APPENDIX F

Technical Memorandum 6

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To: Montana Department of Environmental Quality

From: Environmental Resources Management

Date: December 29, 2017

Subject: Black Butte Copper Project - Whether there is an advantage to requiring additional source controls (prevention of water inflow or application of treatment to rock faces) to limit oxidation during operation

BACKGROUND

During operation, Tintina plans to backfill production workings with a paste of tailings, cement, and binders. The backfill would provide structure to prevent subsidence; it would minimize groundwater contact with exposed rock both during operation and through closure and provide some neutralizing capability. The estimated surface area of the underground mine exposed to both air and groundwater inflow water would thereby be reduced at any given time. The Mine Operation Plan (MOP) also describes the grouting of fractures to limit intrusion of groundwater and collection and treatment of groundwater inflow (Tintina Montana, Inc. 2017). Water inflow would supply all of the water for the mine operation, although only 40 percent of the predicted inflow would actually be needed. All groundwater inflow would be collected and treated to non-degradation standards.

If inflow could be reduced, less water would have to be collected and treated. This Technical Memorandum explores the advantages of additional control measures to limit inflow and oxidation during operation.

CURRENT MOP

The groundwater inflow is estimated to be in the 420 to 500 gallons per minute (gpm) range during active mining, with occasional spikes of up to 1,000 gpm. Inflow and exposure to sulfates and metal oxide in the mined areas would need to be reduced as much as practical during operation. To limit inflow and groundwater contamination, planned procedures in the MOP include:

- Grouting – Tintina plans to grout major water bearing fractures or faults as they are encountered using pressure grouting techniques (sealing fractures by injecting a cement-based grout or a solution-based chemical mixture and diverting water around openings). One of the areas where grouting is anticipated to eliminate significant inflow due to fractures is underlying Coon Creek. According to the MOP, grouting the near-surface portion of the decline would substantially reduce mine inflow, with a ten-fold reduction in the first year according to model predictions.
- Use of Pilot Holes – Pilot holes ahead of the advancing mined face would be drilled to locate water-bearing geological structures. When or if large amounts of water are encountered in a

pilot hole, a packer would be installed to seal the hole. Following installation of the packer, directional grouting would be done prior to advancing.

- Collection and Treatment of Inflow – Groundwater inflow would provide the water needed for mine operation; however, only 40 percent of the estimated groundwater inflow would be needed. The remaining 60 percent would be treated to non-degradation standards and discharged to the upland underground infiltration galleries (UIGs) or to the alluvial UIGs if necessary.
- Cemented Tailings Backfill – During operation, a plant would be constructed to produce a paste (79 percent total solids by weight of mixture) comprised of fine-grained tailing from the milling process and 2-4 percent cement with proposed binders such as locally available cement, slag, and fly ash. The cement binder used to make the cemented tailings paste would also contain hydrated lime and should have neutralizing abilities. The low hydraulic conductivity of the backfilled tailings would reduce contact with groundwater.

ENVIRONMENTAL IMPACTS

The environmental impact of inflow would be the contamination of groundwater by exposure to oxidized surfaces and the dissolution of sulfates and heavy metals. Control of groundwater contamination would substantially reduce the amount of treatment needed and promote the ability of the planned treatment system to meet non-degradation standards.

TECHNICAL APPROACH

Methods of controlling groundwater inflow and contamination during operations are summarized in the following table (Kauppila 2011):

Method	Description	Applicability to Tintina BBC Mine
Paste Cover	Mixing fine-grained millings, cementitious materials, and water into pastes and covering tailings and exposed rock provides a barrier to oxidation	Planned use
Blending and backfilling mined areas	Blending waste rock and/or tailings with paste or neutralizing rock and returning to the excavated areas that are either filled with water or sealed from groundwater intrusion	Planned use
Sealed waste handling structures/dams	Sealing/liners/dam structures to prevent water intrusion and pickup of acid forming materials and heavy metals	Planned use

Method	Description	Applicability to Tintina BBC Mine
Depyritizing	Full or partial removal of iron sulfide from the waste to remove the acid-forming material prior to backfilling or placement in waste ponds	Evaluated in another Technical Memorandum
Water Cover	Owing to the significantly lower concentration and diffusion of oxygen in water, oxidation and acid production on tailings, waste rock and exposed rock surfaces can be limited through a water cover	Planned for by Tintina at closure (i.e., saturation of backfill with ambient groundwater), not practical during operation
Separation of acid and alkaline wastes	Acid forming tailings are separated to reduce the amount of material needing treatments to reduce oxidation	Applicable to tailings treatment, does not apply to underground mine surfaces
Encasing acid wastes within alkaline wastes	Carbonate/neutralizing tailing or waste rock coats or cover acid-forming material for either aboveground disposal or backfilling	Applicable to tailings treatment, does not apply to underground mine surfaces
Reactive Surface Coating	Coating tailings and/or waste rock with reactive materials such as organics to neutralize acid and bind or precipitate heavy metals	Use of organics to promote biofilms evaluated in another Technical Memorandum
Chemical Addition	Adding lime or other chemicals to neutralize acids	Lime and other alkaline materials would be a component of the cemented tailings backfill

Traditional and non-traditional surface coatings for sealing mined surfaces were evaluated in literature studies and are summarized in the following table (Haug and Pauls 2001):

Method	Description	Applicability to Tintina BBC Mine
Asphalt	Production of asphalt in a batch plant and application to mined surfaces	Can be used to limit oxidation, is subject to degradation over time, not practical for underground mine applications
Cementitious cover	Polypropylene fiber reinforced shotcrete	Planned use
Cement-stabilized coal fly ash grout	Fly ash mixtures and geopolymers	Planned use

Method	Description	Applicability to Tintina BBC Mine
Synthetic liners and covers	Geomembranes, spray-on membranes barriers, and geosynthetic clay liners	Spray on membrane barriers can be effective in limiting oxidation
Bentonite modified soil barriers	Soil-bentonite mixtures, polymer modified soil, and polymer surfactants	Can be used to limit oxidation, more appropriate for tailings piles and ponds
Mine Waste Tailings	Tailings and waste rock covers	Planned use
Wax barriers	Wax application to mined surfaces	Can be used to limit oxidation, are subject to degradation over time, not practical for underground mine applications

Some of these materials are only appropriate for covers or containment and not appropriate for surface treatments designed to mitigate acid formation. Prevention of acid formation requires the coating to be impermeable to oxygen transfer and resistant to acid degradation. The results of the evaluations showed that asphalt, wax, and spray-on membrane could be somewhat successful to limit oxygen transfer and liners such as geosynthetic clay liners and soil; modified soil barriers are only effective if they are maintained in a saturated state. Asphalts and waxes are subject to degradation if exposed for extended periods of time. None of these would be appropriate for sealing underground workings during operation to limit oxidation. The modification of fine grained and waste rock with bentonite, fly ash, or other materials could provide a surface cover that would limit oxygen transfer, be resistant to degradation, and provide structural support (Haug and Pauls 2001). This is similar to the Tintina MOP planned use of cemented tailings.

Butler (2014) describes using waste rock/tailings and grouting to seal cracks and fractures, and grout curtains to intercept groundwater flow paths. Additionally, flooding the mine workings before oxidation occurs can help to establish an anaerobic environment (Butler 2014). A large zinc-copper mine near Crandon, Wisconsin proposes to use grouting of underground mine working and active treatment of contaminated groundwater (Leopold et al. 2001). All of these methods except the grout curtains are in the Tintina MOP. Shotcrete could be produced that exhibits characteristics of high strength, low permeability, and good homogeneity. If shotcrete were to be applied over the top of rock surfaces, it would need to occur shortly after exposure. If the rock surfaces have already oxidized, the sulfate could attack the shotcrete and deteriorate the lining. Sulfate resistant cement could be used where sulfate attack is likely (Ma 2011).

CONCLUSIONS AND RECOMMENDATIONS

A technical review of the available sources compared to the MOP finds that most of the commonly used methods to control inflow are planned for use by Tintina. Other methods may have potential application but should only be considered if the control measures tested during the operations phase are unsuccessful.

REFERENCES

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