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Golder Associates

**REPORT ON**

# WORK PLAN FOR BACK BAY TAILINGS SAMPLING

Submitted to:

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Canada's 50 Best Managed Private Companies

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## 1.0 INTRODUCTION

### 1.1 Purpose

Indian and Northern Affairs Canada (INAC) is evaluating the options for the final management of the historic mine tailings deposited in the Back Bay area from Giant Mine in the early years of the operation. A plan is to be developed to manage the tailings that were historically placed in the uplands beside Back Bay and then along a beach area ("beach tailings") in the bay. The tailings extend into Back Bay and at present a narrow beach is exposed near the original discharge area.

This document proposes a work plan to:

i. assess the biogeochemical conditions associated with the near-shore area of the submerged tailings to determine if mitigative measures are warranted, and if so
ii. evaluate several options that may be appropriate management strategies for the submerged tailings.

It should be noted that this study addresses as an initial option the capping of a limited area of the tailings at the beach to minimize on going erosion. It should also be noted that this is a focussed study which does not address other sources of mine-related contamination entering Great Slave Lake. Other studies are in progress which collectively address such issues.

### 1.2 The Environmental Issue

Mine tailings have been produced and deposited at various locations at the Giant Mine site since production began in 1948. Initially, the tailings were deposited in a drainage channel leading to "Back Bay – Great Slave Lake". The tailings were deposited on the uplands above Back Bay, on the beach and in the bay/lake until 1951, at which time they were redirected to a small lake situated northeast of the mine (Abandonment and Restoration Plan, Royal Oak Mines 1998). Figure 1, indicates the general area of interest, and Photographs 1-2 illustrate the uplands, beach and lake setting where tailings were placed.

The tailings deposits adjacent to and in Back Bay have remained inactive for the last 50+ years and have been subject to weathering, erosion and various environmental fate and transport processes. However, recent but limited sampling of submerged tailings in Back Bay beach area indicate elevated total arsenic on the order of 700-1000 mg/kg (Mace 1998). There is potential for diffusive flux or metal precipitation reactions to result in geochemical changes in the surficial layers of the submerged tailings, where benthic invertebrates and other aquatic organisms may be present. The thickness of and concentrations in the surficial submerged tailings may control the release of arsenic and metals to the overlying water at the sediment/water interface. As well, contaminant flux from the beach tailings via surface water runoff and groundwater transport may also affect the water quality in Back Bay-Great Slave Lake.

The submerged and upland tailings are to be left in place because of the volume of material. Excavation and relocation of the upland and submerged tailings may result in the re-suspension of acidity, arsenic, mercury and other metals in the tailings and subsequent release to the surface water. Consequently, the present plan for the upland tailings is to cover and vegetate this area, and then conduct a monitoring program to determine the effectiveness of the reclamation method. To assess options for the submerged tailings, additional information regarding the geochemical conditions and potential for biological effects is required.

### 1.3 Geochemistry of tailings

Prior studies indicate that the arsenic and metal concentrations measured in submerged tailings during 1987-88 surveys were similar to those of historic studies (HydroQual 1989).

More recent but limited geochemical testing (EBA 2001) conducted on cores collected under ice in February 2000 concluded:

- The submerged tailings are net-acid consuming with significant buffering capacity;
- Porewater sampling showed elevated concentrations of arsenic and antimony in the porewater of the tailings deposit. A concern for mercury concentrations has been noted previously but mercury concentrations were below detection (i.e., 0.00005 mg/L);
- Short-term extraction tests and bulk tailings analysis indicate that there is a soluble arsenic load associated with the tailing solids and that this soluble load could be a long-term source of dissolved metals; and,
- The elevated concentrations in the porewater also suggest that there is likely a long-term source of dissolved metals in the tailings solids, and that remediation/reclamation measures may be warranted to protect water quality.

There is also a speculative concern that the geochemistry of arsenic and hydrogeology of the area may affect reclamation options. For example, as submerged tailings/sediment become anoxic it is postulated that upward diffusion of arsenic into the overlying sediment and water column could occur, and therefore simply capping the submerged tailings may not prevent further redistribution of contaminants (Azcue and Nriagu, 1994 cited in Mace 1998).

In addition, it is not yet resolved if groundwater migrating from the uplands/beach area discharges to the lake via the submerged tailings. If this is the case, the groundwater may become an advective vehicle which also transports arsenic/metals upwards through any proposed cap causing recontamination.

### 1.4 Objectives

We have defined three fundamental objectives for this study which we believe are key to assisting INAC in making management decisions respecting the submerged tailings:

*Objective 1: Collect and analyze a limited number of sediment samples and porewater, and conduct a limited number of bioassays to determine if adverse chemical conditions exist for aquatic organisms in the study area; with this information form an opinion as to whether mitigative action is warranted.*

*Objective 2: Investigate the local hydrogeology in Back Bay to characterize groundwater flow from the uplands area of Back Bay, and its potential to contaminate capping material which may be placed as a cover on the submerged tailings.*

*Objective 3: Make recommendations addressing whether or not mitigative actions are needed and if so, provide options and a recommendation respecting conceptual mitigative strategies.*

To achieve these objectives, we have identified several specific goals for the study:

- Delineate the foot print and volume of the submerged tailings in Back Bay;
- Conduct a limited local hydrogeological evaluation to determine the flux and location of groundwater flows in the Back Bay uplands area where tailings have been placed;
- In a limited area of the near shore tailings, analyze contaminants in the bulk sediments, porewater, and sediment-water interface as an indication of the prevailing conditions of the benthic habitat;
- Conduct limited toxicity tests and benthos evaluation as determine, if the present conditions cause adverse effects to the benthic community that warrant mitigative actions;
- Report key findings and options so a closure plan for the tailings in Back Bay can be developed.

## 2.0 APPROACH

To address the objectives and goals of this study, Golder proposes to conduct a limited investigative program that will assist in selection of a management option. Specifically, Golder proposes to conduct geophysical survey in concert with limited field sampling for environmental chemistry and bioassays. A limited groundwater program is also proposed.

The following sections provide a detailed description of the tasks involved.

### 2.1 Task 1: Geophysical Survey

Delineation of the spatial extent of the submerged tailings is desirable to facilitate efficient sampling both within and outside of the submerged tailings. This information will also be needed for developing management options. The proposed approach uses a combination of two noninvasive geophysical techniques (conductivity and radar contrast mapping) to delineate the footprint and volume of the submerged tailings. This noninvasive approach is preferred because it is rapid and will not cause resuspension of the submerged tailings.

The primary objective of the geophysical survey is to delineate the spatial extent of submerged tailings as well as characterize the thickness and volume of the tailings. Auger holes drilled during February 2000 (EBA 2001) suggest tailings thickness varies from less than 0.5 m to approximately 2.5 m in water that is less than 1 m deep. For our planning purposes, we have estimated that the survey area is approximately 5 hectares.

We propose to delineate the spatial extent of submerged tailings based on its electrical conductivity by using a Geonics EM-31 terrain conductivity meter. We expect that tailings will exhibit sufficiently higher conductivity than the native silt, clay, and peat so that the contrasting signal can be mapped.

A ground penetrating radar (GPR) survey will be conducted to obtain detailed stratigraphic profiles and to estimate tailings volume. Moreover, GPR will also place into context the physical shape of the tailings deposit for the detailed sampling program To this end, GPR profiling would be directed, in part, to traverse regions within the tailings as identified by the EM survey. A more detailed explanation of these proposed methods is provided as an attachment.

These surveys would be carried out on calm water with a fiberglass canoe or rubber zodiac (with wood deck). After establishing shore and off-shore traverse endpoints, EM-31 measurements would be digitally recorded on a 5 m grid with GPS tracking. Additional survey control will be provided by GPS mapping of key grid locations and landmarks of primary interest. We estimate that within a 10 hour day follow-up GPR profiling could cover approximately 750 to 1300 lineal metres, depending on actual site conditions and layer resolution requirements.

The acquired EM-31 data would be computer processed in the field office to produce color contour maps of apparent terrain conductivity and in-phase response (please see the attached explanation of the EM-31). Interpretation of the resulting map will indicate the extent of submerged tailings. Preliminary interpretation of GPR profiles would also be accomplished in the field to assure sufficient data quality and coverage.

### 2.2 Task 2: Water/Sediment Sampling

In addition to the geophysical survey, we propose to collect approximately three tailings samples to assess environmental chemistry, assess toxicity, observe benthic biota, and characterize grain size distribution.

Sample stations will be located on the submerged tailings below the shoreline as indicated by EBA (in their January 2001 report). There were two boreholes below the shoreline which were estimated to occur at the elevation of 158.7 m (BH-9 and BH-10). We propose that one of these same stations be sampled again in this study to maintain some comparability with the results of the EBA study. Two additional but deeper sample stations will be located on the submerged tailings, and a fourth station located on the adjacent lake sediments. The rationale for these sample locations is to provide for three (3) stations on the tailings at different elevations (which could result in different processes occurring such that the bioavailability of As or other constituents may change), and one (1) station off the tailings for comparison. A transect perpendicular to the shoreline will assist in determining if a chemical gradient exists.

Each sampling location will be located with global positioning system coordinates (GPS) or relocated using the coordinates from previously sampled stations/bore holes. The location of each station will be marked on base maps produced for the study. Once the sampling location at each station has been identified, water quality (i.e., dissolved oxygen, pH, temperature, and conductivity) will be measured. Notes on overall field conditions will be made, and will include water depth, substratum composition of the general area, species/percent cover of emergent macrophytes, odour, and other pertinent observations such as visible pollution, disturbance by animals or humans and weather conditions. A photographic record/sketch of the site and nearby landmarks will also be made. Sampling will be conducted according to Golder Technical Procedures. This information will be collected at the three stations where samples are collected; however, additional geophysical stations may be sampled for visual observations of the sediment, and if so, this information will also be recorded for the visual observation stations.

Collected samples will be placed in coolers with ice, and transported to the analytical lab as soon as possible. Chain-of-custody and analytical request forms will accompany all samples. Golder will follow a comprehensive quality assurance and quality control (QA/QC) program. The main goal of sample quality assurance and quality control (QA/QC) is to monitor for various sources of contamination during sample collection, transport and analysis. This process will often include the use of field, travel and other test blanks as well as duplicates. At present one duplicate sample for each matrix (i.e., for surface water, porewater, sediment chemistry) has been included in the work plan.

### 2.2.1 Water Sample Collection

Three (3) tailings stations will be sampled during the geophysical survey. Surface and boundary layer (just above the sediment surface) water samples will be collected at each station using either a horizontally mounted Van Dorn Bottle or tubing and peristaltic pump, and then transferred into pre-cleaned bottles supplied by the analytical laboratory. Sampling equipment will be washed with soap and water, acid washed and rinsed with distilled water between stations. Bottles will be rinsed three times with site water prior to filling, unless prefilled with sample preservative. Each sample bottle will be labelled with a permanent marker or water proof label with the station location, date/time, collector, and analysis requested.

### 2.2.2 Water Chemistry

We propose that the following parameters be analyzed: total suspended solids (TSS), total dissolved solids (TDS), total and dissolved metals scan (including As, Hg), arsenic speciation, alkalinity and hardness, major ions, total acidity (i.e., acidity at pH 8.3), biological oxygen demand (BOD), and total organic carbon (TOC).

### 2.2.3 Bulk Sediment Sampling

Three (3) tailings stations will be sampled coincident with water chemistry samples. Sediment samples will be collected at each station using a corer. The biologically active layer and a layer below will be sampled for a total of 6 samples. Multiple cores (if required, to satisfy volume requirements for analysis) will then be homogenized and transferred into pre-cleaned bottles supplied by the analytical laboratory. A single surficial sediment sample will also be collected from a lake-sediment location. Sampling equipment will be washed with soap and water, acid washed and rinsed with distilled water between stations. Each sample bottle will be labelled with a permanent marker or water proof label with the station location, date/time, collector, and analysis requested.

### 2.2.4 Porewater Sampling

Three (3) tailings stations will be sampled coincident with water/bulk sediment chemistry samples. Porewater samples will be collected at each station using either drive point well sampler or Waterloo profiler. Alternatively, if porewater cannot be extracted due to grain size, then a bulk sample will be collected for centrifuge in the lab to extract porewater. The biologically active layer and a layer below will be sampled in the tailings profile at each station for a total of 6 samples. If drive point well sampler is used it may be installed and left to equilibrate for as long as possible (e.g., on the order of days) prior to sampling. Sampling equipment will be washed with soap and water, acid washed and rinsed with distilled water between stations. Each sample bottle will be labelled with a permanent marker or water proof label with the station location, date/time, collector, and analysis requested.

### 2.2.5 Sediment Chemistry

We propose that the following parameters be analyzed:

- Porewater: Acid Base Accounting (ABA; including paste pH, total sulphur, sulphate sulphur, sulphide sulphur, acid generation potential-AP, neutralization potential (NP), net neutralization potential, NP/AP ratio), Dissolved Metals by ICP-MS (including As, Hg), arsenic speciation.
- Solids: Total Metals by ICP, bioavailable metals by AVS/SEM, Particle Size Distribution, and total organic carbon (TOC), detailed mineralogy of select samples.

## 2.3 Task 3: Groundwater Investigation

A limited groundwater investigation is proposed to assist in determining if groundwater transports contaminants upward through the submerged tailings. Remediation of the submerged tailings may include the placement of a cap for stabilization purposes. Should it be found that groundwater transports dissolved metals from the tailings upwards, then the cap would need to be designed to prevent contamination of the cap over time. Critical parameters for the design of the cap will be the upward hydraulic gradients (if they exist) and hydraulic conductivity of the tailings, native sediments, and underlying bedrock. These parameters will be determined from the proposed field investigation.

A total of ~~three~~ TWO multilevel wells are proposed just above the beach area at the bay. The location of these wells would be revised following initial site visit and review of geophysical data, as discussed in Section 2.1. Each installation would consist of two piezometers screened at different depths in bedrock or the silt beneath the tailings and one standpipe completed in the tailings. Once all wells are installed and developed, single well response tests would be conducted in all wells to estimate hydraulic properties of tailings and underlying bedrock or silt. The top of casing of each well would be surveyed to a common datum and a benchmark would be established for the measurements of water level in the lake. Water level data collected from the wells and the lake would be used to estimate vertical hydraulic gradient and hydraulic properties of the native sediments.

Following collection and analysis of hydrogeological data a conceptual model of groundwater flow and transport of dissolved chemicals within the beach area would be developed. This would include an estimate of groundwater flux through the tailings for the current hydrogeological conditions, and predictions of future groundwater flux and changes to the hydrogeological regime resulting from vegetating the tailings.

## 2.4 Task 4: Sediment Toxicity Bioassay

To assess whether the metals associated with the submerged tailings and adjacent lake sediments present adverse conditions to the benthic community, toxicity bioassays will be conducted using *Hyallela*, a freshwater amphipod. The value in this task is that the bioassay will inherently address both the bioavailability of sediment-associated arsenic (and other metals) as well as the potential interactive effects of the metals. Neither of these parameters is effectively addressed through chemistry evaluation and comparison to sediment quality guidelines.

The proposed approach is to collect three sediment samples from the biologically active zone (i.e., upper 20 cm) of the submerged tailings. The sample locations would be coincident with sample stations for benthos evaluation and sediment chemistry. In addition, one lake sediment sample would be collected within the area immediately outside but adjacent to the tailings area. This latter sample is designed to assess whether or not the influence of the submerged tailings on benthic biota extends beyond the tailings footprint. All sediment samples will be collected using a Ponar grab. Samples will be stored on ice and shipped with chain-of-custody forms to HydroQual, a CAEL-certified aquatic toxicity laboratory in Calgary. Bioassays will be conducted according to Environment Canada protocol. A reference toxicant will be tested concurrently for internal quality assurance. In addition, "internal grain size controls" will be included in the experimental design. The grain size controls will be based on results from grain size analysis of tailings and lake sediments. These controls will provide an interpretive basis to ascertain whether observed effects are associated with contaminants or grain size. The latter can be an important confounding factor in sediment bioassays, especially in the present case where submerged tailings versus natural lake sediments are involved.

## 2.5 Task 5: Benthic Invertebrate Collection

Benthic invertebrates will be collected at three submerged tailings stations coincident with water and sediment chemistry sampling and one reference station. Three grab samples will be collected at each station; two of the three samples will be analyzed, and the third will only be analyzed if the variability warrants. Benthic invertebrate samples will be collected using a stainless steel petite Ponar Grab or Ekman sampler for community composition analysis. Macroinvertebrates retained on 500 μm sieve will be fixed with 10% buffered formalin. Labelling and field records will be prepared as for water chemistry and accompany samples to the analytical lab and sorting and taxonomic facility.

## 3.0 REPORTING

### 3.1 Interpretation of Results

Following the collection, collation and QA/QC of monitoring data, the data will be reviewed in the context of the objectives of the program. A geochemical and hydrogeological model which addresses the flux of metals in submerged tailings will be developed.

To evaluate the water and sediment chemistry results and their environmental significance, the data will be compared with:

- Available information for the Yellowknife Area and similar systems in the region; and
- Provincial (NT and BC) and Federal (CCME) water and sediment quality guidelines.
- Results of the limited bioassay program.

### 3.2 Development of Management Plan

Based on the results of the study, Golder will develop a recommended position on each of the goals stated earlier, and this information will be used to develop a position respecting the three key objectives. The management plan will first consider whether mitigative actions concerning the submerged tailings are warranted and secondly, if so, what is a reasonable and long-term beneficial strategy. In addition, other possible strategies will be considered at the conceptual level. Alternative approaches considered in previous reports would be re-evaluated based on the data collected for this effort.

## 4.0 CLOSURE

We trust this work plan meets your needs at this time. We would be pleased to discuss it further should you require additional information, so please contact the undersigned.

**GOLDER ASSOCIATES LTD.**

Michael G. Rankin, M.Sc.
Associate

John A. Hull, P.Eng.
Associate

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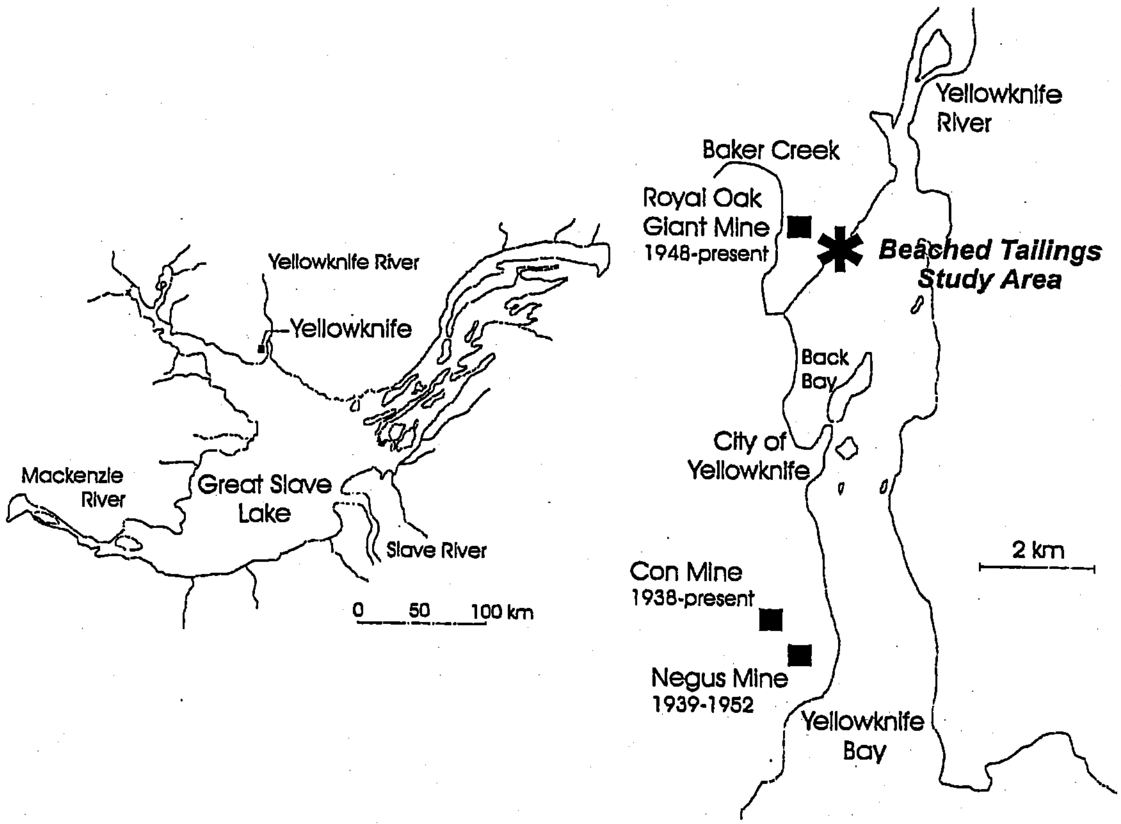


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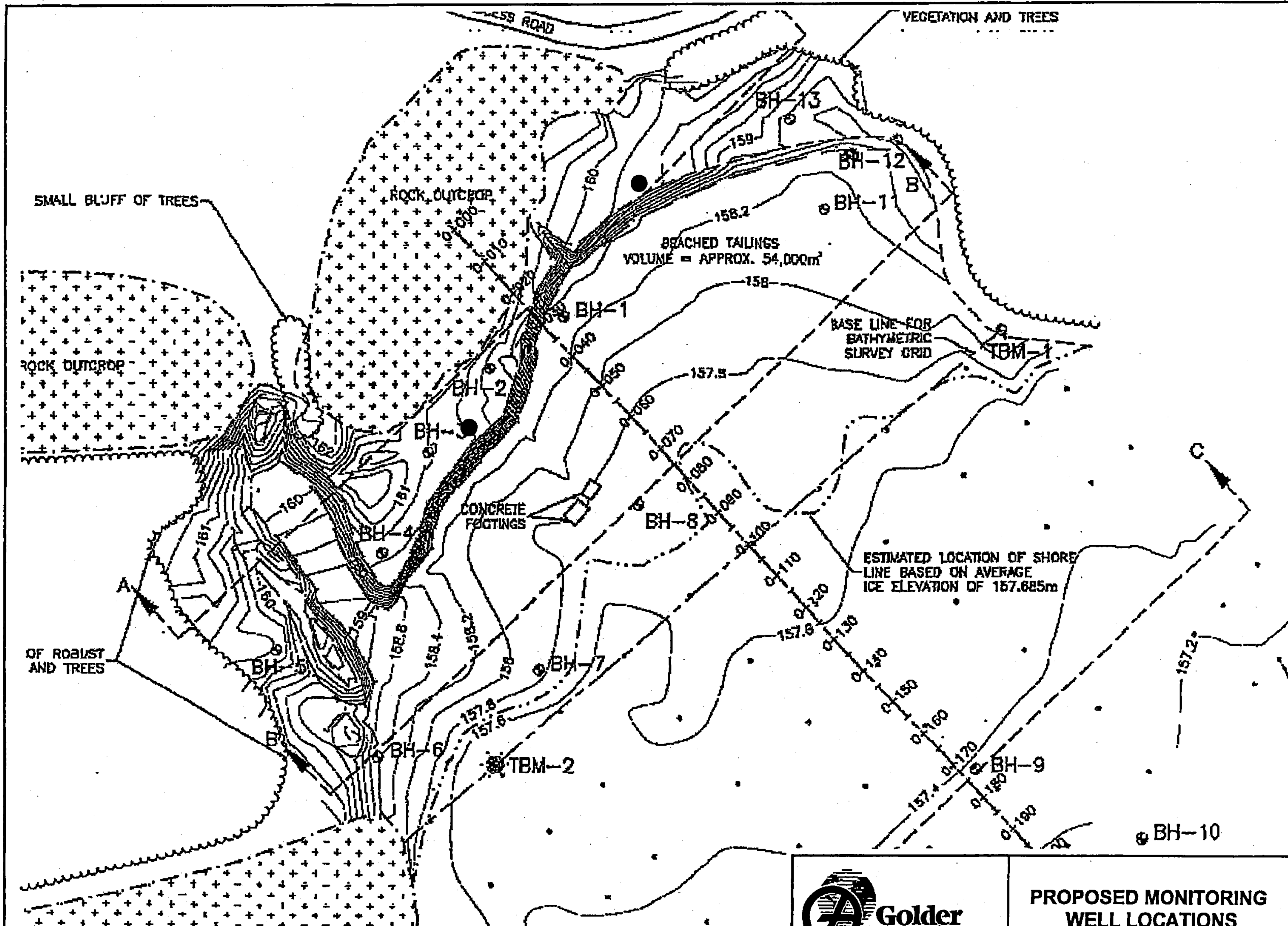
**STUDY AREA**
(Source : Mace 1998)

Figure 1

Drawing: N:\Work\1400\012-1431 Mirimar Mine Back Bay Tailings Giant Mine\p1431-01.dwg Plotted: Jun 07, 2001 - 10:45am By: jkownacki




**LEGEND:**

● Proposed Location of Monitoring Wells

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## PROPOSED MONITORING WELL LOCATIONS

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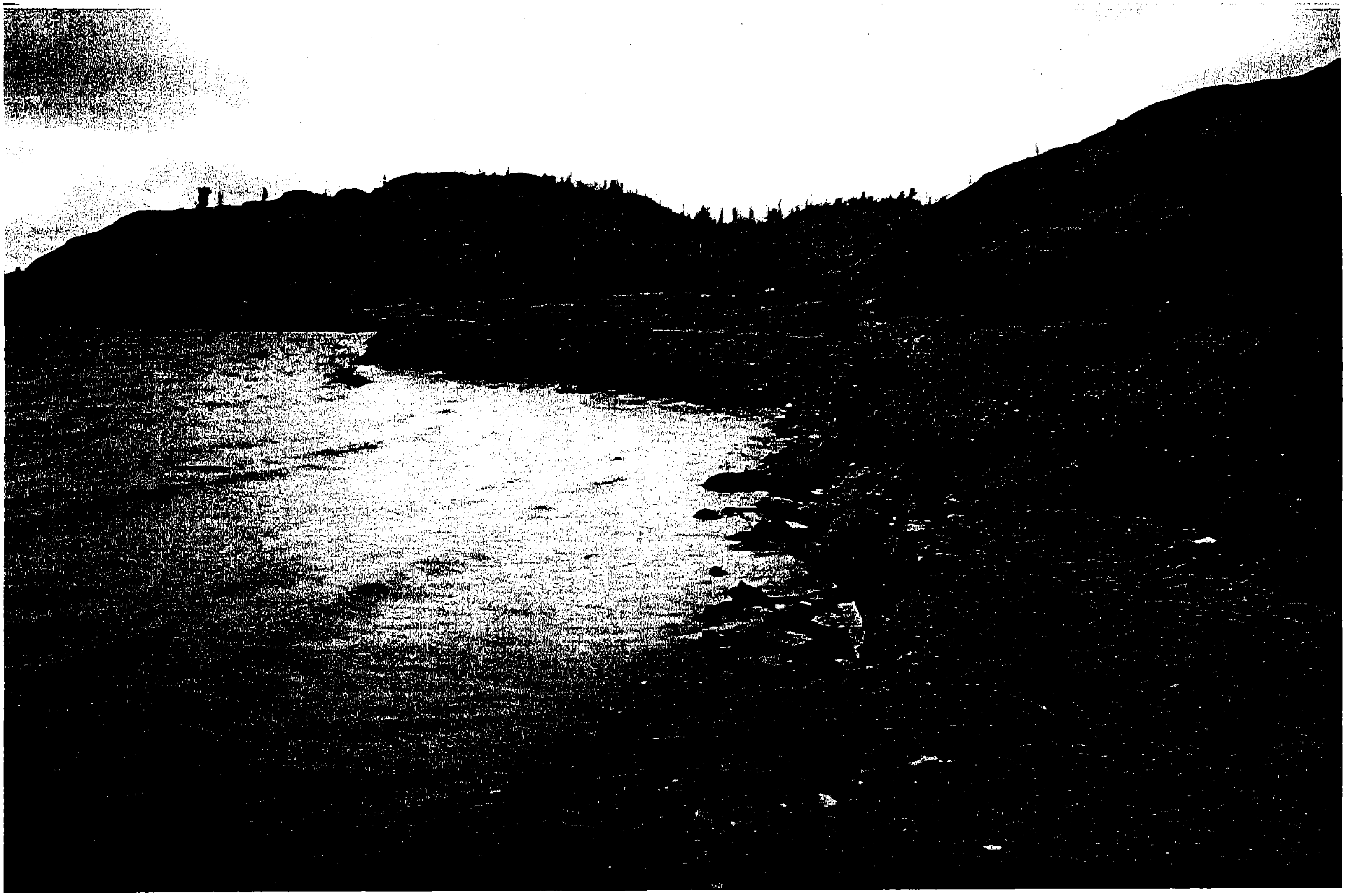

**PHOTOGRAPH 1**

Upland beached tailings illustrating erosion conditions.

**PHOTOGRAPH 2**

Beached tailings under low water conditions.

# APPENDIX I

# DETAILED GEOPHYSICAL SURVEY METHODS

## ELECTROMAGNETIC TERRAIN CONDUCTIVITY MAPPING (EM-31)

The Geonics EM-31 electromagnetic terrain conductivity meter measures soil conductivity from the inductive response of the ground. Basic principles of electromagnetic conductivity mapping are illustrated in Figure 1. An alternating current is supplied to a wire transmitter coil, producing a time-varying magnetic field (9.8 KHz) that penetrates the ground and induces electrical eddy currents within the subsurface materials. These eddy currents give rise to a secondary magnetic field that is measured, together with the primary field, by the receiver coil. Two components of the secondary field are measured: in-phase and quadrature. The quadrature component yields a direct measure of average ground conductivity in mS/m. The in-phase response, measured in parts per thousand (ppt) of the primary field, has no direct physical interpretation but is a useful indicator of buried metallic objects.

Under natural geologic conditions, induced current flow and, consequently, the strength of the secondary magnetic field are approximately proportional to subsurface conductivity. This soil conductivity is controlled principally by porosity, relative pore saturation and pore-water ion concentrations. Finally, both surface and subsurface metal (ferrous and non-ferrous), including fences, steel frame structures and underground utilities and storage tanks, produce a characteristic negative-valued response flanked by anomalously high apparent conductivities.

The EM-31 conductivity meter can be operated in vertical or horizontal dipole mode, meaning that transmitter and receiver coils are oriented such that their axes, and the resulting magnetic dipole field, are vertical or horizontal relative to the ground surface. Depth (range) sensitivity is significantly different for the two modes as illustrated in Figure 2. Note that the depth axes in Figure 2 are normalized by intercoil separation. For the EM-31 coil spacing, s = 3.7 metres, Figure 2 indicates that the horizontal mode yields maximum sensitivity at the surface, z/s = 0.0, while the vertical mode possesses peak sensitivity at approximately 1.3 metres, 35 percent of intercoil separation, and a range of about 5.6 metres. For practical purposes, the EM-31 response should be interpreted as a weighted average (apparent) conductivity for hemispherical subsurface volumes that have a radius approximately equivalent to the 5.6 m range.

## GROUND PENETRATING RADAR (GPR)

Ground penetrating radar (GPR) operates on the principle that electromagnetic waves, emitted into the ground by a transmitter (Tx) antenna, are partially reflected at subsurface interfaces and subsequently can be detected by a receiver (Rx) antenna as illustrated in Figure 3a. Reflections arise due to contrasts in the dielectric constant of subsurface materials due primarily to variations in soil moisture content. In particular, there is a strong reflectivity contrast between porous, partially saturated soils and relatively impervious crystalline bedrock or most utilities. Radar range, or maximum penetration, is limited by the electrical conductivity of subsurface materials, i.e., increasing conductivity increases intrinsic attenuation. Conductivity is enhanced by increasing moisture content, concentration of dissolved salts and fraction of clay minerals present.

The radar system incorporates precise timing electronics to measure the reflection transit-time, from transmitter to receiver, which depends on reflector range and radar wave velocity. A radar profile is acquired by moving transmitter and receiver antennas and, concurrently, recording a series of soundings at equal intervals along a traverse. Resulting data are displayed as a series of oscilloscope-like traces having amplitude proportional to reflection strength as illustrated in Figure 3b. Given an estimate of radar wave velocity, corresponding reflector depths may be determined.