DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
RISK MANAGEMENT CENTER
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LAKEWOOD, CO 80228

REPLY TO
ATTENTION OF

CEIWR-RMC 05 October 2015

MEMORANDUM FOR Chief, Engineering and Construction (CECW-CE), ATTN: Richard Olsen, CECW-CE, 441 G Street NW, Washington, DC 20314

SUBJECT: Review of the Technical Evaluation of the Gold King Mine Blowout, San Juan County, CO

1. The Department of the Interior, Bureau of Reclamation has been asked by the EPA to do an independent assessment of:

a. The cause of the mine waste water release on 5 August 2015;

b. A review of the actions currently being taken by the EPA;

c. Lessons learned from the incident; and

d. A summary of industry practice regarding opening abandoned and flooded mines.

2. It is noted that Reclamation had previously performed worked for EPA Region 8 on an evaluation of the bulkhead design for the Red and Bonita Mine adit, which is located in the same area and on the same mountain as the Gold King Mine. The Bureau of Reclamation prepared the draft report on 25 September 2015 for EPA Region 8. The USGS and USACE have been asked by EPA to review Reclamation's report. The draft report was reviewed by Nate Snorteland, Todd Loar, and Dave Paul from the RMC

3. Overall, Reclamation's report, assessment, and findings of the Gold King Mine blowout conveys an accurate evaluation of the technical interpretations of the site conditions made by the project managers and on-site personnel, the details of the communication between responsible parties and stakeholders, and a thorough discussion of the sequence of construction events and decisions that occurred at the project site since about 2009 that collectively contributed to the Gold King Mine blowout on 5 August 2015.

4. Reclamation's interpretation of the site conditions, likely geotechnical characteristics of the earthen plug, and the likely factors and mistakes in judgment are all appropriate given the information available to the reviewers. The construction timeline provided by the EPA is consistent with the interpretations described in the report. The RMC cannot conceive of a potential failure mechanism different than that postulated in the report.

5. There are still some details pertaining to the content of the report that USACE believes would improve the description of the site conditions and events that led to the blowout.

a. The geologic section of the report discusses regional geology, but does not include site specific information of factors that contributed to the blowout. The geology section should be expanded to discuss the following topics:

i. The Geomechanical/geotechnical conditions of the rock and tunnels including discontinuities, faults, shears, contacts, different lithologies with variable engineering properties of the rock and rock mass should be described. This description should include the potential for and temporal/spatial interpretation of the occurrence of tunnel cave-ins and how these changing areas of plugged tunnels and subsequent draining might change the groundwater flow system and interaction with the underground workings.

ii. The Hydrogeology needs to be summarized in the report. The regional and mine-wide groundwater regime is important to describe because some basic hydrogeologic conditions can be interpreted based on general understanding of the GW flow, likely recharge areas, tunnel capture zone, geologic influences on GW movement, fault and discontinuity flow, interconnection between the underground working networks, and potential for tunnel flooding and reasoning for changing discharge observations over time. This is important because a generalized hydrogeological conceptual model of the site suggests there would be relatively high potential for groundwater to flood the Gold King Mine, and that previous observations from years before when the Gold King Mine or Red and Bonita Mine did not flood would not be reliable lines of evidence given the changing flow system and high recharge in the underground system. This information could have been used to estimate the potential groundwater storage and release capacity which would have been used to size the containment facilities or to make decisions regarding the removal of the embankment plug in the Gold King Mine adit.

b. Several figures should be edited to more accurately portray the conditions at the site.

i. The existing figures – particularly figures 5 and 7 – should be improved to show all referenced adits or any feature referenced in the report, provide information on elevations of the underground workings, show the Red and Bonita mines interconnected with the Gold King Mine if it is connected, and make sure all symbols on the map are presented on the legend.

ii. Add an additional figure including a cross section from the American portal, across the Gold King Mine and Sunnyside mine underground workings including those portions that extend to the upper parts of the mine system. Show the underground levels and tunnels with elevations; add Lake Emma; add faults/shears and geologic

contacts, bedding, and different lithology from the volcanic flows; add wells and any subsurface penetrations including known plug locations; and develop interpretation of the groundwater surface and any other pertinent information. Enclosure 1 to this document shows an example of what this might look like. This graphic would help describe the scale of the mine interactions and the potential for interconnections and the potential groundwater volume.

iii. Develop a smaller scale site plan view, with topography and aerial photos defining the Gold King Mine project area at the scale to show the old and new Gold King Mine adits, slopes, settling ponds, and Red and Bonita Mine. It was difficult to completely understand the spatial location and relationship between all the primary features described in the report.

c. It would be important to provide complete project layout descriptions. Add additional descriptions of the mine layout, geometry and configurations including actual or approximate tunnel dimensions, construction methods, invert slopes, how the underground workings are interconnected or separated, and elevations of pertinent components of the underground infrastructure. Describe how the earthen plug was constructed (or not constructed), the approximate dimensions, and where the material in the plug came from.

d. Describe the current treatment system. Provide additional description of the current treatment system or process in place at the site. It appears that seepage is only conveyed through settling ponds to remove the solid phase (sediments and precipitated minerals) and then the waters are discharged into Cement creek without any treatment of the dissolved phase of heavy metals. Describe the ponds and the capacity and holding times of the settling ponds and any additional treatment if it is performed. The purpose of this would be to describe the existing capacity compared to what was envisioned or existed at the site at the time of the blowout.

e. Miscommunication appears to have been a significant contributor to the blowout. This should be more thoroughly described in the report. The fact that the EPA OSC Project Leader (OSC) contacted Reclamation implies there was concern with re-opening the Gold King Mine. It would be valuable to know what those concerns were. There appears to have been a breakdown in authority or communication of those concerns to the interim OSC when the primary OSC went on vacation. However, these concerns were not evident to the OSC on site, as EPA immediately began to remove material from the face at the Gold King Mine. This is a serious oversight or poor decision that may have been the key factor in the blowout. There was concern about a potential problem, but the OSC ignored these concerns and/or directions and moved forward with the plug removal, and mis-interpreted the conditions of the mine water and plug acting as a dam for the pressurized adit.

f. The RMC agrees with the conclusions presented in the report with the following proposed corrections:

i. Page 61 indicates that the “DRMS drain [installed in 2009] was poorly executed and was liable to blowout”. This should say the “DRMS drain was poorly executed and was likely to blowout”, as liable is a misleading word in this sentence. The plug itself may have continued to hold back large amounts of water, and the drains may have exacerbated this situation, but they are likely not the primary cause of the blowout.

ii. Standards and procedures should be developed when re-opening a previously plugged mine adit. However, the report should acknowledge the challenges in developing these standards. The technical complexities of temporal and spatial changes in groundwater flow, interconnectivity between flooded and open tunnels, the high likelihood of tunnel collapse and interior plugging and effects on the groundwater system are all too complex to characterize definitively and will result in a high level of uncertainty. At many mine sites the geology and hydraulic connections between discontinuities tend to be highly complex due to the genesis and nature of the ore deposits. A one-size-fits-all procedure is not practical for all sites, so this will be a significant effort.

iii. Installing a piezometer or transducer into the adit to measure the water pressure at the plug is the only practical, and tangible, way to know if a plug is safe to remove or not. These procedures need to be developed to ensure that all measures were taken prior to making a final decision.

iv. Page 69 of Reclamation’s report indicates “Besides a bulkhead at Red and Bonita Mines, try to locate the inflow fractures and grout them at both Red and Bonita and Gold King”. While grouting may be applicable in some specific instances to control water inflows into a mine opening, grouting would not likely be an effective groundwater control measure compared to the cost. Identifying open and high permeability discontinuities is extremely challenging unless the grout program is extensive and comprehensive. All the geologic features would need to be identified and characterized. Red and Bonita Mine and Gold King Mine are very likely hydraulically interconnected with the other underground workings in the area (e.g. Sunnyside workings) through large scale and spatially distributed discontinuity systems (faults, shears, alteration zones, bedding or volcanic flow features) that creates a complex potential for the location and orientation of high flow geologic features. A very expensive site characterization effort would be needed to understand where all these features are located throughout the Red and Bonita Mine and Gold King Mine system, and grouting would have a high likelihood of failure given the conditions. While grouting may work in some instances, this is not a successful type of groundwater control unless effort there is evidence and information that was not presented to suggest that it would be highly successful.

6. For further information, please contact me at 303-963-4573.

Encls

NATHAN J. SNORTELAND
Director
Risk Management Center

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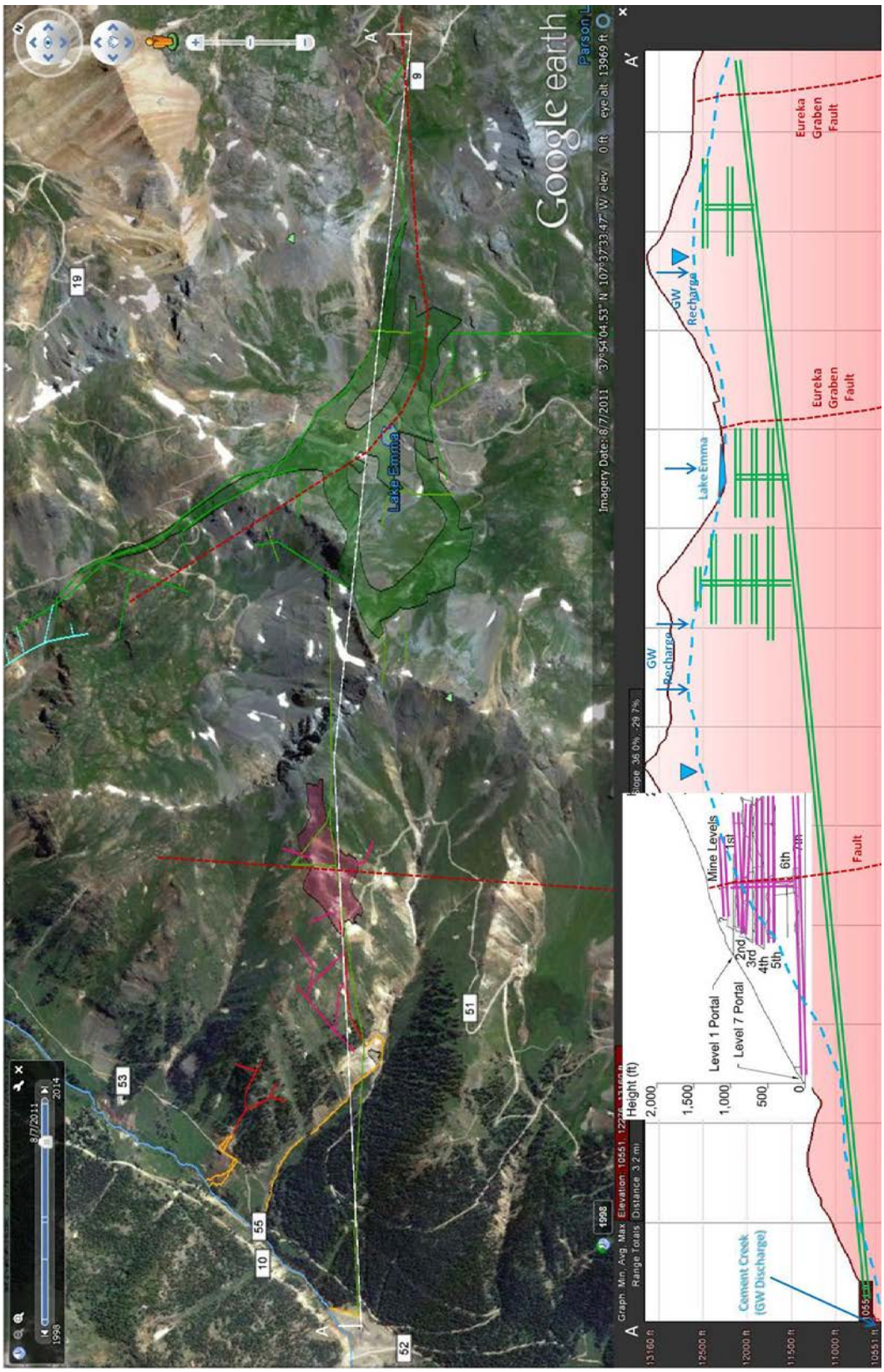

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General Review Comments and Observations

The following subsections present descriptions of the general comments and/or observations derived from review of the technical evaluation of the GKM blowout report prepared by the Bureau. This section may repeat some of the information presented in the Key Findings section but it attempts to provide more detail and specificity with respect to the Key Findings presented above.

Report:

The following subsections/bullets present review comments relative to the technical evaluation of the GKM blowout report.

General Comments

1. The term "*Highwall*" is used in the report to describe the cut slope above the portal for the GKM's. However, this term is typically used to reference large open pit mining or longwall coal mining, and is not typically used to describe excavated cut slopes. This area around the GKM adit entrance should be referenced as the "portal cut slope" rather than a highwall.
2. The geometry/configuration and performance of the adits and various levels/elevations needs more thorough description because it is difficult to understand how all the underground workings are spatially related to each other:
    a. Size and shape of the GKM adit; invert slope; how was it excavated (D&B?); what was the support type used; were there stability problems or issues throughout the mining?;
    b. Where do different mines tie into each other (RBM and GKM); relative separation between the underground workings (GKM and American tunnel).
    c. A cross section along the American Tunnel alignment, showing the GKM and its various levels, the Sunnyside mine levels, and where the RBM connects to the GKM. This would help the reviewer understand the relative spatial configuration of the system (see Figure 1 as an example).
3. The report should describe the treatment process a bit better. It appears that seepage water is collected and diverted to settlement ponds where the acidic sediment falls out of suspension, or precipitates and "clean" water is decanted off the top of the settling ponds and directed into the river. However, is there treatment of the dissolved phase of contaminants in the mine water? What is the treatment capacity of the system?

4. The term “Bulkhead” should be a bit further described. These are typically permanent structures with significant amounts of reinforced concrete and steel socketed or tapered into the rock, often with rock anchoring, grouting, and appropriate drain and monitoring lines. Perhaps a typical design drawing of a bulkhead could be inserted as an example.
    a. This is potentially important because the bulkhead is significantly different from the earthern berm plug that was at the GKM, and a description could alleviate confusion between these two different fixes to stop water at a mine portal.
5. More descriptions as to how the earthern berm plug was constructed. The RMC assumes they excavated material from the surrounding slopes with an excavator bucket and dumped it into the mine opening. Is this colluvial or glacial material? Did they tamp the material into place with the bucket or a compaction roller? Was water flowing at the time?
6. Page 40 – 41. Discussions between the Bureau and EPA indicate that the EPA Project Manager was concerned about the GKM adit opening issue because he requested that the Bureau shelve work on Red/Bonita adit, and try to get to the site to look at the GKM. This site visit was scheduled for Aug. 14, 2015 because the EPA OSC had vacation planned (starting July 29) over this time period. Additionally, there is a statement that the EPA OSC gave instructions to his temporary replacement “…*not to touch the adit*” while he was away. Photos on July 29 clearly show excavation to clear the slump, and then later to expose the buried pipes and manifold
    a. This was apparently a critical breakdown in EPA OSC authority and instructions. The EPA OSC should have communicated and documented his concerns better, and this apparent breakdown in authority and the temporary site PM not following directions seems to be a significant issue for the sequence of events.
    b. While it is possible the adit closure berm could have failed over the 2 weeks of vacation due to the increasing pressure head on the plug, it also may have helped prevent the blowout event if a different decision was made regarding the adit opening procedures when the EPA OSC and Reclamation engineers were able to discuss his concerns.
    c. This authority and communication breakdown with the EPA between the OSC and temporary OSC may be a significant part of the issues associated with the blowout failure and should be highlighted in the conclusions of Reclamation’s report.

Geology at the Site

1. The geologic section of the report provides a generalized, regional overview of the geology at the project site, references the large-scale faulting system and mineralization, and provides a general discussion of the stock works or ore emplacement configuration.
2. However, these geologic descriptions do not offer much insight into the mechanics of the GKM blowout, tunnel conditions, or the site specific engineering geology relative to the conditions at the scale of the mine(s), rock and rock mass conditions, or how water moves throughout the system.
3. A simplified, generalization of the following topics presents an understanding of the mine geologic conditions that should be understood by all the remediation parties involved.
4. While these are potentially complex topics and difficult to quantify or fully understand given the time and data restrictions, some basic interpretations can be developed that describe the geomechanical, geotechnical, and hydrogeological conditions at GKM. The following are sub-sections and descriptions that should be added to and expanded upon in the geologic section of the report:
    d. Engineering Geology:
        i. Descriptions of the rock and rock mass engineering conditions: fracturing (e.g. continuity, interconnection, infilling, intensity of fracturing); local discontinuities/structure (contacts, faults/shears); weathering/degradation/alteration; strength; rock mass descriptions; permeability of rock mass and discontinuities; construction issues with tunneling and cave-ins or support requirements within the mine system. The tunnel continues to swell into the opening if there is a high clay content, and degrade and fail, opening up the stress relief or relaxation zone around the tunnel.
        ii. Geomorphology: there appear to be surface settlement features (sinkhole) above the GKM new adit, which are referenced in the Bureau report. These features should be described in the geology section before they are referenced later in the report.
        iii. The tunnel stability may be significantly compromised throughout the mine. Cave-ins are highly likely in the GKM, and also throughout the entire Sunnyside, Red and Bonita mines (RBM).

These cave-ins occur sporadically, damming up groundwater upstream of the failed debris, possibly pressurizing previously unpressurized tunnels, causing groundwater to move in different directions or through discontinuities to other parts of the underground system and establishing new hydraulic connections between the different mines and levels. Perhaps a cave-in eventually is eroded away, and the water pressures are redistributed they are not likely to return to a previous equilibrium, as infilling in discontinuities is washed out/opened and new high flow features are established.

iv. Geologic features such as faults, shears, contacts, alteration zones, veins/dikes, etc… can hydraulic connect all the underground openings (and between the Sunnyside and GKM).

e. Hydrogeology:

i. There should be a thorough discussion on the hydrogeology of the area, as the changing groundwater regime within the mining area appears to play an important role in the events and decisions made (based on previous observations of tunnel flooding).

ii. The following are specific observations on the hydrogeology at GKM that could be briefly discussed/presented in the report:

1. Significant recharge area located above the mine with visible water ponding in low areas, and snow fields melting on the surface in the uplands area above the tunnels.

2. A generalized groundwater profile would reflect a subdued topographical profile across the area, with discharge areas directed toward the lower valleys and rivers. Because the GKM is parallel to a ridge bounded by tributary drainages to the north and south, the GW may be lower as it radiates or fans outward toward the topographic low drainages.

3. How interconnected and continuous are the discontinuities throughout the project and how does water could be communicated through these structures? Much of the upper portions of the mine appear to extend into the Eureka Graben area. This area is defined by a fault bound, down-dropped structural block that likely consists of hundreds to thousands of large to micro-scale NE-SW trending normal/extensional fault structures. These may be open and

highly continuous, and trend from the upper Sunnyside mine area (and Lake Emma) toward the GKM ridge line. These structures represent hydraulic connection between all the underground workings (Sunnyside and GKM).

4. In 1978 Lake Emma rapidly drained into the Sunnyside mine through geologic features near the upper level of the mine blew out the American and Terry tunnels, and took 2 years to clean up and repair the damage to the underground system.
5. Closure of the American adit in 1997 is interpreted to have resulted in increased flows measured at the Mogul adit located 772 ft above the American adit by 2000, and by 2002 there was observed increased flows in the GKM adits, located 812 ft above the American adit, and at RBM adit, located 272 ft above the American adit but connects to the lower level of the GKM. Clearly there is interconnection between all the underground mine workings through the geologic rock structure.
6. Groundwater flows could be preferentially directed into the underground tunnel system because of gradients along discontinuities, so the capture area for the tunnels could be quite large and irrespective of surface drainage basins (meaning groundwater flows can cross topographic boundaries along flow paths).

Figures 5 and 7 from Reclamation's report:

1. Figure 5:
    a. Provide some elevations of the mine workings if possible. It is difficult to tell how all these underground workings are related to each other in the plan view so perhaps some spot elevations at important reference points, ranges for the levels, and tunnel slopes might help.
    b. Add Lake Emma to the figures.
    c. This appears to show the Red/Bonita Mines being distinct from the KGM. But the text indicates the RBM connects to the GKM. This should be updated.
    d. Make sure all adits or structures referenced in the report content are shown on the maps. For example, the following mines or adits are

mentioned in the report but not shown on the maps: Silver Ledge, Blackhawk, Lark, and Sampson.

2. Figure 7:
    a. Figure 7 needs a legend for the different workings, the black squares (are these wells?), orange dots (adits).
    b. Add Lake Emma to the figures.
    c. This appears to show the Red/Bonita Mines being distinct from the KGM. But the text indicates the RBM connects to the GKM. This should be updated.
    d. Cut a cross section from the American Portal along the alignment of the GKM, through Lake Emma and to the Gold Prince portal. Add information on the mine openings/workings, elevations and how these underground workings are spatially/geometrically related. Add any geologic information that is available (faults, contacts, alteration/mineralization zones, monitoring wells and groundwater elevations.
    e. Make sure all adits or structures referenced in the report content are shown on the maps. For example, the following mines or adits are mentioned in the report but not shown on the maps: Silver Ledge, Blackhawk, Lark, Level 1 adit, and Sampson.
3. Additional Figures: It may be appropriate to have a plan map layout of the GKM with the two different adits. It took reviewing photos and some detective work to understand that there were two adits in the same area, and which one was the old and new adit. Also add a cross section across the American adit, KGM, Sunnyside mine workings and show important features such as Lake Emma, geologic features (faults, alteration zones, volcanic layers/sequencing if available, sinkholes, or other geologic discontinuities).