Appendix IR1-15-A
TMF Closure Objectives

Red Mountain Underground Gold Project
IDM Mining Ltd. Responses to
Canadian Environmental Assessment Information Request #1

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MEMORANDUM

To:	Mr. Max Brownhill	Date:	January 15, 2018
Copy To:	Ryan Weymark (IDM), Jasmin Flores (Falkirk)	File No.:	VA101-00594/07-A.01
From:	Jim Fogarty	Cont. No.:	VA18-00069
Re:	Red Mountain CEAA Comment Response – Annex 1 – IR1-15: TMF Closure Objectives		

1 – INTRODUCTION

IDM has received Information Requests (IRs) from the Canadian Environmental Assessment Agency (CEAA) on the initial review of the Red Mountain Underground Gold Project Environmental Assessment Application (EAA).

IR1-15, relating to TMF closure objectives, states:

"The EIS Guidelines states "mitigation measures should be specific, achievable, measurable and verifiable, and described in a manner that avoids ambiguity in intent, interpretation, and implementation."

The TMF dramatically changes the pre-existing landform. The primary objective of closure and reclamation initiatives, as presented in Appendix 1-H, is to "return the TMF site to a self-sustaining condition with pre-mining usage and capability". Proposed closure mitigation measures include the use of a geomembrane to cover the tailings. Geomembrane covers are challenging to construct and eventually deteriorate."

The IR requests additional information to clarify the closure objectives for the Bromley Humps TMF. This memo provides a combined response to IR1-15(c) and IR1-15(d).

IR1-15(c) requests that the proponent *"provide information on the construction and life expectancy of the geomembrane cover".* **IR1-15(d)** requests the proponent to *"describe contingencies for achieving the critical function of the geomembrane should it deteriorate".*

2 – RESPONSE

2.1 PHYSICAL LINER DEGRADATION

Degradation of HDPE geomembranes is typically caused by oxidation, which is primarily driven by either thermo-oxidative ageing (temperature based) or photo-oxidative (UV exposure based). Degradation may increase the likelihood of stress cracking or failure and limiting exposure of the geomembrane to sunlight and heat is the most effective way to maximize its lifespan.

The lifespan of a geomembrane liner is defined by three stages (Koerner et al, 2005):

- Stage 1 – Depletion time of antioxidants
- Stage 2 – Induction time to onset of degradation, and
- Stage 3 – Time to reach service life (specified as the 50% degradation or "half-life" of the geomembrane).

Although the industry standard for the service life of geomembranes is defined as the half-life, the geomembrane still exists and functions (although at a reduced performance level) beyond the 50% degradation point.

The half-life of HDPE geomembranes has been estimated through laboratory testing of samples and monitoring of existing lined impoundments (Tarnowski and Baldauf, 2006). Laboratory testing involves incubating samples of HDPE geomembrane at high temperatures in dry and wet conditions for extended periods of time. Measurements of anti-oxidant depletion and physical degradation of the samples are taken and the results are used to extrapolate geomembrane performance at lower temperatures.

The performance of some lining systems installed in the 1970's has been monitored by various parties over the years (Tarnowski and Baldauf, 2006; Rowe and Sangam, 2002). The anti-oxidant levels and stress crack resistance has been measured on samples from different impoundments around the world. It was found that anti-oxidant depletion occurred on the exposed surfaces of the geomembranes, indicating that geomembrane thickness plays a significant role in the durability of liners (Tarnowski and Baldauf, 2006). It was further observed that there was no detectable decrease in the tensile resistance of the samples, despite the anti-oxidant depletion.

Lifetime predictions of unexposed liners (such as is proposed for the Bromley Humps TMF) are determined primarily by the average field temperature. Lining systems at 20°C have been estimated to last up to 449 years (Koerner et al, 2005), although higher temperatures may decrease the service life.

2.1.1 Conclusion

The service life of an HDPE geomembrane liner is defined as its half-life (i.e. the point at which 50% of the geomembrane has degraded). Lining systems that have reached their half-life will still continue to function at a decreased level of performance.

Liner degradation is caused by oxidation, which is promoted by exposure to heat and UV radiation. The liners for the Bromley Humps TMF (top and bottom) will be covered by tailings (bottom) and fill materials (top) by the end of the mine life, creating optimal conditions to maximize the service life of the geomembrane liners.

Average (monthly) field temperatures at the project site are anticipated to range from -10°C to 10°C. The temperature variations that the lining system will be exposed to will be considerably less than this range due to the covered nature of the liners. The service life of the TMF liners (lower and upper) is therefore expected to be in excess of 400 years for ambient temperatures within this range.

2.2 CHEMICAL LINER DEGRADATION

Chemical decomposition of HDPE lining systems is considered to be a non-issue for most municipal uses, i.e. landfills. Degradation via oxidation and the formation of the stress cracks are the primary cause of liner failures (Peggs, 2003). The chemical resistance of HDPE products has been investigated in several studies over the past decades, and results of these studies have shown that most chemical compounds across a wide range of concentrations (including sulfuric acid) do not cause mechanical or chemical degradation (GSE, 2012).

All materials are permeable to some extent, including HDPE geomembranes, however the rate of permeation through HDPE is so low that it is considered insignificant (GSE, 2012). The permeability of HDPE geomembranes is affected by the temperature, pressure, and concentration of leachates contacting the liner.

Since HDPE is a petroleum product, it can absorb other hydrocarbon based compounds, as well as some other chemicals, when present at high concentrations. This absorption is not an immediate process, it takes significant time to occur, and that time is dependent on the specific chemicals involved, their concentration, and their temperature. This absorption results in the softening of the geomembrane, but does not compromise the integrity of the geomembrane or reduce its capacity to act as a barrier. HDPE geomembranes will return to their original state if exposure ceases, as the absorption is not permanent.

The upper geomembrane liner, intended as a component of the closure cover of the TMF, will not be continuously exposed to reactive chemicals or water. As a result of this condition, and for the reasons described above, chemical dissolution of the top HDPE geomembrane liner is not a consideration.

Similar to the upper geomembrane liner, the lower geomembrane liner is exposed to a drained tailings mass only. At closure, the consolidation of the tailings mass will have slowed to negligible rates (KP, 2017), i.e. there will be negligible release of water from the tailings voids post-closure to affect the geomembrane liner.

2.2.1 Conclusion

Chemical resistance testing has been conducted on HDPE geomembrane lining systems for several decades. It has been demonstrated that HDPE is resistant to most chemical compounds and will not exhibit chemical or mechanical degradation, especially at average climatic temperatures of 20°C or less.

HDPE can absorb certain chemicals, if present in high enough concentration, specifically hydrocarbon products. Absorption will soften the geomembrane, but not compromise the integrity or performance of the geomembrane. The effects of absorption are reversible when exposure ceases.

The drained tailings mass above the lower TMF geomembrane liner, and the soil and rock closure cover above the upper geomembrane liner will reduce the risk of continuous exposure of reactive chemicals or water to each of the geomembrane liners.

2.3 HDPE LINER REPLACEMENT

Given the information presented above on the service life of HDPE liners and the covered nature of both liners, there are no plans to replace the HDPE geomembrane liners for the Bromley Humps TMF at any point during operations, closure or post-closure.

2.4 CONCLUSIONS

HDPE geomembranes are durable products, designed with service lives of up to several hundreds of years under optimal conditions. The service life of an HDPE geomembrane is typically defined as its half-life, which is the point at which 50% of the geomembrane has degraded.

The primary cause of degradation of lining systems is oxidation of the geomembrane, which eventually weakens the geomembrane and allows stress cracks to form. Oxidation is inhibited by limiting exposure of the geomembrane to UV radiation and open air environments, and maintaining lower average ambient temperatures around the lining system. HDPE is chemically resistant to most substances, especially at lower temperatures (20° or less), and chemical degradation of lining systems is generally considered a non-issue for most municipal uses.

The Bromley Humps TSF includes many factors to minimize potential degradation of the HDPE geomembrane liners. The lower HDPE liner will be mostly covered during construction of the TMF, and will be progressively submerged by tailings during operations, limiting its exposure to UV radiation and air. The upper HDPE liner will be covered immediately after installation with a cover layer consisting of soil and rock, with a revegetated topsoil layer at surface, thus limiting its exposure to UV radiation and air.

Average monthly temperatures at the project site range from -10°C to 10°C, which is optimum for inhibiting chemical degradation of the geomembranes. Durability testing completed in laboratory and field conditions estimate that HDPE geomembranes can have service lives (50% degradation) of over 400 years. Under the conditions described, it is reasonable to expect that the service life of the TMF liners will be of similar duration. As such the liners are not planned to be replaced given the expected long service life of several centuries or more.

3 – REFERENCES

The following papers and information sources were utilized for this study:

GSE Environmental (GSE), 2012. Technical Note: *Chemical Resistance for Geomembrane Products*, GSE Environmental, LLC. http://www.gseworld.com/content/documents/technical-notes/Chem_Resist_Geomembrane_Technical_Note.pdf. July 2012.

Koerner, R.M., Hsuan, G.Y., and Koerner, G.R., 2005. *Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions – GRI White Paper #6*. Geosynthetic Institute. Issued June 7, 2005.

Knight Piésold Ltd. (KP), 2017. *Tailings and Water Management Feasibility Study Design*. Prepared for IDM Mining Ltd. Ref. No. VA101-594/4-4, Rev.1. Issued August 4, 2017.

Peggs, I.D., 2003. *Geomembrane liner durability: contributing factors and the status quo.* Geosynthetics: protecting the environment, Thomas Telford, London, 31 pp.

Rowe, R.K., and Sangam, H.P., 2002. *Durability of HDPE geomembranes.* Geotextiles and Geomembranes 20.2, p. 77-95.

Rowe, R.K., Rimal, S., and Sangam, H. P., 2009. *Ageing of HDPE geomembranes exposed to air, water and leachate at different temperatures.* Geotextiles and Geomembranes 27.2, p. 137-151.

Tarnowski, C., and Baldauf, S., 2006. *Ageing resistance of HDPE geomembranes – Evaluation of long-term behaviour under consideration of project experiences.* Geosynthetics. Edited by J. Kuwano and J. Kosaki. Millpress, Rotterdam, NLD, p. 359-362. Literature Review.

We trust that the information presented above satisfies your requirements at this time. If you have any questions, please do not hesitate to contact the undersigned.

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