APPENDIX K-3: Life Expectancy of HDPE Geomembrane Lining Systems

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Mr. Bob Jacko
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Dear Bob,

Re: Black Butte Copper Project - Life Expectancy of HDPE Geomembrane Lining Systems

1 – INTRODUCTION

Knight Piésold completed the feasibility design of the waste and water management facilities for the Black Butte Copper Project. Approximately half of the mill tailings will be used for underground mine backfill. The other half will be permanently stored on surface in the Cemented Tailings Facility (CTF), which utilizes a geomembrane lining system to provide containment of tailings solids and residual process water. This system includes two layers of 100 mil HDPE geomembrane with a layer of 7.6 mm high-flow geonet between the geomembrane layers.

A common question is related to the life expectancy of the lining system, and the consequences of degradation over time. This letter addresses this topic specifically, and considers the following items:

- Physical degradation of HDPE geomembrane
- Chemical resistance of HDPE geomembrane
- Potential for groundwater flow into and through tailings

2 – PHYSICAL DEGRADATION

2.1 LITERATURE REVIEW SUMMARY

Degradation of HDPE geomembrane 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 A: Depletion time of antioxidants
- Stage B: Induction time to onset of degradation
- Stage C: Time to reach the service life, specified as the 50% degradation point (half-life) of the geomembrane

Although the industry standard for service life of a geomembrane 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 lining systems (Tarnowski and Baldauf, 2006). It was also observed that there was no detectable decrease in the tensile resistance of the samples, despite the anti-oxidant depletion.

Lifetime predictions of unexposed liners 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.

2.2 KEY POINTS

The service life of an HDPE geomembrane lining system is defined as its half-life; which is 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 lining system designed for the CTF will be completely covered by tailings and fill materials by the end of the mine life, creating optimal conditions for maximizing the service life of the geomembrane.

Average (monthly) field temperatures at the project site range from -10°C to 16°C. The temperature variations that the lining system will be exposed to will be considerably less due to the cover materials, including deposited tailings. The service life of the CTF lining system is expected to be in the order of 400 years or more for ambient temperatures within this range.

3 – CHEMICAL RESISTANCE

3.1 LITERATURE REVIEW SUMMARY

Chemical decomposition of HDPE lining systems is considered to be a non-issue for most municipal uses, such as in 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 by several groups over the past decades, and test results have shown that most chemical compounds across a wide range of concentrations (including sulfuric acid) do not cause mechanical or chemical degradation (Rowad).

All materials are permeable to some extent, including HDPE geomembrane, however the rate of permeation through HDPE is so low it is considered insignificant (Rowad). The permeability of HDPE geomembrane 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 immediate, 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 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 is ceased, as the absorption is not permanent.

Double-lined containment with a seepage collection and removal system, which is included for the CTF, effectively prevents continuous exposure to the secondary geomembrane. As a result of this, and for the reasons described above, chemical dissolution of the HDPE geomembrane is considered a non-issue.

3.2 KEY POINTS

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 does not compromise the integrity or performance of lining system. The effects of absorption are reversible when exposure is ended.

The CTF has a double-lined system with integrated seepage collection and removal. This prevents continuous exposure of the secondary liner to water and effectively decreases the overall permeability of the lining system.

4 – FLOW MODELLING

4.1 SEEPAGE ANALYSES

Seepage analyses were completed to demonstrate the potential impact of failure of the lining system on the flow of groundwater through the CTF. Hydraulic conductivity testing of cemented tailings samples and the CTF foundation materials shows that the tailings are an order of magnitude less permeable than the foundations. As such, groundwater would tend to flow preferentially around the tailings mass, even if the lining system is compromised.

Two simplified models were developed for this analysis. Groundwater pressure is simulated using a source point upstream of the CTF. Both models assume that the CTF is full, with a capping layer of rockfill in place to reflect post-closure conditions. The first model utilizes an intact lining system that fully encompasses the tailings mass. The second model assumes that the lining system is fully degraded.

Figure 4-1 shows the results of the seepage analysis on the CTF with a fully intact lining system. Water flow is indicated by the black arrows, with larger arrows indicating higher concentrations of water flow. It can be seen that with a fully intact lining system, the majority of groundwater will flow around the cemented tailings mass in the CTF.

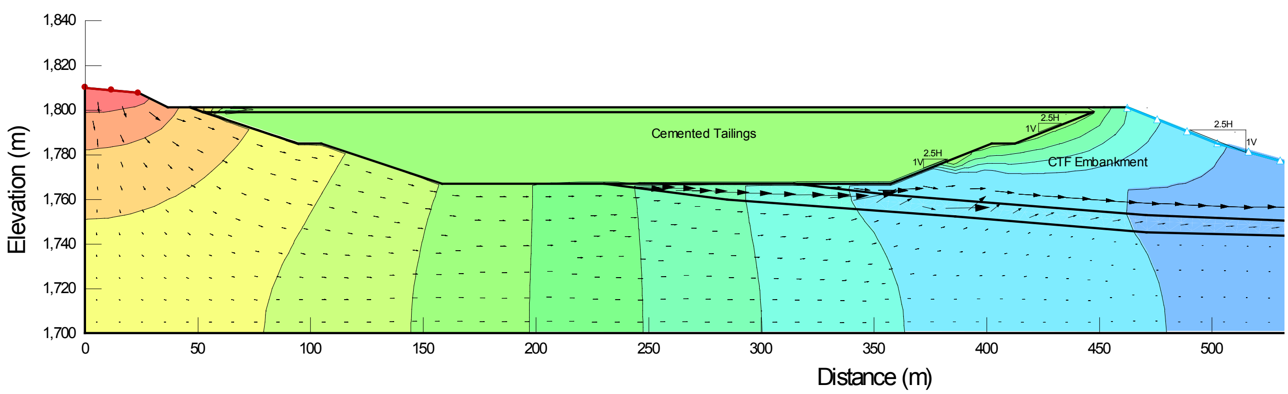

Figure 4-1 Groundwater Flow with Intact Lining System

Figure 4-2 shows the results of groundwater flow with a fully degraded lining system. It can be seen, based on the size of the arrows indicating flow path, that while a minor amount of groundwater flow can permeate through the tailings mass the majority of flow is preferentially transported through the underlying bedrock.

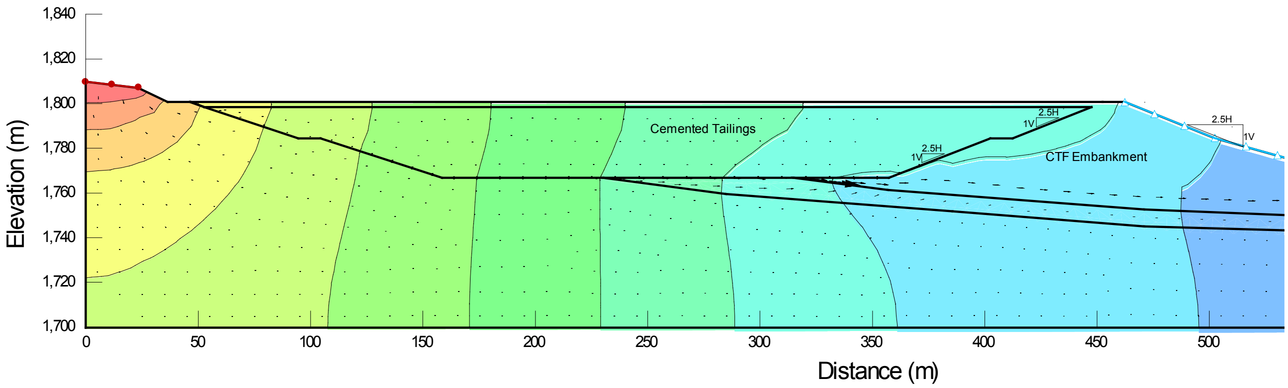

Figure 4-2 Groundwater Flow with Degraded Lining System

It is important to note that the CTF design includes 300 mm thick protective layers of sand and gravel placed above and below the lining system (600 mm total thickness), as well as a foundation drain system that has been designed to capture and redirect groundwater flow around the liner system. These systems were not included in the seepage models shown above. They are highly permeable and will serve as a preferential flow path for groundwater around the tailings mass, which will greatly decrease the amount of water that could pass through the tailings should the lining system degrade.

4.2 KEY POINTS

The cemented tailings mass is estimated to have a permeability that is approximately one order of magnitude lower than the surrounding foundation bedrock. Groundwater would preferentially flow around the tailings mass through the surrounding bedrock, even after complete degradation of the lining system. Flow around the tailings mass will be further enhanced by the sand and gravel material that will be placed above and below the lining system as a protective layer, and by the foundation drain system that encompasses the impoundment.

5 – CONCLUSIONS

HDPE geomembranes are extremely durable products, designed with service lives up to several hundreds of years under ideal 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 membrane and allow 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°C or less), and chemical degradation of lining systems is generally considered a non-issue for most municipal uses.

The CTF includes many factors to minimize potential degradation of the lining system. It utilizes a double lining system with two layers of 100 mil HDPE geomembrane sandwiched around a hi-flow 7.6 mm HDPE geo-net layer. The upper geomembrane layer will be mostly covered during construction of the CTF, and will be progressively submerged by tailings during operations, limiting its exposure to UV radiation and air. The lower geomembrane will be covered during construction and will not be exposed to UV radiation. Average monthly temperatures at the project site range from -10°C to 16°C, which is optimum for inhibiting chemical degradation of the geomembrane. Durability testing completed in laboratory and field conditions estimates that an HDPE geomembrane can have a service life (50% degradation) of over 400 years. Under the conditions described it is reasonable to expect that the service life of the CTF lining system is for several centuries or more.

Lastly, the cemented tailings mass will have a low permeability, causing groundwater to preferentially flow around the tailings mass through the surrounding bedrock. Groundwater ingress into the tailings mass would be minimal, even if there was complete degradation of the lining system. Flow around the tailings mass will be further enhanced by the sand and gravel layers that will be placed above and below the geomembranes during construction.

6 – REFERENCES

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

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Technical Note: Geochemical Resistance for Geomembranes, Rowad International Geosynthetics Co. Ltd., http://www.rowadgeo.com/Chemical_Resistance.pdf

Yours truly,
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