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Assessing, remediating and performance monitoring abandoned mine sites in the Northwest Territories

By **Reid Smith** and **Arlen Foster**

The Northwest Territories has a long history of mining activity that has resulted in a number of abandoned mine sites with varying levels of environmental liabilities. These sites present a range of risks to the environment and public health and safety, and can represent substantial financial liabilities for governments.

The Bullmoose Area mine sites remediation and monitoring project encompasses the assessment, remediation, and performance monitoring at seven abandoned mine sites (Ruth, Bullmoose, Beaulieu, Spectrum, Chipp, Storm, and Joon) located between 70 and 90 kilometres east of Yellowknife.

These sites were active between 1939 and 1988, with various ownership and activities ranging from open-pit mining to exploratory drilling. Once abandoned, several environmental concerns arose from the materials and debris left behind. These include hazardous and non-hazardous debris, underground mine openings and trenches, petroleum hydrocarbon and/or metal impacted soil and sediment, tailings and waste rock. Due to the insolvency of previous operators, Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) inherited the mine sites.

Stantec was contracted to conduct an expert peer review of the human health and ecological risk assessments (HHERAs) for several of the Bullmoose Area mine sites on behalf of Public Services and Procurement Canada.

As a result of this review, the HHERAs were redeveloped for four of the Bullmoose Area mine sites: Bullmoose, Ruth, Spectrum and Beaulieu. The objective was to determine whether on-site concentrations of metals posed unacceptable risks to human and/or ecological receptors, derive ecological site-specific target levels (Eco-SSTLs), and provide recommendations for future work.

An aquatic assessment field team prepares the boat and field equipment for slinging by helicopter to the next lake involved in the monitoring program.

These results were used to aid in the development of an updated remedial action plan (RAP) and cost estimate for all the Bullmoose Area mine sites. Additional engineering studies/designs and tender package development to support the remediation program and necessary permits (water licence, land use permit, quarry authorization, etc.) and community engagement activities were also completed, followed by a two-year construction period and long-term monitoring.

The Bullmoose project provides a valuable case study for currently operating mines that are actively managing environmental liabilities. These include:

- Successful treatment of petroleum hydrocarbon impacted soils by landfarming during the short summer season.
- Use of dominant geochemical dynamics in natural wetlands for attenuating mine portal seepage with elevated metals.
- Vegetation techniques in difficult substrates with a short growing season.
- Capping impacted soils in place for closure.
- Development of baseline geotechnical and other performance data for tailings storage facilities.

SUSTAINABLE DEVELOPMENT AND MINIMIZED ENVIRONMENTAL IMPACTS

While returning the impacted sites to a stable, safe condition for future land use is the overarching objective of the project, sustainable remediation and monitoring methods have been incorporated into the project.

Sustainable approaches were first considered in the development of a RAP, which included a coupled remediation and risk management approach. These included the development of site-specific risk-based criteria and considered

human and ecological health risks, limited unnecessary disturbance associated with heavy equipment use during excavation or soil capping construction activities at low-risk areas, and requiring less physical maintenance and inspection.

The RAP also recommended further evaluation of a natural wetland, with potential to provide long-term contaminant attenuation, rather than pursuit of contaminant removal by excavation or construction of costly engineered wetland features.

Substantial reductions in greenhouse gas emissions were also achieved, as construction activities were completed one year ahead of schedule. This removed the need for another year of construction and operation of a winter ice road. Sustainable methods during performance monitoring efforts have included the design and implementation of automated monitoring instrument stations, with telemetry capabilities allowing for reduced maintenance and fewer trips to the site.

AQUATIC EFFECTS MONITORING PROGRAM (AEMP)

Following completion of remediation activities, an AEMP was designed to assess if fish species in Bullmoose Lake were abundant, healthy and suitable for human consumption. This was due to suspected impacts to the lake from mining activities throughout the Bullmoose Area mine operations. The AEMP would also be used to monitor for positive changes in surface water and lake sediment chemistry and overall fish health as a result of remediation work.

The AEMP used a control-impact study design, to assess fish health and abundance within the Bullmoose Lake compared to a reference area. Two sentinel, or "target" fish species, which are culturally important to the local communities, were selected for monitoring fish health and three species were selected for monitoring fish tissue based on the species present in Bullmoose Lake.

The fish tissue study targeted fish from different trophic levels (e.g., piscivorous or planktivorous species) to assess metal accumulation within the aquatic food web. The approach, methodology and fish health metrics applied were consistent with those for existing mines subject to the *Metal and Diamond Mining Effluent Regulations* (MDMER).

Fish health field dissection of a Northern Pike.

Lake sediment sampling as part of the Aquatic Effects Monitoring Program.

Results indicated that concentrations of contaminants in water and sediment within Bullmoose Lake and the reference lake were generally below Canadian Water Quality Guidelines for Protection of Aquatic Life and Canadian Sediment Quality Guidelines Probable Effects Levels. Comparisons in abundance of targeted fish, fish health and tissue chemistry between Bullmoose Lake and the reference lake did not identify differences due to suspected effects of historical mining.

Findings to date provide valuable insight into the likely extent of aquatic effects in Bullmoose Lake, considering the site's lengthy history of mining activities, and disturbances to the terrestrial and lake environments during the remediation program.

The Bullmoose AEMP provides a case study, methodology and recommendations, that may be used to assess effects of abandoned mines sites with varying levels of environmental liabilities on aquatic receiving environments for comparable sites across Canada, in particular for northern regions. The study design of the AEMP incorporated the findings of environmental site assessments, risk assessments and site-specific monitoring to assess fish community health and establish a baseline. This can potentially be used in the future to monitor potential changes over time, following remediation of the site and to inform local Indigenous communities and stakeholders.

IMPLEMENTING EROSION AND SEDIMENT CONTROL AND RUNOFF CONTROL

Working in remote areas with limitations for site access has provided unique project constraints. Specifically, the fly-in only Bullmoose mine sites have restrictions on the size/weight of construction equipment, number of available personnel, and available construction materials. These include full size excavators, large rip-rap materials, concrete, etc.

To address these challenges and pursue long-term, low maintenance solutions, different stabilization techniques were piloted on slopes prone to erosion and weathering to compare effectiveness after a growing season. The ultimate outcome for exposed slopes prone to erosion would be to have vegetative stability established for long-term erosion protection. Suitable rock protection material is difficult and costly to source at the mine sites. However, a short growing season and low availability of organic soils leads to difficulty in establishing vegetative cover.

The trials included the use of different biodegradable erosion control blankets (ECBs), a variety of native seed mixes and mulches, biodegradable coir logs, live-staking and small berms. In 2020, areas of the Bullmoose mine experiencing minor erosion and poor re-vegetation were divided into sections and stabilized with different trial methods. These included coir matting, jute matting and seeding with mulch. Areas with more significant erosion were stabilized

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using minor grading works to repair rilling and gully erosion areas. Flow breaks of coir logs were placed across the slope.

A large area of erosion at a former access road was repaired with a temporary stabilization method using filter fabric and the largest substrate available on site. Plans for permanent stabilization of this erosion area have been prepared. These include an engineered articulated concrete block product that is light enough to be flown in and installed with small equipment and manual labour.

Overall, as indicated by site monitoring to date, the treated areas are stabilizing satisfactorily and vegetative cover for erosion control is considered achievable on site within shorter timelines than expected. The results of these pilots have been incorporated into designs for other site areas, such as landfill cover upgrades. Previously, the erosion control objectives would have been pursued using borrow excavation and coarse material production methods with much higher costs and levels of disturbance.

NATURAL WETLAND MECHANICS AND ATTENUATION CAPACITY

During the frost-free months, a slow steady amount of water seeps from the capped entrance of the Bullmoose Mine. It flows into a wetland area, before migrating east to Bullmoose Lake, or south to Bullmoose Creek, which also flows into Bullmoose Lake.

Contaminants of concern (COCs) in this seepage water are iron, manganese and arsenic. The wetland is a natural feature, which formed following the 1988 mine closure activities when overlying waste rock was used to backfill the underground mine workings and portal entry.

During the environmental site assessments and remedial design phase, it was suspected that the wetland may have the ability to sequester COCs from the portal seepage prior to discharge into Bullmoose Lake. However, annual and seasonal mass loading rates were uncertain. Therefore, the long-term reductive capacity as a natural treatment system without engineered controls remained a critical question.

Remedial options that were considered included a range of passive and active approaches for portal seepage treatment, as well as small-scale augmentation techniques for the natural wetland and/or excavation of the entire wetland/impacted sediments and construction of an engineered wetland. Due to a lack of available site data at the time, and the high cost of select options (e.g., active water treatment unit, construction/ maintenance of engineered wetland), it was recommended that remediation of other project components move forward. Continued monitoring and assessment was to be completed at the portal seepage and wetland area, in order to determine next steps.

A performance monitoring program was designed for evaluating the natural wetland that included surface water flow and chemistry, sediment chemistry and vegetation tissue chemistry. A detailed review of monitoring data indicated that the wetland continues to effectively remove COCs via filtration through wetland vegetation and sedimentation onto wetland sediments. There is also likely support by chemical oxidation and adsorption reactions.

> **Long term sequestration of COCs in wetland sediment occurs via chemical reduction and metal precipitation reactions.**

Long term sequestration of COCs in wetland sediment occurs via chemical reduction and metal precipitation reactions. Plant tissue samples collected from the wetland indicate that vegetation does not hyperaccumulate, or bioconcentrate, trace elements from the portal discharge.

The natural wetland vegetation contributes to the overall removal and retention of metals within the wetland by promoting ideal settling conditions across the wetland, attenuating discharge velocities and promoting sedimentation. Particulates, such as iron oxide precipitates, are filtered as water passes through wetland vegetation.

Vegetation root systems also help to stabilize the sediment. This decreases the potential for resuspension of settled particles. Decomposition of the wetland vegetation provides a continuous source of organic matter to the wetland substrate, facilitating reducing conditions and increasing sequestration capacity for COCs within the deeper underlying sediments.

ASSESSMENT, CLASSIFICATION AND REMOTE MONITORING ARRAY INSTALLATION

There are two separate inactive tailings areas at the Bullmoose mine site: the Beta Lake Dam and Skeeter Lake Dam. These dams are currently in the active closure state, as minor improvements to them are underway.

The Beta and Skeeter Lake Dams are earth embankments approximately five to six metres high that provide containment for small tailings areas about 5 and 20 hectares in size, respectively. Limited information was available regarding the embankment construction materials, although it was assumed that the majority of the structures are comprised of waste rock from historical mining activities.

A list of deficiencies and non-conformances that did not meet the Canadian Dam Association standards were noted. As a result, additional studies were completed, including dam break analyses and dam classification, and evaluation of options for autonomous remote monitoring.

InSAR monitoring, in combination with GNSS and piezometer monitoring, was identified as the preferred option. A detailed instrumentation design was developed, and installations were completed in 2022. This allows for ongoing data collection and monitoring.

Overall, the Bullmoose Area mine sites project is a great example of how sustainability and reducing environmental impacts can extend beyond just soil remediation. ■

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