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ATLIN RUFFNER MINE REMEDIATION AND WATER MANAGEMENT: CAN'T PLUG THE SOURCE? PLUG THE FLOW

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Abstract: The case study presented herein focuses on water management design challenges related to a remote, cold climate, subalpine site requiring a low maintenance solution for contaminant facilities and abandoned mine remedial works. The resulting design included an innovative application of automatic siphon technology in combination with an integrated geomembrane cover and interceptor trench system to provide resiliency and redundancy for effective environmental stewardship.

1 Site Background and Overall Project Objectives

The Atlin Ruffner Mine is an abandoned mine site located in northern British Columbia, approximately 28 km northeast of the community of Atlin and is accessible by road only via the Yukon on Atlin Road. Mining operations commenced in 1900 and continued intermittently until 1981. A total of 3,535 tonnes of ore were milled, with recovery of 138,493 kg lead, 13,540 kg zinc, 2,079 kg silver, 920 kg copper, 15 kg cadmium and 3.4 kg gold (MINFILE, 2010). The mine had an onsite mill facility, several underground mine adits, and one artesian borehole (the adit) purposefully drilled to provide a continuous supply of groundwater to the mill to meet processing needs. When the mine was abandoned, these groundwater flows continued do discharge to surface, presenting a risk to the physical and chemical stability of the site.

Figure 1: Site photo (left, 2010) taken prior to remedial activities; mill building left and tailings pond right. Site photo (right, 2017) taken during remedial activities; mill building demolished, site capped and liner being installed on tailings and sedimentation ponds.

1.1 Project Objectives and Guiding Principles of Remedial Plan

The Crown Contaminated Sites Program (CCSP) of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development manages prioritized high risk Crown contaminated sites on provincial land to ensure the protection of human health and the environment. The Atlin Ruffner mine site was classified through the CCSP risk ranking process (Power 2009) as a high priority site and this designation lead to the development of the *Remedial Plan* (AECOM, 2012). The purpose of the plan was to:

- Mitigate contaminant concentrations in open, high-significant, exposure pathways; and
- Reduce long term risk related to chemical contaminates at the abandoned mine site.

The guiding principles the CCSP provided for the *Remedial Plan* included the following:

- Provide a robust, long term, risk-based remedial solution that is cost–effective and achievable;
- Consider innovative approaches and potential alternative delivery methods to ensure project efficiencies and cost effectiveness; and
- Comply with the standards and guidelines defined in the B.C. *Environmental Management Act,* Contaminated Sites Regulation and Hazardous Waste Regulations (HWR) and the B.C. Ministry of Environment and Climate Change Strategy protocols on contaminated sites. The site qualifies for a Historical Hazardous Waste Contaminated Site Exemption under the HWR.

1.2 Monitoring, Planning and Phase One Remedial Activities

AECOM Canada Ltd. was engaged in 2010 to support development of the remediation plan for the mill area of the mine. Since that time, field investigation activities have been conducted including: surface water monitoring, groundwater monitoring, surveying, soil sampling, geotechnical slope stability assessment, hazardous waste assessments, and volumetric assessments.

Phase One of the remedial activities were completed in 2012 and included the demolition of the mine mill facility, removal or contained onsite disposal of hazardous waste, and the installation of a 1.0 metre thick capping layer over the accessible contaminated areas of the site including the mill facility, tailings pond, two sedimentation ponds, and access/connection roads. The cap was constructed using non-contaminated onsite material to physically isolate contaminated soils. A geotextile layer was used to visual demarcate the clean capping materials from the underlying visually similar contaminated materials.

2 Water Management: Phase Two Remedial Activities Design Considerations

The Phase Two remedial goal, on which this case study focuses, was water management to prevent interaction with site contaminants including waste rock and tailings and considered three sources; surface water, groundwater and adit drainage (daylighted groundwater). Generally, the motto of ‘keep clean water clean’ was applied wherever reasonably achievable to prevent contaminant transport and reduce or eliminate water treatment requirements.

2.1 Site Constraints and Challenges

The adit water source originates from a collapsed portal, and prior to Phase One, flowed through both the upper and lower sedimentation ponds prior to infiltrating into ground. After the Phase One works, the water was directed into a drainage channel, undefined in some high gradient areas, and diverted around the site. Post-Phase One it was determined that 20 to 50%, dependent on seasonal flow rates, of the adit flow was re-infiltrating and reporting to the contaminant containment facilities.

The primary challenges that constrained the design were:

- Requirement for passive methods to manage surface and groundwater water in cold regions;
- Upgradient slopes prone to movement and/or rockslides;
- Naturally occurring open graded granular materials with high permeability allowing rapid infiltration and groundwater transport;

- Limited working area to preserve existing vegetation due to low revegetation potential due to climatic region, subalpine altitude, site orientation, and limited available growing medium;
- High topographic gradients upwards of 30% grade; and
- Provisions for redundancy and risk evaluation for remote sites, particularly sites with the long-term objective to limit or eliminate maintenance and inspection requirements.

Monitoring data could not verify the minimum seasonal flow rate from the adit source because water level readings were affected by superficial ice during a portion of the monitoring period. However, the temperature readings were always above zero degrees at the adit daylighting point, suggesting continuous flows throughout the winter.

2.2 Adit Flow Management Options Analysis

Several options were developed and evaluated; some of which were determined unsuitable. Source control could be achieved by accessing the adit origin point to plug the borehole source of the water and in turn prevent the daylighting of groundwater. Cost risk and uncertainty of a desired outcome being achievable were evaluated due to limited information being available on the depth of the adit tunnel. As a result, it was not considered feasible to pursue source control due to a lack of access to the underground workings (i.e., collapse) and to minimize health and safety risks.

The second option analyzed was overland channel control which required the construction and upgrading of an open channel to convey discharge from the adit and divert flow around the site, including import of a low permeability liner. The design challenges identified included risk of obstruction from rockslides, treefall, freezing, and erosion due to high gradients. Routing the channel through the site with sufficient depth and definition to mitigate the risk of icing was deemed undesirable due to the volume of contaminated materials which would require relocation. Locating the channel adjacent to the slope exposed it to risk of obstruction from rockslides.

The final option reviewed was a buried pipeline control that would divert flows around and/or through the site. The perceived risks were driven by low winter flow rates (i.e. trickle flows) and cold climate driven frost potential which could subject the pipe to freezing and in turn obstruction. Protecting the buried piping by means of insulation was not considered feasible. The depth of frost penetration at the site was conservatively estimated as between 4.3 – 5.8 m assuming 2500 °C-days freezing index, 3% soil moisture, granular material, and no snow cover. An automatic siphon was considered to accumulate low flows and discharge the stored volume thereby reducing the risk of freezing the discharge. Based on the options review, the adit drainage pipeline with an automatic siphon was determined to be the most cost effective and reliable option.

2.3 Automatic Siphon and Adit Diversion Pipeline

Automatic siphons are not a new technology and have been in use for over 100 years to flush livestock yards, in sewage treatment plants to dose trickling filters, and to dose recirculating sand filters (Ball 1996). A dosing system provides for the periodic discharge of a determined volume of effluent. In the application for the Atlin Ruffner project a passive system without the requirement for electrical power or mechanical parts facilitated the temporary storage of adit flows followed by the automatic discharge of the stored water less susceptible to freezing. Based on an assumed minimum flow rate of 0.2 L/s, the maximum time between discharges of a siphon chamber with capacity of 660 L was every 55 minutes.

A minimum depth of 1.5 m was selected to place the pipeline below the influence of extreme daily temperatures and a maximum depth of 2.5 m was selected for constructability purposes. Where possible, the slope of the pipe was matched to the slope of the existing ground surface. The heat loss through the pipeline was based on the flow velocity and residence time and determined that the adit drainage pipe would likely glaciate due to the low winter flow rates. When combined with foam board insulation above the pipeline, the automatic siphon provides sufficient flow to protect the pipeline from glaciation. Based on the hydraulic properties of the section of the pipeline with the least grade, the flow capacity of the pipe was calculated (Q_{FULL}) as 29.3 L/s in comparison to the 26.6 L/s maximum discharge of the siphon.

The maximum potential velocities within the pipeline were calculated as 4.1 m/s in part due to the steep site grades. Energy dissipation and limiting of the flow rate were reviewed as a means to limit the maximum pipe velocity. However, the low sediment load of the discharge reduced the risk of pipe scour and an increased wall thickness was selected to provide sacrificial material meanwhile providing freeze-thaw cycle resilience.

2.4 Geomembrane Cover System and Interceptor Trenches

It is anticipated that the adit diversion pipeline will significantly decrease the volume of groundwater within the perched aquifer and the volume of groundwater reporting to the tailings and sedimentation ponds. However, infiltration due to precipitation and snowmelt provides a secondary source of water to the perched aquifer, and management by groundwater interceptor trenches and an impermeable liner was required.

A water balance was developed which incorporated groundwater inputs based on Darcy's Law and infiltration. The groundwater reporting to the interceptor trenches was anticipated to range from 0.2 to 5.3 L/s based on a water balance model sensitivity analysis that considered precipitation, hydraulic conductivity, and saturated thickness of the perched aquifer. The predicted range of flows was compared to seepage losses from the adit drainage and was in general agreement.

The interceptor trenches are a low permeability near vertical geomembrane liner on the downgradient wall combined with a perforated HDPE pipe at the base of the trench surrounded by high permeability drainage rock to collect and convey water downslope and away from the tailings and sedimentation ponds. The liner was designed to integrate with the surface liner to minimize ingress of groundwater, moisture and oxygen to the tailings from the interceptor trenches and the perched aquifer to the tailings.

3 Conclusions

The case study presented was selected due to its combination of unique design challenges in water management on a contaminated site to prevent freezing of low flow rates within a cold climate environment. The combination of an automatic siphon with a surface and groundwater interceptor trench geomembrane liner system meet the project objectives while also providing a passive low maintenance designed solution with the reliability and redundancy desired of the site *Remedial Plan* guiding principles.

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