Assessment of Atlin-Ruffner Abandoned Metal Mine, BC, Canada

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Abstract The Atlin-Ruffner Mine (silver-lead-zinc) operated between 1900 and 1981. The BC Ministry of Agriculture and Lands (MAL) identified it as a candidate contaminated site and a modified preliminary site investigation (PSI) was initiated in 2008. A detailed site investigation (DSI) by AECOM in 2009 indicated that in the mill area, infiltration of waters discharging from the adit and tailings facility into the ground and subsequent groundwater flow and discharge to down slope wetlands results in reduced concentrations of the major contaminants of concern (arsenic, cadmium, lead and zinc). Elsewhere on the site, adit discharges, acid rock drainage and metal leaching (ARD/ML) from mine wastes are sources of metals to the environment, but their impact on the natural environment is limited when viewed at a landscape or watershed scale.

Key Words Abandoned mine, contamination, risk assessment

Introduction

The Atlin Ruffner abandoned mine and mill site (the "Site") is located in northwestern British Columbia, approximately 28 km NE of the community of Atlin, BC. The Site occupies 30 crown owned District Lots which collectively cover an area of 5.1 km^2. The mine site was developed following discovery of mineralization within the Crater Creek drainage in 1899. Mining commenced in 1900 and continued intermittently until 1981. During its mining life, a total of 3,535 tonnes of ore were milled at the Site, 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 from a total of 13 different adits.

Waste rock piles in close proximity to the 13 observed adits have ARD/ML potential that reflects the mixture of country rock (primarily coarse-grained granodioritic rock of the Fourth of July batholith: feldspar porphyritic quartz syenite to granite) and material from the mineralized veins and sheers, which may include sphalerite, galena, arsenopyrite, pyrite, pyrrhotite, chalcopyrite, pyargyrite and other minerals. It is estimated that over 33,000 m^3 of waste rock is present on site with potential to release metals or acidity (initially as sulfate) to the surrounding environment, depending on the relative composition of highly mineralized versus granodioritic rock, as well the accessibility of sulfides for oxidation. Waste rock samples exhibited relatively high sulfide sulfur levels (mostly >1% to 2.8%) with little carbonate neutralizing potential.

The British Columbia Ministry of Agriculture and Lands' (MAL) Crown Land Opportunities and Restoration Branch (CLORB) is responsible for the management of high risk Crown contaminated sites in BC. Following a modified preliminary site investigation (PSI) in 2008 (Worley Parsons, 2009), a Risk Ranking Methodology (RRM) workshop conducted by CLORB brought forward two exposure units (EUs) for the Atlin Ruffner mine site, both of which were deemed to merit management actions.

- EU1, identified as the Mill Area including nearby mine workings and tailings facilities, was ranked third in 2008/09 among sites in BC for which a PSI has been completed and was subsequently designated a higher priority site to proceed to a Detailed Site Investigation (DSI).
- EU2 was identified as the "remainder of the site" and was ranked 5th in the 2008/09. The suggested management action was to evaluate opportunities for risk reduction through a supplemental investigation.

Under a contract from MAL, AECOM conducted a DSI of the "Mill Area" and a Supplemental Preliminary Investigation (SPSI) at the "Other Mine Areas" that make up the Atlin-Ruffner mine site (AECOM, 2010). A team of senior scientists with expertise in risk assessment, hydrology and hydrogeology investigated the Atlin-Ruffner mine site to fulfill the requirements of the DSI as defined in the BC Contaminated Sites Regulation (CSR). An important component was the evaluation of potential for and magnitude of contaminant exposures for humans or non-human biota, such

as aquatic life. The 2009 methods and results are described below for the "Mill Area" and "Other Mine Areas".

EU1 Mill Area Detailed Site Investigation Methods

The DSI of EU1 involved completion of the following tasks:

- A groundwater investigation including: drilling and installation of nine monitoring wells, water elevation and permeability measurements and groundwater quality sampling on two dates;
- A soil and tailings investigation including: sampling of surface soil grid outside the mill, surface soil inside the mill, deeper samples collected from boreholes, test pits to determine the depth of tailings in the pond, leachate testing and acid base accounting tests on selected soil/waste rock samples, assessment of the lateral/ vertical extent and volume of contaminated soil and a preliminary geotechnical assessment of the tailings impoundment;
- A surface water and sediment investigation that included: mapping of surface water drainages, measurement of stream flows and surface water quality on three dates and sediment quality sampling; and
- A statistical risk evaluation including preparation of summary statistical tables, completion of the CLORB Risk Ranking Input Sheet and an overall risk evaluation.

EU1 Mill Area Results

The Contaminants of Concern in soil within EU1 that most frequently exceeded the BC CSR Industrial Land Use (IL) standards by the highest margins were arsenic, cadmium, lead and zinc. The total area of soil contamination at the mill site (including the mill building, tailings pond and settling ponds) that exceeds IL standards was estimated to be about 3 hectares with a volume greater than 26,000 m^3. Sediment samples in the tailings and settling ponds near the mill site greatly exceeded CSR typical standards for a number of metals but at a distance of 150 m downslope, only arsenic exceeded standards and there was no defined surface water channel for off site sediment movement. Groundwater samples collected at the mill site exceeded the CSR standards for Freshwater Aquatic Life (FAL) only for cadmium and zinc and met standards 100 m downgradient. Surface water quality in the settling ponds exceeded British Columbia Approved and Working Water Quality Guidelines (BCWQG) for fluoride and numerous total and dissolved metal species. However, within 90 m of the settling ponds surface water dissolved metal concentrations met BCWQG. Most of the surface flow infiltrates to ground in this area.

EU1 Mill Area Risk Evaluation and Conclusions

AECOM concluded that risks to aquatic life from Exposure Unit 1 (EU1) in the Fourth of July watershed, or to wetlands or terrestrial biota in forested areas within the valley bottom area, are very low for two important reasons.

- First, the observed concentrations of potential contaminants of concern (except cadmium and zinc) were below BC CSR numerical groundwater standards for the protection of aquatic life in groundwater samples collected in very close proximity to major contaminant source areas. In addition, the data indicate a substantial decrease in concentrations of cadmium and zinc in groundwater over distances of one hundred meters or less.
- Second, the groundwater transport pathway between the mill site and the major exposure areas of interest (Fourth of July Creek) is largely inoperable. While metal leaching from contaminated soils/sediment to the groundwater table is undoubtedly occurring, the groundwater flow path has an estimated minimum length of >0.5 km prior to day-lighting in wetlands, and Site groundwater would need to travel a minimum of 1.0 km prior to entry into a direct tributary or the mainstem of Fourth of July Creek. The distance along the groundwater flow pathway would appear to be far in excess of that required to attenuate metal/metalloid concentrations to background groundwater concentrations due to reactive processes within soil. The surface flows infiltrate into the ground in several locations along the flow path as a result of the high permeability of glaciofluvial outwash sand and gravel deposits and may provide for sorption/attenuation of dissolved phase metals.

Overall, the results of the DSI suggest no immediate need for shorter term risk management actions to protect aquatic life in Fourth of July Creek, lower areas of tributaries that are ecologically productive, or biota within the riparian zone. Further site characterization and/or modelling work could be considered but this should be tempered by an appreciation that oxidation of sulphide minerals has been occurring at the mill site for nearly half a century, and current site conditions reflect this relatively long period for ARD/ML evolution.

However, direct exposure risks to humans, wildlife, plants or other ecological receptors associated with the very high concentrations of arsenic, cadmium and lead in surfacial soils and tailings at the mill site merits further consideration. These metal concentraions exceed CSR Protocol 11 Upper Cap Concentrations for Wild Lands (Urban Park) and therefore the site would be classified as a High Risk site under the BC CSR. The site is visited quite often in the summer time by campers, hikers and sightseers. In addition, there is evidence that the site is regularly used by wildlife including woodland caribou that were observed to access the tailings pond and settlement ponds.

Managing the toxicological risks associated with arsenic, cadmium, lead or zinc exposures from contaminated soils at the mill site might include one or more of the following:

- Institutional controls such as fencing or other means of limiting site access by receptors in light of the highly contaminated surface soils across virtually the entire mill site;
- Completion of a detailed quantitative human health and/or ecological risk assessment; and/or
- Capping of the contaminated soils with uncontaminated soil to curtail the surface exposure pathway. This option is substantially facilitated by the presence of large quantities of glaciofluvial outwash sand and gravel material in the immediate vicinity of the contaminated soil areas.
- Excavation of hotspot areas would only be feasible in several small areas of black soil where mine concentrate has been spilled and the soil greatly exceeds acceptable standards.

EU2 Other Mine Areas—Supplemental Preliminary Investigations Methods

The SPSI involved completion of the following tasks:

- A soil and waste rock investigation that included: surface soil and waste rock sampling at a number of former mining locations that were not visited in 2008 to better assess the lateral extent and geochemical attributes of the waste materials;
- A surface water and sediment investigation that included: surface water flow measurement and collection of surface water quality samples on three dates and sediment quality sampling; and
- A statistical risk evaluation including preparation of summary statistical tables, completion of the CLORB Risk Ranking Input Sheet and an overall risk evaluation.

EU2 Other Mine Areas Results

The Contaminants of Concern identified in EU2 that most frequently exceeded the IL standards within soil and waste rock were arsenic, cadmium, lead and zinc, similar to EU1.

Sediment samples collected adjacent to adit entrances were contaminated by arsenic, cadmium, lead and zinc. Concentrations of these metals in sediment samples decreased with greater distance from adit entrances, although some remain above BC CSR sediment standards. Background samples show naturally elevated concentrations of arsenic and cadmium. Sediment quality in the Trident Creek, Vulcan Creek and Crater Creek drainages is clearly impacted by historical mining activities, but sediment quality improves with distance away from adits and mine waste deposits.

Surface water discharging from the adits in the Trident Creek drainage basin contains elevated metal and fluoride concentrations that exceed numerous BCWQG and CSR standards. Of particular concern is Adit I which appears to be showing the effects of acid rock drainage and metal leaching processes. However, Trident Creek receiving water is of relatively good quality with only fluoride and cadmium exceeding BCWQG and/or CSR-FAL standards.

Surface water discharging from the adits was not identified or sampled in the Vulcan Creek/Crater Creek drainage basin. Vulcan Creek/Crater Creek receiving waters are of relatively

good quality but might be slightly impacted relative to background quality. Fluoride, arsenic and cadmium exceed BC surface water quality guidelines, largely due to background conditions. Waste rock samples from mine areas in this drainage basin have a lower ARD/ML potential than those in the Trident Creek basin suggesting reduced potential for future water quality deterioration.

EU2 Other Mine Areas Risk Evaluation and Conclusions

The mining areas within EU2 are in the Trident Creek and Crater/Vulcan Creek drainage basins. The surface water and sediment data collected in both 2008 and 2009 demonstrate that:

- mine wastes and surface water discharging from underground workings along with sulfate associated with ARD/ML are a source of metals to the environment; and
- Despite this, the influence of ARD/ML is limited when viewed at a landscape or watershed scale.

There is no evidence of metal/metalloid loading to water or sediment within downstream sections of Crater/Vulcan Creek, Trident Creek, Mill Creek, or Fourth of July Creek in areas where it is important to protect the viability of freshwater biota, including fish. No environmental effects monitoring has been completed but sediment and water quality data suggests that water quality in downstream sections have only been minimally affected by contaminant releases from the Atlin-Ruffner mine site.

The 2009 study concluded that waste rock samples from two areas of potential environmental concern within the Crater/Vulcan Creek catchment tend to have a lower acid generation potential than waste rock samples from surface deposits in the Trident Creek sub-watershed. Thus, the historical mining-related risk to aquatic ecosystems from the Crater/Vulcan Creek drainage (comprising ≈ 16 km^2) are qualitatively assessed as being much lower than for the Trident Creek drainage (≈ 3.6 km^2).

Unlike the situation for arly definable based on well defined surface drainages, which integrate both the localized influences in subwatersheds of ARD/ML and runoff of snowmelt or rainfall in areas removed from mining disturbances. The available surface water quality data beyond the confluence of the high elevation tributaries at the Site indicate that there is little if any potential risk to aquatic life based on current conditions.

Should water quality from areas affected by the Upper Camp and associated three adits deteriorate in the future, there are opportunities to further enhancing the sorption/attenuation of contaminants along the flow path in light of the presence of a large, natural wetland within the bowl of the upper summit. Other possible actions to reduce the flux of metals to the catchment include:

- arresting or impeding active surface water discharges from adits using an engineered plugs;
- consolidation of waste rock by placing it back into the remnant trench from which it originated, accompanied by passive treatment of contaminated water at the lower end of disturbed trenches.

References

AECOM, 2010: Atlin Ruffner Abandoned Mine Detailed Site Investigation (DSI) of Mill Area and Supplemental Preliminary Site Investigation (SPSI) of Other Mine Workings Areas, Prepared for BC Ministry of Agriculture and Lands. February, 103 p.

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