BRITANNIA MINE CLOSURE PLAN

Gerry O'Hara, M.Phil.P.Eng.

Golder Associates Ltd.
500 – 4260 Still Creek Drive
Burnaby, B.C. V5C 6C6

ABSTRACT

The BC Ministry of Sustainable Resource Management (BCMSRM), is undertaking a program of environmental remediation at the Britannia Mine site, located 45km north of Vancouver, BC. The Britannia Mine operated for around 70 years and produced mainly copper and zinc concentrates. During its operating life, and since its closure in 1974, the mine has discharged large volumes of acidic water, elevated in metals toxic to aquatic life, including copper, zinc and cadmium. Metal loadings to Howe Sound are estimated at an average of around 300kg/day each of copper and zinc. Using funding derived from the former mine owners and operators, the BCMSRM (the Province) developed a remedial concept based around using the mine workings as a storage reservoir to balance seasonal flows to a water treatment plant prior to discharge to Howe Sound. In addition to the acid rock drainage (ARD) from the mine, various mine infrastructure and mineral processing activities across the extensive mine site have resulted in the presence of many secondary sources of metal contamination of soils, groundwater and surface water. To date (July, 2003), the major investigation phase of the project has been completed and remedial planning and implementation commenced in early-2003.

INTRODUCTION

The Britannia Mine is located at Britannia Beach on the east shore of Howe Sound, approximately 45 km north of Vancouver (Fig.1). The main mining activity was some 5 to 7 km inland from Britannia Beach, with mineral processing activities taking place at Mount Sheer, around 5km inland, and the Britannia Beach town area on the coast, to the south of Britannia Creek. The mine site covers an extensive area, with mineral tenure associated with the mine extending over some 36.5 sq. km. (9,000 acres).

Topography

Elevation markers at the mine ascend with decreasing elevation above sea level. The zero level datum used by the mine is 1,310 metres (4,300 ft) above sea level, representing the elevation of the initial surface mineralized outcrop and shallow workings in the open pit mining complex located at the top of

Britannia Ridge. In this configuration, zero feet above sea level corresponds to the '4300 (ft) Level', with the '2200 Level' being around half way down the hillside in the mine's nomenclature. The ore body at the mine is contained within Britannia Ridge, which is flanked to the north by the Britannia Creek valley and to the south by the Furry Creek valley. The Ridge drops sharply to the west into the Howe Sound fjord with only a small level alluvial fan area ('Fan Area') proximal to the mouth of Britannia Creek, traversed by Highway 99 and a BC Rail track.

Mine Geology

The Britannia Mine is located in the coast crystalline tectonic belt. The geology of this area can be divided into two major components: older volcanic and sedimentary rocks belonging to the Lower Cretaceous Gambier Group and younger plutonic rocks of the Coast Plutonic Complex. A major feature of the mine is a broad zone of complex shear deformation and metamorphism known as the Britannia Shear Zone dipping steeply south and striking north westerly, which hosts the massive sulphide orebodies within the Gambier Group. The mineralogy of the sulphide orebodies is dominated by pyrite with lesser amounts of chalcopyrite and sphalerite (Ref. 1).

Mine History

The Britannia Mine was operated from 1905 to 1963 by the Britannia Mining and Smelting Company Ltd. and from 1963 to 1974 by the Anaconda Mining Company. A total of some 48 million tones of ore was extracted during the life of the mine (Ref. 2). The mine was closed in 1974 and since that time has remained largely derelict. A concrete plug was installed in the lowest major entry to the mine (400 metres into the 4100 Level adit) in 1978. The 4100 Level (Fig. 2) exits immediately to the east of the concentrate mill (Fig. 3). Seven ore bodies were mined through a combination of open pit, gloryhole and underground developments. The main access points to the mine were through portals at the 2200 Level, 2700 Level, 4100 Level and the Victoria shaft. The mine generated its own hydro-electric power from water impounded in a series of dams constructed along the Britannia Creek watershed (Ref. 3).

Since the mine ceased operations, surface water continues to enter the mine workings through the open pits and glory holes in the Jane Basin area. Drainage is routed through the underground workings, eventually discharging at the 4100 Level. Drainage from this Level is currently directed via a raise to a sub-level (local to the 4100 Level portal), at the 4150 Level, to a discharge pipe into Howe Sound at a depth of approximately 26 m below sea level.

Regulatory Background

The mine is currently out of compliance with both Provincial (Waste Management Act and the Contaminated Sites Regulation) and Federal (Fisheries Act) legislation. The Provincial regulator, the BC Ministry of Water, Land and Air Protection (BCMWLAP) is responsible for ensuring that the remediation activities undertaken at the mine bring the mine into compliance with the requirements of the BC Contaminated Sites Regulation. Environment Canada and the Department of Fisheries and Oceans (DFO) are responsible for ensuring that Federal requirements are met by the remedial actions at the site.

Remediation Funding and Project Structure

In 2001, the Province (then as BCMWLAP) secured a fund of (Cdn.) $30 million from the former mine owners and operators in exchange for indemnity against further environmental liability associated with the mine. Studies have indicated that the net present value of the remediation works required at Britannia exceed these funds, due primarily to the operation and maintenance costs associated with a water treatment plant needed to treat the acid rock drainage (ARD) emanating from the mine workings in perpetuity. The shortfall in funding is being sought by a combination of government funding provision, pursuit of other potentially responsible parties and environmental levies and/or payment in kind from landowners and/or future developers of the mine property.

Once the Province had secured the initial $30 million of funding in mid-2001, they appointed Golder Associates Ltd. (Golder) as overall Project Manager for the Britannia Mine Remediation Project. Four technical consultants were subsequently appointed to evaluate four major technical areas associated with the Province's remedial concept. These consultants are: SRK (Mining and Hydrogeology), URS (Contaminated Sites), AMEC (Water Treatment) and WMC (Flood Risk Assessment). Each were tasked with addressing a specific scope of work, which fed into the water treatment plant feasibility study (Fig. 4).

ENVIRONMENTAL ISSUES

Acid Rock Drainage

The mine water discharge is harmful to aquatic environment, having a pH of around 3.5, with elevated concentrations of dissolved copper, zinc and cadmium,. Following mine closure, the majority of this water discharged from the 4100 Level (to Howe Sound) and the 2200 Level (to Britannia Creek), (Fig 5). Around 5 million cubic metres of water typically drains through the mine annually (Ref. 5). Typical concentrations of these metals in the 4100 Level discharge water are 30mg/L copper, 25mg/L zinc and

0.1mg/L cadmium, though concentrations fluctuate with rate of water flow through the mine. SRK have estimated that of an average of almost 300 kg/day each of copper and zinc discharge to Howe Sound via the outfall pipe from the 4100 level (Fig 6), (Ref.s 4, 5, 8, 9, 10).

Contaminated Sites

The second environmental issue at the mine site is the presence of large quantities of metal rich ore, waste rock, concentrate and other mining and process wastes located around the mine property. The largest accumulation of these materials (with the exception of Jane Basin) is in the southern portion of the Britannia Beach area, referred to as the Fan Area (Fig.3). Other areas of note are the 2200 Level, 2700 Level and Victoria camp areas, the latter being adjacent to Furry Creek (Ref.s . 9, 10, 11, 12, 13, 14).

Offshore

Offshore of the site in the deeper waters of Howe Sound, some 40 million tonnes of mine process waste ('tailings') were deposited during the operational life of the mine. Environment Canada are undertaking a program to evaluate the nature and distribution of these tailing deposits to establish whether remediation is required. The Province's remediation project does not currently include addressing these materials.

REMEDIATION PROJECT

Mine Closure Concept

ARD discharging from the 4100 Level of the mine represents around 95% of the metal contaminant loading to Howe Sound from the mine and was therefore identified as a priority for remediation. The secondary environmental issue is that of groundwater and soil contamination from the former mineral processing operations and associated mine infrastructure, in particular on the Britannia Creek alluvial fan bordering Howe Sound. Fig. 7 illustrates the remedial concept developed by the Province for the mine.

One of the first issues to be assessed by the project was that of whether rainfall infiltration could be prevented from entering the mine workings. It was identified that the majority of infiltration occurred in and around the Jane Basin area, however, prevention of inflows in this area is very problematic due to the extensive area of open pit and glory hole mining, which has resulted in large areas of talus slopes and fractured bedrock over the area of infiltration.

The second issue to be addressed as a priority for the project was to ensure that the majority of the ARD reported to a single discharge point (at the 4100 Level). This entailed re-directing mine water discharging from the 2200 Level portal back into the mine. This was achieved in late-2001 by the installation of a concrete plug in the 2200 Level adit by a combined effort of the University of British Columbia (UBC) and the mine landowner (Britannia Mines and Reclamation Corp., formerly Copper Beach Estates Ltd.).

The volume of the ARD discharge from the mine varies seasonally (Ref. 5), peaking in the early summer due to snow melt (freshet) and then again in late fall. To mitigate this seasonal variation in the mine discharge rate (up to an order of magnitude, typically ranging from 40 to 400 L/sec), it was suggested that the mine could potentially be utilized as a storage reservoir, regulating the flows to the water treatment plant. This required the establishment of an elevation versus volume relationship for the part of the mine to be used for storage, together with the evaluation of a number of technical and safety concerns associated with this concept. These included the integrity of the 25 year old concrete plug located in the 4100 Level adit, stability issues associated with other mine entries and the general water-tightness of the mine host rock under elevated pressures resulting from water storage in the mine workings. In addition, storing water in the mine by flooding sections of previously un-wetted mine workings was identified as having the potential to affect the chemistry of the stored water prior to discharge. These issues needed careful investigation, including a full-scale flooding trial run (Ref. 5, 8, 23, 24).

Earlier work on water treatment technologies appropriate to ARD were evaluated by the Province and others prior to commencing the current project. The conventional approach to ARD water treatment has been selected: that of a high density sludge technology (HDS), developed in the mid-1970's. This technology comprises adding lime to the ARD influent water, which precipitates dissolved metals by pH adjustment. The water is then clarified and the supernatant is discharged as treated effluent and the denser sludge is partly recycled into the influent water in order to promote crystal growth and increased efficiency of the clarification process. Surplus sludge, a stable metal hydroxide at 25% to 40% solids, is wasted and must be disposed appropriately (Ref.s 6, 7).

The second major component of the mine closure plan is to address the various contaminated sites issues. A risk-based approach to investigation and remediation under the BC Waste Management Act Contaminated Sites Regulation was adopted by URS (Ref.s 10, 11, 12, 13, 14, 16, 17, 18). Use of a risk based approach requires a thorough understanding of base line environmental conditions and effective monitoring of changes resulting from remedial measures (Ref. 4).

Remedial Components

The following sub-sections provide a brief summary of the scope of work of each major technical consultant engaged by the Province and some of the more significant findings. The referenced reports on the Province's website (www.britanniamine.ca) should be consulted for more information (Ref.s 3 to 27).

Mining and Hydrogeology

The mining and hydrogeology study, undertaken by SRK, included a mine safety and rehabilitation assessment (Ref. 21), various geological, hydrogeological and hydrological studies (Ref.s 5, 8, 21, 22), a stability assessment of the concrete plug in the 4100 Level adit (Ref. 23) that would act as the primary flow regulation device to the water treatment plant, and tests to ascertain the elevation-volume relationship of the mine (Ref. 24), as well as changes in ARD chemistry resulting from water storage in the mine (Ref. 8).

The plug was found to be in very good condition, as was the contact with the host rock surrounding the plug. SRK subsequently undertook a test filling of the mine by closing valves at the plug and observing the rate of filling. The mine reservoir was filled to approximately 250 metres head above the 4100 Level plug, allowing a safety freeboard to the next highest mine entry (at the 3250 Level). The available dynamic storage volume in the mine was ascertained to be approximately 450,000 cubic meters. The chemistry of the mine discharge water altered due to storage, with copper peaking at over 60mg/L. From this work, SRK developed a mine reservoir inflow model that simulated mine discharge data for the 24 years (1977 to 2001) for which data was available. This model was adapted by Golder to simulate reservoir operation and develop a number of simple operating rules related to prevailing water level in the mine, rate of inflow and depth of the spring snow pack in Jane Basin.

An additional area of study addressed by SRK and others, was the stability of a large rock mass located to the west of Jane Basin. Concern was expressed as to the effect of a failure of this rock mass and the consequent impact to underlying areas of Jane Basin and the Britannia Creek valley. The studies confirmed that this large block has potential for instability, however, two much smaller sub-blocks were identified as being more susceptible to failure (Ref. 22, 26).

Water Treatment Plant Feasibility

A 'best estimate' of plant inflows and chemistry was made by SRK based on desktop studies, review/analysis of historical mine records and the available plug test records. This information was fixed into the design basis by July, 2002, before the mine flooding tests were completed. The subsequent reservoir simulation modelling confirmed that a treatment plant capacity of 1,050m3/hr and a hydraulic capacity of 1,400m3/hr was appropriate. The feasibility study plant size would be capable of treating in excess of 96% of the mine water discharge observed during the 24 years of outflow data used in the mine reservoir simulation modelling.

AMEC completed the feasibility study for an HDS plant in late-2002 (Refs 6 and 7). Apart from the conceptual plant design itself, this included assessment of ancillary systems such as access roads, water feed lines, sludge disposal and the offshore outfall. The primary plant components will comprise a lime slaking plant, two main reactor vessels and a nominal 33m diameter clarifier.

Contaminated Sites

Initial investigations of the Fan Area commenced in February 2001 (Ref. 9), and included the installation of a number of boreholes and monitoring wells. Testing and sampling of soil and groundwater confirmed that the southern portion of the Fan Area is largely comprised of metal-contaminated soil, waste rock, mine tailings and concentrate materials deposited over natural alluvium and these materials have contaminated groundwater flowing through them. This groundwater enters Howe Sound through sediments in the inter-tidal zone and is of particular environmental significance as this zone is important aquatic biota habitat. Groundwater flux calculations, combined with sample analysis undertaken by URS (Ref. 10), indicated that up to 10 kg/day of copper and 16 kg/day of zinc are entering the surficial waters of Howe Sound via this pathway (Fig. 6).

The detailed site investigation by URS comprised a grid of shallow soil samples taken from across the Fan Area, drilled boreholes and excavated test pits (Ref.s 10, 11). In order to obtain a better appreciation of the flux component for calculation of contaminant loading to Howe Sound, two short-term groundwater pumping tests were undertaken. Aquifer parameters were derived and used as input into a MODFLOW groundwater model. Additional Areas of the site (areas outside the Britannia Creek Fan Area) were also investigated by URS using the same risk-based approach and investigation techniques as for the Fan Area (Ref. 13, 17). These investigations identify the most significant contributions to contaminant loading to Britannia Creek and Furry Creek were from the 2200 Level area and Victoria

Camp area respectively. Contaminant loadings to Howe Sound derived from the Additional Areas was estimated by URS at 4kg/day of copper and 5 kg/day of zinc (Fig. 6).

Using the information gained during the detailed site investigations, URS developed remediation planning documents for both the Fan Area and the Additional Areas (Ref. 12, 14).

Flood Risk Assessment

Water Management Consultants (WMC) were engaged to undertake a flood risk assessment for Britannia Creek (Ref. 3), a water course noted for significant flood and debris torrent events. This study was required to select the site for the water treatment plant, as the relatively flat and conveniently located (though flood-prone) Fan Area was the location of three potential sites for this plant. The Fan Area is also the potential location of other remedial works and associated infrastructure, such as engineered caps, groundwater pumps, surface drainage systems and their associated infrastructure. The WMC study included the development and preliminary evaluation of mitigating measures to minimize the effects of floods and debris torrents in Britannia Creek.

SCHEDULE

The major investigation phase of the remediation project was completed in late-2002 with evaluation of the results and the development of remediation plans taking place in early-2003.

The water treatment plant feasibility study for HDS technology was completed in late-2002 and, depending on the selected plant delivery method, a plant could be operational by late-2004.

Implementation of the first stage of the contaminated sites remediation (Fan Area) commenced in June, 2003 and will proceed through the remainder of the year. Once the evaluation of groundwater capture in the Fan Area has been completed, remedial planning for this area of the Site will be finalized with either a long-term groundwater capture system being designed and implemented and/or the implementation of other remedial actions such as capping, soil management and additional surface water drainage improvements. Remedial actions in the Additional Areas are scheduled to commence in 2004.

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Figure 1. Site Location

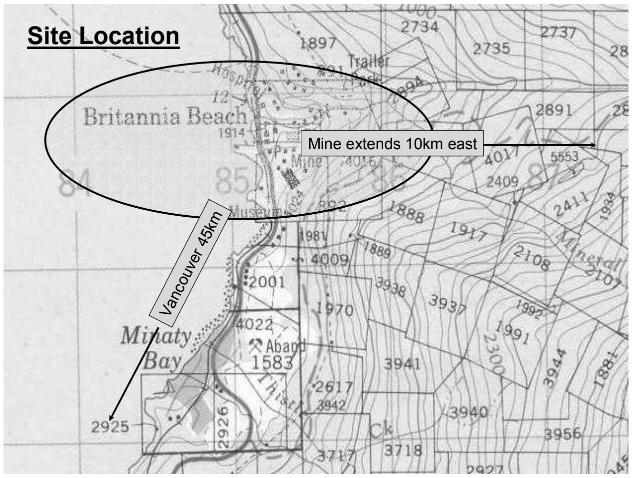

Figure 2. Cutaway View of Britannia Mine (SRK)

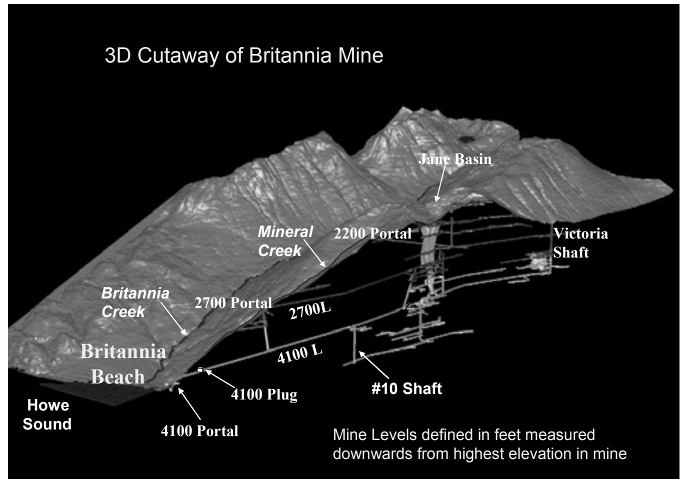

Figure 3. The southern Fan Area

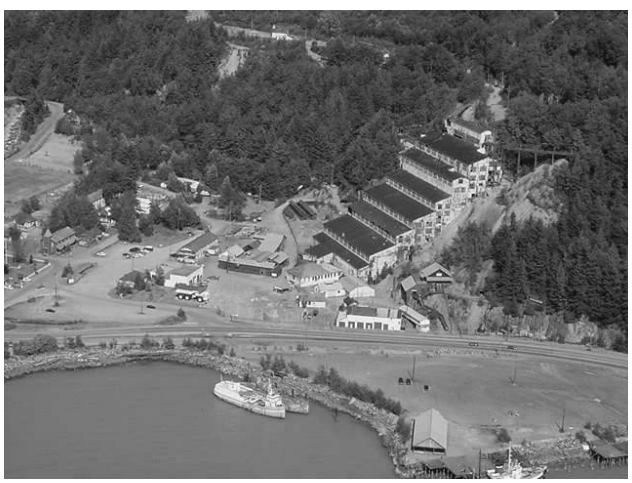

Figure 4 – Project Structure

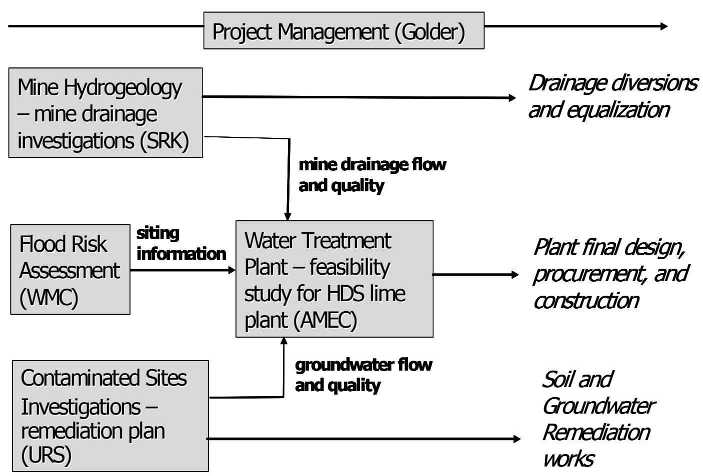

Figure 5 – Schematic Illustrating Post-Mining Conditions

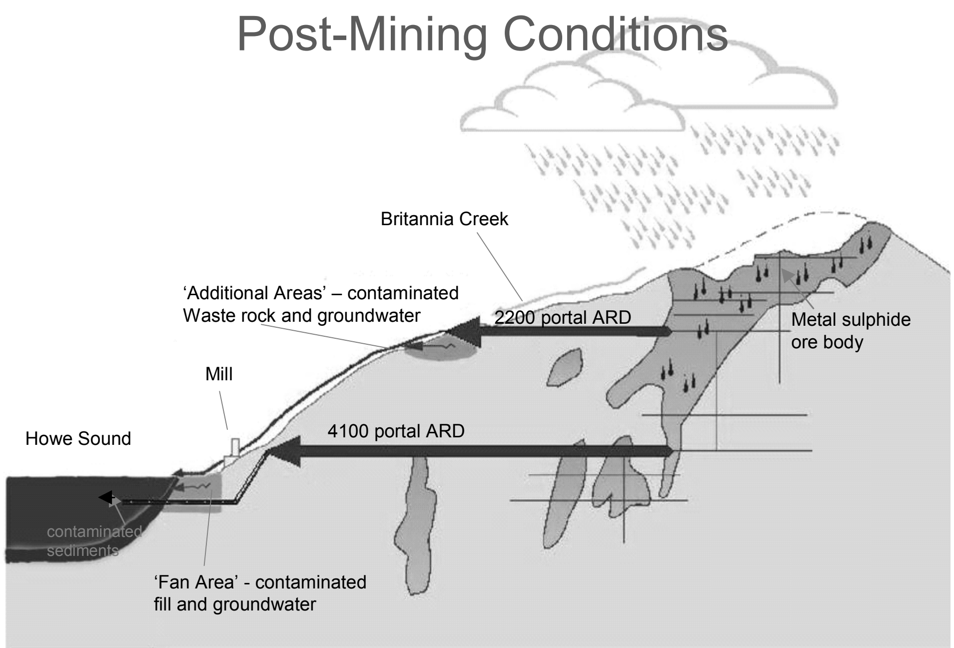

Figure 6 – Contaminant Loading Estimates (SRK and URS)

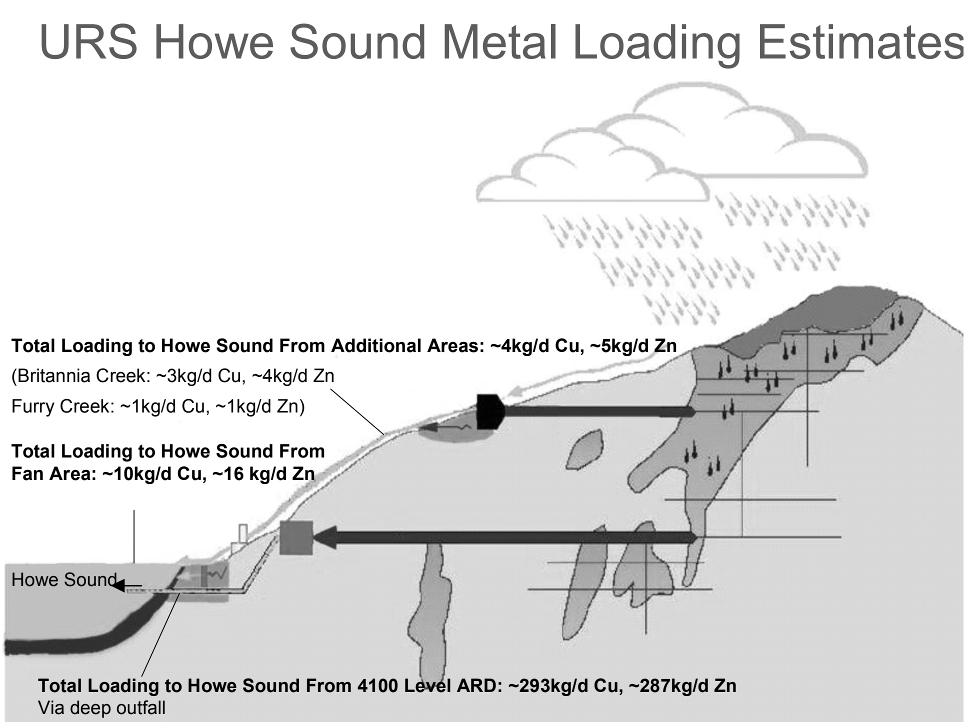

Figure 7 – The Province's Remedial Concept