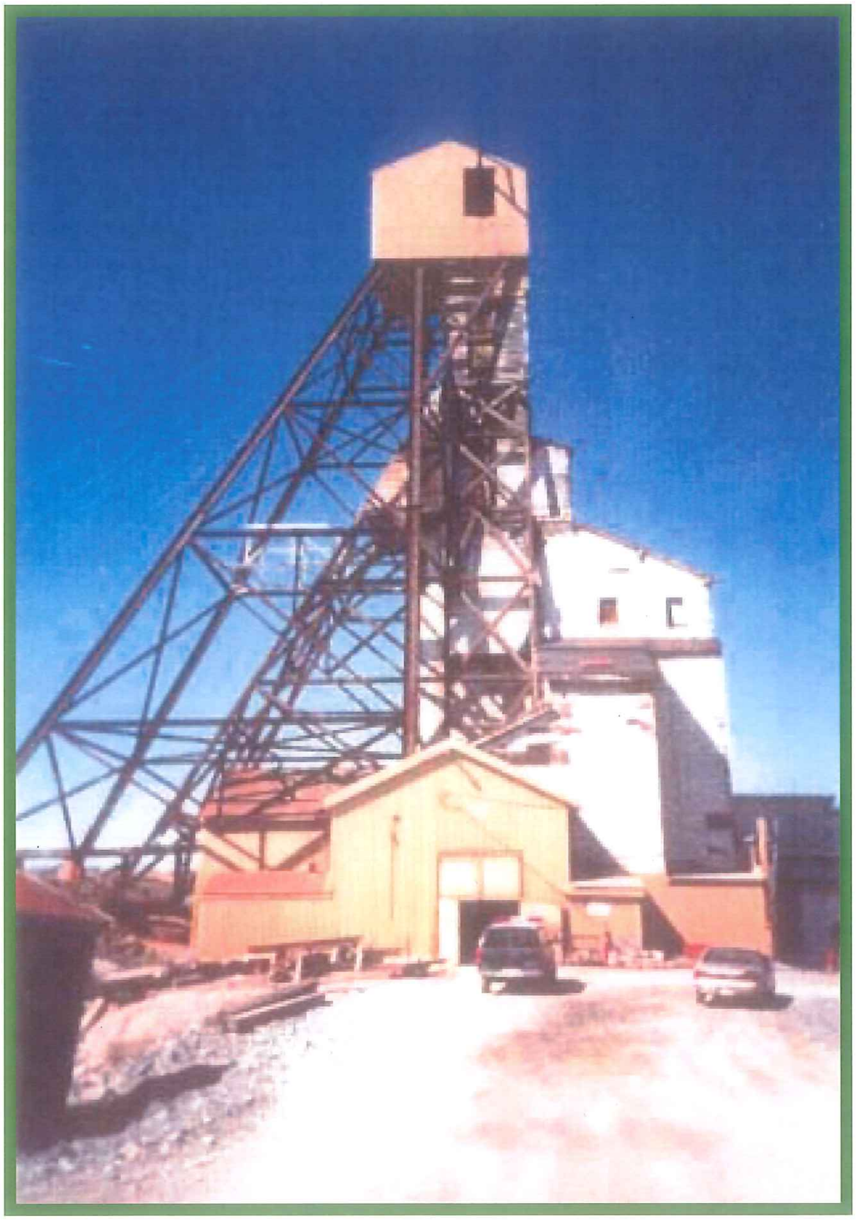
Final Abandonment and Restoration Plan Miramar Giant Mine Ltd.



Submitted to:

VOLUME II OF III

Miramar Giant Mine Ltd.
Yellowknife, NT

September 26, 2001

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REPORT ON

FINAL ABANDONMENT AND RESTORATION PLAN PREPARED FOR INDIAN & NORTHERN AFFAIRS CANADA BY MIRAMAR GIANT MINE LTD. YELLOWKNIFE, NT

VOLUME II OF III

Submitted to:

Miramar Giant Mine Ltd.
Yellowknife, NT

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APPENDIX A-2

FISHERIES

A2-1 OBJECTIVES

The objectives of the fish habitat study in Baker Creek were to document the current physical conditions in the creek, assess the current fish habitat potential in the creek, identify habitat limitations, and provide options for restoration of fish habitat in Baker Creek as part of the Giant mine closure plan. This survey did not consider the water or sediment chemistry in Baker Creek (see Section A1-9 and data provided in Table A1-20).

A2-2 INVESTIGATIONS/SAMPLING

The fisheries investigation consisted of two components: 1) a field investigation to map current habitat characteristics in Baker Creek; and 2) a review of existing information regarding fish species presence in Baker Creek, the historical fish habitat in Baker Creek, and previously proposed reclamation options.

The fish habitat assessment was conducted in September 2000, according to procedures developed by Golder for characterizing fish habitat. In general, habitat characteristics measured included channel type, habitat type (e.g., riffle, run, pool), substrate type, presence of in-stream and overhanging vegetation, channel depth (m) and width (m), and gradient (%). Flow measurements were taken during spring freshet in May 2001, and historical flows were provided by the Water Survey of Canada in Yellowknife. The habitat assessment was conducted from the mouth of Baker Creek, upstream of the effluent discharge point to the upstream sediment sampling location (i.e., BC-US-SD). Photographs of key habitat characteristics were taken during the field assessment and are provided with the habitat maps. Habitat maps were produced in AutoCAD.

Fish species presence and habitat characteristics in Baker Creek are described below.

A2-3 RESULTS

Fish Species in Baker Creek

Based on a review of existing information, a number of fish species had been observed in Baker Creek prior to seasonal effluent discharge from the Giant Mine. These species, as reported by Dillon (1998), include:

- Northern pike (*Esox lucius*);
- Longnose sucker (*Catostomus catostomus*);
- White sucker (*Catostomus commersoni*);
- Trout-perch (*Percopsis omiscomaycus*);
- Ninespine stickleback (*Pungitius pungitius*);
- Lake chub (*Couesius plumbeus*);

- Spottail shiner (*Notropis hudsonius*);
- Emerald shiner (*Notropis atherinoides*);
- Walleye (*Stizostedion vitreum*); and
- Juvenile Arctic char (*Thymallus arcticus*).

During periods of effluent discharge , Dillon (1998) reported the presence of spottail shiners and northern pike downstream of the mine effluent discharge point and the possible presence of burbot upstream of the mine effluent discharge point, although this was not confirmed. During periods of no effluent discharge northern pike and longnose sucker were observed in Baker Creek (Dillon 1998). Other species, such as grayling and pickerel, have been observed at the mouth of Baker Creek and may migrate further upstream (R. Connell, 2001). However, the fish habitat assessment described below focussed on suitable habitat for northern pike and longnose sucker, as they are the species that will most likely use Baker Creek after mine closure (i.e., no effluent discharge) based on Dillon (1998).

Specific habitat requirements for northern pike and longnose sucker are provided in Tables A2-1 and A2-2, respectively. Habitat requirements described in Tables A2-1 and A2-2 were compiled from the literature as part of a "No Net Loss Plan" for the Diavik Diamond Mine (Golder, 1998). In general, northern pike prefer shallow areas along stream banks with submergent and emergent aquatic vegetation for spawning and rearing. Spawning occurs in the early spring. Longnose sucker prefer areas of faster flow and gravel substrate, and usually spawn in small tributaries. Spawning occurs in the spring. Adult suckers prefer moving water such as found in back eddies or river mouths, while juveniles prefer shallow, weedy areas with reduced current velocities.

Habitat Assessment in Baker Creek

Baker Creek flows into Yellowknife Bay (Figure A2-1). General habitat characteristics are provided in Table A2-3. A large marsh area is located on the west bank of the bay, which supports predominantly *Equisetum* sp. and a smaller patch of *Potamageton* sp. (Figure A2-1; Photograph 1). To the east of the marsh area, the water from Baker Creek flows along the breakwater and into the main body of Yellowknife Bay. No macrophytes were observed in this area. The substrates are dominated by fine material (e.g., silt and sand) and are representative of a depositional area. Although no site-specific information is available regarding northern pike use of this area, it provides suitable habitat for northern pike spawning and rearing.

A conveyor crosses the mouth of Baker Creek (Figure A2-1; Photograph 2), and the creek flows through Culvert 1 underneath Ingraham Trail (Figure A2-1; Photograph 3). The habitat in this area is largely a run with a pool located just downstream of Culvert 1. The substrate consists predominantly of gravel and cobble, and has the potential to provide suitable spawning habitat for longnose sucker. However, fish habitat is limited in this area by shallow water depths (e.g., 0.38 m), lack of habitat diversity, and a channelized streambed. These habitat characteristics are similar to those observed by Dillon (1998). Dillon (1998) reported the capture of three spottail shiners and one northern pike in this area.

Upstream of Culvert 1 the creek has been re-directed and makes a 90° turn to the north (Figure A2-1). The creek has been channelized in this section as a result of road development. Substrate predominantly consists of boulders, likely as a result of bank stabilization associated with road development activities, (Figure A2-1; Photograph 4) and bedrock outcropping (Figure A2-1; Photograph 5). No riparian vegetation exists in this area. This section of the creek provides only poor quality habitat for both northern pike and longnose sucker, and likely serves only as a migratory corridor to areas further upstream.

The channel widens further upstream of a bedrock outcropping to form a pond (Figure A2-1; Photograph 6). Dillon (1998) reported that the pond was formed by back-watering associated with the placement of Culvert 2. Substrate in the pond consists predominantly of fines. Emergent (e.g., cattails) and submergent vegetation were observed. Depth of the pond measured in September 2000 averaged 0.6 m. This section likely provides moderately suitable spawning and rearing habitat for northern pike.

The channel narrows slightly and deepens (average 0.9 m) as it approaches Culvert 2 (Figure A2-1). Culvert 2 seems to be collapsing under the road (Figure A2-1; Photograph 7a). Substrates consist predominantly of gravel and cobble immediately upstream and downstream of Culvert 2. Minimal instream cover is provided by overhanging willows. This section of the creek could provide moderately suitable spawning habitat for longnose sucker.

Upstream of Culvert 2 the creek shows minimal signs of disturbance. The channel in this area is not confined by bedrock outcropping, but lies in a floodplain (Figure A2-1; Photograph 8). The channel provides a series of pool and run habitat. Substrates consist predominantly of fines with some gravel and cobble. Overhanging vegetation in some areas provides minimal cover for fish. In general, this area likely provides moderately suitable migration and spawning habitat for northern pike (i.e., fines, vegetation) and longnose sucker (i.e., gravel substrate). Dillon (1998) recorded one pike and one sucker in this area during a period of non-discharge of mine effluent.

A large pool exists at the upstream section of this floodplain, before the creek becomes more confined by bedrock outcroppings (Figure A2-1). In-stream cover in this pool is provided by emergent vegetation and the substrate is dominated by gravel. Consequently, this section provides moderately suitable spawning and rearing habitat for both species.

Immediately upstream of this pool, the creek diverts to the west to accommodate the development of C1 pit (Figure A2-1). Channel characteristics in this area are shown in Photographs 9, 10, and 11 (Figure A2-1). Little cover is provided in this area and the substrates are dominated by fines and gravel. The channel is straight and provides little habitat complexity. These habitat characteristics continue until Culvert 3. Historically this section of the creek provided riffle habitat and suitable spawning habitat, although low flows were thought to create a migration barrier for fish at certain times of the year (Dillon 1998). Dillon (1998) reported the capture of one pike and one sucker in this section of the creek during a period of non-discharge of mine effluent; no fish were reported during a period of discharge.

Culverts 3 and 4 have been installed to provide access over the creek for the mine road and Ingraham Trail, respectively (Figure A2-2). Placement of these culverts has resulted in a backwatering effect in the creek downstream of Culvert 4. As a result, the naturally flat and straight channel found prior to mine development, as described by Dillon (1998), has been flooded, thereby increasing the wetted width of the creek and flooding riparian vegetation, creating a pond. Currently, little emergent or riparian vegetation exists along the banks of the creek in this area – that was historically densely vegetated an area. Dillon (1998) observed one juvenile northern pike between Culverts 3 and 4.

Similarly, a backwatering effect on the channel has occurred further upstream as the result of the placement of Culverts 5 and 6 (Figure A2-2). Again, the channel wetted width has increased, and flooding has resulted in a decrease in riparian vegetation. A decrease in riparian vegetation has also resulted from road and mine development in this area. Photograph 12 shows the pooled area located just downstream of Culvert 5 (Figure A2-2). Some emergent and riparian vegetation provides minimal cover. Average water depth in September 2000 was 0.5 m. This was largely classified as a depositional area and the substrate was dominated by fines. Photograph 13 shows the pond that was created by the backwatering effect of Culvert 6 (Figure A2-2). Substrates are dominated by gravel with some fines, and minimal submergent vegetation was observed. Overall, the value of the habitat in this area is of low quality for northern pike and longnose sucker due to limited vegetation and unsuitable substrate, respectively.

The creek upstream of Culvert 6 was historically a meandering channel with riffle habitat, constricted bedrock outcrops in certain locations, and densely vegetated riparian zones and narrow bands of emergent vegetation (Dillon 1998). Historically, this section may have provided spawning habitat for northern pike and longnose sucker (Dillon 1998). However, the development of B1 pit has resulted in the removal of vegetation, the flooding of the channel creating frequent pooled areas and the loss of the meandering channel, in-filling of the creek with sediment, and die-back of vegetation. Most of the creek's banks in this area now consist of riprap rather than natural vegetation or bedrock. A potential barrier (chute 0.4 m height) to the upstream migration of fish also exists in this area, near the vent plant site (Figure A2-2; Photographs 14a and b).

A large pond exists upstream of the potential barrier to fish migration (Appendix A2-2; Photographs 15 and 16). Emergent and submergent vegetation was observed in this section of the creek, which provides a source of nutrients and cover for fish. However, no fish were observed by Dillon (1998) in this section of Baker Creek. The east creek bank in this section consists predominantly of riprap that provides stabilization associated with the road development on this side. Consequently, this area of Baker Creek has also been impacted by mine development and provides moderate quality spawning and rearing habitat for northern pike and longnose sucker.

Another large pond, historically referred to as Lower Baker Creek Pond, exists just downstream of Culvert 8 and the mine effluent discharge (Figure A2-3). Mine effluent drains into Trapper Creek, just downstream of Culvert 7 (Figure A2-3; Photograph 18), flows through Culvert 8 (Figure A2-3; Photograph 17), and into the northeast end of Lower Baker Creek Pond. Historically Lower Baker Creek Pond supported a dense macrophyte population as well as densely vegetated riparian zone (Dillon 1998). However, road construction has resulted in the removal of riparian vegetation on the east side and replaced it with riprap. The placement of Culverts 8 and 9 has had a backwatering effect downstream, thereby widening and flattening the creek bed and impacting vegetation. Mine effluent and tailings deposits/spills have resulted in the sedimentation of mine tailings, in-filling sections of the creek in this area.

Upper Baker Creek flows into the northwest end of Lower Baker Creek Pond (Figure A2-3). This section of Baker Creek has not been subject to physical impacts (e.g., channel realignment) as a result of mine development. Consequently, the habitat described in September 2000 largely reflects its historical nature as described by Dillon (1998). Upper Baker Creek is characterized by a series of pond and wetland areas starting at the inflow to Lower Baker Creek Pond. Further upstream, the channel meanders irregularly through bedrock outcrops forming pool, riffle, and run habitat (Figure A2-3; Photographs 20 and 21). However, flows upstream of the effluent discharge were very low in September 2000. An initial investigation of this section of the creek in July 2000 also showed very low flows upstream of the effluent discharge. Photograph 22 shows the streambed upstream of the bedrock outcropping, which is dominated by a riffle habitat with cobble substrate and very little water flow. Further upstream the channel changes to a series of narrow riffle/pool sequences over bedrock (Figure A2-3; Photograph 24). A potential barrier to the upstream migration of fish exists in this section (Figure A2-3; Photograph 23). Habitat limitations in the "unimpacted" Upper Baker Creek include the presence of chutes that may limit the upstream migration of fish, potentially intermittent water flows, a lack of instream cover, and a lack of suitable spawning habitat.

A2-4 DISCUSSION

Mine activities, open pit development, and infrastructure development have resulted in alterations to the natural configuration of Baker Creek. These alterations include loss of riparian vegetation and macrophytes, channel diversion and realignment, changes in water quality, and increased sedimentation due to mine effluent discharge and tailings deposits/spills, and atmospheric deposition. . These impacts were observed downstream of the effluent discharge, and the overall quality of fish habitat for both northern pike and longnose sucker was classified as poor. Based on historical information provided by Dillon (1998), a loss of suitable spawning habitat due to channel realignments, sedimentation, and a loss of rearing habitat in the form of vegetative cover have been observed. Culvert placement has resulted in a backwatering effect that has increased the frequency of pool habitat. However, this pool habitat is likely of poor quality as cover is minimal and sedimentation has resulted in the in-filling of the creek bed.

Fish habitat above the effluent discharge point in Baker Creek has remained relatively undisturbed. Natural limitations to the creek include low/intermittent water flows that may limit the upstream migration of fish, extensive bedrock outcrops that result in the channelization of the creek in some areas and limit suitable spawning and rearing habitat. Overall the quality of the habitat in this relatively undisturbed section of Baker Creek is classified as low.

Rationale for Restoration Options

Hydrological Regime in Baker Creek

Historical and recent fish habitat assessments have indicated that much of Baker Creek has been disturbed by mine and infrastructure development, and that flows are unnaturally increased during periods of effluent discharge (i.e., June to October). Historical data obtained from the Water Survey of Canada in Yellowknife indicate that, Baker Creek, particularly upstream of the mine discharge outside the spring freshet, has limited or no natural flows in summer, fall, and especially winter (see Attachment A2-2). Flows are highest during freshet. Discharge measured during the 2001 freshet was $0.2 m^3/s$, and peak discharge was $3.5 m^3/s$. The discharge from the mine comprises a significant proportion of the flows in Baker Creek outside of the spring freshet. Therefore, prior to mine development, this creek only had sufficient flows to provide spring spawning and early rearing habitat.

Consequently, restoration efforts should be aimed at improving conditions for spawning and rearing of spring spawning species residing in Yellowknife Bay. It is doubtful, given the flow conditions, that a resident fish population exists in Baker Creek. The habitat survey showed little or no potential overwintering habitat. Consequently, the habitat created would be for fish from Yellowknife Bay that would use Baker Creek on a seasonal basis.

Metal Concentrations in Baker Creek Sediments and Water

The results of the water and sediment quality testing for Baker Creek indicated the following:

- Baker Creek water and sediment upstream of the mine has not been impacted by mining activities, but naturally elevated concentrations of arsenic (0.0145 to 0.0399 mg/L) and aluminum (0.05 to 0.07 mg/L) exist in the watershed.

- Water quality at and downstream of the effluent discharge point fell within the limits of the Water License, but concentrations of aluminum, arsenic, copper, nickel and cyanide were above CCME guidelines for the protection of aquatic life.

- Comparison of water quality data collected on September 20, 2000 (period of effluent discharge) and on May 15, 2001 (period of no effluent discharge and freshet) indicate that increased concentrations of metals (e.g., arsenic) are introduced into Baker Creek during periods of effluent discharge and that arsenic is released from the sediments into the overlying water particularly during periods of higher flow (i.e., freshet).

- The concentrations of metals (e.g., arsenic) measured in Baker Creek sediments are above the sediment quality guidelines for the protection of aquatic life downstream of the effluent discharge.

- The sediments will continue to be a source of metal and arsenic contamination to the creek even after closure and re-mobilisation of contaminated sediments to Yellowknife Bay is anticipated.

Despite the elevated concentrations of arsenic and other metals and the continued source of arsenic from the sediments to Baker Creek and Yellowknife Bay, concentrations will likely remain constant or decrease following mine closure. As previously mentioned, Moore et al. (1978) reported low concentrations of metals in northern pike and whitefish from Yellowknife Bay and Back Bay despite high sediment metal concentrations and during a period of active mining. Thus, an increased impact to the fish community in Yellowknife Bay and Great Slave Lake is not anticipated since loadings into Yellowknife Bay will remain constant or decrease over time. Consequently, habitat restoration efforts are recommended for some areas of Baker Creek to enhance spring spawning and rearing habitat. These recommendations are provided in more detail below. In addition, a monitoring program should be implemented to determine the fish use pattern in Baker Creek and to assess the potential for impact to the fish community.

A2-5 BAKER CREEK RESTORATION OPTIONS

The following suggestions are made for restoration options in Baker Creek..

Restoration Options

- Improvement of existing spawning habitat for hard substrate spawners such as longnose sucker. This option may include changes in channel configuration to optimize flow over substrates, addition of suitable substrates, and excavation of channel to provide more depth.
- Stabilization or preservation of existing macrophyte beds for northern pike spawning.
- Enhancement of existing habitat in Baker Creek below Culvert 1. Enhancement may include planting of additional riparian vegetation to increase cover for all fish species, addition of instream structures (boulders) to create pool habitat and diversify the habitat, and the addition of suitable substrate for longnose sucker.
- Planting of riparian vegetation and other erosion control measures along sections of the Creek with unstable banks (banks in close proximity to the road).

Restoration options should be revised if additional information on the potential impact of arsenic on the aquatic life in Baker Creek and Yellowknife Bay becomes available (e.g., ecological risk assessment for pump & treat scenario).

REFERENCES

Connell, R. 2001. Personal Communication. August 2001.

Golder Associates Ltd. (Golder). 1998. Diavik No Net Loss Plan. Prepared for Diavik Mines Inc.

Dillon Consulting Ltd.(Dillon). 1998. Baker Creek Fish Habitat and Rehabilitation Study for Abandonment and Restoration Planning. Prepared for Royal Oak Mines Inc., Yellowknife, NWT. 40 pp.

ATTACHMENT A2-I

WATERCOURSE HABITAT MAPPING SYSTEM

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CHEMICAL ANALYSIS REPORT

GOLDER ASSOCIATES LTD

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BURNABY BC V5C 6C6

DATE: June 13, 2001

Lab Work Order #: L32566 **Sampled By:** CP **Date Received:** 16-MAY-01

Project P.O. #:

Project Reference:

Comments:

APPROVED BY: ______________________________

TONY CIARLA

Project Manager

ACCREDITATIONS: STANDARDS COUNCIL OF CANADA (SCC), IN COOPERATION WITH THE CANADIAN ASSOCIATION FOR ENVIRONMENTAL ANALYTICAL LABORATORIES (CAEAL): FOR SPECIFIC TESTS AS REGISTERED BY THE COUNCIL (EDMONTON, CALGARY, SASKATOON, WINNIPEG, THUNDER BAY)
AMERICAN INDUSTRIAL HYGIENE ASSOCIATION (AIHA) FOR INDUSTRIAL HYGIENE ANALYSIS (EDMONTON, WI STANDARDS COUNCIL OF CANADA IN COOPERATION WITH THE CANADIAN FOOD INSPECTION AGENCY (CFIA) FOR FERTILIZER AND FEED TESTING (SASKTOON)

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-1	BC-US-SW-05/01							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Dissolved Metals						
		Dissolved Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.02	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.012	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.001	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	<0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.048	0.005	mg/L		17-MAY-01	MD
		Titanium (Ti)	<0.001	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.003	0.001	mg/L		17-MAY-01	MD
		Dissolved Major Metals						
		Calcium (Ca)	12.9	0.5	mg/L		18-MAY-01	EC
		Potassium (K)	1.3	0.1	mg/L		18-MAY-01	EC
		Magnesium (Mg)	4.25	0.01	mg/L		18-MAY-01	EC
		Sodium (Na)	3.9	0.5	mg/L		18-MAY-01	EC
		Iron (Fe)	0.090	0.005	mg/L		18-MAY-01	EC
		Manganese (Mn)	0.054	0.001	mg/L		18-MAY-01	EC
		Total Metals						
		Total Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.07	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.013	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.002	0.002	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.003	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	<0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	0.08	0.05	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.052	0.002	mg/L		17-MAY-01	MD
		Titanium (Ti)	0.001	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.004	0.001	mg/L		17-MAY-01	MD
		Total Major Metals						
		Calcium (Ca)	12.7	0.5	mg/L		17-MAY-01	EC
		Potassium (K)	1.5	0.1	mg/L		17-MAY-01	EC

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID / Sample ID / Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-1 BC-US-SW-05/01						
Sample Date: 15-MAY-01 01:00 PM						
Matrix: WATER						
Total Metals						
Total Major Metals						
Magnesium (Mg)	4.4	0.1	mg/L		17-MAY-01	EC
Sodium (Na)	3	1	mg/L		17-MAY-01	EC
Iron (Fe)	0.179	0.005	mg/L		17-MAY-01	EC
Manganese (Mn)	0.097	0.001	mg/L		17-MAY-01	EC
Routine Water Analysis						
Chloride (Cl)	4	1	mg/L		22-MAY-01	CNP
Nitrate+Nitrite-N	<0.1	0.1	mg/L		22-MAY-01	CNP
pH, Conductivity and Total Alkalinity						
pH	7.4	0.1	pH		17-MAY-01	CMN
Conductivity (EC)	135	0.2	uS/cm		17-MAY-01	CMN
Bicarbonate (HCO3)	57	5	mg/L		17-MAY-01	CMN
Carbonate (CO3)	<5	5	mg/L		17-MAY-01	CMN
Hydroxide	<5	5	mg/L		17-MAY-01	CMN
Alkalinity, Total	47	5	mg/L		17-MAY-01	CMN
Ion Balance Calculation						
Ion Balance	107		%		24-MAY-01	
TDS (Calculated)	65		mg/L		24-MAY-01	
Hardness	54		mg/L		24-MAY-01	
ICP metals and SO4 for routine water						
Calcium (Ca)	14.0	0.5	mg/L		23-MAY-01	MOR
Potassium (K)	1.7	0.1	mg/L		23-MAY-01	MOR
Magnesium (Mg)	4.6	0.1	mg/L		23-MAY-01	MOR
Sodium (Na)	4	1	mg/L		23-MAY-01	MOR
Sulfate (SO4)	8.2	0.5	mg/L		23-MAY-01	MOR
Antimony (Sb)-Dissolved	0.0017	0.0004	mg/L		17-MAY-01	MD
— Arsenic (As)-Dissolved	0.0360	0.0004	mg/L		17-MAY-01	MD
Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD
Antimony (Sb)-Total	0.0019	0.0004	mg/L		17-MAY-01	MD
— Arsenic (As)-Total	0.0399	0.0004	mg/L		17-MAY-01	MD
Mercury (Hg)-Total	<0.0002	0.0002	mg/L		17-MAY-01	MD
Ammonia-N	0.20	0.05	mg/L		22-MAY-01	LAK
Dissolved Organic Carbon	13	1	mg/L		22-MAY-01	HAN
Nitrate-N	<0.1	0.1	mg/L		22-MAY-01	CNP
Nitrite-N	<0.05	0.05	mg/L		22-MAY-01	CNP
Total Suspended Solids	<3	3	mg/L		18-MAY-01	WNG
L32566-2 BC-EFF-SW-05/01						
Sample Date: 15-MAY-01 01:00 PM						
Matrix: WATER						
Dissolved Metals						
Dissolved Trace Metals						
Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
Aluminum (Al)	0.06	0.01	mg/L		17-MAY-01	MD
Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
Barium (Ba)	0.012	0.003	mg/L		17-MAY-01	MD
Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-2	BC-EFF-SW-05/01							
Sample Date: 15-MAY-01 01:00 PM								
Matrix:	WATER							
		Dissolved Metals						
		Dissolved Trace Metals						
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.005	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	<0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	0.014	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.061	0.005	mg/L		17-MAY-01	MD
		Titanium (Ti)	0.002	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.006	0.001	mg/L		17-MAY-01	MD
		Dissolved Major Metals						
		Calcium (Ca)	18.9	0.5	mg/L		18-MAY-01	EC
		Potassium (K)	1.7	0.1	mg/L		18-MAY-01	EC
		Magnesium (Mg)	5.88	0.01	mg/L		18-MAY-01	EC
		Sodium (Na)	5.1	0.5	mg/L		18-MAY-01	EC
		Iron (Fe)	0.153	0.005	mg/L		18-MAY-01	EC
		Manganese (Mn)	0.078	0.001	mg/L		18-MAY-01	EC
		Total Metals						
		Total Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.72	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.019	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.002	0.002	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.006	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	0.004	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	0.08	0.05	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.064	0.002	mg/L		17-MAY-01	MD
		Titanium (Ti)	0.087	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	0.002	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.022	0.001	mg/L		17-MAY-01	MD
		Total Major Metals						
		Calcium (Ca)	19.4	0.5	mg/L		17-MAY-01	EC
		Potassium (K)	2.2	0.1	mg/L		17-MAY-01	EC
		Magnesium (Mg)	6.4	0.1	mg/L		17-MAY-01	EC
		Sodium (Na)	5	1	mg/L		17-MAY-01	EC
		Iron (Fe)	0.633	0.005	mg/L		17-MAY-01	EC
		Manganese (Mn)	0.081	0.001	mg/L		17-MAY-01	EC
		Routine Water Analysis						
		Chloride (Cl)	9	1	mg/L		22-MAY-01	CNP

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-2	BC-EFF-SW-05/01							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Routine Water Analysis						
		Nitrate+Nitrite-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		pH, Conductivity and Total Alkalinity						
		pH	7.3	0.1	pH		17-MAY-01	CMN
		Conductivity (EC)	197	0.2	uS/cm		17-MAY-01	CMN
		Bicarbonate (HCO3)	53	5	mg/L		17-MAY-01	CMN
		Carbonate (CO3)	<5	5	mg/L		17-MAY-01	CMN
		Hydroxide	<5	5	mg/L		17-MAY-01	CMN
		Alkalinity, Total	43	5	mg/L		17-MAY-01	CMN
		Ion Balance Calculation						
		Ion Balance	102		%		24-MAY-01	
		TDS (Calculated)	103		mg/L		24-MAY-01	
		Hardness	79		mg/L		24-MAY-01	
		ICP metals and SO4 for routine water						
		Calcium (Ca)	21.1	0.5	mg/L		23-MAY-01	MOR
		Potassium (K)	2.1	0.1	mg/L		23-MAY-01	MOR
		Magnesium (Mg)	6.5	0.1	mg/L		23-MAY-01	MOR
		Sodium (Na)	5	1	mg/L		23-MAY-01	MOR
		Sulfate (SO4)	33.7	0.5	mg/L		23-MAY-01	MOR
		Antimony (Sb)-Dissolved	0.0193	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As) 3+-Dissolved	0.0231	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As) 5+-Dissolved	0.113	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As)-Dissolved	0.136	0.0004	mg/L		17-MAY-01	MD
		Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Antimony (Sb)-Total	0.0258	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As)-Total	0.166	0.0004	mg/L		17-MAY-01	MD
		Cyanide, Total	<0.002	0.002	mg/L	18-MAY-01	18-MAY-01	SF
		Mercury (Hg)-Total	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Ammonia-N	0.09	0.05	mg/L		22-MAY-01	LAK
		Dissolved Organic Carbon	13	1	mg/L		22-MAY-01	HAN
		Nitrate-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		Nitrite-N	<0.05	0.05	mg/L		22-MAY-01	CNP
		Total Suspended Solids	9	3	mg/L		18-MAY-01	WNG
L32566-3	BC-DS1-SW-05/01							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Dissolved Metals						
		Dissolved Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.02	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.009	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.007	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-3	BC-DS1-SW-05/01							
Sample Date:	15-MAY-01 01:00 PM							
Matrix:	WATER							
		Dissolved Metals						
		Dissolved Trace Metals						
		Nickel (Ni)	0.003	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.055	0.005	mg/L		17-MAY-01	MD
		Titanium (Ti)	<0.001	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.004	0.001	mg/L		17-MAY-01	MD
		Dissolved Major Metals						
		Calcium (Ca)	22.7	0.5	mg/L		18-MAY-01	EC
		Potassium (K)	1.5	0.1	mg/L		18-MAY-01	EC
		Magnesium (Mg)	4.92	0.01	mg/L		18-MAY-01	EC
		Sodium (Na)	4.1	0.5	mg/L		18-MAY-01	EC
		Iron (Fe)	0.078	0.005	mg/L		18-MAY-01	EC
		Manganese (Mn)	0.044	0.001	mg/L		18-MAY-01	EC
		Total Metals						
		Total Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.56	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.010	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.002	0.002	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.008	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	0.003	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	0.08	0.05	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.054	0.002	mg/L		17-MAY-01	MD
		Titanium (Ti)	0.013	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	0.002	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.006	0.001	mg/L		17-MAY-01	MD
		Total Major Metals						
		Calcium (Ca)	22.6	0.5	mg/L		17-MAY-01	EC
		Potassium (K)	1.7	0.1	mg/L		17-MAY-01	EC
		Magnesium (Mg)	5.3	0.1	mg/L		17-MAY-01	EC
		Sodium (Na)	3	1	mg/L		17-MAY-01	EC
		Iron (Fe)	0.874	0.005	mg/L		17-MAY-01	EC
		Manganese (Mn)	0.049	0.001	mg/L		17-MAY-01	EC
		Routine Water Analysis						
		Chloride (Cl)	4	1	mg/L		22-MAY-01	CNP
		Nitrate+Nitrite-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		pH, Conductivity and Total Alkalinity						
		pH	7.5	0.1	pH		17-MAY-01	CMN
		Conductivity (EC)	180	0.2	uS/cm		17-MAY-01	CMN

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-3	BC-DS1-SW-05/01							
Sample Date:	15-MAY-01 01:00 PM							
Matrix:	WATER							
		Routine Water Analysis						
		pH, Conductivity and Total Alkalinity						
		Bicarbonate (HCO3)	61	5	mg/L		17-MAY-01	CMN
		Carbonate (CO3)	<5	5	mg/L		17-MAY-01	CMN
		Hydroxide	<5	5	mg/L		17-MAY-01	CMN
		Alkalinity, Total	50	5	mg/L		17-MAY-01	CMN
		Ion Balance Calculation						
		Ion Balance	104		%		24-MAY-01	
		TDS (Calculated)	93		mg/L		24-MAY-01	
		Hardness	75		mg/L		24-MAY-01	
		ICP metals and SO4 for routine water						
		Calcium (Ca)	21.2	0.5	mg/L		23-MAY-01	MOR
		Potassium (K)	1.8	0.1	mg/L		23-MAY-01	MOR
		Magnesium (Mg)	5.3	0.1	mg/L		23-MAY-01	MOR
		Sodium (Na)	4	1	mg/L		23-MAY-01	MOR
		Sulfate (SO4)	26.5	0.5	mg/L		23-MAY-01	MOR
		Antimony (Sb)-Dissolved	0.0121	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As) 3+-Dissolved	0.119	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As) 5+-Dissolved	0.593	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As)-Dissolved	0.656	0.0004	mg/L		17-MAY-01	MD
		Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Antimony (Sb)-Total	0.0131	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As)-Total	0.662	0.0004	mg/L		17-MAY-01	MD
		Cyanide, Total	<0.002	0.002	mg/L	18-MAY-01	18-MAY-01	SF
		Mercury (Hg)-Total	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Ammonia-N	0.16	0.05	mg/L		22-MAY-01	LAK
		Dissolved Organic Carbon	13	1	mg/L		22-MAY-01	HAN
		Nitrate-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		Nitrite-N	<0.05	0.05	mg/L		22-MAY-01	CNP
		Total Suspended Solids	12	3	mg/L		18-MAY-01	WNG
L32566-4	BC-DS2-SW-05/01							
Sample Date:	15-MAY-01 01:00 PM							
Matrix:	WATER							
		Dissolved Metals						
		Dissolved Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.03	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.011	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.005	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID / Sample ID / Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-4 BC-DS2-SW-05/01						
Sample Date: 15-MAY-01 01:00 PM						
Matrix: WATER						
Dissolved Metals						
Dissolved Trace Metals						
Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
Strontium (Sr)	0.051	0.005	mg/L		17-MAY-01	MD
Titanium (Ti)	<0.001	0.001	mg/L		17-MAY-01	MD
Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
Zinc (Zn)	0.005	0.001	mg/L		17-MAY-01	MD
Dissolved Major Metals						
Calcium (Ca)	15.3	0.5	mg/L		18-MAY-01	EC
Potassium (K)	1.5	0.1	mg/L		18-MAY-01	EC
Magnesium (Mg)	4.76	0.01	mg/L		18-MAY-01	EC
Sodium (Na)	4.0	0.5	mg/L		18-MAY-01	EC
Iron (Fe)	0.097	0.005	mg/L		18-MAY-01	EC
Manganese (Mn)	0.065	0.001	mg/L		18-MAY-01	EC
Total Metals						
Total Trace Metals						
Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
Aluminum (Al)	1.43	0.01	mg/L		17-MAY-01	MD
Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
Barium (Ba)	0.033	0.003	mg/L		17-MAY-01	MD
Beryllium (Be)	<0.002	0.002	mg/L		17-MAY-01	MD
Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
Cobalt (Co)	0.005	0.002	mg/L		17-MAY-01	MD
Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
Copper (Cu)	0.018	0.001	mg/L		17-MAY-01	MD
Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
Nickel (Ni)	0.008	0.002	mg/L		17-MAY-01	MD
Phosphorus (P)	0.17	0.05	mg/L		17-MAY-01	MD
Lead (Pb)	0.006	0.005	mg/L		17-MAY-01	MD
Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
Strontium (Sr)	0.104	0.002	mg/L		17-MAY-01	MD
Titanium (Ti)	0.087	0.001	mg/L		17-MAY-01	MD
Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
Vanadium (V)	0.004	0.001	mg/L		17-MAY-01	MD
Zinc (Zn)	0.024	0.001	mg/L		17-MAY-01	MD
Total Major Metals						
Calcium (Ca)	15.3	0.5	mg/L		17-MAY-01	EC
Potassium (K)	1.8	0.1	mg/L		17-MAY-01	EC
Magnesium (Mg)	5.1	0.1	mg/L		17-MAY-01	EC
Sodium (Na)	4	1	mg/L		17-MAY-01	EC
Iron (Fe)	0.869	0.005	mg/L		17-MAY-01	EC
Manganese (Mn)	0.079	0.001	mg/L		17-MAY-01	EC
Routine Water Analysis						
Chloride (Cl)	4	1	mg/L		22-MAY-01	CNP
Nitrate+Nitrite-N	<0.1	0.1	mg/L		22-MAY-01	CNP
pH, Conductivity and Total Alkalinity						
pH	7.5	0.1	pH		17-MAY-01	CMN
Conductivity (EC)	156	0.2	uS/cm		17-MAY-01	CMN
Bicarbonate (HCO3)	58	5	mg/L		17-MAY-01	CMN
Carbonate (CO3)	<5	5	mg/L		17-MAY-01	CMN
Hydroxide	<5	5	mg/L		17-MAY-01	CMN

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-4	BC-DS2-SW-05/01							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Routine Water Analysis						
		pH, Conductivity and Total Alkalinity						
		Alkalinity, Total	47	5	mg/L		17-MAY-01	CMN
		Ion Balance Calculation						
		Ion Balance	106		%		24-MAY-01	
		TDS (Calculated)	77		mg/L		24-MAY-01	
		Hardness	64		mg/L		24-MAY-01	
		ICP metals and SO4 for routine water						
		Calcium (Ca)	16.8	0.5	mg/L		23-MAY-01	MOR
		Potassium (K)	1.8	0.1	mg/L		23-MAY-01	MOR
		Magnesium (Mg)	5.3	0.1	mg/L		23-MAY-01	MOR
		Sodium (Na)	4	1	mg/L		23-MAY-01	MOR
		Sulfate (SO4)	17.1	0.5	mg/L		23-MAY-01	MOR
		Antimony (Sb)-Dissolved	0.0073	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As) 3+-Dissolved	0.0150	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As) 5+-Dissolved	0.0798	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As)-Dissolved	0.0933	0.0004	mg/L		17-MAY-01	MD
		Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Antimony (Sb)-Total	0.0196	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As)-Total	0.231	0.0004	mg/L		17-MAY-01	MD
		Cyanide, Total	<0.002	0.002	mg/L	18-MAY-01	18-MAY-01	SF
		Mercury (Hg)-Total	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Ammonia-N	0.20	0.05	mg/L		22-MAY-01	LAK
		Dissolved Organic Carbon	13	1	mg/L		22-MAY-01	HAN
		Nitrate-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		Nitrite-N	<0.05	0.05	mg/L		22-MAY-01	CNP
		Total Suspended Solids	21	3	mg/L		18-MAY-01	WNG
L32566-5	BC-DS2-SW-05/01-C							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Dissolved Metals						
		Dissolved Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	0.03	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.011	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.005	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.051	0.005	mg/L		17-MAY-01	MD
		Titanium (Ti)	<0.001	0.001	mg/L		17-MAY-01	MD

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-5	BC-DS2-SW-05/01-C							
Sample Date:	15-MAY-01 01:00 PM							
Matrix:	WATER							
		Dissolved Metals						
		Dissolved Trace Metals						
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.005	0.001	mg/L		17-MAY-01	MD
		Dissolved Major Metals						
		Calcium (Ca)	15.3	0.5	mg/L		18-MAY-01	EC
		Potassium (K)	1.4	0.1	mg/L		18-MAY-01	EC
		Magnesium (Mg)	4.71	0.01	mg/L		18-MAY-01	EC
		Sodium (Na)	4.0	0.5	mg/L		18-MAY-01	EC
		Iron (Fe)	0.097	0.005	mg/L		18-MAY-01	EC
		Manganese (Mn)	0.065	0.001	mg/L		18-MAY-01	EC
		Total Metals						
		Total Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	1.77	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	0.034	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.002	0.002	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	0.005	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	0.018	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	0.008	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	0.18	0.05	mg/L		17-MAY-01	MD
		Lead (Pb)	0.007	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	0.102	0.002	mg/L		17-MAY-01	MD
		Titanium (Ti)	0.061	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	0.005	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.034	0.001	mg/L		17-MAY-01	MD
		Total Major Metals						
		Calcium (Ca)	15.2	0.5	mg/L		17-MAY-01	EC
		Potassium (K)	1.8	0.1	mg/L		17-MAY-01	EC
		Magnesium (Mg)	5.1	0.1	mg/L		17-MAY-01	EC
		Sodium (Na)	4	1	mg/L		17-MAY-01	EC
		Iron (Fe)	1.08	0.005	mg/L		17-MAY-01	EC
		Manganese (Mn)	0.080	0.001	mg/L		17-MAY-01	EC
		Routine Water Analysis						
		Chloride (Cl)	4	1	mg/L		22-MAY-01	CNP
		Nitrate+Nitrite-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		pH, Conductivity and Total Alkalinity						
		pH	7.5	0.1	pH		17-MAY-01	CMN
		Conductivity (EC)	157	0.2	uS/cm		17-MAY-01	CMN
		Bicarbonate (HCO3)	58	5	mg/L		17-MAY-01	CMN
		Carbonate (CO3)	<5	5	mg/L		17-MAY-01	CMN
		Hydroxide	<5	5	mg/L		17-MAY-01	CMN
		Alkalinity, Total	48	5	mg/L		17-MAY-01	CMN
		Ion Balance Calculation						
		Ion Balance	105		%		24-MAY-01	

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-5	BC-DS2-SW-05/01-C							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Routine Water Analysis						
		Ion Balance Calculation						
		TDS (Calculated)	79		mg/L		24-MAY-01	
		Hardness	64		mg/L		24-MAY-01	
		ICP metals and SO4 for routine water						
		Calcium (Ca)	16.9	0.5	mg/L		23-MAY-01	MOR
		Potassium (K)	1.9	0.1	mg/L		23-MAY-01	MOR
		Magnesium (Mg)	5.2	0.1	mg/L		23-MAY-01	MOR
		Sodium (Na)	4	1	mg/L		23-MAY-01	MOR
		Sulfate (SO4)	17.8	0.5	mg/L		23-MAY-01	MOR
		Antimony (Sb)-Dissolved	0.0074	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As) 3+-Dissolved	0.0148	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As) 5+-Dissolved	0.0808	0.0002	mg/L		12-JUN-01	JJ
		Arsenic (As)-Dissolved	0.0927	0.0004	mg/L		17-MAY-01	MD
		Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Antimony (Sb)-Total	0.0206	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As)-Total	0.229	0.0004	mg/L		17-MAY-01	MD
		Cyanide, Total	<0.002	0.002	mg/L	18-MAY-01	18-MAY-01	SF
		Mercury (Hg)-Total	<0.0002	0.0002	mg/L		17-MAY-01	MD
		Ammonia-N	0.20	0.05	mg/L		22-MAY-01	LAK
		Dissolved Organic Carbon	13	1	mg/L		22-MAY-01	HAN
		Nitrate-N	<0.1	0.1	mg/L		22-MAY-01	CNP
		Nitrite-N	<0.05	0.05	mg/L		22-MAY-01	CNP
		Total Suspended Solids	28	3	mg/L		18-MAY-01	WNG
L32566-6	BC-DS2-SW-05/01-D							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Dissolved Metals						
		Dissolved Trace Metals						
		Silver (Ag)	<0.005	0.005	mg/L		17-MAY-01	MD
		Aluminum (Al)	<0.01	0.01	mg/L		17-MAY-01	MD
		Boron (B)	<0.05	0.05	mg/L		17-MAY-01	MD
		Barium (Ba)	<0.003	0.003	mg/L		17-MAY-01	MD
		Beryllium (Be)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cadmium (Cd)	<0.001	0.001	mg/L		17-MAY-01	MD
		Cobalt (Co)	<0.002	0.002	mg/L		17-MAY-01	MD
		Chromium (Cr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Copper (Cu)	<0.001	0.001	mg/L		17-MAY-01	MD
		Molybdenum (Mo)	<0.005	0.005	mg/L		17-MAY-01	MD
		Nickel (Ni)	<0.002	0.002	mg/L		17-MAY-01	MD
		Phosphorus (P)	<0.1	0.1	mg/L		17-MAY-01	MD
		Lead (Pb)	<0.005	0.005	mg/L		17-MAY-01	MD
		Tin (Sn)	<0.05	0.05	mg/L		17-MAY-01	MD
		Strontium (Sr)	<0.005	0.005	mg/L		17-MAY-01	MD
		Titanium (Ti)	<0.001	0.001	mg/L		17-MAY-01	MD
		Thallium (Tl)	<0.05	0.05	mg/L		17-MAY-01	MD
		Vanadium (V)	<0.001	0.001	mg/L		17-MAY-01	MD
		Zinc (Zn)	0.003	0.001	mg/L		17-MAY-01	MD

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L32566-6	BC-DS2-SW-05/01-D							
Sample Date: 15-MAY-01 01:00 PM								
Matrix: WATER								
		Dissolved Metals						
		Dissolved Major Metals						
		Calcium (Ca)	<0.5	0.5	mg/L		18-MAY-01	EC
		Potassium (K)	<0.1	0.1	mg/L		18-MAY-01	EC
		Magnesium (Mg)	0.03	0.01	mg/L		18-MAY-01	EC
		Sodium (Na)	<0.5	0.5	mg/L		18-MAY-01	EC
		Iron (Fe)	0.016	0.005	mg/L		18-MAY-01	EC
		Manganese (Mn)	0.006	0.001	mg/L		18-MAY-01	EC
		Antimony (Sb)-Dissolved	<0.0004	0.0004	mg/L		17-MAY-01	MD
		Arsenic (As)-Dissolved	0.0004	0.0004	mg/L		17-MAY-01	MD
		Mercury (Hg)-Dissolved	<0.0002	0.0002	mg/L		17-MAY-01	MD

Methodology Reference

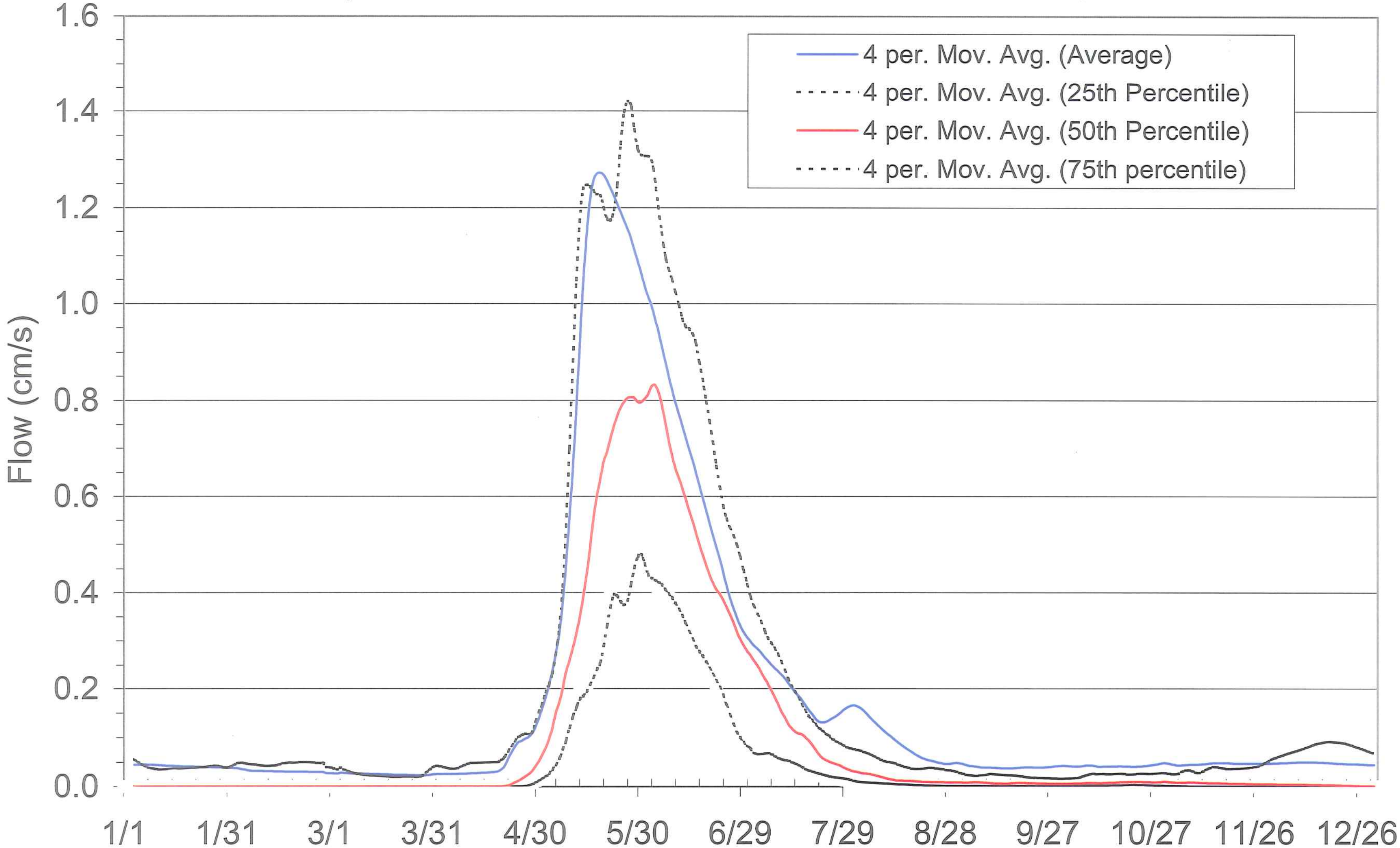
ETL Test Code	Test Description	Methodology Reference (Based On)
AS-AS3-DIS-ED	Arsenic (As) 3+-Dissolved	APHA 3114 C-AAS - Hydride
AS-AS5-DIS-ED	Arsenic (As) 5+-Dissolved	APHA 3114 C-AAS - Hydride
AS-DIS-HYD-ED	Arsenic (As)-Dissolved	APHA 3114 C-AAS - Hydride
AS-TOT-HYD-ED	Arsenic (As)-Total	APHA 3114 C-AAS - Hydride
C-DIS-ORG-ED	Dissolved Organic Carbon	APHA 5310 B-Instrumental
CL-ED	Chloride (Cl)	APHA 4500 Cl E-Colorimetry
CN-TOT-TB	Cyanide, Total	APHA 4500CN C E-Strong acid Dist Colorim
ETL-ROUTINE-ICP-ED	ICP metals and SO4 for routine water	APHA 3120 B-ICP-OES
HG-DIS-HYD-ED	Mercury (Hg)-Dissolved	APHA 3112 B-AAS Cold Vapor
HG-TOT-HYD-ED	Mercury (Hg)-Total	APHA 3112 B-AAS Cold Vapor
IONBALANCE-ED	Ion Balance Calculation	APHA 1030E
MET1-DIS-ED	Dissolved Trace Metals	APHA 3120 B-ICP-OES
MET1-TOT-ED	Total Trace Metals	APHA 3120 B-ICP-OES
MET2-DIS-ED	Dissolved Major Metals	APHA 3120 B-ICP-OES
MET2-TOT-ED	Total Major Metals	APHA 3120 B-ICP-OES
N2N3-ED	Nitrate+Nitrite-N	APHA 4500 NO3H-Colorimetry
NH4-ED	Ammonia-N	APHA4500NH3F Colorimetry
NO2-ED	Nitrite-N	APHA 4500 NO2B-Colorimetry
NO3-ED	Nitrate-N	APHA 4500 NO3H-Colorimetry
H/EC/ALK-ED	pH, Conductivity and Total Alkalinity	APHA 4500-H, 2510, 2320
SB-DIS-HYD-ED	Antimony (Sb)-Dissolved	APHA 3114 C-AAS-Hydride
SB-TOT-HYD-ED	Antimony (Sb)-Total	APHA 3114 C-AAS-Hydride
SOLIDS-TOTSUS-ED	Total Suspended Solids	APHA 2540 D-Gravimetric

ATTACHMENT A2-2

BAKER CREEK FLOW SUMMARY

Baker Creek - Flow Summary

(data obtained from the Water Survey of Canada - 1968-2000)



APPENDIX II

TABLES

Table A2-1
Habitat Requirements for Northern Pike (*Esox lucius*)

Life Stage		Arctic	Non-Arctic
Spawning **(Spring)**	depth	- 0.05 to 70 cm (Machniak, 1975) - high spring water levels can create spawning habitat if terrestrial and wetland vegetation is flooded; depends on shoreline topography and amount of adjacent vegetation (Inskip, 1982)	- < 0.25 m (Brynildson, 1958) - both shallow (<1.5 m) and deep (1.5 to 2.6 m) stations in a marsh off of St. Lawrence River (Farrell *et al.*, 1996) - greatest density of eggs found at depths of 0.2 to 0.45 m (McCarraher and Thomas, 1972) - < 0.5 m, observed spawning with backs out of the water (Clark, 1950)
	substrate	- vegetation mat should provide abundant surface area for eggs to adhere to, yet allow circulation of water to remove metabolic waste and supply oxygen (Inskip, 1982) - bottom is typically soft, organic, and silty with decaying vegetation (Machniak, 1975), but eggs falling to this type of bottom are unlikely to survive because of anoxic conditions and hydrogen sulphide (Ford *et al.*, 1995) - thinly scattered vegetation would provide little, if any, shelter for eggs (Inskip, 1982)	- optimal substrate is a dense mat of short vegetation in a shallow wind sheltered area (Inskip, 1982) - flooded prairie grasses; mowed hay and hay bales used when flooded natural grasses not available (McCarraher and Thomas, 1972) - scatter eggs over three dominant genera of vegetation: pondweed *Potamogeton*, duckweed *Lemna*, stonewort *Chara* (Farrell *et al.*, 1996) - eggs on vegetation consisting mostly of *Elodea*, *Myriophyllum*, and *Nitella* (Frost and Kipling, 1967)
	temperature	- spawning migrations initiated when sufficient clearance exists between inshore ice and bottom to provide access to spawning grounds (Franklin and Smith, 1963; Machniak, 1975)	- entered spawning areas when temperature was between 1 and 4°C - spawn after ice-out when water has warmed (8 to 12°C) (Inskip, 1982) - spawn at 4.4 to 17.2°C (Scott and Crossman, 1973)
	turbidity		- silt deposition (on eggs) of 1.0 mm/d during first 5 d of incubation caused 97% mortality, after 5 d, silt deposition did not affect survival (Hassler, 1970)
	misc.	- availability of suitable spawning habitat is the factor most limiting occurrence and population size in waterbodies (Inskip, 1982)	
Adults	depth	- 90% of pike captured in gill net survey of Great Slave Lake were caught within 400 m of shore and very few taken at depths > 10 m (Rawson, 1951)	- lakes containing pike typically have littoral areas < 6.0 m deep, which are 60 to 80% of the total lake surface area (Johnson *et al.*, 1977) - remain in areas with submerged and emergent aquatic vegetation, in water shallower than 4 m, and within 300 m of shore (Diana *et al.*, 1977) - large pike use a wider range of depths (up to 27 m) than do small pike (typically < 10 m) (Koshinsky, 1979)

Life Stage		Arctic	Non-Arctic
Adults (con't)	substrate	- mud and silt (coincident with vegetation) (Ford *et al.*, 1995) - ambush style of feeding requires cover, typically in the form of aquatic vegetation but will also use tree stumps, fallen logs (Inskip 1982) flooded terrestrial vegetation, shoals, drop-offs, and boulders (K. Sobey, pers. obs.)	
	temperature	- average max. temp. in limnetic zone of Great Bear Lake is 5 to 7°C (Johnson, 1966) and can reach 16°C in protected bays where most pike occur (Miller ,1947)	- summer habitat of northern pike is limited in some lakes by a combination of high surface water temperatures and low oxygen concentrations in deeper, cooler strata (Inskip, 1982) - can tolerate 0 to 29.4°C; optimal is 19 to 21°C (Ford *et al.*, 1995)
	turbidity		- lakes containing pike typically have secchi depths of 2 to 4 m and TDS between 50 and 125 mg/L (Johnson *et al.*, 1977) - significant relationship between pike weight and secchi depth; water clarity influences feeding, body condition and growth (Craig and Babaluk, 1989)
	feeding	- omnivorous carnivore, eating any available vertebrate it can engulf; estimated that each pound increase in body weight of northern pike requires 5-6 pounds of food (Scott and Crossman, 1973) - cannibalism more prevalent in waters with few fish species than where fish community is diverse (Inskip, 1982)	- consumption rates vary seasonally peaking in spring (post-spawn) and summer (max. body growth) (Diana, 1979) - voracious, visual predators, mostly active during the day feeding primarily on fish but also leeches, aquatic insects, crayfish, waterfowl and small mammals (Lagler, 1956, Lawler, 1965, Diana, 1980)
Juveniles	depth		- may move off-shore to deeper water in search of prey, but typically remain along shoreline if adequate food and cover available (Scott and Crossman, 1973) - < 2.0 m (Ford *et al.*, 1995) - minimum size of pike positively associated with depth (Koshinsky, 1979)
	substrate		- mud and silt (coincident with vegetation) (Ford *et al.*, 1995) - submerged vegetation is important because it provides refuge from predation and cannibalism (Ford *et al.*, 1995)
	temperature	- growth and survival rates depend on temperature with poor survival < 5.8°C (Inskip, 1982)	- growth rate increased sharply > 10°C ceased above 28°C and was about 4% of the maximum at 3 to 4°C (Casselman, 1978) - can tolerate 5.8 to 33°C; optimal is 26°C (Ford *et al.*, 1995) - peak feeding between 15 and 18°C (Weithman and Anderson, 1977)
	turbidity		
	feeding		- opportunistic, piscivore, prevalent incidence of cannibalism if suitable sized forage fish unavailable (Inskip, 1982)
	misc.		- survival to adulthood is highly variable; 6%, 22% and 63% in three consecutive summers through the first summer (Inskip,

Life Stage		Arctic	Non-Arctic
			1982)
Embryo & Fry	depth & substrate	- spawning habitat is also fry habitat (Franklin and Smith, 1963) - invertebrate fauna associated with dense vegetation in the shallows is a key component of the fry's early planktivorous feeding, thick vegetation provides refuge from predators including other pike (Inskip, 1982) - after hatching yolk sac fry have papillae on the tops of their heads that they can attach to vegetation, and thus remain suspended above the sediments, while the yolk sac is being absorbed (Frost and Kipling, 1967) - fry are thus removed from potentially high levels of hydrogen sulphide and low levels of oxygen, typical of organic sediments coincident with heavily vegetated areas (Inskip, 1982) - decreased water levels and food shortages cause fry to depart nursery areas (Royer, 1971)	
	temperature		- tolerate 3.0 to 24.2°C (high % deformities at extremes); optimum is 6.4°C (Ford *et al.*, 1995) - incubation time is approximately 26 d at 6°C, 17 d at 8°C, 12 d at 10°C, 9 d at 12°C, and 5 d at 16 to 20°C (Swift, 1965; Hokansen *et al.*, 1973)
	feeding		- exogenous feeding about 10 d (10-12 mm) after hatching (Franklin and Smith, 1963) - initial diet consists of zooplankton but broadens to include aquatic insect larvae and at ~5 wks (50 to 60 mm) is mostly fish; cannibalistic as small as 21 mm (Hunt and Carbine, 1951; Frost, 1954) - food habits of Y-O-Y mirrored those of adults where fish dominated in terms of frequency, weight, and volume consumed (Stephanson and Momot, 1991)

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Table A2-2
Habitat Requirements for Longnose Sucker (*Catostomus catostomus)*

Life Stage		Arctic	Non-Arctic
Spawning **(Spring)**	depth	- depths of 15-30 cm; velocity of 0.3-1.0 m/s or wave-swept shorelines (Edwards, 1983) - depths of 152-279 mm; current of 30-45 cm/s (Scott and Crossman, 1973) - usually takes place in tributary streams or in shallow parts of lakes (Hatfield *et al.*, 1972)	
	substrate	- eggs broadcast over clean (silt-free) gravel and rocks (Edwards, 1983) - prefer gravel or rocky bottom (Hatfield *et al.*, 1972) - gravel of 50-100 mm in diameter (Scott and Crossman, 1973)	
	temperature	- at 5-9°C movement starts; spawning at 10-15°C; movement related to temperature and discharge (Edwards, 1983) - enter spawning streams as soon as stream temperature reaches 5°C (Scott and Crossman, 1973)	
		- spawn from ice cover breakup in May to June 15 at water temperatures < 15°C (Great Slave Lake) (Hatfield *et al.*, 1972)	- spawning related to water temperature changes (Brown and Graham, 1953)
	turbidity		
	misc.	- migrant spawners, spawn in tributaries or shallow areas of large waterbodies starting in spring and peaking in June (Edwards, 1983) - no nest (Edwards, 1983) - move upstream between noon and midnight; greatest numbers move in evening hours; spawning occurs between 6 a.m. and 9 p.m. (Scott and Crossman, 1973)	
Adults	depth	- most common at depths up to 30 m; will move inshore at night to feed or spawn; have been found at depths up to 187 m (Edwards, 1983)	
		- found in depths from 1-24 m (Great Slave Lake) (Hatfield *et al.*, 1972) - found in areas of slow water, such as back eddies or river mouths (Mackenzie River) (Hatfield *et al.*, 1972) - not reported below 80 feet in Great Slave Lake (Scott and Crossman, 1973) - common at depths of 10 and 20 m; rare at depths beyond 30 m (Great Slave Lake) (Rawson, 1951)	- reported as deep as 600 feet in Lake Superior (Scott and Crossman, 1973)

Life Stage		Arctic	Non-Arctic
	substrate		
Adults (con't)	temperature	- prefer 10-15°C; recorded in lakes ranging from 3°C to 18.5°C (Edwards, 1983) - upper lethal temperature is 26.5°C when acclimated at 14°C or 27°C when acclimated to 11.5°C (Scott and Crossman, 1973)	
	turbidity	- appears to have a high tolerance of turbidity (Hatfield *et al.*, 1972)	
	feeding	- usually omnivorous, consuming amphipods, benthic insects, and other invertebrates (depending on availability); will also eat plants, algae, and detritus; more 'pelagic' feeders than other suckers (Edwards, 1983) - food varies with site, season, and by size; consumption of vertebrates has not been reported; erroneously considered a fish egg predator (Scott and Crossman, 1973)	
		- predominant foods include plecopterans, corixids, trichopterans, coleopterans, and hymenopterans; also ate vegetation (Mackenzie River); amphipods, chironomid larvae, aquatic insects, and sphaeriids (Great Slave Lake) (Hatfield *et al.*, 1972) - amphipods, chironomid larvae, caddisfly larvae (and other aquatic insects), aphaeriids; also gastropods, mayfly, and damselfly nymphs (Great Slave Lake) (Rawson, 1951)	- in tributary streams: algae, aquatic plants, aquatic insects (Brown and Graham, 1953) - amphipods, snails, insect larvae, and nymphs (Alberta); algae and higher aquatic plants (Wyoming) (Hatfield *et al.*, 1972)
Juveniles	depth	- frequent shallow, weedy areas; remain in subsurface; like some current (Edwards, 1983)	
	substrate		
	temperature		
	turbidity		
	feeding	- have not been observed feeding on bottom; start with zooplankton, shifting to larger benthic organisms as they grow (Edwards, 1983)	
			- zooplankton and insect larvae (Hatfield *et al.*, 1972)
Embryo & Fry	depth	- fry seek food and shelter in quiet, shallow water; fry congregate in top 150 mm of water within 2 m of shore (Edwards, 1983) - fry remain in gravel for 1 to 2 wks (Scott and Crossman, 1973)	
		- fry most abundant in the mouths of fast-flowing, clear, rocky streams; also in shallow pools within rapids of these streams (Mackenzie River) (Hatfield *et al.*, 1972)	- cover is important to young fish, found in quiet water with aquatic vegetation (Brown and Graham, 1953) - fry migration downstream peaks with periods of high water levels (Hatfield *et al.*, 1972)

Life Stage		Arctic	Non-Arctic
Embryo & Fry (con't)	substrate	- gravel, near the tail of a riffle; fry drift downstream after emerging from gravel (fry spend first summer in river) (Edwards, 1983)	
	temperature	- incubation takes 8 days at 15°C and 14 days at 12.2°C; fry assumed to tolerate fluctuations in temp associated with shallow water (Edwards, 1983)	
	turbidity		
	feeding	- fry feed on zooplankton and diatoms (Edwards, 1983)	
			- feed on zooplankton and insect larvae (Hatfield *et al.*, 1972)
	misc.	- increase in fry abundance in fall–most likely due to downstream movements prior to freeze-up (Hatfield *et al.*, 1972)	- downstream migration of fry occurs one month after spawning, usually at night (Hatfield *et al.*, 1972)

General:

- Longnose suckers occur in Siberia and in North America from Alaska to Labrador, south to Pennsylvania, Maryland, and the northern margin of the Mississippi River; frequents both large and small lakes and streams; tolerant of a wide range of turbidity (Hatfield *et al.*, 1972)
- individuals in north are significantly smaller than those in south (Edwards, 1983)
- food supply is an important limit to growth (Edwards, 1983)
- most abundant in cold, oligotrophic lakes (34-40 m deep) (Ford *et al.*, 1995)
- the longnose sucker is the most successful and widespread cypriniform in the north occurring almost everywhere in clear, cold water in moderately large numbers (Scott and Crossman, 1973)

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Table A2-3
Habitat Characteristics in Baker Creek

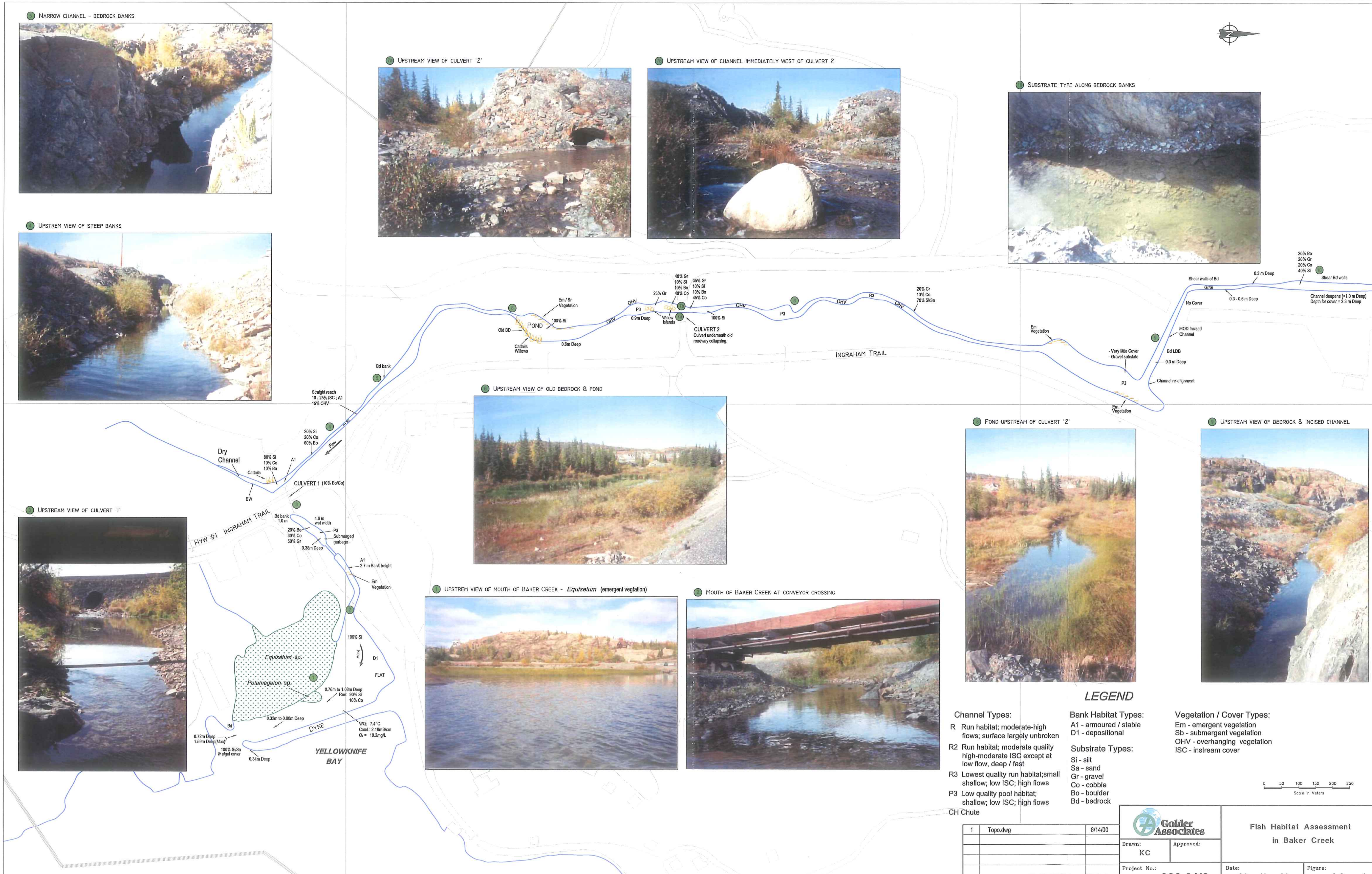
Location	Channel Type	Bank Habitat Type	Substrate	Vegetation/Cover	Photograph
Marsh area in Yellowknife Bay at the mouth of Baker Creek	Bay	Depositional area; gently sloping bank	90% silt, 10% cobble	Emergent vegetation; instream cover	1
Mouth of Baker Creek	Run; low quality; generally shallow	Armoured, stable; uniform shoreline	50% gravel; 30% cobble; 20% boulder	Low instream cover	2
Baker Creek at Culvert 1	Pool; low quality; shallow and small	Armoured, stable; bedrock; uniform shoreline	50% gravel; 30% cobble; 20% boulder	No instream cover	3
Baker Creek upstream of Culvert 1	Run; low quality; generally shallow	Armoured, stable; uniform shoreline	20% silt, 20% cobble; 60% boulder	Low instream cover	4
Baker Creek upstream of Culvert 1	Run; low quality, generally shallow	Bedrock banks	80% boulder, 20% silt	No instream cover	5
Pond located downstream of Culvert 2	Pool; moderate quality	Depositional	100% silt	Moderate instream cover; cattails and emergent vegetation	6
Culvert 2	Pool/Run; low quality; shallow, small		40% gravel; 40% cobble; 10% silt; 10% boulder	No instream vegetation; willows on gravel bars	7a,b
Pond upstream of Culvert 2	Pool; low quality, shallow, small	Depositional	70% silt/sand, 20% gravel, 10% cobble	Low instream vegetation	8
Upstream of pond and 90° turn in channel bed	Run; low quality, shallow, small	Armoured, stable; uniform shoreline, bedrock banks	70% gravel, 30% silt	No instream vegetation	9
Channelized section upstream of Photograph 9	Run; low quality, shallow, small	Armoured, stable; uniform shoreline, bedrock banks	20% boulder, 20% gravel, 20% silt, 40% cobble	No instream vegetation	10
Channelized section upstream of Photograph 10	Run; moderate quality, deep and fast	Armoured, stable; uniform shoreline, bedrock banks	40% silt, 20% gravel, 20% cobble, 20% boulder	No instream vegetation	11
Pond between Culverts 4 and 5 in front of mill	Pool; low quality, shallow	Depositional	80% silt, 20% gravel	Moderate instream cover; low emergent vegetation	12
Pond between Culverts 5 and 6	Pool; low quality, shallow	Depositional	60% silt, 30% gravel, 10% cobble	No instream cover	13
Chute at Old Plant	Chute; bedrock intrusions	Canyon	100% bedrock	No instream cover	14a,b
Pond upstream of chute	Pool; low quality, shallow	Depositional; armoured (rip-rap)	80% silt, 20% gravel	Moderate instream cover	15
Pond upstream of chute	Pool; low quality, shallow	Depositional; armoured (rip-rap)	80% silt, 20% gravel	Low instream cover; moderate emergent vegetation	16
Effluent discharge entry between Culverts 7 and 8	Run; low quality, shallow	Depositional; armoured (rip-rap)	80% silt, 20% gravel	No instream cover	17
Trapper Creek upstream of Vee Lake Road	Run; low quality, shallow, low flows (intermittent)	Depositional	100% silt	Grassy swales	18

Table A2-3
Habitat Characteristics in Baker Creek

Location	Channel Type	Bank Habitat Type	Substrate	Vegetation/Cover	Photograph
Baker Creek upstream of large pond and upstream of effluent discharge	Run; low quality, shallow	Armoured, stable (bedrock banks)	60% cobble, 10% gravel, 30% boulder	No instream vegetation	19
Baker Creek upstream of effluent discharge and upstream of Photograph 19	Chutes, bedrock intrusions	Armoured, stable (bedrock banks)	90% bedrock, 10% boulder	No instream cover	20
Baker Creek downstream of Surveillance Network Program Sampling Station (SNP)	Riffle; low flows (intermittent)	Armoured, stable	90% boulders, 10% cobble	No instream cover	21
Baker Creek upstream of SNP	Chute, bedrock intrusions	Canyon; steep, bedrock banks (upstream migration barrier to fish)	100% bedrock	No instream cover	22
Baker Creek upstream of chutes	Cascade (moderate velocity and gradient)	Armoured, stable; bedrock banks	90% bedrock, 10% boulder	No instream cover	23

APPENDIX II

FIGURES



NO.	REFERENCE DRAWINGS	DATE
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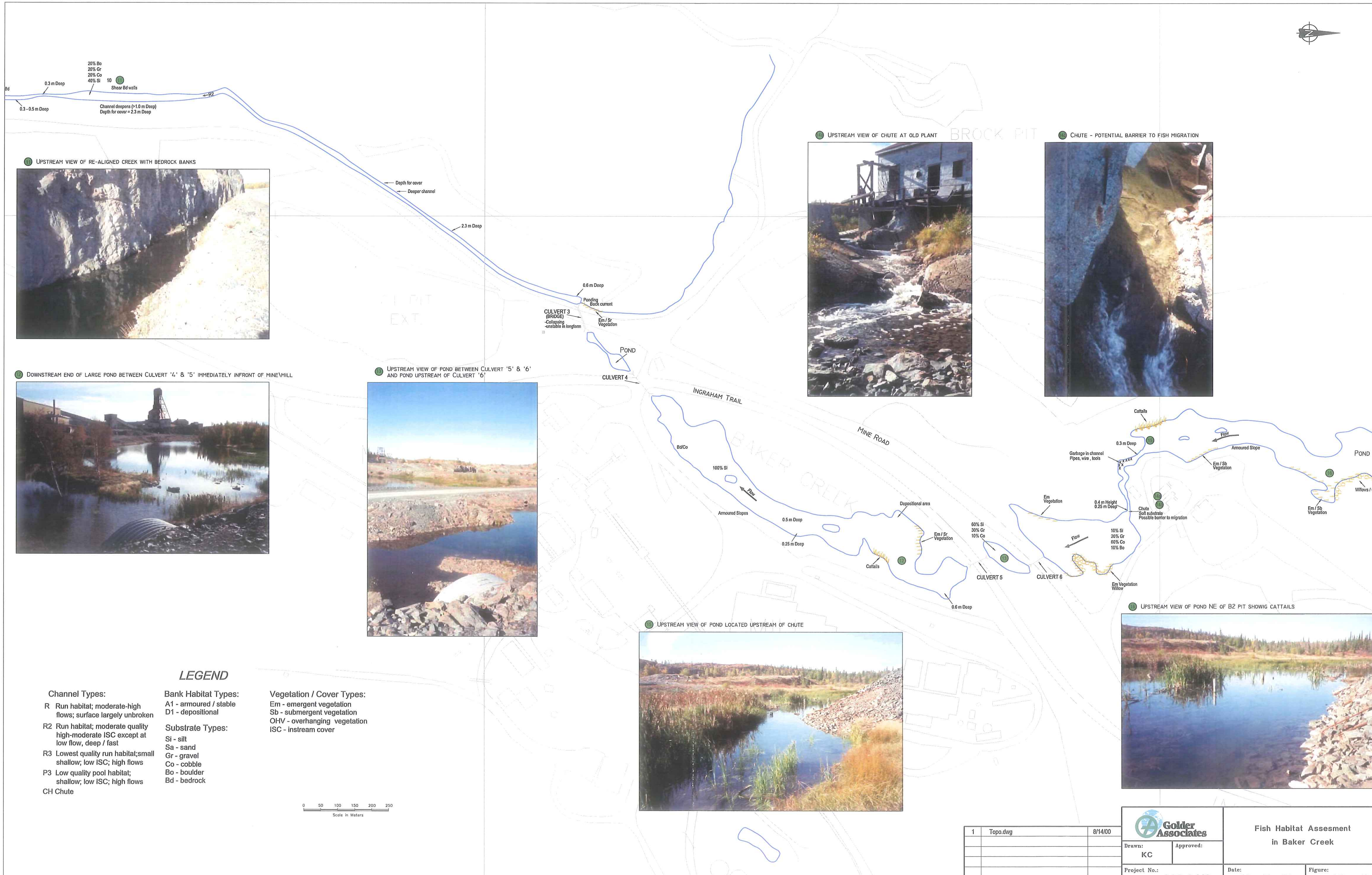
Golder Associates

Fish Habitat Assessment in Baker Creek

Drawn: KC
Approved:
Project No.: 002-2418
Date: 03 - 12 - 01
Figure: A2 - 1



(11) UPSTREAM VIEW OF RE-ALIGNED CREEK WITH BEDROCK BANKS

(12) DOWNSTREAM END OF LARGE POND BETWEEN CULVERT '4' & '5' IMMEDIATELY INFRONT OF MINE\MILL

(13) UPSTREAM VIEW OF POND BETWEEN CULVERT '5' & '6' AND POND UPSTREAM OF CULVERT '6'

(14a) UPSTREAM VIEW OF CHUTE AT OLD PLANT

(14b) CHUTE - POTENTIAL BARRIER TO FISH MIGRATION

(15) UPSTREAM VIEW OF POND LOCATED UPSTREAM OF CHUTE

(16) UPSTREAM VIEW OF POND NE OF B2 PIT SHOWIG CATTAILS

LEGEND

Channel Types:
- R Run habitat; moderate-high flows; surface largely unbroken
- R2 Run habitat; moderate quality high-moderate ISC except at low flow, deep / fast
- R3 Lowest quality run habitat;small shallow; low ISC; high flows
- P3 Low quality pool habitat; shallow; low ISC; high flows
- CH Chute

Bank Habitat Types:
- A1 - armoured / stable
- D1 - depositional

Substrate Types:
- Si - silt
- Sa - sand
- Gr - gravel
- Co - cobble
- Bo - boulder
- Bd - bedrock

Vegetation / Cover Types:
- Em - emergent vegetation
- Sb - submergent vegetation
- OHV - overhanging vegetation
- ISC - instream cover

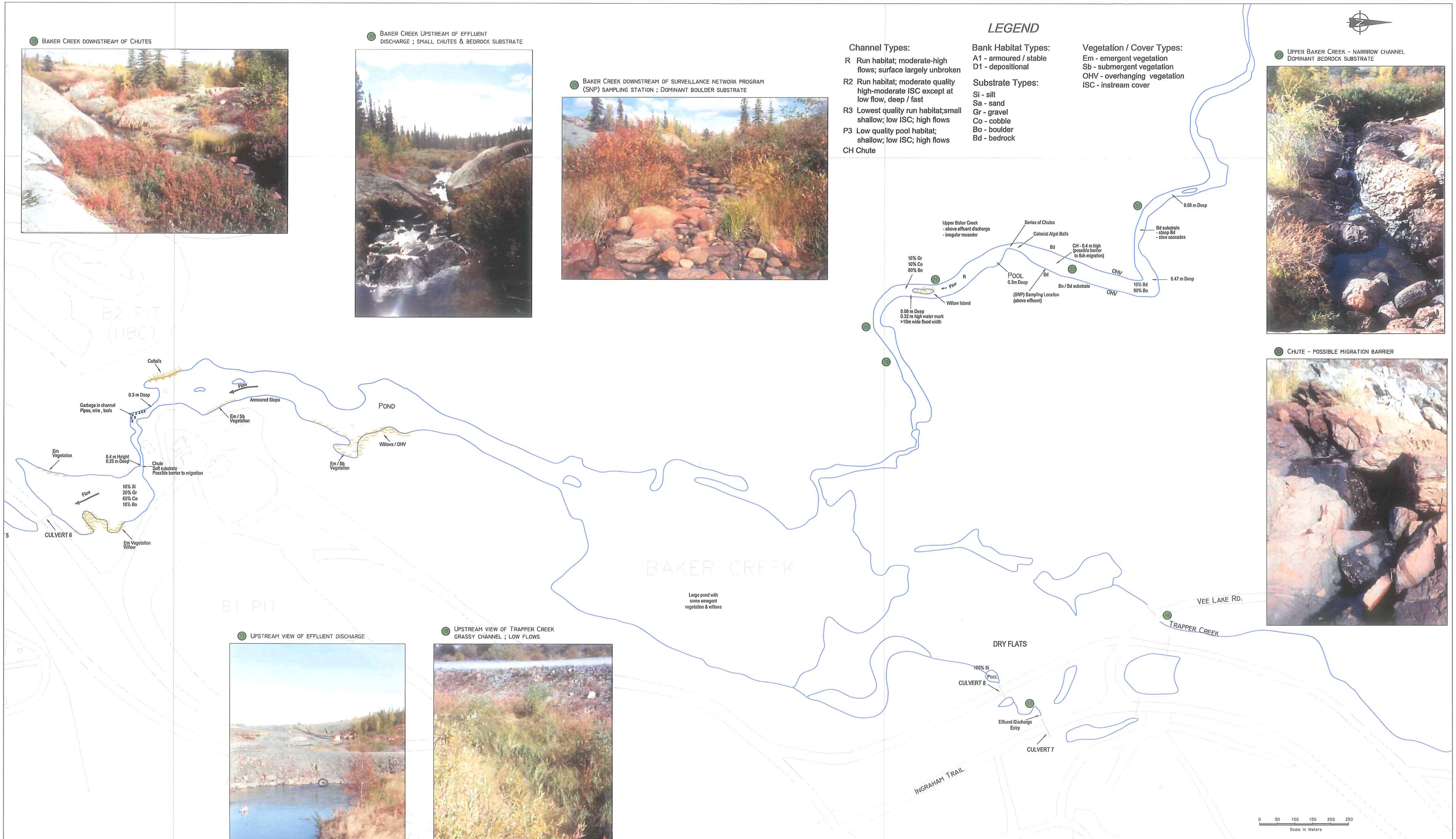
0 50 100 150 200 250
Scale in Meters

NO.	REFERENCE DRAWINGS	DATE
1	Topo.dwg	8/14/00

Golder Associates

Fish Habitat Assesment in Baker Creek

Drawn:	Approved:	Project No.:	Date:	Figure:
KC		002-2418	03 - 12 - 01	A2 - 2



LEGEND

Channel Types:

- R Run habitat; moderate-high flows; surface largely unbroken
- R2 Run habitat; moderate quality high-moderate ISC except at low flow, deep / fast
- R3 Lowest quality run habitat;small shallow; low ISC; high flows
- P3 Low quality pool habitat; shallow; low ISC; high flows
- CH Chute

Bank Habitat Types:

- A1 - armoured / stable
- D1 - depositional

Substrate Types:

- Si - silt
- Sa - sand
- Gr - gravel
- Co - cobble
- Bo - boulder
- Bd - bedrock

Vegetation / Cover Types:

- Em - emergent vegetation
- Sb - submergent vegetation
- OHV - overhanging vegetation
- ISC - instream cover

Baker Creek downstream of Chutes

Baker Creek Upstream of effluent discharge ; small chutes & bedrock substrate

Baker Creek downstream of surveillance network program (SNP) sampling station ; Dominant boulder substrate

Upper Baker Creek - narrow channel dominant bedrock substrate

Chute - possible migration barrier

Upstream view of effluent discharge

Upstream view of Trapper Creek grassy channel ; low flows

NO.	REFERENCE DRAWINGS	DATE
1	Topo.dwg	8/14/00

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Fish Habitat Assesment in Baker Creek

Drawn: KC | Approved:

Project No.: 002-2418 | Date: 03 - 12 - 01 | Figure: A2 - 3

APPENDIX A-3

MINE HISTORY AND DEVELOPMENT

1.0 MINING HISTORY

The original Giant group (Giant 1-21, Giant X1 - X5, Law 2-3) was staked in July of 1935 by C. J. Baker of Burwash Yellowknife Gold Mines Limited. Early exploration by Frobisher Exploration, Consolidated Mining and Smelting Company of Canada, and Anglo-Huronian included a number of test pits, an 80 foot incline shaft in the Ole shear zone, a small incline shaft in the Brock zone, and extensive diamond drilling in the Bake Creek Valley. In 1939, Yellowknife Gold Mines acquired assets of Burwash, but it was Frobisher Exploration Company who acquired operating control of the Giant properties in 1943 when exploration in the Baker Creek Valley marked the discovery of the largest tonnage of gold ore known in the Northwest Territories.

The No. 1 (A-Shaft) and No. 2 (B-Shaft) Shafts were sunk in 1946, while the No. 3 (C-Shaft) was collared in 1947. Akaitcho Yellowknife Gold Mines (Akaitcho) was incorporated in 1945 to develop the Supercrest group of claims. In 1948, the Akaitcho Shaft was collared. Giant acquired 87.5% of the Lolor group of claims in 1948 and in 1953, Lolor Mines was incorporated.

Plans for the crushing, milling and roasting plants also began in 1947. Milling operations began in 1948 when a 450 tons per day (tpd) mill was put into production and the inaugural brick was poured on August 24 of that same year. Original bullion was produced by amalgamation of jig concentrates while flotation concentrates were stockpiled until roasting and cyanidation plants were completed in 1949.

The mill capacity was increased to 700 tpd in 1952 and then to 900 tpd in 1960. Also in 1960 Giant Yellowknife Gold Mines amalgamated with Consolidated Sudbury Basin Mines Ltd. to form Giant Yellowknife Gold Mines Ltd. In 1962, Giant Yellowknife merged with Ventures Ltd. to become one of the Falconbridge Group of Companies.

Giant Yellowknife Gold Mines Ltd. and Akaitcho jointly formed Supercrest Mines Ltd. in 1964 to develop the Supercrest property. In 1967, both Lolor Mines Ltd. and Supercrest Mines Ltd. went into production.

Sharply increasing gold prices in 1973 and 1974 prompted an increase in exploration in areas that were previously considered to be submarginal. In 1974, production started from the A-1 open pit. Soon after, other open pits were developed and accounted for nearly 40% of the mill feed.

In 1986, Pamour Inc. acquired Falconbridge Ltd.'s 19.2% share in Giant Yellowknife Mines Ltd. as well as 36.7% held in Akaitcho Yellowknife Gold Mines Ltd. Giant Yellowknife acquired Pamour's mines in the Timmins area of Ontario, increasing Pamour's interest in Giant to 50.2%.

In 1987, a 100 tpd pilot plant was built to determine the feasibility of recovering gold from the tailing. After a three month trial period and a recovery rate of 38%, a decision was made to construct a Tailing Retreatment Plant (TRP). The TRP went into production in 1988, but recovery rates were only 17.1% in 1988 and 28.6% in 1989.

In 1990, Royal Oak Mines Inc. purchased control of the Pamour Group of Companies. Upon a review of the corporate mining strategy and a search for ways to reduce the overall production cost, the TRP project was shut down. By 1991, Royal Oak Mines Inc. was formed as a result of the amalgamation of Royal Oak Resources Ltd., Pamour Inc., Giant Yellowknife Mines Ltd., Pamorex Minerals Inc., and Akaitcho Yellowknife Gold Mines Ltd. [J.A. Brophy, 1985].

Royal Oak Resources Ltd. went bankrupt in 1999 and the Government of Canada obtained the property. INAC was appointed the operator of the mine. In November of 1999, Miramar Giant signed an agreement with INAC to operate the mine, but INAC retained responsibility for the mill and most of the surface facilities. Miramar Giant agreed as part of the operation of the underground mine to prepare a Final Abandonment and Restoration Plan. Miramar Giant plans to operate the underground mine until at least December 2001.

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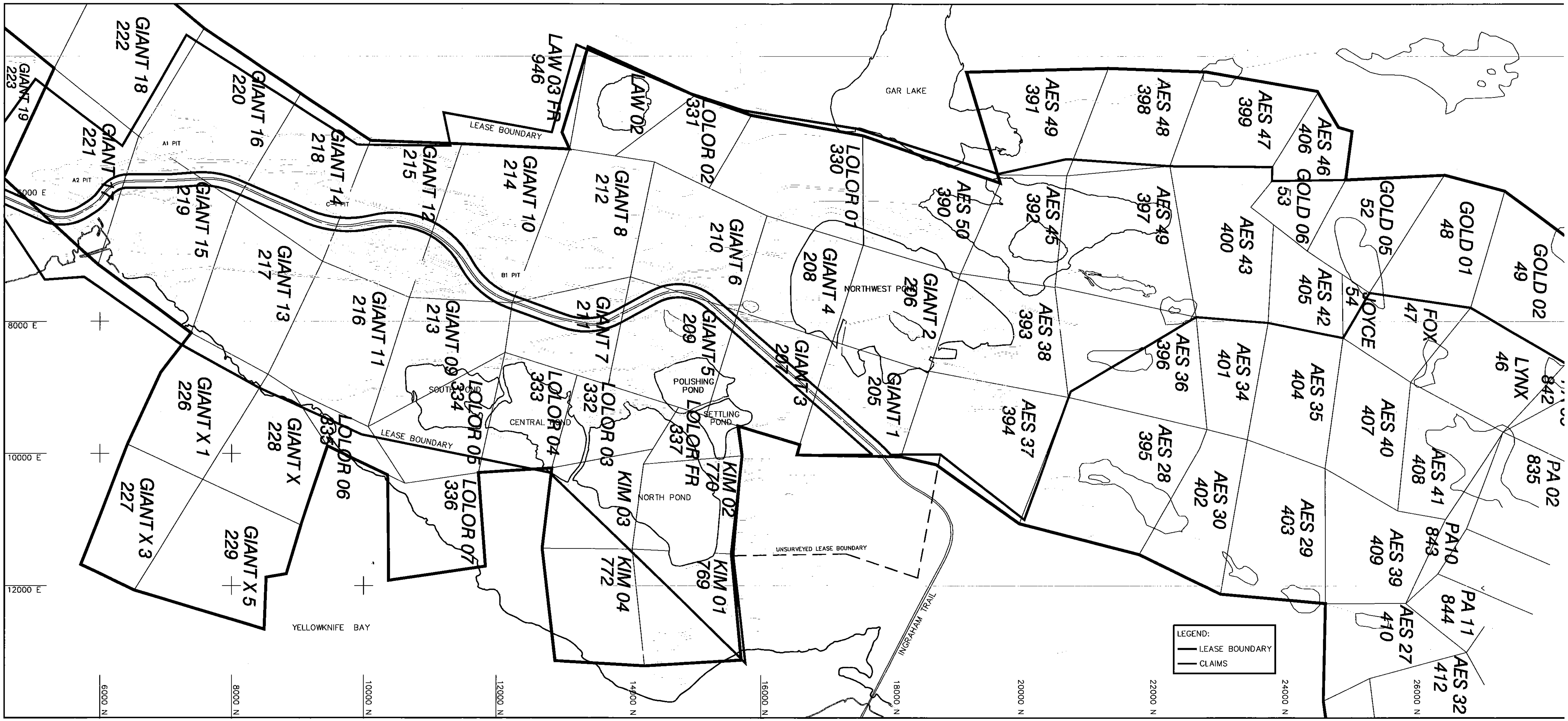

GIANT MINE ABANDONMENT AND RESTORATION PLAN
CLAIMS AND LEASES

Golder Associates

Drawn: JK	App'd:	Date: Nov 15, 01	Figure: **A-3-1**

Project No.: 002–2418

Revision No.:

Drawing: N:\Work\2000\002–2418 A&R Miramar Giant\Drawings\Giant\FIGURE A–3–1.dwg Plotted: Nov 15, 2001 – 2:05pm By: RRoque

APPENDIX A-4

MILL HISTORY AND PROCESS

1.0 MILLING PROCESS

Gold is removed from the ore through a series of crushing and grinding, flotation, roasting and cyanidation circuits. A simplified flow sheet of the process is shown on Figure A-4-1 and described below.

Crushing and Primary Grinding

Blasted ore is crushed underground in a primary jaw crusher and then hoisted to a three stage crushing plant on the surface. Ore removed from underground is reduced to 3/8 inch size or less. Historically, once on surface, ore was reduced through two parallel primary grinding circuits, each consisting of a ball mill working in closed circuit with a spiral classifier. Water was added with the feed to the ball mills, where 3 inch steel balls ground down the ore. The larger particles were separated through spiral classifiers and returned to the primary ball mills for additional grinding. The fine particles overflowed the classifier and passed on to the next stage of processing.

Froth Flotation

The froth flotation process recovered approximately 95 percent of the gold in the form of a sulphide mineral concentrate. The sulphide minerals, primarily pyrite and arsenopyrite, were separated from the ground ore slurry. Copper sulphate was added to the ball mills, in order to coat and activate the sulphide minerals contained within the ore. A flotation collector chemical called *xanthate* was added to the classifier overflow and attached itself to the activated sulphide mineral surface. The coated sulphide particles had a high affinity for air, which is bubbled through the flotation cells. A frothing agent was added to help the mineral rich bubbles from a strong and stable froth. At the surface of the flotation cell, the froth was skimmed off into a launder as flotation concentrate. This step acted primarily as a mass reduction step for the 1300 tons of ore that were processed in a day. Approximately 130 tons of the 1300 tons reported to the flotation concentrate. The remaining 1070 tons, called flotation tailing, was deposited directly into the tailing pond. The flotation concentrate was thickened to 75 percent solid prior to further treatment in a two stage fluid bed roaster.

Roasting

Arsenopyrite, which is an arsenic-iron sulphide mineral, hosts the majority of the gold, which is interstitially locked in its mineral matrix. This makes the gold difficult to recover without first destroying the mineral structure. Breakdown of the arsenopyrite mineral was accomplished in a two stage fluid bed roaster at high temperature. The flotation concentrate was dewatered to a density of 77% solids in a circuit using a dewatering cyclone and a thickener, then was sprayed into the first stage of the roaster. The water was returned to the grinding circuit to be re-used. The sulphur and arsenic contained in the pyrite and arsenopyrite were oxidized by the addition of air, which is blown in at the bottom of each roaster stage. The roasting process was 'autogenous', in that heat is provided by the sulphur oxidation reactions and no additional fuel was required during normal operation. The arsenic contained in the arsenopyrite was oxidized and fumed off as gaseous arsenic trioxide. The remaining partially oxidized mineral was transferred into the second stage of the roaster and again oxidized at high temperature, to remove more of the contained sulphur as gaseous sulphur dioxide. Off gases from the two stages of roasting were combined, cycloned to remove coarse entrained dust particles, and then passed through an electrostatic precipitator. The electrostatic precipitator used electrical energy to charge the fine particles of entrained dust contained in the gas and then to remove these particles from the stream by collecting them on oppositely charged rods. The dust collected in the precipitator was slurried with water and processed to recover the contained gold.

Tail gas from the precipitator was cooled by mixing the gas with large volumes of outside air. As the gas cooled, arsenic trioxide condenses from the gas as solid arsenic trioxide dust. The arsenic trioxide dust particles were filtered from the gas stream in a baghouse style dust collector. The remaining gas stream, which was a dilute mixture of sulphur dioxide and air, passed through the fabric dust collection bags and was exhausted to the atmosphere through a 46 m high stack. The arsenic trioxide dust, which was collected in the baghouse, was pneumatically conveyed into specially prepared underground storage chambers.

The material remaining after roasting the flotation concentrate is called calcine. Roaster calcines are the gold bearing iron oxides that remain after the majority of the sulphur and arsenic has been removed. The roaster calcines were water quenched and then ground in two ball mills that work in a closed circuit with hydro-cyclone particle size classifers. The ground calcines were washed in a thickener to remove soluble impurities and increase the slurry density for subsequent gold leaching. The wash thickened overflows were rejected to the tailing containment area. The regrinding process breaks down the iron oxide particles and exposes the contained gold.

Cyanidation

The slurry was made alkaline (pH 11.0) through the addition of lime. Sodium cyanide was added to the alkaline calcine slurry and the gold was leached from the calcine in a two stage agitated leach circuit. The gold was dissolved into solution, which produces a gold cyanide complex. After the first stage of leaching, the calcine was partially dewatered in a thickener. Fresh cyanide solution was added to the thickened calcine slurry and then leached in a second stage of agitated leaching. The slurry was once again dewatered in a thickener with the solution recovered for subsequent processing. The thickened slurry was then filtered to remove the gold bearing solution. The filtered solids are called calcine residue and were rejected to the tailing containment area.

The gold bearing solutions (pregnant solution) recovered from the calcine leach circuit were combined and filtered in a leaf clarifier using canvas bags coated with diatomaceous earth. The pregnant solution was then deoxidized in a Merrill Crowe tower. Zinc dust was added to the de-oxygenated solution, allowing the gold cyanide complex contained in solution to precipitate on to the zinc dust. The zinc dust was then filtered from the solution using a press filter. Lead nitrate was added to the pregnant solution at the clarifier to enhance the precipitation of gold onto the zinc dust by complexing competing ionic species. The gold bearing filtered zinc dust was periodically removed from the press and melted to form gold dore bullion. The solution that passes through the press was aerated and returned to the circuit as barren solution. The barren solution was recycled to the leach circuit to make effective use of the contained un-reacted cyanide. A portion of the barren solution was bled to the tailing containment area to remove the build up of impurities.

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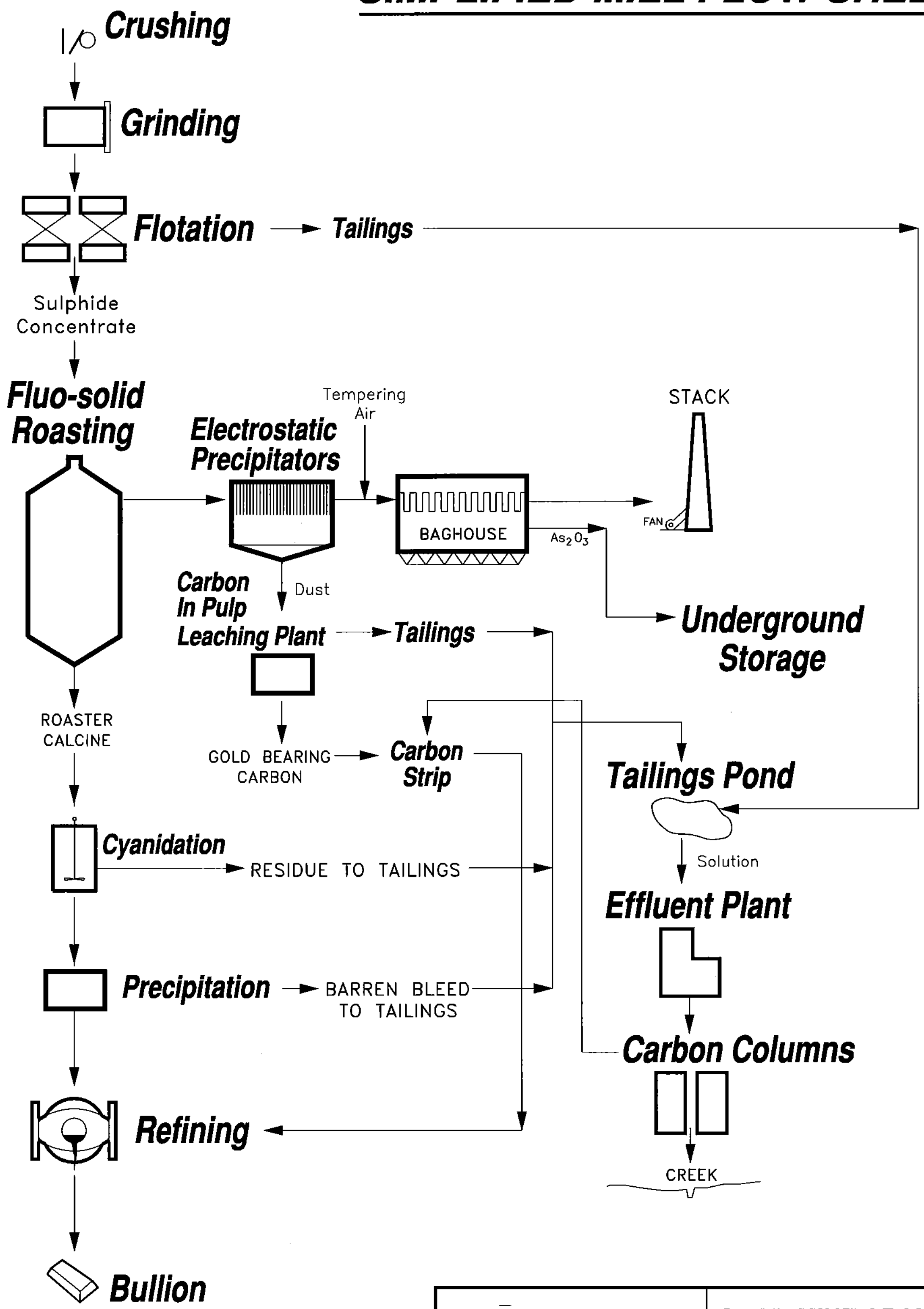
SIMPLIFIED MILL FLOW SHEET



Golder Associates

GIANT MINE ABANDONMENT
AND RESTORATION PLAN
MILL FLOW SHEET

Drawn: JK	App'd:	Date: Nov 15, 01	Figure: **A-4-1**

Project No.: 002–2418 Revision No.:

Drawing: N:\Work\2000\002–2418 A&R Miramar Giant\Drawings\Giant\FIGURE A-4-1.dwg Plotted: Nov 15, 2001 - 2:01pm By: RRoque

Photo A4 Composite 1a. North side of C1 Pit, looking north-east.

Photo A4 Composite 1b. North side of C1 pit looking south-east.

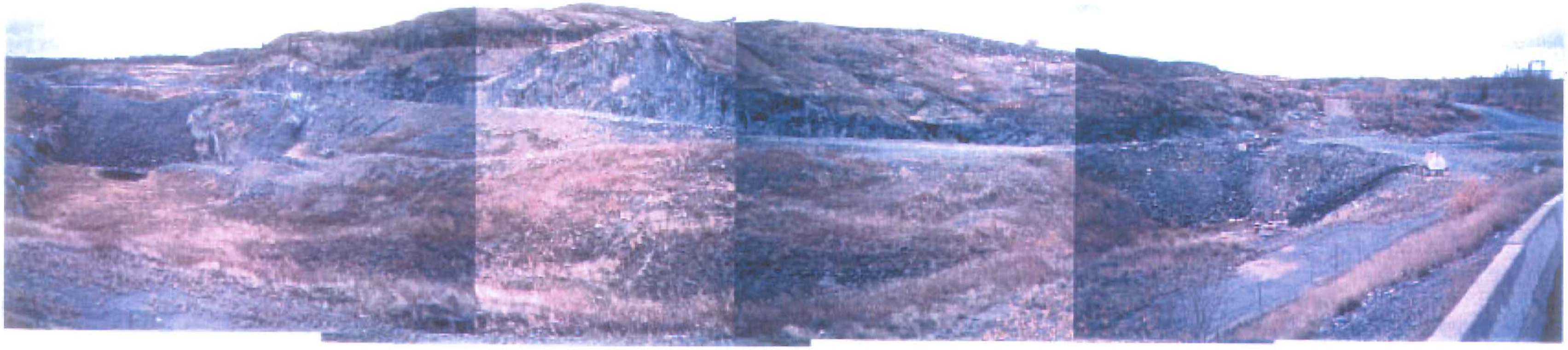


Photo A4 Composite 2a. C1 Pit, looking west.

Photo A4 Composite 2b. C1 Pit, looking north over highway, close to entrance to C Shaft.

Photo A4 Composite 3. View of A1 Pit, looking south-east, showing both the southern portal and eastern portals.

APPENDIX A-5

OPEN PIT INSPECTION NOTES

INSPECTION REPORT
GIANT OPEN PITS

The Giant Mine open pits were inspected for the Final Abandonment and Restoration Plan for the Miramar Giant Mine in Yellowknife. The inspection reports, attached describe the conditions of the pits and the pit slopes at the time of the inspections. The recommendations for the closure of the pits are discussed on the inspection reports.

In general, the pit slopes are in good condition, with only the southeast slope of A-1 Pit showing any distress. The slope should be flattened or re-graded as part of the closure of the open pit areas. The re-grading would improve drainage and provide a long term stable slope. The remainder of the pits require low berms along the crests of the pit slopes to act as warning berms at the top of the steep pit walls. Most of the open pits have openings to the underground operation. At the conclusion of mining, the openings that are no longer required should be plugged. The last of the openings would be plugged as part of the arsenic trioxide clean up in the main area of the mine.

INSPECTION REPORT
A-1 PIT

General Conditions

The overall pit and the pit slopes are generally in good condition and appear stable. The rock on the west pit slope has raveled and is collecting on the slope benches. This is as anticipated. The slope in the northeast corner of pit appears to be creeping towards the pit. The movement appears to be minor.

Slopes

The west and south pit slopes appear to be in good condition and there is no concern with these pit walls. The benches on the west slope are partly covered with rock that has raveled from the slopes above each bench.

The waste rock and overburden appear to have been placed on the north slope of the pit. There is evidence of minor movement of the northeast slope in the upper sections of the overburden material. The slope should remain stable provided the pit is not allowed to flood.

The east pit slopes are creeping at the north end of the pit. This has resulted in minor settlement of the access road on the east side of the pit. The movement does not appear to be continuing at this time. The slope may require minor re-grading to flatten the slope to provide a long term stable slope configuration.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit slopes do not require any maintenance at this time.

The opening to the underground on the east side of the pit will have to be closed with the final abandonment of the underground mine. The opening should be seal with a concrete plug.

The west and southwest pit slopes may be left as they are at present, with a low earth berm around the outside edge. The northeast slope should be re-graded at final closure.

PHOTOGRAPHS

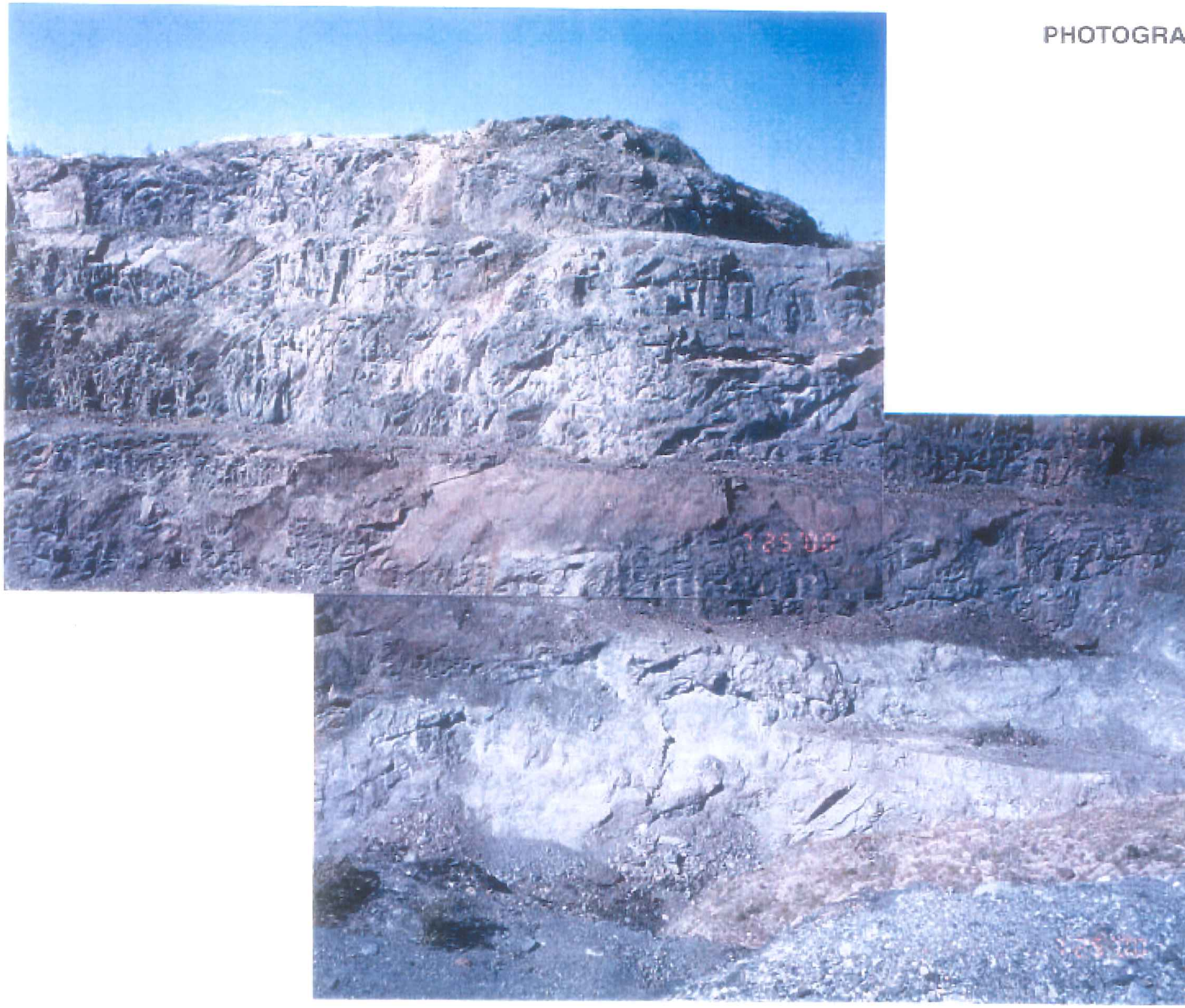


Photo 1: West Slope with rock on benches.

Photo 2: Southeast corner of pit. Slope in good condition.

INSPECTION REPORT
A-2 PIT

General Conditions

The overall pit slopes are in good condition and appear stable. The rock on the west pit slope has raveled and is collecting on the slope benches.

Slopes

The pit slopes appear to be in good condition and there is no concern with the pit slopes. The benches on the west slope are partly covered with rock that has raveled from the slopes above each bench.

Waste rock and overburden appear to have been placed at the north end of the pit to form part of the north slope of the pit. There is evidence of some minor movement of the north slope in the upper sections of the overburden material. The slope will remain stable provided no additional material is placed on the slope and/or the pit remains dry. If the pit is allowed to flood, the slope should be re-inspected.

The east pit slopes are near vertical and are in very stable condition. The opening to the underground on the east wall will have to be plugged at closure. The slope should remain stable and it should not be necessary to provide additional slope protection to maintain Baker Creek in its present course.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit slopes do not require any maintenance at this time.

The opening to the underground mine at the toe of the east wall will have to be plugged at closure. The slope should remain stable and it should not be necessary to provide additional slope protection to maintain Baker Creek in its present course.

The east slope should also be stable for the long term provided the Ingraham Trial is not relocated closer to the crest of the pit slope. If the road is re-located closer to the crest of the pit slope, it may be necessary to re-evaluate the slope.

In general, the pit slopes may be left as they are at present, with a low earth berm around the outside edge. This is most critical along the west and southwest slope.

PHOTOGRAPHS

Photo 3: South slope with rock on benches.

Photo 4: East pit wall. Opening to underground is to be plugged at closure of underground operation.

INSPECTION REPORT
C-1 PIT

General Conditions

The overall pit slopes are in good condition and appear stable. The rock on the south pit slope has raveled and the rock is collecting at the toe of the pit slope. This is as anticipated.

Slopes

The pit slopes appear to be in good condition and there is no concern with the pit slopes.

The waste rock and overburden appear to have been placed on the north slope of the pit. There is no evidence of movement of the slope. The slope will remain stable provided the pit is not allowed to flood.

The rock slope west of the Baker Creek diversion is in good condition.

Groundwater

There was a small pond of water in the bottom of the pit. In general the pit remains dry as the underground workings below the pit are pumped.

Summary

The pit slopes do not require any maintenance at this time.

The pit slopes may be left as they are at present, with a low earth berm around the outside edge. This is most critical along the west and southwest slope. The other slopes may be left as they are at present.

The slope on the west side of the Baker Creek diversion will require a further evaluation once the closure plan for the underground arsenic storage chambers is finalized and the long term plan for Baker Creek is finalized.

PHOTOGRAPHS

Photo 5: North Slope of C-1 Pit.

Photo 6. Northeast Slope of C-1 Pit with mill in background.

Photo 7 and 8: South and southeast C-1 Pit slope.

Photo 9: Rock slope on west side of Baker Creek diversion. Slope is in good condition.

INSPECTION REPORT
B-1 PIT

General Conditions

The overall pit and the pit slopes are in good condition. There is some rock on the pit slopes that has raveled and has collected on the access road to the pit floor or at the bottom of the pit.

The perimeter berm around the pit is in place and is functioning as desired. The pit perimeter berm will have to be extended at closure to include the access road area.

Slopes

The pit slopes appear to be in good condition and there is no concern with any of the pit slopes. The access road on the west side of the pit is partly covered with rock that has raveled from the slopes above the road. The underground arsenic storage vaults (B212, B213, B214) are very close to the east and north slope of the pit. The separation between these chambers and pit slopes is estimated at 3 to 6 meters.

Waste steel from the Giant operation has been placed in the pit. The steel was cleaned before it was placed in the pit. This is not causing any concerns at present with access or pit slope conditions.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit does not require any maintenance at this time.

The opening to the underground on the east side of the pit will have to be closed with the final abandonment of the underground mine. The opening should be seal with a concrete plug.

The pit slopes may be left as they are at present. The arsenic storage chambers or stopes that are within 6 meters of the east and north side of the pit will have to be stabilized. The proposal for this work will depend on the final solution for the arsenic trioxide in the underground stopes and storage chambers. The approach for this area will be determined as part of another study.

PHOTOGRAPHS

Photo 10: North Slope of B-1 Pit.

Photo 11: West Slope of B-1 Pit. Note scrap steel in pit.

Photo12: South slope of B-1 Pit. Baker Creek is just beyond crest of pit.

Photo 13: East slope of B-1 Pit.

INSPECTION REPORT
B-2 PIT
(UBC PIT)

General Conditions

The overall pit slopes are in good condition and appear stable.

Slopes

The pit slopes appear to be in good condition and there are no concerns with the pit slopes. The north slope adjacent to Baker Creek is in good condition and there is no indication of seepage.

The underground opening at the toe of the east slope is in good condition and slope above the opening appears to be in good shape.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit does not require any maintenance at this time.

The opening to the underground on the east side of the pit will have to be closed with the final abandonment of the underground mine. The opening should be seal with a concrete plug.

The west and south pit slopes may be left as they are at present. A low earth berm will be required at closure around the outside edge of the pit.

The north side of the pit is adjacent to Baker Creek and the dyke on the north side of the pit may require an additional height of fill to provide protection from flood flows on Baker Creek. This would be determined with the detailed design of the closure for the underground arsenic storage chambers.

PHOTOGRAPHS

Photo 14: West side of B-2 Pit.

INSPECTION REPORT
B-3 PIT

General Conditions

The overall pit and the pit slopes are in good condition at present.

Slopes

The pit slopes appear to be in good condition and there is no concern with the south or west pit walls.

The north and northeast slopes of the pit are part of the downstream slope of Dam #1. The upper portion of the slope appears to be developed in waste rock and overburden. There is evidence of minor movement of the slope in the upper sections of the overburden material. The slope will remain stable, but may require monitoring to confirm the long-term condition of the slope, if the polishing pond behind Dam #1 remains in operation for the long-term water management needs of the closed mine operation.

The east pit slopes also appear to be creeping at the north end of the pit. This has resulted in minor settlement of the access road on the east side of the pit. The movement should be monitored.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit does not require any maintenance at this time.

The opening to the underground operation on the west side of the pit will have to be closed with the final abandonment of the underground mine. The opening should be seal with a concrete plug.

The pit slopes may be left as they are at present, with a low earth berm around the outside edge. This is most critical along the west and southwest slope.

The north and east slopes should be monitored and if Dam #1 is used as a water retention structure in the long term for site water management with the arsenic trioxide project, it may be necessary to provide an additional evaluation of the slope in the future.

PHOTOGRAPHS

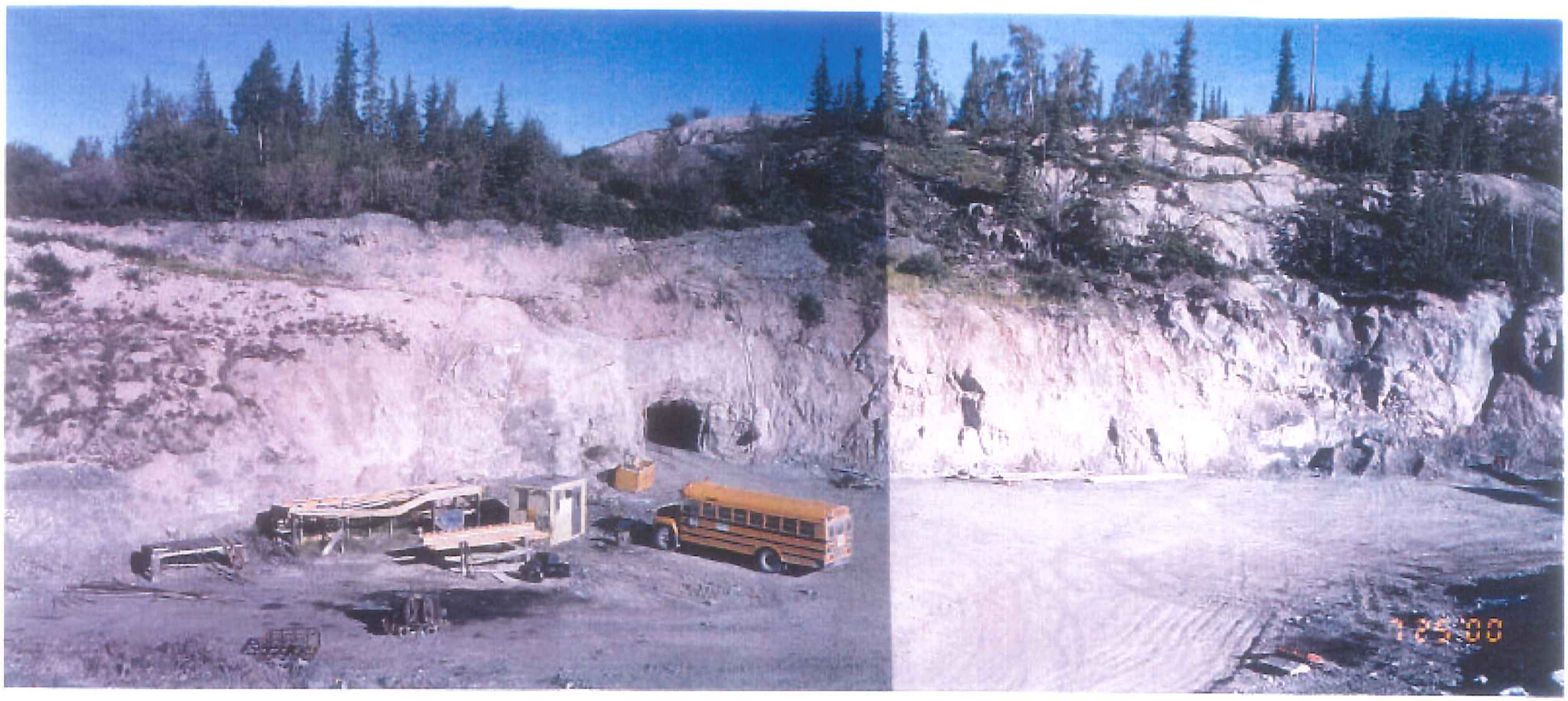


Photo 15: West side of B-3 Pit. Access to underground in center of photo.

INSPECTION REPORT
B-4 PIT

General Conditions

The overall pit and the pit slopes are in good condition and appear stable.

Slopes

The pit slopes appear to be in good condition and there is no concern with the north and west pit walls.

Groundwater

There was no water in the bottom of the pit as the underground workings below the pit are maintained in a dry condition.

Summary

The pit does not require any maintenance at this time.

The pit slopes may be left as they are at present, with a low earth berm around the outside edge. This is most important along the west and northwest slope.

The other slopes may be left as they are at present.

PHOTOGRAPHS

Photo 16: West side of B-4 Pit.

INSPECTION REPORT
BROCK PIT

General Conditions

The overall pit and the pit slopes appear stable.

Slopes

The pit slopes appear to be in good condition and there is no concern with the west pit wall.

Groundwater

There was no water in the bottom of the pit.

Summary

The pit slopes do not require any maintenance at this time.

The opening to the decline on the west side of the pit will have to be closed with the final abandonment of the underground mine. The opening should be seal with a concrete plug.

The pit slopes may be left as they are at present, with a low earth berm around the outside edge. This is most critical along the west and northwest slope.

The other slopes may be left as they are at present.

PHOTOGRAPHS

Photo 17: West side of Brock Pit.

Photo 18: South side of Brock Pit.

APPENDIX A-6

MIRAMAR GIANT MINE
UNDERGROUND EXCAVATIONS

TABLE OF CONTENTS

LIST OF DRAWINGS

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Summary

Crown pillars above underground workings and various openings to surface have been assessed in order to define underground mine remediation requirements for the Giant Mine Abandonment and Reclamation Plan.

The open pits (adjacent to A Shaft, B Shaft and C Shaft) have in some cases been mined out to within a few metres of the top of the mining excavations, so that there are effectively no crown pillars above the underground workings in these areas. In the C Shaft area, some of the shrinkage stopes have been used as storage chambers for arsenic trioxide dust and two of these lie within the footprint of the B1 pit. Although the stability of stopes containing arsenic trioxide is outside the scope of this report, crown pillar stability may have implications on the stability of pit walls. The crowns of both B208 and B213/214/215 are potentially unstable and will require significant rehabilitation to maintain long-term stability. This issue must be addressed in the arsenic trioxide management plan.

In addition to the crown stability concerns about the shrinkage stopes, there is also the issue of their proximity to other stopes, now filled and scheduled for abandonment. The rock pillar between the B208 cavern and the gravel-filled B306 stope below is only about 10 ft and the integrity of this pillar should be assessed as part of the arsenic trioxide management plan. Similarly, the assurance of the integrity of bulkheads that prevent arsenic trioxide solids migrating from the storage chambers into other parts of the mine will fall within the scope of the management plan.

The Akaitcho Mine has a conventional crown pillar some 100 m thick and presents no significant stability concern.

There are approximately twenty-six excavations that connect the surface to the underground workings - shafts, ramp portals, raises and drifts. These will have to be sealed and capped and although in one or two cases this may be difficult and slightly more costly than normal, in general none of these excavations present a serious concern.

1.2 General

This appendix describes the conditions at Miramar Giant Mine during the period September 24 to 29, 2000. The purpose of the visit was to assess the stability of the near-surface excavations, the existing crown pillars and the various connections between the surface and underground workings. During this period all the accessible excavations on the First and Second Levels of the mine were visited and photographed as were the several open pits in the area and the adjacent surface outcrops.

The mine visit included inspection of the rock mass around many of the chambers and stopes used to contain arsenic trioxide dust, and their associated concrete bulkheads. However, the comments in this report will be restricted to impacts of the chambers or stopes on ground surface stability and on adjacent underground workings not presently containing arsenic trioxide dust.

There are four main types of excavations that connect the surface with the underground workings, shafts and ramps (portals) which are relatively large and raises and drifts that are relatively small. There are three figures that will be referred to throughout this report, as follows:

Figure 1. Map of the Giant Mine Plant. This shows all the facilities including all the shafts, (A-, B- C-Shaft and the Akaitcho Shaft) and open pits from A1 in the south to B4 in the north. Also shown are all the mine roadways and tailings facilities and the Yellowknife Bay.

Figure 2. Contour Map of the area around C-Shaft, from the north end of C Pit to the B1 Pit. This shows all surface plant and roadways and shows the position of the underground Arsenic Storage Chambers relative to these facilities.

Figure 3. Plan of the underground workings around the Arsenic Storage Chambers. This plan also shows the location of some of the surface plant relative to the chambers.

2.0 UNDERGROUND EXCAVATIONS

There are several mining areas that comprise operations at the Giant Mine, the A-Shaft, B-Shaft, C-Shaft operations and the Akaitcho operations also called the Supercrest Mine about 4.7 km to the north of C-Shaft (Figure 1). Adjacent to the A-, B- and C-Shafts are the open pits (A1, A2, C1, B1, B2, B3 and B4). All of these pits except B4 have a connection to underground workings and will be described individually. Underground excavations include numerous ramps, drifts and stopes, some of which are backfilled and others that remain open. Finally, there are a series of arsenic trioxide storage chambers that are being treated separately from the remaining mine workings for the purposes of this Final Abandonment and Reclamation Plan. These are only considered in terms of their impact on other mine workings or surface stability for the purposes of this report.

2.1 Underground Arsenic Trioxide Storage Chambers

The underground storage chambers at the Giant mine are distributed in four areas AR1, AR2, AR3 and AR4 (Figure 3). The main accesses to the mine are via the C-Shaft and the ramp portal in B2 Pit. The B-Shaft is now used for ventilation.

AREA	CAVERN	WIDTH	LENGTH	HEIGHT
AR1	#11	30 ft.	120 ft.	70 ft.
	#12	40 ft.	200 ft.	110 ft.
	#14	40 ft.	185 ft.	70 ft.
	#15	50 ft.	210 ft.	120 ft.
AR2	C212	15-20 ft.	150 ft.	150 ft.
	#9	40 ft.	100 ft.	170 ft.
	#10	30 ft.	70 ft.	160 ft.
AR3	B208	50 ft.	130 ft.	165 ft.
	B230	20 ft.	70 ft.	70 ft.
	B233	20 ft.	120 ft.	120 ft.
	B234	30 ft.	120 ft.	140 ft.
	B235	40 ft.	120 ft.	180 ft.
	B236	40 ft.	120 ft.	160 ft.
AR4	B212/13/14	170 ft.	270 ft.	180 ft.

In AR1, the four storage chambers (#11, #12, #14 and #15) were excavated in waste rock for the purpose of storing the waste material from the process. The smallest of these is #11, which lies immediately adjacent to the B2 pit. Of these chambers #15 cavern was never used for storage and remains empty while the others have been filled with arsenic trioxide dust.

In AR2 there are three chambers, two of which were developed in waste as storage chambers (#9 and #10) and one which was mined as a shrinkage stope (C212) upwards from the Second Level to just below the First Level. Chambers #9 and #10 (also referred to as C9 and C10) are small compared to those in AR1, extending from the First Level to the Second Level. The C212 stope is the same height since it was mined as a narrow shrinkage stope from the First to the Second Level.

In AR3 there are six chambers, five of which were excavated in waste as storage chambers (B230, B233, B234, B235 and B236) and one of which was excavated as a shrinkage stope (B208 stope). The largest cavern in this area is the former shrinkage stope B208, which is very irregularly shaped, both in plan and along its length. Its most important characteristic is that it lies partially within the footprint of the B1 Open Pit and is located very close to the eastern wall of the pit.

AR4 has three storage chambers (B212, B213 and B214) all of which were initially excavated as shrinkage stopes. They are all relatively large and irregularly shaped, and although they were originally mined as individual stopes, at the upper elevations they essentially form one excavation. Stopes B212 and B213 were mined from the Second Level to about 20 ft. above the First Level. The B214 end of the excavation lies within the footprint of the B1 Open Pit and B213 and B212 are very close to it. From the photographs of the B1 pit (A2-5) it is possible to see the two drifts that used to form the B208 Arsenic Distribution Drift that was driven about 5-6 ft. above the First Level. The B212/213/214 cavern lies some 5-10 ft immediately below these drifts.

2.2 Storage Chamber Bulkheads

A number of the bulkheads that contain arsenic trioxide within the storage chambers were inspected in order to gain a general impression about the risks posed to the remainder of the mine. Many could not be inspected due to flooding of access drifts or inadequate ventilation, so this assessment was not exhaustive. All the bulkheads that were observed were constructed of concrete 0.6 to 2 m thick and are doweled to the drift walls. It is understood that bulkheads in recent chambers were pressure-tested with air while others may have tailing backfill placed behind them. All bulkheads inspected were in good structural condition, but a few, such as #50 in C212 (Photo A5-16) showed some signed of seepage. None indicated deterioration that might compromise their structural integrity, although it was impossible to assess whether some might be retaining large heads of water that might negatively affect their stability. It is understood that detailed assessment of all chambers will be undertaken during completion of the arsenic trioxide management plan.

2.3 Crown Pillars

At the Akaitcho Mine there is a crown pillar of about 100 m. above stopes that are effectively very narrow. The crown pillar is considered to be stable. There is one shaft that passes through this crown pillar the Akaitcho Shaft, latterly used as an exhaust raise. The shaft will be sealed with a vented concrete cap.

There are several open pits that have mined into the crown pillars above underground workings in the A, B and C shaft areas. The A1, A2, C1, B1, B2 and B3 pits have all mined through the historical crown pillars. The greatest concerns with respect to crown pillar stability relate to arsenic trioxide storage chambers, which are not part of this assessment. The major issues are documented below for the sake of completeness.

The proximity of the arsenic storage chambers to surface ranges from about 100 ft. to as little as 10 ft. In the AR2 area, the distance of the chambers from the surface in the AR2 area is around 100ft. since these are located below the First Level. In the AR1 area there is about 30-50 ft of rock between the roofs of the chambers and the surface of bedrock, which is overlain by little or no soil (see Attachment I). In the case of the chambers in AR3 and AR4, the B1 pit has been mined through some of the underground access drifts, including the Arsenic Distribution Drift (ADD) and the chambers B208 and B214 lie in within the footprint of the pit, some 10-20 ft. from the pit wall. These two chambers, which are abandoned shrinkage stopes, require detailed stability assessments, and crown pillar reinforcement will probably be required in order to prevent caving into the B1 pit wall. In the case of chambers #11, #12 the long-term stability considerations should include assessment of the lateral proximity of the open B2 pit.

2.4 Sill Pillars below Storage Chambers

There are two stopes (C212 and B208) which, although they are sealed by adequate bulkheads, have rock/gravel filled stopes below them (C312 and B306). In the case of the C212 cavern there is 50 ft. of rock between the top of the gravel-filled stope and the bottom of the dust-filled chamber above it. In the case of the B208 cavern there is about 10 ft. of rock between the top of the gravel-filled stope and the bottom of the dust-filled stope above. In both cases there were raises that connected the lower, gravel-filled stopes to the Second Level access drift and these have been filled and capped. It is anticipated that security provided by these sill pillars will be assessed as part of the arsenic trioxide management plan, and no additional containment measures are proposed as part of the general mine abandonment plan.

3.0 SURFACE OPENINGS

3.1 Shafts

There are five main access shafts at the Giant Mine operations, all of which are rectangular timbered shafts. The dimensions of the shafts are: A Shaft 10 ft. x 16 ft.; B Shaft 10 x 20 ft.; C Shaft 16 ft. x 20 ft. and Akaitcho Shaft 10 ft. x 16 ft.

The A and B Shafts are no longer functioning but are used for ventilation. C Shaft was equipped and used for hoisting at the time of the visit. The Akaitcho shaft is used as a return ventilation shaft.

3.2 Portals and Access Drifts

There are seven open pits at the Giant Mine site, (A1, A2, C1, B1, B2, B3 and B4) and all except the B-4 pit have served as an access to the underground workings by way of a portal in the pit wall. The dimensions of the ramps that access the underground from these portals are all nominally 10 ft. by 14 ft. wide. It is noted that because of the development over-break that is common in such excavations, an estimated dimension of 12 ft. by 15 ft. wide (4 m by 5 m) should be assumed for assessment and closure estimating purposes. Portals should be sealed with concrete bulkheads dowelled to the rock walls.

The portals of each of the open pits are presented in the photographs presented in Attachments II, III and IV.

3.3 Raises

There are several man-access raises and fill raises that connect surface to underground. These are un-timbered and are typically 5-6 ft. square, inclined between 60-80 degrees. One of these, the raise located north of the B1 Pit has already been capped (Photo A2-16 and A2-17). In another case, there is a fill raise that opens in the floor of the B1 Pit (Photo A2-9) and which exits underground in the 209 E. cross-cut (Figure 3). This is shown in photo A5-15 as a mechanical chute draining water and tailings into the mine. This raise will have to be capped but removal of the debris around the collar will make placing a secure cap more difficult and expensive than for other raises.

There are three man-access raises that open on surface that are currently available for use. These should be easily capped with concrete and sealed in the conventional way. One opens on surface in the north end of the C1 Pit (Photo A4-8), to the west for the highway and is designated as an emergency escapeway. The other two are connections to the arsenic distribution drifts in areas AR2 and AR3. One opens on surface west of the mill, east of the plant roadway and the other opens north of the bag-house.

4.0 CONCLUSION

No significant stability issues were observed during inspections of the Giant Mine underground workings with the exception of the B208 and B212/213/214 arsenic trioxide storage chambers. It is assumed that the issues related to abandonment of those chambers will be covered in the arsenic trioxide management plan.

Numerous openings to surface exist, and all will require caps or bulkheads. In a few cases there be minor problems clearing away existing structures and excavating to suitable quality rock, but concrete caps and bulkheads, doweled into the adjacent rock, will be straightforward to construct in most cases.

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ATTACHMENT I

PHOTOGRAPHS OF AR1 HILL

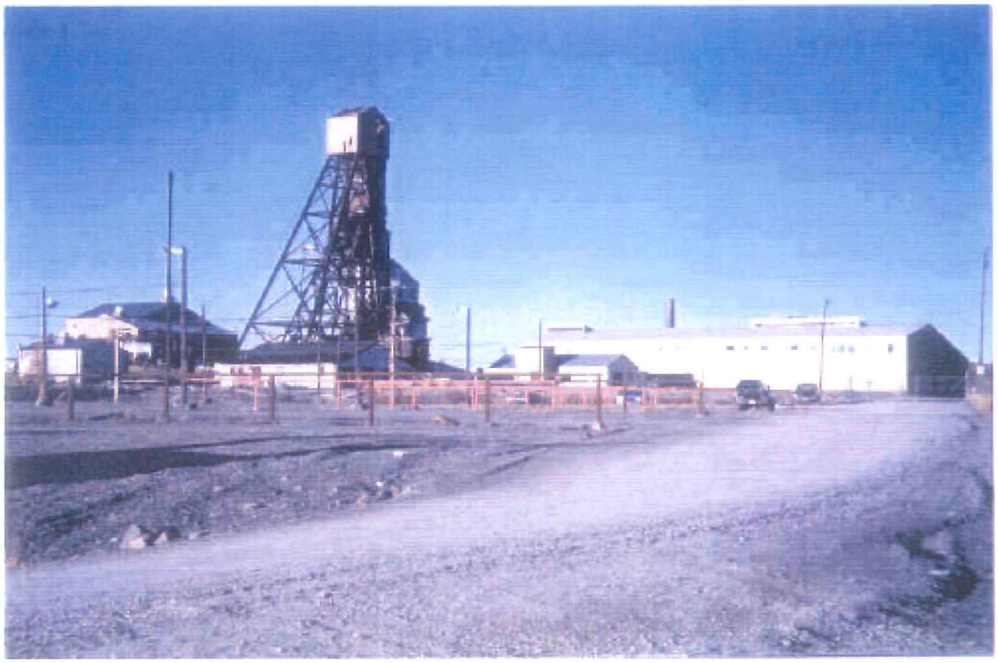


Photo A1-1.   C Shaft Head-frame looking north.

Photo A1-2   AR1 Hill, looking north-west. Under this hill lie the storage caverns #11, #12, #13, #14 and #15.

Photo A1-3. AR1 Hill, north end, looking north over Beaver Creek.

Photo A1-4. AR1 Hill, southern end, looking south-west.

Photo A1-5. AR1 Hill, looking west south-west. (Red dot is capped bore-hole).

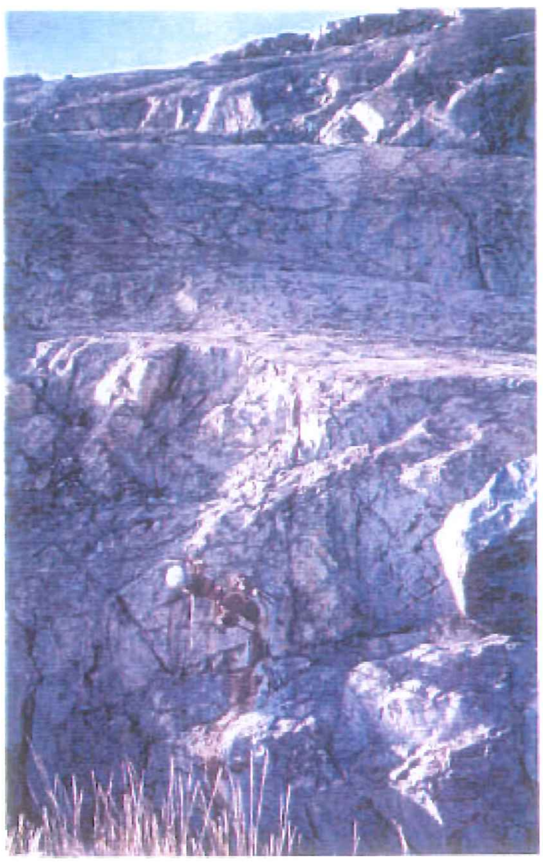
Photo A1-6. AR1 Hill, looking west.

Photo A1-7. AR1 Hill, looking west north-west.

Photo A1-8. AR1 Hill, looking north-west.

Photo A1-9. AR1 Hill, looking north north-west.

Photo A1-10. AR1 Hill, looking north, over Beaver Creek.



A1-11. AR1 Hill, showing capped vertical drill-hole for monitoring arsenic storage cavities.

Photo A1-12. AR1 Hill, showing angled drill-hole for monitoring arsenic storage cavities.

ATTACHMENT II

PHOTOGRAPHS OF THE B1 OPEN PIT

Photo A2-1. B1 Pit, looking north-east from the southern rim of the pit. Shows the floor of the pit plus the scrap on top of the fill plateau.

Photo A2-2. B1 Pit, looking east north-east towards the highway, over the scrap on the fill plateau.

Photo A2-3. B1 Pit, looking east towards the highway, across the southern rim of the pit.

Photo A2-4. B1 Pit, looking south, over the fill plateau and the southern rim of the pit towards C Shaft.

Photo A2-5. B1 Pit looking north-east, showing two underground drifts (2-09) on the northern wall of the pit. Also shows the proximity to bedrock surface.

Photo A2-6. B1 Pit, looking east north-east, showing overburden and bedrock surface.

Photo A2-7. B1 Pit, looking east.

Photo A2-8.
B1 Pit, looking east south-east.

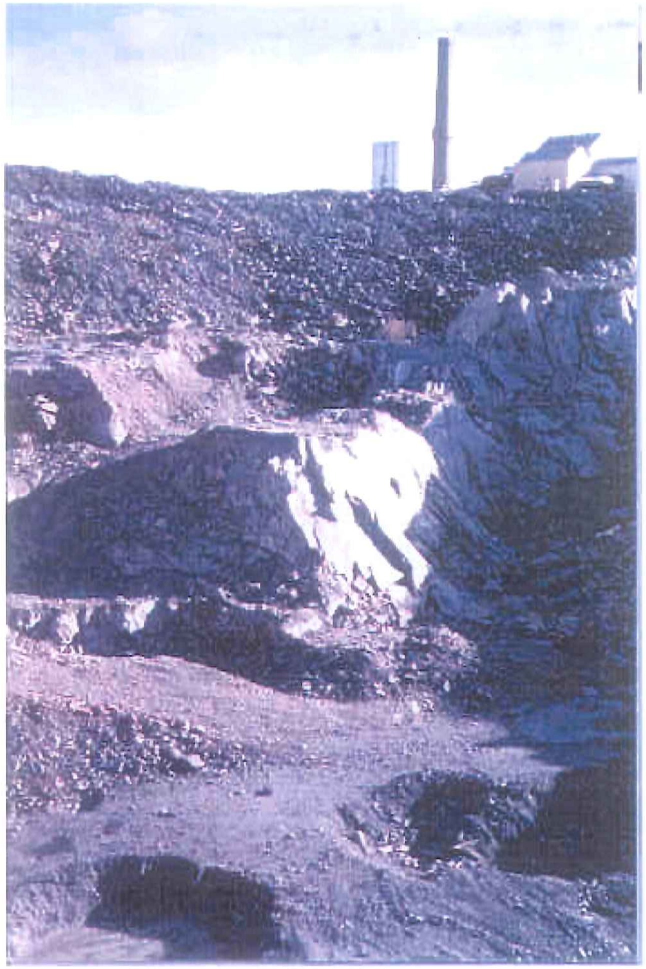


Photo A2-9. B1 Pit, looking south-east.
Showing broken timber from the fill raise in the floor of the pit

Photo A2-10. B1 Pit, looking south south-east.
Showing eastern side of the fill plateau, bedrock and overburden, with the mill in the background.

Photo A2-11. B1 Pit, looking east. Showing bedrock conditions.

Photo A2-12. B1 Pit, looking north north-west, towards the access ramp, showing bedrock conditions.

Photo A2-13. B1 Pit, looking north-west towards access ramp and showing bedrock conditions.

Photo A2 -14. B1 Pit, looking west north-west, showing bedrock conditions.

Photo A2-15   B1 Pit, looking west, showing bedrock conditions.

Photo A2-16. General view, looking south, of the mill and C Shaft. The capped raise in the foreground is located north of the B1 Pit, to the east of the mine road.

Photo A2-17. Close-up of the capped raise north of B1 Pit.

ATTACHMENT III

PHOTOGRAPHS OF THE B2 AND B3 OPEN PITS

Photo A3-1. B2 Pit, looking south south-west, along access ramp.

Photo A3-2. B2 Pit, looking south, with hydro station in the background.

Photo A3-3. B2 Pit, looking north-west.

Photo A3-4. B2 Pit, looking south-east. Behind the hut in the foreground, the portal entrance can be seen to be meshed, with the tag-in hut to the right.

Photo A3-5. B2 Pit, looking north-east from southern rim of the pit.
The portal is located directly behind the tag-in hut in the south-east wall of the pit.

Photo A3-6. B2 Pit (UBC) portal entrance.

Photo A3-7 composite. B2 Pit, showing south-west wall, south of portal.

Photo A3-8. B4 Pit, looking north, with portal access and tag-in hut.

Photo A3-9. B4 Pit, north-east end, looking north.

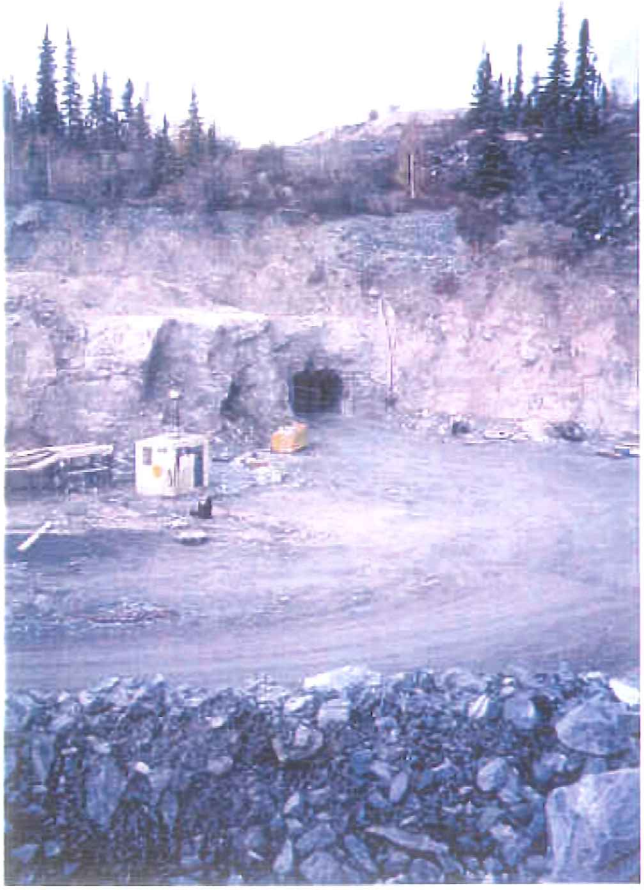


Photo A3-10. B4 Pit, looking north-west. Showing equipment portal and to the left, the small man-access portal, both connected to the same ramp.

ATTACHMENT IV

PHOTOGRAPHS OF THE C1 OPEN PIT AND THE A1 AND A2 OPEN PITS

Photo A4-1.   Baker Creek, looking north-east, over the highway towards the mill.

PhotoA4-2.   Mine Road, looking south south-west, over culvert for Baker Creek.

Photo A4-3. Baker Creek, looking south south-west along Mine Road.

Photo A4-4. Mine Road looking south, with Baker Creek on the right and the access ramp to the C1 Pit going off to the left.

Photo A4-5. Access ramp into C1 Pit, looking south-west.

PhotoA4-6. C1 Pit, looking south-west, showing southern end of the pit partially filled.

Photo A4-7. C1 Pit, north end, looking north-west. Shows the ladder-way that is part of the emergency escape-way.

Photo A4-8. C1 Pit, north end, looking north-east, towards C Shaft. Showing the top of the emergency escape-way from underground.

Photo A4-9. A1 Pit, looking south-east, showing portal in eastern wall and A-Shaft Head-frame in the background.

Photo A4-10. A1 Pit, northern end, looking east south-east, showing fuel storage tanks on the eastern side of the highway.

Photo A4-11. A1 pit, southern end, looking south, showing access ramp leading to the portal and the near-vertical south-western wall.

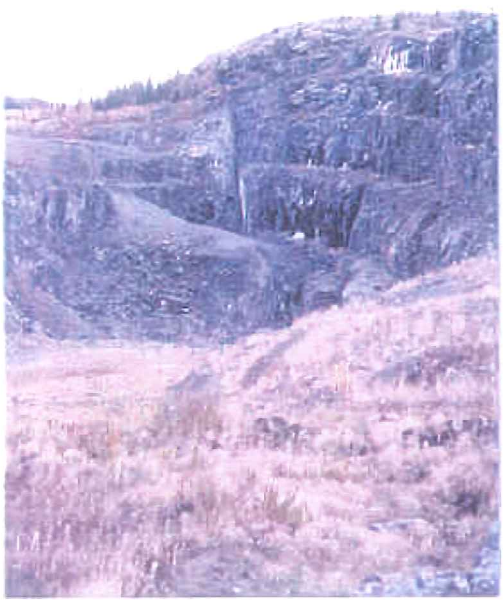


Photo A4-12. A1 Pit, looking south-west, showing the benches on the south-western wall.

Photo A4-13. Baker Creek, looking north towards the C1 Pit.

Photo A4-14. Baker Creek, looking west towards the access road to the A1 Pit.

Photo A4-15. Baker Creek, looking south-west, towards the A1 Pit, with the highway on the left.

Photo A4-16. A Shaft head-frame on the east side of the highway.

Photo A4-17. A1 Pit, looking south, showing the southern portal. To the left the highway curves round south of the pit.

Photo A4-18. View of a glory hole, partially filled, looking west from the highway. This excavation lies due south of the southern portal in the A1 Pit.

Photo A4-19. A2 Pit, looking south

Photo A4-20. A2 pit. looking south-east towards the portal on the eastern side of the pit.

ATTACHMENT V

PHOTOGRAPHS OF THE STORAGE CAVERN BULKHEADS AND UNDERGROUND FACILITIES

Photo A5-1. Upper bulkhead of the #12 arsenic storage cavern (#67). This shows the pipelines used for arsenic dust delivery and the inspection hatch.

Photo A5-2. Upper bulkhead showing the four 4-inch pipelines used for pneumatic delivery of arsenic trioxide dust and the one 6-inch pipeline for return air.

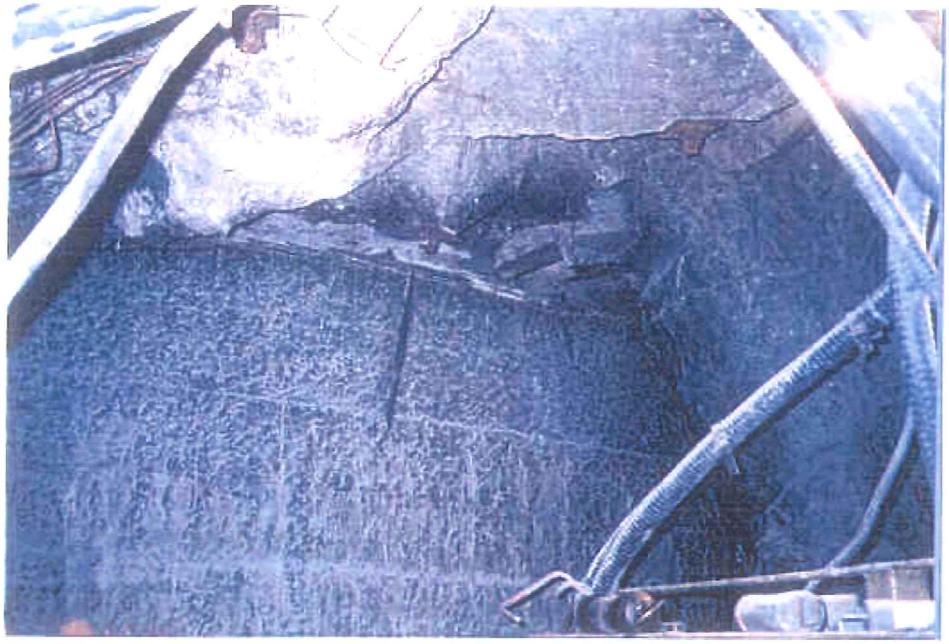


Photo A5-3. The lower concrete bulkhead of the #11 storage cavern.

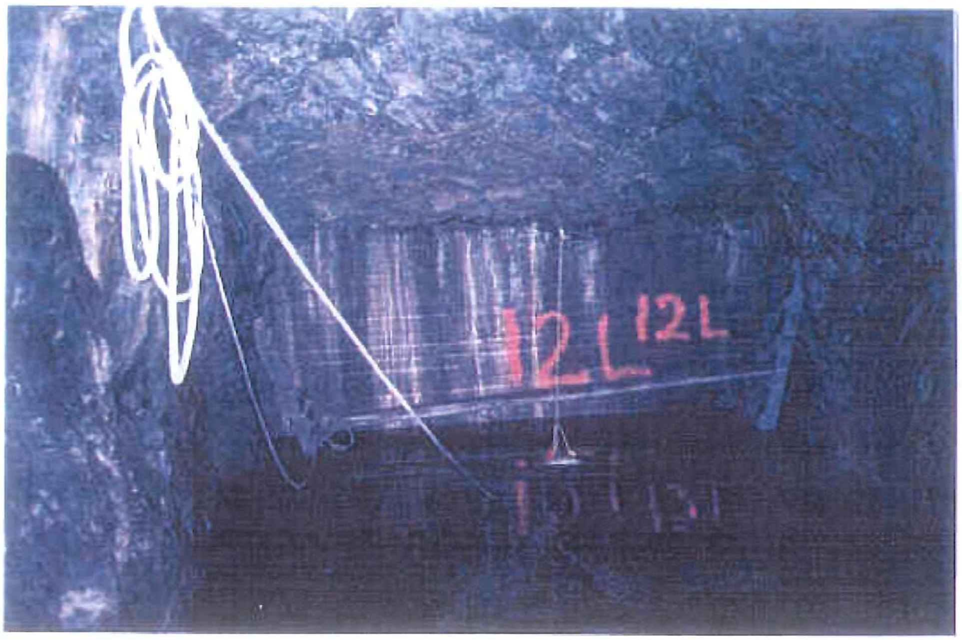


Photo A5-4. The lower bulkhead of the#12 storage cavern, partially flooded.

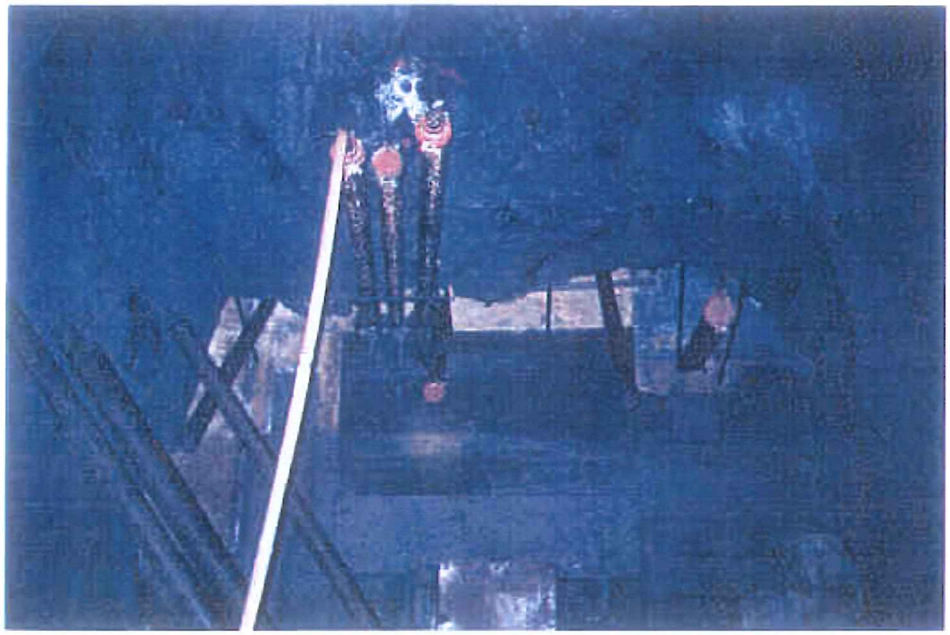


Photo A5-5. The Upper Bulkhead of the #15 storage cavern. Shows three 4-inch pipelines for arsenic dust delivery and one 6-inch pipe for return air.

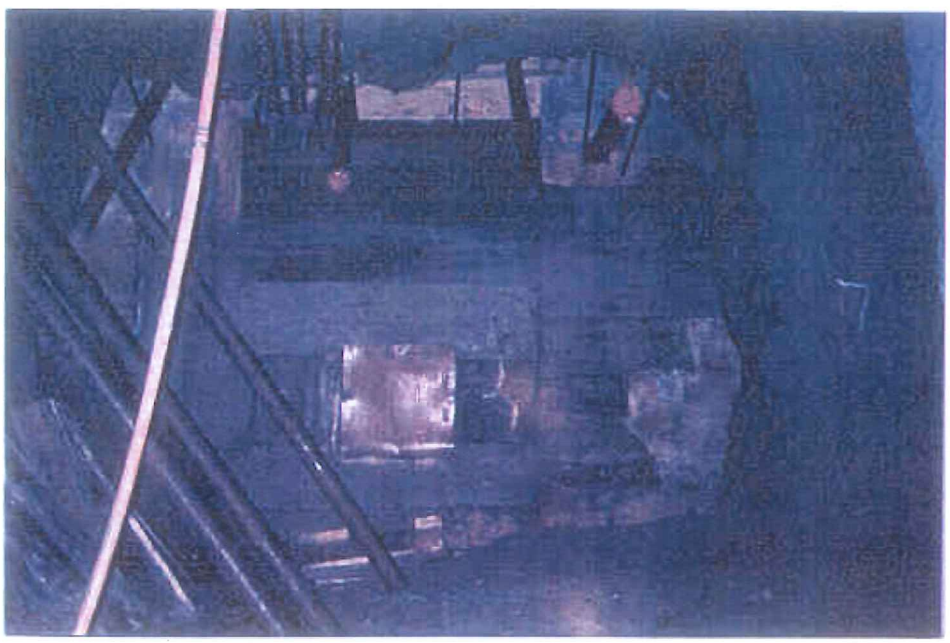


Photo A5-6. The inclined 4-inch pipelines used for delivery of concrete to seal the bulkheads, plus the steel inspection hatch.

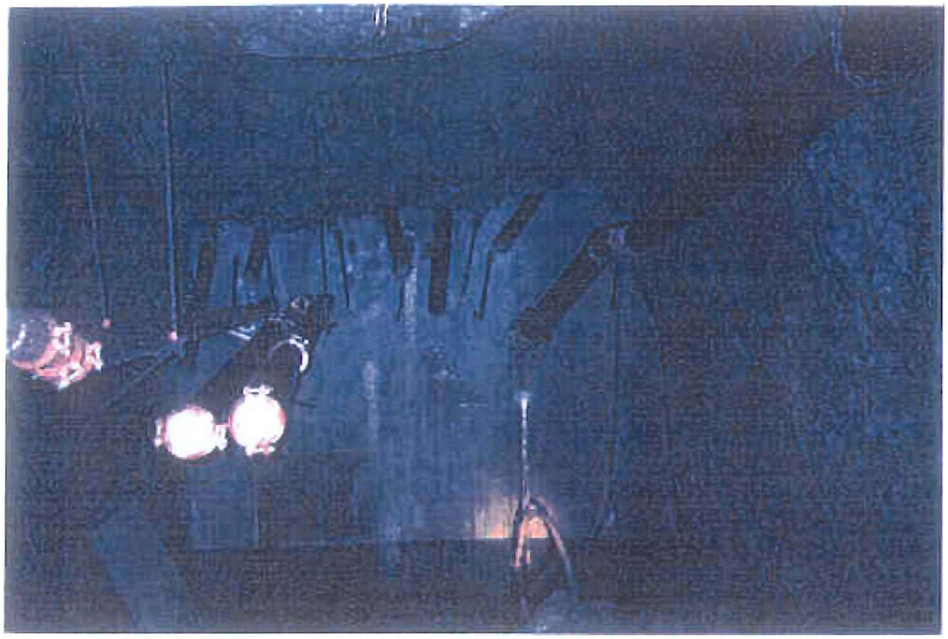


Photo A5-7. The Upper Bulkhead of the #14 storage cavern, partially flooded.

Photo A5-8. The #12 Arsenic Distribution Drift (ADD) leading to the caverns B230/33/34/35/36 to the south and B208 cavern to the north.

Photo A5-9. The floor of the ADD on the south-east of the main access drift. In this area above caverns B230/33/34/35/36 the conditions are not frozen.

Photo A5-10. Raise and ladder-way to surface at the south end of the ADD.

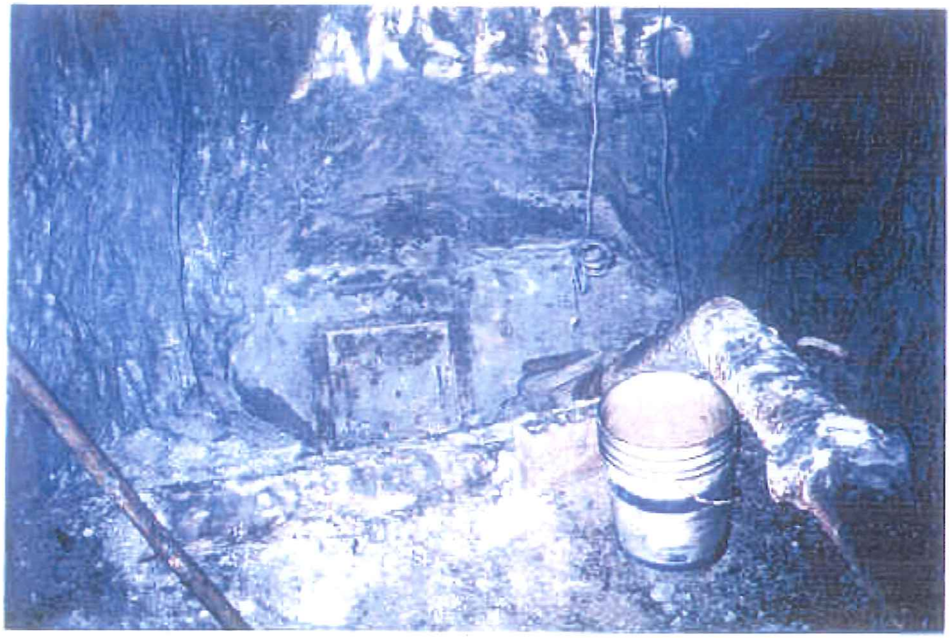


Photo A5-11. The inspection hatch into the storage cavern B208 in the floor of the northern end of the ADD. The floor is covered with frost.

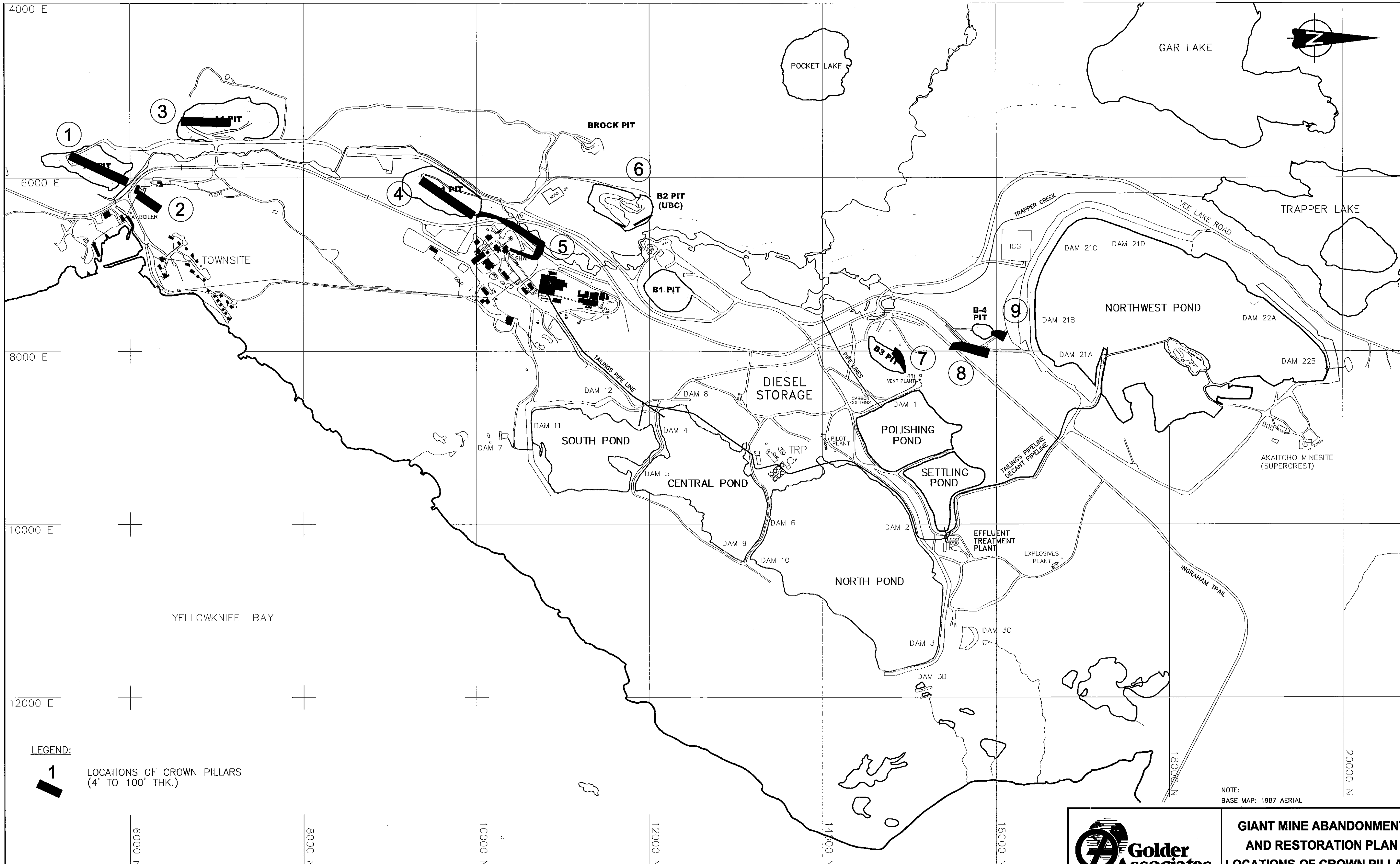
Photo A5-12. The pipelines in the floor of the ADD supplying the B208 cavern with arsenic dust. ice stalagmites and frost on the floor (late September).

Photo A5-13. The frost in the stub drift on the north-west side of the ADD immediately above the B208. The wall is covered in frost and ice (late September).

Photo A5-14. The north-west bulkhead at the end of the ADD, leading to the B208 storage cavern. The floor is covered in 4-6 inches of ice.

Photo A5-15. The waste chute leaking water and fines. This fill raise is connected directly to surface, opening in the floor of the B1 Pit.

Photo A5-16. Bulkhead #50 in the AR1 area, leading to the C212 shrinkage stope (storage cavern). This bulkhead is the "sandfill type" and on the right there is evidence of leakage.



Golder Associates

GIANT MINE ABANDONMENT AND RESTORATION PLAN LOCATIONS OF CROWN PILLARS

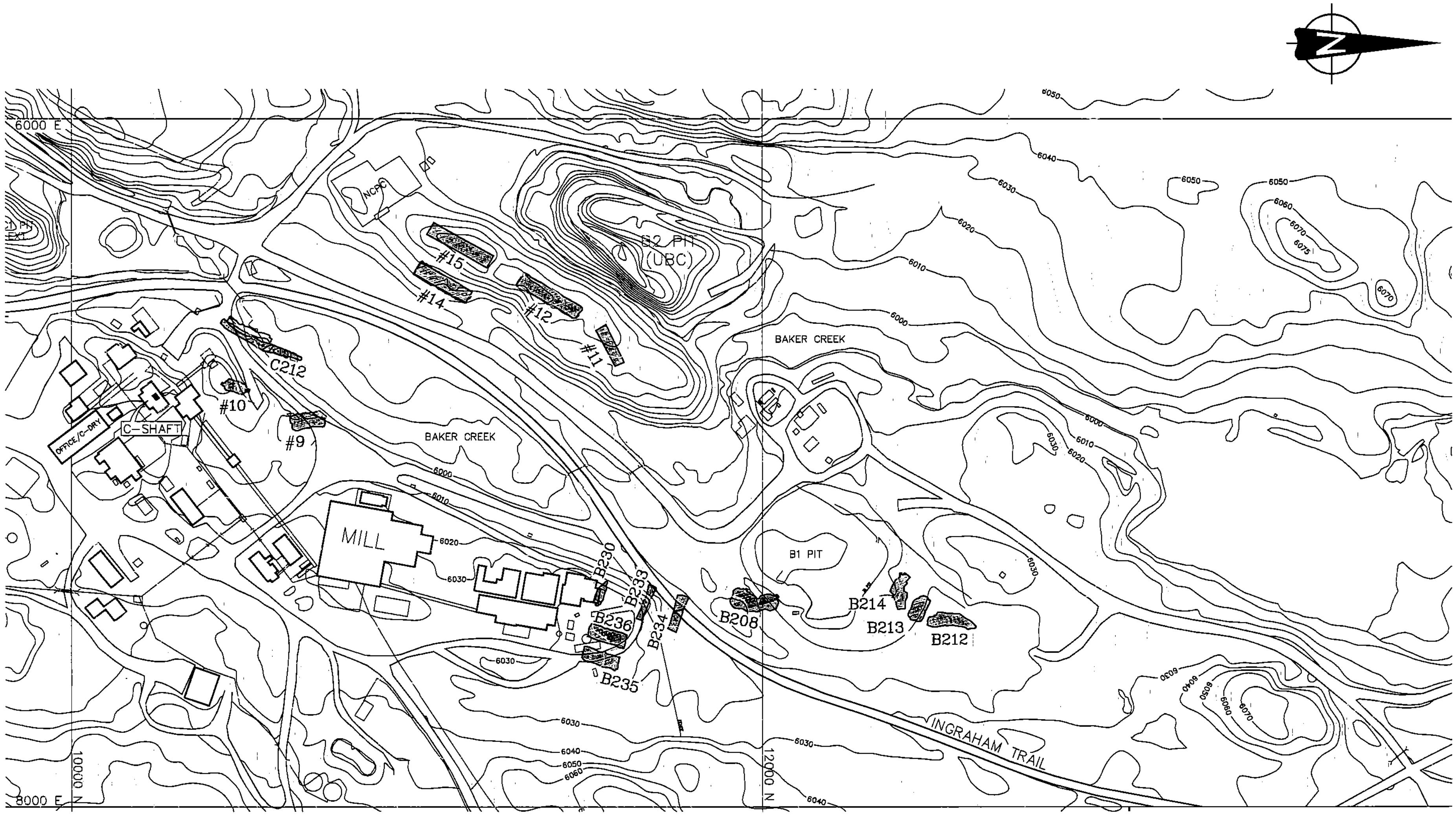
Drawn: JK	App'd:	Date: Nov 15, 01	Figure: **A6-1**

Project No.: 002-2418

Revision No.:

Drawing: N:\Work\2000\002-2418 A&R Miramar Giant\Drawings\Giant\FIGURE 66.dwg Plotted: Nov 15, 2001 - 1:41pm By: RRoque

Drawing: N:\Work\ \002-2418 A&R Miramar Giant\Drawings\Giant\FIGURE 88.dwg Plotted: Nov 15, 2001 - om By: RRoque



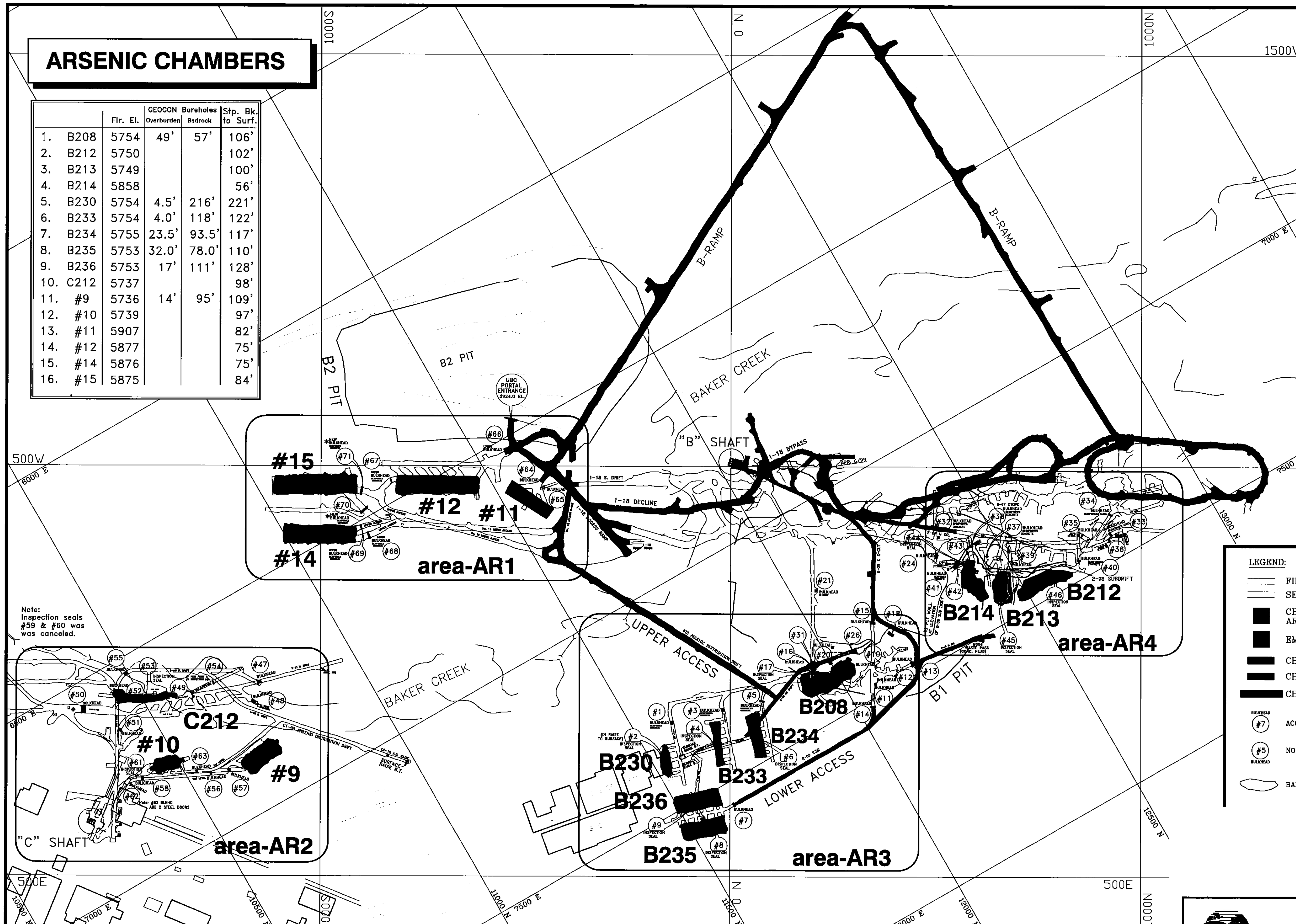
Golder Associates	**GIANT MINE ABANDONMENT AND RESTORATION PLAN SURFACE PLAN ARSENIC CHAMBER LOCATIONS**
Drawn: JK / App'd:	Date: Nov 15, 01 / Figure: **A6-2**

Project No.: 002-2418

Revision No.:

ARSENIC CHAMBERS

		Flr. El.	GEOCON Boreholes Overburden	GEOCON Boreholes Bedrock	Stp. Bk. to Surf.
1.	B208	5754	49'	57'	106'
2.	B212	5750			102'
3.	B213	5749			100'
4.	B214	5858			56'
5.	B230	5754	4.5'	216'	221'
6.	B233	5754	4.0'	118'	122'
7.	B234	5755	23.5'	93.5'	117'
8.	B235	5753	32.0'	78.0'	110'
9.	B236	5753	17'	111'	128'
10.	C212	5737			98'
11.	#9	5736	14'	95'	109'
12.	#10	5739			97'
13.	#11	5907			82'
14.	#12	5877			75'
15.	#14	5876			75'
16.	#15	5875			84'



Golder Associates

UNDERGROUND STORAGE LOCATIONS

Drawn: JK	App'd:	Date: Nov 15, 01	Figure: **A6-3**
Project No.: 002-2418			Revision No.:

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APPENDIX A-7

TAILING DEPOSITS AND CONTAINMENT AREAS

APPENDIX A-7A

TAILING DEPOSITS

1.0 TAILING HISTORY

Mine tailing has been continuously deposited at the Giant Minesite since production began in 1948. Historical aerial photographs indicate that tailing was initially deposited east of the mill site in a small drainage channel that leads to Yellowknife Bay. In 1951, tailing from the operation was re-directed through a new pipeline and deposited into a small lake north-east of the mine (Bow Lake). The liquid portion of the tailing drained both into Baker Creek, which discharges into Yellowknife Bay, and northeastward into the head of the Yellowknife River. The flow northward continued until 1968, when this flow was stopped [D. Sutherland, 1989].

The bulk of mine tailing was deposited northeast of the mill in an area that is known today as the Central and North Ponds. The natural topography directed surface runoff and mine tailing towards Baker Creek. In the late 1980's, the Northwest Tailing Pond was created and this is where the bulk of tailing is presently deposited.

A portion of the tailing (flotation tail) was used for mine backfill from 1956 to 1978. During this period, approximately 2,700,000 tons of flotation tail was used for backfill [G. Halverson, 1984].

Tailing up to the end of the operation of the mill was deposited in the Northwest Pond, which was put into service in late 1987. The North Pond, South Pond and a small portion of the Central Pond, were used from 1987 to the end of the operation in 1999.

2.0 RETENTION STRUCTURES

Rock fill dams were constructed to direct and hold back tailing solids at the present day sites of Dams 1, 2, 3 and 4. These dams were constructed in stages and are composed of mine waste rock fill over bedrock, silty clay or mine tailing [Geocon, 1974]. In 1974, the original rock fill dams had reached their operating capacity and additional storage was required. Subsequently, Dams 1, 2, 3, and 4 were engineered and lined with an upstream clay layer and raised to provide additional storage and create a two pond clarification system.

Dams 5, 6 and 7 were constructed in 1976. Dam 8 was constructed by 1979 and further construction was complete for Dams 2, 3, 4A, 4B, 4C, 5, 6 and 8 [Geocon, 1980].

Dams 9, 10 and 11 were constructed in 1983 and further raised in 1984 to create additional storage and form what is now called the South Pond. With construction of the South Pond, some of the internal dams and dykes became redundant.

Additional tailing storage requirements prompted the design and construction of the Northwest tailing area. Subsequently, Dams 21A, B, C and D, and Dams 22A and B, were designed and constructed in 1987. No major construction of retention structures has taken place since the construction of the Northwest tailing area. The locations of the tailing retention structures are identified on Figure A-7-1.

3.0 INSPECTION AND STABILITY

As a requirement of the Water Licence, annual tailing dam inspections are carried out each year. Conditions in the Water Licence that apply to the annual inspection include continuously maintaining a minimum freeboard of 0.5 m, erosion remediation, and forwarding the inspection report to the Mackenzie Valley Land and Water Board within 60 days. Inspections of the Dams have been categorized into three main areas:

- *Original Tailing Areas Dams,*
- *Northwest Tailing Area, and*
- *Other Dams.*

The function of each dam is summarized in Table 1.

Table 1
Function of Tailing Structures

Dam Number	Location	Function
1	West end of Polishing Pond	- final decant before entering the environment; - retains Polishing Pond
2	Northwest end of North Pond	- minor retention of water and tailing
3	Northeast side of North Pond	- principally holds back dry tailing
3C	North of Dam 3	- seepage collection for Dam 3
3D	East of Dam 3	- seepage collection for Dam 3
Dyke 4	Northwest side of South Pond	- access road
Dyke 5	Northeast side of South Pond	- access road
Dyke 6	North side of Central Pond	- retains some dry tailing
7	South of South Pond and Dam 11	- seepage collection for Dam 11
8	West side of Central Pond	- retains dry tailing from Central Pond
9	Northeast side of Central Pond	- retains dry tailing
10	Southeast side of North Pond	- retains dry tailing
11	South limit of South Pond	- tailing retention and return seepage hold back
12	West side of South Pond	- retains tailing beach
Settling Pond Dyke	West side of Settling Pond	- partition between Settling and Polishing Pond
21A	Southeast side of Northwest Pond	- east abutment of Dam 21
21B	South side of Northwest Pond	- retains water and tailing
21C	Southwest side of Northwest Pond	- retains water and tailing
21D	West side of Northwest Pond	- retains water and tailing
22A	Northwest side of Northwest Pond	- retains water and tailing
22B	North side of Northwest Pond	- retains water and tailing
B-2	North side of B-2 Pit	- directs Baker Creek away from B-2 Pit

In general, it has been concluded from the last inspection that the dams were performing acceptably in terms of their present function.

The stability of the structures was reviewed and the evaluation is based on designs by Geocon [Geocon, 1975]. The present review is based on data from Geocon drawings provided in the Royal Oak Abandonment and Restoration Plan report dated December

1998. The slope stability program XSTABL was used to reproduce the static stability analyses initially performed by Geocon. The same strength parameters and dam configurations were then used to determine the seismic stability of the dams using seismic accelerations obtained from a site specific seismic risk calculation by the Pacific Geoscience Centre in Victoria.

Static and seismic stability analyses were carried out on the Polishing Pond (Dam 1), South Pond (Dam 11), and the Northwest Pond Dams 21B, 21C, 21D and 22B. Geocon stability sections for Dam 1 dated 1975 and Dam 11 dated 1982 were used for the geometry and short-term undrained strength foundation material properties. A report titled, Northwest Tailing Pond, Original Dam Stability Analysis, by Rik Norgan, June 1988 was used for geometry and long-term c-ϕ' strength foundation material properties for the Dams 21B, 21C, 21D and 22B. XSTABL was used to calculate a static FOS for both the case of no phreatic surface and for an assumed phreatic surface for each of these dam sections.

A summary of the static stability results is presented in Table 2. XSTABL output figures are presented in the Attachment I.

Table 2 – Static Stability Results

	Original Stability Results			Current Stability Results			
Dam	Crest Elevation (feet)	Pond Water Level (feet)	Reported Static FOS (Bishop)	Crest Elevation (feet)	Pond Water Level (feet)	XSTABL Static FOS (Bishop)	Strength parameters of layer controlling stability
1	6040	6037	1.48	6038	6035	1.5	Cu muskeg 250 psf
1 (first bench)	6040	6037	1.92	6038	6035	2.0	Cu muskeg 250 psf
11 (unfrozen zone)	6090	6088	1.8	6090	6084	1.8	Cu silty clay unfrozen =675 psf
11 (thawed zone)	6090	6088	1.5	6090	6084	1.5	Cu silty clay thawed =1200 psf
21B no phreatic surface	6095	6093	1.89	6100	6095	2.6	Foundation clay c=200psf,ϕ'=20° *
21B assumed phreatic surface			-	6100	6095	2.2	Foundation clay c=200psf,ϕ'=20° *
21C no phreatic surface	6095	6093	1.95	6100	6095	2.1	Foundation clay c=200psf,ϕ'=20°
21C assumed phreatic surface			-	6100	6095	1.6	Foundation clay c=200psf,ϕ'=20°
21D no phreatic surface	6095	6093	1.95	6100	6095	2.1	Foundation clay c=200psf,ϕ'=20°
21D assumed phreatic surface			-	6100	6095	1.6	Foundation clay c=200psf,ϕ'=20°
22B no phreatic surface	6095	6093	2.5	6100	6095	1.6	Foundation clay c=200psf,ϕ'=20°
22B assumed phreatic surface			-	6100	6095	1.4	Foundation clay c=200psf,ϕ'=20°

Following reproducing the static stability results, all the same dam sections were analyzed for pseudo static (seismic) stability. Input seismic accelerations were based on a seismic risk calculation for a location approximately at Dam 1 (location described by 62.5 degrees North and 114.35 degrees West). Table 3 presents the results of the seismic risk calculation provide by Pacific Geoscience Centre.

Table 3 – Seismic Risk Accelerations

Return Period (years)			
1 in 100	1 in 200	1 in 475	1 in 1000
Probability of Exceedance per year			
1%	0.5%	0.21%	0.1%
Probability of Exceedance in 50 years			
40%	22%	10%	5%
Peak horizontal ground acceleration (g)			
0.010	0.012	0.015	0.018

Input seismic accelerations of 0.018 g (1 in 1000 year return period) and 0.05 g (based on the conservative assumption of Seismic Zone 1 of the National Building Code of Canada) were used for each dam section for the pseudo static analysis. Both Bishop and Janbu methods of stability analysis solutions were carried out. The results of the pseudo static stability analyses are summarized in the Table 4 and the XSTABL output figures are presented in the Attachment II.

Note in calculating the pseudo static FOS for Dams 1 and 11, the short term foundation soil undrained strengths were assumed and for Dams 21B, C and D and 22B, the long term foundation soil strengths and a phreatic surface were assumed.

Table 4 – Pseudo Static (Seismic) Stability Analysis Results

	a=0.018 g		a=0.050 g	
Dam	Pseudo static FOS (Bishop)	Pseudo Static FOS (Janbu)	Pseudo static FOS (Bishop)	Pseudo Static FOS (Janbu)
1	1.32	1.35	1.12	1.14
11	1.39	1.36	1.19	1.16
21B	2.02	1.87	1.82	1.67
21C	1.47	1.38	1.31	1.23
21D	1.64	1.54	1.46	1.36
22B	1.34	1.24	1.26	1.14

XSTABL was also used to determine a critical seismic acceleration resulting in a FOS of 1.0 for each dam analyzed and the results are summarized in Table 5.

Table 5 – Critical Seismic Acceleration by Dam

Dam	Critical acceleration ag for FOS=1.0(Janbu)
1	0.08
11	0.08
21B	0.25
21C	0.11
21D	0.17
22B	0.10

The minimum pseudo static FOS of 1.24 was found for Dam 22B with an applied ag = 0.018. The minimum critical acceleration was found for Dam 1 and 11 at ag = 0.08g.

Figure 1 : Dam 1 - Static Conditions

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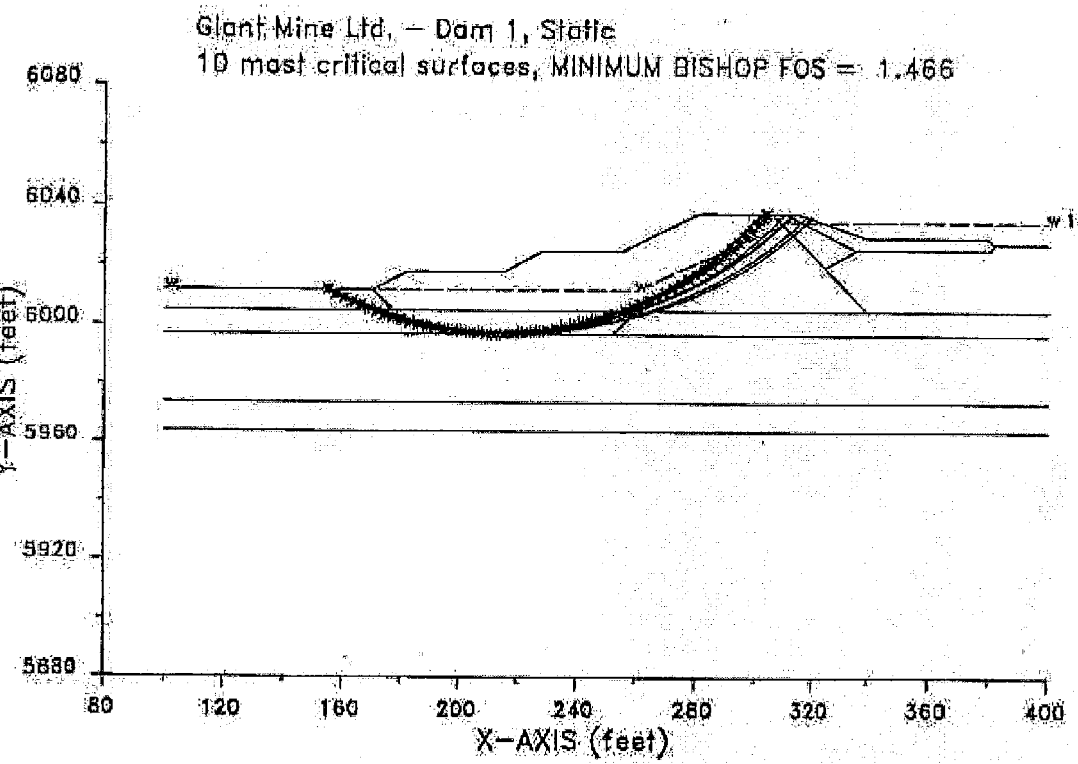


Figure 2: Dam 1 (First Bench) - Static Conditions

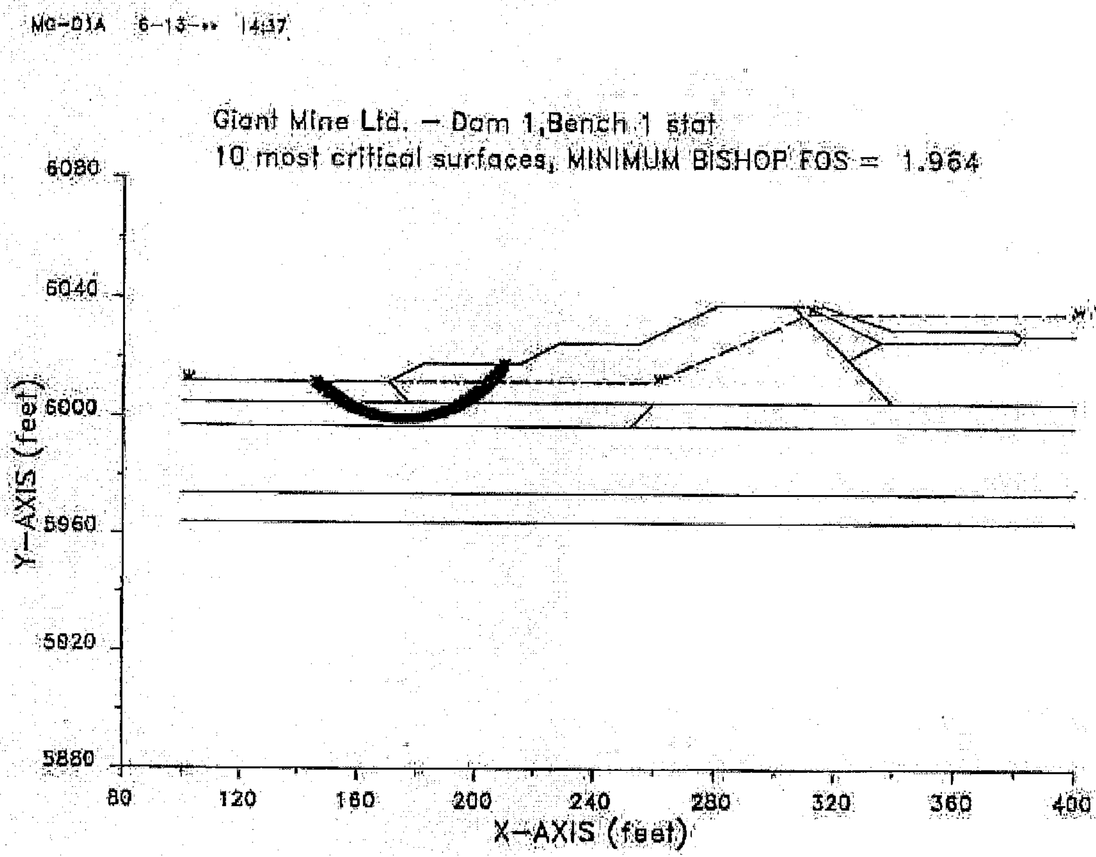


Figure 3: Dam 11 - Static Conditions - Slip Through Unfrozen Zone

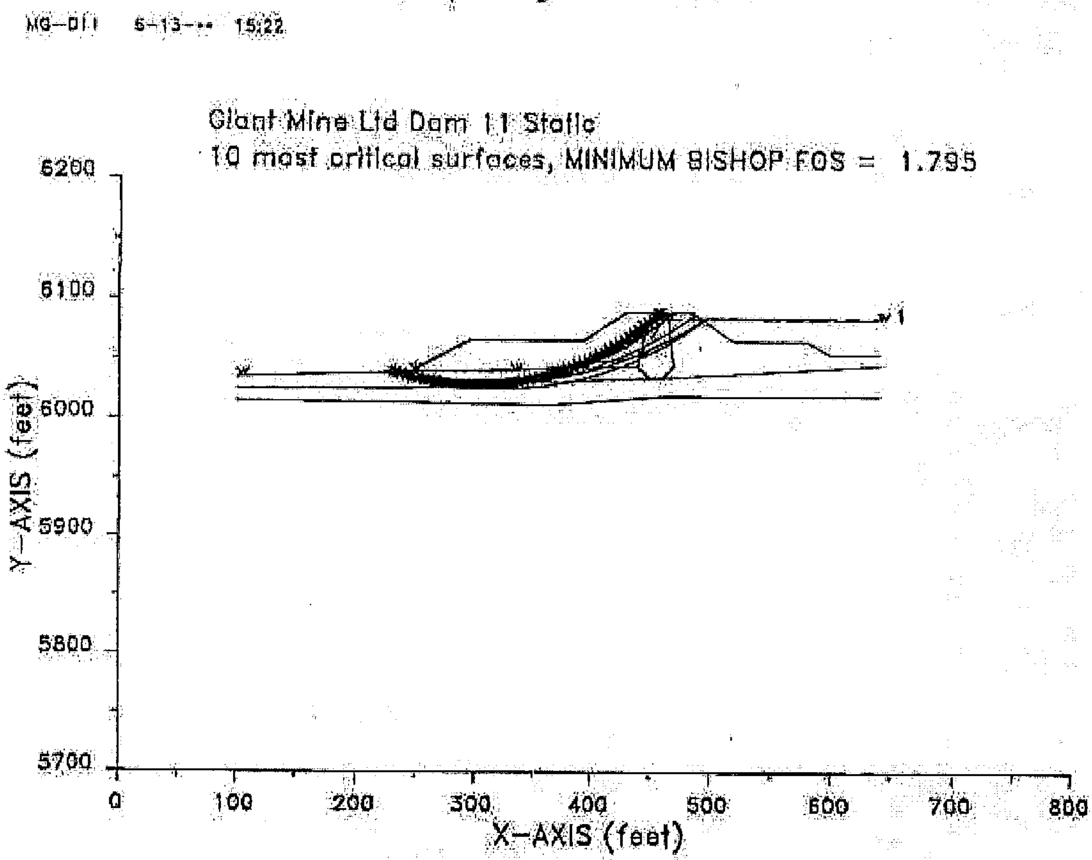


Figure 4: Dam 11 - Static Conditions - Slip Through Thawed Zone

MO-D11 6-13-** 15:41

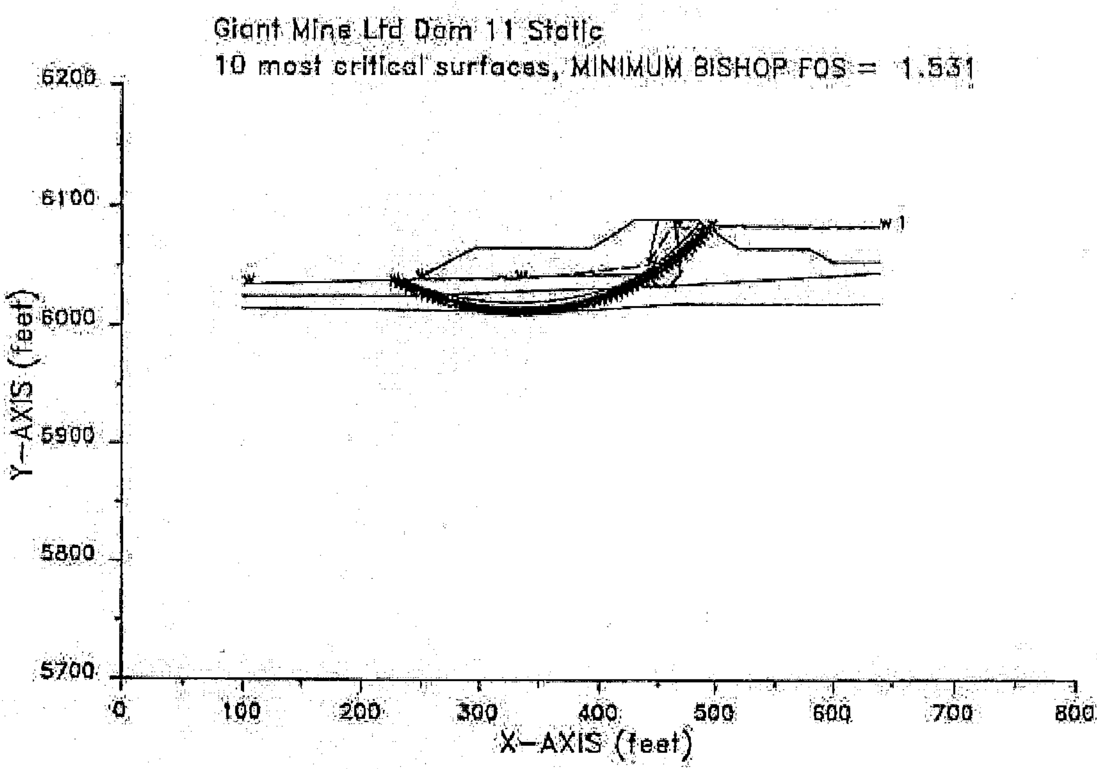


Figure 5: Northwest Pond - Dam 21B - Static Conditions - No Phreatic Surface

MG-D21BN 6-13-** 14:43

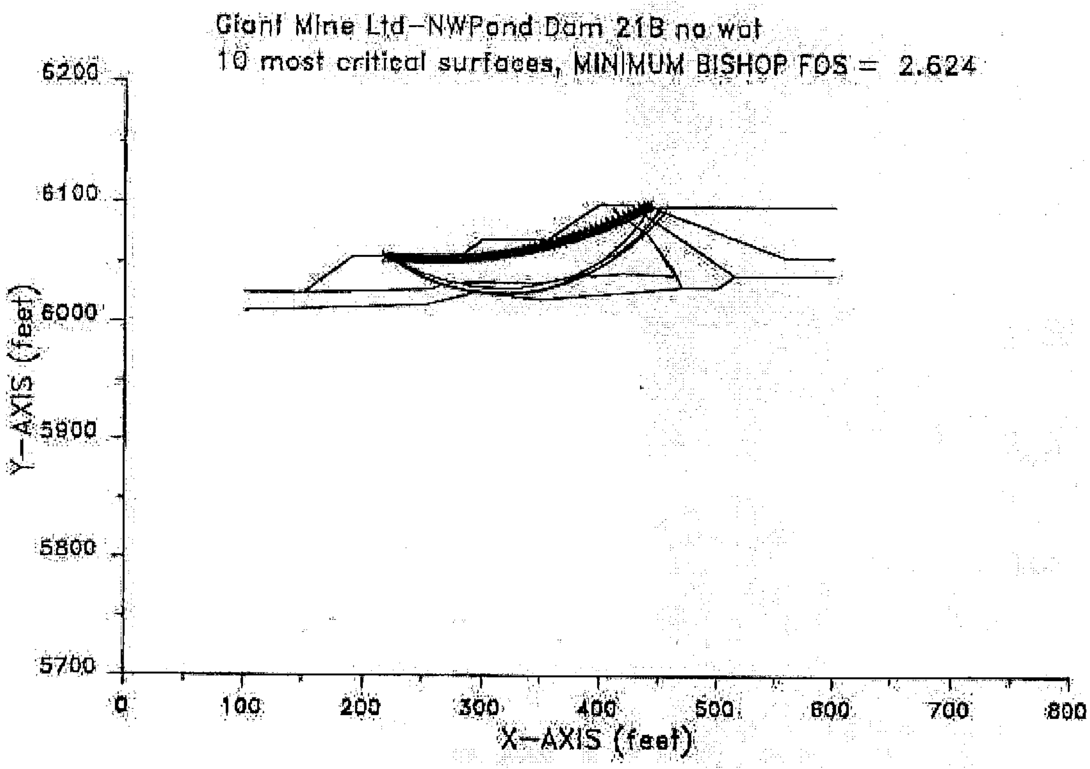


Figure 6: Northwest Pond - Dam 21B - Static Conditions - Phreatic Surface Assumed

MG-D21BL 6-13-** 14:44

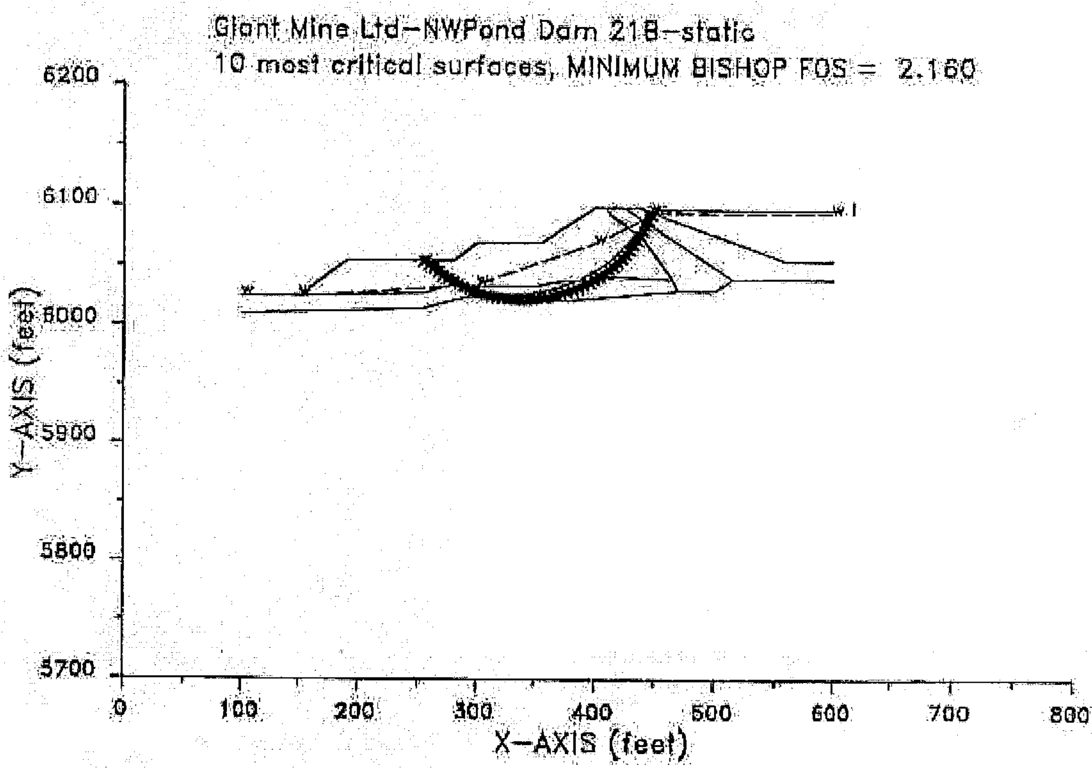


Figure 7: Dam 21C - Static Conditions - No Phreatic Surface

MG-D21CN 5-13-** 14:46

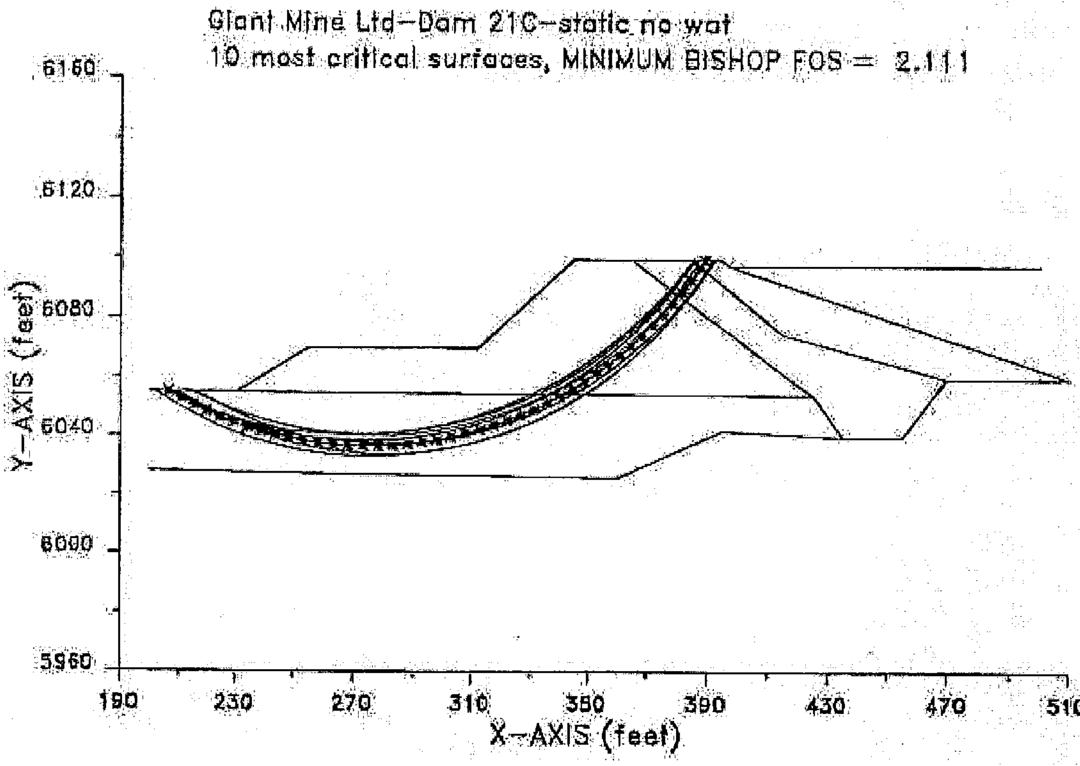


Figure 8: Dam 21C - Static Conditions - Phreatic Surface Assumed

MG-021C 6-13-** 14:47

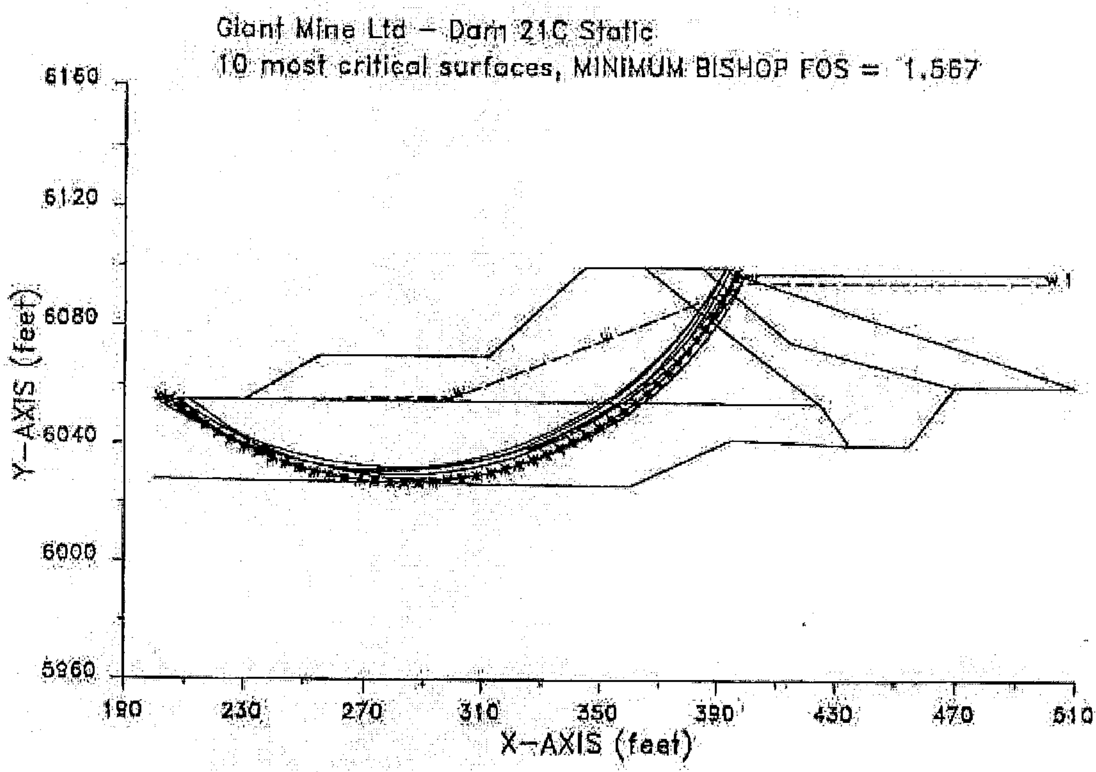


Figure 9: Dam 21D - Static Conditions - No Phreatic Surface

MG-D21DN 6-13-** 14:48

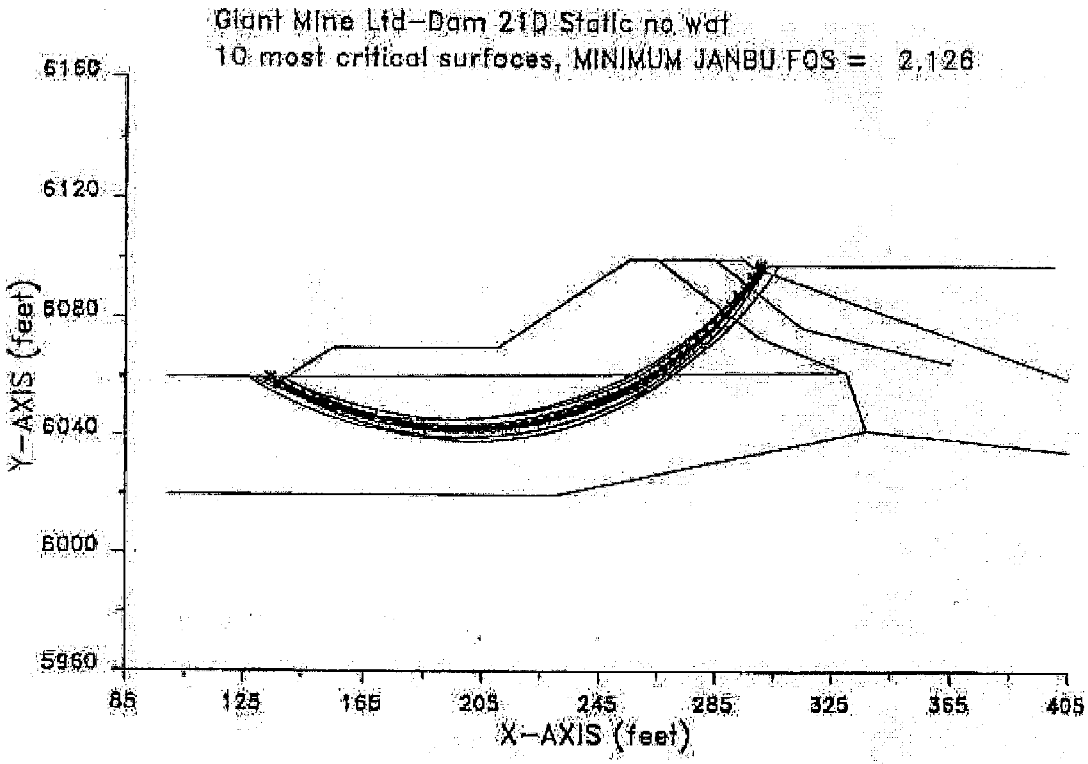


Figure 10: Dam 21D - Static Conditions - Phreatic Surface Assumed

MC-D21D 6-13-** 14:49

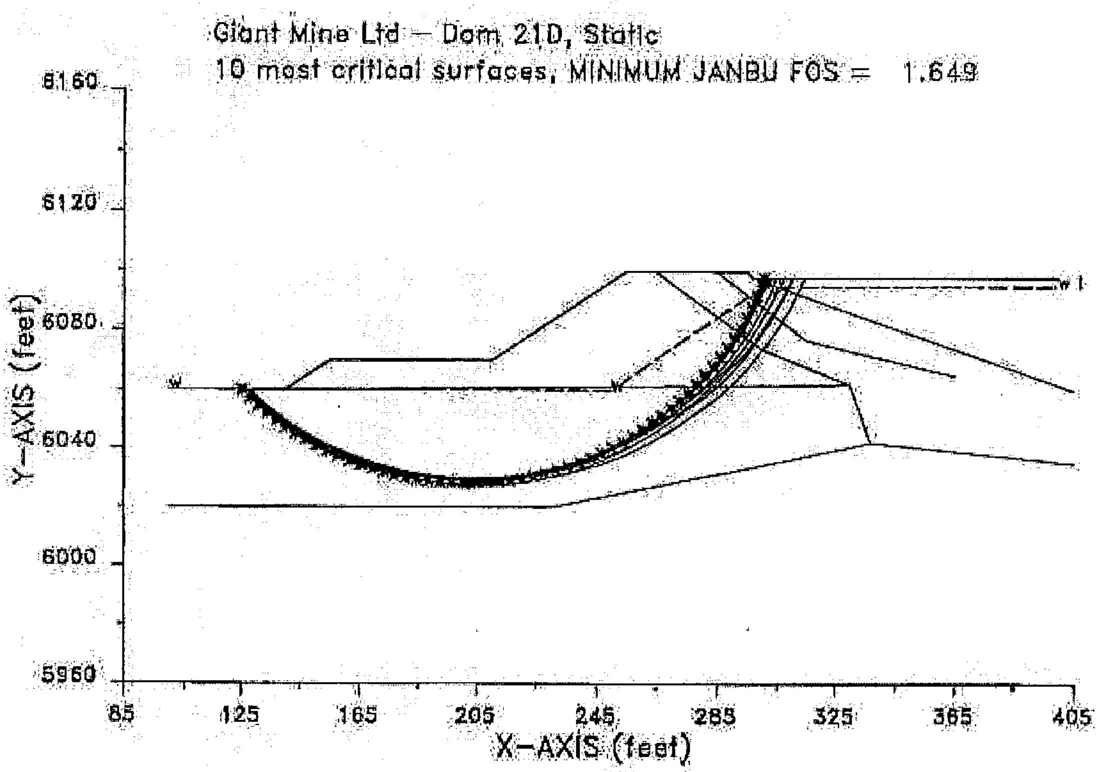


Figure 11: Dam 22B - Static Conditions - No Phreatic Surface

MG-D22BN 5-13-** 14:51

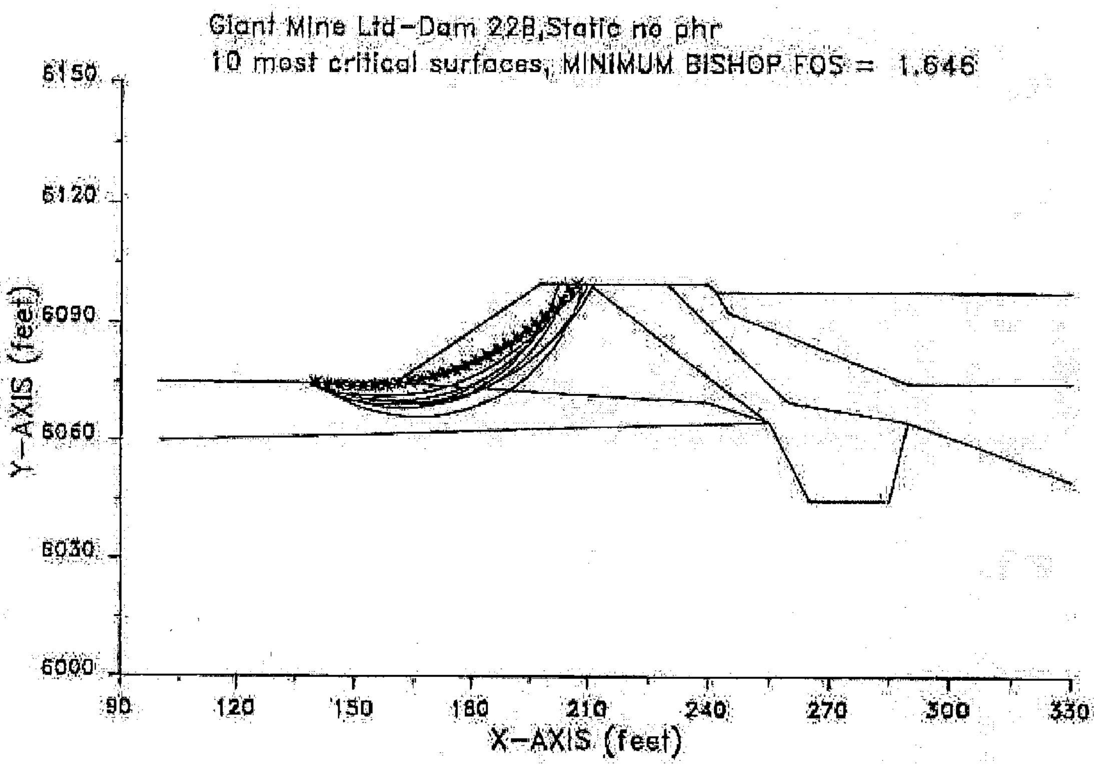
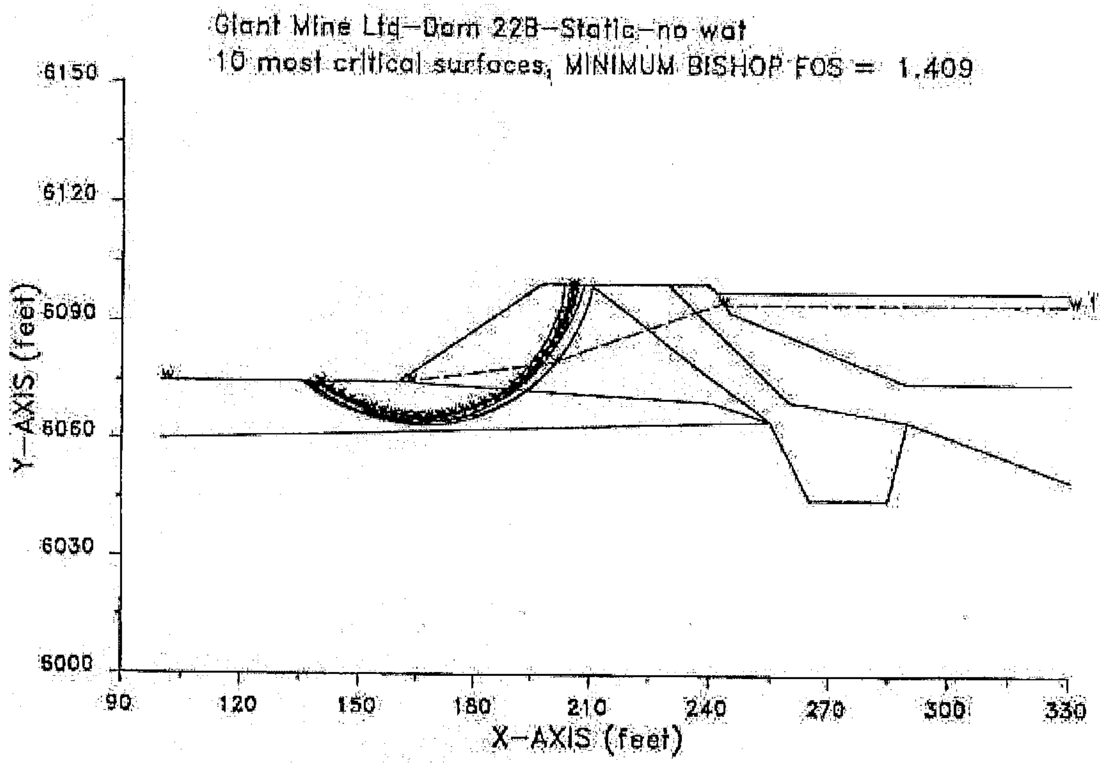


Figure 12: Dam 22B - Static Conditions - Phreatic Surface Assumed

MG-D22B 6-13-** 15:20



ATTACHMENT II

SEISMIC STABILITY RESULTS

Figure 13: Dam 1 - Seismic Loading - a = 0.018g (Bishop Analysis)

MO-DIS 6-13-** 15:51

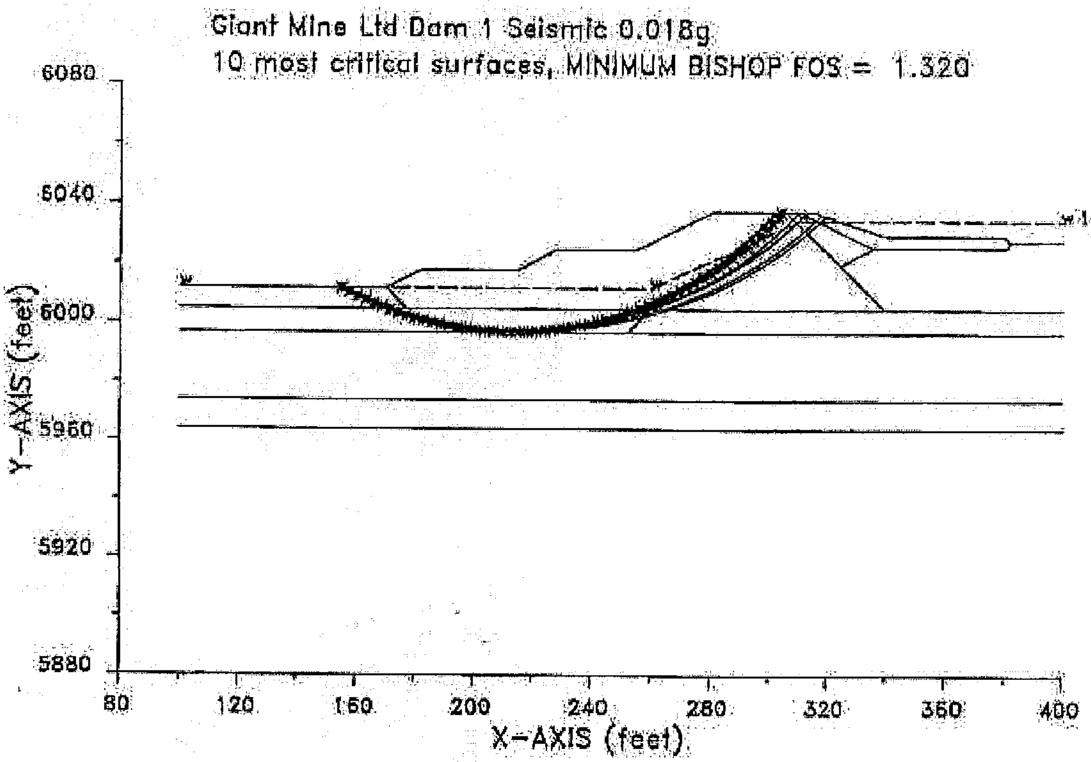


Figure 14: Dam 1 - Seismic Loading - a = 0.018g (Janbu Analysis)

MG-015 6-13-** 13:53

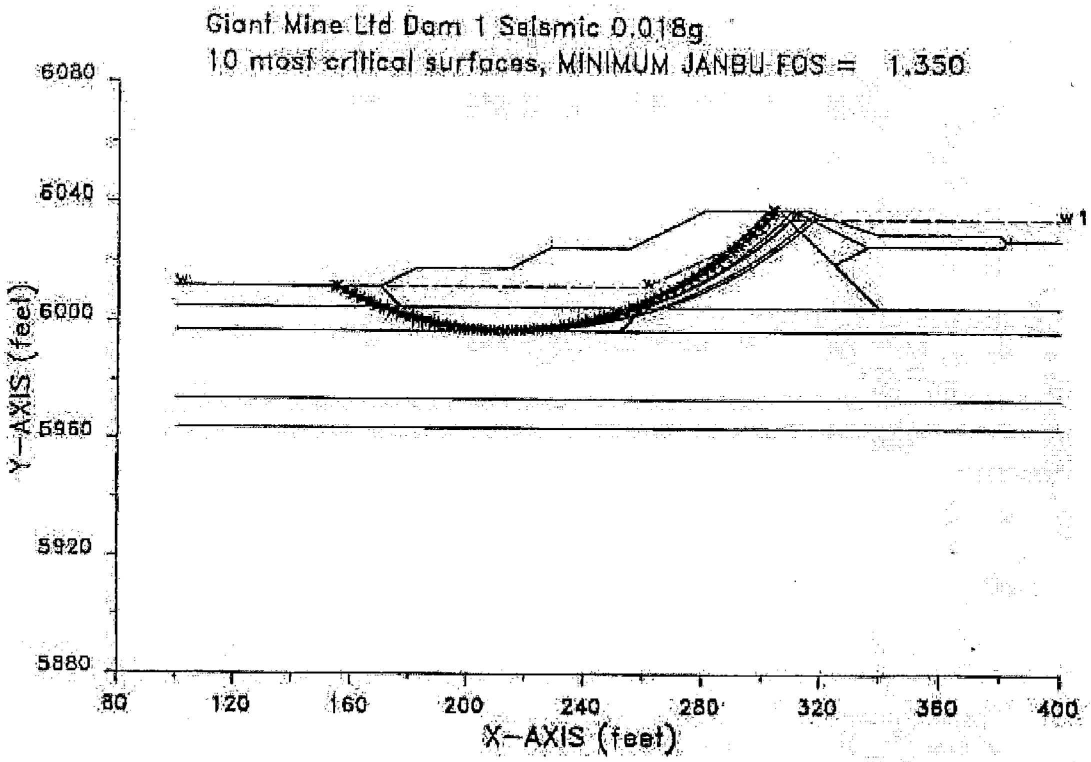


Figure 15: Dam 11 - Seismic Loading - a = 0.018g (Bishop Analysis)

MQ-011S 8-13-** 15:55

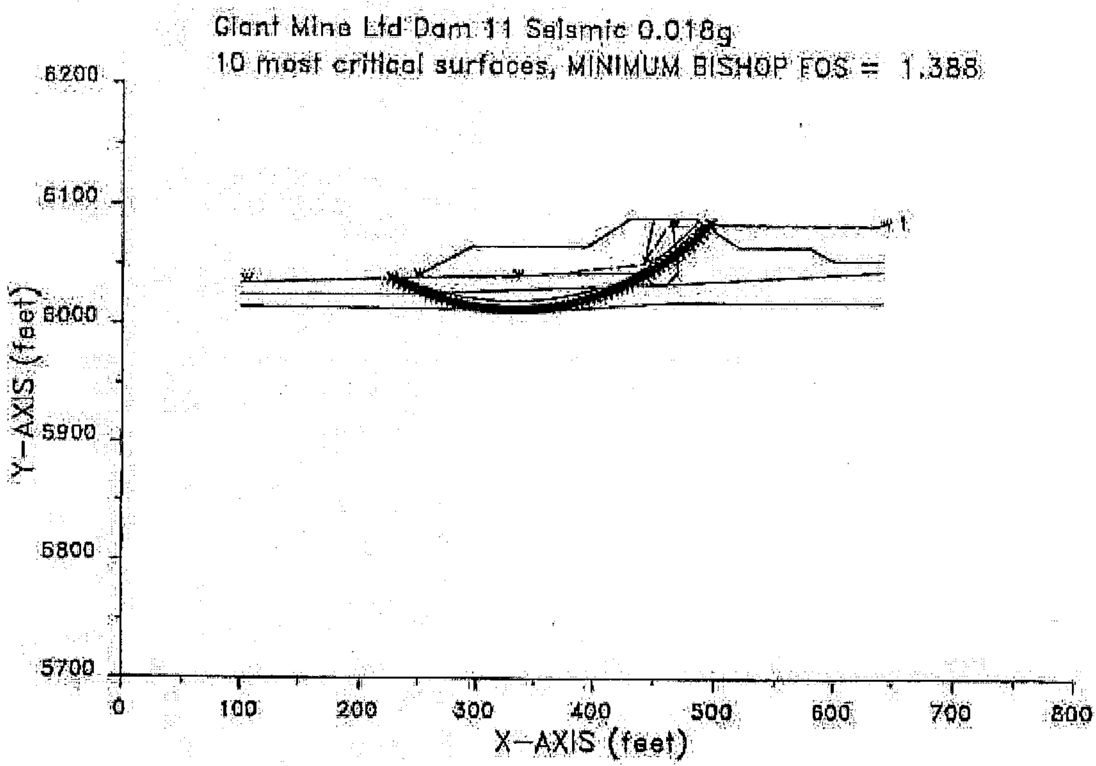


Figure 16: Dam 11 - Seismic Loading - a = 0.018g (Janbu)

MG-D11S 6-13-** 15:56

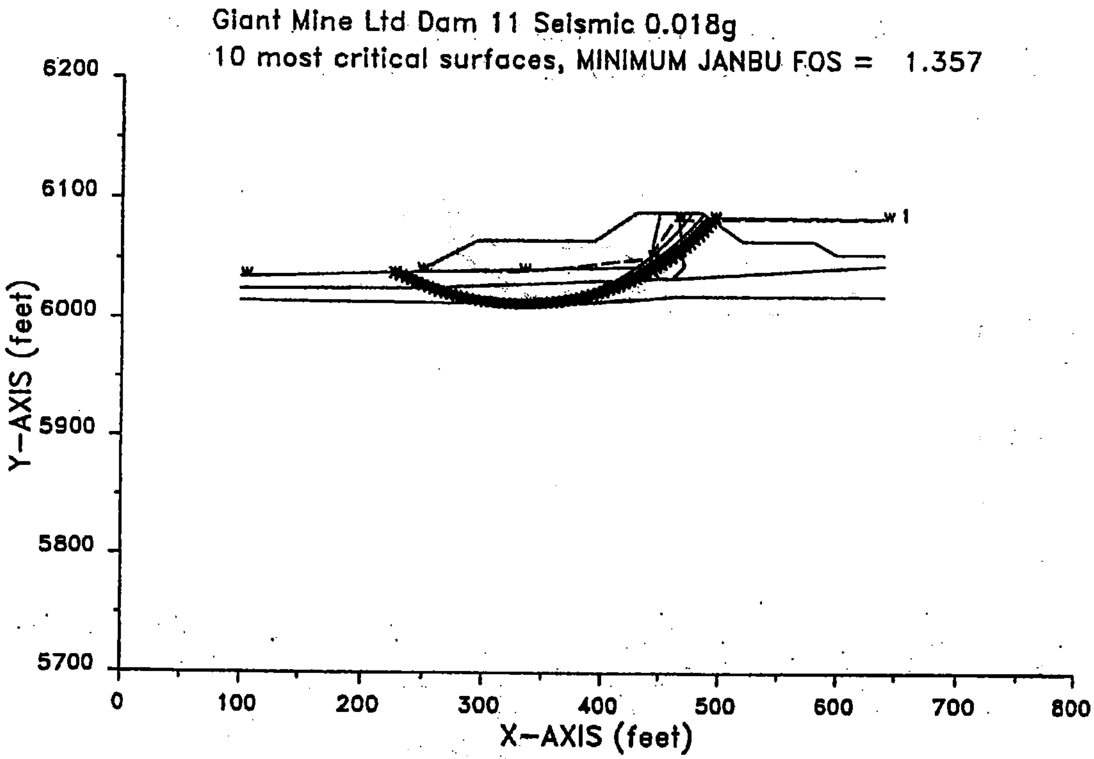


Figure 17: Dam 21B - Seismic Loading - a = 0.018g (Bishop Analysis)

MO-D21BT 6-13-** 15:59

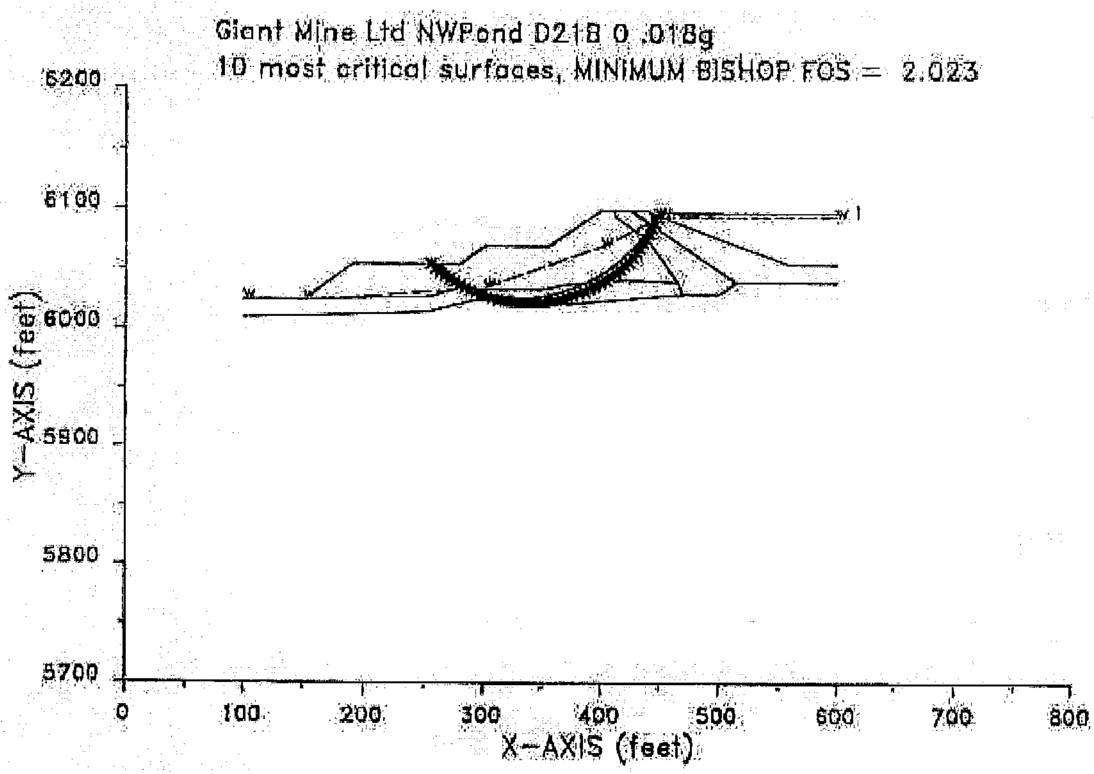


Figure 18: Dam 21B - Seismic Loading - a = 0.018g (Janbu Analysis)

MG-0218S 8-13-** 16:00

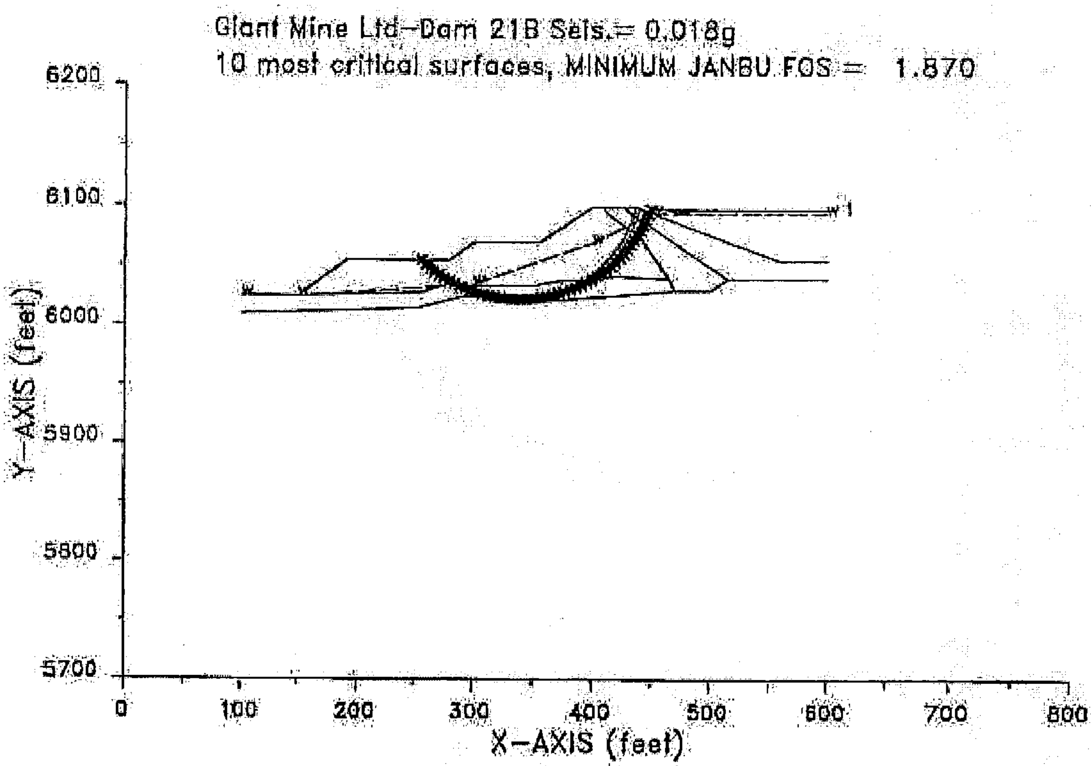


Figure 19: Dam 21C - Seismic Loading - a = 0.018g (Bishop Analysis)

MG-D21CS 6-13-** 16:06

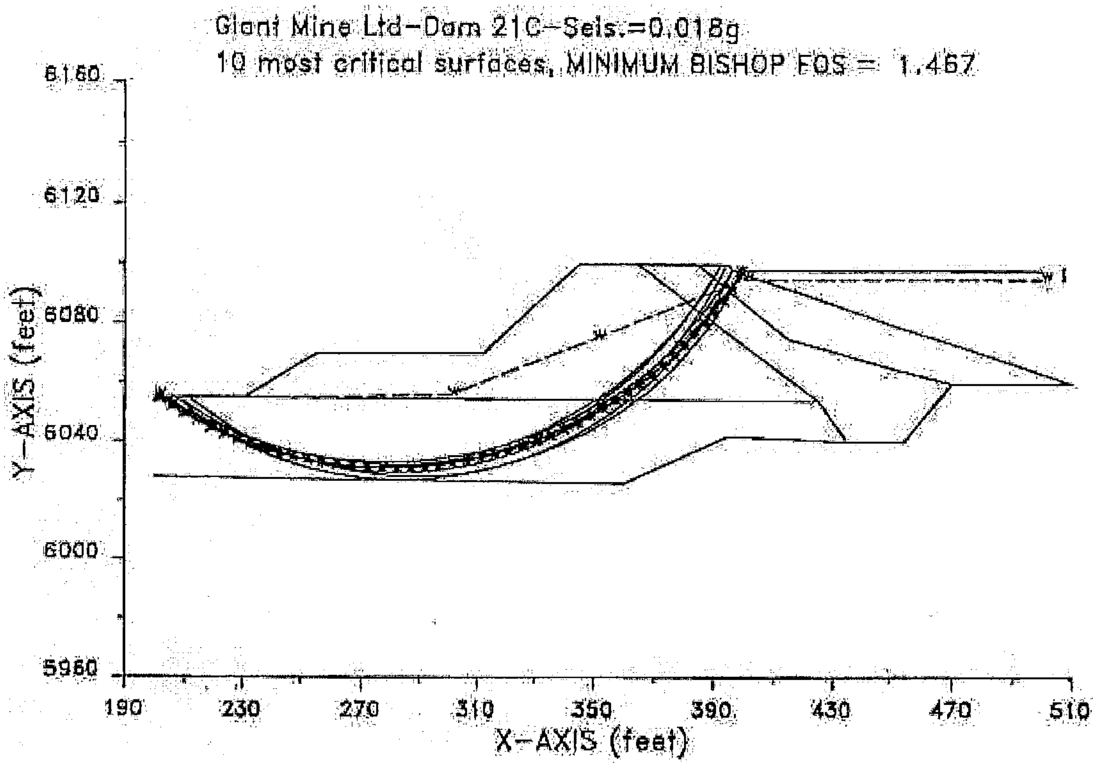


Figure 20: Dam 21C - Seismic Loading - a = 0.018g (Janbu Analysis)

MG-D21CS 8-13-** 16:08

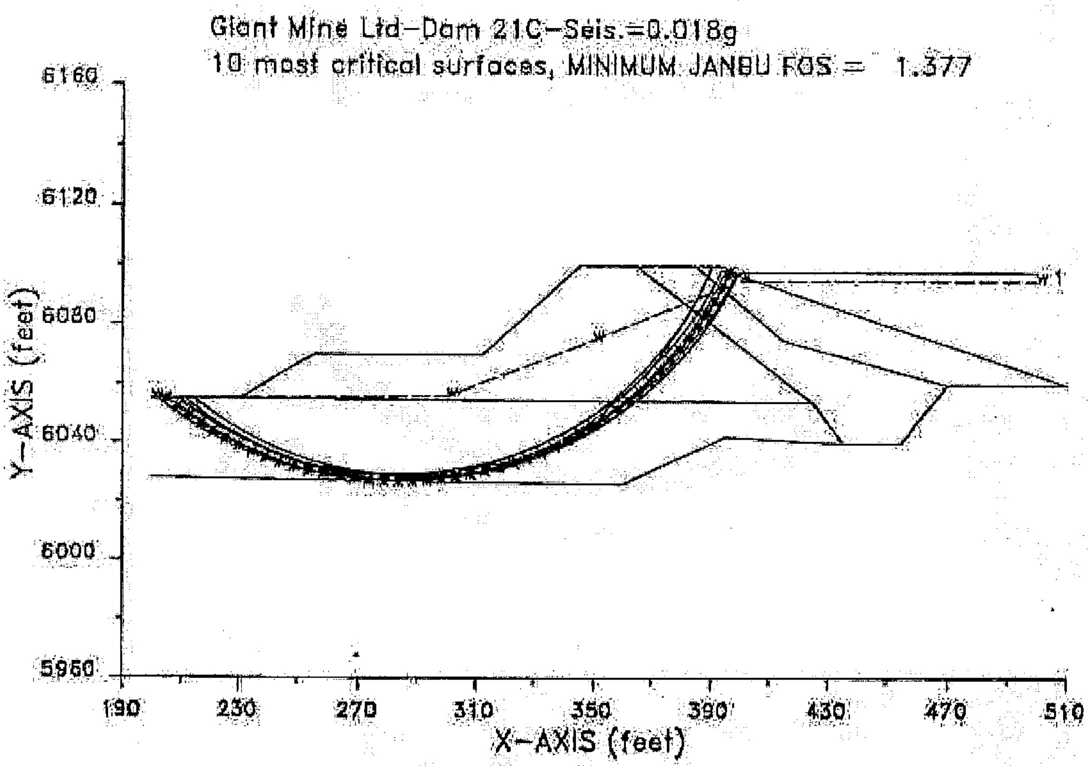


Figure 21: Dam 21D - Seismic Loading - 1 = 0.018g (Bishop Analysis)

MG-021DS 6-13-** 15:09

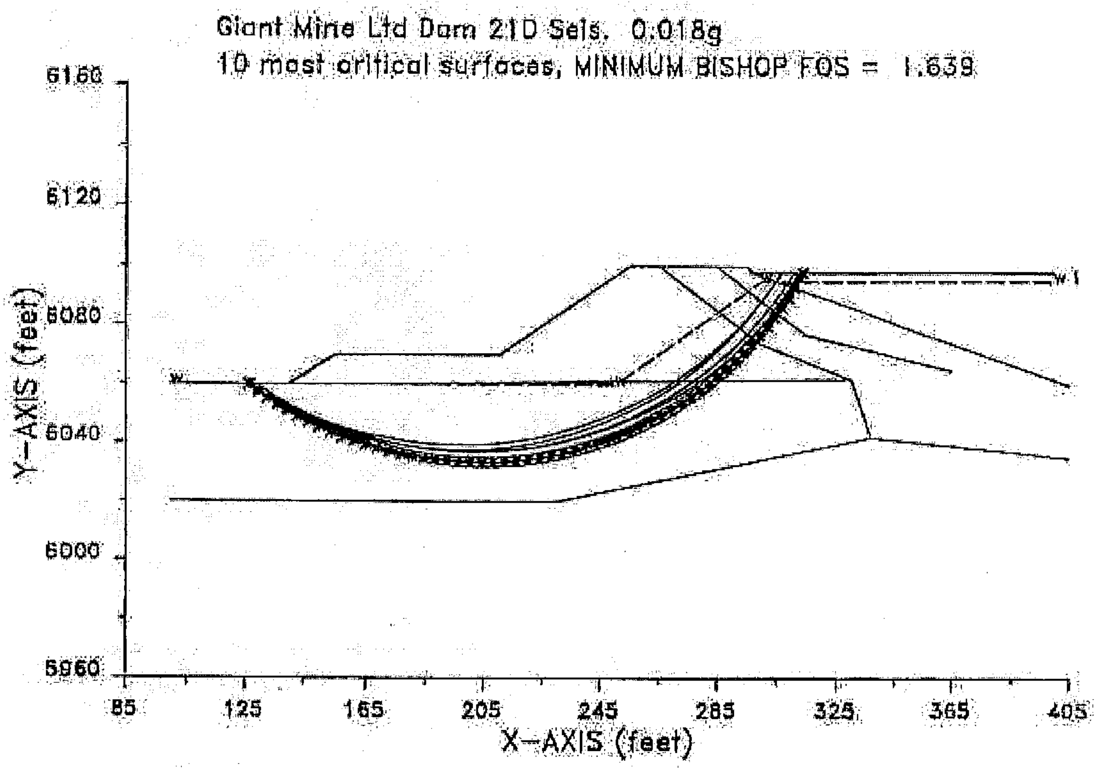


Figure 22: Dam 21D - Seismic Loading - a = 0.018g (Janbu Analysis)

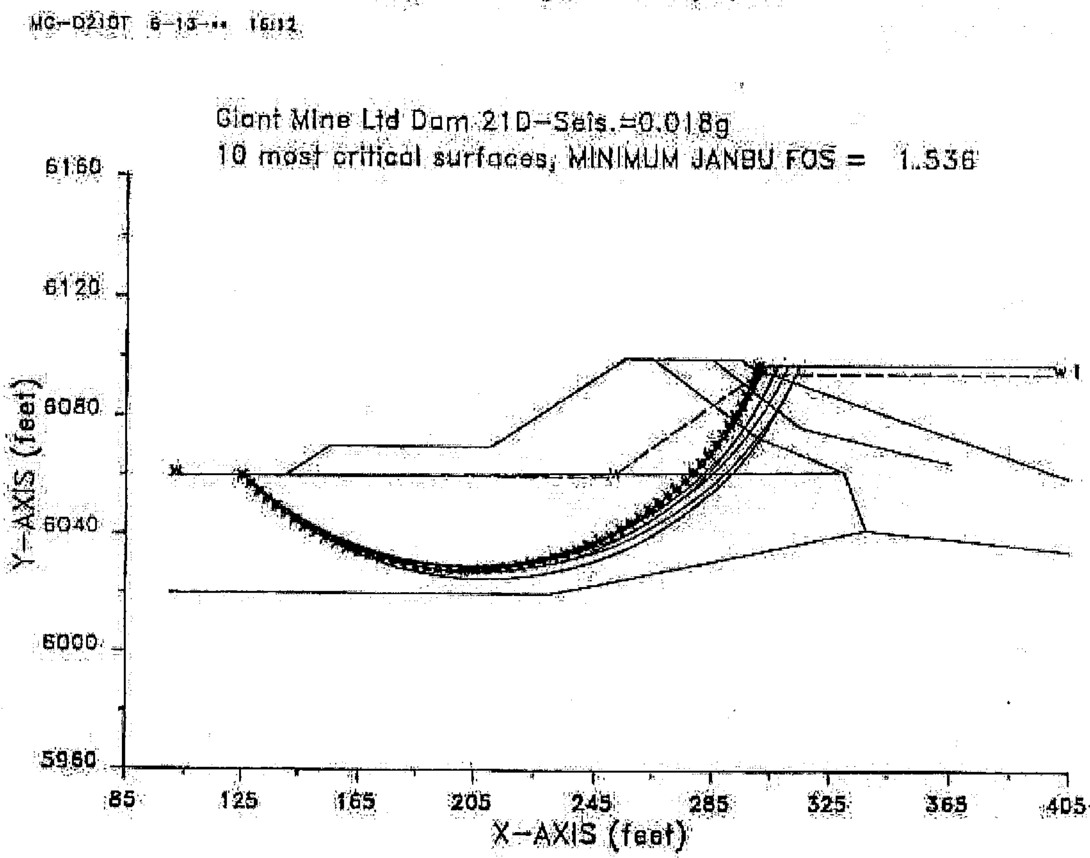


Figure 23: Dam 22B - Seismic Loading - a = 0.018g (Bishop Analysis)

MO-D22BS 6-13-** 16:14

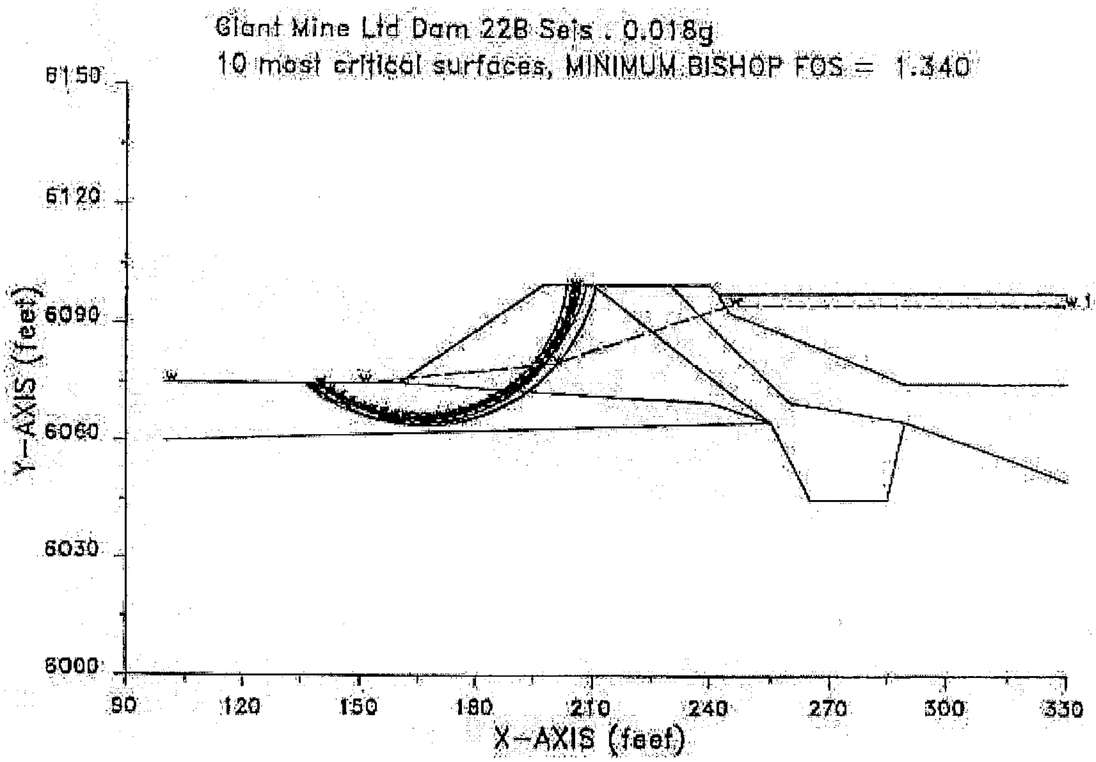
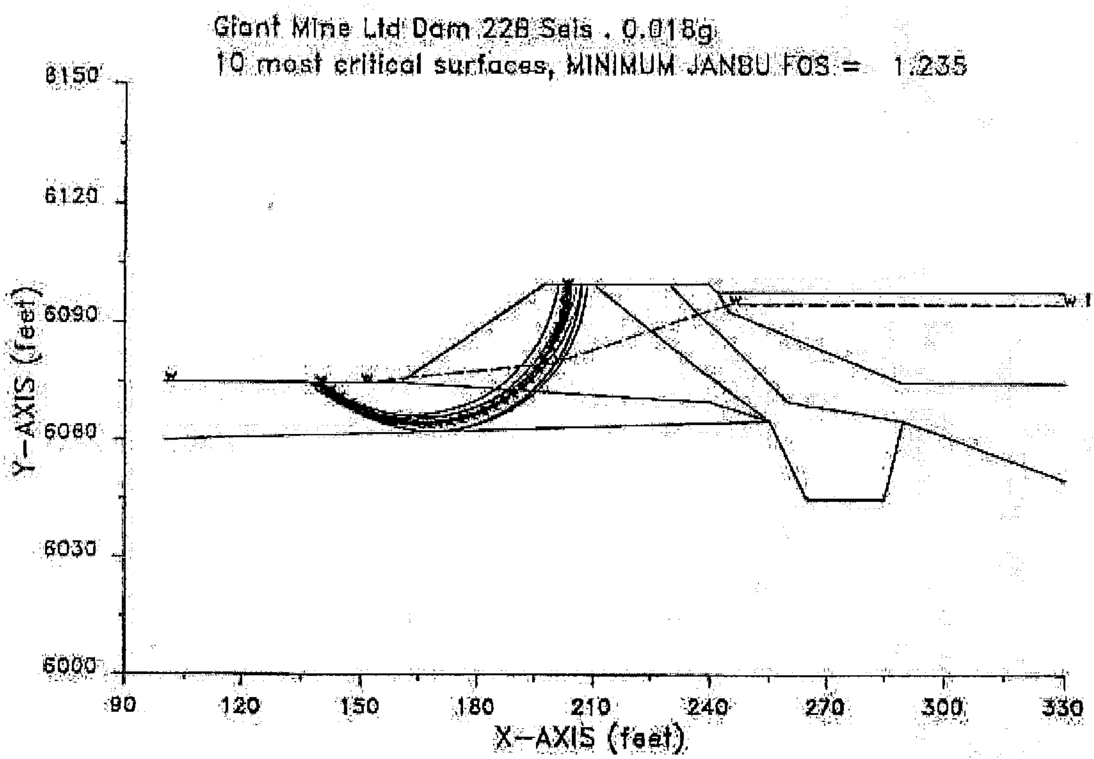


Figure 24: Dam 22B - Seismic Loading - a = 0.018g (Janbu)

MC-D22BS 6-13-** 16:16



APPENDIX A-7B

TAILING COVER MODEL

TAILING COVER MODEL
WATER BALANCE MODELING

A water balance was used to evaluate the tailing cover options. The water balance model considered the exposed tailing and proposed capping systems for the tailing disposal areas at the Giant Mine in Yellowknife.

Water Balance Modelling

The water balance modelling was performed to assess the anticipated seepage or infiltration rate of precipitation through the existing tailing and proposed capping systems. This was performed using the HELP computer program (Hydrologic Evaluation of Landfill Performance, Version 3.07) which was developed by the Environmental Laboratory USAC Waterways Experiment Station for the USEPA Risk Reduction Engineering Laboratory (Schroeder et al, 1997).

The water balance model output consists of the percentage of precipitation which becomes surface runoff, evapotranspiration and infiltration through the tailing.

Input Weather Data

Input weather data includes:

- daily precipitation, temperature and solar radiation;
- quarterly relative humidity; and
- average annual windspeed.

For these simulations, we used climate data for 17 years between 1981 to 1997 supplied by Environment Canada. Precipitation, temperature, humidity and wind data are from Yellowknife Airport. Solar radiation data is from Fort Smith airport as data was not available for Yellowknife. Fort Smith is located approximately 240 km south-southeast of Yellowknife. The modelling assumed a growing season from June to the end of September.

The average annual precipitation for the 17 years of weather data is 283 mm. It is noted that this is approximately 5% greater than the precipitation of 267 mm reported by Environment Canada in the Canadian Climate Normals 1961-1990.

Other Input Data

Other input data include details of the capping system and tailing such as:

- subsurface material layers which allow vertical percolation of water;
- evaporative zone depth;
- surface slope; and
- grass cover.

Water balance modelling has been performed for the following cases:

- 10 m thickness of tailing with no cover, a surface slope of 2% and evaporative zone depth of 250 mm;
- proposed cap over the tailing inclusive of 750 mm of clayey sand (hydraulic conductivity of 2.7 x 10^{-8}m/s), a surface slope of 2%, good grass cover and evaporative zone depth of 500 mm; and
- proposed cap over the tailing inclusive of 500 mm of clayey sand rip rap cover (hydraulic conductivity of 1.2 x 10^{-6} m/s) overlying 750 mm of clayey sand (hydraulic conductivity of 2.7 x 10^{-8} m/s), a surface slope of 50%, fair grass cover and evaporative zone depth of 250 mm.

The assumed material properties for subsurface materials are summarized in the following table:

Table A1
Properties of Subsurface Materials for HELP Water Balance Modeling

Material	Porosity (vol %)	Field Capacity (vol %)	Wilting Point (vol %)	Effective Saturated Hydraulic Conductivity (m/sec)
Tailing				
- clay (CL)	46.4	31.0	18.7	6.4x 10^{-7}
- clayey silt (ML)	50.1	28.4	13.5	1.9 x 10^{-6}
Soil cover – clayey sand (SC)	36.5	30.5	20.2	2.7 x 10^{-8}
Rip rap cover – clayey sand (SC)	39.8	24.4	13.6	1.2 x 10^{-6}

Water Balance Modelling Results

The results of the water balance modelling are presented in Table A2. The average annual precipitation for the 17 years of weather data is 283 mm. The range of values for the exposed tailing reflects the assumed different material properties for the tailing. A printout of the output from the HELP model for the soil cover case is attached.

Table A2
Results of Water Balance Modelling

Case No.	A	B1	B2	C
Description	**Exposed Tailing**	**Soil cover – clayey sand**		**Rip rap cover – clayey sand overlying soil cover**
Surface Slope (%)	2	2		50
Evaporative Zone Depth (mm)	250	350	500	250
Grass Cover	Bare	Good		Fair
WATER BALANCE (average annual total)				
Evapotranspiration (%)	*70 - 73*	*75*	*78*	*69*
Runoff (%)	*19.5 - 24*	*21*	*19.5*	*19*
Infiltration through Soil Liner/Tailing (%)	*6.5 - 8*	*4*	*2.5*	*12*

The results indicate that, with the tailing exposed, approximately 6.5% to 8% of the precipitation will infiltrate through the tailing. If the cover has a hydraulic conductivity of 2.7 x 10^{-8} m/sec or lower, approximately 2.5% to 4% of the precipitation will infiltrate through the cover. If the cover comprises a waste rock or mine muck or sandy rip rap with a hydraulic conductivity of 1.2 x 10^{-6} m/sec overlying the soil cover or tailing noted above, approximately 12% of the precipitation will infiltrate through the cover.

The proposed cover with the 750 mm of silt will reduce the infiltration and provide a soil medium that will allow a good grass cover quickly. The mine muck or sandy rip rap on the steeper slopes of the re-contoured tailing deposit will not be as effective in reducing the infiltration, but will minimize erosion and thus, protect the tailing and allow the grass or vegetative cover to become well established.

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Attachment: Printout of HELP Water Balance Modeling for Case B2 Soil Cover

COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 24

THICKNESS	=	75.00 CM
POROSITY	=	0.3650 VOL/VOL
FIELD CAPACITY	=	0.3050 VOL/VOL
WILTING POINT	=	0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3081 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.270000010000E-05 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 11

THICKNESS	=	1000.00 CM
POROSITY	=	0.4640 VOL/VOL
FIELD CAPACITY	=	0.3100 VOL/VOL
WILTING POINT	=	0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.639999988000E-04 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #24 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 100. METERS.

SCS RUNOFF CURVE NUMBER	=	86.80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	50.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	15.486	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	18.250	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	10.100	CM
INITIAL SNOW WATER	=	1.373	CM
INITIAL WATER IN LAYER MATERIALS	=	333.108	CM
TOTAL INITIAL WATER	=	334.481	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
yellowknife nw territores

STATION LATITUDE	=	62.50 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	151
END OF GROWING SEASON (JULIAN DATE)	=	273
EVAPORATIVE ZONE DEPTH	=	50.0 CM
AVERAGE ANNUAL WIND SPEED	=	15.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	60.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA FOR yellowknife
northwest territory
WAS ENTERED FROM CANADIAN ENVIRONMENTAL DATA.

NOTE: TEMPERATURE DATA FOR yellowknife northwest
WAS ENTERED FROM CANADIAN ENVIRONMENTAL DATA.

NOTE: SOLAR RADIATION DATA FOR fort smith
northwest territory
WAS ENTERED FROM CANADIAN ENVIRONMENTAL DATA.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1981 THROUGH 1997

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	14.54	15.00	14.79	10.65	18.75	32.21
	38.74	32.03	33.72	32.19	24.39	15.89
STD. DEVIATIONS	7.40	6.80	9.10	7.27	13.08	22.19
	26.71	24.02	15.06	11.52	11.04	7.80

RUNOFF

TOTALS 0.000 0.000 0.589 23.496 23.783
4.734
1.570 0.278 0.300 0.320 0.000
0.000

STD. DEVIATIONS 0.000 0.000 2.428 13.375 26.152
6.705
4.474 1.129 1.159 1.181 0.000
0.000

EVAPOTRANSPIRATION

TOTALS 4.215 4.376 8.593 17.756 8.505
42.153
60.724 29.783 22.518 11.873 6.136
3.605

STD. DEVIATIONS 2.579 1.711 2.595 3.906 6.531
10.338
19.295 19.923 6.800 2.500 2.033
1.697

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS 0.5982 0.4183 0.5115 0.3358 0.2329
0.3170
0.3012 0.2235 0.4604 0.5775 0.8360
0.8304

STD. DEVIATIONS 1.2302 1.1845 1.4456 1.0201 0.9603
1.0953
0.4874 0.3823 0.7476 1.1452 1.5753
1.7333

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1981 THROUGH
1997

	MM		CU. METERS	PERCENT
PRECIPITATION	282.96	(46.318)	2829.6	100.00
RUNOFF	55.069	(27.8702)	550.69	19.461
EVAPOTRANSPIRATION	220.238	(32.3601)	2202.38	

77.832

PERCOLATION/LEAKAGE THROUGH 5.64265 (8.50683) 56.427
1.99412
LAYER 2

CHANGE IN WATER STORAGE 2.014 (1.1617) 20.14
0.712

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PEAK DAILY VALUES FOR YEARS 1981 THROUGH 1997

	(MM)	(CU. METERS)
PRECIPITATION	66.00	660.000
RUNOFF	31.870	318.6987
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.237568	2.37568
SNOW WATER	117.49	1174.8717
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3561
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.2020

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FINAL WATER STORAGE AT END OF YEAR 1997

LAYER	(CM)	(VOL/VOL)
1	22.4814	0.2998
2	309.9971	0.3100
SNOW WATER	5.427	

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**
  **            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
  **            HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
  **             DEVELOPED BY ENVIRONMENTAL LABORATORY
**
  **               USAE WATERWAYS EXPERIMENT STATION
**
  **         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
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 PRECIPITATION DATA FILE:      C:\help3\YKNIFE.D4
 TEMPERATURE DATA FILE:        C:\help3\YKNIFE.D7
 SOLAR RADIATION DATA FILE:    C:\HELP3\FTSMITH.D13
 EVAPOTRANSPIRATION DATA:      C:\HELP3\YK702.D11
 SOIL AND DESIGN DATA FILE:    C:\HELP3\YK210.D10
 OUTPUT DATA FILE:             C:\HELP3\yK702.OUT


TIME:  16:19       DATE:   5/ 6/2001


******************************************************************************
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      TITLE:  giant mine, yellowknife

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      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
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APPENDIX A-8

THE GIANT MINE MASS BALANCE MODEL

1.0 INTRODUCTION

An arsenic mass balance model of present conditions at the mine was developed as part of the Abandonment and Reclamation Plan. This model was developed in a proprietary modeling package developed by Golder Associates called GoldSim. The model was developed to be a description of arsenic transport processes at the mine, including arsenic sources (e.g. the tailing ponds and mine-site soils), pathways (e.g. shallow groundwater and surface runoff), and receptors (e.g. the effluent treatment plant and Yellowknife Bay). Understanding the mass transport system at the site allows remediation and reclamation strategies to be examined, and the model allows the importance of the relative contributions of each arsenic source to be assessed as a system. The model also allows the benefit and cost of various design choices to be examined prior to implementation. For example, the changes in arsenic flux to Yellowknife Bay due to reducing infiltration in the Northwest tailing pond can be examined.

Although detailed consideration of underground arsenic sources is beyond the scope of this report, the underground arsenic chambers and underground tail has been considered and are explicitly represented in the GoldSim model. This is to allow calibration of the model using parameters such as minewater arsenic concentrations, which is otherwise not possible if the chambers are not considered. Also, modeling underground sources allows the significance of each surface arsenic source to be assessed in the context of the overall system. The information required to model the underground sources was provided by Steffen Robertson Kirsten Consulting Inc. ('SRK') of Vancouver.

2.0 GOLDSIM

GoldSim is an extremely powerful, highly graphical object-oriented simulation program developed by Golder Associates. The program allows mathematical systems to be modeled and examined. In a sense, GoldSim is like a 'visual spreadsheet' in that it allows the visual creation and manipulation of data and functions operating on the data. However, GoldSim is much more powerful that this; it also contains predefined functions such as contaminant transport and solute mixing equations, and allows models to be run probabilistically and/or dynamically. For this reason, GoldSim is an excellent tool with which to model a mass balance at the mine.

The GoldSim website at www.goldsim.com contains more information about GoldSim.

3.0 CONCEPTUALIZATION

The mass transport model has been conceptualized to describe present conditions at the mine. Dewatering is ongoing, and sources such as contaminated soil around the mine buildings and the tailing pond are modeled in their present condition, i.e. they have not been removed or mitigated by placing cover material. Minewater is passed through the existing effluent treatment system prior to discharge to Baker Creek. Because the current preferred abandonment plan involves perpetual mine dewatering, configuring the model in this way represents present conditions and provides a base case which can easily be modified to examine future conditions.

The only contaminant considered by the model is arsenic. The model is designed to provide a gross indication of the relative importance of contaminant sources at the site and arsenic is considered the main contaminant of concern. If required, the model could be expanded to consider other metals in addition to arsenic.

The two primary arsenic transport mechanisms considered are surface runoff and infiltration/shallow groundwater transport. For the former, mass flux occurs as surface runoff picks up arsenic from the soils at the site. The source of this arsenic is both anthropogenic impacts from the mine (i.e. stack fallout) and the naturally occurring elevated arsenic levels in the soil on a regional scale. Arsenic is then transported to Yellowknife Bay via drainage features such as Baker Creek. The second transport mechanism, shallow groundwater, transports arsenic from sources such as the contaminated soils around the mill and the tailing ponds. Due to the large vertical hydraulic gradient caused by dewatering at the minesite, the majority of this arsenic is assumed to enter the mine and is then transported to Baker Creek via the mine sumps and the effluent treatment plant. However, in order to match field observations, the model also allows some arsenic to escape capture by the mine. For instance, seeps are observed at the old tailing area and these are represented in the model as direct transportation of arsenic from these areas to receptors such as Baker Creek.

It is important to note that the GoldSim model is not a groundwater flow model. Groundwater movement is important in the model, but only because it is one of several transport mechanism for the arsenic. The model does not explicitly contain or model a detailed groundwater regime. Instead, previous reports and field observations have been used to make simplifying assumptions about the groundwater regime, which are then used in the model.

All source terms in the model are considered infinite and will not deplete with time. This assumption is made for simplicity, although the model could easily be adapted to use depleting arsenic sources if required. The model is run dynamically for 100 one year timesteps. However, because source terms do not deplete and no other time-dependent processes have been considered, the dynamic model simply produces constant mass flux between sources and receptors over time.

The model is also deterministic, i.e. no stochastic parameters are used. However, the model is easily adapted to produce probabilistic results if required. For instance instead of using one value for the concentration of arsenic in the porewater, the concentration could be represented as a standard deviation function of all the results and a deterministic Monte Carlo simulation applied.

Figure 1 describes the model conceptualization. Individual sources of arsenic have been identified and source terms defined for each one using available field data or reasonable assumptions. Each source and pathway is described in Section 5.

The model is intended to be a gross representation of mass transport at the mine, and as such, it successfully allows the relative importance of the various arsenic sources to be assessed. Some simplifying assumptions are made in the model and it is noted that some contaminant uptake and transport processes occurring at the site may be more complex than represented. It is also noted that some processes, such as sedimentation in Baker Creek, are not explicitly modelled, as it is felt that detailed examination of these processes would not add to the value of the model.

4.0 METEOROLOGICAL DATA

Because the primary transport mechanisms are shallow groundwater and surface runoff, accurate characterization of the meteorological system at the site is essential. The model uses a simple water balance to define water input to the site. Because precipitation, infiltration and runoff primarily drive the model, correctly defining these parameters is essential to the accuracy of the model.

Precipitation is assumed to be 267 mm/yr, based on data from Yellowknife airport and the Giant tailing management report. Infiltration is extremely difficult to estimate as it varies considerably both temporally and spatially at the site. Following discussion with SRK and examination of recent work by Environment Canada (Spence *et al.*, 2000. A Hydrological Investigation of a Canadian Shield Basin. In Proceedings of the 6th Scientific Workshop of the Mackenzie GEWEX Study. Strong, G.S. and Y.M.L. Wilkinson (eds.), Saskatoon.) a value of 44% infiltration was used in the model, producing a vertical flow of 3.7×10^{-6} $l/m^2/s$. This value calibrates well with the minewater balance. Net annual surface runoff is estimated to be 40% of precipitation, or 3.6 $l/s/km^2$.

5.0 MODEL SOURCE TERMS AND PATHWAYS

As described in Figure 1, the following source terms have been identified:

Source 1A – Infiltration into Contaminated Soil around the Mine Buildings

Field investigation indicates that areas of elevated arsenic in soils occur immediately around the mine complex. These impacts are anthropogenic and represent arsenic from mine operations such as arsenic trioxide dust from the bag house and stack fallout. Based on Golder's field investigation, an area of impact of 26 ha has been assumed for these soils, which broadly corresponds to the area of soil around the mill buildings with arsenic concentrations >350mg/kg. Although these are several distinct areas, a simplifying assumption is that they all occur in a single area.

Based on soil testing carried out, this soil is assumed to produce a groundwater concentration of 100mg/l arsenic. The transport mechanism for this arsenic is precipitation and infiltration. Because of the large hydraulic gradient caused by mine dewatering, this groundwater is assumed to directly enter the mine. No attenuating processes are modeled.

This source has been modeled explicitly so the effects of removing this soil as part of the closure plan can be assessed.

Source 1B – Runoff from Contaminated Soil around the Mine Buildings

The contaminated soils immediately around the mine also impact surface runoff. Based on data from the minesite, an arsenic concentration of 0.5 mg/l in the surface runoff is assumed. This runoff flows directly to Baker Creek.

Source 2A – Other Soils at the Minesite

In addition to the highly contaminated soils at the site, other soils at the site contain elevated levels of arsenic due to the regional-scale arsenic anomaly. These are also assumed to contribute mass to the system. Based on soil testing carried out, this soil is assumed to produce a groundwater concentration of 0.1 mg/l arsenic. The transport mechanism for this arsenic is precipitation and infiltration. Because of the large hydraulic gradient caused by mine dewatering, this groundwater is assumed to flow directly to the mine.

Because these soils cover the entire site, their areal extent is assumed to be equal to the area of the drawdown cone as this is the effective area of mass transport to the mine. This is estimated to be 420 ha. No attenuating processes are modeled.

The regional-scale arsenic anomaly is also assumed to impact surface runoff. This is considered separately as Source 9.

Source 2B – Tails Spills at the Minesite

The minesite contains several areas of tails spills that have been considered as sources of arsenic. Based on field investigations, 30 ha of tails spills have been assumed, with an average source concentration of 4.0mg/l. Because of the large hydraulic gradient caused by mine dewatering, this groundwater is assumed to flow directly to the mine.

Source 3 – Beached Back Bay Tails

Tails was previously disposed of directly to Back Bay (Section 4, EBA report 0701-99-14263.008) and a portion of this tails is visible above the waterline. This is assumed to have an area of 5 ha and produce an arsenic concentration of 0.05 mg/l (EBA report 0701-99-14263.008). The tails is also assumed to have an infiltration of 15% (consistent with other tail on the site). Arsenic is transported by infiltration and shallow groundwater to Yellowknife Bay.

Source 4 – Submerged Back Bay Tails

In addition to beached tail in Back Bay (Source 3), the tails is also known to have been deposited directly into Back Bay. The impacts of this tail to water quality in the Bay is unknown, and is the subject of further study. This source term was included in the model for future use but set to zero. This can be changed at a later date if necessary.

Source 5A – South Tailing Pond

The south tailing pond is assumed to have an area of 28 ha and an infiltration of 15% (representative of pre-closure conditions). Mass transport from this tail is assumed to be by infiltration and shallow groundwater flow. Geochemical testing indicates that porewater in the tailing has a concentration of 4.4 mg/l.

Based on field observations and geochemical data, mass from this source is assumed to be transported to four different receptors. 60% of the arsenic is assumed to be transported via seepage to the adjacent central tailing pond. 20% of this mass is transported via seepage to Baker Creek and 15% is transported to Yellowknife Bay. The remaining 5% of the arsenic mass is assumed to be transported to the mine.

Supernatant processes and the possible presence of supernatant water have not been considered.

Source 5B - Central Tailing Pond

The central tailing pond is assumed to have an area of 12.6 ha and an infiltration of 15% (representative of pre-closure conditions). Mass transport from this tails is assumed to be by infiltration and shallow groundwater flow. Geochemical testing indicates that porewater in the tailing has a concentration of 4.4 mg/l.

Based on field observations and geochemical data, mass from this source is assumed to be transported to four different receptors. 60% of the arsenic is assumed to be transported via seepage to the adjacent north tailing pond. 20% of this mass is transported via seepage to Baker Creek and 15% is transported to Yellowknife Bay. The remaining 5% of the arsenic mass is assumed to be transported to the mine.

Supernatant processes and the possible presence of supernatant water have not been considered.

Source 5C – North Tailing Pond

The north tailing pond is assumed to have an area of 9.3 ha and an infiltration of 15% (representative of pre-closure conditions). Mass transport from this tail is assumed to be by infiltration and shallow groundwater flow. Geochemical testing indicates that porewater in the tailing has a concentration of 4.4 mg/l.

Based on field observations and geochemical data, mass from this source is assumed to be transported to four different receptors. 80% of the arsenic is assumed to be transported via seepage to the adjacent polishing pond and settling pond (for simplicity, these have been modeled as one model element). 15% of the arsenic is transported to Yellowknife Bay and the remaining 5% of the arsenic mass is assumed to be transported to the mine via vertical groundwater flow.

Supernatant processes and the possible presence of supernatant water have not been considered.

Source 6 – Northwest Tailing Pond

The northwest tailing pond is assumed to have an area of 45.7 ha and an infiltration of 15% (representative of pre-closure conditions). Mass transport from this tail is assumed to be by infiltration and shallow groundwater flow. Geochemical testing indicates that porewater in the tailing has a concentration of 4.4 mg/l.

Based on field observations and geochemical data, mass from this source is assumed to be transported to four different receptors. 50% of the arsenic is assumed to be transported to the underground workings, predominantly via the open exploration boreholes thought to exist under the pond. 15% of the arsenic is transported to Trapper Lake. 20% is assumed to be transported to the Trapper Creek, and the remainder is assumed to be transported via shallow groundwater flow to the polishing pond and settling pond.

Supernatant processes and the possible presence of supernatant water have not been considered.

Source 7 – Open Pits

The minesite contains several open pits. In the model, Pits A1, A2, B1, B2, B3, B4, C1 and Brock are considered. These are conceptualized as being directly connected to the mine workings. Each pit has a small catchment area that allows surface runoff to transport arsenic from the pit walls and waste rock into the mine. Geochemical testing suggests that the average arsenic concentration in the pit wall runoff is 0.19 mg/l. The total area is 53.6 ha.

Source 8 – Deep Regional Groundwater Flow into the Mine

Deep regional groundwater flow into the mine is also considered a source of arsenic. The minewater balance reported in the work by Fracflow (Preliminary Hydrogeological, Geochemical and Isotopic Investigations at the Giant Mine, Yellowknife, NWT. Fracflow and Gale, 1998) indicates that arsenic concentrations in deep groundwater flow are approximately 0.02 mg/l. A total inflow of 1l/s is used in the model.

Source 9 – Surface Runoff in Drainage Basins

This source represents surface runoff across soils which contain elevated arsenic concentrations at a regional scale. It is assumed that runoff in the drainage basins at the minesite picks up and transports arsenic. The area assumed for each drainage basin is given in Table 4, Figure 1. A runoff concentration of 0.08 mg/l is assumed.

The receptors for this source are Trapper Creek, Baker Creek and ultimately Yellowknife Bay. The surface drainage system is conceptualized as a simple pipe system, and no attenuation processes or mass sinks such as sedimentation processes in Baker Creek are considered. This is a conservative assumption as any mass sink in Baker Creek would reduce impacts to Yellowknife Bay which is considered the model receptor. In the presentation of results, this source is referred to as the Baker Creek watershed.

Source 10 – Underground Arsenic Chambers

As noted, the underground arsenic chambers are considered as a source in the mass transport model. Although consideration of the chambers is not in the scope of this work, it is not possible to build a calibrated mass transport model for the surface features without considering the mass they contribute. For this reason, a simple conceptual model for the arsenic chambers has been developed.

Following discussion with SRK, the arsenic chambers are conceptualized as being 15 separate chambers with a total plan area of 1.1 Ha. A uniform vertical groundwater flow of 3.7×10^{-6} $l/s/m^2$ through the plan area is assumed, which corresponds to surface infiltration.

Sampling by SRK suggests an arsenic concentration of 3.2 g/l in water exiting the chambers. However, work by Gale and Fracflow (1998) indicates a saturation concentration of approximately 12 g/l at temperatures expected to occur in the mine. Given the vertical dimensions of the chambers, the relatively long estimated residency time and the fine-grained nature of the arsenic trioxide in the chambers, concentrations approaching the saturation concentration may be expected exiting the chambers. The concentration of 3.2 g/l may represent flow from the chambers which has been subsequently diluted. Also, when calibrating the model, initial calculations underestimated the arsenic concentration in the mine sumps. For this reason, a concentration of 6100 mg/l was assumed for water exiting the chambers.

Whilst the conceptualization of the arsenic chambers is considered appropriate for this model, actual processes within and around the chambers may be significantly more complex. It is understood that these will be addressed in detail by SRK.

Source 11 – Underground Tailing

Historically, tailing from the mill was used as backfill in the mine. Work by SRK indicates that approximately 100 ha of tails exists underground. This is modeled in a similar way to the arsenic chambers; a vertical flow of 3.7×10^{-6} $l/s/m^2$ through the plan area of the tails and a concentration exiting the tails of 4.4 mg/l is assumed. 100% infiltration through this tails is assumed. This water is collected in the mine sumps and pumped to the northwest pond and then to the northwest pond and then to the effluent treatment plant.

6.0 OTHER MODEL COMPONENTS

The Surface Water System

The model uses a simplified conceptual surface water system as shown in Figure 1. The four elements are Trapper Lake, Trapper Creek, Baker Creek and Yellowknife Bay (and their respective drainage basins). The areas of each basin are given in Figure 1. Runoff in each basin transports arsenic as described in Section 5 (Source 9). Trapper Lake flows into Trapper Creek which in turn flows into Baker Creek. This transports arsenic to Yellowknife Bay. Mass flux to Yellowknife Bay also occurs due to direct surface runoff from the minesite.

A leakage of 4 l/s is allowed from Baker Creek into the mine. This is included for completeness and has a minor affect on the model results.

As noted, the model uses a simplified conceptualization of the surface hydrology and is not intended to be a detailed representation of processes at the site. In particular, the creeks and lakes are considered as mixing cells and processes such as lacustrine mixing, sedimentation and precipitation of arsenic are considered. GoldSim is extremely well-suited to modeling these additional if required at a later date.

The Mine

The mine is modeled as a single mixing cell. Arsenic is transported into the mine from a variety of sources as described in Section 5 and instantaneously mixed to produce a single uniform concentration. Water from the mine is then passed to the northwest pond and then the effluent treatment plant.

For simplicity, individual levels, sumps and seeps within the mine are not considered, although these can readily be added to the model if required.

The Effluent Treatment Plant

Water from the mine is passed to the effluent treatment plant. This plant effectively acts as a mass sink as it removes arsenic without affecting flow rates. Giant mine staff have indicated that the combined efficiency of the plant and the settling and polishing ponds is approximately 97.5%. As noted below, the model considers the settling pond and polishing pond as a single entity. The model assumes that the plant and the ponds are equally efficient, and therefore uses individual efficiencies of 84.1% for each stage. These efficiencies combine to result in a total system efficiency of 97.5% i.e. 100-[100*{1-0.841}]*(1-0.841). The treated water is then passed to settling pond and polishing pond.

The Settling Pond/Polishing Pond

To aid conceptualization, these features are modeled as a single entity. This effectively removes 84.1% of the arsenic mass without effecting flow volumes. The mass accumulates in a sink in the model which represents the sludge in the ponds. This efficiency combined with the efficiency of the effluent treatment plant results in a total treatment efficiency of 97.5%.

The model contains a secondary source of arsenic to the settling pond and polishing pond. This is due to direct surface runoff into the ponds. This represents a minor source of arsenic and is included only for completeness.

7.0 RECEPTORS AND MASS SINKS

Two primary receptors are considered in the GoldSim model; the mine workings and Yellowknife Bay. The mineworkings are considered an intermediate receptor as this allows the model to be calibrated against arsenic concentrations in the minewater. The final receptor is Yellowknife Bay.

The model contains three mass sinks; the effluent treatment plant, the polishing pond/settling pond and Yellowknife Bay. The first two are representations of mass sunk into the sludge in the ponds or removed by the effluent treatment plant. Yellowknife Bay is considered a mass sink to satisfy the internal mathematics of the GoldSim model.

8.0 MODEL CALIBRATION

The model was calibrated by comparing predicted arsenic concentrations in both the minewater and effluent discharged to Baker Creek with actual chemical data.

Preliminary runs of the model resulted in underestimates of minewater arsenic concentrations. As the model water balance in the mine approximated that reported by Giant, it was assumed that this underprediction resulted from less arsenic mass being available in the model than in the mine (as opposed to an overestimate of water volume in the model). The model was calibrated by using a source term of 6100 mg/l arsenic for water exiting the arsenic chambers. The model then predicted minewater arsenic concentrations of 11 mg/l and discharge concentrations of 0.3 mg/l (compared with average values reported by Giant Mine of 10 to 20 mg/l and 0.4 mg/l respectively).

9.0 BASE CASE MODEL RESULTS

As discussed in Section 7, the model accurately predicts minewater concentrations and effluent discharge concentrations for arsenic. Additionally, the model can be used to predict arsenic transport between various parts of the site, i.e. the flux to Yellowknife Bay from various sources in the model.

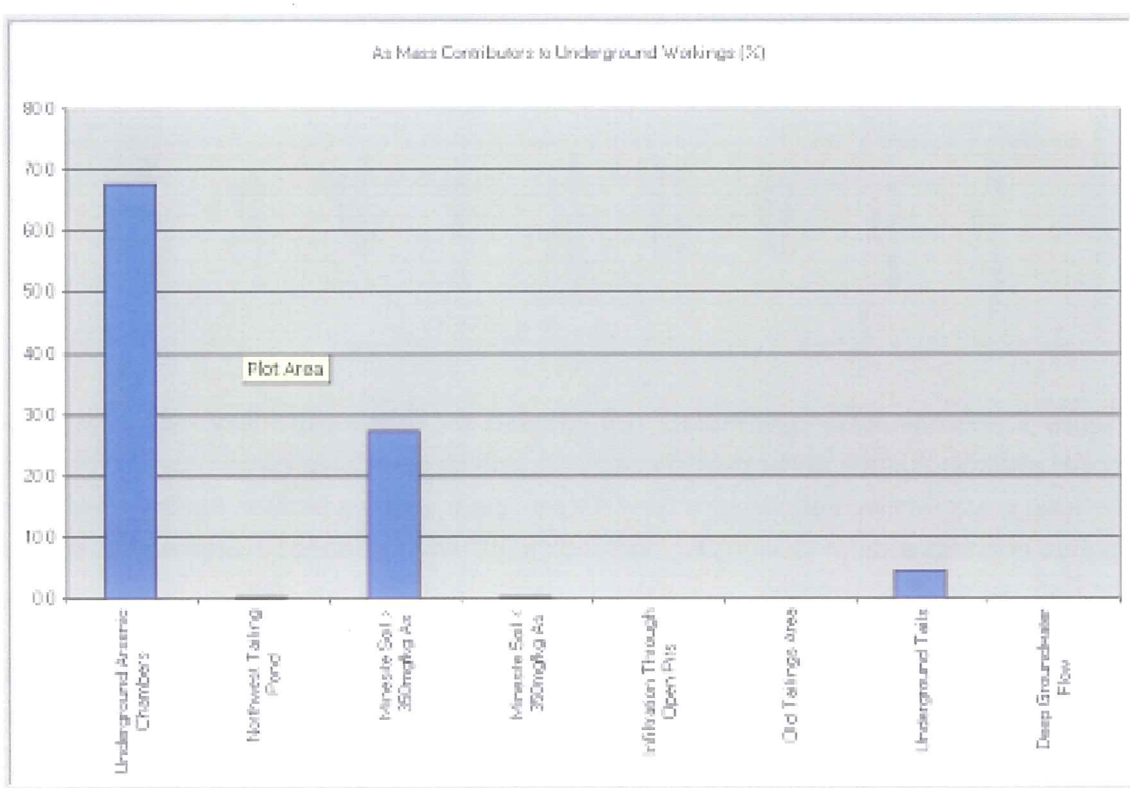
Table 1 below reports the mass flux (per year) from various sources to the mine and to Yellowknife Bay.

Table 1
Mass Flux from Different Sources to the Mine Workings and Yellowknife Bay

Source	Flux to Mine Workings (Kg/yr.)	Flux to Yellowknife Bay (Kg/yr.)
Underground Arsenic Chambers	7880	197
Northwest Tailing Pond	40	31
Minesite Soil > 350mg/kg Arsenic	3190	91
Minesite Soil < 350mg/kg Arsenic	25	1
Infiltration from open pits	6	0
Old Tailing Area	6	36
Underground Tail	516	13
Deep Groundwater Flow	1	Not Calculated
Submerged Back Bay Tail	0	Not Calculated
Beached Back Bay Tail	0	0
Surface Runoff from Watersheds	0	446

These flux can also be reported as percentage contributions to the mine and to Yellowknife Bay. Figure 2 indicates the mass flux into the mine from various sources

Figure 2
Present Conditions - As Contributors to the Underground Workings (by percent)



As Figure 2 shows, the model predicts that approximately 67.6% of the arsenic contained in the minewater is from the underground arsenic trioxide chambers. Other main contributors include soil on the site with arsenic concentrations > 350 mg/kg (27.3%) . The transport mechanism for both these sources is infiltration of shallow groundwater into the mine. The model predicts that underground tail contributes about 4.4% of mass to the minewater. All other sources including the tailing ponds contribute less than 1% in total.

Figure 3
Present Conditions - As Contributors to Yellowknife Bay (by percent)

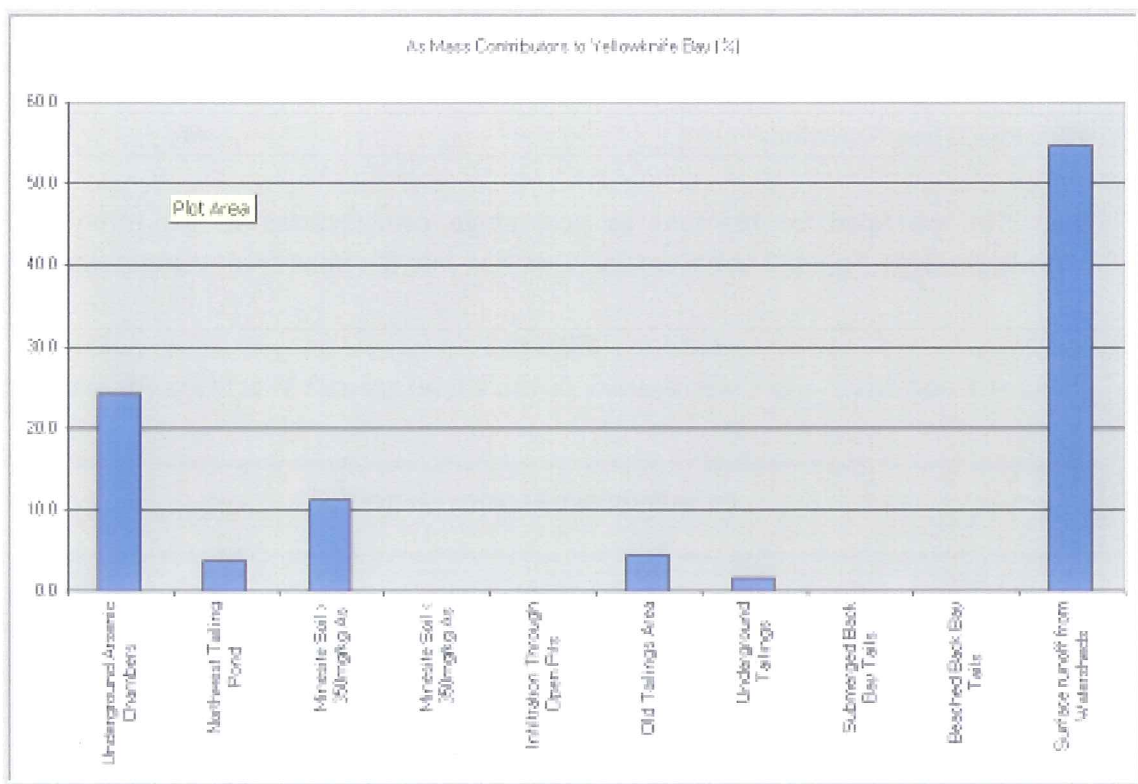


Figure 3 presents mass contributors (by percent) to Yellowknife Bay. As shown, the model predicts that the underground arsenic chambers contribute approximately 24.2% of the total mass flux to Yellowknife Bay. Other major sources include minesite soils with arsenic concentrations > 350mg/Kg, surface runoff from drainage basins on the site and the four tailing ponds on site.

The influence of the effluent treatment pond and the settling pond and polishing pond are displayed in the above figures. Mine dewatering effectively acts as a pump-and-treat system as all water captured by the mine has 97.5% of arsenic mass removed prior to discharge. This can be seen by examining the relative contributions of each source to the mine and to Yellowknife Bay. For instance, the arsenic chamber contribute 68% of the arsenic to the mine and 24% of the arsenic to Yellowknife Bay, compared to the Northwest tailing pond which contributes 0.3% of total mass to the mine but 4% of total mass to Yellowknife Bay. This is because all mass flux from the arsenic chambers is attenuated by 97.5% due to the water treatment system, whereas 50% of the mass from the Northwest tailing pond is transported directly to Yellowknife Bay without treatment.

10.0 CLOSURE MODEL

Following successful calibration, the base case model was redeveloped to examine the chosen closure strategy for the site. As discussed in the main body of the report, the infiltration of the south, central and north ponds is reduced from 15% to 3% by use of an engineered cover. The soil with a concentration of > 350mg/kg arsenic on the site is disposed of in the Northwest tailing pond, which also has an engineered cover with an infiltration of 3%. In the closure model, this source is assumed to generate the same arsenic mass as in the base case model.

The following table shows the arsenic flux calculated by the model for the closure case:

Table 2
Closure Model Mass Flux from Different Sources to the Mine Workings and Yellowknife Bay

Source	Flux to Mine Workings (kg/yr)	Flux to Yellowknife Bay (kg/yr)
Underground Arsenic Chambers	7880	197
Northwest Tailing Pond	20	15
Minesite Soil > 350mg/kg Arsenic	0	0
Minesite Soil < 350mg/kg Arsenic	25	1
Infiltration from open pits	6	0
Old Tailing Area	1	7
Underground Tail	516	13
Deep Groundwater Flow	1	Not Calculated
Submerged Back Bay Tail	0	Not Calculated due to Lack of Data
Beached Back Bay Tail	0	0
Surface Runoff from Watersheds	0	446

As expected, most flux do not change as they are not directly influenced by the closure measures. However, mass contributions from the minesite soil > 350mg/kg arsenic and the tails spills reduce to zero as this source has been removed. Mass contribution from the south, central and north tailing pond reduce by a factor of 15 as infiltration has been reduced by this amount. Mass contributions from the northwest tailing pond actually increase. This is the net effect of reducing the infiltration by a factor of 5 but increasing the arsenic mass available for transport in the pond due to the disposal of minesite soils.

These flux changes effect the percentage contributions to various sources following closure. These are shown in figures 4 and 5:

Figure 4
Closure Model - As Contributors to the Underground Workings (by percent)

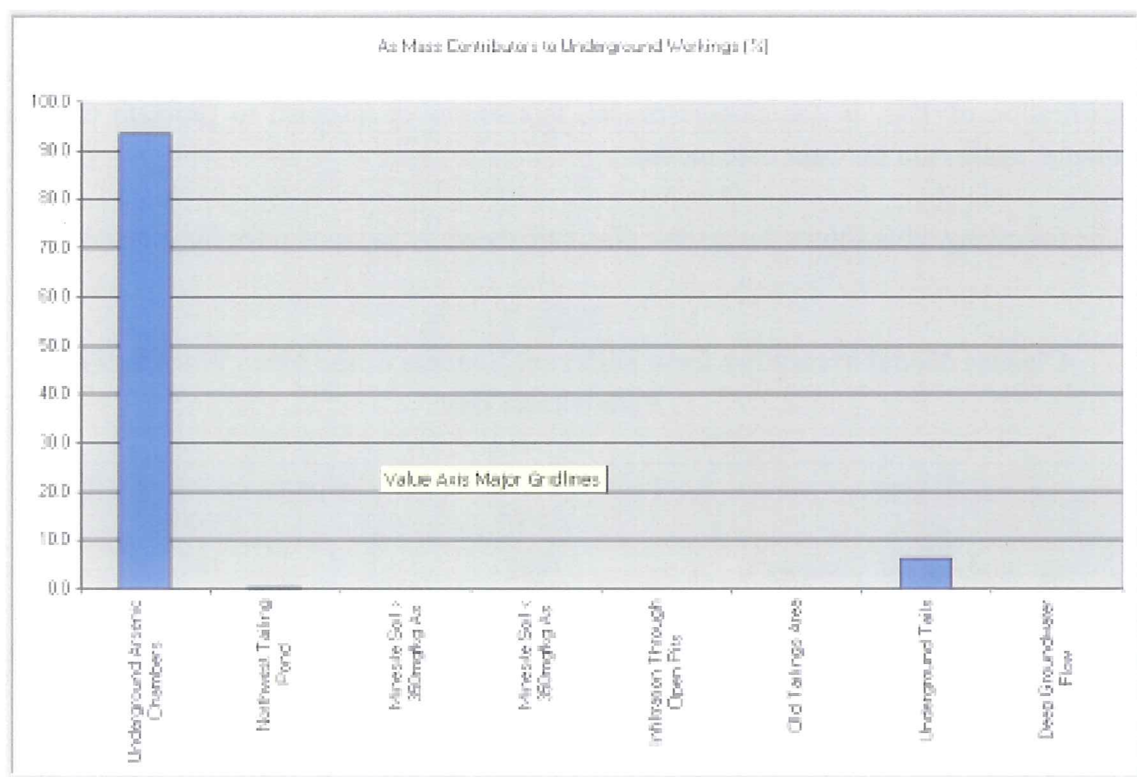


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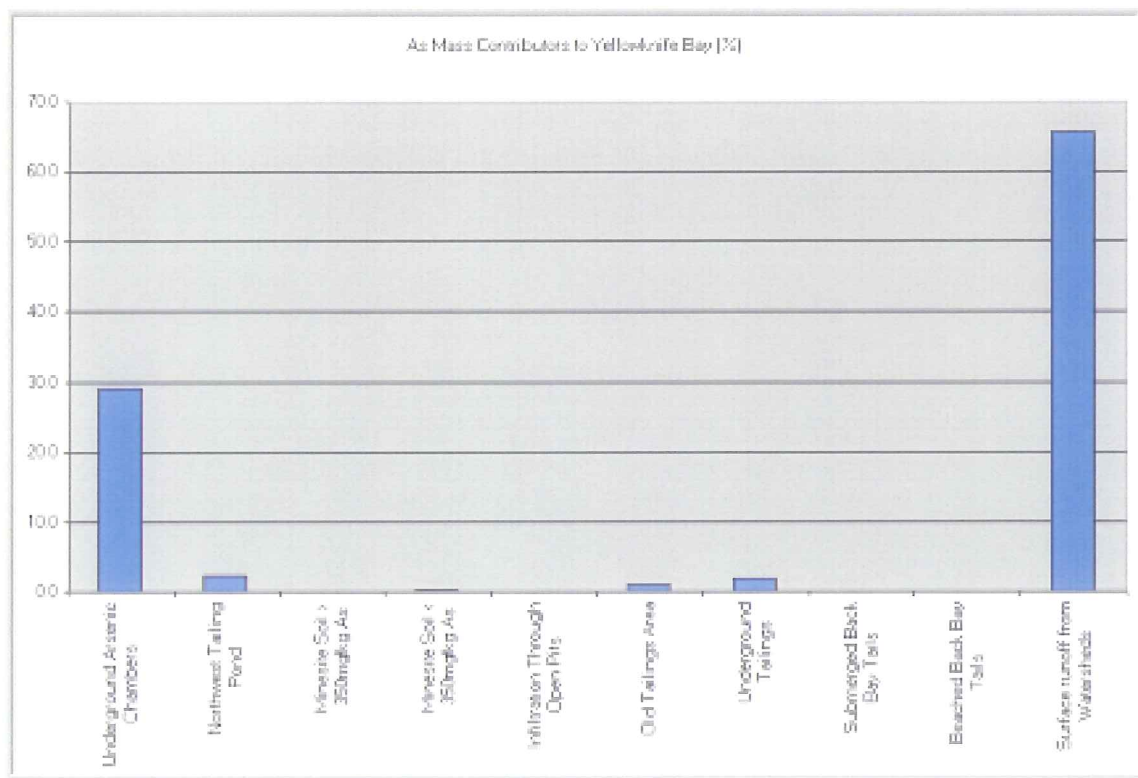
Figure 5
As Contributors to Yellowknife Bay (by percent)



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