Royal Oak Mines Inc.

Arsenic Trioxide Management
Giant Mine
Yellowknife NT

March 31st, 1998

Prepared for:

NWT Water Board
Water Register: N1L2-0043

Prepared by:

Royal Oak Mines Inc.
Giant Mine
Yellowknife NT

March 1998

Royal Oak Mines Inc.
Arsenic Trioxide Management

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1.0 Introduction:

1.1 General:

This report is submitted in accordance with the Terms of Reference that were developed for a special study of the arsenic trioxide storage chambers, required as a condition of Water Licence N1L2-0043, issued May 1, 1993. The Terms of Reference were submitted in final form on October 21, 1993, after review by the Water Board's Technical Advisory Committee..

Since the first production of arsenic trioxide dust, resulting from the refining of refractory ores, Giant Mine has constantly re-evaluated and updated its arsenic trioxide disposal practices to ensure adherence to existing regulations and to maintain the practice of environmentally acceptable disposal methods using the best available technology of the day.

With the implementation of underground arsenic storage at the site in the 1950's, the Giant Mine was recognized as providing "an environmentally sound disposal concept" which was readily accepted by the regulators of the day. In particular, this acceptance was noted in the recommendations to the Canadian Public Health Association (CPHA) by the Task Force on Arsenic (1977).

Arsenic management plans subsequently developed for the Giant Mine in the early 1990's, as a component of the mine's abandonment and restoration plan, proposed that the arsenic trioxide material would continue to be placed underground in specially designed storage areas as a final disposal procedure. The arsenic storage areas would be isolated by bulkheads and permanently frozen to minimize the potential for the material to leach into the groundwater.

With a better understanding of arsenic chemistry, mine conditions, and emerging technologies, it became evident that the continued practice of underground arsenic storage was not a completely risk free disposal method, and that other options were available.

This report describes in detail the history of the underground storage practice, the status of the individual chambers, the options for permanent disposal, and the focus of current and future work to find a viable and acceptable permanent disposal option.

1.2 Water Licence N1L2-0043:

This Water Licence was issued to Royal Oak Mines Inc. for water use and waste disposal at its Giant Mine in Yellowknife NWT, on May 1st, 1993. The Water Licence was for a 5 year term, with an expiry of April 30th, 1998.

As a condition of this Licence, Royal Oak Mines Inc. was directed in Part G: Abandonment and Restoration, to:

> "*.....submit to the Board for approval, a proposed terms of reference for a study of the arsenic storage vaults, which shall include: investigation and evaluation of the rock mechanics, geohydrology, geochemistry, permafrost, and risk assessment. The proposed study shall include an implementation schedule.*"

Royal Oak Mines Inc. submitted Terms of Reference for a study as follows:

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

The study was intended to meet several key goals, one of which was the collection of relevant scientific data related to the arsenic trioxide, and the conditions under which it is handled and stored. Secondly, to use the data to develop an acceptable closure plan, and thirdly to assess the risk involved with the closure options.

The Terms of Reference were developed around five main areas of study as follows:

- the physical stability of the storage chambers, including the bulkheads
- a review of options for permanent abandonment
- an analysis of permafrost conditions in the existing chambers
- an analysis of hydrology in the area of the chambers
- a risk assessment of the permanent abandonment options

1.3 Management Plan:

Royal Oak Mines Inc. confirms its commitment of ensuring that the long term objective of preventing the untreated release of arsenic trioxide, to the surrounding environment, is achieved.

To reach this goal, studies and investigations, according to the Terms of Reference, have been and are currently being carried out. Permanent abandonment options are currently under evaluation that include underground abandonment as well as methods to recover the material for re-processing.

As work progressed on the original study it became apparent that permanent abandonment underground was not the most attractive, or technically feasible, option, and contained inherent risk.

In 1997 Royal Oak Mines Inc. changed the focus of its attention to the investigation of the technical and economic viability of recovering the arsenic trioxide bearing dust from the underground storage areas, and bringing it to the surface where it would be processed and upgraded into a marketable product.

This work is focused on three primary areas:

i) Development of mining techniques to safely and effectively recover the arsenic trioxide bearing dust from the underground vaults and to transport it to surface storage facilities.

ii) Development of process technology to upgrade the arsenic trioxide bearing dust into a refined arsenic trioxide product suitable for sale.

iii) Analysis of the current market status and the outlook for world supply for an upgraded arsenic trioxide product.

The work also includes identification and evaluation of methods to handle and treat final residues that will account for 10 to 15% of the total recovered material. These residues contain significant quantities of gold which may be recovered, as well as containing significant residual quantities of arsenic trioxide.

Royal Oak believes that if technical and economic viability can be established, the removal of the arsenic bearing dusts from underground storage and conversion to a marketable product offers the best long term solution to mitigate potential environmental impacts with the storage of arsenic trioxide at the Giant Mine.

2.0 Site Description:

2.1 Physiography and Infrastructure:

The Giant Mine Site is situated approximately five kilometres north of the City of Yellowknife, adjacent to Great Slave Lake along the western shore of Yellowknife Bay (Figure 1- *Location Plan*). The mine is situated within a zone of discontinuous permafrost and the local topography is characterized by a series of exposed bedrock highs with minor overburden deposits in low lying areas.

The mine site infrastructure consists of several buildings which are required for the production of gold. Included within the infrastructure are the mill, several office buildings, the mine headframe, and various buildings housing support service such as engineering, carpentry, electrical, and mechanical shops.

Waste produced by the mining operation, from processing the ore, is deposited in two tailings impoundments, the Northwest Pond (primary) and the North Pond (secondary). There are also two additional ponds which are used for water treatment purposes, the Settling and Polishing ponds. All effluent discharge is treated in a plant then passed through the two ponds before final release to the environment (ie: Baker Creek). A detailed site description is provided as Figure 2 - *Site Plan*.

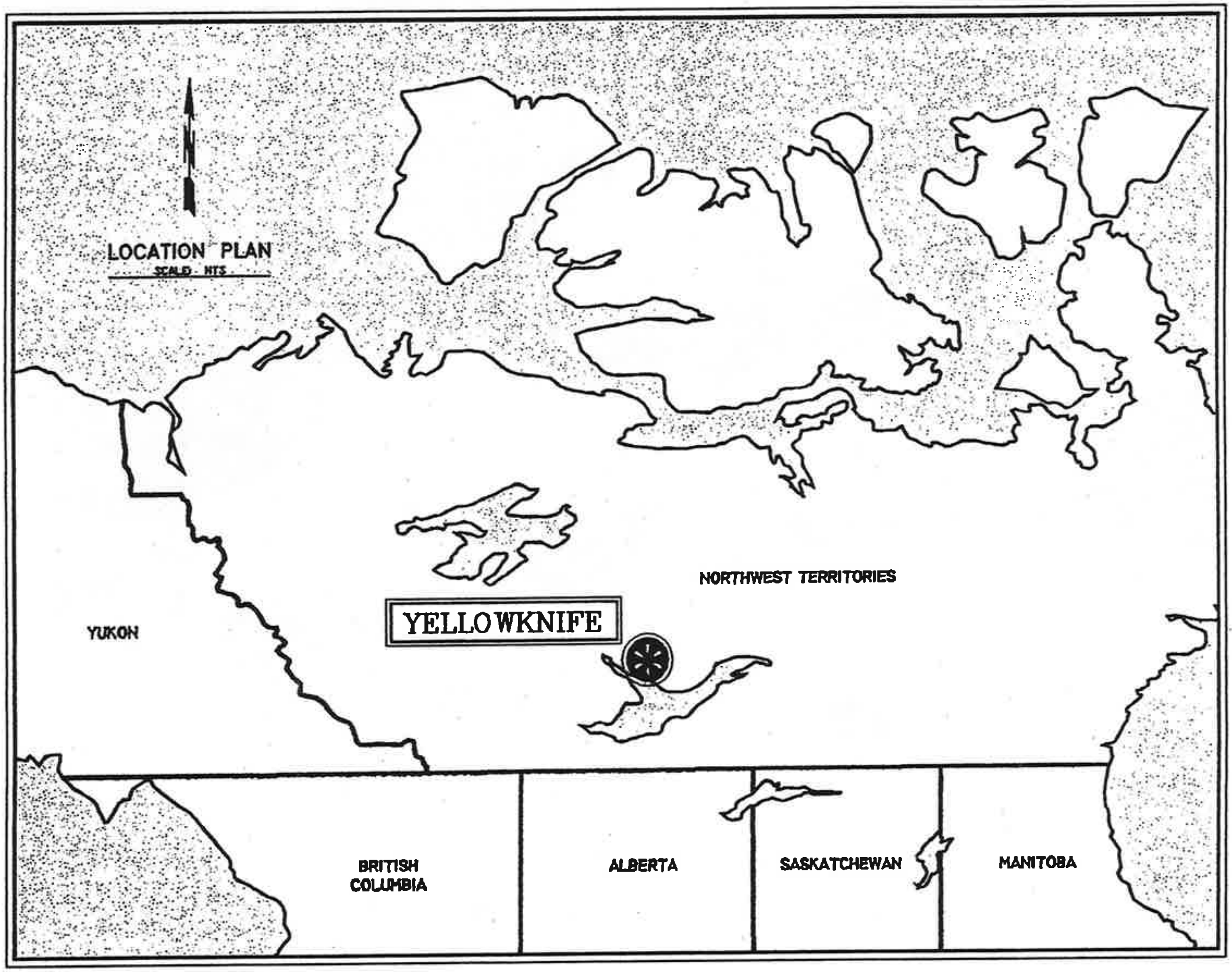
The site is located within a northerly trending valley, at an approximate surface elevation of 220 metres, with prominent topographical highs forming the valley walls. Baker Creek flows southerly toward Yellowknife Bay along the valley floor. (Figure 3 - *Air Photo*)

2.2 Geological Setting:

The Giant Mine is located within the structurally complex Yellowknife Greenstone Belt of Archean Age on the geological time scale. The belt extends from Great Slave Lake for a distance of over 50 kilometres. and is comprised of a homoclinal steep easterly to vertically dipping sequence of metabasalts and metagabbros intruded by sheeted dykes and overlain by sedimentary units. The package of rocks was subsequently intruded by granitic intrusions. (Figure 4 - *Regional Geology*)

Gold mineralization is present within the metabasalt units, associated with arsenopyrite mineralization. The rocks have undergone middle greenschist to middle amphibolite facies metamorphism. Arsenopyrite is a naturally occurring arsenic bearing mineral. The gold mineralization is refractory meaning that the arsenopyrite mineralization must be broken down and oxidized to allow the recovery of the gold.

The Yellowknife Greenstone Belt is a structurally complex sequence of rocks. Three prominent fault trends exist within the Giant Mine; 000 to 025° , 060° , and 160°,



Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEMENT

TITLE: LOCATION MAP

LEVEL: SURFACE	SCALE: 1" = NTS
DRAWN: MSL CHECK:	DATE: DEC. 8, 1997

Figure 1

NOTES:
BASE MAP: 1997 AERIAL

Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEMEN

TITLE:
SITE PLAN

LEVEL: SURFACE		SCALE: 1"= NTS	
DRAWN: MSL	CHECK:	DATE: JAN. 29, 1997	

Figure 2

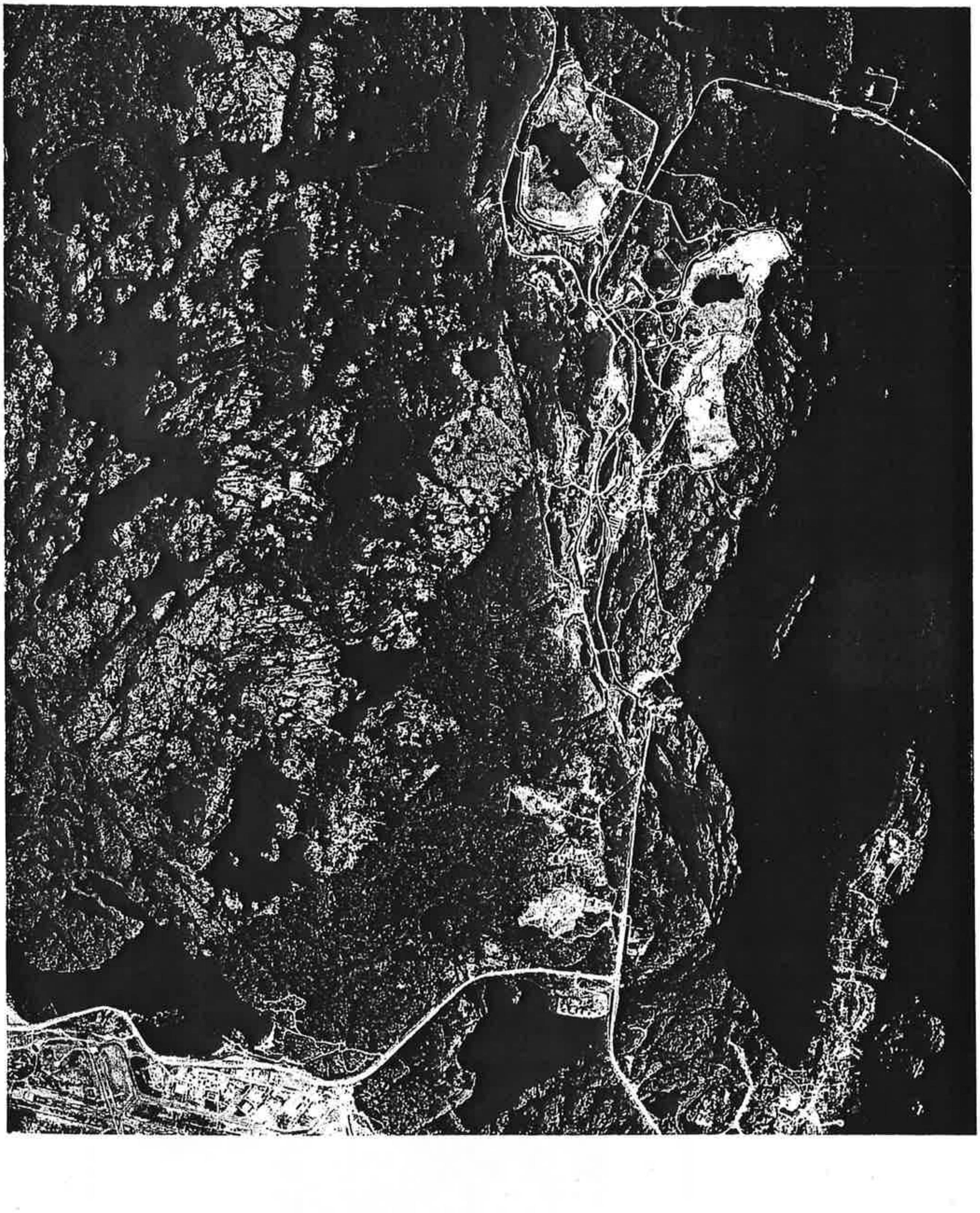
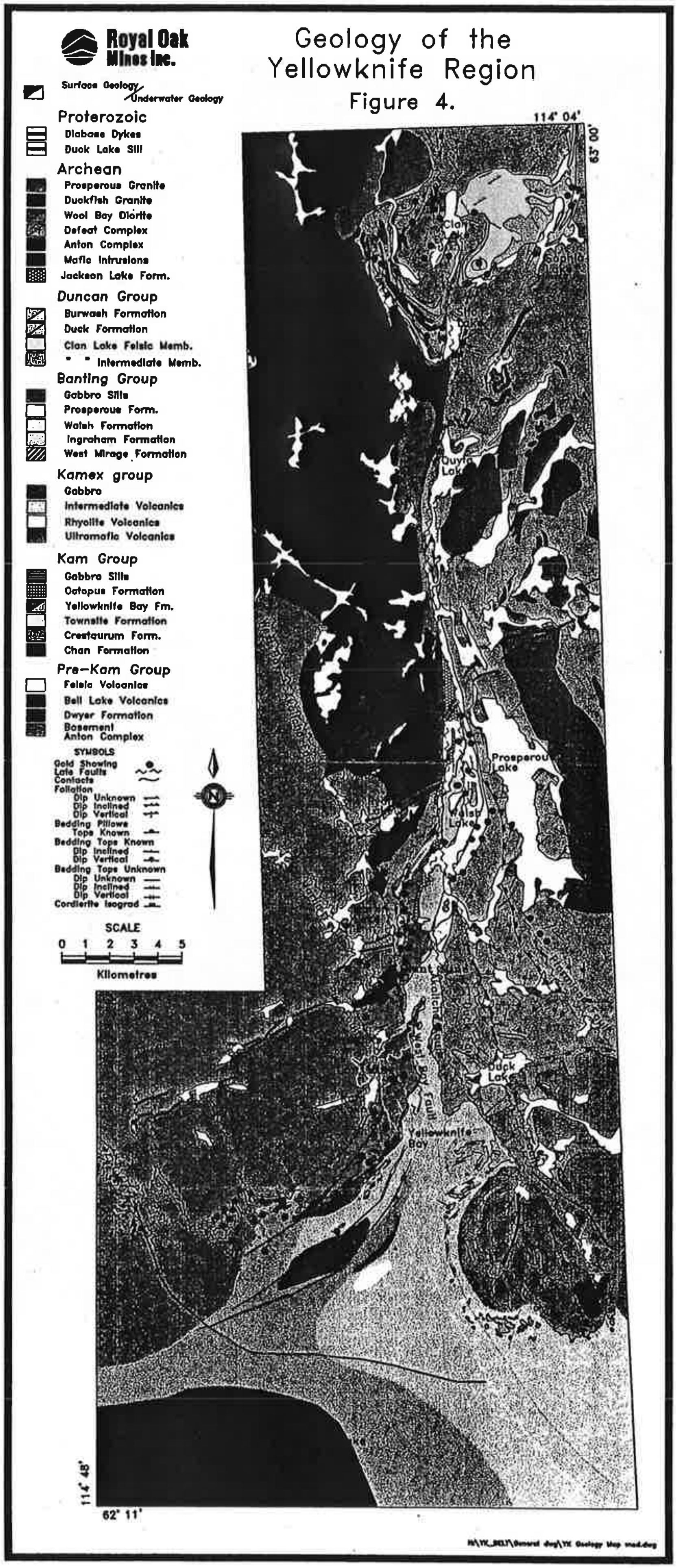


FIGURE 3


Geology of the Yellowknife Region
Figure 4.

with the main structural features known as the Town site Fault, the 3-12 Fault, and the West Bay Fault. The 160° faults are prominent faults with variable easterly dips and are characterized by clay fault gouge and breccia. The sense of movement on these faults is sinistral. The 060° faults are generally characterized by having little or no clay gouge and may appear as thin hairline fractures. The sense of motion on these faults is dextral and they dip to the west. Faults with the 060° trend may occur as major faults or appear as lesser faults. Water seepage into the mine generally occurs along the major fault zones.

2.3 Hydrogeological Setting:

Hydrogeologically, the groundwater regime present at the Giant Mine is controlled by the regional topography and complex structural geology. Groundwater movement will occur predominantly as fracture flow, as is evidenced from observations noted within the mine workings.

The mine currently produces approximately 450 igpm of water which is collected and discharged to the tailings pond for seasonal treatment. Of this total discharge, approximately 120 igpm is fresh water pumped into the mine for use in mine operations. The remainder (330 igpm) is water that flows into the mine from surface water bodies or underground aquifers through fractures, precipitation that collects and drains into the mine from pits, ramps, shafts and open raises, and seepage from the active NW tailings pond through fractures and boreholes.

Little evidence or reports of original groundwater movement are available. The mine has been in production for 50 years and therefore the regional groundwater table has been severely depressed in the mine area.

Baker Creek is the main water course through the mine property, and discharges to Great Slave Lake at Yellowknife Bay, at the extreme south end of the property. The stream channel is a potential groundwater discharge zone, with the local topographic highs representing recharge areas.

3.0 Mine History:

3.1 General:

The first major discoveries of gold in the Yellowknife area were made in 1934. The original claims on the Giant property were staked in 1935 by C.J. Baker and H. Muir. Giant Yellowknife Mines was subsequently incorporated in 1937.

The mine has been in operation since 1948 producing over seven million ounces of gold since the initial discovery.

The Giant Mine is operated primarily as an underground mine, at an approximate production rate of 1100 tonnes/day. Several inactive open pits, mined in the 1980's, are also present on the site. The ore body has a strike length of over 4500 metres and is currently accessed through a main production shaft and two ramp systems. Several inactive shafts, adits, ramps and raises are evident throughout the property. Mining is principally by mechanized cut and fill methods.

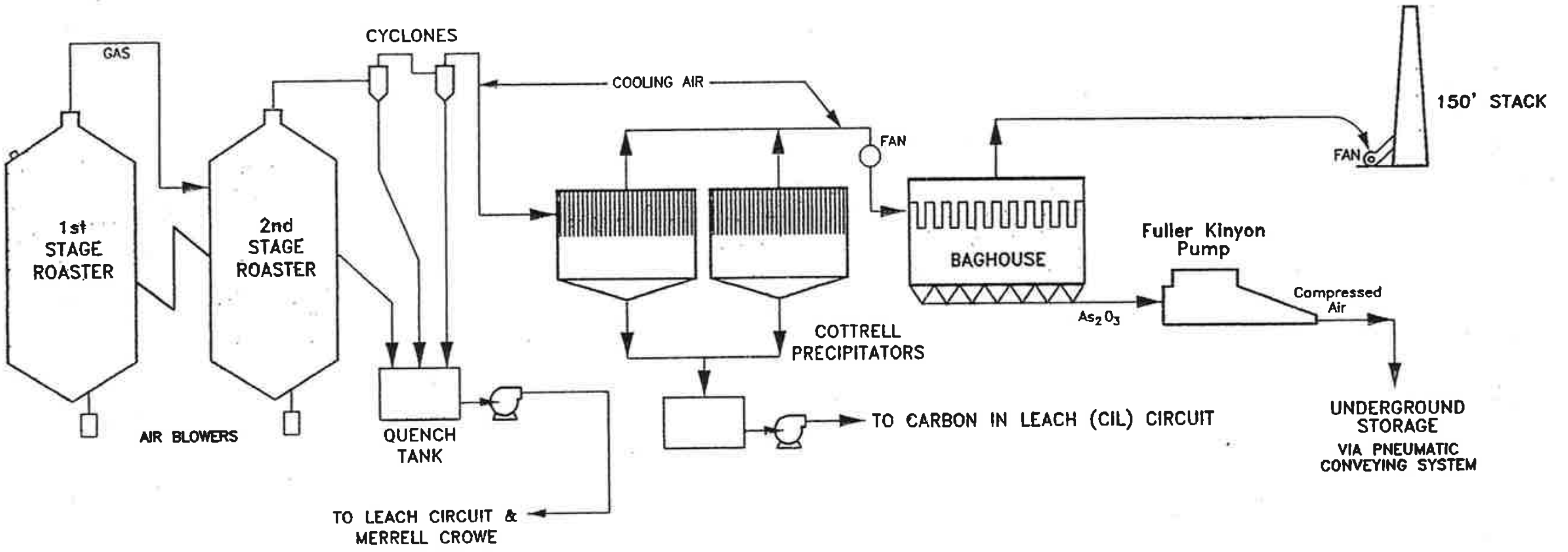
3.2 Arsenic Trioxide Management:

Arsenic trioxide dust is currently produced at the Giant Mine at an approximate rate of 9 to 12 tonnes per day as a by product of the gold milling operation.

The primary gold bearing mineral at the Giant Mine is arsenopyrite. The gold contained in this arsenopyrite is not recoverable until the arsenopyrite crystal lattice has been physically broken apart and the contained arsenic and sulphur mineralization is removed. The conversion process employed at the Giant Mine consists of high temperature roasting of an arsenopyrite concentrate from the flotation circuit. The arsenic is oxidized to form volatile arsenic trioxide which is condensed from the roaster gas stream and recovered in a conventional baghouse dust collector. The baghouse dust is then pneumatically conveyed into underground storage chambers. A schematic of the roaster operation is provided as Figure 5 - *Roaster Gas Flowsheet.*

The underground storage of arsenic trioxide dust was initiated in 1951, with the arsenic placed in specially designed chambers excavated in waste rock (massive volcanic units). The first series of chambers were located within several hundred feet and to the north of the baghouse, and accessed by raise to surface. From 1962 through 1976 the dust was placed in abandoned production stopes (B208, B212, B213, B214, and C212). Since 1976 the dust has been placed in specially designed chambers excavated in waste rock, in various locations.

Currently, there are a total of fifteen storage chambers in which arsenic trioxide bearing dust has been stored. A new storage chamber, identified as B15, is under development, and will be put in service late in 1998. Storage locations are identified on Figure 6 - *Surface Plan with Chamber Locations*.



ROASTER GAS FLOWSHEET

Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEME

TITLE:
ROASTER GAS FLOWSHEE

LEVEL: | SCALE: "= NTS
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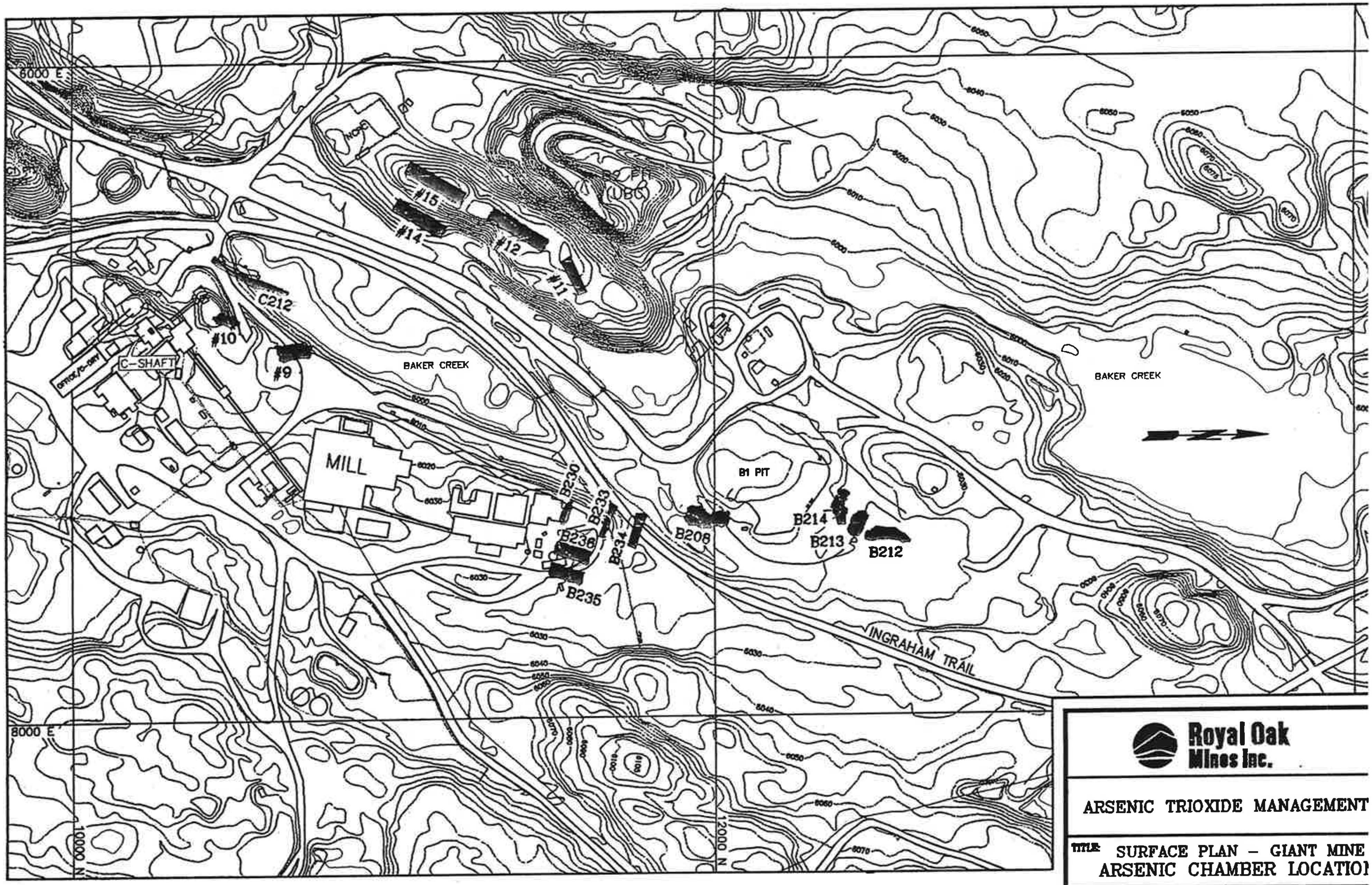
Figure 5



Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEMENT

TITLE: SURFACE PLAN – GIANT MINE
ARSENIC CHAMBER LOCATIO

LEVEL: SURFACE
SCALE: 1" = NTS
DRAWN: MSL
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DATE: MARCH 20, 1998

Figure 6

4.0 Review of Arsenic Chemistry:

4.1 General:

A review of the current understanding of arsenic chemistry, its occurrence, species, fate, and toxicity, was commissioned by Royal Oak Mines Inc. in 1996. Seacor Environmental Engineering Inc. completed the study, which was intended to be a reference document. Excerpts are included here for the purposes of this report. The information in the report was meant to be used for routine safety and hygiene planning and monitoring, site contamination and remediation planning, as well understanding the properties of arsenic trioxide, the main focus of this report.

4.2 Occurrence:

Arsenic is a naturally occurring element found in soils and minerals and air and water. Arsenic occurs in the environment as a native element, alloy, arsenide, sulphide and oxide.

Natural background concentrations of arsenic in the atmosphere arise primarily from wind blown dust, plants, sea salt spray, forest fire smoke, and volcanic emissions.

The abundance of arsenic in common igneous, sedimentary and metamorphic rocks varies from less than one ppm to several hundred ppm. In mineral form, arsenic is usually found in association with sulphur, and most commonly as arsenopyrite (FeAsS).

The abundance and distribution of different arsenic-containing rocks affect arsenic levels in the soils derived from these rocks. Natural background levels of arsenic in soil, across Canada, rarely exceed 15 ppm, and are typically around 5 to 6 ppm, depending on the geographic region. Arsenic levels within bedrock from the Yellowknife area can range from less than 5 ppm to values in excess of 6500 ppm (Boyle, 1979). For additional information on the occurrence of arsenic in the Yellowknife area, refer to the report '*Surface Contamination Study - Giant Mine*', prepared by EBA Engineering Ltd. for Royal Oak, and submitted to the NWT Water Board, March 11th, 1998.

4.3 Properties of Arsenic:

Arsenic is a metalloid within the Group VA elements of the Periodic Table, together with nitrogen, phosphorus, antimony and bismuth. Arsenic shares several chemical properties with phosphorus. As a result, arsenic competes with phosphorus compounds for binding sites within organisms, which is one of the principal means through which its toxicity is expressed.

The normal valence states of arsenic are 0, +3, and +5. Arsenic occurs occasionally in nature in its elemental state As(0), but more typically is found in higher oxidation states in combination with sulphur alone or in combination with various metals.

The most important commercial arsenic component is arsenic(III) oxide. The solubility of arsenic trioxide increases with temperature, and is highly soluble in both acid and alkali conditions. Solutions of arsenic trioxide are slightly acidic.

4.4 Species, Fate and Toxicity:

Arsenic undergoes oxidation-reduction, precipitation-dissolution, adsorption-desorption, and organic-biochemical methylation reactions depending on site conditions. Mobilization and bioaccumulation of arsenic in the environment is ultimately controlled by these reactions.

Concentrations of arsenic in the environment and its availability to living organisms, and hence its potential toxicity, is governed more by the species of arsenic present than total abundance of arsenic. As(III) compounds are many times more toxic than As(V) compounds. A dose of 100 mg of arsenic trioxide induces toxic affects in humans.

Arsenic can enter the human body via ingestion of contaminated food and water, inhalation of arsenic containing dust, or absorption through the skin.

Human absorption of arsenic can be assessed through the measurement of arsenic in the blood, hair, and urine. Due to the short half-life of arsenic in blood, the blood arsenic determination has been found to be of little practical value in assessing occupational exposure to arsenic. The major drawback to the determination of arsenic in hair is that it does not distinguish systematically absorbed from externally deposited arsenic. Urine sampling is considered the best indicator of current or recent (1 to 3 days) past exposure to arsenic.

5.0 Current Practice - Storage and Handling of Arsenic Trioxide:

5.1 Production and Delivery Systems:

(operational notes updated March 1998)

The existing roaster installed at the Giant mine consists of a two stage Dorrco Fluo-solids roaster. This roaster currently operates with two Cottrell hot precipitators, one active, the other on standby, which collect dust from the roaster exhaust gas. After passing through the hot Cottrells, the roaster gases are air cooled to 224° F for arsenic fume condensation before entering the baghouse. Filtered gases from the baghouse continue on through a booster fan to a 45.7 metre (150 foot) brick discharge stack. The dust from the hot Cottrells is processed for gold recovery and the arsenic collected in the baghouse is pneumatically conveyed to underground storage. (Figure 5 - *Roaster Gas Flowsheet*)

The baghouse for the collection of arsenic is an eight compartment, No. 30 Dracco type. Each compartment contains three hundred, 5 in. dia. by 10 ft. long Orlon bags. A shaking device (triggered by pressure drops across the filter), is provided for dislodging the dust from the bags. Each of the eight compartments is provided with a V shaped hopper and screw conveyor for the collection and removal of the arsenic. A cross collection conveyor and a Fuller Kinyon pump are provided to transfer the arsenic to underground storage.

The gas volume leaving the roaster is approximately 14,700 cfm at 850° F. These gases are air tempered to a volume of 15,300 cfm at 792° F before entering the hot Cottrell. The temperature drop across the Cottrell is 100° F. The average of 9 tonnes of dust collected daily in the Cottrells contains 85 % of the gold in the roaster exhaust gases. Further air tempering at the mixing fan gives a volume entering the baghouse of approximately 29,260 cfm at 224° F. The baghouse dust product contains greater than 99% of the arsenic content in the gases leaving the hot precipitator. The final arsenic bearing dust that is transported underground has a composition as shown in Table 1 (current production).

Transportation of the arsenic dust produced by the roaster operations, is by pneumatic stowage-conveyance of the material passing through a standard 100 millimetre (4 in.) diameter steel pipe from the baghouse building to the particular arsenic chamber being filled. The pipes are run underground in drifts used for this purpose only. These distribution drifts are remote from the active production mine workings.

In the more recent designs, several delivery pipes enter the chamber through an engineered concrete bulkhead, in the upper access to the chamber. The delivery lines are of varying lengths inside the chamber. The longest line into a chamber is utilized first, filling from the back of the chamber towards the front. As the chamber fills, the lines are switched to each shorter line. In some of the older chambers, full utilization of the chamber volume was ensured by multiple delivery points in some cases using 76 millimetre (3 in.) diameter boreholes.

The air used to transport the dust into the chamber is returned by a parallel 150 millimetre (6 in.) diameter pipe and is vented back into the baghouse inlet flue. The system is therefore a closed system. Dust loss does not occur during transportation, as the only place for the dust to settle out of the transportation air bed is inside the storage chamber being filled. Normal operating pressure, during filling of the chambers is .14 to .28 bar (2 to 4 psi). Maximum pump pressure is 1.1 bar (15 psi).

A back-up system of transporting the arsenic trioxide dust, is also in place at the mine site in the event of mechanical problems with the pneumatic transportation system. The dust can be pumped directly into the storage chamber from the surface via reamed long-hole drill holes or diamond drill holes. A vacuum or bulk delivery truck is used in the contingency program to transport the dust from the baghouse to the surface access points using the existing road network on the property.

A silo structure of 425 cubic metres capacity (15,000 cubic foot), situated adjacent to the baghouse is also used for arsenic storage purposes in the event of a shut down of the underground pneumatic disposal system. The silo can store 10 to 15 days of baghouse dust at current production rates. The silo is maintained under negative pressure as air is displaced while it is filled. The air is drawn through a fabric baghouse type filter and returned to the roaster gas handling system. Precautions are taken, by way of safety devices, and lock-outs, to prevent any material leaving the silo and entering the loading equipment when a truck is not in position.

As a component of the mine's existing arsenic trioxide recovery and storage system, safety measures to minimize the potential exposure to arsenic have been implemented. These measures include the wearing of protective clothing, dusk masks and respirators and the implementation of regular testing to accurately measure a worker's exposure to arsenic.

5.2 Chamber Locations and Description:

Currently there are 15 underground storage chambers, including the active B14 storage chamber (Figure 6 - *Surface Plan with Chamber Locations)*. The storage areas contain approximately 235,000 tonnes (260,000 tons) of dust containing approximately 182,000 tonnes (200,000 tons) of arsenic trioxide (to Dec. 1997). The underground storage of arsenic was initiated in October 1951 and continues to the present day. A detailed inventory of each of the 15 storage chambers is provided in Table 2.

The current arsenic storage chambers are specially designed storage chambers, rectangular in shape, however five of the chambers are mined out production stopes, of irregular shape.

Table 2

Underground Arsenic Trioxide Inventory - December 31, 1997

Stope	Date Filled	Volume cu. ft.	Tons Dust	Percent Arsenic	Tons Arsenic	Tons Equiv. As2O3	opt Gold	Ounces Gold
B 230	Oct. 28/51-Dec. 15/52	100,000	3,125	45.31%	1,416	1,869	0.724	2,263
B 233	Dec. 16/52-Mar. 1/56	434,626	12,595	36.93%	4,651	6,139	1.671	21,046
B 234	Mar. 2/56-July 10/58	425,000	13,281	36.10%	4,794	6,328	2.332	30,971
B 235/238	July 11/58-Mar. 15/62	1,125,000	35,156	53.37%	18,763	25,852	0.790	27,773
B 235	Aug. 22/88-Nov. 29/88		1,160	60.78%	705		0.142	165
B 236	Dec. 12/88-Dec. 30/88		184	63.59%	117		0.228	42
B 208	Mar. 16/62-Dec. 31/64	806,840	25,033	65.75%	16,458	28,055	0.381	9,526
	Jan. 1/72-Sept. 1/72		4,704	64.86%	3,051		0.330	1,600
	July 1/75-July 31/75		394	63.71%	251		0.120	48
	Dec. 17/75-Jan. 9/76		355	65.92%	234		1.950	69
	Mar. 11/86-Sept. 26/86		1,882	66.95%	1,260		0.120	225
B 212/213/214	Jan.1/65-Dec. 31/71	1,920,000	60,410	61.48%	37,141	53,269	0.468	28,273
	Sept. 1/72-June 14/73		4,945	64.99%	3,214		0.262	1,294
C 212	June 14/73-June 30/75	638,139	10,243	64.23%	6,579	16,175	0.217	2,224
	Aug. 1/75-Dec. 17/75		1,794	65.44%	1,174		0.130	234
	Jan. 10/76-May 21/76		1,875	65.12%	1,221		0.140	258
	June 1/80-Jan. 9/82		3,757	69.68%	2,618		0.101	378
	May 22/85-Mar. 1/86		1,011	65.48%	662		0.120	121
C 9	May 21/76-May 31/80	471,000	20,276	67.48%	13,683	18,062	0.124	2,512
C 10	Apr. 1/82-May 22/85	200,000	10,548	66.83%	7,049	9,305	0.134	1,408
B 11	Sept. 26/86-Aug.22/88	347,250	6,331	67.52%	4,275	5,747	0.137	867
	Nov. 30/88-Dec. 12/88		128	61.72%	79		0.227	29
B 12	Dec. 30/88-Dec. 31/94	900,000	27,417	69.78%	18,048	23,823	0.174	4,769
	Nov. 15/97-Dec. 31/97		353	68.72%	243	321	0.133	47
B 14	Jan. 1/95-Nov. 14/97	424,000	10,036	65.48%	6,572	8,675	0.159	1,597
	Jan. 98 ==> active							
Total:	Oct. 28/51 - Dec. 31/98	7,791,855	266,993	60.02%	164,258	203,620	0.536	137,739
			Eq. % As2O3:	79.2%				

* data compiled from historic, daily mill reports

Table 1

Analysis of Baghouse Dust

(Composite Sample September 1997)

Element	Unit	Giant Lab	Lakefield	Maxxam
Arsenic	%	66.09	68.50	58.10
Antimony	%	1.05	1.16	1.39
Iron	%	2.50	1.50	1.61
Aluminum	ppm		5500	2540
Barium	ppm		15	2
Beryllium	ppm		<1.0	<0.1
Cadmium	ppm		<5.0	1.1
Calcium	ppm		3900	3540
Chromium	ppm		14	11.3
Cobalt	ppm		20	17.1
Copper	ppm		350	143
Lanthanum	ppm		<50	1.61
Lead	ppm		490	453
Lithium	ppm			2.9
Magnesium	ppm		2600	2270
Manganese	ppm		80	94.1
Mercury	ppm			14.3
Molybdenum	ppm		<10	1.9
Nickel	ppm		44	41.3
Phosphorus	ppm		62	41
Potassium	ppm		1600	178
Selenium	ppm		<50	<1
Silicon	ppm			429
Silver	ppm			3.1
Sodium	ppm		390	185
Tellurium	ppm		<10	
Thallium	ppm			0.13
Tin	ppm		<20	
Titanium	ppm			12.7
Uranium	ppm			<50
Vanadium	ppm			10.9
Yttrium	ppm		<5.0	
Zinc	ppm		170	137
Zirconium	ppm			1.27

Each of the storage areas is isolated from the mine workings by a reinforced concrete bulkhead. It is noted that in some areas the isolation of these areas has been upgraded with the addition of secondary concrete bulkheads, or cement/tailings plugs. All bulkheads have been designed to withstand hydrostatic pressures.

The fifteen arsenic storage chambers are grouped into four specific groupings, representing the various years in which disposal occurred, and common access points.

The first grouping includes the earliest chambers used and hence the location of these chambers are in the immediate vicinity, and almost directly below, the baghouse and roaster stack. This grouping is composed of chambers numbers B208, B230, B233, B234, B235, and B236.

The second grouping is located about 300 metres (1,000 ft.) northeast of the mill, adjacent to the northeast side of B1 pit, and is comprised of chambers B212, B213, and B214. These chambers were originally serviced by an Arsenic Distribution drift (208 A.D. Dr.), located some 25 ft above the 1st level (100 lvl), however the mining of B1 pit resulted in the A.D. drift and 1st level being mined out between B208 stope and the B214 stope.

The third grouping consists of chambers C9, C10, and C212 and is located southwest of the mill. This group is accessed from the C Shaft and also from a raise which extends to surface. C212 was a production stope, while C9 and C10 are specially designed chambers.

The fourth grouping includes the most recently developed storage chambers, B11 to B15. The location of these chambers is west of the mill on the west side of Baker Creek under a local topographical high. It should be noted that storage chamber B15 is currently under development, with the storage capacity of B14 expected to be reached by the fall of 1998.

5.3 Design Criteria:

Data indicates that the concept of storing arsenic in underground chambers was proposed for the first time in 1950 by Senior Mine Personnel. The scheme was considered viable at that time based on evidence of extensive occurrence of permafrost in the bedrock, during mining, and confirmation by exploratory drilling and temperature measurements. The first storage chamber (designated B230) was constructed in 1951, and was filled in about one year.

There is evidence that cold air was circulated into empty chambers and also the upper part of filled chambers to reinstate permafrost, that may have receded during mining or filling operations.

By 1960, the Mine concluded that any underground opening would be suitable for arsenic trioxide storage "provided not so much that the area is in permafrost, but that the area is free from water flow or seepage". In 1962, for the first time, a former production stope was converted to use for arsenic storage. This practice continued until 1976, when C212 was filled. C212 was the last of the candidate 'production stopes' that fulfilled the design criteria, including being above the perceived lower elevation of permafrost.

In 1976 the mine began again, the practice of constructing special chambers for arsenic trioxide storage.

The design of the storage chambers has considered the following general criteria since the practice began:

-the chambers were to be located and enclosed in an envelope of permafrost

- the openings were to be sealed to prevent the escape of arsenic trioxide dust

- the storage areas were to be excavated in competent ground and the storage area was to be dry before arsenic storage commenced

It should be noted that the dust compacts dramatically after initially being delivered to the chamber, such that the chamber can be 'topped off' several times before it is really full. These repeat fillings are noted in Table 2.

5.4 Assessment of Chamber Integrity:

Various studies have been implemented by the staff at the Giant Mine with the objective of evaluating the long term stability of the underground storage chambers. Each of the individual chambers has been drawn or reformatted into an AutoCad drawing format for presentation, and further review for stability, and recovery potential. These drawings have been placed in Appendix I.

There is no evidence in any of the available data base of any instability in any of the vaults during or subsequent to construction.

5.4.1 Chamber Stability:

Storage chambers B14 and B15 were evaluated in 1996 for structural features that may contribute to potential groundwater migration of the stored arsenic trioxide material. Five diamond drill holes were collared within the lower sill of the storage chamber B15 to assess the rock competency and to locate any major structural features near the chamber. Evaluation using the CSIR RMR (Rock Mass Rating), a modified NGI Q (Tunnelling Quality Index), and RQD (Rock Quality Description) techniques indicate rock of good quality. RMR values ranged from 61 to 75 in the chlorite schist unit to 67 to 83 in the massive volcanic unit.

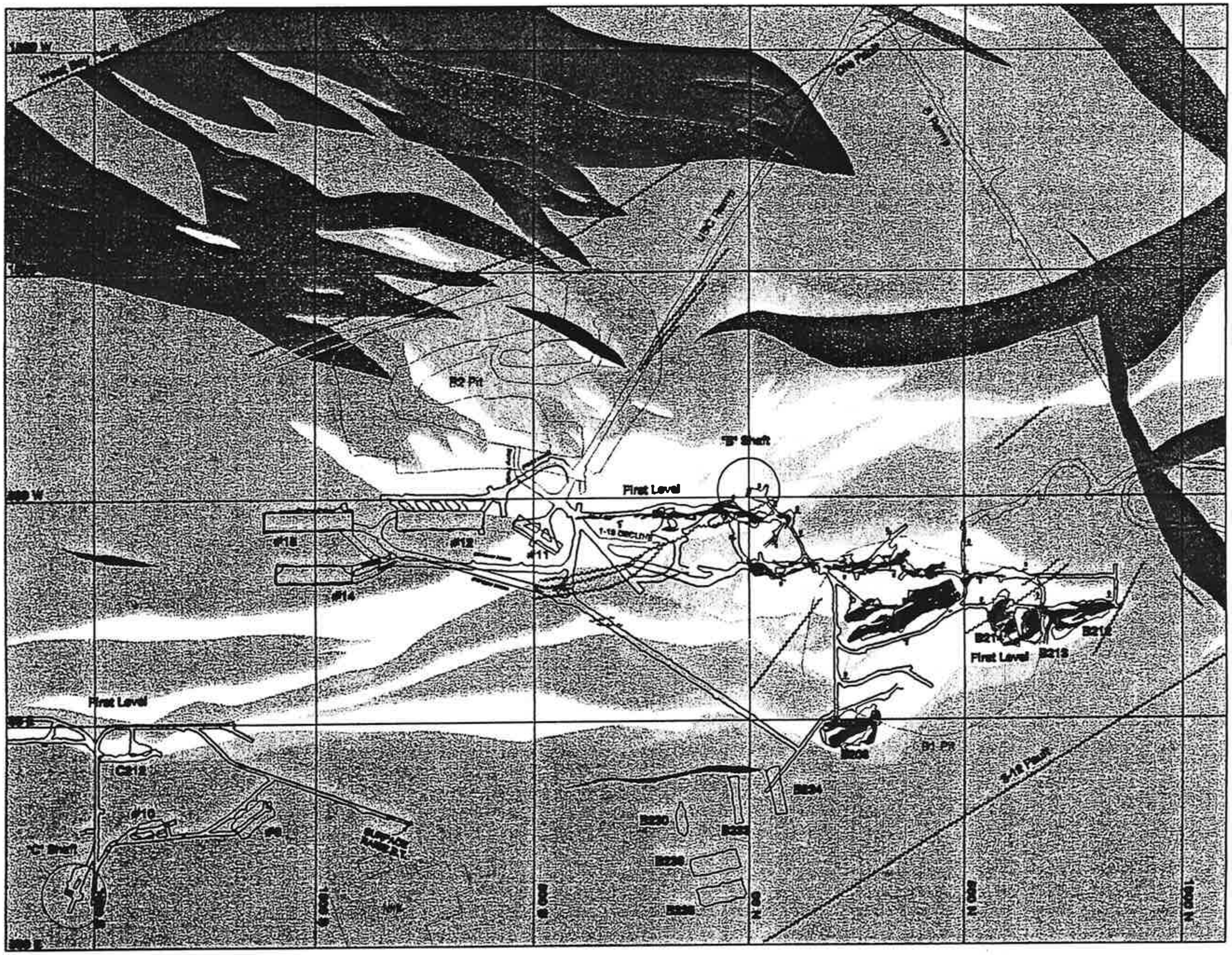
Storage chambers B11, B12, B14 and B15 are located within the greenstone belt of meta-volcanic rocks, the composition of which varies from a dacite to a basalt. Additionally, historical data indicates that storage areas B230, B233, B235, B236, C9, and C10 are located within massive basaltic volcanic flows containing minor chlorite schist zones.

Chambers B208, B212, B213, B214, and C212 were formerly production stopes converted for arsenic trioxide storage. The mineralization and ore zones in these areas were characterized as broad zones of silicification and/or quartz carbonate veining with disseminated sulphide mineralization. The mineralization is hosted within a shear zone with the lithology varying from a chlorite schist to a sericite schist. The chambers lie entirely within the sericite schist shear zone.

Figures 7 and 8 illustrate the location of the chambers on the 1st and 2nd levels respectively. These figures depict the known geologic and structural information in the area of the storage chambers.

The location of the chambers reflected a design to place the material in potential zones of permafrost. Therefore the chambers are located near to the surface, positioned between the first and second levels. These levels are 30 metres (100 ft.) and 80 metres (250 ft.) below surface, respectively, referenced to the collar of B Shaft (6015 ft - mine datum). Refer to Figure 9 - *Longitudinal Section of Mine and Chamber Locations*, to see the vertical positioning of the chambers.

The storage chambers vary considerably in actual vertical depth below surface, in reference to crown pillar dimensions. The minimum thickness of the rock between the top of the storage chambers and the surface varies from 9.1 metres (30 feet) to 57 metres (188 feet) with an average thickness of approximately 24 metres (80 feet). Crown pillar dimensions for each chamber are illustrated in Table 3.



Legend

- ■ Ore – quartz, arsenopyrite, pyrite and stibnite in sericite schist
- ☐ Shear Zone – sericite altered
- ▨ Shear Zone – chlorite altered
- ▨ Mafic Volcanics – Massive and pillow
- ■ Metagabbro
- ▨ Break Dacite
- ▨ Break Tuffs
- ▨ Granodiorite
- 〰 Fault

0 100' 250'

Royal Oak Mines Inc.

Giant Mine

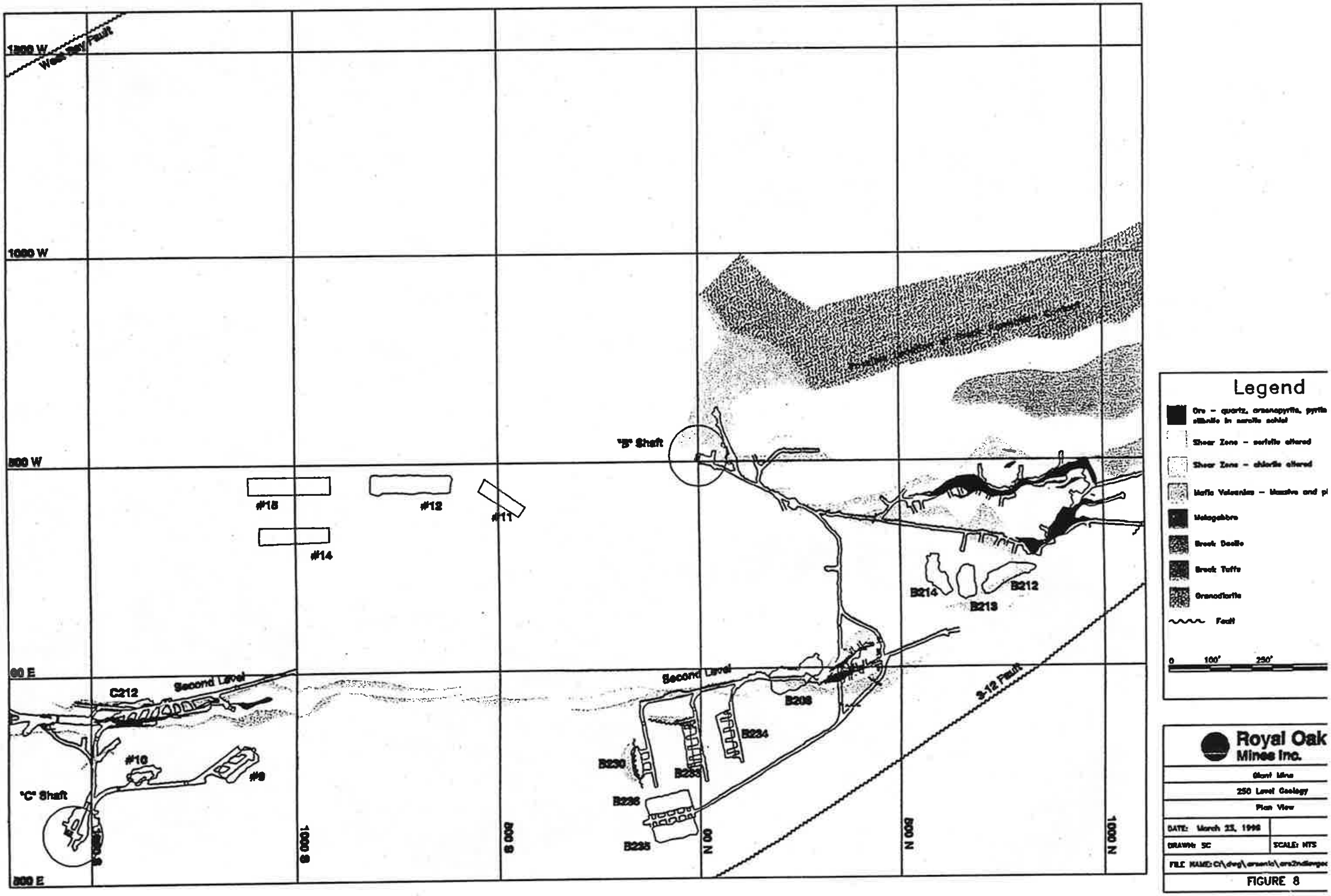
100 Level Geology

Plan View

DATE: March 27, 1998	
DRAWN: SC	SCALE: NTS

FILE NAME: C:\dwg\arsenic\ars1alkingscore.d

FIGURE 7



Royal Oak Mines Inc.

Giant Mine

250 Level Geology

Plan View

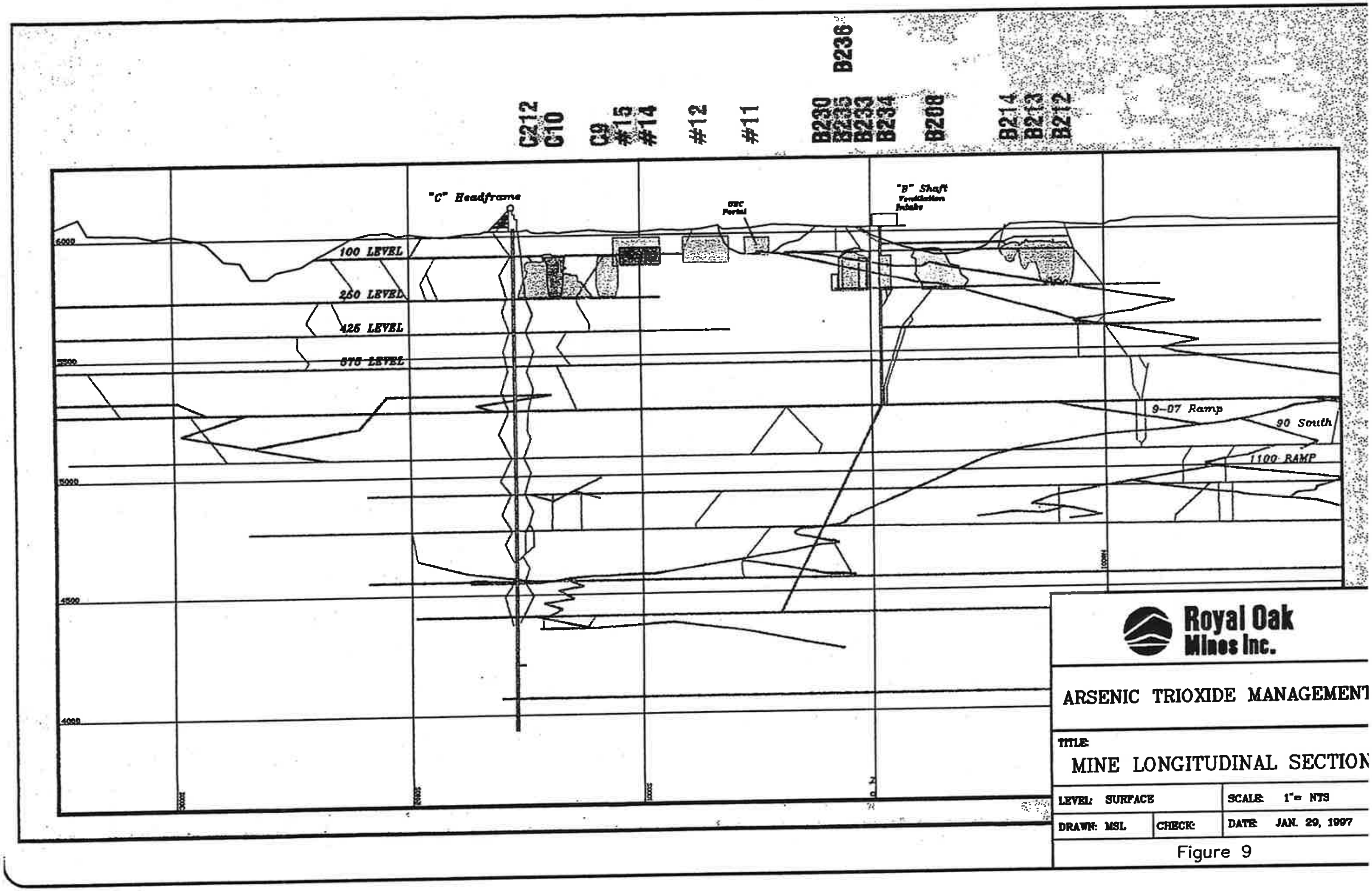
DATE: March 25, 1998

DRAWN: SC

SCALE: NTS

FILE NAME: C:\dwg\arsenic\ars2ndlevge

FIGURE 8



Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEMENT

TITLE:
MINE LONGITUDINAL SECTION

LEVEL: SURFACE
SCALE: 1"= NTS
DRAWN: MSL
CHECK:
DATE: JAN. 29, 1997

Figure 9

Table 3

Crown Pillar Dimensions

Chamber	Chamber Dimension (Plan)	Vertical Pillar Thickness (ft)	Rock Type	Overburden Conditions	General Comments
B 208	irregular shape 125' long x 60 to 80' wide	35	chlorite-sericite shist	up to 50 ft of clay, with sands and gravel	- located at SE corner of B1 Pit
B 212	140' x 40'	30	chlorite-sericite shist	up to 60 ft of clay, with sands and gravel	- located at N end of B1 Pit
B 213	45' x 80'	25 - 40	chlorite-sericite shist	up to 60 ft of clay, with sands and gravel	- located at N end of B1 Pit
B 214	35' x 100'	30	chlorite-sericite shist	up to 50 ft of clay, with sands and gravel	- located at immediate N end of B1 Pit
B 230	25' x 75'	188	mafic volcanic	no overburden	- located directly under the baghouse
B 233	15 to 20' x 105'	115	mafic volcanic	no overburden	- located slightly north of the baghouse
B234	25 to 30' x 105'	72	mafic volcanic	minor till at contact, clay up to 30' thick	- located slightly north of the baghouse and B 233
B 235	115 x 40'	83	mafic volcanic	up to 30'	- located slightly NW of baghouse, by B 235
B 236	115 x 40'	103	mafic volcanic	15 to 20'	- located slightly NW of baghouse, by B 236
C 212	150' x 20 to 25'	30 to 70	chlorite-sericite shist	25 to 35'	- located NW of C Shaft, partly under Baker Creek
C 9	80' x 10' (at level) (stope widens below)	70	mafic volcanic	15'	- located N of C Shaft, and N of # 10
C 10	80' x 10' (at level) (stope widens below)	70	mafic volcanic	est. 15' (no drill info)	- located N of C Shaft
B 11	125' x 45'	70	mafic volcanic	no overburden	- located in bedrock knob between UBC and Baker Creek, west of C Shaft
B 12	200' x 40 to 45'	75	mafic volcanic	no overburden	"
B 14	175' x 40'	105	mafic volcanic	no overburden	"
B 15 (under construction)	200' x 45'	75	mafic volcanic	no overburden	"

5.4.2 Bulkhead Stability:

In 1996, Ferguson, Simek and Clark Engineers (FSC), of Yellowknife, were retained by Royal Oak to carry out the following scope of work:

- review the engineering plans of the existing storage chamber bulkheads to determine their hydrostatic load capacity

- model the structural loads on these bulkheads

- report on the adequacy of the bulkheads to meet their design objectives

Structural modeling of bulkheads # 10, 11, 12, 13, 14 and 15 was completed. The results indicate that all of these bulkheads meet the engineering design criteria and would sustain the full hydrostatic force that would be placed on them if the mine were flooded.

An attempt was made to model bulkheads #'s 47, 48, 49, 50 and 51 however there was insufficient information regarding the construction of the bulkheads to complete the design check.

It will be necessary to conduct further evaluation of the integrity of other bulkheads prior to mine closure. As many of these bulkheads are isolated and there is minimal design information available it may not be possible to verify and model each one. In this case the final closure options must take into account this lack of certainty.

5.4.3 Inspection Procedures:

Under normal operating conditions, the integrity of the delivery system and pipelines is monitored by the baghouse operator, who monitors the system pressure. This routine check occurs several times during each scheduled shift.

A regular monthly inspection schedule of active storage areas has been implemented to ensure all services are in place, that bulkheads are secure, and that no unusual conditions are developing. In-active areas are not inspected on a routine basis.

The majority of the arsenic storage areas are currently accessible through existing workings and can be thoroughly inspected. Some others are difficult or impossible to inspect at this time due to historic mining activity. For example, storage areas B212, B213, and B214 are isolated from the mine workings and are not accessible following the mining of the B1 Pit. More detail on accessibility is provided in Table 4. Also refer to Appendix I - *Storage Chamber Drawings* for detailed drawings that indicate the location and travel route, in the mine, to access the storage areas. In 1998 and 1999, it is anticipated that mine crews will re-open access to many of the chambers in an attempt to determine and/or test, potential extraction methods.

Table 4

Location and Status of Bulkheads

No.	Designation	Inspection Date	Level or Access Point	Drift or Other Location	Comments	DWG File Reference
1	B 230 - bottom	No access	250 Lvl	230 E x/c and 210 S Dr.	Area blocked by secondary bulkhead in 209 N Dr.	7150-002, 003
2	B 230 - top	No access	Surface	N/A	Surface raise covered by concrete slab north of baghouse	7150-002, 003
3	B 233 - bottom	No access	250 Lvl	233 E x/c and 210 S Dr.	Area blocked by secondary bulkhead in 209 N Dr.	7150-002, 003
4	B 233 - top	March 98	Surface	N/A	Need surface fan on for inspection, good condition, dust visible at -52 ft. (dry)	7150-002, 003
5	B 234 - bottom	No access	250 Lvl	234 E x/c and 210 S Dr.	Area blocked by secondary bulkhead in 209 N Dr.	7150-002, 003
6	B 234 - top	No access	Surface or 100 Lvl / UBC	208 A.D. Dr.	Top of raise covered in muck, several feet thick below 208 A.D. Dr.	7150-002, 003
7	B 235/236 - bottom	March 98	250 Lvl	2-09 S Dr.	Good condition, dry	7150-002, 004
8	B 235 - top	March 98	Surface (off 233 raise)	N/A	Good condition, dry, inspection hatch could not be opened (rust)	7150-002, 004
9	B 236 - top	March 98	Surface (off 233 raise)	N/A	Good condition, dry, dust visible @ -50 ft. down, (inspection hatch)	7150-002, 004
10	B 208 - bottom #1	No access	250 Lvl	208 N Dr. off 210 S Dr.	Located in a raise which is in the back of B3-06 stope	7150-002, 005
11	B 208 - bottom #2	No access	250 Lvl	219 N Dr. off 210 S Dr.	Located in a raise which is in the back of B3-06 stope	7150-002, 005
12	B 208 - bottom #3	No access	250 Lvl	219 N Dr. off 210 S Dr.	Located in a raise which is in the back of B3-06 stope	7150-002, 005
13	B 208 - bottom #4	March 98	250 Lvl	235 E x/c and 219 N Dr.	Heavy staining, minor concrete deterioration	7150-002, 005
14	B 208 - bottom #5	March 98	250 Lvl	209 E x/c	Heavy staining, minor concrete deterioration	7150-002, 005
15	B 208 - bottom #6	March 98	250 Lvl	209 E x/c	Heavy staining, contaminated water ponded in front of bulkhead	7150-005
16	B 208 - 100 #1	No access	100 Lvl	109 E x/c	No access - on southern side of B1 Pit	7150-002, 005
17	B 208 - 100 #2	March 98	100 Lvl	208 A.D. Dr.	Good condition, dry, frosty, dust visible @ -20 ft., installed thermistor Feb 97	7150-002, 005
18*	#1 B1 Pit	No access	100 Lvl	119 N Dr.	Isolates U/G from B1 Pit mining	7150-002, 006
19*	#2 B1 Pit	N/A	100 Lvl	113 N. Dr.	Gone - mined out by B1 pit activity	N/A
20	#3 B1 Pit	No access	100 Lvl	106 N Dr.	Isolates U/G from B1 Pit mining	7150-002, 005
21*	#4 B1 Pit	No access	100 Lvl	Raise 109 to 205	Isolates U/G from B1 Pit mining	ARSMAP97
22*	#5 B1 Pit	N/A	250 Lvl	205 #46 B.H. raise	Gone - mined out by B1 pit activity	N/A
23*	#6 B1 Pit	N/A	100 Lvl	no reference available	Gone - mined out by B1 pit activity	N/A
24 *	#7 B1 Pit	March 98	100 Lvl	113 N Dr., via 118, 207 stope	Timber forms still in place, isolates U/G from B1 Pit mining	7150-006, 007
25*	#8 B1 Pit	N/A	100 Lvl	106 N. Dr.	Gone - mined out by B1 pit activity	N/A
26*	#9 B1 Pit	March 98	100 Lvl	208 A.D. Dr.	Timber forms still in place, isolates U/G from B1 Pit mining	7150-005
27*	B 208 - 100 #3	N/A	100 Lvl	113 N. Dr.	Gone - mined out by B1 pit activity	N/A
28*	B 208 A.D #1	N/A	N/A	205 (center sub) off 208	Gone - mined out by B1 pit activity	N/A
29*	B 208 A.D. #2	N/A	N/A	Raise 208 to 119	Gone - mined out by B1 pit activity	N/A
30 *	B 208 A.D. #3	N/A	N/A	208 A.D. Dr.	Gone - mined out by B1 pit activity	N/A
31*	B 208 A.D #4	July 3/ 98	100 Lvl	Up raise from 109 (208 A.D. Dr.	Good condition - isolates U/G from B1 Pit mining	7150-002, 005
32	B 212 - bottom #1	March 98	250 Lvl	202 N Dr. (west)	Good condition, dry	7150-006
33	B 212 - bottom #2	No access	250 Lvl	202 N Dr. (east)	No access found - isolated by mining activity	7150-006
34	B 212 - bottom #3	No access	250 Lvl	218 N Dr.	No access found - isolated by mining activity	7150-006
35	B 212 - bottom #4	No access	250 Lvl	#2 fill raise	No access found - isolated by mining activity	7150-006

Table 4

Location and Status of Bulkheads

No.	Designation	Inspection Date	Level or Access Point	Drift or Other Location	Comments	DWG File Reference
36	B 212 - bottom #5	No access	250 Lvl	# 2 pillar scram	No access found - isolated by mining activity	7150-006
37	B 212 #6	March 98	100 Lvl	Raise from 110 N Dr.	Timber forms still in place, good condition, access through 118 and207 stope	7150-006, 007
38	B 212 #7	March 98	100 Lvl	214 raise, dwn from 110 N Dr.	Good condition - dwn raise about 40 ft, dry	7150-006
39	B 212 #8	March 98	100 Lvl	112 E x/c	Timber forms still in place, good condition, dry	7150-006, 007
40	B 212 #9	March 98	100 Lvl	105 E x/c	Timber forms still in place, good condition, dry	7150-006, 007
41	B 212 #10	Aug 7 /98	100 Lvl	108 N Dr.	No access- on north side of B1 pit	7150-006, 007
42*	B 212 - top #1	Aug 7 /98	100 Lvl	208 A.D. Dr.	Visible on N side of B1 pit, as well as in 208 A.D. Dr.	7150-006, 007
43	B 212 - top #2	Aug 7 /98	100 Lvl	208 A.D. Dr.	Good condition	7150-006, 007
44	B 212 - top #3	Aug 7 /98	100 Lvl	208 A.D. Dr.	Good condition (214 Inspection seal)	7150-006, 007
45	B 212 - top #4	Aug 7 /98	100 Lvl	208 A.D. Dr.	Good condition (213 Inspection seal)	7150-006, 007
46	B 212 - top #5	Aug 7 /98	100 Lvl	208 A.D. Dr.	Good condition (212 Inspection seal)	7150-006, 007
47	C 212 - bottom #1	No access	250 Lvl	212 N Dr.	Isolates C311 stope, below 250 Lvl	7150-008, 009
48	C 212 - bottom #2	No access	250 Lvl	311 raise	Isolates C311 stope, below 250 Lvl	7150-008, 009
49	C 212 - bottom #3	No access	250 Lvl	Raise below 250 Lvl	Isolated by mining (C3-12 stope)	7150-008, 009
50	C 212 - bottom #4	June 28 /98	250 Lvl	211 S Dr.	Some minor seepage, surface concrete deterioration	7150-008, 009
51	C 212 - bottom #5	June 28 /98	250 Lvl	212 N Dr.	Timber forms still in place, small ground fall in front	7150-008, 009
52	C 212 - top #1	June 28 /98	100 Lvl	212 #1 service raise	Good condition	7150-008, 009
53	C 212 - top #2	No access	100 Lvl	212 upper	Inspection seal 212 upper	7150-008, 009
54	C 212 - top #3	No access	100 Lvl	212 #2 service raise	No access due to lack of ventilation in raise, inspection seal	7150-008, 009
55	C 212 - top #4	June 28 /98	100 Lvl	105 N Dr.	Good condition, reinforced concrete bulkhead	7150-008, 009
56	C 9 - bottom	No access	250 Lvl	# 9 bottom access	No access - isolated by bulkhead # 58 (for # 10)	7150-008, 010
57	C 9 - top	June 28 /98	100 Lvl	# 9 top access	Good condition, reinforced concrete bulkhead	7150-008, 010
58	C 10 - bottom	June 28 /98	250 Lvl	# 10 bottom access	Timber froms still in place, good condition, damp	7150-008, 010
59	C 10 - top #1	No access	100 Lvl	#10 top access	No access - Isolated by #62 and #57 bulkheads (Inspection seal)	7150-008, 010
60	C 10 - top #2	No access	100 Lvl	#10 top access	No access - isolated by #62 and #57 bulkheads (Inspection seal)	7150-008, 010
61	C 10 - top #3	No access	100 Lvl	#10 top access	No access - isolated by #62 and #57 bulkheads (Inspection seal)	7150-008, 010
62	C 10 - top #4	June 28 /98	100 Lvl	#10 top access	Good condition, reinforced concrete bulkhead	7150-008, 010
63	C 10 - top #5	June 28 /98	100 Lvl	#10 top access	Isolates north side of # 10	7150-008, 010
64	B 11 - bottom	March 98	UBC Ramp from surface	1-18 access ramp	Good condition, dry	7150-011,012
65	B 11 - top	July 3 /98	Raise from 1-18 acc.	1-18 access ramp	Good condition	7150-011,012
66	B 12 - bottom	March 98	UBC Ramp from surface	#12 Lower sill, off UBC ramp	Good condition, small sump @ bulkhead, remnant staining, not leaking	7150-011,012
67	B 12 - top	March 98	UBC Ramp from surface	#12 Upper sill Dr.	Good condition, dry, full of dust to inspection hatch	7150-011,012
68	B 14 - bottom	March 98	UBC Ramp from surface	#14 Lower access	Good condition, no signs of leaks following grouting in 1995	7150-012
69	B 14 - top	March 98	UBC Ramp from surface	#14 Upper access	Good condition, dry, dust visible, active chamber, ground conditions inside - go	7150-012

* indicates a bulkhead that is not critical and not known to be in direct contact with arsenic trioxide bearing dust

A total of 69 individual bulkheads have been identified on drawings and/or through inspections underground. (Table 4) These bulkheads were constructed either directly to contain the dust, as inspection and delivery points, or as secondary stoppings to isolate a storage area from mining activity. Some of the 69 bulkheads identified are related to isolating the B1 Pit from the underground workings (ventilation and blasting concerns), and are not related to arsenic storage. However, they have been listed because they may affect accessability to storage areas, or may cause confusion in subsequent inspections, if not carefully identified on mining plans. The bulkheads identified as being not critical, are identified in Table 4 (*by an* *).

There are 36 bulkheads that can be inspected on a regular basis. In addition there are 8 bulkheads that were removed during the mining of B1 Pit. The remaining bulkheads are inaccessible due to isolation because of mining activities, or the bulkheads are located behind a subsequent (or secondary) bulkhead.

6.0 Options for Permanent Abandonment:

6.1 General:

The basic premise behind the permanent abandonment of the arsenic trioxide is whether the material should, or can, be left underground or whether it should, or can, be removed and transported to surface for final stabilization and abandonment.

If the material is left underground there are options to either leave the mine pumps on forever, thus keeping the material "dry", or allowing the mine to flood naturally.

The current dewatering of the mine could be continued after its economic life, given that a significant financial commitment is in place, and the technical and logistical modifications are in place. The length of the term of the dewatering effort is however, given to some risk due to unforeseen economic and political considerations. Leaving the mine pumped out indefinitely is not seen as a realistic option.

If the mine is allowed to flood naturally after its economic life, there is potential for groundwater to contact the arsenic trioxide. This contact could lead to a migration of contaminated fluids, through fractures in the rock, to eventual release into the environment. Given this scenario, it is important to understand the solubility of the material, potential migration pathways, and potential impacts to the environment. When these impacts are modeled, the best available technology can be applied to attempt to mitigate or eliminate the problem. Figure 10 - *Abandonment with Natural Groundwater Flow* illustrates the natural conditions that would be evident when the mine floods.

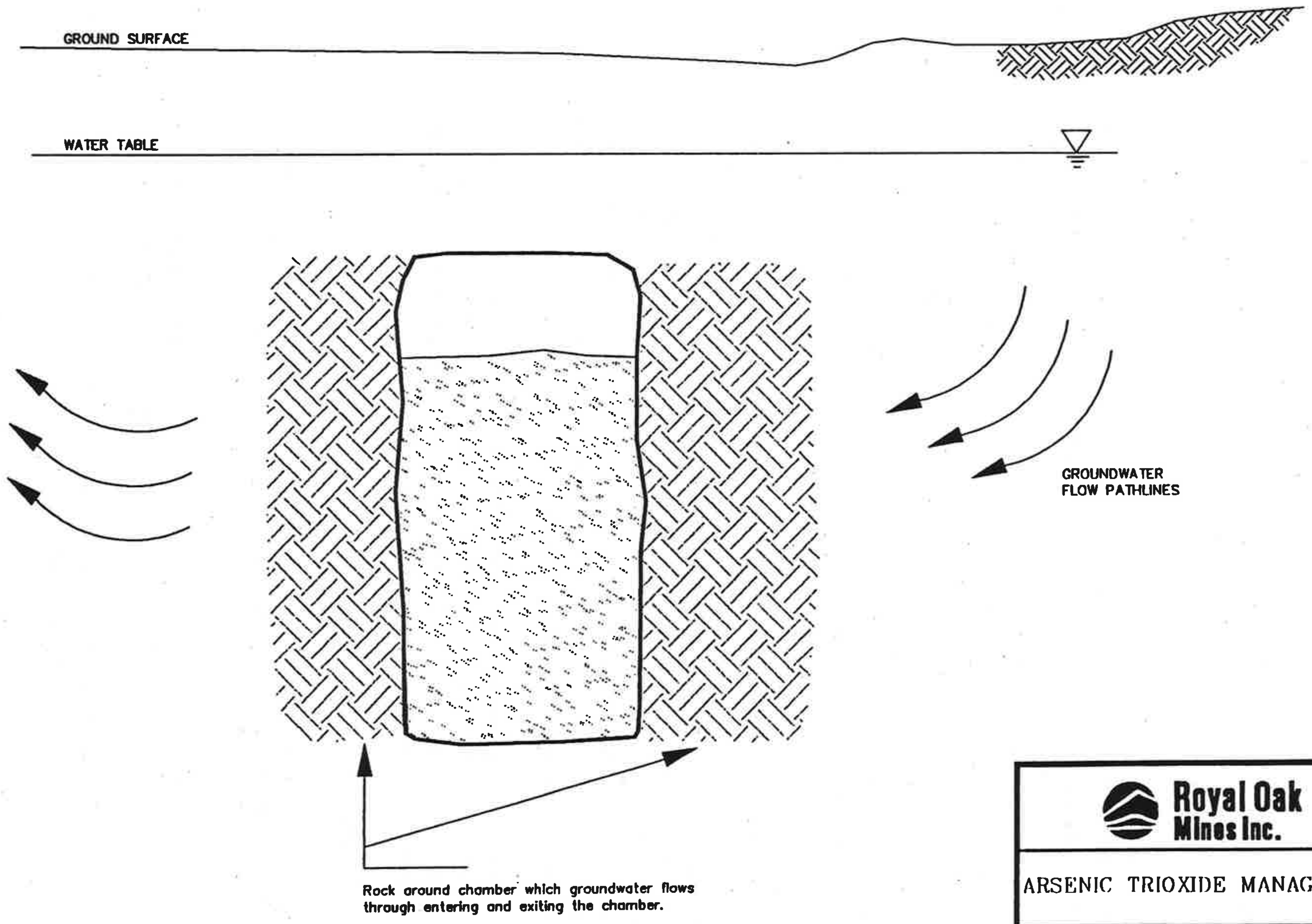
As part of ongoing hydrogeology studies the mine is conducting a review of the amount of time it will take to flood after closure. Results are not yet confirmed but preliminary calculations show that the mine will flood to the approximate level of Baker Creek (assumed water table, 6000' mine datum) within 15 years.

6.2 Underground Abandonment:

Four potential options for the permanent abandonment and closure of the underground arsenic storage chambers were initially reviewed in 1993. These various options included:

1) Use of winter air by means of forced circulation to enhance the re-establishment of permafrost in the vicinity of the storage areas

2) Use of additional or secondary bulkheads to isolate the storage chambers from the groundwater regime



VOLUME OF FLOW, Q=KxIxA
K = hydraulic conductivity
I = hydraulic gradient of slope of groundwater table
A = area which flow passes through = length (into page) x height

(FROM BRODIE CONSULTING LTD.)

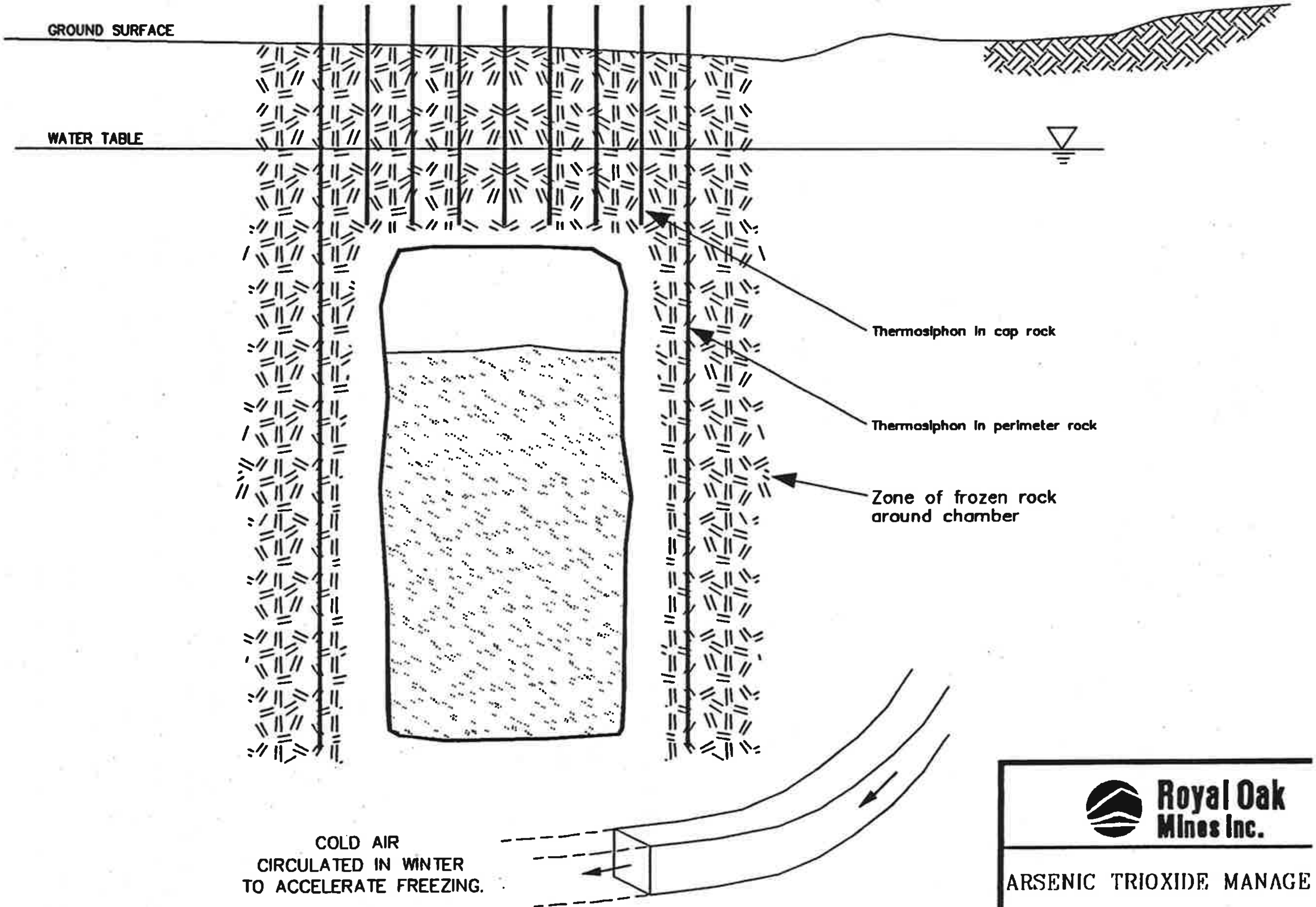
Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEME

TITLE: ABANDONMENT WITH NATURA
GROUNDWATER FLOW

LEVEL:		SCALE: 1" = NTS
DRAWN: MSL	CHECK:	DATE: MARCH 29,

Figure 10



(FROM BRODIE CONSULTING LTD.)

Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGE

TITLE: ABANDONMENT WITH ENHANCED PERMAFROST

LEVEL:

SCALE: 1"= N

DRAWN: MSL

CHECK:

DATE: MARCH

Figure 11

3) Use of grout curtains to isolate the storage areas from the groundwater regime

4) Creation of artificial ice plugs behind the bulkheads to enhance the isolation of the storage chambers from the groundwater regime

The technical feasibility of these preceding disposal options were evaluated and the potential arsenic abandonment options considered to be viable were upgraded in 1994 to include the options of:

1) Leave the baghouse dust in place in the underground storage chambers and use winter air by means of forced ventilation to enhance the re-establishment of the permafrost in the vicinity of the storage chambers

2) Leave the baghouse dust in place in the storage chambers and continue to depress the groundwater table by pumping so that no groundwater comes into contact with the stored material

3) Leave the baghouse dust in place in the underground storage chambers and create a preferential pathway for groundwater to move around the arsenic storage chambers

4) The removal of the arsenic trioxide from the underground storage chambers

Yellowknife is located in an area of discontinuous permafrost. As a general rule permafrost exists where there is a blanket of till or organic soil of sufficient thickness to insulate the permafrost from summer warming. The permafrost does not exist in areas below bedrock outcrops or below large bodies of water. Permafrost will commence at a depth of 50 to 75 feet below surface and continue to a depth of 300 to 400 feet. The existence of permafrost in the Giant Mine area has been disturbed by the removal of the insulating till layer by open pit mining, and the underground mining activity that has caused heat transfer into the rock from warm ventilation air.

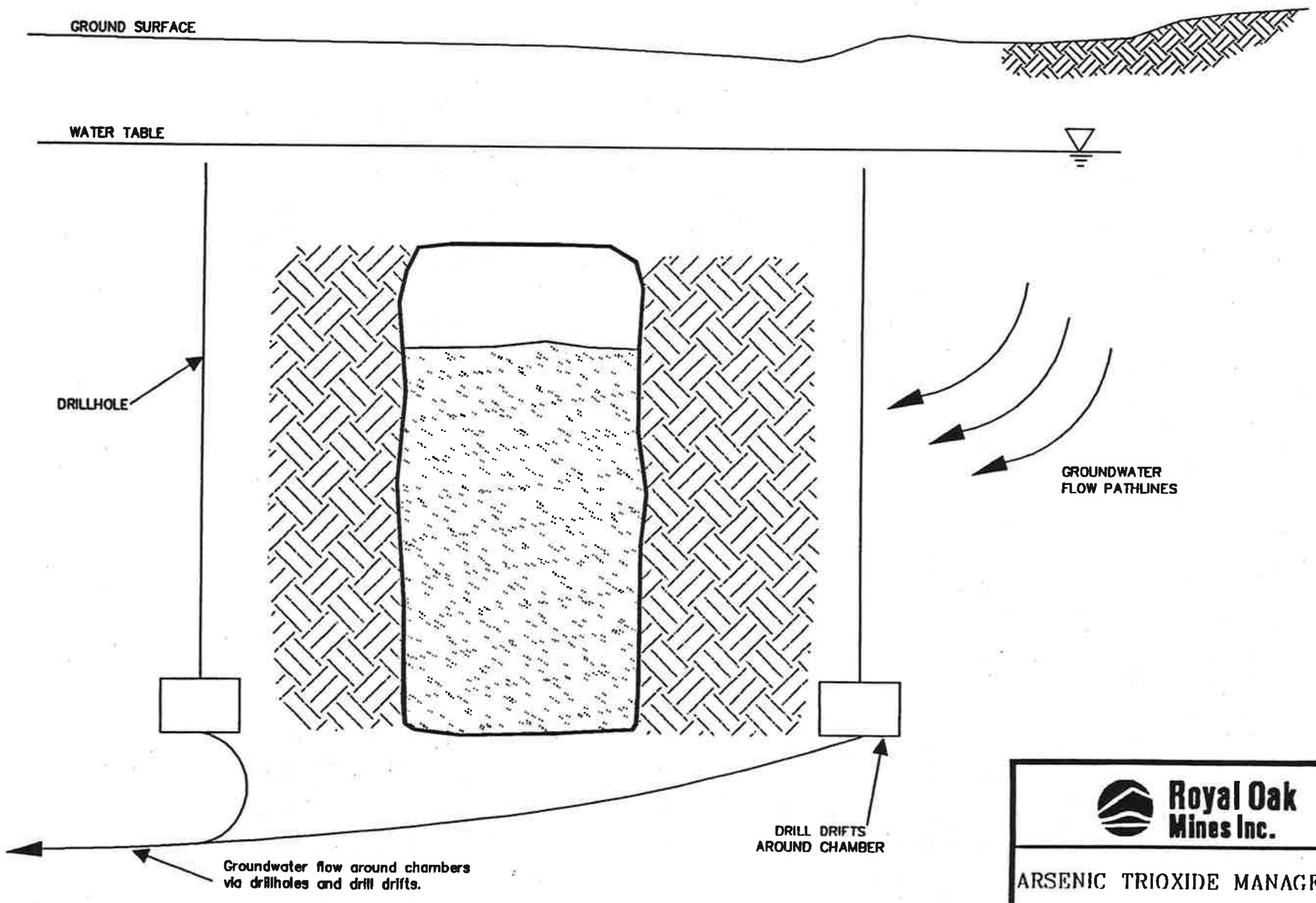
There is an opportunity to re-establish permafrost in the mine after cessation of operations by using the mine ventilation system to pump cold air into the mine through the vast system of tunnels and other openings. It may also be possible to instal a system of thermosiphons in the rock surrounding the chamber to enhance the return of permafrost. An insulating blanket of till or other suitable soil would have to be placed on surface across the entire area under which the chambers exist to maintain the permafrost that is re-established. This option is considered technically viable and is still open for further investigation. Figure 11 - *Abandonment within Permafrost Option* illustrates the concept. It is recognized that this option would have risk attached which would require ongoing maintenance and monitoring to ensure success, but it does offer significant opportunity.

Currently the mine is monitoring the conditions of the A Shaft area in the context of this option. This area lies at the extreme southern end of the orebody and mining ceased in 1996 with the depletion of reserves. Cold mine air is being allowed to flow naturally into the mine, and there is evidence that the rock is freezing and may take on its natural permafrost state. This area is also the natural preferential pathway for groundwater migrating towards Yellowknife Bay and if an ice plug is being formed, there will be less risk of future contamination from the stored arsenic trioxide. This situation will be closely monitored in 1998 and 1999.

The current practice used to prevent any release of arsenic trioxide to the environment is to keep the groundwater table depressed. This is achieved through routine pumping operations which collect groundwater from the mine workings. The water is pumped to the Giant mine tailings impoundment area where it is subsequently treated in the mine's effluent treatment plant. In this effluent treatment process arsenic is precipitated from the water in the form of ferric arsenate. The resulting ferric arsenate precipitate is removed from the treated water in a polishing pond. The treated water which typically contains concentrations of total arsenic below 0.5 mg/l is then released to the environment (Baker Creek into Great Slave Lake).

One closure option is to keep the groundwater table depressed by continuous pumping, which means the pumping and treatment system would have to be operated in perpetuity. The treatment system would be required in order to remove arsenic and other metal levels contained in the mine water. It is recognized that this option has some risk attached and requires a permanent commitment of financial resources for ongoing operation, maintenance and monitoring to ensure success. It is not a risk free solution but does offer a viable alternative.

Theoretically it is possible to create a preferential pathway underground for groundwater to move away from and around the storage chambers. This would create an area of stagnant groundwater in the immediate vicinity of the storage chambers from which contaminants would not flow. Hydraulically, groundwater will follow the path of least hydraulic resistance. The use of grout curtains and ice plugs can be combined with the construction of 'drains' around the storage chambers so the groundwater will naturally flow away from and around the chambers. This is a viable option although not risk free, and still requires a long term commitment to maintenance and monitoring. Figure 12 - *Abandonment with Preferential Hydraulic Pathways* illustrates the concept.



(FROM BRODIE CONSULTING LTD.)

Royal Oak
Mines Inc.

ARSENIC TRIOXIDE MANAGEMEN

TITLE:
ABANDONMENT WITH PREFERENTIA
HYDRAULIC PATHWAYS

LEVEL:
SCALE: 1"= NTS
DRAWN: MSL
CHECK:
DATE: MARCH 29, 199

Figure 12

6.3 Removal Options:

6.3.1 General:

Removal of the arsenic trioxide bearing dust from the underground storage chambers would appear to be the best option to reduce the risk of groundwater contamination at some point in the future. The problem becomes one of what to do with the material once it is on surface. Transferring the dust to surface storage only transfers the problem and the associated risks. In fact the risk factors of contamination associated with long term surface storage would appear to be greater than underground storage when the relative transport methods (wind and water erosion, corrosion etc.) are considered.

The second problem to be faced in removing the dust from underground is overcoming the technically difficult challenge of removing all of the baghouse dust with a mining method that is safe to both the environment and the workers.

Assuming that the baghouse dust can be effectively and safely removed from the underground storage chambers, there are basically only three options for dealing with the arsenic trioxide once it is on surface:

a) Store the material in a suitable facility constructed on surface for that purpose. The required volume to store the 260,000 tons of dust would be from 6 to 13 million cubic feet, depending on the degree of compaction that may be utilized. The storage volume requirements are unrealistic, and the risks of contamination are of concern. As such this option is not considered viable.

b) Convert the contained arsenic trioxide to ferric arsenate. The arsenic trioxide would first have to be leached into solution, the valency changed from +3 to +5 using a strong oxidant such as hydrogen peroxide and then the arsenic precipitated as ferric arsenate using a soluble ferric ion solution such as ferric sulphate. The required stoichiometric addition rate of ferric ion would be in the order of 5 to 7 units per unit of arsenic. This process would produce enormous amounts of ferric arsenate which would then have to be stored in an environmentally safe manner. Concern has been expressed in scientific literature about the long term stability of arsenic precipitated as ferric arsenate. Given the quantities of arsenic trioxide stored underground, the conversion of all of the arsenic trioxide into ferric arsenate is not a viable solution and is not being investigated further. The process would be cost prohibitive, and the vast quantities of ferric arsenate produced would be difficult to safely store. The risk associated with arsenic re-solubilizing from the ferric arsenate would be a major concern.

c) Convert or upgrade the arsenic trioxide containing baghouse dust into a usable form where it can be transported out of Yellowknife for use in the world market place. The primary end use of arsenic is as CCA (copper chromated arsenate) which is the primary wood preservative used around the world. This option is undergoing detailed evaluation as will be discussed further, and appears to be the best solution to eliminating the long term risk.

6.3.2 Material Quality and Characteristics:

The stored material has variable physical properties but can generally be categorized into one of the following:

- dry and dusty (similar to processed flour)
- dry and compacted
- damp and compacted

In 1981, Geocon Inc. conducted a program of recovery and materials testing of the material in the underground chambers. The program involved drilling into seven of the chambers and recovering material from various horizons within each chamber. The material was found to have densities ranging from 41.6 to 91.9 lb/cu.ft., and moisture contents ranging from <1% to 6.4%. Table 5 summarizes the material characteristics found in this investigation.

Two samples of the recovered dust were tested by Jenike & Johanson Ltd. for flow properties at ambient temperature and with an 'as received' moisture content of 0.7%. They describe the dust as "*a very fine powder (similar to flour) which is highly compressible. The bulk density varies from 57 lbs/cuft to 100 lbs/cuft at an effective head of 80 feet. ......shows a material which has a strong tendency to ratholing. ....*"

Table 5

Summary of Conditions of Arsenic Chambers - Geocon Test in 1981

Chamber	Geocon Hole #	Density (range) (lb./cu.ft.)	Specific Gravity	Angle of Repose	Moisture Content
B 230	#5	48.3 - 77.3	3.17	47.7	6.4% (wet on bottom)
B 233	#6	50.7 - 82.3	3.15	46.7	2-6% (wet on bottom)
B 234	#7	55.6 - 85.3	3.23	46.1	1-4% (moister on top)
B 235 / 236	#8	53.3 - 84.2	2.59	46.7	<2%
	#9	41.6 - 74.6	3.79	48.7	<1%
B 208	#4	39.7 - 69.1	3.22	46.4	2.8% (wet on bottom)
C 9	#11	55.1 - 91.1	3.06	48.0	1-2%

6.3.3 Mining Recovery Methods:

The goals of a potential arsenic trioxide dust mining recovery program are:

- to recover the material to process for arsenic and gold revenue
- to empty the chambers that were production chambers so as to recover remnant ore, adjacent to, or closely located to the chamber
- to stabilize or contain, remnant arsenic trioxide bearing dust, not recoverable by mining, for permanent disposal in place

As part of the development of this mining program, a test chamber has been considered to evaluate methods of recovery from underground to a surface storage location or a process plant. Design restrictions include materials handling properties and technology, worker safety and hygiene, and the risk of environmental contamination.

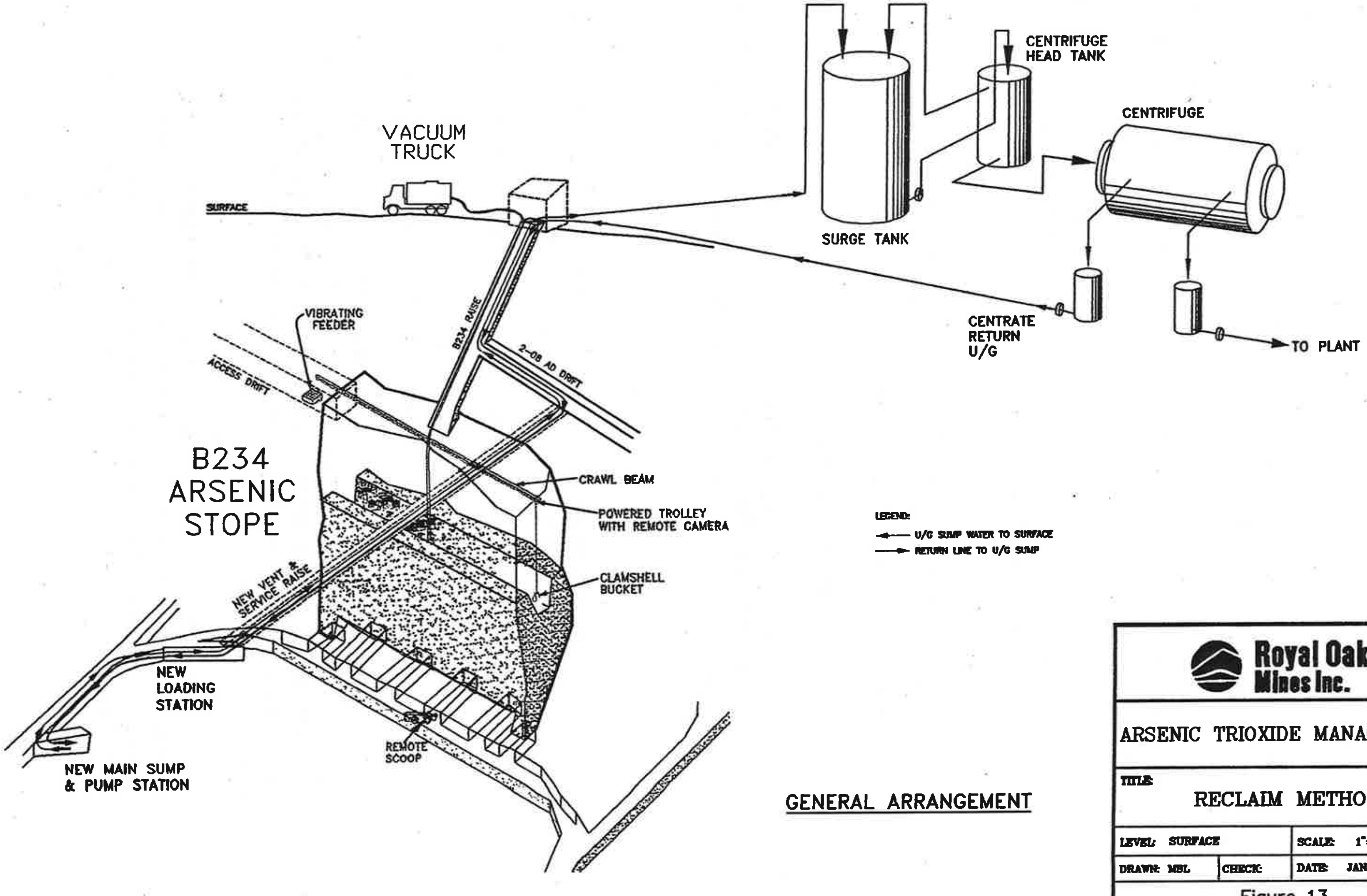
In addition to the variable physical properties, the condition of the storage chambers varies. Some of the chambers were specifically excavated for dust storage and consequently have vertical, regular shaped walls. Other chambers (5) are completed production chambers, converted for dust storage. These chambers are quite irregular in shape.

Due to the variability of material characteristics and geometry, a variety of excavation methods will have to be used. The potential methods include:

- vacuuming from boreholes, overhead and drawpoint locations
- clam bucket from an overhead access
- drawpoint mucking with remote controlled LHD's (Load Haul Dump units referred to as scooptrams), or continuous miner systems
- slurry pumping systems

It is anticipated that a combination of methods will be required in order to achieve maximum extraction from a given chamber. Consideration will be given to each method at such time as a test mining area can be prepared. Various mining methods that could be implemented are outlined in Figure 13 - *Mining Recovery Options*.

The main concern in handling the arsenic trioxide bearing dust is the potential for the dust to become airborne, or contact and solubilize into surface waters or groundwater.



GENERAL ARRANGEMENT

Royal Oak Mines Inc.

ARSENIC TRIOXIDE MANAGEM

TITLE: RECLAIM METHODS

LEVEL: SURFACE		SCALE: 1"= NTS
DRAWN: MBL	CHECK:	DATE: JAN. 29, 1

Figure 13

Any system under consideration must ensure containment during transport. The transport distance should be kept to a minimum to reduce risk. Rehandle or transfer must also be reduced or eliminated.

A vacuum system would allow the material to be piped directly to a surface storage facility. Dust collection systems would ensure that releases to atmosphere are minimized.

Slurry systems, which are most likely to be used for removing (washing) remnant material, will deliver the material by pipe directly to the process facility. The use of slurry systems will be kept to a minimum to reduce the potential impact to the groundwater.

All mechanical recovery systems would primarily use tubular drag conveyors for transporting the material to surface, and into storage or the process plant. These systems are enclosed, and have a low maintenance component. However they are also restricted in length and geometry, so transfer points and rehandle, possibly by truck, may be required.

6.3.4 Processing Technology:

Several options are being investigated for processing and upgrading of the arsenic trioxide at the Giant Mine, after it has been reclaimed from underground and brought to surface. In all cases a new processing plant would be required as the existing mill facilities are not suited for this work.

The objectives of a new process are:

- to upgrade the arsenic trioxide to a marketable quality, which includes lowering impurity levels to acceptable values

- to recover gold values from the residue from the upgrading process

- to provide a stabilization technique for the final process waste that must be disposed of, likely at the site, either in a tailings pond or underground

The stored material contains from 48 % to 92 % arsenic trioxide, and from 0.12 opt (ounces per ton) to over 2.00 opt gold. The product must be upgraded to >95% arsenic trioxide to meet market specifications (wood preservative manufacturers average specification). Antimony and iron contained in the dust, are considered impurities, and these concentrations must be reduced significantly.

There are four processes that have been considered for producing a marketable product. They are hot water leaching, ammonia leaching, methanol leaching, and fuming. Test work is ongoing at the Giant Mine laboratory where extensive modifications to the lab have taken place in order that this work can be conducted to the highest standards.

Extensive testing was done at Giant in the 80's, the results of which will shorten the current testing process.

Efforts are currently being directed towards the hot water leach method, similar to that previously used at the Con Mine, in Yellowknife. The process is based on the solubility difference of arsenic trioxide in hot and cold water. Arsenic is dissolved in hot water to produce a saturated solution. The saturated solution is separated from the residue and cooled. As the solution cools, As_2O_3 crystallizes and is recovered. This process allows for the additional advantage of using slurry systems to recover the material from underground, including recycling of the process water. The process has proven viable in producing a high quality arsenic trioxide product, with the problem remaining being that of reducing impurities (antimony, iron) to marketable specifications.

The ammonia leach process is based on the effect of the NH_4 ion on the solubility of As_2O_3. Ammonia solubility at 30° C hits a maximum at a molar ratio of 1 and falls to ½ when the molar ratio NH_4 / As is increased to 2. NH_4 AsO_2 is precipitated by the added ammonia. The solution returns to the leach operation and the solids are either sold 'as is' or calcined to drive off NH_3, which is recycled. Problems with this process include dissolution of antimony and iron with the arsenic and difficult solid-liquid separation of the saturated solution from the residue. High levels of residual ammonia in final solutions and effluents hinder the viability of this option.

The methanol leach process is based on the solubility difference of As_2O_3 and Sb_2O_3 (antimony) in methanol. Arsenic is dissolved in methanol, while antimony reportedly is not. This is due to a chemical conversion of the arsenic into a methanol compound. The saturated solution is separated from the residue and evaporated to recover the arsenic oxide. Off-gases are treated to condense and recover the methanol. Questions exist with the solubility of arsenic, antimony, and other impurities in methanol, the ease of separating saturated solution from residue, recovery of methanol, the arsenic circulating load in the methanol, and the effect of moisture in the feed. The lack of existing technology, and safety risks, tend to eliminate this process option. Limited testing has produced inconclusive results.

Fuming is a process based on the boiling point difference between As_2O_3 (221°C), and antimony (Sb_2O_3, 1380°C). The flue dust would be heated to a point where the arsenic evaporates, leaving the impurities in the residue. Arsenic would be recovered by cooling the air, condensing the arsenic, and recovering the powder. The process developed at the Giant Mine using this principle concept, was code named 'WAROX' for White ARsenic OXide. The material produced is extremely fine which creates a handling, and hygiene problem, however the process is viable, and will be examined further.

6.3.5 Marketing Potential:

The primary use for arsenic is in the wood preservative industry (90% of total demand). The major markets are in the United States where the wood preservative industry would use the high grade arsenic trioxide as a feed source for copper chromated arsenate (CCA). CCA is recognized world wide as the most acceptable wood preservative product. There are three major producers of wood preservatives in the United States.

The United States accounts for 2/3 of the total world demand for arsenic trioxide and China is the largest single supplier. A total of 28,000 tons of arsenic trioxide was imported to the U.S. in 1996.

Although it will be several years before product from the Giant mine would be available to compete on the market, it is feasible to believe that there will be a market at that time.

Environmental pressures may result in decreased demand for arsenic as a wood preservative in the long term. New alternative products, such as Ammoniacal Copper Quaternary (ACQ), avoids the use of arsenic and chrome, and may impact the CCA market if it becomes widely accepted.

7.0 Current and Proposed Technical Evaluations:

7.1 Permafrost Conditions:

A review of historical data was undertaken by mine engineering personnel regarding observations and records relating to permafrost in the underground mine workings at the Giant Mine. Documentation indicates that discontinuous zones of permafrost were encountered throughout various areas of the mine during development and led to the initial plan to store the arsenic trioxide containing baghouse dust in secure vaults in a complete permafrost envelope.

No long term monitoring of bedrock temperatures and conditions is available from the mines data base.

Six diamond drill holes were drilled into the bedrock from surface to investigate the status of permafrost in the bedrock surrounding the storage chambers, in June of 1994. Five of the six holes are located in the vicinity of the active and inactive arsenic storage areas. The sixth hole was drilled in an area of bedrock not influenced by active mining conditions.

In each of the holes a string of thermistors (electronic temperature measurement device) was installed to monitor rock temperatures at various depths. The strings read temperatures at surface, at a 20' depth below surface, and then at 55 foot intervals down until the bottom of each hole. An approximate depth of 350 feet was used as the bottom of each hole as no storage chamber is located below this elevation.

These thermistors have been read on a regular basis since installation in 1994 and have been reported in previous years annual updates. Appendix II is a complete summary of the recorded data, including graphical representation, hole locations and drill hole logs.

Drill holes # AS1 and AS2 are located in the bedrock surrounding the currently active storage chamber B14. Drill hole # AS3, AS4, and AS5 are located in bedrock near the older inactive storage chambers. Drill hole #AS6 is located away from active mining, south east of C Shaft, and acts as a point of comparison.

Several conclusions are evident from the data:

1) Underground and surface mining activities at the Giant Mine have disturbed the existence of permafrost in the rock.

2) The influence of ambient temperature extends down to a depth of 15 feet below surface although there is a noticeable lag time between the surface temperature and the rock temperature.

3) At a depth of 70 feet and below there is no measurable impact from ambient temperatures on the rock temperature.

An additional thermistor was imbedded approximately 10 ft. into the exposed arsenic trioxide bearing dust in B208 chamber. This work was completed on February 19th, 1998. There was evidence of frost penetration from the B1 Pit, and it was hoped that this installation would provide additional temperature data for the material 'in-situ'. Temperatures recorded to date are from 0.0° to 0.17° C.

These existing installations will continue to be maintained and monitored. Additional installations are being considered in areas of interest, such as the A Shaft area where cold air has been entering the inactive area for the past two winters, and there is evidence that the ground is freezing.

7.2 Hydrogeology:

Royal Oak is currently undertaking a joint cooperative hydrogeological study in association with DIAND - Water Resources Division.

The objective of this study is to obtain a better understanding of the complexities of current and future groundwater movement within the mine area. It is anticipated that the study will provide data which will enable a further comparison and evaluation of the potential risks associated with the underground storage of waste materials and the proposed removal techniques.

The initial phase of work will be completed in the first quarter of 1998, and is expected to include the following information:

- reconnaissance water sampling program to characterize the fundamental geochemical nature of the mine waters

- an approximation of flowrates, rock mass permeability and transmissivity

- a hydrogeological model that should identify the main hydrogeological units that are assumed to control flow into the mine, estimate the rock mass anisotropy and identify the main surface water bodies that are assumed to interact with the groundwater flow system that has developed around the mine

As the study progresses, several key determinations will be made;

- identify the major sources of water and pathways for groundwater ingress and egress from the mine

- mixing relationships and geochemical reactions that may affect the fate and transport of arsenic trioxide in the groundwater under current mining conditions, and when the mine floods

- the risk of arsenic trioxide migrating beyond the underground vaults and reaching the surface under current mining conditions and when the mine floods

Water sampling and analyses is underway at time of writing, and therefore can not be presented in this report. However reference is made to several figures that have been prepared to assist with the study;

Figure 7	1st Level Plan of Geology and Mine Workings
Figure 8	2nd Level Plan of Geology and Mine Workings

These two figures show the locations of mine workings, and arsenic storage chambers with respect to major structural features and geology, within a section of the mine.

Appendix III Mine Level Plans

The level plans included here (100, 250, 425, and 575 levels) represent the mine workings, and main structural features in areas surrounding and below (425 and 575 level) the arsenic chambers.

Appendix IV Typical Mine Sections

Several mine cross sections are included to show the position of the storage chambers, and mining areas, in relation to approx. East - West boundaries, and structural controls.

Figure 3	Air Photo
Figure 4	Regional Geology Map

These figures illustrate the complex structural nature of the Yellowknife Greenstone Belt. A major feature, the West Bay Fault, dominates the western boundary of the unit, and the mine workings.

The relationships that these geological and structural features have on the hydrogeology will become evident following the completion of the report. The first phase of site work is now complete, and the initial report will be prepared in the first quarter of 1998. Further site work is anticipated later in 1998.

7.3 Risk Assessment:

7.3.1 General

A risk assessment has not yet been carried out on the options for arsenic trioxide management at the Giant Mine.

This will be a difficult and critical task, and there is insufficient data available at the present time to select a preferred disposal option, or properly carry out the risk assessment. There has however been much discussion between Royal Oak and regulatory agencies, including industry experts, that has clarified the alternatives, and the basis of the risk assessment. These discussions included a Technical Meeting on Arsenic Trioxide Management, jointly sponsored by Royal Oak and DIAND (Water Resources Division), held in October 1997. A summary of the Proceedings from that meeting are included as Appendix V.

It will be necessary for Royal Oak, in cooperation with regulatory agencies, to complete data gathering in several key areas, in order to complete a risk assessment. These areas are summarized as (but not limited to) the following:

- hydrogeology of the mine area, and identification of potential pathways and impacts to groundwater

- a study of human receptors, sensitive or high risk sites, and an evaluation of existing data on the level of arsenic in drinking water, fish, and food plants

- an ecological assessment of potential pathways and receptors

- thorough technical analysis of each management option to determine technical and economical viability

The following discussion presents an approach to risk assessment that Royal Oak is considering. This approach has been previously outlined in a Scoping Document entitled Arsenic Trioxide - Surface Handling and Storage, submitted to the NWT Water Board in December 1997.

7.3.2 Identification of Potential Receptors and Pathways

7.3.2.1 Human

The potential health risks to human receptors from exposure to arsenic trioxide (or arsenic in another form) must take into consideration all known and projected pathways of exposure. For onsite workers, the key routes of exposure would include inhalation (of soil/dust), ingestion (of soil/dust), and dermal contact. However, given that not all workers would necessarily be exposed to the same degree of risk depending on the type of work they might be involved in, it will be necessary to review current or proposed occupational health and safety procedures/plans associated with the various work practices. Included in this review will be an assessment of the numbers of workers who would potentially be exposed, their specific job assignments, their location(s), their magnitude/duration of potential exposure, and measures in place to mitigate exposure.

In order to estimate the magnitude of health risks that could be experienced by the public at large, it will be necessary to identify all human receptors who might be exposed in the area from airborne or surface water contamination by arsenic trioxide. This would include a critical evaluation of atmospheric dispersion modeling done to date for this site, as well as identification of typical non-occupational receptors. This would include identification of both normal and sensitive sub-populations (e.g. children, elderly etc.), potential high risk sites (e.g. homes, buildings). Also included in this assessment will be an evaluation of existing reports/data pertaining to the level of toxicologically significant arsenic in drinking water, fish, local food plants etc. Local topography and site drainage conditions would also be part of this assessment.

The issue of arsenic bioavailability will also be identified as a component of a risk assessment study. The degree of bioavailability will be an important step in identifying the toxicity of the arsenic that is evident within the environment.

7.3.2.2 Ecological

The goal of ecological risk assessment will be to predict potential adverse effects and when appropriate, to measure existing adverse effects of chemical contaminants on the biota on or near the mine site, and to determine levels of those chemicals in the environment that would not be expected to adversely affect the biota.

An ecological assessment will be undertaken as a component of a risk assessment for a selected arsenic trioxide disposal option. The assessment would determine potential ecological receptors, the potential levels of the arsenic trioxide, the degree of bioavailability, and potential exposure pathways. The area to be considered would be the area that could be affected by the waste As_2O_3 byproduct, given a particular management option. This would include soil, air, surface and ground water, and biota.

It is important to note that it cannot be assumed that the human health risk assessment will provide an estimate of threat to biota. Ecological receptors are frequently more sensitive to adverse contaminant-induced effects than humans. In addition, many terrestrial organisms may be exposed to higher concentrations of contaminants than humans.

Pathway assessment will be conducted once potential species and habitats are identified. Pathway assessment identifies the potential for contact between biota and chemicals of concern in any medium and by any route. Media to be considered will include soil, air, surface and ground water, and biota. Of particular importance will be consideration and evaluation of physical and chemical characteristics which influence environmental fate and transport of arsenic trioxide.

Pathways may be direct, such as inhalation of air, or indirect, such as movement through the food web. Direct exposure routes to be considered will include inhalation, ingestion, and dermal contact. Indirect exposure via consumption of food items also warrants evaluation, especially for those chemicals of concern with physical parameters which indicate a potential to bioaccumulate.

Pathways will be assessed according to whether:

- There was or is a potential release to the environment, based on site-history or preliminary characterization data.
- Transport of the contaminant to a point of exposure is possible based on preliminary site characterization data, or fate and transport modeling.
- A point of contact exists for the contaminant and potential receptors.
- An exposure route, such as inhalation or ingestion, exists at the point of contact.

Pathways shall be considered complete unless there is scientific justification to demonstrate arsenic trioxide will not enter the medium or the receptor will not contact the medium, either directly or indirectly, now or in the future. For completeness, a qualitative description of the magnitude, duration and frequency of exposure to the various biological receptors, representing multiple trophic levels or area of contamination, will be summarized.

7.3.3 Contingency Planning

Contingency planning will be a major component of the risk evaluation of the many management options for the arsenic trioxide bearing material. Contingency plans will be developed which will outline the emergency response actions to be implemented in the event of an accidental release of the material. The plans will address the transport, handling and storage aspects of the options. The scope and types of contingency plans prepared for review will ultimately be dependent upon the various components of each option.

Several contingency plans for the handling and storage of arsenic trioxide currently exist within Royal Oak's database. These plans will be reviewed and revised as required and will provide the basis from which proposed contingency plans are produced.

8.0 Summary and Conclusions:

The following conclusions can be drawn from the work completed to date:

1) Under current operating conditions, the systems in place for the handling and storage of arsenic trioxide are adequate to ensure that the material is not being released to the environment.

2) Completion of technical studies such as hydrogeology, mining methods, and processing techniques is required before conducting a risk assessment on preferred or viable options.

3) The option of removal from underground of the arsenic trioxide bearing dust for processing and sale, is the option with the least long term risk.

4) There will be remnant arsenic trioxide bearing material left in the storage chambers, because total mining recovery is unlikely. The fate of this material will need to be decided, and will involve a permanent underground disposal option.

5) There will be residual arsenic concentrations in the final process wastes, and the fate of this material will need to be decided.

6) Permafrost has receded from the mine area due to mining activity. The option or ability to re-establish permafrost is untested, and will require further study.

Ongoing studies include the joint cooperative hydrogeology study between Royal Oak and DIAND (Water Resources Division), and internal laboratory test work on processing and upgrading techniques. Efforts are being made to monitor the bedrock temperature regime, including supplementing existing data with new installations.

During 1998 Royal Oak will be involved in developing concepts and plans to recover the baghouse dust from underground storage chambers. This exercise will include some initial mine development that will improve access to areas currently difficult or impossible to inspect. This development is required so that areas can be explored and checked for condition and potential reuse in recovery systems.

Further efforts will be placed on chamber stability and bulkhead integrity as they become incorporated into the planning of recovery techniques, and / or permanent disposal options.

According to previous and proposed commitments, there will be a substantial commitment of time and resources over the next six to twelve months, from Royal Oak and others. Royal Oak has proposed that the Giant Mine Abandonment and Restoration Plan will be updated by November 1, 1998. Obviously the permanent disposal option for the arsenic trioxide bearing dust will be a major part of that Plan. In addition, Royal Oak has committed to delivering a Scoping Document for the Recovery and Processing of Arsenic Trioxide to the Water Board by March 31st, 1999. This document would initiate CEAA screening for the project dealing with the recovery of the dust from underground, processing, marketing, and disposal of final waste products.