ABSTRACT

The Emerald Glacier Mill and Tailings Site is an abandoned, base metal, ore processing site located on Crown Land approximately 80 km southwest of Houston BC that was prioritized for remedial action by the BC Crown Contaminated Sites Program (CCSP). The investigations, analysis and decisions required for developing an effective, risk based, remedial plan to return the site to a safe, healthy forest environment are described. Field investigations were conducted in a progressive manner to identify and quantify physical and chemical risks to human health and the environment and to develop remedial objectives. Detailed quantitative risk assessment was conducted to identify and prioritize the various exposure pathways that warranted mitigation. Sustainability issues and conflicts with remedial action were identified, such as maintaining intact forest and riparian vegetation along the creek.

A risk based remedial plan was developed to address the following objectives:

i) Prevent physical erosion and off-site migration of the tailings as suspended sediments;
ii) Mitigate or eliminate contaminant exposure pathways that confer a high risk for the Site, including:
   a. Human Health - Remediate/manage site contamination to a state where future traditional or recreational human use will not cause unacceptable health risks, with specific consideration for ingestion of site water and locally harvested game; and
   b. Environmental Protection - Remediate/manage site contamination to a state where residual contaminated soil poses acceptable or tolerable risks to ecological receptors such as mammals, birds, soil invertebrates and plants.

The risk management that involved physical remediation included: a) containment and capping of the tailings; b) capping of the ore processing and mill area; and, c) decommissioning of a small water supply dam on the creek upstream of the tailings facility. Environmental contamination that was not subject to physical remediation, due to lesser and tolerable risk or sustainability conflicts, included metals in groundwater, stream sediments and soil located in high value forest areas.

KEY WORDS: Abandoned Mine, Risk Assessment, Remedial Planning, Crown Land, HHERA

PURPOSE

The purpose of this paper is to present a case history of how the environmental risks from metal contaminants at an abandoned mill and tailings site were investigated, quantified, and prioritized for physical remediation in order to return the land to productive forest and ecological habitat. In some
instances trade-offs and risk tolerance were required for sensitive forest and riparian areas that had metal-contaminated soil above standards that could not be physically remediated without destroying important productive ecological habitat.

BACKGROUND

This project was completed under the BC Crown Contaminated Sites Program (CCSP). The CCSP is part of the LNG, Crown Land Opportunities and Restorations Branch (CLORB) within the Ministry of Forests, Lands and Natural Resource Operations (MFLNR). Within the MFLNR, the CCSP leads the management of contaminated provincial lands to reduce risks to human health and the environment. The CCSP works under a Cabinet approved policy that commits the MFLNR to identify and prioritize contaminated sites that are a provincial responsibility using a science-based and risk assessment approach that draws, in part, from the BC Contaminated Sites Regulation (CSR).

The Emerald Glacier mine and mill site is located in west-central BC on the Sweeny Lake/Morice-Tahtsa Forest Service Road, approximately 80 km southwest of Houston. Huckleberry Mine is located about 5 km further south.

Between 1915 and 1971, lead, zinc, copper, cadmium, silver and gold were intermittently mined from underground works located on an alpine ridge (~1500 m asl) approximately 2.5 km north of the mill site (~1000 m asl). Available information suggests that ore was transported off site for processing until 1966 when on site processing commenced at the Mill and Tailings Site (the Site). Mining and on-site milling ended in 1968. The Mill and Tailings site is located 2.5 km south at an elevation of 1000 m within 100 m of Tahtsa/Sweeny Lake Forest Services Road. During operation, tailings were deposited in a low-lying area contiguous with and within the riparian zone of an unnamed creek that flows to Sweeney Lake. A small upstream dam and reservoir on the creek was used to supply water to the mill (Figure 1).

PHASED ENVIRONMENTAL FIELD INVESTIGATIONS

Environmental investigations are typically completed in a series of phases, particularly when the magnitude and extent of contamination is completely unknown at the outset. A phased approach is most likely to identify the extent and magnitude of the problem without undue effort and expense. In a phased approach, identified contamination is followed up with step-out samples in order to delineate the extent of contamination. Several phases are often required to fully investigate an abandoned site, particularly where little or no documentation of the historical activities that caused the contamination.

Initial Investigations and Site Prioritization for Remediation

CCSP has developed protocols for conducting preliminary site investigations of abandoned contaminated sites on Crown Lands, including historical mines and associated facilities. CCSP has also developed a standard methodology for prioritizing remedial efforts at the highest risk sites.
The initial environmental investigations at the Emerald Glacier Mine Site and Mill and Tailings Site were conducted between 2008 and 2010. This provided CCSP with sufficient data to assess relative risks between other sites on Crown Land in BC and to prioritize further assessment and remediation actions.

The Site is accessible to people due to proximity of the Forest Service Road. The two remaining mine cabins are located a short distance away along the Forest Service Road and are reportedly used by a local snowmobile club. CCSPs risk grading methodology prioritized the Mill and Tailings Site as a high risk site that warranted further investigation and remediation based on high metal concentrations (arsenic, copper, lead, and zinc) and accessibility to people. The Mine Site is located on a high mountain ridge that is much less accessible to people and therefore it was not considered a high priority for remediation.

Specific conditions at the Mill and Tailings Site that caused the high risk designation included the following factors:

- Poor containment and lack of a cover system on the tailings, which are located within 10 m of a creek area (Photographs 1 and 2);
- Visual evidence of tailings erosion into the adjacent creek;
- Highly elevated metal concentrations (arsenic, lead, zinc, copper, cadmium) in mill soils and tailings;
- Elevated concentrations of metals in stream sediments;
- Potential for high creek flows to further erode the tailings;
- A poorly constructed, unmaintained dam for the mill water supply reservoir on the creek located 700 m upstream of the tailings facility that could fail and cause flooding and erosion of tailings. (Photograph 3)
- Dilapidated mill buildings posing a physical risk (Photograph 4);
- Close proximity to an active Forest Service Road and knowledge that the Site is accessed for recreational activities.

Table 1 provides a summary of the environmental investigation and remedial planning stages and how the findings of each investigation led to further investigations to resolve data gaps or to remedial planning decisions.

Figure 2 summarizes the soil and sediment sample metal concentrations relative to applicable Contaminated Sites Regulation (CSR) Standards and shows areas of concern that were eventually remediated by physical capping or were concluded to have acceptable/tolerable risk.
**Photograph 1:**
Tailings Disposal Area with Creek in Forest along Right Side of Photo

**Photograph 2:**
Mill Debris and Ore Bin at Base of Ore Chute

**Photograph 3:**
Mill Reservoir Photo taken from Dam

**Photograph 4:**
Tailing Area with Erosion Channel and Former Wooden Containment Structure. Creek is in Trees within 10 m to right side of Tailings area
<table>
<thead>
<tr>
<th>Stage</th>
<th>Scope</th>
<th>Findings</th>
<th>Decision/Milestone</th>
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<tbody>
<tr>
<td>Modified Preliminary Site Investigation (PSI) 2008</td>
<td>Visual inspection, surface soil/rock, surface water, sediment sampling, elevated total and leachable metal concentrations (As, Cd, Co, Cu, Pb, Ag, Zn) in soil, sediment, tailings; PAG rock present but no surface water ARD effects noted</td>
<td>CCSP determines that Emerald Glacier Mill and Tailings Site is a high priority for a DSI.</td>
<td></td>
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<tr>
<td>Supplemental Site Investigation (Mine Site) and Limited Detailed Site Investigation (DSI) (Mill and Tailings Site), 2009-2010</td>
<td>Drilling, soil sampling with depth, XRD tailings mapping, groundwater and surface water sampling, delineation of tailings and soil chemistry</td>
<td>Mine Site – adequate neutralization potential and minimal surface water impact Mill Site – 2500 m³ of tailings and metal contaminated soil delineated; erosion of tailings into creek; high metal concentrations in tailings and groundwater within tailings; but diluted in underlying gravel and no surface water impact</td>
<td>No further investigation of remote high elevation Mine Site required. Mill and Tailings Area beside Forest Service Road ranked as high priority for further assessment and remediation</td>
</tr>
<tr>
<td>Gap Analysis and Supplementary DSI Investigations, 2011</td>
<td>Topographic mapping; Further delineation of metals in tailings/soil; Sediment quality/benthic community/surface water quality toxicity effects assessment; Seasonal assessment of surface water and groundwater quality; Assessment of reservoir dam and creek hydrology</td>
<td>Tailings area delineated further; As, Cu, Pb, Zn exceed high risk CSR Protocol 11 Upper Cap Standards; Sediment contamination not as widespread as expected but erosion of tailings is occurring; Dam in poor condition but low risk of catastrophic failure; Mill buildings and debris are physical hazard and prevent full sampling of area; Historic camp area metals in soil are minor risk</td>
<td>Need to remove buildings and debris prior to further sampling; Need to contain and cap tailings which are the highest priority; Adequate data for preliminary remedial option evaluation</td>
</tr>
<tr>
<td>Remedial Options Evaluation, 2012</td>
<td>Assessed feasibility, effectiveness and cost for four main options</td>
<td>1. Risk management alone 2. Partial on-site disposal 3. On-site disposal 4. Off Site disposal</td>
<td>Risk management alone inadequate; full off-site disposal neither feasible or affordable</td>
</tr>
<tr>
<td>Phase 1 Remediation (Building Removal) 2012</td>
<td>Removal of mill buildings and debris for further soil assessment</td>
<td>To remove physical hazard and facilitate complete contaminant delineation</td>
<td>BC Bid Tender for building removal</td>
</tr>
<tr>
<td>Stage</td>
<td>Scope</td>
<td>Findings</td>
<td>Decision/Milestone</td>
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<tr>
<td>Supplementary Investigations 2012</td>
<td>Topographic mapping; Borrow pit investigations; Geotechnical assessment of tailings berm and water supply reservoir dam; Step-out soil contamination delineation; Paired vegetation/ soil sampling; physiologically based extraction testing of soils; Riparian area habitat assessment; Tailings Acid-Base accounting and leachable metals testing, Groundwater quality</td>
<td>Identified potential borrow pit area and geotechnical requirements for tailing berm and dam decommissioning; Geochemical considerations for tailings capping; Potential need to cap ore stockpile area; Habitat assessments confirmed dense forest and riparian areas</td>
<td>Adequate information to proceed with HHRA and Risk-based Remedial Plan</td>
</tr>
<tr>
<td>Preliminary Detailed Human Health and Ecological Risk Assessment (HHERA) Winter 2013</td>
<td>Quantification of risks for the tailings facility, mill area, ore chute, ore stockpile areas, and adjacent forest and riparian areas. Test efficacy of preferred remedial option relative to site protection goals.</td>
<td>Preliminary results of the HHERA, based on the preliminary conceptual design of the preferred remedial option predicted unacceptable residual risks for both human and ecological receptors in the mill area, tailings area, ore chute and ore stockpile area.</td>
<td>Areas of highly contaminated soil in the mill area, tailings area, ore chute and ore storage area require further consideration in the proposed remedial option. No need or benefit to physical remediation of creek bed or riparian areas or adjacent heavily forested areas that are functioning adequately</td>
</tr>
<tr>
<td>Remedial Options Evaluation Update Winter 2013</td>
<td>Revised most favourable remedial options with updated environmental information and HHERA results. Cost estimate for budget purposes</td>
<td>1m cap and berm and drainage required for the tailings, mill area; 1m cap required for ore storage, ore chute and portion of mill area. New spillway required to lower reservoir water level by 1 m;</td>
<td>Decision to proceed with conceptual remedial design and issue RFP for detailed design build contract.</td>
</tr>
<tr>
<td>Stage</td>
<td>Scope</td>
<td>Findings</td>
<td>Decision/Milestone</td>
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| Final Detailed Human Health and Ecological Risk Assessment (HHERA) Winter 2013 | Quantify residual risks to human end ecological receptors following revision of the preferred remedial option based on preliminary HHERA results. | **Human Health Risks**  
- Negligible risks due to exposure to threshold contaminants through ingestion, inhalation, or dermal contact with residual contaminated soils, consumption of locally sourced drinking water and locally sourced game.  
- Potential increased incremental lifetime cancer risk (ILCR) as a result of ingestion of grouse tissue collected from the site. The exposure assessment carries significant uncertainties associated with a literature-sourced arsenic transfer factor and may overestimate the dose/risk for this exposure pathway.  
**Ecological Receptors**  
Wildlife:  
- Low risk of impacts to small wildlife receptors with small home ranges (e.g. rodents or birds).  
- Negligible risks to secondary wildlife consumers (e.g. red fox) in spite of conservative assumptions.  
- Negligible risks to wildlife populations and individual species under post remedial scenario.  
Vegetation:  
- Localized risks to plants in some areas of residual contamination. Risks are unlikely to result in population impacts for valued ecological receptors or major ecological impairment. | Proposed remedial activities are predicted to be:  
- Sufficiently protective of human health, when considering uncertainties and conservatism inherent in the assessment.  
- Protective of ecological receptors are a scale relevant to ecological protection at the population level. |
**INITIAL REMEDIAL PLAN**

**Remedial Objectives**
In 2012 the CCSP initiated remediation of the Site with the following objectives:

i) Prevent physical erosion and off-site migration of the tailings as suspended sediments;

ii) Mitigate or eliminate contaminant exposure pathways that confer a high risk for the Site, including:
   a. Human Health - Remediate/manage site contamination to a state where future traditional or recreational human use will not cause unacceptable health risks, with specific consideration for ingestion of site water and locally harvested game; and
   b. Environmental Protection - Remediate/manage site contamination to a state where residual contaminated soil poses acceptable or tolerable risks to ecological receptors such as mammals, birds, soil invertebrates and plants

**Environmental Standards**
The BC Contaminated Sites Regulation (CSR) scheduled standards were applied for this project. Wildland land use was applied. Soil samples were compared to BC CSR Schedule 4 and 5 soil standards for (1) human contact, (2) toxicity to soil invertebrates and plants, and (3) livestock ingestion soil & fodder and 4) freshwater aquatic life. Sediment samples were compared to the Schedule 9 sensitive criteria. Surface water quality results were compared to the BC Approved and Working Ambient Water Quality Criteria. The applicable CSR Protocol 11 Upper Cap Concentrations were used to delineate higher risk areas within in the various sampling media.
Groundwater was compared to the Schedule 6 aquatic life standards. There are no water wells within many kilometers of the Site. CCSP added a notation to the Crown Lands management system that prevents any future use of groundwater or surface water for drinking water. Therefore the groundwater and surface water quality data were not compared to drinking water standards.

**Preliminary Remedial Options Evaluation**

Conceptual remedial options were evaluated and order of magnitude cost estimates were prepared for each Area of Environmental Concern (AEC). To simplify the cost estimates assessment, four overall project remediation scenarios were considered. These four scenarios cover the full range of potential costs and are considered appropriately representative of the four broad remedial approaches that could be taken: (1) risk management alone; (2) partial on-site capping (reduction of risk) with risk management; (3) extensive on-site capping (reduction of risk) with risk management; and (4) remediation to numerical standards with complete excavation and off-site disposal.

The preferred remediation scenario was Scenario 2 partial on-site disposal. This scenario actively remediates the highest risk contamination (erosion and direct exposure to tailings and soil with metal contamination above the CSR Upper Cap Standards) but uses a risk management approach to deal with lower risk aspects of the site.

It was determined that Scenario 1 Risk Management was not adequate to meet CCSP’s objectives or regulatory requirements. Similarly, Scenario 4 Off-site Disposal was not a viable rehabilitation technique for an abandoned mine and the potential costs were not justifiable.

**HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT (HHERA)**

A quantitative HHERA was conducted in accordance with Health Canada, Environment Canada, and BC Ministry of Environment Guidance documents based on inferred site conditions following the implementation of the preferred remedial option described above. The purpose of the HHERA was to predict residual risks to human health and ecological health, based on the remedial options put forward, and to refine the remedial options if the risk assessment identified unacceptable residual risks.

Based on the site investigations it was apparent that physical remediation was immediately required in some areas to reduce/eliminate certain risks posed by the Site, and that other areas were likely more suitable for managing the existing tolerable risks due to a variety of factors including:

1. potential conflicts between physical remediation and ecological impact,
2. evidence of limited environmental effects,
3. low probability of exposure to sensitive receptors or valued ecosystem components, and;
4. ecological risks in disagreement with the site protection goals.

Human receptors included in the quantitative risk assessment were assumed to be adults and toddlers engaged in traditional land use activities which may include hunting and gathering activities and summertime encampment and harvesting. People engaged in traditional land uses are expected to have
the greatest potential magnitude of exposure based on duration of visit and activities they are involved in. By developing risk-based remedial strategies that protect a traditional lifestyle, other types of site use (e.g. hiking and non-hunting/camping short-term recreational visits) would be predicted to experience negligible risks.

Valued ecological components were identified based on a review of the federal and provincial conservation lists, species indigenous to the biogeoclimatic zone, site observations by AECOM biologists, habitat scale, and economic or cultural significance. For example, the wolverine (a provincially listed species) was not assessed based on their large habitat range relative to the very small footprint of terrestrial contamination; these conditions would result in a low exposure and ecological risk that may misrepresent more highly exposed species with smaller roaming ranges. Ecological receptors included in the HHERA were spruce grouse, red squirrel, red fox, western toad, and terrestrial vegetation.

For the purposes of the HHERA, the site was subdivided into two areas of environmental concern based on differences in expected site usage by human and terrestrial ecological receptors, and the physical characteristics of the site.

- **AEC 1** - The lower site comprised of the mill pad, the tailings area, and the surrounding forest representing ~90% of the Site footprint contains contaminated soils, ground water and sediment associated with post milled materials and tailings.
- **AEC 2** - The ore stockpile area is isolated from the remainder of the site by a steep forested slope, accounts for only 10% of footprint, is poorly vegetated and is dominated by large fragments of unprocessed rock and rock dust.

These areas were assessed as contiguous units, and total risks were adjusted for the relative proportion of the site comprised by each area.

Contaminant exposure point concentrations were based on the 95% upper confidence limit of the mean (95UCLM) where data allowed, otherwise the maximum concentration measured in a given medium was used. For dietary intake of plant or animal tissue, tissue concentrations were modelled using literature derived bioaccumulation factors. Exposure as a result of ingestion of contaminated soil was adjusted for the relative bioaccessibility based on Physiologically Based Extraction Testing (PBET) results. PBET approximates the amount of contaminant actually absorbed via the digestive tract.

Risks to human and ecological receptors were calculated based on toxicity reference values (TRV) sourced from either the US EPA or Health Canada (in accordance with BC MoE Technical Guidance 7). For human receptors, risks posed by non-carcinogenic contaminants were assessed by calculating a hazard quotient (HQ, also known as exposure ratio) using published tolerable daily intake (TDI) values. Risks posed by carcinogenic contaminants were estimated by calculating an incremental lifetime cancer risk (ILCR) for adult receptors only. Ecological receptors were assessed relative to non-threshold TRVs protective of effects to reproduction, growth and long term survival.
Risks to human receptors were deemed negligible if HQs were calculated to be below a value of 1 and ILCRs were below a value of $1.0 \times 10^{-5}$. Interpretation of the hazard quotients for ecological receptors was guided by the categorical descriptions provided below, which were defined to provide additional perspective for CCSP in relation to management of its site portfolio. It is important to note that the magnitude of the HQ exceedances is not linear, and after accounting for the ameliorating effects of conservative assumptions, HQs in the upper range of magnitude are essentially the same and indicate high potential for impacts.

- **Negligible Risk of Impact (HQ < 1):** Given the feasible exposure pathway, residual exposure is acceptable for the future, and may or may not warrant continued management and periodic monitoring;
- **Low Risk of Impact ($1 \leq HQ < 10$):** Based on exceedances of no adverse effect levels and conservative assumptions, a low level of stressor effect(s) to long-term survival, growth, or reproduction of certain species may be present; if not mitigated, a decision to accept and manage of this sustained level of effect should be scrutinized and monitored;
- **Moderate Risk of Impact ($10 \leq HQ < 20$):** Based on higher exceedances of no adverse effect levels, stressor effects towards the assessment endpoint are likely present and should either be resolved through a refined analysis, mitigated through risk management options, or the potential adverse consequences recognized and accepted;
- **High Risk of Impact (HQ $\geq 20$):** High exceedances of no adverse effect levels underscore the need and priority to resolve the situation through a combination of refined analyses and/or mitigation of the causal risk factors.

**RISK-BASED REMEDIAL PLAN**

Remedial planning was conducted in conjunction with the HHERA in an iterative manner. Preliminary results of the HHERA, based on the initial remedial plan provided to the risk assessors, identified residual contamination posing appreciable risks to human and ecological health in the mill area, tailings area, ore chute and ore stockpile area. These preliminary results were used to modify and update the scope of physical remedial works to reduce risks to acceptable levels in these areas. After several iterations an acceptable Risk-Based Remedial Plan was developed.

The original preferred remedial option, Scenario 2 partial capping of contaminated areas, was modified based on the HHERA and discussions with the client. The preferred option was expanded to include capping of additional areas including the ore stockpile area, which was closer to Scenario 3, complete onsite disposal. A revised Risk-Based Remedial Plan was developed that:

- addressed the risks that were quantified in the HHERA;
- confirmed that the proposed remediation scenario was preferable to other options;
- updated the remediation areas, volumes and cost estimates;
- identified regulatory requirements for the remediation;
- included a post-remedial monitoring plan to evaluate the effectiveness of remediation;
- provided the basis for issuing a request for proposals for a design/build remediation contact.
The final Risk-based Remedial Plan is summarized below for the various areas of concern at the Site.

**Tailings Area**
Tailings represented the greatest potential exposure media for human and ecological receptors and appreciable risks were predicted. The tailings also were a physical risk to adjacent creek. The Risk-Based Remedial Plan recommended that the Tailings Area be subject to *in situ* capping similar to what was originally proposed but the cap extents were better defined due to the additional delineation, topographic mapping and borrow material investigations. The Risk-Based Remedial Plan recommended the following components.

- Construction of a containment berm around the NE and SE sides of the tailings deposits, capping of the tailings in place with locally available fine-grained till, construction of a containment berm and construction of appropriate drainage diversion ditches and sediment ponds.
- Minor excavation (0.3 m deep scrapes) of thin layers of tailings along the former tailings trough, eroded tailings between tailings facility and Unnamed Creek and eroded tailings along the Site access road.
- Risk management of tailings in high value forest or riparian areas that cannot be sustainably excavated.
- Revegetation of all excavated and capped areas.

**Ore Stockpile/ Ore Chute Slope/ Mill Pad**
Appreciable risks to human and ecological receptors predicted for ore stockpile, ore chute and a portion of the Mill pad areas. The Risk-based Remedial Plan recommended that remediation of this area include the following components.

- Off-site disposal of metal debris from Phase 1 demolition activities.
- The Ore Stockpile area and surrounding non-forested area will be capped with 1.0 m of fine-grained till.
- The steep Ore Chute slope will no longer be risk managed (due to high metal concentrations and potential for erosion). The upper slope of the Ore Chute is to be excavated to 0.5 m depth. Excavated material will be consolidated on top of the lower portion of the Ore Chute and NW portion of the Mill Pad.
- The NW portion of the Mill Pad and the entire ore chute will then be capped with 1.0 m of compacted fine-grained till.
- Drainage, erosion control and re-vegetation measures will be undertaken.

**Historical Camp**
The historic camp was predicted to pose negligible risk to human and ecological receptors of concern in the context of the overall site protection goals.
Adjacent Forested and Riparian Areas
Physical remediation involving excavation and 1 m till cap is unlikely to provide ecological benefit in a healthy forested environment. The probability of ecological effects outside the immediate area of contamination is considered negligible. Small areas of contaminated soil remaining in healthy and productive forested areas were therefore left in place.

Creek Sediments
Initial sediment testing and evidence of tailings erosion into the creek suggested the potential need for creek sediment remediation. A more comprehensive assessment based on the sediment quality triad approach (sediment chemistry, benthic community analysis, and laboratory toxicity testing) indicated minimal impacts from existing metal concentrations in creek sediment. Therefore, the Risk-Based Remedial Plan recommended no a physical remediation involving excavation or capping that would remove or damage mature riparian vegetation.

Surface Water
Surface water ingestion by humans from the creek was included for human and wildlife receptors in the HHERA. Risks to human receptors were determined to be negligible. Surface water ingestion for wildlife receptors represents less than 1% of total dose. Environmental effects assessment indicates effects are unlikely to the aquatic environment. The Risk-Based Remedial Plan recommended that surface water quality be risk managed by monitoring surface water quality in the post remediation period. A notation on the Crown Land management system was recommended to prohibit any future drinking water intakes on the creek near the Site.

Groundwater
Groundwater quality in the tailings has elevated metal concentrations. Metal concentrations are much less in groundwater from the sand and gravel below the tailing and the pH is within a neutral range. Groundwater from the tailings area discharges to the nearby creek but metal concentrations in the creek are near background levels. The Risk-Based Remedial Plan recommended that groundwater contamination be risk managed by monitoring groundwater quality in the post remediation period. A notation on the Crown Land management system was recommended to prohibit development of drinking water wells near the Site.

Water Supply Reservoir and Dam
The geotechnical inspection of the reservoir dam suggested that the failure risks presented by the dam condition required some degree of physical remedial action. Therefore, the Risk-based Remedial Plan recommended that the reservoir dam be decommissioned by lowering the water level 1 m by excavating and removing the decaying spillway and re-establishing the “natural” stream channel bypass.

Borrow Areas
A potential borrow area for clay or silt-rich glacial till was identified on the forestry cut block located less than 1 km east of the Site. CCSP was responsible for obtaining authorization. The contractor was required to confirm the volume of glacial till required, clear and grub the area and provide proper
drainage and environmental controls, excavate the required volumes of fill material and rehabilitation the borrow area.

**SUMMARY**

The development of a Risk-based Remedial Plan for an abandoned mill and tailings site required an iterative investigation and remedial planning approach over a number of years that included:

- A sequence of phased environmental and engineering investigations to: identify physical and chemical risks; assess potential land use and habitat values; and delineate contamination in various areas and media
- Identification of remedial goals and applicable environmental quality standards;
- A human health and ecological risk assessment (HHERA) to quantify contaminant risks and need for remediation;
- An iterative remedial planning approach that includes an interdisciplinary review of the remedial plan’s effectiveness in achieving project objectives.

**REFERENCES**


