ROYAL OAK MINES INC. (NWT Division)
GIANT MINE

Memo To: P. Bengts, T. Canam, S. Piercey

cc. L. Flewelling, D. Anthony

From: M. Hoffman

Date: May 25, 1995

Subject: Storage of Arsenic Trioxide Underground Study

Attached is a letter from the NWT Water Board describing deficiencies in Royal Oak's studies on the Underground Storage of Arsenic Trioxide. I have also attached a scope of work that has been submitted by Royal Oak. You will note that some of you have been assigned some of these items for completion. Please proceed with this work and use the noted completion dates as targets. We will meet in the near future to discuss this. Please contact me if you have any questions or concerns.

M. Hoffman
Superintendent Technical Services

NORTHWEST TERRITORIES WATER BOARD

WATER REGISTER NO. N1L2-0043

May 2, 1995

Mr. Larry Connell
Manager Environmental Services
Royal Oak Mines Inc.
5501 Lakeview Drive
KIRKLAND, WASH. 98033
U.S.A.

Dear Mr. Connell:

RE: STORAGE OF ARSENIC TRIOXIDE UNDERGROUND - ANNUAL REPORT

The Northwest Territories Water Board has completed its review of the aforementioned report dated January 25, 1995 and is concerned that Royal Oak has not completely fulfilled their obligation in regards to the approved Terms of Reference for this study.

There are numerous deficiencies which were to have been initiated or completed in the 1994 season. Specific deficiencies are as follows:

A) ASSESSMENTS OF PHYSICAL STABILITY OF THE STORAGE CHAMBERS

Engineering assessments were not included for rock competency or bulkhead competency. Historical data assembled to date was not summarized; the report should have indicated what information exists for the storage chambers, and assessed data gaps as well as identified and initiated actions to be taken to address information deficiencies.

This section did not identify which chambers are currently not accessible, their location, and the company's proposed means to collect information.

B) ANALYSIS OF THE TECHNICAL OPTIONS FOR PERMANENT ABANDONMENT

This section should have described in detail the various options for abandonment, identified information required for an engineering feasibility study, and initiated collection of data. Overall, the work on this section appears to have been delayed or omitted altogether.

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C) ANALYSIS OF THE PERMAFROST REGIME IN THE AREAS OF THE STORAGE CHAMBERS

The report states that only six thermistors were installed to monitor the 14 chambers. A more defined monitoring program should be established to provide data for the remainder of the chambers.

D) ANALYSIS OF THE HYDROGEOLOGY IN THE AREA OF THE ARSENIC STORAGE CHAMBERS

It appears that the data collection program was not designed, collected, analyzed, nor implemented.

E) UNDERGROUND ARSENIC STORAGE - RISK ASSESSMENT

The work scheduled for the 1994 season under this section has been delayed or neglected altogether.

The Board considers this entire study very important in determining the final abandonment of this hazardous material. It appears that Royal Oak has considered this study low key and has not allocated the required personnel and effort to undertake it. The Board strongly suggests that your company seek a professional consulting firm with appropriate expertise to undertake the remainder of this study by following the approved Terms of Reference and time schedules.

If you require further assistance, please do not hesitate to contact this office. If your inquiry is of a technical nature, please feel free to contact Mr. Erik Madsen at (403) 920-8141 or Mr. John Witteman at (403) 920-8240 of the Water Resources Division.

Sincerely,

Gordon Wray
Chairman
N.W.T. Water Board

Royal Oak Mines Inc.

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2nd Floor - 1425 W. Pender St
Vancouver B.C.
V6G 2S3

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Mr. Gordon Wray, Chairman
Northwest Territories Water Board,
P.O. Box 1500,
Yellowknife, NT X1A 2R3

January 25th, 1995

Dear Mr. Wray,

Re: Storage of Arsenic Trioxide Underground at the Giant Mine - Water License N1L2-0043

Please find enclosed, two copies of the annual report on the study of scientific data relating to the permanent storage of arsenic trioxide in the underground mine workings at the Giant Mine.

This years activities were primarily that of researching historic data. In addition, a series of drill holes have been completed, and installed with thermistors, to collect data on the rock temperature.

In 1995 data collection continues and analysis of the stability of the chambers and the bulkheads begins. An updated schedule of events and completion dates for this project is also included.

This study is being conducted in accordance with Part G: Item 6 of the Giant Mine Water Use License.

If additional information is required please contact the undersigned at your earliest convenience

Regards,

Royal Oak Mines Inc.

Larry Connell
Manager of Environmental Services

cc: K. Weston
D. Anthony
M. Hoffman
R. Allan

Royal Oak Mines Inc.
NWT Division
Giant Mine

Assessment of Scientific Data Relating to Permanent Storage of Arsenic Trioxide in the Underground Workings at the Giant Mine

1994 Annual Report
Water Use License # N1L2-0043

Prepared: January 23rd, 1995

1994 Annual Report

Assessment of Scientific Data Relating to Permanent Storage of Arsenic Trioxide in the Underground Workings at the Giant Mine

Introduction:

This annual report describes the activities in 1994 towards the 5 year study to collect and assess scientific data relating to the permanent storage of arsenic trioxide in the underground mine workings at the Giant Mine.

The study is multi-disciplinary, involving geologists, mining and civil engineers, hydrologists and chemists. The study will consist of both the collection and assessment of existing data as well as new data to specifically address areas of concern.

The areas of investigation are as follows:

A) Assessment of the Physical Stability of the Storage Chambers.
This includes the following:

T. Canam — An analysis of the rock type and competency surrounding each chamber.

P. Bengts — An analysis of the competency of the concrete bulkheads isolating each of the storage chambers.

P. Bengts — An analysis of the forced ventilation in the vicinity of these storage chambers.

S. Piercey started → Preparation of plan and section views through each storage chamber indicating access drifts, raises, bulkheads etc. that have an impact on the conditions in and around these storage chambers.

Started #14 & #15 as a result of ↑ P. Bengts — Preparation of a written engineering standard for the development of future arsenic storage chambers.

P. Bengts/M. Hoffman — Development of a written monitoring program for both active and inactive storage chambers.

B) Analysis of the Technical Options for Permanent Abandonment

P. Bengts / M. Hoffman — The intent of this portion of the study is to further develop the engineering feasibility of options to close out the storage chambers in a permanently frozen state. The technical review will include the potential impact on the groundwater regime in the area of each stope.

C) Analysis of the Permafrost Regime in the area of the Storage Chambers.

Consultants. — This portion of the study will lead to a more complete understanding of how zones of discontinuous permafrost behave, in the area of the storage chambers. The goal would be to provide a mapping of rock temperatures in both the horizontal and vertical dimensions.

D) Analysis of the Hydrogeology in the area of the Arsenic Storage Chambers.
Data will be generated/collected that would lead to an understanding of the risks associated with large volumes of water coming into contact with stored arsenic trioxide.

Consultants

E) Risk Assessment Related to Underground Arsenic Storage.
A qualitative risk assessment is to be conducted in order to assist in managing possible risks that have both a high degree of hazard and a high probability of occurrence.

Consultants.

Discussion:

The following itemizes the work completed in 1994 in a format that compares to the items listed in the Introduction. This way it is possible to identify directly the progress on individual topics.

A) Assessment of the Physical Stability of the Storage Chambers:

S. Piercey
P. Bengts
Completion Sept 1995

Data files have been prepared for each of the storage chambers. Work concentrated on assembling available data on each chamber through a thorough search of data on and off site. This included plans, sections, design criteria and as-built drawings where possible.

T. Canam?

As part of the requirement for studying the permafrost regime, 6 drill holes were drilled in the mine area surrounding the storage chambers. The core was geotechnically logged and has been saved for future reference. This data will help with future stability and hydrogeological analyses where data has been found to be insufficient.

The majority of the chambers are currently not accessible, the old drifts and raises being cut-off or bypassed over years of mining. Only the active storage chamber is routinely monitored by mine personnel. The majority of the arsenic storage areas are located in the 'B' shaft area. This area includes both the main downcast ventilation system (B shaft) and the main exhaust (B ramp). The mine air is not allowed to drop below freezing and as such the local underground rock temperatures are nominally +1 to +2 degrees Celsius.

Book prepared by M. Drennan
Completion June 1995
Done

Written engineering standards are being prepared for future storage chambers at this time. The bulkhead design is being prepared by mine staff and will be reviewed by a consulting structural engineer (Ferguson, Simek and Clark in Yellowknife) as well as the Mines Inspection Branch. Construction standards are also being drawn up. The chamber design of the next storage area (#14) has been completed and will form the basis of designs in the future. The construction of #14 storage chamber will be complete in the first quarter of 1995. Following the

This is only for #14. Will this be the standard for future chambers.

commissioning of this chamber a report will be prepared outlining standards to be used in future.

B) Analysis of the Technical Options for Permanent Abandonment:

Completion of Proposal Sept 95 H.H + P.B.

No formalized work has been completed on this portion of the study.

C) Analysis of the Permafrost Regime in the area of the Storage Chambers:

Historical data on the permafrost regime is extremely limited. As such it was determined that a program to install thermistors in the area of the storage chambers was required.

In total six holes were drilled in June of 1994. Five of the holes are in the vicinity of active/inactive storage areas and one hole was drilled between the "C" and "A" shafts, in an area not influenced by active mining conditions.

Require data for 1995 from these holes

In each of the holes a string of thermistors were installed. Each of the strings reads temperatures starting 20' below surface and then at 55' intervals down to the bottom of the hole. A summary of the data from 1994 has been attached as Appendix 1, and a location map has been attached as Appendix 2. The holes were drilled to 350' below surface which is below the lowest point of any of the storage chambers. Hole A-4 was only drilled to 240' due to the proximity of underground workings.

The instrumentation was read once a week in 1994, and has proved to be very consistent week to week. As such the readings for 1994 have been presented as monthly averages, and readings in 1995 will be taken only once a month.

Isolate Storage Chambers

P. Bengts + M. Hoffman — Completion Sept 1995

Mine air is heated in winter, and as such is not allowed to fall below +2 degrees Celcius at any time of the year. The area where the storage chambers exist is also the area where the mine ventilation air enters the mine. It is also the area where the major portion of the mine air exhausts from the mine. Exhaust air generally is not less than +10 degrees Celcius. The ventilation conditions and the effect this heat source has on the rock temperatures will require further data collection and review. Will need to work on in 1996.

D) Analysis of the Hydrogeology in the area of the Arsenic Storage Chambers:

The core from the diamond drilling completed in 1994 has been saved for further analysis under this portion of the study. No formalized work has otherwise been completed.

Hire consultant. Mapping after Done + observations completion Sept 95

E) Risk Assessment Related to Underground Arsenic Storage:

Hire Consultant after Data collected

Due to the lack of basic data at this stage of the project, there has not been any formalized work completed on this particular portion of the study.

Work Schedule by Study Area:

The following outlines the projected schedule of work up to completion of this project.

A) Assessment of the Physical Stability of the Storage Chambers:

S. Piercey P. Bengts T. Carman complete Sept 95

1995 - Complete the compilation of data for each individual storage area, including preparation of plans and cross-sections.
Provide engineering assessments of rock competency and the competency of concrete bulkheads related to each storage chamber. → Status

P. Bengts M. Hoffman complete Aug 95

1996 - Complete the preparation of written engineering standards for the development of future storage chambers.
Formalize a monitoring program for active and inactive storage chambers.

1997 - Preparation of a final study report complete with stability assessments and drawings, and including engineering standards and monitoring programs.

B) Analysis of the Technical Options for Permanent Abandonment:

P. Bengts M. Hoffman complete Sept 95

1995 - Develop a list of options to be investigated and additional data required in order to develop the technical feasibility of the options. Results from 1995 research for Study A will form a basis for this work.

Status Not done Must be done in 1996.

1996 - Update results and data collection for a presentation of the feasibility of the options. Each of the options will be presented for discussion and consideration.

1997 - Further updating of results, together with a final study report outlining conclusions and recommendations for permanent abandonment of the arsenic storage chambers.

C) Analysis of the Permafrost Regime in the Areas of the Storage Chambers:

P. Bengts/M. Hoffman Consultant complete Sept 95

1995 - Continue monitoring rock temperatures from thermistor installations in 1994. Include the data in the annual progress report.
Provide a preliminary report concerning the state of the permafrost regime, by 2 and 3 dimensional analyses. Modify the monitoring program as required for better coverage and consistency.

1996 - Continue monitoring rock temperatures from thermistor installations in 1994. Include the data in the annual progress report. Update the analyses of the permafrost regime.

1997 - Continue monitoring rock temperatures and update the analyses of the permafrost regime. Prepare and submit the final study report.

D) Analysis of the Hydrogeology in the Area of the Arsenic Storage Chambers:

T. Canar Consultant complete 4pt 95

1995 - Design and implement a data collection program with input from a hydrologist and mine geologists. Prepare a report regarding predictions of possible groundwater flows and the implications of mine flooding.

Has this been done. Only know of work for #14 & #15.

1996 - Continue data collection and assessment of same.

1997 - Prepare a final study report.

E) Underground Arsenic Storage - Risk Assessment

Collect Data Consultant - Preliminary Consulting 95?

1995 - Establish the technique to be used in preparing the risk assessment. Complete the Hazard, Exposure, and Consequence portion of the risk assessment. Initiate programs to collect data and missing information as required.

1996 - Update the risk characterization portion of the risk assessment if required.

1997 - Update the risk assessment to include all data collected by other portions of the study. Complete a risk management plan based on the risk assessment.

Richard Allan, P.Eng.
Technical Services Manager - NWT Division

Appendix 1

Royal Oak Mines Inc. - NWT Division
Giant Mine

Arsenic Storage Study - Thermistor Data - Monthly Average (weekly readings) in Degree Celcius

Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-1	Collar	0	6023.43	--	--	--	--	--	--	--
	Pin 1	20	6003.43	0.0	0.0	0.0	-0.1	0.1	0.6	0.5
11198.57 N	Pin 2	75	5948.43	0.5	0.4	0.4	0.3	0.3	0.3	0.3
6262.97 E	Pin 3	130	5893.43	0.5	0.4	0.4	0.4	0.4	0.4	0.4
	Pin 4	185	5838.43	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Pin 5	240	5783.43	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Pin 6	295	5728.43	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	Pin 7	350	5673.43	0.8	0.9	0.9	0.8	0.8	0.8	0.8

Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-2	Collar	0	6047.96	--	--	--	--	--	--	--
	Pin 1	20	6027.96	0.1	1.4	3.4	5.1	5.5	4.9	4.0
10930.74 N	Pin 2	75	5972.96	2.0	1.9	1.9	1.8	1.0	1.7	1.7
6298.76 E	Pin 3	130	5917.96	1.4	1.4	1.4	1.4	1.4	1.3	1.3
	Pin 4	185	5862.96	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	Pin 5	240	5807.96	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	Pin 6	295	5752.96	0.9	0.9	0.9	0.8	0.9	0.8	0.8
	Pin 7	350	5697.96	0.9	0.9	0.9	0.8	0.8	0.8	0.8

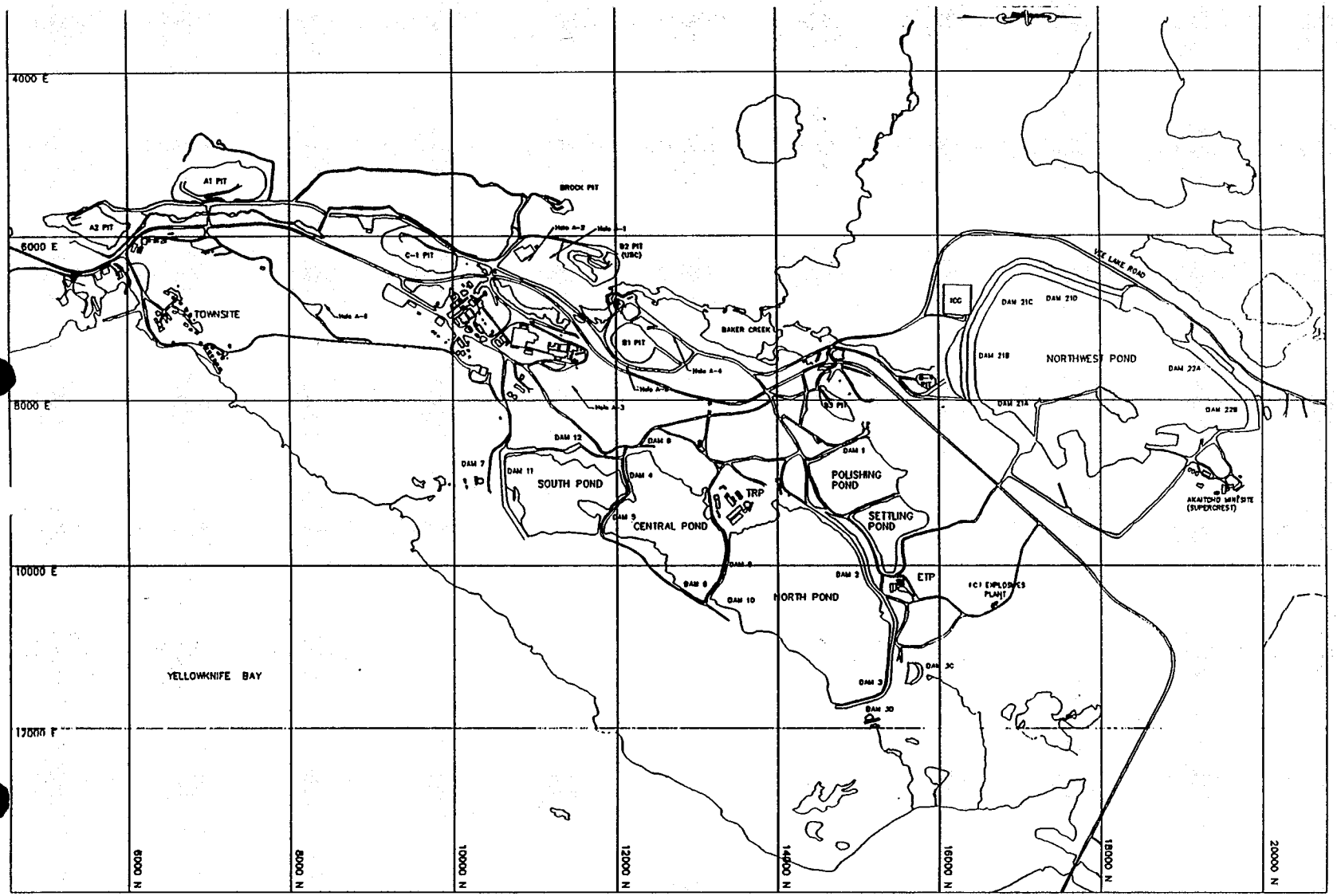
Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-3	Collar	0	6040.09	--	--	--	--	--	--	--
	Pin 1	20	6020.09	0.4	1.5	2.9	4.1	4.1	3.6	2.8
11462.13 N	Pin 2	75	5965.09	1.3	1.2	1.9	1.2	1.2	1.2	1.2
7831.88 E	Pin 3	130	5910.09	1.0	1.0	1.4	1.0	1.0	1.0	1.0
	Pin 4	185	5855.09	0.9	0.9	1.1	0.9	0.9	0.8	0.8
	Pin 5	240	5800.09	0.8	0.8	0.9	0.8	0.8	0.8	0.8
	Pin 6	295	5745.09	0.9	0.9	0.9	0.9	0.9	0.8	0.8
	Pin 7	350	5690.09	1.0	1.0	0.9	1.0	1.0	1.0	1.0

Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-4	Collar	0	6028.51	--	--	--	--	--	--	--
	Pin 1	15	6013.51	1.8	4.5	7.2	7.6	6.1	3.9	2.6
12719.98 N	Pin 2	90	5938.51	2.1	1.9	1.8	1.7	1.7	1.6	1.6
7234.30 E	Pin 3	165	5863.51	2.7	2.7	2.8	2.8	2.8	2.8	2.8
	Pin 4	240	5788.51	3.8	3.8	3.8	3.9	3.9	3.9	3.9

Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-5	Collar	0	6023.42	--	--	--	--	--	--	--
	Pin 1	20	6003.42	--	--	3.5	4.2	4.0	3.5	
12133.84 N	Pin 2	75	5948.42	--	--	0.4	0.3	0.3	0.3	
7614.36 E	Pin 3	130	5893.42	--	--	0.4	0.4	0.4	0.3	
	Pin 4	185	5838.42	--	--	0.6	0.5	0.5	0.5	
	Pin 5	240	5783.42	--	--	0.8	0.8	0.8	0.8	
	Pin 6	295	5728.42	--	--	1.1	1.1	1.1	1.1	
	Pin 7	350	5673.42	--	--	1.4	1.4	1.4	1.4	

Hole #	Location	Depth	Elevation	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A-6	Collar	0	6062.41	--	--	--	--	--	--	--
	Pin 1	15	6047.41	0.9	2.4	4.5	5.8	5.3	4.1	3.1
8442.86 N	Pin 2	70	5992.41	1.5	1.5	1.4	1.4	1.3	1.3	1.3
6837.13 E	Pin 3	125	5937.41	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Pin 4	180	5882.41	1.0	1.0	1.0	0.9	0.9	0.9	0.9
	Pin 5	235	5827.41	1.0	1.0	1.0	0.9	0.9	0.9	0.9
	Pin 6	290	5772.41	1.1	1.1	1.1	1.1	1.1	1.0	1.0
	Pin 7	345	5717.41	1.2	1.1	1.2	1.1	1.1	1.1	1.1
	Pin 8	400	5662.41	1.3	1.1	1.3	1.3	1.3	1.3	1.3

Appendix 2



NOTES:
BASE MAP: 1987 AERIAL

Royal Oak Mines Inc.

GIANT MINE
SURFACE PLAN

Thermistor Location

BY: PIERCEY / ALLAN	SCALE AS SHOWN
CHKD'	DATE SEPT. 1996

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S-92-14

NORTHWEST TERRITORIES WATER BOARD

WATER REGISTER NO. N1L3-0043

April 30, 1993

Mr. Larry Connell
Manager of Environmental
and Metallurgical Services
Royal Oak Mines Inc.
2nd Floor - 1425 West Pender Street
VANCOUVER, BC V6G 2S3

Dear Mr. Connell:

RE: GUIDELINES FOR DEVELOPING TERMS OF REFERENCE FOR THE REQUIRED ENVIRONMENTAL STUDIES: GIANT MINE

In your presentation to the Technical Advisory Committee, dated February 18, 1993, you made reference to a number of environmental studies to be conducted by Royal Oak Mines Inc. These studies are also identified in the your Licence Renewal. A Terms of Reference for each of these studies will be required to be submitted to the Board for approval.

To allow you as much lead time as possible to prepare the Terms of Reference for these studies, the Board and it's Technical Advisory Committee have prepared some objectives/guidelines for your consideration. They are as follows:

1. Arsenic Storage Vaults

a) a review of all records on bulkheads to ensure they were constructed to acceptable engineered standards and that they will isolate the arsenic wastes from the water that will infill the mine following abandonment;

b) an assessment of the competency of the rock surrounding each stope including groundwater movement now and when the mine is flooded;

c) an assessment of the status of permafrost in the stopes and an estimation of the length of time it will take for the stopes to freeze;

d) an assessment of the geochemical properties of the arsenic waste including it's solubility and its potential for and predicted extent of mobilization if it were to thaw and become exposed to water in the flooded mine;

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e) plans for future arsenic disposal, including a description of the factors considered when selecting stopes for disposal of arsenic wastes;

f) recommendations for future monitoring of existing and active stopes, including but not limited to water quality, bulkhead stability, and freezing;

g) risk assessments of the potential impacts and associated health risks after abandonment; and

h) the studies should be conducted by experts who are fully qualified in the area being assessed.

The above noted objectives were also sent to HBT AGRA Limited-Engineering & Environmental Services for their review. Their comments are attached.

2. Assessment of Acid Generation Potential and Leachability of Old and Current Tailings/Waste Rock

a) in developing the Terms of Reference, Royal Oak should consider the procedures developed by the British Columbia Acid Mine Drainage Task Force in the report entitled, "Draft Acid Rock Drainage Technical Guide Vol. 1";

b) a sufficient number of samples should be collected and analyzed to adequately represent heterogenity of the waste rock and tailings;

c) the type of predictive test (static) that will be conducted on each representative sample;

d) any further tests that may be initiated to confirm the results of the static tests; and

e) as a result of this study, identify ongoing monitoring that will be implemented.

3. Evaluate the Proposed Concept of Covering Tailings

a) the use of on-site experimental test plots is recommended to evaluate several types of covers;

b) various thicknesses should be evaluated; and

c) a monitoring program should be identified which will provide hard data such as thermistors readings and results of runoff leachate quality analyses.

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