

**SOCIO-ECONOMIC ANALYSIS
OF THREE MANAGEMENT OPTIONS
TO REDUCE ATMOSPHERIC EMISSIONS
OF ARSENIC FROM GOLD ROASTING**

Submitted to:

Environment Canada

Prepared by:

**Resource Futures International
1 Nicholas Street, Suite 406
Ottawa, Ontario
K1N 7B7**

September 9, 1996

DISCLAIMER

The definition of a covenant contained within this report and all assumptions with respect to covenants, were made solely for the purposes of this study. The policy with respect to covenants is currently under development within Environment Canada. As such, both the definition and the assumptions are subject to change in the future.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	iii
1. INTRODUCTION.....	1
1.1. OBJECTIVE OF THIS STUDY.....	1
1.2. BACKGROUND	2
1.3. METHODOLOGY	4
1.4. ORGANIZATION OF THIS REPORT	5
2. HUMAN HEALTH AND ENVIRONMENTAL EFFECTS ARISING FROM CURRENT AMBIENT CONDITIONS	5
2.1. EXISTING HUMAN HEALTH EFFECTS	7
2.1.1. Inhalation effects.....	8
2.2. EXISTING ENVIRONMENTAL EFFECTS	10
3. HUMAN HEALTH AND ENVIRONMENTAL BENEFITS OF CONTROLLING AIR EMISSIONS OF ARSENIC	11
3.1. TECHNICAL CONTROL OPTIONS TO REDUCE ARSENIC EMISSIONS TO THE AIR ...	11
3.2. ESTIMATED HUMAN HEALTH BENEFITS OF REDUCED ARSENIC AIR EMISSIONS...	12
3.3. ESTIMATED ENVIRONMENTAL BENEFITS	14
3.4. REVIEW OF ASSUMPTIONS AND UNCERTAINTY RELATED TO THESE ESTIMATES.	15
4. OVERVIEW OF THE MANAGEMENT OPTIONS.....	16
4.1. REGULATED PERFORMANCE STANDARD.....	16
4.2. STRUCTURED VOLUNTARY AGREEMENT (SVA)	17
4.3. COMMUNITY COVENANT	18
4.4. LEGAL ISSUES WITH RESPECT TO THE DESIGN OF SVAS AND COVENANTS	18
4.5. COMPARISON OF OPTIONS	19
5. SOCIO-ECONOMIC ANALYSIS OF THE MANAGEMENT OPTIONS	20
5.1. EVALUATION CRITERIA	20
5.2. IMPACT ON EMISSIONS	21
5.3. IMPACT ON INDUSTRY	21
5.3.1. Technical control costs	21
5.3.2. Possible impact of costs on industry.....	22
5.3.2.1. Financial context (Royal Oak).....	22

5.3.2.2. Financial context (Giant Mine)	22
5.3.3. Summary of cost implications	27
5.3.4. Benefits to industry	27
5.3.5. Added impact of negotiated options.....	28
5.3.6. Summary of the likely financial impacts on industry.....	29
5.4. IMPACTS ON GOVERNMENT	30
5.4.1. Regulated performance standard	30
5.4.2. Structured Voluntary Agreement (SVA)	31
5.4.3. Community covenant	32
5.5. INDIRECT ECONOMIC IMPACTS	32
5.5.1. Yellowknife.....	32
5.5.2. Northwest Territories.....	37
5.5.3. Canada	38
5.5.4. Summary of indirect impacts.....	38
6. SUMMARY AND RECOMMENDATIONS.....	38
6.1. REGULATED PERFORMANCE STANDARD.....	39
6.2. STRUCTURED VOLUNTARY AGREEMENT	40
6.3. COMMUNITY COVENANT.....	41
6.4. RECOMMENDATIONS AND RATIONALE.....	43
REFERENCES.....	44
APPENDIX A:	49
APPENDIX B:	57
APPENDIX C:	62

Executive Summary

Introduction

In June of 1995, the House of Commons Standing Committee on Environment and Sustainable Development recommended that the Minister of Environment and the Minister of Health conclude their determination of the measures they planned to take with respect to arsenic, a substance deemed toxic under the *Canadian Environmental Protection Act (CEPA)*. While the recommendation itself is quite broad, the information preceding the recommendation appears to restrict it to arsenic releases in the Northwest Territories.

Currently, it is only atmospheric releases of arsenic in the Northwest Territories (NWT) which are not subject to any form of regulatory control, nor are they being addressed by any other federal or territorial regulatory initiatives. The sole anthropogenic source of arsenic releases to the air in the NWT is the gold roaster at the Royal Oak Giant Gold Mine in Yellowknife. Only one other gold roaster exists in Canada - the Golden Bear Mine in British Columbia - and it has been out of operation since 1994. As a result, the study "A Socio-economic Analysis of Three Management Options to Reduce Atmospheric Emissions of Arsenic from Gold Roasting" focuses exclusively on the Giant Mine in Yellowknife.

The study examined the following three potential management options:¹

- a regulated performance standard under the *Canadian Environmental Protection Act (CEPA)*;
- a "structured voluntary agreement" (SVA) between the federal government (ie. Environment Canada) and Royal Oak Mines, owner of the Giant Mine in Yellowknife; and

¹ The Task Force examined the full range of management options which could be used to address the issue. It was determined that these three management options were potentially the most cost-effective, efficient and feasible.

- a "covenant" between Royal Oak Mines and representatives of the communities of Yellowknife.

For the purposes of this study the three management options have been defined as follows. A regulated performance standard under CEPA would establish a legally enforceable maximum limit for atmospheric emissions of arsenic from the gold roasting process. The latter two options are examples of the range of negotiated agreements that could be applied in this situation. A structured voluntary agreement and a community covenant are defined as formal negotiated agreements which include clearly stated environmental goals and recommended approaches to achieve them, quantitative targets and explicit schedules. They have been defined specifically for the purposes of this study; the definitions are not intended to indicate that alternative versions are inappropriate. The SVA considered in the study would be between Royal Oak Mines and government, whereas the signatories to the covenant would be representatives of the communities of Yellowknife and Royal Oak Mines, with the federal government acting as a facilitator.

The study provides a socio-economic analysis of each of the three management options as they relate to controlling arsenic exclusively in air emissions. In addition, however, it explores how the two negotiated options could potentially be made more effective if expanded to address a wider range of issues related to the activities of the Giant Mine. Accordingly, the study identifies these additional issues but does not analyze them in detail.

Estimated benefits and costs of reducing atmospheric emissions of arsenic from the Giant Gold Mine

Current atmospheric emissions from the Mine are approximately 26 to 29 kg/day, at a concentration of 24 mg/m³. These emissions have affected, and will continue to affect, ambient levels of arsenic in air, water, soil and food. Due to data limitations, however, it is not possible to predict the magnitude of the impact of these emissions for any medium except air.

The average ambient concentrations of airborne arsenic measured in downtown Yellowknife over the period from 1991 to 1994, ranged from

0.006 to 0.015 $\mu\text{g}/\text{m}^3$, averaging 0.009 $\mu\text{g}/\text{m}^3$ (GNWT, 1993, 1994, 1995). This compares with an average annual concentration of 0.001 mg/m^3 measured in cities across the rest of Canada (Dann 1990), and a range of between 0.0086 and 0.22 mg/m^3 measured near industrial arsenic point sources in Canada. The highest daily concentration measured in Yellowknife during this period was 0.251 mg/m^3 in 1993, which is less than Ontario's ambient air quality standard of 0.3 mg/m^3 . According to the Government of the Northwest Territories (GNWT), this standard has only been exceeded twice since 1985, both instances occurring during pollution control malfunctions at Giant Mine.

The criteria established by the Federal Government's *Toxic Substances Management Policy* (TSMP) indicate that arsenic is a "Track 2 toxic substance" and should therefore be subjected to "full life-cycle management" to "prevent or minimize" its release into the environment (Government of Canada, 1995: p. 6). The *Priority Substances List Assessment Report on Arsenic and its Compounds* (Government of Canada, 1993), estimated a "potency"² for arsenic of between 7.83 and 50.0 $\mu\text{g}/\text{m}^3$. The "potency index"³ in Yellowknife is therefore between 1.14×10^{-3} and 1.8×10^{-4} . Based on these results, Health Canada criteria indicate that the priority for further action with respect to reducing overall arsenic exposure in the Yellowknife area is "moderate to high."⁴

Although some of the arsenic contributing to these ambient conditions may be attributable to natural sources (DIAND, 1995), the GNWT

² Health Canada (1994) defines "potency as the concentration or dose that induces a 5% increase in the incidence of tumors or heritable mutations considered to be associated with exposure.

³ A potency index is the ratio of exposure to potency.

⁴ According to Health Canada (1994), the priority for further action is high for EPIs of approximately 2.0×10^{-4} or greater, moderate for EPIs between 2.0×10^{-4} and 2.0×10^{-6} , and low for EPIs less than 2.0×10^{-6} . Alternatively, the priority is low when the estimated exposure is only a very small proportion of the concentration or dose that induces a 5% increase in tumors.

maintains that the Royal Oak Giant Mine is the most significant anthropogenic source of airborne arsenic in the Yellowknife region (GNWT, 1994).

A previous report (Hatch, 1996) identified four technical control options that would potentially reduce the atmospheric arsenic emissions from Giant Mine by 90 to 95%, (i.e. leaving less than 1.0 mg/m³ of arsenic in the emissions): a scrubber, a wet electrostatic precipitator (wet ESP), an alternative form of a wet ESP, and activated carbon. Dispersion modelling conducted by Environment Canada officials predicted that the resulting emission reductions would significantly lower ambient levels of atmospheric arsenic in the Yellowknife region.

Estimation of the overall potential benefits associated with these reductions is extremely difficult due to data limitations and prevailing scientific uncertainty about the behaviour of arsenic. Assuming a linear dose-response relationship, the existing ambient air levels are creating an increased cancer risk ranging between 9×10^{-6} and 5.74×10^{-5} over normal expected rates of cancer. Alternatively stated, if one million people were exposed to this range of airborne arsenic over an average 70 year lifetime, between 9 and 57 additional deaths due to lung cancer would probably be observed over what would otherwise occur. Assuming a population for Yellowknife of 15,175 (Statistics Canada 1993), this translates to between 0.14 and 0.86 additional deaths due to lung cancer attributable to exposure to airborne arsenic via inhalation over the 70 year life span of the exposed population⁵. By reducing ambient concentrations

⁵ It should be noted that there is a level of uncertainty in regards to these estimates. It is assumed that the current population has been exposed to levels of arsenic presently observed in air for an entire 70 year life span. In fact, concentrations in Yellowknife have been much higher in past years than they are at present. In addition, most of the non-aboriginal population currently living in and around Yellowknife did not grow up there, and many will not live in the region for the rest of their lives. For these people, their overall lifetime exposure to arsenic will likely be less than predicted. On the other hand, members of the Yellowknife Dene band are more likely to have been exposed to higher

to negligible levels, the proposed technical control options could reduce mortality due to lung cancer from inhalation of arsenic, saving between 0.14 and 0.86 lives over the 70 year lifespan of a population the size of Yellowknife's.

The present net value of this benefit ranges from \$50,000 to \$2 million, depending on the choice of discount rate and the assumed value of the health benefits (see Table E-1). For purposes of this study, we adopted the standard Environment Canada practice of a 7.5% discount rate, with sensitivity analyses at 5% and 10%. The estimates also rely on the range of values of a "statistical life" adopted by the Canadian Council of Ministers of the Environment (CCME) in its study on cleaner vehicles and fuels (Lang *et al.*, 1995).

Due to data limitations, these estimated benefits do not account for the health related benefits of reduced ingestion or of reduced sub-mortality effects, nor do they account for potential environmental benefits. Scientific evidence suggests that ingestion of arsenic at the ambient levels at which it is found in soil, water and food in the Yellowknife region could have adverse health effects. However, there is insufficient information to estimate the impact of reduced airborne emissions on these effects. Scientific evidence also suggests that the current ambient levels of arsenic in the region of the Giant Mine stack are probably adversely affecting small mammals, terrestrial plants and invertebrates. Again, however, there is insufficient information to predict the impact of reduced air emissions on these effects.⁶

historical concentrations of arsenic in air, water and food, and are also likely to remain in the region for a larger proportion of their lives. All other things being equal, this is likely to result in a greater risk of arsenic attributable impacts on members of this community.

⁶ For more information on potential effects from ingestion of arsenic and on the potential environmental effects in the region, see Appendix A to the study on which this report is based (RFI, 1996).

It should be noted that the calculated benefits based upon estimated cancer deaths carry with them all the uncertainties that are inherent in the estimation of the cancer risk. This may extend over orders of magnitude. Similarly, the resulting net value of the benefits is subject to the assumptions adopted in the economic analysis, which may have uncertainties associated with them. It is also important to understand that the monetary value for health benefit analysis is based upon an assessment of "willingness to pay to avoid premature death", and is not intended to represent the "value of a human life". The reader should note that considerable uncertainty surrounds estimates of health effects at the very low concentrations observed in Yellowknife air.

The costs to Royal Oak Giant Mine of reducing emissions by means of the four technical control options identified by Hatch (1996), could range from \$1.2 to \$2.2 million in capital investment and between \$168,000 and \$206,000 in annual operating costs, plus approximately \$180,000 per year in monitoring costs. The present net value of these costs ranges from \$3.5 to \$5.2 million, depending on the discount rate. The estimated annualized costs to the company are between \$550,000 to \$707,000 using a discount rate of 7.5%.

This range of annualized costs is less than 2% of the average annual operating costs of the Mine, and approximately 9% of the net cash flow from the Giant Mine to its owner, Royal Oak Mines.

Management options

The Task Force examined the full range of management options which could be used to address atmospheric emissions of arsenic from gold roasting. It was concluded that a regulated performance standard, a structured voluntary agreement (SVA) and a "covenant" were potentially the most cost-effective, efficient and feasible options to consider. The socio-economic analysis of the three management options applies four criteria:

- impacts on emissions;
- impacts on industry;

- impacts on government; and
- indirect economic impacts.

Since each of the three management options analyzed offers considerable flexibility in terms of how environmental performance objectives will be achieved, they are roughly comparable with respect to likely impacts on emissions and in terms of the costs they will impose on Royal Oak Giant Mine.

The costs to government of a regulation should be similar to the costs of a structured voluntary agreement (SVA) and a covenant. The cost of scientific, technical and economic analysis to support the development of these options will likely be equivalent, as will associated process and public information costs. The main difference between the two negotiated options and a regulation will likely be with respect to the negotiation and consultation costs and the enforcement costs. The costs associated with the negotiation process for an SVA and covenant would probably be higher than the consultation costs for a regulation, particularly if multiple jurisdictions are involved. On the other hand, since one of the main benefits of negotiated agreements is assumed to be increased industry "ownership" of the objectives, the enforcement costs would likely be lower than those for a regulation. Assuming that these two differences roughly cancel each other, the overall costs to government of the two negotiated agreements should be approximately equal to those of a regulation.

The indirect effects of the three management options are likely to be similar. Assuming that Giant Mine does not shut down in response to the proposed measures, the indirect effects should be minimal. Locally, the increased expenditures associated with upgrading the control technology could add a short term "pulse" of economic activity in the community. Over the long term, implementation of the measures could increase employment slightly. If Giant Mine does shut down, the indirect effects to the local economy would be significant in the short term since Giant Mine is the fifth largest employer in the region. However, Yellowknife's relatively robust economy, which is bolstered by a number of forthcoming

prospects, should facilitate a fairly rapid recovery. The regional and national impacts of either scenario are likely to be negligible.

Regulated Performance Standard

A regulated performance standard would specify a maximum limit for arsenic emissions from gold roasters, typically in terms of an emission rate (eg. volume or mass of emissions per hour or day), a loading (eg. in kilograms per year), or an emission concentration.

A regulated performance standard would offer three main advantages over the two negotiated options. First, it would provide certainty. Second, it would enhance government control over the final outcome. Third, the performance standard set forth in the regulation could potentially be applied to the development of additional regulatory and non-regulatory initiatives for arsenic.

The primary challenge with respect to a regulated performance standard, in light of the gaps in the scientific data, is demonstrating that the overall benefits of a proposed regulation will outweigh the costs. It should be noted that while this is an important consideration, it is never the sole determining factor governing the decision to regulate.

A second consideration with respect to this approach is that most parties - including Giant Mine officials, Environmental Non-Government Organizations (ENGOS), the aboriginal community and the local government - question whether airborne arsenic is a priority issue relative to other environmental issues involving the Mine.

Structured Voluntary Agreement (SVA)

Both negotiated agreement options (ie. the the structured voluntary agreement and the covenant) offer the potential to address other aspects of the Giant Mine's environmental performance rather than being restricted to atmospheric emissions of arsenic. The key issue with respect to these options is whether the relevant parties would willingly consent to enter into such an agreement.

For the purposes of this study, a structured voluntary agreement is defined as a formal negotiated agreement between industry and government which includes environmental goals and recommended approaches to achieve them, quantitative targets, and explicit schedules. It could be made legally binding and subject to the law related to contracts and to any relevant legislative provisions related to Environment Canada contracts.

Although the precise content of the SVA would depend on the negotiations, in this context an SVA could take one of two general forms: a negotiated agreement between Royal Oak Mines and the federal government focused on atmospheric emissions of arsenic only, or an agreement among Royal Oak Mines, the GNWT and the federal government, addressing a more complete set of Giant Mine's environmental issues. There may be few prospects for the first model, as Royal Oak Mines may not be willing to negotiate with respect to atmospheric emissions of arsenic alone.

Royal Oak and other parties might, however, be interested in an SVA that addresses a wider range of environmental issues. The main reasons for such interest relate to the opportunities that negotiations might provide to: i) avoid the creation of inconsistent regulatory requirements from different government agencies; ii) set priorities among the environmental issues related to Giant Mine and the communities; and iii) create some long-term certainty with respect to the environmental regime facing Giant Mine.

Two questions with respect to the parties' willingness to negotiate such an agreement are:

- Would these incentives be sufficient to induce Royal Oak Mines to include atmospheric emissions of arsenic in the negotiations?
- What are the prospects of inter-jurisdictional cooperation between levels of government with respect to such an approach?

The preliminary interviews conducted for the study suggest that the answer to both questions is positive. Although they did not indicate precisely which issues they would be willing to discuss, Giant Mine

officials suggested that they would be interested in negotiating a comprehensive package of the environmental issues they face. And while the GNWT is pursuing the promulgation of the regulation for sulphur dioxide (SO₂), it would be interested in exploring whether negotiations could help resolve other concerns such as the liability for the contaminated site upon closure of the Giant Mine.

An SVA would also have to address at least two additional questions in order to be effective in these circumstances. First, it would have to address concerns on the part of various parties about the need for effective enforcement powers. More analysis is required in order to determine whether the community would be satisfied with a non-regulated approach. Second, it would be important to ensure that community representatives trust the federal and territorial governments to negotiate on their behalf. Many of the local aboriginal groups and ENGOs have expressed concerns about the historic failure of the federal government to address adequately their concerns regarding the operations of the Giant Mine.

Community Covenant

For the purposes of this study, a covenant is defined as a negotiated agreement between Royal Oak Mines and representatives of the communities in the Yellowknife area. It would include clearly stated environmental goals and recommended approaches to achieve them, quantitative targets and explicit schedules. It could be structured to be legally binding or not. If it is intended to be legally binding, it would take the form of a contract, and would be enforceable under civil law by the parties to the agreement, but not by third parties or the federal government.

The preliminary interviews conducted for the study suggest that although some of the parties might be interested in negotiating a covenant, many have reservations about such an approach. The local ENGOs and the Yellowknives Dene First Nation have expressed an interest in addressing a wider range of issues with respect to the past and present operations of the Giant Mine, issues which could not be included in a regulation that

addressed atmospheric releases of arsenic from gold roasters. A covenant might provide the opportunity for negotiation of such issues, and also for opening up lines of communication and restoring trust.

On the other hand, there appear to be few incentives for Royal Oak Mines to enter into such an agreement. A covenant could potentially benefit the company by addressing atmospheric arsenic emissions and other issues relevant to the Mine's operation in an integrated manner. The main incentive, however, would likely come from the credible threat of federal government intervention to limit arsenic in emissions from gold roasting, in the absence of an agreement.

Conclusions

The federal government has two options - it can focus exclusively on atmospheric emissions of arsenic, or it can attempt to be a catalyst to ensure that a broader range of environmental issues related to the operation of the Royal Oak Giant Mine are addressed.

If a decision is made to focus solely on atmospheric emissions of arsenic from gold roasters, the government should do so by means of a regulation. There do not appear, at this point in time, to be any considerations that would induce Royal Oak Mines to negotiate an agreement focused exclusively on atmospheric arsenic emissions, with either the community or the government.

If the government is willing to expand the focus of this initiative beyond atmospheric emissions of arsenic, it should consider a structured voluntary agreement with Royal Oak Mines. The benefits to the company of addressing other environmental issues relevant to the Giant Mine's operations, in an integrated manner, might induce it to add atmospheric emissions of arsenic to those matters to be negotiated in reaching an agreement. This option raises several issues which the study did not analyze thoroughly, but which should be reviewed more fully before committing to this option.

Table E-1: Comparison of Costs and Benefits

PRESENT NET VALUE OF COSTS							
		Capital	Operating	Monitoring	PNV	Total PNV**	Annualized cost
		Cost	Costs	costs*	Operating		(10 years)
10% discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,322,646	\$3,503,646	\$570,202
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,138,309	\$4,154,309	\$676,095
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,144,454	\$4,188,454	\$681,652
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,371,803	\$4,577,803	\$745,016
7.5% Discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,594,623	\$3,775,623	\$550,055
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,388,700	\$4,404,700	\$641,703
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,395,564	\$4,439,564	\$646,782
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,649,535	\$4,855,535	\$707,383
5% Discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,918,816	\$4,099,816	\$530,945
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,687,164	\$4,703,164	\$609,081
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,694,885	\$4,738,885	\$613,707
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,980,590	\$5,186,590	\$671,687
* Assumes monthly tests costing \$15,000 each							
** Assumes PNV is calculated over 10 years							
PRESENT NET VALUE OF HEALTH BENEFITS OF REDUCED LUNG CANCER MORTALITY							
	Dollars per fatal cancer case*	Estimated avoided lung cancer mortality**	Value of lung cancer mortality	Annual value***	PNV (5% discount)	PNV (7.5% discount)	PNV (10% discount)
Low	\$2,500,000	0.14	\$350,000	\$5,000	\$96,713	\$86,245	\$49,937
		0.86	\$2,150,000	\$30,714	\$594,096	\$408,932	\$306,754
Central	\$4,200,000	0.14	\$588,000	\$8,400	\$162,478	\$111,291	\$83,894
		0.86	\$3,612,000	\$51,600	\$998,082	\$683,645	\$515,347
High	\$8,300,000	0.14	\$1,162,000	\$16,600	\$321,088	\$219,932	\$165,790
		0.86	\$7,138,000	\$101,971	\$1,972,400	\$1,351,013	\$1,018,423
* From Lang et al, 1995							
** From Section 3.2.2							
*** Assuming mortality may occur anywhere during an average 70 year lifespan							

1. Introduction

1.1. Objective of this study

This report has been prepared to provide information to a federal government Task Force, established to respond to the determination by the Ministers of Environment and Health that arsenic is a "toxic" substance under the *Canadian Environmental Protection Act (CEPA)*, and that atmospheric emissions of arsenic from gold roasting in the NWT are not adequately addressed.

Currently, the Royal Oak Giant Gold Mine in Yellowknife, NWT is the only gold mine in Canada roasting ore and thereby emitting arsenic to the atmosphere. This study provides a socio-economic analysis of three proposed management options to control these emissions:

- a regulated performance standard under *CEPA*;
- a structured voluntary agreement (SVA) between the federal government and Royal Oak Mines, the owner of the Giant Mine; and
- a "covenant" between Royal Oak Mines and representatives of the communities of Yellowknife.⁷

For the purposes of this study, the three management options have been defined as follows. A regulated performance standard under *CEPA* would establish a legally enforceable maximum limit for atmospheric emissions of arsenic from the gold roasting process. The latter two options are examples of the range of negotiated agreements that could be applied in this situation. A structured voluntary agreement and a community covenant are defined as formal negotiated agreements which include clearly stated environmental goals and recommended approaches to

⁷ The Task Force examined the full range of management options that could be used to address the issue. It was determined that these three management options were potentially the most cost-effective, efficient and feasible.

achieve them, quantitative targets, and explicit schedules. They have been defined specifically for the purposes of this study; the definitions are not intended to indicate that alternative versions are inappropriate. The SVA considered in this study would be between Royal Oak Mines and government, whereas the signatories to the covenant would be representatives of the communities of Yellowknife and Royal Oak Mines, with the federal government acting as a facilitator. These management options are more fully discussed in Section 4 of the report.

The study's main focus is on estimating the costs and benefits of controlling arsenic, exclusively in air emissions, by means of each of the proposed management options. In addition, however, it explores how the two negotiated options could potentially be made more effective if they were expanded to address a wider range of issues related to the activities of the Giant Mine. Accordingly, the study identifies these additional issues but it does not analyse them in detail.

1.2. Background

Arsenic is a naturally occurring element found most often in compounds with sulphur, either alone or in combination with various metals. It enters the environment from natural sources and from human activities including metal processing, the use of arsenical pesticides, operation of coal-fired power generation plants and the disposal of domestic and industrial waste material.

In 1994, the federal government concluded that arsenic and its inorganic compounds were "toxic" under section 11 of the *Canadian Environmental Protection Act* (CEPA). The criteria established in the federal government's *Toxic Substance Management Policy* (TSMP), indicate that arsenic is a "Track 2" substance, and should be managed throughout its lifecycle to prevent or minimize releases to the environment.

In 1995, the House of Commons Standing Committee on Environment and Sustainable Development released its review of CEPA entitled, *Its About Our Health! Towards Pollution Prevention*. Responding to concerns aired at a series of meetings in Yellowknife during the Committee's

hearings in the spring of 1995, Recommendation No. 107 of that report urged the Minister of the Environment and the Minister of Health "to conclude their determination of the measures they plan to apply to arsenic by December 1995."

In response to this recommendation, Environment Canada assembled a Task Force in August, 1995. The mandate of the Task Force was to review the current status of arsenic releases in the NWT and to investigate management options which could potentially be applied to this issue if it was determined that current management practices were inadequate. The Task Force concluded that releases of arsenic to water from all anthropogenic sources in the NWT are adequately managed by existing regulations, pending the results of the AQUAMIN programme, but that arsenic releases to air are not managed by existing regulations or by any other regulatory or non-regulatory initiatives. The only anthropogenic source of arsenic releases to the air in the NWT is the gold roaster at Royal Oak's Giant Mine in Yellowknife.⁸ Accordingly, it is the focus of this study.

The environmental regulatory regime applicable to Giant Mine is quite complex. The Mine is now subject to regulation by the GNWT (surface land use), DIAND (which regulates water use and waste disposal through the Water License issued under the *Northwest Territories Waters Act*) and Environment Canada (the *Fisheries Act* and the *Canadian Environmental Protection Act*). There is good reason to believe that this regime will become increasingly complex in the future. The GNWT has announced its intention to control sulphur dioxide emissions through a new regulation, and the Water Board may decide to address issues related to the underground storage of arsenic trioxide from baghouse dust when the Mine's Water License comes up for renewal. Also, since

⁸ Other Canadian mines which have employed a gold roasting process have either suspended operations (i.e. Golden Bear) or decommissioned their roasting operations (e.g. Campbell Red Lake Mines and Dickenson Mines). We are not aware of any plans for new mines in Canada which will use this process.

several different owners have operated the Mine over the last 40 years, there are difficult questions with respect to assigning liability for existing unremediated contamination of the surrounding environment.

The Mine is also the subject of considerable local attention. It is the fifth largest employer in Yellowknife, and recently was the center of a protracted and violent labour strike that gained international attention. Local aboriginal residents have several long-standing grievances against the Mine. The local Yellowknives Dene First Nation has expressed concern over the human health effects related to the consumption of food and water, and the inhalation of air containing elevated levels of contaminants, including arsenic. A number of aboriginal spokespersons made presentations to the Standing Committee in 1995 about the failure of the government and successive Mine owners to respond to their historic concerns about the human health and environmental effects of the Mine's operation.

Although this study is able to address only a narrow aspect of the overall environmental and human health issues related to the Giant Mine, it does emphasize the potential importance of accounting for the "bigger picture" when determining what action or management option may be appropriate.

1.3. Methodology

The report draws mainly upon existing, publicly available information, although it is supplemented by interviews with selected parties living in the Yellowknife area. We conducted data collection and interviews for the study both from Ottawa and from Yellowknife between May 15th and June 30th, 1996. We relied heavily upon government officials with the GNWT, DIAND and Environment Canada for information on loadings of arsenic to the environment and ambient conditions in various media. For estimating the relative health risk associated with arsenic exposure, we drew upon information in the *PSL Assessment Report for Arsenic* (Government of Canada, 1993) and on *Canadian Environmental Protection Act: Human Health Risk Assessment for Priority Substances* (Health Canada, 1994). In addition, we commissioned GlobalTox, a toxicological consulting firm, to review our health assessment section to ensure that calculations were

properly applied and that assumptions were properly communicated. Finally, our analysis of the three management options draws on our previous analysis of such options and, in particular, on our previous work on negotiated agreements.

1.4. Organization of this report

The study is structured as follows:

- Section 2 estimates the human health and environmental effects resulting from current emissions of arsenic from Giant Mine;
- Section 3 estimates the impacts on human health and the environment of reducing current emissions of arsenic to the air from Giant Mine;
- Section 4 describes the three proposed management options;
- Section 5 presents the socio-economic analysis of the three management options; and
- Section 6 concludes with a discussion of the relative merits of each of the three management options, both with respect to reducing emissions of arsenic to the air and with respect to their capacity to address the broader set of issues faced by Giant Mine and the communities of Yellowknife.

2. Human Health and Environmental Effects Arising from Current Ambient Conditions

This study presents a socio-economic analysis of the costs and benefits of three proposed management options to reduce emissions of arsenic to the air from Giant Mine. Ideally, this analysis would have been based on a study of the impacts on human health and the environment of reducing those emissions. However, such an analysis had not been completed prior to undertaking this study. Within the time and financial constraints established by the terms of reference (Appendix C), we collected the information needed to estimate the environmental and human health effects upon which benefits could be calculated. Given these constraints, we emphasize that these estimates are likely based on incomplete

information. This section, together with Appendix A, summarizes the results of our review and provides the basis for our estimates of the potential benefits of reduced emissions of arsenic to air.

Emissions to air are one of many sources of arsenic released into the environment. Some of these are natural and some are the result of human activities. Natural sources are geological in origin. The Yellowknife region is underlain by mineral formations containing arsenic and associated metals such as copper, zinc, lead and nickel. Weathering of the bedrock contributes to elevated levels of arsenic in the environment (primarily the aquatic environment) (DIAND, 1995). The roasting of arsenic-containing gold ore is the most significant anthropogenic source of arsenic releases in the Yellowknife region. These sources have contributed past and present loadings to the environment via air, water and solid waste.

Human health and environmental effects arise when people and organisms are exposed to elevated ambient concentrations of arsenic. Therefore, to estimate human health and environmental effects we need to know not only the ambient conditions, but also, the ways in which humans and other organisms respond when exposed to these ambient concentrations. In this case, we also need to know the contribution of air emissions to these ambient conditions. Understanding this link demands information on: 1) the relative contribution and species of arsenic from existing sources; 2) the distribution and partitioning of these emissions among media; 3) remobilization of past arsenic emissions; and 4) movement and bioaccumulation of arsenic in the food web.

Unfortunately, there is limited scientific information available on these issues. In particular, there is little information available to help us predict how changes to air emissions from the Giant Mine's ore roaster might affect ambient conditions in water, food or soil. Even effects on ambient air are not completely understood because we do not know what impact resuspended arsenic might have on ambient concentrations.

In the face of this uncertainty, we restricted our analysis of current environmental and health effects to airborne arsenic only. For the same

reason, our analysis of the effects and benefits of applying technical control options to reduce atmospheric emissions (see Section 3) focuses exclusively on airborne arsenic. Evidence exists in the literature to suggest that exposure to arsenic, via ingestion, may lead to cancer under certain conditions. However, because we lacked information on average arsenic concentrations in food, water and soil in the Yellowknife region, and on the link between roaster stack emissions and these arsenic concentrations, we were unable to include these impacts in our calculations. We return to a fuller discussion of the assumptions and uncertainties underlying our results in Section 3.4.

Appendix A summarizes the available information on air and water loadings from the Giant Mine and ambient arsenic concentrations in Yellowknife. In the remainder of Section 2, we estimate the existing health and environmental effects resulting from current ambient levels of airborne arsenic in the Yellowknife region.

2.1. Existing human health effects

This section presents estimates of the human health effects arising from the current ambient airborne arsenic in the Yellowknife environment. In the late 1970's, the Canadian Public Health Association coordinated a study of the health impacts of arsenic in the Yellowknife area (CPHA, 1977). Although we relied on the findings of that study to review our work, we based our analysis of current effects (and therefore of the potential benefits of reducing emissions) on ambient air quality monitoring data collected in downtown Yellowknife, on an ongoing basis, by the GNWT Department of Renewable Resources.⁹

Between 1991 and 1994, average annual atmospheric concentrations of arsenic ranged from between 0.006 - 0.015 mg/m³. The average of the four annual mean concentrations over this period was 0.009 mg/m³. This

⁹ Although a station has also recently been established in N'Dilo, results from samples collected at this site were not yet available in June, 1996 when we completed the data collection for this study.

compares with an average annual atmospheric concentration of 0.001 mg/m^3 measured in cities throughout the rest of Canada (Dann 1990), and a range of between 0.0086 and 0.22 mg/m^3 measured near industrial arsenic point sources in Canada. The highest daily measurement during this period was 0.251 mg/m^3 in 1993, which is less than Ontario's ambient standard of 0.3 mg/m^3 . According to the GNWT, this standard has only been exceeded twice since 1985, both instances occurring during pollution control malfunctions at Giant Mine.

The Priority Substance List (PSL) assessment for arsenic is silent on the synergistic effect of exposure via more than one route, or the effect of exposure to other chemicals along with arsenic. Thus, we cannot comment on the overall effect of total arsenic exposure, or on the relative contribution of inhalation to overall arsenic-related health effects. We must, therefore, evaluate the health effects of each exposure route independently, treating each route as if it were the only source of arsenic exposure.

Although the PSL assessment report concluded that arsenic is carcinogenic by two routes of exposure in humans, inhalation and ingestion, we include only inhalation in our estimate of human health effects for reasons discussed earlier in this report.¹⁰

2.1.1. Inhalation effects

The *Priority Substances List Assessment Report for Arsenic and its Compounds* (Government of Canada, 1993) reviewed the scientific literature and estimated the respiratory cancer potency for inhaled arsenic to be between 7.83 and 50.5 mg/m^3 . Health Canada (1994) defines potency as the concentration or dose that induces a 5% increase in the

¹⁰ We include an estimate of the current health effects associated with ingestion of drinking water in Appendix A, but we were unable to include this in our analysis of health benefits because we could not estimate the current contribution of roaster stack emissions to drinking water concentrations.

incidence of tumours or heritable mutations considered to be associated with exposure.

Comparing the average ambient arsenic concentrations measured in Yellowknife between 1991 and 1995 (0.009 mg/m^3) to this potency, the exposure/potency index for arsenic in Yellowknife ranges from 1.14×10^{-3} to 1.8×10^{-4} . Based on these results, Environment Canada/Health Canada criteria for further action suggest the priority with respect to reducing *overall* arsenic exposure in the Yellowknife area is moderate to high.¹¹

Health Canada does not convert the potency of a substance to an increased probability of tumours or mutations at low ambient concentrations because uncertainties become very large at the low end of the dose-response curve. We found it necessary to make this conversion and incorporated these estimates into our economic calculations. In doing so, we have assumed that the relationship between dose and response, as measured by the potency, is linear at doses below those used to calculate the potency. It is important to emphasize the large uncertainties surrounding these estimates of cancer risk at low concentrations.

Assuming a linear dose-response relationship, we calculate an increased cancer risk ranging between 9×10^{-6} and 5.74×10^{-5} . In other words, if one million people were exposed to this range of airborne arsenic over an average 70 year lifetime, between 9 and 57 additional deaths, due to lung cancer, would probably be observed over what would otherwise occur. Since the population of Yellowknife is less than one million, this risk must be reduced proportionately. Assuming a population for Yellowknife of 15,175 (Statistics Canada 1993), this translates to between 0.14 and 0.86 additional deaths due to lung cancer attributable

¹¹ According to Health Canada (1994), the priority for further action is high for EPIs of approximately 2.0×10^{-4} or greater, moderate for EPIs between 2.0×10^{-4} and 2.0×10^{-6} , and low for EPIs less than 2.0×10^{-6} . Put differently, the priority is low when the estimated exposure is only a very small proportion of the concentration or dose that induces a 5% increase in tumours.

to exposure to airborne arsenic, via inhalation, over the 70 year lifespan of the exposed population. Table 1 summarizes the potency, exposure/potency index and the risk associated with inhalation of arsenic.

Table 1: Summary of Estimated Potency and Risk Estimates

Medium	Potency*	Exposure-Potency Index	Probability of Increased Lung Cancer Mortality
Inhalation	7.83 - 50.5 mg/m ³	1.14×10^{-3} to 1.8×10^{-4}	9×10^{-6} and 5.74×10^{-5}

* Based on the *Priority Substances List Assessment Report for Arsenic and its Compounds* (Government of Canada, 1993)

2.2. Existing environmental effects

As with human health effects, environmental effects arise from exposure to arsenic via air, water, soil and food. Airborne arsenic emissions from the Giant Mine's roaster stack contribute to ambient concentrations in all four media. Unfortunately, we cannot predict the relative contribution of airborne arsenic emissions to ambient concentrations in each medium.¹² We do know, however, that airborne emissions from the Giant Mine represent the most significant source of ambient airborne arsenic (GNWT, 1994) and have focused our analysis accordingly.

Monitoring data exists for downtown Yellowknife only. For the purposes of this study, we also relied upon air dispersion models run by Environment Canada using existing stack and emission parameters to estimate maximum daily concentrations throughout the Yellowknife region. The model predicted hourly concentrations as high as 0.3 mg/m³ near the base of the stack (McDonald and Murtha 1996), decreasing to less than 0.02 mg/m³ at distances beyond 6 kms.

¹² In appendix A-4 we discuss some of the potential environmental effects that may arise from arsenic exposure via water and soil.

The PSL assessment developed two scenarios to determine whether environmental levels of arsenic are adversely affecting wildlife. One of these scenarios is analogous to the situation being investigated in this study. That scenario considered the effect of elevated airborne arsenic concentrations around two base metal smelters and concluded that airborne arsenic has the potential to cause harmful effects in small mammals at concentrations above 0.13 mg/m^3 .

Since this threshold is exceeded on certain days in the vicinity of the Giant Mine stack (McDonald and Murtha 1996), small mammals living close to the Mine may be experiencing harmful effects arising from airborne arsenic concentrations.

In summary, comparing the findings in the literature with modeled arsenic levels predicted in the air around the Giant Mine suggests that existing conditions may be adversely affecting some of the terrestrial organisms in the region. Unfortunately, we do not have sufficient information to estimate the magnitude and extent of this effect.

3. Human Health and Environmental Benefits of Controlling Emissions of Arsenic to the Air

3.1. Technical control options to reduce arsenic emissions to the air

A previous report (Hatch, 1996) identified four technical control options that could potentially reduce the atmospheric arsenic emissions from Giant Mine by 90% to 95% (i.e. leaving less than 1.0 mg/m^3 residual arsenic in the emissions): a scrubber, a wet electrostatic precipitator (wet ESP), an alternative form of a wet ESP, and activated carbon.¹³

¹³ Hatch (1996) also identified several non-arsenic emission producing alternatives to roasting, including pressure leaching using an autoclave. The Hatch study (1996) estimated capital costs for this option to be in the neighbourhood of \$23.6 million, but acknowledged that a thorough study of capital and operating costs would have to be carried out. Mine officials placed the capital costs closer to \$30 million. We did not

In order to estimate the impacts on human health and the environment of such reductions, we relied on the air dispersion modeling outlined previously (MacDonald and Murta, 1996). Environment Canada officials ran the model using three scenarios:

- 1) current emissions;
- 2) predicted emissions following modifications to Giant Mine's existing control technology; and
- 3) predicted emissions following installation of any of the four emission control technologies described previously.

The model results predict that the average annual ambient concentrations in downtown Yellowknife, after installation of any of the technical control options, should be approximately 0.00023 mg/m^3 . This is significantly lower than the average concentration observed in other cities throughout Canada (Dann 1990). These estimates, however, are subject to considerable uncertainty at these low concentrations. For the purposes of our benefits estimates, we assume that the resulting levels of airborne arsenic in downtown Yellowknife, after application of any of the technical control options, will be the same as levels observed in other city locations. In short, any one of the four technical control options would reduce the effect of Giant Mine stack emissions to negligible levels in downtown Yellowknife.

3.2. Estimated human health benefits of reduced arsenic in air emissions

In theory, the human health benefits of reduced air emissions equals the number of lethal and sub-lethal cancers avoided due to reduced exposure to inhaled and ingested arsenic. Due to data gaps, we cannot calculate the effect of reduced air emissions on ambient drinking water conditions. We are able to partially estimate the benefits due to reduced exposure via inhalation. The sub-lethal effects of arsenic in air are not adequately

include this option in the analysis due to the high capital costs involved.

understood at this time, therefore, it is possible to estimate only the benefits from reduced cancer deaths. Thus, the benefits estimates presented in this study should be considered to be a very conservative and not representative of the total possible benefits.

In Section 2.1.1, it was estimated that current ambient levels of arsenic in air are probably creating an added risk of between 0.14 and 0.86 deaths due to lung cancer over the 70 year lifespan of a population the size of Yellowknife's. Section 3.1 suggests that implementation of any one of the four technical control options identified by Hatch (1996) would reduce these ambient levels to normal background levels. Accordingly, implementation of any one of the technical control options could result in between 0.14 and 0.86 fewer deaths due to lung cancer over the 70 year lifespan of a population the size of Yellowknife's.

Strictly for purposes of facilitating a comparison of the costs and the benefits of reducing airborne arsenic in Yellowknife, the benefits of this reduced risk may be put into monetary terms.¹⁴ There is wide variation in the methodologies and the estimates that have been developed for such analyses. Based on a survey of studies, Viscusi (1992) concluded that the most appropriate range for the value of a "statistical life" was \$3 to \$8 million (1994 U.S. dollars). The study on cleaner vehicles and fuels (Lang *et al.*, 1995) for the Canadian Council of Ministers of the Environment (CCME) used a range based on many of the same studies. For purposes

¹⁴ This approach assumes that people are willing to pay to avoid the pain and suffering associated with illnesses. Some people object to any attempt to value illness (and human life) in monetary terms. The analysis in this report does not depend on this estimate. We present the numbers as a point of comparison and as a way of presenting as complete a picture as possible. Such numerical estimates have been made in many other contexts, including developing regulations for controlling ozone-depleting substances under CEPA (e.g. ABT Associates, 1989, 1993; Apogee Research, 1994), estimating the benefits of cleaner vehicles and fuels in Canada (e.g. Lang *et al.*, 1995) and assessing the effects of Clean Air Act Amendments for sulfate reductions in the United States (e.g. Chestnut, 1995).

of this analysis, we have used the monetary values cited in the CCME study.¹⁵ It is important to understand that the monetary value for health benefit analysis is based upon an assessment of "willingness to pay to prevent premature death", and is not intended to represent the actual "value of a human life".

Table 2 summarizes the range of benefits which vary depending on the assumed level of risk reduction, the discount rate applied and the monetary value assigned to health impacts. We have followed Environment Canada's practice of using a 7.5% discount rate with sensitivity analyses at 5% and 10%. These estimates suggest that the human health benefit (expressed as a present net value) of installing air emission control technologies and reducing lung cancer mortality due to inhalation of airborne arsenic would be between \$50,000 and \$2 million.

3.3. *Estimated environmental benefits*

Due to scientific data gaps, it is not possible to quantify the environmental benefits that might arise from reducing emissions of arsenic to the air from Giant Mine. If the proposed technical control options reduce air emissions to negligible levels, we can assume that these controls will prevent further increases in ambient soil and water levels due to atmospheric deposition from the Giant Mine roaster. In order to estimate the benefit of this impact, however, we need to know what impact the avoided emissions would have had on ambient levels. As noted previously, that information is not available because of inadequate information on how arsenic loadings into one medium affect concentrations in other media. We also have relatively little information on how arsenic moves and bioaccumulates in the food chain.

¹⁵ For comparison, recent studies relied on by the Government of Canada to estimate the benefits of controlling ozone-depleting substances used figures of \$10 million (1992 C\$) for the value of a statistical life and \$21,000 per incidence of melanoma (ABT Associates, 1993; Apogee Research, 1994).

Table 2: Summary of Health Benefits From Reduced Cancer Deaths Due to Inhalation

	Dollars per fatal cancer case*	Estimated avoided lung cancer mortality**	Value of lung cancer mortality	Annual value***	PNV (5% discount)	PNV (7.5% discount)	PNV (10% discount)
Low	\$2,500,000	0.14	\$350,000	\$5,000	\$96,713	\$66,245	\$49,937
		0.86	\$2,150,000	\$30,714	\$594,096	\$406,932	\$306,754
Central	\$4,200,000	0.14	\$588,000	\$8,400	\$162,478	\$111,291	\$83,894
		0.86	\$3,612,000	\$51,600	\$998,082	\$683,645	\$515,347
High	\$8,300,000	0.14	\$1,162,000	\$16,600	\$321,088	\$219,932	\$165,790
		0.86	\$7,138,000	\$101,971	\$1,972,400	\$1,351,013	\$1,018,423
* From Lang et al, 1995							
** From Section 3.2.2							
*** Assuming mortality may occur anywhere during an average 70 year lifespan							

3.4. Review of assumptions and uncertainty related to these estimates

It is important to emphasize the assumptions and uncertainty inherent in the benefits estimates presented above. They do not account for the health related benefits of reduced ingestion or of reduced sub-mortality effects. Nor do they account for potential environment-related benefits. The estimates further assume that the current population has been exposed to currently observed levels of arsenic in the atmosphere for an entire 70 year lifespan. In fact, concentrations in Yellowknife have been much higher in past years than they are at present. One must also consider that most of the non-aboriginal population currently living in and around Yellowknife did not grow up there, and many will not live in the region for the rest of their lives. For these people, their overall lifetime exposure to arsenic will likely be less than predicted in our estimates, and the probability of increased mortality would be reduced proportionally. On the other hand, members of the Yellowknives Dene First Nation are more likely to have been exposed to higher historical concentrations of arsenic in air, water and food, and are also likely to remain in the region for a larger proportion of their lives (Corriveau, 1996). All other things being equal, this should lead to a greater risk of arsenic-attributable impacts on members of this community. Unfortunately, insufficient demographic, health and/or exposure information exists to accurately estimate a disaggregated risk for the Yellowknives Dene population (Corriveau, 1996).

It is also important to acknowledge that we relied on a 70 year lifespan for our analysis despite the fact that the estimated life of Giant Mine is likely less than 70 years. Royal Oak officials observe that even if all of the mineralized material in the site could be mined economically, ore stocks would likely be depleted in about 23 years (Connell, 1996). However, Mine officials also acknowledge that ore located at other properties could potentially be transported to the Giant Mine site for processing. Based on all the information provided to us, we concluded that it would be very difficult to predict, with any precision, the remaining lifespan of the Mine. In addition, while our translation of the dose-response relationship to a

possible risk over a lifetime relies on relatively standard methods, it would be much more controversial to attempt to translate the numbers into a risk per year of exposure.

Finally, we have relied on a linear extrapolation from Health Canada's potency estimates and dose-response curve for arsenic to estimate the probability of mortality at very low ambient concentrations. The assumptions and uncertainties underlying these estimates are significant, and at present Health Canada generally does not make any estimates of mortality at these low doses (Hughes, 1996).

4. Overview of the Management Options

The three potential management options reviewed in this study are:

- a regulated performance standard under CEPA;
- a structured voluntary agreement between Environment Canada and Royal Oak Mines; and
- a covenant between Royal Oak Mines and the communities of Yellowknife.

The Task Force selected these three options for further analysis out of the larger set of possible management options that could be applied in this situation.

4.1. Regulated performance standard

Performance standards work like a speed limit. They generally specify the maximum emissions permitted from a given stack or plant. There are several ways in which performance standards can be framed. Relevant options in this case include the following:

- an emission rate (i.e. volume or mass of emissions per unit of time - ie. per hour or day);
- a loading (ie. total quantity of residuals over a longer interval of time - e.g. in kilograms per year); and

- emission concentration - usually adjusted to standard conditions (humidity, pressure and oxygen concentration).

More than one standard may be set for the same substance (e.g. a maximum release per 24 hour period and a maximum release per year). This may be designed to accommodate standard operating conditions as well as upset conditions when, for brief periods, larger releases may be permitted.

Although this analysis focuses on the one facility using the gold roasting process currently in operation in Canada, a regulation would be designed to apply more generally to all gold roasters in Canada. This would include those gold roasters which have suspended operations, should they become active once again, and also any potential new gold roasting operations. In theory, it would also be possible to apply the performance standard set forth in the regulation to the development of additional regulatory and non-regulatory initiatives related to arsenic. This study does not address this latter option as it was outside of the terms of reference.

4.2. Structured voluntary agreement (SVA)

For the purposes of this study, a structured voluntary agreement (SVA) is defined as a formal negotiated agreement between government and industry which includes environmental goals and recommended approaches to achieve them, quantitative targets and explicit schedules. Although the precise content of the SVA would depend on the negotiations, in this context an SVA could take one of two general forms: a negotiated agreement between Royal Oak Mines and the federal government, focused on atmospheric emissions of arsenic only; or an agreement among Royal Oak Mines, the GNWT and the federal government, addressing a more complete set of Giant Mine's environmental issues. If desired, it could be made legally binding and subject to the law related to contracts and to any relevant legislative provisions related to Environment Canada contracts. Within this context, the decision to enter into the agreement would be voluntary, however, the commitments set forth in the agreement would be binding.

4.3. Community covenant

For the purposes of this study, a community covenant is defined as a negotiated agreement between Royal Oak Mines and representatives of the communities of Yellowknife, with government acting as a facilitator. Again, the agreement would stipulate clearly stated environmental goals and recommended approaches to achieve them, quantitative targets and explicit schedules. It could also include a description of the context of the agreement, definitions of important terms and guiding principles, and outline the commitments of each signatory. Covenants could also be structured to be legally binding, if so desired. If it is intended to be legally binding, it would take the form of a contract and would be enforceable under civil law by the parties to the agreement, but not by third parties or the federal government.

4.4. Legal issues with respect to the design of SVAs and covenants

As stated previously, both the covenant and the SVA options could potentially be structured to be legally binding. If they are intended to be legally binding, both would have the status of a contract. This has several important implications. First, the federal government may be limited in terms of what promises it can make. For example, the government cannot enter into an agreement to waive or alter existing regulatory requirements. Additionally, the government can probably not provide an absolute commitment concerning future policy developments or future courses of action with respect to the implementation of laws and policies.

A contract also has implications for the federal government with respect to enforcement-related issues:

- in most cases, the parties to such agreements would only be able to sue for damages related to non-performance, and would have only a limited capacity to sue for injunctive relief or for "strict performance" (i.e. to compel the polluter to comply with the agreement and meet emission standards);

- without legislative amendments granting such authority, no specific penalty clause could be included;
- without a specific penalty clause, damages would have to be shown. This would be very difficult due to the lengthy time it takes for many environmental effects/damages to manifest themselves, of disaggregating possible intervening causes, and the prospect that many effects may occur in other jurisdictions; and
- third parties (e.g. the public and, in the case of the type of covenant contemplated in this study, the government) would not be able to sue for breach of such a contract.

Addressing these limitations could be difficult. For example, in order for the government to enter into a contract providing for an effective civil penalty scheme, legislative amendments would be required.

The concern about third party rights could be addressed either by adding them as parties to the agreement, or by including effective access to information and public reporting provisions in the agreement.

4.5. Comparison of options

Each of the three management options offers considerable flexibility in terms of its precise content. The final form of each option would depend in part on the resolution of the following issues:

- the precise level of emissions permitted;
- the basis for the standard (i.e. technology-based or risk-based);
- the timing of implementation;
- the monitoring protocol (i.e. end of stack; ambient; biomonitoring; health monitoring);
- the accountability process (i.e. which party is responsible for monitoring; how much self reporting is required; how much public access to information is provided for); and

- the enforcement process, including the type of sanctions available.

There are four main distinctions between the two negotiated options and the regulated performance standard:

- application* - a regulation would apply to all gold roasters in Canada, whereas the two negotiated agreements would be specific to the operations of Giant Mine;
- scope of issues* - both negotiated agreements can address issues that extend beyond emissions of arsenic to the atmosphere;
- flexibility* - the negotiated agreements could provide greater flexibility should either signatory wish to modify the terms of the agreement at some future date (this could be important, for example, in the case of sudden shifts in gold prices); and
- timing* - while there is not necessarily a difference among the options on this, presumably a negotiated agreement could give greater weight to Royal Oak's current investment plans.

The main difference between the two types of negotiated agreements (as defined) would be the role played by government - ie. that of signatory to the SVA but not to the community covenant. This will influence the possible scope of issues that can be addressed within the agreements and the possible linkages that can be made to the regulatory regime.

5. Socio-Economic Analysis of the Management Options

5.1. Evaluation criteria

In this section we evaluate the three proposed management options according to four criteria:

- impacts on emissions;
- impacts on industry;
- impacts on government; and

- indirect economic impacts.

Our evaluation also takes into account other community and stakeholder issues.

5.2. *Impacts on emissions*

Each of the three management options could result in emission rates of less than 1 mg/m³ through the installation of the technological control options discussed previously. No aspects associated with any of the management options would restrict or enhance the company's ability to achieve any emission target, the government's ability to set a particular target, or the timing of implementation.

5.3. *Impact on industry*

5.3.1. *Technical control costs*

The costs to Giant Mine of implementing the technical control options are summarized in Table 3. The capital and operating costs are based on the estimates provided in the Hatch study (1996). In addition to the costs of the control equipment and its operation, there would also be monitoring and reporting costs. Given that commercially available continuous emission monitors do not exist, we assume that the required monitoring program will consist of monthly grab samples, which would cost approximately \$15,000 per month, or about \$180,000 per year.

As discussed previously, if the scope of the control effort under a covenant or structured voluntary agreement was expanded beyond atmospheric arsenic emissions to include other issues relevant to the operation of Giant Mine (eg. releases of arsenic to other media), the total cost to the company would obviously be higher. However, when compared to the costs potentially incurred by the company under separate regulations for sulphur dioxide, atmospheric arsenic emissions, other arsenic-related releases, and/or underground storage issues, it is possible that an integrated approach could potentially result in economic efficiencies, which would translate into lower overall costs,

Table 3: Summary of Industry Control Costs

		Capital	Operating	Monitoring	PNV	Total PNV**	Annualized cost
		Cost	Costs	costs*	Operating		(10 years)
10%	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,322,646	\$3,503,646	\$570,202
discount	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,138,309	\$4,154,309	\$676,095
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,144,454	\$4,188,454	\$681,652
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,371,803	\$4,577,803	\$745,016
7.5%	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,594,623	\$3,775,623	\$550,055
Discount	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,388,700	\$4,404,700	\$641,703
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,395,564	\$4,439,564	\$646,782
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,649,535	\$4,855,535	\$707,383
5%	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,918,816	\$4,099,816	\$530,945
Discount	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,687,164	\$4,703,164	\$609,081
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,694,885	\$4,738,885	\$613,707
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,980,590	\$5,186,590	\$671,687
* Assumes monthly tests costing \$15,000 each							
** Assumes PNV is calculated over 10 years							

5.3.2. Possible impact of costs on industry

The implications of implementing the chosen management option will depend on the financial and regulatory context applicable to Giant Mine and its owner, Royal Oak Mines. The additional capital and operating costs will reduce the operating margin of the Mine. In the worst case scenario, Giant Mine could suspend operations or shut down completely. This section reviews some of the factors that could potentially impact the economic viability of the Mine upon implementing the selected control option. We conclude that the resulting financial impacts associated with any one of the three management options would probably not compromise the economic viability of Giant Mine.

5.3.2.1. Financial context (Royal Oak)

Royal Oak Mines is one of Canada's top mining companies and is in sound financial condition. The *Financial Post* (1996) ranked it in the top 500 of Canada's companies (at 440), with revenues of \$208.3 million in 1995. Net income for 1995 was \$23.2 million and has been increasing steadily over the last few years. Of the top 500 companies in Canada in 1995, it ranked 45th in terms of its profit margin at 11.1% (*Financial Post*, 1996).

5.3.2.2. Financial context (Giant Mine)

The Giant Mine is an important asset in Royal Oak Mine's total holdings of gold properties. In 1995, the Giant Mine represented 25% of Royal Oak's gold production and 8.9% of its mineable gold reserves.

Our understanding is that Royal Oak evaluates the viability of the Mine independently of other Royal Oak operations. This means that control options should be assessed on the basis of Giant Mine's operations, specifically its operating costs, rather than on the basis of the overall financial status of Royal Oak Mines.

The future financial status of Giant Mine will depend on four main factors: i) the price of gold; ii) the size of reserves; iii) the grade of the reserves; and iv) operating costs. The first factor influences the profitability and

competitiveness of the industry overall. The next three factors affect the specific situation at Giant Mine. We address each of these factors in turn.¹⁶

Price of gold

The price of gold may fluctuate dramatically over short periods of time in response to political and economic events. For example, in 1993, London gold prices ranged between \$326 and \$406 per ounce(US) (American Metal Market, 1995). The short-term fluctuations create uncertainty for the operation of gold mines, but affect all gold mines in much the same way. Canada is a price taker for gold prices given its relatively small share of world production (approximately 7%).

Over the longer term, the price of gold increased and peaked through the 1970's, but has settled at a relatively stable plateau in recent years (Figure 1). The latest figures (1995 and early 1996) indicate that gold prices are approximately 3% higher than in 1986. The factors driving the future price of gold are difficult to predict (e.g. Mackenzie and Gesing, 1987), however no drop in price is anticipated in the near future.

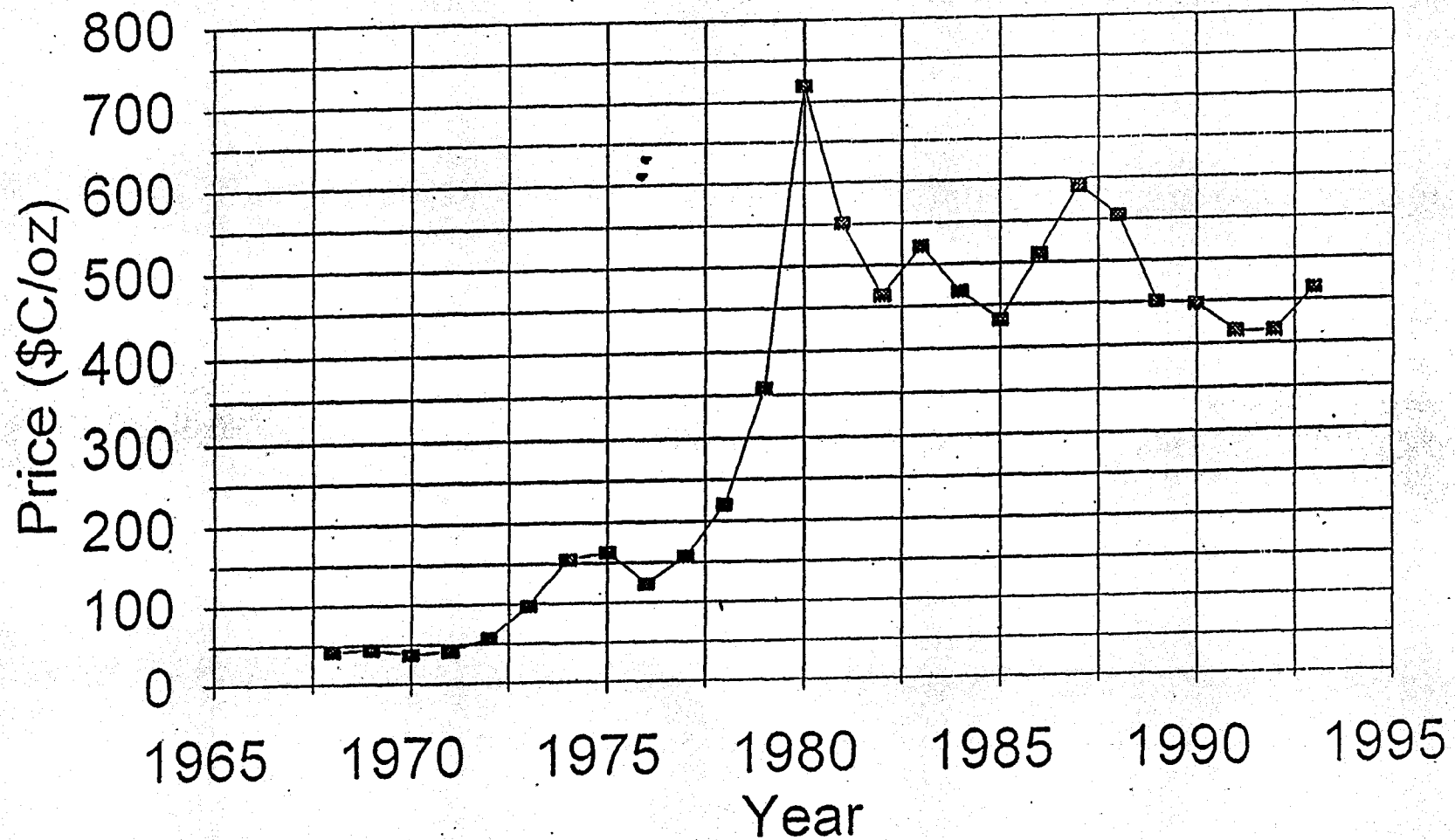
Size of reserves

The size of the reserves will determine the expected lifespan of the Mine, based on current prices and mining technologies. Mineable reserves at Giant Mine, as of December 31, 1994, amounted to 763,000 oz. of gold compared with 840,000 oz. of mineable gold on December 31, 1993 (Giancola, 1996). The decrease in mineable reserves at the Giant Mine was due to an engineering review of mineability and production. The figure rose again to 826,000 oz. in 1995.

¹⁶ We were not able to address the relative competitiveness of the Giant Mine compared to other Royal Oak holdings or to other mining companies. It is difficult to compare mines operating in the NWT with those operating elsewhere because wages and other costs are significantly different.

Figure 1

Gold prices (1968-1993)



To be meaningful in this context, the reserves need to be compared to the production levels. Figure 2 shows that annual production has remained approximately in the range of 90,000 to 100,000 ounces over the last few years (the 1995 value is 91,423 oz.). Based on current reserves, this indicates a remaining lifespan for the Mine of approximately eight years. Mine officials estimate the lifespan of the current reserves to be closer to 5 years, but did not provide figures to substantiate their estimates.

It is important to note that the reserves are not fixed, and may grow with exploration and development. For example, in 1989 the estimated reserves were 325,614 ounces, giving the Mine a remaining lifespan of just over three years at current production levels. Reserves also fluctuate due to improved extraction efficiencies. In fact, most of the current production comes from areas that have been mined previously, utilizing ore that was considered unproductive in past years. Mine officials indicated that exploration continues to be active.

Grade of the reserves

The grade of reserves has been relatively high for Giant Mine recently. The 1995 level was 0.254 oz./ton, compared to 0.286 for 1992, 0.264 for 1993 and 1994, and a projected level of 0.262 for 1996.

Royal Oak's Supercrest project is located near the Giant Mine and is in an advanced stage of development. Mine officials stated to us that the higher grade mineable ore from Supercrest will offset the reduced quality expected elsewhere, maintaining the grade at its current level.

Thus the size and grade of reserves do not indicate any particular financial difficulty for Giant Mine.

Operating costs

The operating costs for the Giant Mine are documented in the latest annual report for Royal Oak and are summarized in Table 4, together with historic revenue and cashflow information.

Figure 2

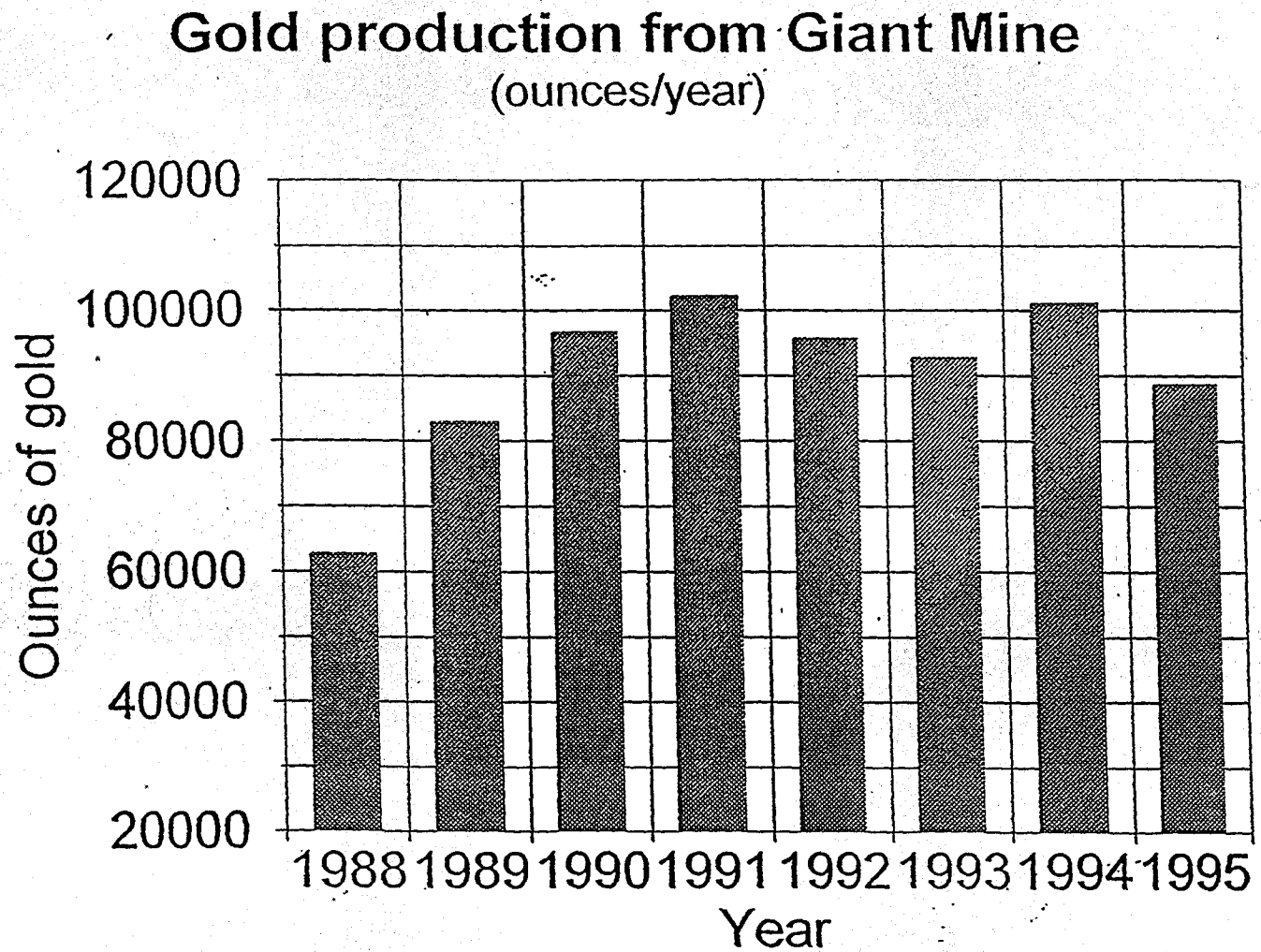


Table 4: Financial status of Giant Mine

	1991	1992	1993	1994	1995
Mine revenue *	\$37.0	\$33.0	\$33.5	\$38.9	\$35.1
Operating costs	\$34.7	\$31.1	\$30.7	\$29.2	\$30.1
Mine net cash flow	\$2.3	\$1.9	\$2.8	\$9.6	\$5.0

* Figures are in millions of US dollars.

The data in this table should be qualified in two ways. First, the figure for operating costs does not include depreciation and amortization of existing capital, nor does it include new investments. In 1995, \$1.7 million U.S. was invested in the purchase of replacement equipment and in development of the Supercrest ore reserves. Taking these two factors into account, the net cash flow for 1995 would be \$2.4 million U.S.. Unlike other operating costs, there is usually discretion in the timing and amount of investments. The second qualification is that the revenue figures are based on the "spot" price of gold, not on the price of gold actually realized by Royal Oak Mines. The difference between the two is due to trading on the gold futures market. For example, in 1995 the average "spot" price was \$ US 384 per ounce, and the realized price was \$ US 409 per ounce. If the assumption is made that these hedge gains could not be realized without a base of gold production, then the realized price should be the one used in the analysis. Thus in 1995, the net cash flow for the Giant Mine would be \$7.3 million U.S..

Operating costs for gold mines are frequently reported in terms of cost per ounce of gold. The cost figures for Giant Mine have been well below the selling price for gold for the last few years. In fact, the Mine experienced a decline in operating costs from 1993 to 1994. Thus, on the basis of these crude measures, there is scope for the Giant Mine to increase its operating costs and remain profitable. Using the annualized cost for the

least expensive technical control option (a scrubber) at a 7.5% discount rate, the operating costs would rise by approximately 1.8%.

Regulatory context

In addition to existing regulations applicable to Giant Mine, there is a good prospect that the regulatory regime will become increasingly complex in the near future. The government of the NWT is currently proposing to control the release of sulphur dioxide and other pollutants from gold roasters through *Gold Roaster Discharge Control Regulations* under section 34(1)(b) of the Northwest Territories' *Environmental Protection Act*. The Department of Renewable Resources has prepared draft regulations and is now circulating them for public consultation. These draft regulations do not address arsenic emissions. A backgrounder released by the GNWT estimates Royal Oak's short-term capital costs of compliance with the regulations to be in the range of \$2 million dollars. Longer term costs (beyond the year 2006) range from \$18 million capital and \$4.4 million annual operating costs for end-of-stack systems, to \$30 - 50 million for alternatives to the gold roasting process.

As a result of the proposed GNWT regulations and the federal government initiative to address airborne arsenic from gold roasting, the Giant Mine could be required to address two air pollution issues simultaneously. Given that the proposed technical solutions to arsenic and sulphur dioxide emissions are different, the costs would be additive - approximately double the costs, in the short term, for arsenic control alone.

The *Northwest Territories Water Act* also requires Giant Mine to obtain a Water License from the NWT Water Board for its water use, liquid effluent emissions and waste disposal. The License specifies a maximum allowable concentration of arsenic in liquid effluent, and also includes a series of requirements and studies related to the long-term storage/disposal of arsenic-bearing dust collected by the air emission control equipment. The current Water License expires in April 1998, and increasing concerns over the underground storage issue may lead to additional financial demands on the Mine when the License is renewed.

There also exists the issue of environmental clean-up and remediation in the event that Giant Mine shuts down on a permanent basis. Once the Mine is closed, water may seep back into the underground storage vaults, remobilizing the soluble arsenic trioxide and possibly contaminating the groundwater. The current Water License requires that the company post and maintain a \$400,000 security deposit against clean-up costs deemed to be the responsibility of Royal Oak Mines. Water Board officials are currently contemplating imposing a much larger security deposit in the next Water License which would have an economic impact on Royal Oak. In any event, the *Northwest Territories Water Act* authorizes the territorial government to order the Mine to pay any costs required to prevent or remedy risks to human health or the environment. The precise extent of Royal Oak's potential liability related to this issue is uncertain due to ongoing disputes concerning the degree to which Royal Oak Mines is responsible for contamination caused by previous owners of the Mine.

5.3.3. Summary of cost implications

On the basis of the data obtained in this study, it appears unlikely that financial considerations alone would cause Royal Oak to close the Giant Mine if required to control airborne arsenic emissions. The combined economic impact of the sulphur dioxide regulations proposed by the GNWT, plus the liquid effluent controls and measures regulating underground arsenic storage that may arise during upcoming water license renewals, could create more serious financial challenges. However, cumulatively, these added costs should not significantly affect the economic viability of Giant Mine.

5.3.4. Benefits to industry

Royal Oak Mines could potentially benefit from the implementation of arsenic emission control measures through generation of a marketable commodity, arsenic trioxide (As_2O_3), by diverting it from their waste stream. This scenario, however, appears to be unlikely. According to Hatch (1996), arsenic trioxide has sold for \$2.20 per kilogram to preservative producers (based on a 1969 reference). The Hatch study further notes that supply has often exceeded demand and that only

arsenic compounds of the highest purity have found a market. Historical instability in the price has lead to a growing inventory of baghouse dust containing arsenic trioxide. No arsenic trioxide was sold commercially in Canada in 1992, 1993, or 1994 (Mining Association of Canada, 1995).

5.3.5. Added impact of negotiated options

Both an SVA and a covenant could potentially address issues in addition to atmospheric emissions of arsenic. This approach could offer several benefits to the Mine not available under a regulated approach:

- the opportunity to identify and discuss all or many of the environmental issues relevant to the operation of the Giant Mine, including the arsenic issue, thus facilitating a more comprehensive multi-media, ecosystem approach (this would not include currently regulated requirements),
- increased flexibility for the Mine in terms of how and when to address an issue(s);
- some assurances in terms of how government policy will develop and be applied, providing a degree of long-term certainty;
- a new relationship with government; and
- an improved public image.

The company is potentially interested in this approach. Faced with the prospect of several costly additional environmental control measures, Giant Mine officials, in informal interviews, indicated their preference for a management option that ensures an integrated approach to environmental management and greater flexibility in terms of implementation. Specifically, the company would prefer a management option which permits an integrated (and hence potentially lower cost) resolution of all environmental issues, including atmospheric emissions of arsenic, underground storage, remediation, and sulphur dioxide emissions. As indicated previously, a negotiated agreement could not reduce any existing regulated requirements (ie. with respect to sulphur

dioxide emissions), however, they could be taken into account when negotiating an integrated agreement.

The company is likely to have reservations about negotiating a community covenant for reasons outlined in Appendix B of the report. In theory, however, such a covenant could allow the company to address many of the local community's concerns. In particular, it could provide a vehicle for the company to acknowledge and resolve broader community concerns (such as the need for risk communication, compensation and/or remediation). At minimum, it could establish a process whereby parties can resolve issues face-to-face, provided they believe that such a dialogue would be fruitful.

5.3.6. Summary of the likely financial impacts on industry

In theory, each of the three management options should impose the same costs on the company with respect to the technical control measures required to reduce atmospheric emissions of arsenic. Each option can be structured to provide the company with considerable flexibility in terms of how to achieve a prescribed reduction, thereby allowing Giant Mine to respond in a cost-effective manner. Similarly, the timing of each could be structured so as to provide for a realistic investment period for the company. In practice, however, the negotiated options may provide more opportunities for the company to ensure that the timing requirements do not impose undue costs.

The two negotiated options could potentially address a wider range of issues, resulting in a different net impact on the company. An integrated approach might allow for a more cost-effective resolution of the issues facing the Giant Mine when compared to the costs associated with discrete regulatory initiatives. Furthermore, if a covenant were to address issues of concern to the community (e.g. risk communication, compensation or remediation), it might cost more to implement than a regulation, but would provide the added benefit of reducing the current tensions between certain segments of the Yellowknife community and Giant Mine.

5.4. Impacts on Government

5.4.1. Regulated performance standard

A regulated performance standard offers government three main advantages over the two negotiated options. First, it provides all parties with certainty. Second, it enhances government control over the final outcome. Third, the performance standard set forth in the regulation can potentially be applied to the development of additional regulatory and non-regulatory initiatives for arsenic.

The costs to government of designing, promulgating, administering and enforcing a regulation are fairly well understood, albeit difficult to predict with any precision. Generally, the costs incurred are those associated with:

- the background scientific, technical and socio-economic analysis;
- public consultations;
- legal drafting;
- publication in the Canada Gazette;
- training of enforcement personnel;
- provision of information to the regulated community;
- monitoring (e.g. reviewing self-reported information);
- enforcement (including regular inspections, and also, inspections and investigations in response to public complaints or perceived violations);
- responding to public requests for information; and
- administration (such as providing information to CEPA annual reports, Minister's briefing notes, etc.).

A regulation to address atmospheric emissions of arsenic from gold roasting is not likely to be complex, consequently, the background analysis and drafting work inherent in the regulation development process will not be significant. Similarly, because Environment Canada officials are already in regular contact with Giant Mine, the incremental monitoring, administration and enforcement costs will not likely be high. Therefore, the main government expenses are likely to be the costs associated with the public consultation process.

5.4.2. Structured Voluntary Agreement (SVA)

The main benefit to the federal government of an SVA is that it should enhance industry "ownership" of the environmental issue, leading to improved performance. In addition, an SVA would provide government with the opportunity to address a range of issues in a comprehensive integrated manner. This would respond to stakeholders' perceptions and concerns that air emissions are a minor aspect of the overall environmental performance of Giant Mine.

The government costs with respect to the development of an SVA would likely be more or less equivalent to those incurred in the development of a regulation. The requirement for additional background analysis will likely be similar, since the government will want to substantiate its negotiating position with scientific, technical and economic analysis and information. Similarly, the process -related costs and public information costs will likely be equivalent. The main differences will probably be with respect to negotiation and enforcement costs. The negotiation costs will likely be higher, particularly if multiple jurisdictions are involved. On the other hand, as previously stated, if one of the main benefits of such an agreement is assumed to be increased industry "ownership" of the environmental objectives, then enforcement costs would probably be lower. Assuming that these two differences roughly cancel each other, the overall costs of an SVA should be approximately equal to those of a regulation.

5.4.3. Community covenant

A structured voluntary agreement and a community covenant, as defined for the purposes of this study, share many of the same characteristics, therefore, the costs to the federal government of negotiating either option will likely be roughly equivalent. Like the SVA, the covenant option should enhance industry "ownership" of the environmental issue(s), leading to improved performance and, hence, reduced government enforcement costs. A covenant will also benefit the federal government in that it will allow the affected communities to be directly involved in the negotiation process, thereby ensuring their issues and concerns are addressed as part of that process.

Within the definition of a covenant set forth in this study, the government would serve as a facilitator to the negotiations. It would also monitor the negotiations and the performance under the covenant in order that, in the event of an unsatisfactory outcome either of the negotiation process or of performance under the agreement, it would be aware of the necessity to intervene.

5.5. Indirect Economic Impacts

The indirect economic impacts of implementing any of the management options would occur at three levels: locally, on Yellowknife itself; regionally, on the Northwest Territories; and nationally. For the purposes of assessing these impacts, we have considered two scenarios: 1) the Giant Mine reduces emissions and does not change its operations significantly; and 2) the Mine closes - the worst case scenario. Some of the analysis in this section draws on an earlier study which looked at the effects of the anticipated closure of the Giant and Con-Rycon Mines in 1974 (St. Pierre, 1972).

5.5.1. Yellowknife

The indirect impacts on the community of Yellowknife are a function of the way the Giant Mine is linked economically to the community. There are three ways in which the operation of the Mine supports the community:

i) employment and related payroll expenditures; ii) the purchase of goods and services; and iii) payment of taxes, utility bills (ie. water, electricity) and other fees. There may also be several additional "spin-off" effects.

If Giant Mine implements one of the proposed technical control options there will be a small positive impact on the economy of Yellowknife. First, there will be the temporary increase in economic activity due to implementation of the pollution control equipment. The magnitude of the effect on the local economy will depend on the extent to which equipment, labour and supplies are purchased locally. Second, there will be a small increase in employment associated with the operation and maintenance of the equipment once it is installed. Hatch (1996) estimated an additional 0.5-0.6 person-years would be required.

By contrast, closure of the Mine could have a significant negative impact on the local economy. The duration and magnitude of the impact would depend in part on the availability of alternative employment and the income associated with that employment. For example, with the potential development of the BHP diamond mine, a loss of employment at the Giant Mine might be reflected in a slower growth rate in aggregate employment rather than in an actual increase in unemployment.

Employment and payroll impacts

The employment situation in Yellowknife is significantly more diversified and more stable than in many small communities in Canada which are dominated by a single employer. The Giant Mine is the fifth largest employer in the region with approximately 300 workers from the Yellowknife area. The federal and territorial governments combined employ approximately 2,300 workers, the Stanton Yellowknife Hospital 400, and the Miramar-Con Mine approximately 370 workers,. The total labour force in 1991 was 9,730. This diversification means that Yellowknife would be better able to withstand the employment loss should the Mine close. This diversification also means that Yellowknife should be better able than many communities to take advantage of the increase in demand for goods and services associated with the installation and operation of the pollution control equipment.

The short-term effect of the worst case scenario would be a substantial increase in the unemployment rate for men in Yellowknife. Using the 1991 census information, with 5,225 men in the labour force and recognizing that employment associated with mining is overwhelmingly weighted towards men, the unemployment rate for men would rise from the base of 4.3% to 11.0%. The unemployment rate for women would not change significantly.

Over the longer term, the unemployment rate should come down as Mine workers obtain jobs in other mines, shift to other kinds of work, or move to other communities. Although the mobility between different employers in Yellowknife may be relatively limited given the heavy emphasis on the public sector, the mobility of the Yellowknife work force¹⁷ could facilitate a relatively speedy recovery for the community. This, however, should be placed within the larger context of the historical downward trend in employment in metal mining in Canada (from 69,000 in 1975 to an estimated 34,000 in 1994) (Mining Association of Canada, 1995) which suggests that there could potentially be a surplus of labour.

The second dimension of the employment impact is the payroll or wage impact. If the Giant Mine continues to operate, the aggregate wage impact (i.e. total wages paid by the Mine to the community) of the installation and operation of the pollution control equipment will be small and positive. With only an additional 0.5-0.6 person-year associated with operation of the equipment, the long-term net effect will be difficult to detect. If the Mine shuts down, the adverse impacts will be significant in the short run. In many small communities with a single large employer, alternative employment, when it is available, is only available at a reduced wage. The average per capita income in Yellowknife in 1994 was \$25,600, 43% above the national average. The metal mining industry contributes to the high wages, but in Yellowknife it is not the only source of high wages. The average weekly wage for workers in primary

¹⁷ In the 1991 Census, only 23% of the residents of Yellowknife had lived in the community for more than five years.

industries in January, 1996 was \$1,000, only slightly higher than the average wage of \$957 for government employees in the NWT.

Thus, if the Mine continues to operate, the installation of any of the technical control options will produce a relatively small positive impact on the total personal income in Yellowknife. Under the worst case scenario, the short term impact of total income loss would be disproportionately greater than the number of jobs lost.

Purchase of goods and services

Both scenarios would result in a change in purchases of goods and services, affecting mainly small businesses in Yellowknife.

Under the first scenario, there would be a pulse of capital spending during installation of the pollution control equipment. Based on the estimates in Hatch (1996), the largest fraction of this spending would be on the equipment itself, which would be imported to Yellowknife. The amount that might be spent locally could be in the order of \$300,000, primarily related to construction activities. The annual operation of the equipment would require \$18,000 to \$33,000 worth of supplies depending on the technical control option chosen. These activities would have a small positive impact on the Yellowknife economy. Once again, the magnitude of the impact on the local economy will depend on the extent to which equipment, labour and supplies are purchased locally.

In the worst case scenario, the ongoing purchases by Giant Mine would cease. The Mine made purchases worth \$2.6 million in the Yellowknife area in 1979 (the most recent data made available to us).

Payment of taxes, utilities and other fees

Under the first scenario, the addition of new pollution control equipment to Giant Mine will increase the requirements for water and electricity by a small amount. It will not affect the other taxes and fees the Mine pays to the community (eg. property, business and school taxes).

If the Mine closes, the community will lose a significant source of revenue. In 1995, Royal Oak Mines was the third largest taxpayer, paying \$683,934

in municipal and school property taxes (4% of the total). This could lead to an increase in taxes and charges for other users of the infrastructure and social services in Yellowknife.

Indirect effects

In addition to the direct economic impacts associated with changes in employment and purchases, there will also be indirect or "spin-off" effects. Such estimates need to be treated with caution to avoid possible double-counting, however, it is important to recognize the full extent of the economic linkages between Giant Mine and the Yellowknife community.

Indirect effects can be viewed in two ways. First, from the perspective of employment, the spouses and dependents of workers in the Mine will be affected by changes in the operations of the Mine. In 1979, for example, it was estimated that as a result of 300 people being employed by Giant Mine, 900 people were actually dependent on the Mine. This ratio of 3:1 has probably dropped since 1979 with the greater participation of women in the labour force.

The employment effect can be extended by calculating an employment multiplier to estimate the number of indirect jobs which depend, in the short-term, on the Mine's operations. An earlier study (St. Pierre, 1972) estimated a value of 0.35 for Yellowknife (i.e. for the 300 Giant Mine workers there would be 105 indirect jobs).

The second way of describing indirect effects is through a multiplier for overall economic activity. St. Pierre (1972) estimated a value of 1.25 for Yellowknife, implying that for each dollar of activity generated by the Mine, \$1.25 of activity in indirect and induced activity would result.

These estimates are crude and should be treated very carefully. They do, however, underscore the fact that the impact of the potential changes in economic activity, resulting from the installation of any one of the technical control measures under consideration, will probably extend beyond the direct impacts.

5.5.2. Northwest Territories

The Northwest Territories, as a region, has higher unemployment and lower wages than Yellowknife. Thus, adverse impacts on the Yellowknife economy may extend to other parts of the territories. For example, in the hypothetical worst-case scenario where the Mine is forced to shut down, there may be impacts on the rest of the NWT through lower tax revenues, and through lower levels of economic activity. Both personal income taxes and corporate taxes might potentially be affected.

The regional economic impacts associated with changes in operations at the Giant Mine would be noticeable, but not large. To put this in perspective, Table 5 summarizes the role Giant Mine plays in the overall gold mining industry in Canada. Mining is very important to the economy of the NWT, accounting for about 47% of total economic output (Van Geest and Corrigan, 1996). Gold, however, is not the only valuable mineral which is mined. Zinc, for example, is roughly comparable in terms of the value mined each year. Thus policies and options which affect the perceived economic attractiveness of mining in the NWT may have significant impacts on the territories' economic outlook.

Table 5: Summary of gold mining activity in Canada

	Giant Mine	Yellowknife	Northwest Territories	Canada
Number of gold mines (January 1995)*	1	2	4***	50
Gold production (kg) (1993)	3,517 *		13,205 **	153,129 **
Value of gold production (\$000) (1993)	52,480 *		197,043 **	2,284,991 **

* from Royal Oak Mines 1995 *Annual Report*

** from Mining Association of Canada (1995)

*** There are currently 6 gold mines in the NWT

5.5.3. Canada

The likely socio-economic impacts, at a national level, of implementing any one of the management options are negligible. There would be no detectable effect on national indicators such as inflation, employment, balance of payments, or national competitiveness, even with the worst case scenario. For example, Canada is a net exporter of gold. In 1992, we exported a net amount of 168,402 kilograms of gold worth \$2.37 billion (Natural Resources Canada, 1994). Of this, the Giant Mine's production was 3,627 kilograms (or 2.2%).

5.5.4. Summary of indirect impacts

There are few differences among the management options with respect to indirect economic impacts. Assuming that Giant Mine does not close, indirect impacts at the local, regional and national level are likely to be minimal. If the Mine does close, local effects could be significant in the short-term, although the economy of Yellowknife is more diversified and therefore much less vulnerable than that of most other northern communities.

6. Summary and Recommendations

Each of the management options reviewed in this report offers considerable flexibility in terms of how environmental performance objectives will be achieved. Also, they are roughly comparable with respect to likely impacts on emissions and in terms of the costs they will impose on the company. The costs to government of a regulation and an SVA should also be roughly equivalent, while a community covenant could potentially require less government investment.

The main differences between the three management options lies in their ability to address or respond to many of the environmental issues, concerns, relationships and dynamics involving the Yellowknife communities and Giant Mine. We review each option in greater detail below.

6.1. Regulated Performance Standard

A regulated performance standard offers three main advantages over the two negotiated options. First, it would provide all stakeholders with certainty. Second, it would enhance government control over the final outcome. Third, the performance standard on which the regulation is based could be applied to other industrial emitters of arsenic to the air.

The primary challenge with respect to a regulated performance standard, in light of the gaps in the scientific data, is demonstrating that the overall benefits of a proposed regulation outweigh the costs. The present net value of the health benefits from reduced mortality due to lung cancer from inhalation of arsenic ranges from \$50,000 to \$2 million depending upon the choice of discount rate and the assumed monetary value of the predicted health impacts (see Table 6). These estimates do not account for human health benefits arising from reduced arsenic ingestion or reduced sub-lethal impacts, nor do they account for potential environmental benefits. By comparison, costs to the company could range from \$1.2 to \$2.2 million in capital investment, between \$168,000 and \$206,000 in annual operating costs and about \$180,000 per year to conduct monthly monitoring. The present net value of the possible costs to the company thus ranges from \$3.5 million to \$5.2 million (see Table 6). It is important to note that while the benefits and costs of a proposed regulation are important considerations, they are never the sole factor governing the decision to regulate.

It is unlikely that these added costs would cause the Mine to shut down. The 10 year annualized costs to the company range from \$550,000 to \$707,000 at a discount rate of 7.5%. These costs are less than 2% of the average annual operating costs of the Mine, and are less than 9% of the net annual cash flow from the Giant Mine to its owner, Royal Oak Mines.

A second consideration with respect to the regulatory approach is that many stakeholders - including the Mine, the NGOs, the aboriginal community and the local government - question whether airborne arsenic is a priority issue relative to other environmental issues involving the Mine.

Table 6: Comparison of Costs and Benefits

PRESENT NET VALUE OF COSTS							
		Capital	Operating	Monitoring	PNV	Total PNV**	Annualized cost
		Cost	Costs	costs*	Operating		(10 years)
10% discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,322,646	\$3,503,646	\$570,202
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,138,309	\$4,154,309	\$676,095
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,144,454	\$4,188,454	\$681,652
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,371,803	\$4,577,803	\$745,016
7.5% Discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,594,623	\$3,775,623	\$550,055
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,388,700	\$4,404,700	\$641,703
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,395,564	\$4,439,564	\$646,782
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,649,535	\$4,855,535	\$707,383
5% Discount	Scrubber	\$1,181,000	\$198,000	\$180,000	\$2,918,816	\$4,099,816	\$530,945
	Wet ESP	\$2,016,000	\$168,000	\$180,000	\$2,687,164	\$4,703,164	\$609,081
	alt. Wet ESP	\$2,044,000	\$169,000	\$180,000	\$2,694,885	\$4,738,885	\$613,707
	Activated carbon	\$2,206,000	\$206,000	\$180,000	\$2,980,590	\$5,186,590	\$671,687
* Assumes montly tests costing \$15,000 each							
** Assumes PNV is calculated over 10 years							
PRESENT NET VALUE OF HEALTH BENEFITS OF REDUCED LUNG CANCER MORTALITY							
	Dollars per fatal cancer case*	Estimated avoided lung cancer mortality**	Value of lung cancer mortality	Annual value***	PNV (5% discount)	PNV (7.5% discount)	PNV (10% discount)
Low	\$2,500,000	0.14	\$350,000	\$5,000	\$96,713	\$66,245	\$49,937
		0.86	\$2,150,000	\$30,714	\$594,096	\$406,932	\$306,754
Central	\$4,200,000	0.14	\$588,000	\$8,400	\$162,478	\$111,291	\$83,894
		0.86	\$3,612,000	\$51,600	\$998,082	\$683,645	\$515,347
High	\$8,300,000	0.14	\$1,162,000	\$16,600	\$321,088	\$219,932	\$165,790
		0.86	\$7,138,000	\$101,971	\$1,972,400	\$1,351,013	\$1,018,423
* From Lang et al, 1995							
** From section 3.2.2							
*** Assuming mortality may occur anywhere during an average 70 year lifespan							

6.2. Structured Voluntary Agreement

Both negotiated agreement options offer the potential to address additional aspects of the Giant Mine's environmental performance rather than being restricted to atmospheric arsenic emissions. The key issue with respect to both options is whether the relevant parties would be willing to enter into such an agreement.

The precise structure and content of an SVA would be shaped by the negotiations, however, it could take one of two general forms: a negotiated agreement between the Mine and the federal government focused on atmospheric emissions of arsenic only, or, an agreement among the Mine, the GNWT and the federal government addressing a more comprehensive set of the Mine's environmental issues.

The first model is not likely to be effective. In theory, there are three factors that might induce Royal Oak to consider negotiating an agreement focused only on airborne arsenic:

- significant community concerns with respect to airborne arsenic that may impair the Mine's ability to continue to operate profitably;
- market pressures that might compel the Mine to want to "green" its image; or
- sufficient concern on the part of the Mine with respect to maintaining good will with the community.

Although this study has not addressed these considerations in great detail, our preliminary observations suggest that none of these conditions may exist in this case.

Royal Oak Mines and other stakeholders might, however, be interested in an SVA that addresses a wider range of environmental issues. The main reasons for which they might be interested in such an agreement relate to the opportunities that negotiations might provide to: i) avoid inconsistent regulatory requirements from different government agencies; ii) set priorities among the environmental issues related to the Mine and the

community; and iii) create a degree of long-term certainty with respect to the environmental regime facing the Mine.

There are two questions with respect to the parties' willingness to negotiate such an agreement:

- Would these incentives be sufficient to induce the Mine to include atmospheric emissions of arsenic in the negotiations?
- What are the prospects of inter-jurisdictional cooperation with respect to such an approach?

Although we did not pursue these questions in detail, our preliminary observations suggest that the answer to both is positive. Although they did not indicate to us precisely which issues they would be willing to negotiate, Giant Mine officials suggested that they would be interested in negotiating a comprehensive package of the environmental issues they face. And while the GNWT intends to pursue the promulgation of the SO₂ regulation, it would be interested in exploring whether negotiations could help resolve other environmental concerns, such as the liability for the contaminated site upon closure of the Mine.

An SVA would also have to address at least two additional factors in order to be effective in these circumstances. First, it would have to overcome concerns on the part of various stakeholders about the need for effective enforcement powers. More analysis is required in order to determine whether the community stakeholders would be satisfied with a non-regulated approach. Second, it would be important to ensure that the community trusts the federal and territorial governments to negotiate on its behalf. Many of the local aboriginal groups and ENGOs have expressed concerns in several fora about the historic failure of the federal government to address adequately their concerns about the Giant Mine.

6.3. Community Covenant

Although some stakeholders might be interested in a covenant between community representatives and the Mine, this option is unlikely to be effective. Again, the issue is whether the parties would be willing to

negotiate. The local ENGOs and the Yellowknives Dene First Nation are interested in addressing a wider range of concerns with respect to the past and present operations of the Mine, than could be included in a regulation. A covenant might provide the opportunity for resolution of these issues. Aside from the actual substantive issues it could address, a covenant might also provide an opportunity for opening up lines of communication and restoring trust.

On the other hand, there appear to be few incentives to entice or compel the Mine to enter into such an agreement. As with the SVA, the company might be interested in negotiating a community covenant if any of the following conditions exist:

- significant community concerns with respect to airborne arsenic are likely to impair the Mine's ability to continue to operate profitably;
- market pressures that might compel the Mine to want to "green" its image; or
- sufficient concern on the part of the company about maintaining good will with the community.

Again, although this study has not addressed these considerations in great detail, our preliminary observations suggest that these conditions probably do not exist in this case.

The main incentive, therefore, would have to come from the knowledge that government would intervene in the absence of an agreement. Can the federal government create a credible enough threat of intervention to bring Royal Oak to the table with the community? Presumably, the answer to this issue depends in large part on the strength of the case that can be made for the development of a regulation under *CEPA*. The threat to intervene could not be contained in this type of covenant itself, since the federal government would not be a party to it. Moreover, as we noted previously, the government can probably not provide an absolute commitment about how it will act in the future.

Additional questions articulated to us by a number of stakeholders are: Which parties should participate in such an agreement? Who speaks for the community? If the list of participants grows in order to accommodate the diversity of interests, would the negotiations be manageable? If the government is interested in pursuing this option further, it will have to resolve these questions.

6.4. Recommendations and Rationale

The federal government can choose to focus on atmospheric emissions of arsenic from all gold roasters in Canada, or it can attempt to be a catalyst for addressing a broader range of issues related to the Giant Gold Mine.

If the government decides to control only atmospheric emissions of arsenic from gold roasters, it should do so by means of a regulation. There do not appear to be compelling reasons that might induce Royal Oak Mines to negotiate an agreement focused exclusively on atmospheric arsenic emissions with either the community or the government.

If the government is willing to expand its focus beyond atmospheric emissions of arsenic, however, it should consider an SVA. The benefits to Royal Oak Mines of addressing all environmental issues relevant to its operations, in an integrated manner, might induce it to negotiate such an agreement. This option raises a number of considerations which this paper has not analyzed thoroughly (see Section 6.2 above). These should be reviewed more fully before committing to this option.

References

Abt Associates. 1989. Costs of Alternative Scenarios to Exceed the Requirements of the Montreal Protocol. Prepared for Environment Canada.

Abt Associates. 1989. Socio-Economic Assessment of Amendments to Regulations Related to Ozone Depleting Substances. Prepared for Environment Canada.

American Metal Market. 1995. Metal Statistics 1995: The Statistical Guide to North American Metals. Nonferrous Edition. Chilton Publications, New York.

Anthony, D. Letter to Emery Paquin. October 17, 1995.

Apogee Research. 1994. Assessment of Alternative Economic Options Available for the Control of Production and Consumption of Methyl Bromide. Prepared for Environment Canada.

Canadian Employment and Immigration Advisory Council. 1987. Canada's Single-Industry Communities: A Proud Determination to Survive. Prepared for the Minister of Employment and Immigration.

Canadian Public Health Association. 1977. Task Force on Arsenic - Final Report, Yellowknife, Northwest Territories.

Chestnut, L. 1995. Human Health Benefits from Sulfate Reductions Under Title IV of the 1990 Clean Air Act Amendments. Final Report. Prepared for the United States Environmental Protection Agency.

Connell, L., Manager of Environmental Services, Royal Oak Mines, 1996. Letter to Ed Collins, Chief, Environmental Engineering, Environmental Protection Branch, Prairie and Northern Region, Environment Canada, July 11.

Corriveau, A. 1996. Medical Officer of Health, GNWT Department of Health and Social Services. Personal Communication, June 12, 1996.

Dann, T. 1990. Unpublished data. Environment Canada, Pollution Measurement Division, Conservation and Protection.

Department of Indian and Northern Affairs. 1995. Yellowknife - Back Bay Study on metal and trace element contamination of water, sediment and fish. November 1995. Unpublished.

Environmental Protection Division. Department of Renewable Resources. Government of the Northwest Territories. 1993. An Investigation of Atmospheric Emissions from the Royal Oak Giant Yellowknife Mine.

Environmental Protection Division. Department of Renewable Resources. Government of the Northwest Territories. 1996. Backgrounder: Gold Roaster Discharge Control Regulations.

Financial Post Datagroup. 1995. Survey of Mines and Energy Resources 1995. Financial Post, Toronto.

Financial Post. 1996. The Financial Post 500: An Investors' Handbook of Canada's Largest Companies.

Freeman, A.M., 1993. The Measurement of Environmental and Resource Values; Theory and Methods. Resources for the Future, Washington, D.C.

Giancola, D. (ed.) 1996. Canadian Mines Handbook 1995-96. Southam Magazine and Information Group.

Government of Canada. 1993. Canadian Environmental Protection Act: Priority Substance List Assessment Report - Arsenic and its Compounds. Prepared jointly by the Government of Canada, Health and Welfare Canada and Environment Canada. Canada Communications Group. pp. 56.

Government of Canada. 1995. Toxic Substances Management Policy. Ottawa.

Government of Canada. Health and Welfare Canada and Environment Canada. 1993. Priority Substances List Assessment Report: Arsenic and Its Compounds. Minister of Supply and Services.

Government of the Northwest Territories. 1994. Yellowknife Air Quality Monitoring Reports. 1994 Data.

Green, A.G. 1984. Productivity and Price: The Case of Gold Mining in Ontario. Centre for Resource Studies, Queen's University, Kingston, Ontario. Working Paper No. 32.

Halliwell, D. 1996. Unpublished data. Atmospheric Environment Branch, Prairie and Northern Division, Environment Canada.

Hamilton, F. 1996. Senior Health Officer, MacKenzie Regional Health Services. Personal Communication, June 12, 1996.

Health Canada. 1994. Canadian Environmental Protection Act: Human Health Risk Assessment for Priority Substances. Canada Communications Group. p.p. 36.

Hatch Engineering Ltd. 1996. Arsenic Emission Control from Pyrometallurgical Operations. Submitted to Environment Canada.

Hughes, K. 1996. Health Policy Specialist, Health Canada. Personal Communication. June 3, 1996.

Hutchinson, T.C., and K.M. Meema (eds.). 1987. Lead, Mercury, Cadmium and Arsenic in the Environment. Scope 31. John Wiley and Sons, Chichester.

Indian and Northern Affairs Canada. 1993. Mines and Mineral Activities 1993. Minister of Supply and Services.

Jackson, F. 1996. Pollution Control Specialist, Indian and Northern Affairs. Personal Communication, June 12, 1996.

Jamieson, N., Manager, Public Works and Engineering. Personal communication, June 13, 1996

Jaworski, J.F. 1980. Executive Reports: Effects of Chromium, Alkali Halides, Arsenic, Asbestos, Mercury and Cadmium in the Canadian Environment. National Research Council of Canada. NRCC Associate Committee on Scientific Criteria for Environmental Quality.

Lang, C., G. Yarwood, F. Lalonde, and R. Bloxam. 1995. Environmental and Health Benefits of Cleaner Vehicles and Fuels. Prepared for the Canadian Council of Ministers of the Environment. Task Force on Cleaner Vehicles and Fuels.

Mackenzie, B., and R. Gesing (eds.) 1987. Long Term Prospects for Gold Mining. Centre for Resource Studies, Queen's University, Kingston, Ontario.

McDonald, K. and J. Murtha. 1996. Atmospheric Arsenic Dispersion from Yellowknife Giant Mine. Unpublished report prepared by Environment Canada.

Mining Association of Canada. 1995. Mining in Canada: Facts and Figures 1994.

Natural Resources Canada. 1994. 1993 Canadian Minerals Yearbook: Review and Outlook.

NWT Water Board. 1996. Water License Annual Report 1995, Appendix IV: Royal Oak Mines - Giant Mine Surface Contamination Study - 1995 Final Report. Submitted to the NWT Water Board December 31, 1994.

NWT Water Board. 1994. License No. NIL2-0043, Issued to Royal Oak Mines Inc. for the Giant Mine.

Planning, Policy and Analysis Branch. Environmental Protection Service. Department of the Environment. 1979. Socio-Economic Impact Analysis of Proposed Federal Regulation on Arsenic from Gold Roasting. Draft.

Royal Oak. 1993. Terms of Reference for an environmental study for the NWT Water Board - An assessment of scientific data relating to the permanent storage of arsenic trioxide in the underground mine workings at the Giant Mine.

Sangris, F. 1996. Councillor, Yellowknives Dene Band. Personal Communication June 13, 1996.

St. Pierre, M. 1972. The Socio-Economic Implications of Gold Mine Closure in the Yellowknife Region. Regional Planning and Manpower Section, Economic Staff Group, Northern Economic Development Branch, Department of Indian Affairs and Northern Development.

Van Geest, F., and C. Corrigan. 1996. Mineral Policy Update 1990-1994: Policy and Program Changes Affecting the Canadian Mineral Industry. Centre for Resource Studies, Queen's University, Kingston, Ontario.

Viscusi, W.K. 1992. Fatal Tradeoffs: Public and Private Responsibilities for Risk. Oxford University Press, New York.

Appendix A:

Summary of Information on Arsenic Loadings, Ambient Concentrations and Environmental Effects by routes other than Inhalation.

Appendix A presents limited information on loadings, ambient concentrations and environmental effects by routes other than inhalation. We present this information because it contains some interesting emission trends, however, we were unable to use this information in subsequent impact calculations.

A-1 Arsenic Loadings

This section reports the limited information available on the magnitude of arsenic loadings to water, solid waste and air from the Giant Mine.

Water

Liquid effluent from the Giant Mine settles first in a tailings pond before it is treated and released into Baker Creek. Estimated total arsenic loadings are presented in Table A-1 for 1991 - 1993. Annual loadings ranged from 956 - 1237 kgs, and the average annual effluent concentration ranged from 0.58 mg/L in 1992 to 0.35 mg/L in 1993. This latter concentration was below the NWT Water Board's effluent quality limit in place at that time (80 mg/L), but above the current effluent limit of 0.5 mg/L in the current water licence.

Table A-1: Estimated arsenic loading to water from Giant Mine

Year	Avg. Concentration (mg/L)	Total Loading (kgs)
1991	.39	956.75
1992	.58	1237.06
1993	.35	1098.64

Solid Waste

Air emissions from gold roasters pass through a series of fabric filters before being emitted from the Mine's roaster stack (Hatch, 1996). The arsenic-bearing dust from these emissions has been stored in underground chambers since 1951. Currently, there are approximately 226,000 tons of dust containing nearly 141,000 oz. of gold and 185,000 tons of arsenic trioxide. Current production at the Mine adds approximately 5500 tons of dust to these underground storage chambers per year (Royal Oak, 1993).

Air

Figure A-1 shows how airborne emissions have been reduced since the commencement of mining operations in the late 1940s. Although emissions have dropped significantly since the 1940s and 1950s, total loadings to air have remained relatively stable since 1980 (see Figure A-2). Since 1990, six stack samples have been analyzed. Daily loadings to air fell between 3.2 and 37 kgs/day, with concentrations ranging from 3.2 to 34 mg/m³. Values reported by an independent contractor, for the period 1991 to 1993, indicate an average concentration of 24 mg/m³ total inorganic arsenic (particulate and gaseous) over this period.

Figure A-1: Daily Arsenic Air Emissions (1949 - 1994)

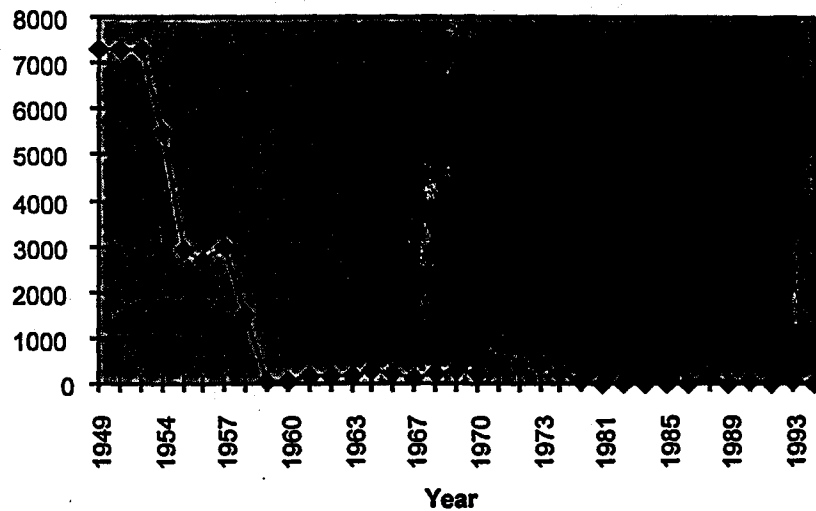
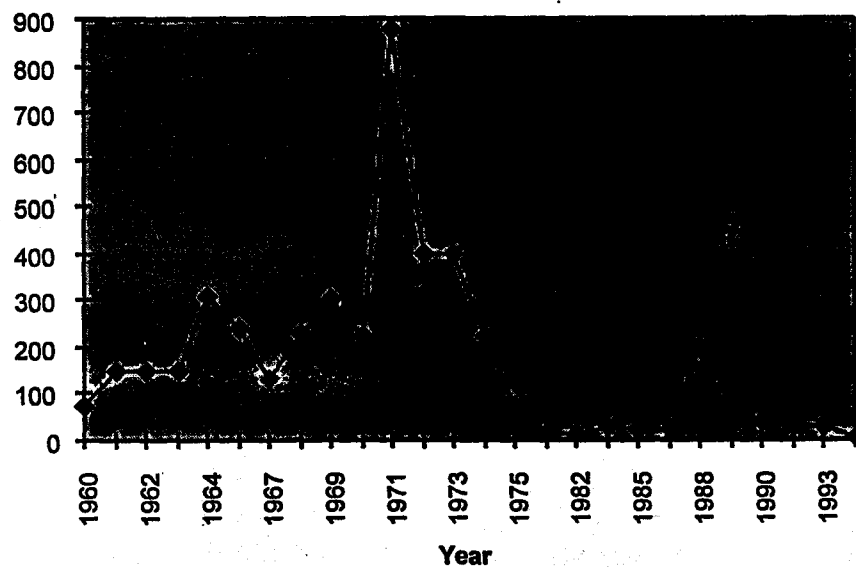


Figure A-2: Daily Arsenic Air Emissions Since 1960



Source: Hatch 1996 and GNWT 1993.

A-2 Ambient arsenic concentrations in Yellowknife

Table A-2 summarizes the ambient concentrations of arsenic measured in the Yellowknife region. The air and water concentrations are based on monitoring data collected in the region.¹⁸ Recent data on concentrations in Yellowknife food, in particular country foods, were unavailable. Data from a 1977 study conducted by the Task Force on Arsenic (CPHA, 1977) was considered to be outdated. The Yellowknife Bay - Back Bay study (DIAND, 1995) is analyzing fish samples to determine if they pose a risk to human health, however, Health Canada has not yet completed their assessment.

Table A-2: Estimated Ambient Arsenic Concentrations

Medium	Ambient Concentration	Location
Air	0.006 - 0.015 mg/m ³ average = 0.009 mg/m ³	Downtown Yellowknife *
Surface Water	Ind. Samples ranged from <0.3 - 247 mg/L; site averages ranged from 1 - 70 mg/L	Yellowknife-Back Bay study area**
Drinking Water	0.3 mg/L	Yellowknife municipal water intake***

¹⁸ We estimated airborne concentrations using monitoring data collected from a monitoring station located in downtown Yellowknife. Between 1991 and 1994, average annual concentrations ranged from between 0.006 - 0.015 µg/m³. The average annual mean over this period was 0.009 µg/m³. Surface water concentrations were obtained from the Yellowknife-Back Bay study (DIAND 1995). Annual averages at the 13 sites sampled in this study ranged from 1 - 70 µg/m³. Drinking water concentrations were based on samples collected in 1994-95 near the Yellowknife water intake on the Yellowknife river north of the Giant Mine site. Concentrations averaged 0.3 µg/L (Hamilton 1996, Halliwell 1996, Jamieson 1996). In emergency situations, the city of Yellowknife takes its raw drinking water from Back Bay. Since this occurs less than seven days per year, according to municipal officials (Jamieson 1996), we rely on a drinking water concentration of 0.3 µg/L.

- * GNWT (1993, 1994, and 1995). Air quality monitoring results from 1991-1994.
- ** DIAND (1995)
- *** Hamilton (1996) and Halliwell (1996)

A-3 Health effects arising from exposure via ingestion

The PSL assessment report for arsenic determined a study of 40,421 individuals exposed to elevated levels of arsenic in drinking water to be the most appropriate for quantifying the potency of arsenic.¹⁹ Based on this study, Health Canada estimated the drinking water potency to be between 844 and 906 mg/L. Using Yellowknife's observed drinking water concentration of 0.3 mg/L, the exposure/potency index for arsenic in Yellowknife ranges from 3.3×10^{-4} to 3.6×10^{-4} . Based on these results, Environment Canada/Health Canada's criteria for further action suggests that the priority for reducing total levels of arsenic ingested in Yellowknife is moderate to high.

Assuming a linear dose-response relationship, we calculate an increased cancer risk of between 1.7×10^{-5} and 1.8×10^{-5} due to ingestion of arsenic in Yellowknife drinking water. Put differently, if one million people were exposed to Yellowknife's average of 0.3 mg/L of arsenic in their drinking water over their lifetime, we would expect to observe between 17 and 18 additional cases of skin cancer than would otherwise occur. Assuming a population for the City of Yellowknife of 15,175, this translates to between 0.26 and 0.27 additional cases of skin cancer over the 70 year lifetime of the exposed population.

These estimates for ingestion are particularly problematic due to the fact that they do not account for exposure via food. The PSL assessment for arsenic reported that there was insufficient evidence to develop an

¹⁹ According to the PSL report, the intake of inorganic arsenic by the general population is greater in food than in drinking water, but insufficient data exists to estimate exposure/potency indices for food. Thus, we must rely on water indices, keeping in mind that this will underestimate the total exposure/potency.

exposure potency for food, so intake via ingestion is based solely on exposure via drinking water. The PSL report acknowledges that this likely underestimates the risks associated with ingestion since a larger portion of total arsenic intake will be attributable to food. This limitation creates a significant problem for our estimates since human health effects related to the consumption of country foods, in particular fish, by members of the local aboriginal community, is a priority issue for the aboriginal communities in the Yellowknife area (Sangris, 1996).

As discussed in Appendix A-3, the only recent data concerning arsenic levels in country foods is from the Yellowknife Bay - Back Bay study (DIAND, 1996), which analyzed muscle samples from fish caught at six locations around the study area. Mean arsenic concentrations at the six sampling locations ranged from 0.015 to 0.43 mg As/g. In no case did the levels of arsenic in muscle exceed or even approach the limit of 5 mg As/g set for human consumption in the *Food and Drug Regulations* (DIAND, 1995). Health Canada is currently assessing the health effects of fish consumption by aboriginal groups living in the Yellowknife region, based on the fish muscle concentrations measured in the Yellowknife - Back Bay study. Results from this assessment are expected in the near future (Jackson, 1996). Because of their preliminary nature, we have not factored these data into our numerical estimates.

A-4 Potential Environmental Effects due to exposure to arsenic in surface water and soil

DIAND (1995) identified several studies documenting the possible environmental effects of arsenic on the aquatic environment. Moore *et al.* (1979) observed that the density and diversity of benthic fauna increased progressively with increasing distance from the mouth of Baker Creek, finally showing signs of recovery 1000-1200 m into Back Bay. Baker Creek receives the treated tailings pond effluent from the Giant Mine and is associated with elevated levels of arsenic and other heavy metals (DIAND, 1995). Although Moore *et al.* (1979) further speculated that the reduction in density of bottom fauna probably reduced the food supply for bottom feeding fish such as lake whitefish, the actual impacts have never

been investigated (DIAND, 1995). According to Falk *et al.* (1973), mayflies were not present in the shallow portions of Back Bay, and their absence is likely related to their sensitivity to the pollutants present in the water column.

The Yellowknife Bay - Back Bay study (DIAND, 1995) attempted to document the effects of contaminant loading on the health of fish populations. The report concluded that the populations inhabiting the Yellowknife-Back Bay area appear "in good condition relative to other fish collected from selected other lakes in the Northwest Territories" (DIAND, 1995, p. 93). The report acknowledges, however, that information on the biology and ecology of these northern populations is limited and that further study would be required to assess the extent to which populations may be experiencing adverse effects.

With specific reference to arsenic, the Yellowknife-Back Bay study found elevated²⁰ levels of arsenic in muscle, kidney and liver tissue samples from most species collected from various locations around the study area. A review of the literature by the study's authors revealed that fish often accumulate arsenic in their liver and kidney and exhibit signs of sub-lethal toxicity. However, the authors did not check for sub-lethal indicators of toxicity and were, therefore, unable to conclude that such effects were taking place in Yellowknife-Back Bay fish populations.

The PSL assessment also reported adverse effects on pelagic organisms (amphibians and algae) exposed to arsenic in surface waters. The PSL assessment reviewed studies that reported chronic responses at concentrations of 40 mg As(III)/L and 10 mg As(V)/L. Surface water concentrations of total arsenic ranged from 0.3 -247 mg/L in the Yellowknife/Back Bay Study (DIAND, 1995). Mean concentrations ranged from 1 - 70 mg/L, with the highest concentrations measured at the mouth of Baker Creek which drains from tailings ponds used by the Giant Mine. Although it is difficult to compare total arsenic to chronic responses to As(III) and As(V), the high concentrations observed in selected samples

²⁰ Elevated in comparison to levels observed at a control site just outside Yellowknife Bay.

suggest that adverse effects on pelagic organisms due to arsenic releases from the Giant Mine are possible in surface waters located near the Mine.

The PSL assessment reported reduced growth in plants (green beans and spinach) grown in soils containing inorganic arsenic at concentrations of 10 mg As(V)/kg and 25 mg As(III)/kg. By comparison, concentrations of more than 10,000 mg/kg total arsenic have been reported in soil near two arsenic storage areas at the Miramar Con Mine site south of Yellowknife. Samples analyzed on the Giant Mine site ranged from 22 - 2380 mg/kg total arsenic (NWT Water Board, 1996). The average concentration of the 57 samples analyzed in the Giant Mine study was 777 mg/kg, and all but two exceeded CCME's remediation criteria of 50 mg/kg. Clearly arsenic in these areas of elevated concentrations is likely having a harmful effect on terrestrial plants and invertebrates. We cannot, however, estimate the extent of this impact without more information on arsenic soil concentrations throughout the region and more information on the toxicity of arsenic to local vegetation.

In summary, the accumulated effect of historic release, together with ongoing releases of arsenic from the Giant Mine are likely responsible for a variety of adverse environmental effects in the region. We lack sufficient data, however, to estimate the precise nature of these impacts and, in particular, the precise nature of the impacts arising from ongoing airborne emissions.

Appendix B:

Summary of Stakeholder Interviews

In addition to Environment Canada, Health Canada and DIAND, there are several stakeholders with an interest in how the federal government manages arsenic emissions from the Giant Mine, including:

- _ the Northwest Territorial government ;
- _ the NWT Water Board;
- _ the local municipal government;
- _ the local aboriginal community (Yellowknives Dene First Nation);
- _ Royal Oak Mines; and
- _ local environmental groups

This appendix summarizes some of the concerns and comments communicated to us by these groups. In some cases these concerns are directly relevant to airborne arsenic. In other cases, they may not be directly relevant, but may nonetheless influence the relative success of the management options and should, therefore, be taken into consideration.

We emphasize that the following are observations based on informal discussions with interested parties. Analysis of these issues was well beyond the terms of reference for our study. Accordingly, we present these concerns as possible issues to be addressed in the future if deemed appropriate by the Task Force. We have not attributed comments to specific individuals.

GNWT Department of Renewable Resources

The main concern of the GNWT Department of Renewable Resources is with respect to sulphur dioxide emissions from Giant Mine. The Department has prepared a draft regulation to control SO₂ and has circulated it for public comment. According to GNWT officials, the Territorial government has attempted, without success, to convince officials at the Giant Mine to comply voluntarily with SO₂ guidelines. As a

result, it now believes that regulations are required. When asked whether the GNWT would consider participating in a broader discussion of management options applied to the Giant Mine, perhaps in the form of an SVA or community covenant, officials replied in the affirmative, but emphasized that they would not consider delaying the regulations to accommodate such a process.

NWT Water Board

We did not meet with representatives of the Water Board, but it is clear from discussions with other stakeholders and from a review of the Giant Mine's water license, that this body plays a central role in the overall regulatory regime applied to the Mine. All parties expressed concern over the arsenic trioxide storage issue. The chief concern has to do with allocating responsibility for what are likely to be very high costs of cleaning up the site once the Mine closes. At present, the water license requires Royal Oak to conduct a study of the issue and to amend its Abandonment and Restoration Plan based on the results of this study. Some members of the Water Board Technical Advisory Committee (TAC) are apparently dissatisfied with Royal Oak's progress to date on this issue. It is difficult to predict what effect this issue may have on the upcoming license renewal in 1998.

Municipal Government

Municipal government officials are concerned about the health effects of arsenic and about the public's concern with regard to these health effects. They are, however, less concerned about airborne arsenic. They are also aware of the economic benefits flowing from the Giant Mine in terms of both direct tax contribution and indirect economic effects. The officials with whom we spoke made it clear that they would not want to see the Mine close.

Yellowknives Dene First Nation

Yellowknives Dene First Nation members are concerned about human health effects arising from past and present operation of the area's two gold mines. They do not generally make a distinction between arsenic

and other contaminants. Rather, they are concerned about the health effects from exposure to chemical contaminants in general. They believe that their water is unsafe to drink, that their food (in particular the fish from Yellowknife Bay and Back Bay) is unsafe to eat, and that the air is unsafe to breathe. They base their concerns on the historical observations of the elders, and on the fact that the incidence of cancer appears to be rising in recent years. In particular, they noted that over the last winter, two elders who had continued to fish in Yellowknife Bay died of cancer. The community attributes these deaths to exposure to chemical contaminants from fish, and see this as further evidence of a significant health risk.

According to Yellowknives Dene First Nation representatives, relations between the band and the Mine have never been good. They believe that a verbal commitment was made in the late 1940s, by the original Mine officials, to pay royalties to the Yellowknives Dene family who first discovered gold in the region and reported this find to members of the non-aboriginal community. The community still believes that the family should receive these royalties. At present, no member of the Yellowknives Dene community is employed by the Mine.

When asked about their preferred management option, Band officials expressed no strong opinion. They did, however, say that they have made several attempts to open lines of communication with Mine officials without success, and that a community covenant might be an excellent way to improve relations.

When asked what issues they would like to negotiate, band officials listed the following:

1. redirection of surface water effluents out of Back Bay to allow the Bay to recover;
2. control of stack emissions;
3. control of dust from the tailings area;
4. resolution of the underground storage issue since the community sees this as a long term threat to the entire Yellowknife Bay;
5. compensation for water bills, as the community can no longer drink the water from the Back Bay;

6. compensation for additional fishing and food gathering costs, since community members now have to travel greater distances to reach fishing and gathering areas; and
7. resolution of the royalty dispute between Giant Mine and the family who first discovered gold in the area.

Royal Oak Giant Yellowknife Mine

Royal Oak officials acknowledged to us that their relationship with the Yellowknife communities is poor. Their view is that the communities assume that a lack of regulations for SO₂ and arsenic means that the company is emitting pollutants in an uncontrolled fashion. The company acknowledges that they have made few attempts to publicize their environmental control efforts, or the fact that their record of compliance with existing regulations is good. They further acknowledged that relationships between the company and the community have soured over the last several years.

Mine officials expressed considerable interest in an SVA. The main reason for their interest was the opportunity such an approach might provide to deal directly with government agencies within a single management process. They expressed concern over a potential lack of coordination between forthcoming SO₂ and arsenic control options, and hoped that a "one-window" approach would lead to a more integrated regulatory regime that would provide an opportunity to set priorities among issues.

Local Non-Governmental Organizations

Local environmental NGOs have pushed hard for stricter regulations on Giant Mine. They have focused particular attention on airborne arsenic emissions because, in their opinion, CEPA already provides the federal government with adequate jurisdiction with respect to this issue, and that all that is currently lacking is political will. When pressed, ENGO representatives agreed that a comprehensive, integrated approach to the environmental problems surrounding the Mine would be the ideal approach, and further agreed that other issues, such as the underground storage of arsenic, pose a greater environmental threat than do

atmospheric emissions of arsenic. They felt that an SVA or community covenant sounded attractive, however, they also expressed a lack of confidence in Royal Oak's ability to negotiate in good faith. They also cautioned that these negotiation sessions should not present an opportunity to delay action. ENGO representatives also expressed a lack of confidence in the federal government acting or negotiating on their behalf. In their opinion, the federal government has not demonstrated sufficient willingness to move quickly on this issue, and expressed concern that ENGOs have not been engaged more directly in the deliberations of the Task Force.

Appendix C:

Terms of Reference for the Study

TERMS OF REFERENCE

STUDY TO ASSESS THE SOCIO-ECONOMIC IMPACTS OF REDUCING ARSENIC RELEASES TO THE AIR FROM GOLD ROASTING

BACKGROUND

The Priority Substances List (PSL) identifies substances, including chemicals, groups of chemicals, effluent and waste, which may be harmful to the environment and/or to human health.

The Canadian Environmental Protection Act (CEPA) requires Environment Canada and Health Canada to assess these substances and, where toxic as defined by the Act, to take appropriate action.

In 1994, "Arsenic and its Compounds (Priority Substances List Assessment Report) was released. The report concluded that "the current concentrations of inorganic arsenic in Canada may be harmful to the environment and may constitute a danger in Canada to human life or health". Therefore, arsenic and its compounds are considered to be toxic as interpreted under section 11 of CEPA.

Arsenic is a naturally occurring substance found most often in compounds with sulphur, either alone or in combination with various metals. Arsenic is present in the environment because of natural processes and human activities, including metal processing, the use of arsenical pesticides, coal-fired power generation and the disposal of domestic and industrial waste materials. Metal production facilities are the principal sources of arsenic released into the Canadian environment from human activities.

In 1995, the House of Commons Standing Committee on Environment and Sustainable Development released its report entitled "It's About our Health! Towards Pollution Prevention".

Chapter 13 of this report deals with "the North" and Recommendation No. 107 in this chapter states "the committee recommends that the Minister of the Environment and the Minister of Health conclude their determination of the measures they plan to apply to arsenic by December 1995". While the Recommendation itself is quite broad, the information preceding the recommendation appears to restrict it to arsenic releases in the Northwest Territories.

As a result of these two actions, the federal departments of Environment and Health have undertaken a study of arsenic releases in Canada. The first phase of the project examined:

- the effectiveness of the existing regulatory regime and control measures in reducing arsenic releases to the environment; and,
- whether further reductions in arsenic releases should be recommended given current human exposure and/or release levels, taking account of scientific, technological and socio-economic considerations.

Results of the first phase indicate that arsenic releases to the environment from most anthropogenic sources in Canada are being adequately addressed by existing regulations or the

Strategic Option Processes (SOPs) for base metal smelters, coal-fuelled power plants, iron and steel mills and wood preservation facilities.

Arsenic releases from gold roasting in the Northwest Territories are not covered by either regulations or current SOPs. Studies of existing release data and available control technologies, and their associated costs, indicate that the industry may be capable of further reductions.

SCOPE

The major sources of arsenic releases in the NWT are mines, mills and smelters. Although Environment Canada and Health Canada recognize that existing levels of arsenic in the environment may be due, in part, to historical release practices, the focus is releases resulting from current daily operations. This approach is consistent with the division of environmental protection responsibilities between the federal government and the Government of the Northwest Territories.

Environment Canada has examined arsenic releases to water for all mines operating in the Northwest Territories. Releases to water are presently controlled through the Water Licensing process of the Northwest Territories Waters Act, the general prohibition provisions of the Fisheries Act and the Metal Mining Liquid Effluent Regulations (MMLER) under the Fisheries Act. All mines generally are in compliance with the existing requirements for allowable releases of arsenic to water. Presently the AQUAMIN Program is examining the adequacy of the release limits contained in the MMLER with a view toward amending the MMLER if the program finds that the existing limits do not adequately protect the environment. As a result this study will not examine arsenic releases to water.

The only facility in the Northwest Territories currently releasing quantities of arsenic to the air is Royal Oak Mines Incorporated's Giant Mine in Yellowknife, from its gold roasting operation. CEPA, however, was not intended to be used to control activities on a site-specific basis. Therefore, the analysis of management options of a regulatory nature must be conducted on a national industry-wide basis.

OBJECTIVE

The purpose of this contract is to:

- assess the costs and benefits of three management options for reducing arsenic releases to the air from gold roasting:
 - a regulated performance standard under CEPA;
 - a structured voluntary agreement between Environment Canada and Royal Oak Mines; and,
 - a covenant between Royal Oak Mines and the community.
- recommend the management option which would be the most cost-effective and environmentally efficient should further reductions be recommended.

The key is to integrate the scientific and technical issues with the socio-economic issues so that the best management option to achieve the environmental objective is identified.

STATEMENT OF WORK

The Contractor shall complete the following tasks:

1. Assess the impacts on the groups/activities which will bear the incremental costs associated with each proposed management option:
 - a) **industry** - costs of compliance; competitiveness and trade impacts; employment effects, etc.
 - b) **government** - administrative costs; monitoring and enforcement costs, etc.
 - c) **consumers/society** - costs of inaction; employment impacts; consumer prices; availability of product; etc.
2. Assess the incremental benefits for the groups/activities which will gain from each proposed management option:
 - a) **industry** - enhanced competitiveness; new product or process marketing opportunities; etc.
 - b) **government** - political considerations, reduced administrative costs, etc.
 - c) **consumers/society** - improved health and reduced environmental risk, enhanced environmental quality, etc.
3. Assess the indirect impacts of each proposed management option to the Canadian economy or society, including the impacts on:
 - a) inflation
 - b) employment
 - c) redistribution of wealth
 - d) balance of payments
 - e) competitiveness
 - f) potential impact on small businesses
4. Recommend the management option which would be the most cost-effective and environmentally efficient should further reductions in arsenic emissions to air from gold roasting be recommended, and **provide the justification and rationale for the recommendation.**
5. In addition to the final written report based on the socio-economic study, provide a summary of the study for inclusion in Reducing Arsenic Releases to the Environment in the Northwest Territories - Final Technical Report

PROJECT COORDINATOR

Ms. Barbara Green, Economist
Regulatory and Economic Assessment Branch
Regulatory Assessment and Program Integration Division
16th Fl., Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec K1A 0H3

Telephone: (819) 953-1169

Fax: (819) 997-2769

PROGRESS REVIEWS AND MILESTONES

1. The Contractor shall meet with the Project Coordinator at the outset of the project to review and ensure understanding of the work programme.
2. Four paper copies of a draft final report (WordPerfect 6.0) will be submitted to the Project Coordinator by June 14, 1996.
3. Review comments will be submitted to the Contractor, following which the Project Coordinator and the Contractor will meet to finalize/resolve any outstanding issues.
4. Four paper copies of a final report (WordPerfect 6.0), plus a copy of the report on diskette will be submitted to the Project Coordinator by June 28, 1996.

METHOD OF PAYMENT

The Contractor will be paid upon submitting invoices, after completion and acceptance of the deliverables by the Project Coordinator.

ESTIMATED COST

The total cost of the project shall not exceed \$20,000, GST included.

BIBLIOGRAPHY

Socio-Economic Impact Analysis of Proposed Federal Regulation on Arsenic From Gold Roasting. Planning, Policy & Analysis Branch, Environmental Protection Service, Environment Canada, May 8, 1979.

Arsenic Emission Control From Pyrometallurgical Operations, W.R. Hatch Engineering Ltd., February, 1996.

Priority Substances List Assessment Report for Arsenic and its Compounds, Environment Canada, Health Canada

Reducing Arsenic Releases to the Environment in the Northwest Territories - Action Plan to Develop Management Options, Environmental Protection Branch, Environment Canada, April 23, 1996.