 (August 2015 zoom view provided in Figure 34). So, there was the potential for the alluvial aquifer to draw river water, possibly including dissolved metals, during the time the GKM release plume passed. These (aquifer) gaining conditions were sustained for about a week, followed by an approximate 10-day period when the aquifer was losing to the river near the gaging station. LM’s nonroutine sampling took place at that time (i.e., under losing conditions). These conditions probably apply to all near-river wells evaluated in this subset except well 0612 (see Section 5.3.3).

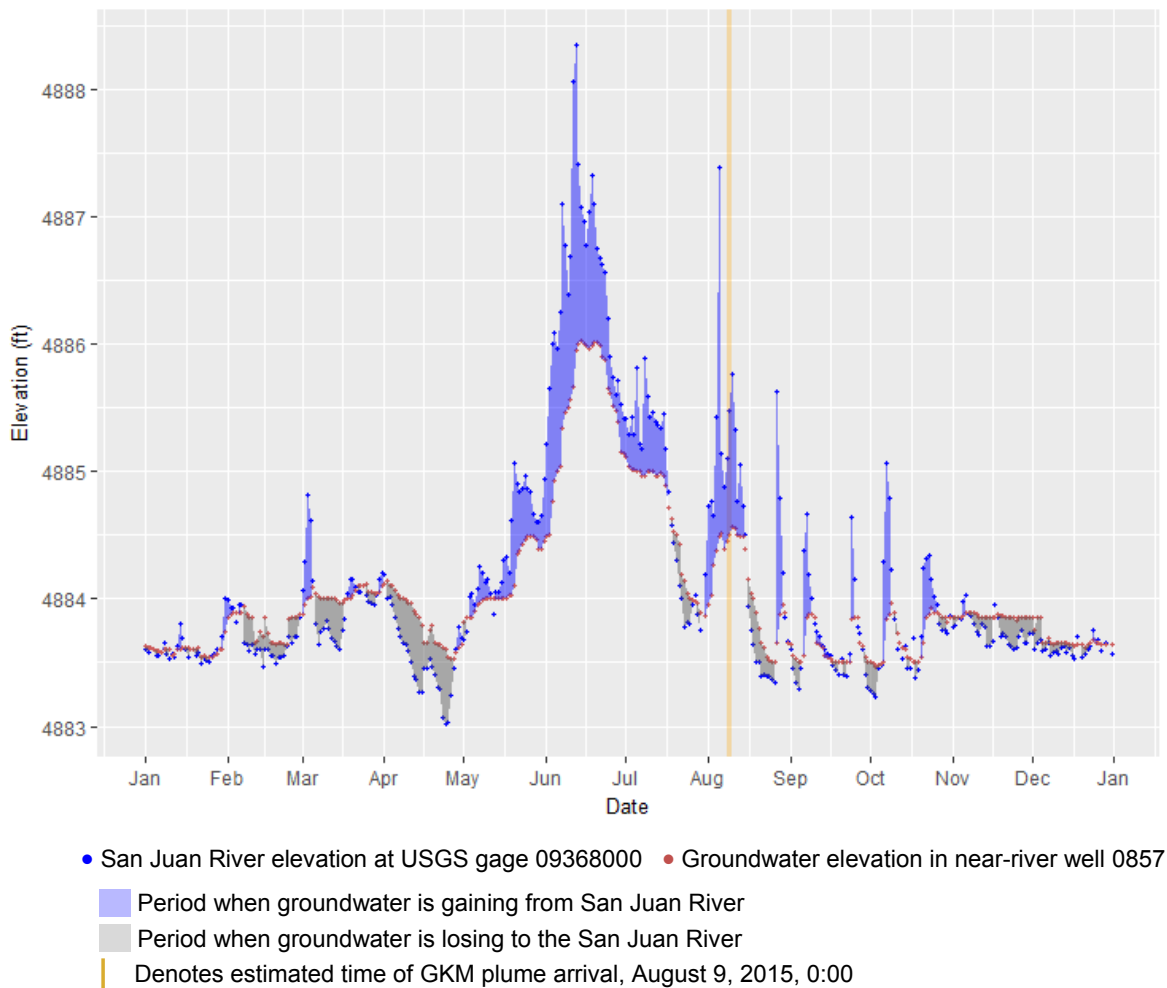
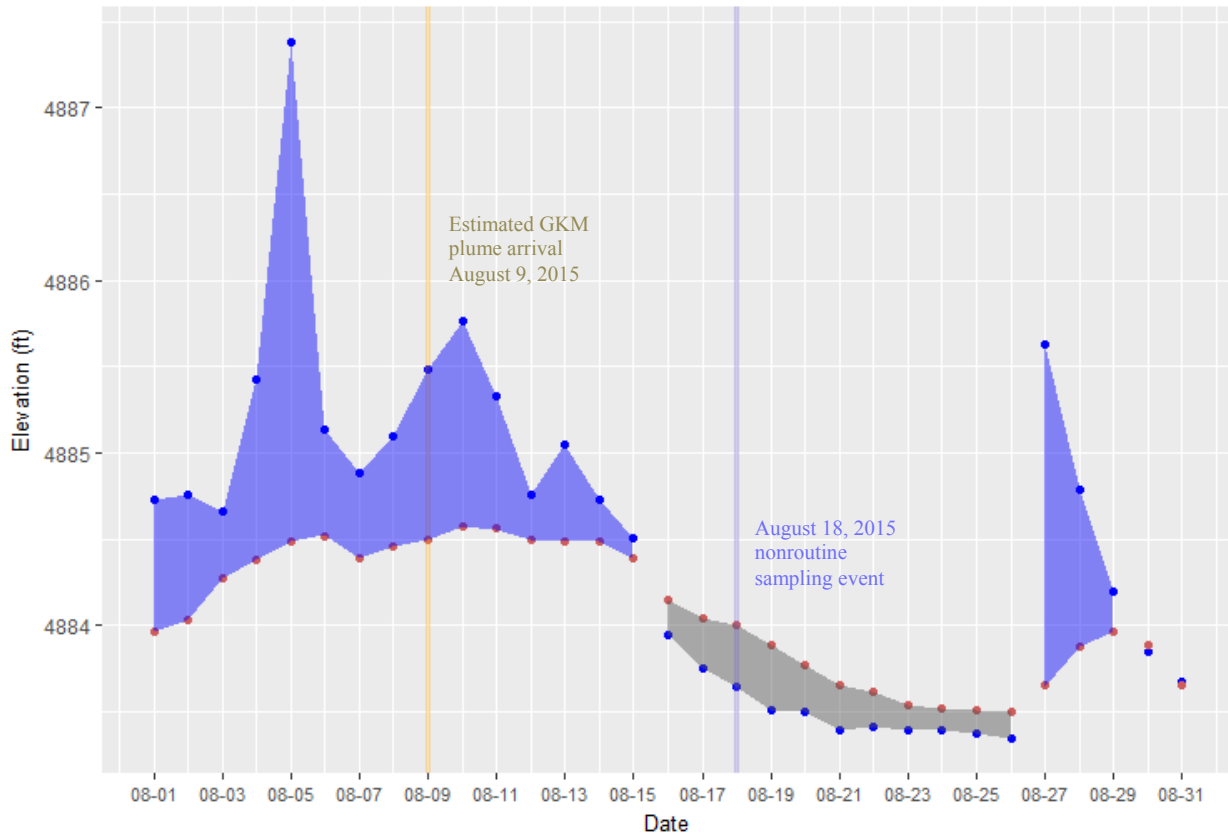


Figure 33. Elevations Measured at Shiprock Gage 09368000 and Nearby Well 0857 in 2015



- San Juan River elevation at USGS gage 09368000 • Groundwater elevation in near-river well 0857
- Period when groundwater is gaining from San Juan River
- Period when groundwater is losing to the San Juan River
- | Denotes estimated time of GKM plume arrival, August 9, 2015, 0:00
- | Denotes LM's August 18, 2015, nonroutine sampling event

Figure 34. Zoom View of San Juan River vs. Well 0857 Groundwater Elevations, August 2015

5.3.4 Groundwater Sampling Results

Figure 35 plots historical metals concentrations measured in Shiprock site monitoring wells sampled in August 2015, the post-GKM plume nonroutine sampling event. As has been the case for several media–analyte combinations addressed in this report, this figure illustrates the relative lack of data for most metals, namely, zinc, copper, cadmium, arsenic, lead, silver, and mercury. Acknowledging these limitations, as well as inconsistencies in historical sampling and analytical approaches (e.g., for total and dissolved fractions¹²), in most cases, results are consistent with historical ranges. Additionally, concentrations of arsenic, cadmium, lead, mercury, and silver are all well below corresponding UMTRCA groundwater standards listed in Table 5—0.05 mg/L except for cadmium (0.01 mg/L) and mercury (0.002 mg/L).

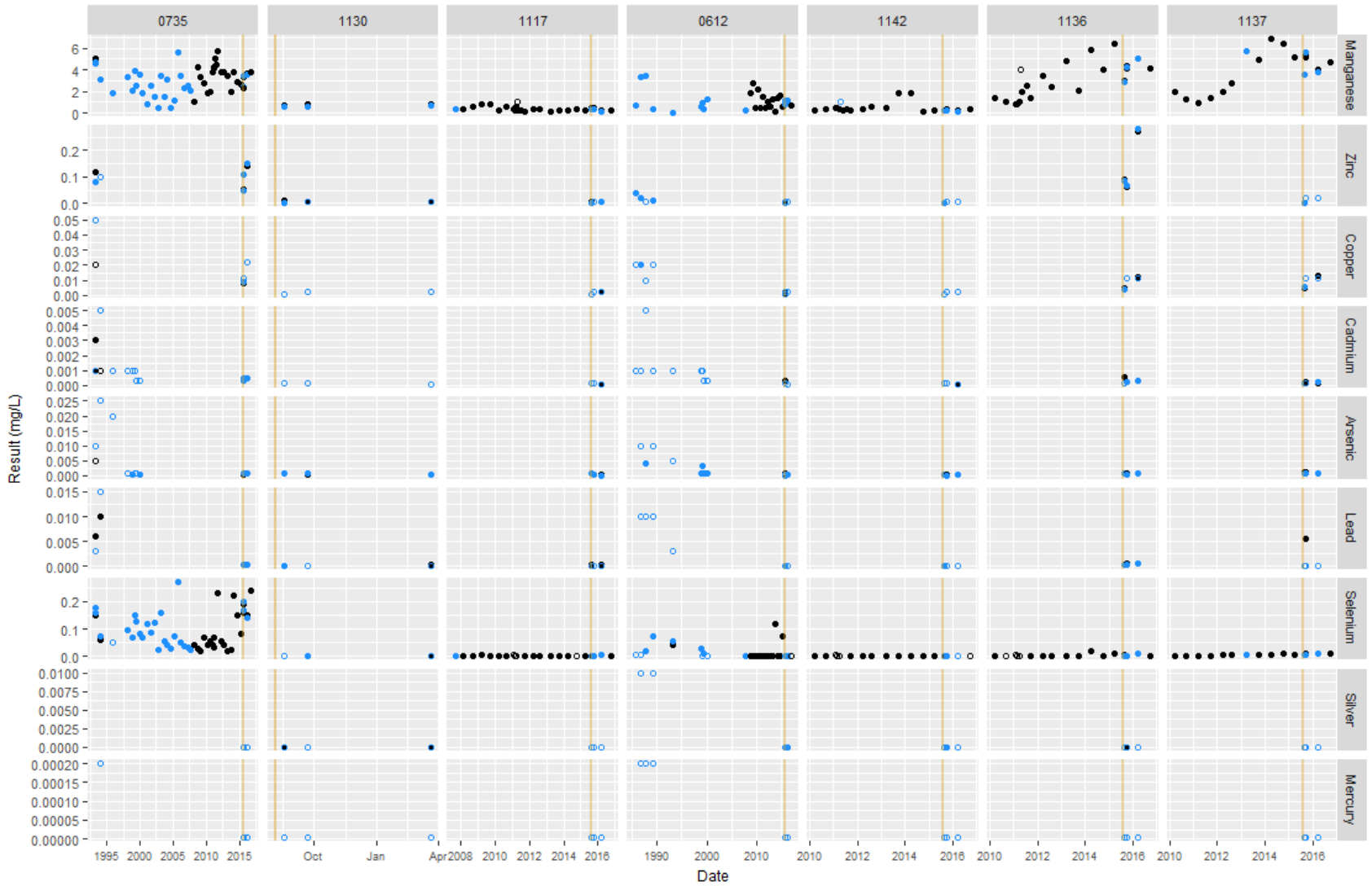
Zinc, a potential tracer of the GKM plume, was slightly elevated in the most recent (March 2016) sample from well 1136. Total and dissolved concentrations (both 0.3 mg/L), although higher than those measured in any near-river alluvial well in this study subset, are over an order of magnitude less than the 5.0 mg/L secondary MCL (Table 5). As true for all wells in this study subset except 0612 and 0735, there are no historical heavy-metals data for the 1136 location, precluding an evaluation of the significance of this result (it could just reflect normal variation). However, because of the timing relative to the August 2015 GKM release, this spike is probably not indicative of GKM plume impacts.

Of the wells evaluated in this subset, well 0612 is most susceptible to inflow of river water under all flow conditions (DOE 2016c). For all metals, recent (2015–2016) results in this well are within the range of historical measurements (Figure 35). Overall, no deviation in metals concentrations, including manganese, is apparent based on results from the post-GKM (August 2015) and subsequent (September 2015 and March 2016) semiannual sampling events. Of the metals data plotted in Figure 35, manganese would most likely indicate GKM plume impacts. To provide greater resolution of these results, Figure 36 plots manganese concentrations using a unique scale for each well. On the basis of these results, there is no evidence of GKM-related impacts.

Figure 37, which plots historical sulfate concentrations, pH, and SC, also indicates no deviations in trends for these parameters that could be associated with the GKM release.

As a final step in this assessment, groundwater data from the site extraction wells were evaluated to assess potential GKM release impacts. Figure 38 presents historical data for the Shiprock site pumping wells network for the following parameters: manganese, sulfate, pH, and SC. These wells were not sampled for GKM metals other than manganese until July 2016. Therefore, data for remaining metals potentially indicative of GKM plume impacts are too limited to address. On the basis of these data, there are no trend deviations indicative of impacts from the GKM plume (Figure 38).

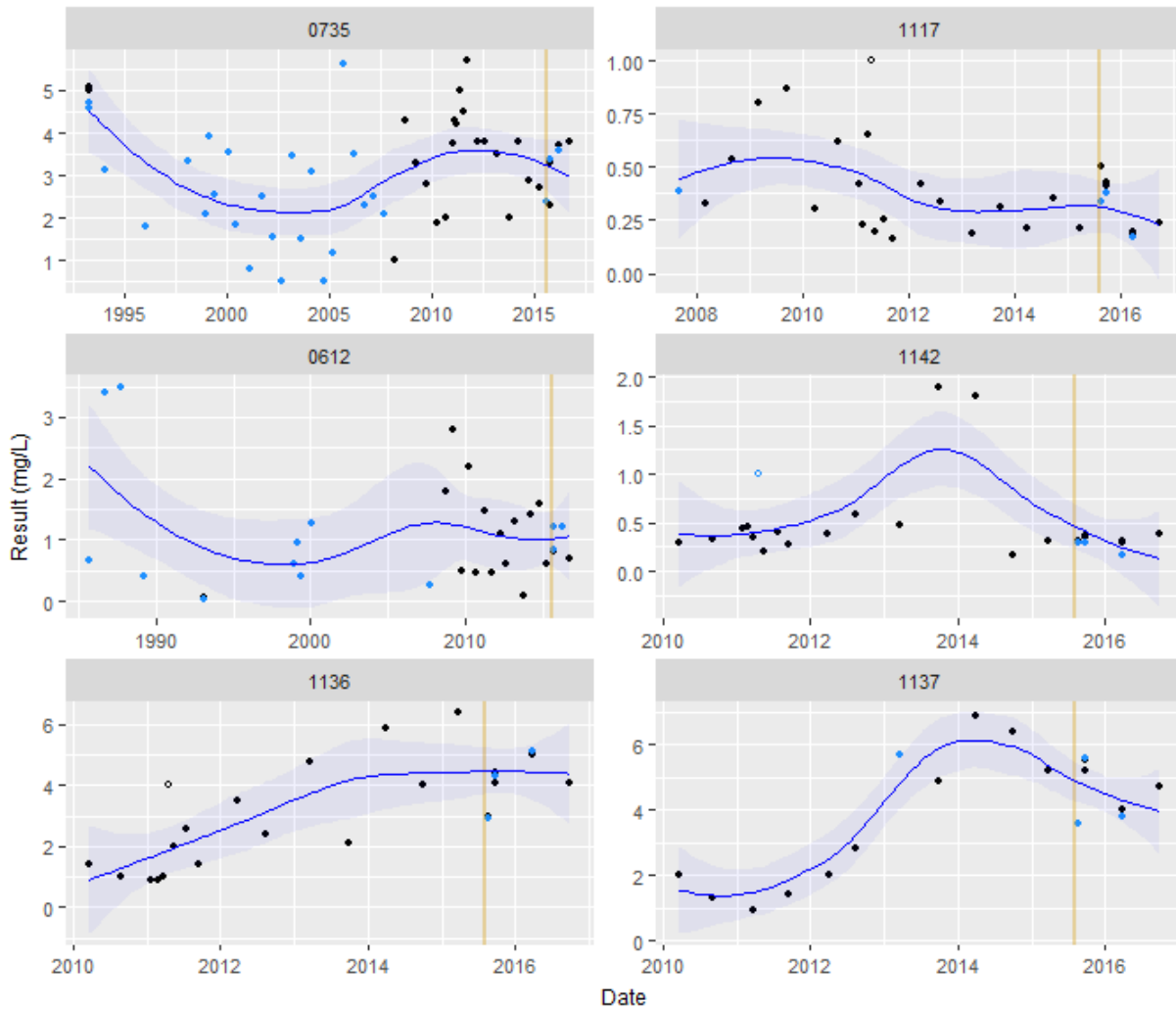
¹² LM's current approach for groundwater sampling is to measure total concentrations (vs. dissolved) unless turbidity exceeds 10 nephelometric turbidity units (NTU). This approach is different than earlier protocols, when often only dissolved concentrations were measured. These inconsistencies hinder comparisons of recent vs. historical results.



Notes:

- Total fraction ● Dissolved fraction ○ Analytical result below the detection limit | Vertical line denotes August 5, 2015, GKM release
- Wells are listed in order of upstream to downstream; metals are listed in general order of relative proportion in GKM plume.
- In the upper left plot for manganese in well 0735, an anomalous BDL result was excluded for scaling purposes: <80 mg/L (April 19, 2011 result)

Figure 35. Historical Metals Concentrations in Shiprock Site Groundwater Samples



Notes:

Fraction: ● total ● dissolved

○ Analytical result below the detection limit

| Vertical line denotes August 5, 2015, GKM release

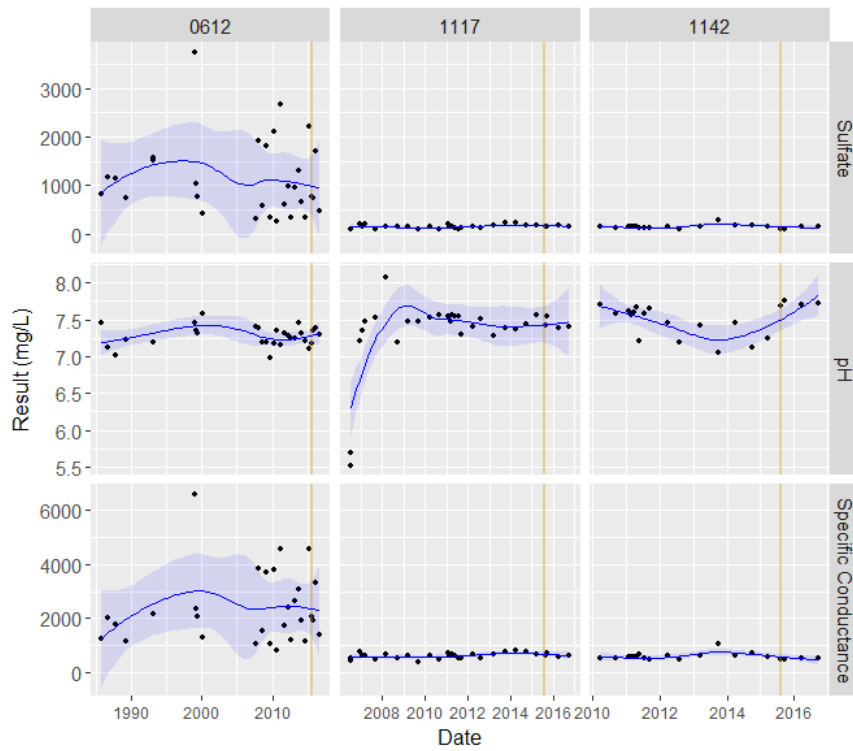
— Blue line is LOESS local regression line (dissolved results only)

Shaded area is the corresponding 95% pointwise confidence interval

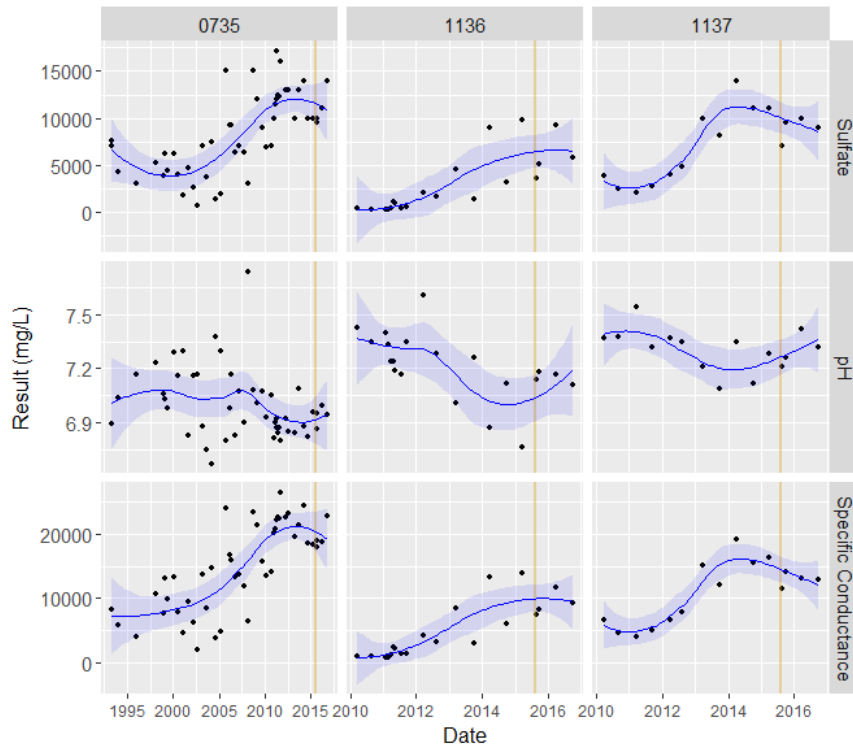
Smoothing done on both total and dissolved fractions combined; it is only intended for visualization purposes.

Data for well 1130 are not shown here given the paucity of results in Figure 35.

Figure 36. Historical Manganese Concentrations in Shiprock Site Floodplain Alluvial Wells



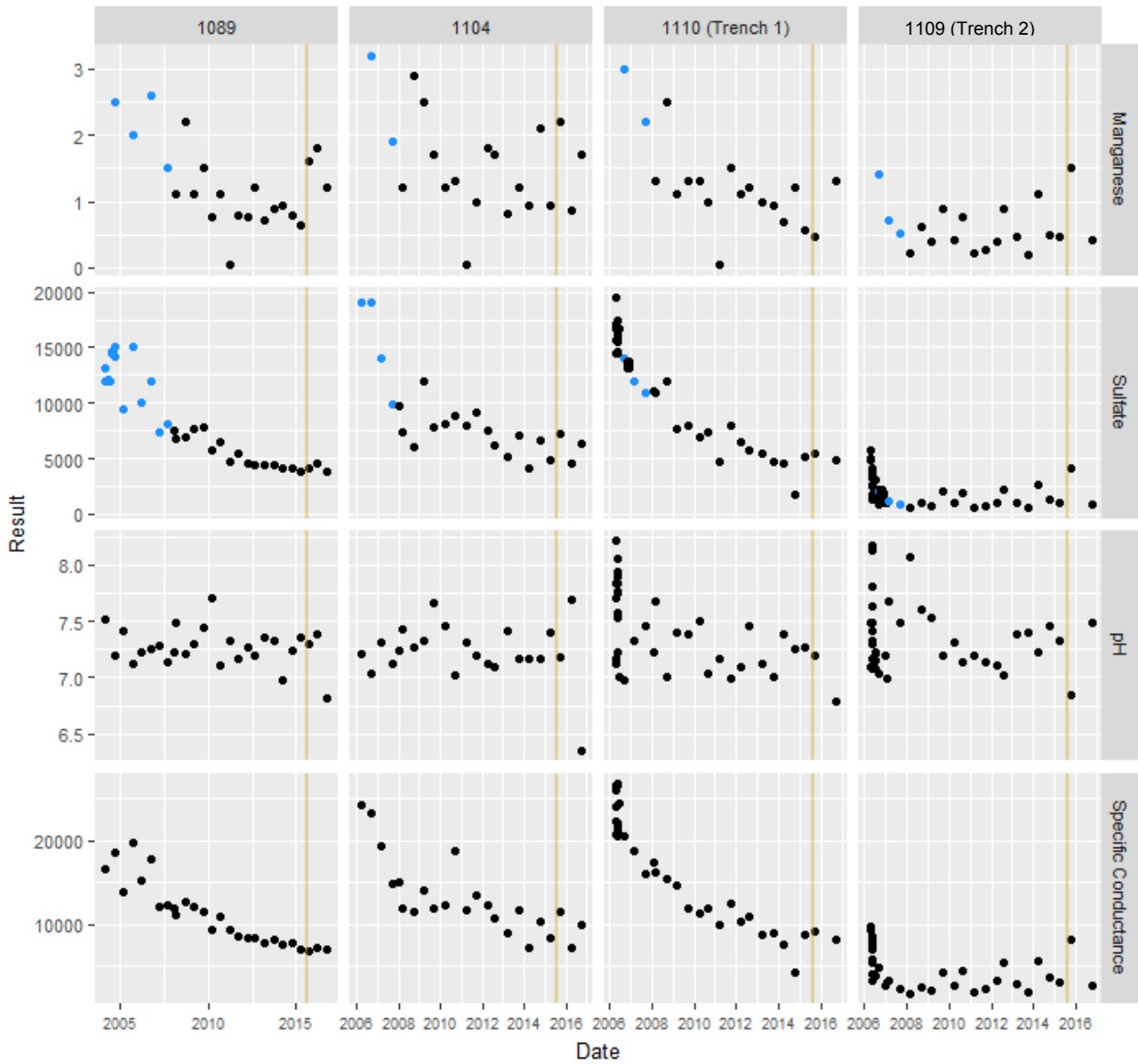
(a) Wells with Lower Magnitude Sulfate and SC: 0612, 1117, and 1142



(b) Wells with Higher Magnitude Sulfate and SC: 0735, 1136, and 1137

— Blue line is LOESS local regression line (dissolved results only). Denotes 95% pointwise confidence interval
 | Vertical line denotes August 5, 2015, GKM release

Figure 37. Historical Sulfate Concentrations and Field Measurements in Shiprock Site Wells



Notes:

Fraction: ● total ● dissolved

| Vertical line denotes August 5, 2015, GKM release

Figure 38. Selected Historical Analyte Results for Shiprock Extraction Wells

5.4 Summary

Analysis of GKM plume-related impacts to the Shiprock site was complicated by a number of factors: the distance of the site from GKM (about 150 river miles), the inability to detect a discernible plume (plume arrival time was estimated), increased water flows from the Navajo Dam, and rain events. Evaluation of USGS and EPA data corresponding to the time of estimated plume arrival (August 9, 2015) showed consistent increases in concentrations across all metals. But these were of low magnitude and not sustained. No GKM plume-related impacts to surface water were discernible based on LM sampling data. As confirmed by BOR (2016), some data indicate that storm event effects resulted in higher metals concentrations than those that could be attributed to the GKM release.

At the time of the release and estimated GKM plume arrival, groundwater was being pumped from three floodplain locations, but pumping was shut down shortly thereafter and remained off until November 2015. Evaluation of river vs. groundwater elevations revealed that there was a potential for the alluvial aquifer to receive river water, possibly including dissolved metals, during the time the GKM release plume passed (the aquifer was gaining from the river at that time). Despite these two factors, which could have increased the likelihood of incursion of river-borne contaminants to the floodplain aquifer, data indicate there were no impacts to the Shiprock site groundwater system or monitoring network resulting from the GKM release.

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6.0 Conclusions

To assess potential impacts of the GKM plume on groundwater (and adjacent surface water) at the Durango and Shiprock sites, LM mobilized a nonroutine sampling effort on August 18, 2015, about 2 weeks after the August 5, 2015, GKM release. At the outset, LM recognized that there would likely be little overlap between LM COCs and AMD-related constituents, as many of the elements likely associated with AMD have not been included in LM's analytical program since the 1980s and 1990s. Therefore, LM relied heavily on data from other agencies, primarily EPA, MSI, and River Watch, especially when characterizing post-GKM plume impacts to surface water.

The analysis was a step-by-step process. First, to better understand what constituents were most indicative of plume impacts, LM reviewed fate and transport data compiled by EPA. Then, given the lack of pre-GKM spill (or baseline) data for many sample locations, LM assessed historical data for select stations along the Animas River drainage that had been extensively sampled before the release. For each site, impacts to surface water were evaluated first, as this allowed better understanding of the levels of GKM metals that could potentially enter the groundwater system, assuming incursion of river-borne contaminants. River discharge and groundwater–river interactions were also evaluated. For each site, the assessment culminated in a comparison of pre- versus post-GKM release analytical results.

Short-term impacts to surface water in the Animas River in Durango have been well documented by other agencies. LM's analysis of those data corroborated those findings. These impacts were indicated by short-term increases in metals concentrations that declined within days to pre-release levels (for the stations with baseline data). Data collected by MSI at Rotary Park showed some rebound corresponding to high spring runoff, after which levels declined. No GKM plume-related impacts to groundwater are discernible based on LM sampling data. Slight increases in total manganese concentrations measured in two alluvial wells could be attributed to natural variation.

Analysis of GKM plume-related impacts to the Shiprock site was confounded by the distance of the site from GKM, the inability to detect a discernible plume in the river near the site, increased water flows from the Navajo Dam, and rain events. Review of other agency data indicated slight increases in metals concentrations when comparing pre- vs. post-plume arrival sample results. However, these were of low magnitude and not sustained. For surface water, no plume-related impacts were apparent based on LM's data set, with the possible exception of increases observed at the upgradient (background) location, where sampling occurred shortly after a rain event.

At the time of the release and estimated GKM plume arrival, groundwater was being pumped from three Shiprock site floodplain locations, but pumping was shut down shortly thereafter and remained off until November 2015. Evaluation of river vs. groundwater elevations revealed that there was a potential for the alluvial aquifer to receive river water, possibly including dissolved metals, during the time the GKM release plume passed (the aquifer was gaining from the river at that time). Despite these two factors, which could have increased the likelihood of incursion of river-borne contaminants to the floodplain aquifer, no impacts from the GKM release to the alluvial aquifer within the site monitoring well network were observed.

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Appendix A

**Data Review and Validation Report for August 18, 2015
Durango, Colorado, Processing Site
Groundwater and Surface Water Sampling**

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Data Review and Validation Report

General Information

Report Number (RIN): 15087295
Sample Event: August 18, 2015
Site(s): Durango, Colorado, Disposal and Processing Sites (Groundwater and Surface Water)
Laboratory: ALS Laboratory Group
Work Order No.: 1508336
Analysis: Metals and Wet Chemistry
Validator: Stephen Donivan
Review Date: October 1, 2015

This validation was performed according to the Environmental Procedures Catalog (LMS/POL/S04325), "Standard Practice for Validation of Environmental Data." The procedure was applied at Level 3, Data Validation. See attached Data Validation Worksheets for supporting documentation of the data review and validation. All analyses were successfully completed. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 1.

Table 1. Analytes and Methods

Table with 4 columns: Analyte, Line Item Code, Prep Method, Analytical Method. Rows include Sulfate, Metals (Cu, Hg, Mn, Zn), and Metals (Ag, As, Cd, Mo, Pb, Se, U).

Data Qualifier Summary

Analytical results were qualified as listed in Table 2. Refer to the sections below for an explanation of the data qualifiers applied.

Table 2. Data Qualifier Summary

Table with 5 columns: Sample Number, Location, Analyte(s), Flag, Reason. Rows show qualified results for Copper, Selenium, and Uranium at location 0584.

Sample Number	Location	Analyte(s)	Flag	Reason
1508336-1	0584	Zinc	J	Equipment blank result
1508336-2	0584	Uranium	J	Equipment blank result
1508336-2	0584	Zinc	J	Equipment blank result
1508336-5	0612	Copper	J	Negative method blank
1508336-7	0631	Copper	J	Negative method blank
1508336-8	0652	Copper	J	Negative method blank
1508336-9	0652	Uranium	J	Equipment blank result
1508336-9	0652	Zinc	J	Equipment blank result
1508336-10	0652	Uranium	J	Equipment blank result
1508336-10	0652	Zinc	J	Equipment blank result
1508336-11	0678	Selenium	J	Equipment blank result
1508336-11	0678	Uranium	J	Equipment blank result
1508336-11	0678	Zinc	J	Equipment blank result
1508336-12	0678	Uranium	J	Equipment blank result
1508336-12	0678	Zinc	J	Equipment blank result
1508336-13	0857	Copper	J	Negative method blank
1508336-13	0857	Lead	U	Less than 5 times the method blank
1508336-16	0866	Zinc	J	Negative method blank

Sample Shipping/Receiving

ALS Laboratory Group in Fort Collins, Colorado, received 19 water samples on August 21, 2015, accompanied by a Chain of Custody form. The receiving documentation included copies of the shipping labels listing the air waybill numbers. The form was checked to confirm that all of the samples were listed with sample collection dates and times, and that signatures and dates were present indicating sample relinquishment and receipt. The Chain of Custody form was complete with no errors or omissions.

Preservation and Holding Times

The sample shipment was received intact with the temperature inside the iced cooler at 2.6 °C, which complies with requirements. All samples were received in the correct container types and had been preserved correctly for the requested analyses. All samples were analyzed within the applicable holding times.

Detection and Quantitation Limits

The method detection limit (MDL) was reported for all metal and wet chemical analytes as required. The MDL, as defined in 40 CFR 136, is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. The practical quantitation limit (PQL) for these analytes is the lowest concentration that can be reliably measured, and is defined as 5 times the MDL. The reported MDLs for all analytes demonstrate compliance with contractual requirements.

Laboratory Instrument Calibration

Compliance requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable qualitative and quantitative data for all analytes. Initial calibration demonstrates that the instrument is capable of acceptable performance in the

beginning of the analytical run and of producing a linear curve. Compliance requirements for continuing calibration checks are established to ensure that the instrument continues to be capable of producing acceptable qualitative and quantitative data. All laboratory instrument calibrations were performed correctly in accordance with the cited methods. All calibration and laboratory spike standards were prepared from independent sources.

Method SW-846 6010B

Calibrations for copper, manganese, and zinc were performed on August 24, 2015, using three calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the calibration curve near the PQL and all results were within the acceptance range.

Method SW-846 6020A

Calibrations for arsenic, cadmium, molybdenum, lead, selenium, silver, and uranium were performed on August 25, 2015, using four calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the calibration curve near the PQL and all results associated with the samples were within the acceptance range. Mass calibration and resolution verifications were performed at the beginning of each analytical run in accordance with the analytical procedure. Internal standard recoveries associated with requested analytes were stable and within acceptable ranges.

Method SW-846 7470

Calibration for mercury was performed on August 24, 2015, using six calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the calibration curve near the PQL and all results were within the acceptance range.

Method SW-846 9056

Initial calibrations were performed for sulfate using five calibration standards on August 18, 2015. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration check results within the acceptance range.

Method and Calibration Blanks

Method blanks are analyzed to assess any contamination that may have occurred during sample preparation. Calibration blanks are analyzed to assess instrument contamination prior to and during sample analysis. All method blank and calibration blank results associated with the samples were below the PQL for all analytes. In cases where a blank concentration exceeds or equals the MDL, the associated sample results are qualified with a “U” flag (not detected) when the sample result is greater than the MDL but less than 5 times the blank concentration.

Inductively Coupled Plasma Interference Check Sample Analysis

Interference check samples were analyzed at the required frequency to verify the instrumental interference and background correction factors. All check sample results met the acceptance criteria.

Matrix Spike Analysis

Matrix spike and matrix spike duplicate (MS/MSD) samples are used to measure method performance in the sample matrix. The MS/MSD data are not evaluated when the concentration of the unspiked sample is greater than 4 times the spike. The spike recoveries met the acceptance criteria for all analytes evaluated.

Laboratory Replicate Analysis

Laboratory replicate analyses are used to determine laboratory precision for each sample matrix. The relative percent difference for replicate results that are greater than 5 times the PQL should be less than 20 percent. For results that are less than 5 times the PQL, the range should be no greater than the PQL. All replicate results met these criteria, demonstrating acceptable precision.

Laboratory Control Sample

Laboratory control samples were analyzed at the correct frequency to provide information on the accuracy of the analytical method and the overall laboratory performance, including sample preparation. All control sample results were acceptable.

Metals Serial Dilution

Serial dilutions were prepared and analyzed for the metals analyses to monitor chemical or physical interferences in the sample matrix. Serial dilution data are evaluated when the concentration of the undiluted sample is greater than 50 times the MDL. All evaluated serial dilution data were acceptable.

Completeness

Results were reported in the correct units for all analytes requested using contract-required laboratory qualifiers.

Chromatography Peak Integration

The integration of analyte peaks was reviewed for all ion chromatography data. There were no manual integrations performed and all peak integrations were satisfactory.

Electronic Data Deliverable (EDD) File

The EDD file was received on September 4, 2015. The Sample Management System EDD validation module was used to verify that the EDD file was complete and in compliance with requirements. The module compares the contents of the file to the requested analyses to ensure

all and only the requested data are delivered. The contents of the EDD were manually examined to verify that the sample results accurately reflect the data contained in the sample data package.

Sampling Protocol

All monitoring wells were sampled using the Category I or II low-flow sampling criteria. Sample results for monitoring wells meeting the Category I or II criteria were qualified with an “F” flag in the database, indicating the wells were purged and sampled using the low-flow sampling method.

Wells DUR01 0857 and DUR02 0594 were classified as Category II due to water level drawdown. The sample results for these wells were qualified with a “Q” flag, indicating the data are qualitative because of the sampling technique.

Equipment Blanks

Equipment blanks are prepared and analyzed to document contamination attributable to the sample collection process. One equipment blank was submitted with these samples. Manganese, zinc, selenium, and uranium were detected in the blank. Associated sample results for these analytes that are greater than the MDL but less than 5 times the blank concentration are qualified with a “J” flag as estimated values.

Field Duplicate Assessment

Field duplicate samples are collected and analyzed as an indication of overall precision of the measurement process. The precision observed includes both field and laboratory precision and has more variability than laboratory duplicates, which measure only laboratory performance. Duplicate samples were collected from location DUR01 0612. The relative percent difference (RPD) for duplicate results that are greater than 5 times the PQL should be less than 20 percent. The duplicate results met the criteria.

STEPHEN DONIVAN

(Affiliate)

2017.02.06

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Report Prepared By: _____

Stephen Donivan
Laboratory Coordinator

SAMPLE MANAGEMENT SYSTEM

General Data Validation Report

RIN: 15087295 Lab Code: PAR Validator: Stephen Donovan Validation Date: 10/01/2015
Project: AS&T PrMgmt&Planning Analysis Type: Metals General Chem Rad Organics
of Samples: 19 Matrix: WATER Requested Analysis Completed: Yes

Chain of Custody

Present: OK Signed: OK Dated: OK

Sample

Integrity: OK Preservation: OK Temperature: OK

Select Quality Parameters

- Holding Times
- Detection Limits
- Field/Trip Blanks
- Field Duplicates

All analyses were completed within the applicable holding times.

The reported detection limits are equal to or below contract requirements.

There was 1 trip/equipment blank evaluated.

There were 2 duplicates evaluated.

SAMPLE MANAGEMENT SYSTEM

Validation Report: Equipment/Trip Blanks

RIN: 15087295 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/01/2015

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508336-19	SW6010	Manganese	2.2	J	0.11	UG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508336-1	NJS 249	0584	97	1		
1508336-10	NJS 248	0652	87	1		
1508336-11	NJS 259	0678	91	1		
1508336-12	NJS 260	0678	75	1		
1508336-2	NJS 250	0584	80	1		
1508336-9	NJS 247	0652	95	1		

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508336-19	SW6010	Zinc	10	J	0.72	UG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508336-1	NJS 249	0584	39	1		J
1508336-10	NJS 248	0652	21	1		J
1508336-11	NJS 259	0678	38	1		J
1508336-12	NJS 260	0678	21	1		J
1508336-2	NJS 250	0584	21	1		J
1508336-9	NJS 247	0652	33	1		J

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508336-19	SW6020	Selenium	0.37	J	0.32	UG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508336-1	NJS 249	0584	0.75	10	J	J
1508336-10	NJS 248	0652	0.32	10	U	
1508336-11	NJS 259	0678	0.5	10	J	J
1508336-12	NJS 260	0678	0.32	10	U	
1508336-2	NJS 250	0584	0.32	10	U	
1508336-9	NJS 247	0652	0.32	10	U	

SAMPLE MANAGEMENT SYSTEM

Validation Report: Equipment/Trip Blanks

RIN: 15087295 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/01/2015

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508336-19	SW6020	Uranium	1.5		0.029	UG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508336-1	NJS 249	0584	0.79	10		J
1508336-10	NJS 248	0652	0.82	10		J
1508336-11	NJS 259	0678	0.8	10		J
1508336-12	NJS 260	0678	0.75	10		J
1508336-2	NJS 250	0584	0.8	10		J
1508336-9	NJS 247	0652	0.97	10		J

SAMPLE MANAGEMENT SYSTEM
Validation Report: Field Duplicates

Page 1 of 1

RIN: 15087295 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/01/2015

Duplicate: 2755

Sample: 0612

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Arsenic	0.94	J		10	0.81	J		10	14.86		UG/L
Cadmium	54			10	55			10	1.83		UG/L
Copper	1.2	J		1	1.8	J		1			UG/L
Lead	3.8			10	3.2			10	17.14		UG/L
Manganese	5700			1	5800			1	1.74		UG/L
Mercury	0.0029	U		1	0.0029	U		1			UG/L
Molybdenum	77			10	81			10	5.06		UG/L
Selenium	0.32	U		10	2.2			10			UG/L
Silver	0.03	J		10	0.017	U		10			UG/L
SULFATE	1800			50	1700			40	5.71		MG/L
Uranium	1400			100	1300			100	7.41		UG/L
Zinc	2000			1	2000			1	0		UG/L

Duplicate: 2756

Sample: 0612

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Arsenic	0.45	J		10	0.48	J		10			UG/L
Cadmium	55			10	57			10	3.57		UG/L
Copper	1.5	J		1	0.97	U		1			UG/L
Lead	0.068	U		10	0.2	J		10			UG/L
Manganese	5700			1	5700			1	0		UG/L
Mercury	0.0029	U		1	0.0029	U		1			UG/L
Molybdenum	77			10	79			10	2.56		UG/L
Selenium	2.5			10	1.1			10			UG/L
Silver	0.017	U		10	0.02	J		10			UG/L
Uranium	1300			100	1400			100	7.41		UG/L
Zinc	2000			1	2000			1	0		UG/L

SAMPLE MANAGEMENT SYSTEM

Metals Data Validation Worksheet

RIN: 15087295 Lab Code: PAR Date Due: 09/03/2015
 Matrix: Water Site Code: AST01 Date Completed: 09/04/2015

Analyte	Method Type	Date Analyzed	CALIBRATION				Method Blank	LCS %R	MS %R	MSD %R	Dup. RPD	ICSAB %R	Serial Dil. %R	CRI %R
			Int.	R^2	CCV	CCB								
Arsenic	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	107.0	116.0	104.0	11.0	101.0		115.0
Cadmium	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	111.0	108.0	106.0	2.0	100.0		120.0
Copper	ICP/ES	08/24/2015	0.0000	1.0000	OK	OK	OK	102.0	109.0	110.0	1.0	109.0		107.0
Lead	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	103.0	105.0	104.0	1.0	110.0		104.0
Manganese	ICP/ES	08/24/2015	0.0000	1.0000	OK	OK	OK	106.0	109.0	107.0	2.0	98.0	2.0	106.0
Mercury	CVAA	08/24/2015	0.0000	1.0000	OK	OK	OK	102.0	105.0	98.0	7.0			101.0
Mercury	CVAA	08/25/2015	0.0000	1.0000	OK	OK	OK	103.0	94.0	105.0	11.0			98.0
Molybdenum	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	106.0	112.0	109.0	3.0	102.0		101.0
Selenium	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	106.0	109.0	104.0	5.0	97.0		124.0
Silver	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	110.0	117.0	112.0	5.0	109.0		115.0
Uranium	ICP/MS	08/25/2015	0.0000	1.0000	OK	OK	OK	101.0	102.0	102.0	1.0	99.0		110.0
Zinc	ICP/ES	08/24/2015	0.0000	1.0000	OK	OK	OK	110.0	111.0	105.0	6.0	93.0		105.0

SAMPLE MANAGEMENT SYSTEM

Wet Chemistry Data Validation Worksheet

RIN: 15087295 Lab Code: PAR Date Due: 09/03/2015
 Matrix: Water Site Code: AST01 Date Completed: 09/04/2015

Analyte	Date Analyzed	CALIBRATION				Method Blank	LCS %R	MS %R	MSD %R	DUP RPD	Serial Dil. %R
		Int.	R^2	CCV	CCB						
SULFATE	08/29/2015	0.000	1.0000	OK	OK	OK	101.0	109.0	115.0	2.00	

Appendix B

**Data Review and Validation Report for August 18, 2015
Shiprock, New Mexico, Disposal Site
Groundwater and Surface Water Sampling**

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Data Review and Validation Report

General Information

Report Number (RIN): 15087296
Sample Event: August 18, 2015
Site(s): Shiprock, New Mexico
(Laboratory: ALS Laboratory Group
Work Order No.: 1508337
Analysis: Metals and Wet Chemistry
Validator: Stephen Donivan
Review Date: October 2, 2015)

This validation was performed according to the Environmental Procedures Catalog (LMS/POL/S04325), "Standard Practice for Validation of Environmental Data." The procedure was applied at Level 3, Data Validation. See attached Data Validation Worksheets for supporting documentation of the data review and validation. All analyses were successfully completed. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 1.

Table 1. Analytes and Methods

Table with 4 columns: Analyte, Line Item Code, Prep Method, Analytical Method. Rows include Ammonia as N, Nitrate + Nitrite as N, Chloride, Sulfate, Metals (Ca, Cu, Hg, K, Mg, Mn, Na, Sr, Zn), and Metals (Ag, As, Cd, Pb, Se, U).

Data Qualifier Summary

Analytical results were qualified as listed in Table 2. Refer to the sections below for an explanation of the data qualifiers applied.

Table 2. Data Qualifier Summary

Sample Number	Location	Analyte(s)	Flag	Reason
1508337-1	0612	Arsenic	U	Less than 5 times the calibration blank
1508337-1	0612	Silver	J	Negative method blank
1508337-2	0612	Arsenic	U	Less than 5 times the calibration blank
1508337-2	0612	Silver	J	Negative method blank
1508337-3	0735	Arsenic	U	Less than 5 times the calibration blank
1508337-5	0899	Silver	J	Negative method blank
1508337-6	0899	Zinc	J	Equipment blank result
1508337-7	0940	Silver	J	Negative method blank
1508337-8	0940	Zinc	J	Equipment blank result
1508337-9	0967	Silver	J	Negative method blank
1508337-11	1117	Manganese	J	Field duplicate result
1508337-13	1130	Silver	J	Negative method blank
1508337-21	1203	Silver	U	Less than 5 times the method blank
1508337-22	1203	Copper	U	Less than 5 times the calibration blank
1508337-22	1203	Silver	U	Less than 5 times the method blank
1508337-22	1203	Zinc	J	Equipment blank result
1508337-23	1117 Duplicate	Copper	U	Less than 5 times the calibration blank
1508337-23	1117 Duplicate	Manganese	J	Field duplicate result
1508337-23	1117 Duplicate	Zinc	J	Negative calibration blank
1508337-24	1117 Duplicate	Zinc	J	Negative calibration blank
1508337-25	Equipment blank	Calcium	U	Less than 5 times the method blank
1508337-25	Equipment blank	Copper	U	Less than 5 times the method blank
1508337-25	Equipment blank	Potassium	U	Less than 5 times the method blank
1508337-25	Equipment blank	Sodium	U	Less than 5 times the method blank
1508337-25	Equipment blank	Strontium	U	Less than 5 times the method blank
1508337-25	Equipment blank	Uranium	U	Less than 5 times the method blank
1508337-25	Equipment blank	Zinc	J	Negative calibration blank

Sample Shipping/Receiving

ALS Laboratory Group in Fort Collins, Colorado, received 25 water samples on August 21, 2015, accompanied by a Chain of Custody form. The receiving documentation included copies of the shipping labels listing the air waybill numbers. The form was checked to confirm that all of the samples were listed with sample collection dates and times, and that signatures and dates were present indicating sample relinquishment and receipt. The Chain of Custody form was complete with no errors or omissions.

Preservation and Holding Times

The sample shipment was received intact with the temperature inside the iced cooler at 2.6 °C, which complies with requirements. All samples were received in the correct container types and had been preserved correctly for the requested analyses. All samples were analyzed within the applicable holding times.

Detection and Quantitation Limits

The method detection limit (MDL) was reported for all metal and wet chemical analytes as required. The MDL, as defined in 40 CFR 136, is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. The practical quantitation limit (PQL) for these analytes is the lowest concentration that can be reliably measured, and is defined as 5 times the MDL.

The reported MDLs for all analytes demonstrate compliance with contractual requirements.

Laboratory Instrument Calibration

Compliance requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable qualitative and quantitative data for all analytes. Initial calibration demonstrates that the instrument is capable of acceptable performance in the beginning of the analytical run and of producing a linear curve. Compliance requirements for continuing calibration checks are established to ensure that the instrument continues to be capable of producing acceptable qualitative and quantitative data. All laboratory instrument calibrations were performed correctly in accordance with the cited methods. All calibration and laboratory spike standards were prepared from independent sources.

Method EPA 350.1

Calibration for ammonia as N was performed on August 24, 2015, using six calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria.

Method EPA 353.2

Calibration for nitrate+nitrite as N was performed on August 27, 2015, using seven calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria.

Method SW-846 6010B

Calibrations for copper, manganese, and zinc were performed on August 25–26, 2015, using three calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the calibration curve near the PQL and all results were within the acceptance range.

Method SW-846 6020A

Calibrations for arsenic, cadmium, molybdenum, lead, selenium, silver, and uranium were performed on August 26–27, 2015, using four calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the

calibration curve near the PQL and all results associated with the samples were within the acceptance range. Mass calibration and resolution verifications were performed at the beginning of each analytical run in accordance with the analytical procedure. Internal standard recoveries associated with requested analytes were stable and within acceptable ranges.

Method SW-846 7470

Calibration for mercury was performed on August 24, 2015, using six calibration standards. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration checks meeting the acceptance criteria. Reporting limit verification checks were made at the required frequency to verify the linearity of the calibration curve near the PQL and all results were within the acceptance range.

Method SW-846 9056

Initial calibrations were performed for sulfate using five calibration standards on August 18, 2015. The calibration curve correlation coefficient values were greater than 0.995 and the absolute values of the intercepts were less than 3 times the MDL. Initial and continuing calibration verification checks were made at the required frequency with all calibration check results within the acceptance range.

Method and Calibration Blanks

Method blanks are analyzed to assess any contamination that may have occurred during sample preparation. Calibration blanks are analyzed to assess instrument contamination prior to and during sample analysis. All method blank and calibration blank results associated with the samples were below the PQL for all analytes. In cases where a blank concentration exceeds or equals the MDL, the associated sample results are qualified with a “U” flag (not detected) when the sample result is greater than the MDL but less than 5 times the blank concentration.

Inductively Coupled Plasma Interference Check Sample Analysis

Interference check samples were analyzed at the required frequency to verify the instrumental interelement and background correction factors. All check sample results met the acceptance criteria.

Matrix Spike Analysis

Matrix spike and matrix spike duplicate (MS/MSD) samples are used to measure method performance in the sample matrix. The MS/MSD data are not evaluated when the concentration of the unspiked sample is greater than 4 times the spike. The spike recoveries met the acceptance criteria for all analytes evaluated.

Laboratory Replicate Analysis

Laboratory replicate analyses are used to determine laboratory precision for each sample matrix. The relative percent difference for replicate results that are greater than 5 times the PQL should be less than 20 percent. For results that are less than 5 times the PQL, the range should be no greater than the PQL. All replicate results met these criteria, demonstrating acceptable precision.

Laboratory Control Sample

Laboratory control samples were analyzed at the correct frequency to provide information on the accuracy of the analytical method and the overall laboratory performance, including sample preparation. All control sample results were acceptable.

Metals Serial Dilution

Serial dilutions were prepared and analyzed for the metals analyses to monitor chemical or physical interferences in the sample matrix. Serial dilution data are evaluated when the concentration of the undiluted sample is greater than 50 times the MDL. All evaluated serial dilution data were acceptable.

Completeness

Results were reported in the correct units for all analytes requested using contract-required laboratory qualifiers.

Chromatography Peak Integration

The integration of analyte peaks was reviewed for all ion chromatography data. There were no manual integrations performed and all peak integrations were satisfactory.

Electronic Data Deliverable (EDD) File

The EDD file was received on September 4, 2015. The Sample Management System EDD validation module was used to verify that the EDD file was complete and in compliance with requirements. The module compares the contents of the file to the requested analyses to ensure all and only the requested data are delivered. The contents of the EDD were manually examined to verify that the sample results accurately reflect the data contained in the sample data package.

Sampling Protocol

All monitoring wells were sampled using the Category I low-flow sampling criteria. Sample results for monitoring wells meeting the Category I criteria were qualified with an "F" flag in the database, indicating the wells were purged and sampled using the low-flow sampling method.

Equipment Blanks

Equipment blanks are prepared and analyzed to document contamination attributable to the sample collection process. One equipment blank was submitted with these samples. Sulfate and zinc were detected in the blank. Associated sample results for these analytes that are greater than the MDL but less than 5 times the blank concentration are qualified with a "J" flag as estimated values.

Field Duplicate Assessment

Field duplicate samples are collected and analyzed as an indication of overall precision of the measurement process. The precision observed includes both field and laboratory precision and has more variability than laboratory duplicates, which measure only laboratory performance.

Duplicate samples were collected from location 1117. The relative percent difference (RPD) for duplicate results that are greater than 5 times the PQL should be less than 20 percent. The duplicate results met the criteria with the exception of the manganese result for the unfiltered sample. The associated sample and duplicate manganese results are qualified with a “J” flag as estimated values.



STEPHEN DONIVAN
(Affiliate)
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Report Prepared By: _____

Stephen Donovan
Laboratory Coordinator

SAMPLE MANAGEMENT SYSTEM

General Data Validation Report

RIN: 15087296 Lab Code: PAR Validator: Stephen Donovan Validation Date: 10/02/2015
Project: AS&T PrMgmt&Planning Analysis Type: Metals General Chem Rad Organics
of Samples: 25 Matrix: WATER Requested Analysis Completed: Yes

Chain of Custody

Present: OK Signed: OK Dated: OK

Sample

Integrity: OK Preservation: OK Temperature: OK

Select Quality Parameters

- Holding Times
- Detection Limits
- Field/Trip Blanks
- Field Duplicates

All analyses were completed within the applicable holding times.

The reported detection limits are equal to or below contract requirements.

There was 1 trip/equipment blank evaluated.

There were 2 duplicates evaluated.

SAMPLE MANAGEMENT SYSTEM
Validation Report: Equipment/Trip Blanks

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RIN: 15087296 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/02/2015

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508337-25	SW6010	Zinc	1.1	J	0.72	UG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508337-10	NJS 268	0967	8	1	J	
1508337-21	NJS 269	1203	28	1		
1508337-22	NJS 270	1203	0.89	1	J	J
1508337-5	NJS 273	0899	25	1		
1508337-6	NJS 274	0899	3.5	1	J	J
1508337-7	NJS 271	0940	19	1		
1508337-8	NJS 272	0940	1.4	1	J	J
1508337-9	NJS 267	0967	20	1		

Blank Data

Blank Type	Lab Sample ID	Lab Method	Analyte Name	Result	Qualifier	MDL	Units
Equipment Blank	1508337-25	SW9056	SULFATE	0.54		0.5	MG/L

Sample ID	Sample Ticket	Location	Result	Dilution Factor	Lab Qualifier	Validation Qualifier
1508337-21	NJS 269	1203	110	2		
1508337-5	NJS 273	0899	110	2		
1508337-7	NJS 271	0940	110	2		
1508337-9	NJS 267	0967	110	2		

SAMPLE MANAGEMENT SYSTEM
Validation Report: Field Duplicates

RIN: 15087296 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/02/2015

Duplicate: 2757

Sample: 1117

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
AMMONIA AS N	0.1	U		1	0.1	U		1			MG/L
Arsenic	0.92	J		10	0.21	J		10			UG/L
Cadmium	0.12	U		10	0.12	U		10			UG/L
Calcium	67000			1	68000			1	1.48		UG/L
CHLORIDE	15			5	15			5	0		MG/L
Copper	0.97	U		1	1.3	J		1			UG/L
Lead	0.24	J		10	0.31	J		10			UG/L
Magnesium	11000			1	12000			1	8.70		UG/L
Manganese	500			1	380			1	27.27		UG/L
Mercury	0.0029	U		1	0.0029	U		1			UG/L
Nitrate+Nitrite as N	0.01	U		1	0.01	U		1			MG/L
Potassium	3400			1	3500			1	2.90		UG/L
Selenium	0.8	J		10	0.32	U		10			UG/L
Silver	0.017	U		10	0.017	U		10			UG/L
Sodium	51000			1	54000			1	5.71		UG/L
Strontium	730			1	770			1	5.33		UG/L
SULFATE	160			5	160			5	0		MG/L
Uranium	6			10	6			10	0		UG/L
Zinc	7.5	J		1	2.4	J		1			UG/L

Duplicate: 2758

Sample: 1117

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Arsenic	0.64	J		10	0.73	J		10			UG/L
Cadmium	0.12	U		10	0.12	U		10			UG/L
Calcium	68000			1	69000			1	1.46		UG/L
Copper	0.97	U		1	0.97	U		1			UG/L
Lead	0.068	U		10	0.068	U		10			UG/L
Magnesium	12000			1	12000			1	0		UG/L
Manganese	340			1	350			1	2.90		UG/L
Mercury	0.0029	U		1	0.0029	U		1			UG/L
Potassium	3500			1	3500			1	0		UG/L
Selenium	0.32	U		10	1.1			10			UG/L
Silver	0.017	U		10	0.017	U		10			UG/L
Sodium	53000			1	54000			1	1.87		UG/L
Strontium	770			1	780			1	1.29		UG/L
Uranium	6.3			10	5.9			10	6.56		UG/L

SAMPLE MANAGEMENT SYSTEM
Validation Report: Field Duplicates

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RIN: 15087296 Lab Code: PAR Project: AS&T PrMgmt&Planning Validation Date: 10/02/2015

Duplicate: 2758

Sample: 1117

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Zinc	3.2	J		1	1.9	J		1			UG/L

SAMPLE MANAGEMENT SYSTEM

Metals Data Validation Worksheet

RIN: 15087296 Lab Code: PAR Date Due: 09/03/2015
 Matrix: Water Site Code: AST01 Date Completed: 09/04/2015

Analyte	Method Type	Date Analyzed	CALIBRATION				Method Blank	LCS %R	MS %R	MSD %R	Dup. RPD	ICSAB %R	Serial Dil. %R	CRI %R
			Int.	R^2	CCV	CCB								
Arsenic	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	110.0	116.0	112.0	3.0	101.0		115.0
Arsenic	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	114.0	109.0	109.0	1.0	101.0		111.0
Cadmium	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	115.0	103.0	108.0	4.0	100.0		120.0
Cadmium	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	111.0	111.0	108.0	3.0	103.0		129.0
Calcium	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	101.0	102.0	102.0	0.0	103.0	0.0	104.0
Calcium	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	103.0	102.0	103.0	0.0	106.0		106.0
Copper	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	104.0	104.0	105.0	1.0	105.0		103.0
Copper	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	102.0	105.0	105.0	0.0	109.0		103.0
Lead	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	101.0	107.0	106.0	1.0	110.0		104.0
Lead	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	108.0	101.0	108.0	7.0	101.0		103.0
Magnesium	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	101.0	102.0	102.0	0.0	102.0	1.0	100.0
Magnesium	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	101.0	101.0	101.0	0.0	105.0		101.0
Manganese	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	106.0	108.0	108.0	0.0	93.0	2.0	105.0
Manganese	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	102.0	99.0	100.0	0.0	96.0		105.0
Mercury	CVAA	08/24/2015	0.0000	1.0000	OK	OK	OK	98.0	104.0	102.0	2.0			101.0
Mercury	CVAA	08/25/2015	0.0000	1.0000	OK	OK	OK	99.0	98.0	100.0	2.0			98.0
Potassium	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	105.0	105.0	106.0	1.0			88.0
Potassium	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	101.0	111.0	111.0	0.0			89.0

SAMPLE MANAGEMENT SYSTEM

Metals Data Validation Worksheet

RIN: 15087296 Lab Code: PAR Date Due: 09/03/2015
 Matrix: Water Site Code: AST01 Date Completed: 09/04/2015

Analyte	Method Type	Date Analyzed	CALIBRATION				Method Blank	LCS %R	MS %R	MSD %R	Dup. RPD	ICSAB %R	Serial Dil. %R	CRI %R
			Int.	R^2	CCV	CCB								
Selenium	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	105.0	98.0	100.0	2.0	97.0		124.0
Selenium	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	109.0	110.0	108.0	2.0	107.0		125.0
Silver	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	112.0	114.0	107.0	7.0	109.0		115.0
Silver	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	110.0	107.0	111.0	3.0	103.0		75.0
Sodium	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	105.0	105.0	106.0	1.0		1.0	94.0
Sodium	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	102.0	111.0	110.0	0.0			91.0
Strontium	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	101.0	101.0	103.0	1.0	98.0	2.0	102.0
Strontium	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	99.0	99.0	99.0	0.0	101.0		92.0
Uranium	ICP/MS	08/26/2015	0.0000	1.0000	OK	OK	OK	101.0	100.0	100.0	0.0	99.0	0.0	110.0
Uranium	ICP/MS	08/27/2015	0.0000	1.0000	OK	OK	OK	107.0	102.0	105.0	2.0	102.0		100.0
Zinc	ICP/ES	08/25/2015	0.0000	1.0000	OK	OK	OK	105.0	107.0	107.0	0.0	93.0		102.0
Zinc	ICP/ES	08/26/2015	0.0000	1.0000	OK	OK	OK	108.0	104.0	106.0	1.0	90.0		101.0

SAMPLE MANAGEMENT SYSTEM
Wet Chemistry Data Validation Worksheet

RIN: 15087296 **Lab Code:** PAR **Date Due:** 09/03/2015
Matrix: Water **Site Code:** AST01 **Date Completed:** 09/04/2015

Analyte	Date Analyzed	CALIBRATION					Method Blank	LCS %R	MS %R	MSD %R	DUP RPD	Serial Dil. %R
		Int.	R^2	CCV	CCB	Blank						
AMMONIA AS N	08/24/2015	0.000	0.9980	OK	OK	OK	103.00	89.0	85.0	3.00		
CHLORIDE	08/28/2015	0.000	1.0000	OK	OK	OK	98.00					
CHLORIDE	08/29/2015							98.0	99.0	0		
Nitrate+Nitrite as N	08/27/2015	0.000	1.0000	OK	OK	OK	98.00	108.0	110.0	2.00		
SULFATE	08/28/2015	0.000	1.0000	OK	OK	OK	97.00					
SULFATE	08/29/2015							95.0	96.0	1.00		