# Supporting Document F1

## Review of Yellowknife Bay Tailings Environmental Assessments (SRK, 2004)

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**Report Prepared for**

## Department of Indian and Northern Affairs Canada

**Report Prepared by**


**April 2004**

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## Department of Indian and Northern Affairs Canada

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**SRK Project Number 1CP001.32**

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# 1 Introduction and Scope of Report

The Giant Mine, located 5 km north of the City of Yellowknife began producing gold in 1948. During the first 5 years of operation tailings from the gold extraction process were deposited on the shore of Yellowknife Bay. In recent years, the impacts of these tailings have been assessed. The general conclusion of these assessments was that in the immediate vicinity of the tailings there was a low but measurable impact. There was little or no information on the significance of this impact on Yellowknife Bay as a whole.

This report reviews the environmental assessment of tailings in Yellowknife Bay studies, completed between May 1998 and January 2004. A summary of the purpose, results and conclusions of each study is presented. Comments from this review are included where appropriate. Recommendations for further consideration are provided.

# 2 Background and Brief

## 2.1 Background of the Project

The Department of Indian Affairs and Northern Development (DIAND) is managing the reclamation and remediation of historical impacts from the Giant Mine near Yellowknife, NWT. Prior to and as part of this reclamation and remediation process a number of engineering/scientific studies were commissioned to assess the environmental impact of the historic discharge of tailings into Yellowknife Bay in Great Slave Lake. The results and recommendations of these reports have not completely resolved DIAND's concerns.

This review was requested by DIAND to draw together the results and findings of a series of 7 reports dated from 1988 to 2004, and to provide an expert opinion on the accuracy and completeness of their findings. DIAND's main interest is to insure that any environmental impacts from the Giant Mine are measured, understood and mitigated

## 2.2 Nature of the Brief

In the process of reclaiming the Giant Mine in Yellowknife, DIAND and Miramar Giant Mine Ltd. have sponsored or initiated a number of environmental assessments of historic tailings in Yellowknife Bay. The conclusions of these reports have not resolved all of the concerns the parties have on the environmental impact of the tailings on Yellowknife Bay.

As such, SRK was asked to provide a broad overview of the work presented in these reports and to provide recommendations on resolving these parties' concerns.

The outcome of this report is to create a sense of perspective on the relationship of the tailings deposited on the shore of Yellowknife Bay and to Yellowknife Bay as a whole. Focusing on the immediate area of tailings deposition is important to determining the contribution tailings make to elements of concern in Yellowknife Bay. Looking at the broader region allows the assessment of impact to the ecosystem as a whole and ultimately the risk that the various reclamation options have on Yellowknife Bay.

In a region where environmental impacts have been created by historical activities and these impacts come from a variety of sources, no single source should be looked at in isolation when considering reclamation options (e.g. tailings in Yellowknife Bay and upland tailings management facilities).

Successful reclamation is the result of assessing risk and mitigating those risks that are found to be unacceptable.

# 3 Program Objectives and Work Program

## 3.1 Program Objectives

The objectives of this report were to:

- Review a series of 7 reports provided to SRK by DIAND
- Summarize the objectives, results and recommendations from these reports
- Evaluate the results and recommendations
- Provide direction for resolving DIAND's concerns

Of the 7 documents provided to SRK for review two were academic research or written for an academic institution. The remaining 5 were produced by 2 independent commercial consultants and included a work plan, a presentation of the work plan and three engineering/scientific assessment reports. The diversity in the sources of these documents allowed for a broad scope of assessment. However, the tight focus of attention, on the immediate vicinity of the tailings deposition may have restricted the understanding of the overall impact on Yellowknife Bay.

## 3.2 Work Program and Project Team

The project was conducted in March 2004 and included the following tasks:

- Receipt and review of the documents
- Producing document summaries
- Developing recommendations
- Writing the report

The project team consisted of Diana Sollner in SRK's Vancouver office and Ian Horne in the Toronto office.

# 4 Program Results

## 4.1 Summary of Previous Reports

### 4.1.1 A Study of Arsenic Contamination From the Royal Oak Giant Mine, Yellowknife, Northwest Territories

This study was authored by Ian Mace in May 1988 and submitted to the Royal Military College of Canada Department of Chemistry and Chemical Engineering in partial fulfillment of the requirements for the degree of Master of Engineering. The specific goals of the thesis were to:

- Apply methods of arsenic analysis to sediment and tailings
- Determine background concentrations of arsenic in the study area
- Estimate arsenic contamination due to the Giant Mine
- Evaluate the stability and bioavailability of arsenic
- Evaluate the cost of possible reclamation options

The experimental procedure included collecting samples of surface sediments, sediment cores, sediment porewater, tailings and surface water. A total of 35 locations were sampled in and around the Giant Mine in the summer of 1997. The locations were grouped into 4 broad areas, Mine Tailings Baker Creek, Yellowknife River and Yellowknife Bay, and the Beach Area (site of historic tailings deposition).

Surface water samples collected in Yellowknife Bay were below 10 ug/L arsenic with the exception of Stations 4 (55 ug/L) near the discharge of Baker Creek and Station 27 (67 ug/L) in the Beach Area. Both of these stations are in close proximity to surface water drainage from the mine site and directly above arsenic bearing sediments (tailings solids).

Sediment samples collected along the western shore of Yellowknife Bay, closest to the mine site and directly off the City of Yellowknife were all above 100 mg/L. The highest concentrations were found at Station 4 (3140 mg/L), Station 21(1193 mg/L), located directly east of Station 4 and Station 25 (302 mg/L) near the City of Yellowknife, well south and downstream of Stations 4 and 21 also had an elevated arsenic concentration (302 mg/L). Two stations found distant from the mine in Yellowknife River, Station 1 (6.5 mg/L) and on the eastern shore of Yellowknife Bay, Station 23 (88.1 mg/L) had sediment arsenic values below 100 ug/L. These two stations likely represent areas not impacted by the Giant Mine tailings.

Porewater arsenic concentrations in Yellowknife Bay are higher at stations with elevated sediment arsenic concentrations. These elevated porewater arsenic concentrations have been shown by other researchers to have detrimental effects on freshwater invertebrates.

Conclusions from this study include:

- Arsenic found in Yellowknife Bay from the Baker Creek outlet (51 tonnes) and the Beach Area (44 tonnes) is several orders of magnitude less that that contained in the on-land tailings disposal facilities (41,400 tonnes) and in underground storage (~200,000 tonnes)
- Surface water discharge from Baker Creek is responsible for increasing sediment arsenic concentration in Yellowknife Bay
- Arsenic contained in sediments is capable of leaching into the environment
- Sediments at depth in Yellowknife Bay approach background concentrations of arsenic (25 mg/L)

Recommendations from this study for additional work include determining:

- The extent of elevated arsenic in Yellowknife Bay sediments from
    - Baker Creek outlet
    - Beach Area
- Arsenic speciation and their toxicological effects on the local environment
- The current area and extent of tailings originally deposited in the Beach Area

### 4.1.2 Assessment of Back Bay Tailings Deposit, Giant Mine, Yellowknife, NT

This report was prepared by EBA Engineering Consultants Ltd. in January 2001. It is focused on the Back Bay tailings deposit (Mace 1998 described this as the Beach Area tailings). Based on production figures from 1948 to 1951 EBA estimated that 375,000 tonnes of tailings were discharged in this area.

EBA's field sampling program included:

- Drilling 13 boreholes in the tailings, above the waterline to collect tailings samples for analysis
- Conducting a bathymetric and survey program to create site contours, depth profiles and sections

The laboratory testing program included

- Acid base accounting
- Metals analysis on solids and porewater
- Shake flask extraction tests

This test work was conducted to determine:

- Effect of tailings solids on porewater chemistry in short and long term
- Identification of contaminants in tailings
- Evaluation of alternative reclamation measures

The results of the field analysis showed that of the 375,000 tonnes of tailings discharged to Back Bay approximately 35% are found above the waterline. The remaining 65% entered the bay directly or were eroded into the bay over time.
The result of acid base accounting testing showed that the average Neutralizing Potential to Acid Potential (NP/AP) ratio was 119. This ratio indicates a significant excess of neutralization potential and therefore the risk of acid generation from the tailings is very low.

The concentration of metals in tailings solids were similar to natural elemental values except for Sb, As, Pb and Zn. Porewater extracted from the tailings solids showed elevated levels of Sb, As and Zn. Mercury was not found in any samples. While all samples met the NWT Water Board Guidelines and the Water Licence for a grab sample further evaluation of seepage water is required for closure.

Extraction testing on 12 samples showed that dissolved metals in the leachate samples were relatively low with the exception of As (4 samples), Ba (2 samples), Cu (1 sample), Sb (4 samples) and Zn (2 samples).

Reclamation options were provided for beached tailings and submerged tailings. For beached tailings EBA recommended chemical stabilization options such as liners and physical stabilization options such as regrading or removal. For submerged tailings EBA suggested that more sampling may be required to determine if an environmental impact is occurring. If there are impacts they recommend considering covers or dredging. In any case if tailings are to be left *in situ* a risk assessment would most likely be required.

Recommendations for additional work includes:

- Re-sampling submerged tailings porewater
- Analyze tailings solids from submerged tails and compare to beached tails
- Sample the water column over the submerged tails
- Determine the bioavailability of arsenic
- Assess impacts of beached tailings in the gully area
- Assess risks associated with the disturbance of submerged tails vs. in-situ stabilization vs. the status quo

### 4.1.3 Final Report: A Remediation Study on the Arsenic Contaminated "Beach Tailings" of the Giant Mine, Yellowknife, Northwest Territories

This report was written by A. Beattie and A. Easton and submitted to the Management Board, Department of Geological Sciences and Geological Engineering, Queens University, Kingston, Ontario in March 2001.

The purpose of this report was to find a suitable remediation technique for the "Beach Tailings" area. It evaluates whether the site needs remediation and then considers four remediation approaches including dredging, excavation, containment and phytoremediation.

The report includes a review of previous studies and the proposed remediation technologies. The only original work was conducting leaching studies on 7 tailings samples.

The recommended reclamation option was to excavate the tailings and establish plants such as water horsetails, *Equisetum fluviatile*, and pondweed *Potamogeton pectinatus* in the excavation.

Further study was recommended in the following areas:

- Detailed study on the speciation of arsenic
- Hydrogeological study to determine groundwater table and flow direction
- Determine thickness of beach tailings for volume calculations
- Collect additional sediment samples from Yellowknife Bay and Great Slave Lake if dredging to be considered
- Perform regular water quality analysis to monitor arsenic concentrations
- Perform a health study on users of Yellowknife Bay water, measure arsenic concentrations
- Upgrade transportation cost analysis

### 4.1.4 Work Plan for Back Bay Tailings Sampling

This proposal was prepared by Golder Associates for Miramar Giant Mine Limited, Yellowknife, NT in June 2001. It presents a workplan to:

- Assess the biogeochemical conditions of the submerged tailings
- Determine if mitigative measures are warranted
- Evaluate several options

The approach of this proposal was to conduct a geophysical survey, water/sediment sampling, groundwater assessment, sediment toxicity bioassay and benthic invertebrate collection.

### 4.1.5 Environmental Assessment Yellowknife Bay Tailings Giant Mine Yellowknife, NT

This report was prepared by Golder Associates for Miramar Giant Mine Limited, Yellowknife NT in March 2002. The purpose of the report was to access the biogeochemical conditions of the near shore area of submerged tailings and assist INAC in evaluating options for the long term management of the tailings.

The objectives of the study were to:

- Collect and analyze a limited number of sediment and pore water samples and conduct some bioassay tests
- Investigate local hydrogeology into characterize groundwater flow
- Recommend potential mitigative strategies

The achievement of these objectives was demonstrated by having:

- Delineated footprint and defined approximate volume of submerged tails
- Determined flux and flows of groundwater at the Beach area
- Collected and analyzed samples of near-shore tailings for selected parameters
- Conducted toxicity tests and benthos evaluations to determine if any adverse affects

Based on the studies completed a conceptual model of the study area was developed. The model showed that:

- Groundwater flows through fractured bedrock with minor flow through tailings, which results in upward flow through the beach tailings 50 to 75 m beyond the shoreline. It is suggested that the groundwater carries As to the lake.
- Primary zone of submerged tails cover ~50,000 $m^2$ and the zone of redistributed tails to the north covers 50 to 60,000 $m^2$, the total volume of tails is ~45,000 $m^3$
- There are 2 primary sources of arsenic to Yellowknife Bay – the submerged tails (~16 g/day) and seepage from on-land tailings containments (~552 g/day)
- Lake sediments along the foreshore of Yellowknife Bay (near the mine site) are predominantly tailings. As such, use of the area for fish spawning and rearing habitat is unlikely, benthos demonstrated adverse affects to survival and growth in the primary and peripheral areas of tailings deposition

Management options for the submerged tailings were considered with the goal to minimize ongoing contamination following reclamation. Five options were considered and of these two were felt to warrant further evaluation. The two best options were:

- Closure of South and Central Tailings Ponds
  - These are the source of the greatest flux of As to Yellowknife Bay (~552 g/day)
  - Tailings in the bay would be left as is, with continued monitoring
- Risk Assessment
  - Using environmental risk assessment principals combined with a cost/benefit decision analysis

In summary the results of this study show that the submerged tailings in Yellowknife Bay:

- Have a LOW impact on the environment in Yellowknife Bay
- Water column above the tailings MEETS water quality guidelines for aquatic life

The recommendation from the report was to conduct a risk assessment with the local stakeholders to establish and confirm long-term goals for the remediation. According to Golder Associates the best outcome would be to agree and accept the most appropriate technology based on the available information and the appropriate regulatory standards and policies

### 4.1.6 Call-up # 01-11, Restoration of Back Bay Historical Tailing Area, Construction of Beach Protection, Miramar, Giant Mine, Yellowknife, NT

This report was prepared by Golder Associates for Miramar Giant Mine Limited, Yellowknife NT in March 2002. The purpose was to detail activities undertaken to improve upland drainage works and construct beach protection works in October and November 2001.

A drainage ditch and drainage channels were constructed and/or upgraded from Dam 7 to the beach. These drainage works were designed and built to pass the 1:100 year event.

The tailings scarp on the beach was flattened to a 4 Horizontal : 1 Vertical slope. A geotextile was placed over the recontoured area (~11 m wide) and covered with gravel. Course rock or rip rap was then placed over the gravel.

### 4.1.7 Draft Report on Environmental Assessment, Yellowknife Bay Tailings, Giant Mine, Yellowknife NT

This report was prepared by Golder Associates for Miramar Giant Mine Limited, Yellowknife NT in January 2004. It reports on the first of two monitoring programs to evaluate historical mine tailings in Yellowknife Bay. These monitoring programs were recommended in the report described in Section 4.1.5 above.

The reclamation activities described in Section 4.1.6 above, were conducted between the time of the monitoring program described in Section 4.1.5 and the current report. This reclamation may have resulted in a decrease in levels of contamination reporting to the submerged tailings area.

The objectives of the study were to:

- Collect and analyze surface water, sediment and pore water and conduct some bioassay samples
- Collect and analyze groundwater samples from 6 wells,
- Confirm groundwater direction and flow
- Compare with data collected in 2001
- Assess fish utilization of submerged tails area

The achievement of these objectives was demonstrated by having:

- Collected groundwater samples to verify chemical flux of arsenic and flow paths described in 2001
- Evaluated contaminant levels in sediment, pore water, surface water and sediment/surface water interface at the same locations as in 2001
- Evaluated whether present conditions continue to affect the benthos community
- Conducted fish presence / absence investigation
- Conducted hydrogeological evaluation of lake substrate for flux of seepage in submerged tails area

These studies were compared to the results of an earlier study described above in Section 4.1.5 and were found to support the proposed conceptual model. The new studies showed:

- Water quality and hydrogeological results support results of the 2001 sampling study
- Flux of arsenic to Yellowknife Bay from the South and Central Tailings Impoundments was estimated at 198 g/day compared to the 2001 estimate of 552 g/day
- Flux of arsenic to Yellowknife Bay from the submerged tails was 20 g/day compared to the 2001 estimate of 16 g/day

- Therefore the contribution of arsenic to Yellowknife Bay from on land groundwater sources is an order of magnitude higher than that from the submerged tailings
- Lake sediments along the foreshore of Yellowknife Bay (near the mine site) are predominantly tailings. As such the use of the area for fish spawning and rearing habitat is unlikely
- Limited benthos bioassays demonstrated adverse affects to survival and growth

In summary the results of the study show that:

- Submerged tailings have a LOW impact on the environment in Yellowknife Bay
- Water column above the tails generally satisfies guidelines for aquatic life
- Water quality in groundwater show statistically significant improvement
- Elevated metal levels in sediment affects colonization by benthic organisms

The report recommends that a third monitoring event be held in 2005, following the approach taken in 2001 and 2003. However, changes in the sediment metal concentrations and their subsequent impact on benthos survival and growth are unlikely to change by 2005 and so further sampling of sediment is not recommended.

# 5 Conclusions

The study by Mace (1998) identified several important issues with respect to the potential sources of arsenic to Yellowknife Bay. It clearly showed that the on-land tailings disposal facilities contain several orders of magnitude more arsenic than the tailings in Yellowknife Bay. Therefore, controlling contaminant release from these facilities is vitally important to managing potential long term impacts of arsenic on Yellowknife Bay. This was confirmed by Golder (2002) and Golder (2004). It also identified Baker Creek as a source of arsenic. Interestingly, none of the later studies appears to have dealt with discharges of arsenic contaminated water from Baker Creek or the tailings deposited at the mouth of the creek. The studies by Golder Associates focused on the Beach Tailings area further north from the mouth of Baker Creek and the unnamed drainage that discharges to the Beach Tailings area.

Mace (1998) also identified that arsenic in sediments is capable of leaching into the environment. This result was confirmed by later studies (EBA, 2001; Beattie and Easton, 2001; Golder 2002). However, he was also the only one who looked at arsenic concentration in sediments in the broader Yellowknife Bay area and concluded that sediments at depth (away from the shoreline) approach background concentrations of arsenic. This means that the impacts of arsenic in sediments do not affect the entire Yellowknife Bay area.

EBA (2001) completed a study to determine the area and extent of tailings deposited in the Beach Tailings area, which addressed one of the recommendations in Mace (1998). In addition they determined that the risk of acid generation from the Beach Tailings area was very low. Remediation options were provided for both the beached and submerged tailings. The remediation option for the beached tailings was acted on as reported in Golder (2002b). The remediation option for the submerged tailings suggested that more sampling may be required and a risk analysis be performed. Golder (2002) and Golder (2004) present the results of additional testing and recommend a third program in 2005.

Beattie and Easton (2001) completed what was mostly an academic study of remediation techniques for the Beach Area. They recommended excavation of the beached tailings and planting of horsetails

and pondweed in the excavation. In addition, they made a number of good recommendations that were acted on by Golder Associates in their later studies.

Golder (2002) and (2004) developed and undertook a comprehensive monitoring program focused specifically on the beached and submerged tailings in the Beach Tailings area. Their objectives were to obtain a clear understanding of the environmental impacts of the tailings deposit and to develop a conceptual model of the study area. While they did identify impacts from the tailings, particularly on the growth and survival of benthic organisms, their overall conclusions were that submerged tailings:

- Have a LOW impact on the environment in Yellowknife Bay
- The water column above the tailings generally SATISFIES guidelines for aquatic life

Golder (2002) and EBA (2001) concluded that the best outcome for all concerned people or groups would be to:

- Conduct a risk assessment with the local stakeholders to establish and confirm long term goals for the remediation and to reach agreement on the most appropriate technology based on available information and the appropriate regulatory standards and policies

# 6 Recommendations

Most of the studies discussed in this report have focused their efforts on specific areas of known or suspected impact in Yellowknife Bay. It is understood by the author of this report that concerns expressed over environmental and human health impacts from the Giant Mine extend to include the greater Yellowknife Bay area. As a result, conclusions and recommendations in these reports, which are directed to very specific and limited areas, are interpreted to be indicative of the greater Yellowknife Bay. This is an unfortunate, but not unusual circumstance.

The main conclusion of this report is to conduct a risk assessment with the local stakeholders (communities of interest) and confirm long term goals for the remediation and to reach agreement on the most appropriate technology based on available information and the appropriate regulatory standards and policies. This process may be enhanced by conducting more monitoring. Therefore, it is recommended that any further monitoring studies include a consideration for the greater Yellowknife Bay area.

With respect to water, sediment and biological sampling a zone of influence needs to be established. This can be determined by taking samples at increasing distance away from the areas of known or suspected impact until, if possible, a background or reference area is found. Sample locations should be established on a bathymetric chart of Yellowknife Bay and include stations that represent deep water, mid-depth water and shallow water areas across the width and breadth of the bay.

It may be valuable to establish a contour map of thickness of tailings deposition in greater Yellowknife Bay. Outside the visible contours of tailings deposition a chemical signature may be established. Figures in Mace (1998) show results of sediment arsenic concentrations at a number of locations in Yellowknife Bay. Any further monitoring of sediments should consider and compare to these historical locations. Tailings thickness may be determined by coring. Beyond the visible boundary a zone of chemical influence may be established. While Mace (1998) suggests that a background concentration of arsenic in sediment in Yellowknife Bay is 25 mg/kg it may be appropriate to establish a higher estimate of chemical influence by tailings. For example, 100 mg/kg

could be indicative of "salting" of natural sediments by tailings. In a survey of sediment arsenic concentrations any results greater than 100 mg/kg would indicate a chemical influence by tailings.

It has been shown that sediments, composed almost entirely of tailings, impacts the growth and survival of benthic organisms. It may be worthwhile determining at what thickness of tailings deposition or what concentration of arsenic in sediments these impacts are not observed. This would allow the quantification of the aerial extent of biological impact by tailings and arsenic in Yellowknife Bay.

Based on the reviewed reports water quality monitoring in Yellowknife Bay appears to be infrequent and separated by periods as long as two or three years. Regardless, results are compared to each other and conclusions are stated. Does this variability in results represent "real" changes? It is important in all monitoring programs to determine the instantaneous variability that can occur at any station using any sampling protocol. If further monitoring is conducted it is recommended that a select group of stations and sampling protocols be repeated on three separate occasions during the period that the monitoring program is being run. For instance, the water column above the submerged tailings could be sampled three times on three separate days at the same location and depths. The results would be compared and the variability representative of the natural and normal flux in the area. This would help to distinguish real from perceived changes in water quality.

Since the cessation of tailings deposition in the Beach Tailings area the tailings have eroded and spread over an area at least twice the size of the original footprint. Based on this historical movement and the recent physical reclamation of the beached tailings it may be appropriate to estimate the rate of erosion and the extent of the spread of materials over the next 50 to 100 years.