A Case Study of the Rehabilitation of Sulphide Tailings At the Coldstream Mine, Tailings Management Area No. 2

R. CECIL BURNS*
Golder Kirtec Division, Golder Associates Innovative Applications Inc., 662 Falconbridge Road
Sudbury, Ontario P3A 4S4, Canada

DAVID A. ORAVA
SENES Consultants Limited, 121 Granton Drive, Unit 12
Richmond Hill, Ontario, L4B 3N4, Canada

MICHAEL ZUROWSKI
Jascan Resources Inc., Suite 1414, 181 University Avenue
Toronto, Ontario, M5H 3M7, Canada

ROBERT J. MELLOW
LI Group, 308 Charlotte Street
Sydney, Nova Scotia, B1P 1C7, Canada

ABSTRACT

The North Coldstream Copper Mine which is located in Northwestern Ontario, ceased operations in 1967. Over a period of about five years ending in 1967, an estimated one half million tonnes of sulfide tailings were placed into a licensed management area (TMA) that is now referred to as TMA-2. The closure planning for TMA-2, which includes an exposed tailings beach within the tailings pond, has recently been completed and follows a two year long field investigation and technical program and discussions with regulatory authorities. The closure plan involves the relocation of approximately 80,000 m^3 of tailings to a metre below the surface of the TMA-2 tailings pond. The paper discusses the process that was applied to develop the detailed closure plan and focuses on the methods by which the characteristics and status of the site and the receiving environment were assessed; a biological survey of the TMA; the closure options considered (e.g. construction of an engineered cover); the search for locally available cover materials; long term site care and maintenance; regulatory aspects; and the selection of the preferred option. In addition, the implementation program is also reviewed in terms of ameliorative measures implemented and operational monitoring.

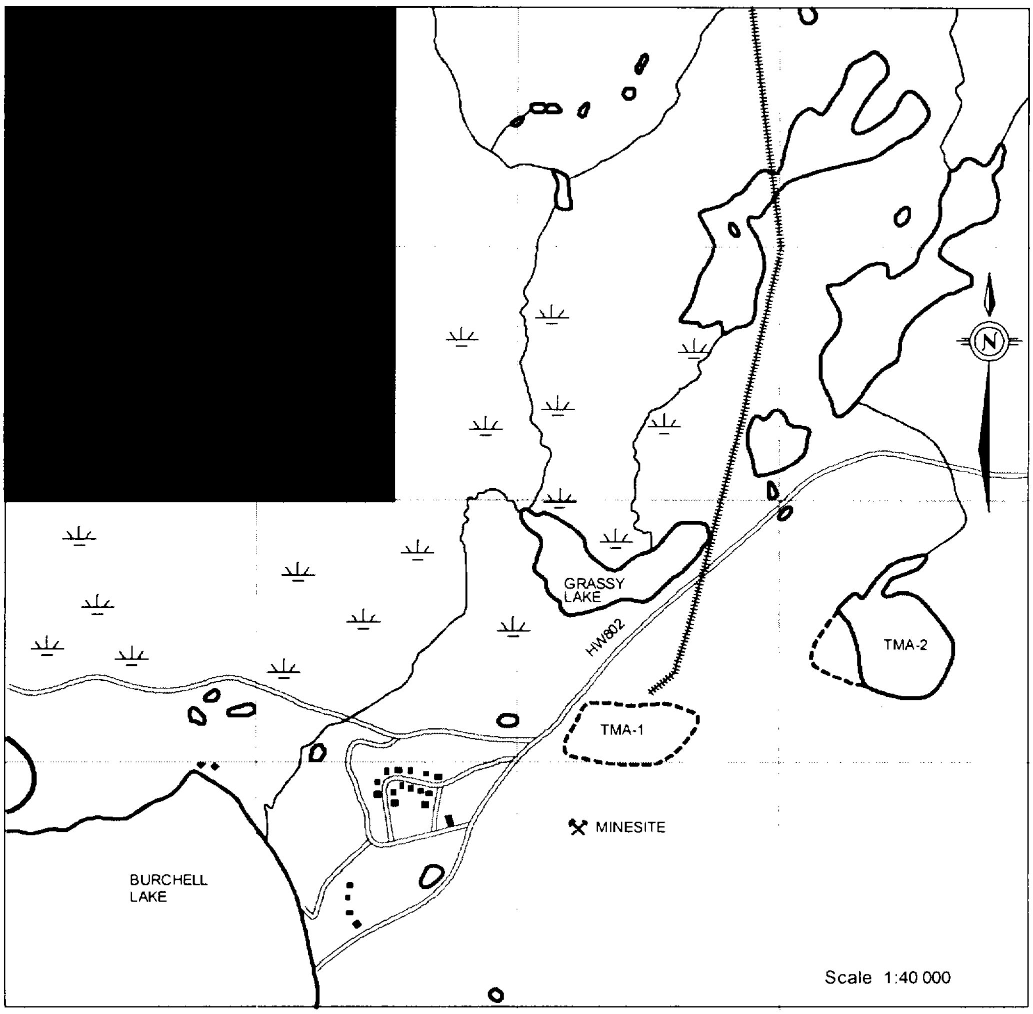
Key Words: mine reclamation, acid mine drainage, water covers, environmental rehabilitation

INTRODUCTION

The North Coldstream Copper Mine Property is located in northwestern Ontario at the terminus of a tertiary road, Highway 802, approximately 11 km south of the hamlet of Kashabowie. Figure 1 shows the site layout and a key plan to the location. Copper deposits were first discovered in the area in 1870 and about 6000 tonnes of ore were mined during the First World War. Mining commenced on the site in the early 1950's and the mine operated on and off until 1967 when operations ceased and the mine became dormant. A total of approximately 2.7 million tonnes of sulphide tailings were produced during the life of the mine and discharged to two licensed tailings impoundment areas designated TMA-1 and TMA-2. From the early 1950's until about 1962 tailings were discharged to a natural valley to form TMA-1. The impoundment was controlled by a containment structure constructed of stacked tailings and waste rock. Once this area was filled the company received approval from the then Department of Lands and Forests to utilize a small lake, locally known as Halet Lake, as its tailings disposal area designated TMA-2. Approximately one half million tonnes of sulphide tailings were discharged to this basin to the end of the mine's life, creating a tailings beach of about 3.0 ha in area and covering the bottom of the pond with tailings.

COLDSTREAM COPPER TAILINGS PROJECT
SITE LOCATION PLAN

FIGURE 1



LEGEND

▬▬	WATER LINE	═══	ROADWAY	swamp symbol	SWAMPY AREA
——	RIVER OR STREAM	++++++	POWERLINE	■	BUILDINGS

Date ....FEB 1999.......

Project ...981-9804....

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Through a series of ownership transitions and land acquisitions, AEC West Ltd. became an indirect owner of the site. In 1996, AEC West Ltd. retained Kirtec Resources Ltd. in partnership with SENES Consultants Limited to conduct site investigations and develop a Closure Plan for the tailings areas in compliance with the requirements of the Ontario Mining Act. Based on 1996 field work, a Tailings Options Study was developed suggesting a number of options for the rehabilitation of the tailings areas and recommending additional detailed field work for 1997 that would lead to the production of an acceptable Closure Plan.

The discussions below summarize the results of the 1996-97 field programs, which led to the development of the accepted Closure Plan and the selected option for rehabilitation of the TMA-2 tailings area.

INVESTIGATIVE WORK

Previous assessment work that had been conducted by the Ministry of Environment (MOE) in 1991, Canada Centre for Mining and Energy Technology (CANMET) in 1994, and Golder Associates Ltd. (Golder) in 1995, was reviewed to assist in the development of the 1996 field program.

The 1996 program involved the installation of groundwater monitoring wells in and around TMA-1, additional characterization of the TMA-1 and TMA-2 tailings, examination of TMA-1 and TMA-2 watershed areas, characterization of TMA-1 and TMA-2 tailings porewater, analysis of surface water quality and surveys of the tailings areas.

Examination of records indicated that the Coldstream ore contained 2 to 8% chalcopyrite and roughly the same amount of pyrite. The mine waste rock was predominantly siliceous with a 1 to 5% sulphide content. Ore was ground to about 50% minus 200 mesh in the milling process. Initial acid:base accounting (ABA) tests conducted by CANMET in 1994 indicated that the tailings had a net neutralizing potential (NNP) from between –27 to –159 kg $CaC0_3$/tonne. Additional ABA testing conducted in 1997 determined a NNP of –140.5 to –174 kg $CaC0_3$/tonne. The average sulphide sulphur content of the tailings was about 5.7% by weight.

The physical survey of the TMA-2 area determined that the tailings beach occupied a surface area of 2.8 hectares and the water pond had a surface area of approximately 10 hectares. The TMA-2 pond drained through a series of small beaver ponds, under the tertiary road, to an unnamed lake, through a wetland to Grassy Lake and finally to the Wawiag River and Burchell Lake. The watershed of the TMA-2 pond was small only encompassing about 35 ha and there was no drainage connection to TMA-1. Initial surface water quality results of the TMA-2 pond water indicated a pH 6.5 to 6.9 and elevated levels of iron (0.9 to 2.6 mg/l), copper (0.0065 to 0.016 mg/l) and cobalt (0.006 to 0.011 mg/l).

A detailed examination of the TMA-2 pond was conducted in 1997. The survey involved a bathymetric survey, collection and analysis of benthic organisms, sediments, surface waters and fish. The bathymetric survey indicated that the TMA-2 pond was relatively deep for a small water body with an average depth of about 7 m and a maximum depth of about 13 m.

Six replicate benthic samples were collected from two locations in the TMA-2 pond; one in the profundal zone and one in the littoral zone. Benthic densities (0.33 organisms/0.023 m^2) in the profundal zone were extremely low with only one organism *(Chaoboris sp.)* found from a total of six replicates. Benthic densities in the littoral zone were somewhat higher (6.68 organsims/0.023 m^2) but much lower than those of other lakes in the same area (38.4 to 46.8 organisms/0.023 m^2). Sediment samples of the TMA-2 pond indicated that tailings had covered much of the bottom of the pond with very little organic detritus present. Chemical analysis of the sediments revealed elevated levels of cadmium, cobalt, copper, nickel and silver. Overnight trap sets resulted in an abundant catch of finescale dace (*Chrosomus neogaeus*) and northern redbelly dace (*Chrosomus eos*). No other fish species were detected or noted.

REVIEW OF REHABILITATION ALTERNATIVES

Based on the information collected from the 1996-97 field programs, five alternatives for rehabilitation of TMA-2 were considered; in-situ flooding of the exposed tailings; raising the TMA-2 pond level to flood the exposed tailings; installing a simple cover and revegetating; installing an engineered cover and revegetating; and relocation of the exposed tailings to below the pond water level.

In-Situ Flooding

In order to flood the tailings in-situ, the upper portion of the exposed tailings beach would have to be relocated to minimize the final elevation of the flooded area which was expected to be a minimum of 3 m above the pond level. A water-controlling dam and spillway would have to be installed in a suitable location downstream of the existing water pond. Additional land area would have to be flooded in order to allow the pond level to be elevated. Because the pond has a fairly small watershed, it was expected that it would require about 2 to 3 years for the pond level to naturally rise to its final elevation.

The advantages of this method would be that the tailings would have an effective water cover that would curtail acid generation within the tailings mass by blocking the transfer of oxygen. The major disadvantages of this method were the need for a substantial engineered water controlling structure and significant long term maintenance requirements. It could also be subject to low water conditions that expose the tailings for various time periods.

Elevated Water Table

The use of an elevated water table would require the regrading of the upper portion of the exposed tailings beach to minimize the final elevation of the raised water table. A robust, low-head, water control dam would have to be installed at the outlet of the TMA-2 water pond. This would raise the water table to effectively saturate the tailings. The exposed tailings surface would be capped and revegetated. In contrast to the in-situ flooding scenario, this alternative would require raising the water level about 1.0 m and the final water level would be reached within a year.

The major advantage of this method would be to saturate the exposed tailings and effectively mitigate oxygen transfer to the sulphide solids. It would not require as substantial a water control structure as in-situ flooding. It would also reach its effective water level much earlier. This method would still require the construction of a water controlling structure that would require significant long term maintenance. In addition, it would also be subject to potential problems related to low water level conditions.

Simple Soil Cover

The use of a simple mono-layer soil cover would require some regrading of the tailings surface to provide an even base for the construction of the cover. A soil cover, using locally available materials, would be installed directly on the regraded tailings surface to a depth of about 30 cm. Rip rap would be installed at the tailings:pond interface to reduce erosion from wave action. The cover would be fertilized and seeded.

The major advantage of this method would be that it would be fairly inexpensive, since a minimal amount of locally available construction materials would be required. The vegetative cover would provide significant esthetic improvement to the site. It would not require the construction of any water control structures and would not be significantly effected by fluctuations in the pond water level. The major disadvantage of this method would be that it would not provide the amount of control of oxygen transfer that would be required to significantly reduce acid generation within the tailings. It would also require maintenance of the vegetative cover and rip rap barrier. In addition the vegetation could be subject to damage from contaminants drawn up into the growing medium by capillary action.

Engineered Cover

The installation of an engineered cover over the exposed tailings would require the same preparatory work as a simple cover. The engineered cover would require placement of a layered cover to provide a bottom capillary break layer, an oxygen transfer/moisture retaining barrier and a surface vegetative layer. A low perimeter rip rap barrier would be installed at the pond edge and the surface of the cover would be fertilized and seeded. The technical basis for the use of covers and elevated water tables within tailings is well founded and has been described on numerous occasions (e.g. MEND 1994, MEND, 1996, Orava et al, 1997).

The major advantage to the installation of an engineered cover would be to ensure that an effective oxygen transfer barrier would be created and that the potential migration of contaminants to the vegetative horizon by capillary action would be addressed. As with the simple cover, no water control structures would be required, the site would not be affected by pond level fluctuations and significant esthetic improvements would be made to the site. The major disadvantage to this method would be the cost associated with constructing this type of cover. Very specific materials would be required and the depth of cover would be a metre or more. Maintenance of the rip rap barrier and the vegetative cover would also be required over the long term.

Relocation by Dredging

The exposed tailings would be relocated to at least a metre below the pond surface by the use of a dredge or high pressure water cannons. This scenario would likely require the washing and revegetation of the original shoreline. The technical basis for water covers is also well founded and has been described many times (e.g. Ludgate et al, 1997, MEND 1998).

The major advantage of using this method would be that once the tailings have been relocated, the tailings mass would be submerged, thereby eliminating acid generation. No additional maintenance would be required once the relocation was completed and this method could be considered a walk-away solution. The disadvantages to this method would be the relative cost of relocating the tailings compared to other methods and the challenges in obtaining regulatory approval. This method may also result in a temporary increase in the contaminant loadings in the water pond and necessitate treatment.

REGULATORY ISSUES

One of the major considerations in selecting a preferred option for TMA-2 was the likelihood that the method would receive regulatory approval or concurrence from a number of Federal and Provincial government agencies.

The primary approval that was required was the acceptance of the Closure Plan submitted to the Ontario Ministry of Northern Development and Mines (MNDM). This agency has primary responsibility for the rehabilitation of mines in Ontario and worked in conjunction with the Ministry of Labour (MOL), the Ministry of the Environment (MOE) and the Ministry of Natural Resources (MNR) to ensure that the plan was acceptable to the Province. During the development of the Closure Plan, regular meetings and discussions were held with representatives of the Ministries.

From the discussions that were held with the provincial regulators it was determined that approval by the Federal Department of Fisheries and Oceans (DFO) would be required should relocation by dredging be the selected option. Discussions with DFO indicated that with appropriate documentation, operational safeguards and follow-up monitoring, the dredging option would be considered in a favourable light.

The Closure Plan was accepted by the Director of Mine Rehabilitation (MNDM) with the concurrence of all provincial agencies. A conditional approval by the DFO was received for tailings relocation by dredging which had been selected as the preferred option (see below).

In addition to approval by provincial and federal regulators, a public information session was held in Thunder Bay to allow the general public to review the rehabilitation plans and provide comments. The session was well attended by the public and the project was generally well received. Many of the people in attendance were pleased that rehabilitation of these areas was to take place.

SELECTION OF PREFERRED OPTION

A number of factors were considered in determining the most appropriate option for the rehabilitation of TMA-2:

- regulatory acceptance,
- overall environmental impact,
- feasibility,
- long term maintenance requirements, and
- cost.

The first two options, in-situ flooding and elevating the water table, were rejected because of the cost and long term maintenance requirements of the water control dams and spillways. In addition both options would result in flooding of additional land and there was the potential of damage to the tertiary road should the structures fail. These options did not provide walk-away solutions. The use of a simple cover was rejected because mathematical modeling indicated that this option would not provide a sufficient barrier to oxygen transfer.

The final two options, the application of an engineered cover and tailings relocation, were both considered as suitable for rehabilitation of TMA-2. Both options would provide effective control of acid generation. The engineered cover would provide a suitable structure for establishment of vegetation but would require long term monitoring and maintenance. Relocation of the tailings would provide a walk-away solution, but could result in a short term deterioration of water quality in the tailings pond. Both options were roughly equivalent in estimated capital costs. In the final analysis, the relocation of the tailings by dredging was selected as the preferred option over the engineered cover for two reasons:

1. this option would be considered a walk-away solution, and
2. it was acceptable to the regulators.

REHABILITATION OF TMA-2

In order to mobilize/demobilize the dredge to the TMA-2 pond and service the operating dredge, a temporary road was constructed along the old tailings line route from TMA-1 to TMA-2. A temporary landing was created on the TMA-2 tailings beach for off-loading of the dredge.

Dredging of the tailings commenced in mid-July using a 25 cm cutterhead suction dredge and was completed at the end of September, 1998. The dredging operation was relatively straightforward with the dredge working across the face of the tailings beach. The dredge was set to remove tailings to one metre below the pond water level. The dredge was aided by excavators and bulldozers that moved tailings to make them more accessible to the dredge.

Dredged tailings were discharged through a 20 cm diameter floating discharge line and directed to the deep areas of the pond. The location of the discharge was continuously moved to provide even placement. Dredging proceeded smoothly until the old shoreline of the pond was reached. Stumps and large boulders were encountered in this area and made continued dredging difficult. Selective movement of tailings to the dredge from these areas was accomplished using excavators. Some of the remaining tailings could not be successfully dredged and in these areas the tailings were excavated and trucked to TMA-1.

On completion of the dredging and excavation, the shoreline area was washed with high pressure hoses to remove any remaining exposed tailings. Following washing, fill was placed over the exposed shoreline and graded. This area was then fertilized and seeded.

AMELIORATIVE MEASURES

A number of ameliorative and protective measures were incorporated into the planning and implementation of this project. The two primary measures that were used during the project were the installation of sediment control barriers and the control of the water flow from the TMA-2 pond. In addition, an extensive monitoring program was instituted for the duration of the project and provisions were made for pH control.

It was anticipated that a significant amount of sediment and turbidity would be generated by the dredging operation. In order to ensure that this sediment would not be transported downstream from the TMA-2 pond, a series of sediment control barriers was installed in the pond outlet. These barriers consisted of non-woven geosynthetic fabric with pockets sewn into the top and bottom. The top pocket accepted a continuous polyethylene pipe, which provided flotation. The bottom pocket accepted a chain to weigh down the bottom of the barrier to provide an effective seal to the bottom of the pond. These barriers provided effective control of suspended solids from the dredging operation. Measured suspended solids levels downstream of the site did not increase during the dredging project.

As part of their approval the DFO and MOE required that should the pH drop below 6.0 during dredging that the operations be halted until the pH of the outfall was restored to at least 6.5 or the outflow stopped. In anticipation of possible fluctuations in the pH of the pond water as a result of the dredging operation, the outflow of the TMA-2 pond was stopped off prior to the start of dredging. Flow was stopped at a low beaver dam located at the outlet of TMA-2 with a series of sandbags placed along the face of the dam. The dam was inspected daily to ensure that the outlet was not in danger of overtopping or breaking through.
The pH of the pond was monitored daily and water samples were collected for laboratory analysis on a weekly basis during the dredging operations. The pH level remained relatively constant during the dredging and only began to drop during the later stages of the operation. During this time period approximately 250 tonnes of quick lime and hydrated lime were added to the pond. The pH and contaminant levels will be monitored over the winter months on a regular basis. Prior to the 1999 spring melt, the results of the monitoring will be evaluated and additional pH control measures will be implemented if required.

Routine monitoring will be carried out on a regular basis for a number of years to evaluate the effectiveness of this method of acid generation control. Surface water will be monitored three times per year and in the year 2002 a repeat of the 1997 biological survey will be completed to evaluate the response of the biological communities.

RESULTS

The exposed tailings beach was successfully relocated to the TMA-2 pond. Because of unanticipated shoreline conditions, approximately 4,000 m^3 were excavated and trucked to the TMA-1 tailings area. The exposed shoreline was restored and revegetated.

As expected the water quality of the TMA-2 pond deteriorated during the dredging operation with reductions in pH and increases in dissolved metals. Continued monitoring of the water quality shows some improvement and it is expected that the pond water quality will return to pre-dredging conditions within a short period of time.

The site will be monitored for an extended period of time to evaluate the effectiveness of the reclamation project. It is expected that the short term deterioration of water quality will be offset by the long term chemical stability of the relocated tailings.

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