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De Beers

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MACKENZIE VALLEY
ENVIRONMENTAL IMPACT
REVIEW BOARD

28 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: Minewater Assessment and Variability

Please accept the attached technical memo titled "Snap Lake Diamond Project – Minewater Assessment and Variability" for submission to the Public Registry. This memorandum was compiled in response to issues raised by intervenors during the MVEIRB Technical Sessions.

Additionally, information contained within this memo should address the outstanding concerns identified by Indian and Northern Affairs Canada in their Request for Ruling to the Board dated 22 January 2003.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

ORIGINAL SIGNED BY

Robin Johnstone
Senior Environmental Manager

Technical Memorandum

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TO:	Robin Johnstone De Beers Canada Mining Inc.	**DATE:**	February 28, 2003
FROM:	Dawn Kelly and Rick Schryer	**JOB NO:**	03-1322-017/5460
Prepared by:	Ken DeVos and Don Chorley		
RE:	**SNAP LAKE DIAMOND PROJECT MINE WATER ASSESSMENT AND VARIABILITY**		

EXECUTIVE SUMMARY

This memorandum presents a discussion of the factors affecting the quality of Snap Lake Diamond Project mine water inflow as well as the results of variability modelling. "Variability modelling" is the process by which one or more parameters or assumptions of the model are altered to assess the changes that would result. In this case, the input parameters or assumptions in the Site Water Quality (GoldSim) model were adjusted to investigate the potential variation in the water quality of the treated discharge. Clarifications or alternative scenarios were requested by Environmental Assessment (EA) interveners in the Technical Sessions (November 26 to December 6, 2002) and follow-up phone conversations with Indian and Northern Affairs Canada (INAC). As a result of these intervener requests and discussions, six scenarios were agreed upon and are presented in this memorandum:

1. "EA Assessed" case – as modelled in the environmental assessment
2. "Expected" case – "EA Assessed" case adjusted to reflect current understanding of the mine and treatment system.
3. "+ 1 SD Flow" – "Expected" case with inflow to mine increased by 1 standard deviation
4. "+1 SD Conc" – "Expected" case with concentrations increased by 1 standard deviation
5. "Depth Average" – "Expected" case adjusted to account for area weighted depth average of the mine
6. "Depth Average + Upwell" – "Depth Average" case adjusted to account for potential upwelling of deeper, more saline groundwater.

A discussion of the variability assessment for each of these scenarios is provided in sections 5 through 7. The memo also, however, provides the background information and detail required for proper review of the input parameters applied to each scenario. Section 2 provides details on the key input parameters (connate water concentrations and profiles, average depth of mine, and hydraulic conductivity profiles) required to complete the variability assessment. Section 3 provides a detailed description and discussion of the hydrogeological modelling completed to specifically address connate water upwelling. Section 4 provides an overview of the Site Water Quality (GoldSim) model and any adjustments to the Site Water Quality model that affect the currently predicted water quality estimates.

The following are highlights from Sections 2 and 3:

- Additional data on the mine water inflow concentrations confirm that the values used in the original EAR are high relative to the updated average, and that the values used in the EAR are not unduly influenced by drill water contamination.
- The average depth of mine, weighted by area, is roughly 210 m below the surface of Snap Lake.
- The total dissolved solids (TDS) concentration with depth profile developed for Snap Lake (Section 2.3) assumes that the Snap Lake profile parallels the Diavik profile and that relative changes in the Snap Lake profile are the same as those in the Diavik profile. This profile has been adjusted upwards (i.e., concentrations in the Snap Lake profile are higher than those of the Diavik profile) to account for the average measured concentration at a depth of 155 m at the Snap Lake site.
- The Snap Lake hydraulic conductivity profile uses the Diavik profile as a reference. The Diavik profile is considered to be conservative as it is expected to underestimate the reduction in hydraulic conductivity with depth relative to other locations in the Canadian Shield (or crystalline rock in general). Because of this, the Snap Lake profile is expected to overestimate the amount of connate water upwelling.
- As discussed in Section 3, using the Snap Lake chemistry profile and the Snap Lake hydraulic conductivity profile, modelling of connate water upwelling results in a long-term increase in connate water concentration of 1.45 times the average value. As indicated above, the amount of upwelling would be significantly lower if the hydraulic conductivity profile from other crystalline-rock settings was used.

The following key points and changes to the Site Water Quality model are discussed in Section 4:

- The concentrations applied to the lake water recharge component of the mine water inflow are appropriate since the simple mixing model overestimates the lake water concentrations relative to the RMA lake water mixing model.
- The Site Water Quality model was adjusted to account for treatment of dissolved-phase mass. The limits and values provided as treated discharge concentrations are based on the upper level (i.e., high concentrations) of proven treatment technology that would be feasible for the Snap Lake site if required.

Key results from the variability assessment are summarized as follows:

- Concentrations for parameters with similar values in the "Saline" water and the "Expected" water (e.g., silver, aluminum, cobalt, chromium, iron, lead, selenium, zinc, dissolved phosphorus, and orthophosphate) are not expected to experience significant depth-related concentration changes (e.g., from upwelling of connate water).
- If required, treatment will result in discharge concentrations of dissolved phosphorus similar to those predicted in the "EA Assessed" case. The treatment technology as currently proposed for the Snap Lake site can be modified to include treatment for phosphorus if necessary by the addition of ferric sulphate or an equivalent process.
- By conducting the variability assessment scenarios as proposed (varying each parameter independently of the other influencing factors), TDS concentrations in the discharge to Snap Lake are predicted to be higher. This increase ranges from 7% to 53% above the "EA Assessed" case, depending on the specific scenario evaluated. The greatest increase results when Expected + 1 standard deviation concentrations are used in the "+1 SD Conc" case. For the "Depth Average" case, the TDS values are similar to the "EA Assessed" case while the "Depth Average + Upwelling" case results in a 27% increase with respect to the "EA Assessed" case.

As discussed in Section 7 of this memo, we have provided a sensitivity analysis for mine water quality at the Snap Lake Diamond Project. In essence, this provides interveners with a number of scenarios that each differ in their conservatism. In other words, six scenarios have been evaluated, each increasing in the level by which they are considered "worst-case".

The values of mine water chemistry assessed in the EA were based on the field data and conclusions made by Gascoyne (1997). Gascoyne (1997) observed large variability in TDS data in the upper 500 m of Canadian Shield crystalline rock and concluded that TDS concentrations in the upper 500 m of the Canadian Shield is likely indicative of local flow conditions, with higher concentrations of TDS found in discharge zones and lower concentrations measured in recharge zones. This suggests that TDS and chloride concentrations within 500 m depth do not likely increase as rapidly as the concentrations below approximately 500 m depth.

In the variability runs, we have considered that these values can increase with depth and have applied what is considered to be a conservatively high increase in concentration with depth. The EA assessed value also included an incremental addition of chloride as a function of mining. However, since the only significant source of chloride addition to the mine is the connate water, the incremental addition from mine activity is considered to be unwarranted. Nevertheless, the removal of this incremental addition and the conservative increase in concentration with depth (by using the depth average mine water concentration) has resulted in TDS values similar to those used in the environmental assessment. It is considered that the variability run that includes the increase in concentration with depth is reasonable and not unduly conservative.

Other assumptions used in the variability runs that were suggested by the interveners that likely overestimate the TDS values include:

- Use of a hydraulic conductivity profile that is expected to result in an overestimate of the brackish water upwelling since it likely underestimates the reduction in hydraulic conductivity with depth (the upwell portion of the "Depth Average + Upwell" case).

- The scenario where the mine inflow is increased by a factor of 1.33 (the "+ 1 SD Flow" case) assumes that this increased water consists of the same proportions of connate water to lake water as the water used for the EAR. In contrast to this assumption, it is expected that any increased flows over the expected case are likely due to a greater hydraulic connection between Snap Lake and the mine. In this case, most of the additional inflow would consist of lake water and would result in lower concentrations than predicted.

The assumption that the baseline concentrations over the upper 500 m increase rapidly with depth ("Depth Average + Upwell" case; and, "+ 1 SD Conc" case) suggests that the hydraulic connection between Snap Lake and the groundwater flow system is less than estimated such that diffusion is the dominant transport mechanism in the 500 m of rock between Snap Lake and the mine workings. In this case, the baseline concentrations in connate water would increase with depth in the 500 m below Snap Lake. However, this would also imply that the groundwater inflows will be less than expected. Conversely, should the inflows be 1.33 times greater than the expected value, it is likely that most of this increased water would be coming from Snap Lake, and therefore would have little incremental effect on water quality in Snap Lake.

Having closely examined available information, the underlying assumptions used in the modelling and the modelling output, it is our scientific and professional opinion that a reasonable "worst-case" mine discharge quality lies somewhere between the "EA Assessed" value and the variability scenarios provided and discussed above. In other words, the "EA Assessed" scenario represents a lower "worst-case" bound, and the various variability scenarios (particularly those with rapid connate water concentration increase with depth and no corresponding decrease in connate water inflow to the mine), result in concentration estimates that are higher than a reasonable "worst-case" alternative.

There are two key issues for interveners to resolve to their satisfaction with respect to mine water inflow quality for the Snap Lake Diamond Project. The first issue is how severe the "worst-case" scenario is, and if it should be regarded as conservative enough to ensure there is an adequate safety margin applied in predicting the impacts of the Snap Lake Diamond Project on water quality and the receiving aquatic environment. The second issue is whether there are available mitigation measures that can be used as contingency.

As indicated above, it is our scientific and professional opinion that a reasonable "worst-case" mine discharge quality lies somewhere between the "EA Assessed" value and the variability scenarios provided. However, it should be emphasized that if the concentrations in the mine discharge approached the values postulated by interveners and those assessed in the variability analyses, mitigation or contingency measures are available to reduce the impact. For example, contingency and mitigation applied in the mining operations (such as grouting of high salinity inflows in the ramp and drifts) could be implemented. This would reduce the mass load from the connate water and result in reduced concentrations in mine water discharge.

TABLE OF CONTENTS

SECTION **PAGE**

1.0 INTRODUCTION 7
2.0 FACTORS AFFECTING CONNATE WATER CONCENTRATIONS 7
2.1 Baseline Connate Water Chemistry Concentrations 7
2.2 Depth Average of the Mine 11
2.3 Chemistry Profiles 11
2.4 Hydraulic Conductivity Profiles 13
3.0 UPWELLING OF CONNATE WATER 14
3.1 Modelling Brackish Water Migration 14
3.2 Results of Upwelling Modelling 15
3.3 Discussion of Upwelling Results 19
4.0 SITE WATER QUALITY MODEL 20
4.1 Water Quality Interactions Prior to Treatment 20
4.2 Treatment and Other Model Adjustments 24
5.0 MINE WATER VARIABILITY ASSESSMENT 26
5.1 Flow Rates 26
5.2 Connate Water Concentration Values 26
6.0 RESULTS OF VARIABILITY ASSESSMENT 29
7.0 CLOSING STATEMENT 40
7.1 Context 40
7.2 Contingency Measures/Mitigation 41

LIST OF TABLES

TABLE 1 GROUNDWATER QUALITY 8
TABLE 2 SUMMARY OF AVERAGE MEASURED CONCENTRATIONS FOR SELECTED PARAMETERS 10
TABLE 3 GEOMETRIC AVERAGES OF HYDRAULIC CONDUCTIVITY BY 100 M DEPTH INTERVALS. 13
TABLE 4 HYDRAULIC CONDUCTIVITY PROFILE USED TO MODEL BRACKISH WATER MIGRATION AT SNAP LAKE 14
TABLE 5 TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN CONNATE WATER DURING MINE OPERATIONS 20
TABLE 6 PREDICTED MAXIMUM DISSOLVED CONCENTRATIONS FOR SELECTED PARAMETERS 25
TABLE 7 MODEL RUNS TO ASSESS VARIABILITY OF KEY PARAMETERS - MINE 26
TABLE 8 SUMMARY OF MINE WATER INFLOW 27

TABLE 9 SUMMARY OF MAJOR ION CONCENTRATIONS USED IN VARIABILITY ASSESSMENT .. 28
TABLE 10 SUMMARY OF MAJOR ION CONCENTRATIONS AND LOADING FOR VARIOUS MINE WATER INFLOW SCENARIOS 30
TABLE 11 SUMMARY OF NUTRIENT CONCENTRATIONS AND LOADING FOR VARIOUS MINE WATER INFLOW SCENARIOS 33
TABLE 12 SUMMARY OF SELECTED TRACE METAL CONCENTRATIONS AND LOADING FOR VARIOUS MINE WATER INFLOW SCENARIOS 34

LIST OF FIGURES

FIGURE 1 SNAP LAKE DIAMOND PROJECT UNDERGROUND DEVELOPMENT 12
FIGURE 2 TDS VS. DEPTH PROFILES CANADIAN SHIELD 16
FIGURE 3 HYDRAULIC CONDUCTIVITY DEPTH PROFILES 17
FIGURE 4 PREDICTED TDS CONCENTRATION 18
FIGURE 5 COMPARISON OF LAKEWATER CHLORIDE CONCENTRATIONS FROM GOLDSIM AND RMA MODELLING 23
FIGURE 6 TDS LOADING AND CONCENTRATION SUMMARY 36
FIGURE 7 TDS LOADING AND CONCENTRATION SUMMARY 37
FIGURE 8 DISSOLVED P LOADING AND CONCENTRATION SUMMARY 38
FIGURE 9 DISSOLVED P LOADING AND CONCENTRATION SUMMARY 39

1.0 INTRODUCTION

This memorandum presents a discussion of the factors affecting mine water inflow quality as well as the results of variability modelling. "Variability modelling" is the process by which one or more parameters or assumptions of the model are altered to investigate the changes that would result. In this case, the input parameters or assumptions in the Site Water Quality (GoldSim) model were adjusted to investigate the potential variation in the water quality of the treated discharge. Clarifications or alternative scenarios were requested by Environmental Assessment (EA) interveners in the Technical Sessions and follow-up phone conversations with Indian and Northern Affairs Canada (INAC). As a result of these intervener requests and discussions, six scenarios are presented in this memorandum:

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2.0 FACTORS AFFECTING CONNATE WATER CONCENTRATIONS

2.1 Baseline Connate Water Chemistry Concentrations

Measured concentrations in groundwater reporting to the mine workings during the Snap Lake advanced exploration program (AEP) are provided in Table 1. The information in Table 1 is sorted by rock type and by depth (for granite only), and includes six additional samples collected from the granite unit during the AEP that were not available during the initial development of the GoldSim model. The granite samples are used to represent connate water chemistry since they will make up the majority of the host rock of the mine. For the samples from the granite, correlation coefficients between depth and total dissolved solids (TDS), chloride and dissolved phosphorus are 0.4, 0.5, and 0.2, respectively. (A correlation coefficient of 1 indicates a perfect linear relationship; whereas less than 0.2 can, in most instances, be attributed to an essentially random distribution.) The data show significant variability, with a weak association between depth and TDS or chloride, and no association between depth and dissolved phosphorus.

TABLE 1
GROUNDWATER QUALITY

Sample	Elevation (m.a.s.l.)	Depth Below Snap Lake Surface (444 m)	Conventional Parameters								Nutrients			
			pH	Alkalinity	TDS	TSS	Hardness	Specific Conductivity	Colour	Turbidity-Unfiltered	Total NH_3	NO_3/NO_2	Total P	Dissolved P
			unitless	mg/L as $CaCO_3$	mg/L	mg/L	mg/L	uS/cm	TCU	NTU	mgN/L	mgN/L	mgP/L	mgP/L
Metavolcanics														
DDH#4 1/15/2001 Whole (L24552-3)	319.1	124.9	7.7	104	-	< 3	149	489	5	0.23	0.865	0.016	0.132	0.103
DDH#8 1/15/2001 Whole (L24552-4)	324.4	119.7	7.7	106	-	< 3	181	661	5	0.91	0.76	< 0.006	0.103	0.069
DDH#8 5/27/2001 9:49:00 AM Whole (1000-59)	324.4	119.7	8.2	115	220	6	101	365	< 3	1.9	0.953	< 0.006	0.081	0.069
DDH#8-01 5/27/2001 Whole (1000-69)	324.4	119.7	-	-	150	< 3	-	-	-	0.2	-	-	-	-
DDH#8-45 5/27/2001 Whole (1000-70)	324.4	119.7	-	-	140	< 3	-	-	-	0.1	-	-	-	-
Groundwater Seep 7208 8/13/2000 Whole (201618)	335.0	109.0	7.75	626	1420	< 3	567	1580	5	0.3	2.02	0.193	0.008	-
ND#3 1/15/2001 Whole (L24552-1)	320.6	123.4	7.7	124	-	< 3	101	336	5	0.26	0.788	< 0.006	0.136	0.127
SD#3 1/15/2001 Whole (L24552-2)	321.0	123.0	7.7	96	-	17	222	730	5	7.1	0.888	< 0.006	0.087	0.062
Seep MTVC 6/7/2001 Whole (1000-98)	337.5	106.5	8	86	270	3	175	571	-	0.3	0.44	0.056	0.012	0.005
UG-083-0128 5/31/2001 Whole (1000-88)	327.1	116.9	8.4	34	300	93	118	510	5	38	1.02	0.154	0.016	0.017
UG-083-084FR1 6/12/2001 Whole (1000-125)	330.3	113.7	8.7	132	330	84	147	519	25	40	0.7	0.11	0.114	0.067
UG-083-084FR2 6/12/2001 Whole (1000-126)	330.3	113.7	8	128	290	< 3	128	481	10	0.3	0.247	0.021	0.09	0.086
UG-083-084FR3 6/12/2001 Whole (1000-127)	330.3	113.7	8	127	290	< 3	120	480	10	0.3	0.237	0.017	0.094	0.089
UG-147 8/1/2001 Whole (1001-274)	324.8	119.2	8.1	110	< 10	79	87	338	25	50	0.381	0.014	0.17	0.17
UG-149 8/1/2001 Whole (1001-275)	326.7	117.3	8.3	76	70	46	36	174	10	15	0.328	0.009	0.181	0.182
P-08 8/1/2001 Whole (1001-273)	324.3	119.7	8.2	116	100	< 3	101	365	20	1.6	0.427	0.01	0.113	0.118
Kimberlites														
Seep K-01 6/7/2001 Whole (1000-96)	324.5	119.5	8	87	120	< 3	55	198	-	0.1	0.331	0.007	0.113	0.111
Seep K-02 6/7/2001 Whole (1000-97)	319.5	124.5	7.8	85	550	< 3	325	1050	-	0.45	0.013	0.187	0.039	0.035
KIM-1 8/1/2001 Whole (1001-271)	319.5	124.5	8	87	660	28	269	928	10	32	0.453	0.017	0.279	0.279
UG-094 8/1/2001 Whole (1001-272)	321.3	122.7	8.1	89	300	< 3	244	850	10	0.6	0.49	0.016	0.022	0.022
Granites														
UG-176-270ft 2001_08_12 Whole (1001-332)	362.2	81.8	8.7	127	220	4	106	369	15	1.5	0.344	0.217	0.03	0.023
UG-084-0609 6/8/2001 Whole (1000-100)	322.8	121.2	8.1	47	400	29	206	646	< 3	8.4	0.833	0.132	0.027	0.015
UG-083-1150 6/24/2001 8:00:00 PM Whole (1000-149)	317.1	126.9	11.8	356	1110	31	-	2900	5	17	4.23	4.92	0.095	0.035
UG-084-1299 6/24/2001 8:30:00 PM Whole (1000-150)	315.5	128.5	7.5	90	490	16	-	897	50	38	2.09	2.38	0.013	0.01
UG-045-0158 5/15/2001 Whole (1000-41)	315.2	128.8	8.2	109	920	44	189	700	10	68	0.668	0.023	0.083	0.076
UG-045-0778 5/25/2001 Whole (1000-56)	308.3	135.7	11	80	610	313	286	1130	< 3	105	4.06	1.27	0.083	0.003
UG-045-0988 5/25/2001 Whole (1000-58)	302.8	141.2	9.2	51	1260	520	621	2200	5	270	19.3	20.1	0.287	0.138
*UG-106-0565 5/23/2001 Whole (1000-57)	292.4	151.7	9.6	52	1340	34	756	2360	15	38	11.4	8.15	0.097	0.092
*UG-174-320ft 2001_07_27 Whole (1001-230)	291.1	152.9	7.9	80	580	33	369	1250	15	18	1.27	1.83	0.029	0.025
*UG-174-235 ft 2001_07_27 Whole (1001-229)	288.4	155.6	8	97	540	3	310	1060	10	2.2	0.788	0.096	0.017	0.017
*UG-173-100m 2001_07_24 Whole (1001-176)	288.3	155.7	7.9	94	480	50	221	821	10	30	1.06	0.69	0.027	0.028
*UG-173-67m 2001_07_23 Whole (1001-175)	286.0	158.0	10.8	63	590	143	337	1230	5	40	1.41	0.264	0.026	0.027
UG-175-401ft 2001_07_31 Whole (1001-299)	281.3	162.7	7.8	75	1360	3	510	1730	10	2	1.11	0.031	0.03	0.033
UG-106-1125 5/31/2001 Whole (1000-89)	280.4	163.6	9.3	50	1630	56	731	2230	5	37	25.4	22.2	0.072	0.032
GRA-P 7/31/2001 Whole (1001-269)	280.3	163.7	8.1	122	360	3	189	672	10	1.9	0.653	0.009	0.105	0.13

Notes: Detection limits are discussed in Appendix 9.5, Table IX.5-1 of the EA.

Indicates supplemental data not avaialble when original model runs were completed

* Indicates data averaged to determine concentrations at 155 m depth

TABLE 1
GROUNDWATER QUALITY

Sample	Nutrients			Major Ions											Dissolved Metals													
	$o\text{-}PO_4$	TKN	TOC	HCO_3	Ca	CO_3	Cl	F	OH	Mg	K	SiO_2	Na	SO_4	Al	As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	Se	Ag	Zn
	mgP/L	mgN/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Metavolcanics																												
DDH#4 1/15/2001 Whole (L24552-3)	-	0.83	3	127	43.2	< 5	84	0.76	-	9.91	4.03	15.8	32.7	7.19	0.4	0.41	< 0.05	1.4	< 0.1	< 0.6	< 5	< 0.05	18.9	2.3	0.07	0.4	< 0.1	1.3
DDH#8 1/15/2001 Whole (L24552-4)	-	0.67	2	129	58.7	< 5	138	0.95	-	8.31	3.79	14.7	51.6	8.32	0.5	0.6	< 0.05	1.8	< 0.1	1.1	< 5	< 0.05	14.3	3.86	< 0.06	< 0.4	< 0.1	< 0.8
DDH#8 5/27/2001 9:49:00 AM Whole (1000-59)	0.126	0.9	3	141	31.9	< 5	42	0.86	< 5	5.07	3.01	16.2	31.3	2.31	4	0.24	< 0.05	1.92	< 0.1	0.7	56	0.12	10.7	4.1	0.29	< 0.4	< 0.1	< 0.8
DDH#8-01 5/27/2001 Whole (1000-69)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.12	< 0.05	0.89	< 0.1	< 0.6	38	< 0.05	8.5	3.89	0.31	0.2	< 0.1	< 0.8
DDH#8-45 5/27/2001 Whole (1000-70)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	0.11	< 0.05	0.77	< 0.1	< 0.6	54	0.08	8.8	3.89	0.48	0.1	< 0.1	1
Groundwater Seep 7208 8/13/2000 Whole (201618)	< 0.002	-	3.8	-	137	-	431	0.69	-	54.4	3.57	11.2	88.8	6	< 30	-	< 0.1	1.1	0.2	0.7	< 30	0.1	37.4	5.2	1	-	< 0.1	< 10
ND#3 1/15/2001 Whole (L24552-1)	-	0.64	3	151	31.2	< 5	32	0.89	-	5.54	3.18	16	28.7	1.63	0.5	0.16	< 0.05	0.93	< 0.1	0.8	6	< 0.05	16.1	2.42	< 0.06	< 0.4	< 0.1	1.1
SD#3 1/15/2001 Whole (L24552-2)	-	2.72	2	117	66.1	< 5	165	0.69	-	13.8	4.76	16	41.4	14.5	0.4	0.78	< 0.05	1.81	< 0.1	2.1	< 5	0.14	29.6	2.28	< 0.06	< 0.4	< 0.1	2.1
Seep MTVC 6/7/2001 Whole (1000-98)	0.009	0.55	-	105	24.7	< 5	122	0.64	< 5	27.6	2.05	9.8	30.3	8.36	0.9	0.74	< 0.05	0.8	0.1	1.7	< 5	1.43	8.1	1.77	2.94	< 0.4	< 0.1	1.3
UG-083-0128 5/31/2001 Whole (1000-88)	< 0.001	1.23	6	40	41.3	< 5	107	0.73	< 5	3.52	6.12	15.2	41.9	21.2	10.8	0.7	< 0.05	< 0.06	< 0.1	1	< 5	0.05	1.5	7.07	0.7	< 0.4	< 0.1	1
UG-083-084FR1 6/12/2001 Whole (1000-125)	0.072	0.76	4	136	47.6	13	81	0.81	< 5	6.89	3.21	15.2	50.7	2.45	12.6	0.43	< 0.05	0.55	< 0.1	1	< 5	0.5	3.2	2.33	0.86	< 0.4	< 0.1	0.8
UG-083-084FR2 6/12/2001 Whole (1000-126)	0.094	0.41	4	154	40.4	< 5	73	0.79	< 5	6.52	2.61	15.9	46.2	1.82	7.5	0.32	< 0.05	0.77	< 0.1	< 0.6	45	0.67	5.1	2.18	0.36	< 0.4	< 0.1	1.7
UG-083-084FR3 6/12/2001 Whole (1000-127)	0.101	0.4	4	155	38	< 5	70	0.79	< 5	6.18	2.38	16.2	44.1	1.75	3.7	0.3	< 0.05	0.75	< 0.1	2.3	46	0.59	5	2.13	0.13	< 0.4	< 0.1	1.3
UG-147 8/1/2001 Whole (1001-274)	0.159	0.44	5	134	28.5	< 5	36	-	< 5	3.87	2.7	-	32.9	3.56	< 10	0.4	< 0.1	1.4	0.4	< 0.6	33	1.8	9	4.3	0.5	< 0.4	< 0.2	2
UG-149 8/1/2001 Whole (1001-275)	0.159	0.37	3	91	12	< 5	4	-	< 5	1.56	1.6	-	16.8	1.56	< 10	< 0.4	< 0.1	0.7	0.3	< 0.6	43	1.1	4	3.8	19.8	< 0.4	< 0.2	< 2
P-08 8/1/2001 Whole (1001-273)	0.003	0.52	3	142	32.2	< 5	42	-	< 5	5	2.98	-	33.7	1.34	< 10	< 0.4	< 0.1	1.8	0.3	2.8	14	1.8	19	4.2	0.2	< 0.4	< 0.2	< 2
Kimberlites																												
Seep K-01 6/7/2001 Whole (1000-96)	0.203	0.33	-	106	17.7	< 5	6	1	< 5	2.73	1.93	16.4	24.6	16.1	1.8	0.08	< 0.05	0.45	< 0.1	4.2	< 5	0.68	3.1	1.95	1.08	< 0.1	< 0.1	3.6
Seep K-02 6/7/2001 Whole (1000-97)	0.031	0.12	-	104	74.4	< 5	261	0.79	< 5	33.7	3.17	13.6	56.9	23.1	0.8	0.88	< 0.05	0.47	0.2	3	< 5	2.19	8.6	2.35	8.43	< 0.4	< 0.1	2.1
KIM-1 8/1/2001 Whole (1001-271)	0.021	0.54	3	106	61.6	< 5	216	-	< 5	28	3.04	-	52	21.5	30	1.6	< 0.1	9.9	0.6	1.5	240	0.3	10	2.6	29.7	< 0.4	< 0.2	< 2
UG-094 8/1/2001 Whole (1001-272)	0.083	0.56	2	108	54	< 5	200	-	< 5	26.6	3.08	-	50.1	16.9	< 10	1.5	< 0.1	5.7	0.4	< 0.6	26	< 0.1	12	2.3	1.4	< 0.4	< 0.2	< 2
Granites																												
UG-176-270ft 2001_08_12 Whole (1001-332)	0.1	0.73	4	127	37.1	14	35	1.2	< 5	3.25	10.1	16.1	28.6	1.6	0.9	< 0.03	< 0.05	< 0.06	< 0.1	0.8	6	0.1	17.7	7.79	1.15	< 0.1	< 0.1	3.2
UG-084-0609 6/8/2001 Whole (1000-100)	0.006	0.84	3	57	73.8	< 5	160	0.9	< 5	5.26	3.93	15.9	49.5	6.17	3.6	0.61	< 0.05	0.47	< 0.1	< 0.6	< 5	1.42	7.5	2.59	0.06	< 0.4	< 0.1	< 0.8
UG-083-1150 6/24/2001 8:00:00 PM Whole (1000-149)	0.012	4.01	4	< 5	226	75	372	0.34	78	0.21	17.2	3.6	76.7	9.97	7.6	2.48	< 0.05	0.06	< 0.1	0.7	106	0.37	0.1	3.83	0.87	< 0.4	< 0.1	< 0.8
UG-084-1299 6/24/2001 8:30:00 PM Whole (1000-150)	0.002	2.16	4	110	100	< 5	213	0.28	< 5	12.1	5.46	14.2	25.5	8.97	4.7	1.08	< 0.05	1.05	0.2	2.9	3460	0.17	252	3.29	1.56	< 0.4	< 0.1	5.5
UG-045-0158 5/15/2001 Whole (1000-41)	0.024	0.77	3	133	63.2	< 5	148	0.81	< 5	7.59	3.34	16.9	48.2	6.65	9.8	0.38	< 0.05	0.38	0.1	< 0.6	< 5	0.13	28.9	2.64	0.79	< 0.4	< 0.1	9.3
UG-045-0778 5/25/2001 Whole (1000-56)	0.002	3.2	3	< 5	110	19	248	0.73	16	2.79	13.7	7.2	78	28.9	1.2	0.93	< 0.05	< 0.06	< 0.1	< 0.6	15	< 0.05	< 0.1	6.48	0.49	< 0.4	< 0.1	0.9
UG-045-0988 5/25/2001 Whole (1000-58)	0.003	14.1	7	9	212	26	555	0.59	< 5	22.3	9.33	12	110	56.9	14.5	2.62	< 0.05	< 0.06	0.2	5.1	< 5	< 0.05	2.1	7.05	0.78	< 0.4	< 0.1	2.7
*UG-106-0565 5/23/2001 Whole (1000-57)	0.003	9.99	6	5	274	29	599	0.51	< 5	17.4	13.3	7.9	121	78.6	6.7	2.76	< 0.05	< 0.06	0.1	2.6	21	0.19	0.3	7.85	0.79	< 0.4	< 0.1	< 0.8
*UG-174-320ft 2001_07_27 Whole (1001-230)	< 0.001	1.39	3	97	118	< 5	305	1.01	< 5	18	6.76	15.1	72.2	30.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*UG-174-235 ft 2001_07_27 Whole (1001-229)	0.002	0.9	3	119	97.6	< 5	250	0.96	< 5	16.2	5.1	15.1	67.5	17.3	2.2	1.17	< 0.05	5.49	< 0.1	0.7	< 5	< 0.05	38.3	3.05	< 0.06	< 0.4	< 0.1	4
*UG-173-100m 2001_07_24 Whole (1001-176)	0.005	1.16	2	115	70.4	< 5	191	0.9	< 5	10.9	4.89	14.5	69.7	15.3	4.2	0.96	< 0.05	3.37	< 0.1	< 0.6	< 5	< 0.05	13.9	6.83	< 0.06	< 0.4	< 0.1	1.1
*UG-173-67m 2001_07_23 Whole (1001-175)	0.004	1.41	5	< 5	133	26	291	0.87	7	1.15	13.1	12.1	59.5	38.6	3.1	1.37	< 0.05	4.56	< 0.1	0.8	< 5	< 0.05	< 0.1	9.01	< 0.06	0.4	< 0.1	1.2
UG-175-401ft 2001_07_31 Whole (1001-299)	< 0.001	1.03	2	91	165	< 5	442	0.62	< 5	23.9	7.6	15.5	83	34.1	1.1	1.88	0.05	9.69	< 0.1	10.2	36	0.45	72.9	1.59	< 0.06	< 0.4	< 0.1	1.6
UG-106-1125 5/31/2001 Whole (1000-89)	0.002	14.6	5	< 5	247	36	557	-	< 5	27.7	18.9	13	127	57.2	40.2	3.33	< 0.05	< 0.06	0.2	24.6	< 5	< 0.05	6.7	11	4.81	< 0.4	< 0.1	1
GRA-P 7/31/2001 Whole (1001-269)	0.057	0.72	3	148	62.9	< 5	121	-	< 5	7.83	4.61	-	56.4	9.03	< 10	0.9	< 0.1	3.5	0.1	2.3	10	0.2	26	5.6	0.6	< 0.4	< 0.2	4

A summary of different combinations of inflow chemistry data is provided in Table 2. The inflow chemistries were used to investigate a number of assumptions with respect to data quality. The average expected values ("Expected" case) and the average expected values + 1 Standard deviation ("+1 SD Conc" case) were based on the samples available from the granite unit at the time of initial GoldSim model setup. The "EA Assessed" case represents the actual values used in the EAR. Although the connate water concentrations in the "EA Assessed" and "Expected" cases are the same, in the model calculations for the "EA Assessed" case, an additional 88 mg of chloride per litre of inflow was incrementally added in the working areas. This was done to account for site observations made during the early phases of mine development. During operation, chloride is not expected to be added in the working areas of the mine. The only significant source of chloride is the connate water (grout and cement are not a significant source of chloride to the mine relative to the mass load from the connate water). Therefore, in the "Expected" case and variability assessment, the incremental addition of chloride is not included. Incremental addition of other chemical parameters (e.g., calcium) as a function of the working area is, however, incorporated in the "Expected" case as discussed in Appendix IX.1 of the environmental assessment report (EAR; De Beers 2002).

Table 2 is intended to illustrate data characteristics and provide clarification. Data in some of the columns (e.g., the data in columns "155 m Depth" and "Saline") are used to calculate water quality in sections 2.3 and/or 5.2 of this Technical Memorandum. However, three columns were not used in variability modelling: "Expected (including additional data)", "Expected (excluding high pH and nitrate)" and "155 m Depth (excluding high pH and nitrate)". These three columns are presented to clarify issues as discussed below.

The currently-expected values are from the granite unit (Expected [including additional data] column in Table 2) and include the additional six data points that were collected during the latter part of the AEP. Five of these samples were collected from between 152 and 162 m depth in the granite (155 m depth). As can be observed in Table 2, the averages that include the additional data points are all lower than those used in the EAR (De Beers 2002).

Interveners expressed concern that some of the water samples included in the EAR were affected by mine operations based on their elevated nitrate and pH values. To address this concern, averages were recalculated without these seven samples, the results of which are presented in the "Expected (excluding high pH and nitrate)" column in Table 2. Once again, the recalculated averages are all lower than those used in the EAR, indicating that the inclusion of these samples resulted in concentrations that were biased high.

Since five data points were available centred around the "155 m Depth", this datum was used as the starting point for calculation of the depth-averaged concentrations as discussed in Section 2.3. The data are presented in Table 2. Note that the exclusion of the two high pH and nitrate samples at about 155 m depth ("155 m Depth (excluding high pH and nitrate)" yielded values lower in concentration than the "155 m Depth" average. Also provided in Table 2 are averages for the "Saline" chemistry data, which represent the average of the three data points in the AEP that contained the highest chloride and TDS values. These high values are used in the GoldSim model variability runs to model increases in chemical concentrations as discussed in Section 4.

Table 2: Summary of Average Measured Concentrations for Selected Parameters

		Granite							All Rock-Types
NEEDS TO BE FULL NAMES (BELOW)	Units	"EA Assessed" and "Expected"	Expected + 1 SD	Expected (including additonal data)	Expected (excluding high pH and nitrate)	155m Depth	155m Depth (excluding high pH and nitrate)	Saline	All Samples
n		9	9	15	8	5	3	3	30
TDS	mg/L	902	1,362	793	624	706	533	1,410	570
Cl	mg/L	330	525	299	218	327	249	570	200
Ca	mg/L	152	238	133	91	139	95	244	86
Na	mg/L	77	113	72	56	78	70	119	55
K	mg/L	10	16	9	6	9	6	15	6
SO4	mg/L	29	57	27	15	36	21	64	17
Alkalinity	mg/L	106	204	100	90	77	90	51	116
Dissolved P	mg/L	0.06	0.11	0.05	0.03	0.04	0.02	0.09	0.07

"EA assessed" and "Expected" based on 9 samples available at the time of model set-up
"Expected (including additional data)" based on all granite samples available
"155 m Depth" based on samples within 5 m of 155 m depth
"Saline" includes the three samples that contained high TDS and Chloride
"All Samples" includes all samples of groundwater collected from ports and seeps during the AEP

2.2 Depth Average of the Mine

An approximate area-weighted depth average for the mine was calculated by assigning average depths to areas as determined from the mine plan (Figure 1). The areas were based on the surface outline of the mine. Only areas expected to receive groundwater inflows were included; that is, areas where the mine was expected to be in permafrost were excluded from the calculations. Inclusion of the mine area that is expected to be in permafrost would result in a shallower (i.e., closer to surface) average mine depth. The depth average of the mine was taken as the mid-point depth below which and above which ½ of the mine *area* is located. This depth was calculated to be 209 m below the surface of Snap Lake as indicated in Figure 1.

2.3 Chemistry Profiles

Chemistry profiles for Snap Lake groundwater are based on measured values and comparison with chemistry profiles from other locations in the Canadian Shield, notably Diavik (Frape and Fritz 1997; Gascoyne 1997; Golder 1998). Two TDS/depth profiles (Profile #1 and Profile #2) were developed for the Diavik Project. Profile #3 was developed for the Snap Lake site based on site-specific data from the Snap Lake Diamond Project augmented by the Diavik Profile. The three profiles are shown in Figure 2.

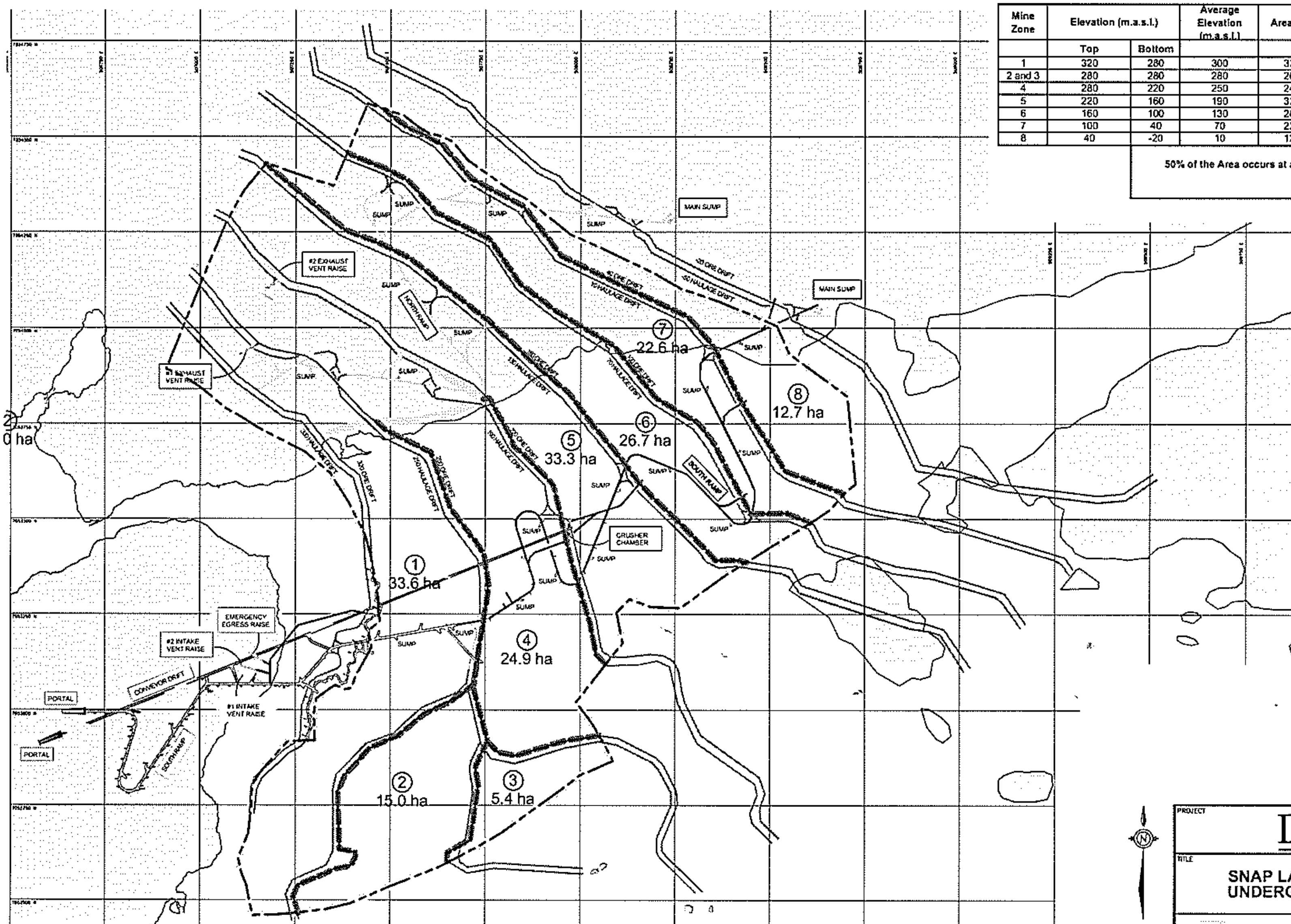
Profile #1 is based on chemical analyses of deep saline water collected by various investigators from several mines in the Canadian Shield, including mines in the Yellowknife area. These analyses are presented in Frape and Fritz (1997). The data used for development of Profile #1 are considered the most comprehensive data set available for the composition of deep groundwater in the Canadian Shield. Using the Frape and Fritz data, Profile #1 was developed by Blowes and Logsdon (1997) in support of the Diavik project, and accounts for dilution of water samples that may have occurred during collection. There is a *logarithmic* increase in TDS in relation to depth.

Profile #2 is based on site-specific data from Diavik (Golder 1998) augmented by data from the Lupin mine located approximately 200 km north of Diavik. The Diavik data were collected from seeps and ports in an exploratory decline, from a five-day pumping test, and from deep delineation drilling. The maximum depth of the Diavik chemistry data is about 400 m. Based on tritium concentrations, none of the Diavik samples showed evidence of dilution by modern waters such as drilling fluids or lake water. Profile #2 is hereafter referred to as the Diavik Profile.

Profile #3 in Figure 2, hereafter referred to as the Snap Lake Profile, is based on site-specific data from the Snap Lake Diamond Project augmented by the Diavik Profile. Using the measured concentrations in five groundwater samples from within 5 m of 155 m below Snap Lake, the average chloride and TDS concentrations at this depth were 327 mg/L and 706 mg/L, respectively. At greater depths, it is assumed that the Snap Lake profile parallels the Diavik Profile and that relative changes in the Snap Lake Profile are the same as those in the Diavik Profile. For example, at 155 m depth, the Diavik Profile indicates a TDS concentration of 239 mg/L and, at 450 m depth, it is 813 mg/L or an increase of approximately 3.4-times over that depth interval. At Snap Lake, the TDS concentration was found to be approximately 706 mg/L at 155 m depth. Therefore, the corresponding TDS concentration at 450 m depth would also be 3.4 times greater or approximately 2,400 mg/L.

Mine Zone	Elevation (m.a.s.l.)		Average Elevation (m.a.s.l.)	Area (ha.)	Percentage of Total Area	Cumulative Percentage
	Top	Bottom				
1	320	280	300	33.6	19.3%	19.3%
2 and 3	280	280	280	20.4	11.7%	31.0%
4	280	220	250	24.9	14.3%	45.3%
5	220	160	190	33.3	19.1%	64.4%
6	160	100	130	26.7	15.3%	79.7%
7	100	40	70	22.6	13.0%	92.7%
8	40	-20	10	12.7	7.3%	100.0%

50% of the Area occurs at approx. 235 m.a.s.l.
or 209 m depth below Snap Lake



LEGEND

- APPROXIMATE MINE LIMITS
- APPROXIMATE BOUNDARY OF MINE AREA CONTRIBUTING TO GROUNDWATER INFLOW
- SUBDIVISIONS FOR PURPOSES OF CALCULATING DEPTH AVERAGE
- ⑧ 12.7 ha APPROXIMATE AREA BETWEEN ORE DRIFTS, USED IN DEPTH AVERAGE CALCULATION

MINE DEVELOPMENT

- HAULAGE DRIFTS
- ACCESS DRIFTS
- ORE DRIFTS
- SUMPS
- CONVEYOR DRIFT/ PREPRODUCTION DEVELOPMENT

50 0 50 100 150 200 250
METRES

PROJECT
DE BEERS

TITLE
SNAP LAKE DIAMOND PROJECT
UNDERGROUND DEVELOPMENT

Golder Associates
Mississauga, Ontario

PROJECT No. 031-322017			FILE No. 0313220177AA01.DWG
DESIGN			SCALE AS SHOWN | REV. 0
CADD	TDR	13/2/03	FIGURE: 1
CHECK			
REVIEW			

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2.4 Hydraulic Conductivity Profiles

A number of investigators have conducted extensive hydraulic conductivity testing in the crystalline bedrock of the Canadian Shield and at other, similar locations. These studies include Davison et al. (1994a,b), Stevenson et al. (1996a,b), and Ophori et al. (1996) at the Whiteshell Research Area in Manitoba; Ophori et al. (1994) at the Atikokan Research Area in Manitoba; Raven et al. (1987) at East Bull Lake in Ontario; and Burgess (1979) at various sites in Sweden. Hydraulic conductivity-depth profiles developed for these sites from field measurements are presented in Figure 3a. Profiles resulting from calibration of groundwater flow and transport models at the Whiteshell Research Area and at the Atikokan Research Area are shown on Figure 3b. Hydraulic conductivity of the rock mass decreased with depth at all locations.

At Diavik, hydraulic conductivity testing was conducted to a maximum depth of 590 m. To assess the hydraulic conductivity with depth, geometric averages of the hydraulic conductivity were calculated over 100 m depth intervals. The resulting profile is presented in Figure 3a and is summarized in Table 3.

Table 3 Geometric Averages of Hydraulic Conductivity by 100 m Depth Intervals

Depth Interval (m)	Number of Measurements	Hydraulic Conductivity (m/s)
30 to 100	116*	2.5×10^{-7}
100 to 200	67	1.8×10^{-7}
200 to 300	30	2.0×10^{-7}
300 to 400	9	3.1×10^{-8}
400 to 500	5	3.0×10^{-8}**
500 to 600	3	6.7×10^{-9}

* The results of tests conducted in the upper 30 m were excluded from the average.

** Average calculated without a possible outlier (test #5 in borehole GTH-42) that was conducted over a broken zone using a shorter packer interval than other packer tests.

The results indicate a trend in the reduction of the hydraulic conductivity of the country rock with increasing depth that, as shown in Figure 3a, is in general agreement with data collected at other locations in the crystalline bedrock of the Canadian Shield and elsewhere.

Figure 3b presents the hydraulic conductivity profile that was used for the modelling of brackish water upwelling at Diavik. Compared to the other profiles, the Diavik profile assumes the smallest reduction of hydraulic conductivity with depth. This profile was considered to be conservative as it is expected to underestimate the reduction in hydraulic conductivity with depth and thereby overestimate the amount of upwelling.

At Snap Lake, the hydraulic conductivity profile used for the modelling of brackish water migration was based on data used in the hydrogeologic model developed to estimate mine inflows (MINEDW) for the upper 400 m, together with the relative changes in depth as indicated in the Diavik Profile. Specifically, this profile is shown in Table 4.

Table 4 Hydraulic Conductivity Profile Used to Model Brackish Water Migration at Snap Lake

Hydrostratigraphic Unit	Horizontal Hydraulic Conductivity (m/s)
Granite – exfoliated	2.3E-05
Granite - hanging wall	2.3E-06
Granite - footwall (above 400 m)	4.6E-07
Granite -footwall (400 m to 700 m)	4.6E-08
Granite - footwall (below 700 m)	4.6E-09

In summary, the hydraulic conductivity profile used to assess connate water upwelling for the Snap Lake Diamond Project is based on the Diavik profile. Compared to other testing conducted in similar type bedrock, the Diavik profile underestimates the reduction in hydraulic conductivity which results in an overestimate in the connate water upwelling. Consequently, the Snap Lake hydraulic conductivity is considered to result in a conservatively high estimate of connate water upwelling.

3.0 UPWELLING OF CONNATE WATER

The potential for migration of deep-seated connate groundwater into the Snap Lake mine workings was assessed based on the assumed (but not measured) Snap Lake chemistry profile and the assumed Snap Lake hydraulic conductivity profile as discussed above. The assumed Snap Lake profile also considered the effect of the concentrations on the density of the groundwater with TDS concentrations varying from 1,000 mg/L to 31,000 mg/L corresponding to densities of 1.0007 g/cm^3 to 1.0229 g/cm^3.

The assumed Snap Lake hydraulic conductivity profile is considered conservative in that it results in greater upwelling and therefore higher chemical concentrations in the connate water than would actually occur. The purpose of the supplemental hydrogeological mass transport modelling was to provide a conservative estimate of the potential for upwelling of this deep connate water and to provide an estimate of the potential concentration changes of constituents (principally chloride and TDS) over time in order to address the scenarios proposed by the interveners.

3.1 Modelling Brackish Water Migration

The potential increase in concentration of connate water due to the upward migration of brackish water was assessed using a three-dimensional model that was developed using FEFLOW. FEFLOW is a finite element code, which is capable of simulating three-dimensional thermohaline flow and transport in heterogeneous porous media under a variety of boundary conditions. The code provides a solution to the simultaneous flow and transport problem coupled with a density gradient. (In most groundwater modelling studies, density effects are ignored because the differences in water density within the groundwater regime are essentially negligible. However, high-density contrasts may result in the formation of density gradients that will affect groundwater movement and mass transport.)

An area equivalent to six months of mining was simulated in the FEFLOW model. This was represented as one mine opening in the kimberlite that was 220 m wide by 220 m in length. The mine opening is located at the weighted average depth of 210 m below Snap Lake. The entire mine plan could not be simulated because the computational requirements for the three-dimensional (density-coupled) mass and transport simulation that incorporated detailed mine geometry were excessive. In the model, the mine opening is assumed to be opened in the first year of mining and then left open for the life of the mine (22 years). In reality, mine workings in the kimberlite, would be open for approximately six months at which time the mine area would be backfilled. Consequently, the approach that was used to incorporate the mine plan in the FEFLOW model is considered conservative, in that it will tend to overestimate the upwelling of deep-seated brackish water.

Because it is difficult to estimate the total mass to the entire mine plan, based on the simulation of the single mine opening (representative of six months of mining), the FEFLOW model was used to assess the increase in the TDS concentration of the connate water caused by the upwelling of brackish water. The MINEDW model was then used to assess the proportion of lake water to connate water for the entire mine throughout the mine life.

In the simulation of upwelling, the following assumptions were made:

- All hydrogeologic parameters used in the MINEDW model presented in the EA were assumed for the FEFLOW model including leakance values, hydraulic conductivity values, depth of permafrost, porosity, etc.

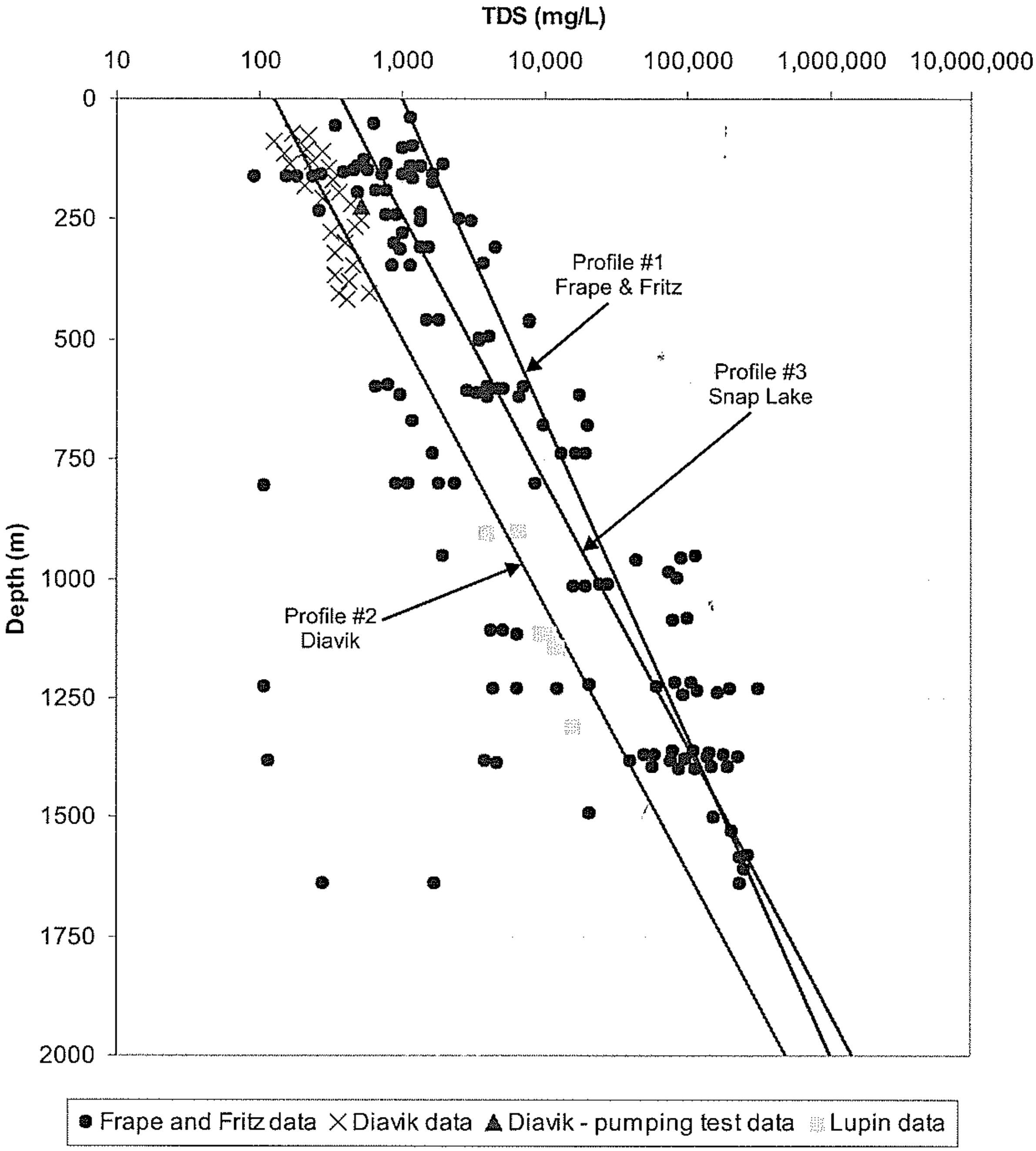
- At depths of greater than 400 m (the approximate depth of the model at the location of the assumed mine workings), the relative reduction of hydraulic conductivity with depth is equivalent to that of Diavik (as presented above).

- The TDS-depth profile is assumed to be that of Diavik. The relative changes observed from the modelling would then be applied to the TDS concentrations observed at Snap Lake. That is, if modelling showed a 1.2 times increase in the connate water TDS concentration, then the same relative increase would be expected for the Snap Lake TDS-depth profile.

3.2 Results of Upwelling Modelling

To assess the changes in the concentrations of the TDS in the connate water, the following procedures were used:

1) Plots of TDS contours for each year that the mine workings are open were plotted as shown in Figure 4. All concentration contours that originated from below the mine level were assumed to represent connate water. The areas of the mine intersected by this connate water were identified.



PROJECT

SNAP LAKE PROJECT

TITLE

TDS vs. DEPTH PROFILES
CANADIAN SHIELD

Golder Associates

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CADD	WZ	10FEB03	
CHECK	WZ	10FEB03	**FIGURE 2**
REVIEW			

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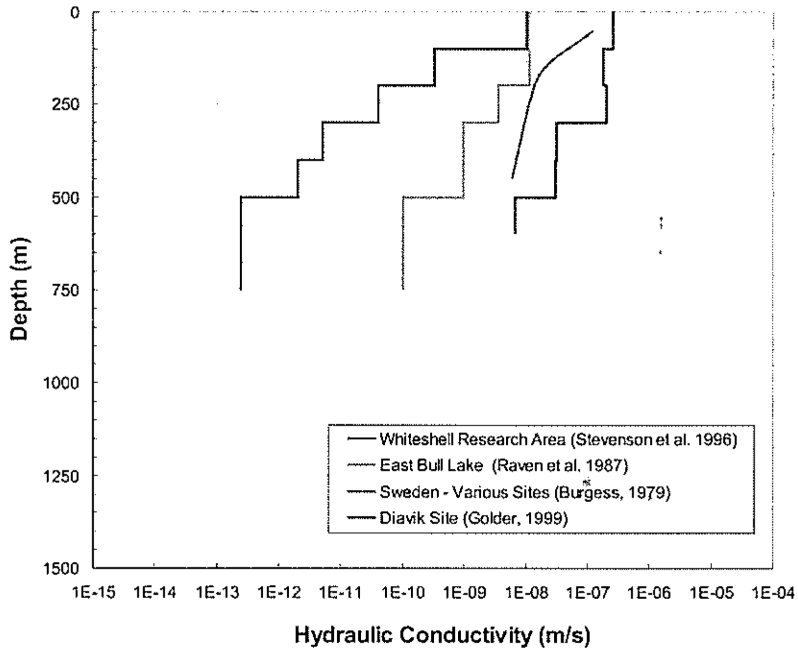
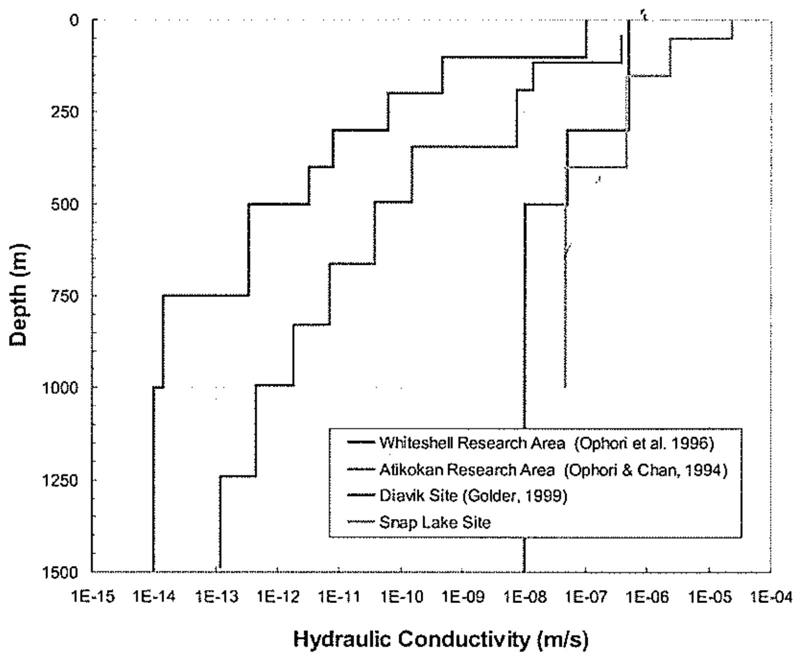


A. Measured Hydraulic Conductivity



B. Hydraulic Conductivity Used in Calibrated Models

PROJECT

SNAP LAKE PROJECT

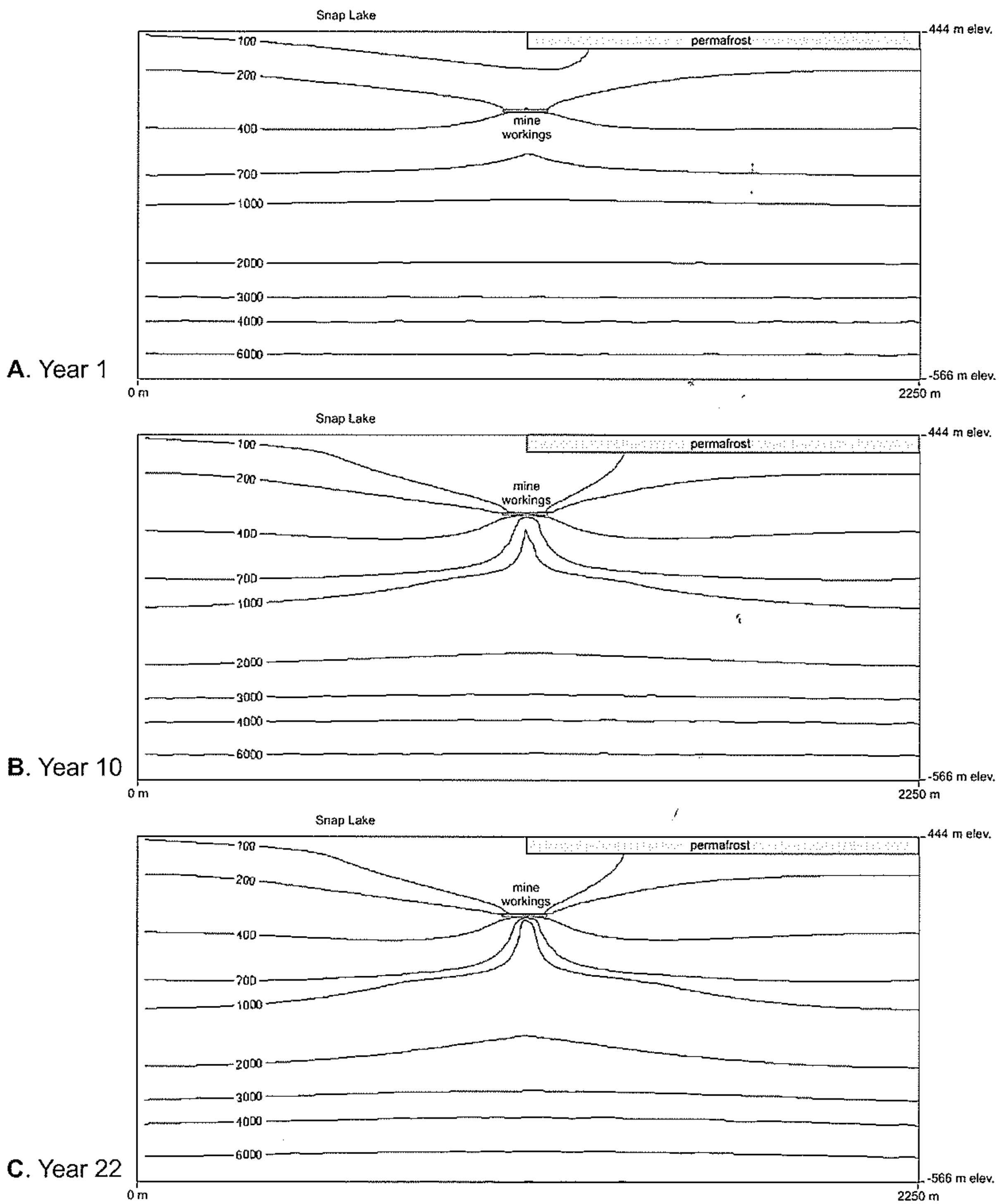
TITLE

HYDRAULIC CONDUCTIVITY
DEPTH PROFILES

Golder Associates

PROJECT No.		022-6659	FILE No. Figures_upwelling.cdr	
DESIGN	WZ	10FEB03	SCALE NTS	REV.
CADD	WZ	10FEB03	FIGURE 3	
CHECK	WZ	10FEB03		
REVIEW				

PROJECT NO. 022-6659 DRAWN BY: wz REVIEWED BY: wz DATE: FEB-10-03 FILE LOCATION: O:\Active\6000\2002\022-6659\Drawings\Figures_upwelling.cdr



Note
TDS contours are in mg/L.
Scale is approximate.

PROJECT

SNAP LAKE PROJECT

TITLE

PREDICTED TDS CONCENTRATION

Golder Associates

PROJECT No.		022-6659	FILE No. Figures_upwelling.cdr	
DESIGN	WZ	10FEB03	SCALE NTS	REV.
CADD	WZ	10FEB03	**FIGURE 4**	
CHECK	WZ	10FEB03		
REVIEW				

PROJECT NO. 022-6659 DRAWN BY: WZ REVIEWED BY: WZ DATE: FEB-10-03 FILE LOCATION: O:\Active\6000\2002\022-6659\Drawings\Figures_upwelling.cdr

2) A weighed average of the TDS concentrations along the bottom of the mine areas identified above was calculated. This value was then used to determine the increase in connate water TDS concentrations. For example, if the TDS concentration in original connate water below the mine workings was 100 mg/L and the calculated concentration after one year was 130 mg/l, that would represent a 1.3 times increase in the connate water TDS concentration.

Figures 4a, 4b and 4c present the connate upwelling for 1, 10 and 22 years of mining. Table 5 provides the increase in connate water TDS concentration for each year that the mine workings are assumed to be open. The connate water TDS concentration increases rapidly in the first year. Then, for the next eight years, it remains constant at approximately 1.45 times the background value. After eight years, the connate water TDS concentration gradually rises to 1.58 times that of the background value at year 22.

3.3 Discussion of Upwelling Results

The model simulations assume that one mine area (representing approximately six months of mining) is open for the entire 22 years of mine life. In reality, each of these mine areas will only be open for approximately six months at which time they are backfilled. Once they have been backfilled, inflows to these backfilled mine blocks are much reduced and the panels no longer act as sinks for the upward migration of brackish water (this has been confirmed with the MINEDW model). In addition, as discussed above, the reduction in hydraulic conductivity with depth used for Snap Lake is considered conservatively low and, in reality, the reduction with depth will likely be much greater. The hydraulic conductivities used in the FEFLOW simulation would therefore tend to promote more upwelling than would actually occur.

The results of the modelling indicate that the connate water concentration increases by 1.45 times in the first year and remains at that value for approximately eight years. Considering the conservative approach described above, a 1.45 times increase in the TDS concentration of the connate water is considered appropriate and conservative for estimating TDS concentrations of connate water in the mine.

Table 5 Total Dissolved Solids Concentrations in Connate Water During Mine Operations

Time (year)	Factor of Increase in Connate Water TDS Concentration
1	1.43
2	1.45
3	1.46
4	1.45
5	1.44
6	1.44
7	1.45
8	1.45
9	1.46
10	1.47
11	1.48
12	1.49
13	1.50
14	1.51
15	1.52
16	1.53
17	1.54
18	1.54
19	1.55
20	1.56
21	1.57
22	1.58

4.0 SITE WATER QUALITY MODEL

The variability assessment was completed using the Site Water Quality model (GoldSim) to investigate mine water inflow and chemistry variability as suggested by interveners at the Technical Sessions in November and December, 2002. A detailed description of the Site Water Quality model and associated assumptions and linkages can be found in Appendix IX.1 of the EAR. A brief description outlining the site interactions that affect the discharge water quality is provided below. Also presented is a summary of adjustments to model assumptions and changes to model linkages that were made in the model to better represent our current understanding of site interactions and treatment.

4.1 Water Quality Interactions Prior to Treatment

The mine water management system for the Snap Lake Diamond Project will collect and treat water from the underground mine workings, and runoff and seepage from disturbed areas, prior to discharging it to Snap Lake. These "site" waters account for nearly all (over 99%) of the water affected by the project. Mine water alone represents greater than 95% of all the water affected by the project. The sources of site water include the following:

- connate groundwater inflow to the mine;
- Snap Lake water contribution to the mine;
- runoff and seepage from the North Pile; and
- site runoff from developed and undeveloped areas.

Flows and concentrations have been predicted for each of these waters on a weekly basis for the duration of construction and operations, and at post-closure. In addition to the mass loading (flow multiplied by concentration) associated with each source water, the groundwater inflow to the underground mine workings will also receive a mass loading due to additional sources:

- water-rock interactions at the active mine face; and
- water released due to consolidation of paste backfill placed in mined-out workings.

The water discharged to Snap Lake will also include tertiary treated effluent from the sewage treatment plant (STP).

A brief description of each main site water source used in EA modelling is provided as follows:

Connate Groundwater – During initial mining, the majority of groundwater inflow to the mine workings will be connate groundwater. In the environmental assessment, the overall chemistry and TDS concentrations in connate groundwater were based on measured mean values from nine borehole samples from the granitic unit, which is the source of the majority of groundwater inflow to the mine.

Lake Water Contribution to Mine – As connate groundwater seeps into the mine workings, the water will be replaced by recharge from Snap Lake, which overlies much of the mine workings. This groundwater recharge from Snap Lake will have a very short residence time (weeks to months) in the rock mass between the mine and Snap Lake compared to connate groundwater (centuries). The contribution of lake water to mine inflows will increase over time, to a maximum contribution of about 70% near the end of operations. Lake water inflow concentrations are based on modelled concentrations in Snap Lake. Concentrations were assumed not to change along the flow pathway between Snap Lake and the mine workings because of the very short residence time.

To account for the feedback between the lake water contribution to the mine and the effect of the treated water discharge on lake concentrations, a simple, yet conservative mixing model was incorporated into the GoldSim Site Water Quality model. The model assumes that the treated water discharge and watershed runoff from areas upstream of the discharge (96% of the total watershed runoff) mix in 10% of the volume of Snap Lake (8.7 Mm^3). The mixed concentrations are then allowed to recharge the mine workings.

The approach is conservative since the inherent assumption of mixing 10% of the volume of Snap Lake will overestimate concentrations compared to the expected concentrations (i.e., those predicted by the Snap Lake [RMA] mixing model results). In order to assess the appropriateness of this assumption, Figure 5 provides a comparison between the lake water concentrations from the simplified mixing model and those calculated for the same case using the RMA lake mixing model. As can be observed in Figure 5, the simple Site Water Quality mixing model overestimates the concentrations in the lake water recharging the mine relative to the RMA model. The differences in the shape of the concentration over time curves presented in Figure 5 are a result of the volume of lake water that is assumed in the model. If a larger percentage of lake water were allowed to mix with the discharge, the Site Water Quality model values in Figure 5 would be more similar to those of the RMA model.

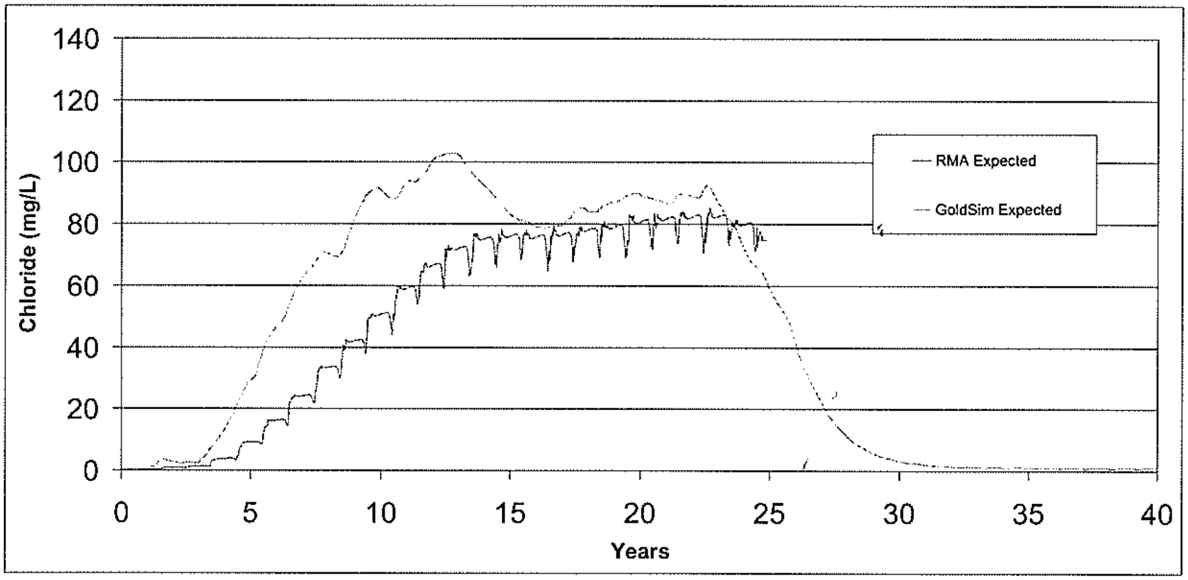
North Pile and Site Runoff –North Pile runoff and seepage, and site runoff from developed areas are combined in this technical memorandum because their contribution is very small relative to mine waters. Runoff and seepage from the North Pile will be collected in a settling pond, prior to discharge to the water treatment plant. Runoff from developed and undeveloped areas of the mine footprint will be collected in the Water Management Pond (WMP) prior to being discharged to the water treatment plant. Concentrations in North Pile runoff and seepage were based on average results from laboratory kinetic tests (EAR Appendix III.2 and IX.1), adjusted for site factors, temperature and solubility constraints where appropriate. Concentrations in site runoff concentrations were based on measured values of runoff from areas developed during the AEP (EAR Appendix IX.1).

Working Area Contribution – Groundwater inflow at working areas (areas being actively mined) is expected to receive an incremental increase in concentrations of some parameters (as determined during the AEP) due to interactions of mine water with fine rock material, explosives, grout and cement. The effects of explosives, grout and cement were considered separately and are discussed below. The increase in concentrations due to interactions of mine water with fine rock material in active working areas was based on the difference observed between the inflow values and discharge values during the AEP at Snap Lake in 2001. For example, if the measured inflow chemistry for a parameter during the AEP was 0.2 mg/L and the measured mine water discharge chemistry was 1 mg/L, then the difference between these two values (0.8 mg) would be added per litre of groundwater to working areas of the mine.

Conservatively, in the "EA Assessed" case, an incremental addition of 88 mg of chloride per litre of water flowing through the working area of the mine was included in the model. This is conservative since no additional source of chloride is expected from the mine workings during operation. In the "Expected" case, this incremental addition of chloride is therefore not included.

Explosives, Grout, and Cement – Contributions assigned to explosives, grout, or cement use were based on their composition and usage rates as determined from the manufacturer data sheets and mining plan, respectively.

Comparison of Lakewater Chloride Concentrations from GoldSim and RMA modelling	Figure 5



Date: February, 2003
Project: 03-1322-017

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Chkd KJD

Golder Associates

Paste Backfill – Paste backfill that is placed into inactive mine areas will consolidate over time, releasing water to the mine. It was assumed that consolidation would release 14% of the paste porewater to the mine workings. Concentrations in consolidation water from paste backfill were based on laboratory test measurements of short-term leachate concentrations from paste backfill samples obtained during the AEP. Supplemental long term testing shows that the concentration used in the EAR are conservatively high; that is, the values used in the EAR overestimate the potential impacts.

Sewage Treatment Plant Effluent – Sewage treatment plant effluent characteristics are based on the design specifications and are not included in the Site Water Quality model, but are included in the Snap Lake RMA model.

4.2 Treatment and Other Model Adjustments

Treatment – Removal of suspended solids was the only form of water treatment accounted for in the EAR. The current model results include limits on the maximum expected concentrations in the dissolved phase (as determined from the pilot plant testing discussed in EAR Appendix IX.8). Maximum dissolved concentrations currently allowed at the treated discharge are shown in Table 6.

An additional level of conservatism was included in the EAR since removal of chemical mass contained in recycle water (water from treatment to the process plant) was not included (i.e., no mass was removed from the treated discharge reporting to Snap Lake as a function of recycling of treated water back to the process plant). In the current model version, this mass is removed from the system since it will be contained in the process water discharged to the North Pile, and is already accounted for in mass released from the North Pile.

The treated discharge maximum concentrations currently incorporated in the model are based on the maximum values expected due to solubility constraints that occur in the treatment system and processes such as co-precipitation or adsorption. In a treatment system, these processes are enhanced due to treatment additives. The limits and values provided as treatment discharge concentrations are based on the upper level (i.e., high discharge concentrations) of proven treatment technology that would be feasible for the Snap Lake site if required.

Total Phosphorus - In the EAR, lake water inflow concentrations (to the mine) for phosphorus represented total phosphorus (including particulate from the lake water). This represented a conservatively high estimate of lake water phosphorus contribution to the mine since particulate phosphorus would be removed in the lake bed sediments or along the groundwater flow pathway. In the model calculations presented in this technical memorandum, only dissolved phosphorus was included in the lake-water contribution to the mine.

Other Adjustments – Another minor adjustment to the model structure included refinement of the natural recharge rate to Snap Lake. This refinement had little or no effect on modeled concentrations in Snap Lake. There was no change in the average annual rate applied. However, rather than applying the recharge averaged over the year as was done in the EA model, the recharge in the current model is proportioned by month using the same proportionality factors as the site runoff (Appendix IX.1). This will better reflect natural runoff variability.

Table 6: Predicted Maximum Dissolved Concentrations for Selected Parameters

Parameter	Units	Max Applicable Dissolved Feed	Thickener/Filter Treatment System		Site Water Qualtiy Model Limit Used
			Predicted Max*	Ave	
Suspended Solids	mg/L		6	3	5
Dissolved Phosphorus	mg/L			0.02	0.02
Orthophosphate	mg/L			0.02	0.02
Metals					
Aluminum	µg/L	150	150	100	150
Arsenic	µg/L	5	4	2	4
Cadmium	µg/L	1	0.1	0.1	0.1
Chromium	µg/L	20	16	8	16
Cobalt	µg/L	2	2	1	2
Copper	µg/L	100	7	3	7
Iron	µg/L	2000	100	50	100
Lead	µg/L	2	0.5	0.3	-
Mercury	µg/L	**	0.02	0.02	0.02
Molybdenum	µg/L	20	12	6	12
Nickel	µg/L	5	3	3	3
Selenium	µg/L	1	1	1	1
Silver	µg/L	**	0.05	0.05	0.05
Zinc	µg/L	60	10	5	10

*- Full scale operation
** - would be removed with S-2 if required.

5.0 MINE WATER VARIABILITY ASSESSMENT

A number of variability scenarios with respect to mine water flows and concentrations were suggested by interveners. Based on the input received at the Technical Sessions, it was decided to use the GoldSim Site Water Quality model to assess potential variability in mine water inflow and chemistry variability based on some of these scenarios. These scenarios are intended to incorporate some of the suggestions of the interveners to develop what we consider to be the upper end of possible mine water inflows and concentrations postulated by the interveners.

A summary of the variability runs completed using the Site Water Quality model is provided in Table 7.

Table 7 Model Runs to Assess Variability of Key Parameters - Mine

Model Run	Description	Assumptions
R1	**EA ASSESSED CASE**	Conditions as assessed in the EA (De Beers 2002)
R3	**EXPECTED CASE**	Conditions as currently understood
	MINE	
R3a	+1 SD Flow	Expected flow plus 1 standard deviation of flow
R3b	+1 SD Conc	Expected concentration plus 1 standard deviation of concentration
R3c	depth average	Concentration adjusted based on estimated depth average of mine (210 m) and water quality profile developed for Snap Lake (Profile #1)
R3d	depth average plus upwell	Upwelling of connate water results in about 45% increase in concentrations of TDS after year 1 of operations

5.1 Flow Rates

Table 8 provides the average annual mine inflow rates (averaged from year 15 to 22 of the mine life) for the "EA Assessed" case, the "Expected" case and the "+1 SD Flow" case. An increase of 1 standard deviation equates to 1.33 times the expected inflows. The standard deviation on the flows was provided in Appendix IX.3 of the EAR based on an assessment of mine inflow variability.

5.2 Connate Water Concentration Values

Table 9 provides a summary of connate water concentrations used in the variability assessment as proposed by the interveners. These include "EA Assessed" (values as used in the EA), "Expected", and "+1 SD Conc" values adjusted to reflect the average depth of the mine ("Depth Average" case), and average depth of mine plus an upwelling component ("Depth Average Plus Upwell" case). The use of the average depth of mine in assigning concentrations for the variability assessment is considered reasonable since the panels will be developed at various locations and elevations over the mine life. The timing of planned mine development is provided in Appendix IX.3 of the EAR.

Table 8
Summary of Mine Water Inflow

Flows - Average of Years 15 - 22

Component		"EA Assessed" - Flows (m3/d)	"Expected" - Flows (m3/d)	"Expected" Flows + 1SD (m3/d)
Loadings to Mine	Recharging Groundwater	6894	6894	9169
	Recharging Lakewater	15934	15934	21192
	Paste Bleedwater	182	182	182
	Incremental Chemistry at Working Face	13965	13965	18574
Treatment Feed	from the Mine [sump]	23010	23010	30543
	from the North Pile Temp Pond [runoff]	533	533	533
	from the Water Management Pond [site runoff]	185	185	185
	Treatment Feed [Total]	23728	23728	31261
Treated Discharge		23701	22913	30446

Note: Difference in Feed Volumes and Discharge Volumes Due to Recycle water in mill

	Measured Values				Calculated Values	
	"EA Assessed"	"Expected"	"Expected + 1SD flow"	"Expected + 1 SD Conc"	"Depth Average"	Depth Average + Upwell
n (# of samples)	9	9	9	9		
TDS	902	902	902	1,362	882	1160
TDS (sum of major ions)	599	599	599	949	736	1054
Chloride	330	330	330	525	410	595
Calcium	152	152	152	238	183	254
Sodium	77	77	77	113	91	123
Potassium	10	10	10	16	11	14
Sulphate	29	29	29	57	41	68
Alkalinity	106	106	106	204	106	106

Note: Measured values are from granite.
"Expected" values are the same as the "EA Assessed" however in the "EA Assessed" model an incrimental 88 mg/L chloride is added to the working area inflows.
Adjusted for Average Depth of Mine (210 m Depth)
Adjusted for Average Depth of Mine plus Upwelling

Depth-averaged connate water concentrations were derived assuming an initial concentration at a depth of 155 m as shown in Table 2. An increase in the overall TDS concentrations and chloride was then applied based on the Snap Lake TDS Profile (Section 1.3). For the remaining parameters, a linear increase was assumed using the "Expected" value and the "Saline" (Table 2) values. The chloride values were used to determine the relative proportional increase that was then applied to the remaining parameters.

For example:

At 210 m depth, the adjusted chloride value is 410 mg/L. The difference between the "Depth Adjusted" value (410 mg/L) and the "Expected" value (330 mg/L) is 0.33 times the difference between the "Saline" chemistry (570 mg/L) and the "Expected" value.

This value (0.33) is then used to calculate the relative differences for the remainder of the parameters that showed increases between the "Expected" and "Saline" chemistries. For instance:

Depth Adjusted [Na] = Expected [Na] (77 mg/L) +
(Saline [Na] (119 mg/L) –Expected [Na] (77 mg/L)) * 0.33
= 91 mg/L [Na]

To account for upwelling, the depth-adjusted values are multiplied by a factor of 1 in the first year of mining and increasing linearly to a factor of 1.45 in Year 2 of mining. A constant factor of 1.45 times the depth adjusted inflow concentrations was used following the second year of mining. A discussion of this factor is provided in Section 3.3.

6.0 RESULTS OF VARIABILITY ASSESSMENT

Tables 10 through 12 provide summaries of the long-term average chemistry values for each of the variability scenarios. The calculated TDS value and dissolved phosphorus concentrations at the discharge for each of the above scenarios are provided in Figures 6 through 9.

A summary of key results from the variability assessment is as follows:

- Concentrations for parameters with similar values in the "Saline" water and the "Expected" water (e.g. silver, aluminum, cobalt, chromium, iron, lead, selenium, zinc, dissolved phosphorus, and orthophosphate) are not expected to experience significant depth-related concentration changes (e.g. from upwelling of connate water).
- If required, treatment will result in discharge concentration of dissolved phosphorus similar to those predicted in the "EA Assessed" case. The treatment technology as currently proposed for the Snap Lake site can be modified to include treatment for phosphorus if necessary by the addition of ferric sulphate or an equivalent process.

Summary of Major Ion Concentrations and Loading for Various Mine Water Inflow Scenarios

a) TDS (Calculated) - Average of Years 15 - 22

Component		Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	692	692	692	1125	836	1171	4768	4768	6341	7756	5765	8072
	Recharging Lakewater	233	207	249	357	233	295	3706	3292	5270	5686	3716	4695
	Paste Bleedwater	1117	1117	1117	1117	1117	1117	203	203	203	203	203	203
	Incremental Chemistry at Working Face	256	168	168	408	168	408	3578	2349	3125	5692	2349	5692
Treatment Feed	from the Mine [sump]	606	527	566	919	597	758	13946	12128	17281	21149	13732	17442
	from the North Pile Temp Pond [runoff]	250	250	250	250	250	250	133	133	133	133	133	133
	from the Water Management Pond [site runoff]	144	144	144	144	144	144	27	27	27	27	27	27
	Treatment Feed [Total]	594	518	558	898	585	742	14101	12281	17436	21307	13887	17601
Treated Discharge		594	517	558	897	585	742	13615	11857	16979	20564	13408	16994

b) Cl - Average of Years 15 - 22

Component		Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	330	330	330	525	410	595	2275	2275	3026	3619	2827	4102
	Recharging Lakewater	92	62	75	97	76	110	1460	980	1599	1551	1214	1756
	Paste Bleedwater	9	9	9	9	9	9	2	2	2	2	2	2
	Incremental Chemistry at Working Face	88	0	0	0	0	0	1229	0	0	0	0	0
Treatment Feed	from the Mine [sump]	243	160	174	254	199	288	5600	3685	5323	5847	4572	6624
	from the North Pile Temp Pond [runoff]	24	24	24	24	24	24	13	13	13	13	13	13
	from the Water Management Pond [site runoff]	47	47	47	47	47	47	9	9	9	9	9	9
	Treatment Feed [Total]	237	156	171	247	194	280	5622	3705	5343	5869	4593	6646
Treated Discharge		237	156	171	247	194	280	5428	3577	5203	5667	4435	6418

c) Ca - Average of Years 15 - 22

Component		Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	152	152	152	238	183	254	1049	1049	1395	1641	1260	1748
	Recharging Lakewater	60	62	75	97	67	80	955	985	1580	1547	1074	1282
	Paste Bleedwater	389	389	389	389	389	389	71	71	71	71	71	71
	Incremental Chemistry at Working Face	77	77	77	129	77	129	1074	1074	1428	1802	1074	1802
Treatment Feed	from the Mine [sump]	158	160	171	252	174	209	3629	3672	5225	5798	4012	4798
	from the North Pile Temp Pond [runoff]	39	39	39	39	39	39	21	21	21	21	21	21
	from the Water Management Pond [site runoff]	25	25	25	25	25	25	5	5	5	5	5	5
	Treatment Feed [Total]	154	156	168	245	170	203	3653	3696	5249	5823	4036	4822
Treated Discharge		154	156	168	245	170	203	3527	3569	5112	5623	3897	4656

Notes:
EA Assessed = Values as used in EAR
Expected = Current expected values
R3a = Expected values using +1 standard deviation of Flow
R3b = Expected values using +1 standard deviation of connate water Concentration
R3c = Expected values using +1 standard deviation of Flow and of Concentration
R3d = Expected values adjusted for Depth Averaged connate concentrations
R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling
TDS results are calculated as the sum of the major ions

Table 10
Summary of Major Ion Concentrations and Loading for Various Mine Water Inflow Scenarios

d) Alkalinity - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	106	106	106	204	106	106	731	731	972	1406	731	731
	Recharging Lakewater	76	78	92	160	78	78	1209	1245	1960	2553	1245	1245
	Paste Bleedwater	760	760	760	760	760	760	138	138	138	138	138	138
	Incremental Chemistry at Working Face	124	124	124	370	124	370	1732	1732	2303	5167	1732	5167
Treatment Feed	from the Mine [sump]	196	198	209	410	198	198	4500	4552	6388	9434	4552	4552
	from the North Pile Temp Pond [runoff]	91	91	91	91	91	91	49	49	49	49	49	49
	from the Water Management Pond [site runoff]	1	1	1	1	1	1	0	0	0	0	0	0
	Treatment Feed [Total]	192	194	206	399	194	194	4545	4597	6434	9475	4597	4597
Treated Discharge		192	194	206	399	194	194	4388	4439	6266	9149	4439	4439

e) Na - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	77	77	77	113	91	123	530	530	705	779	627	851
	Recharging Lakewater	14	15	18	21	17	23	230	237	383	342	278	373
	Paste Bleedwater	19	19	19	19	19	19	3	3	3	3	3	3
	Incremental Chemistry at Working Face	0	0	0	0	0	0	0	0	0	0	0	0
Treatment Feed	from the Mine [sump]	38	38	41	56	45	61	870	880	1264	1280	1036	1396
	from the North Pile Temp Pond [runoff]	10	10	10	10	10	10	6	6	6	6	6	6
	from the Water Management Pond [site runoff]	2	2	2	2	2	2	0	0	0	0	0	0
	Treatment Feed [Total]	37	37	41	54	44	59	876	886	1270	1287	1042	1402
Treated Discharge		37	37	41	54	44	59	846	855	1237	1242	1006	1354

f) K - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	10	10	10	16	11	14	69	69	91	110	78	98
	Recharging Lakewater	5	5	6	18	5	6	80	82	131	293	86	94
	Paste Bleedwater	19	19	19	19	19	19	3	3	3	3	3	3
	Incremental Chemistry at Working Face	8	8	8	40	8	40	107	107	142	560	107	560
Treatment Feed	from the Mine [sump]	13	13	14	48	13	15	293	296	425	1094	310	343
	from the North Pile Temp Pond [runoff]	11	11	11	11	11	11	6	6	6	6	6	6
	from the Water Management Pond [site runoff]	2	2	2	2	2	2	0	0	0	0	0	0
	Treatment Feed [Total]	13	13	14	46	13	15	299	302	430	1101	316	349
Treated Discharge		13	13	14	46	13	15	288	292	419	1063	305	337

Notes:
EA Assessed = Values as used in EAR
Expected = Current expected values
R3a = Expected values using +1 standard deviation of Flow
R3b = Expected values using +1 standard deviation of connate water Concentration
R3c = Expected values using +1 standard deviation of Flow and of Concentration
R3d = Expected values adjusted for Depth Averaged connate concentrations
R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling

Summary of Major Ion Concentrations and Loading for Various Mine Water Inflow Scenarios

g) Fe - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.4020	0.4020	0.4020	1.5495	0.4020	0.4020	2.7715	2.7715	3.6860	10.6825	2.7715	2.7715
	Recharging Lakewater	0.0808	0.0461	0.0499	0.0461	0.0461	0.0461	1.2876	0.7347	1.0581	0.7347	0.7347	0.7347
	Paste Bleedwater	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091
	Incremental Chemistry at Working Face	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Treatment Feed	from the Mine [sump]	0.2006	0.1662	0.1703	0.5100	0.1662	0.1662	4.616	3.824	5.201	11.735	3.824	3.824
	from the North Pile Temp Pond [runoff]	0.003	0.003	0.003	0.003	0.003	0.0032	0.002	0.0017	0.0017	0.0017	0.0017	0.0017
	from the Water Management Pond [site runoff]	0.0519	0.052	0.052	0.052	0.052	0.0519	0.0096	0.0096	0.0096	0.0096	0.0096	0.0096
	Treatment Feed [Total]	0.1946	0.1616	0.1667	0.4950	0.1616	0.1616	4.618	3.835	5.212	11.746	3.835	3.835
Treated Discharge		0.1926	0.0999	0.0999	0.0999	0.0999	0.0999	4.4126	2.289	3.042	2.289	2.289	2.289

h) Mn - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.04	0.04	0.04	0.12	0.04	0.04	0.25	0.25	0.33	0.81	0.25	0.25
	Recharging Lakewater	0.0091	0.0094	0.0107	0.0162	0.0094	0.0094	0.14	0.15	0.23	0.26	0.15	0.15
	Paste Bleedwater	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
	Incremental Chemistry at Working Face	0	0	0	0	0	0	0	0	0	0	0	0
Treatment Feed	from the Mine [sump]	0.02	0.02	0.02	0.04	0.02	0.02	0.45	0.46	0.66	0.86	0.46	0.46
	from the North Pile Temp Pond [runoff]	0.06	0.06	0.06	0.06	0.06	0.06	0.03	0.03	0.03	0.03	0.03	0.03
	from the Water Management Pond [site runoff]	0.21	0.21	0.21	0.21	0.21	0.21	0.04	0.04	0.04	0.04	0.04	0.04
	Treatment Feed [Total]	0.02	0.02	0.02	0.04	0.02	0.02	0.52	0.53	0.73	0.93	0.53	0.53
Treated Discharge		0.02	0.02	0.02	0.04	0.02	0.02	0.51	0.51	0.71	0.90	0.51	0.51

i) SO4 - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	29	29	29	57	41	68	201	201	268	393	282	468
	Recharging Lakewater	7	7	8	12	9	14	113	116	177	197	150	229
	Paste Bleedwater	5	5	5	5	5	5	1	1	1	1	1	1
	Incremental Chemistry at Working Face	0	0	0	0	0	0	0	0	0	0	0	0
Treatment Feed	from the Mine [sump]	16	16	17	29	22	35	364	368	522	676	497	797
	from the North Pile Temp Pond [runoff]	51	51	51	51	51	51	27	27	27	27	27	27
	from the Water Management Pond [site runoff]	43	43	43	43	43	43	8	8	8	8	8	8
	Treatment Feed [Total]	17	17	18	30	22	35	399	404	558	712	533	833
Treated Discharge		17	17	18	30	22	35	386	390	543	688	515	804

Notes:

EA Assessed = Values as used in EAR

Expected = Current expected values

R3a = Expected values using +1 standard deviation of Flow

R3b = Expected values using +1 standard deviation of connate water Concentration

R3c = Expected values using +1 standard deviation of Flow and of Concentration

R3d = Expected values adjusted for Depth Averaged connate concentrations

R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling

Table 11
Summary of Nutrient Concentrations and Loading for Various Mine Water Inflow Scenarios

a) NH_4 - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	7.63	7.63	7.63	16.70	11.32	19.85	52.60	52.60	69.96	115.13	78.04	136.87
	Recharging Lakewater	2.10	2.16	2.43	5.29	2.84	4.41	33.40	34.41	51.45	84.23	45.21	70.19
	Paste Bleedwater	6.60	6.60	6.60	6.60	6.60	6.60	1.20	1.20	1.20	1.20	1.20	1.20
	Incremental Chemistry at Working Face	0.00	0.00	0.00	3.90	0.00	3.90	0.00	0.00	0.00	54.46	0.00	54.46
Treatment Feed	from the Mine [sump]	5.50	5.56	5.56	13.75	7.34	11.45	126.50	127.97	169.72	316.33	168.89	263.51
	from the North Pile Temp Pond [runoff]	2.27	2.27	2.27	2.27	2.27	2.27	1.21	1.21	1.21	1.21	1.21	1.21
	from the Water Management Pond [site runoff]	0.90	0.90	0.90	0.90	0.90	0.90	0.17	0.17	0.17	0.17	0.17	0.17
	Treatment Feed [Total]	5.38	5.44	5.47	13.39	7.17	11.16	127.69	129.16	170.92	317.72	170.13	264.85
Treated Discharge		5.38	5.44	5.47	13.39	7.17	11.16	123.29	124.72	166.46	306.78	164.27	255.73

b) Dissolved P - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.0590	0.0590	0.0590	0.1110	0.0893	0.1595	0.4068	0.4068	0.5410	0.7653	0.6159	1.0995
	Recharging Lakewater	0.0105	0.0028	0.0024	0.0028	0.0028	0.0028	0.1681	0.0447	0.0499	0.0447	0.0447	0.0447
	Paste Bleedwater	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	Incremental Chemistry at Working Face	0.5910	0.5910	0.5910	1.8990	0.5910	1.8990	8.25	8.25	10.98	26.52	8.25	26.52
Treatment Feed	from the Mine [sump]	0.3869	0.3793	0.3795	1.1887	0.3883	0.4094	8.9031	8.7265	11.5918	27.3517	8.9356	9.4192
	from the North Pile Temp Pond [runoff]	0.1713	0.1713	0.1713	0.1713	0.1713	0.1713	0.0913	0.0913	0.0913	0.0913	0.0913	0.0913
	from the Water Management Pond [site runoff]	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Treatment Feed [Total]	0.3793	0.3719	0.3739	1.1568	0.3807	0.4011	9.00	8.82	11.69	27.45	9.03	9.52
Treated Discharge		0.01998	0.00002	0.00002	0.00002	0.00002	0.00002	0.4578	0.0005	0.0006	0.0005	0.0005	0.0005

c) PO_4 - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.0120	0.0120	0.0120	0.0306	0.0120	0.0120	0.0827	0.0827	0.1100	0.2110	0.0827	0.0827
	Recharging Lakewater	0.0041	0.0009	0.0008	0.0009	0.0009	0.0009	0.0655	0.0143	0.0160	0.0143	0.0143	0.0143
	Paste Bleedwater	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	Incremental Chemistry at Working Face	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Treatment Feed	from the Mine [sump]	0.0078	0.0046	0.0044	0.0102	0.0046	0.0046	0.1801	0.1055	0.1352	0.2337	0.1055	0.1055
	from the North Pile Temp Pond [runoff]	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160
	from the Water Management Pond [site runoff]	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
	Treatment Feed [Total]	0.0083	0.0052	0.0049	0.0106	0.0052	0.0052	0.1974	0.1226	0.1523	0.2508	0.1226	0.1226
Treated Discharge		0.00831	0.00002	0.00002	0.00002	0.00002	0.00002	0.1905	0.0005	0.0006	0.0005	0.0005	0.0005

Notes:
EA Assessed = Values as used in EAR
Expected = Current expected values
R3a = Expected values using +1 standard deviation of Flow
R3b = Expected values using +1 standard deviation of connate water Concentration
R3c = Expected values using +1 standard deviation of Flow and of Concentration
R3d = Expected values adjusted for Depth Averaged connate concentrations
R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling

Table 12
Summary of Selected Trace Metal Concentrations and Loading for Various Mine Water Inflow Scenarios

a) Ag - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00034	0.00034	0.00046	0.00034	0.00034	0.00034
	Recharging Lakewater	0.00004	0.00003	0.00003	0.00003	0.00003	0.00003	0.00060	0.00055	0.00073	0.00055	0.00055	0.00055
	Paste Bleedwater	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
	Incremental Chemistry at Working Face	0.00001	0.00001	0.00001	0.00006	0.00001	0.00006	0.00007	0.00007	0.00009	0.00084	0.00007	0.00084
Treatment Feed	from the Mine [sump]	0.00006	0.00005	0.00005	0.00009	0.00005	0.00005	0.0013	0.0012	0.0016	0.0020	0.0012	0.0012
	from the North Pile Temp Pond [runoff]	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.0001	0.00011	0.00011	0.00011	0.00011	0.0001
	from the Water Management Pond [site runoff]	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.0000	0.00001	0.00001	0.00001	0.00001	0.00001
	Treatment Feed [Total]	0.00006	0.00006	0.00006	0.00009	0.00006	0.00006	0.0014	0.0013	0.0017	0.0021	0.0013	0.0013
Treated Discharge		0.00006	0.00005	0.00005	0.00005	0.00005	0.00005	0.0014	0.0011	0.0015	0.0011	0.0011	0.001

b) Cd - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00017	0.00017	0.00023	0.00021	0.00018	0.00021
	Recharging Lakewater	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00068	0.00068	0.00088	0.00068	0.00068	0.00068
	Paste Bleedwater	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.000027	0.000027	0.000027	0.000027	0.000027	0.000027
	Incremental Chemistry at Working Face	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Treatment Feed	from the Mine [sump]	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.0011	0.0012	0.0015	0.0012	0.0012	0.0012
	from the North Pile Temp Pond [runoff]	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.0005	0.00049	0.00049	0.00049	0.00049	0.0005
	from the Water Management Pond [site runoff]	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.0000	0.00002	0.00002	0.00002	0.00002	0.00002
	Treatment Feed [Total]	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007	0.0017	0.0017	0.0020	0.0017	0.0017	0.0017
Treated Discharge		0.00007	0.00007	0.00006	0.00007	0.00007	0.00007	0.0016	0.0015	0.0019	0.0015	0.0015	0.002

c) Cr - Average of Years 15 - 22

	Component	Concentration (mg/l) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	Load (kg/d) EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.0006	0.0006	0.0006	0.0018	0.0006	0.0006	0.004	0.004	0.006	0.012	0.004	0.004
	Recharging Lakewater	0.0008	0.0019	0.0021	0.0019	0.0019	0.0019	0.013	0.030	0.044	0.030	0.030	0.030
	Paste Bleedwater	0.3130	0.3130	0.3130	0.3130	0.3130	0.3130	0.057	0.057	0.057	0.057	0.057	0.057
	Incremental Chemistry at Working Face	0.0040	0.0040	0.0040	0.0102	0.0040	0.0102	0.056	0.056	0.074	0.142	0.056	0.142
Treatment Feed	from the Mine [sump]	0.0046	0.0046	0.0046	0.0046	0.0046	0.0046	0.106	0.106	0.140	0.106	0.106	0.106
	from the North Pile Temp Pond [runoff]	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	from the Water Management Pond [site runoff]	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	Treatment Feed [Total]	0.0046	0.0046	0.0046	0.0046	0.0046	0.0046	0.108	0.108	0.143	0.108	0.108	0.108
Treated Discharge		0.0020	0.0046	0.0046	0.0046	0.0046	0.0046	0.05	0.10	0.14	0.10	0.10	0.10

Notes:
EA Assessed = Values as used in EAR
Expected = Current expected values
R3a = Expected values using +1 standard deviation of Flow
R3b = Expected values using +1 standard deviation of connate water Concentration
R3c = Expected values using +1 standard deviation of Flow and of Concentration
R3d = Expected values adjusted for Depth Averaged connate concentrations
R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling

Summary of Selected Trace Metal Concentrations and Loading for Various Mine Water Inflow Scenarios

d) Cu - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.0043	0.0043	0.0043	0.0121	0.0065	0.0115	0.0299	0.0299	0.0398	0.0834	0.0448	0.0791
	Recharging Lakewater	0.0013	0.0013	0.0014	0.0027	0.0017	0.0026	0.0200	0.0204	0.0302	0.0431	0.0267	0.0413
	Paste Bleedwater	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.00093	0.00093	0.00093	0.00093	0.00093	0.00093
	Incremental Chemistry at Working Face	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Treatment Feed	from the Mine [sump]	0.0026	0.0026	0.0028	0.0063	0.0036	0.0060	0.059	0.060	0.084	0.146	0.084	0.139
	from the North Pile Temp Pond [runoff]	0.007	0.007	0.007	0.007	0.007	0.0070	0.004	0.0037	0.0037	0.0037	0.0037	0.0037
	from the Water Management Pond [site runoff]	0.0034	0.003	0.003	0.003	0.003	0.0034	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
	Treatment Feed [Total]	0.0027	0.0027	0.0028	0.0063	0.0037	0.0061	0.064	0.064	0.088	0.151	0.088	0.144
Treated Discharge		0.0027	0.0027	0.0028	0.0063	0.0037	0.0061	0.0616	0.062	0.086	0.145	0.085	0.139

e) Mo - Average of Years 15 - 22

	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave Mine + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.00559	0.00559	0.00559	0.00840	0.00659	0.00891	0.03854	0.03854	0.05126	0.05791	0.04546	0.06145
	Recharging Lakewater	0.00356	0.00357	0.00393	0.00487	0.00374	0.00412	0.05675	0.05690	0.08338	0.07758	0.05959	0.06562
	Paste Bleedwater	0.08110	0.08110	0.08110	0.08110	0.08110	0.08110	0.01474	0.01474	0.01474	0.01474	0.01474	0.01474
	Incremental Chemistry at Working Face	0.00251	0.00251	0.00251	0.00840	0.00251	0.00840	0.03505	0.03505	0.04662	0.11731	0.03505	0.11731
Treatment Feed	from the Mine [sump]	0.00737	0.00738	0.00760	0.01308	0.00785	0.00892	0.1696	0.1698	0.2320	0.3010	0.1806	0.2052
	from the North Pile Temp Pond [runoff]	0.07777	0.07777	0.07777	0.07777	0.07777	0.07777	0.0415	0.04147	0.04147	0.04147	0.04147	0.0415
	from the Water Management Pond [site runoff]	0.00161	0.00161	0.00161	0.00161	0.00161	0.00161	0.0003	0.00030	0.00030	0.00030	0.00030	0.00030
	Treatment Feed [Total]	0.00901	0.00902	0.00883	0.01455	0.00947	0.01051	0.2137	0.2139	0.2761	0.3452	0.2247	0.2494
Treated Discharge		0.00894	0.00879	0.00870	0.01199	0.00924	0.01016	0.2049	0.2015	0.2649	0.2747	0.2116	0.233

f) Se - Average of Years 15 - 22

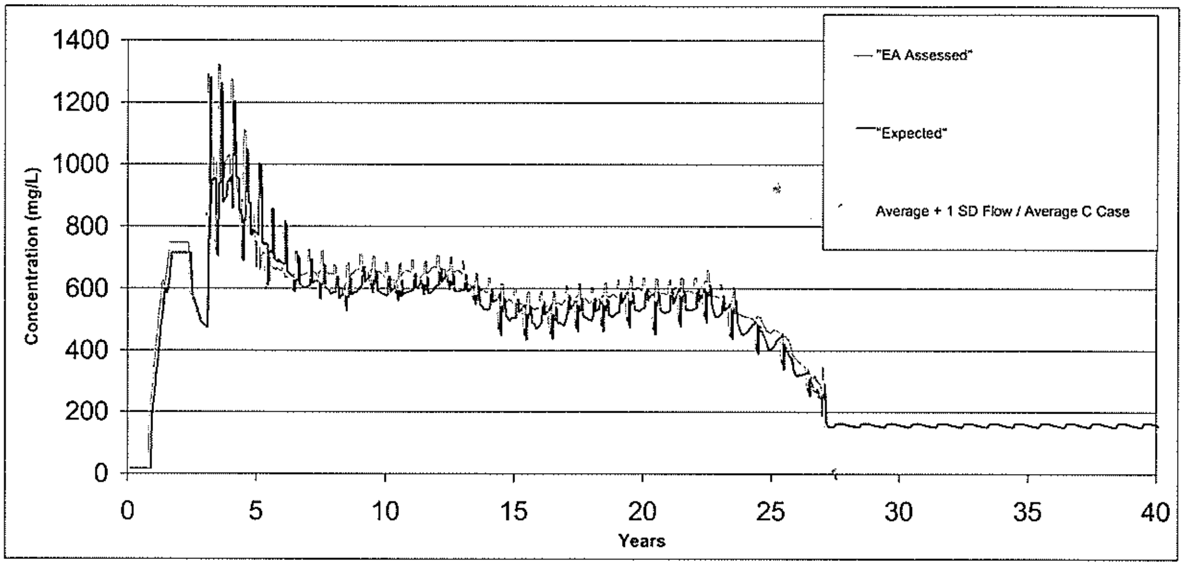
	Component	Concentration (mg/l)						Load (kg/d)					
		EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)	EA Assessed	Expected	R3a (+1SD Flow)	R3b (+1SD Conc)	R3c (Depth Average)	R3d (Depth Ave + Upwell)
Loadings to Mine	Recharging Groundwater (connate)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0014	0.0014	0.0018	0.0014	0.0014	0.0014
	Recharging Lakewater	0.0001	0.0003	0.0004	0.0004	0.0003	0.0003	0.0016	0.0052	0.0075	0.0067	0.0052	0.0052
	Paste Bleedwater	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
	Incremental Chemistry at Working Face	0.0002	0.0002	0.0002	0.0018	0.0002	0.0018	0.0034	0.0034	0.0045	0.0251	0.0034	0.0251
Treatment Feed	from the Mine [sump]	0.0003	0.0005	0.0006	0.0016	0.0005	0.0005	0.007	0.012	0.017	0.036	0.012	0.012
	from the North Pile Temp Pond [runoff]	0.014	0.014	0.014	0.014	0.014	0.0140	0.007	0.0075	0.0075	0.0075	0.0075	0.0075
	from the Water Management Pond [site runoff]	0.0019	0.002	0.002	0.002	0.002	0.0019	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	Treatment Feed [Total]	0.0006	0.0009	0.0008	0.0019	0.0009	0.0009	0.015	0.020	0.025	0.044	0.020	0.020
Treated Discharge		0.0002	0.0008	0.0007	0.0010	0.0008	0.0008	0.0046	0.017	0.023	0.023	0.017	0.017

Notes:

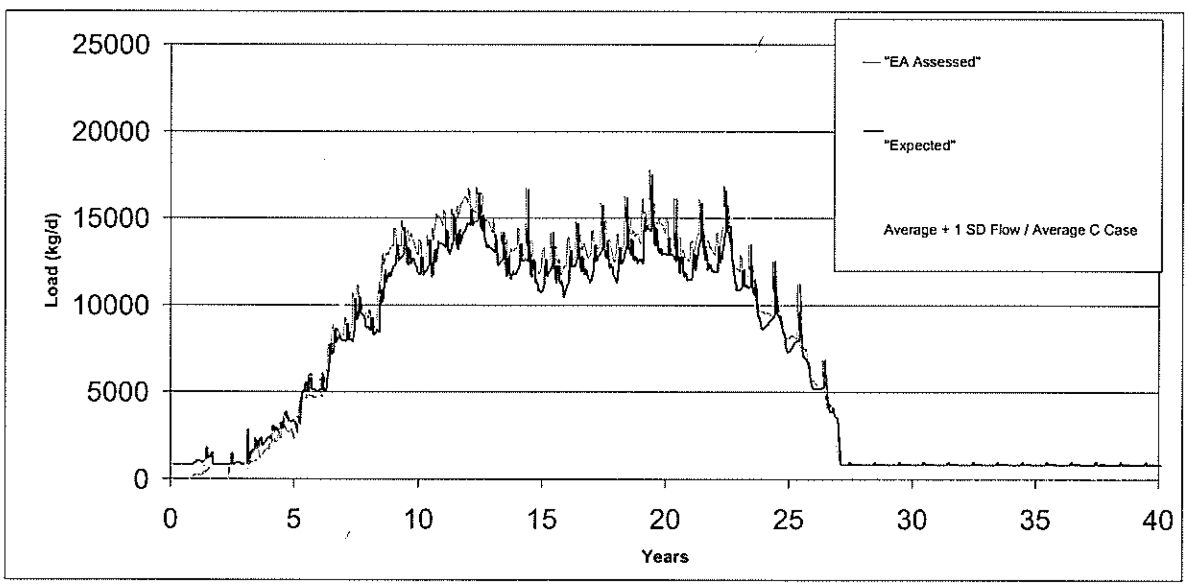
EA Assessed = Values as used in EAR
Expected = Current expected values
R3a = Expected values using +1 standard deviation of Flow
R3b = Expected values using +1 standard deviation of connate water Concentration
R3c = Expected values using +1 standard deviation of Flow and of Concentration
R3d = Expected values adjusted for Depth Averaged connate concentrations
R3e = Expected values adjusted for Depth Averaged connate concentrations + adjustment for deep upwelling

TDS Loading and Concentration Summary	FIGURE __6

a) Final Discharge Concentration Comparison



b) Final Discharge Loading Comparison



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Project: 022-6659-5300

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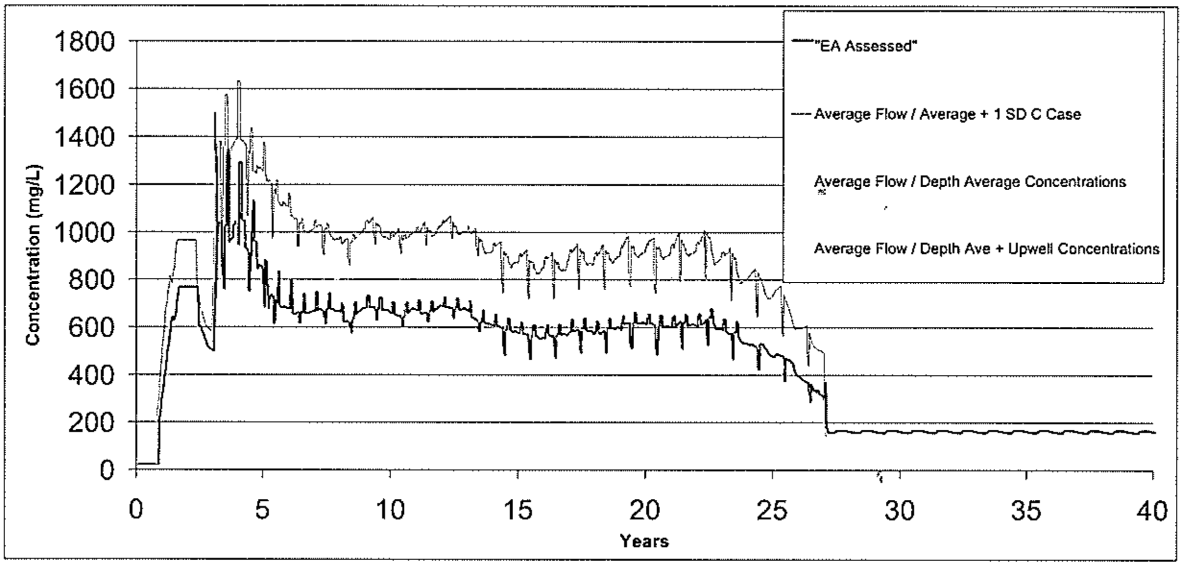
Chkd

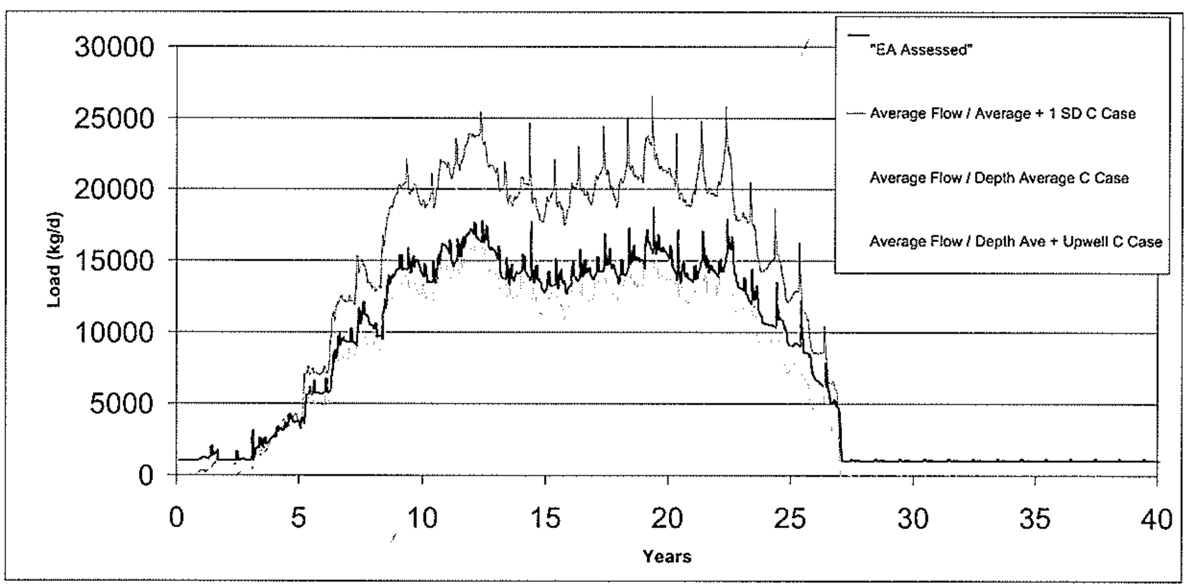
Golder Associates

TDS Loading and Concentration Summary	FIGURE __7

a) Final Discharge Concentration Comparison



b) Final Discharge Loading Comparison



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Project: 022-6659-5300

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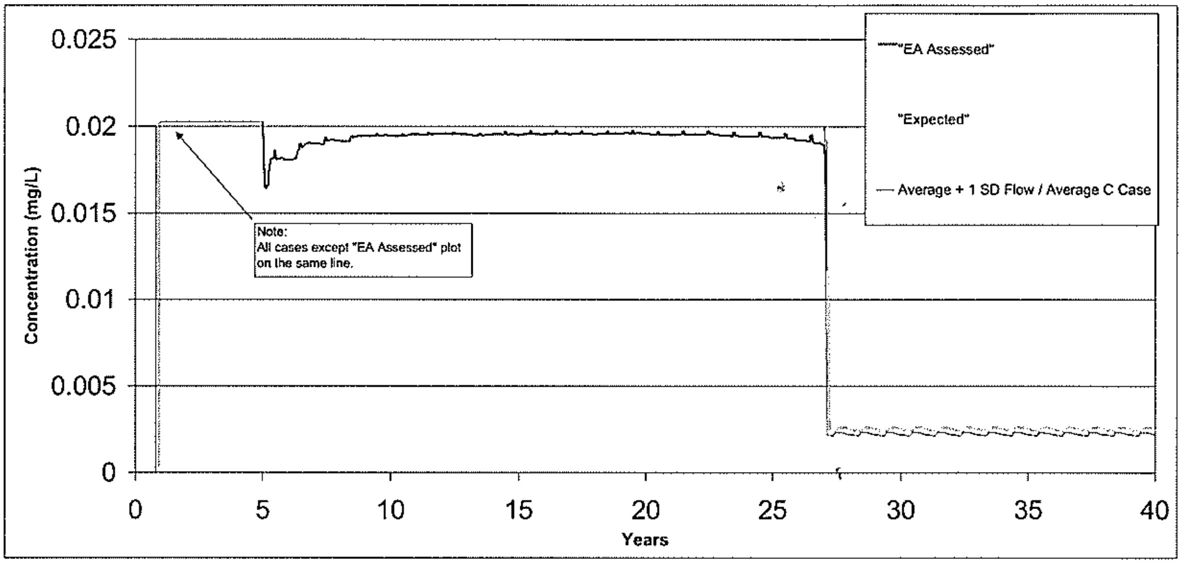
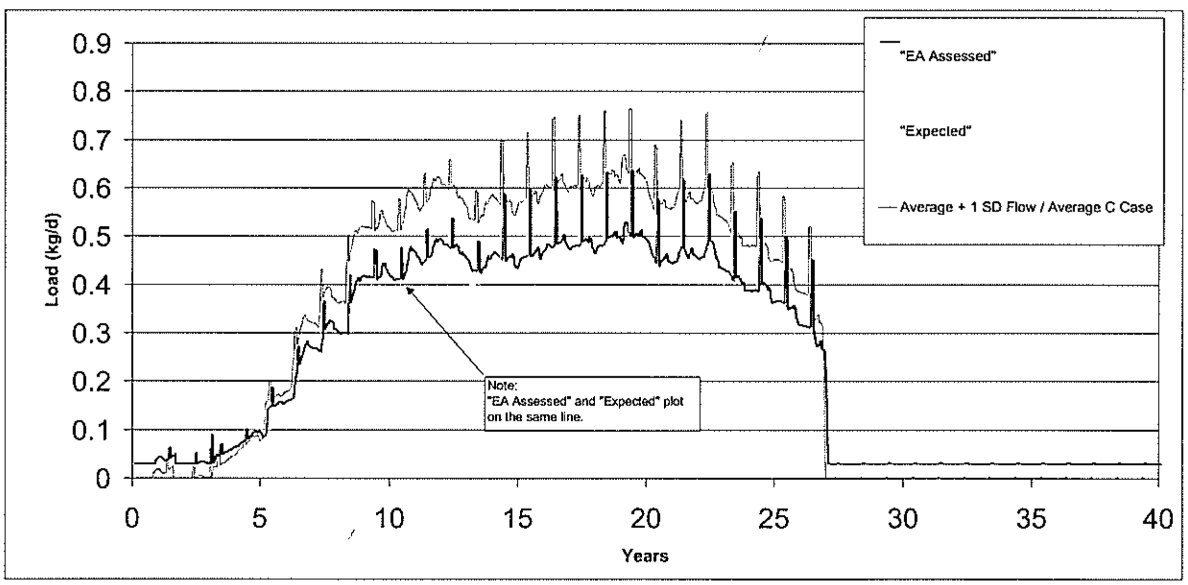
Dissolved P Loading and Concentration Summary

FIGURE __8

a) Final Discharge Concentration Comparison



b) Final Discharge Loading Comparison



Date: January, 2003
Project: 022-6659-5300

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Chkd KJD

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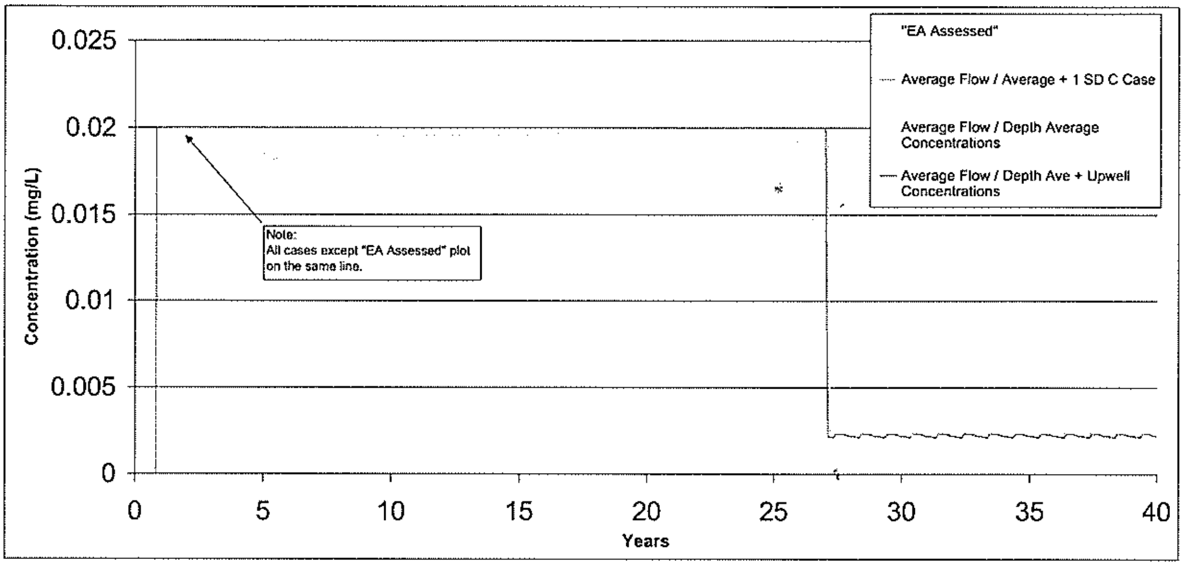
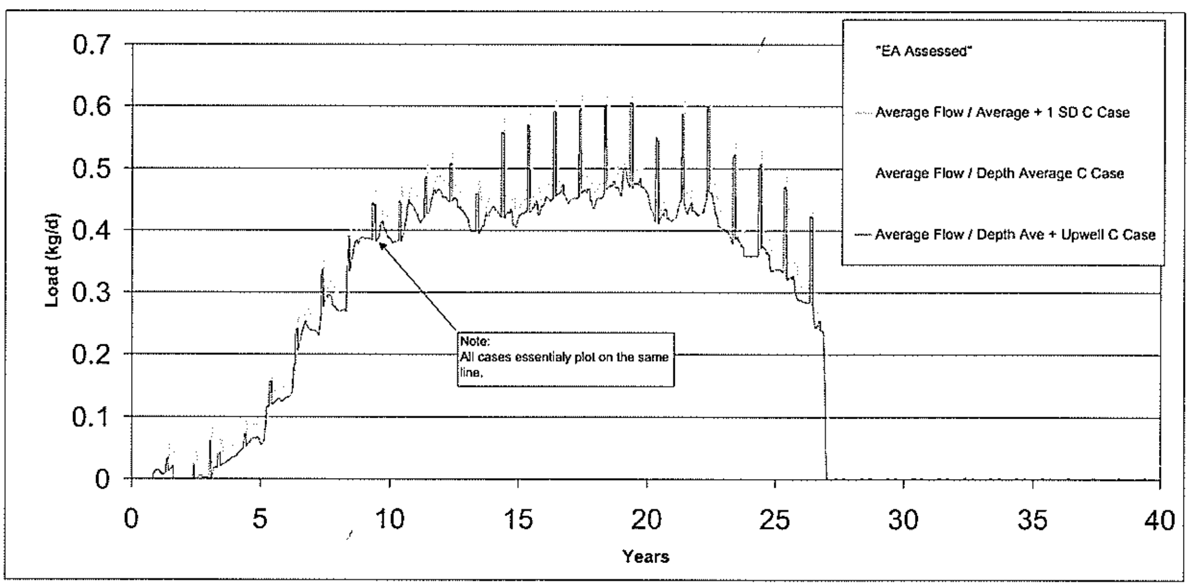
Figures 8 and 9.xls-Figure 8

Dissolved P Loading and Concentration Summary	FIGURE __9

a) Final Discharge Concentration Comparison



b) Final Discharge Loading Comparison



Date: January, 2003
Project: 022-6659-5300

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Chkd KJD

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- Independently increasing the flow to the mine by 1 standard deviation (keeping other factors such as connate water concentration and the proportions of groundwater and connate water the same as in the "Expected" case) results in an increase in discharge TDS concentrations to 558 mg/L. This is approximately 8% higher than the "Expected" case (517 mg/L), and is lower than the "EA Assessed" case (594 mg/L).
- Independently increasing the concentration of the connate water by 1 standard deviation (keeping flow rates and proportions the same as in the "Expected" case) results in an increase in discharge TDS concentrations to 897 mg/L. This is an increase by about 51% over the "EA Assessed" case.
- Using concentrations derived from the depth average of the mine ("Depth Average" case) (keeping flow rates and proportions the same as in the "Expected" case) results in similar discharge TDS concentrations (585 mg/L) as the "EA Assessed" value (594 mg/L).
- Using concentrations derived from the depth average of the mine and accounting for upwelling ("Depth Average + Upwelling" case) (keeping flow rates and proportions the same as in the "Expected" case) results in an increase in discharge TDS concentrations to a value of 742 mg/L. This is an approximately 25% increase over the value assessed in the EAR (594 mg/L).

7.0 CLOSING STATEMENT

7.1 Context

The variability assessment discussed herein was completed at the request of the interveners to assess a range of potential mine water inflow scenarios.

The values of mine water chemistry assessed in the EA were based on the field data and conclusions made by Gascoyne (1997). Gascoyne (1997) observed large variability in TDS data in the upper 500 m of Canadian Shield crystalline rock with some concentrations increasing with depth and others remaining the same or decreasing. He concluded that TDS concentrations in the upper 500 m of the Canadian Shield are likely indicative of local flow conditions with higher concentrations of TDS found in discharge zones and lower concentrations measured in recharge zones. This suggests that TDS and chloride concentrations within 500 m depth do not likely increase as rapidly as the concentrations below approximately 500 m depth. In the variability runs, we have considered that these values can increase with depth and have applied what is considered to be a conservatively high increase in concentration with depth. The "EA Assessed" value also included an incremental addition of chloride as a function of mining. However, since the only significant source of chloride addition to the mine is the connate water, the incremental addition from mine activity is considered to be unwarranted. Nevertheless, the removal of this incremental addition and the conservative increase in concentration with depth (by using the depth average mine water concentration) has resulted in TDS values similar to those used in the environmental assessment. It is considered that the variability run that includes the increase in concentration with depth is reasonable and not unduly conservative.

Other assumptions used in the variability runs that were suggested by the interveners that likely overestimate the TDS values include:

- Use of a hydraulic conductivity profile that is expected to result in an overestimate of the brackish water upwelling since it likely underestimates the reduction in hydraulic conductivity with depth (the upwell portion of the "Depth Average + Upwell" case).
- The scenario where the mine inflow is increased by a factor of 1.33 (the "+ 1 SD Flow" case) which assumes that this increased water consists of the same proportions of connate water to lake water as the water used for the EAR. In contrast to this assumption, it is expected that any increased flows over the expected case are likely due to a greater hydraulic connection between Snap Lake and the mine. In this case, most of the additional inflow would consist of lake water and would result in lower concentrations than predicted.

The assumption that the baseline concentrations over the upper 500 m increase rapidly with depth ("Depth Average + Upwell" case and "+ 1 SD Conc" case) suggests that the hydraulic connection between Snap Lake and the groundwater flow system is less than estimated such that diffusion is the dominant transport mechanism in the 500 m of rock between Snap Lake and the mine workings. In this case, the baseline concentrations in connate water would increase with depth in the 500 m below Snap Lake. However, this would also imply that the groundwater inflows will be less than expected. Conversely, should the inflows be 1.33 times greater than the expected value, it is likely that most of this increased water would be coming from Snap Lake, and therefore would have little incremental effect on water quality in Snap Lake.

In this memo, we have provided a sensitivity analysis for mine water quality at the Snap Lake Diamond Project. In essence, this provides intervenors with a number of scenarios that each differ in their conservatism. In other words, six scenarios have been evaluated, each increasing in the level by which they are considered "worst-case". Having closely examined available information, the underlying assumptions used in the modelling and the output, it is our scientific and professional opinion that a reasonable "worst-case" mine discharge quality lies somewhere between the "EA Assessed" value and the variability scenarios provided and discussed above. In other words, the "EA Assessed" scenario represents a lower "worst-case" bound, and the various variability scenarios (particularly those with rapid connate water concentration increase with depth and no corresponding decrease in connate water inflow to the mine) result in concentration estimates that are higher than a reasonable "worst-case" alternative.

7.2 Contingency Measures/Mitigation

There are two key issues for intervenors to resolve to their satisfaction with respect to mine water inflow quality for Snap Lake Diamond Project. The first issue is how severe the "worst-case" scenario is, and if it should be regarded as conservative enough to ensure there is an adequate safety margin applied in predicting the impacts of the Snap Lake Diamond Project on water quality and the receiving aquatic environment. The second issue is whether there are available mitigation measures that can be used as contingency.

As indicated above, it is our scientific and professional opinion that a reasonable "worst-case" mine discharge quality lies somewhere between the "EA Assessed" value and the variability scenarios provided. However, it should be emphasized that if the concentrations in the mine discharge approached the values postulated by interveners and assessed in this variability analyses, mitigation measures are available that could be taken to reduce the impact to or below that predicted. For example, contingency and mitigation could be applied in the mining operations to reduce the mass load from the connate water and result in lower mine water discharge concentrations.

Over one-third of the total inflow from the mine originates from ramps and drift development. Monitoring of the mine water quality will be conducted on an ongoing basis over the life of mine. Contingency measures, if required, might include grouting of the areas with high-salinity groundwater inflows, especially those in the ramps and drift development, to reduce the overall TDS and salinity loading to the mine. These grouting activities, while resulting in some short term spikes in TDS due to cement use, would reduce the overall TDS load to the mine and discharge over the long term.

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