APPENDIX H

Technical Memorandum 8

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To: Montana Department of Environmental Quality

From: Environmental Resources Management

Date: December 29, 2017

Subject: Black Butte Copper Project - Analysis of the effectiveness of the proposed end of mine flushing of the underground workings to remove oxidation products, including an evaluation of the length of time needed to accomplish this procedure

INTRODUCTION

The basis for this technical memorandum is the Mine Operating Permit Application (Tintina Montana, Inc. 2017) submitted to the Montana Department of Environment Quality on July 14, 2017. That document is referenced in the body of this memo as “MOP”, with the particular section and page numbers as appropriate.

BACKGROUND

MINERAL SALT ACCUMULATION

Mineral salt accumulation is expected locally on access drift sills, backs, and ribs during the life of mine. Some of the salts would be highly soluble and susceptible to migration into groundwater upon inundation following mine closure.

FLUSH PROGRAM EXTENT

Humidity cell testing indicates that a three- to six-cycle flush program would be needed to wash down salts (MOP Section 7.3.3.6, pp. 428-433). Locally, that could extend to ten cycles. Conservatively, the duration of each cycle across the various zones would lead to a total program length on the order of 1 year.

CURRENT MOP

PHASED RO PERMEATE FLUSHING

The Proponent proposes to flush underground access workings initially with unbuffered RO permeate and subsequently with buffered RO permeate. The unbuffered RO permeate would have a relatively elevated capacity to scavenge solutes, whereas the buffered RO permeate would have a reduced capacity to scavenge solutes from bedrock (MOP Section 7.3.3.6, p. 428; Section 3DEQ [Response to Comments], p. 481).

POST-RINSE GROUNDWATER INUNDATION

Following these rinse phases, groundwater inundation would occur, creating anoxic conditions that are expected to result in groundwater characteristics meeting background conditions.

MONITORING AND REMEDIATION

Groundwater monitoring throughout the closure process would guide the rinsing and any remediation procedures (MOP Section 4.3.2, pp. 381-383; Section 6, pp. 391-406; Section 7.3.3.5, pp. 421-428; Section 7.3.3.6, pp. 428-433; Section 7.3.3.9, p. 435). This has been queried (Smith 2017), and the proposed MOP entails diligent and thorough background, operational, and closure monitoring programs. It would be prudent to allow these state-of-the-art investigations to shape and guide the closure and post-closure plans.

CONSTRUCTION ISSUES

EQUIPMENT DEPLOYMENT AND RINSE PROVISION

The Proponent is considering high-pressure washing of oxidation products and possibly shotcreting exposed high sulfide zones to isolate and immobilize those oxidation products (MOP Section 7.3.3.9, p. 435).

Typical shotcrete is not recommended as a chemical barrier over high sulfide zones. It is relatively permeable and susceptible to sulfate attack.

SUMP STAGING TO RECOVER RINSATE

In addition to the proposed monitor wells (MOP Section 7.3.3.7, p. 434), staging sumps could be appropriate to handle rinsate. It is appropriate to include the concept in the Environmental Impact Statement (EIS), with specific details to be based on the developing conditions during operational and closure monitoring.

EIS ENVIRONMENTAL ISSUES

COMPLIANCE WITH DEQ NON-DEGRADATION CRITERIA

Though the Humidity Cell Test (HCT) program was rigorous, it is appropriate to investigate whether salt build-up on the access and development drift surfaces is an environmental liability with respect to volume, concentration, potential dissolution, precipitation, or reaction to inert compounds, travel times, and distances to potential beneficial use of impacted groundwater. Those investigations are or can be part of the operational and closure water monitoring programs.

ADDITIONAL QUERIES

Increased Solute Loading

The question has been raised as to whether the greater surface area of broken rock, tailing, and open drifts would result in greater solute loading (Jepson 2017). There would be a broken rind around the access drifts, but the extent would be remarkably minimized with controlled blasting techniques and in any event is expected to be no more than a drift radius. Blasting breaks preferentially follow pre-existing fractures, and energy outside the individual blast pattern perimeter would tend to open those rather than introduce new fractures. Pre-splitting or smoothing the shots could virtually eliminate fracturing outside the blast pattern (Langefors and Kihlström 1963). Those techniques or their corollaries – in common use since the 1950s – are typical for permanent drill and blast openings in mining as well as virtually all drill and blast civil infrastructure openings.

The cemented tailing would present little internal surface area. With the overhand mining method, the superjacent fill would be poured directly on the hardened subjacent fill, and there would be no significant gaps between levels. The only air gap would be approximately 1.5 feet on the final level, and that could be readily filled with expansive grout or other media suitable for that application. Thus, the pre-mining naturally fractured rock would be replaced by a relatively tight and massive cemented formation.

It is reasonable to expect that the presented drift surface area would be similar to the pre-mining fracture surface area in the same volume. It could be less, depending on original local fracture frequency.

With these tailings and geology properties and prudent mining, no significant increase in surface area is expected. The essential change would be in exposure to atmosphere, which is proposed to be handled by the multiple flushing cycles.

Flushing Effectiveness

Questions have been raised as to whether oxidation products in fractures, voids between paste backfill and stope backs, and/or within the paste backfill would be effectively flushed out by the proposed rinsing (Jepson 2017). Will they continue to dissolve and bleed out slowly into the groundwater flow paths after active mining ceases, resulting in greater loading rates to the groundwater system than under the pre-mining condition?

Means for field evaluation of flushing effectiveness could be conducted during development and mining, with reasonable time to consider modifications to the closure procedures if needed. The field testing, which can begin relatively early in the mine life, would confirm whether the HCT results of “no significant salt loading” remain valid guidelines.

The post-mining anoxic conditions would significantly reduce or halt the tendency for producing additional salts. The relatively lower permeability of the cemented tailings (MOP Section 2.2.5, pp. 56-61; Table 2-13, p. 60) and low-permeability construction concrete would result in groundwater flow diverting around these structures; therefore, they are not expected to significantly contribute to salt loading of the groundwater.

Non-Degradation Compliance

Questions have been raised as to whether groundwater or surface water non-degradation criteria would be exceeded at some point post-closure (Jepson 2017).

The operational monitoring programs (MOP Section 6.3.1, pp. 391-398; Section 6.3.2, pp. 398-399) would provide years of data, providing opportunities for understanding trends and predicting behavior. The mining and milling processes are designed to prevent exceedances, and the background and operational monitoring are designed to assist in predicting exceedances.

Though testing to date indicates there would be no exceedances post closure, the post-operational closure monitoring for water quality (MOP Section 6.4.2, p. 405)

> … will occur until such time as the mine is certified as fully reclaimed and all bonding release milestones are met, or as determined in the post-operational monitoring program to be developed in conjunction with DEQ.

Nitrogen Flooding

A question has been raised as to whether nitrogen flooding would be suitable control for oxidation on the surfaces of underground openings. The procedure presented (Brown 2017) is:

> At closure, after the plugs are in… starting at the lowest level, flood the workings with low pressure N2 gas to displace oxygen/air moisture and limit oxidation. As that is being done, control fill with polished water. Once the lowest area is full, move on to the next higher. N2/polished water injection and monitoring wells would have to be installed in each, but the wells could be used for water monitoring post closure.

At first pass, this procedure does not eliminate the rinsing or flushing but is an additional action to supplant or augment the eventual groundwater inundation. An initial consideration is the suitability of the rock for gas flooding. Would gas seepage into the rock occur simply due to concentration gradient? Would that reduce or increase gas flooding efficiency? Would pressurization be needed to maintain efficiency?

Some of the wells for N2 and polished water injection would be close to and perhaps east of Sheep Creek in order to reach the lower ore zone and its access drifts. In order to intercept mine openings (16 feet wide at approximate depths from 300 to 1,300 feet), directional drilling would be necessary for both the lower and upper workings, as well as the ramp between them and on toward the portal. Though technically feasible, that adds considerable cost and constraints to the drilling. As injection wells with the attendant tankers and pump rigs, the drill sites would be larger than typical mineral exploration or water monitoring pads.

Nitrogen gas is handled in many industrial settings, even in bulk quantities. Historically, the use of nitrogen gas in the mining industry has been for extinguishing coal mine fires. However, even the fire retarding potential of flooding coal mines with nitrogen gas has not advanced beyond the research phase (Trevits 2009). Safety, skill, and experience may not easily be found for nitrogen flooding. Some of the uncertainties center on the quantity of nitrogen needed, whether onsite production would be beneficial to the use of delivered cryogenic nitrogen, how well the mine is sealed to prevent the escape of the nitrogen and influx of other gases, and the timing.

Nitrogen flooding entails installing all plugs and then drilling/injecting. The Proponent proposed that flushing is done sequentially before the plug construction, with the plugs subsequently contributing to the desired and natural anoxic condition. If the nitrogen is applied following flushing, would it in fact contribute to resolving salt generation and infiltration into groundwater? If flushing is not done before the nitrogen and polished water addition, would those alone achieve salt removal? Since the nitrogen program would be monitored only by remote means (drill holes), could the salt removal be verified?

Would sequential flushing be significantly more efficient than nitrogen flooding simply based on the plug construction timeline? As a very effective asphyxiant, it is not prudent to plan on nitrogen flooding with personnel in the mine, even with plugs above the nitrogen and below the personnel. The use of nitrogen in this application would have to be very reliably engineered to supplant the proposed closure flushing program. The RO permeate closure flushing is comparatively very benign from the perspective of personnel safety.

TECHNICAL APPROACH

CONFIRMATION THAT RINSING IS EFFECTIVE

Rinsate Infiltration

The drifts are not impermeable vessels; they are openings excavated in naturally fractured rock. Whether high pressure washing or inundation is used, what amount of rinsate would infiltrate into the back, ribs, and sill, and escape recovery? With high pressure washing, the rinsate would run to and over the sill to final collection. With inundation, the rinsate would stand or pond on the sill, against the ribs, and then against the back. Would infiltration significantly diminish the effectiveness of rinsing by seeping into the surrounding rock? Could infiltration be monitored and evaluated during the operational testing and design of the rinse procedures?

Rinsate Volume versus Inundation/Groundwater Volume

The predicted duration of rinsing cycles (MOP Section 7.3.3.7, p. 434) is a state of the art hydrological analysis. As queried above, could infiltration be monitored and evaluated during the operational testing and design of the rinse procedures? This could refine the model analysis and provide field scale guidance in designing rinse procedures.

Local versus Extensive Flushing

There is a reasonable expectation that surface oxidation would be localized to high-sulfur zones within the rock formations. The investigations during mine operations should include evaluating local versus extensive flushing aspects of the proposed rinsing program.

Salt Generation Time versus Salt Dissolution Time

When operational field testing can begin, it would be appropriate to investigate the efficacy of pressure washing versus inundation. An aspect of that could be the salt generation rate, which may resume or continue between high pressure wash cycles. That phenomenon could indicate that inundation is the most appropriate rinsing technique, or a combination of local pressure washing followed by inundation for subsequent rinses.

Implementation Cost

The implementation cost of closure flushing has been questioned (Freshman 2017). The Proponent is asked to provide that support. If appropriate, costs can be developed by the technical memo author(s) or other third party in either cursory or detailed analysis based on heads, volumes, equipment, and personnel. Conceptually, flushing as proposed appears to be a relatively low-cost approach. Apart from the hydrologic plugs, the essential material handled is water, which already is part of the process stream.

Implementation Duration

The duration of closure flushing has been questioned (Jepson 2017). The most conservative estimate (MOP Section 7.3.3.7, p. 434) is between 12 and 13 months. Post-closure monitoring would continue after the flushing program (MOP Section 6.4.2, p. 405).

MINIMIZE/ELIMINATE SALT GENERATION

Since the generation of the mineral salts is expected to be related to oxidation, eliminating or minimizing exposure of susceptible high sulfur zones to the mine air flow should be considered.

An additional aspect of operational testing could be to investigate whether preventive fillings or coverings could effectively minimize or eliminate salt generation. In various mining, tunneling, and infrastructure settings, these have been used to good effect for controlling gas, vapor, and water inflow. Using them as a low-pressure airflow barrier can readily be investigated.

Below are common items in underground construction and can be used separately or in combination, dependent on the specific application.

Grout Injection

Grout rings have a long and successful history in control of water and weak ground. In a high-sulfur zone, they could be used to flood and encapsulate that rock within a distance of several meters from the opening surface – sill, ribs, and back. If done with or soon after initial excavation, grout rings might eliminate much of the potential salt generation. Injected grout typically is packed or staged to prevent blowouts to the collar (surface). In this application, it would be appropriate to follow the grouting with concrete or shotcrete to seal the opening surface.

Concrete

Alternatively, concrete lining could be formed and poured to a sufficient thickness to retard or eliminate salt generation. Admixes to reduce permeability are recommended for this application.

A concrete lining would entail sub-excavation of the entire drift perimeter to establish the lining without encroaching on the drift cross-section. The sill must be taken deep enough to form and armor a running surface, which would withstand the mine vehicular traffic.

Constructing a concrete lining over grout rings could provide substantial reduction in the potential to oxidize high sulfur ground.

Shotcrete

Shotcrete has a long history in underground mining and construction for mechanical support of soil and rock. If admixtures to minimize permeability are used and applied thickly enough (typically in multiple passes), it can retard passage of liquids and gases. Shotcrete is aerated in application and typically is not an effective barrier to liquid or gases.

Shotcrete typically is of lesser utility on the sill of active drifts, as most configurations are not designed for vehicle traffic.

Sprayable Membranes

Synthetic sprayable membranes have applications as atmospheric and liquid barriers. In a mine setting, they typically are protected with either shotcrete or concrete. Across the sill, concrete is more appropriate for protecting against vehicular traffic. Conceptually, these membranes are a spray application of moisture/vapor/gas barriers used in conventional construction.

Rock Dusting

Rock dusting with limestone and/or lime could be investigated as a preliminary control measure in neutralizing the sulfur reactions, which initiate on exposure to the air. Though mine water treatment is common in plant settings (Geldenhuys et al. 2003), the drift setting with dry application could warrant consideration as the mine development were to proceed.

Rock dust is envisioned as an immediate application upon exposure of a high sulfur zone. Even if repetitive applications would be needed, it is a field scale investigation that may diminish formation of deleterious compounds but which would not preclude or impede adoption of closure flushing.

CONCLUSIONS AND RECOMMENDATIONS

CLOSURE FLUSHING OF ACCESS AND ANCILLARY OPENINGS

The hydrologic and geochemical analyses to date indicate that flushing the salt out of access and ancillary openings is a feasible and appropriate method of reaching groundwater discharge compliance.

Salt-laden rinsate infiltration should be analyzed in detail prior to commitment to closure flushing as the primary control for achieving post-closure water quality.

SHOTCRETE ALONE IS NOT RECOMMENDED

Shotcrete alone is suggested by the proponent (MOP Section 7.3.3.9, p. 435). Shotcrete alone is not recommended as a chemical barrier over high sulfide zones. Even vulcanized shotcrete can be susceptible to sulfate attack, losing adhesion to the rock surface and subsequently cracking or spalling.

MINIMIZE/ELIMINATE SALT GENERATION

The Proponent is asked to evaluate whether isolating potential salt generation zones is feasible and would eliminate their impact on groundwater discharge. Those evaluations could commence during the development and proceed through the operational phases, with the object of determining whether salt generation could be minimized or prevented during the life of mine, thus eliminating the need for or reducing the extent of closure flushing.

Various techniques are discussed above.

CEMENTED TAILINGS BACKFILL OF ACCESS OPENINGS

The proponent is asked to evaluate or confirm evaluation of the suitability of flushing as opposed to select plugs of salt zones or complete cemented tailings fill of access and ancillary openings.

REFERENCES

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