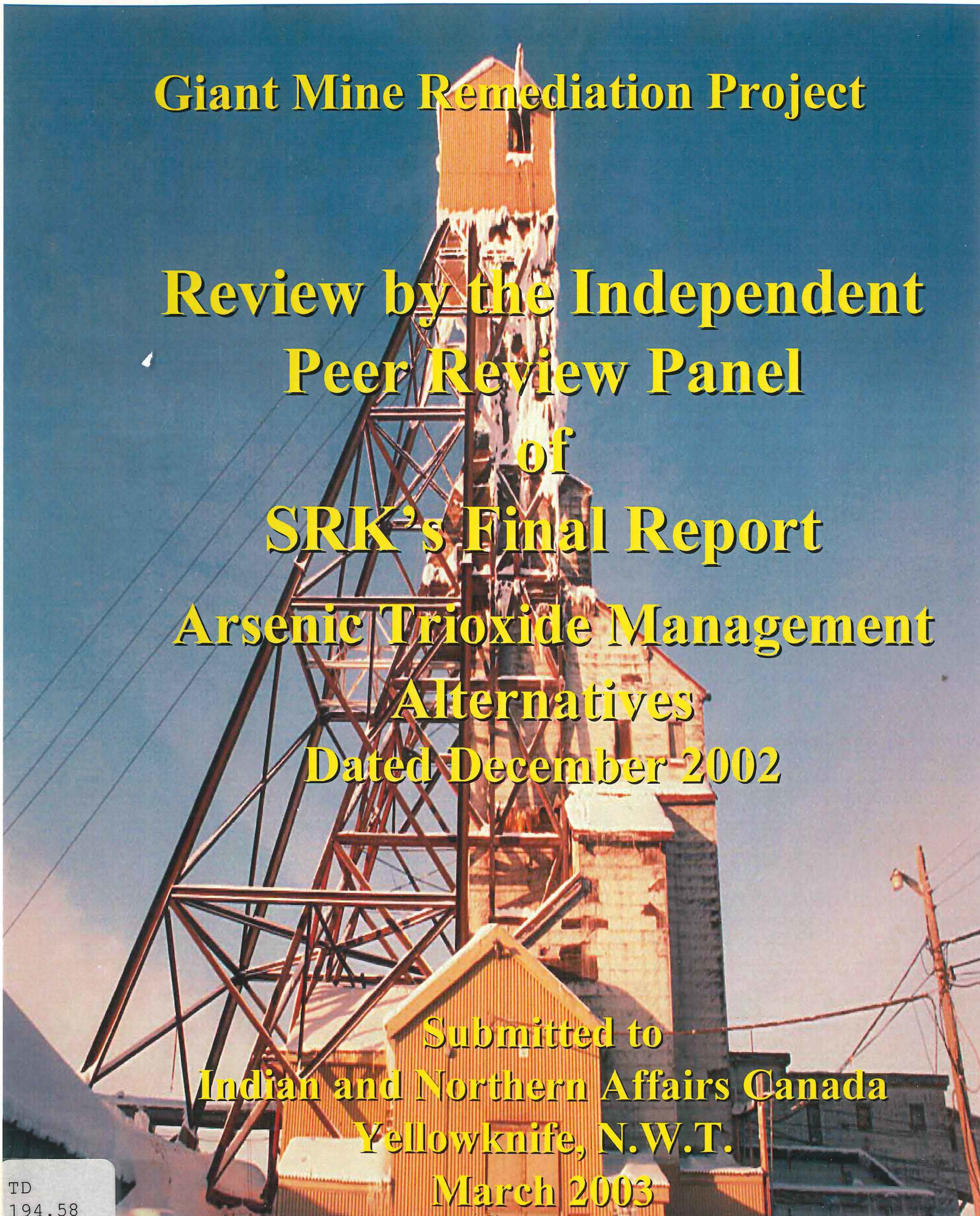

Giant Mine Remediation Project

Review by the Independent Peer Review Panel of SRK's Final Report

Arsenic Trioxide Management Alternatives

Dated December 2002

Submitted to
Indian and Northern Affairs Canada
Yellowknife, N.W.T.
March 2003

Independent Peer Review Panel

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REVIEW OF SRK'S FINAL REPORT DATED DECEMBER 2002 'ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES' GIANT MINE, YELLOWKNIFE, N.W.T.

BY

INDEPENDENT PEER REVIEW PANEL

PREPARED FOR

THE GIANT MINE REMEDIATION PROJECT TEAM
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

Submitted to:

Department of Indian Affairs and Northern Development
Yellowknife, NT

March 2003

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SUMMARY

This report covers the findings of the Independent Peer Review Panel (IPRP) formed by the Department of Indian Affairs and Northern Development (DIAND) to carry out a technical review of the work of a team headed by SRK Consulting Inc. (SRK), Technical Advisor to DIAND, on the study of management alternatives for arsenic trioxide dust stored underground at the Giant Mine in Yellowknife, NT.

SRK produced a comprehensive Draft Final Report for DIAND dated September 2002 entitled 'Study of Management Alternatives for Giant Mine Arsenic Trioxide Dust'. The IPRP were tasked with conducting a technical review of this draft document. Following this review the IPRP met with DIAND and SRK in Yellowknife and again in Vancouver. Through these meetings, the IPRP had an opportunity to visit the Giant Mine and to interview SRK on its approach and findings. The IPRP used the Vancouver meeting to pass its comments and recommendations on the draft report to DIAND and SRK, providing an opportunity for further work and modification of the report. SRK completed its Final Report and issued it in December 2002. The IPRP presents, in this Report, its review of the December, 2002 SRK Final Report and Supporting Documents.

It should be noted that the phased approach adopted for the technical peer review process was warranted because of the technical complexity and multi-disciplinary nature of the project and the complete lack of precedent for the overall remedial works called for in this instance. The SRK Final Report, in fact, incorporates virtually all of the IPRP's technical review comments on the September 2002 version. The IPRP considers that the December 2002 version of the Report is appropriate for the presently planned level of the studies. Throughout this report the IPRP has identified many instances where additional work is considered necessary. However, such work is generally seen as following the public consultation process and directed at either generating the Project Description, or providing data for detailed design, construction planning, and the implementation phase. The IPRP is cognizant of the fact that the SRK December 2002 Report and Supporting Documentation do not represent the final assessment, nor is it intended to be a basis for detailed engineering design, but rather to support an evaluation of alternatives.

The geological, hydrogeological, water chemistry and arsenic release characterizations of arsenic source areas completed by SRK are thorough and well done. They are of sufficient scope and detail to adequately support the current evaluation of management alternatives for arsenic trioxide dust at Giant Mine. The identified areas for improvement of source area characterization can be addressed in subsequent evaluations. It is recognized that numerous additional studies will be needed to refine long-term arsenic release estimates in support of detailed design, environmental assessment and permitting activities.

The SRK Final Report recommends that at least two management alternatives (from among a short list of seven) be taken through to further public consultation, and that they should include the best 'in-situ' alternative and the best 'ex-situ' alternative. The IPRP is in general agreement with this recommendation. The best 'in-situ' (leave it underground) alternative identified by SRK utilizes ground freezing techniques to transform the rock immediately surrounding a given storage stope (or chamber) together with the arsenic trioxide dust in storage, into a frozen block.

The best "ex-situ" (take it out) alternative identified by SRK involves extracting the arsenic trioxide dust, bringing it to surface, encapsulating the dust by mixing the dust with cement (or possibly bitumen) and then placing the encapsulated material into a secure landfill to be located on surface. The IPRP agrees with SRK's selection of these two generic management alternatives.

As a general statement, the IPRP agrees with the direction taken by SRK in narrowing down the potential arsenic trioxide management alternatives, and in the selection of two preferred alternatives to be taken through to public consultation. However, there are a number of issues that the Panel recommends be given further consideration as the Project proceeds into the Project Description Phase:

1. DIAND should maintain an open attitude with respect to new technologies that develop in the future to take advantage of any that are proven and could provide technical improvements and/or cost savings to the basic alternative selected.

2. DIAND should integrate the planned surface remedial activities related to mine closure with the proposed arsenic trioxide management undertakings.

3. DIAND should consider carrying out verification testing, (such as perhaps a test demonstration of the ground freezing option on one of the smaller arsenic filled chambers).

4. DIAND should develop in greater detail, descriptions of the tasks and schedules that will be involved in producing designs, drawings and specifications, and construction planning for the management alternative designated for inclusion in the Project Description as discussed in the report. Further consideration of precedent in terms of mining and construction methodology; indirectly-related precedent applications; experience with toxic waste disposal, and the like should be made for reference in developing designs, specifications, construction planning and schedules, and so forth.

5. Among the issues, which are prominent in the assessment of the various alternatives, are the matters of the degree to which the arsenic trioxide can be recovered, and the extent to which arsenic contamination has permeated into the bedrock surrounding the stopes/chambers. There is a considerable uncertainty and importance to the numerical values in this regard. The 2% non-recoverable assumption needs to be better quantified.

6. The IPRP challenges the use of the words "in perpetuity" used by SRK in respect to the duration of maintenance of the remediation measures. Whereas the IPRP agrees that monitoring should continue indefinitely, it recommends that DIAND continue to strive towards an end result that will produce acceptable environmental conditions (such as water quality) in the long run, with resultant properly justified discontinuation of maintenance requirements.

7. The IPRP is cognizant of the importance of the public consultation process in the selection of the most suitable management alternative from among the candidates. It looks forward to participation in future in the process leading to the development of a final Project Description.

1.0 INTRODUCTION

This report covers the findings of the Independent Peer Review Panel (IPRP) formed by the Department of Indian Affairs and Northern Development (DIAND) to carry out a technical review of the work of SRK Consulting Inc. (SRK), Technical Advisor to DIAND, on the study of management alternatives for arsenic trioxide dust stored underground at the Giant Mine in Yellowknife, NT.

SRK produced a comprehensive Draft Final Report for DIAND dated September 2002 entitled 'Study of Management Alternatives for Giant Mine Arsenic Trioxide Dust', which included a main Report and two Volumes of Supporting Documentation. At DIAND's request, the IPRP were tasked with conducting a technical review of this draft document. Following this review the IPRP met with DIAND and the SRK team in Yellowknife and again in Vancouver. Through these meetings, the IPRP had an opportunity to visit the Giant Mine and to question SRK on its approach and findings. The IPRP used the Vancouver meeting to pass its comments and recommendations on the draft report to DIAND and SRK, providing an opportunity for the SRK report to be modified.

The results of the IPRP's review of the September draft report were compiled by the IPRP as a Progress Review Report, a copy of which forms Appendix A to this Report.

SRK completed its Final Report and issued it in December 2002. The IPRP presents, in this Report, its review of the December 2002 SRK Final Report and Supporting Documents. Subsequent to receiving the SRK December, 2002 Report, the IPRP met in Toronto on January 8, 2003. In addition, seven of the nine IPRP Members participated in a Technical Workshop on Giant Mine Arsenic Trioxide Management Alternatives in Yellowknife, NWT on January 14-15, 2003. The IPRP Presentation to the Workshop was a summary statement of its technical review of the SRK Reports. This presentation formed the basis for the main text of the report, which follows herein.

The phased approach to the technical peer review process adopted on this Project was warranted because of its technical complexity and multi-disciplinary nature, and the lack of precedent for the overall remedial measures required in this instance. This phased approach enabled DIAND to consider the peer review comments progressively and, as DIAND saw fit, arrange for SRK to act on the review comments.

The IPRP comprises nine recognized experts whose qualifications and experience collectively cover the various specialty fields important to the subject study of management alternatives, namely, geotechnical, mining, mineral processing and environmental engineering, as well as toxicology, hydrogeology, risk assessment and public health. The members of the IPRP are: C.O. Brawner; Laurie H. M. Chan; Lawrence J. Connell; Steve E. Hrudey; Jean-Marie Konrad; Robert E.J. Leech; M.A.J. (Fred) Matich; Craig Nowakowski; and Kenneth G. Raven. The IPRP Members' credentials and abridged curriculum vitae are included as Attachment 'B" to Appendix A of this report, which also presents the IPRP's terms of reference. In the course of selecting the members of the IPRP, DIAND invited suggestions from stakeholder communities and the interested local public.

An important aspect of the terms of reference of the IPRP (and the predecessor Review Team of Larry Connell and Fred Matich) is that an independent stance must be maintained in respect to the subject reviews of the SRK Reports. In practice, the IPRP (and predecessor Review Team) were provided with every opportunity to function effectively in an independent role. The IPRP made a variety of requests which included briefings by DIAND and SRK, site visits, access to all available pertinent documentation, and working meetings of the IPRP as a group. These requests were granted by DIAND. As part of this process a number of relevant historic documents relating to the past management of arsenic trioxide baghouse dust and tailings were transferred to DIAND in Yellowknife.

In addition to participation in the January 14-15, 2003 Technical Workshop, the IPRP has indicated its willingness to be included in future consultation or workshops.

At an early date, DIAND brought together a panel of experts in the field of hydrogeology (chaired by Ken Raven). This Hydrogeology Experts Panel was tasked with reviewing the available data on the hydrogeology of the Giant Mine and with advising and assisting DIAND in carrying out appropriate studies and investigations to advance this key area of understanding. Similarly, at an early date, DIAND hosted several technical workshops in Yellowknife to which it invited key engineers and scientists to help identify the component technologies and/or processes that could play a role in development of an overall management alternative for the arsenic trioxide baghouse dust stored underground at the Giant Mine.

There is merit in holding additional working sessions that would see appropriate technical experts brought together to further address key aspects of the selected management alternative following public consultation and in advance of finalizing the Project Description.

Throughout the report, the IPRP has identified many instances where additional work is considered necessary. However, such work is generally connected either with the Project description pertinent to the selected alternative or for providing data for detailed design, construction planning, and the implementation phase.

2.0 PROCEDURE

The IPRP Progress Review Report in Appendix A includes (in the introductory section) a detailed account of the circumstances whereby (i) DIAND assumed responsibility for the preparation of an arsenic trioxide Project Description for the Giant Mine, and (ii) DIAND retained as Technical Advisor a team headed by SRK and including SENES Consultants Ltd.; Lakefield Research Ltd., and HG Engineering Ltd. The Progress Review Report also describes the relevant activities of the IPRP and of a two-member team consisting of Lawrence J. Connell and M.A.J. (Fred) Matich who were retained to carry out an independent technical review of a pre-feasibility level version of SRK's Draft Report released in May 2001.

In reviewing the SRK Final Report dated December 2002, the IPRP notes that it incorporates virtually all of the IPRP's technical review comments on the September 2002 version. The format used herein, by way of commenting on the December 2002 SRK Report, has therefore been to highlight the main items previously commented on and to include a number of additional points on other specific matters arising out of reading the December, 2002 Report and presentations by the IPRP at the January 14-15, 2003 workshop in Yellowknife. It is essential therefore that Appendix A hereto be read in conjunction with the main text.

The IPRP members have carefully compared the September draft report with the December final report and consequently where Figures and Tables are referenced in this report they refer to the Figures and Tables as they appear in the December final report.

It should be noted that the IPRP's technical review comments on the SRK Draft Reports and Supporting Documents have been made largely at concept level. Where SRK has elected to act on the IPRP's review comments, the responsibility for development of technical details appropriate for the level of this study has rested completely with SRK.

As in the case of the September 2002 Draft SRK Report, the IPRP considers that the December 2002 version of the Report is appropriate for the presently planned level of the studies. The IPRP also reiterates its cognizance of the fact that the SRK December 2002 Report and Supporting Documentation does not represent the final assessment, nor is it intended to be a basis for detailed engineering design, but rather to support an evaluation of alternatives and a presentation of preferred options considering a balanced assessment of several alternatives.

The IPRP has been advised by DIAND that it is DIAND's intent to continue to utilize the services of the IPRP as this Project moves through public consultation, through selection of a management strategy, through development of a detailed Project Description, through environmental review and into implementation. Consequently the IPRP recognizes that this report is likely to represent only the first report in its ongoing review of the elements of this Project.

As indicated in Section 4.0, the main text of this report is organized under six key headings: (a) Source Area Characterization, (b) Arsenic Pathways and Assessing Human and Ecological Risks from Arsenic Trioxide Dust Storage, (c) Arsenic Trioxide Management Alternatives, (d) Arsenic Dust Isolation by Ground Freezing, (e) Summary of IPRP Recommendations, and (f) Conclusions.

3.0 REVIEW OF SRK SEPTEMBER 2002 DRAFT REPORT

As indicated in the introductory section to this report, DIAND arranged for the independent peer review process to be carried out in three main phases. A phased approach was warranted because of the technical complexity and multi-disciplinary nature of the Project and the complete lack of precedent for the overall remedial works of the type called for in this instance. The main phases were: **(i)** at a prefeasibility level based on an SRK pre-feasibility report released in May 2001 (DIAND arranged for both a two person review team of Connell & Matich and for the Hydrogeology Experts Panel to conduct independent reviews of this report), **(ii)** at a September 2002 draft report stage, and **(iii)** by reference to the SRK Final Report dated December, 2002. This process has resulted in virtually all of the recommendations by the Review Team, the Hydrogeology Experts Panel and the IPRP on the prefeasibility and draft level reports respectively, being incorporated into the SRK Final Report. It also set the stage for the way that the IPRP packaged this report. To be consistent with the phased review approach, and for convenience of the reader, the IPRP is presenting its review comments on the SRK Final Report in Section 4.0 herein, and summarizing briefly in this Section its review comments on the predecessor reports.

3.1 Recommendations arising from the January 2002 review by Connell and Matich were as follows:

The following summarizes the main review comments made by Connell and Matich following their review of the May 2001 SRK Pre-Feasibility level report.

i. Significant gaps exist in the database used. Additional data must be obtained in a number of important areas such as the historical development of the mine site as a whole, and the permafrost (cold regions) issues, both natural and man-made influences.

ii. There must be a better understanding of the arsenic trioxide in storage in an engineering sense.

iii. The best available successful precedent (albeit necessarily not directly-related) should be accessed to a greater extent.

iv. DIAND has produced some excellent 3-D models for several of the storage stopes and chambers. Similar models should be made selectively for other vaults.

v. Additional consideration needs to be given to issues relating to closure of the site.

vi. Secure storage in the Yellowknife region will likely be a feature of the selected management alternative.

vii. Extraction of the arsenic trioxide will leave significant residual arsenic contamination behind and make long term monitoring, care and maintenance mandatory.

viii. There are no prospects for marketing the arsenic trioxide in the foreseeable future.

ix. DIAND should focus more on the in-situ management alternatives of freezing and permanent dewatering. It should also carry out additional work on a fall back option such as extraction from the vaults and processing or stabilization into a storable product.

x. The independent technical Review Team should be expanded to incorporate expertise in other disciplines.

xi. Increased public/stakeholder/community consultation activity associated with the development of a management alternative is recommended.

3.2 Recommendations arising from the June, 2001 review by the Hydrogeology Experts Panel were as follows:

The following summarizes the main recommendations arising out of the review conducted by the Hydrogeology Experts Panel of the May 2001 SRK Pre-Feasibility Study report.

i. Tailings backfill and waste rock need to be investigated and characterized as potential long-term sources of dissolved arsenic. The necessary program should focus on characterization of drainage waters and solids for both tailings backfill and waste rock.

ii. The available data from the 1990 surface exploratory drilling program needs to be reviewed and assessed for possible incorporation into a surface-based groundwater monitoring program.

iii. A surface-based groundwater monitoring network and program needs to be established within and in close proximity to Giant Mine. The program should use existing exploration boreholes and newly drilled boreholes completed with multi-level monitoring casings. It should focus on characterizing the hydrogeologic properties of major faults east and west of Giant Mine that are potential groundwater migration pathways and provision of baseline water quality data for longer term compliance monitoring purposes.

iv. The existing underground water sampling and chemical testing program should be continued and expanded. In particular, the program should focus on sampling the area of the arsenic chambers and deeper in the Mine below the 750 ft level.

v. A water balance of the Northwest Tailings Pond should be completed.

vi. A flux-weighted and constrained arsenic mass balance should be undertaken to improve the estimates of arsenic release under mine reflood scenarios. The existing area-weighted arsenic mass balance contains large uncertainties.

vii. Investigations of the arsenic dust storage chambers should be completed to provide better information on arsenic releases under existing and Mine re-flood scenarios.

viii. Monitoring of surface water and sediment in potential receiving environments (e.g., Baker Creek, Back Bay, Great Slave Lake) should be undertaken to fulfil a long-term regulatory compliance need and to provide background data for subsequent risk assessments.

ix. Continue the development of 3-D representations of the Mine workings, arsenic chambers, geology, drillholes and sampling locations.

x. Commence a program to study arsenic transport and attenuation processes in groundwater at Giant Mine. The existing assessments conservatively assume arsenic is not attenuated, but little is known about arsenic transport and attenuation mechanisms in the Mine setting.

xi. Continue the development and refinement of conceptual models for groundwater flow and arsenic transport at Giant Mine.

xii. Enhance the screening level risk assessment, by considering more detailed and comprehensive characterization of arsenic sources, migration pathways and receptors.

3.3 IPRP Review of the SRK Final Draft Report dated September 2002

At DIAND's request the IPRP conducted a review of the draft version of the SRK Final Report that was dated September of 2002. Following its review the IPRP prepared a Progress Review Report providing both DIAND and SRK with substantial input on the contents and direction of the draft. A copy of this Progress Review is attached as Appendix A.

In preparation for the January 2003 workshop hosted by DIAND in Yellowknife, the IPRP prepared a summary of its findings following the Panel's review of the September 2002 Draft Report. This summary is included with this report as Appendix B. The objective was to aid the Panel members in comparing the recommendations put forward by the panel following its review of the September 2002 SRK Draft Report with the content of the December 2002 SRK Final Report. Appendix B should nevertheless be read in conjunction with this report.

DIAND have acted on most of the recommendations made by the IPRP following this earlier review and this is reflected in the SRK Final Report dated December 2002. Consequently for the purposes of this report it is the opinion of the IPRP that the September draft is now redundant and that all focus should be placed on the Final SRK management alternatives report dated December of 2002.

4.0 REVIEW OF SRK DECEMBER 2002 FINAL REPORT

4.1 SOURCE AREA CHARACTERIZATION

Source area characterization is the definition of the nature and distribution of various underground arsenic sources and the local hydrogeologic and geochemical conditions near the sources that will control arsenic releases into and from Giant Mine under both current and future re-flood scenarios. Our review of the adequacy of the source area characterization work undertaken at Giant Mine by the Technical Advisor (SRK Team) considers the following elements: historical background and mine setting, geology, hydrogeology, water chemistry and estimates of arsenic release rates.

4.1.1 Historical Background and Mine Setting

Source area characterization work at Giant Mine and peer reviews of such work predate SRK and the IPRP and it is useful to briefly summarize these undertakings to provide context to the current review. Fracflow Consultants Inc. completed initial hydrogeological and geochemical investigations of arsenic sources in Giant Mine in 1997 to 1999 on behalf of DIAND. Subsequent source area characterization work was undertaken by SRK following their selection as Technical Advisor in early 2000. Expert reviews of source area characterization work were completed in March 2000 and September 2001 by an independent panel of hydrogeology experts. These expert reviews identified for DIAND and SRK, hydrogeologic issues and information needs, and directions and recommendations for future work. The results of these workshop meetings are summarized in two reports prepared by Duke Engineering & Services (Canada), Inc: Giant Mine Hydrogeology Experts Group Meeting, November, 30, 2000, and Giant Mine Hydrogeology Experts Group Meeting #2, September 26, 2001.

Giant Mine is situated within permafrost and fractured bedrock, two site characteristics that are important to source area characterization. Mining activity in the form of extensive underground workings, open pits, surface tailings ponds and numerous deep exploration boreholes, has significantly changed the original setting of the Mine. Permafrost has been degraded and there is enhancement of surface water flow into the Mine and vertically through the Mine envelope to the lower Mine levels.

4.1.2 Geological Characterization

SRK's characterization of the geology of the Mine and surrounding area correctly focuses on the mapping of structural discontinuities including faults and fracture zones. Regional bounding faults (e.g., West Bay, Akaitcho Faults), regional faults (e.g., 3-12, Rudolph and Townsite Faults), regional litho-structural domains, and local faults are identified and characterized based on available surface mapping. The limited information on hydraulic properties of the faults is also summarized. The geological characterization completed by SRK provides a suitable framework for later hydrogeological and geotechnical assessments of arsenic source areas.

Several areas for further work in the geological characterization of arsenic sources were identified. The current SRK characterization lacks a depth component and more effort should be focussed on incorporating the underground structural information from the Mine to develop a more complete 3-D representation. The IPRP are aware that DIAND has already initiated activities to meet this need through its support of the re-logging of mine drill core under the Extech III Project and through support of the 3-D structural interpretation work of James Siddorn (PhD thesis). Such data will be available to provide an enhanced structural framework to support detailed design. Although Yellowknife is situated in a region of low seismic activity, for completeness, the issue of the potential for seismic events to affect the long-term performance of existing underground arsenic storage chambers and stopes, purpose-built storage chambers, or any landfill constructed on surface needs to be addressed as discussed later.

4.1.3 Hydrogeological Characterization

The hydrogeological characterization of the Giant Mine summarizes the available groundwater data for the mine, looks at water flows into and through the mine, and develops a conceptual model of current and future water flows through the arsenic sources under various mine re-flood scenarios. SRK have developed a reliable mine water flow conceptual model and balance that is supported by precipitation data, by direct underground flow measurements and by interpretation of groundwater geochemical and isotopic data. The partitioning of vertical and horizontal flows through underground arsenic sources is also reliable and provides a rational basis for estimating arsenic loading under various re-flood scenarios. Estimates of bulk rock hydraulic properties from interpretation of deep groundwater inflows and from surface-based borehole drilling and testing are comparable and consistent with expectations. Initial results from the hydraulic testing and pressure monitoring completed, suggest that regional faults may be barriers to groundwater flow. The hydrogeological characterization of the Giant Mine completed by SRK is well done, addresses many of the recommendations of the Hydrogeology Experts Panel, and is a substantial improvement over earlier efforts. The understanding of groundwater flows around and within Giant Mine, while always subject to improvements with the collection of additional hydrogeological data, is considered adequate to support the current comparative evaluation of management alternatives for arsenic trioxide dust at Giant Mine.

Areas for recommended further work to characterize the hydrogeology were also identified. Additional surveys of Mine water inflows should be completed to confirm and refine existing interpretations, water balances and arsenic release estimates, particularly on some of the long flow paths and near the arsenic chambers, during the spring freshet. There is little to no integration of the structural geology information with hydrogeological information. These data sets need to be integrated or at least jointly assessed to determine if there are linkages between structural geology and groundwater flow and the shape and extent of the Mine drawdown cone. Expansion of the surface-based groundwater monitoring program should proceed to assess structural controls on the Mine drawdown cone and to provide down-gradient monitoring locations for establishing groundwater quality for future compliance monitoring purposes. The further work required to characterize hydrogeology is not considered to be a "show stopper" by the Panel but as something that should be done for final design purposes once a management alternative has been selected.

4.1.4 Water Chemistry Characterization

Characterization of water chemistry at Giant Mine was completed to provide an understanding of the sources of water inflow to the Mine, to quantify the concentrations of different underground arsenic sources, and to develop water and arsenic mass balances. The SRK work in this area is comprehensive, well done and responsive to many of the recommendations of the

Hydrogeology Experts Panel. Sources of water inflow to the Mine have been reliably defined and characterized. All of the important arsenic source concentrations appear to have been characterized based on laboratory testing and substantiated based on underground seep sampling. The source concentrations of 0.05 mg/L for bedrock and mine walls, 5 mg/L for backfilled tailings and Northwest Tailings Pond inflows, and 4,000 mg/L for arsenic trioxide dust appear credible and supportable. Water and arsenic balances close with an acceptable degree of accuracy and show that more than 90% of the arsenic load in the main Mine sump derives from the area of the Mine influenced by the arsenic dust storage chambers and stopes.

Areas for recommended further work to characterize water chemistry were identified. Additional work should be done to refine the arsenic loading calculations by increased sampling at additional sampling points, in particular assessing the effects of old exploration boreholes and direct releases from arsenic dust chambers and stopes. There has been no work undertaken on assessing the fate of arsenic in natural groundwater systems. Existing assessments have considered arsenic to be a conservative and non-reactive chemical. Natural attenuation mechanisms for dissolved arsenic should be investigated. Consideration should also be given to partitioning the high concentration arsenic water from the Mine for pre-treatment. This could lead to efficiencies in the treatment process and could potentially save on treatment costs.

4.1.5 Estimates of Arsenic Release

The estimates of arsenic release are important calculations that integrate the results of several source area characterization efforts. Long-term arsenic releases and loadings are calculated for surface sources, underground sources and all sources including the water treatment plant. The releases are calculated by multiplying the estimated or measured vertical and horizontal water flows through each arsenic source by the measured arsenic source concentration. This is an appropriate and reasonable method for quantifying arsenic releases under various Mine re-flood and arsenic trioxide management alternatives. All of the arsenic releases are assumed to be to Baker Creek and for those alternatives that involve dust removal and freezing of the chambers, the release rates do not include an intensive 10 to 20 year period of flushing and groundwater recovery to remove arsenic dust residuals. The characterization of arsenic releases from surface and subsurface sources at Giant Mine, while subject to unavoidable uncertainties, is considered adequate to support the current comparative evaluation of management alternatives for arsenic trioxide dust.

Areas for recommended further work relating to estimates of arsenic release were identified. Only arsenic releases by water flow are quantified. Other release pathways, such as airborne releases during dust removal and surface/underground handling may be important and should be quantified. All arsenic releases are conservatively assumed to be to Baker Creek, which in turn are directed to Back Bay and Yellowknife Bay of Great Slave Lake. Direct releases by surface water or groundwater flow to other receptors such as Back Bay may need to be considered.

4.1.6 Summary of Findings and Recommendations

The geological, hydrogeological, water chemistry and arsenic release characterizations of arsenic source areas completed by SRK are adequate for the level necessary at this phase of the study to support the current evaluation of management alternatives for arsenic trioxide dust at Giant Mine.

The identified areas for improvement of source area characterization can be addressed in subsequent evaluation of the selected alternative. It is recognized that numerous additional studies will be needed to refine long-term arsenic release estimates in support of detailed design, environmental assessment and permitting activities. Many of the required studies will be specific to each alternative.

4.2 ARSENIC PATHWAYS AND ASSESSING HUMAN AND ECOLOGICAL RISKS FROM ARSENIC TRIOXIDE DUST STORAGE

4.2.1 What Was Done

The assessment of human and ecological risks performed for the SRK Final Report was intended to be a 'Tier 2 risk assessment', described according to the Canadian Council of Ministers of the Environment (CCME 1996, 1997) as being: '*Preliminary quantitative risk assessment (PQRA or Tier 2): focuses on filling gaps identified at the screening level.*' The previous screening level, or Tier 1 risk assessment is described as being essentially qualitative as well as entirely preliminary in nature. These qualifiers should be taken together with the following observations about the nature of risk assessment, in general, to gain a perspective that the findings of the risk assessment in the SRK report should be taken as neither definitive nor final statements about what the risk to human health or the environment will be. However, the Tier 2 risk assessment does provide an improved understanding about what is known concerning these risks while revealing some important matters that require more or better knowledge as discussed later.

Some general observations about the nature of risk assessment include:

- There is no single 'correct" way to do environmental risk assessment;
- There can be wrong ways (scientific or judgmental errors);
- Environmental risk assessment is inherently predictive;
- Environmental risk assessment must rely on inferences, assumptions and modeling;
- Environmental risks assessment faces inherent and substantial uncertainty;
- Quality judgment and transparency of the risk assessment process are critical; and
- Answers from environmental risk assessment are usually only very clear when risks are either very high or extremely low.

The findings of the Tier 2 risk assessment, given the inevitable predictive and hypothetical nature with associated uncertainties can be better appreciated if they are placed in a broader context of what is known about the circumstances of the arsenic trioxide dust problem in Yellowknife. Some of starting premises or realities of these circumstances include:

- There are no zero risk alternatives;
- Taking no action will ultimately risk serious environmental exposures (humans and wildlife) to arsenic in the future;
- If the exposure of any living thing to arsenic in a toxic form can be limited to very low levels (i.e., in the range of undisturbed regional background arsenic levels) then the effects caused by arsenic will likely be too small to measure or will be non-existent;
- Arsenic is an element that cannot be destroyed by any chemical reaction, it can only be combined in various chemical forms that exhibit a wide range of toxicity and stability;
- The arsenic that is now present in the waste arsenic trioxide dust came from processing the ore that was mined from the Giant Mine over its operating life;
- The arsenic trioxide dust, being in a size range that promotes maximum respiratory uptake, poses a severe health risk if it is ever released back to the atmosphere in the form of fine particulate during handling; and
- There is no possible option for completely removing all of the arsenic trioxide dust that is currently stored in Giant Mine; a few percent of the total tonnage is destined to remain under any plausible management scenario.

The predicted risks to human health and the environment associated with future projected arsenic release scenarios (between 950 and 16,450 kg/a of arsenic released via Baker Creek to Back Bay including a background estimate of 450 kg/a) could be better appreciated by considering the estimated past releases of arsenic to the Yellowknife regional environment from Giant Mines operations (Table 4.2-1)

Table 4.2-1 Approximate Estimates of Arsenic Release During Giant Mine Operations

Time Period	Estimated Arsenic Releases to Baker Creek, kg/a	Estimated Arsenic Releases to Air kg/a	Total Annual Arsenic Releases to the Regional Environment, kg/a
1993 to 1999	500[1]	5,700[2]	6,200[3]
1983 to 1993	1,300[1]	17,900[2]	19,000[3]
1972 to 1982	14,000[1]	61,700[2]	78,000[3]
1959 to 1971	25,000[1]	84,000[2]	110,000[3]
1954 to 1958	25,000[1]	1,090,000[2]	1,100,000[3]
1949 to 1951	25,000[1]	2,600,000[2]	2,600,000[3]

[1]Various sources of estimates for arsenic release to Baker Creek were available, but the estimates used in this table were chosen to correspond to the mean values summarized in 4.1.1 of Supporting Document 6 chosen for the purposes of calibrating the water quality model used in the risk assessment.
[2]Historical atmospheric emission levels calculated from Tables 4-1 and 4-2 of EC (1997) with conversion of daily emission estimates in kg per day, to annual emissions in kg/a, assuming 350 operating days per year
[3]Total annual emissions were rounded to 2 significant figures because of the considerable uncertainty in the emission estimates making any higher degree of precision in these estimates potentially misleading.

The pathways of arsenic exposure in the Yellowknife region that were evaluated for the Tier 2 risk assessment can be summarized as:

- The ecological risk assessment considered sediment and water-mediated routes of arsenic exposure to a variety of ecological receptors chosen to represent an appropriate range of local fish and wildlife;
- The human health risk assessment considered water-based, soil and food routes together with background air routes of arsenic exposure;
- Arsenic emissions from arsenic trioxide management alternatives were all presumed to occur via Baker Creek; and
- Some important uncertainties were revealed that need to be addressed and these are addressed in the conclusion and recommendations of this Panel.

The main findings of the Tier 2 ecological and human health risk assessment are:

- Baker Creek remains an arsenic contaminated environment under all release scenarios because of historic contamination;
- Some ecological risk concerns arise at an overall release rate through Baker Creek at or above 4,450 kg/a (450kg/a is background), but impacts are limited below this level;
- Child consumers (receptors 3 and 4) pose a concern in relation to Health Canada RfD (Reference Dose) at arsenic release rates at or above 4,450 kg/a;

- Although cancer risks appear high in relation to commonly cited numbers, the maximum predicted excess cancers would not be detectable in a population of 20,000; and
- In search of caution, a project release rate of 2,000 kg/a (2,450 kg/a including background) was proposed and this level provides a reasonable upper bound criteria for assessing arsenic trioxide risk management options.

Operational, implementation and construction risks are also evaluated in Supporting Document 18. These risks are judged semi-quantitatively under three risk categories:

- Short term arsenic release;
- Long term arsenic release; and
- Worker health and safety.

For short-term release, the various arsenic trioxide management options are judged against a criterion that a single arsenic release of 1,000 kg would constitute a significant release, and then the probability of a release of that size was estimated. For long-term release, the probability of continuous periods of 1 year, 10 year or 100 year of total failure of treatment and management were judged for magnitude of arsenic release for each management option. For worker safety and health risk, each management option was judged for the risk involved in component activities as well as the estimated degree of arsenic exposure to rate the combined overall worker safety and health risks as high, moderate or low.

4.2.2 IPRP Findings on Risk

1. The final report has been improved substantially and most of the comments and recommendations made by the reviewers have been addressed. Considering the available evidence and the stage of project detail at which the risk assessments were performed the judgments that are made are generally reasonable.
2. However, some key questions need better answers to refine risk predictions and raise overall confidence. These include:
   - Arsenic speciation in local fish to determine the presence of potentially toxic arsenic species is needed to replace assumptions.
   - Biomonitoring of current levels of arsenic exposure is needed to validate the general predictions used in the Tier 2 risk assessment and to provide context in relation to other arsenic-contaminated situations in the world.
   - Although soil-based exposure to arsenic is generally a small factor in overall human exposure to arsenic, some refinement in the expected bioavailability of arsenic from soils affected by arsenic trioxide dust emissions would be preferable to the assumptions currently made to use a bioavailability factor of 50%.
   - As project details are refined and the expectations for a final detailed risk assessment can be judged, any planning toward such an assessment must maximize the use of local and traditional knowledge to assure the relevance of the assessment.

3. All risk management alternatives other than 'no action" can likely satisfy the 2,000 kg/a arsenic release criterion. As a result, the human and ecological risk assessment does not drive the selection of alternatives.
4. The ex-situ options may give rise to arsenic release by routes other than Baker Creek (i.e. air release of arsenic trioxide dust) making supplementary specific risk assessments necessary for further development of any of the ex-situ alternatives. The present preliminary evaluation may be too optimistic in the qualitative risk assessment of the ex-situ options.
5. The past arsenic emissions leading to high arsenic in Baker Creek sediments remain an environmental problem that is not addressed by the arsenic trioxide management options. The overall management of arsenic in the Yellowknife area needs to address the issue that the water quality of Baker Creek is below the acceptable range, which may impact the local wildlife like mink and muskrat and fish regardless of the arsenic release scenario presented. The option of cleaning up the Creek should be explored, however it is acknowledged that this was not part of SRK's Terms of Reference.
6. The previous designation of Receptors 3 and 4 and 5 and 6 in the draft report that were based on the incorrect definitions of local and regional diets have been changed. The revised designation of the Receptors based on average and frequent fish consumption is appropriate and relevant. In the draft final report, the designation was not clearly defined on p.3-3 where the Receptors are first introduced. The changes of the definition of the Receptors have also not been made in the conclusion statement on p.7-2.
7. The use of a log-normal distribution to model the intake of country food is better justified in the final report. Using a standard deviation of 3 instead of 2 is a better and more conservative approach. The distribution of arsenic intake from ducks, land birds and mammals is clearly not log-normal but the error of using a log-normal model may be minimal as the intake from these sources is less than 2%.
8. The incorporation of the sensitivity analysis to estimate the intake of the high consumer of fish and wildlife (Table 6.3-8) is a good way to show that the high risk populations are being captured in the distribution model.
9. While it is reasonable to use the Health Canada guideline, the rationale given in p. 6-69 that it can be used to determine the best management option for the mine site is not correct. Given the technical difficulties, the use of 3% of inorganic arsenic in fish and the incorporation of the sensitivity analysis is a reasonable approach for this study, it is our concern that the intake will exceed the EPA guideline if the percentage is 5% in fish. The speciation of arsenic in fish and their relative availability and toxicity should be an area of on-going research.
10. The characterization of cancer risk needs further consideration. The difficulty of detecting an increase in incidence, morbidity or mortality in small communities is not a reason to discount predictions of an increased risk. The IPRP recommends that DIAND consult with the appropriate communities to identify their health concerns in their communities and to explore the best means that current scientific approaches offer for dealing with those concerns.

4.2.2.1 References Cited

Canadian Council of Ministers of the Environment (CCME). 1996. *A Framework for Ecological Risk Assessment: General Guidance.* March.

Canadian Council of Ministers of the Environment (CCME). 1997. *A Framework for Ecological Risk Assessment: Technical Appendices.* March.

EC (1997). Controlling Arsenic Releases to the Environment in the Northwest Territories. Discussion of Management Options. Environment Canada, Health Canada, Government of the Northwest Territories Health and Social Services. For Consultation. April 1997

4.3 ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES

The initial identification of potential management alternatives was made in a prefeasibility level study by SRK released in a report dated May 2001. The approach adopted by SRK in assessing the alternatives was a wide-ranging one, which began with consideration of all factors (technologies, etc.), which would likely be relevant, followed by an initial selection of alternatives and then identifying the most promising candidates. This initial approach was a logical one given the complexity of the Giant Mine Project and the many factors which had to be considered concurrently to meet even the initial objective of identifying a short list of alternatives which would be submitted for further public consultation. The basic approach was continued with progressive refinements into the Draft Report submitted by SRK in September 2002 and ultimately to the selection of management alternatives presented in the SRK Final Report.

Review comments on potential management alternatives were first made in Report No. 1 by the Review Team of Connell and Matich. The Report is included in Appendix A hereto as Attachment A. The initial review related to the SRK prefeasibility level study, and led to a number of recommendations to DIAND which are summarized earlier herein in Section 3.0, and include the following:

i. A number of significant gaps in the database were identified. Potential ways and means for filling the gaps were discussed.

ii. There should be additional characterization of historic and current conditions at the site impacting secure storage of the arsenic trioxide dust. This applied particularly to the permafrost (cold regions) characteristics.

iii. A number of issues fundamental to both potential "in-situ" and "ex-situ" management were identified.

iv. DIAND should focus more attention on the in-situ management alternatives, particularly in-situ active freezing and permanent dewatering.

v. DIAND should also carry out additional work on a fall back option such as extraction of the arsenic trioxide dust from storage and stabilization of it into a storable product.

DIAND has acted positively on these recommendations.

SRK's initial review of management alternatives is described in their September 2002 Draft Report. An important step in this respect was the convening of a Senior Technical Workshop attended by some of the top engineering specialists in Canada convening in March of 2000. The stated objectives were to review relevant work already carried out by others, identify other potentially applicable "methods", and develop complete alternatives that could be carried through further analysis. A Phase I assessment (June 2000 - June, 2001) led to selection of four main groups of alternatives, namely:

- In-situ management of the arsenic trioxide dust
- Removal of the dust and processing to recover gold and high purity arsenic
- Removal of the dust and processing to recover gold and stabilize arsenic
- Removal of the dust and processing to create a stabilized waste.

A Phase 2 assessment (July 2001 - July 2002) led to the inclusion of additional in-situ alternatives and some basic changes to the ex-situ alternatives previously identified. The alternatives selected were in seven main groups under the following headings:

A. Perpetual Water Collection and Treatment (3 variants)
B. Dust Isolation by Ground Freezing (3 variants)
C. Removal and Deep Disposal
D. Removal and Surface Disposal
E. Removal and Purification
F. Removal and Conversion
G. Removal and Stabilization (2 variants)

A set of 19 Supporting Documents was provided by SRK with their September 2002 Draft Report. The Draft Report also included assessment of risks of significant arsenic discharges under each alternative; ranges of estimated costs for each alternative; and the recommendation that at least two alternatives be taken through to Public Consultation, where one of the alternatives should be an in-situ and one should be an ex-situ variant. The in-situ alternative considered most suitable by SRK was ground freezing utilizing the "frozen shell" concept; the most suitable ex-situ alternative was identified as dust extraction and stabilization with cement (and possibly bitumen, if proven).

The IPRP carried out an extensive review of the SRK September 2002 Draft and Supporting Documentation and its review comments were provided to DIAND in a Progress Review Report dated January 2003. A copy is included herewith as Appendix A. By Reference to Appendix A, and Section 3.0, it will be evident that some key issues pertinent to both the main text of the SRK Final Report and the Supporting Documentation originated with recommendations made by the IPRP. Also, that the IPRP recommended that serious consideration be given to a new 'frozen block' variant of Alternative B 'Dust Isolation by Ground Freezing'.

The SRK Final Report still carried seven alternatives in groups designated A to G inclusive, and included assessment of risks and estimated costs for the alternatives. It reiterated the recommendation that the best in-situ and ex-situ alternatives be taken through to public consultation. It made a basic change from the September 2002 position, however, in that the 'frozen block' concept was selected as the best in-situ management alternative.

The IPRP review comments on the SRK Final Report and supporting documentation are largely incorporated in Sections 4.1, 4.2 and later in 4.4 herein. Because of the extensive review comments by the IPRP with respect to arsenic trioxide dust stabilization by ground freezing, Alternative B is discussed herein separately in Section 4.4, which follows.

As a general statement, the IPRP agrees with the direction taken by SRK in narrowing down the potential arsenic trioxide management alternatives to the seven groups, and in the selection of two alternatives to be taken through to public consultation. However, there are a number of issues in addition to the items identified earlier in this report, which the Panel recommends be given consideration as the Project proceeds through the selection process and into the preparation of a Final Project Description:

1. DIAND should maintain an open attitude with respect to new technologies that develop in the future to take advantage of any that are proven and could provide technical improvements and/or cost savings to the basic alternative selected.

2. DIAND should coordinate remediation/closure issues relating to surface facilities at the Mine site as a whole, and the below-surface remediation measures, respectively. This should be done on a priority basis and the IPRP understands that this activity has already been initiated.

3. In concert with maintaining an open attitude, the Panel suggests that DIAND review the merits of combining certain aspects of the short-listed management alternatives as it moves forward in the preparation of a final Project Description. For example; if the "in-situ" alternative is selected, would there be any net benefit in placing the water treatment plant sludges back underground and freezing them in combination with the dust to limit the amount of material requiring surface management in a landfill; or if the "ex-situ" alternative is selected, would there be any net benefit from combining extraction with encapsulation and deep disposal of the encapsulated product rather than disposal on surface in an engineered landfill.

4. DIAND should consider carrying out verification testing, (such as perhaps a test demonstration of the ground freezing option on one of the smaller arsenic filled chambers), as discussed in the Report.

5. SRK Supporting Document 19 summarizes the cost estimates for each of the alternatives considered for management of the arsenic trioxide. DIAND did not ask the IPRP to review the costs estimates in detail, rather the Panel's activities were focussed on the technical merits of the various alternatives. Nevertheless, our review of the cost data provided shows that the costs have been developed in a consistent fashion, and applied appropriately in the various alternatives where there are similar cost components. It is the panel's view that both the capital and operating cost estimates provided by SRK are reasonable at this time to allow comparison between alternatives, as required. Once a preferred alternative has been selected then detailed cost estimating would be required.

   At the recent workshop in Yellowknife, the IPRP heard from several stakeholders that cost should not be a factor in selecting the preferred alternative, rather the preferred alternative should be selected based *only* on technical and risk related factors. This is not the IPRP's view. The IPRP believes that if technical and risk comparison factors are similar for two or more alternatives, then costs should be a factor in the selection of the final management alternatives. It is our view that it would be inappropriate to ignore costs as a factor in selecting a preferred option.

6. DIAND should develop in greater detail descriptions of the tasks and schedules involved in producing designs, drawings and specifications, and construction planning for the two alternatives designated for public consultation for inclusion in the Project Description. Further consideration of precedent in terms of mining and construction methodology; indirectly-related precedent applications; experience with toxic waste disposal, and the like should be made for reference in comparing the alternatives and developing designs, specifications, construction planning and schedules, and so forth.
7. Among the issues, which are prominent in the assessment of the various alternatives, are the matters of the degree to which the arsenic trioxide can be recovered, and the extent to which arsenic contamination has penetrated into the bedrock surrounding the stopes/chambers. There is a considerable uncertainty and importance to the numerical values in this regard. The 2% non-recoverable assumption needs to be quantified more definitively.
8. The IPRP challenges the use of the words 'in perpetuity' used by SRK in respect to the duration of maintenance of the remediation measures in the long term. Whereas the IPRP agrees that monitoring should continue indefinitely, it recommends that DIAND continue to strive towards an end result that will produce acceptable environmental conditions (such as water quality) in the long run, and result in properly justified discontinuation of maintenance requirements.

   The amount of residual arsenic trioxide dust remaining in the stopes/chambers and in fractures in the surrounding bedrock after extraction is an important factor in determining the viability of properly justified discontinuation of maintenance measures, and the timing of such a discontinuation. The efforts directed at producing environmental conditions acceptable for discontinuation of maintenance measures should therefore focus not only on the numerical value of the residual arsenic trioxide more definitively, but also on the possibility of reducing the 2% value now assumed. A reduction of this number would correspondingly reduce the time required for acceptable water quality to be attained.

   Despite its robustness, the in-situ "frozen block" alternative is nevertheless reliant on maintenance in the long-term. The ex-situ "extract-and-encapsulate" alternative on the other hand carries with it the prospect of discontinuation of maintenance in the future, at least as far as the underground workings are concerned. The value of such a prize to the Project should be carefully weighed. The extract-and-encapsulate alternative does, of course, require long-term maintenance of the associated facility for secure disposal of the encapsulated arsenic trioxide. A special effort would therefore appear warranted at design stage aimed at reducing the long-term maintenance of the disposal facility.

   Whereas, the IPRP is in general agreement with the findings by SRK to the effect that the best "in-situ" and "ex-situ" management alternatives should be carried forward into the public consultation and final selection process, it recommends however, that two important issues be focussed on in more detail for the "ex-situ" case in carefully weighing, at time of selection between the alternatives, the question of possible discontinuation of maintenance works in the long term. These are:

(i) The potential net benefits that could accrue from reducing the residual arsenic trioxide percentage left underground against the logistical and other efforts required to achieve it in practice, and

(ii) The merits of reducing the time to properly justified discontinuation of maintenance measures against the time and expense required to achieve it.

9. The IPRP is cognizant of the importance of the public consultation process in the selection of the most suitable management alternative from among the candidates. It looks forward to participation in future in the process leading to the preparation of a final Project Description.

4.4 ARSENIC DUST ISOLATION BY GROUND FREEZING

The SRK Final Report recommends that at least two management alternatives be taken through to further public consultation, and that they should include the best 'in-situ' alternative and the best 'ex-situ' alternative. The IPRP is in general agreement with this recommendation as discussed in Section 4.3. The best 'in-situ' (leave it underground) alternative identified by SRK utilizes ground freezing techniques to transform the rock immediately surrounding a given storage stope (or chamber) together with the arsenic trioxide dust in storage, into a frozen block. The IPRP agrees with SRK's selection. However, as discussed earlier in respect to the SRK Draft Report, the ground freezing approach at that time warranted considerably more discussion by SRK, which is reflected in their Final Report. The IPRP's review comments are, in fact, extensive on this management alternative and for convenience are presented separately in this section.

The IPRP notes that almost all of the review comments made on the SRK Draft Report have been responded to in the SRK Final Report. The comments included items such as the following:

i. Results of historic ground temperature monitoring at the Mine. Additional data should have been provided, however, on the Thermistor Installations AS1 to AS6 made previously by others, such as borehole logs, rationale for selecting the hole locations, and the like.

ii. More comprehensive discussion on potential ground freezing options that examined natural influences and the frozen block concept, in addition to the frozen shell concept presented previously.

iii. Additional discussion was required on geological details (fractures, etc.) in the bedrock

iv. Identification of all locations where permafrost had been encountered in the past within the Giant Mine property limits.

v. Recognition that the lower parts of some (if not all) of the arsenic trioxide storage repositories were saturated and should be modelled as such.

vi. Recognition of the influences of factors such as chemistry and rock fractures in lowering the freezing temperature of the arsenic affected groundwater.

vii. Assessment of the potential circulation of cold winter air as a resource to assist in maintaining frozen conditions in the long term.

viii. Modifications to the geometry of the frozen zone around the arsenic trioxide dust repositories (e.g. freezing of the bottom of each after first refurbishing the bulkheads), and upgrading of thermal modelling to incorporate new acceptance criteria such as freezing to –2°C rather than 0°C.

ix. Recognition of the potentially detrimental thawing effect of Baker Creek and consideration of remedial measures such as limiting water seepage from the Creek.

x. Discussion on additional investigations required to properly characterize site conditions in a geotechnical and thermal sense, particularly the arsenic trioxide dust in storage.

xi. Additional consideration to modifications to surface features, such as possible backfilling of Open Pits B-1, B-2 and C-1.

xii. A variety of other changes (such as computed times for freezing and thawing scenarios) resulting from implementation of the recommendations of the IPRP. Other factors required additional consideration, particularly for purposes of final design based on the in-situ freezing option, as discussed below.

The IPRP recognizes, of course, that the SRK Final Report needs to be viewed as the final step in the production of information for the selection of a management alternative. The IPRP also recognizes that a considerable amount of additional work will be required to develop detailed designs and construction plans for the selected alternative.

A number of general review comments are considered timely at this juncture with respect to both the in-situ freezing concepts presented by SRK and issues related to their implementation in practice.

4.4.1 Favourable Features of SRK's Ground Freezing Alternative.

The final report proposes three alternatives associated with freezing:

Alternative B1 – Re-Establish Natural Permafrost
Alternative B2 – Frozen Shell
Alternative B3 – Frozen Block

Concerning Alternative B1, the IPRP agrees with the results of the analyses carried out by SRK and their conclusions that it would be difficult to sustain naturally frozen conditions at the bottom of the chambers.

While Alternative B2 (frozen shell around the chambers and arsenic stopes using a series of cooling devices installed in holes drilled from the surface) is a conceptually sound option, IPRP recommends Alternative B3, the frozen block concept. It consists of creating a solid frozen block by freezing the inside of the chambers and stopes and the surrounding host rock, providing thus significant thermal inertia in the mine area, capable of withstanding long periods of accidental shut downs or excessive climate warming, should they occur.

It is important to stress that the frozen block concept can take advantage of the existing mine shafts and tunnels to access the bottom of each chamber and stope to drill horizontal and subhorizontal holes permitting the freezing of the bottom of each chamber. Since the freezing scheme uses a salt brine chilled at around -30 to -40 °C, the bottom area of each chamber will be completely sealed off from the surroundings over a significant thickness, which, in turn, provides correspondingly effective protection against seepage of arsenic contaminated water.

In Alternative B3, the sides of the stopes and chambers will also be frozen using vertical drill holes. These holes will be accessible in the long term to provide additional heat extraction if needed, thus allowing a certain control of the thermal conditions prevailing in the frozen dust below.

Alternative B3 is also versatile since the freezing conditions can be adjusted to the climate warming that may be more significant in the more northerly regions of the hemisphere. Thermal simulations have indicated that the concept is feasible and that sufficient time would be available (a number of years) to adjust to such events impacting the thermal regime in the mine.

The IPRP reiterates its recommendation regarding the use of a new criteria that would ensure a solid frozen mass around the chambers and stopes: Rather than the 0 °C isotherm at 10 m, SRK should, at this stage, use the -2 °C isotherm and ensure that it would be located at least 5 m from the chamber/stope boundaries. The rock surrounding the chamber/stope would, under current understanding, be sufficiently cold to freeze water with dissolved solutes such as impurities or contaminants. The intent is to eliminate the possibility of unfrozen 'windows'. This criterion is subject to review at final design stage.

4.4.2 Aspects of SRK's Freezing Alternative Requiring Additional Consideration

More consideration in the future should be given to the use of cold air during winter, a natural resource for centuries to come, to optimize the frozen block option. IPRP feels that this should be given special consideration in the detailed design phase for the frozen block option. Cold air circulation atop of the chambers and stopes during the winter may also compensate for effects of global warming in the northerly regions of Canada.

Power availability in the long term is an issue that SRK has not addressed. IPRP suggests that power sources such as solar energy be investigated either as alternatives or as contingency measures.

SRK's Final report considers implicitly that 'perpetual care" with respect to water treatment is required in all management alternatives. IPRP feels, however, that the frozen block option, if correctly implemented, has the prospect of providing a long-term solution for the water issue, especially if the frozen zone around the chambers and stopes would be increased (longer freezing periods or lower freezing temperatures as freezing technology progresses in the future). In this connection, consideration might be given to merits of a grout curtain around the stopes/chambers to reduce the effects of long-term thawing of the frozen repository by groundwater flow.

IPRP also feels that SRK's Final report does not stress enough the importance of verification testing. While the freezing method is a well-accepted technology in the mining and civil engineering fields, valuable lessons can be learned from even a short-term demonstration freezing project at Giant mine. Good practice can then be confirmed and applied to optimize the freezing sequence of all the chambers and stopes. Furthermore, a demonstration project would also be useful in testing monitoring instruments and training local engineers and other personnel for data acquisition and analysis.

The coordination of surface reclamation and below surface arsenic management activities is very important but was not within the terms of reference of SRK's Final report. For instance, should Baker Creek be relocated or not? The decision has an important bearing on the freezing activities of chambers located below or near Baker Creek.

SRK's report has not considered the potential of ground freezing as a construction expedient. For example, the use of advanced freezing of previously saturated arsenic could be used to prevent mud rushes due to liquefaction.

Alternative B3 creates a fully frozen mass of both rock and dust that is near saturation, and hence has a significant amount of stored thermal energy due to the latent heat of the pore water in the frozen mass. Furthermore, by maintaining the air above the frozen dust at temperatures well below freezing during at least 6 to 8 months each year, a relatively cold permafrost condition will be maintained throughout the frozen arsenic dust. If the climate remains relatively stable with the present day characteristics, the temperature in the frozen dust may vary between -6 and -4 °C. However, in view of recent data on climate warming, especially in the northerly regions, IPRP recommends that more thermal simulations of alternative B3 be conducted for final design purposes to better establish the reaction time available to adjust to evolving conditions in Yellowknife in a timely manner.

4.4.3 Issues Related to the Implementation of Ground Freezing

In order to develop any scheme related to the freezing option, additional data needs to be collected before the final design can be established. These include:

- Establish more specific data on the air space above the arsenic dust;
- Depth of the surface of the dust (see Table 1 in SD9) is required for B212, B213, B214, C212, C10, B11, B12 B14 and B15;
- Establish the water content profile more definitively in each arsenic dust storage area;
- Thermal conductivity of wet unfrozen and frozen dust should be established by appropriate testing;
- Establish the unfrozen water content characteristics of saturated arsenic dust at the density conditions present in the storage areas;
- Establish the pore water chemistry in the host rock and its freezing temperature;
- Further consideration to the implications of chamber/stope sidewall stability as it may influence locations of freezing pipes etc. and also the integrity of the crown above each chamber/stope; also, consideration of possible application of grouting to fill fractures in the bedrock prior to freezing;
- Further consideration should be given to the merits of locating freezing pipes internally within individual chambers/stopes; the Geocon 1998 drilling investigation

has established the practical feasibility of inserting protective pipes (such as closed-end steel pipe piles) into the arsenic trioxide dust in storage;

- More specific examples of successful precedent for the use of ground freezing would have been helpful, e.g., applications of thermosyphons (including experience with their robustness and maintenance needs) and ground freezing for deep shaft construction through water-bearing formations at mines in Saskatchewan and elsewhere;
- Further consideration to the practical issues related to freezing pipe (or thermosyphon) configurations in the irregularly shaped stopes;
- Precautions to prevent possible flooding of the underground workings by overflow of UBC Dam B2, or Baker Creek; such flooding has been experienced in the past due to overflow of Baker Creek into an open pit(s);
- Practical considerations related to backfilling of Open Pits B1, B2 and C1, and the possibility of utilizing them as engineered repositories for some components of the contaminated material at the mine site; the present specification of 'any reasonable backfill' should be reviewed with a preference given to selected natural low permeability material, where available; ponding above backfilled open pits must be prevented as planned;
- The proposed lining for Baker Creek should be reviewed to ensure that flow does not occur to a detrimental extent below a lining as proposed;
- A review of the present estimate of 2% non-recoverable arsenic trioxide, and particularly the extent to which the arsenic trioxide may have permeated into the bedrock around and below the chambers/stopes, is important as already mentioned; and
- More specific consideration should be given to the beneficial effects of circulating cold winter air through existing mine workings while they remain open.

5.0 SUMMARY OF IPRP RECOMMENDATIONS

The following is a summary of the recommendations put forward by the IPRP following its review of the December 2002 SRK Final report. The Panel's recommendations are directed particularly at the higher priority management alternatives presented in the SRK report.

i. Although the database is sufficient for present purposes, work should be continued to address the key deficiencies in the information database as identified by SRK and by the IPRP to support the preparation of the Project Description.

ii. The best available successful precedent (albeit necessarily not directly related) should be accessed to a greater extent (ground freezing, cement encapsulation of waste, as cases in point).

iii. DIAND has produced some excellent 3-D models for several of the storage stopes and chambers. Similar models should be made selectively for the other vaults.

iv. Additional consideration needs to be given to issues relating to closure of the site, specifically in the context of integrating surface and sub-surface closure and reclamation measures.

v. Extraction of the arsenic trioxide will leave significant residual arsenic contamination behind and make long term monitoring, care and maintenance mandatory.

vi. For the purposes of the preparation of the Project Description, DIAND should focus on the in-situ management alternative of freezing but continue to carry out additional work on a fall back option such as extraction from the vaults and processing or stabilization into a storable product.

vii. Continued public/stakeholder/community consultation activity associated with the development of a management alternative is strongly supported by the Panel.

viii. DIAND should continue the monitoring and other activities that were recommended by the Hydrogeology Experts Panel that relate to advancing the key areas of understanding necessary for the implementation of the alternatives being carried forward for public consultation. As cases in point, it is recommended that monitoring of the existing well network continue. As well, monitoring of flows within the mine and of surface drainage should also continue.

ix. As discussed in the report more work needs to be undertaken to assemble and integrate the underground structural information with the surface structural information to provide a 3-D representation of the geological mapping. Such data would provide an enhanced structural framework to support detailed designs and future alternative assessments.

x. Although the site is in a region of low seismic activity, for completeness, the issue of potential for seismic events to affect the long-term performance of the existing underground storage chambers and stopes, any future purpose-built storage chambers or any landfill facility constructed on surface needs to be addressed at the final design stage.

xi. More needs to be done to understand the detailed water balance within the mine. Several of the flow paths are long and breaking them into sections will allow more accurate definition of groundwater flow to various parts of the mine. Integration of the structural geology domains into the hydrogeology would be an important step forward.

xii. More attention needs to be placed on defining the zone of capture created by the mine dewatering. In particular, it would be most instructive to understand the influence of the structural geological domains on the shape of the drawdown cone. This information could be critical to full assessment of remedial alternatives.

xiii. Additional work should be done to refine the arsenic loading calculations by increased sampling at additional sampling points, in particular assessing the effects of old exploration boreholes.

xiv. The IPRP recommends that future investigative work be directed at understanding the fate of arsenic migration in the natural groundwater environment under saturated conditions. If as suspected, arsenate precipitates under certain groundwater chemistry conditions, then a natural attenuation approach could potentially be considered as a method or a component of an alternative for remediation.

xv. Consideration should be given to partitioning the high concentration arsenic bearing water within the mine for pre-treatment. This could lead to efficiencies in the treatment process and could potentially save on treatment costs.

xvi. For final design purposes, a better knowledge of the engineering (geotechnical and thermal) properties of the arsenic trioxide in storage is required, the scope of which would depend on the management alternative selected. The arsenic trioxide is unusual in a geotechnical sense and must be investigated by appropriate adaptations of current state-of-the-art techniques.

xvii. The current state of permafrost in all arsenic trioxide storage stopes and chambers, i.e., whether frozen or not; saturated or not, is of fundamental importance and should be established for detailed design purposes.

xviii. With respect to risk assessment, it is recommended that other release pathways, such as airborne releases during dust removal and surface/underground handling may be important and should be quantified. All arsenic releases are conservatively assumed to be to Baker Creek, which in turn are directed to Back Bay and Yellowknife Bay of Great Slave Lake. Direct releases by surface water or groundwater flow to other receiving areas, such as Back Bay, may also need to be considered.

xix. With respect to risk assessment, some key questions need better answers to refine risk predictions and raise overall confidence. These include:

- Arsenic speciation in local fish to determine the presence of potentially toxic arsenic species is needed to replace assumptions;
- Biomonitoring of current levels of arsenic exposure is needed to validate the general predictions used in the Tier 2 risk assessment and to provide context in relation to other arsenic-contaminated situations in the world;
- Although soil-based exposure to arsenic is generally a small factor in overall human exposure to arsenic, some refinement in the expected bioavailability of arsenic from soils affected by arsenic trioxide dust emissions would be preferable to the assumptions currently made to use a bioavailability factor of 50%; and

- As project details are refined, a final detailed risk assessment can be conducted for the preferred management option. Any planning toward such an assessment must maximize the use of local and traditional knowledge to assure the relevance of the assessment.

xx. With respect to the re-assessment of mining methods, there are a number of practical issues that still need to be addressed relating to the mining of the baghouse dust and in achieving an overall recovery of 98% of the stored dust. The IPRP recommends that these outstanding issues continue to be addressed as resolution is critical to better understanding how much of the dust will remain behind following extraction. The assumption that 2% of the dust will not be recovered needs to be better quantified as it represents a critical assumption with high sensitivity in determining the relative cost of implementing overall management strategies as well as the extent and time schedule of application of a number of the alternatives.

xxi. With respect to ground freezing, the IPRP recognizes that SRK has accepted its recommendation regarding the use of a new criteria that would ensure a solid frozen mass comprising the chambers, stopes and their contents. Rather than the 0 degree-C isotherm at 10m, SRK has accordingly adopted the -2 °C isotherm located at least 5m from the chamber/stope boundaries. The surrounding rock will then be sufficiently cold to freeze water with dissolved solutes such as impurities or contaminants. The intent is to eliminate the possibility of unfrozen 'windows" or zones. This criterion is subject to review at final design stage.

xxii. With respect to ground freezing: more consideration is recommended for the use of cold air during winter, a natural resource for centuries to come, to optimize the frozen block option. IPRP feels that this should be given special consideration during the detailed design phase. Cold air circulation atop of the chambers and stopes during the winter may also assist in compensating for any effects of global warming in the northerly regions of Canada.

xxiii. IPRP also feels that SRK's Final report does not examine sufficiently the merits of verification testing, such as a short duration freezing test on one of the smaller storage chambers. While the freezing method is a well-accepted technology in the civil engineering and conventional mining fields, important lessons can be learned from pre-production tests in a non-conventional situation as exists at the Giant Mine. Good practice can then be developed and applied to optimize the freezing strategy of all the chambers and stopes containing arsenic trioxide. Furthermore, a demonstration project can also be useful in testing monitoring instruments and training local engineers and other personnel for data acquisition and analysis.

xxiv. The IPRP recommends more thermal simulations of Alternative B3 to be conducted as discussed in the report.

xxv. The IPRP recommends that additional site-specific data, properties and practical implementation issues be collected and/or addressed as stated in Section 4.4.3 as related to final design and construction planning, etc. to assist in the determination of the most suitable alternative.

xxvi. With respect to any further consideration of the pressure oxidation process as an option, the IPRP recommends that test work be conducted on arsenic trioxide dust from the Giant Mine to determine whether scorodite can be formed under the conditions proposed. If DIAND should consider this as a fall back option, it is essential that it have confidence that the arsenic contained within the baghouse dust can be effectively converted into a stable scorodite form under the process conditions proposed.

xxvii. With respect to cement encapsulation for surface storage, the IPRP recommends that DIAND consider the key issues identified by the IPRP as needing to be addressed in moving forward on cement stabilization as a component of any management alternative.

xxviii. With respect to bitumen encapsulation for secure surface storage, the IPRP feels that the test results are encouraging and warrant further investigation of this approach. Given the encouraging results it would be worthwhile giving consideration to conducting further pilot scale trials of this technique. It is also worthwhile considering bitumen encapsulation in the context of deep disposal.

xxix. The IPRP recognizes the potential difficulty involved in permitting a hazardous waste landfill site outside of the Giant Mine property for this project. Nevertheless the merits of locating a disposal site elsewhere within the Yellowknife area should be considered in the context that there maybe other sites within the local area that provide better natural containment than is available on the mine property and that could be successfully utilized for this purpose.

xxx. The final report should have addressed the contaminating life span of the landfill (i.e., the time frame over which the landfill and its contents will continue to be a potential source of contaminant release). It is critical that the appropriate studies be carried out to address this issue if a secure landfill is considered further as a viable alternative.

xxxi. The final SRK report (page 106) indicated that a secure landfill must be built to accommodate the sludge wastes from the water treatment facilities, whether or not Alternative G1 or G2 is selected. The Panel disagrees with this conclusion. Certainly if the ground freezing option is selected there will be viable opportunities for disposal of sludges below ground and thus reduce the needs for active surface waste management facilities to be operated indefinitely. The IPRP strongly urges DIAND to consider this option for management of water treatment sludges over the long term.

xxxii. The IPRP concurs with SRK's recommendation that management alternatives B3 (in-situ frozen block) and G (dust extraction and encapsulation) should be more fully described in a plain language document. This document should include sufficient figures to illustrate all of the critical elements in a non-technical manner. The objective is to create a document that will assist in informing the public as to what is being proposed in each of these two management alternatives as the two alternatives are carried forward for public consultation.

xxxiii. There are a number of other areas as discussed in the report where the IPRP has identified additional recommended work that should be undertaken to support the preparation of a final Project Description. Cases in point are, expansion of the groundwater monitoring program, improvement of the characterization of the water chemistry and improvement in the estimates of arsenic release, etc.

6.0 CONCLUSIONS

In arriving at the conclusions presented below, the IPRP has been guided by its terms of reference as reproduced in an attachment to Appendix A herein. The IPRP conclusions are also based on the data provided by DIAND through documentation, workshops, briefings, site visits, etc. and are made largely at concept level. The conclusions are also made in the context of: (i) the objective which was to assess the scope, and quality of the Technical Advisor's work in respect to evaluation of potential management alternatives, and (ii) the recognition that the SRK December 2002 Report does not represent the final assessment nor a basis for detailed engineering design, but rather support for an evaluation of alternatives and a presentation of preferred options considering a balanced assessment of several alternatives.

The main conclusions are:

1. The IPRP considers that the December 2002 SRK Report is appropriate for the presently planned level of the studies (i.e. comparison and assessment of management alternatives). The database now available is adequate for the current level of assessment. The IPRP has made recommendations for improvements to the available data base and studies in a number of key areas, some of which (such as engineering properties of the stored arsenic; pathways for arsenic release; ecological and human health risk assessments; etc) warrant further consideration by DIAND on a priority basis, as discussed in the report.
2. The SRK Final Report recommends that at least two management alternatives (from among a short list of seven) be taken through to further public consultation, and that they should include the best "in-situ" alternative and the best "ex-situ" alternative. The IPRP is in general agreement with this recommendation. The best "in-situ" (leave it underground) alternative identified by SRK utilizes ground freezing techniques to transform the rock immediately surrounding a given storage stope (or chamber) together with the arsenic trioxide dust in storage, into a frozen block. The best "ex-situ" (take it out) alternative identified by SRK involves extracting the arsenic trioxide dust, bringing it to surface, encapsulating the dust by mixing it with cement (or possibly bitumen) and then placing the encapsulated material into a secure landfill to be located on surface. The IPRP agrees with SRK's selection of these two basic management alternatives. However more consideration should be given to the issue of possible discontinuation of maintenance measures in the long-term, as discussed in conclusion number 5.
3. In principle the IPRP agrees with the direction that was taken by SRK to develop and evaluate the management alternatives, and agrees with SRK's recommendation that two preferred basic alternatives be carried forward by DIAND into the public consultation process. However, because of concerns such as the long-term performance of a landfill scenario, and in concert with maintaining an open attitude, the Panel suggests that DIAND maintain under review the possible net benefits of combining certain aspects of the short-listed management alternatives as it moves forward in the preparation of a final Project Description.
4. There are several issues that are prominent in the assessment of the management alternatives, as discussed in the report. One is the degree to which the arsenic trioxide in storage can be extracted mechanically from within the vaults, including some that has permeated into the surrounding bedrock. There is considerable

uncertainty and importance to the numerical value of such 'non-recoverable" arsenic trioxide. For the final design phase the assumption of 2% made by SRK should be quantified more definitively. Similarly a significantly better understanding of the engineering properties (geotechnical, thermal, etc.) of the arsenic trioxide in storage should be made for the final design phase.

5. DIAND should continue to strive towards an end-result that will produce acceptable environmental conditions (such as water quality) in the long term with resultant properly justified discontinuation of maintenance requirements rather than accepting the premise at this stage that maintenance (other than perhaps monitoring) will be an open-ended task.

   As discussed in the report, the IPRP recommends that the issue of possible discontinuation of maintenance works in the long term be carefully weighed at time of final selection between alternatives.

6. DIAND should ensure that there is effective coordination of remediation/closure planning relating to the surface and underground components, respectively, of the Giant Mine.

7. Because of its important, unusual, and complex character, the Giant remediation project would reasonably be expected to benefit from new technologies that develop in the future, irrespective of which candidate alternative is selected for implementation. DIAND should therefore maintain an open attitude with respect to such future opportunities.

8. Notwithstanding the considerable effort that has been necessary (Workshops, testing, studies, etc.) to reach the objectives for this stage in the evaluation process, much work still remains to be done before implementation of the selected alternative can begin, as alluded to in the report. DIAND should establish the scope, time schedule, and costs for such additional work (at least in preliminary fashion), so that they can be factored into ongoing decisions such as the selection of the preferred management alternative, Project Description, etc. In this regard, consideration should be given to additional working sessions of technical experts to further address key aspects of the preferred alternative after public consultation and in advance of finalizing the Project Description.

7.0 ACKNOWLEDGEMENTS

The IPRP acknowledges the assistance and courtesy extended to it by Mr. Dave Nutter and Mr. Bill Mitchell and other personnel of DIAND in facilitating meetings, site visits, attendance at Workshops, as well as responding promptly to all requests pertinent to documentation and other aspects of the Panel's role in its independent review capacity. The IPRP is similarly appreciative of the assistance provided by Miramar Giant Mine Ltd. (MGML).

The IPRP has, in this report, generally mentioned only SRK when referring to the SRK Draft and Final Reports. The IPRP acknowledges that the SRK Reports were produced by DIAND's Technical Advisor Team headed by SRK but also including SENES Consultants Limited, H.G. Engineering Ltd., and Lakefield Research Ltd. Further, that some credit is also due to a variety of other organizations and individuals in generating the data and documentation that was reviewed, including DIAND; the Hydrogeology Workshop Participants; MGML; Petra Science Consultants Inc.; Jenike & Johanson; Royal Oak Mines Inc; CANMET; ECN; Layne Christensen Canada Limited; Environtec Waste Management Inc.; Arctic Foundations of Canada Inc.; Moretrench American Corporation; Dynatech Corporation; and Klohn Crippen Consultants Ltd; plus interviews with Senior officials of the Inspection Department of the NT Department of Mines, and with present and former personnel associated with the Mine.

Respectfully submitted,
INDEPENDENT PEER REVIEW PANEL

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APPENDIX A

PROGRESS REVIEW OF SRK's DRAFT FINAL REPORT – SEPTEMBER 2002

ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES GIANT MINE

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ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES GIANT MINE

PROGRESS REVIEW

OF

SRK's DRAFT FINAL REPORT – SEPTEMBER 2002
ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES
GIANT MINE

YELLOWKNIFE, N.W.T.

BY

INDEPENDENT PEER REVIEW PANEL

PREPARED FOR THE

GIANT MINE REMEDIATION PROJECT TEAM
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

Submitted to:

Department of Indian Affairs and Northern Development
Yellowknife, NT

January 2003

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ATTACHMENTS

1.0 INTRODUCTION

During the period 1948 to 1999, representing most of its service life, the Giant Mine located near Yellowknife, NWT, generated arsenic trioxide dust as a by-product of the process used to liberate gold from the ore. The dust was collected after 1951 when the first precipitators were installed. Approximately 237,000 tonnes of dust was produced and was stored underground in the bedrock at the Giant Mine in five mined-out stopes and ten purpose-built chambers. On exposure the arsenic dust is hazardous to both people and the environment.

The Giant Mine was conveyed to the Department of Indian Affairs and Northern Development (DIAND) in 1999 after the owner Royal Oak Mines Inc. went out of business. DIAND subsequently sold the property to Miramar Giant Mine Ltd. while releasing and indemnifying Miramar of responsibility for pre-existing environmental conditions on the property. In addition, DIAND assumed responsibility for the preparation of an arsenic trioxide project description and engaged an independent Technical Advisor to assist it in meeting this responsibility. One of the key tasks assigned to the Technical Advisor was to analyse a wide range of options for management of the arsenic trioxide dust and recommend a limited number of alternatives for further consideration by DIAND and other stakeholders. DIAND selected as its Technical Advisor a team headed by SRK Consulting Inc. (SRK). The team included SENES Consultants Ltd., Lakefield Research Ltd., and HG Engineering Ltd.

The Technical Advisor has produced a comprehensive Draft Final Report, "Arsenic Trioxide Management Alternatives, Giant Mine", dated September, 2002. The Report is supported by two volumes of detailed documentation containing a total of nineteen sections on individual issues (such as technical, human health, ecological, environmental, risk assessment, comparative economics) pertinent to the subject study of management alternatives. The SRK Report presents two Alternatives that the Technical Advisor considers to be the most attractive options.

As indicated in the SRK Report, it is intended to serve as an important reference document in a number of respects including providing (i) a basis for a program of intensive public consultation that will assist DIAND in choosing a single preferred management alternative, (ii) essential documentation in support of DIAND's arsenic trioxide Project Description which will be submitted to the Mackenzie Valley Land and Water Board (with anticipated review by the Mackenzie Valley Environmental Impact Review Board), and (iii) basic data for further public and technical consultation following review by the Mackenzie Valley Environmental Impact Review Board.

DIAND initiated peer review of hydrogeological issues associated with management of arsenic dust at Giant Mine in 1999. Workshop meetings of hydrogeological experts were convened in March, 2000 and in June, 2001 to review and provide direction to hydrogeologic work completed for DIAND in support of development of management alternatives for arsenic dust. The results of these workshop meetings are summarized in two reports prepared by Kenneth Raven of Duke Engineering & Services (Canada) Inc: Giant Mine Hydrogeology Experts Group Meeting, November 30, 2000 and Giant Mine Hydrogeology Experts Group Meeting #2, September 26, 2001.

DIAND also initiated a process of independent peer review of the SRK Reporting on the study of arsenic trioxide management alternatives. This began with the retainer (in the fall of 2001) of a two-member team consisting of Larry Connell and M.A.J. (Fred) Matich, to carry out an independent technical review of a prefeasibility level version of SRK's "Study of Management Alternatives for Giant Mine Arsenic Trioxide Dust" released in May, 2001. A progress report by the Connell/Matich Review Team was submitted to DIAND on January 15, 2002. A copy is appended hereto as Attachment "A". The progress review was, however, made only from the perspective of the areas of expertise of the original Team members. DIAND enlarged the independent review team to include members with other areas of expertise represented in the multi-disciplinary study of management alternatives for the arsenic trioxide dust project.

DIAND's Independent Peer Review Panel includes the following members:

C.O. Brawner, M.Sc., Geotechnical Engineering, FCIMM, FCAE, P.Eng.,. Mr. Brawner is a specialist in tailings dam engineering, rock mechanics and mine stability with experience in local, national and international projects. He is a member of numerous review panels and is the owner of C.O. Brawner Engineering.

Laurie H.M. Chan, B.Sc., Ph.D. Dr. Chan is an expert in Indigenous Peoples' nutritional and environmental issues. He is a specialist in toxicology and assessing potential human health risks. He is Associate Professor at McGill University's Centre for Indigenous People's Nutrition and Environment. As well he is Chair of NSERC Northern Research.

Lawrence J. Connell, B.Sc., P.Eng. Mr. Connell is a specialist in water treatment, mineral processing, arsenic upgrading, arsenic treatment, environmental assessment and the metallurgy of Giant Mine. He is a Senior Environmental Mining Specialist with AMEC.

Steve E. Hrudey, B.Sc., M.Sc., Ph.D., DSc (Eng), P.Eng. Professor Hrudey is a specialist in the assessment of human exposure to arsenic and the assessment and the metallurgy of Giant Mine. He is a member of the Department of Public Health Sciences with the Faculty of Medicine and Dentistry at the University of Alberta.

Jean-Marie Konrad, M.Sc., Ph.D., Ing., FCAE. Dr. Konrad is a specialist in ground freezing, cold regions engineering and permafrost regimes. He is a member of the Department of Civil Engineering at Université Laval, Québec.

Robert Leech, B.Sc., M.Eng.Sc., P.Geo., Mr. Leech is a specialist in hydrogeology, specifically in groundwater flow and contaminant transport. He is Chairman of Gartner Lee Ltd.

M.A.J. (Fred) Matich, B.Eng., MSc., FEIC, FCAE, P.Eng.. Mr. Matich is a specialist in applied geotechnical engineering. He has over 40 years of experience that include: numerous projects world-wide; approximately 30 published papers and presentations, and over 20 appointments to peer review boards. Mr. Matich has experience with Giant Mine. He is the owner of MAJM Corporation Ltd.

Craig Nowakowski, CPHI (c). Mr. Nowakowski is a specialist in public and environmental health. He is Senior Environmental Health Officer with Stanton Territorial Health Authority in Yellowknife, Northwest Territories.

Kenneth G. Raven, M.Sc., P.Eng., Mr. Raven is a specialist in fractured rock hydrogeology, aqueous geochemistry, structural geology and conceptual hydrogeologic models. He is a Senior Hydrogeologist and President of INTERA Engineering Ltd.

Summary curriculum vitae for each IPRP Member are included herein as Attachment "B".

DIAND has specified that the "*role of the Independent Peer Review Panel (IPRP) is to provide the Department with expert, independent peer review of management alternatives for the arsenic trioxide currently stored underground at the Giant Mine, beginning with a review of the Draft Final Report entitled "Arsenic Trioxide Management Alternatives - Giant Mine" by SRK Consulting Inc. This study will form the basis for public consultation leading to an Arsenic Trioxide Management Project Description to be submitted to the Mackenzie Valley Land and Water Board.*

Independent Peer Review Panel members provide strong expertise in areas of geotechnical, mining, mineral processing and environmental engineering, as well as toxicology, hydrogeology, risk assessment and public health. The objectives for the Independent Peer Review Panel will be to:

Provide DIAND with an independent, technical review of the selection process and subsequent assessment of options considered for the long-term management, removal, secure storage or stabilization of the arsenic trioxide-bearing dust stored underground within the Giant Mine;

Provide DIAND with an assessment of any gaps in the data/information collected that are important in assessing the technical and economic feasibility of a long-term management alternative(s);

Provide DIAND with recommendations as to what additional information or data should be collected or developed to enhance public consultation and support for the development of a Project Description;

Provide DIAND with a recommendation as to which management alternatives are most likely to lead to a technically feasible, publicly supported and licensable Project Description, given the current level of technology, information and understanding of public health, occupational and ecological risk.

The Independent Peer Review Panel will be maintained to provide ongoing independent technical review throughout the development, environmental assessment and licensing of a long term management plan for the arsenic trioxide dust stored within the Giant Mine, as well as expert review of DIAND's other management proposals, such as surface remediation initiatives, at the Giant Mine."

IPRP Members met with representatives of DIAND and SRK in Yellowknife, September 30 to October 2, 2002 for a first-hand briefing on the available database and to plan ongoing review activities. Two Members participated via teleconference. The Attendees in Yellowknife were given an opportunity to inspect the Giant Mine site on surface and also view a number of the arsenic storage stopes and chambers underground. Each Member undertook to participate in an initial review of portions of the SRK Draft Report corresponding to his area of expertise. A second meeting of the IPRP was held in Vancouver on October 25, 2002 allowing the IPRP to clarify items, where necessary, with SRK and representatives of DIAND and to allow the IPRP to finalize arrangements for the completion of this progress review report.

The format used in preparing this progress report was to organize review comments into sections, which correspond with the SRK Final Draft Report and individual Supporting Documents thereto. (dated September, 2002) In preparing review comments, the IPRP was cognizant of the fact that, at this stage, the objective was to assess the scope and quality of the Technical Advisor's work in the context of evaluation of potential management alternatives. Further, the IPRP acknowledged that the SRK Report and Supporting Documentation did not represent the final assessment, nor were they intended to be a basis for detailed engineering design, but intended rather to support an evaluation of alternatives and a presentation of preferred options considering a balanced assessment of several alternatives.

Throughout this report, the following abbreviations have been adopted for convenience:

- Department of Indian Affairs and Northern Development — DIAND
- Mackenzie Valley Land and Water Board — MVLWB
- SRK Consulting Inc. — SRK
- Independent Peer Review Panel — IPRP
- Supporting Document — SD

As a general statement, the IPRP considers that SRK have done an excellent job in bringing together a multidisciplinary team of professionals to describe and recommend remedial alternatives to a most complex problem. Based on the IPRP member's background reading the most recent reports have significantly advanced the state-of-the-art of knowledge of the mine and its surroundings. As well, they have addressed many of the concerns and data gaps previously identified by the hydrogeology peer review groups.

It was planned that the progress review comments presented herein would be followed by review of the updated version of the SRK Final Draft Report.

2.0 REVIEW COMMENTS. STRUCTURAL GEOLOGY

SD No. 1 describes the structural geological framework of the Giant Mine and surrounding area. It focuses on description of the Proterozoic structural discontinuities (faults, fault zones, shear zones, fracturing) within the rock mass. SD No. 1 is intended to provide context to hydrogeological and geotechnical assessments of the Mine and environs. It is based on review of existing maps and reports and underground and surface field checks.

The main observations and technical review comments of the IPRP on SD No. 1 are summarized as follows:

- The SD describes the occurrence of regional bounding structures (West Bay and Akaitcho faults), major faults (3-12, Rudolph, Townsite faults), and minor faults and fracture zones;

- Grouping of regional rock mass fracture characteristics (density, orientation, type) is done using 11 litho-structural domains (zones of rock with similar lithology and fracturing);

- Faults in the area of the mine are described as:

  -1st order structures - 100s of metres in length, 10 to 100's metres displacement, kilometre scale spacing, e.g., West Bay, Akaticho and Townsite faults;

  - 2nd order structures - 10s of m in length, displacement less than 1 m, spaced 3 to 50 m; and

  - 3rd order structures - <20 m length, displacement less than 5 cm, spaced at centimetre to metre scale

- No observable relationship between structure orientation and permeability;

- No noticeable relationship between 1st order structures and fault permeability (some wet in places, some dry in places);

- 2nd and 3rd order structures thought to be the most important hydrogeologically at the Mine. They are preferentially developed within the sericite schist that bounds the ore zone. They are the wettest and most permeable, particularly in sericite schist around arsenic stopes B208, B212, B213, B214 and C212. (i.e, most fractured and most likely to leak);

- Stopes B212, B213 and B214 are also in the nose of a major fold, and are expected to be less stable and most likely to leak;

- The Ole fault (2nd order structure) and associated fracturing likely intersects chamber #15, and this likely explains the significant water inflows reported;

- There is no discussion of the seismicity of the Mine and surrounding area and the potential for seismic events to affect the long-term performance of underground arsenic storage chambers;

- There is no significant integration of structural geology information (i.e. lithostructure domains and ordered structural discontinuities) and hydrogeological information; and

- The litho-structural domain characterization is based entirely on just surface mapping, the underground structural information is of poor quality and has not been used (there are only limited underground geological plans available). Therefore, the characterization misses the important depth dimension, which can be very important due to the frequent occurrence of pervasive, open horizontal stress relief fractures;

2.1 Further Issues to be Addressed

- More work needs to be undertaken to assemble and integrate the underground structural information with the surface structural information to provide a 3-D representation of the geological mapping, the ongoing 3-D structural interpretation work of James Siddorn (PhD thesis), and the re-logging of core under the Extech III Project should be critically reviewed and used. Such data would provide an enhanced structural framework to support particular detailed designs and future alternative assessments.
- The structural geology information (i.e., lithostructural domains and ordered structural discontinuities) needs to be integrated and jointly assessed with hydrogeological information to determine if there are linkages between structural geology and groundwater flows and the nature and extent of the Mine drawdown cone.
- The issue of potential for seismic events to affect the long-term performance of the existing underground storage chambers and stopes and any future purpose – built deeper storage chambers needs to be addressed

2.2 Recommendations

Notwithstanding the above comments, structural characterization and associated inferences and conclusions are appropriate and consistent. The description of the structural geology provides an adequate framework for hydrogeological and geotechnical studies. Most importantly, the data have not been over-interpreted.

3.0 REVIEW COMMENTS - HYDROGEOLOGY

SD No. 2 summarizes the available hydrogeological information for the Giant Mine site and develops the conceptual and groundwater flow estimates for both the current (fully dewatered to 610 m depth) and various re-flood mine conditions. The major effort in this SD is the continued development, testing and refinement of conceptual hydrogeological models for the Mine site.

The 2001/2002 hydrogeological work included re-logging of existing surface boreholes, and field drilling and testing (establishment of an initial groundwater monitoring network, assessment of rock mass and fault hydraulic conductivity, hydraulic heads and gradients). Many of the hydrogeological activities undertaken in 2001/2002 addressed specific recommendations from the Hydrogeology Experts Group Meetings of 2000 and 2001.

The main observations and technical review comments of the IPRP on SD No. 2 are summarized as follows:

- An appropriate major focus of the 2001/2002 was assessing the role of major faults (West Bay, Rudolph and Townsite faults). The results of the field-testing suggest based on measured flows and hydraulic head profiles, that these faults may be barriers to groundwater flow and that they are not enhanced permeability features;

- In December 2001 the mine drainage piping system was reconfigured to allow for refinement of volumes of water pumped from the mine to the Northwest Tailings Pond. This allowed for improved mine water and Northwest Tailings Pond water balances and hence arsenic balances for the mine;

- The first actual field measurements of bedrock hydraulic conductivity (K) are reported from the drilling and testing of boreholes at Giant Mine. K values ranged from 1×10^{-8} to 2×10^{-5} m/s with a geometric mean of 2×10^{-7} m/s for the upper 150 m of rock. These values are similar to expectations and data from other similar sites; and

- There is inconsistency in the description of pumping requirements for the freezing option in SD No. 2 versus the main SRK Report. Section 5.1 of SD No. 2 indicates the freezing option has no pumping, i.e. groundwater allowed to recover to natural levels. This is contradictory to the main SRK Report which has perpetual pumping associated with this option.

The IPRP agrees with geochemical interpretation and the revised water balances (checked against infiltration estimates based on annual precipitation) show that most of the lateral groundwater inflow (1,100 m^3/day) occurs below a depth of 500 m, that the volume of seepage from the Northwest Tailings Pond averages 400 m^3/day, and that most of the seasonal mine inflow is vertical infiltration of precipitation over the mine footprint are reasonable and supportable.

The simple Dupuit-Forchheimer equation for lateral 2-D flow to a vertical drain under conditions of average infiltration is used to back calculate a bulk estimate of hydraulic conductivity of the mine envelope rock mass. This is an appropriate model given the available data, and we agree with the calculations, the sensitivity analyses presented, and the noted limitations to the calculations.

The bulk mine envelope hydraulic conductivity from Dupuit-Forchheimer analysis is estimated at 1×10^{-8} m/s for deep rock and 1×10^{-7} m/s for shallow rock, which is entirely consistent with the available field data. If anything this estimate likely overestimates the hydraulic conductivity, and hence the arsenic loading estimates under re-flood scenarios are conservative overestimates. Ranges of hydraulic conductivity for other areas of the mine including disturbed rock near pit areas (1×10^{-6} m/s for deep rock, 1×10^{-5} m/s for shallow rock), larger regional estimates (1×10^{-9} m/s for deep rock, 1×10^{-8} m/s for shallow rock), and for fault zones (1×10^{-6} m/s for deep rock, 1×10^{-5} m/s for shallow rock) are presented and appear quite reasonable given experience elsewhere on the Canadian Shield.

Funnelling effects of surface water to open pits and other structures are now noted and higher infiltration flowrates through selected chambers have been incorporated into the arsenic mass balance, based on actual measured flows from selected chambers. This is an important refinement to the arsenic mass balance.

We agree with the conceptual hydrogeological models and the flow estimates though source areas presented for both the current dewatered conditions and the re-flood scenarios. We believe, based on the existing data, that the conclusions drawn by SRK are reasonable.

3.1 Further Issues to be Addressed

More needs to be done to understand the water balance within the mine. Several of the flow paths are long and breaking them into sections will allow more accurate definition of groundwater flow to various parts of the mine. Integration of the structural geology domains (defined in SD No. 1) into the hydrogeology would be an important step. For example, SRK importantly identified major faults as potential barriers to flow; however, they concluded that secondary discontinuities were likely the major conduits for groundwater movement. This being the case it would be instructive to confirm this conclusion with more detailed investigation results from the mine, i.e., introducing the third dimension.

The SRK Draft Report identifies several of the remedial alternatives that require re-flooding of the mine to various levels. More evidence is required to support why these levels were selected and a description of the calculations made to determine how long the mine would take to reach the design re-flood level. As well, if the "Minimal Drawdown" capture system is used for the selected alternative, further investigation is required to confirm no contaminant flow at deeper levels in the mine occurs while achieving capture near the surface.

More attention needs to be placed on defining the zone of capture created by the mine dewatering. In particular, it would be most interesting to understand the influence of the structural geological domains on the shape of the drawdown cone. This information could be critical to full assessment of remedial alternatives.

3.2 Recommendations

There will never be enough hydrogeological information to have complete accord between the practitioners. However, the steps taken over the past year or so have greatly improved our knowledge. It is recommended that monitoring of the existing well network continue. As well, monitoring of flows within the mine and of surface drainage should also continue. As mentioned above, new work should include defining more accurately the relationship of structural control on groundwater flow.

The hydrogeological understanding of the groundwater flows around and within Giant Mine, while always subject to improvements with the collection of additional hydrogeological data, appear to be adequate to support the comparative evaluation of management alternatives for arsenic trioxide dust at Giant Mine. SRK have done a good job of hydrogeologically characterizing the Mine.

4.0 REVIEW COMMENTS - WATER CHEMISTRY

The SRK report provides in SD No. 3 a comprehensive summary and description of the underground water sampling programs that have been conducted at the Giant Mine over the past three years with the following objectives:

- The Identification of different water types within the underground mine;
- The identification of arsenic source water types;
- The delineation of water flow paths within the underground mine; and
- The development of an overall water balance and arsenic balance for the water flows within the underground mine.

These are important objectives that appropriately reflect the recommendations made in 2000 and 2001 by the Hydrogeology Experts Panel that was brought together by DIAND to review existing work, to identify hydrogeologic issues and information needs, and to provide direction for future investigative work. The information provided in SD No. 3 and summarized within the main body of the report provides an important contribution to the conceptual hydrogeological model for the mine. The geochemical and isotopic sampling and analyses provided in this work represent a comprehensive and site-wide data set that adds significantly to the overall understanding of the hydrogeology at the Giant Mine.

The information database on water chemistry that has been developed over the past three years is adequate to support an evaluation of the management alternatives and will allow a balanced assessment in the selection of preferred alternatives.

4.1 Comments on the Conclusions

The main observations and comments by the IPRP on technical review of SD No. 3 are as follows.

1. Work over the past two years has been focused on more accurately partitioning the sources of arsenic leaching to the main sump. The new information confirms earlier results and provides a much better understanding of arsenic concentrations discharging from the backfilled tailings. Ditch and sump sampling within the mine has integrated the hydrogeology work with the mine water chemistry. Most of the arsenic enters the mine system between C Shaft and 1000N. Average arsenic loads from the mine discharge are about 40 kg/day but range up to about 110 kg/day based on pump cycling and seasonal variations. These arsenic loads can now be used to calculate arsenic concentrations in discharge water under several mine re-flood scenarios.

2. The 2001/2002 work correctly focussed on characterization of the seepage quality and quantity emanating from backfilled tailings and waste rock stopes. This was an important task because previous data erroneously indicated that tailings backfill was a potential major source of dissolved arsenic in the Mine at depth. The data shows that this is not the case (backfill arsenic sources of 0.4 to 6.6 mg/L for tailings and 0.23 to 1.6 mg/L for waste rock).

3. An important reconnaissance-level survey of water flows and arsenic concentrations throughout the mine was also performed in 2001/2002 to firm up the water and arsenic mass balance. This data set is now much more complete and the water and mass balances are fully described and probably cannot be improved upon without significant additional effort.

4. Water samples for geochemical and isotopic analyses were collected following accepted protocols.

5. The IPRP agrees with the conceptual model of Mine inflows presented in SD No. 3, all of the major sources of water inflow have been identified and characterized.

6. The interpretation of available chemical and isotopic data ($\delta^{18}O$ and $\delta^{12}H$) concerning direct rapid infiltration of precipitation and Baker Creek water to depth in the mine, are consistent with interpretations provided by others (Dr. Ian Clark, University of Ottawa, and Dr. John Gibson).

The IPRP concur with SRK's listing of current condition arsenic sources concentrations (Table 3.7), in particular arsenic chambers (4,000 mg/L), backfilled tailings (5 mg/L), backfilled waste rock (1.5 mg/L), Northwest Tailings Pond and South, Central and North Tailings Ponds (5 mg/L), Polishing/Settling Ponds (1 mg/L) and soils, bedrock and mine walls (0.05 mg/L). These data and the flow numbers show that 92% of the arsenic loading to mine water is from the arsenic chambers, with most of the remainder from seepage from the Northwest Tailings Pond. These are important conclusions. The IPRP agree with SRK's findings in this area.

Considerable progress has been made over the past two years in understanding the mine water chemistry. SRK have done a good job on partitioning flows in the mine and determining the associated arsenic loadings. The mine water balance is now quite well defined. The conclusions presented by SRK are reasonable and are supported by the data.

4.2 Further Issues to be Addressed

- Some of the flow paths sampled in the mine are long, e.g., Figs 2.2 and 2.3 – it would be useful to have samples further up the flow path in addition to the discharge point. This additional work could be used to assist in providing more detail on seepage into the mine, particularly if it is focused on rock type and geological structure.

- Several parts of the SRK Report and supporting documents note that old exploratory boreholes may be significant conduits for migration of mine water and arsenic loads. However, to date very little work has been done to assess this effect. Evidence is presented which indicates that arsenate precipitates with calcium and magnesium under oxidizing conditions at seeps below the chambers – would this occur along groundwater flow paths if the chambers were flooded and would the precipitate lower the hydraulic conductivity of the fractures?

4.3 Recommendations

- Additional work should be done to refine the arsenic loading calculations by increased sampling at additional sampling points, in particular assessing the effects of old exploration boreholes.

- The IPRP would like to see more work completed on the fate of arsenic in the natural groundwater environment of the site. If as suspected, arsenate precipitates under certain groundwater chemistry conditions, then a natural attenuation approach could potentially be considered as an alternative or combination alternative for remediation. This could lead to significant cost savings.

- Consideration should be given to partitioning the high concentration arsenic within the mine for pre-treatment. This could lead to efficiencies in the treatment process and could potentially save on treatment costs.

5.0 REVIEW COMMENTS - GEOCHEMICAL CHARACTERIZATION OF OTHER SOURCES

SD No. 4 describes the 2001/2002 field sampling and laboratory testing program undertaken by SRK to characterize other potential arsenic sources found within the Giant Mine. The work evaluated the arsenic leaching potential of other mine arsenic sources, e.g., backfilled mill tailings (both combined flotation and leached roaster calcine tailings (brown) and flotation tailings (grey), waste rock, wall rock, track ballast, and track slimes.

The primary objective was to determine if these materials would be a significant source of soluble arsenic under mine re-flood scenarios. These data have been integrated with the information developed from the seep sampling and testing completed over the past two years (the data presented in SD No. 3) to develop arsenic source terms for each of these materials.

In terms of the two types of backfill tailings, it was concluded that the brown tailings have a greater potential to be a long-term source of arsenic leaching to the environment than the grey. Wall rock and track ballast have similar geochemical properties to waste rock, they are a potential source of low arsenic contamination, they have a low potential for acid generation under unsaturated conditions and even less under saturated conditions. However, the track slime chemistry is more similar to the leachable brown backfill tailings.

The main observations and technical review comments by the IPRP on SD No. 4 are as follows:

- The testing program appears complete including, rinse tests, mineralogy, metal analyses, sulphur analyses, acid base accounting analyses, pore water extraction tests, leach extraction tests and sequential extraction tests; and

- The tailings characterization program identified brown (combined flotation plus leached roaster calcine with iron oxide, 1957 to 1967 era) tailings and grey (flotation tailings, 1967 to 1978 era) tailings present in about equal proportions.

The summary of arsenic source concentrations given in Table 4.1 in SD No. 4 for re-flood scenarios reasonably reflect the site conditions. The results are consistent with the data from the seep-sampling program described in SD No. 3 and with data from the literature. The arsenic source concentration for the brown iron rich roaster tailings is appropriately increased from 5 to 10 mg/L based on a reductant-oxidant balance, to account for reductive release of arsenic bound to secondary iron oxy-hydroxides on re-flooding.

The arsenic source concentrations for these other sources have been well characterized and are significantly less (1.5 to 10 mg/L) than the source concentrations for the arsenic chambers (4000 mg/L).

Given the information provided in this supporting document the conclusions drawn by SRK are reasonable and are supported by the data.

5.1 Further Issues to be Addressed

Additional laboratory testing to quantify the potential release of arsenic from iron oxy-hydroxides within backfilled tailings under flooded mine conditions would be valuable in providing a better understanding of this potential arsenic. SRK advised the IPRP at a meeting held in Vancouver on October 25, 2002 that such testing is underway. SRK indicated that the initial test results confirm the 10 mg/L assumption made in SD No. 4. The IPRP have not had an opportunity to review this work yet.

5.2 Recommendations

The IPRP would recommend that future investigative work be directed at understanding the fate of arsenic migration in the natural groundwater environment under saturated conditions.

6.0 REVIEW COMMENTS - TAILINGS BACKFILL

SD No. 4B provides a summary of the available historical information on tailings backfill use and placement within the Giant Mine as gleaned from a review of available monthly records, stope records and mine annual reports. This supporting document describes where both flotation and roaster tailings were used as backfill within the underground mine.

This document provides useful information on understanding when and where mill tailings were used as underground backfill within the Giant Mine and contributes to providing an understanding of the contribution that these materials make as a source of soluble arsenic to the overall arsenic balance in the mine water both under current and potential flooded conditions.

The IPRP concurs with the observations and conclusions made by SRK.

7.0 REVIEW COMMENTS - ARSENIC TRIOXIDE DUST PROPERTIES

The main Reference document for SD No. 5 in this respect is the Geocon Inc. 1981 Report on "Mine Backfill Sampling Programme". SRK have made best use of the geotechnical data included in this Reference document. However, it is important that the work done in 1981 is viewed in proper context, particularly inasmuch as the objectives at the time differ significantly from those under consideration in the present studies.

The work carried out in 1981 was directed primarily at recovering bulk samples of the arsenic in storage from the various stopes investigated, and to obtain an initial indication of the feasibility of recovering the arsenic by airlift type methods. The exploration equipment that was used, therefore, was suited to these objectives but was not standard for conventional geotechnical field investigations. There appeared to be a market for the arsenic trioxide at the time, and recovery would only be carried out to the extent required to meet market needs. There was no requirement at the time to carry out extraction consistent with current environmental considerations, nor was underground mining for extraction purposes etc. contemplated at the time. It was important, of course, to check whether the arsenic trioxide was frozen and whether it was dry or saturated.

One of the features of the Geocon Report is that it described in considerable detail the drilling, sampling, and bulk recovery procedures used at every one of the seven boreholes put down. It would be useful for SRK to describe these procedures, as they would be meaningful to the geotechnical reader of the SRK report. The geotechnical characteristics of the arsenic trioxide, as determined by the testing in the boreholes as well as through the laboratory testing programme are, of course, of value to the present studies of management alternatives. However, since no additional geotechnical field or laboratory testing was carried out as part of the present work, it appears that SRK were satisfied that the 1981 investigation by Geocon was adequate for this stage of the Alternatives Study. If this were the case, it would have been appropriate for SRK to indicate accordingly.

The IPRP considers that the SRK Report should include recommendations for additional geotechnical investigations of the arsenic trioxide in storage, where the scope of such investigations would depend on the management alternative selected. This additional work should supplement the available data on index properties (grain size, Atterberg Limits, specific gravity, etc.) as well as characteristics such as strength, compressibility, in-situ density, permeability, and susceptibility to liquefaction ("mud-rushes"). This material is unusual in a geotechnical sense and current state-of-the-art investigation methods would have to be organized accordingly, with safety protocols, etc. The extent to which the arsenic trioxide in storage has become saturated (or frozen) in the last 20 years would also be of importance, of course.

As noted in the Geocon 1981 Report, the crowns above several of the stopes containing arsenic trioxide were permafrost. It would be of interest to check whether this is still the case. As noted also, the drill holes through the crowns above stopes were plugged in such a way that they could be redrilled in the event that access in the future for drilling or video inspection by camera, etc. were required.

8.0 REVIEW COMMENTS - HUMAN AND ECOLOGICAL RISK ASSESSMENT

SD No. 6 entitled: "*Giant Mine Human and Ecological Risk Assessment*" was written by SENES Consultants Ltd.. SENES performed a Tier 2 risk assessment on ecological and human receptors. This provided an ecological risk assessment (ERA) and a human health risk assessment (HHRA) following a commonly used generic framework for environmental risk\ assessments. Tier 2 refers to a preliminary quantitative process that focuses on filling gaps that were identified in a previous Tier 1 (screening level) risk assessment.

The Tier 2 risk assessment included:

- Compilation of data on historical arsenic releases to the environment;
- Assessment and theoretical prediction of arsenic uptake by aquatic plants and animals;
- Compilation of historical data on arsenic levels in soils, sediments and biota in the study area;
- Limited discussion of arsenic levels in the atmospheric environment;
- Assessment and theoretical prediction of arsenic uptake by terrestrial vegetation and animals;
- Identification of exposure pathways for ecological species and hypothetical human receptors;
- Theoretical prediction of arsenic pathways in the environment and transfer along the food chain; and
- Use of multiple calculated realizations of exposures, drawing parameter values from specified probability distributions derived from judgement and limited evidence for each parameter, to address uncertainty in the assessment of exposure and dose levels.

These assessments focused on future scenarios of arsenic release to the aquatic environment, all releases being assumed to flow via Baker Creek, ranging from an increase (approximate doubling) over current estimated background arsenic discharges in Baker Creek (totalling 950 kg of arsenic per year) to four other scenarios reflecting progressively higher arsenic emissions, reaching a high of 16,450 kg/yr. The highest level was estimated to correspond to future uncontrolled aquatic releases of arsenic from the arsenic trioxide dust currently stored in the mine.

8.1 Summary of Findings, Conclusions and Recommendations

Predictive modeling of water quality and sediment quality was performed for the five arsenic release scenarios using a model treating Back Bay, North Yellowknife Bay and South Yellowknife Bay (see Figure 4.2, SRK Final Report) as each consisting of homogeneous water and sediment compartments. The model was calibrated against past arsenic release and monitoring data. These predictions showed for Canadian water quality criteria that:

- The current Canadian arsenic drinking water guideline (25 µg/L) was exceeded for all arsenic release scenarios in Baker Creek and in Back Bay for the highest arsenic release scenario (16,450 kg/yr);
- The current Canadian arsenic water quality guideline for the protection of aquatic life (5 µg/L) was exceeded for all arsenic release scenarios in Baker Creek, for all but the lowest (950 kg/yr) arsenic release scenario in Back Bay and even in North Yellowknife Bay for the two highest arsenic release scenarios (4,450 and 16,450 kg/yr).

The model predictions showed that most published sediment quality criteria that were considered were exceeded under all arsenic release scenarios at Baker Creek, Back Bay and North Yellowknife Bay. Only the most stringent sediment quality criteria (CCME) were exceeded for all arsenic release scenarios in South Yellowknife Bay. These sediment quality comparisons were insensitive to arsenic release scenarios because of the major impact of historical arsenic releases on existing levels of arsenic in sediment.

The Tier 2 ERA and HHRA employed commonly used risk assessment conventions. The ERA considered ecological receptors selected to exhibit differing dietary characteristics to span a range of arsenic exposure pathways. Specifically the ERA considered:

- <u>Aquatic receptors</u>;
    - Benthic invertebrates;
    - Fish (northern pike and whitefish);
    - Ducks (merganser, mallard and scaup);
- <u>Terrestrial receptors</u>;
    - Moose;
    - Hare;
    - Bear;
    - Grouse;
    - Caribou;
    - Wolf; and
    - Mink.

This preliminary quantitative ERA predicted that no arsenic release scenario would affect the assessed aquatic receptors except for:

- Benthic invertebrates in Baker Creek (at 4,450 kg/yr and 16,450 kg/yr);
- White sucker in Baker Creek (all release scenarios except 950 kg/yr); and
- Ducks (all species) on Baker Creek for the highest (16,450 kg/yr) release scenario.

Likewise, the ERA predicted that no arsenic release scenario would affect any of the terrestrial receptors except for:

- Moose and bear for 16,450 kg/yr; and
- Muskrat and mink for all release scenarios.

The HHRA considered 6 different pairs (adult and child) of hypothetical human receptors, as follows:

- An adult only worker at the mouth of Baker Creek;
- An adult and child in the City of Yellowknife;
- An adult and child on Latham Island with a regional country foods diet;
- An adult and child on Latham Island with a local country foods diet;
- An adult and child in the Dettah community with a regional country foods diet; and
- An adult and child in the Dettah community with a local country foods diet.

These receptors were assessed for non-carcinogenic and carcinogenic health risks following intake pathways modeling of arsenic exposure according to the defined characteristics assigned to each hypothetical receptor. For the non-carcinogenic health risks measured against the Health Canada reference dose (RfD) of 2 µg/kg-d only the child receptor on a regional country food diet at Latham Island (receptor 3c) was predicted to have an inorganic arsenic intake exceeding that RfD, only for the highest arsenic release scenario (16,450 kg/yr).

For cancer risk, the comparison was made with the cancer risk that is implicit in the current Canadian drinking water guideline for arsenic (25 µg/L). In this case, only composite adults (a combination of a child growing to an adult because cancer risk is assessed on a 70 year lifetime risk basis) consuming either the local or regional country foods diet at Latham Island would exceed that risk comparison for only the highest arsenic release scenario (16,450 kg/yr). This finding reflects the HHRA methodology having chosen to assume that these receptors consumed their drinking water directly from Back Bay rather than using the City of Yellowknife municipal water supply.

8.2 Report Conclusions

The SENES report concludes on the basis of both the ERA and HHRA that an arsenic release rate of 4450 kg/yr may be acceptable, but recommends being more cautious by limiting the release rate to 2,450 kg/yr. The report states: "*This will ensure that there is minimal impact on the ecosystems of Back Bay and Yellowknife Bay, while providing a safe level of exposure to all people using the area.*"

The impact of past arsenic releases is noted by observing: "*Existing water and sediment levels in Baker Creek pose a risk to some aquatic and terrestrial species that reside in and along the creek. The predicted effects for the arsenic release scenarios showed that the same species would potentially be at risk for scenarios with a load equal to less than 4,450 kg/yr.*"

8.3 Report Recommendations

The SENES report did not include any specific recommendations in the two paragraphs of Section "*7.5 Overall Conclusions and Recommendations*" for SD No. 6.

Although not explicitly made as a recommendation, the SENES report did state, immediately before Section 7.5, that:

"*Biological monitoring (urinary speciated arsenic levels) in the affected population, coupled with food consumption diaries for the period preceding sampling, can provide external confirmation of the assumptions used in this risk assessment. Such monitoring has been done in other areas in Canada and can provide empirical evidence of the arsenic exposure burden on the population. This exposure burden can be translated into health impact, and provide a scientific basis for action.*"

8.4 Comments on Recommendations and Conclusions Reached by SENES Consultants

- The exposure pathways analysis is nicely summarized in Figures 6.3-1 to 6.3-6 and in Tables 6.3-2 to 6.3-6 in SD No. 6 . The Figures show that proportional contributions to total arsenic exposure from market basket food, terrestrial (soil, vegetation and game meat) and aquatic (water and local fish ingestion). The Tables break these categories out in detail for each receptor for each of the 5 arsenic release scenarios, with one table in each case showing the estimated arsenic intake (mg of arsenic / kg of body mass each day) and the proportion of total arsenic intake that can be attributed to each category. A striking feature from these data is the dominance of fish as a route of arsenic exposure. According to the description on page C-22 (Appendix C), the fish flesh concentrations are derived from modeled water concentrations using a simple linear bioconcentration factor to convert water arsenic concentration into fish flesh concentration. This conversion parameter itself is presented as a probability distribution to allow for probabilistic runs that were presumably done using Monte Carlo simulation, although that process is not clearly explained and probability distribution outputs are not shown.

The cause for concern about this analysis is that while this exposure pathways analysis has clearly shown that the receptors who are most highly exposed to arsenic receive their exposure via ingestion of fish, SENES has made the assumption that absolutely all (100%) of the arsenic to be found in fish flesh is present as organically bound arsenic and furthermore that all such organically bound arsenic is essentially non-toxic. SENES presents some rationale for these choices, but given the central role that this aspect of the arsenic exposure plays in the total HHRA, these judgments are not adequately justified and they certainly cannot be characterized as cautionary ("conservative" in the language used by the report).

The first assumption that all arsenic is organically bound in fish is based primarily on SENES interpretation of the work of Koch 1998, a PhD thesis from the University of British Columbia, under the supervision of Dr. W. Cullen. This reported "*semi-quantitative*" [1] analyses for 3 whitefish, 2 suckers, 2 walleye and 2 pike from the outlet of Baker Creek. Likewise, the study found arsenic extraction efficiencies ranged from 19 to 78% except for one fish that exceeded 100%.

The author observed that:
"*Protease digestion was expected to have solubilized most of the arsenic, although time constraints did not allow determinations of the total arsenic in the protease digestions to be made. However, if most of the arsenic was solubilized, a large amount of arsenic is unaccounted for in these results. This arsenic may be bound to molecules such as peptides or incompletely hydrolysed proteins that may precipitate or remain irreversibly bound on the chromatographic systems used here.*"

The finding in the Koch thesis of very low to non-detectable levels of inorganic arsenic (As(V)) taken together with similar reports of low inorganic arsenic in other studies of freshwater fish was adopted by SENES as justification that inorganic arsenic can be considered to be 0% in all fish that may be consumed by the designated receptors.

The second presumption made by SENES is that all of the organic arsenic, including dimethyl arsenic acid (DMA [V]), arsenosugar XI and at least two unidentified arsenic compounds, are all as non-toxic and innocuous as arsenobetaine and arsenocholine. The presumption that arsenobetaine and arsenocholine are essentially non-toxic is well established and secure. The relative lack of concern over DMA [V] has been commonplace, including some relatively recent compilations on arsenic toxicity (e.g.

[1] Koch, I. 1998. Arsenic and Antimony Species in the Terrestrial Environment. PhD Thesis. Department of Chemistry. University of British Columbia. page 182.

ATSDR 2000). However, research published very recently **may** call these assumptions into question. Very little is known about the toxicology of the arsenosugars, but some have been shown to be metabolized.[2] Pentavalent arsenic, (e.g. DMA [V]) which was thought to be innocuous has been shown to be metabolized through intermediates to some trivalent species monomethylarsonous acid (MMA [III]) and dimethylarsenous acid DMA [III] both of which have been shown to be at least as toxic as inorganic arsenic.[3] There is also some evidence of these trivalent species being genotoxic.[4] These new findings are certainly too early and limited to be considered conclusive evidence to warrant attaching the same level of toxicological concern for DMA that currently exists for inorganic arsenic. However, arsenic toxicology is currently one of the hottest areas of research in environmental toxicology and a risk assessment for long-term arsenic management must consider the possibility that these emerging toxicological findings will become conventional wisdom in the foreseeable future.

Taken together, the two foregoing presumptions by SENES to discount 100% any arsenic exposure from fish in the overall risk assessment is certainly not cautionary. Given that fish were found, through the exposure pathways analysis, to be the dominant human exposure route for arsenic, total discounting of this route of arsenic exposure will be difficult to defend. The Tier 2 risk assessment seeks to be more "realistic" than the screening level Tier 1 risk assessment. In this case, the total arsenic exposure estimate for fish should not have been discounted any more than 90%, leaving at least 10% of total predicted arsenic in fish being carried through the complete risk assessment. If the entire risk assessment is to be defended as being reasonably cautionary, some consideration of arsenic exposure via fish must be included. Suitable qualifiers about the limited confidence that should be placed in the newer, preliminary findings on arsenic toxicology for MMA [III] and DMA [III} is appropriate.

The explanation that discounting arsenic exposure via fish 100% is balanced by the cautionary assumption that all of the arsenic found in wild game is present as inorganic arsenic. While there is no question that the wild game assumption is cautionary, it is not justified and there has been no analysis provided to illustrate that this assumption over or under compensates for the decision to discount fish arsenic 100%. A quick look at the proportion of arsenic loading coming from various sources shows that the contribution of arsenic from wild game exceeds 40% for an occasional receptor and scenario, but these are different receptors and scenarios than would be affected by allowing any arsenic contribution from fish consumption. Accordingly, viewing the one, perhaps overly

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[2] Le, X.C. 2002. Arsenic Speciation in the Environment and Humans. Chapter 4, In: *Environmental Chemistry of Arsenic*. Ed. W.T. Frankenberger. 95-116.
[3] Cohen, S.M., L.L. Arnold, E. Uzvolgyi, M. Cano, M. St. John, S. Yamamoto, X. Lu and X.C. Le 2002. Possible role of dimethylarsinous acid in dimethylarsinic acid-induced urothelial toxicity and regeneration in the rat. *Chemical Research in Toxicology*. 15: 1150-1157.
[4] Mass, M.J., A. Tennant, B.C. Roop, W.R. Cullen, M. Styblo, D.J. Thomas and A.D. Kligerman. 2001. Methylated trivalent arsenic species are genotoxic. *Chemical Research in Toxicology*. 14: 355-361.

cautious assumption as directly compensating for the other inadequately cautious assumption is not borne out by the data presented.

- The SENES exposure pathways analysis uses a model called "Lakeview" to account for the distribution of the arsenic discharged in Baker Creek out into Back Bay and ultimately into Yellowknife Bay. The model represents this region in terms of three compartments (Back Bay, North Yellowknife Bay and South Yellowknife Bay) and each compartment is divided into two zones surface water and sediment. The model allows for the transport of arsenic discharged into Back Bay to be partitioned between surface water and sediment and/or transferred to the next compartment. This model apparently provides for uniform concentrations within each compartment. In other words, the model is not set up to track the arsenic plume dispersion that would occur for Baker Creek as it discharges into Back Bay and ultimately into Yellowknife Bay. Rather, the model apparently distributes the arsenic contribution from Baker Creek uniformly throughout the entire volume of Back Bay. The further downstream one goes from Baker Creek, the less difficulty that this approach creates, but in the immediate vicinity of Baker Creek (first few hundred meters), the arsenic concentrations in the actual Baker Creek plume will be much higher than would be assumed by instantaneously diluted Baker Creek flow into the entire volume of Back Bay, as apparently is done with this compartment model. This impact on risk estimates of this concern could be evaluated by looking at the finer scale (smaller compartment) run of the Lakeview model that was performed for evaluating the acute spill risk for SD No. 18.

  The effect of using the compartment model vs. a plume dispersion model is that the compartment model represents the dispersal of impact over a wider area, but the peak arsenic concentrations estimated for Back Bay will not be as high they would actually be under the various arsenic input scenarios from Baker Creek. A very cautious approach might place and keep a receptor in a zone that was influenced more by the expected higher Baker Creek plume arsenic concentrations. In such circumstances, higher arsenic exposures would be predicted than is predicted with the compartment model. The higher concentrations can be argued as more realistic, but fixing a receptor strictly within the influence zone of the Baker Creek plume is likely too pessimistic. Yet, the description of Receptors 1, 3 and 4 does make them sound like they are fixed at the locations shown in Figure 3.2-1, so it is important to realize that the Receptors may be located at any point in the large defined compartments of the Back Bay, north and south Yellowknife Bay.

- The authors have not presented any data on validation of the model as those presented for the Lakeview model in their Appendix B. Is it possible to run a similar exercise to compare predicted values to historical measured values as presented those for sediment and water in Figure B.6.3-1 and B. 6.3-2 in SD No. 6.

- A comparatively minor issue concerns how bioavailability of arsenic from local soils was addressed in section 4.2.3 (page 4-5) of SD No. 6. This section describes bioavailability as the fraction of an administered dose that reaches the blood stream. The default assumption that was used in the previous Tier 1 risk assessment was that 100% of the external applied dose would reach the blood stream and thereby be available for subsequent toxic action within the body. Most metals found in soils by chemical analysis are not 100% bioavailable, so assuming 100% is certainly a cautionary assumption.[5] In the current risk assessment, literature evidence, provided in Section C6.0 (Appendix C, pages C-37 to C-46) was used as a basis to select a bioavailability factor of 50% for arsenic in soil. The logic applied was stated as:

"*To put bioavailability studies in context of risk assessment, one should recall that there are large uncertainties surrounding other steps of the risk assessment process. For instance, exposure factors and transfer factors to drive the oral dose to humans and other biological receptors inherently carry uncertainties possibly as large as one order of magnitude. Considering the fact that more than 70% of the bioavailability results range from 25 to 70%, the use of 50% bioavailability in the Tier 2 risk assessment is reasonable.*"

This assumption is not cautionary under the circumstances outlined. Assuming 100% bioavailability would clearly overestimate risk because it is not conceivable that 100% of soil arsenic will be absorbed across the gut based on any experimental evidence. Yet, as was evident in Figure 6.3-1 (from Ruby et al. 1999), presence of arsenic trioxide in soil will contribute to greater bioavailability. Many of the literature reports cited in Table C6.3-1 with low arsenic bioavailability were for slags or arsenic minerals in native soils. The source of elevated soil arsenic in the region influenced by the Giant Mine was atmospheric deposition of arsenic trioxide dust. Hence, a truly cautionary assumption for bioavailability of arsenic in soil that is derived from the influence of Giant Mine should be at the higher end of literature reported values, not the middle, if Figure 6.3-1 that was cited from Ruby et al. (1999) is given any credence.

This concern is not likely to be a pivotal error in the overall arsenic exposure calculations because the arsenic exposure from soil uptake was small in absolute terms and was generally small in relative terms. The only exception was Receptor 2c (Yellowknife child), who had as much as 46% of his or her exposure from soil, but the total arsenic exposure for this receptor was 0.0002 mg/kg-d for all scenarios except scenario 5 (16,450 kg/yr) where it was 0.0004 mg/kg-d. For this receptor, the market basket exposure to arsenic is reported as 0.00048 mg/kg-d. Given the low profile of soil exposure anyway, it would have been prudent to use a more precautionary bioavailability factor for arsenic from soil, say 80%, to be closer to the upper bound of bioavailability values in the literature review.

- The Canadian drinking water guideline for arsenic that is used as a basis for comparing the cancer risk assessment predictions from the HHRA has remained as an Interim

[5] Hrudey, S.E., Chen, W. & C. Rousseaux. (1995). Bioavailability in Environmental Health Risk Assessment. Lewis Publishers, CRC Press, Boca Raton, Florida, 291 pp.

Maximum Acceptable Concentration (IMAC) since last evaluated in 1989 and arsenic is currently on the Health Canada priority list for review and update. There is a very real possibility that this number will be lowered in the future, given that it is now 2.5 times higher than both the U.S. and the World Health Organization drinking water criterion for arsenic. Because the distinct possibility, if not likelihood of the Canadian guideline being lowered is eminently foreseeable, the HHRA discussion of that basis for an arsenic cancer risk comparison should acknowledge that possibility and the impact that it would have on the comparison that was made to summarize and interpret cancer risk from arsenic..

- The comparison of actual and predicted arsenic levels in sediments, which are largely attributed to historic arsenic releases, reveals widespread sediment levels that exceed most of the published quality criteria. This reality needs to be discussed more fully with a view to outlining what ecological impacts the legacy of these arsenic levels in sediment are having now and are expected to have in the future.

- The ERA of terrestrial receptors, mink and muskrat are identified as being adversely affected by arsenic for all discharge scenarios. The ERA notes that these receptors were assumed to be present on the downstream segment of Baker Creek for the entire year "*which may result in an overestimation of exposure for these two species.*" This limited discussion of this adverse prediction is inadequate. The projections of Figures 6.2-5c and 6.2-5d in SD No. 6 appear to show that adverse effects might still be a problem at even 50% of the estimated exposure level. Some discussion of whether adverse impacts are truly expected and some suggestions for how these predictions could be validated through field studies are warranted. It may be important to highlight in the document that no matter which approach is to be adopted, the water quality of Baker Creek is marginal at best for drinking water purpose and the sediment quality of the Baker Creek will remain to be poor.

- Even though it will be a challenge, it is useful to summarize the ecological effects and interpret the significance. Can the people expect the return of more sensitive species? Or on the other hand, what is the significance of certain species being affected?

- The authors of this report calculated the fish intake by using the mean intake calculated from the 24-hr dietary recall data for late winter or fall (whitefish 226 g/day in Dogrib male 20-40, Table 12C, Receveur et al, 1996) times the percentage of the population consuming the food (89% for whitefish) and frequency of consumption in winter and fall (1.2 days/week, Table 8, Receveur 1996) to arrive at 38 g which they assume to be an average annual intake for the entire population. They also use the food frequency data from the Backbay study (Receveur et al., 1998) to calculate the annual intake to be 33 g/d. Their numbers of course is different from the IPRP's estimate of 44 g/d for consumers only (Table 21, Receveur, 1998). It is because they mixed up the data from the 2 dietary assessment instruments that reflects the intake of four different seasons and consumer vs the whole population. The difference between the regional diet and the local diet as suggested by the authors is not real. Therefore, the receptor 3 and 4, and 5 and 6 should be the same. The estimate for annual intake for traditional food needs to be re-calculated. The IPRP has done an estimate of contaminants intake in the region. SRK should consult the following paper for reference.

> Berti, P.R., Receveur O, Chan H.M., Kuhnlein, H.V. (1998) Dietary exposure to chemical contaminants from traditional food among adult Dene/Métis in the western Northwest Territories, Canada. Environ. Res., 76:131-142.

- To assess usual intake is a major challenge even for the seasoned nutritionist. It is commendable that the authors try to use a probabilistic model to describe usual intake in the communities. It will probably work for the estimate of market food but will not work for traditional food. In Table 4.4-2, the authors presented the average daily intake for meat and poultry in traditional food and the "fraction" which can be assumed as the percentage of the participants responded positively of eating the food. This value ranges from 0.004 to 0.79 for ducks and caribou, respectively. It is obvious that the intake distribution curve for these food items will be very different. The authors, however, use a single log-normal distribution model developed by Richardson (1997) for the Canadian population to describe the total intakes from meat, poultry and fish (p.4-15). All the parameters used (min, max and the geometric standard deviation of 1.5, in particular) are likely to be invalid.

- It is suggested that the authors calculate mean intake for each food item and estimate the high users' intake by adding 2 standard deviations, assuming the coefficient of variations is 100% (see Akaitcho 2000 for example).

- It is not clear whether the authors have used Monte Carlo simulation to account for the variability of As concentrations in the food items to calculate the exposure estimate. It will be useful to create a table similar to Table 6.1-1 for different food species used for intake estimates.

- It is not clear how intake of market food was estimated for Receptor 1 and 2. The equation presented in Page C-48 does not make sense as Table 7.1-1 is for As levels in foods.

- The choice of RfD for the HHRA was taken as 2 µg/kg-d from Health Canada in preference to the U.S. EPA value of 0.3 µg/kg-d was made. The SENES report only notes that the Health Canada value is almost 10 fold higher than the U.S. value and that the latter is based on epidemiological studies of arsenic in drinking water. Given the large difference between RfD values and the corresponding large difference the choice of RfD makes to determining if estimated exposures exceed the RfD, a defensible justification should be made for choosing the Health Canada RfD. To choose the higher RfD solely because it was recommended by Health Canada is not very persuasive about its merit for use in a Tier 2 HHRA.

- Throughout the text, the authors use the term "benchmark" and "reference" for intake level or dose. These terms are now widely used by USEPA for their assessment protocol and they have a specific definition based on statistical analysis of the dose-response relationships. The effective dose (ED) that causes some critical effect in a specified percentage of the test animals (e.g., ED05 or ED10) is established and the lower confidence limit for the effective dose is designated as the "benchmark dose." This benchmark dose may then be adjusted by uncertainty factors to arrive at the reference dose (RfD) or reference concentrations (RfC). To avoid confusion, it is better to use more generic terms such as effective dose for NOEL or LOEL and guideline level for guidelines used by different agencies.

- The current approach to risk assessment for toxic non-carcinogenic chemicals is based on the assumption that there exists a threshold below which no adverse non-cancer health effects are expected under lifetime exposure. Various regulatory agencies estimate a "safe" exposure by first determining an exposure level which has been shown to cause no adverse effect in animals or humans and then apply "uncertainty" factors to account for missing information. All the guideline levels have an uncertainty factor associated with it. The magnitude of the uncertainty factor depends on the quality of the data. Since uncertainty is the intrinsic nature of the risk assessment process, it is NOT necessary to discuss the uncertainty of the guideline repeatedly throughout the text. Besides, the Taiwan data is a pretty strong data set because of the large sample size. The newer data from Bangladesh also show similar findings.

- It will be useful to include a table like the following and discuss the rationale for the use of different study results and UF for different agencies.

Guideline levels for non-carcinogenic end-points

Inorganic As Intake (ug/kg/day)	Guideline	Authority
2.0	Tolerable Daily Intake	World Health Organization
2.0	Tolerable Daily Intake	Health Canada
0.3	Minimal Risk Level	Agency for Toxic Substances and Disease Registry
0.3	Reference Dose	US Environmental Protection Agency

- There is no evidence of any validation of the human receptors in terms of diet with corresponding negative impact on the credibility of the predictions.

- There may be other sources of As in the diet. For example, we have just completed a study that shows significant As intake from herbal tea made from local herbs in the area. It is prudent to add a 10% intake from miscellaneous sources.

- A consequence of the approach taken for the HHRA and ERA, which relies on a selected range of arsenic release rates, independent from the estimated arsenic release rates established for various arsenic trioxide management alternatives, is that the HHRA and ERA stands somewhat independent of the quantitative process risk assessment (QPRA) for the various arsenic trioxide management alternatives. In the overall risk assessment taxonomy that has been adopted, there are two ways of comparing the arsenic trioxide management alternatives in relation to risk, one that looks at differing consequences for different arsenic emission rates and one that looks at different probabilities of occurrence for a specified maximum tolerable arsenic emission rate (2000 kg/yr). The HHRA and ERA provided a reference point for the overall QPRA by characterizing the maximum recommended levels of arsenic release below which environmental consequences might be deemed tolerable (i.e. 2,450 kg/yr including background). Subsequently the QPRA in Supporting Document 18, has taken this arsenic emission level to fix the magnitude of a process failure, focusing on estimating the probability of such a failure.

- The conclusion that arsenic release rates should be limited to less than 2,450 kg/yr is likely defensible, but this report does not offer a very robust defence of this choice. Furthermore, the claim that this level will provide a "*safe level of exposure to all people using the area*" is likely to attract substantial, but largely unproductive debate. The cancer risk estimates of 1 in a 1000 lifetime cancer risk is associated with the Canadian drinking water guideline and has been used as the reference point. The supporting document for the Canadian guideline states[6]: "*The MAC is designated as interim because the lifetime skin cancer risk associated with the ingestion of drinking water containing arsenic at the IMAC is greater than the range that is considered to be essentially negligible.*" This statement provides a weak basis to buttress the "safety" of arsenic exposures in the Yellowknife region that only just meet the IMAC. Safe is an important, but inherently controversial judgement that must be used with very defensible evidence.

The risks clearly can be classified as small cancer risks that will certainly be undetectable in the population. For a 1 in 1000 lifetime cancer risk in a population of 10,000 (approximately the population of Yellowknife), if the entire population was exposed at the maximum level, would predict 10 cases of cancer over 70 years, or an average of 1 extra case every 7 years. Such a low cancer rate would be impossible to detect under any conceivable health surveillance system given that more than 35% of all Canadian females and 40% of all Canadian males are expected to contract some form of cancer some time in their lifetime.[7]

- The conclusion about risks to some aquatic and terrestrial species from existing water and sediment levels in Baker Creek needs to be expanded, at least to the extent of suggesting how or if it might be possible to measure the current impacts that are being predicted.

- The discussion about possible monitoring of urinary excretion of local residents in relation to their documented arsenic intake deserves to be made as an explicit recommendation. This is one of the few tangible actions that can be taken to gather evidence and provide context relevant to future health effects assessment.

8.5 Further Issues to be Addressed

1. The calibration results for the Lakeview model (pages B-47 to B-50 of SD No. 6) may be as good as can be achieved under the circumstances, but the appearance of the predictions in relation to the data do not instil great confidence that this model is accurately depicting the water quality results for the periods in question.

2. The approach described for relating the model to the monitoring data may qualify as <u>calibration</u>, but there does not appear to have been either <u>verification</u> or <u>validation</u> of the model. According to Schnoor:[8] "*Calibration is a statistically acceptable*

[6] Supporting Document for Arsenic. February 1989 (edited August 1992). Guidelines for Canadian Drinking Water Quality. The Federal-Provincial-Territorial Subcommittee on Drinking Water. Ottawa.
[7] National Cancer Institute of Canada: Canadian Cancer Statistics 2001, Toronto, Canada. 2001. Table 12, p. 54.
[8] Schnoor, J.L. 1996. *Environmental Modeling – Fate and Transport of Pollutants in Water, Air and Soil.* J. Wiley and Sons, Inc. New York. p.10

comparison between model results and field measurements; adjustment or tuning of model parameters is allowed within the range of experimentally determined values reported in the literature" vs. "*Verification is a statistically acceptable comparison between model results and a second (independent) set of field data for another year or at an alternate site model parameters are fixed and no further adjustment is allowed after the calibration step.*" vs "*Validation is scientific acceptance that (1) the model includes all major and salient processes, (2) the processes are formulated correctly, and (3) the model suitably describes observed phenomena for the use intended.*"

8.6 Omissions

1. Uncertainty in the exposure and corresponding risk predictions is not fully addressed by doing the Monte Carlo method. The predictions must acknowledge model error as a source of error that cannot be simulated by such methods.
2. The environmental risk assessment in this case, as a basis for informing risk management decision-making, should outline the context of this problem in more explicit terms than is currently apparent. In particular, there is a need for a thorough evaluation of known arsenic exposure scenarios around the world to allow for an informed comparison of where Yellowknife fits on the spectrum of arsenic exposure levels and potential health outcomes, both now and under any future arsenic emission scenarios.
3. In SD No. 6, Section 5.0 Hazard Assessment, it is important to present a summary of the current knowledge of the toxicity of As in both the ecosystem and human health. For example, studies have linked long-term exposure to arsenic to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Non-cancer effects of ingesting arsenic include cardiovascular, pulmonary, immunological, neurological, and endocrine (e.g., diabetes) effects.

8.7 Extra Data Required

1. There is a need for a focused evaluation of arsenic speciation in fish for a well-documented arsenic exposure scenario so that the future predictions can be made on a stronger foundation. Reliance upon the Koch thesis is not recommended. In this regard, Professor Cullen, the thesis supervisor was contacted to inquire about these specific studies and whether the data provided is a defensible basis for health risk assessment conclusions and Professor Cullen advised that he would not be comfortable with defending those data being used for that purpose.

8.8 Further Studies Required

The following studies do not need to be completed before developing a project description for arsenic trioxide management:

1. Human biomonitoring studies to validate the levels of arsenic exposure that currently exist for different real individuals in Yellowknife in relation to their documented exposure to various sources of arsenic (natural, dietary, etc.) are needed. These will provide a more convincing foundation for future discussions with the community about the health risks that arsenic in the environment poses.

2. Fish studies are needed to address the nature of arsenic speciation in fish that are directly affected by arsenic from Baker Creek, compared with fish that are not. These studies will provide a better evidentiary base for future risk management decisions.

8.9 IPRP Recommendations on SD No. 6 for SRK's Final Report

8.9.1 Boundary Conditions

The environmental risk assessment in this case, as a basis for informing risk management decision-making, should outline the context of this problem in more explicit terms than is currently apparent. In particular, there are a number of boundary conditions to the problem that can be described with a high degree of certainty. Because most elements of risk assessment will inevitably encounter substantial uncertainty in many of the key elements, prescribing what can be known with a high degree of certainty can provide an important frame of reference for informing the risk management decision-making process.

The boundary conditions in this case are a combination of some conditions that will apply to any similar case along with a few conditions that are unique to this set of circumstances. The boundary conditions are, at a minimum:

- There are no zero risk alternatives;
- Any zero action alternatives will ultimately risk serious environmental consequences in the future;
- If the exposure of any living thing to arsenic in a toxic form can be limited to very low levels (in the range of undisturbed regional background arsenic levels) then the effects caused by arsenic on any living thing will likely be too small to measure or be non-existent;

- Arsenic, is an element that cannot be destroyed by any chemical reaction, it can only be combined in various chemical forms that exhibit a wide range of differing degrees of toxicity and stability;

- The arsenic that is now present in the arsenic trioxide dust came from processing the ore that was mined from the Giant Mine over its operating life;

- The arsenic trioxide dust, being in a size range that promotes maximum respiratory tract uptake, poses a severe health risk if released back to the atmosphere in the form of fine particulate during handling; and

- There is no possible option for completely removing all of the arsenic trioxide dust that is currently stored in Giant Mine, with a few per cent of the total tonnage destined to remain under any plausible management scenario.

The predicted risks to human health and the environment associated with future projected arsenic release scenarios (between 950 and 16,450 kg/yr of arsenic released via Baker Creek to Back Bay including a background estimate of 450 kg/yr) could be better appreciated by considering the estimated past releases of arsenic to the Yellowknife regional environment from Giant Mines operations (Table 8.1)

Table 8.1 Approximate Estimates of Arsenic Release During Giant Mine Operations

Time Period	Estimated Arsenic Releases to Baker Creek, kg/yr	Estimated Arsenic Releases to Air kg/yr	Total Annual Arsenic Releases to the Regional Environment, kg/yr
1993 to 1999	500[1]	5,700[2]	6,200[3]
1983 to 1993	1,300[1]	17,900[2]	19,000[3]
1972 to 1982	14,000[1]	61,700[2]	78,000[3]
1959 to 1971	25,000[1]	84,000[2]	110,000[3]
1954 to 1958	25,000[1]	1,090,000[2]	1,100,000[3]
1949 to 1951	25,000[1]	2,600,000[2]	2,600,000[3]

[1]Various sources of estimates for arsenic release to Baker Creek were available, but the estimates used in this table were chosen to correspond to the mean values summarized in 4.1.1 of Supporting Document 6 chosen for the purposes of calibrating the water quality model used in the risk assessment.
[2]Historical atmospheric emission levels calculated from Tables 4-1 and 4-2 of EC (1997) with conversion of daily emission estimates in kg per day, to annual emissions in kg/yr, assuming 350 operating days per year
[3]Total annual emissions were rounded to 2 significant figures because of the considerable uncertainty in the emission estimates making any higher degree of precision in these estimates potentially misleading

8.9.2 Other Contextual Comparisons

SD No. 6 would be much more useful for community consultation if it provided an extensive review and comparison of other high arsenic exposure scenarios within Canada and around the world. If Yellowknife residents were able to see where their exposure to arsenic falls within a well characterized summary of arsenic exposures elsewhere, particularly if relevant health studies can be summarized along-side, they would be much better placed to put some sense of context on this problem. Setting an appropriate context for the problem, after problem definition, is the first and most important step in assessing and managing health risk.[9]

Part of this exercise of establishing context would be to explore the meaning of lifetime cancer risk of 1 in 1000 for small communities. As noted elsewhere in this review, that level of lifetime risk for a community of 10,000 (assuming that everyone in the community was exposed to that risk level), would predict 10 cases of cancer over 70 years, or on average, one case every 7 years. That is not likely to be a cancer rate that individuals in the community would judge as "acceptable" but they would likely be able to appreciate that such a level would be impossible to detect in the population when cancer rates are running from 35 to 40% over the lifetime of all Canadians. For cancer rate, it will be useful to compare the increased risk to other known risk factors such as smoking and alcohol consumption. It is also useful to show how many cases of fatal and non-fatal cancer will be increased in a small size population like Yellowknife and how would it compared to the background cancer rate due to unknown causes.

8.9.3 Confidence in Estimates Used

The reporting and use of numbers in Supporting Document 6 conveys a misleading impression of the true confidence in most predictions. For example, starting with an estimate of 450 kg/day for background arsenic level has led, by simple arithmetic to the high scenario being 16,450 kg/yr. It is very unlikely that we know this number to more than one significant figure (i.e. we might know it is more likely 20,000 kg/yr than 10,000 kg/yr). The perception of confidence in these estimates must be realistic to ensure that all parties involved in stakeholder discussions will be accurately informed, ranging from health professionals to the public at large.

8.9.4 Understanding Fluctuation in Predictions

The Lakeview Model has been relied upon for projecting the arsenic concentrations in water and sediment for all release scenarios and thus all exposure and resulting risk predictions are dependent on these predictions. Given this importance, there is a need to look closely at understanding what is driving these predictions. In particular, there needs to be an explanation for the fluctuations in concentrations predicted for the period of approximately 2030 to 2050 (Fig 6.1-1, p. 6.3; Fig 6.1-2, p.6.5; and Fig 6.1-3, p.6.6). These are most evident in Scenario 5 because of the high values depicted, but it appears this fluctuation occurs in all scenarios.

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9 Presidential / Congressional Commission on Risk Assessment and Risk Management. 1997. Washington, D.C.

Understanding what is driving those predicted fluctuations is an important element of believing the model predictions.

8.10 Errata

SD No. 6 misuses the term "*precision*" and "*precise*" in reference to risk estimates. Precise means how narrow is the distribution of possible risk estimates around the central estimate of risk that is used. Precise is distinctly different from accurate (i.e. correct or true) because it is possible to have an extremely precise estimate that is thoroughly wrong. As a rule, precise risk estimates are not possible in a case like this and any apparently "precise" estimates should be viewed with suspicion. The objective of quality in a risk assessment is to maximize the accuracy of the risk estimate, with precision very much a secondary and largely unachievable consideration.

The following are also noted in respect to SD No. 6.

p. 5-4, line 13 "*...current risk assessment highly imprecise* (Cantor 2001)" "*Imprecise*" is not Cantor's wording and it is not correct for this statement.

p. 6-2, line 3: "*and for drinking water (0.25 mg/L)*" should read "*and for drinking water* (<u>0.025</u> mg/L)"

p. 6-2, Table 6.1-1: The arsenic emission numbers are wrong as 450 kg/yr is repeated in the last 4 lines of this table.

p. 6-49, lines 8-9 and approximately repeated on p.7-5, bottom of page: "*Epidemiological studies in communities such as Wawa, Deloro and the Sydney area with high levels of arsenic in Canada have not reported a high incidences of skin cancer.*" This statement is not accurate and is misleading in the context that it is made. The study report cited for Wawa (O'Connor Associates 2000) is strictly a predictive risk assessment and it makes no mention of any epidemiological studies in that community. The Deloro study included a section that was described as an "*epidemiological study*", but this was limited to a review of descriptive statistics from the Ontario Cancer Registry which is stretching the meaning of an "*epidemiological study*". Regardless of the nuances, skin cancer was not included among the cancer sites that were reviewed so that this case does not support the statement in SD No. 6. The Sydney area had three epidemiological studies reported (Band and Camus 1998), Guernsey et al. (1998) and Dewar (1998)). Neither Band and Camus (1998) nor Guernsey et al. (1998) reported any skin cancer data according to the Expert Review Panel on the Epidemiology of Cancer in Cape Breton County (1999). Dewar (1998) reports only on melanoma (a specific type of skin cancer primarily caused by sunlight). If there were any explicit data that would support the statement made in SD No. 6, it should be directly quoted and cited. As it stands now, any reader seeking to pursue the basis for this statement will appear to find difficulty in finding such a basis.

p. A-48, Table A.5-3: The value for maximum (last column on the right) has to be wrong. It likely should be $4.1x10^{-4}$, not $4.1x10^{-6}$, based on the value that is reported on page 4-4 in Table 4.2-1.

p. C-1, line 19: "*As a result of these kind of uncertainties, the assessment is often undertaken within a probabilistic framework to minimize uncertainties*." The use of probabilistic methods can reveal the scale of some uncertainties in risk assessments, but these techniques do nothing to minimize uncertainties.

p. C-43, Table C6.3-1: Citations for Casteel et al. 1997b, Casteel et al. 1996a-d and Casteel et al. 1998a-e do not appear to be correct citations because their titles only refer to lead, not to arsenic.

Many references are cited that are not listed in the reference list for the main report (some are included in separate reference lists for the Appendices, but this is poor formatting). A partial sampling of those cited in the main report and missing from the main report reference list include:

Akaitcho 2000
Dillon (2002)
Elkin et al. (1998)
Elkin et al. (1999)
Elkin and MacDonald (2000)
Gamberg and Palmer (1998)
ICPS 2000
Kennedy et al. (1998)
Lorax (1999)
Mace (1998)
NEPI 2000
Ontario MOE 2001
Receveur et al. (1996)
Receveur et al. (1998)
Sahtu Dene Council (1998)
US EPA 1999

8.11 Editorial Clarification

There is some terminology used in the report that is capable of causing misunderstanding and confusion. These are dangerous characteristics in risk communication.

Some terms that should be reconsidered for subsequent public review are:

"*Conservative*" is used extensively in the report with the intended meaning of being cautious or assuming a value that will lead to intentionally overestimating risk. Where ever possible, "cautious" should be used where that is the intended meaning.

"*Safe*" is used for reaching conclusions about the ultimate levels of risk that are projected for Yellowknife residents. This is done in the context of arsenic exposure having acknowledged the truth that arsenic is a human carcinogen. There is much confusion about the ideas of safety when it comes to carcinogens. Polls have found that a majority of the public believes that there can be no safe level of exposure to a carcinogen.[10] While this belief is unfounded, depending on one's definition of safety, a pragmatic definition would require that cancer risk was extremely small to be considered safe by those thinking carefully about the subject. In this case, the risk is arguably too small to detect, but likely will not qualify as being too small for many residents of Yellowknife to completely dismiss.

"*Acceptable risk*" is used or implied as being something that can be determined in a risk assessment. What is acceptable is not something that the scientific method can reveal, at best scientific methods of polling public opinion might be able to capture an accurate view of what the affected public believes they would be willing to accept. However, it is a trap for risk assessors to speak about defining acceptable risk, because the risk assessment methodology is simply not capable of determining what is acceptable to potentially affected parties.

It is better to express all the intake level in μg/kg bw/day instead of mg to avoid the confusion of extra decimal spaces (eg. Table 6.3).

p.1-8, line 1: "*Organic arsenic is less toxic than inorganic arsenic.*" should read: "*Organic arsenic is* generally *less toxic than inorganic arsenic.*"

p. 1-8, line 8: "*...reference risk level.*" should read: "*...reference* lifetime *risk level.*"

p. 4.3, lines 3-5: "*To account for uncertainty in past and future arsenic loadings and in several of the model input parameters, the model was run in a probabilistic mode.*" This statement is inscrutable to a non-specialist and is inadequately explanatory (nor is it elaborated elsewhere in the report) for a specialist. The statement suggests that Monte Carlo simulations were run with assumed probability distributions for key parameters, but this is not explained clearly. On the face of it, the statement is not accurate because such methodology cannot fully or even primarily account for the uncertainties that exist.

p.6-32, lines 7-10: "*Given that most of the potential impacts on aquatic species are due to historic build-up of arsenic in sediments and not from the discharge of arsenic from the underground vaults, it is unlikely that any aquatic or terrestrial species would be adversely impacted except in Scenario 5.*" The logic of this statement based on the predictions obtained

[10] Hrudey, S.E. and Krewski, D. 1995. Is there a safe level of exposure to a carcinogen? Environmental Science and Technology. 29: 370A-375A.

may be sound, but the impression of reading this section after reading about excessive arsenic levels impacting on ecological receptors like mink and muskrat is that this statement may appear to be a direct contradiction of the earlier statements. The distinction of incremental impact from future arsenic trioxide management options vs. continuing impacts from historical arsenic emissions has not been adequately clarified in the report. This leaves this statement sounding like an attempt to discount anything that might appear to be a problem, an impression that seriously undermines the credibility of the risk assessment.

p. 6-32, lines 21-22: "*A number of different conservative assumptions were made in order to assess different levels of impacts on human receptors.*" Given that the largest human exposure route to total arsenic is via fish, the claim for "conservative" assumptions is not valid if the arsenic exposure for fish intake is set to zero.

p. 6-49, lines 26-27: "*Of the food commitment, most is from fish and seafood, which contains organic arsenic in the form of arsenobetaine and arsenocholine.*" This statement should read something like: "*Of the food commitment, most is from fish and seafood, which* <u>generally</u> *contains* <u>predominantly</u> *organic arsenic* <u>mainly</u> *in the form of arsenobetaine and arsenocholine.*"

p. 6-59, lines 3-4. "*It is believed that this slope factor over-estimates risk due to arsenic exposure.*" This statement is not clear about who believes this, but more important, beliefs about over-estimate would only apply to risk at doses much lower than were used in the Taiwanese study.

Many cited references are not in the Reference list, e.g. Kennedy et al. 1998, Receveur et al. 1996, 1998 etc.

p. 4-13, Table 4.4-3, bottom line LN(147, 210?......

p.4-15, Table 4.4-4 bottom line, Total protein? These numbers include berries and vegetable?

9.0 REVIEW COMMENTS - REASSESSMENT OF MINING METHODS

SD No. 7 was prepared by SRK with input from various sources including archives at Giant Mine, interviews with Mining Personnel and Mine Inspectors, and data from specialist Firms such as Layne Christensen Canada Limited and DELTREX Australia. It makes reference to three mining methods, namely Wet Borehole Mining; Underground Mining; and Open Pit Mining, and describes potential applications of each on the project. Consideration is also given to relevant matters such as working with arsenic trioxide. Various risks are identified including the possibility that the assumed 98 percent recovery of the arsenic dust might not be achieved in practice. Cost estimates are given but limited to only extracting the arsenic trioxide dust to the surface.

The following comments, in summary, are presented:

(i) The use of reverse circulation air lift drills to remove the arsenic dust from stopes and chambers is reasonable.
(ii) After preliminary extraction the walls must be washed and laser surveyed.
(iii) Underground mining to remove arsenic from exits and dump points will require protective contamination clothing for miners. Remote mining should be considered. Bulkhead stability must be reviewed. Pillar stability between stopes must be assessed. The need for backfilling of stopes must be established, including specifics of the backfill material where required.
(iv) A risk assessment is required to deal with the potential of hanging wall or pillar collapse.
(v) Detailed mining extraction plans must be developed before commencement.
(vi) The condition and need for upgrading of the mine facilities must be performed, i.e. shaft cage, cables, ventilation, drainage pumps, electrics, etc.
(vii) Health and safety procedures must be developed.

Additional observations on SD No. 7 are:

1. Open Pit Mining Alternative.
The IPRP agrees that mention should be made of the alternative of secure storage of the As_2O_3 in engineered fashion in an open pit(s), particularly if the open pit(s) would serve the dual role of facilitating effective removal of the As_2O_3 from the presently unsatisfactory storage arrangements, and providing secure storage for the long term.

2. In respect to the comments on "Stope and Cavern Underground Mining of Arsenic Dust", the following should be considered:
(i) The objective of 98% recovery of the As_2O_3 should be explained in greater detail. Is this a practical limit for the mining approach proposed and dilution anticipated?

(ii) Is the 2% residual As_2O_3 (plus whatever is already in fractures, etc. in the bedrock) acceptable from an environmental standpoint?

(iii) What is the tolerance on the 98% recovery objective, and how would "clean-up" to meet this assumed criterion be verified in practice?

3. There are significant uncertainties in respect to the configuration/condition of the As_2O_3 in the various stopes and chambers, e.g. the extent of saturation; extent of support to hanging walls; the extent of migration into the rock structures; and perhaps whether locally cemented or frozen. There should be a recommendation to the effect that these matters are better understood through further site investigations.

4. A detailed understanding of the geotechnical engineering properties of the As_2O_3 in storage is important for the evaluation of the proposed mining and extraction tasks in a number of respects, e.g.
   (i) drainage of the As_2O_3 (at bulkheads and to facilitate restoping, etc.)
   (ii) assessment of susceptibility to liquefaction (risk of "mud rushes"), and treatment to prevent liquefaction where required.
   (iii) capability to support the backfill used to stabilize the upper parts of stopes prior to restoping at the lower levels (any advance benefication needed for this purpose, and perhaps to also avoid excessive mixing with the backfill).

   The available geotechnical data obtained by Geocon in the 1981 "Mine Backfill Sampling Programme" was not obtained with underground mining of As_2O_3 in storage in mind, and needs to be supplemented by further geotechnical drilling, sampling, in-situ testing, laboratory testing as well as further geotechnical studies and analyses. There should be a recommendation to this effect in more specific terms, if the mining alternative is to be pursued further.

5. Preparation in advance of mining should also include works to ensure that no flooding occurs through the existing open pits and possible overtopping or failure of Dam B-2.

10.0 REVIEW COMMENTS - WATER TREATMENT

SD No. 8 is entitled "Engineering Studies Water Treatment" and was prepared by SENES Consultants Limited. The objective for this supporting document is to:

- Provide a technical assessment of water treatment options for the removal of arsenic from the various wastewater streams that will result from the various arsenic trioxide management alternatives being considered; and

- Provide pre-feasibility level designs and capital and operating cost estimates for implementation of these wastewater treatment processes.

The report provides a wealth of information and data to support the selection of various wastewater treatment schemes over a wide range of flow rates and concentrations. The report's major findings are summarized as follows:

- Wastewater treatment costs and residue management can be material to the feasibility of any of the management alternatives being considered;

- Prior review of industry practise indicates that arsenic removal with iron is the best available technology (BAT) for arsenic removal. Typically BAT plants produce treated effluent with average arsenic concentrations of 0.025 to 0.18 mg/L with 95% of all monthly averages below 0.40 mg/L. The current effluent limit for arsenic under the

Federal Metal Mining Effluent Regulation (MMER) is a monthly average concentration of 0.50 mg/L.

- The study identified five wastewater treatment options for dealing with the wide range of flow rates and arsenic concentrations expected:

    - Oxidation and Direct Precipitation – hydrogen peroxide or chlorine is used to oxidize arsenic in the wastewater; followed by arsenate precipitation using iron salts. This option is most applicable to low strength solutions;

    - Direct Precipitation with Lime – All arsenic is precipitated from the wastewater with lime at high pH. This process is most suitable for medium and high strength wastewaters;

    - Evaporation/Crystallization – wastewater is acidified, heated and crude crystalline arsenic trioxide is formed by evaporative crystalliser. This process is most applicable to high strength wastewater;

    - Concentration followed by Evaporation/Crystallization – low to medium strength wastewaters are filtered, concentrated by reverse osmosis such that evaporation/crystallization becomes an economic alternative to oxidation and precipitation;

    - Concentration followed by Direct Precipitation with Lime – low to medium strength wastewater is filtered, concentrated by reverse osmosis such that direct precipitation with lime becomes an economic alternative to oxidation and precipitation.

- The report provides an excellent comparison of estimated capital and operating costs for each treatment option over a range of flow rates and arsenic concentrations in the wastewater streams being treated;

- The report provides an excellent discussion and projection of estimated capital and operating costs and sludge production volume for water treatment requirements for each of the following management alternatives:
    - Base Case;
    - Ground Freezing;
    - Arsenic and Gold Recovery;
    - Gold Recovery and Arsenic Stabilization;
    - Dust Stabilization

The data provided allows for assessment of wastewater treatment requirements and cost estimates for a variety of wastewater treatment configurations, flow rates and arsenic levels in wastewater.

The following observations are offered for consideration:

- The data provided focuses solely on arsenic removal, however in two of the management alternatives (Arsenic and Gold Recovery; and Gold Recovery and Stabilization) a component of the wastewater streams from the process plant will contain residual cyanide levels, which will have to be addressed at the wastewater treatment facility. A cyanide detoxification step can be incorporated into the options as presented. In SRK's final report it is recommended that this issue be acknowledged and addressed;

- Most metal contaminants will be removed as precipitated hydroxides by the treatment options put forward, however the study does not explicitly indicate the fate of the metal contaminants in wastewater treatment. The final report should recognize the presence of other metal contaminants and advise the reader as to how they would be dealt with during wastewater treatment and what their fate will be (i.e. will they report with the sludge);

- The information provided is based on industry wide experience and is not specific to the wastewater streams that may be produced at the Giant Mine. Nevertheless the information provided is of great value at this level of assessment. In final assessment of a selected option, it is recommended that site-specific test work be carried out to prove the viability of the selected wastewater treatment scheme and to obtain site-specific data for process design and cost estimating purposes;

- Inclusion of precedent for the use of the various treatment options elsewhere in the mining industry along with a brief discussion of past performance would be of value in providing confidence in the technical viability of the various options presented.

11.0 REVIEW COMMENTS - GROUND FREEZING

SD No. 9: and the text of the SRK Draft Final Report were reviewed using the following approach:

- Checking factual data given in reports with relevant literature;
- Analysis of technical content of SD No. 9;
- Comments on SRK's recommendations in light of the analysis of SD No. 9;
- Further issues to be addressed in the SRK Final Report;
- Essential additional data required;
- Monitoring and warning system;
- Further studies needed;
- Recommendations; and
- Errata in SD No. 9.

11.1 Factual Data. - Comments

SD No. 9 consists of 4 main sections with factual data. Section 2, entitled "Background Information", gives data on surface conditions and geology, arsenic trioxide chambers and stopes (geometries and locations), climate and past thermal regimes in Yellowknife (i.e. permafrost characteristics). Section 2.1 should include factual data on faults and small-scale fissures in host rock, as was done in the Draft Final Report (DFR).

Section 2.4, entitled "Previous Studies of Local Permafrost", contains relevant and accurate data on past thermal regimes. This literature review showed clearly that permafrost in the Yellowknife area was relatively warm, i.e. with temperatures between -1 and 0° C and extended to depths of about 60 to 80 m. For permafrost to exist however, requires a set of conditions (peat cover, sufficient distance from a warm water body, to name a few). It was not found when rock outcropped. The data on physical and thermal properties of greenstone rock from the Yellowknife area are also relevant and adequate.

The summary points given at the end of Section 2.4 are consistent with the various published technical articles reviewed and depict well the evolution of the thermal regime at Yellowknife since the late 1940's.

Section 2.4.2, entitled "Geotechnical Investigations", needs to be expanded. As it stands now it simply indicates that considerable observations were made during the mine operations by several geotechnical consultants. A summary of their reports is attached in Appendix A entitled: "Review of Geotechnical Reports at Giant Mine". SRK should take the opportunity to highlight how permafrost was changed with the activities of the mine, how sensitive warm permafrost can be and for instance how efficient restoring permafrost using cold air during winter has been. There is a direct link with alternative B3, or perhaps alternative B4, that will be discussed herein.

Section 2.5 presents data on current ground temperature monitoring at the Giant Mine and also gives preliminary data on a special thermosyphon experiment. It is suggested that Section 2.5 be changed to Section 3 entitled "Current Temperature Data at Giant Mine". Section 3 would have the following subsections:

3.1 Current temperature monitoring between 1995 and 2002

3.2 Thermosyphon experiment

Other than these comments, the data are well presented and of considerable value. A plot of past and present thermal conditions with actual data on permafrost temperature from the literature would be a useful addition to this new Section 3.

Section 3 in SD No. 9 on Ground Freezing contains factual data that is accepted by practice. The proposed spacing between freeze pipes is adequate and the cost estimates provided also appear reasonable when compared to other projects throughout the world which could be cited (e.g. in Japan, Germany, USA and Canada). It is suggested that the Final Report indicate that, while the freezing capacities could maintain a cooling temperature down to -40 °C at the refrigeration plant (page 30 in SD No. 9), actual temperatures in the field would generally range between -22 and -28 °C owing to energy losses in the pipes.

Section 3.3 "Other Considerations". The various paragraphs in this section are all relevant to the problem under study. However, they would be more appropriately placed in Section 3.2, with subsections 3.3.1 to 3.3.8. "Proposed Freezing Design" should follow as Section 3.3 and Section 3.3.9 on "Monitoring" should stand alone as Section 3.4. This would reduce possible confusion between issues and cost. A table showing the cost associated with each issue would help.

It is suggested that Section 3.3.9 on "Monitoring" of temperature be rewritten and expanded. This is a key element of the proposed solution for a long-term containment of the toxic waste at Giant. It is important that thermistors be installed in strategic, well-justified locations and monitored automatically with solar panels (or other well proven backup systems). Furthermore, these data should be available to the public via internet for example and should be compared to pre-established values which guarantee acceptable conditions. There is also a need to establish an alert program associated with measures to be implemented for different situations. A colour code using three colours: Green, Yellow and Red is sufficient to help the decision-making process. Green for OK, continue monitoring. This would correspond to temperatures in each strategic location lower than a specified minimum value. When the temperature rises above this minimum value, a code Yellow is engaged with the corresponding measures. When the temperature rises above a critical value, Code Red is initiated with its specific measures. In practice, Code Red should never be triggered.

With respect to cost of the long term monitoring, a special fund could be created which would allow for maintenance, analysis and reporting to the authorities. The amounts given in SD No. 9, $ 30 000, appear to be underestimated.

Section 4 deals with thermal modelling to assess the time required to freeze the rock surrounding the arsenic trioxide dust storage areas and evaluate various scenarios related to the different freezing schemes. The thermal code TEMP/W version 5.11 developed by Geo-Slope International Ltd is robust and widely used in engineering practice. It is reliable provided that input parameters and boundary conditions are adequate.

This section is important since it establishes the feasibility of the alternatives associated with freezing. It is therefore critical that the section be written in a very clear and concise way. It is suggested that this Section be improved in order to transmit the information contained therein more effectively to the reader.

The following revised structure of Section 4 is suggested:

4. Thermal modelling
4.1 Overview
4.2 Material properties
4.3 Validation of model
4.4 Simulation of freezing of dust chambers and stopes
4.5 Simulation of thawing
4.6 Discussions and conclusions

For each case simulated, boundary conditions and geometry should be defined separately. (This means removing section 4.2.2 on page 39 of SD No. 9 and including parts in new sections 4.3, 4.4. and 4.5). As mentioned above, the IPRP has concerns about the temperature used to simulate active and hybrid freezing systems (-40 and -30 °C respectively). It is recommended that – 25 °C be used.

The material properties provided in SD No. 9 are adequately representative of average characteristics of the ground at Giant for the present level of the studies.

The section on model validation indicates clearly that TEMP/W with the proposed input parameters and specific boundary conditions is adequately predicting the current temperature profile at hole AS5. SRK needs, however, to provide a complete set of boundary conditions (top, bottom, stratigraphy used).

Section 4.3.2 provides key information about the thermal regime around the freeze pipes, at least for a specialist in the field. It is not clear however whether the public would be able to grasp the importance of these simulations. An effort should be made to present the simulations in a more accessible manner. For instance, area of frozen material could be highlighted (shaded area, hatched area). Additional graphs showing position of frost front with time would certainly be helpful. Since it is a 2D geometry, frost front position could be shown for different locations (centreline of chamber, lower and upper third in the dust stope, etc...). The same holds for Section 4.3.3 which clearly shows that the ground around the arsenic trioxide storage would remain frozen for significant amounts of time in case of failure of the cooling system. This needs to be highlighted.

In summary, it can be stated that the freezing and thawing simulations around the various arsenic trioxide storage areas performed by SRK provide relevant information about the thermal regime and the time required to establish it. It must be emphasized, however, that the results are only correct and valid in light of the assumptions made, which are clearly stated in SD No. 9.

Section 5 entitled "Discussions and Conclusions", raises important concerns about the whole freezing concept. These are associated essentially with the interpretation of the freezing simulations and are discussed in detail below.

11.2 Concerns about the interpretation of the Freezing Simulation

(viii) Although not clearly stated, SRK's criterion to create an acceptable frozen condition around the arsenic trioxide dust storage areas is related to the position of the 0° C isotherm in the centreline below the storage areas. It is assumed that sufficient cold ground is present around the storage areas when the 0° C isotherm is at least 10 m below the bottom of any storage area. SRK then assumes that upon controlled and slow flooding, water percolating in the fissures and cracks of the fractured rock would progressively freeze and thus create an impervious barrier around the toxic waste. This scheme is theoretically possible for perfect conditions of pure bulk water. In reality, however, water in situ may not necessarily freeze at 0° C. Depending on the actual freezing temperature of the in-situ water, there may be important implications in respect to the scheme analysed by SRK.

It is well known that the freezing temperature of water in the ground is influenced by pore water chemistry and pore size as well as geometry. For instance, the freezing temperature of saline water with a NaCl concentration of 30% is about -2 °C. Freezing point is also depressed by pore geometry since there is a minimum temperature for ice to penetrate into the pore space. The minimum temperature is related to the surface tension between ice and water and the radius of the ice-water interface. This is especially relevant to fractured rock with hairline cracks. For ice to penetrate into a crack of aperture 1 micrometer, the temperature needs to be lower than – 0.05 °C. Combined with the presence of some dissolved solids, the freezing temperature of the fractured rock may be several tenths of degree below 0 °C. This concern is further supported by evidence that open space in small fractures may not be completely filled with ice as reported by J.D. Bateman in a memo to Mr. A.K. Muir (page 16 in Appendix A of SD No. 9).

Consider that a minimum temperature of -2 °C is required to provide a secure confinement to the toxic waste. Re-analysis of the thermal field obtained from the simulations suggests that an unfrozen window of about 4 m width would be present at the bottom of chamber B12 (Fig. 14 SD No. 9). For chamber C9 (Fig. 15 in SD No. 9), the width of the unfrozen window would be 8 m and for stope B 208, it would be about 14 to 16 m. If the minimum required temperature is -1 °C, only stopes B208 and B212-213-214 would have an unfrozen window of 2 m and 10 m width, respectively. This analysis shows the extreme sensitivity of the solutions to the assumptions, especially those related to minimum temperature required to provide a safe confinement. As a final note on this subject, it must be emphasized that the above analysis was done using the computed results with a freeze pipe temperature of -30 °C. As mentioned above, it is more likely that the actual pipe freeze temperature would be around -22 to -20 °C. This then, of course, would result in increases in unfrozen window width and of freezing duration.

In summary, the proposed criterion that the computed 0 °C isotherm be at least 10 m below the bottom of any arsenic trioxide dust storage area may be questionable since it may not provide an adequate margin for actual field conditions where pore fluid chemistry and fracture geometry may depress the freezing temperature of the pore water.

It is strongly recommended to use a criterion that requires that the base of the storage area must be at a temperature lower than a minimum temperature to be specified as a function of dust properties.

(ii) Another concern is related to SRK's proposed sequence of freezing and flooding. SRK indicates (on page 79 of the FDR), that "*all of the Alternative B variants would include freezing of the ground around the arsenic chambers and stopes, then allowing the area to reflood slowly so that ice would form in the chambers and stopes.*" This statement needs also to be read with Section 3.3.6 in SD No. 9 where attention is drawn to the effect of incoming water during flooding and its effect on freezing efficiency. SD No. 9 also implicitly assumes that the stored arsenic dust is relatively dry. All the simulations showed that the temperature inside the storage areas was below 0 °C, although very close to it (only a few tenths of a degree below 0 °C) when the arsenic dust was dry. However, when the dust was considered to be fully saturated, Fig. 18 of SD No. 9 reveals that the dust did not freeze after an elapsed freezing period of 0.7 years. This result indicates clearly that the energy provided by the freezing system is not sufficient to remove the latent heat released when dust is frozen at the chamber's outer limits.

The implications here are also important. During the IPRP's site visit to the Giant Mine, seepage was occurring through some of the bulkheads inspected. The seepage water contained arsenic trioxide as noted in SRK's FDR. It is therefore reasonable to assume that the arsenic dust in the bottom part of the underground storage areas is likely to be saturated or close to it. This was not considered in the thermal modelling for the case with relatively dry dust. Assuming, however, that the dust is close to saturation in a zone near the bottom of each storage area will have a considerable effect on the thermal regime. In simple terms, it will affect the shape and location of the isotherms. The unfrozen windows below each storage area will be even larger than those anticipated in (i) above.

There is also a problem with the statement on page 79 of the FDR: "*so that ice would form in the chambers and stopes*". Assuming that flowing water freezes in the host rock, creating a perfect impervious barrier, how can ground water reach the dust inside the chambers and stopes and be transformed into ice?

Another concern is related to the thermal disturbance in relatively "warm" dry frozen ground as water at a temperature of at least + 4 °C surrounds the fragile frozen zone. There is no evidence in SD No. 9 that freezing of this water will occur naturally.

In summary, SRK's proposed freezing scheme, in the most favourable case, would provide a frozen shell around the arsenic dust that would remain wet and most likely unfrozen. The thickness of the frozen shell would depend upon freezing characteristics (pipe spacing, chilling fluid temperature, duration of freezing) and ground properties (such as ground water velocity, pore water chemistry, crack and fracture density, hydraulic conductivity of host rock and thermal properties of each material). The analogy one could make is to compare the proposed solution to a refrigerator in which food is preserved in an unfrozen state.

In the most unfavourable case, the freezing scheme as proposed may not provide adequate and secure confinement of the arsenic trioxide waste.

This critical assessment of the proposed freezing scheme does not invalidate the freezing option. Rather, the freezing scheme needs to be modified in order to provide the desired level of confinement of the toxic arsenic trioxide dust stored in the ground. A modified freezing scheme is proposed and discussed below.

It should be noted that the following comments are made by the IPRP in a review context only and as recommendations to DIAND. It is assumed that the specifics and merits of the Alternatives presented herein would be examined in detail by SRK.

11.3 Proposed Freezing Scheme – new Alternative B3

Alternative B1: restore natural permafrost conditions.

Alternative B2: create a frozen shell around the arsenic trioxide in storage using vertical freeze pipes and active freezing for a given period, followed by passive freezing to maintain frozen conditions (corresponds to SRK's Alternative B3.)

Alternative B3: create a fully frozen solid island (both arsenic trioxide in storage and the host rock) using the variant scheme presented below.

Objective: Immobilize the arsenic trioxide dust and associated wastes stored underground at the Giant Mine.

Methodology: Using artificial freezing and passive freezing to create a solid frozen block (including surrounding host rock and rewetted arsenic trioxide dust.)

Analogy: Instead of the refrigerator analogy (Alternative B2), it is proposed to use the freezer analogy and create a frozen solid block (Alternative B3), which intuitively provides greater security in that the contents ("food") are now frozen and maintained at a temperature well below the melting point.

11.3.1 New Alternative B3

Step 1: Use artificial freezing to freeze the bottom part of wet arsenic dust in all storage areas. Drilling would be conducted from drifts and galleries in the mine close to each storage area. The objective is to provide a solid frozen and impervious plug extending well beyond the lower parts of each storage area. There are numerous examples of precedent elsewhere which could be cited (e.g. in Japan, Germany, Canada, UK and United States where artificial freezing has been successfully used to provide impervious barriers).

The criterion is to have the -2 °C isotherm located about 5 m above the lowest elevation of the dust in the storage areas.

Step 2: Install thermosyphons from the surface down to a depth that would be 10 m below the – 2°C isotherm created in the host rock by Step 1. The thermosyphon would be installed according to a scheme similar to that of SRK's Alternative B3. Prior to freezing the rock, water injection using a packer system is recommended to i) measure the hydraulic conductivity of the rock and identify any critical zone with high flow values, ii) to saturate the host rock prior to freezing. Freezing will be carried out using an active system in order to create a frozen mass surrounding the waste in storage.

Step 3: Saturation of the arsenic from the surface in a controlled manner. Water pressures would be resisted by the frozen ground surrounding the chambers and stopes.

In addition to the systematic saturation of the arsenic trioxide dust, it is essential to provide a minimum water thickness above the dust in each chamber.

This procedure will also compact the dry dust and increase the volume of the air space at the top of the stopes and chambers.

Step 4: Install ventilation ducts through the crown of each storage area in order to chill the air above the dust using the abundantly available (low cost) cold winter air. Since there would be water (and eventually ice) above the dust, circulation of cold air should not create any hazardous dust re-circulation. Obviously, these ducts would be equipped with an automatic and reliable system to shutdown any outside air circulation when the air temperature rises above a critical temperature that is specified by the designer.

11.3.1.1 Additional Considerations

As rightly mentioned in SD No. 9, special attention needs to be given to infiltration from Baker Creek, and from the wetland areas. Any land surface use must imperatively preserve the air chambers above the arsenic dust storage areas as well as the circulation ducts. The responsible authorities must therefore consider future use of the land carefully. The technology for providing an adequate surface (engineered covers, river diversion, and the like) is a matter of design.

11.3.1.2 Advantages of New Alternative B3

With this procedure, each chamber can be frozen independently and mine flooding can proceed once all the chambers have been successfully frozen. No special care will have to be taken during flooding, in addition to that required in the "frozen shell" proposed by SRK.

The proposed procedure also lends itself to an initial demonstration project which would not only confirm viability but, perhaps more importantly, would also provide valuable data for use in optimizing design and implementation of the production remediation measures at the other stopes and chambers.

In summary, New Alternative B3 as described above creates a fully frozen mass of both rock and arsenic trioxide dust that is near saturation, hence with a significant amount of stored thermal energy due to the latent heat of the pore water in the frozen mass. Furthermore, by maintaining the air above the frozen dust at temperatures well below freezing during at least 6 to 8 months each year, a relatively cold permafrost condition will establish in the whole frozen arsenic dust. Preliminary calculations show that in the most pessimistic case, the temperature at the top of the dust would be around – 4°C and at its bottom around -2.5 °C. Needless to say, the pessimistic case makes allowance for possible global warming effects. If the climate remains relatively stable with present day characteristics, the temperature in the frozen dust may vary between -6 to -4 °C.

The proposed New Alternative B3 is intended to sustain these permafrost conditions, as long as there will be cold winters at Yellowknife. This is most likely to be the case for say, the next 1000 years. Moreover, once frozen, using simply the top air chambers cooled down with cold air from the surface would be a significant help in maintaining the man-made permafrost conditions.

Even in the hypothetical case where winters would disappear at Yellowknife, several tens of decades (perhaps several centuries) would elapse before complete thawing of the originally frozen arsenic trioxide dust would occur.

It is recommended that SRK performs thermal simulations to investigate the thermal stability of New Alternative B3 at the different periods of its lifespan.

11.4 Proposed Freezing Scheme – New Alternative B4

Objective: Immobilize the arsenic trioxide dust and associated waste in storage underground at the Giant Mine.

How: Using artificial freezing and passive freezing to create a solid frozen block (including surrounding host rock and rewetted arsenic trioxide dust.

Analogy: Instead of the "refrigerator" analogy (Alternative B3), it is proposed to create a "freezer" analogy (Alternative B4), which intuitively provides a greater security in that the "food" is now frozen and maintained at a temperature well below the melting point.

This concept is intrinsically different from that used in Alternative B3 but uses the same well-accepted freezing technology. It differs in the sequence of events as explained below. Furthermore, its overall cost may not be much different from those of Alternative B3. It could even be lower since the duration of freezing might be reduced.

11.4.1 New Alternative Scheme B4

Step 1: Use artificial freezing to freeze the bottom part of wet arsenic dust in all storage areas. Drilling is to be conducted from drifts and galleries in the mine close to each storage area. The objective is to provide a solid frozen and impervious plug extending well beyond the lower parts of each storage area. There are numerous examples of successful indirectly-related precedent elsewhere which could be cited (e.g. in Japan, Germany, Canada, UK and United States) where artificial freezing has been successfully used to provide impervious barriers.

The criterion is to have the -2 °C isotherm located about 5 m above the lowest elevation of the dust in the storage areas.

Step 2a: Install thermosyphons from the surface down to a depth that would be 10 m below the – 2°C isotherm created in the host rock by Step 1. The thermosyphon would be installed according to a scheme similar to that of Alternative B3. Prior to freezing the rock, water injection using a packer system is recommended to i) measure the hydraulic conductivity of the rock and identify any critical zone with high flow values, ii) to saturate the host rock prior to freezing. Freezing of rock should be carried out in vertical stages of about 10 m maximum.

Step 2b: Raise water table slightly above the frozen wall around the storage area in order to slowly saturate the dust contained inside the chambers and stopes.

Once the dust is saturated or close to saturation, redo step 2a for an additional 10 m stage vertically. It is important to perform a water injection test prior to freezing. Follow through with Step 2b and repeat both steps until the top of the arsenic trioxide dust in storage is fully wetted and frozen.

When saturation reaches the top of the arsenic dust, a minimum water cover above the dust in each chamber should be provided.

Step 3: Install ventilation ducts through the crown of each storage area in order to chill the air above the dust using locally available (low cost) cold winter air. Since there would be water (and eventually ice) above the dust, such ventilation should not create any hazardous dust re-circulation. Obviously, these ducts would be equipped with an automatic and reliable system to shut-down any outside air circulation when the air temperature raises above a critical temperature that is specified at the design stage.

During Step 3, the freezing system used in Step 2, i.e. the thermosyphons may be progressively reverted to a passive mode. The freezing system used in Step 1 can either be dismantled or kept in action on demand if necessary to supplement the thermosyphon's output. This must be considered in more detail at the design stage.

Step 4: Provide a drainage system surrounding each storage area to maintain an air space above the frozen arsenic trioxide dust. This also requires further detailed analysis but it is believed to be feasible in principle. A passive system is preferred to an active one. It is noted that the collected water would be surface water which would not be affected by contact with the arsenic trioxide in storage.

11.4.2 Additional Considerations

As rightly mentioned in SD No. 9, special attention needs to be given to infiltration from Baker Creek, and from the wetland areas. Any land surface use must imperatively preserve the air chambers above the arsenic dust storage areas as well as the circulation ducts. The responsible authorities must therefore consider future use of the land carefully. The technology for providing an adequate surface (engineered covers, river diversion, and the like) is available and is a matter of design.

In summary, New Alternative B4 as described above would create a fully frozen mass of both rock and dust that is near saturation, hence with a significant amount of stored thermal energy due to the latent heat of the pore water in the frozen mass. Furthermore, by maintaining the air above the frozen dust at temperatures well below freezing during at least 6 to 8 months each year, a relatively cold permafrost condition would establish in the whole frozen arsenic dust. Preliminary calculations show that in the most pessimistic case, the temperature at the top of the dust would be around – 4°C and at its bottom around -2.5 °C. Needless to say that the pessimistic case makes allowance for possible global warming effects. If the climate remains relatively stable with present day characteristics, the temperature in the frozen dust may vary between -6 to -4 °C.

The proposed New Alternative B4 would be intended to sustain these permafrost conditions, as long as there will be cold winters at Yellowknife. This is most likely to be the case for say, the next 1000 years. Moreover, once frozen, using simply the top air chambers cooled down with cold air from the surface would be a significant factor in maintaining permafrost conditions.

Even in the hypothetical case where cold winters would no longer be a part of Yellowknife's climate, several tens of decades (perhaps several centuries) would elapse before complete thawing of the originally frozen arsenic trioxide dust would occur.

11.5 General comments on SRK's Draft Final Report

First, this report is well written from a general point of view. It addresses correctly and efficiently the main issues, gives sufficient background information and provides conclusions and recommendations that are consistent with the contents of the report.

As already mentioned above, minor changes are needed to Section 5.2.2 in the DFR in accordance with the discussions presented herein. However, if SRK includes New Alternative B4 in the final DFR, at least in concept with details given in the updated SD No. 9, then the recommendations given on page 94 of the DFR would hold if the best in-situ alternative is New Alternative B4. The public will then have the choice between a very robust in-situ solution, and an acceptable ex-situ solution.

It is reiterated that there is a need to have adequate temperature monitoring, available to the public and well-established contingency plans would be activated in the event that temperatures in key locations should raise above a critical value(s).

11.6 Recommended Additional Data

In order to develop any of the Alternatives related to the freezing option, additional data needs to be obtained for final design purposes, including:

- Establish details of the space above the arsenic dust in storage;
- Depth to the surface of the dust (see Table 1 in SD No. 9) is required for B212, B213, B214, C212, C10, B11, B12 B14 and B15;
- Establish the water content profile in each arsenic dust storage area;

  This could be done (as part of additional geotechnical investigations recommended by the IPRP herein) by drilling and sampling using the SPT procedure similar to that previously used by Geocon in 1981. This is very important since it has a direct bearing on freezing of the bottom part of each storage area. Spacing and duration of freezing will depend on the water content in the dust. These drill holes could be used to install thermistors, which in turn can monitor the progress of freezing and, in a later stage, be incorporated into the monitoring and alarm system.

- Thermal conductivity of wet unfrozen and frozen dust should be measured;
- Establish the unfrozen water content characteristics of saturated arsenic dust in the density conditions in the storage areas (freezing point depression);
- Establish the pore water chemistry in the host rock and its freezing temperature;

12.0 REVIEW COMMENTS - ASSESSMENT OF DEEP DISPOSAL

SD No. 10 provides an engineering assessment and costing of the deep burial concept for management of arsenic trioxide wastes at the Giant Mine. SD No. 10 provides background, describes a method for removal and transport of arsenic dust from the existing stopes and chambers to new purpose-built chambers, and describes the conceptual designs for construction of new underground disposal chambers below a depth of 670 m in the Mine.

The main observations and technical review comments by the IPRP on related hydrogeological issues are summarized as follows.

- Design objectives for this concept are premised on removal of 98% of arsenic trioxide dust from the existing stopes and chambers. Leaving 2 % of the dust (about 5300 tonnes) means an important source of arsenic would remain in the shallow bedrock. Using re-flood groundwater flow data assumed for the chambers (4 m^3/day, Table B2, SD No. 17) the remaining dust would provide an arsenic release loading of several hundred to several thousand kg/year for several hundred years. This is a large loading and suggests that additional recovery and treatment of contaminated groundwater is required.
- Preliminary assessment of the deep disposal alternative is considered technically feasible but detailed assessment and designs have not been developed and are required for the three key components of dust transfer raise design, new storage chamber design, and long-term environmental impact.
- SD No. 10 notes that no hydrogeological work was performed to support the selected depth for reburial and that a hydrogeological assessment would be necessary. A limited assessment of groundwater flow and arsenic release rate is however provided in SD No. 17 and this assessment concludes that a low loading of 90 to 150 kg/year might result if flows were directed to surface. These loading estimates appear reasonable and supportable

The hydrogeological interpretation developed for the nearby deeper Miramar Con Mine provides some insight into the issue of deep groundwater flows at 670 m and deeper in the Giant Mine. Detailed hydrogeological, geochemical and isotopic studies completed at Con Mine in the mid 1990s showed that Holocene glacial waters and older deeper brines were preserved at depth in the Con Mine. The data from Con Mine indicated that glacial melt water was preserved at a depth of 700 to 1070 m for about 10,000 years. This suggests that groundwater flow at and below the 670m level at Giant Mine will be very slow and may not resurface for many thousands of years.

The understanding of the conceptual deep disposal designs and deep hydro-geological conditions in Giant Mine, while lacking in detail, appear to be adequate to support comparative evaluation of management alternatives for arsenic trioxide dust at Giant Mine.

Additional technical review comments, primarily from a mining perspective are:

(i) Deep disposal in nine new chambers below a depth of 2000 feet (600m) is considered an option. The arsenic dust would be transported wet via raises in a closed system. The chamber excavation would use standard underground mining methods.
(ii) The filled chambers would be sealed off with concrete bulkheads. The mine would then be flooded.
(iii) The lower levels of the Mine require upgrading along with a new ventilation raise.
(iv) Selection of the chamber locations requires a geotechnical investigation.
(v) Rock excavated from the chambers will be brought above ground for stockpiling – possibly in the open pits.
(vi) After clean-up and debris removal the mine can be flooded. Dewatering during mining must be addressed.
(vii) Detailed design and the mining program must be refined.
(viii) The long-term environmental considerations of arsenic trioxide disposal at depth require assessment.
(ix) Long-term water treatment would be required.

13.0 REVIEW COMMENTS - DUST PREPARATION

SD No. 11 was prepared by SRK with support from Lakefield Research. The objective for this supporting document is to provide data with respect to the settling and filtration characteristics of the Giant mine arsenic trioxide rich baghouse dust material. A test program was conducted by Lakefield Research in June/July of 2002 on a sample of baghouse dust material taken from the Giant Mine roaster gas cleaning circuit baghouse in 1999. The findings of the report on the work are summarized as follows:

- Conventional settling tests indicated good settling characteristics with initial pulp densities of 10% solids (by weight). Initial settling rates varied between 7.2 m^3/m^2/day for the control sample (no flocculant use) to 275.5 m^3/m^2/day with a combination of Magnafloc 351 + E10 flocculants. Flocculant use improved the initial settling rate but increased the moisture retention in the thickened pulp. Final settled pulp densities ranged from 36% to 43% solids and indicate that maximum densities can probably be achieved with conventional pulp thickening equipment in a full scale plant;

- The results indicated a poor thickening performance at 25% solids under all conditions with no significant response to flocculant additions;

- Vacuum filtration tests conducted on the settled pulps from the settling tests indicated good filtration rates but relatively high final moisture content in the filter cake. Filter feed densities varied from 36% to 49% solids. Filter cake moisture content ranged from 34% to 37%. Filterability of the thickened pulp ranged from 0.5 to 0.6 $T/hr/m^2$.

The IPRP concurs that this initial laboratory work is adequate to provide the basic data on settling and filtration characteristics of the arsenic trioxide rich baghouse that is required to facilitate adequate engineering assessment of the arsenic trioxide management alternatives at this level of project development. More detailed test work will be required to support design level engineering for any of the alternatives involving the settling and/or filtration of slurried arsenic trioxide dust.

13.1 Recommendations

It has been observed that it can be difficult to fully wet dry arsenic trioxide baghouse dust from the Giant Mine. The material appears to have some hydrophilic properties when in the dry state. This initial test work was conducted on dry dust material, however it is suspected that the material stored underground is likely present in a wide range of moisture contents, ranging from dry to fully saturated. It is suspected that the settling and filtration characteristics may vary with the degree of initial material saturation. The test work conducted by SRK on dry material probably represents worst case conditions, however it is recommended that additional test work be conducted on material taken from the stopes to better represent varying degrees of saturation at a future point in time to provide the information that will be needed for process design engineering and equipment sizing.

14.0 REVIEW COMMENTS - ARSENIC TRIOXIDE PURIFICATION

SD No. 12 was prepared by SRK with support from Lakefield Research and H.G. Engineering Limited. The objective for this supporting document was to provide an assessment of a metallurgical process to recover a saleable arsenic trioxide product and gold from the arsenic rich baghouse dust stored underground at the Giant Mine.

The report's findings are summarized as follows:

- Two primary metallurgical process alternatives were identified that can be applied to meet the objective of recovering a marketable arsenic trioxide product and gold from the Giant Mine baghouse dust:

- A hydrometallurgical route involving the leaching of arsenic into solution with a suitable solvent (hot water, hot ammonium hydroxide, sodium hydroxide or methanol) and the subsequent production of a crystalline arsenic trioxide product and recovery of gold by cyanide leaching of the solid residue; and
- A pyrometallurgical route involving heating the baghouse dust to produce an arsenic rich fume (gas + dust) by sublimation, followed by gas cleaning and the subsequent recovery of an upgraded arsenic trioxide dust and the recovery of gold by cyanide leaching of the solid residue from the gas cleaning operation.

- The hydrometallurgical approach (hot water leach) was demonstrated at full scale at the Con Mine in Yellowknife in the 1980's with limited success. The process produced an upgraded arsenic trioxide product that met market specifications but overall recoveries were poor and the plant proved troublesome to operate. No other commercial use of the hydrometallurgical approach was identified;

- The pyrometallurgical approach has been demonstrated at full scale at other sites in the world (for example: the fuming process employed at the El Indio Mine in Chile where stored arsenic rich baghouse dust was upgraded by combining it with flotation concentrate and processing it through an active gold mine fluid bed roaster with an improved gas cleaning circuit). The pyrometallurgical approach was successfully tested on baghouse dust material from the Giant Mine at the laboratory and pilot scale in the early 1980's (the WAROX process);

- SRK focussed their assessment on the pyrometallurgical approach;

- A process rate of 2.1 tonnes per operating hour was selected. This results in a plant with capacity to treat all of the stored baghouse dust within a 15-year period, producing on average, 11,400 tonnes per year of an upgraded arsenic trioxide product and 8,170 ounces of gold. This output would represent 40% of the average annual North American consumption of arsenic trioxide in the period 1994 to 1999;

- The capital cost for the process facilities were estimated at $66.9 million (+/- 25%) with an annual operating cost estimated at $7.8 million. Revenue from sale of the arsenic and gold were estimated at $8.6 million per year ($5.1 million from arsenic trioxide ($450 per tonne after transportation) and $3.4 million from gold ($270 US per oz)). These numbers do not include the cost of extracting the dust from underground nor the cost of long term secure disposal/water treatment associated with the residues produced by this upgrading facility. A recovery rate of 90% was chosen for arsenic and for the gold contained in the feed to the processing plant;

- The fuming process that was assessed, consists of the following major elements:
    - Receipt of a dilute slurry of baghouse dust from the underground extraction phase of the project;
    - Screening of this slurry to remove rock and debris;
    - Thickening of the slurry with the excess water recycled to mining;
    - Filter and dry the thickener underflow;
    - Fluid bed roasting of the dry thickener u/f (roaster fuelled by propane);
    - The arsenic is fumed off as a gas mixed with dust;
    - Recovery of the dust from roaster off gas using a hot electrostatic precipitator;
    - Cool the arsenic rich gas using water after removing the entrained dust in the electrostatic precipitator;
    - The arsenic trioxide will condense as a dust from the gas following cooling;
    - Filter out the upgraded arsenic trioxide dust in a baghouse;
    - Compact, granulate and package the baghouse dust catch;
    - Clean the gas exiting the baghouse by passing it through a wet scrubber before exhausting the gas to the outside environment.
    - The dust from the electrostatic precipitator is processed for gold recovery using a batch autoclave followed by a cyanide leach in a carbon in leach circuit.

14.1 Technical Risks

- There are technical risks of being able to produce an upgraded arsenic trioxide product that meets market and customer specifications relating to arsenic trioxide content; minimum acceptable level of contaminants, especially iron and antimony; and dusting properties of the product during handling. This risk factor can only be addressed by carrying out additional pilot testing if this option were to receive further consideration as a component of a viable management alternative.

14.2 Economic Risks

- There are risks of not being able to sell all of the upgraded arsenic trioxide produced as a result of prevailing market conditions. This could lead to additional cost incurred in stabilizing the excess arsenic trioxide that cannot be sold, involving alternate disposal in a secure managed landfill;

- The risk of a future collapse in the market for an upgraded arsenic trioxide product. The primary market for arsenic trioxide is the North American wood preservative market.

CBC has reported that in February of 2002, lumber companies in the US agreed to phase out the use of arsenic based preservatives in pressure treated wood by 2003. In a news release, the US Environmental Protection Agency announced a voluntary agreement with the lumber industry to end the use of chromated copper arsenate (CCA) in almost all lumber used for residential projects. Switzerland, Vietnam and Indonesia have banned pressure treated wood. Seven other countries have proposed similar restrictions. This voluntary agreement effectively puts in question the future viability of a market for purified arsenic trioxide, given that wood preservatives represented the most significant use of arsenic trioxide. This action is likely to result in a glut of arsenic trioxide in the marketplace world-wide.

14.3 Comments

Following review of this supporting document, the IPRP offer the following points for consideration:

1. The pyrometallurgical process alternative has great appeal in that it provides an apparent way of removing the stored baghouse dust from the Yellowknife area while at the same time generating some offsetting revenue. However the pending collapse of the US market for purified arsenic trioxide as the base for wood preservatives is likely to be a major controlling factor relating to the future economic viability of producing and marketing any purified arsenic trioxide product produced by such a facility in Yellowknife. It is obvious that this marketplace is about to undergo significant change. Other producers of arsenic trioxide will have to take action to respond to this change in demand. The likely outcome in the short term is dumping of arsenic trioxide at any price to clear out oversupply. The suppliers of arsenic trioxide will look for alternative markets but it is unlikely that the oversupply issue will be resolved in the short term and uncertainty will make the long term market difficult to assess and risky. Market conditions are likely to render this management alternative non-viable. The risk of proceeding under these market conditions is, the opinion of the IPRP, very high. The cost of constructing and operating an upgrading facility may not meet the objective if there is no market for the product produced. The net outcome could be that the upgraded product has to be converted into a more stable form at a significant extra cost and then have to be placed into a long-term managed landfill facility.

2. It is recognized that the first bullet point dominates with respect to further consideration of this treatment alternative, however the following comments are provided for consideration:

    - Under section 3.4 in SD No. 12, the report indicates that high concentrations of dissolved arsenic in gold leaching pulps typically result in poor gold recovery and an efficient process would probably require the chemical conversion of arsenic to an insoluble form in the advance of a gold recovery circuit. This is a big assumption and should be better supported. The need for a batch autoclave circuit is an assumption. Test work may show that such a step is not required and that satisfactory gold recoveries may be achieved without this unit process. In the long term the addition and/or deletion of the batch autoclave is unlikely to change the material selection of an alternative but this assumption is not self-evident and should be used with more caution. It may be perceived that this step is being added to unfairly drive up the cost of this alternative;

- The selected processing alternative suggests the use of an electrostatic precipitator to recover the dust from the fluid bed roaster. Why should a combination of a hot electrostatic precipitator/ cold baghouse produce a better grade arsenic trioxide product today than it did in the 1990's when the Giant Mine roaster was in operation? How does the alternative assessed ensure a better quality product? The WAROX program considered the use of metal sintered filter technology to replace the electrostatic precipitator. This technology seemed to offer better dust removal performance at the higher temperatures needed to keep the arsenic from condensing from the gas stream;

- The flowsheet and cost estimate makes no provision or mention of the requirement for a cyanide detoxification step following the cyanide leach unit process. Water treatment issues dealt with elsewhere focus solely on arsenic and metal removal;

- A market price of $500 per tonne has been used for purified arsenic trioxide FOB point of use. Given the uncertainty of future market price for arsenic trioxide it is unlikely that this price will hold in the future. To reflect this uncertainty and to assist in demonstrating the effect of price, one suggestion is to show a high and low potential market price in estimating potential revenue, say for example a low of $100 Us and a high of $500 US. This will demonstrate that as the price drops the revenue stream from the continued sale of arsenic trioxide will become negative very quickly;

- An average gold price of $270 US has been used to estimate potential revenue. While it is acknowledged that predicting the future price for gold is crystal ball gazing at best, public perception may be that too conservative an estimate has been used to render this alternative less favourable. A more realistic value of $300 to $325 may remove such potential criticism. It is recognized in the overall scale, use of the higher gold price is unlikely to change the overall outcome in the selection process;

15.0 REVIEW COMMENTS - PRESSURE OXIDATION PROCESS

SD No 13 was prepared by SRK with support from Lakefield Research and H.G. Engineering Limited. The objective for this supporting document is to provide an assessment of a process to recover gold from the Giant Mine arsenic trioxide bearing baghouse dust and to convert the arsenic into a stable chemical form for long term secure storage. The major findings of this report are summarized as follows:

- The only process alternative identified that is technically feasible and capable of meeting both of these objectives involves the oxidation and combination of arsenic and iron, at high temperature and high pressure, in an autoclave. This pressure oxidation process involves the chemical conversion of arsenic trioxide to crystalline iron arsenate compounds, predominantly of, or closely related to, the scorodite mineral form, and the recovery of gold by conventional cyanide leaching. This process is well demonstrated on a commercial scale and a variant is being applied at the Con Mine in Yellowknife where arsenic rich residues from a former roasting operation are being stabilized in a pressure oxidation circuit;

- Two pressure oxidation circuit alternatives were considered; first the use of a new 120m^3 autoclave and second the use of a new 70m^3 autoclave installed in parallel with the existing 50m^3 autoclave in use at the Con Mine in Yellowknife. The processing rate would be 2.7 tonnes per hour when dealing with low arsenic grade dust and 1.9 tonnes per hour when dealing with the higher arsenic grade material. The processing time required to deal with the total inventory of baghouse dust would be 15 years;

- The pressure oxidation process requires an ongoing supply of chemically reactive iron to combine with the arsenic. A number of alternate sources were explored, ranging from scrap iron to iron sulphide mineral concentrates. A pyrite flotation concentrate produced specially for this application in Flin Flon Manitoba and shipped to Yellowknife was selected as the option for assessing the economics of this process;

- The pressure oxidation circuit would require an Fe/As molar ratio of 1.1/1 and would operate at 20% solids. Magnesium oxide slurry would be added to the autoclave to neutralize sulphuric acid generated by the exothermic oxidation of the pyrite. Oxygen would be added to the autoclave under pressure to allow oxidation of pyrite to proceed. Approximately 96% of the contained arsenic would be converted to insoluble iron arsenate in the form of scorodite within the process. Gold recovery has been estimated at 90%, yielding 122,500 ozs of gold per year on average.

- The pressure oxidation process circuit assessed, would consists of the following major elements:
    - Receipt of a dilute slurry of baghouse dust from the underground extraction phase of the project;
    - Screening of this slurry to remove rock and debris;
    - Thickening of the slurry with the excess water recycled to mining;
    - Mixing of the thickener u/f with pyrite concentrate;
    - Pressure oxidation of the mix of thickener u/f and pyrite concentrate in an autoclave, operated at 120°C, 2,600 kPa pressure with a residence time of 90 minutes;
    - Washing of the autoclave slurry product in a counter current thickener circuit with neutralization and disposal of the wash liquor;
    - Raise the washed slurry pH by adding lime and leach out the gold using a dilute sodium cyanide solution in a carbon-in-leach circuit;
    - Recover the leached gold on granular carbon:
    - Separate the carbon by screen and process for gold recovery;
    - Treat the leach residue through a cyanide detoxification circuit and send to a secure storage pond (tailings impoundment).

- Capital cost for the pressure oxidation process was estimated at $98.5 million (+/- 25%) with an annual operating cost estimated at $17.8 million. Offsetting revenue from the recovery of gold has been estimated at $3.5 million per year ($270 gold price);

15.1 Comments

This supporting document provides the reader with a good level of information regarding the use of pressure oxidation as a component of a management alternative. Following review, the IPRP offer the following points for consideration:

- The flowsheet and cost estimate makes no provision or mention of the requirement for a cyanide detoxification step following the cyanide leach unit process. Water treatment issues dealt with elsewhere focus solely on arsenic and metal removal;

- An average gold price of $270 US has been used to estimate potential revenue. While it is acknowledged that predicting the future price for gold is crystal ball gazing at best, public perception may be that too conservative an estimate has been used to render this alternative less favourable. A more realistic value of $300 to $325 may remove such potential criticism. It is recognized in the overall scale, use of the higher gold price is unlikely to change the overall outcome in the selection process;

- Under the plant description (Section 4 of SD No. 13, page 10), it indicates that following cyanide leaching, the leach pulp from the CIL tanks will be directed to a pressure filtration circuit where "the leached autoclave residue, containing arsenic in a stable chemical form, would be filtered from the pulp and transported to the on-site stabilized waste disposal facility". This does not agree with the process flow diagram (Figure 1), which does not show the filtration unit process. The flow arrow on this Figure appears to be pointed in the wrong direction in relation to the tailings pond. Does the proposal envision a conventional tailings impoundment or a lined storage facility for the secure permanent storage of this stabilized residue?;

- The operating cost estimate for the pressure oxidation circuit assumes a workforce of 24 operators working 12 hour shifts. This would suggest a workforce of approximately 6 operators per shift, assuming four work crews to allow full 24/7 coverage. In a new automated facility this number of shift operators seems high. Without more detail as to the breakdown of the proposed workforce it is not possible to determine what the ratio of support personnel to operators has been assumed for the purpose of this estimate. However the cost impact of this item is likely inconsequential in the overall assessment picture.

- The level of detail provided in the capital cost estimate is insufficient to provide any opinion. It is recognized that this detail will be provided within SD No. 19, which is currently in preparation.

16.0 REVIEW COMMENTS - STABILIZATION OF ARSENIC TRIOXIDE

SD No. 14 was prepared by SRK with support from Lakefield Research Limited. The primary objective for this document is to provide support data on the leaching behaviour of arsenic from cement and bitumen stabilized materials. The major findings are summarized as follows:

- In March 2002 Lakefield Research conducted a laboratory program to investigate the leaching behaviour of arsenic from arsenic trioxide baghouse dust samples stabilized with varying ratios of cement and with varying amounts of bitumen. Nine cylinders each of cement and bitumen were prepared, each containing a unique amount of arsenic trioxide baghouse dust. Actual dust contents were 0%, 11%, 17%, 22%, 28%, 34%, 45%, 57% and 68% respectively. After curing, a standard tank leaching procedure was employed where each cylinder was submerged in a tank of deionised water. The leachant was removed at set intervals and analyzed for arsenic. This test work is ongoing;

- The test work indicates that for samples stabilized with cement, the proportion of dust in the concrete mix could not exceed 40% on a weight basis without significantly jeopardising physical stability (crumbling). The samples were prepared such that the cement content remained at 20.5% of the dry weight charge; therefore an increase in arsenic trioxide dust was compensated by a decrease in aggregate. Test cylinders achieved full strength within two weeks of curing. Unconfined compressive strength testing indicates that strength decreases as the content of baghouse dust within the concrete mix increases;

- Leachate test results for the cement stabilized cylinders over the first 30 days of leaching time indicate that arsenic appears to be steadily leaching out of the cement stabilized samples. At 10% dust in concrete, arsenic in the leachate varied (over 30 days) from 10 to 37 mg/L. At 40% dust in concrete, arsenic in the leachate varied from 430 to 819 mg/L. Samples containing 50% and 60% dust in concrete were not subjected to leachate testing due to insufficient structural integrity. As expected arsenic concentrations in leachate increases as the amount of time the leachate contacts the cylinder increases.

- The laboratory results suggest that cement monoliths containing up to 34% arsenic trioxide baghouse dust will have sufficient strength to remain intact in the landfill. Leachates from the landfill can expected to be saturated with arsenic to a concentration of 5,600 mg/L;

- Leachate test results for the bitumen stabilized samples over the first 30 days of leaching indicate low arsenic release as compared to the cement stabilized samples, with arsenic in the leachate rarely exceeding 0.2 mg/L. Leachate results did not show any significant increase in arsenic release as the proportion of cement stabilized in bitumen increased (up to 60%, i.e., 60% dust-40% bitumen);

- Analysis indicates that after 30 days of leaching, the bitumen stabilized samples do not show any significant release or leaching of organics;

- The laboratory results suggest that bitumen can be an effective stabilization agent, with mixes up to 40% dust. Mixes beyond 40% were difficult to physically mix. Leachates from landfills containing bitumen stabilized waste are expected to be approximately 350 mg/L.

Areas of technical risk include:

- This cement stabilization test work indicates that the leachate from a landfill used to store cement stabilized arsenic trioxide baghouse dust will likely be at saturation concentrations for arsenic (5,600 mg/L). Consequently integrity of the landfill liner is a key component of secure storage of this material. The questions that come to mind include:
  - What is the impact of leakage through the liner?
  - How long will the liner under the landfill remain secure?
  - How will the liner and concrete monolith perform under frost cracking and heaving conditions?
  - Can concrete stabilized material be placed into a landfill under winter conditions? Will it cure properly under winter conditions?
  - Will arsenic release rates increase as a result of increased exposed surface area resulting from cracking of the concrete monolith?
  - What must be done if the liner system is compromised at some point in the future?

- These questions will need to be addressed in moving forward on cement stabilization as a component of any management alternative.

- The bitumen stabilization results show good results but little is known as to the technical viability of implementation. Given the encouraging stability results would it not be worthwhile to conduct further trials of this stabilization technique? It is recognized that we know of no large-scale use of bitumen stabilization, however it may be worthwhile conducting further investigations to better understand the technical and economic challenges associated with this option. For example, can bitumen stabilization be carried out under winter conditions? Can we get the stabilized material into the landfill before it sets up under winter conditions?

17.0 REVIEW COMMENTS - CEMENT STABILIZATION

17.1 Introduction

SD No. 15 presents a process to stabilize the Giant Mine arsenic trioxide bearing dust by mixing it with cement and aggregates to form a concrete. The concrete so formed would be disposed in a secure surface waste containment facility.

The cement stabilization process is described and the conceptual design of a plant to produce the concrete is described. Cost estimates are also presented.

17.2 The Process

The cement stabilization process is proposed to stabilize arsenic trioxide dust without changing the chemical form of the arsenic. The cement would control the contact between arsenic trioxide and water in a disposal facility, thus limiting the release of arsenic from the stabilized waste. This stabilization, if successful, would reduce the long-term cost of treating leachate.
This method of stabilization has been used extensively in other applications on a large scale internationally. The process is technically proven and is relatively simple. Arsenic trioxide slurry from the underground extraction mining would be thickened and filtered, mixed with Portland cement and local aggregate, transported to the waste containment facility for discharge and curing. The plant equipment is conventional. Environmental and occupational health concerns should be manageable.

17.3 Process Design

The duration of the arsenic trioxide dust extraction and re-processing of the project was assumed to be 5 years. This timing is partly based on the economics of dust mining for over a short-term project. Assuming a plant availability of 85%, a processing rate of 6.4 dry tonnes per hour would be required to meet this time estimate.

The consumption of raw material required is dependent on the maximum acceptable concentration of arsenic trioxide in the concrete. Laboratory test work was performed to assess leaching characteristics of concrete with varying amounts of arsenic trioxide dust. The program suggests the concrete would contain up to 35% dust, on a dry basis and remain suitably stable.

The proposed mix as a percent of dry weight is:

Arsenic trioxide	-	35%	-	153 dry tonnes/day
Portland Cement	-	25%	-	109 dry tonnes/day
Coarse Aggregate	-	29.5%	-	129 dry tonnes/day
Fine Aggregate	-	10.5%	-	46 dry tonnes/day

Note – This mix design given in SD No. 15 is incomplete – percent water is not given.

17.4 Practical Considerations

A number of practical considerations, as follows are considered relevant:

(i) A major concern with cement stabilization is the potential for arsenic to leach from the cement-stabilized mass. An impervious landfill design on surface will be required.
(ii) Climatic conditions would likely preclude winter storage or construction.
(iii) An advantage of cement stabilization is its compatibility with the wet mining procedure.
(iv) Bitumen, not being compatible with water, would require dry dust. The cost of drying is considerable.
(v) The process was uses conventional procedures and is technically proven.
(vi) Long-term water treatment would be required.

18.0 REVIEW COMMENTS - ENGINEERING STUDIES ON RESIDUE DISPOSAL

18.1 Summary of Recommendations and Conclusions

SD No. 16 summarizes conceptual designs for surface disposal of arsenic wastes using a secure landfill concept. The report estimates between 0.3 to 1.3 Mm^3 of stabilized waste will be disposed over a 5 to 15 year timeframe. This waste could be a mixture of stabilized (solidified) arsenic dust and treatment sludges from the water treatment plant. It is expected that the water treatment sludge waste stream could range from 4,000 to 36,000 tonnes over a period of 100 years.

Ten potential landfill sites were assessed within the mine property area. Of these sites six were rejected and four carried forward for conceptual design consideration. In the absence of landfill site selection regulations/criteria in the NWT, SRK used the British Columbia criteria to guide site selection activities. It is estimated by SRK estimated that the capital costs would range from \$7 to 12 M and the operating costs from \$1 to 2 M/a.

18.2 Comments on Conclusions

A significant limitation of this work is that potential sites were confined to the Giant Mine property only. Other more suitable sites may be available within a reasonable distance of the mine. A secure landfill has to isolate wastes for a considerable period of time. Also one of the fundamental design criteria for such landfills is to have the natural environment act as a backup system when the engineering features of the landfill fail. Generally the site conditions at the mine are unfavourable for selection of a secure landfill site; shallow quite permeable glacial deposits over fractured rock is the norm. There are a number of wetlands with peat deposits that could potentially act as a natural barrier to contaminant flow; however, one of the screening criteria for site selection was to avoid wetlands. While peat may be a suitable geological environment, it settles and could potentially compromise the integrity of the liner and leachate collection facilities.

The conceptual designs discussed for the short listed sites all have common features: 1.5 m of low permeability materials over rock, impermeable liner on the low permeability materials, berms to control runoff and a low permeability cover. No details are provided in the design on how leachate will be handled during the operational phase of the landfill or after it has been capped.

Given the size of the sites described it is unlikely that one site will have sufficient capacity to deal with the whole waste stream (stabilized waste and water treatment sludge). Therefore this alternative may require two secure landfills to be built. The cost estimates defined in this report are reasonable for the designs proposed.

18.3 Further Issues to be Addressed

If it is determined that a secure landfill is an appropriate technology to carry forward in the alternative evaluation process, It is recommended that consideration be given to developing site selection criteria that are more appropriate to the North. This could be done with input from all interested stakeholders.

Some key questions arise out of this report that must be addressed if this alternative is going to receive serious future consideration. For example, what is a reasonable life span of the landfill; how stable is stabilized waste in the long term (its leachability characteristics); what materials and design components are appropriate for northern climates; are there special operational requirements?

18.4 Recommendations

The designs proposed for a secure landfill are not state-of-the-art compared with designs in other jurisdictions. If this alternative is carried forward the IPRP recommends a significant amount of new work would need to be completed to ensure that it's a viable option. This work would include:

- Defining site selection criteria specifically for the North;
- Consideration of areas other than the mine property;
- Leachability studies on the stabilized waste and water treatment plant sludge to predict leachate quality over time (i.e., how long will leachate be generated and require treatment);
- Leachability studies are required on the liner to assess its effect on retarding advective flow and accessing the potential for diffusion of arsenic through the liner;
- Review state-of-the-art designs for secure landfills; and
- Define special conditions and materials that would be required to build such a facility in this environment.

19.0 REVIEW COMMENTS - ESTIMATES OF ARSENIC RELEASE

SD No 17 gives estimates of arsenic release for the existing surface sources at Giant Mine, and for each of the management alternatives. For each management alternative, arsenic release is estimated for:

- Underground sources;
- Seepage from existing sources; and
- Any surface sources resulting from water treatment and/or arsenic trioxide dust stabilization.

This important Supporting Document describes the calculations of arsenic release and loading from surface sources, subsurface sources and from the water treatment plant under various arsenic trioxide management alternatives. This is an important section that integrates the results of many of the other supporting documents in the SRK Draft Report.

The main observations and technical review comments of the IPRP are summarized as follows:

- Arsenic releases for surface sources are calculated my multiplying the source area footprint by a runoff coefficient and the total precipitation to give the flow for each mine site component and then multiplying the resulting flows by source concentrations. This is a reasonable and acceptable approach for the problem at hand. We concur with this approach;

- Estimates of arsenic releases from surface sources to underground workings are made by multiplying the vertical and lateral groundwater flows associated with each source (SD-2) by their corresponding arsenic concentrations (SD-3, 4 and 5). The arsenic releases are then added together to give the total arsenic released to underground workings. We agree with this approach;

- Simple calculations are made for groundwater flow and arsenic release from the new arsenic chambers to be constructed below 700 m., using increased arsenic source concentrations (5600 to 9600 mg/L) for the deeper chambers due to increased ground temperatures. The calculations and the conclusion that the arsenic release will likely be low, around 100 kg/year are appropriate and supportable; and

- Estimates of arsenic releases from underground sources are also made by multiplying the vertical and lateral groundwater flows associated with each source (SD-2) by their corresponding arsenic concentrations (SD Nos. 3, 4 and 5), with the modifications of increasing vertical flows through the arsenic chambers to account for flow funnelling effects, and using the water balance for the Northwest Tailings Ponds to estimate seepage to underground workings. We agree with this approach and believe the summaries of source concentrations for unsaturated and saturated conditions (Tables 3.3 and 3.4) are credible.

It is assumed in the calculation of arsenic releases for all of the removal and ex-situ alternatives and also for the deep reburial (SD No. 17, page 14), that there are zero releases from the former chambers and stopes. For the deep reburial, the engineering assessment assumes 2% of the dust will remain. If 2 % of the dust is left behind, the loadings will be much greater than the 490 kg/year assumed to come from other residual sources. The arsenic releases and loadings calculated for the former chamber and stopes under ex-situ and reburial alternatives, seem underestimated in SD No. 17.

The arsenic release calculations are provided in Tables B1 to B6 and these tables are clear and understandable.

19.1 Conclusions

- Arsenic releases from existing surface sources were estimated based on current observed releases to Baker Creek;
- Direct discharges to the receiving environment would occur for all of the management alternatives where the mine is fully flooded;
- Arsenic releases from the underground workings would flow laterally towards Great Slave Lake, but would likely be dispersed over a very large area before daylighting in the receiving environment;
- Assumed that all of the arsenic would be discharged directly into Baker Creek; and
- All of the alternatives including freezing would require water treatment.

19.2 Comments & Recommendations

- The assumption was made by SRK that all remediation measures as described in the Abandonment and Restoration Plan will be carried out. Also, that those remediation measures are successful, and carried out on a time-line that works with whatever management alternative is chosen. Some mention of how the A&R plan is related to these management alternatives needs to be discussed in the report. Also, are the estimates different if the A&R Plan is not implemented as indicated?
- Another assumption made in the report is that all of the arsenic release would be to Baker Creek. The question should be asked if release to other sources need to be considered.
- Groundwater supplies/sources not accounted for. It is mentioned that arsenic releases from the underground workings would flow laterally towards Great Slave Lake. Should this be explained or communicated better?

- Also, if an alternative is chosen where the arsenic is brought to the surface for further treatment, can there be an arsenic release into the air instead of the water, once it is brought up. Will the mining methods used to bring the arsenic to the surface contribute to more arsenic release not mentioned, such as airborne release?

- There should also be better mention of time frames for the arsenic release. Are the release estimates the same for Year #1, Year#5, Year #65, Year #158, etc.? Will they always be the same number or decrease over time? There appears to be mention of time frames in some of the other supporting documents and text of the Final Draft Report, but not in SD No.17.

19.3 General Comments

SD No. 17 is well laid out and very straightforward. The Tables make it easy to follow and understand the calculations.

Some issues that need to be addressed/answered in the SRK Final Report, as outlined above include:

- The connection/distinction between this Management Alternative Plan and the Abandonment & Restoration Plan;
- Are there any other routes of arsenic release other than water? and
- An explanation of the arsenic release estimates as they relate to time frames.

20.0 REVIEW COMMENTS - RISK ASSESSMENT OF PHASE II ATERNATIVES

SD No. 18 was designed to assess in semi-quantitative terms the comparative risks of the various management alternatives identified in Phase 2. This was done by considering risk to human or ecological receptors under 3 categories:

- short-term risk (release of sufficient arsenic to cause an adverse effect during the preparation or implementation phase of an alternative),
- long-term risk (release of sufficient arsenic to cause an adverse effect after complete implementation of the alternative, within a period of 500 years)
- worker health and safety risks (safety and arsenic-related health risks faced by workers in the preparation, implementation and post-implementation activities

For short-term risk, a single release of 1,000 kg of arsenic was taken as sufficient to cause an adverse effect and probabilities of such releases were estimated under qualitative categories related to a quantitative scale as:

Qualitative Term	Typical Risk of Significant Arsenic Release
High	≥1 in 100
Moderate	≥1 in 1000
Low	>1 in 10,000
Very Low	≤1 in 10,000

For long-term release, the probability of continuous periods of 1 year, 10 year or 100 year of total failure of treatment and management were judged for magnitude of arsenic release for each management option. For worker safety and health risk, each management option was judged for various activities and the estimated degree of arsenic exposure to rate the risks as high, moderate or low.

20.1 Summary of Findings, Conclusions and Recommendations

This application of experience and judgment was used to produce a general summary of the level of risks in these three categories for each Phase 2 alternative, as shown below

Alternative	Probability of Significant Arsenic Release		Worker Health & Safety Risk
	Short Term	Long Term	
A1. Water Treatment with Minimum Control	Low	High	Low
A2. Water Treatment with Drawdown	Low	Moderate	Low
A3. Water Treatment with Seepage Control	Low	Moderate	Low
B2. Passive Ground Freezing	Very Low	Low	Low
B3. Active Ground Freezing	Very Low	Low	Low
C. Deep Disposal	Low	Very Low	Moderate
D. Removal & Surface Disposal	High	Very Low	Moderate
F. Removal Au Recovery & As Stabilization	Moderate	Very Low	Moderate
G1. Removal & Cement Stabilization	Moderate	Low	Moderate

20.2 Comments on Recommendations and Conclusions Reached by SRK

The insights provided by this exercise are reasonable and useful for the overall need of comparing alternatives. The items B2 and B3 have been recast to be Frozen Shell and Frozen Block respectively, but these titles were not carried over into the final report.

The only substantive comment on this assessment is that the assessment of the handling options (C, D, F and G1) may be rating the worker health and safety risk too favourably by considering them to be moderate. More detailed consideration of these risks and of the corresponding risks of allowing airborne release of arsenic trioxide dust into the environment will be warranted if any of these alternatives are developed in greater detail. If the worker health and safety risks prove to warrant a "moderate" risk rating this will need to be recognized as depending on a very high level of worker protection to keep the risks at this level.

21.0 REVIEW COMMENTS - COST ESTIMATES

SD No. 19 was still in preparation when the IPRP completed this progress review of the September 2002 Draft SRK report. Consequently the IPRP did not carry out a review of the cost estimates in any detail.

Respectfully submitted,
INDEPENDENT PEER REVIEW PANEL

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ATTACHMENT A
Initial Review Report by Connell / Matich

COPY NO. 7

INDIAN AFFAIRS AND NORTHERN DEVELOPMENT CANADA
STUDY OF MANAGEMENT ALTERNATIVES FOR GIANT MINE ARSENIC TRIOXIDE DUST

TECHNICAL REVIEW
PROGRESS REPORT #1
(REF. NO. 11855/1-1)

Rev. No.	Revision	Date	Approved
0	Issued in Final	January 15, 2002	JJC

INDIAN AFFAIRS AND NORTHERN DEVELOPMENT CANADA
STUDY OF MANAGEMENT ALTERNATIVES FOR
GIANT MINE ARSENIC TRIOXIDE DUST

TECHNICAL REVIEW
PROGRESS REPORT #1
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TECHNICAL REVIEW
PROGRESS REPORT #1
(REF. NO. 11855/1-1)

SECTION 1.0 - INTRODUCTION

Indian Affairs and Northern Development Canada (DIAND) took management control of the Giant Mine property in Yellowknife in 1999 after the former property holder, Royal Oak Mines Inc. went into receivership. In December of 1999, the property was sold under agreement to a subsidiary of Miramar Mining Corporation, Miramar Giant Mine Ltd. Under this agreement the new company assumed control over the day to day management of the site including site security, effluent treatment and maintenance of access to the underground mine workings, however the liability for all pre-existing conditions remained with DIAND.

The Giant Mine produced gold over a 50 year operating life, stretching from 1948 to 1999. At this operation gold is associated with the arsenic sulphide bearing mineral arsenopyrite. The process used to extract the gold involved roasting an arsenopyrite rich mineral concentrate in which heat and oxygen are used to break down the arsenopyrite mineral structure. This liberates an arsenic rich gas stream as a by-product. Between 1951 and the cessation of operations in 1999 this gas stream was subsequently processed to recover most of the arsenic in the form of an arsenic trioxide bearing baghouse dust. This arsenic rich dust was stored underground in mined out stopes or purpose built storage chambers, referred to herein collectively as storage vaults. Approximately 237,000 tonnes of baghouse dust containing approximately 60 wt% arsenic are currently stored underground at the Giant Mine site. Arsenic is a naturally occurring element that in sufficient concentration is known to be toxic to many organisms and both toxic and carcinogenic to humans.

DIAND and Miramar Giant Mine Ltd. are currently managing the stored dust within these storage chambers. Contaminated drainage from the storage areas is being collected in the surrounding mine workings and is pumped to surface via dewatering pumps, where the contaminated mine water is impounded and treated for arsenic and metals removal before being released into Baker Creek. This system is being used to maintain this stored hazardous material while long-term management options are assessed and developed. All of the evidence available to the review team indicates that this system is effective in meeting this role.

DIAND has created and staffed a project team based in Yellowknife that is tasked with the responsibility of overseeing the short-term management of this hazardous material and the development, assessment, permitting and implementation of a viable long-term management strategy to deal with it. The DIAND team have retained the services of a number of consulting specialists in a broad range of technical disciplines to conduct work to further these objectives. DIAND has also sponsored a number of Workshops and Expert Group Meetings pertinent to this project. In 2000 DIAND appointed SRK Consulting (SRK) to the position of Technical Advisor - Arsenic Trioxide Dust Management. SRK and its partners on this project have undertaken a number of investigations over the intervening time period culminating in the preparation of a "pre-feasibility level" report entitled "A Study of Management Alternatives for Giant Mine Arsenic Trioxide Dust" released in May of 2001.

In the fall of 2001, Indian Affairs and Northern Development Canada retained the services of M.A.J. (Fred) Matich and Larry Connell (the Review Team) to jointly conduct an independent technical review of the SRK report. The report herein is the first progress report of the review team.

SECTION 2.0 - SCOPE OF REVIEW

The objectives of this review have been developed in conjunction with DIAND and can be summarized generally as follows:

- Provide DIAND with an independent technical review of the selection process and subsequent assessment of options considered for the long term management, removal, disposal or stabilization of the arsenic trioxide bearing baghouse dust stored underground within the Giant Mine;

- Provide DIAND with an independent assessment of whether other technically feasible management alternatives exist and whether such alternatives warrant investigation by DIAND;

- Provide DIAND with an assessment of any gaps in the data/information collected that are important in assessing the technical and economic feasibility of a permanent management alternative(s);

- Provide DIAND with recommendations as to what additional information or data should be collected or developed to enable feasibility assessment of a management alternative for this material; and

- Provide DIAND with a recommendation as to which management alternatives are most likely to lead to a technically feasible management alternative given the current limitations of technology, information and acceptable degree of risk.

This review is being carried out from the standpoint of the main fields of expertise of the Review Team members, both of whom have some knowledge of the Giant Mine through previous involvement in operations there (Geotechnical, mining, mineral processing and environmental engineering). One specific area that has not been well covered by the review team due to its lack of specific expertise in this area is the implications on the management alternatives, of the geochemistry of arsenic.

SECTION 3.0 - REVIEW PROCEDURE

The review team was provided with copies of the SRK report and subsequently met with various members of both the DIAND and SRK Project teams on the following two occasions:

- October 29th, 30th, 31st, 2001 - Yellowknife: The review team travelled to Yellowknife and were provided with a guided tour of the underground mine and surface facilities at the Giant Mine. An effort was made to visit as many of the accessible underground arsenic storage vaults as possible and to inspect as much of the surrounding mine openings as possible in the time available. The authors also toured the surface facilities, focussing on the tailings impoundment areas and on those areas where arsenic rich materials are currently being stored. The authors met with the DIAND Project Team members and reviewed the status of the work conducted to date. Supporting documentation and files were reviewed to a preliminary level and copies of key documents were obtained for more in depth review by the authors. The review team had the opportunity to meet with several key members of the SRK technical advisory team and to be briefly informed on the studies, investigations and documents that formed the background for the SRK report. The review team had an opportunity to visit a drilling program that was underway to obtain further knowledge of the hydrogeological regime of the groundwater in the vicinity of the Giant Mine.

- December 19th and 20th, 2001 - Vancouver: The review team met with the SRK Technical Advisory Project Manager at the SRK offices in Vancouver and was informed on how SRK developed the management options considered and how SRK selected the representative management alternatives that were subsequently assessed at a pre-feasibility level. The SRK team provided the review team with a summary review of the studies, investigations and processes that were used by SRK to develop the pre-feasibility report.

- The review team have used the information collected from these two meetings and from its initial reading of the available supporting documentation to prepare this technical assessment of the SRK report and to put forward the preliminary recommendations contained herein.

Inasmuch as the Review Team has not yet had the opportunity to review in detail the total background of reference considered pertinent to the subject pre-feasibility level report, this report is necessarily a preliminary, progress type document.

SECTION 4.0 - IDENTIFICATION OF DATA GAPS

A number of significant gaps in the available data base, as follows, have been identified by the Review Team based on the briefings by DIAND and its Consultants, and after an initial review of available documentation, and the Review Team's prior knowledge of operations at the Giant Mine:

(a) Additional data on the historical development of the surface facilities and underground workings of the mine should be accessed to produce a better overall characterisation of the site, if possible on a year-by-year basis. It is believed that such data is available in documentation in various sources, and could be obtained also through interviews with additional "old timers" knowledgeable in the history of the mine - Dr. Sadek El-Alfy for example.

(b) Background information on the site and environs need to be covered more adequately in one particularly important respect, namely the permafrost (cold regions) aspect. The publication, Northwest Territories Water Board, 1987 Guidelines for Tailings Impoundment in the Northwest Territories, and a Report by Laval University on permafrost aspects of the original tailings area, are cases in point.

There appear to be omissions also in the reference documents relating to previous work, particularly (a) the work carried out by and for Giant on the issue of arsenic trioxide storage relating to its Water License renewal application, (b) work carried out by several consultants over the years relating to tailings disposal and (c) publications by Mine personnel.

(c) The assumptions in respect to extreme earthquake and flood events applicable to closure need to be elaborated on.

(d) The hydrogeology of the site has been covered extensively from the standpoint of lateral flow through the underground workings. Little attention appears to have been given to vertical flow of contaminated water through the bedrock surrounding the mine workings and below the arsenic storage vaults.

(e) The present condition of the arsenic trioxide in storage in the various storage vaults, in an engineering sense, is not well defined. There is no detailed knowledge, for example, on whether the arsenic trioxide is in a dry, saturated, or frozen condition. Reliance to date has been on the arsenic storage vault and mine backfill sampling program carried out by Geocon in 1981. This 20 year gap is substantial, particularly given the current thinking in respect to freezing of the stored arsenic trioxide in place, in which case additional engineering properties such as thermal conductivity, are obviously of importance.

(f) Additional reference is required in respect to directly and indirectly related precedents of the various management alternatives considered, particularly the proposed use of thermosyphons for freezing of deep ground.

The Review Team does not have specifics of the proposed thermosyphon test other than that a test on a single unit is planned. A test on a group under the conditions and depths representative of the proposed application, would appear essential.

Precedent should also be accessed on the use of active systems, such as refrigeration, to freeze ground elsewhere. It is known that there are several applications where ground has been actively frozen to facilitate development activity.

(g) Some of the storage stopes and chambers are highly irregular in shape, as are other underground workings of the mine. There would be merit in preparing 3-D models on each for illustration and working purposes, along the lines of the excellent models already completed.

(h) Little consideration appears to have been given to the availability of suitable earth borrow materials (such as clay) for possible use in remedial works, such as providing a low permeability cover to some stopes, infilling open pits, and the like.

(j) The hydrogeological drilling and piezometer installations currently under way will provide important data, and the Review Team looks forward to receiving results when available.

Other data gaps may emerge as the peer review progresses.

SECTION 5.0 - RECOMMENDATIONS

On the basis of the review team's involvement to date, and in consideration of the scope of the review, as mentioned earlier, the following preliminary recommendations are offered to assist the DIAND project team in pursuing a course of action that will provide a technically and economically sound alternative for management of the arsenic trioxide dust that meets community/stakeholder acceptance.

5.1 ADDITIONAL CHARACTERIZATION OF HISTORIC AND CURRENT CONDITIONS IMPACTING SECURE STORAGE OF DUST

Obtaining a thorough understanding of where, and under what conditions, zones of permafrost previously existed at the Giant Mine and how site development altered these zones is a prerequisite for understanding how future in-situ management alternatives involving the restoration of frozen ground either as an hydraulic barrier or by freezing the arsenic trioxide dust and surrounding rock mass can be expected to perform. It is recommended that a more complete historic characterization of the site be conducted to define how the site developed over time, where and under what conditions permafrost was encountered, how mine development impacted this permafrost, how Baker Creek has been re-routed over time and what impact this has had on the permafrost regime and how open pit mining and the amount of precipitation runoff entering the underground workings in the vicinity of the arsenic storage vaults has impacted the arsenic storage vaults, etc. This characterization, and the lessons learned, should be taken into consideration when developing future management alternatives for the arsenic storage chambers.

5.2 SECURE LONG TERM MANAGEMENT VERSUS EXTRACTION

It is recommended that future stakeholder and community consultation focusses increasingly on the fact that no matter what management alternative is finally accepted and implemented, long term management of this hazardous material, or some derivative of the material, within a storage site in the Yellowknife region is the most likely outcome.

All of the management alternatives that have been identified will result in some waste by-product that must be securely stored and managed over the long-term (perpetual care).

All of the potentially viable management alternatives for the extraction of the arsenic trioxide baghouse dust are likely to leave significant residual arsenic contamination behind. This contamination could be in the form of residual arsenic dust left in the storage vaults or material that has migrated away from the storage vaults through fractures within the surrounding rock mass. It is unlikely that any of the mining or extraction methods can assure 100% removal of this material. Consequently all of the extraction options are likely to result in a requirement for some form of long term monitoring and ongoing assessment of the potential movement of contaminated groundwater away from the post-extraction area of the storage vaults.

The viability of being able to manufacture and sell a marketable product from the extracted dust is a function of market conditions for product lines containing arsenic. At the current time this market is extremely small (primarily wood preservatives in North America) and there is risk that this market will diminish over time as regulatory pressures within the U.S. result in less use of arsenic based wood preservatives. Even if market conditions were to improve, the extraction technology will result in a residual waste product that is significantly high in arsenic that will require secure storage and management in perpetuity. This is a function of the fact that the processes used to upgrade the extracted dust into a marketable product can only achieve recoveries in the 90-95% range leaving 5-10% of the arsenic in the residue.

Community concerns will likely centre on the need to feel comfort that this material is being, and will continue to be, cared for in a responsible manner that reduces the risk to the environment or human health. There appears to be little likelihood that any alternative can fully remove the hazard from theYellowknife area and the community needs to understand this.

5.3 IN-SITU MANAGEMENT ALTERNATIVES

In view of the comments made in Section 5.2 regarding the likely drawbacks with the extraction options, the review team feels that DIAND should focus more attention on the in-situ management alternatives. These management alternatives have the potential to provide maximum long-term security and care of this hazardous material. The review team feels that DIAND and its technical team should consider a stepped up investigation of the following management alternatives:

- In-Situ Active Freezing: Use of an active refrigeration system to freeze the storage vaults and the surrounding rock mass. Active freezing could involve circulating a refrigerated brine solution and/or cold air in winter through selected zones to freeze the storage vaults and the surrounding ground. In tandem with this approach the following issues should be addressed: backfilling of the B1 open pit with a material that can be actively frozen, placement of a suitable insulation cover on top of frozen storage vaults, relocation of Baker Creek away from frozen storage vaults, use of by-pass drifts to provide a path of least resistance to move groundwater around frozen storage vaults and use of thermosyphons as a passive means of maintaining the ground in a frozen condition;

- Permanent Dewatering: The establishment of a means of ensuring a permanent drawdown of the groundwater in the area of the storage vaults so that the vaults remain hydraulically isolated from the surrounding areas. In tandem with this approach it would be prudent to look at installing a low permeability surface cap over selected storage vaults to minimize the infiltration of surface runoff, redirecting surface water flows including Baker Creek away from the area of the storage vaults and providing a means for groundwater to preferentially pass around the storage chambers using by-pass drifts and selective hydraulic plugs. Under this option the water removed from the drawdown pumping system will likely require treatment for removal of arsenic and other contaminants over the long-term (perhaps perpetually). The contaminated sludge produced by this treatment would require long-term storage and care.

These options may seem more aggressive than those currently proposed but it is the Review Team's view that a more aggressive approach to in-situ management is required. The review team believes that the most suitable option will be one that has been successfully used in similar conditions, is conservative enough to provide the community with the assurance that the risk of release is low and is flexible enough to provide an assurance that there will always be adequate time for contingency measures to be implemented if things do not operate as planned.

5.4 STABILIZATION

While the in-situ management options would appear to be the most secure and cost effective means of managing the long term care of the arsenic storage vaults, it is recommended that additional work be conducted to develop a fall back option. Most likely this would involve extraction of the baghouse dust from the vaults and stabilization of it into a storable product. The two leading candidates are conversion of the arsenic trioxide into a form of ferric arsenate using pressure autoclave process technology and encapsulation of the arsenic trioxide dust in concrete. It is recommended that additional work be conducted on the following fronts to better understand these two possible fall back options should in-situ management prove to not be technically viable or acceptable in this case:

- The current data for concrete encapsulation as a stabilization technique is not adequate to allow this option to be fully evaluated and costed. It is recommended that a comprehensive program of laboratory pilot scale testing of concrete encapsulation of the arsenic trioxide baghouse dust be conducted to obtain better data on the optimum cement to dust ratios and to determine the long term stability (leachability) of the cement stabilized arsenic bearing material;

- Pressure autoclave technology has been used widely for the pre-treatment of arsenopyrite sulphide mineral concentrates so that the contained gold can be subsequently extracted. This process uses the sulphur contained in the arsenopyrite to provide the energy required to break down the arsenopyrite mineral matrix. The contained arsenic is converted into a form of ferric arsenate (possibly scorodite) using ferric iron provided by the arsenopyrite itself. At the Miramar Con Mine arsenic trioxide bearing sludges were combined with the arsenopyrite mineral concentrate at pre-fixed ratios to convert the arsenic contained within these sludges into the more stable form of ferric arsenate. However, at Giant, any application of this process to treat the material extracted from the arsenic storage chambers will have to rely on external sources of ferric iron and sulphur. Theoretically, these can be supplied in a number of forms such as pyrite concentrate, elemental sulphur, etc., however the effectiveness of materials in the conversion process has not, to the review team's knowledge, been tried on a commercial scale. Consequently additional testing of this process should be conducted at a laboratory using a small pilot scale pressure autoclave to obtain information on how these materials will respond. Alternatively, batch treatment through the Con Mine autoclave may provide information that can be used to develop better performance and cost factors for use of this technology.

5.5 SUPPLEMENTARY TECHNICAL REVIEW

It is recommended that the independent technical Review Team for this project be expanded in size to incorporate expertise in other disciplines, such as permafrost performance, hydrogeology, geochemistry of arsenic, risk assessment, etc. The issue of effectively dealing with the long term care and management of the arsenic trioxide bearing material stored at the Giant Mine is of critical importance to the citizens of the Northwest Territories and Yellowknife in particular. A strong credible independent technical review of the management alternatives proposed will be key to aiding DIAND achieve a management alternative that is acceptable to the community at large.

5.6 PUBLIC/STAKEHOLDER CONSULTATION

It is recommended that public/stakeholder/community consultation activity associated with the development of a management alternative be increased. Final acceptance of the selected management alternative will ultimately rest with the community and will be based on its understanding of the issues and risks involved and its comfort that a viable technical management alternative is being proposed that is proven, conservative and flexible. The objective should be to assure the public that this material is being cared for in a manner that reduces to acceptable levels the risk of environmental harm or human exposure. This will have to include ongoing monitoring and contingency plans should the proposed management alternatives not meet expectations. This consultation process can involve a variety of approaches including:

- Creation of a community/stakeholder advisory board;
- Public information sessions;
- Dissemination of information using the local news media outlets;
- Meetings with community and stakeholder groups;
- Poster and published materials, etc.

SECTION 6.0 - GENERAL

It is assumed that the pre-feasibility report estimates of cost will be re-assessed in light of the recommendations made herein. The review team has not made a detailed evaluation of the cost estimates provided in the SRK report.

This document is intended to be a progress report which will be expanded upon in a follow up report. The Review Team trusts that this report is sufficient for DIAND's purposes at this time, and would be pleased to elaborate on any point should DIAND require this.

The Review Team acknowledges and appreciates the excellent cooperation and assistance provided to them by the Representatives of DIAND, SRK, and Miramar Giant Mine Ltd. involved.

Respectfully submitted,

REVIEW TEAM

M.A.J. (Fred) Matich, P.Eng.(Ont.)

Larry Connell, P.Eng.(B.C.)

Scientific Review
Study of Management Alternatives Giant Mine Arsenic Trioxide Dust

Listing of Documents Reviewed by L. Connell & F. Matich
Updated: July 16, 2002

1) "Study of Management Alternatives Giant Mine Arsenic Trioxide Dust", prepared for INAC by SRK Consulting Engineers and Scientists, Senes Consultants Limited, HGE and Lakefield Research, dated May 2001.

2) "Study of Management Alternatives Giant Mine Arsenic Trioxide Dust – Supporting Document A", prepared for INAC by SRK Consulting Engineers and Scientists, Senes Consultants Limited, HGE and Lakefield Research, dated May 2001.

3) "Study of Management Alternatives Giant Mine Arsenic Trioxide Dust – Supporting Documents B and C", prepared for INAC by SRK Consulting Engineers and Scientists, Senes Consultants Limited, HGE and Lakefield Research, dated May 2001.

4) "Letter of Invitation – Technical Advisor – Giant Mine Arsenic Trioxide Dust, Contract No. 99-0035" prepared by INAC, dated October 26, 1999.

5) "Proposal for Technical Advisor – Giant Mine Arsenic Trioxide Dust – RFP Number 99-0035" prepared by SRK Consulting Engineers and Scientists for INAC, dated December 1999.

6) "Addendum to Proposal: Technical Advisor – Giant Mine Arsenic Trioxide Dust – RFP Number 99-0035" prepared by SRK Consulting Engineers and Scientists for INAC, dated January 2000.

7) "Second Addendum to Proposal: Technical Advisor – Giant Mine Arsenic Trioxide Dust – RFP Number 99-0035" prepared by SRK Consulting Engineers and Scientists for INAC, dated January 2000.

8) Letter entitled "Giant Mine Arsenic Trioxide Project" from SRK to the INAC Royal Oak Project Team, dated July 14, 2000.

9) Letter entitled "Giant Mine Arsenic Trioxide Pre-Feasibility Study Task Descriptions and Detailed Scope of Work" from SRK to INAC Royal Oak Project Team, dated December 4, 2000.

10) "Environmental Site Assessment and Cost Estimate Giant Mine Final Report", prepared by Deton'Cho Environmental Alliance for GNWT and INAC, dated November 1999.

11) "Giant Mine Arsenic trioxide Management Technical Meetings Proceedings October 28, 29 and 30, 1997", prepared by Dillon Consulting Limited for INAC.

12) "Giant Mine Arsenic Trioxide Management Technical Meeting Proceedings October 28, 29 and 30, 1997 - Appendices", prepared by Dillon Consulting Limited for INAC.

13) "Giant Mine Arsenic Trioxide Technical Workshop Draft Summary Report (#3), October 1999", prepared by Dillon Consulting Limited for INAC.

14) "Giant Mine Arsenic Trioxide Technical Workshop Final Summary Report", prepared by Dillon Consulting Limited for INAC, November 1999.

15) "Giant Mine Underground Arsenic Management Alternatives Workshop, June 11 – 12, 2001, Yellowknife, NT – Workshop Report" prepared by Terriplan Consultants Ltd and IER – Planning, Research and Management Services for INAC, dated August 2001.

16) "Giant Mine Arsenic Trioxide Management Alternatives Workshop – June 11-12, 2001 – Powerpoint Presentation Slides"

17) "Giant Mine – Bulkheads Assessment Final Report" prepared by SRK Consulting for INAC, dated September 2001.

18) Bulkheads General Descriptions – 8 page summary by M. Lim

19) Task Descriptions for Giant Mine 2002/2003 Planning prepared by SRK Consulting.

20) Copy of Giant Mine Reference Material Listing, "Ge_Projects/INAC/1CI001.05-Giant Mine/Project Management/Giant-Ref-List-SRK.xls", dated December 19, 2001

21) "Sources of Water and Arsenic in Mine Waters Giant Mine, Yellowknife, NWT – Interpretation of Geochemical and Isotope Data" prepared by Dr Ian D. Clark, University of Ottawa for DIAND Royal Oak Project Team, dated September 20, 2001

22) "Giant Mine Hydrogeology Experts Group Meeting #2 – Final Report" prepared for INAC by K. Raven of Duke Engineering & Services (Canada) Inc., dated September 26, 2001, Project No. 01-214-1.

23) "Giant Mine – Update (March 2001)" prepared by the DIAND Royal Oak Project Team.

24) INAC Information Bulletin – Work Related to Arsenic Trioxide at Giant Mine

25) INAC Information Bulletin – Questions and Answers – Arsenic Trioxide Stored at Giant Mine

26) INAC Information Bulletin – A Day in the Life of Arsenic Trioxide

27) INAC Information Poster – Management of Arsenic Trioxide Bearing Dust at Giant Mine, Yellowknife, Northwest Territories

28) "S/S Studies of Arsenic-Containing Mine Dust and Mine Fungus Identification" prepared by Dr. W.R. Cullen of the Chemistry Department at the University of British Columbia for the INAC Royal Oak Project Team.

29) "Royal Oak Project Team Library – Giant Mine Reports" listing, dated May 31, 2001

30) "Royal Oak Project Team Library – Giant Mine Reports" listing, dated October 4, 2001

31) Arsenic Trioxide Management Project – Progress Report August 11, 2000, prepared for Mackenzie Valley Land and Water Board by INAC

32) Arsenic Trioxide Management Project – Progress Report - Fourth Quarter 2000 dated December 14, 2000, prepared for Mackenzie Valley Land and Water Board by INAC

33) Arsenic Trioxide Management Project – Progress Report - First Quarter 2001 dated April 30, 2001, prepared for Mackenzie Valley Land and Water Board by INAC

34) Arsenic Trioxide Management Project – Progress Report - Second Quarter 2001 dated July 31 15, 2001, prepared for Mackenzie Valley Land and Water Board by INAC.

35) Arsenic Trioxide Management Project – Progress Report - Third Quarter 2001 dated October 15, 2001, prepared for Mackenzie Valley Land and Water Board by INAC.

36) SRK Progress Report – Arsenic Trioxide Management, letter dated October 15, 2001 prepared by SRK for INAC Royal Oak Project Team.

37) Two page spreadsheet – Analysis of Baghouse Dust, Composite Sample September 1997 and Underground Arsenic Trioxide Inventory – December 31, 1997.

38) Bulkhead Location Maps as follows:
   C:Master\Vent\VCB-100.DWG
   C:Master\Vent\VCB-250.DWG
   C:Master\Vent\VCB-425.DWG
   C:Master\Vent\VCB-425.DWG
   Spreadsheet "Summary of Arsenic Bulkhead Information"
   Marked to show October 31, 2001 underground tour route

39) Surface Infrastructure Map MSL C:\Master\Surface\Surf1998.DWG, Figure 18, Royal Oak Giant Mine Abandonment and Restoration Plan, updated September 30, 1998.

40) Composite Level Plans – 2000 Level, 1650 Level,1500 Level, 1250 Level, 1100 Level, 950 Level, 750 Level, 575 Level, 425 Level, 250 Level, and 100 Level.

41) Copy of the powerpoint Presentation – Management of the Giant Mine, Presentation to Operations Committee, October 15, 2001.

42) Copy of the powerpoint presentation – Management of the Giant Mine, Presentation to Western & Northern Liberal Caucus, August 20, 2001.

43) Hand Calculation – Groundwater Contamination after Extraction.

ATTACHMENT B
Summary Curriculum Vitae for the IPRP Members

C.O. BRAWNER, P.ENG., FCAE., FEIC., FCIM.
SPECIALIST GEOTECHNICAL ENGINEER

EDUCATION: B.Sc., Civil Engineering, University of Manitoba, 1953
M. Eng., Civil Engineering, Nova Scotia Technical University, 1958

AFFILIATIONS: Registered Professional Engineer in British Columbia, Alberta, Alaska and Utah.
Member, American Society of Civil Engineers; Chartered Arbitrator - B.C. and Canada.
Member, American Institute of Mining Engineers; Canadian Institute of Mining Engineers.
Member, International Society of Rock Mechanics; Member, Canadian Geotechnical Society.

EXPERIENCE:

1995 — President, C.O. Brawner Engineering Ltd., North Vancouver, B.C.

1978-1994 — Professor of Geomechanics; Mining, Geological and Civil Engineering, University of B.C.
President, C.O. Brawner Engineering Ltd., West Vancouver, B.C.

1963-1978 — Principal and President, Golder Brawner and Associates. Specialist in soil and rock mechanics, foundations, pavement evaluation, groundwater, muskeg engineering, landslides, earth and tailings dams and stability in mining on over 3,000 national and international projects, engineering and construction contracts.

1953-1963 — Soils Engineer and Senior Materials Engineer, B.C. Department of Highways. Geotechnical investigations, analysis, design and construction control for provincial highway projects.

SPECIALTIES: Soil Mechanics and Foundations; Landslide engineering; Design and construction in muskeg; Geotechnical engineering for transportation; Earth and tailings storage dams; Rock mechanics and rock stabilization; Stability and drainage control in mining; Contract, construction and engineering litigation.

TECHNICAL COMMITTEES: (past and present)

Member, National Research Council of Canada, Committee for Geotechnical Research
Vice-Chairman, Canadian Advisory Committee on Rock Mechanics
Chairman, National Research Council of Canada Muskeg Sub-Committee
Consultant, Dept. of Mines "Design Guide for Mine Waste Embankments in Canada"
Special Technical Advisor, World Health Organization on Mine Waste Disposal
Special Technical Advisor, B.C. Royal Commission of Uranium Waste
Member, Workshop to Define Research Needs for Mine Waste Disposal, ASCE, U.S.A.
Official Spokesman on Geotechnical Engineering, Assoc. Professional Engineers of B.C.
Chairman, CANCOLD Committee on Industrial and Tailings dams
Member, Highways Research Board Committee on Soil and Rock Mechanics, U.S.A.
Chairman, 1st, 2nd and 3rd International Conferences on Surface Mine Stability
Chairman, 1st International Conference on Stability in Coal Mines
Chairman, 1st International Conference on Mine Drainage
Chairman, 1st and 2nd International Conferences on Stability in Underground Mining
Chairman, 1st International Conference on Uranium Mine Waste Disposal
Chairman, 1st and 2nd International Conferences on Gold Mining
President, International Mine Water Association
Member, Ministers Advisory Committee on Mining, Government of Canada
Member, MITEC Technical Advisory Committee on Mining, Canada
Workshop, Minerals and Mining Sector Consultations, Mining Assoc. of Canada

AWARDS:

Canadian Construction Association Book Award, 1953
Brunner Mond Research Fellowship, 1956
Editorial Award, Association of Professional Engineers of B.C., 1967
President's Medal, Canadian Good Roads Association, 1967
Award of Merit, Association of Consulting Engineers of Canada, 1973
Engineering Service Award, World Health Organization, 1978
Bell Memorial Medallion - For Service to the Canadian Mining Industry, 1978
Meritorious Achievement Award, Association of Professional Engineers of B.C., 1979
Publication Award, American Society of Mining Engineers, 1980, 1982, 1983, 1984
Walter Gage Teaching Award, University of British Columbia, 1981
Distinguished Member, American Society of Mining Engineers, 1982
University Medal, Beijing University of Iron and Steel, P.R. of China, 1985
Daniel C. Jackling Award, American Society of Mining Engineers, 1985
Distinguished Cross-Canada Lecturer, Canadian Institute of Mining and Metallurgy, 1988
Distinguished Citizen Award for Engineering Excellence - City of North Vancouver
Elected Fellow, The Canadian Academy of Engineers, 1995
McParland Memorial Medal, CIMM, 1997
Elected Fellow, Engineering Institute of Canada, 1997
Elected Fellow, Canadian Institute of Mining and Metallurgy, 1999
R.F. Leggett Award, Canadian Geotechnical Society, 1999
SME Book Dedication - Slope Stability in Surface Mining, 2001

PUBLICATIONS AND PRESENTATIONS:

"Stability in Open Pit Mining" (AIME), Co-Editor
"Geotechnical Practice in Open Pit Mining" (AIME), Co-Editor
"Muskeg and Northern Environment in Canada" (NCR), Co-Editor
"Stability in Coal Mining" (Miller Freeman Publications), Co-Editor
"Mine Drainage" (Miller Freeman Publications), Co-Editor
"Stability in Underground Mining", Volume 1 (AIME), Editor
"Stability in Underground Mining", Volume 2 (AIME), Editor
"Uranium Mine Waste Disposal", (AIME), Editor
"Stability in Surface Mining" Volume 3 (AIME), Editor
"Gold Mining 87", Volume 1 (AIME), Editor
"Gold Mining 88", Volume 2 (AIME), Editor
"Rockfall Mitigation" 1993, Federal Highways Agency, Washington, D.C.
Editor, International Journal of Mining Science and Technology
Associate Editor, Tunnelling
Chapter in Muskeg Engineering Handbook - "Road Construction in Muskeg" (NCR)
Chapter in Mine Waste Disposal - "Metal Mine Waste Disposal" (ASCE)
Supplementary Reporter, Third International Rock Mechanics Conference, Denver
Penrose Lecture, Geological Society of America
Seminar Lecturer (2 weeks) Beijing University of Iron and Steel
Daniel C. Jackling Lecture, American Society of Mining Engineers - 115th SME conference
Keynote Speaker, First International Conference - Stability in Coal Mining
Keynote Speaker - 4th GAME (Groundwater and Mining Exploration) Conference, Bangkok
Keynote Speaker - Rock Characterization Techniques - 115th SME-AIME Conference
Keynote Speaker - 40th Conference, Canadian Geotechnical Society
Keynote Speaker, 6th Generic Conference on Rock Mechanics (U.S.A.)
Keynote Speaker - 1993 Annual Pacific Northwest Geotechnical Conference, Anchorage, AK
Keynote Seminar Speaker - Geological Society of America, Portland - 1997
Seminar Speaker on Groundwater in Mining, University of Florida (Annual)
Seminars on Rockfall Mitigation to 32 State Highway Depts. (FHWA-U.S.A.)
Invited Chapter - 50th Commemorative Jubilee Edition of Geotechnical News - 1997
Author of over 80 technical papers on geotechnical engineering in practice
Invited lecturer at over 90 Universities and Institutes internationally including U.S.A., China and Russia

RESEARCH AND ENGINEERING

Developed the principle of large scale pre-consolidation of peat deposits, without excavation, for freeway construction - Trans Canada Highway - Burnaby and Malliardville, B.C.
Established a provincial wide highway monitoring and pavement thickness design program using the Benkelman Beam.
Developed the first programs in Canada to stabilize soil landslides with horizontal drains.
Designed and constructed the first rolled concrete slope protection in Canada - Nakusp waterfront - B.C. Hydro Arrow Reservoir, B.C.
Co-developed the dredged sand island program to develop oil drilling platforms in the Arctic Ocean-Humble Oil, U.S.A.
Developed slope stability tripod monitoring systems for high mine spoil piles - Fording Coal Mine, Dennison Coal Mine.
Applied the use of electronic distance measurement monitoring of open pit mine slope movement in rock - Canadian Johns Manville, Quebec.
Developed the procedure for vacuum horizontal drains to stabilize major rock slides - Malibu, California (50 million cu. yds.), Columbia River Gorge rock slide, Oregon (2 billion cu. yds.)
Developed the first drainage adits to dewater and stabilize major open pit mine rock slope failures - Twin Buttes Mine for Anaconda, Arizona (25 million cu. yds.) and Atlas Consolidated Mine, Philippines (55 million cu. yds.).
Expanded the base friction modeling procedure by R. Goodman to evaluate rock slope failure modes.
Applied controlled blasting used on transportation projects for applications to develop final stable slopes in open pit mining. The use of controlled blasting results in steeper pit slopes averaging 5 - 7°. Cleveland Cliffs Mine, Michigan; Gortdrum Mine, Ireland.
Developed the relationship between Rock Quality Index (RQI) and blasting fragmentation.
Developed initial recognition and stability analysis for block type failures rather than circular slides in the Athabaska Tar Sands, Syncrude.
Developed the drop raise procedure using delayed blasting to fill major underground openings prior to open pit mining through the openings, Mascot Mine, Hedley, B.C.

SUMMARY OF TYPICAL EXPERIENCE

Review Consultancy
Chairman, Syncrude Geotechnical Review Bd., Alberta
Chairman, Pine Point Seepage Review, N.W.T.
Annual Reviews, Yukon Water Board, Yukon
State Electric Commission, Morwell Coal Project, Australia
State Electric Commission, Yallorn Coal Project, Australia
Tumbler Ridge Review Board, B.C. Rail, B.C.
CODELCO Stability Review - Chuquicamata Mine, Chile
Atlas Consolidated Mine Stability Review, Philippines
Rio Tinto Huelva Open Pit Stability Review, Spain
Yaamba Oil Shale Project, Queensland, Australia
Suncor Tar Sand Geotechnical Review, Alberta
Teck Corp San Nicolas Project, Mexico
Burlington Northern Railway Rock Stability Review, Washington
Canadian Pacific Railway Rock Stability Reviews, Canada
Tosco (The Oil Shale Corp) Mine Review, Colorado
OK Tedi Tailings Site Failure Review, Papua New Guinea
Electricity Generation Authority, Lam Pang, Thailand
Titania Mine Slope Stability Review, Norway
Sante Fe Gold Corp Stability Review (6 projects), U.S.A.
Baja Descent Highway Rock Stability Review, Saudi Arabia
Lihir Gold Project Review, Papua New Guinea
American Barrick Goldstrike Pit Stability Review, Nevada
Hammersley Iron Mine Stability Review, Australia
Westar Elkview Waste Pile Stability Review, B.C.
Princeton Mining Huckleberry Project Review, B.C.
El Pachon Pit Slope and Tailings Dam Stability, Argentina
La Granja Pit Slope and Tailings Dam Stability, Peru
OMAI Gold Mine Tailings Outflow Review Board, Guyana
Marcopper tailings outflow, Independent Review Expert, Philippines
Kemess Mine Review Board, B.C.
Carlota Project pit slope and leach dump Review, Arizona
Cambior Gros Rosbel tailings dam Review, Surinam
Tech Corp Petraquippa project pit slope Review, Panama
Sagamosa Hydro Project rock stability, Columbia
Placer Dome las Cristinas tailings dam Review, Venezuela
Cambior Metallica Mine Rock Slope Review, Mexico
Newmont Mining - Yanacocha Pit Slope Review, Peru
Placer Dome Seminar and Stability Review, Ontario
Placer Dome Cortez Stability Review, Nevada
Placer Dome Western Deeps Water Control, South Africa
Wabush Iron Mine Dewatering Review, Nfld.
Highland Valley Copper Overburden Review, B.C.
Crystallex San Gregorio Mine, Uruguay
Empire Iron Mine Slope Stability, Michigan

Stability for Surface Mining (non-coal)
Amok Cluff Lake Uranium Mine, Saskatchewan
B.C. Molybdenum Project, B.C.
Kennco Stikine Galore Creek Project, B.C.
Cassiar Asbestos, B.C.
Bethlehem Copper, Highland Valley, B.C.
P.T. Pacific Nickel project, Indonesia
Kaiser Cement and Gypsum, California
EXXON Highland Uranium Mine, Wyoming
Cyprus Anvil Mine, Yukon
Roan Consolidated Chambishi & Kalalushi Mines, Zambia
Nichanga Consolidated Copper Mine, Zambia
Falconbridge Westrob Mine, B.C.
Canadian Johns Manville, Quebec
Flintkote Asbestos Mine, Quebec
Lake Asbestos Mine, Quebec
Rio Tinto Zinc Project, Wales
Utah International Molybdenum, Port Hardy, B.C.
Placer Endako Mine, B.C.
Placer Gibraltar Mine, B.C.
Viceroy Castle Mountain Project, Nevada
Cleveland Cliffs Iron Co., Michigan
Iron Ore Co. of Canada - Schefferville, Quebec
Iron Ore Co. of Canada - Labrador City, Labrador
Quebec Cartier Mining, Gagnon, Quebec
Marcopper Mining Corporation, Philippines
Lornex Highland Valley Mine, B.C.
Highmont Highland Valley Mine, B.C.
Valley Copper Highland Valley Mine, B.C.
Afton Mine, B.C.
Gortdrum Mine, Tipperary, Ireland
Tara Mine, Ireland
Hammersley Iron Mine, Australia
Hanna Mining Company, Michigan
First Miss Getchel Mine, Nevada
Oslo Tar Sand Project, Alberta
Molycorp, Questa, New Mexico
Dye Mine, Wuhan, P.R. of China
Bell Mine, Granisle, B.C.
Colomac Gold Mine, N.W.T.
Steep Rock and Caland Mine Closure, Ontario
Anamax Twin Buttes Mine, Arizona
Marindique Mining, Philippines
Princeton Similkameen Mine, B.C.
Pegasus Beal Mt. Gold Mine, Montana
Cambior Omai Gold Mine, Guyana
Goldenbell Mariposa Gold Project, California
Valdez Creek Gold Mine, Alaska
Mascot Gold Mine, Hedley, B.C.
INCO Thompson Mine, Manitoba
New Imperial Mt. Polly Project, B.C.
Porgera Mine, Papua New Guinea
Missima Mine, Papua New Guinea
La Granja Project - Cambior, Peru
El Pachon Project - Cambior, Argentina
Empire Iron Mine, Michigan
Crystellex Victoria Mine, Venezuela
North Kemess Project, B.C.

Stability for Surface Coal Mining
Quintette Coal Mine, B.C.
Teck Bullmoose Coal Mine, B.C.
Utah Blackwater and Goonyella Projects, Australia
Lochiel Coal Project, South Australia
Hail Creek Coal Project, Queensland, Australia
Rotowara Coal Mine Stability, New Zealand
Line Creek Coal Mine, B.C.
Byron Creek Coal Mine, B.C.
Fording Coal Pit slopes, tailings dams and waste piles, B.C.
Saskatchewan power open pit stability, Saskatchewan
Highvale and Wabamun pit stability, Alberta
Cardinal River Coal, Alberta
Luscar Coal Mine, Alberta
Consolidation Coal pit stability, Illinois
Rocky Mountain Energy Coal Project, Colorado
Kaiser Resources pit and waste pile stability, B.C.
Greenhills Coal Mine pit and waste pile stability, B.C.
Morrison Knudsen Elk Valley Project, B.C.
Sukunka Coal Project, B.C.
Manalta Coal Mine Stability, Alberta
Westar Waste Dump Stability, B.C.

Tailings Dams
Bethlehem Copper Corp., Highland Valley, B.C.
Lornex Highland Valley Mine, B.C.
Syncrude Tar Sand Mine, Alberta
Suncor Tar Sand Mine, Alberta
Craigmont Mines Ltd., B.C.
Dalton Mines Ltd., B.C.
Giant Mascot Mine, Hope, B.C.
Treminco, Silvana Mine, Sandon, B.C.
Lepanto Mining Corp., Philippines
Marcopper Copper Mine, Philippines
Mines du Rif, Morocco
Pinchi Lake Mercury Mine, B.C.
Bouchard Hebert Mine, Quebec
Coeur d'Alene Mines, New Zealand
Fording Coal Wash Plant tailings, B.C.
Westmin Premier Mine, B.C.
Ranger Uranium Mine, Australia
Barahona and Colihues Dams, El Teniente, Chile
Endako Mine, B.C.
Bell Mine, Granisle, B.C.
OMAI No. 2 tailings dam, Guyana
Cypress Anvil Mine, Yukon
Mina Matilda Mine, Bolivia
Avoca Mines Ltd., Ireland
Pine Point Mines Ltd., N.W.T.
Centromin Casapalen Mine, Peru
Eskay Creek Mine Tailings Dam Review, B.C.
Princeton Huckleberry Mine, B.C.
Golden Bear Tailings Dam Review, B.C.
Hecla Grouse Creek Mine, Idaho
Westmin Myra Creek Mine, B.C.
El Pachon Mine, Argentina
Imperial Metals, Mt. Polly Mine, B.C.
Kemess Project - Northgate, B.C.
La Doyon Mine, Barrick Cambior, Quebec
Niobec Mine, Quebec
Comsur Mine, Bolivia
La Granja project, Peru

Tunnels
B.C. Dept. of Highways, Sailor Bar Tunnel
B.C. Dept. of Highways, Saddle Rock Tunnel
B.C. Dept. of Highways, China Bar Tunnel
C.P. Rail, Mt. Macdonald Tunnel Alignment, B.C.
C.P. Rail Mile 9 Tunnels, Revelstoke, B.C.
C.P. Rail, Mink Tunnel, Ontario
C.P. Rail, Red Sucker Tunnel, Ontario
C.P. Rail, Beaver Tunnel, B.C.
C.P. Rail, Spiral Tunnels drainage control, B.C.
C.P. Rail, Jackfish Tunnel, Ontario
C.P. Rail, Ruby Creek Tunnel, B.C.
B.C. Rail Wolverine Tunnel, B.C.
B.C. Rail Table Tunnel, B.C.
B.C. Rail Seton Lake Tunnel, B.C.
Melbourne City Center Subway Tunnel, Australia
Greenvale Railway Tunnel, Queensland, Australia
Snettisham Penstock Tunnel, Alaska
Russian River Fish Ladder Tunnel, Alaska
Alaska Railway Whittier Tunnels, Alaska
Mile 17 tunnel, White Pass and Yukon R.R., Alaska
Arch Cap Highway Tunnel, Oregon
Blue Mountain Tunnel, Union Pacific Railway, Oregon
Mossier Tunnels Rehabilitation, Oregon
Elk Creek Tunnel, Oregon
Sagamoso Penstock Tunnels and Powerhouse, Columbia
Tazamina Power Project, Alaska

Landslides - Rockslides
Black Canyon Rockslide, B.C.
Jefferson County Landslide, Oregon
Dryrock Slide, Spences Bridge, B.C.
Park Bridge Slide, Golden, B.C.
Lakelse Lake Slides, Terrace, B.C.
King Kamehameha Highway Slide, Oahu
Malibu Landslide Stabilization, Malibu, California
C.P. Rail Mile 52, Thompson Subdivision, B.C.
Osweg Creek Landslide litigation, Oregon
Queensland Railway slides, Australia
C.N.R. Mile 12 Slide, Fraser Canyon, B.C.
Cassiar Clinton Creek Waste Pile Slide, Yukon
Keystone Canyon Rock Slide, Alaska
Fort Smith Landslide, N.W.T.
Peace River Valley Slides - B.C. Rail, B.C.
Bonnyville Dam Lock Stability, Oregon
Rocky Point Stability, Oregon
Ketchikan Jail Rock Slopes, Alaska
Squamish Highway rockslides, B.C.
Hungry Horse Canyon, Montana
Skagway harbor submarine slide, Alaska
Quintette Coal Waste Dump Slides, B.C.
Fording Coal Waste Dump Slides, B.C.
Downie Slide - C.P. Rail, B.C.
B.C. Dept. of Highways, - Peace River Valley slides, B.C.
South Okanagan Valley silt slides, B.C.
Aberdeen Hills Subdivision Slide, B.C.
Showbread slide, Idaho Dept. of Highways, Idaho
Dutchman Creek Rockslide - Mica Dam, B.C.
Arrow Lake Landslides, B.C. Hydro, B.C.
Mile 47.9 slide, C.P. Rail, Ashcroft, B.C.
Makapuu Rock Fall Control - Hawaii
Waimea Rock Fall Control - Oahu, Hawaii

Industrial and Building Foundation Projects
Lafarge Cement Plant, Kamloops, B.C.
Annacis Island Cement Plant, Vancouver, B.C.
Development of Beaufort Sea Dredged Islands, Humble Oil Co.
Horseshoe Bay Ferry Terminal, Vancouver, B.C.
Skagway Deepsea Port, Alaska
Pioneer Grain Elevator, Vancouver, B.C.
Bulkley Valley Sawmill, Houston, B.C.
Fording Coal Plant Facilities, B.C.
Simon Fraser University, Vancouver, B.C.
Westcoast Transmission Building, Vancouver, B.C.
Bank of Nova Scotia Building, Vancouver, B.C.
Pacific Coliseum, Vancouver, B.C.
Canadian Pacific Marshalling Yard, Coquitlam, B.C.
Deuba Beach Resort, Fiji
Delta Municipal Hall, B.C.
Kelowna Court House, B.C.
Revelstoke Hospital, B.C.
Johns Manville World Headquarters, Colorado

Transportation Projects
Burnaby-Freeway, Trans Canada Highway, B.C.
Fraser Canyon Highway, Trans Canada Highway, B.C.
Rogers Pass Highway, Trans Canada Highway, B.C.
Anchorage-Seward Highway, (5 projects), Alaska
Canadian Pacific Railway, B.C., Alta., Ontario, N.B. and Maine
Burlington Northern Railway, Washington, U.S.A.
Greenvale Railway, Queensland, Australia
Tahsis Company Logging Road Stability, B.C.
Mt. St. Helens National Park Highway, Washington, U.S.A.
White Pass and Yukon Railway, Alaska
Detroit Lakes Rock Slope Stabilization, Oregon
B.C. Railway, Seton Lake Rockslide, B.C.
Rocky Point Rock Stabilization, Oregon
Keystone Canyon Rockslides, Alaska
Stevens Pass Slope Stabilization, Washington
White Pass Railway Snow Avalanches, Alaska
Lytton North Siding Extention, C.N.R., B.C.
Banks - Loman Rock Stability, Montana
Haines - Canadian Border, Alaska
Iceland Dept. of Highways - Rock Seminar, Iceland
Ketchikan Bypass, Alaska
Arizona D.O.T., Rock Bolting Seminar, Arizona
Thompson Pass Reconstruction, Idaho
Montpelier East Reconstruction, Idaho
Ahba Descent Highway Stability Review, Saudi Arabia
Alaska Dept. of Highways, Thane Road, Juneau, Alaska
Public Works Canada, Fort Nelson west rock stability, B.C.
Hawaii Dept. of Highways - rock slope inspections, Hawaii
Hungry Horse Canyon, Montana Dept. of Highways, Montana
Kicking Horse Canyon, Trans Canada Highway, B.C.
Coast Highway Rock Slope Stabilization, Oregon
Dept. of Transportation, Mile 4.1 Historic Highway, Oregon
Denver and Hudson Railway, New York, U.S.A.
Goff Bridge - Riggins, Idaho, U.S.A.

Bridge Foundation Projects
Alexander Bridge, Fraser Canyon, B.C.
Fraser River Bridge, Prince George, B.C.
Fraser River Bridge, Port Mann, B.C.
Qualicum River Bridge, B.C.
Fraser River Bridge, Quesnel, B.C.
Nechako River Bridge, B.C.
Okanagan River Bridges, Penticton, B.C.
Sicamous Bridge, B.C.
Columbia River Bridge, Trail, B.C.
Columbia River Bridge, Castlegar, B.C.
Elk River Bridge, Fernie, B.C.
Columbia River Bridge, Golden, B.C.
Clanwilliam Overpass, Eagle Pass, B.C.
Dechutes River Bridge, Oregon
Thompson River Bridge, Spences Bridge, B.C.
Columbia River Bridge, Revelstoke, B.C.
Fraser River Bridge, Williams Lake West, B.C.
Skeena River Bridge, Terrace, B.C.
Thompson River Bridge, Kamloops, B.C.
Sikanni River Bridge, Fort Nelson, B.C.
Kootenay River Bridge, Creston, B.C.
Pine River Bridge, Chetwynd, B.C.
Buckley River Bridge, Smithers, B.C.
Buckley River Bridge, Houston, B.C.
Number 5 Road Overpass, Richmond, B.C.
Serpentine River Bridge, Surrey, B.C.
Kicking Horse River Bridges (3), Golden, B.C.
Crooked River Bridge, Bend, Oregon

Litigation
Foreman vs State of Oregon, Oregon
Govt. of Canada vs Kean Construction, Alta.
Just vs Govt. of B.C., B.C.
Syncrude Canada vs Commonwealth Constr., Alta.
C.P. Rail vs Selkirk Contractors, Alta.
Wolverine Contractors vs B.C. Rail, B.C.
Molosso vs State of Alaska, Alaska
Theiss Constr. vs Freeport Nickel, Australia
C.P. Rail vs Govt of Ontario, Ont.
Cominco vs Cementation, N.W.T
State of Alaska vs Harding Lawson Ltd., Alaska
Craft vs Norfolk Southern R.R., Virginia
CIGNA Insurance Group vs IMC Potash, Sask.
OK Tedi Mining vs Insurance Consortium, PNG
Miller Construction vs Dept. of Transportation, Canada
Gobin vs The Queen, B.C.
Dillingham Construction vs B.C. Hydro, B.C.
Chinook Aggregates vs Matsqui, B.C.
Walton vs The Queen, B.C.
Holt vs The Queen, B.C.
Mochinski vs The Queen, B.C.
Sloan vs North Coast Construction, B.C.
B.C. Rail vs CPCS, B.C.
Watson vs B.C. Highways, B.C.
Tercon vs Noranda, B.C.
Edgeworth Construction vs B.C. Highways, B.C.
Morrison vs SRK Robinson, B.C.
Williams Storage vs SKR Robinson, B.C.
Class Action vs Cyprus Mines, California
Wigmar Cosntruction vs AGRA, B.C.
Ducette vs B.C. Highways, B.C.
TCI Construction vs Bureau of Reclamation, California
Gerling Insurance vs Golder Assoc., Montana
State of Alaska vs PND Engineering, Alaska

Laurie Hing Man CHAN, B.Sc., M.Phil., Ph.D.

I. BIOGRAPHICAL DATA

Present Rank	Associate Professor and NSERC Northern Research Chair
Address	School of Dietetics and Human Nutrition Macdonald Campus of McGill University 21,111 Lakeshore Road, Ste-Anne-de-Bellevue, Québec, Canada H9X 3V9
Tel No.	514-398-7765
Fax No.	514-398-1020
E-mail address	LAURIE.CHAN@MCGILL.CA

II. EDUCATION

	Department	**University**	**Date Awarded**
B.Sc.	Zoology	Hong Kong	1983
M.Phil.	Zoology	Hong Kong	1987
Ph.D.	Biological Sciences	London	1990
Post-doctoral	Pathology	Western Ontario	1993

III. PROFESSIONAL EMPLOYMENT RECORD

Date	**Title**	**Institution**
1999-	Associate Professor	School of Dietetics and Human Nutrition, McGill University
1999-	Associate Member	Department of Natural Resource Sciences, McGill University
1997-	Associate member	Department of Food Sciences and Agricultural Chemistry, McGill University
1995-	Associate member	Faculty of Medicine, McGill University

IV. PRESENT TEACHING

Graduate students

	Graduated	**In course**
M.Sc.	**11**	**6**
Ph.D.	**2**	**4**
Post-doctoral fellow	**4**	**2**

V. RESEARCH INTERESTS

Nutritional and food toxicology; Functional Food; Nutrition and the environment of Indigenous Peoples; Risk assessment of contaminant exposure; Analytical Chemistry; Food Security and effects of climate change.

VI. PUBLICATIONS **55 publications in peer-review journals, 3 book chapters, and over 100 conference presentations**

2000-2002

55. Kuhnlein, H.V., H.M. **Chan**, O. Receveur and G.M. Egeland (in press) "Canadian Arctic indigenous peoples, traditional food systems and POPs." Chapter in: Northern Lights Against POPs: Combating Toxic Threats at the Top of the World. Edited by T. Fenge and D. Downey, McGill Queen's University Press.

54. Kuhnlein, H.V., H.M. **Chan**, D. Leggee and V. Barthet (in press) "Macronutrient, mineral and fatty acid composition of Canadian Arctic traditional food". J. Food Comp. and Anal.

53. Kuhnlein, H.V., O. Receveur and H.M. **Chan** (2001) "Traditional food systems research with Canadian Indigenous Peoples." Intern. J. Circumpolar Health 60(2): 112-122.

52. Parsons, E.C.M. and H.M. **Chan** (2001) "Organochlorine and trace element contamination in bottlenose dolphins (Tursiops truncatus) from the South China Sea". Marine Pollution Bulletin 42(9):780-786.

51. Skopp, S., M. Oehme, F.L. Chu, F. Yeboah and H.M. **Chan** (2002) "Analysis of total toxaphene and selected single congeners in biota by ion trap HRGC-EI-MS/MS using a congener optimized parent ion decay". Environ. Sci. Technol. 15;36(12):2729-35

50. Calciu, C., S. Kubow and H.M. **Chan** (2002) "Interactive dysmorphogenic effects of toxaphene or toxaphene congeners and hyperglycemia on cultured whole rat embryos during organogenesis". Toxicology. 14;175(1-3):153-65.

49. **Chan**, H.M. Kim, C. Leggee, D. (2001) "Cadmium in caribou (*Rangifer tarandus*) kidneys: speciation, effects of preparation and toxicokinetics." Food Addit. Contam.,In press.

48. Regoli, L. **Chan**,H.M. de Lafontaine, Y. and Mikaelian, I. (2001)"Organotins in zebra *mussels (Dreissena polymorpha*) and sediments of the Quebec City Harbour area of the St. Lawrence River." Aquatic Toxicology, 53:115-126.

47. Wen, Y.H. and **Chan**, H.M. (2000) "A pharmaockinetic model for predicting absorption, elimination, and tissue burden of toxaphene in rats." Toxicol. Appl. Pharmacol. 168:235-243.

46. Kuhnlein, H.V. and H. M. **Chan**. (2000). "Environment and contaminants in traditional food systems of northern indigenous peoples." Annu. Rev. Nutr. 2000. 20:595-626.

45. **Chan** HM. Receveur O (2000). "Mercury in the traditional diet of indigenous peoples in Canada." Environ. Pollut. 110(1):1-2, 2000.

44. de Lafontaine, Y; Gagne, F., Blaise, C. Costan, G Gagnon, P. **Chan**, H .M. (2000). "Biomarkers in zebra mussels (*Dreissena polymorpha*) for the assessment and monitoring of water quality of the St Lawrence River (Canada)." Aquatic Toxicology 50:51-73.

43. **Chan**, H.M., Yeboah, F. (2000) "Total toxaphene and specific congeners from the Yukon, Canada." Chemosphere 41:55-63.

42. Chapman, L., **Chan**, H.M. (2000) "The influence of nutrition on methylmecury intoxication" Environ. Health. Perspect. 108(suppl 1):29-56.

VII. Grants currently held

1999-2003	"Metal speciation and toxicology in waterfowl" NSERC network grant: Metals in the environment (with P. Campbell et al.)
2000-2003	"Methods for Rapid Speciation and Determination of Toxic Metals in Soils and Sediments." NSERC strategic grant (co-PI E. Salin, Chemistry)
2001-2006	"An ecosystem approach to Hg and human health" NSERC Network Grant: Mercury in the environment (with Lucotte et al.)
2002-2006	"Dietary effects on toxicity of environmental contaminants" NSERC Research Grant
2002-2007	"Environmental Contaminants, Food Security and Indigenous Peoples of the North" NSERC Northern Research Chair

VIII. Fellowship and Membership of Scientific Societies

Fellow of the Linnaen Society of London, United Kingdom (FLS)
Member of the Society of Toxicology, USA
Member and Councillor (96-99) of the Society of Toxicology of Canada
Member of the Society of Environmental Toxicology and Chemistry
Member of the American Society for Nutritional Sciences

IX. CONSULTING AND OTHER EXPERIENCES

Scientific Advisor to the community of Big Trout Lake, Ontario and 18 other aboriginal communities and organizations.

Member of Expert Panel the review of policies concerning the addition of vitamins and minerals to foods, Health Protection Branch, Health Canada

Member of External Expert Committee for drafting of policies concerning Natural Health Products, Health Canada

Member of review team for the National Institute of Child Health and Human Development Global Network, NIH.

Member of the Review Panel for Environmental Biology of the US Environmental Protection Agency.

Expert Advisor for the Canadian Council for Ministers of Environment on harmonization of mercury and dioxin standards.

Advisor for the Yukon, the Northwest Territories and the Alaskan government on formulating their risk management policies.

Member of the Expert Review Panel for Arsenic Trioxide in Giant Mine, NWT.

amec

Larry Connell, P.Eng.

Senior Mining Environmental Consultant

Professional summary

Mr. Connell is an environmental manager and metallurgist with more than 25 years operating experience in the mining industry in the fields of environmental engineering, mineral processing and operations management. He has had extensive involvement in environmental assessment, environmental permitting, acid rock drainage, mine closure and reclamation planning, rehabilitation and effluent treatment in gold and base metal mining.

Professional qualifications

Professional Engineer in British Columbia, Ontario, and the Yukon:

- British Columbia – License # 23696
- Ontario – License # 9099508
- Yukon – License # 1315

Education

B.Sc. (Hon) Mining Engineering (Mineral Processing Option), Queen's University, Ontario, 1975

Summary of core skills

Environmental Management

Mr. Connell has over 15 years experience as an environmental manager in the Canadian mining industry. He has headed up environmental management teams at a number of operating mines across Canada and at the corporate level. He has assisted a number of clients in assessing the current status of their environmental programs and developing means to ensure on-going environmental compliance including development and implementation of environmental management systems. He has participated in a number of due diligence audits for various clients both in Canada and the US and is familiar with environmental regulations in these respective jurisdictions.

Mine Closure and Reclamation Planning

Mr. Connell has extensive experience in the planning and preparation of closure plans for mining operations throughout Canada and the US. He has been involved in the reclamation of several abandoned mine sites, from initial site investigation through to the design and implementation stage. He has prepared closure plans in Newfoundland, Ontario, Manitoba, British Columbia, the Northwest Territories, the Yukon and Alaska. He has conducted formal reviews of mine closure plans in Montana and Nevada.

Reclamation Cost Estimating

Mr. Connell has developed cost estimates for mine closure plans for both active and dormant mine properties in both Canada and the US. He is well versed with the reclamation costing spreadsheet programs used in Northern Canada, in British Columbia and in South Dakota. He has participated in mine closure bonding negotiations for clients in both Canada and the US and has extensive experience in developing closure cost estimates.

ARD-Metal Leaching Characterization

Mr. Connell has a strong background in acid rock drainage and metal leaching characterization and has conducted waste characterization studies for a number of clients across Canada. He has developed waste rock management plans for several mines in British Columbia and the Yukon and has been involved in developing management plans for both reactive tailings and waste rock.

Waste Management

Mr. Connell has experience in the development and implementation of management plans for a number of different categories of mine waste materials, including waste rock, mill tailings, hazardous waste materials such as waste oils, greases, solvents, etc., PCB's, contaminated soils, asbestos containing products and landfill materials. This experience extends to remediation of contaminated soils, development of remediation options, recycling programs.

Water Treatment

Mr. Connell has been involved in the design, construction, commissioning and operation of several mine effluent wastewater treatment plants at gold mines utilizing alkaline chlorination, hydrogen peroxide, SO_2-Air for cyanide destruction and metals precipitation. He also has experience with use of ferric iron based treatment processes for arsenic reduction and for the treatment of phosphorous in mine wastewater. Mr. Connell has worked on passive treatment processes for mining clients involving land application for nitrogen reduction and enhanced evaporation systems for wastewater volume reduction.

Permitting

Mr. Connell has been involved in the permitting process for mining operations in Newfoundland, Ontario, British Columbia, the Northwest Territories, the Yukon and Alaska. He has developed and led the team in implanting permitting strategies for a number of new mining operations. He has also been involved in amending permits for a number existing mining operations.

Environmental Impact Assessment

Mr. Connell has a strong background in environmental impact assessment and has led teams in the preparation of EIA for both small and large scale mining operations. This experience encompasses preparation of EIA's under the requirements of the Canadian Environmental Assessment Act and the British Columbia Environmental Assessment Act. Mr. Connell is well versed with both the US NEPA process and the World Bank standards covering the EIA process.

Curriculum Vitae

STEVE E. HRUDEY

CURRENT APPOINTMENT:

Title: Professor of Environmental Health Sciences
Department of Public Health Sciences
Faculty of Medicine and Dentistry
University of Alberta
Edmonton, Alberta T6G 2G3

Function: Teaching, research and contributions to society with respect to environmental factors affecting human health.

Specific teaching responsibilities have included: environmental health, risk assessment, risk management and risk communication, exposure assessment, industrial and hazardous waste management, environmental engineering and chemistry, technical communication.

Specific research interests include: drinking water quality and safety, environmental risk management, environmental health criteria; contaminant exposure assessment, risk assessment methodologies; environmental decision-making

EDUCATIONAL QUALIFICATIONS:

D.Sc (Eng), Environmental Health Sciences and Technology,
University of London, 2002 (based on career research publications)

Ph.D., Public Health Engineering,
University of London, 1979 (Advisor: Professor Roger Perry)

M.Sc., Public Health Engineering
Imperial College, University of London, 1971 (Advisor: Professor Roger Perry)

B.Sc., Mechanical Engineering (with electives in life sciences)
University of Alberta, 1970

RESEARCH ACTIVITIES:

Current major activities include:

- drinking water safety and quality management
- disinfection by-products and drinking water quality
- health risk assessment and risk management for environmental protection
- environmental decision-making under uncertainty
- expert knowledge of health risk
- cyanobacterial toxins in water supplies
- community environmental health studies
- environmental health criteria for contaminated site remediation

Dr. Hrudey is an active researcher and he has authored or co-authored over 120 refereed journal articles, 5 books, 10 book chapters, 5 expert panel reports and over 100 other scientific publications relating to environmental risk assessment, risk management, drinking water and environmental quality.

Dr. Hrudey has been awarded the Berry medal for contributions to environmental engineering by the Canadian Society for Civil Engineering and the Emerald Award for excellence in environmental research in Alberta. He has served as Chair of the NATO Priority Panel on Environmental Security in Brussels and as a member of a number of provincial, national and international panels on environmental research. He has also been Chair of the Royal Society Expert Panel assessing Socio-Economic Modeling for the Canada-wide Air Quality Standards for Respirable Particulate and Ozone and Chair of the Expert Advisory Panel of the NSERC Metals in the Environment Research Network. Recently, Dr. Hrudey Chaired an international expert panel for Health Canada to review evidence over the past decade on human health effects of trihalomethanes in drinking water in support of the Federal Provincial Taskforce on chlorinated disinfection by-products in drinking water. Dr. Hrudey leads the Water and Public Health theme of the Canadian Water Network, a newly funded Network of Centres of Excellence in research.

Dr. Hrudey served on the Research Advisory Panel to the Commissioner of the Walkerton Inquiry from August 2000 to May 2002 when the Part 2 Inquiry Report was released and he has served as an administrative law judge for the Alberta Environmental Appeal Board since 1996, twice being re-appointed by provincial Order-in-Council.

Dr. Hrudey has been engaged in interdisciplinary environmental research spanning the health sciences, the natural sciences and engineering, and the social sciences and humanities since 1970. He has supervised or co-supervised 17 doctoral students or post doctoral fellows and 45 masters students in disciplines ranging from anthropology, sociology, philosophy and law to biology, chemistry, engineering and medicine. In addition to basic research about health risk within the environmental health sciences he has taken a particular interest in the nature and role of scientific evidence in environmental risk decision-making.

CURRICULUM VITAE

KONRAD Jean-Marie ing, Ph.D.

Citizenship:	Canadian, French
Languages:	French, English, German
Telephone:	(418) 656 3878 (418) 877 3529 Home (to leave a message) (418) 871 0988 Home (direct)
Address at home :	4743 Perdrix-Grise Saint-Augustin, Quebec Canada, G3A 2H2
Address:	Department of Civil Engineering Pavillon Pouliot Université Laval, Québec City Canada, G1K 7P4

Dr. Konrad is a registred civil engineer with a Master's degree from Unversité Laval and a Doctorate degree from the University of Alberta where he contributed to the development of frost heave mechanics. He worked in the private sector as a geotechnical engineer for SNC-Lavalin and James-Bay hydro electricic Corporation , at the National Research Council with respect to the geotechnical aspects of the artificial drilling islands in the Beaufort Sea, development of interpretation techniques of in situ testing data in weak soils and academia at the University of Waterloo (Ontario) and Université Laval (Québec). He is presently professor of civil engineering at Université Laval, Quebec and is also the Chairholder of an NSERC industrial research chair on frost action in civil enginnering structures. Dr Konrad is the author or co-author of over 110 technical papers. For the last twelve years, he was also a consultant for various projects related to artificial freezing, dam construction and safety assessment.

ASSOCIATIONS

- Ordre des ingénieurs du Québec
- Canadian geotechnical society
- International Soil Mechanics and Foundation Engineering Society
- World Road Association PIARC

- Fellow 1999, Canadian Academy of Engineering
- Fellow 2003, Engineering Institute of Canada

AWRDS

- Canadian geotechnical society: Colloquium awards 1992
- Canadian geotechnical society Roger Brown award 2000

EDUCATION

1980	Ph.D. (Civil Engineering)	University of Alberta
1977	M.Sc. (Civil Engineering)	Universite Laval
1975	Dipl.Ing. (B.Sc.)	ENSAIS (France)

PROFESSIONAL EXPERIENCE

1998-	Professor and NSERC Chairholder on frost action in highways Department of Civil Engineering Université Laval Quebec City
1993- 1998	Professor Department of Civil Engineering Université Laval Quebec City
1992	Consultant at Klohn (Sabbatical leave)
1991	Professor Department of Civil Engineering Université Laval Quebec City
1990-1991	Associate Professor Department of Civil Engineering Université Laval Quebec City
1986-1990	Associate Professor Departments of Earth Science and Civil Engineering University of Waterloo
1982-1986	Research Officer National Research Council of Canada Geotechnical Section (DBR)
1984-1986	Adjunct Professor Department of Civil Engineering University of Ottawa
1980-1982	Geotechnical Engineer Societe d'Energie de la Baie James Lavalin Group , Montreal

RESEARCH EXPERIENCE AND INTERESTS

1. Onshore Geotechnics

* In Situ Testing
  - Piezocone, Flat Plate Dilatometer (DMT)
    Pressuremeter, Permeameter in Sands, Silts and soft clays
* Geotechnical characteristics of silty soils
  - Static and Dynamic loading
  - Tailings dams
* Strength weakening of frost-susceptible soils during freeze-thaw cycles

2. Hydrogeology

* Flow in fractured clays
* Numerical simulation of formation of fractures
* Effect of freeze-thaw in moisture-retaining cover layers as oxygen barriers (acid generation in mine tailings)

3. Offshore Geotechnics

* Liquefaction of hydraulically placed sand island
* Cyclic loading of sands (stability of submarine slopes under wave actions and earthquakes)

4. Permafrost Geotechnics

* Saline Permafrost Characteristics
* Water migration during freezing in saline environment
* Creep properties of frozen soils
* Frozen soil-structure(piles) interface behavior

5. Coupled heat-fluid flow mechanics

* Influence of seepage on the temperature distribution in zoned earth dams
* Staged construction of frozen earth dams

6. Permafrost and Artificial Freezing Projects as Consultant

* GIANT MINE REVIEW (2002-2003) DIAND

* EFFECT OF FREEZE-THAW IN DAM CORES (JAMES BAY) 1999- 2001

* ALCAN : USE OF FREEZE-THAW FOR CONSOLIDATION OF SLURRIES 1998-2000

* BOSTON Freeze project for MORETRENCH Ltd.(1999-2000)

* IZOK (Klohn-Krippen 1993-94)

* HOWELL BRIDGE FOUNDATION REHABILITATION (OIC) Northern Québec 1993-94

* RAGLAN (Roche, Falcon Bridge ; 1991-97)

* UNDERGROUND FREEZING IN KOBE (JAPAN) 1996-98

* HIRANO RIVER FREEZING (OSAKA, JP) 1996-98

*ASSESSMENT OF THERMAL FIELD AT JAMES BAY HYDRO DAMS 1992-99

7. Geotechnical Projects as Consultant

* DESIGN OF BULK TERMINAL ST-LAWRENCE RIVER (2002-2003)

* DESIGN OF FOUNDATIONS FOR TRANSMISSION TOWERS (HYDRO-QUÉBEC) 2002-2003

* STABILITY OF POORLY COMPACTED TILL EMBANKMENT SLOPES – MINISTRY OF TRANSPORTATION - 1999-2001

* REVIEW AND ANALYSIS OF PIEZOCONE TEST DATA FOR TECH IN-SITU BETWEEN 1996 AND 2001 (OVER 15 PROJECTS)
* CYCLIC SIMPLE SHEAR TESTING OF RED MUD (ALCON –TECHMAT) 2000 - 2001

* TRIAXIAL CYCLIC TESTING OF OOTAWA CLAY FOR SEIMIC RETRO FITTING (URKKADA LTD.) 2001

* FOUNDATION DESIGN USING LARGE DIAMETER LAVAL SAMPLER (UQAC) TECHMAT 1996

Robert E.J. Leech

B.Sc., M.Eng.Sc., F.G.S.
Hydrogeologist, Chairman

Gartner Lee

Profile

2001-Present	Chairman, Gartner Lee Limited
1992	Vice-President - Gartner Lee Limited
1982-1992	Principal - Gartner Lee Limited
1981-1982	Associate - Gartner Lee Limited
1979-1981	Senior Hydrogeologist - Gartner Lee Limited
1979	Extension Course, Princeton University, Groundwater Pollution and Hydrology
1978	M.Eng.Sc. - University of New South Wales - Australia
1974	Certificate in Engineering Hydrology and Groundwater Hydrology - University of New South Wales - Australia
1970-1979	Hydrogeologist - Geological Survey of Western Australia
1966-1970	B.Sc. (Honours) - Geology and Chemistry - University of Aston, Birmingham, U.K.

Experience

Bob Leech has worked as a hydrogeologist in Australia, Europe and North America. He has a Bachelor of Science degree from the University of Birmingham, U.K. (1970) and a Master of Engineering Science degree from the University of New South Wales, Australia (1978).

Through his career, Mr. Leech has managed many different scientific, engineering and geological projects. These include regional water resource evaluation projects in arid zones, detailed contaminant studies at small industrial sites and large nuclear and solid waste management undertakings. He has published numerous papers on varying topics, particularly pertaining to water resource investigations and radioactive waste management evaluations in fractured rock terrains.

Bob Leech has served his profession through various professional associations. He has been president of the Canadian Chapter of the International Association of Hydrogeologists, a member of the Geoscience Council of Canada, and a director of the Canadian Geotechnical Society and the Association of Geoscientists of Ontario. He has also served on a number of academic research and review committees. Bob is currently Chairman of Gartner Lee Limited.

Other Professional Activities

- Department of Indian and Northern Affairs, Giant Mine Review Panel Member - 2002
- National Research Council, Networks Review Committee - 1998
- Geological Survey of Canada, Hydrogeology Review Committee - 1997 to 2001
- Association of Geoscientists of Ontario - Director - 1996 to 1998
- Canadian Council for Professional Geoscientists - Director - 1996 to 2001
- Natural Science and Engineering Research Council of Canada, Research Network Committee - 1996-1998
- Natural Science and Engineering Research Council of Canada, Grant Selection Committee - 1994 to 1996
- Canadian Geotechnical Society - Chairman of Hydrogeology Division - 1994-1996
- Canadian Council for Human Resources in the Environmental Industry - Advisor - 1994
- International Association of Hydrogeologists - Science Advisory Board - Member - 1993 to 1996
- Professional Engineers of Ontario - Environmental Task Force - Member - 1993 to 1995
- Centennial College - Environmental Advisory Committee - Member - 1993 to present
- University of Waterloo - Scientific Industrial Advisory Committee - Member - 1992 to 1997
- Canadian Geoscience Council Task Force on Groundwater Research in Canada - Member - 1992 to 1993
- Canadian Committee for Professional Registration of Geoscientists - Member - 1990 to 1993
- Committee for the Professional Registration of Ontario Geoscientists - Vice Chairman - 1989 to 1996
- Government of Canada, Water 2020 - Contributor - 1988
- Canadian Geoscience Council - Member - 1987 to 1995
- Ontario Water Well Association - Technical Committee Member - 1986 to 1988
- International Association of Hydrogeologists - Canadian National Chapter - President - 1986 to 1995

NAME: M.A.J. (Fred) Matich

OCCUPATION: Consulting Engineer

BIRTH DATE: 1928

CITIZENSHIP: Canadian

EDUCATION:

1953 **M.S. (Applied Science, Geotechnical Engineering),**
Harvard University, Cambridge, Massachusetts, U.S.A.

1951 **B. Sc. (Mathematics)**
University of New Zealand, Auckland, N.Z.

1950 **B. Eng. (Hons. Civil, Geotechnical Engineering)**
University of New Zealand, Auckland, N.Z.

ASSOCIATIONS:

- Association of Professional Engineers of Ontario
- Canadian Geotechnical Society
- International Society for Soil Mechanics & Foundation Engineering
- Fellow, Engineering Institute of Canada
- Fellow, Canadian Academy of Engineering
- Member, Arbitration & Mediation Institute of Ontario

SPECIAL COMMITTEES:

- National Research Council, Associate Committee on Geotechnical Research. Chairman, Subcommittee on Marine Geotechnical Engineering, 1975 - 1982.
- Chairman, Soils and Material Technical Committee, Roads and Transportation Association of Canada, 1975 - 1976.
- Member of Canadian Government Transportation Delegation to The Peoples Republic of China, 1980.
- Member, Canadian Standards Association, Technical Committee on Foundations, Code for the Design, Construction and Installation of Fixed Offshore Structures.

ACADEMIC ACTIVITIES:

- Visiting Lecturer on topics in geotechnical engineering at a number of Canadian Universities.
- 1975 National Research Council of Canada, Cross-Canada Lecture in Geotechnical Engineering (for Western Canada).

AWARDS:

- Engineering Medal, Association of Professional Engineers of Ontario, 1978.
- Canadian Geotechnical Society, R.F. Legget Award, 1986.
- Engineering Institute of Canada, K.Y. Lo Medal, 1999/2000

PATENTS:

"Pervious Surround Method of Waste Disposal" (jointly with W.F. Tao).
Canadian Patent No. 1188525 and U.S. Patent No. 4580925

M.A.J. (Fred) Matich

SUMMARY OF EXPERIENCE **1951 - 1999**

1.0 ADMINISTRATIVE:

- **1953 - 1975:** Various positions rising to President and Director of Engineering, Geocon Ltd. (Geotechnical Consulting Division of a major construction Company, The Foundation Company of Canada Ltd.
- **1975 - 1990:** Senior Geotechnical Adviser, Lavalin Inc. (a major multi-disciplinary Canadian Consulting engineering organization).
- **1990 - date:** Own geotechnical engineering consulting practice, MAJM Corporation Ltd.

2.0 TECHNICAL:

Over 40 years of experience in consulting geotechnical engineering involving in excess of 5000 significant projects in various fields, including: civil engineering; heavy construction (foundations, dams and other earthworks, tunnels); thermal and hydroelectric generating facilities; industrial plants (soil, steel, cement, pulp and paper, chemical); mining (strip and underground mines); cold regions engineering; marine structures; road and rail transportation; construction control; condition evaluation of concrete dams and powerhouses; mine waste disposal and other environmentally-related projects.

3.0 PROJECT LOCATIONS:

Experience involved direct participation in projects across Canada and also in about twenty-five other countries including U.S.A.; Ghana; Nigeria; Algeria; Brazil; Argentina; Guatemala; Honduras; Denmark; Pakistan; Oman; Dominican Republic; St.Lucia, W.I.; Guyana; Hong Kong; Indonesia; New Caledonia; Australia; Malaysia; Azores Is.; Portugal; Turkey; Ireland; New Zealand; Chile; Peru; and Uruguay.

4.0 PEER REVIEW:

Member of Review Boards or Panels, or Review Consultant for numerous major projects including: major oil sand mining operations in Alberta (Syncrude Canada Ltd. and Suncor Inc.); Great Belt Road and Rail Crossing, Denmark (The Great Belt Link Ltd.); major tailings dam at Fort McMurray, Alberta (Dept. of Environment, Alberta); high earth dam in British Columbia (Kemess Mines Inc.); major tailings dams in Ontario (Inco Limited); rehabilitation of a high multiple-arch concrete dam in New Brunswick (Avenor Maritimes Inc.); evaluation of thermal power plant sites in Pakistan (Lavalin Inc.); two earth dams in Saskatchewan (Saskatchewan Power Corporation); two major hydro-electric developments in Argentina (Hidronor): foundations for newsprint mills in U.S.A. (Abitibi-Price Inc.); Central Waste Disposal Facility (Ontario Waste Management Corporation); Alyesaka Pipeline, Valdez to Prudhoe Bay, Alaska (U.S. Dept. of Interior); Geotechnical Department of Government Steel Organization (Societe Nationale de Siderurgie, Algeria); Barrick Gold Corp. on projects in Chile, Argentina, Peru, Canada and U.S.A.; Diavik Diamond Mines, Lac De Gras, N.W.T.; Thermal Power Plant in Ghana (Volta River Authority); P.T. Inco, Indonesia; Molycorp Inc., U.S.A., and others.

5.0 PUBLICATIONS AND PRESENTATIONS:

About 30 published technical papers or presentations on geotechnical engineering applications to a variety of major projects.

KENNETH G. RAVEN
Principal and Senior Hydrogeologist
INTERA ENGINEERING LTD.

Education:

- M.Sc., 1980, Hydrogeology, University of Waterloo
- B.A.Sc., 1975, Geotechnical Engineering, University of Toronto

Experience:

2002 -	Principal and Senior Hydrogeologist Intera Engineering Ltd
1997-2001	Manager of Canadian Operations, Duke Engineering & Services (Canada), Inc.
1995-1997	Principal and Senior Engineer, Intera Consultants Ltd.
1991-1995	Principal and Senior Engineer, Raven Beck Environmental Ltd.
1986-1991	Manager and Senior Hydrogeologist, Environmental Sciences Division, Intera Kenting/Intera Technologies Ltd.
1982-1986	Research Contaminant Hydrogeologist, National Hydrology Research Institute, Ottawa
1980-1982	Hydrogeologist, Atomic Energy of Canada Ltd.
1978-1980	M.Sc. student and Research Engineer, University of Waterloo
1975-1978	Field Geologist/Hydrogeologist, Geological Survey of Canada, Atomic Energy of Canada Ltd.

Selected Achievements:

- Author of over 30 scientific and technical papers in refereed journals and conference proceedings on hydrogeology and environmental assessment.
- Project Director for multi-disciplinary performance assessment of proposed low-level radioactive waste management facility at Deep River and Port Hope, Ontario for federal Ministerial Siting Task Force under the CEAA.
- Member, Subsurface Advisory Team to Environment Canada reviewing Atomic Energy of Canada Ltd. proposal for deep geologic disposal of radioactive waste.
- Member, Soils and Groundwater Work Group, Environmental Audit of the East Bayfront and Port Industrial Area. Royal Commission of the Future of the Toronto Waterfront.
- Member, Independent Peer Review Panel, Giant Mine Arsenic Remediation Project, Yellowknife, NWT.
- Advisor to Environment Canada on adequacy of proposed remedial action plans of U.S. hazardous waste sites near the Niagara River and St. Lawrence River, 1988-1998.
- Principal investigator and project co-ordinator for National Hydrology Research Institute studies on fluid flow and contaminant transport in fractured rocks in support of the Canadian Nuclear Fuel Waste Management Program, 1981-1986.
- Completion of environmental site assessments and remedial investigations at over 300 industrial properties including sites contaminated with heavy metals, petroleum hydrocarbons, coal tars, PCBs and chlorinated solvents.

Professional Affiliations:

- Professional Engineers Ontario
- American Chemical Society
- National Ground Water Association

Related Professional Experience:

- Project Manager for wellhead protection studies for communities of Almonte, Beachburg, Haley Station and Killaloe for Mississippi Valley Conservation Authority under MOE 2001/2002 Municipal Groundwater Studies program.
- MOE peer reviewer of GUDI hydrogeological studies completed for municipal groundwater supply systems at Léfaive, Val Harbour, Shelburne, Winchester, Chesterville and Mitchell, Ontario.

INTERA

- Project Manager for 3-year hydrogeological and hydrogeochemical study of groundwater mixing and origin at the Con Mine, Yellowknife, NWT for the Canadian Nuclear Safety Commission. .
- Coordinator and Chairman for hydrogeologic experts meetings, 2000 and 2001, reviewing management options for arsenic trioxide waste buried at Giant Mine, Yellowknife, NWT for Dept of Indian Affairs and Northern Development.
- Manager for standing offer agreements for environmental investigation and assessments for various government and private sector organizations (NCC, Canada Post, PWGSC, INAC, MTO, DCC, DND, etc.).
- Phase 1 and Phase 2 environmental site assessments for over 300 commercial, industrial and institutional property transactions.
- Hydrogeologic investigation of BTEX and PCE contamination of groundwater in fractured Ordovician limestone/dolostone aquifer at Manotick, Ontario for MOEE
- Hydrogeologic and remedial investigations of PCE, TCE and TCA contaminated overburden and bedrock sites in Eastern Ontario for MOE, PWGSC, Beckwith Twp. and private clients.
- Project Manager for in-situ chemical oxidation of TCE in sandy clay aquitard using permanganate injections.
- Project Manager for ex-situ bioremediation of 6000 tonnes of paint solvent contaminated soil, former Ottawa Paint Works.
- Scientific authority and special advisor for site characterization/remediation studies in Lebreton Flats, 1992 to 1995, for the National Capital Commission.
- Successful completion of SSRA/Risk Management reports for PAH and metal contaminated sites under the MOE guideline process.
- Screening-level environmental assessments for proposed cleanup projects for the National Capital Commission under the Canadian Environmental Assessment Act.
- Hydrogeologic characterization (well drilling, borehole geophysics, packer testing, tracer testing, pressure monitoring, groundwater sampling) and 3-D modeling (MODFLOW., MODPATH,) to define wellhead capture zones for Middleton Street Well Field in dolostone bedrock, Cambridge Ontario, for Regional Municipality of Waterloo.
- Hydrogeological review of proposed Snap Lake Diamond Mine Project, NWT for Indian and Northern Affairs Canada.
- Project manager for laboratory and 3D numerical modeling study (FRAC3DVS) of hydrogeologic performance of the in-pit disposal concept for disposal of uranium mine tailings in Saskatchewan for the Canadian Nuclear Safety Commission.
- Development of regional groundwater flow model and delineation of time-of-travel and steady state capture zones for 32 bedrock municipal water supply wells, Cambridge, ON. using 3-D groundwater flow and particle tracking methods (MODFLOW, MODPATH, PEST). This well head protection work was completed for the Regional Municipality of Waterloo, Ontario.
- Hydrogeologic and well head protection study of the Oxford, March and Nepean Formation bedrock aquifers, Connaught Ranges, near Shirleys Bay, Ottawa for Public Works Government Services Canada.
- Water resources study including 3D groundwater flow modeling (SWIFT II) of the bedrock aquifers, Kanata rural area, in support of City of Kanata official plan amendments concerning lot sizes.
- Field investigation and three-dimensional groundwater flow and transport modeling (SWIFT-II) assessment of environmental impact of past deep-well disposal operations at Sarnia, Ontario for Ontario Ministry of the Environment.
- Project Manager for partial cleanup, hydrogeologic study, and development of remedial plan of former gasoline service station, Kemptville for MOE.
- 3-D numerical/analytical modeling assessment of groundwater flow and radionuclide migration to the biosphere from a conceptual radioactive waste disposal facility in fractured rock for Environment Canada
- Project Director for multi-disciplinary performance assessment (SWIFT-II 3D groundwater flow and transport modeling) of proposed low-level radioactive waste management facility at Deep River and Port Hope, Ontario for Federal Ministerial Siting Task Force.

- Development, testing and application of hydraulic testing, tracer testing and groundwater sampling equipment and procedures for deep (to 800m) crystalline rocks. Work completed for Geological Survey of Canada, Environment Canada and Atomic Energy of Canada Ltd.
- Delivery of training seminars on use of groundwater tracers and hydrogeological issues and concerns related to rehabilitation of mine sites in Brazil for Natural Resources Canada/CANMET and Centro de Tecnologia Mineral (CETEM).
- Development of CIDA-sponsored practical guidance manual on hydrogeologic assessment practices for baselining purposes for use at mining sites in Argentina. Manual prepared for CANMET and presented in technology transfer seminar in Buenos Aires in September, 1998.
- Verification, calibration and validation of numerical models of groundwater flow (FEMWATER) and radionuclide transport (FEMWASTE) at the Nordic Mine tailings area, Elliot Lake, Ont for the Atomic Energy Control Board
- Prepared groundwater contribution to Canadian Water Resources Association/Canadian Society of Hydrological Sciences expert panel report on Hydrological Science Research in Canada: Gaps, Issues and Needs, 2000.
- Hydrogeologic characterization of the White Lake, Chalk River, and East Bull Lake Research Areas for Atomic Energy of Canada Ltd. under the Canadian Nuclear Fuel Waste Management Program.
- Development of Quality Plan for hydrogeochemical investigations of Rock Characterization Facility, Sellafield, England for UK NIREX.
- Design of deep bedrock groundwater monitoring well completions and sampling protocols for Ontario Hydro, Environment Canada, Atomic Energy of Canada Ltd., Ontario Ministry of the Environment, Regional Municipality of Waterloo, and several private sector clients including Co-op Atlantic.
- Project Manager for hydrogeological review, assessment of treatment options and performance of treatability studies for radium contaminated groundwater for United Arab Emirates, Ministry of Health and Dewan - Ruler's Representative, Eastern Province, UAE.
- Project Manager for field and office geological and hydrogeological studies completed for Ontario Hydro in support of Hydro's concept of disposal of radioactive waste in or below sedimentary rock sequences in Ontario.
- Scientific and technical advisor to Environment Canada on the Canadian concept for geological disposal of nuclear fuel wastes during the CEAA Panel review of the concept.
- Completion of several review studies for the Atomic Energy Control Board to support regulatory documents and assist the AECB in review of proposed geologic disposal facilities for radioactive waste.
- Critical review of operating and proposed disposal facilities for low- and intermediate-level radioactive wastes in England, Germany, Switzerland and Sweden for Ontario Hydro.
- Identification of hydrogeologic factors to be addressed in disposal guidelines for nuclear fuel wastes for the Atomic Energy Control Board.
- Peer review of environmental documentation for transfer of Ottawa and London airports to local airport authorities.
- Tool development and hydrogeologic testing (packer testing, groundwater sampling and pressure monitoring) of deep sedimentary rock formations in southern Ontario, for Ontario Hydro and New York States for United States Geological Survey.
- Investigation, evaluation of remedial options and cleanup of coal tar waste sites in Ottawa, Kingston, Peterborough, Napanee, Simcoe and Cornwall.
- Expert advice and litigation support to remedial action and cost recovery at fractured bedrock sites contaminated by petroleum hydrocarbons, near Boston, MA and at Fredericton and Saint John, New Brunswick.
- Hydrogeologic reviews of assessments and proposed remedial action plans for US hazardous waste sites located on fractured Lockport dolostone in Niagara Falls, NY for Environment Canada.
- Development of trigger mechanism and action plans for aqueous phase groundwater contamination at the Smithville, ON. PCB DNAPL site for the Phase IV Bedrock Remediation Program.
- Project manager for pilot study, development of terms of reference and completion of an historical land use inventory for Regional Municipality of Ottawa Carleton using ACCESS database.
- Project manager for mapping and assessment study of 177 former industrial sites for the City of Ottawa.
- Project manager and senior engineer for historical mapping, inventory and assessment of 86 coal tar waste sites in Ontario for Ontario Ministry of Environment.

- Organization of and presentation at over 35 public meetings to present results of contaminated site studies, well head protection studies, proposed cleanup plans and Official Plan Amendments.

APPENDIX B

SUMMARY OF IPRP FINDINGS FOLLOWING ITS REVIEW OF THE SEPTEMBER 2002 SRK DRAFT REPORT ENTITLED

ARSENIC TRIOXIDE MANAGEMENT ALTERNATIVES GIANT MINE

APPENDIX B

The following is a summary of the IPRP's findings and recommendations following its review of the SRK Final Draft Report dated September 2002 entitled *Arsenic Trioxide Management Alternatives – Giant Mine.*

B1 SD No. 1 - Structural Geology

i. The litho-structural domain characterization is based entirely on just surface mapping, as the underground structural information is of poor quality and has not been used. Therefore, the characterization misses the depth dimension, which can be very important due to the frequent occurrence of pervasive, open horizontal stress relief fractures.

ii. More work needs to be undertaken to assemble and integrate the underground structural information with the surface structural information to provide a 3-D representation of the geological mapping. Such data would provide an enhanced structural framework to support particular detailed designs and future alternative assessments.

iii. The structural geology information (i.e., lithostructural domains and ordered structural discontinuities) needs to be integrated and jointly assessed with hydrogeological information to determine if there are linkages between structural geology and groundwater flows and the nature and extent of the Mine dewatering drawdown cone.

iv. The issue of potential for seismic events to affect the long-term performance of the existing underground storage chambers and stopes and any future purpose – built deeper storage chambers needs to be addressed.

v. Notwithstanding the above comments, the structural characterization and associated inferences and conclusions are appropriate and consistent. The description of the structural geology provides an adequate framework for hydrogeological and geotechnical studies.

B2 SD No.2 - Hydrogeology

i. SD No. 2 summarizes the available hydrogeological information for the Giant Mine site and develops the conceptual and groundwater flow estimates for both the current (fully dewatered to 610 m depth) and various re-flood mine conditions. Many of the hydrogeological activities undertaken in 2001/2002 addressed specific recommendations from the Hydrogeology Experts Panel Meetings of 2000 and 2001.

ii. The IPRP agrees with the conceptual hydrogeological models and the flow estimates though source areas presented for both the current dewatered conditions and the re-flood scenarios. The IPRP believes, based on the existing data, that the conclusions drawn by SRK are reasonable.

iii. The IPRP agrees with the geochemical interpretation and the revised water balances that show most of the lateral groundwater inflow (1,100 m^3/day) occurs below a depth of 500 m, the volume of seepage from the Northwest Tailings Pond averages 400 m^3/day, and most of the seasonal mine inflow is vertical infiltration of precipitation over the mine footprint.

iv. More needs to be done to understand the detailed water balance within the mine. Several of the flow paths are long and breaking them into sections will allow more accurate definition of groundwater flow to various parts of the mine. Integration of the structural geology domains (defined in SD No. 1) into the hydrogeology would be an important step.

v. The SRK Draft Report identifies several of the remedial alternatives that require re-flooding of the mine to various levels. More evidence is required to support why these levels were selected and a description of the calculations made to determine how long the mine would take to reach the design re-flood level. As well, if the "Minimal Drawdown" capture system is used for the selected alternative, further investigation is required to confirm no contaminant flow at deeper levels in the mine occurs while achieving capture near the surface.

vi. More attention needs to be placed on defining the zone of capture created by the mine dewatering. In particular, it would be most interesting to understand the influence of the structural geological domains on the shape of the drawdown cone. This information could be critical to full assessment of remedial alternatives.

vii. It is recommended that monitoring of the existing well network continue. As well, monitoring of flows within the mine and of surface drainage should also continue.

viii. The hydrogeological understanding of groundwater flow around and within Giant Mine, while always subject to improvements with the collection of additional hydrogeological data, appear to be adequate to support the comparative evaluation of management alternatives for arsenic trioxide dust at Giant Mine. SRK have done a good job of hydrogeologically characterizing the Mine.

B3 SD No. 3 - Water Chemistry

i. SD No. 3 is a comprehensive summary and description of the underground water sampling programs that have been conducted at the Giant Mine over the past three years that appropriately reflect the recommendations made in 2000 and 2001 by the Hydrogeology Experts Panels. The geochemical and isotopic sampling and analyses provided in this work represent a comprehensive and site-wide data set that adds significantly to the overall understanding of the hydrogeology at the Giant Mine.

ii. An important reconnaissance-level survey of water flows and arsenic concentrations throughout the mine was performed in 2001/2002 to firm up the water and arsenic mass balance. This data set is now more complete and the water and mass balances are fully described and probably cannot be improved upon without significant additional effort. SRK have done a good job on partitioning flows in the mine and determining the associated arsenic loadings.

iii. Work over the past two years has been focused on more accurately partitioning the sources of arsenic leaching to the main sump. The new information confirms earlier results and provides a much better understanding of arsenic concentrations discharging from the backfilled tailings.

iv. Additional work should be done to refine the arsenic loading calculations by increased sampling at additional sampling points, in particular assessing the effects of old exploration boreholes;

v. The IPRP would like to see more work completed on the fate of arsenic in the natural groundwater environment of the site. If as suspected, arsenate precipitates under certain groundwater chemistry conditions, then a natural attenuation approach could potentially be considered as a method or a component of an alternative for remediation.

vi. Consideration should be given to partitioning the high concentration arsenic within the mine for pre-treatment. This could lead to efficiencies in the treatment process and could potentially save on treatment costs.

vii. The information database on water chemistry that has been developed over the past three years is adequate to support an evaluation of the management alternatives and will allow a balanced assessment in the selection of preferred alternatives.

B4 SD No. 4 - Geochemical Characterization of other Sources

i. SD No. 4 describes the 2001/2002 field sampling and laboratory testing program undertaken by SRK to characterize other potential arsenic sources found within the Giant Mine. The work evaluated the arsenic leaching potential of other mine arsenic sources, e.g., backfilled mill tailings (both combined flotation and leached roaster calcine tailings (brown) and flotation tailings (grey), waste rock, wall rock, track ballast, and track slimes.

ii. The sampling and testing program appears complete including, rinse tests, mineralogy and metal analyses, sulphur analyses, acid base accounting analyses, pore water extraction tests, leach extraction tests and sequential extraction tests.

iii. The summary of arsenic source concentrations given in Table 4.1 in SD No. 4 for mine re-flood scenarios reasonably reflect the site conditions. The results are consistent with the data from the seep-sampling program described in SD No. 3 and with data from the literature. The arsenic source concentrations for other sources have been well characterized and are significantly less (1.5 to 10 mg/L) than the source concentrations for the arsenic chambers (4,000 mg/L).

iv. Given the information provided in this supporting document, the conclusions drawn by SRK are reasonable and are supported by the data.

v. Additional laboratory testing to quantify the potential release of arsenic from iron oxy-hydroxides within backfilled tailings under flooded mine conditions would be valuable in providing a better understanding of this potential arsenic source. SRK advised the IPRP at a meeting held in Vancouver on October 25, 2002 that such testing is underway. The IPRP have not seen any results derived from such test work as of the date of the writing of this report.

vi. The IPRP recommends that future investigative work be directed at understanding the fate of arsenic migration in the natural groundwater environment under saturated conditions.

B5 SD No. 4B - Tailings Backfill

SD 4B provides a summary of the available historical information on tailings backfill use and placement within the Giant Mine as taken from historical mine records. The document provides useful background on understanding when and where mill tailings were used as underground backfill within the Giant Mine and contributes to providing an understanding of the contribution that these materials make as a source of soluble arsenic to the overall arsenic balance in the mine water both under current and potential flooded conditions.

B6 SD No. 5 - Arsenic Trioxide Dust Properties

i. This section relies virtually entirely for its understanding of the engineering properties of the arsenic trioxide on work carried out in 1981 directed primarily at recovering bulk samples of the arsenic in storage and preliminary assessment of recovery of the arsenic by airlift type methods.

ii. The context of these earlier studies was significantly different from the present evaluation of management alternatives. It envisaged extraction of only some of the arsenic trioxide for marketing purposes and not the vastly more demanding task of secure management of all of the stored arsenic for the long term.

iii. SRK has made best use of the available data in its efforts to assign preliminary geotechnical design properties to the arsenic trioxide. However, additional reference should also have been made to the logistical operations involved in the 1981 field investigation program, as discussed.

iv. A much better knowledge of the engineering properties (geotechnical and thermal) of the arsenic trioxide in storage is required, the scope of which would depend on the management alternative selected. The arsenic trioxide is unusual in a geotechnical sense and must be investigated by current state-of-the-art methods. The SRK Report must include detailed recommendations covering such additional work.

v. The current state of permafrost at the vaults and of the arsenic trioxide in storage, i.e. whether frozen or not; saturated or not, is also of fundamental importance.

B7 SD No. 6 - Human and Ecological Risk Assessment

i. The presumption by SENES to discount 100% of any arsenic exposure from fish in the overall risk assessment is certainly not cautionary. Given that fish were found, through the exposure pathways analysis, to be the dominant human exposure route for arsenic, total discounting of this route of arsenic exposure is difficult to defend. The Tier 2 risk assessment seeks to be more 'realistic' than the screening level Tier 1 risk assessment. Suitable qualifiers about the limited confidence that should be placed in the newer, preliminary findings on arsenic toxicology for MMA[III] (monomethylarsonous acid) and DMA[III] (dimethylarsenous acid) are appropriate.

ii. The Canadian drinking water guideline for arsenic that is used as a basis for comparing the cancer risk assessment predictions from the HHRA (Human Health

Risk Assessment) has remained as an Interim Maximum Acceptable Concentration (IMAC) since last evaluated in 1989. Arsenic is currently on the Health Canada priority list for review and update. There is a very real possibility that this number will be lowered in the future, given that it is now 2.5 times higher than both the U.S. and the World Health Organization drinking water criterion for arsenic. Because the distinct possibility of the Canadian guideline being lowered is eminently foreseeable, the HHRA discussion of the arsenic cancer risk comparison should acknowledge the possible lowering of the Canadian drinking water guideline and the impact that it would have on the comparison that was made to summarize and interpret cancer risk.

iii. The comparison of actual and predicted arsenic levels in sediments, which are largely attributed to historic arsenic releases, reveals widespread sediment levels that exceed most of the published quality criteria. This reality needs to be discussed more fully with a view to outlining what ecological impacts the legacy of these arsenic levels in sediment are having now and are expected to have in the future.

iv. The ERA (ecological risk assessment) of terrestrial receptors, mink and muskrat are identified as being adversely affected by arsenic for all discharge scenarios. The ERA notes that these receptors were assumed to be present on the downstream segment of Baker Creek for the entire year '*which may result in an overestimation of exposure for these two species*." This limited discussion of this adverse prediction is inadequate. Even though it will be a challenge, it is useful to summarize the ecological effects and interpret the significance.

v. The estimate for annual intake for traditional food needs to be re-calculated and suggestions were made about references sources and suitable approaches for this purpose. There is no evidence of any validation of the human receptors in terms of diet with corresponding negative impact on the credibility of the predictions.

vi. The choice of RfD (Health Canada reference dose) for the HHRA was taken as 2 µg/kg-d from Health Canada in preference to the U.S. EPA value of 0.3 µg/kg-d was made. Given the large difference between RfD values and the corresponding large difference the choice of RfD makes to determining if estimated exposures exceed the RfD, a defensible justification should be made for choosing the Health Canada RfD.

vii. The approach taken for the HHRA and ERA, which relies on a selected range of arsenic release rates, independent from the estimated arsenic release rates established for various arsenic trioxide management alternatives makes the HHRA and ERA stands somewhat independent of the quantitative process risk assessment (QPRA) for the various arsenic trioxide management alternatives.

viii. The conclusion that arsenic release rates should be limited to less than 2,450 kg/a is likely defensible, but SD6 does not offer a very robust defense of this choice.

ix. The conclusion about risks to some aquatic and terrestrial species from existing water and sediment levels in Baker Creek needs to be expanded, at least to the extent of suggesting how or if it might be possible to measure the current impacts that are being predicted.

x. The discussion about possible monitoring of urinary excretion of local residents in relation to their documented arsenic intake should be made as an explicit recommendation. This is one of the few tangible actions that can be taken to gather evidence and provide context relevant to future health effects assessment.

B8 SD No.7 - Re-assessment of Mining Methods

i. The preliminary evaluations of candidate mining methods with a focus on three, namely: Wet Borehole Mining; Underground Mining; and Open Pit Mining, are reasonable for this stage.

ii. A significant number of issues remain to be resolved in a more definitive manner. These include consideration of remote mining and other means of personnel protection; stability of bulkheads and pillars between stopes; specifics of backfilling of vaults; upgrading of mine facilities; risks of hanging wall or pillar collapse; and the like.

iii. The objective of 98% recovery of the arsenic trioxide (which has been assumed for assessment of environmental implications) must be considered critically in terms of the practicability of achieving it in practice from a mining perspective.

iv. The physical state of the arsenic trioxide in storage must be better understood in an engineering sense for ongoing development of mining plans.

v. Additional detailed geotechnical investigations are essential to the development of the mining and extraction tasks.

vi. In addition to precautions necessary for protection of personnel underground during working the stored arsenic trioxide, consideration must be given to possible risks from surface-related hazards, such as possible flooding.

B9 SD No. 8 - Water Treatment

i. The requirement to treat wastewater is a certain component for any and all of the arsenic trioxide management alternatives under consideration. Consequently SRK commissioned a study of water treatment options that are technically and economically viable for the removal of arsenic from the various wastewater streams that may result as a consequence of implementation of the various management alternatives under consideration.

ii. The five wastewater treatment options identified for dealing with the wide range of flow rates and arsenic concentrations expected are reasonable and appropriate for this study. The treatment options reviewed included: oxidation and direct precipitation; direct precipitation with lime; evaporation/crystallization; concentration followed by evaporation/crystallization; and concentration followed by direct precipitation with lime.

iii. The report provides an excellent comparison of estimated capital and operating costs for each treatment option over a range of flow rates and arsenic concentrations in the potential array of wastewater streams that may require treatment as a result of the management alternatives under consideration.

iv. The IPRP made the following recommendations: precedent for the use of the various treatment methods as applied elsewhere in the industry be studied along with incorporation of a discussion of the actual performance achieved; site specific test work be conducted on the expected waste water streams that will be produced at the Giant Mine under the management alternatives being considered; and the long term fate of the metal precipitates produced by the treatment methods be studied in some detail so that appropriate management techniques for the sludges produced can be designed.

B10 SD No. 9 - Ground Freezing

The draft report was well written from a general point of view. It addressed correctly and efficiently the main issues, gave sufficient background information, and provided conclusions and recommendations that are consistent with the contents of the report. The IPRP is of the view, however, that the option of ground freezing warrants a more comprehensive treatment even at this level of the study of alternatives. Furthermore, freezing in place has thus far emerged as one of the two most suitable management alternatives.

Some suggestions are made in the IPRP Progress Review report in respect to improvements in the way the material presented in the draft SRK report is organized. Insofar as the technical factors are concerned, the IPRP review covers not only matters given in the SRK Draft Report, but, more importantly, adds significantly to the Report in terms of theoretical and practical considerations and a new more robust 'frozen block' scheme. The main technical review comments are summarized as follows:

i. Additional data should be presented on cold regions related items including geotechnical investigations; patterns of occurrence of permafrost and evidence for its degradation; ground temperature measurements; and the like.

ii. A more comprehensive coverage should be given on the issues of monitoring of temperatures over the long term as a management tool, and the resources for timely action where required in response to the results of the monitoring. The estimated cost of the long term monitoring appears low and should be scrutinized.

iii. SRK's criterion for an acceptable frozen condition around the arsenic trioxide dust storage areas is related to the 0°C isotherm. For reasons discussed in the IPRP Progress review report, (such as pore fluid chemistry and rock fracture geometry), a minimum temperature of –2°C is considered more appropriate to provide a secure confinement to the arsenic trioxide dust.

iv. The field evidence is that the lower part of the arsenic trioxide dust in storage at some of the stopes and chambers is saturated. Thermal modelling must consider this condition and not be limited to the scenario where the arsenic trioxide is assumed to be dry throughout.

v. The 'frozen shell' alternative proposed by SRK should be enhanced by provisions given in the IPRP Progress Review report to produce a "New Alternative B2" which, for convenience of description, is termed analogous to a refrigerator.

vi. A concept not considered in the SRK Report, and which is described in Appendix A hereto as 'New Alternative B3', should also be evaluated. This concept is based on the use of combined active and passive freezing to create a solid 'frozen block' (including the surrounding host rock and rewetted arsenic trioxide dust), a 'freezer' analogy, so to speak.

vii. Circulation of cold winter air into the empty upper part of each stope or chamber should also be considered at least as a supplementary cooling aid, with dust protection measures, etc. as discussed.

viii. The merits of an initial demonstration project at one of the arsenic trioxide storage repositories, based on ground freezing, should be evaluated.

ix. The IPRP agrees that it is important to properly engineer the cover above the arsenic trioxide repositories for adequate protective performance over the long term. Although the necessity for limiting infiltration from Baker Creek has been recognized in principle, ways and means of achieving this effectively in practice should be presented.

B11 SD No. 10 - Assessment of Deep Disposal

The IPRP's preliminary assessment is that the understanding of the conceptual designs and deep hydrogeological conditions in Giant Mine appear to be adequate to support comparative evaluation of management alternatives for the arsenic trioxide dust. However, additional details would have been timely from both hydrogeological and mining perspectives. These include:

i. Design objectives are based on the assumption that it will be feasible to remove 98% of the arsenic trioxide. Even if it is borne out in practice that this degree of removal is achievable, the residual 2% of arsenic trioxide dust is still a large loading with important contamination and treatment implications, as described.

ii. No specific geotechnical investigations have been carried at a potential repository depth for deep disposal at the Mine. Only limited hydrogeological work has been performed for this purpose.

iii. Detailed assessments have not been developed and are required for the key components of dust transfer raise design; new storage chamber design; the mining program; disposal of mining debris; and long term environmental impact.

B12 SD No. 11 - Dust Preparation

SD 11 provides supporting data with respect to the settling and filtration characteristics of the Giant Mine arsenic trioxide rich baghouse dust material. The IPRP concurs that this initial laboratory work is adequate to provide the basic data on settling and filtration characteristics required to facilitate engineering assessment of the management alternatives at this level of project development. More detailed test work will be required to support design level engineering for any of the alternatives involving the settling and/or filtration of slurried arsenic trioxide dust.

B13 SD No. 12 - Arsenic Purification

i. SD 12 entitled 'Giant Mine – Assessment of a Process For Arsenic Trioxide Purification" presents the assessment of a process to recover purified arsenic trioxide from the Giant Mine baghouse dust, for sale to large-scale consumers of the material, typically manufacturers of wood preservatives.

ii. In 2002 the US EPA announced a voluntary agreement with the US based lumber companies that will see the industry phase out the use of arsenic based wood preservative agents (CCA – chromated copper arsenate) in the US market in 2003. This voluntary agreement effectively puts in question the future viability of a market for purified arsenic trioxide from any future upgrading facility at the Giant Mine. This action is likely to result in a glut of arsenic trioxide in the marketplace world-wide. The risk of proceeding under these market conditions, is, in the opinion of the IPRP, very high. The cost of constructing and operating an upgrading facility may not meet the project's objective if there is no market for the product produced. The net outcome could be that the upgraded product has to be subsequently re-processed and converted into a more stable form at a significant extra cost.

iii. The pyrometallurgical process alternative put forward by SRK has great appeal in that it provides an apparent way of removing the stored baghouse dust from the Yellowknife area while at the same time generating some offsetting revenue. However, the pending collapse of the US market for purified arsenic trioxide as the base for wood preservative agents is likely to be a major controlling factor relating to the future economic viability of producing and marketing any purified arsenic trioxide product produced by such a facility in Yellowknife.

iv. The selected upgrading flowsheet and associated cost estimate put forward by SRK made no provision or mention of the requirement for a cyanide detoxification step following the proposed cyanide leach circuit to extract gold from the residue left following arsenic trioxide purification. This needs to be added.

v. In the 1980's there was significant concern and opposition to the transportation of a purified arsenic product from the Giant Mine expressed by communities through which the product would pass, specifically Fort Providence and Enterprise in the Northwest Territories. This concern has not been identified or addressed in the SRK work.

vi. The WAROX process tested by the Giant Mine in the 1980's relied upon the use of sintered metal filter technology to recover a purified arsenic trioxide product from the baghouse dust. The process alternative put forward in the SRK work refers to the use of hot electrostatic precipitator combined with a cold baghouse unit in place of the sintered metal filter technology, which is a departure from the WAROX pilot program. This change would require testing to ensure that product quality objectives could be achieved and to determine operating and design parameters.

vii. The SRK work applies a value of \$500 per tonne for purified arsenic trioxide. It is suggested that a high and low price (\$500 to \$100) be used in evaluating economics to better reflect the uncertainty in future market price for purified arsenic trioxide. Similarly, the SRK work applies a gold price of \$270 US per ounce. t is suggested that a range of gold prices be applied (say \$300 to \$325) to deflect criticism that potential gold revenue has been underestimated to make this option appear less attractive economically, particularly considering the fluctuations in the price of gold at the time of writing of this report.

B14 SD No. 13 - Pressure Oxidation

i. SD 13 entitled 'Assessment of Pressure Oxidation Process For Arsenic Stabilization and Gold Recovery' presents the assessment of a process to recover gold from the Giant Mine baghouse dust, and to convert the arsenic into a stable chemical form. The process selected involves the oxidation and combination of arsenic and iron, at high temperature and high pressure, in an autoclave.

ii. While pressure oxidation has been widely used for the combination and conversion of arsenic into a stable ferric arsenate form at other gold mines around the world, to the best knowledge of the IPRP members, this process has not been used elsewhere to stablize arsenic contained in a baghouse dust similar to that being proposed at the Giant Mine. From a technical standpoint the chemistry is similar and thus the proposed approach should work. However, a program of test work including testing at a pilot plant scale should be considered if this alternative is selected for further consideration. The process flowsheet proposed involves combining baghouse dust with purchased pyrite concentrate transported to Yellowknife for this purpose. This flowsheet needs to be demonstrated through testing to ensure that no unforeseen complications arise and to develop suitable design and operating criteria.

iii. The flowsheet and cost estimate makes no provision or mention of the requirement for a cyanide detoxification step following the cyanide leach process. This needs to be added.

iv. The process flow diagram (Figure 1) needs to be amended to agree with the process description contained in Section 4 of SD 13, page 10. The flow diagram does not show the pressure filtration of the CIL circuit residue discussed in the text.

B15 SD No. 14 - Stabilization of Arsenic Trioxide Dust

i. This document provides support data on the leaching behaviour of arsenic from cement and bitumen stabilized materials and is based on a limited program of test work conducted by Lakefield Research.

ii. This cement stabilization test work indicates that the leachate from a landfill used to store cement stabilized arsenic trioxide baghouse dust will likely be at saturation concentrations for arsenic (5,600 mg/L). Consequently, integrity of the landfill liner is a key component of secure storage of this material. The questions raised by the IPRP include:

- What is the impact of leakage through the liner?
- How long will the liner under the landfill remain secure?
- How will the liner and concrete monolith perform under frost cracking and heaving conditions?
- How will leachate be collected under existing harsh climatic conditions?
- Can concrete stabilized material be placed into a landfill under winter conditions? Will it cure properly under winter conditions?
- Will arsenic release rates increase as a result of increased exposed surface area resulting from cracking of the concrete monolith?
- What can be done if the liner system is compromised at some point in the future?

The IPRP recommends that the above questions be addressed in moving forward on cement stabilization as a component of any management alternative.

iii. The bitumen stabilization tests show good results but little is known as to the technical viability of implementation. Given the encouraging stability results, would it not be worthwhile to conduct further trials of this stabilization technique? It is recognized that we know of no large-scale use of bitumen stabilization, however, it may be worthwhile conducting further investigations to better understand the technical and economic challenges associated with this option. For example, can bitumen stabilization be carried out under winter conditions? Can the stabilized material be transported and placed into the landfill before it sets up under winter conditions?

B16 SD No. 15 - Cement Stabilization

i. This document presents a proposed process facility to physically stabilize baghouse dust by encapsulating the material within a concrete monolith. Arsenic trioxide baghouse dust slurry from the underground extraction mining would be thickened, filtered, and mixed with Portland cement and local aggregate, transported to the waste containment facility for discharge and curing. The plant equipment is conventional. Environmental and occupational health concerns are manageable with appropriate design and implementation of protective measures.

ii. Concerns raised by the IPRP in its review include: (i) whether the process can be operated on a year round basis; (ii) how the cement stabilized dust would fare during winter freezing conditions: and (iii) the integrity of the long-term (permanent) storage and management of the cement stabilized dust.

iii. Additional testing, including piloting should be conducted to obtain better data on the performance of cement stabilized arsenic trioxide baghouse dust.

B17 SD No. 16 - Engineering Studies – Residue Disposal

i. IPRP made a number of significant recommendations on SD 16. These recommendations focused on site selection, secure landfill design components and the contaminating life span for the facility. These comments are outlined in Appendix A.

ii. The final SRK report incorporated several of the panel's recommendations, but also failed to address others. Specifically the final document acknowledged that site-specific site selection criteria would be required for a secure landfill alternative. Existing criteria used are based on BC regulations that are not appropriate for the Yellowknife area. The final document recognizes that both technical factors and public involvement will be required to develop site-specific criteria. One recommendation the SRK report failed to address was that of looking for alternative sites in the Yellowknife area, other than the Giant property. The reason the panel made this recommendation is that there may be local areas that provide more natural containment than is provided on the mine property. We believe that this recommendation is still valid.

iii. The final SRK report provided more details, at a conceptual level, on the design of a secure landfill thus addressing a concern raised by the panel in its review of the draft report. As well, SRK added some detail about the leachate quality expected from the various waste streams at such a facility. However, still a significant oversight is the lack of information, or approach to addressing the contaminating life span of the landfill. It is critical that the appropriate studies be carried out to address this issue if a secure landfill is considered further as a viable alternative. The report also addresses comments made by the Panel for more work on the frozen ground conditions of the tailing impoundments if they are selected for further study for this alternative.

iv. The final SRK report (page 106) indicated that a secure landfill must be built to accommodate the sludge wastes from the water treatment facilities, whether or not Alternative G1 or G2 is selected. The panel disagrees with this conclusion. Certainly if the ground freezing option is selected there will be viable opportunities for disposal of sludges below ground and thus reduce the needs for active surface waste management facilities to be operated in perpetuity. We strongly urge SRK and DIAND to consider this option for management of water treatment sludges over the long term.

B18 SD No. 17 - Estimates of Arsenic Release

i. SD No.17 estimates arsenic release for the existing surface sources at Giant Mine, and for each of the management alternatives. The SD describes the calculations of arsenic release and loading from surface sources, subsurface sources and from the water treatment plant under various arsenic trioxide management alternatives. This is an important section that integrates the results of many earlier SDs.

ii. Arsenic release for surface sources is calculated by multiplying the source area footprint by a runoff coefficient and the total precipitation to give the flow for each mine site component and then multiplying the resulting flows by source concentrations. The IPRP concurs with this approach as it is a reasonable and acceptable for the problem at hand.

iii. Estimates of arsenic releases from surface sources to underground workings are made by multiplying the vertical and lateral groundwater flows associated with each source (SD No. 2) by their corresponding arsenic concentrations (SD No. 3,No. 4 and No. 5). The arsenic releases are then added together to give the total arsenic released to the underground workings. The IPRP agrees with this approach.

iv. Simple calculations are made for groundwater flow and arsenic release from the new arsenic chambers to be constructed below 700 m., using increased arsenic source concentrations (5,600 to 9,600 mg/L) for the deeper chambers due to increased ground temperatures. The IPRP agrees with the calculations and the conclusion that the arsenic release would likely be around 100 kg/a.

v. Estimates of arsenic releases from underground sources are also made by multiplying the vertical and lateral groundwater flows associated with each source (SD No. 2) by their corresponding arsenic concentrations (SD No. 3, No. 4, and No. 5), with the modifications of increasing vertical flows through the arsenic chambers to account for flow funneling effects, and using the water balance for the Northwest Tailings Ponds to estimate seepage to underground workings. The IPRP agrees with this approach and believe the summary of source concentrations for unsaturated and saturated conditions are credible.

vi. It is assumed in the calculation of arsenic releases for all of the removal and ex-situ alternatives and also for deep disposal, that there are zero releases from the former chambers and stopes. For deep disposal, the engineering assumes 2% of the dust will remain. If 2% of the dust is left behind, the loadings will be much greater than the 490kg/a assumed to come from other residual sources. The arsenic releases and loadings calculated for the former chamber and stopes under ex-situ and deep disposal alternatives, seems underestimated in SD No. 17.

vii. There needs to be better documentation in SD No. 17 of the 10 to 20 year program of active flushing of the chambers, conveyed verbally by SRK in our discussions on this issue, to justify the assumption of zero releases from the chambers following removal of arsenic trioxide dust.

viii. SD No. 17 assumes that all remediation measures as described in the surface Abandonment and Restoration Plan submitted by Miramar Giant Mine Limited to the Water Board will be carried out. The assumption is also made that the remediation measures as set out in the A&R plan will be successful, and carried out on a time-line that works with whatever management alternative is chosen. There needs to be coordination of the A&R plan with the management alternatives, and discussion of scenarios or estimates if the A&R plan is not implemented as indicated.

ix. SD No. 17 should also discuss the possibility of arsenic release pathways other than via water movement and other than to Baker Creek. For example, there is no discussion of airborne arsenic release pathways which may be important under various alternatives based on removal of arsenic trioxide to ground surface for treatment, transport or disposal, and there is no discussion of releases directly to Back Bay and Great Slave Lake.

x. SD No. 17 is well organized and presented in a simple straightforward manner. The supporting calculation tables of arsenic release are clear and tractable. The loading calculations are easy to follow and are understandable. This is not intended to infer that the estimation of these release rates is a simple issue, in fact it is acknowledged that the calculation is quite complex.

xi. Notwithstanding the above comments, the estimates of arsenic release are based on a balanced approach that allows for comparative assessment of arsenic releases under different management alternatives. The IPRP supports the estimates of arsenic release presented in SD No. 17 for the purposes of the current level of assessment.

B19 SD No. 18 - Risk Assessment of Phase 2 Alternatives

i. SD No. 18 was designed to assess in semi-quantitative terms the comparative risks of the various management alternatives identified in Phase 2. This was done by considering risk to human or ecological receptors under 3 categories:

- short-term risk (release of sufficient arsenic to cause an adverse effect during the preparation or implementation phase of an alternative);
- long-term risk (release of sufficient arsenic to cause an adverse effect after complete implementation of the alternative, within a period of 500 years); and
- worker health and safety risks (safety and arsenic-related health risks faced by workers in the preparation, implementation and post-implementation activities)

ii. The insights provided by this exercise are reasonable and useful for the overall need of comparing alternatives. The items B2 and B3 have been recast to be Frozen Shell and Frozen Block respectively.

iii. The only substantive comment on this assessment is that the assessment of the handling options (C, D, F and G1) may be underestimating the worker health and safety risk by considering them to be moderate. More detailed consideration of these risks and of the corresponding risks of allowing airborne release of arsenic trioxide dust into the environment will be warranted if any of these alternatives are developed in greater detail. If the worker health and safety risks prove to warrant a 'moderate" risk rating this will need to be recognized as depending on a very high level of worker protection to keep the risks at this level.

B20 SD No. 19 - Cost Estimates

Detailed cost estimates of the various management alternatives were not included in the draft report reviewed by the IPRP. It was indicated that these cost estimates were being prepared while the IPRP carried out its review of the September 2002 Draft Report. Consequently the IPRP did not provide any review comment on the relative cost of the management alternatives at this phase in its work.