CANADA-WIDE SURVEY OF ACID MINE DRAINAGE CHARACTERISTICS

MEND Report 3.22.1

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MINERAL SCIENCES LABORATORIES
L.J. Wilson

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EXECUTIVE SUMMARY

Acidic effluent generation from sulphidic tailings, waste rock piles and mine workings can continue long after cessation of mining activities, posing a long-term liability to Canadian mineral operations. Lime neutralization is a common treatment practice to neutralize acid and precipitate heavy metals. This methodology is simple and economically advantageous. However, it produces large volumes of potentially hazardous sludge, has high maintenance requirements and may fail to meet new, more demanding environmental standards. Hence, the improvement or replacement of lime neutralization technology with new, advanced techniques is becoming a necessity. A data bank on the characteristics of acid mine drainage (AMD) streams in Canada will serve as an important input in helping to define strategies for improving AMD treatment techniques.

Fourteen companies participating in the MEND program were contacted by phone and in writing with respect to their currently acid generating sites. Data on the raw AMD streams at these sites were solicited using a written questionnaire. Detailed information on 72 untreated AMD streams from across Canada has been compiled and is presented in this report. The data were also input into a Lotus 1-2-3 spreadsheet designed to allow further analysis of the stream parameters based on selected criteria. The data on stream sources, flowrates, heavy metal concentrations, acidity, oxidizing conditions and suspended solids content have been extracted from the spreadsheet and are presented in a concise tabular format to allow seasonal comparisons. Graphical concentration distributions are provided for several of these parameters.

Seasonal trends were observed for some of the stream characteristics. As expected, flowrates are almost always higher in the spring and fall compared to summer and winter. When only those streams with measurements for all four seasons are considered, five of nine heavy metals reveal seasonal trends. Copper and zinc concentrations tend to be highest for individual streams in the spring while lead, iron and cobalt concentrations tend to be highest in the winter. Zinc concentrations tend to be lowest for individual streams in the summer and fall, while copper and cobalt concentrations tend to be lowest in the fall alone. Sulphate concentrations and acidity tend to exhibit matching trends: they are highest in winter and lowest in spring. It would appear that confounding factors such as adsorption phenomena, interactions along the AMD migration pathway or other site specific features which are not

seasonal have an overriding impact on many AMD stream characteristics.

A small number of the streams have concentrations of copper or zinc which are high enough for metal recovery to be potentially feasible as a treatment approach. However, many of the streams are diluted by other sources of water (e.g., runoff, mill effluent, etc.) reducing the base metal concentrations. Hence, the metal recovery option may require the interception of AMD streams closer to the source of metals dissolution yielding lower flowrates and higher concentrations.

Very little data were provided on oxidizing conditions in AMD streams (e.g., either as Fe^{2+} concentrations to allow calculation of Fe^{2+}/Fe^{3+} ratios, or as redox potentials), probably because measurements of these parameters are difficult and the results are often suspect. However, this information is necessary for the consideration of many treatment options. Therefore, mining companies may need to be encouraged to collect these data.

Information on problems and successes in dealing with AMD at the various sites was extracted from the questionnaire responses and is summarized in terms of generic issues. The two most common concerns/accomplishments involve the collection of all contaminated flows at a site and the quality of the final effluent.

This report, along with the associated computer spreadsheet, provides a good data bank of Canadian AMD stream characteristics which may be used to assist in developing new or improved AMD treatment techniques. As well, it will allow the formulation of synthetic AMD solutions, which are relevant to the Canadian context, for use in general AMD research.

SOMMAIRE

Les parc à résidus sulfurés, les haldes de stérile et les chantiers miniers laissent échapper des effluents acides longtemps après la fin des activités minières, ce qui impose aux exploitants une responsabilité financière à long terme. La neutralisation à la chaux est très répandue pour neutraliser l'acide et pour précipiter les métaux lourds. Cette méthode est simple et économique. Toutefois, elle produit de grandes quantités de boue potentiellement dangereuse, exige beaucoup de travaux d'entretien et peut ne pas respecter les nouvelles normes environnementales plus rigoureuses. Il importe donc de plus en plus d'améliorer ou de remplacer cette technologie de neutralisation à la chaux par de nouvelles techniques perfectionnées. Une banque de données sur les caractéristiques des effluents du drainage minier acide (DMA) au Canada sera très utile pour définir des stratégies visant à améliorer les techniques de traitement du DMA.

Quatorze entreprises participant au programme NEDEM ont été approchées par téléphone et par écrit concernant leurs sites acidogènes actuels. Des données sur les effluents bruts du DMA dans ces emplacements ont été sollicitées par la voie d'un questionnaire écrit. Des renseignements détaillés sur 72 sources du DMA non traité réparties à travers le Canada ont été compilés et sont présentés dans le présent rapport. Les données ont aussi été entrées dans un chiffrier Lotus 1-2-3 permettant une analyse plus poussée des paramètres des effluents en fonction d'un choix de critères. Les données sur les sources, les débits, les teneurs en métaux lourds, l'acidité, les conditions d'oxydation et les teneurs en matières en suspension des effluents du DMA ont été extraites du chiffrier et sont résumées sous forme de tableaux, ce qui permet des comparaisons entre les saisons. Des distributions de concentration sont présentées graphiquement pour plusieurs de ces paramètres.

Des tendances saisonnières ont été relevées pour certaines caractéristiques des effluents. Comme prévu, les débits sont presque toujours plus élevés au printemps et à l'automne qu'en été et en hiver. Lorsque nous ne comparons que les effluents pour lesquels nous disposons de mesures s'échelonnant sur les quatre saisons, nous observons des tendances saisonnières dans le cas de cinq métaux lourds sur neuf. Les concentrations sont en général les plus élevées au printemps dans le cas du zinc et du cuivre, et en hiver dans le cas du plonb, du fer et du cobalt. Les concentrations de zinc sont

les plus faibles en été et à l'automne, et à l'automne seulement dans le cas du cuivre et du cobalt. Les concentrations de sulphate et de l'acidité présentent les mêmes tendances : elles sont les plus élevées en hiver et les plus faibles en été. Il semblerait que des facteurs portant à confusion, comme des phénomènes d'adsorption, des interactions le long de la trajectoire de migration du DMA ou d'autres caractéristiques particulières du site qui ne sont pas saisonnières, ont un effet prédominant sur les caractéristiques du DMA.

Peu d'effluents renferment assez de cuivre ou de zinc pour justifier un éventuel traitement de récupération de ces métaux. Toutefois, plusieurs effluents sont dilués par d'autres sources d'eau (p. ex. ruissellement, effluents d'usine, etc.), ce qui réduit la concentration de métaux communs. Pour récupérer ces métaux, il est donc possible qu'il faille intercepter les effluents de DMA plus près de la source de dissolution des métaux, ce qui se traduirait par des débits plus faibles et des concentrations plus élevées.

Très peu de données ont été fournies sur les conditions d'oxydation dans les effluents de DMA (p. ex. la concentration de Fe^{2+} qui permet de calculer le rapport Fe^{2+}/Fe^{3+} ou le potentiel redox), probablement parce que ces paramètres sont difficiles à mesurer et que les résultats sont souvent douteux. Cette information est toutefois nécessaire lorsqu'on envisage différents systèmes de traitement. Il se peut donc qu'il faille encourager les sociétés minières à recueillir ces données.

De l'information sur les problèmes et les succès entourant le traitement du DMA de divers sites a été tirée des réponses au questionnaire et est résumée en termes de questions générales. Les deux problèmes/réalisations les plus courants ont trait à la collecte de tous les écoulements contaminés d'un même site et à la qualité de l'effluent final.

Le présent rapport, ajouté au chiffrier électronique connexe, constitue une bonne banque de données sur les caractéristiques des effluents du DMA au Canada. Cette banque peut aider à élaborer des techniques de traitement nouvelles ou améliorées. Elle permettra en outre de synthétizer des solutions du DMA qui seront pertinentes dans le contexte canadien et utiles dans la recherche générale sur le DMA.

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Hudson Bay Mining and Smelting Co. Ltd.: R. Dishaw

Inco Ltd.: C. Hunt

Lac Minerals Ltd.: P. Primeau and T. Kasongo

Noranda Minerals Inc.: G. Johnson, F. Nerron, P. Godbehere and R. Rodrigue

Placer Dome Inc.: M. Aziz and R. Patterson

Rio Algom Ltd.: A. Vivyurka

CONTENTS

TABLES

FIGURES

INTRODUCTION

Acid mine drainage (AMD) occurs as a result of natural oxidation of sulphide minerals exposed to air and water. The process of mining often generates sulphide bearing wastes (tailings and waste rock) or reveals sulphide bearing rock surfaces in the mine workings. Acidic drainage will not ensue if either the sulphide minerals are non-reactive or if the waste contains sufficient alkaline material to neutralize the acid which is formed. The quality and rate of release of AMD is governed by various chemical and biological reactions at the source of acid generation and along the drainage path from the source to the environment (1). Acidic drainage may contain very high concentrations of sulphate and ferrous ions, elevated levels of base metals such as copper, nickel, zinc, aluminium or cadmium, and pH values significantly below 7. If acidic drainage is left uncollected and untreated, the drainage could contaminate groundwater and local watercourses, damaging the health of plants, wildlife and fish (2).

Acidic effluent generation from sulphidic tailings, waste rock piles and mine workings can continue long after cessation of mining activities, posing a long-term liability to Canadian mineral operations. Lime neutralization is a common treatment practice to neutralize acid and precipitate heavy metals. This methodology is simple and economically advantageous. However, it produces large volumes of potentially hazardous sludge, has high maintenance requirements and may fail to meet new, more demanding environmental standards. Hence, the improvement or replacement of lime neutralization technology with new, advanced techniques is becoming a necessity.

A previous report by CANMET for the MEND Treatment Committee provided some information on acid mine drainage streams in Canada (3). This information, although limited, demonstrated the potential of metal values recovery from effluents. The current study was undertaken in order to obtain an overall view of the heavy metal loading in acidic mineral drainage streams. The specific objective of this project was to create a data bank on the composition, flowrates and seasonal fluctuations of AMD streams in Canada. The data gathered will be made widely available and will serve as an important input in helping to define strategies for improving AMD treatment techniques. As well, it will provide a definition of AMD in terms of chemical composition and geographic location. This will allow the formulation of synthetic AMD solutions, which are relevant to the Canadian context, for use in general AMD research.

DATA ACQUISITION

THE QUESTIONNAIRE

A questionnaire was designed to solicit the information required for the database. Copies of the questionnaire, in English and in French, are provided in Appendix I.

The questionnaire was divided into two parts. Part I requested general information about the AMD generating site (e.g., chemical/mineralogical data on acid generating materials, climatic information and comments on problems and successes in dealing with AMD at the site) in order to provide a context for the streams. The climatic profile is included in the database; a summary of the remaining pertinent information is listed by site in Appendix V. All data were supplied by the mining companies for this survey on a confidential basis. Thus, the sites are identified by general geographic region only. Part II of the questionnaire requested information about the AMD streams. A complete set of tables (one for each stream) arranged by general geographic region is compiled in Appendix IV.

PERSONS CONTACTED

The following industrial participants in the MEND program were contacted by phone, facsimile and in writing to obtain data.

Brunswick Mining & Smelting Corp. Ltd.	Inco Ltd.
Cambior Inc.	Lac Minerals Ltd.
Cominco Ltd.	Les Mines Selbaie
Denison Mines Ltd.	Noranda Minerals Inc.
Falconbridge Ltd.	Placer Dome Inc.
Homestake Canada Inc.	Rio Algom Ltd.
Hudson Bay Mining and Smelting Co. Ltd.	Teck Corporation

A list of all individual contacts is provided in Appendix II. Thirteen of the fourteen companies identified AMD sites on their properties. Responses were received (by October 5, 1994) from 30 sites representing twelve companies.

DATA COMPILATION

CHOICE OF SOFTWARE

The personal computer based software package Lotus 1-2-3 was chosen to efficiently process the collected AMD stream information. A computer spreadsheet allows manipulation and graphical presentation of the numerical data, if required. On the other hand, the database feature available in Lotus 1-2-3 allows analysis based on selected criteria. Lotus 1-2-3 is readily available software and its files may be imported into many other software packages. The data were saved as a .WK1 file using version 2.3 of the software. This format may be used with Lotus 1-2-3 version 2.3 and above.

DESCRIPTION OF SPREADSHEET

The spreadsheet has been designed to accommodate the database functions. Each row (database record) provides the information about one item (an AMD stream) in the database. There are 75 records representing 72 streams (69 streams with individual records and three streams with two records each to accommodate ranges of data) entered in the spreadsheet. Each column (database field) is a category of information about the AMD streams. The field names are the labels which identify the fields in the database; they are located in the row immediately preceding the data and they must be unique to allow criteria searches. A portion of the spreadsheet which illustrates the database fields is given in Appendix III.

The first field is the stream code (identified by "Code"). Each site was assigned a letter code upon receipt of the completed survey. A number was assigned to each stream associated with that site (e.g., B-2 is the second stream for site B). The second field (identified by "Table") is the number for the table in Appendix IV which summarizes the stream data in a more conventional format (to allow easy access to the complete set of data for each stream). The third field is the general geographic region in which the site is found (Atlantic, Quebec, Ontario, Manitoba or British Columbia). The AMD streams are entered into the spreadsheet in regional groups to facilitate comparisons. The fourth and fifth fields, which are self explanatory, are mine type and mine status, respectively. The subsequent set of fields falls under the broad heading of climate data and is organized by month. The precipitation fields are labelled with "P-*month*" while the temperature fields are labelled with "T-*month*". The next four fields are stream description, stream source, sample location and sample year.

They provide contextual information about the AMD streams. The following four fields show the month(s) corresponding to each season and will allow correlations to the climate data. The remainder of the fields contain the AMD stream data organized by season and by parameter. Hence, the aluminium concentrations in the spring, summer, fall and winter are designated "Al-sp", "Al-su", "Al-f" and "Al-w", respectively. There are 35 possible parameters listed under each season. The printout in Appendix III includes all fields up to the end of the first listed season (spring) as well as a few of the summer parameters.

When no data were provided, the cells in the spreadsheet were left blank. In terms of significant digits, numeric data were entered as submitted by the company. When a value was supplied as "less than" a concentration limit (i.e., <0.05 mg/L), the cell in the spreadsheet was left blank since both numeric and alphanumeric data cannot be used in the same field. For three of the streams, ranges of data were given for several parameters. Consequently, two records were created for each of these streams; the low values in the ranges were entered in the streams labelled "min" and the high values were entered in the streams labelled "max". A single value rather than a range was submitted for some of the stream parameters; this value was entered in both the "min" and "max" records for that parameter.

RESULTS AND DISCUSSION

Information was collected for 72 individual raw AMD streams from 30 different sites (owned by 12 companies) across Canada. Table 1 provides a listing of the AMD streams, the number for the associated table in Appendix IV, and some basic site information. In the majority of cases, the AMD stream data for each season are associated with a single month which was specified by the respondent (see tables in Appendix IV). It is likely that these sample values represent single "grabs" for that month, although the questionnaire did not request clarification of this point. In some cases, the respondents listed several months for a particular season. This would infer that the associated sample values are averages of several grab samples taken over the season. The data for ten of the streams (at sites Z and P) were provided on an annual basis rather than seasonally and hence, the stream parameters are excluded from the spreadsheet. The annual data are, however, included in the tables in Appendix IV.

FLOWRATES

Seasonal flowrate data were included for 38 of the 72 AMD streams. These data are shown in Table 2 along with stream source and sample location information. As expected, the flowrates are almost always higher in spring and fall compared to summer and winter. In one case (I-3), a low flowrate (maximum 0.5 L/s) landfill drainage stream dried up in the summer. In other cases (D-2, M-1 and DD-1), streams coming from ponded water stopped flowing due to freezing in the winter. The highest flowrates (1000-2000 L/s) are associated with major water collection systems (CC-1, B-2 and N-3) providing feed to treatment plants. Twenty-three percent of the 133 stream flow measurements are >100 L/s; 35% of the flows range from 10-100 L/s and 42% are <10 L/s. These latter flows tend to be associated with streams which originate as drainage from waste rock piles or seepage from tailings or dams. Obviously, the flowrates will increase as streams merge further from the source, both from the combination of the stream volumes and from the inclusion of runoff water. For example, streams G-1, G-2 and G-3 are successively downstream from each other on the same drainage system. G-1 is a small seepage stream below a tailings dam (spring flowrate of 0.2 L/s). G-2 is considered to be drainage creek (spring flowrate of 33 L/s) and G-3 includes uncontaminated lake outflow (spring flowrate of 173 L/s). In fact, the largest volume AMD stream (CC-1) includes mill process water, refinery effluent, sewage treatment plant effluent, runoff, etc.

Table 1 – Listing of AMD streams

Stream Code	Appendix IV Table	Region	Mine Type	Mine Status	Annual Ppt'n (mm)
A–1	1	Atlantic	Pb Zn	Shut	1023
B–1	2	Atlantic	Pb Zn	Open	1023
B–2	3	Atlantic	Pb Zn	Open	1023
B–3	4	Atlantic	Pb Zn	Open	1023
W–1	5	Quebec	Cu Zn Pb	Shut	
X–1min	6	Quebec	Au	Open	917.3
X–1max	6	Quebec	Au	Open	917.3
C–1	7	Quebec	Au	Open	919.7
C–2	8	Quebec	Au	Open	919.7
C–3	9	Quebec	Au	Open	919.7
D–1	10	Quebec	Cu Zn	Open	856.8
D–2	11	Quebec	Cu Zn	Open	856.8
AA–1min	12	Quebec	Cu Zn	Open	887.1
AA–1max	12	Quebec	Cu Zn	Open	887.1
AA–2	13	Quebec	Cu Zn	Open	887.1
AA–3	14	Quebec	Cu Zn	Open	887.1
AA–4	15	Quebec	Cu Zn	Open	887.1
AA–5	16	Quebec	Cu Zn	Open	887.1
BB–1	17	Quebec	Cu Zn	Shut	709.3
R–1	18	Ontario	Cu Zn	Shut	749.8
R–2	19	Ontario	Cu Zn	Shut	749.8
R–3	20	Ontario	Cu Zn	Shut	749.8
R–4	21	Ontario	Cu Zn	Shut	749.8
Z–1	22	Ontario	Cu Zn	Open	
Z–2	23	Ontario	Cu Zn	Open	
Z–3	24	Ontario	Cu Zn	Open	
Z–4	25	Ontario	Cu Zn	Open	
Z–5	26	Ontario	Cu Zn	Open	
Z–6	27	Ontario	Cu Zn	Open	
Z–7	28	Ontario	Cu Zn	Open	
Z–8	29	Ontario	Cu Zn	Open	
Z–9	30	Ontario	Cu Zn	Open	
E–1	31	Ontario	U	Shut	900
E–2	32	Ontario	U	Shut	900
F–1	33	Ontario	U	Shut	900
F–2	34	Ontario	U	Shut	900
F–3	35	Ontario	U	Shut	900
G–1	36	Ontario	U	Shut	966
G–2	37	Ontario	U	Shut	966
G–3	38	Ontario	U	Shut	966
H–1	39	Ontario	U	Shut	966
H–2	40	Ontario	U	Shut	966
H–3	41	Ontario	U	Shut	966
H–4	42	Ontario	U	Shut	966
I–1	43	Ontario	U	Shut	966
I–2	44	Ontario	U	Shut	966
I–3	45	Ontario	U	Shut	966
I–4	46	Ontario	U	Shut	966
J–1	47	Ontario	U	Shut	966
K–1	48	Ontario	U	Shut	966
L–1	49	Ontario	U	Shut	966
L–2	50	Ontario	U	Shut	966
M–1	51	Ontario	U Cu	Shut	966
N–1min	52	Ontario	Ni Cu	Open	860.6
N–1max	52	Ontario	Ni Cu	Open	860.6
N–2	53	Ontario	Ni Cu	Open	860.6
N–3	54	Ontario	Ni Cu	Open	860.6
N–4	55	Ontario	Ni Cu	Open	860.6
O–1	56	Ontario	Ni	Shut	860.6
O–2	57	Ontario	Ni	Shut	860.6
P–1	58	Ontario	Ni Cu	Shut	860.6
Q–1	59	Ontario	Zn Cu	Open	810.9
Y–1	60	Ontario	Ni Cu	Open	871.8
CC–1	61	Ontario	Ni Cu	Open	871.8
DD–1	62	Manitoba	Cu Zn	Open	479.1
DD–2	63	Manitoba	Cu Zn	Open	479.1
S–1	64	BC	Cu Ag Au	Shut	538.9
S–2	65	BC	Cu Ag Au	Shut	538.9
S–3	66	BC	Cu Ag Au	Shut	538.9
S–4	67	BC	Cu Ag Au	Shut	538.9
T–1	68	BC	Cu	Shut	508.8
T–2	69	BC	Cu	Shut	508.8
U–1	70	BC	Pb Zn Ag	Open	627
V–1	71	BC	Pb Zn Ag	Open	409
V–2	72	BC	Pb Zn Ag	Open	409

Table 2 – Seasonal flowrate data and stream source information

Stream Code	AMD STREAM DESCRIPTION	SAMPLE LOCATION	Flowrate (L/s)			
			spring	summer	fall	winter
A–1	Acid water holding pond for site drainage		25	25	25	25
B–1	Drainage from underground mine		30	25	25	25
B–2	Tailings effluent and seepage from tailings dam		1,000	330	600	283
W–1	Tailings pond effluent	Pond overflow		232		
D–1	Drainage from waste rock pile	Collection pond		72	65	
D–2	Surface water from tailings pond	Decant tower	46	27	42	0
AA–2	Site drainage from mine tailings	Creek		17		
E–2	Tailings dam seepage	Near dam 17	2	2	4	
F–2	Seepage stream and site drainage from tailings	Below dam D; before lime treatment	90	11	38	15
F–3	Seepage stream from seepage collection pond	Below dam G	4	2	4	
G–1	Seepage stream from low permeability tailings dam	Below dam A	0.2	0.1	0.2	0.1
G–2	Seepage from tailings dam A plus tailings spill runoff	Drainage creek;downstream from G–1	33	9.6	73	1.8
G–3	Site drainage from tailings and waste rock; includes uncontaminated lake outflow	Downstream from G–2	173	65	193	32.8
H–2	Tailings pond water (minor amounts of waste rock) (some lime added upstream)	Treatment plant feed	181.9	57.2	184.0	68.6
H–3	Site drainage from waste rock	Northwest drainage pathway	2.4	0.1	1.1	0.3
H–4	Site drainage from waste rock (mine seepage, runoff and lake discharge)	Drainage creek at mine road	7.2	1.6	25.4	16.5
I–1	Tailings dam seepage (from tailings zone in low permeability dam)	Downstream of dam B	0.4	0.2	0.5	0.3
I–3	Seepage and runoff from mine waste, landfill and tailings spill	Landfill drainage	0.2	0	0.5	0.1
I–4	Tailings flood water (tailings spill 90% covered with water)	Beaver pond outlet	33.6	4.0	10.7	4.2
J–1	Runoff from tailings site	Discharge from tails area	12.0	0.3	3.5	0.3
L–1	Seepage and runoff from tailings	Treatment plant feed	129.1	28.9	90.8	31.7
L–2	Seepage from tailings	Seepage collection system	9.3	3.1	3.3	2.5
M–1	Seepage and site drainage from minesite and tailings	Treatment plant feed (holding pond)	154	26.4	105.1	0
N–1min	Waste rock, mine water and tailings	Pump house	160	75	110	80
N–1max	Waste rock, mine water and tailings	Pump house	160	75	110	80
N–3	Tailings effluent, mine water and surface runoff from waste rock and tailings	Upstream of neutralization dam	1,540	480	580	430
O–1	Site drainage from waste rock		5.7			
O–2	Site drainage from waste rock		3.0			
Y–1	Storm water collection system (tailings, natural ppt'n and atm'ic deposition)	Treatment plant feed	137	20.8	147	122
CC–1	Effluent collection (mill process water, mine water, refinery effluent, runoff, etc.)	Treatment plant feed	1,718			
DD–1	Runoff from waste rock piles	Collecting pond near open pit	19	12.6	6.3	0
DD–2	Tailings pond runoff (process tailings water decant)	Tailings pond outfall spillway	112	106	106	100
S–1	Pit overflow from open pit mine with acid generating rock fill	Pit overflow	3.2	5.8	1.7	0.93
S–2	Site drainage from waste rock	Creek	8.88	3.73	1.51	2.35
S–3	Seepage from tailings dam #1 (base of dam is waste rock)	Dam #1 seepage	9.91	4.50	3.95	3.29
S–4	Seepage stream from waste rock dump	Main waste dump	7.53	3.27	2.30	3.33
U–1	U/G mine drainage and waste rock dump seepage	Mine drain pipe outflow at tailings pond	77	71	55	49
V–1	Tailings pond seepages	Seepage pump station	68	41	48	33
V–2	Effluent, seepage and mine drainage from tailings, waste rock and mine workings	Treatment plant feed	258	233	233	292

CHEMICAL COMPOSITION

Heavy Metals Content

One of the major concerns with acid production is the release of heavy metals into solution. It is the high metal loadings in the acid mine drainage which is most harmful to the environment. Heavy metals may be solubilized by the acidic dissolution of metal oxides or carbonates or by the oxidation of metal sulphides. There are a number of naturally occurring physical, chemical and biological characteristics of mine waste facilities which control metal solubility and contaminant migration (1). The solubility of metals is generally determined by the pH of the leachate, the type of metal being mobilized and the chemical composition of the leachate (1).

The seasonal stream data for copper, nickel, lead, zinc, arsenic, iron, cadmium, cobalt, aluminium and manganese are collated into Tables 3-7. Examination for seasonal frequency of the maximum concentration value for individual streams reveals trends for just lead and cobalt. These metal concentrations tend to be higher in fall or winter compared to spring and summer. However, if only those streams with measurements for all four seasons are considered (including the values provided as "less than" a concentration limit in the tables in Appendix IV), the following trends emerge for minimum and maximum values. Copper concentrations tend to be highest in the spring and lowest in the fall (both moderate trends). Lead concentrations tend to be highest in the winter (strong trend). Zinc concentrations tend to be highest in the spring (weak trend) and lowest in the summer and fall (strong trend). Iron concentrations tend to be highest in the winter (weak trend). Cobalt concentrations tend to be highest in the winter and lowest in the fall (both strong trends). It would appear that factors such as adsorption phenomena, interactions along the AMD migration pathway or other site specific features which are not seasonal also have an impact on heavy metal concentrations in the AMD streams.

The following paragraphs summarize the results for heavy metals in terms of the percentage of the total number of seasonal measurements (as listed in Tables 3-7) which occur in various concentration ranges. Detailed seasonal concentration distributions for each metal except arsenic are illustrated in Figs. 1-5.

Table 3 – Seasonal stream data for copper and nickel

Stream Code	Copper (mg/L)				Nickel (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
A–1	18.6	15	21.2					
B–1	16.9	10.7	12.1	2.2				
B–2	0.13	0.90	0.36	0.07				
B–3	0.5	0.42	0.15	0.56				
W–1		0.82						
X–1min	0.91		0.010				0.10	
X–1max	3.00		0.010				0.10	
C–1	54			50	11			8.4
C–2	56			63	11			12
D–1	3.81	34.9	219	74.1				
D–2	22.06	0.28	3.04	1.53				
AA–1min		0.005	0.013			0.007	0.016	
AA–1max		0.089	0.138			0.054	0.056	
AA–2	0.049	0.032	0.037	0.127	0.011	0.012	0.017	0.026
AA–3	0.003	0.003	0.006		0.003	0.005	0.009	
AA–4	0.005	0.011	0.025		0.005	0.006	0.014	
AA–5	0.016	0.009	0.011		0.006	0.005	0.013	
BB–1	0.94	0.99	0.69	1.18				
R–1	99.5	78.6	88.2	77.4	0.46	0.35	0.38	0.36
R–2	1.07	1.60		0.562	0.233	0.167		0.180
R–3		0.44		0.82				
R–4	3.276				0.209			
H–2	0.05		0.11		0.13		0.23	
H–4	0.043	0.029	0.014	0.016	0.098	0.075	0.019	0.12
I–1	0.88	1.01	0.83	1.12	0.81	1.6	0.73	1.37
I–2	0.10	0.110	0.110	0.11	0.090	0.15	0.23	0.32
I–3	0.005		0.004	0.005				
I–4				0.01				0.010
L–1	0.02	0.02	0.040	0.040	0.31	0.25	0.10	0.28
L–2	0.070	0.030	0.020	0.070	0.19	0.25	0.28	0.17
M–1	0.66	0.12	0.28		0.20	0.15	0.90	
N–1min	1.1	0.48	0.12	0.08	3.30	3.50	0.35	0.21
N–1max	3.3	3.10	1.50	1.61	7.60	7.20	5.90	4.94
N–2	4.1	3.3	3.3	3.6	12.3	13.8	15.5	14.9
N–3					1.21	1.14	1.5	1.24
N–4	0.21	0.06	1.1	0.11	0.52	0.38	1.15	0.45
O–1	0.18				0.72			
O–2	1.6				1.8			
Q–1		0.09	0.39			0.02		
Y–1	2.98	4.53	0.0212	3.66	12.4	17.3	36.0	17.8
CC–1	0.721				11.4			
DD–1	6.90	11.7	14.75					
DD–2	0.16	0.04	0.14	0.08				
S–1	0.195	0.725	0.219	0.135				
S–2	2.11	2.26	1.46	2.88				
S–3	31.35	29.7	24.1	27.4				
S–4	300.0	239.7	209.3	341.7				
T–1	33.2	41.8	27.4	1.49				0.021
T–2	32.2	40.9	26.6	11.3				0.089
U–1	0.41	0.13	0.11	0.21				
V–1	0.02	0.005		0.005				
V–2	0.25	0.09	0.1	0.05				

Table 4 – Seasonal stream data for lead and zinc

Stream Code	Lead (mg/L)				Zinc (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
A–1	0.12	0.43	0.46		132	153	233	
B–1	1.7	2.3	6.2	1.9	1,674	1,237	2,099	1,064
B–2	3.2	4.6	4.2	1.25	12.9	38.3	28.9	11.6
B–3	0.47	0.31	0.03	0.52	5.1	14.5	40.4	11.4
W–1		0.06				1.74		
X–1min			0.019		2.05		2.94	
X–1max			0.019		6.30		2.94	
C–1	1.9				25			26
C–2	1.8				22			27
D–1					29.87	204.7	951	415
D–2					229	6.5	47.0	17.7
AA–1min		0.001	0.008			0.036	1.508	
AA–1max		0.017	0.023			14.93	14.6	
AA–2	0.017	0.009	0.025	0.040	1.635	0.978	1.268	2.215
AA–3	0.004	0.003	0.008		0.013	0.012	0.014	
AA–4	0.004	0.006	0.015		0.052	0.086	0.464	
AA–5	0.009	0.007	0.008		0.123	0.053	0.072	
BB–1					3.26	3.88	4.57	6.22
R–1		0.08	0.15	0.36	579	480	571	506
R–2	0.404	0.982		1.164	98.3	62.7		47.8
R–3		0.05		0.06		31.5		57.0
R–4	0.033				63.850			
H–2			0.06		0.17		0.42	
H–4					0.11	0.084	0.024	0.052
I–1				0.12	1.61	1.80	1.10	2.10
I–2		0.10		0.32	0.29	0.06	0.07	0.70
I–3					0.17		0.22	0.030
I–4				0.010	0.03	0.02	0.007	0.020
L–1					0.080	0.070	0.10	0.090
L–2				0.22	0.14	0.16	0.110	0.16
M–1					0.18	0.030	0.030	
N–1min					0.08	0.08		0.03
N–1max			0.004		0.35	0.34	0.19	0.25
N–2	0.004	0.003	0.007	0.004	0.37	0.45	0.47	0.50
N–4					0.23		0.055	0.02
O–1					0.04			
O–2					0.07			
Q–1						11.6	21.1	
Y–1		0.771			0.355	0.382	0.704	0.425
CC–1					0.160			
DD–1	0.19	0.68	0.36		450.0	135.50	662.0	
DD–2	0.35	0.21	0.19	0.12	0.53	1.57	1.88	0.23
S–1					4.02	7.26	4.94	4.01
S–2					2.00	1.79	1.45	2.26
S–3					20.89	20.0	18.0	19.6
S–4					217.7	198.7	180.0	224.5
T–1								0.349
T–2								0.954
U–1	1.6	5.6	5.3	23	117	65	87	85
V–1	0.1		0.1		4.2	0.70	1.9	1.5
V–2	3.9	4.4	4.3	3.6	58	22	21	21

Table 5 – Seasonal stream data for arsenic and iron

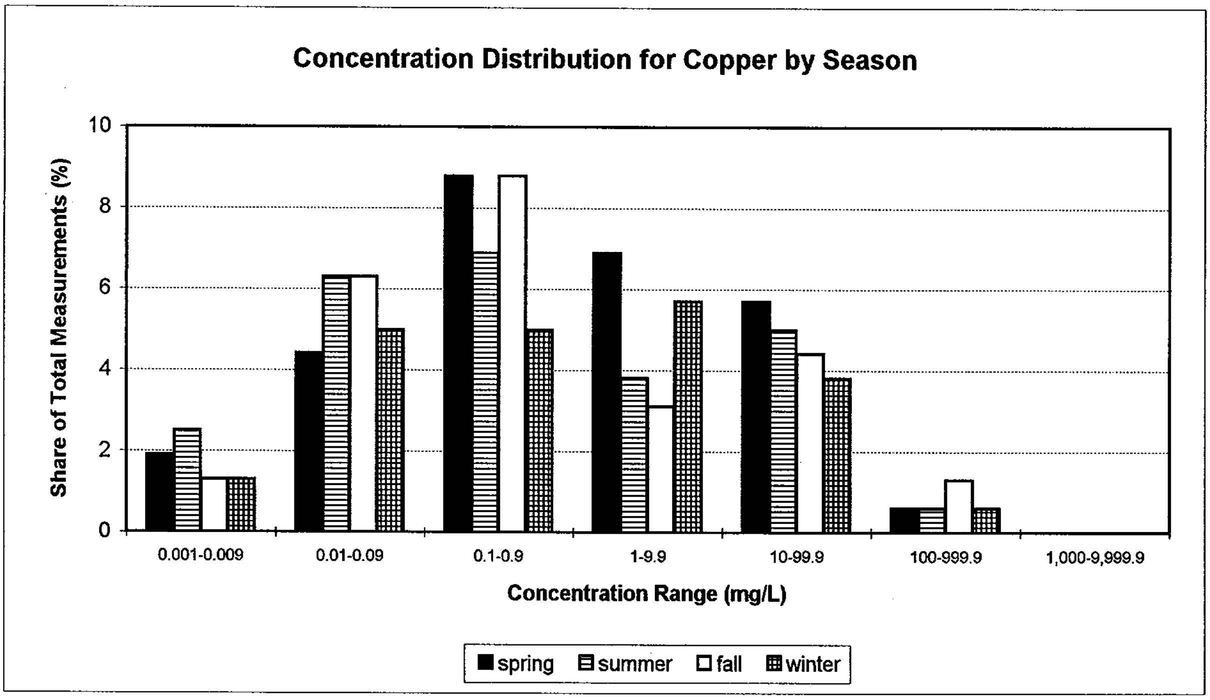
Stream Code	Arsenic (mg/L)				Iron(T) (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
A–1					1,340	513	1,169	
B–1					1,394	714	1,167	645
B–2					31.5	52.5	104	20
B–3					6.5	27.4	2.7	17.1
W–1		0.0016				8.55		
X–1min					10.1		7.65	
X–1max					37.2		7.65	
C–1					20,000	14,000	14,000	8,400
C–2					15,000	11,300	7,200	17,800
C–3						5,600	6,400	
D–1					12.34	231.9	634	205
D–2					401	14.7	29.14	6.29
AA–1min						0.14	0.17	
AA–1max						5.31	2.81	
AA–2					8.875	11.13	12.43	47.99
AA–3					1.285	1.024	1.238	
AA–4					1.962	2.724	3.55	
AA–5					2.673	6.045	3.655	
BB–1					69.6	34.1	47.8	155.0
R–1	0.114	0.124	0.324	0.098	539	468	574	456
R–2					644	169		228
R–3						1.91		1.05
R–4					34.803			
F–3					9.6	8.0	4.6	
G–2					3.00	9.20	3.50	7.90
G–3								0.72
H–2					34	13.70	10.7	53
H–4					0.43	1.20	0.14	
I–1					278	645	372	660
I–2					14.0	22.0	38	44.0
I–3					0.22		0.73	0.14
I–4					0.82	0.61	0.62	19.0
J–1					53.0	51.0	76.0	79.0
K–1					35.0	26.0	28.0	36.0
L–1					300	745	402	828
L–2					131	184	95	177
M–1					16.0	55.0	24.0	
N–1min					0.22	0.22	0.24	0.38
N–1max					1.1	3.2	1.10	1.76
N–2					13.5	5.6	9.8	10.6
N–4					3.3	2.4	3.75	3.2
O–1					0.65			
O–2					6.2			
Q–1						0.05	0.55	
Y–1					10.9	15.3	52.8	30.6
CC–1					36.3			
DD–1					313.9	485.1	420.70	
DD–2					2.20	17.90	22.10	1.80
S–1	0.0006	0.0003	0.0004	0.0005	0.04	0.09	0.038	0.044
S–2					7.98	8.47	9.36	11.97
S–3					825.8	735.1	499.5	589.5
T–1					8.28	2.17	0.509	0.474
T–2					4.29	4.18	3.17	2.31
U–1	0.21	0.07	0.09	0.12	254	100	100	41
V–1					292	168	330	340
V–2					204	104	131	184

Table 6 – Seasonal stream data for cadmium and cobalt

Stream Code	Cadmium (mg/L)				Cobalt (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
W-1		0.008						
X-1min			0.009					
X-1max			0.009					
C-1				0.12				
C-2				0.08				
BB-1		0.011		0.012				
R-1	1.92	1.63	1.84	1.74				
H-2					0.25		0.45	
H-4	0.004				0.062	0.060	0.015	0.018
I-1	0.003		0.002		1.40	2.00	1.20	2.20
I-2					0.07	0.07	0.30	0.33
I-3					0.010		0.050	0.020
I-4								0.020
L-1					0.24	0.30	0.070	0.34
L-2					0.14	0.15	0.11	0.16
M-1					0.29	0.25	0.34	
O-1	0.001							
O-2	0.0011							
Q-1		0.08	0.11					
Y-1	0.0057	0.0121	0.0146		0.500	0.62	1.38	0.707
CC-1	0.0021				0.240			
S-1	0.0382	0.0602	0.0635	0.0321				
T-1								0.146
T-2								0.498
V-1	0.01		0.005	0.005				

Table 7 – Seasonal stream data for aluminium and manganese

Stream Code	Aluminium (mg/L)				Manganese (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
W−1		5				0.92		
X−1min					4.54		7.36	
X−1max					9.37		7.36	
C−1	4,200	3,400	3,500		252	200	210	225
C−2	4,800	4,000	2,500		247	200	140	282
C−3		1,100	1,100			58	61	
R−3		0.66		2.35				
H−2					1.7		3.5	
H−4	3.6	1.7	0.75	0.67	0.65	1.00	0.15	0.19
I−1	140		120		11.0	21.0	12.8	21.0
I−2					0.84	1.59	2	2.3
I−3					0.33		0.87	0.32
I−4					0.020	0.020	0.080	0.32
J−1					0.69	0.83	0.73	0.77
L−1	1.8	1.0	5.4	5.7	3.2	4.5	1.3	5.2
L−2	1.80	1.60	3.80	1.30	0.83	1.13	0.92	1.00
M−1					0.5	0.96	0.84	
Y−1	3.88	6.48	9.35	6.18	0.586		1.42	0.917
CC−1	2.55				0.938			
S−1	0.0501	0.0176	0.0995	0.0660				
T−1	35.3	24.8	14.0	0.049				4.24
T−2	32.3	25.3	14.1	32.1				10.0
U−1					27			5.3
V−1					19	13	15	17



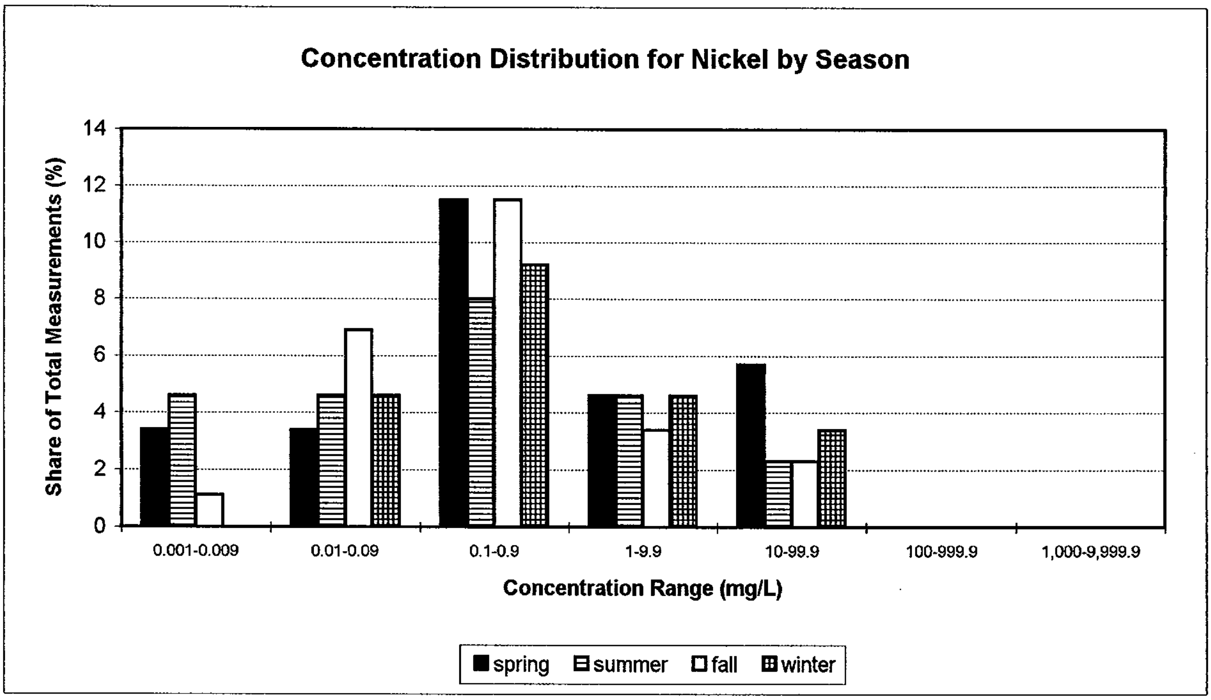
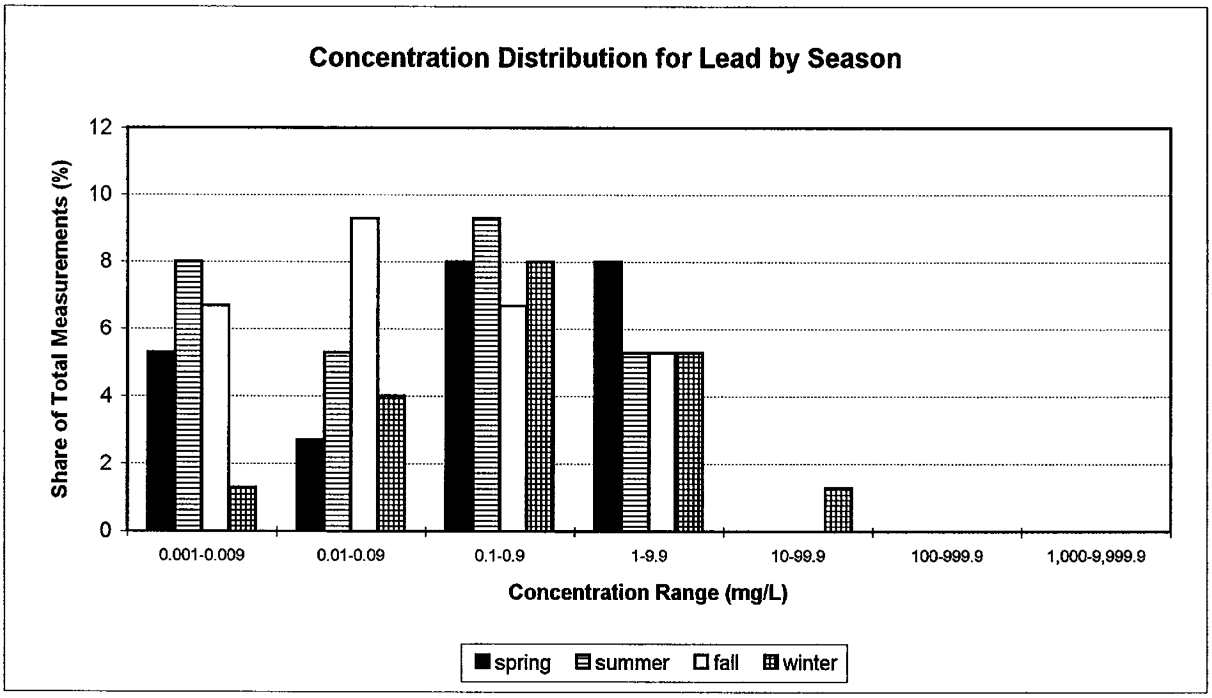


Fig. 1 - Concentration distributions for copper and nickel



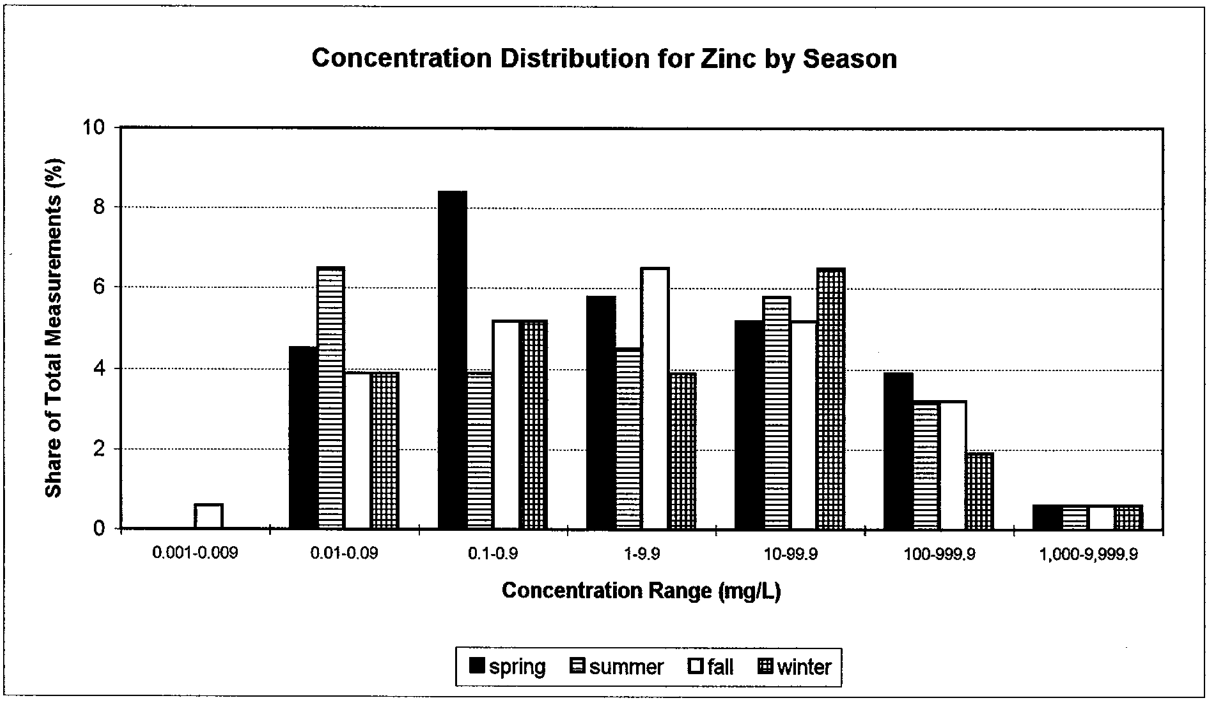


Fig. 2 - Concentration distributions for lead and zinc

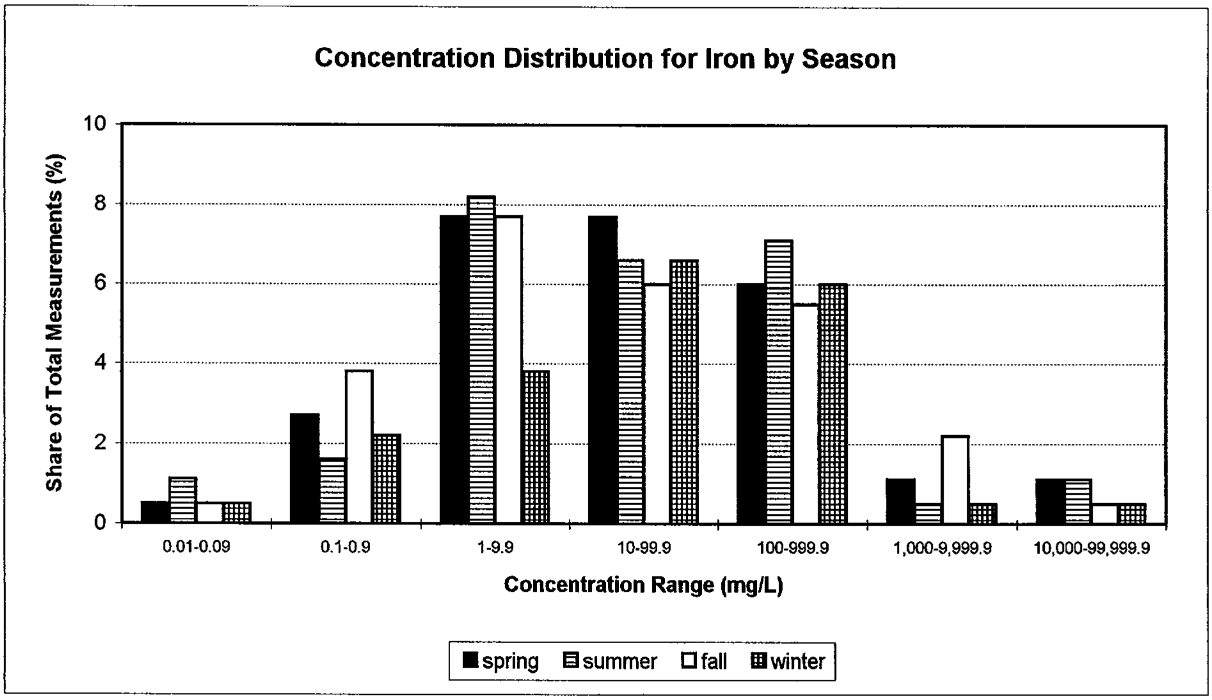


Fig. 3 - Concentration distribution for iron

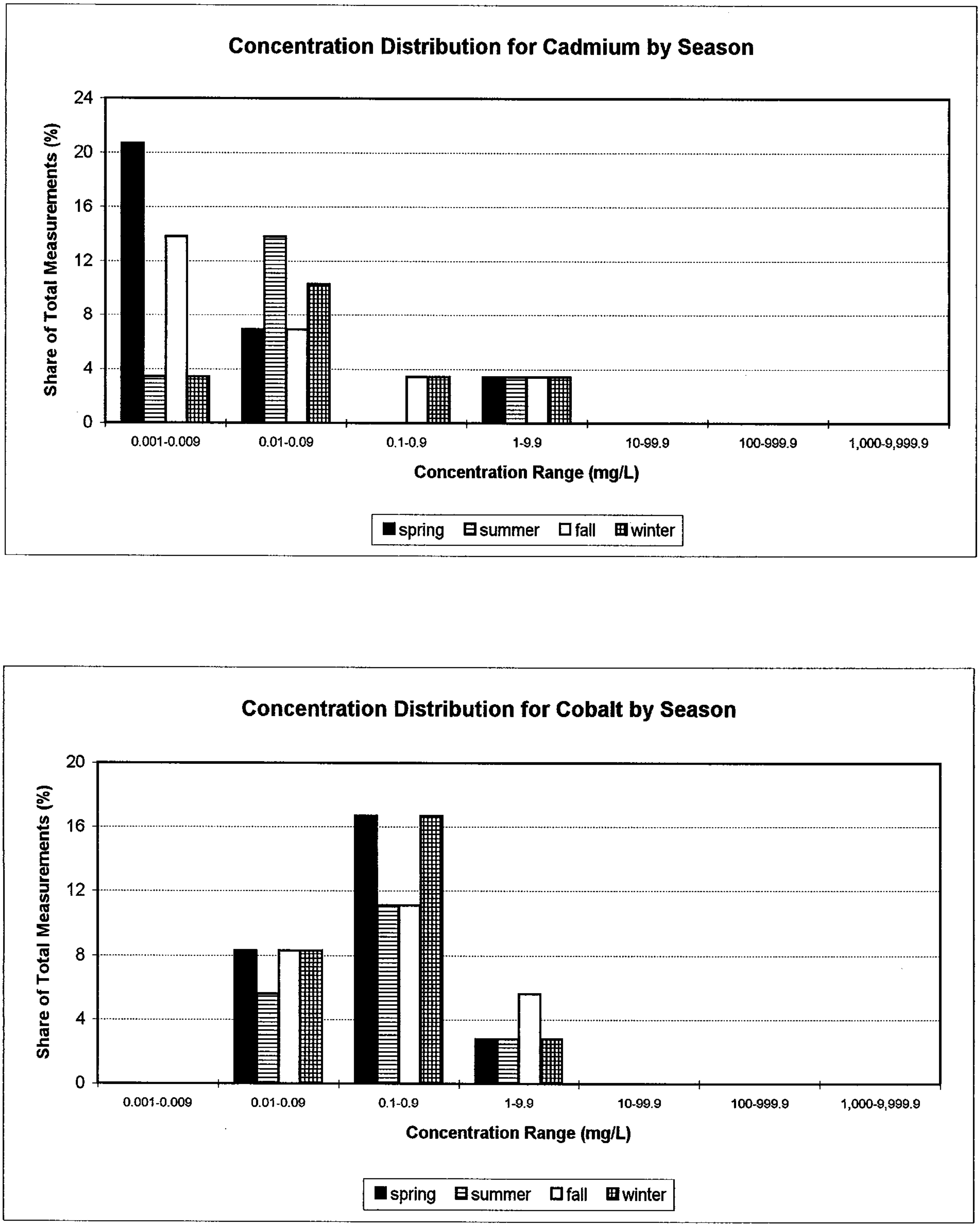
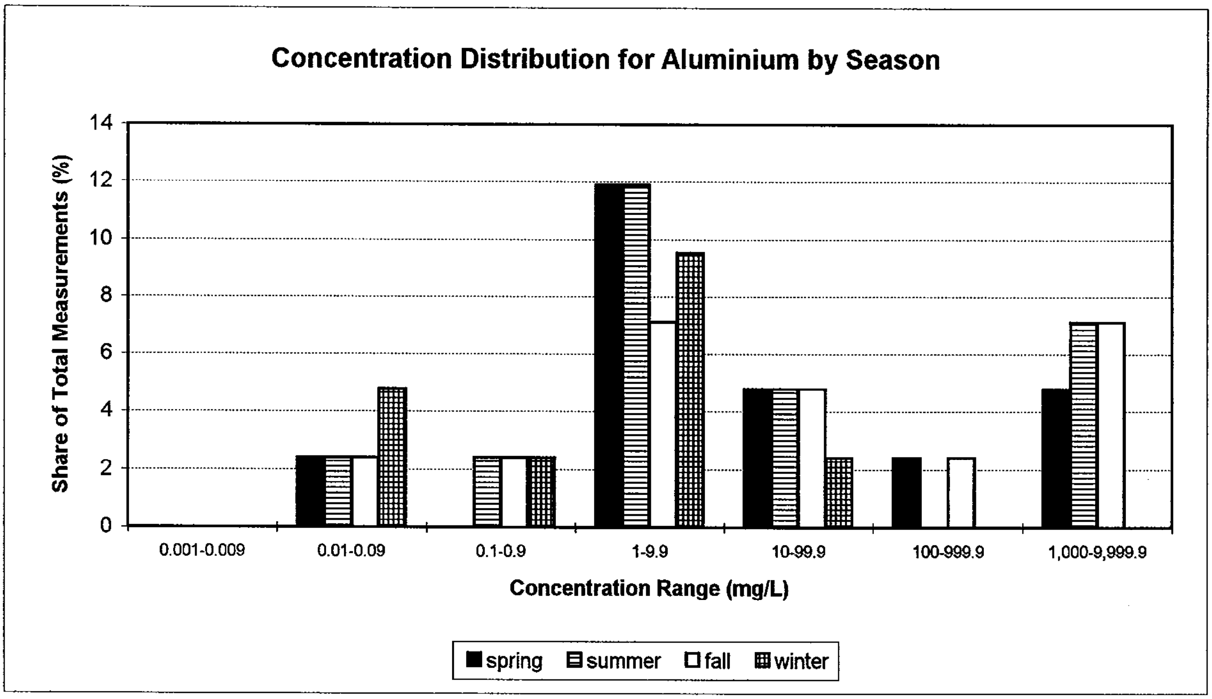


Fig. 4 - Concentration distributions for cadmium and cobalt



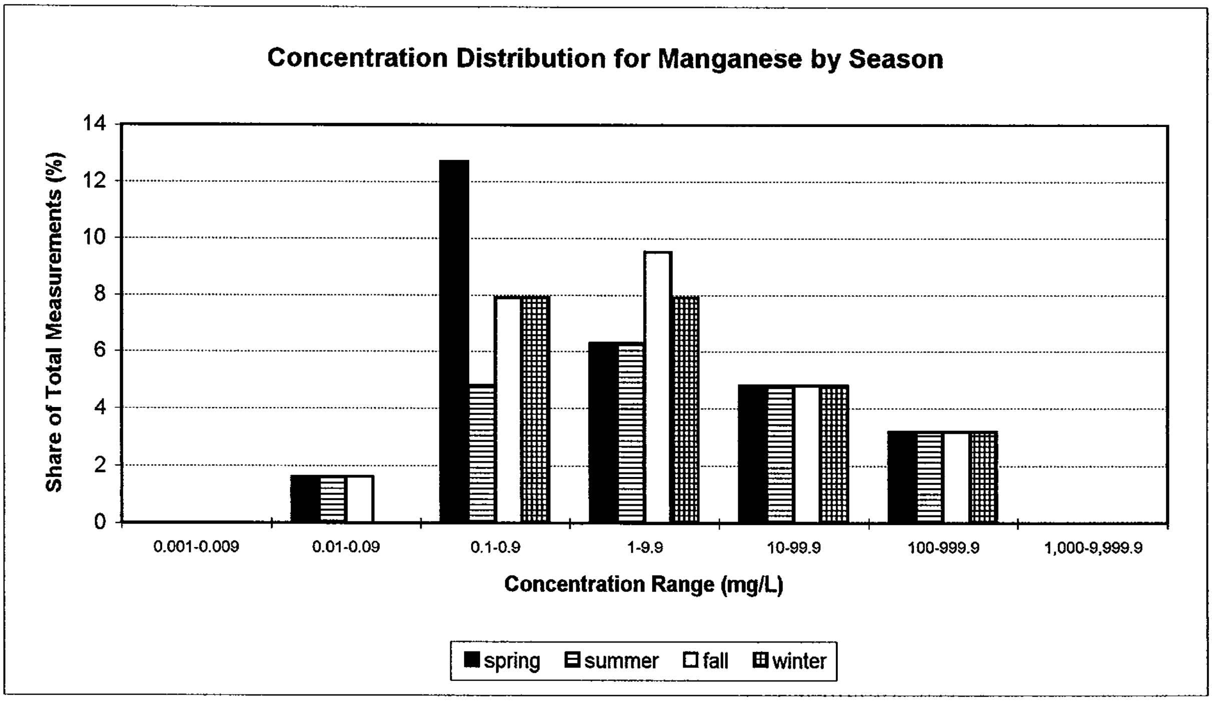


Fig. 5 - Concentration distributions for aluminium and manganese

A 1991 report indicated that copper concentrations exceeding 200 mg/L are required for metal recovery to be potentially feasible (3). The maximum copper concentrations (>200 mg/L) were reported for drainage from waste rock dumps associated with copper mines (S-4 and D-1). There is a large seasonal variation in the level of copper for D-1 (3.8, 34.9, 219 and 74.1 mg/L for spring, summer, fall and winter respectively). This variability is also observed for other streams (e.g., D-2 and Y-1). Twenty-two percent of the 159 seasonal measurements for the 48 streams reporting copper are >10 mg/L, 49% range from 0.1-10 mg/L and 29% are <0.1 mg/L. The Metal Mine Liquid Effluent Regulation (MMLER) limit for copper in a grab sample is 0.6 mg/L.

The maximum nickel concentrations (>10 mg/L) were reported for drainage associated with both nickel and gold mines (Y-1, CC-1, N-2, C-1 and C-2). Thirty-one percent of the 87 seasonal measurements for the 30 streams reporting nickel are >1 mg/L, 40% range from 0.1-1 mg/L while 29% are <0.1 mg/L. The MMLER limit for nickel in a grab sample is 1.0 mg/L.

The maximum lead concentration (23 mg/L) was reported for drainage associated with a Pb/Zn mine (U-1). This is the winter lead level, and the concentrations for the other seasons range from 1.6-5.6 mg/L. Twenty-five percent of the 75 seasonal measurements for the 30 streams reporting Pb are >1 mg/L. The streams with high lead levels are associated with either Pb/Zn mines or drainage from waste rock dumps for gold mines. Thirty-two percent of the measurements range from 0.1-1 mg/L and 43% are <0.1 mg/L. The MMLER limit for lead in a grab sample is 0.4 mg/L.

A 1991 report indicated that zinc concentrations exceeding 1,000 mg/L are required for metal recovery to be potentially feasible (3). The maximum zinc concentrations (>1,000 mg/L) were reported for underground mine drainage associated with a Pb/Zn mine (B-1). Thirty-seven percent of the 155 seasonal measurements for the 48 streams reporting zinc have levels >10 mg/L, 21% range from 1-10 mg/L and 42% are <1 mg/L. The MMLER limit for zinc in a grab sample is 1.0 mg/L.

The maximum iron concentrations (>1,000 mg/L) were reported for drainage from waste rock dumps associated with a gold mine (C-1, C-2 and C-3). These data represent 8% of the 182 seasonal measurements for the 53 streams reporting iron. Seventy-nine percent of the measurements range from 1-1000 mg/L (split almost evenly between the orders of magnitude) and 13% are <1 mg/L. There is no MMLER limit for iron.

Only four streams reported arsenic concentrations. The maximum reported concentration was 0.32 mg/L which falls below the lowest (monthly average) MMLER limit of 0.5 mg/L.

The maximum cadmium concentrations (>1 mg/L) were reported for mine water from a Cu/Zn mine (R-1). These data represent 14% of the 29 seasonal measurements for the 15 streams reporting cadmium. Forty-five percent of the measurements range from 0.01-0.1 mg/L and 41% are <0.01 mg/L.

The maximum cobalt concentrations (>1 mg/L) were reported for tailings dam seepage associated with a uranium mine (I-1). These data represent 14% of the 36 seasonal measurements for the 13 streams reporting cobalt. Fifty-six percent of the measurements range from 0.1-1 mg/L and 30% are <0.1 mg/L.

The maximum aluminium concentrations (>1,000 mg/L) were reported for drainage from waste rock dumps associated with gold mines (C-1, C-2 and C-3). These data represent 19% of the 42 seasonal measurements for the 14 streams reporting aluminium. Twenty-one percent of the measurements range from 10-1,000 mg/L and 60% are <10 mg/L.

The maximum manganese concentrations (>100 mg/L) were reported for drainage from waste rock dumps associated with a gold mine (C-1 and C-2). These data represent 13% of the 63 seasonal measurements for the 21 streams reporting manganese. Forty-nine percent of the measurements range from 1-100 mg/L and 38% are <1 mg/L. The MMLER do not contain limits for cadmium, cobalt, aluminium or manganese.

<u>Sulphate Concentration</u>

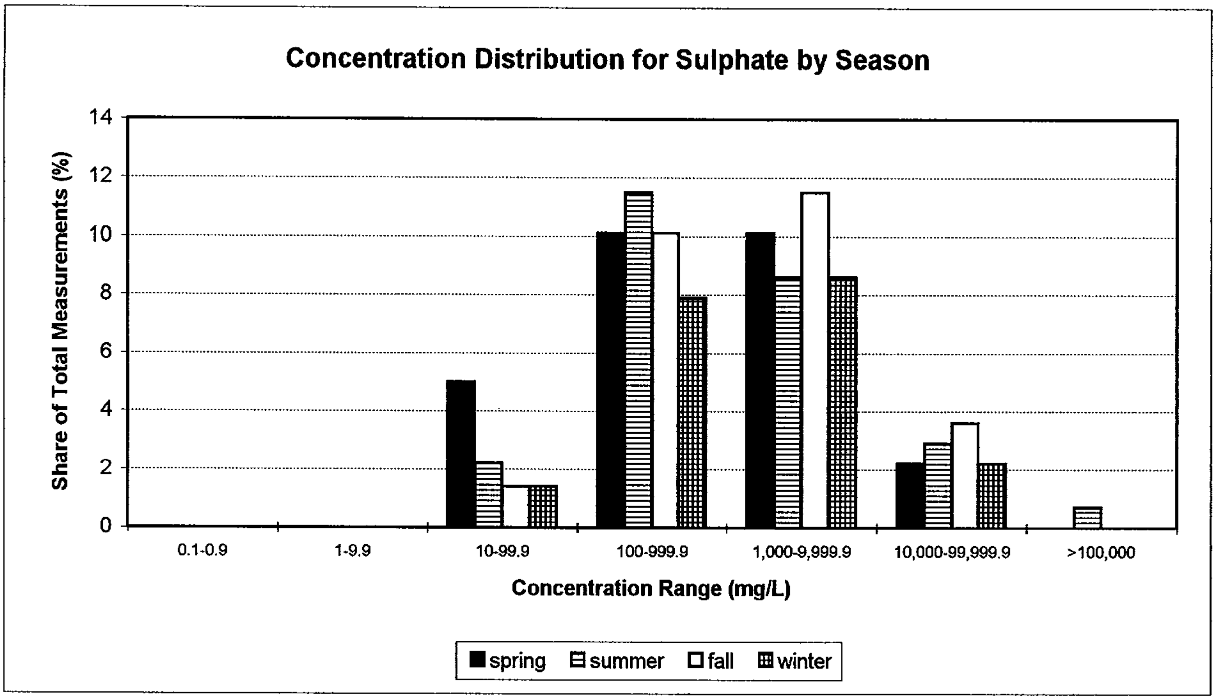
The seasonal stream data for sulphate concentration are presented in Table 8. Examination for seasonal frequencies of the minimum and maximum concentrations for each stream with measurements for all four seasons (including the values provided as "less than" a concentration limit in the tables in Appendix IV) reveals the following: there is a moderate trend towards the occurrence of the highest concentration in the winter, and a strong trend towards the occurrence of the lowest concentration in the spring. The maximum sulphate concentrations (>10,000 mg/L) were reported for drainage from waste rock dumps associated with a gold mine (C-1 and C-2) and a Cu/Au/Ag mine (S-4). These data represent 12% of the 139 seasonal measurements for the 40 streams reporting sulphate. Seventy-eight percent of the measurements range from 100-10,000 mg/L and 10% are <100 mg/L. The concentration distribution by season is illustrated in Fig. 6.

Acidity and pH

The seasonal stream data for acidity and pH are provided in Table 8. As with sulphate concentration, the acidity values for individual streams with measurements for all four seasons exhibit strong trends towards the occurrence of the highest concentration in the winter and the lowest concentration in the spring. The concentration distribution for acidity is illustrated in Fig. 6. The maximum acidity values (>10,000 mg/L) were reported for drainage from waste rock dumps associated with a gold mine (C-1 and C-2) and a Cu/Au/Ag mine (S-4), and for a combined effluent associated with a Pb/Zn mine (V-2). These high acidity values are matched by the maximum sulphate concentrations (see previous section) and by low pH values. Twelve percent of the 129 seasonal measurements for the 38 streams reporting acidity have values >10,000 mg/L, 65% range from 100-10,000 mg/L and 23% are <100 mg/L. The lower acidity values tend to match higher pH values as expected. The majority of pH values reported are between 2 and 5. The minimum MMLER authorized pH value for a grab sample is 5.0. The maximum pH values reported in this survey (8.5 and 9.11) are associated with tailings ponds at Cu/Zn mines in winter (D-2 and DD-2).

Table 8 – Seasonal stream data for sulphate, acidity and pH

Stream Code	SO4 (mg/L)				Acidity (mg/L)				pH			
	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall	winter
A-1	4,023	3,160	4,430						2.8	2.4	2.7	
B-1	8,066	7,807	7,715	6,800					2.5	2.5	3.2	3.5
B-2	1,173	1,837	1,820	1,881					6.0	2.4	2.7	6.2
W-1		240				10				3.2		
X-1min	360		900		77		85		2.94		3.36	
X-1max	760		900		290		85		3.52		3.36	
C-1	85,000	150,000	58,000	55,000	57,500	52,500	25,000	50,000	2.15	2.24	2.23	2.20
C-2	92,500	42,500	37,000	80,000	57,500	52,500	15,000	60,000	2.15	2.27	2.39	2.18
C-3		26,500	26,500			20,000	12,000			2.22	2.18	
D-1					105	1,068	3,240	1,615	4.5	3.04	3.94	2.71
D-2					952		26.5		5.34	7.78	6.12	8.52
AA-2									6.23	6.23	6.33	6.1
AA-3									6.73	6.43	6.65	
AA-4									6.4	6.03	5.95	
AA-5									5.9	5.8	5.65	
BB-1	377	632	905	1,285	162	239	379	546	3.3	2.9	2.6	3.1
R-1	6,400	5,400	6,500	5,600					2.5	2.5	2.7	2.6
R-2									2.9	2.7		3.1
R-3		390		520						3.9		4.0
R-4									3.6			
E-1					9	10	5		5.1	6.8	6.3	
E-2					246	566	294		4.9	4.4	5.0	
F-1					613	2,950	1,651	3,065	3.1	2.4	2.7	2.6
F-2					753	1,520	1,770	2,900	3.0	2.4	2.5	2.5
F-3	62	146	346		45	38	79		3.4	4.2	3.3	
G-1					115	1,160	610	1,305	3.50	2.70	3.30	3.40
G-2	34	101	41	139	40	80	50	113	3.80	3.40	3.50	3.20
G-3	10	28	18	10	7	4	7	3	6.20	6.60	6.30	6.60
H-1					1,039	1,163	691	813	2.91	2.62	2.93	3.23
H-2	1,051		1,872	2,002	168	221	172	367	4.05	3.19	3.64	3.38
H-3	310	492	431	367	190	280	253	173	3.60	3.60	3.70	4.10
H-4	79	37	120	60	30	21	20	4	4.90	5.00	4.90	6.60
I-1	1,208	2,516	2,031	3,089	1,075	2,950	1,525	2,650	2.90	2.70	2.80	3.20
I-2	368	749	868	1,192	160	258	315	371	3.20	2.95	2.70	3.00
I-3					35		53	15	5.00		4.90	6.50
I-4	61	94	105	229	7		14	42	6.80	8.40	6.20	6.80
J-1	466	560	498	560	375	410	460	430	2.80	2.70	2.90	2.80
K-1	412	447	357	491	243	300	315	265	2.80	2.80	3.00	2.70
L-1					761	1,342	917	1,726	3.27	4.54	3.32	4.89
L-2					664	655	793	1,061	3.30	3.24	3.36	3.47
M-1					141	248	154		3.53	2.93	3.12	
N-1min	200	314	594									
N-1max	328	610	1,386									
N-2	578	794	1,175	874					3.5	3.2	3.3	3.3
N-3									4.54	3.14	3.26	5.25
N-4	336	731	1,062	594					5.6	6.0	5.25	5.2
O-1	24.0								4.1			
O-2	95.6								3.3			
Q-1		480	312							7.5	7.2	
Y-1	305	352	774	594					3.44	4.42	3.25	4.28
CC-1	1,524								5.93			
DD-1	7,530.0	13,024.0	10,731.9						3.04	2.44	2.57	
DD-2	1,260.0	1,580.2	1,522.6						8.34	5.17	4.68	9.11
S-1	1,412	1,352	1,236	1,346					7.24	7.46	7.65	7.55
S-2	427	737	718	877	149.67	182.2	165.7	252.5	3.65	3.47	3.62	3.38
S-3	6,030	5,830	6,460	5,364	4,097	3,767	2,990	3,324	2.48	2.58	2.63	2.47
S-4	29,579	24,445	16,318	26,411	20,793	16,811	14,693	23,082	2.45	2.54	2.62	2.38
T-1	1,020	1,450	1,340	954	243	222	116	13.9	4.4	4.5	4.8	7.0
T-2	951	1,260	1,290	1,310	251	221	111	229	4.30	4.20	4.50	5.70
U-1	3,284	2,045	2,493	1,697	2,221			1,263	3.2	3.6	3.4	3.6
V-1	3,680	2,857	3,345	3,710	972			2,380	5.6	6.5	6.1	5.4
V-2					12,295			14,873	3.6	3.4	4.2	4.4



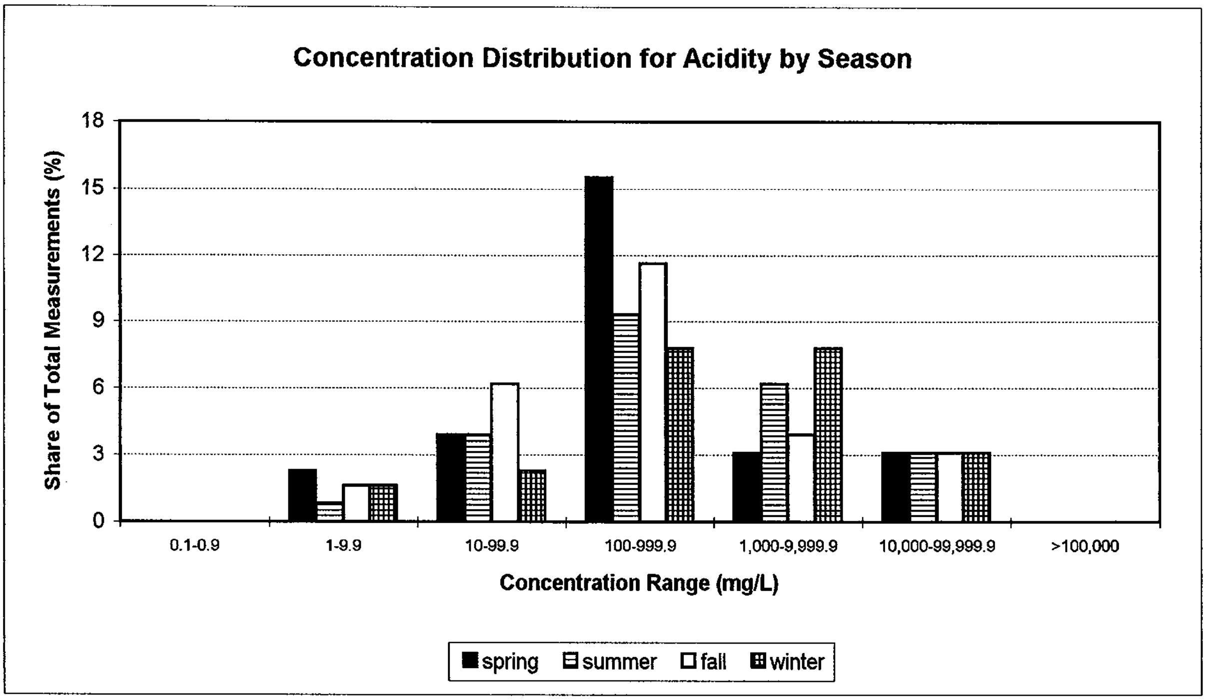


Fig. 6 - Concentration distributions for sulphate and acidity

Oxidizing Conditions

Only four streams reported data on oxidizing conditions, one in the form of the Fe^{+2} concentration and the remainder as redox potentials. The seasonal stream data for these parameters are given in Table 9. The small number of values precludes seasonal trend analysis. Information on oxidizing conditions is necessary for planning treatment options for AMD streams. Measurements are probably not performed because they are difficult and the results are often suspect.

SUSPENDED SOLIDS

The seasonal stream data for total suspended solids (TSS) as well as for total dissolved solids (TDS) are presented in Table 10. The concentration distributions for TSS and TDS by season are illustrated in Fig. 7. There are no apparent seasonal trends for TSS in individual streams. The maximum TSS values (>100 mg/L) were reported for drainage from waste rock dumps associated with a gold mine (C-1 and C-2) and from a combination of drainage from waste rock dumps and underground mine workings associated with a Pb/Zn mine (U-1). These data represent 9% of the 87 seasonal measurements for the 27 streams reporting TSS. Forty-seven percent of the measurements range from 10-100 mg/L and 44% are <10 mg/L. These latter values are usually associated with holding ponds or tailings ponds (e.g., T-1, M-1, I-4 and H-2). The MMLER limit for TSS in a grab sample is 50.0 mg/L. Although TSS is a regulated parameter, its importance with respect to treatment lies in its potential influence (either positive or negative) on the treatment process.

PROBLEMS AND SUCCESSES

Most respondents provided comments on problems and successes in dealing with AMD at their sites (see site information in Appendix V). For example: corrosion of operating equipment due to contact with AMD was noted as a problem at sites X and DD; disposal of water treatment sludge was of concern at sites BB and S; AMD generation was successfully reduced by 75% at site N through the use of a waste rock and sewage cover on the tailings area; and backfilling one of the open pits at site S greatly diminished the rate of

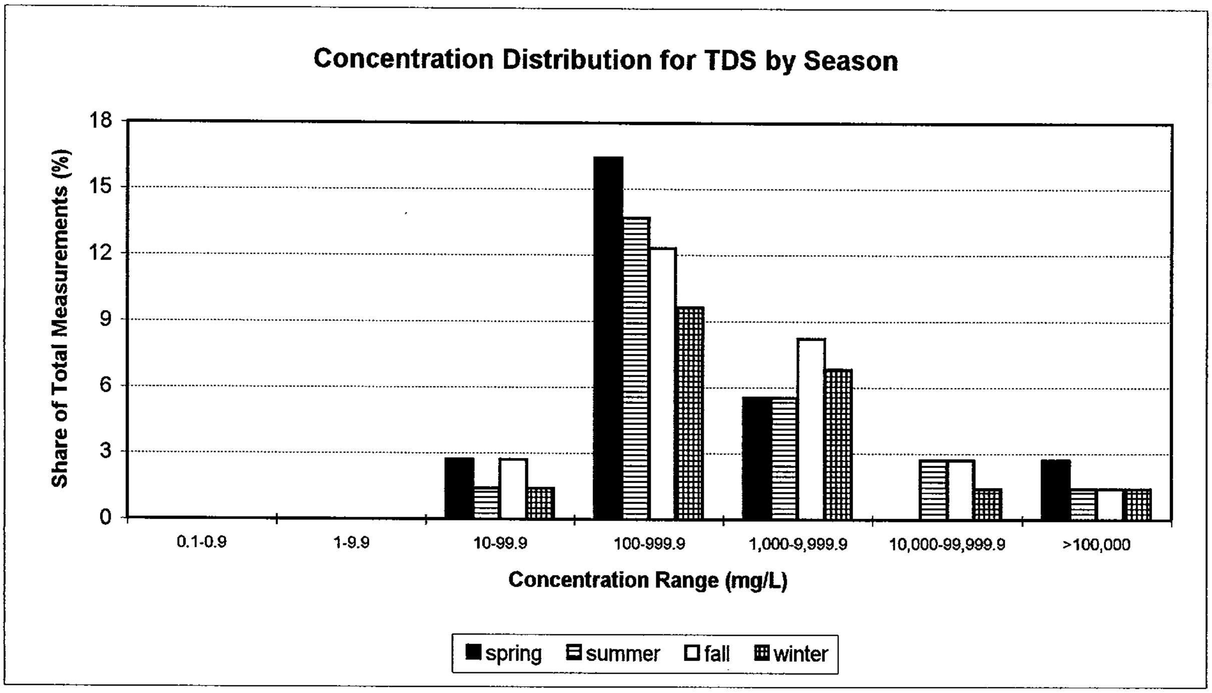
Table 9 – Seasonal stream data for oxidizing conditions

Stream Code	Fe(+2) (mg/L)				Eh (mV)		
	spring	summer	fall	winter	spring	summer	fall
W–1						497	
D–1					465	678	649.9
D–2					429	417	437
L–1	263	638	324	801			

Table 10 – Seasonal stream data for dissolved and suspended solids

Stream Code	TDS (mg/L)				TSS (mg/L)			
	spring	summer	fall	winter	spring	summer	fall	winter
B–2					3.3	6.5	5.2	27.6
W–1						90		
X–1min					23		23	
X–1max					80		23	
C–1	103,400	100,000	105,000	98,000	190			345
C–2	116,060	98,900	65,400	130,000	200			1,070
C–3		57,000	45,000					
AA–1min						0	0	
AA–1max						28.0	13.0	
AA–2					17.53	35.3	52.7	48.9
AA–3					9.4	4.9	5.2	
AA–4					62.4	19.6	11.0	
AA–5					13.6	19.3	4.0	
R–1					7	27	14	10
R–2					8	55		7
R–4					77			
E–1	296	676	474					
E–2	1,200	2,620	1,712					
F–3	312	288	540					
G–2	88	212	66	216				
G–3	51	109	35	64				
H–2	1,664		2,852	3,140	4	9	7	12
H–3	509	817	688	590				
H–4	160	81	246	127	8	10	4	1
I–1	1,873	6,201	3,184	5,925	9	22	4	4
I–2	580	1,184	1,303	1,836				
I–3	142		179	212				
I–4	164	236	228	590	5	1	3	12
J–1	664	780	708	791				
K–1	591	639	500	670				
L–1	2,446	3,418	1,085	4,180				
M–1	470	846	811		13	1	2	
N–2					0.8	1.9	1.7	0.6
N–4					0.6	3.7	6.4	3.7
Y–1	564	802	1,050	1,000	79		54.9	38.9
CC–1	233				23			
T–1					23.0	7.0	5.0	9.0
T–2					12.0	12.0	19.0	9.0
U–1					338	943	659	320
V–1					59	3	72	44
V–2					10	6	10	37

TDS = Total dissolved solids
TSS = Total suspended solids



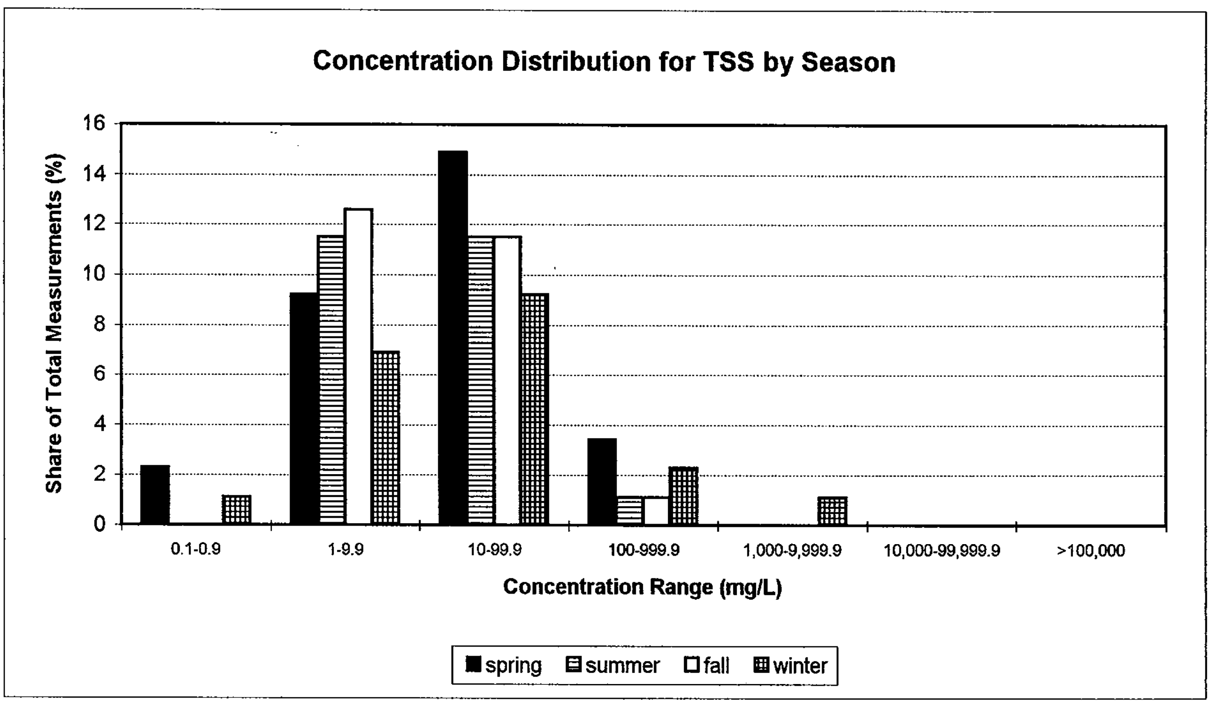


Fig. 7 - Concentration distributions for TDS and TSS

oxidation resulting in lower metal concentrations in the AMD from the pit. The most common problems and related successes are summarized in the following paragraphs.

Sites C and F reported that seasonally variable flows of AMD make treatment difficult; at site F, effective treatment is achieved only during low flow periods. However at site B, a new treatment system effectively handles spring runoff.

Although the fact that tailings are stockpiled above the water table was specified as a significant problem at sites H, I, J and K, the successful use of water covers to prevent further acid generation was noted at sites W, E, H and I.

Waste rock is a major source of AMD at many mines. At site S, the waste rock dumps produce large volumes of strong AMD which must be collected and treated. At sites Z, N and S waste rock used to construct roadbeds, railbeds, plant site foundations and portions of tailings dams generates large volumes of dilute AMD. At site Z, the costly removal of this waste rock has been contemplated due to difficulties in collection and treatment of the resulting contaminated "storm water runoff". To prevent problems with waste rock at site Q, the current milling plan includes the use of all waste rock for backfill purposes within the mine.

Location, interception and collection of all contaminated flows at a site has proven to be difficult in many cases (U, V, Z, L and P). Yet, identification of AMD sources with at least partial collection of flows/seepages for treatment was listed as a success by many operators (C, D, BB, R, F, N, S, T, U, V, Z and P).

Several respondents noted that either metal loadings or pH of the final effluent sometimes caused them problems (sites B, D, AA and P). On the other hand, treatment plants at sites C, BB, R, Z, S and V have consistently operated in 100% compliance with regulatory limits.

CONCLUSIONS

Detailed information on 72 untreated AMD streams from across Canada is compiled in this report. A complete set of tables (one for each stream) arranged by general geographic region is provided. The data were also input into a Lotus 1-2-3 spreadsheet designed to allow analysis based on selected criteria. The data on stream sources, flowrates, heavy metal concentrations, acidity, oxidizing conditions and suspended solids content are presented in a concise tabular format to allow seasonal comparisons. Graphical concentration distributions are provided for several of these parameters.

Seasonal trends were observed for some of the stream characteristics. As expected, flowrates are almost always higher in the spring and fall compared to summer and winter. When only those streams with measurements for all four seasons are considered, five of nine heavy metals reveal seasonal trends. Copper and zinc concentrations tend to be highest for individual streams in the spring while lead, iron and cobalt concentrations tend to be highest in the winter. Zinc concentrations tend to be lowest for individual streams in the summer and fall, while copper and cobalt concentrations tend to be lowest in the fall alone. Sulphate concentrations and acidity tend to exhibit matching trends: they are highest in winter and lowest in spring. It would appear that confounding factors such as adsorption phenomena, interactions along the AMD migration pathway or other site specific features which are not seasonal have an overriding impact on many AMD stream characteristics.

A small number of the streams have concentrations of copper or zinc which are high enough for metal recovery to be potentially feasible as a treatment approach. However, many of the streams are diluted by other sources of water (e.g., runoff, mill effluent, etc.) reducing the base metal concentrations. Hence, the metal recovery option may require the interception of AMD streams closer to the source of metals dissolution yielding lower flowrates and higher concentrations.

Very little data were provided on oxidizing conditions in AMD streams, probably because measurements of these parameters are difficult and the results are often suspect. However, this information is necessary for the consideration of many treatment options. Therefore, mining companies may need to be encouraged to collect these data.

Information on problems and successes in dealing with AMD at the various sites was extracted from the questionnaire responses and is summarized in terms of generic issues. The two most common concerns/accomplishments involve the collection of all contaminated flows at a site and the quality of the final effluent.

This report, along with the associated computer spreadsheet, provides a good data bank of Canadian AMD stream characteristics to assist in defining strategies for improving AMD treatment techniques. As well, it will allow the formulation of synthetic AMD solutions, which are relevant to the Canadian context, for use in general AMD research.

REFERENCES

1. Steffen Robertson and Kirsten Inc., "Draft Acid Rock Drainage Technical Guide", Volume 1, British Columbia Acid Mine Drainage Task Force Report, August 1989.

2. Filion M.P., Ferguson K. and Sirois L.L., "Acidic Drainage Research in Canada", in Proceedings of the 23rd CMP Conference, Ottawa, Ontario, January 22-24, Paper 10, p. 21, 1991.

3. Dinardo O., Kondos P.D., MacKinnon D.J., McCready R.G.L., Riveros P.A. and Skaff M., "Study on Metals Recovery/Recycling from Acid Mine Drainage", MEND Project 3.21.1a, July 1991.

APPENDIX I

QUESTIONNAIRE

in English

en Français

CANADA-WIDE SURVEY OF ACID MINE DRAINAGE

QUESTIONNAIRE

prepared by CANMET
May 1994

Survey Objective
The objective of this survey on acid mine drainage is to create, in cooperation with the mining companies participating in the MEND program, a data bank on the composition, flowrates and seasonal fluctuations of acid mine drainage streams in Canada.

CANMET/MEND Role
CANMET will conduct the survey, analyze the data, and present a written report to the MEND Treatment Committee. MEND will provide access to the information to MEND members. A copy of the final report will be sent to all participants.

Your Participation
The companies taking part in the survey are:

Brunswick Mining & Smelting Corp. Ltd.
Cambior Inc.
Cominco Ltd.
Denison Mines Ltd.
Falconbridge Ltd.
Homestake Canada Inc.
Hudson Bay Mining and Smelting Co. Ltd.
Inco Ltd.
Lac Minerals Ltd.
Les Mines Selbaie
Noranda Minerals Inc.
Placer Dome Inc.
Rio Algom Ltd.
Teck Corporation

We strongly encourage your participation, which involves collection of the information and completion of the questionnaire. Your direct involvement is essential to ensure the timely delivery of this project and to ensure the quality and usefulness of the data. Data gathered in this study will be an important input in helping to define strategies for mitigation of AMD. As well, it will provide a definition of AMD in terms of chemical composition and geographic location. This will allow the formulation of AMD reference solutions relevant to the Canadian context.

It is understood that each participating company has several AMD sites (i.e., separate geographic locations). One questionnaire is required for each site.

Confidentiality
The data and information collected in this survey will be identified by general geographic region only.

CANMET Support
One week following receipt of the questionnaire(s), CANMET will contact you to answer any questions you may have.

GENERAL INSTRUCTIONS

1. Please complete this questionnaire and return it by **June 27, 1994** to:

   Linda Wilson
   Environmental Laboratory
   CANMET
   555 Booth Street
   Ottawa, Ontario
   K1A 0G1

2. The questionnaire is divided into two parts:

   PART I - deals with general information about the AMD generating site.

   PART II - deals with information about the AMD stream(s) at the site.

3. If the answer to any question is "none", "not applicable" or "not available", please indicate which of these situations applies rather than leave the space blank.

4. All AMD stream data is requested on a seasonal basis. If the information is not readily available from your records on this basis, please furnish the information that you have with an explanation.

5. Please provide the numerical information in the requested units.

6. Necessary comments or explanations with respect to any question should be made in the space provided or on separate sheets, and attached to the questionnaire.

7. Any questions regarding this questionnaire or the project should be directed to Linda Wilson at: Phone 613-995-4133 or Fax 613-996-9041

PART I

AMD GENERATING SITE

1. Company name: ____________________

2. Contact person(s): Name Title Phone/fax

____

____

3. Site name: ____________________

4. Type of associated mine (base metal, precious metal, uranium, etc.):

____

5. Location (province/territory, distance and direction from nearest town/city):

____

____

6. Site description:

Facilities present (treatment plant, mill, dam, settling ponds, tailings pile, waste rock dump, mine, etc.):

____

____

____

Geographic features (valley, lake, wetlands, creek, etc.): ____________________

____

____

Type and quantity (tonnes) of each stockpiled material: ____________________

____

____

Chemical and/or mineralogical information on acid generating materials (% or ppm):
(specifically sulphide minerals, S_{Tot}, carbonate minerals, heavy metals)

Number of AMD streams on site (including separate streams flowing into a collection ditch, if applicable):

Number of AMD streams for which there is data:

7. Brief history:

Year that mining-related activities commenced:

Year that AMD was detected:

Mine is: operating G shut down G (if so, what year)

Other information pertinent to acid generation at the site (amendment additions, water cover, revegetation, etc.):

8. Climatic information:

Precipitation profile (mm) Jan ____ Feb ____ Mar ____ Apr ____ May ____ Jun ____ Jul ____
Aug ____ Sep ____ Oct ____ Nov ____ Dec ____ Total _____

Temperature profile (EC) Jan ____ Feb ____ Mar ____ Apr ____ May ____ Jun ____ Jul ____
Aug ____ Sep ____ Oct ____ Nov ____ Dec ____

9. What are your most significant problems with AMD at this site?

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____
____
____
____

10. What are your successes in dealing with AMD at this site?

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____
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____
____
____
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____

PART II

AMD STREAMS

The remainder of the questionnaire consists of two data tables for one AMD stream. Your site might have more than one AMD stream for which applicable data are available. Please photocopy this part of the questionnaire for each AMD stream.

Thank you for completing the questionnaire.

Respondent: Name Title Phone/fax

____

(please print)

Date: ________________________

AMD STREAM

Site name: ______________________________ Stream # ________

AMD stream description[1]: ______________________________

AMD stream source[2]: ______________________________

Sample location and year: ______________________________

Parameters	Spring month:	Summer month:	Fall month:	Winter month:
Al (mg/L)				
As (mg/L)				
Cd (mg/L)				
Cr (mg/L)				
Co (mg/L)				
Cu (mg/L)				
Fe_{Tot} (mg/L)				
Hg (mg/L)				
Mn (mg/L)				
Ni (mg/L)				
Pb (mg/L)				
Zn (mg/L)				
* (mg/L)				
* (mg/L)				
* (mg/L)				

[1] seepage streams, overflow, mine water, tailings pond water, site drainage, etc.

[2] waste rock, open pit mine, underground mine, tailings, ore stockpile, etc.

* Add any other metals which are important constituents of the AMD stream.

Site name: ______________________ Stream # ________

Parameters	Spring month:	Summer month:	Fall month:	Winter month:
SO_4 (mg/L)				
* (mg/L)				
* (mg/L)				
* (mg/L)				
Temperature (EC)				
Flowrate (L/s)				
Acidity (mg/L) (as $CaCO_3$)				
pH				
Ec[1] (µS/cm)				
TSS[2] (mg/L)				
Eh[3] (mV) (if known)				

* Add any other ions which are important constituents of the AMD stream.

[1] Electrical conductivity

[2] Total suspended solids

[3] Redox potential

Comments / Other Information

ÉTUDE À L'ÉCHELLE NATIONALE DU DRAINAGE MINIER ACIDE

QUESTIONNAIRE

préparé par CANMET
mai 1994

Objectif de l'étude
L'objectif du relevé sur le drainage minier acide est de créer, en collaboration avec les entreprises minières participant au programme NEDEM, une banque de données sur la composition, les débits et les fluctuations saisonnières des cours d'eau contaminés par le drainage minier acide au Canada.

Rôle de CANMET/NEDEM
CANMET dirigera le sondage, fera l'analyse des données et présentera un rapport écrit au Comité Traitement du NEDEM. L'information sera rendue disponible par le NEDEM à les membres du NEDEM. Un exemplaire du rapport final sera distribué à chaque membre participant.

Votre participation
Les entreprises qui prennent part à cette étude sont :

Brunswick Mining & Smelting Corp. Ltd.	Inco Limitée
Cambior Inc.	Lac Minerals Ltd.
Cominco Ltd.	Les Mines Selbaie
Denison Mines Ltd.	Minéraux Noranda Inc.
Falconbridge Ltd.	Placer Dome Inc.
Homestake Canada Inc.	Rio Algom Limitée
Hudson Bay Mining and Smelting Co. Ltd.	Corporation Teck

Nous souhaitons fortement votre collaboration, laquelle consistera à recueillir les données demandées et à remplir le présent questionnaire. Votre participation est primordiale afin de compléter cette étude dans les délais requis de même que d'assurer la qualité et la pertinence des données. Ces données revêtiront une importance primordiale lors de l'élaboration de stratégies en vue de réduire l'impact du drainage minier acide. De plus, elles permettront de définir la composition chimique et la localisation géographique du DMA. Ces connaissances aideront à la formulation de solutions témoins adaptées à l'environnement canadien.

Il est entendu que chaque compagnie participante a plusieurs sites de drainage minier acide (i.e., des sites géographiques différents). Il est nécessaire de remplir un questionnaire pour chacun des sites à l'étude.

Confidentialité
Les données et l'information recueillies dans le cadre de cette étude seront présentées uniquement par région géographique.

Soutien de CANMET
Une semaine après réception de ce(s) questionnaire(s), CANMET communiquera avec vous afin de répondre à vos questions.

INSTRUCTIONS GÉNÉRALES

1. Veuillez remplir ce questionnaire et le retouner au plus tard **le 27 juin 1994** à :

   Linda Wilson
   Laboratoire de l'environnement
   CANMET
   555, rue Booth
   Ottawa (Ontario)
   K1A 0G1

2. Le questionnaire est divisé en deux parties :

   PARTIE I - porte sur des renseignements d'ordre général relatifs au site générateur de DMA.

   PARTIE II - porte sur des renseignements spécifiques à un ou des cours d'eau contaminés par le DMA sur le site.

3. Si la réponse à une question est «aucune(s)», «sans objet» ou «non disponible», veuillez l'indiquer. Ne pas laisser d'espace en blanc.

4. Toutes les données sur le DMA sont demandées sur une base saisonnière. Si vous ne pouvez pas tirer facilement de vos dossiers les renseignements demandés selon les saisons, veuillez fournir les renseignements que vous avez en main et donner une explication.

5. Veuillez fournir les données numériques selon les unités indiquées.

6. Veuillez fournir les observations ou explications nécessaires dans l'espace prévu à cette fin ou sur des feuilles détachées que vous joindrez au questionnaire.

7. Toute question se rapportant au présent questionnaire ou au projet doit être adressée à Linda Wilson :

Téléphone 613-995-4133 ou Télécopieur 613-996-9041

PARTIE I

LE SITE GÉNÉRATEUR DE DMA

1. Nom de l'entreprise : ______________________________

2. Personne(s)-ressource : Nom Fonction Tél/télécopieur

____

____

3. Nom du site : ______________________________

4. Nature de la mine (métaux de base, métaux précieux, uranium, etc.) :

____

5. Localisation (province/territoire, distance et direction de la ville la plus proche) :

____

____

6. Description du site :

Installations existantes (usine de traitement, broyeur, barrage, bassin de décantation, amas de résidus, haldes de stérile, mine, etc.) :

____

____

____

Éléments géographiques (vallée, lac, terres humides, ruisseau, etc.) : ______________

____

____

Nature et quantité (tonnes métriques) de chacun des matériaux entreposés :

____

Renseignements d'ordre chimique ou minéralogique sur les matériaux générant de l'acide (% ou ppm) : (particulièrement minéraux de sulfure, S_{Tot}, minéraux de carbonate, métaux lourds)

____

____

____

____

____

____

____

____

Nombre de cours d'eau contaminé(s) par le DMA sur le site (incluant les cours d'eau séparés se déversant dans une tranchée de drainage, le cas échéant) : ____________________

Nombre de cours d'eau contaminé(s) par le DMA pour lesquels les données existent :

____

7. Bref historique :

Année pendant laquelle les activités minières ont débuté : ____________________

Année de détection du DMA : ____________________

La mine est : en exploitation G fermée G (année de fermeture)________

Autres renseignements relatifs à la production d'acide sur le site (addition d'amendements, barrière humide, restauration de couverture végétale, etc.) :

____

____

____

____

8. Données climatiques :

Profil des précipitations (mm)

janv____ févr____ mars____ avr____ mai____ juin____ juill___

août____ sept____ oct____ nov____ déc____ total _____

Profil des températures (EC)

janv____ févr____ mars____ avr____ mai____ juin____ juill___

août____ sep ____ oct ____ nov ____ déc ____

9. Quels sont les plus importants problèmes associés au drainage minier acide que vous pose cet endroit?

____

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____

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____

10. Décrivez vos réussites quant à la gestion du drainage minier acide à cet endroit.

____

____

____

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____

____

____

PARTIE II

COURS D'EAU CONTAMINÉS PAR LE DMA

Le reste du questionnaire comporte deux tableaux de données pour chaque cours d'eau contaminé par le DMA. Votre site peut comporter plus d'un cours d'eau contaminé par le DMA pour lequel les données demandées existent. Veuillez photocopier cette section du questionnaire et la remplir pour chacun des cours d'eau contaminé par le DMA.

Merci pour votre collaboration.

Répondant : Nom Fonction Tél/télécopieur

____

(en lettres moulées, s.v.p.)

Date : ________________________

COURS D'EAU CONTAMINÉ PAR LE DMA

Nom du site : ________________________ Cours d'eau # ________

Description[1] de cours d'eau contaminé par le DMA : ________________________

Source[2] de cours d'eau contaminé par le DMA : ________________________

Lieu de l'échantillonnage et année : ________________________

Paramètres	Printemps mois :	Été mois :	Automne mois :	Hiver mois :
Al (mg/L)				
As (mg/L)				
Cd (mg/L)				
Cr (mg/L)				
Co (mg/L)				
Cu (mg/L)				
Fe_{Tot} (mg/L)				
Hg (mg/L)				
Mn (mg/L)				
Ni (mg/L)				
Pb (mg/L)				
Zn (mg/L)				
* (mg/L)				
* (mg/L)				
* (mg/L)				

[1] infiltration, débordement, eau de mine, eau de bassin de stockage des résidus, drainage du terrain, etc.

[2] roche stérile, mine à ciel ouvert, mine souterraine, résidus, réserve de minerai, etc.

* Ajoutez tout autre métal que vous avez identifié comme étant important dans ce cours d'eau.

Nom du site : ______________________ Cours d'eau # ________

Paramètres	Printemps mois :	Été mois :	Automne mois :	Hiver mois :
SO_4 (mg/L)				
* (mg/L)				
* (mg/L)				
* (mg/L)				
Température (EC)				
Débit (L/s)				
Acidité (en mg/L $CaCO_3$)				
pH				
Ec[1] (µS/cm)				
MES[2] (mg/L)				
Eh[3] (mV) (si connu)				

* Ajoutez tout autre ion que vous considérez important.

[1] La conductivité électrique

[2] Matières en suspension

[3] Le potentiel d'oxydo-réduction

Commentaires / Renseignements additionnels

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APPENDIX II

LIST OF CONTACTS

Table A-II-1 - List of contacts

Company	Location	Contact
Billiton Métal Canada (Les Mines Selbaie)	Joutel, Qué.	Louise Grondin
Brunswick Mining & Smelting Corp. Ltd.	Bathurst, N.B.	Leonard Surges
Brunswick Mining & Smelting Corp. Ltd.	Bathurst, N.B.	Richard Schwenger
Brunswick Mining & Smelting Corp. Ltd.	Newcastle, N.B.	Michael Patterson
Cambior Inc.	Montreal, Qué.	Serge Vézina
Cominco Ltd.	Vancouver, B.C.	Walter Kuit
Cominco Ltd.	Kimberley, B.C.	Robert Gardiner
Denison Mines Ltd.	Elliot Lake, Ont.	Steven Januszewski
Falconbridge Limited	Falconbridge, Ont.	Mark Wiseman
Falconbridge Limided	Falconbridge, Ont.	Bruce Mikkila
Falconbridge Limited	Onaping, Ont.	Michael Wiebe
Falconbridge Limited	Kidd Creek, Ont.	Bernard Swarbrick
Homestake Canada Inc.	Vancouver, B.C.	William Napier
Homestake Canada Inc.	Penticton, B.C.	Barry Given
Homestake Canada Ltd. (Prime Resources Group Inc.)	Smithers, B.C.	Marlin Murphy
Hudson Bay Mining and Smelting Co. Ltd.	Flin Flon, Man.	Wayne Fraser
Hudson Bay Mining and Smelting Co. Ltd.	Flin Flon, Man.	Steven West

Table A-II-1 (cont'd)

Company	Location	Contact
Hudson Bay Mining and Smelting Co. Ltd.	Leaf Rapids, Man.	Robert Dishaw
Inco Limited	Copper Cliff, Ont.	William Kipkie
Inco Limited	Copper Cliff, Ont.	Brian Bell
Inco Limited	Copper Cliff, Ont.	Carolyn Hunt
Inco Limited	Thompson, Man.	David Shefford
Inco Limited	Thompson, Man.	Ralph Chatoor
Lac Minerals Ltd.	Kirkland Lake, Ont.	Bryan Morrison
Minerais Lac Ltée.	Preissac, Qué.	Jaques McMullen
Minerais Lac Ltée.	Preissac, Qué.	Pierre Primeau
Minerais Lac Ltée./Cambior Inc. (La Mine Doyon)	Rouyn-Noranda, Qué.	Tshitende Kasongo
Minéraux Noranda Inc.	Point-Claire, Qué.	Nural Kuyucak
Minéraux Noranda Inc.	Murdochville, Qué.	Claude Jacob
Minéraux Noranda Inc.	Matagami, Qué.	Francois Nerron
Minéraux Noranda Inc.	Rouyn-Noranda, Qué.	Peter Godbehere
Noranda Minerals Inc. (Mattabi Mines Ltd.)	Ignace, Ont.	Al Scott
Noranda Minerals Inc. (Mattabi Mines Ltd.)	Ignace, Ont.	Robert Rodrigue
Noranda Minerals Inc.	Manitouwadge, Ont.	Graham Johnson
Noranda Minerals Inc. (Hemlo Gold Mines Inc.)	Marathon, Ontario	Glen Hall

Table A-II-1 (cont'd)

Company	Location	Contact
Placer Dome Inc.	Vancouver, B.C.	Jim Robertson
Placer Dome Canada Ltd.	Vancouver, B.C.	Keith Ferguson
Placer Dome Canada Ltd. (Equity Silver Mines Ltd.)	Houston, B.C.	Mike Aziz
Placer Dome Canada Ltd. (Gibralter Mines Ltd.)	McLeese Lake, B.C.	Robert Patterson
Rio Algom Limited	Elliot Lake, Ont.	A.J. Vivyurka
Teck Corporation	Vancouver, B.C.	Michel Filion

APPENDIX III

PARTIAL SPREADSHEET PRINTOUT

CANADA–WIDE AMD SURVEY STREAM DATA

Stream Code	Appendix IV Table	Region	Mine Type	Mine Status	Climate Data: Precipitation (mm) P–Jan	P–Feb	P–Mar	P–Apr	P–May	P–Jun	P–Jul	P–Aug	P–Sep	P–Oct	P–Nov	P–Dec	Total	T–Jan	T–Feb	T–Mar
A–1	1	Atlantic	Pb Zn	Shut	87	61	77	79	86	74	97	98	75	100	92	97	1023	−12	−9	−3
B–1	2	Atlantic	Pb Zn	Open	87	61	77	79	86	74	97	98	75	100	92	97	1023	−12	−9	−3
B–2	3	Atlantic	Pb Zn	Open	87	61	77	79	86	74	97	98	75	100	92	97	1023	−12	−9	−3
B–3	4	Atlantic	Pb Zn	Open	87	61	77	79	86	74	97	98	75	100	92	97	1023	−12	−9	−3
W–1	5	Quebec	Cu Zn Pb	Shut																
X–1min	6	Quebec	Au	Open	57.6	48.2	63.8	61.1	71.8	91.1	87.2	99.5	103.0	84.3	80.0	69.7	917.3	−17	−15	−8
X–1max	6	Quebec	Au	Open	57.6	48.2	63.8	61.1	71.8	91.1	87.2	99.5	103.0	84.3	80.0	69.7	917.3	−17	−15	−8
C–1	7	Quebec	Au	Open	60.1	50.7	59.0	50.9	63.8	93.9	101.5	101.1	107.4	82.3	79.2	69.8	919.7	−16.8	−14.9	−8.3
C–2	8	Quebec	Au	Open	60.1	50.7	59.0	50.9	63.8	93.9	101.5	101.1	107.4	82.3	79.2	69.8	919.7	−16.8	−14.9	−8.3
C–3	9	Quebec	Au	Open	60.1	50.7	59.0	50.9	63.8	93.9	101.5	101.1	107.4	82.3	79.2	69.8	919.7	−16.8	−14.9	−8.3
D–1	10	Quebec	Cu Zn	Open	46.8	36.6	46.9	44.2	75.9	93.8	94.0	105	113.2	80.2	63	57.2	856.8	−17.9	−16.1	−8.9
D–2	11	Quebec	Cu Zn	Open	46.8	36.6	46.9	44.2	75.9	93.8	94.0	105	113.2	80.2	63	57.2	856.8	−17.9	−16.1	−8.9
AA–1min	12	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
AA–1max	12	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
AA–2	13	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
AA–3	14	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
AA–4	15	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
AA–5	16	Quebec	Cu Zn	Open	53.5	34.2	47.1	47.0	76.0	100.4	111.4	104.5	109.2	79.8	68.5	55.5	887.1	−19.7	−17.6	−11.1
BB–1	17	Quebec	Cu Zn	Shut	31.8	13.6	20.2	69.8	95.8	55.3	49.2	128.5	57.3	80.1	60.8	46.9	709.3	−15.9	−18.4	−6.7
R–1	18	Ontario	Cu Zn	Shut	55.3	52.5	31.3	35.7	65.7	77.1	87.4	96.1	91.6	51.3	50.2	55.6	749.8	−18.8	−15.2	−8.1
R–2	19	Ontario	Cu Zn	Shut	55.3	52.5	31.3	35.7	65.7	77.1	87.4	96.1	91.6	51.3	50.2	55.6	749.8	−18.8	−15.2	−8.1
R–3	20	Ontario	Cu Zn	Shut	55.3	52.5	31.3	35.7	65.7	77.1	87.4	96.1	91.6	51.3	50.2	55.6	749.8	−18.8	−15.2	−8.1
R–4	21	Ontario	Cu Zn	Shut	55.3	52.5	31.3	35.7	65.7	77.1	87.4	96.1	91.6	51.3	50.2	55.6	749.8	−18.8	−15.2	−8.1
Z–1	22	Ontario	Cu Zn	Open																
Z–2	23	Ontario	Cu Zn	Open																
Z–3	24	Ontario	Cu Zn	Open																
Z–4	25	Ontario	Cu Zn	Open																
Z–5	26	Ontario	Cu Zn	Open																
Z–6	27	Ontario	Cu Zn	Open																
Z–7	28	Ontario	Cu Zn	Open																
Z–8	29	Ontario	Cu Zn	Open																
Z–9	30	Ontario	Cu Zn	Open																
E–1	31	Ontario	U	Shut	60	48	64	68	70	86	80	85	108	83	83	68	900	−13	−12	−8
E–2	32	Ontario	U	Shut	60	48	64	68	70	86	80	85	108	83	83	68	900	−13	−12	−8
F–1	33	Ontario	U	Shut	60	48	64	68	70	86	80	85	108	83	83	68	900	−13	−12	−8
F–2	34	Ontario	U	Shut	60	48	64	68	70	86	80	85	108	83	83	68	900	−13	−12	−8
F–3	35	Ontario	U	Shut	60	48	64	68	70	86	80	85	108	83	83	68	900	−13	−12	−8
G–1	36	Ontario	U	Shut	64	52	56	81	76	86	75	89	112	85	115	75	966	−13	−12	−8
G–2	37	Ontario	U	Shut	64	52	56	81	76	86	75	89	112	85	115	75	966	−13	−12	−8
G–3	38	Ontario	U	Shut	64	52	56	81	76	86	75	89	112	85	115	75	966	−13	−12	−8
H–1	39	Ontario	U	Shut	64	52	56	81	76	86	75	89	112	85	115	75	966	−13	−12	−8
H–2	40	Ontario	U	Shut	64	52	56	81	76	86	75	89	112	85	115	75	966	−13	−12	−8

Temperature (°C)									Stream	
T−Apr	T−May	T−Jun	T−Jul	T−Aug	T−Sep	T−Oct	T−Nov	T−Dec	Description	Source
5	11	15	19	17	13	7	0	−7	Acid water holding pond	Site drainage
5	11	15	19	17	13	7	0	−7	Drainage	Underground mine
5	11	15	19	17	13	7	0	−7	Tailings effluent and seepage	Tailings dam
5	11	15	19	17	13	7	0	−7	Site drainage	Surface drainage (excluding mine and tailings)
									Tailings pond effluent	Tailings pond
0.9	9	14.3	17	15.5	10.4	4.4	3.7	−13.3	Mine water	Underground mine
0.9	9	14.3	17	15.5	10.4	4.4	3.7	−13.3	Mine water	Underground mine
0.9	8.8	14.3	17.1	15.5	10.4	4.4	−3.7	−13.3	Drainage ditch west of waste rock pile	Waste rock
0.9	8.8	14.3	17.1	15.5	10.4	4.4	−3.7	−13.3	Drainage ditch south of waste rock pile	Waste rock
0.9	8.8	14.3	17.1	15.5	10.4	4.4	−3.7	−13.3	Drainage ditch east of waste rock pile	Waste rock
1.0	8.6	14.2	16.8	15.0	10.4	4.8	−3.6	−14.2	Drainage from waste rock pile	Waste rock pile
1.0	8.6	14.2	16.8	15.0	10.4	4.8	−3.6	−14.2	Surface water from tailings pond	Tailings from concentrator
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Wind erosion of concentrate
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Wind erosion of concentrate
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Mine tailings
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Tailings
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Tailings
−1.3	7.5	13.1	16.0	14.3	9.2	3.3	−5.0	−16.0	Site drainage	Tailings
1.9	9.9	14.6	18.8	18.0	9.4	2.2	−5.9	−11.9	Treatment plant feed	Combined tailings dam seepages and runoff
2.1	9.3	15.5	18.8	16.9	11.1	5.0	−4.7	−14.2	Mine water	Pit F
2.1	9.3	15.5	18.8	16.9	11.1	5.0	−4.7	−14.2	Tailings pump pond	Tailings pond water
2.1	9.3	15.5	18.8	16.9	11.1	5.0	−4.7	−14.2	Mine creek	Waste rock stockpile
2.1	9.3	15.5	18.8	16.9	11.1	5.0	−4.7	−14.2	Seepage stream	Waste rock stockpile
									Tailings pond water (recycled to mill)	Tailings surface runoff and mill tailings
									Mine water	Underground mine dewatering
									Treatment plant influent	Tailings pond, mine, surface runoff and seepages
									Tailings pile seepages	Dam toe seepages before dilution by surface runoff
									Backfill quarry water	Runoff from waste rock roads and backfill quarry
									Mill area surface runoff	Conc'trate spill, tailings and waste rock foundations
									Mill area sub−surface seepage	Conc'trate spill, tailings and waste rock foundations
									Plant site area surface runoff	Waste rock foundations
									Plant site area sub−surface seepage	Waste rock foundations
2	8	13	17	15	12	8	0	−9	Dam seepage	Tailings
2	8	13	17	15	12	8	0	−9	Dam seepage	Tailings
2	8	13	17	15	12	8	0	−9	Seepage stream and site drainage	Tailings
2	8	13	17	15	12	8	0	−9	Seepage stream and site drainage	Tailings
2	8	13	17	15	12	8	0	−9	Seepage stream	Seepage collection pond
2	8	13	17	15	12	8	0	−9	Seepage stream from low permeability dam	Tailings area
2	8	13	17	15	12	8	0	−9	Seepage from dam A plus tailings spill runoff	Tailings
2	8	13	17	15	12	8	0	−9	Site drainage (including uncontaminated lake outflow)	Tailings and waste rock
2	8	13	17	15	12	8	0	−9	Tailings pond water (some lime already added)	Tailings and minor amounts of waste rock
2	8	13	17	15	12	8	0	−9	Tailings pond water (some lime added upstream)	Tailings and minor amounts of waste rock

Sample		Season/ Month(s)				Parameters								
						Spring							Spring	
						mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L
Location	Year	Spring	Summer	Fall	Winter	Al-sp	As-sp	Cd-sp	Co-sp	Cr-sp	Cu-sp	Fe(T)-sp	Fe(+2)-sp	Fe(D)-sp
	1993	Apr	Jul	Oct	Feb						18.6	1340		
	1993	Apr	Jul	Oct	Feb						16.9	1394		
	1993	Apr	Jul	Oct	Feb						0.13	31.5		
	1992	Apr	Jul	Oct	Jan						0.5	6.5		
Pond overflow	1986		Sep											
	1982/83	Apr		Nov							0.91	10.1		
	1982/83	Apr		Nov							3.00	37.2		
Monitoring station in drainage ditch	1991	Mar	Jul	Oct	Jan	4200					54	20000		
Monitoring station in drainage ditch	1991	Mar	Jul	Oct	Jan	4800					56	15000		
Monitoring station indrainage ditch	1991		Jul	Oct										
Collection pond	1993	Apr	Jul	Oct	Jan						3.81	12.34		
Decant tower	1993	Apr	Jul	Oct	Jan						22.06	401		
	1993	No months provided												
	1993	No months provided												
Creek	1993	A/M/J	J/A/S	O/N/D	J/F/M						0.049	8.875		
Drainage ditch	1993	A/M/J	J/A/S	O/N/D	J/F/M						0.003	1.285		
Drainage ditch	1993	A/M/J	J/A/S	O/N/D	J/F/M						0.005	1.962		
Ditch	1993	A/M/J	J/A/S	O/N/D	J/F/M						0.016	2.673		
Raw water impoundment pond	1993	Apr	Jun	Aug	Jan						0.94	69.6		
Pit F	1993/94	Mar	June	Sept	Dec		0.114	1.92			99.5	539		
Pump pond	1993/94	Mar	June		Dec						1.07	644		
Pump pond	1993/94		June		Nov									
Ditch D	1994	May									3.276	34.803		
	1993	Annual mean data (see Appendix IV)												
End of pipe	1993	Annual mean data (see Appendix IV)												
Treatment plant feed	1993	Annual mean data (see Appendix IV)												
Toe of dam	1992/93	Typical annual range (see Appendix IV)												
	1991-93	Average data only (see Appendix IV)												
Composite samples of surface runoff	1992	No seasonal data (see Appendix IV)												
Composite samples from test pits	1992	No seasonal data (see Appendix IV)												
Composite samples of surface runoff	1992	No seasonal data (see Appendix IV)												
Composite samples from test pits	1992	No seasonal data (see Appendix IV)												
Near dam 9	1993	Apr	Jul	Oct										
Near dam 17	1993	Apr	Jul	Oct										
Below dam A; before lime treatment	1993	Apr	Jul	Oct	Jan									
Below dam D; before lime treatment	1993	Apr	Jul	Oct	Jan									
Below dam G	1993	Apr	May	Oct								9.6		
Below dam A	1993	May	Aug	Nov	Feb									
Drainage creek-downstream from G-1	1993	May	Aug	Nov	Feb							3.00		
Downstream from G-2	1993	May	Aug	Nov	Feb									
Upstream of treatment plant	1993	May	Aug	Nov	Feb									
Treatment plant feed	1993	May	Aug	Nov	Feb				0.25		0.05	34		

Parameters								Parameters										
Spring					Spring					Spring				Spring				Spring
mg/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	mg/L	mg/L	mg/L	(°C)	L/s	mg/L
Hg-sp	Mn-sp	Mo-sp	Ni-sp	Pb-sp	Sb-sp	U-sp	Zn-sp	SO4-sp	Thio-sp	P-sp	Ca-sp	Mg-sp	Na-sp	Cl-sp	F-sp	Temp-sp	Flow-sp	Acid-sp
				0.12			132	4023									25	
				1.7			1674	8066									30	
				3.2			12.9	1173	541								1000	
				0.47			5.1											
0.00003	4.54						2.05	360			66.0	17.7	6.17					77
0.00008	9.37						6.30	760			190.0	43.4	15.2					290
	252		11	1.9			25	85000										57500
	247		11	1.8			22	92500										57500
							29.87									2.65		105
							229									0.13	46	952
			0.011	0.017			1.635									8.8		
			0.003	0.004			0.013									9.57		
			0.005	0.004			0.052									9.7		
			0.006	0.009			0.123									10.1		
							3.26	377										162
			0.46				579	6400		1.38								
			0.233	0.404			98.3											
			0.209	0.033			63.850											
																		9
																	2	246
																		613
																	90	753
								62									4	45
																	0.2	115
								34									33	40
								10									173	7
																		1039
	1.7		0.13			0.43	0.17	1051									181.9	168

Parameters							Parameters							Parameters				
Spring							Summer							Summer			
mg/L		µS/cm	mg/L	mg/L	mg/L	mV	mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Alkal−sp	pH−sp	Ec−sp	TDS−sp	TSS−sp	Hard−sp	Eh−sp	Al−su	As−su	Cd−su	Co−su	Cr−su	Cu−su	Fe(T)−su	Fe(+2)−su	Fe(D)−su	Hg−su	Mn−su
	2.8											15	513				
	2.5				3537							10.7	714				
	6.0			3.3	332							0.90	52.5				
												0.42	27.4				
							5	0.0016	0.008		0.025	0.82	8.55			0.0002	0.92
	2.94	580		23													
	3.52	1700		80													
	2.15	32000	103400	190			3400						14000				200
	2.15	31000	116060	200			4000						11300				200
							1100						5600				58
	4.5	786				465						34.9	231.9				
	5.34	6360				429						0.28	14.7				
												0.005	0.14				
												0.089	5.31				
	6.23			17.53								0.032	11.13				
	6.73			9.4								0.003	1.024				
	6.4			62.4								0.011	2.724				
	5.9			13.6								0.009	6.045				
	3.3								0.011			0.99	34.1				
	2.5			7				0.124	1.63			78.6	468			0.0005	
	2.9			8								1.60	169				
							0.66					0.44	1.91				
	3.6			77													
	5.1		296														
	4.9		1200														
	3.1																
	3.0																
	3.4		312										8.0				
	3.50																
	3.80		88										9.20				
	6.20		51														
	2.91																
	4.05		1664	4									13.70				

APPENDIX IV

AMD STREAM DATA

Atlantic	Tables A-IV-1 to A-IV-4
Quebec	Tables A-IV-5 to A-IV-17
Ontario	Tables A-IV-18 to A-IV-61
Prairies	Tables A-IV-62 to A-IV-63
British Columbia	Tables A-IV-64 to A-IV-72

Table A-IV-1 - Data for AMD stream A-1

Stream code: A-1

Mine type: Pb/Zn

Region: Atlantic

Mine status: Shut down

AMD stream description:
Acid water holding pond

AMD stream source: Site drainage

Sample location:

Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter February
Cu (mg/L)	18.6	15	21.2	
Fe_{Tot} (mg/L)	1,340	513	1,169	
Pb (mg/L)	0.12	0.43	0.46	
Zn (mg/L)	132	153	233	
SO_4 (mg/L)	4,023	3,160	4,430	
Flowrate (L/s)	25	25	25	25
pH	2.8	2.4	2.7	

Table A-IV-2 - Data for AMD stream B-1

Stream code: B-1

Mine type: Pb/Zn

Region: Atlantic

Mine status: Operating

AMD stream description:
Drainage

AMD stream source: Underground mine

Sample location:

Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter February
Cu (mg/L)	16.9	10.7	12.1	2.2
Fe_{Tot} (mg/L)	1,394	714	1,167	645
Pb (mg/L)	1.7	2.3	6.2	1.9
Zn (mg/L)	1,674	1,237	2,099	1,064
SO_4 (mg/L)	8,066	7,807	7,715	6,800
Flowrate (L/s)	30	25	25	25
pH	2.5	2.5	3.2	3.5
Hardness (mg/L) (as $CaCO_3$)	3,537	2,900		2,536

Table A-IV-3 - Data for AMD stream B-2

Stream code: B-2

Mine type: Pb/ZN

Region: Atlantic

Mine status: Operating

AMD stream description:
Tailings effluent and seepage

AMD stream source: Tailings dam

Sample location:

Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter February
Cu (mg/L)	0.13	0.90	0.36	0.07
Fe_{Tot} (mg/L)	31.5	52.5	104	20
Pb (mg/L)	3.2	4.6	4.2	1.25
Zn (mg/L)	12.9	38.3	28.9	11.6
SO_4 (mg/L)	1,173	1,837	1,820	1,881
Thiosalts (mg/L)	541	385	280	1,106
Flowrate (L/s)	1,000	330	600	283
pH	6.0	2.4	2.7	6.2
TSS[1] (mg/L)	3.3	6.5	5.2	27.6
Hardness (mg/L) (as $CaCO_3$)	332	667	1,029	529

[1] Total suspended solids

Table A-IV-4 - Data for AMD stream B-3

Stream code: B-3

Mine type: Pb/Zn

Region: Atlantic

Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Surface drainage from site (excluding mine and tailings)

Sample location:

Sample year: 1992

Parameters	Spring April	Summer July	Fall October	Winter January
Cu (mg/L)	0.5	0.42	0.15	0.56
Fe_{Tot} (mg/L)	6.5	27.4	2.7	17.1
Pb (mg/L)	0.47	0.31	0.03	0.52
Zn (mg/L)	5.1	14.5	40.4	11.4

Table A-IV-5 - Data for AMD stream W-1

Stream code: W-1

Mine type: Cu/Zn/Pb

Region: Quebec

Mine status: Shut down

AMD stream description:
Tailings pond effluent

AMD stream source: Tailings pond

Sample location: Pond overflow

Sample year: 1986

Parameters	Spring	Summer September	Fall	Winter
Al (mg/L)		5.0		
As (mg/L)		0.0016		
Cd (mg/L)		0.008		
Co (mg/L)		<0.007		
Cr (mg/L)		0.025		
Cu (mg/L)		0.82		
Fe_{Tot} (mg/L)		8.55		
Hg (mg/L)		0.0002		
Mn (mg/L)		0.92		
Ni (mg/L)		<0.02		
Pb (mg/L)		0.06		
Zn (mg/L)		1.74		
SO_4 (mg/L)		240		
Flowrate (L/s)		232		
Acidity (mg/L) (as $CaCO_3$)		10		
pH		3.2		

Table A-IV-5 (cont'd)

Parameters	Spring	Summer September	Fall	Winter
Ec[1] (µS/cm)		750		
TSS[2] (mg/L)		90		
Eh[3] (mV)		497		

[1] Electrical conductivity

[2] Total suspended solids

[3] Redox potential

Table A-IV-6 - Data for AMD stream X-1

Stream code: X-1 — Mine type: Au

Region: Quebec — Mine status: Operating

AMD stream description:
Mine water

AMD stream source: Underground mine

Sample location: — Sample year: 1982-1983

Parameters	Spring Apr/83	Summer	Fall Nov/82	Winter
As (mg/L)	<0.003		<0.003	
Cd (mg/L)	<0.005		0.009	
Cu (mg/L)	0.91-3.00		0.010	
Fe_{Tot} (mg/L)	10.1-37.2		7.65	
Hg (mg/L)	0.00003-0.00008		0.00005	
Mn (mg/L)	4.54-9.37		7.36	
Ni (mg/L)	<0.05		0.10	
Pb (mg/L)	<0.05		0.019	
Zn (mg/L)	2.05-6.30		2.94	
SO_4 (mg/L)	360-760		900	
Ca (mg/L)	66.0-190.0		151.0	
Mg (mg/L)	17.7-43.4		28.7	
Na (mg/L)	6.17-15.2		14.2	
Acidity (mg/L) (as $CaCO_3$)	77-290		85	
pH	2.94-3.52		3.36	

Table A-IV-6 (cont'd)

Parameters	Spring Apr/83	Summer	Fall Nov/82	Winter
Ec[1] (µS/cm)	580-1,700		1,260	
TSS[2] (mg/L)	23-80		23	

[1] Electrical conductivity

[2] Total suspended solids

Table A-IV-7 - Data for AMD stream C-1

Stream code: C-1

Mine type: Au

Region: Quebec

Mine status: Operating

AMD stream description:
Drainage ditch west of waste rock pile

AMD stream source: Waste rock

Sample location: Monitoring station in drainage ditch

Sample year: 1991

Parameters	Spring March	Summer July	Fall October	Winter January
Al (mg/L)	4,200	3,400	3,500	
Cd (mg/L)	<0.05			0.12
Cu (mg/L)	54			50
Fe_{Tot} (mg/L)	20,000	14,000	14,000	8,400
Mn (mg/L)	252	200	210	225
Ni (mg/L)	11			8.4
Pb (mg/L)	1.9			<0.5
Zn (mg/L)	25			26
SO_4 (mg/L)	85,000	150,000	58,000	55,000
Acidity (mg/L) (as $CaCO_3$)	57,500	52,500	25,000	50,000
pH	2.15	2.24	2.23	2.20
Ec[1] (µS/cm)	32,000	29,500	30,000	26,000
TDS[2] (mg/L)	103,400	100,000	105,000	98,000
TSS[3] (mg/L)	190			345

[1] Electrical conductivity

[2] Total dissolved solids

[3] Total suspended solids

Table A-IV-8 - Data for AMD stream C-2

Stream code: C-2 | Mine type: Au

Region: Quebec | Mine status: Operating

AMD stream description:
Drainage ditch south of waste rock pile

AMD stream source: Waste rock

Sample location: Monitoring station in drainage ditch | Sample year: 1991

Parameters	Spring March	Summer July	Fall October	Winter January
Al (mg/L)	4,800	4,000	2,500	
Cd (mg/L)	<0.05			0.08
Cu (mg/L)	56			63
Fe_{Tot} (mg/L)	15,000	11,300	7,200	17,800
Mn (mg/L)	247	200	140	282
Ni (mg/L)	11			12
Pb (mg/L)	1.8			<0.05
Zn (mg/L)	22			27
SO_4 (mg/L)	92,500	42,500	37,000	80,000
Acidity (mg/L) (as $CaCO_3$)	57,500	52,500	15,000	60,000
pH	2.15	2.27	2.39	2.18
Ec[1] (µS/cm)	31,000	26,500	27,000	27,000
TDS[2] (mg/L)	116,060	98,900	65,400	130,000
TSS[3] (mg/L)	200			1,070

[1] Electrical conductivity

[2] Total dissolved solids

[3] Total suspended solids

Table A-IV-9 - Data for AMD stream C-3

Stream code: C-3 Mine type: Au

Region: Quebec Mine status: Operating

AMD stream description:
Drainage ditch east of waste rock pile

AMD stream source: Waste rock

Sample location: Monitoring station in drainage ditch Sample year: 1991

Parameters	Spring	Summer July	Fall October	Winter
Al (mg/L)		1,100	1,100	
Fe_{Tot} (mg/L)		5,600	6,400	
Mn (mg/L)		58	61	
SO_4 (mg/L)		26,500	26,500	
Acidity (mg/L) (as $CaCO_3$)		20,000	12,000	
pH		2.22	2.18	
Ec[1] (µS/cm)		13,000	20,000	
TDS[2] (mg/L)		57,000	45,000	

[1] Electrical conductivity

[2] Total dissolved solids

Table A-IV-10 - Data for AMD stream D-1

Stream code: D-1 — Mine type: Cu/Zn

Region: Quebec — Mine status: Operating

AMD stream description:
Drainage from waste rock pile

AMD stream source: Waste rock pile

Sample location: Collection pond — Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter January
Cu (mg/L)	3.81	34.9	219	74.1
Fe_{Tot} (mg/L)	12.34	231.9	634	205
Zn (mg/L)	29.87	204.7	951	415
Temperature (EC)	2.65	19	4.0	-0.3
Flowrate (L/s)		72	65	
Acidity (mg/L) (as $CaCO_3$)	105	1,068	3,240	1,615
pH	4.5	3.04	3.94	2.71
Ec[1] (µS/cm)	786	3,156	2,834	3,490
Eh[2] (mV)	465	678	649.9	

[1] Electrical conductivity

[2] Redox potential

Table A-IV-11 - Data for AMD stream D-2

Stream code: D-2 Mine type: Cu/Zn

Region: Quebec Mine status: Operating

AMD stream description:
Surface water from tailings pond

AMD stream source: Tailings from concentrator

Sample location: Decant tower Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter February
Cu (mg/L)	22.06	0.28	3.04	1.53
Fe_{Tot} (mg/L)	401	14.7	29.14	6.29
Zn (mg/L)	229	6.5	47.0	17.7
Temperature (EC)	0.13	19.6	3.8	0.2
Flowrate (L/s)	46	27	42	0
Acidity (mg/L) (as $CaCO_3$)	952		26.5	
pH	5.34	7.78	6.12	8.52
Ec[1] (µS/cm)	6,360	1,434	2,279	2,440
Eh[2] (mV)	429	417	437	

[1] Electrical conductivity

[2] Redox potential

Table A-IV-12 - Data for AMD stream AA-1

Stream code: AA-1

Mine type: Cu/Zn

Region: Quebec

Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Wind erosion of concentrate

Sample location:

Sample year: 1993

Parameters	Spring	Summer	Fall	Winter
Cu (mg/L)		0.005-0.089	0.013-0.138	
Fe_{Tot} (mg/L)		0.14-5.31	0.17-2.81	
Ni (mg/L)		0.007-0.054	0.016-0.056	
Pb (mg/L)		0.001-0.017	0.008-0.023	
Zn (mg/L)		0.036-14.93	1.508-14.6	
TSS[1] (mg/L)		0-28.0	0-13.0	

[1] Total suspended solids

Table A-IV-13 - Data for AMD stream AA-2

Stream code: AA-2 Mine type: Cu/Zn

Region: Quebec Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Mine tailings

Sample location: Creek Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Dec	Winter Jan-Mar
Cu (mg/L)	0.049	0.032	0.037	0.127
Fe_{Tot} (mg/L)	8.875	11.73	12.43	47.99
Ni (mg/L)	0.011	0.012	0.017	0.026
Pb (mg/L)	0.017	0.009	0.025	0.040
Zn (mg/L)	1.635	0.978	1.268	2.215
Temperature (EC)	8.8	16.7	1.9	1.3
Flowrate (L/s)		~17		
pH	6.23	6.23	6.33	6.1
TSS[1] (mg/L)	17.53	35.3	52.7	48.9

[1] Total suspended solids

Table A-IV-14 - Data for AMD stream AA-3

Stream code: AA-3

Mine type: Cu/Zn

Region: Quebec

Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Tailings

Sample location: Drainage ditch

Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Dec	Winter Jan-Mar
Cu (mg/L)	0.003	0.003	0.006	
Fe_{Tot} (mg/L)	1.285	1.024	1.238	
Ni (mg/L)	0.003	0.005	0.009	
Pb (mg/L)	0.004	0.003	0.008	
Zn (mg/L)	0.013	0.012	0.014	
Temperature (EC)	9.57	16.9	1.9	
pH	6.73	6.43	6.65	
TSS[1] (mg/L)	9.4	4.9	5.2	

[1] Total suspended solids

Table A-IV-15 - Data for AMD stream AA-4

Stream code: AA-4

Mine type: Cu/Zn

Region: Quebec

Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Tailings

Sample location: Drainage ditch

Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Dec	Winter Jan-Mar
Cu (mg/L)	0.005	0.011	0.025	
Fe_{Tot} (mg/L)	1.962	2.724	3.55	
Ni (mg/L)	0.005	0.006	0.014	
Pb (mg/L)	0.004	0.006	0.015	
Zn (mg/L)	0.052	0.086	0.464	
Temperature (EC)	9.7	17.2	2.3	
pH	6.4	6.03	5.95	
TSS[1] (mg/L)	62.4	19.6	11.0	

[1] Total suspended solids

Table A-IV-16 - Data for AMD stream AA-5

Stream code: AA-5

Mine type: Cu/Zn

Region: Quebec

Mine status: Operating

AMD stream description:
Site drainage

AMD stream source: Tailings

Sample location: Ditch

Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Dec	Winter Jan-Mar
Cu (mg/L)	0.016	0.009	0.011	
Fe_{Tot} (mg/L)	2.673	6.045	3.655	
Ni (mg/L)	0.006	0.005	0.013	
Pb (mg/L)	0.009	0.007	0.008	
Zn (mg/L)	0.123	0.053	0.072	
Temperature (EC)	10.1	16.9	2.1	
pH	5.9	5.8	5.65	
TSS[1] (mg/L)	13.6	19.3	4.0	

[1] Total suspended solids

Table A-IV-17 - Data for AMD stream BB-1

Stream code: BB-1 Mine type: Cu/Zn

Region: Quebec Mine status: Shut down

AMD stream description:
Treatment plant feed

AMD stream source: Combined tailings dam seepages and runoff

Sample location: Raw water impoundment pond Sample year: 1993

Parameters	Spring April	Summer June	Fall August	Winter January
Cd (mg/L)	<0.01	0.011	<0.01	0.012
Cu (mg/L)	0.94	0.99	0.69	1.18
Fe_{Tot} (mg/L)	69.6	34.1	47.8	155.0
Pb (mg/L)	<0.05	<0.05	<0.05	<0.05
Zn (mg/L)	3.26	3.88	4.57	6.22
SO_4 (mg/L)	377	632	905	1,285
Flowrate (L/s)	51.5 (average over 7 months: Jan, Mar-Aug)			
Acidity (mg/L) (as $CaCO_3$)	162	239	379	546
pH	3.3	2.9	2.6	3.1

[1] Electrical conductivity

[2] Total dissolved solids

[3] Total suspended solids

[4] Redox potential

Table A-IV-18 - Data for AMD stream R-1

Stream code: R-1 | Mine type: Cu/Zn

Region: Ontario | Mine status: Shut down

AMD stream description:
Mine water

AMD stream source: Pit F

Sample location: Pit F | Sample year: 1993-1994

Parameters	Spring Mar/94	Summer Jun/94	Fall Sept/93	Winter Dec/93
As (mg/L)	0.114	0.124	0.324	0.098
Cd (mg/L)	1.92	1.63	1.84	1.74
Cu (mg/L)	99.5	78.6	88.2	77.4
Fe_{Tot} (mg/L)	539	468	574	456
Hg (mg/L)		0.0005		0.0003
Ni (mg/L)	0.46	0.35	0.38	0.36
Pb (mg/L)		0.08	0.15	0.36
Zn (mg/L)	579	480	571	506
SO_4 (mg/L)	6,400	5,400	6,500	5,600
P (mg/L)	1.38	1.27	0.74	1.08
pH	2.5	2.5	2.7	2.6
TSS[1] (mg/L)	7	27	14	10

[1] Total suspended solids

Table A-IV-19 - Data for AMD stream R-2

Stream code: R-2

Mine type: Cu/Zn

Region: Ontario

Mine status: Shut down

AMD stream description:
Tailings pump pond

AMD stream source: Tailings pond water

Sample location: Pump pond

Sample year: 1993-1994

Parameters	Spring Mar/94	Summer Jun/94	Fall Not taken	Winter Dec/93
Cu (mg/L)	1.07	1.60		0.562
Fe_{Tot} (mg/L)	644	169		228
Ni (mg/L)	0.233	0.167		0.180
Pb (mg/L)	0.404	0.982		1.164
Zn (mg/L)	98.3	62.7		47.8
pH	2.9	2.7		3.1
TSS[1] (mg/L)	8	55		7

[1] Total suspended solids

Table A-IV-20 - Data for AMD stream R-3

Stream code: R-3

Mine type: Cu/Zn

Region: Ontario

Mine status: Shut down

AMD stream description:
Mine creek

AMD stream source: Waste rock stockpile

Sample location: Pump pond

Sample year: 1993-1994

Parameters	Spring Not taken	Summer Jun/94	Fall Not taken	Winter Nov/93
Al (mg/L)		0.66		2.35
Cu (mg/L)		0.44		0.82
Fe_{Tot} (mg/L)		1.91		1.05
Pb (mg/L)		0.05		0.06
Zn (mg/L)		31.5		57.0
SO_4 (mg/L)		390		520
Ca (mg/L)		71.6		109
pH		3.9		4.0
Ec[1] (µS/cm)		681		1,040

[1] Electrical conductivity

Table A-IV-21 - Data for AMD stream R-4

Stream code: R-4 | Mine type: Cu/Zn

Region: Ontario | Mine status: Shut down

AMD stream description:
Seepage stream

AMD stream source: Waste rock stockpile

Sample location: Ditch D | Sample year: 1994

Parameters	Spring May	Summer	Fall	Winter
Cu (mg/L)	3.276			
Fe_{Tot} (mg/L)	34.803			
Ni (mg/L)	0.209			
Pb (mg/L)	0.033			
Zn (mg/L)	63.850			
pH	3.6			
TSS[1] (mg/L)	77			

[1] Total suspended solids

Table A-IV-22 - Data for AMD stream Z-1

Stream code: Z-1

Mine type: Cu/Zn

Region: Ontario

Mine status: Operating

AMD stream description:
Tailings pond water (recycle water to mill)

AMD stream source: Tailings surface runoff and mill tailings

Sample location:

Sample year: Annual mean for 1993 (monthly frequency)

Parameters	Annual Mean			
Cu (mg/L)	0.114			
Fe_{Tot} (mg/L)	31.7			
Zn (mg/L)	8.9			
SO_4 (mg/L)	1,868			
$NH_{3\ Tot}$ (mg/L)	16.3			
Flowrate (L/s)	28.4			
pH	5.4			
TDS[1] (mg/L)	3,437			
TSS[2] (mg/L)	5.0			

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-23 - Data for AMD stream Z-2

Stream code: Z-2

Mine type: Cu/Zn

Region: Ontario

Mine status: Operating

AMD stream description:
Mine water

AMD stream source: Underground mine dewatering

Sample location: End of pipe

Sample year: Annual mean for 1993 (monthly frequency)

Parameters	Annual Mean			
Cu (mg/L)	5.91			
Fe_{Tot} (mg/L)	87.9			
Zn (mg/L)	138.7			
SO_4 (mg/L)	2,170			
$NH_{3\ Tot}$ (mg/L)	7.4			
Flowrate (L/s)	26.18			
pH	3.5			
TDS[1] (mg/L)	3,635			
TSS[2] (mg/L)	42.4			

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-24 - Data for AMD stream Z-3

Stream code: Z-3

Mine type: Cu/Zn

Region: Ontario

Mine status: Operating

AMD stream description:
Treatment plant influent

AMD stream source: Combination of tailings pond water, mine water, surface runoff and tailings seepages

Sample location: Treatment plant feed

Sample year: Annual mean for 1993 (weekly frequency)

Parameters	Annual Mean			
Cu (mg/L)	1.51			
Fe_{Tot} (mg/L)	475			
Ni (mg/L)	0.05			
Pb (mg/L)	0.07			
Zn (mg/L)	43.5			
SO_4 (mg/L)	2,889			
$NH_{3\ Tot}$ (mg/L)	38.3			
Flowrate (L/s)	84.5			
pH	3.6			
TDS[1] (mg/L)	4,870			
TSS[2] (mg/L)	43.5			

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-25 - Data for AMD stream Z-4

Stream code: Z-4 | Mine type: Cu/Zn

Region: Ontario | Mine status: Operating

AMD stream description:
Tailings pile seepages

AMD stream source: Dam toe seepages before dilution by surface runoff

Sample location: Toe of dam | Sample year: 1992-1993

Parameters	Typical Range			
Cu (mg/L)	1.5-3.9			
Fe_{Tot} (mg/L)	1,000-6,000			
Zn (mg/L)	7-130			
SO_4 (mg/L)	6,780*			
$NH_{3\ Tot}$ (mg/L)	120*			
Flowrate (L/s)	0.3-9.5			
pH	2.6-3.8			

* Average value

Table A-IV-26 - Data for AMD stream Z-5

Stream code: Z-5 Mine type: Cu/Zn

Region: Ontario Mine status: Operating

AMD stream description:
Backfill quarry water

AMD stream source: Runoff from waste rock roads and backfill quarry

Sample location: Sample year: Average 1991-1993

Parameters	Average			
Cu (mg/L)	0.27			
Fe_{Tot} (mg/L)	0.22			
Zn (mg/L)	3.3			
SO_4 (mg/L)	380			
Flowrate (L/s)	11.4*			
pH	7.0			

* Annual mean

Table A-IV-27 - Data for AMD stream Z-6

Stream code: Z-6 Mine type: Cu/Zn

Region: Ontario Mine status: Operating

AMD stream description:
Mill area surface runoff

AMD stream source: Concentrate spillage, historical tailings spill area and waste rock foundations

Sample location: Composite samples of surface runoff Sample year: 1992

Parameters	Runoff* Mean			
Cu (mg/L)	9.8			
Fe_{Tot} (mg/L)	25.8			
Zn (mg/L)	91			
SO_4 (mg/L)	1,070			
Flowrate (L/s)	1.0			

* Runoff season occurs for about six months

Table A-IV-28 - Data for AMD stream Z-7

Stream code: Z-7 Mine type: Cu/Zn

Region: Ontario Mine status: Operating

AMD stream description:
Mill area sub-surface runoff

AMD stream source: Concentrate spillage, historical tailings spill area and waste rock foundations

Sample location: Composite samples from test pits Sample year: 1992

Parameters	Annual Mean			
Cu (mg/L)	16.2			
Fe_{Tot} (mg/L)	9.5			
Zn (mg/L)	226			
SO_4 (mg/L)	1,353			
Flowrate (L/s)	1.1			

Table A-IV-29 - Data for AMD stream Z-8

Stream code: Z-8 Mine type: Cu/Zn

Region: Ontario Mine status: Operating

AMD stream description:
Plant site area surface runoff

AMD stream source: Waste rock foundations

Sample location: Composite samples of surface runoff Sample year: 1992

Parameters	Runoff* Mean			
Cu (mg/L)	0.29			
Fe_{Tot} (mg/L)	0.38			
Zn (mg/L)	5.7			
SO_4 (mg/L)	213			
Flowrate (L/s)	2.3			

* Runoff season occurs for about six months

Table A-IV-30 - Data for AMD stream Z-9

Stream code: Z-9

Mine type: Cu/Zn

Region: Ontario

Mine status: Operating

AMD stream description:
Plant site area sub-surface seepage

AMD stream source: Waste rock foundations

Sample location: Composite samples from test pits

Sample year: 1992

Parameters	Annual Mean			
Cu (mg/L)	0.21			
Fe_{Tot} (mg/L)	7.3			
Zn (mg/L)	57			
SO_4 (mg/L)	877			
Flowrate (L/s)	2.3			

Table A-IV-31 - Data for AMD stream E-1

Stream code: E-1 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Dam seepage

AMD stream source: Tailings

Sample location: Near dam 9 Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter
Flowrate (L/s)	<2	<2	<2	
Acidity (mg/L) (as $CaCO_3$)	9	10	5	
pH	5.1	6.8	6.3	
TDS[1] (mg/L)	296	676	474	

[1] Total dissolved solids

Table A-IV-32 - Data for AMD stream E-2

Stream code: E-2 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Dam seepage

AMD stream source: Tailings

Sample location: Near dam 17 Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter
Flowrate (L/s)	2	2	4	
Acidity (mg/L) (as $CaCO_3$)	246	566	294	
pH	4.9	4.4	5.0	
TDS[1] (mg/L)	1,200	2,620	1,712	

[1] Total dissolved solids

Table A-IV-33 - Data for AMD stream F-1

Stream code: F-1 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage stream and site drainage

AMD stream source: Tailings

Sample location: Below dam A; before lime treatment Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter January
Acidity (mg/L) (as $CaCO_3$)	613	2,950	1,651	3,065
pH	3.1	2.4	2.7	2.6

Table A-IV-34 - Data for AMD stream F-2

Stream code: F-2

Mine type: U

Region: Ontario

Mine status: Shut down

AMD stream description:
Seepage stream and site drainage

AMD stream source: Tailings

Sample location: Below dam D; before lime treatment

Sample year: 1993

Parameters	Spring April	Summer July	Fall October	Winter January
Flowrate (L/s)	90	11	38	15
Acidity (mg/L) (as $CaCO_3$)	753	1,520	1,770	2,900
pH	3.0	2.4	2.5	2.5

Table A-IV-35 - Data for AMD stream F-3

Stream code: F-3 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage stream

AMD stream source: Seepage collection pond

Sample location: Below dam G Sample year: 1993

Parameters	Spring April	Summer May	Fall October	Winter
Fe_{Tot} (mg/L)	9.6	8.0	4.6	
SO_4 (mg/L)	62	146	346	
Flowrate (L/s)	4	2	4	
Acidity (mg/L) (as $CaCO_3$)	45	38	79	
pH	3.4	4.2	3.3	
TDS[1] (mg/L)	312	288	540	

[1] Total dissolved solids

Table A-IV-36 - Data for AMD stream G-1

Stream code: G-1 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage stream from low permeability dam

AMD stream source: Tailings area

Sample location: Below dam A Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Flowrate (L/s)	0.2	0.1	0.2	0.1
Acidity (mg/L) (as $CaCO_3$)	115	1,160	610	1,305
pH	3.50	2.70	3.30	3.40

Table A-IV-37 - Data for AMD stream G-2

Stream code: G-2 | Mine type: U

Region: Ontario | Mine status: Shut down

AMD stream description:
Seepage from dam A plus tailings spill runoff

AMD stream source: Tailings

Sample location: Drainage creek - downstream from G-1 | Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Fe_{Tot} (mg/L)	3.00	9.20	3.50	7.90
SO_4 (mg/L)	34	101	41	139
Flowrate (L/s)	33	9.6	73	1.8
Acidity (mg/L) (as $CaCO_3$)	40	80	50	113
pH	3.80	3.40	3.50	3.20
TDS[1] (mg/L)	88	212	66	216

[1] Total dissolved solids

Table A-IV-38 - Data for AMD stream G-3

Stream code: G-3 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Site drainage (including uncontaminated lake outflow)

AMD stream source: Tailings and waste rock

Sample location: Downstream from G-2 Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Fe_{Tot} (mg/L)				0.72
SO_4 (mg/L)	10	28	18	10
Flowrate (L/s)	173	65	193	32.8
Acidity (mg/L) (as $CaCO_3$)	7	4	7	3
pH	6.20	6.60	6.30	6.60
TDS[1] (mg/L)	51	109	35	64

[1] Total dissolved solids

Table A-IV-39 - Data for AMD stream H-1

Stream code: H-1 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Tailings pond water

AMD stream source: Tailings and minor amounts of waste rock

Sample location: Upstream of treatment plant (some lime has been added) Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Acidity (mg/L) (as $CaCO_3$)	1,039	1,163	691	813
pH	2.91	2.62	2.93	3.23

Table A-IV-40 - Data for AMD stream H-2

Stream code: H-2 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Tailings pond water

AMD stream source: Tailings and minor amounts of waste rock

Sample location: Treatment plant feed (some lime has been added upstream) Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Co (mg/L)	0.25		0.45	
Cu (mg/L)	0.05		0.11	
Fe_{Tot} (mg/L)	34	13.70	10.7	53
Mn (mg/L)	1.7		3.5	
Ni (mg/L)	0.13		0.23	
Pb (mg/L)	<0.10		0.06	
U (mg/L)	0.43		0.70	0.92
Zn (mg/L)	0.17		0.42	
SO_4 (mg/L)	1,051		1,872	2,002
Flowrate (L/s)	181.9	57.2	184.0	68.6
Acidity (mg/L) (as $CaCO_3$)	168	221	172	367
pH	4.05	3.19	3.64	3.38
TDS[1] (mg/L)	1,664		2,852	3,140
TSS[2] (mg/L)	4	9	7	12

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-41 - Data for AMD stream H-3

Stream code: H-3 | Mine type: U

Region: Ontario | Mine status: Shut down

AMD stream description:
Site drainage

AMD stream source: Waste rock

Sample location: Northwest drainage pathway | Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
SO_4 (mg/L)	310	492	431	367
Flowrate (L/s)	2.4	0.1	1.1	0.3
Acidity (mg/L) (as $CaCO_3$)	190	280	253	173
pH	3.60	3.60	3.70	4.10
TDS[1] (mg/L)	509	817	688	590

[1] Total dissolved solids

Table A-IV-42 - Data for AMD stream H-4

Stream code: H-4 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Site drainage (includes mine waste seepage, site runoff and discharge from a small lake)

AMD stream source: Waste rock

Sample location: Drainage creek at mine road Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Al (mg/L)	3.6	1.7	0.75	0.67
As (mg/L)	<0.003	<0.002	<0.003	<0.003
Cd (mg/L)	0.004	<0.002	<0.002	<0.002
Co (mg/L)	0.062	0.060	0.015	0.018
Cr (mg/L)	<0.004	<0.004	<0.004	<0.004
Cu (mg/L)	0.043	0.029	0.014	0.016
Fe_{Tot} (mg/L)	0.43	1.20	0.14	<0.27
Hg (mg/L)	<0.0001	<0.00005	<0.0001	<0.05
Mn (mg/L)	0.65	1.00	0.15	0.19
Ni (mg/L)	0.098	0.075	0.019	0.12
Pb (mg/L)	<0.02	<0.02	<0.02	<0.02
U (mg/L)	0.27	0.33	0.22	0.020
Zn (mg/L)	0.11	0.084	0.024	0.052
SO_4 (mg/L)	79	37	120	60
Ca (mg/L)	41	43	18	19
Flowrate (L/s)	7.2	1.6	25.4	16.5

Table A-IV-42 (cont'd)

Parameters	Spring May	Summer August	Fall November	Winter February

Acidity (mg/L) (as $CaCO_3$)	30	21	20	4
Alkalinity (mg/L) (as $CaCO_3$)				7
pH	4.90	5.00	4.90	6.60
TDS[1] (mg/L)	160	81	246	127
TSS[2] (mg/L)	8	10	4	1

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-43 - Data for AMD stream I-1

Stream code: I-1 | Mine type: U

Region: Ontario | Mine status: Shut down

AMD stream description:
Tailings dam seepage

AMD stream source: Tailings zone in low permeability dam

Sample location: Downstream of dam B | Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Al (mg/L)	140		120	
As (mg/L)	<0.003		<0.003	
Cd (mg/L)	0.003		0.002	
Co (mg/L)	1.40	2.00	1.20	2.20
Cr (mg/L)	<0.004		0.004	
Cu (mg/L)	0.88	1.01	0.83	1.12
Fe_{Tot} (mg/L)	278	645	372	660
Hg (mg/L)	<0.0001		1.2	
Mn (mg/L)	11.0	21.0	12.8	21.0
Ni (mg/L)	0.81	1.6	0.73	1.37
Pb (mg/L)	<0.10	<0.10	<0.10	0.12
U (mg/L)	4.2		2.5	
Zn (mg/L)	1.61	1.80	1.10	2.10
SO_4 (mg/L)	1,208	2,516	2,031	3,089
Cl (mg/L)	12.1	18	21	33
Flowrate (L/s)	0.4	0.2	0.5	0.3

Table A-IV-43 (cont'd)

Parameters	Spring May	Summer August	Fall November	Winter February

Acidity (mg/L) (as $CaCO_3$)	1,075	2,950	1,525	2,650
pH	2.90	2.70	2.80	3.20
TDS[1] (mg/L)	1,873	6,201	3,184	5,925
TSS[2] (mg/L)	9	22	4	4

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-44 - Data for AMD stream I-2

Stream code: I-2

Mine type: U

Region: Ontario

Mine status: Shut down

AMD stream description:
Main tailings pond water

AMD stream source: Tailings and some waste rock

Sample location: Spillway for main tailings basin

Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Co (mg/L)	0.070	0.070	0.30	0.33
Cu (mg/L)	0.10	0.110	0.110	0.11
Fe_{Tot} (mg/L)	14.0	22.0	38	44.0
Mn (mg/L)	0.84	1.59	2.0	2.30
Ni (mg/L)	0.090	0.15	0.23	0.32
Pb (mg/L)	<0.10	0.10	<0.10	0.32
U (mg/L)	1.07	1.76	1.85	3.18
Zn (mg/L)	0.29	0.06	0.070	0.70
SO_4 (mg/L)	368	749	868	1,192
Acidity (mg/L) (as $CaCO_3$)	160	258	315	371
pH	3.20	2.95	2.70	3.00
TDS[1] (mg/L)	580	1,184	1,303	1,836

[1] Total dissolved solids

Table A-IV-45 - Data for AMD stream I-3

Stream code: I-3 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage and runoff

AMD stream source: Mine waste, landfill and tailings spill

Sample location: Landfill drainage Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Co (mg/L)	0.010		0.050	0.020
Cu (mg/L)	0.005		0.004	0.005
Fe_{Tot} (mg/L)	0.22		0.73	0.14
Mn (mg/L)	0.33		0.87	0.32
Pb (mg/L)	<0.010		<0.010	<0.010
Zn (mg/L)	0.17		0.22	0.030
Flowrate (L/s)	0.2	0.0	0.5	0.1
Acidity (mg/L) (as $CaCO_3$)	35		53	15
Alkalinity (mg/L) (as $CaCO_3$)				27
pH	5.00		4.90	6.50
TDS[1] (mg/L)	142		179	212

[1] Total dissolved solids

Table A-IV-46 - Data for AMD stream I-4

Stream code: I-4 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Tailings flood water

AMD stream source: Tailings spill (90% covered with water)

Sample location: Beaver pond outlet Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Co (mg/L)	<0.005	<0.005	<0.005	0.020
Cu (mg/L)	<0.002	<0.002	<0.002	0.010
Fe_{Tot} (mg/L)	0.82	0.61	0.62	19.0
Mn (mg/L)	0.020	0.020	0.080	0.32
Ni (mg/L)	<0.005	<0.005	<0.005	0.010
Pb (mg/L)	<0.010	<0.010	<0.010	0.010
Zn (mg/L)	0.030	0.020	0.007	0.020
SO_4 (mg/L)	61	94	105	229
Flowrate (L/s)	33.6	4.0	10.7	4.2
Acidity (mg/L) (as $CaCO_3$)	7		14	42
Alkalinity (mg/L) (as $CaCO_3$)	20	30	14	185
pH	6.80	8.40	6.20	6.80
TDS[1] (mg/L)	164	236	228	590
TSS[2] (mg/L)	5	1	3	12

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-47 - Data for AMD stream J-1

Stream code: J-1 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Runoff from tailings site

AMD stream source: Tailings

Sample location: Discharge from tailings area Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Fe_{Tot} (mg/L)	53.0	51.0	76.0	79.0
Mn (mg/L)	0.69	0.83	0.73	0.77
SO_4 (mg/L)	466	560	498	560
Flowrate (L/s)	12.0	0.3	3.5	0.3
Acidity (mg/L) (as $CaCO_3$)	375	410	460	430
pH	2.80	2.70	2.90	2.80
TDS[1] (mg/L)	664	780	708	791

[1] Total dissolved solids

Table A-IV-48 - Data for AMD stream K-1

Stream code: K-1

Mine type: U

Region: Ontario

Mine status: Shut down

AMD stream description:
Tailings pond discharge

AMD stream source: Tailings

Sample location: Discharge point from tailings pond

Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Fe_{Tot} (mg/L)	35.0	26.0	28.0	36.0
SO_4 (mg/L)	412	447	357	491
Acidity (mg/L) (as $CaCO_3$)	243	300	315	265
pH	2.80	2.80	3.00	2.70
TDS[1] (mg/L)	591	639	500	670

[1] Total dissolved solids

Table A-IV-49 - Data for AMD stream L-1

Stream code: L-1 | Mine type: U

Region: Ontario | Mine status: Shut down

AMD stream description:
Seepage and runoff

AMD stream source: Tailings

Sample location: Treatment plant feed | Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Al (mg/L)	1.8	1.0	5.4	5.7
Co (mg/L)	0.24	0.30	0.070	0.34
Cu (mg/L)	0.02	0.02	0.040	0.040
Fe_{Tot} (mg/L)	300	745	402	828
Fe^{2+} (mg/L)	263	638	324	801
Mn (mg/L)	3.2	4.5	1.3	5.2
Ni (mg/L)	0.31	0.25	0.10	0.28
Pb (mg/L)	<0.01	<0.10	<0.10	<0.100
U (mg/L)	0.044	0.021	0.040	0.006
Zn (mg/L)	0.080	0.070	0.10	0.090
Flowrate (L/s)	129.1	28.9	90.8	31.7
Acidity (mg/L) (as $CaCO_3$)	761	1,342	917	1,726
pH	3.27	4.54	3.32	4.89
TDS[1] (mg/L)	2,446	3,418	1,085	4,180

[1] Total dissolved solids

Table A-IV-50 - Data for AMD stream L-2

Stream code: L-2 Mine type: U

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage

AMD stream source: Tailings

Sample location: Seepage collection system Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Al (mg/L)	1.80	1.60	3.80	1.30
Cd (mg/L)	<0.020	<0.020	<0.020	<0.005
Co (mg/L)	0.14	0.15	0.11	0.16
Cu (mg/L)	0.070	0.030	0.020	0.070
Fe_{Tot} (mg/L)	131.0	184	95	177
Mn (mg/L)	0.83	1.13	0.92	1.00
Ni (mg/L)	0.19	0.25	0.28	0.17
Pb (mg/L)	<0.10	<0.10	<0.10	0.22
Zn (mg/L)	0.14	0.16	0.110	0.16
Flowrate (L/s)	9.3	3.1	3.3	2.5
Acidity (mg/L) (as $CaCO_3$)	664	655	793	1,061
pH	3.30	3.24	3.36	3.47

Table A-IV-51 - Data for AMD stream M-1

Stream code: M-1 Mine type: U/Cu

Region: Ontario Mine status: Shut down

AMD stream description:
Seepage and site drainage (minesite and tailings)

AMD stream source: Tailings

Sample location: Treatment plant feed (water collected in holding pond and batch treated) Sample Year: 1993

Parameters	Spring May	Summer September	Fall November	Winter February
Al (mg/L)	<0.10		<0.10	
Cd (mg/L)	<0.002		<0.002	
Co (mg/L)	0.29	0.25	0.34	
Cu (mg/L)	0.66	0.12	0.28	
Fe_{Tot} (mg/L)	16.0	55.0	24.0	
Mn (mg/L)	0.50	0.96	0.84	
Ni (mg/L)	0.20	0.15	0.90	
Pb (mg/L)	<0.10	<0.010	<0.010	
U (mg/L)	0.016	0.048	0.050	
Zn (mg/L)	0.18	0.030	0.030	
Flowrate (L/s)	154	26.4	105.1	0
Acidity (mg/L) (as $CaCO_3$)	141	248	154	
pH	3.53	2.93	3.12	
TDS[1] (mg/L)	470	846	811	
TSS[2] (mg/L)	13	1	2	

[1] Total dissolved solids

[2] Total suspended solids

Table A-IV-52 - Data for AMD stream N-1

Stream code: N-1 | Mine type: Ni/Cu

Region: Ontario | Mine status: Operating

AMD stream description:

AMD stream source: Waste rock, mine water and tailings

Sample location: Pump house | Sample year: 1993

Parameters	Spring Apr-May	Summer Jun-Aug	Fall Sept-Nov	Winter Jan-Mar
Cu (mg/L)	1.1-3.3	0.48-3.10	0.12-1.50	0.08-1.61
Fe_{Tot} (mg/L)	0.22-1.1	0.22-3.2	0.24-1.10	0.38-1.76
Ni (mg/L)	3.30-7.60	3.50-7.20	0.35-5.90	0.21-4.94
Pb (mg/L)	<0.002	<0.002	<0.002-0.004	<0.002
Zn (mg/L)	0.08-0.35	0.08-0.34	<0.02-0.19	0.03-0.25
SO_4 (mg/L)	200-328	314-610	594-1,386	
Flowrate (L/s)	160	75	110	80

Table A-IV-53 - Data for AMD stream N-2

Stream code: N-2 Mine type: Ni/Cu

Region: Ontario Mine status: Operating

AMD stream description:
Natural runoff and seepage, plus some lake water (pumped)

AMD stream source: Tailings and waste rock

Sample location: Lake outflow Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Nov	Winter Dec-Mar
Cu (mg/L)	4.1	3.3	3.3	3.6
Fe_{Tot} (mg/L)	13.5	5.6	9.8	10.6
Ni (mg/L)	12.3	13.8	15.5	14.9
Pb (mg/L)	0.004	0.003	0.007	0.004
Zn (mg/L)	0.37	0.45	0.47	0.50
SO_4 (mg/L)	578	794	1,175	874
pH	3.5	3.2	3.3	3.3
TSS[1] (mg/L)	0.8	1.9	1.7	0.6

[1] Total suspended solids

Table A-IV-54 - Data for AMD stream N-3

Stream code: N-3 Mine type: Ni/Cu

Region: Ontario Mine status: Operating

AMD stream description:
Natural precipitation, tailings effluent, mine water and surface runoff

AMD stream source: Waste rock, tailings and underground mine

Sample location: Upstream of neutralization dam Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Nov	Winter Dec-Mar
Ni (mg/L)	1.21	1.14	1.50	1.24
Flowrate (L/s)	1,540	480	580	430
pH	4.54	3.14	3.26	5.25

Table A-IV-55 - Data for AMD stream N-4

Stream code: N-4 Mine type: Ni/Cu

Region: Ontario Mine status: Operating

AMD stream description:
Natural runoff and precipitation, plus tailings effluent from mill (pH 9-11)

AMD stream source: Tailings and mine water (mixed with lake water)

Sample location: Immediately downstream of tailings impoundment dam Sample year: 1993

Parameters	Spring Apr-Jun	Summer Jul-Sept	Fall Oct-Nov	Winter Dec-Mar
Cu (mg/L)	0.21	0.06	1.1	0.11
Fe_{Tot} (mg/L)	3.3	2.4	3.75	3.2
Ni (mg/L)	0.52	0.38	1.15	0.45
Pb (mg/L)	<0.002	<0.002	<0.002	<0.002
Zn (mg/L)	0.023	<0.02	0.055	0.02
SO_4 (mg/L)	336	731	1,062	594
pH	5.6	6.0	5.25	5.2
TSS[1] (mg/L)	0.6	3.7	6.4	3.7

[1] Total suspended solids

Table A-IV-56 - Data for AMD stream O-1

Stream code: O-1 Mine type: Ni

Region: Ontario Mine status: Shut down

AMD stream description:
Site drainage

AMD stream source: Waste rock

Sample location: Sample year: 1994

Parameters	Spring	Summer	Fall	Winter
Cd (mg/L)	0.001			
Cu (mg/L)	0.18			
Fe_{Tot} (mg/L)	0.65			
Ni (mg/L)	0.72			
Zn (mg/L)	0.04			
SO_4 (mg/L)	24.0			
Flowrate (L/s)	5.7			
pH	4.1			

Table A-IV-57 - Data for AMD stream O-2

Stream code: O-2

Mine type: Ni

Region: Ontario

Mine status: Shut down

AMD stream description:
Site drainage

AMD stream source: Waste rock

Sample location:

Sample year: 1994

Parameters	Spring	Summer	Fall	Winter
Cd (mg/L)	0.0011			
Cu (mg/L)	1.6			
Fe_{Tot} (mg/L)	6.2			
Ni (mg/L)	1.8			
Zn (mg/L)	0.07			
SO_4 (mg/L)	95.6			
Flowrate (L/s)	3.0			
pH	3.3			

Table A-IV-58 - Data for AMD stream P-1

Stream code: P-1 Mine type: Ni/Cu

Region: Ontario Mine status: Shut down

AMD stream description:
Tailings pond water

AMD stream source: Tailings

Sample location: Dam #6 Sample year: Annual average

Parameters	Annual Average			
Cu (mg/L)	0.1			
Fe_{Tot} (mg/L)	1.6			
Ni (mg/L)	1.3			
SO_4 (mg/L)	500			
Flowrate (L/s)	91			
pH	6.9			

Table A-IV-59 - Data for AMD stream Q-1

Stream code: Q-1 Mine type: Cu/Zn

Region: Ontario Mine status: Open

AMD stream description:
Runoff from stockpiles plus some mine water

AMD stream source: Waste rock stockpiles

Sample location: Sample year: 1992

Parameters	Spring	Summer	Fall	Winter Frozen
As (mg/L)		<0.05	<0.05	
Cd (mg/L)		0.08	0.11	
Cu (mg/L)		0.09	0.39	
Fe_{Tot} (mg/L)		0.05	0.55	
Hg (mg/L)		<0.001	<0.001	
Ni (mg/L)		0.02	<0.01	
Pb (mg/L)		<0.05	<0.05	
Zn (mg/L)		11.6	21.1	
SO_4 (mg/L)		480	312	
pH		7.5	7.2	
Ec[1] (µS/cm)		1,370	800	
TSS[2] (mg/L)		<10	<10	

[1] Electrical conductivity

[2] Total suspended solids

Table A-IV-60 - Data for AMD stream Y-1

Stream code: Y-1 | Mine type: Ni/Cu

Region: Ontario | Mine status: Operating

AMD stream description:
Storm water collection system (includes small amount of seepage)

AMD stream source: Tailings, natural precipitation and atmospheric deposition

Sample location: Treatment plant feed | Sample year: 1993-1994

Parameters	Spring Mar/94	Summer Jul/94	Fall Oct/93	Winter Dec/93
Al (mg/L)	3.88	6.48	9.35	6.18
As (mg/L)	<0.0131	<0.0238	<0.0262	<0.0262
Cd (mg/L)	0.0057	0.0121	0.0146	<0.0040
Co (mg/L)	0.500	0.62	1.38	0.707
Cr (mg/L)	0.0109	<0.0058	0.0212	0.0062
Cu (mg/L)	2.98	4.53	0.0212	3.66
Fe_{Tot} (mg/L)	10.9	15.3	52.8	30.6
Mn (mg/L)	0.586		1.42	0.917
Ni (mg/L)	12.4	17.3	36.0	17.8
Pb (mg/L)	<0.0150	0.771	<0.0300	<0.0300
Zn (mg/L)	0.355	0.382	0.704	0.425
SO_4 (mg/L)	305	352	774	594
Flowrate (L/s)	137	20.8	147	122
pH	3.44	4.42	3.25	4.28

Table A-IV-60 (cont'd)

Parameters	Spring Mar/94	Summer Jul/94	Fall Oct/93	Winter Dec/93
Ec[1] (µS/cm)	352	362	1,080	640

TDS[2] (mg/L)	564	802	1,050	1,000
TSS[3] (mg/L)	79	<3	54.9	38.9

[1] Electrical conductivity

[2] Total dissolved solids

[3] Total suspended solids

Table A-IV-61 - Data for AMD stream CC-1

Stream code: CC-1 Mine type: Ni/Cu

Region: Ontario Mine status: Operating

AMD stream description:
Effluent collection system (primarily process water with significant storm water component)

AMD stream source: Mill, mine, refinery, sewage treatment plant, runoff, etc.

Sample location: Treatment plant feed Sample year: 1993

Parameters	Spring April	Summer	Fall	Winter
Al (mg/L)	2.55			
As (mg/L)	<0.0131			
Cd (mg/L)	0.0021			
Co (mg/L)	0.240			
Cr (mg/L)	0.0112			
Cu (mg/L)	0.721			
Fe_{Tot} (mg/L)	36.3			
Mn (mg/L)	0.938			
Mo (mg/L)	0.0237			
Ni (mg/L)	11.4			
Pb (mg/L)	<0.0300			
Sb (mg/L)	<0.0100			
Zn (mg/L)	0.160			
SO_4 (mg/L)	1,524			
P (mg/L)	<0.0100			
Cl (mg/L)	83			

Table A-IV-61 (cont'd)

Parameters	Spring April	Summer	Fall	Winter

Ca (mg/L)	358			
Mg (mg/L)	64.3			
Na (mg/L)	150			
Flowrate (L/s)	1,718			
pH	5.93			
Ec[1] (µS/cm)	2,560			
TDS[2] (mg/L)	233			
TSS[3] (mg/L)	23			

[1] Electrical conductivity

[2] Total dissolved solids

[3] Total suspended solids

Table A-IV-62 - Data for AMD stream DD-1

Stream code: DD-1

Mine type: Cu/Zn

Region: Manitoba

Mine status: Operating

AMD stream description:
AMD pond beside open pit

AMD stream source: Runoff from waste rock piles

Sample location: East side of open pit

Sample year: 1993

Parameters	Spring May	Summer August	Fall September	Winter
Cu (mg/L)	6.90	11.7	14.75	
Fe_{Tot} (mg/L)	313.9	485.1	420.70	
Pb (mg/L)	0.19	0.68	0.36	
Zn (mg/L)	450.0	135.50	662.0	
SO_4 (mg/L)	7,530.0	13,024.0	10,731.9	
Temperature (EC)	2	17	10	
Flowrate (L/s)	19	12.6	6.3	0
pH	3.04	2.44	2.57	

Table A-IV-63 - Data for AMD stream DD-2

Stream code: DD-2 | Mine type: Cu/Zn

Region: Manitoba | Mine status: Operating

AMD stream description:
Process tailings water decant

AMD stream source: Tailings pond runoff

Sample location: Tailings pond outfall spillway | Sample year: 1993

Parameters	Spring May	Summer August	Fall September	Winter December
Cu (mg/L)	0.16	0.04	0.14	0.08
Fe_{Tot} (mg/L)	2.20	17.90	22.10	1.80
Pb (mg/L)	0.35	0.21	0.19	0.12
Zn (mg/L)	0.53	1.57	1.88	0.23
SO_4 (mg/L)	1,260.0	1,580.2	1,522.6	
Temperature (EC)	8	22	12	4
Flowrate (L/s)	112	106	106	100
pH	8.34	5.17	4.68	9.11

Table A-IV-64 - Data for AMD stream S-1

Stream code: S-1

Mine type: Cu/Ag/Au

Region: British Columbia

Mine status: Shut down

AMD stream description:
Pit overflow

AMD stream source: Open pit mine with acid generating rock fill and clay cover

Sample location: Pit outflow

Sample year: Average 1990-1994

Parameters	Spring Mar-May	Summer Jun-Aug	Fall Sept-Nov	Winter Dec-Feb
Al (mg/L)	0.0501	0.0176	0.0995	0.0660
As (mg/L)	0.0006	0.0003	0.0004	0.0005
Cd (mg/L)	0.0382	0.0602	0.0635	0.0321
Cu (mg/L)	0.195	0.725	0.219	0.135
Fe_{Tot} (mg/L)	0.040	0.090	0.038	0.044
Sb (mg/L)	0.024	0.014	0.014	0.017
Zn (mg/L)	4.02	7.26	4.94	4.01
SO_4 (mg/L)	1,412	1,352	1,236	1,346
Flowrate (L/s)	3.2	5.8	1.7	0.93
Alkalinity (mg/L) (as $CaCO_3$)	324	287	259	266
pH	7.24	7.46	7.65	7.55
Ec[1] (µS/cm)	2,170	2,370	2,280	2,300

[1] Electrical conductivity

Table A-IV-65 - Data for AMD stream S-2

Stream code: S-2

Mine type: Cu/Ag/Au

Region: British Columbia

Mine status: Shut down

AMD stream description:
Site drainage

AMD stream source: Waste rock

Sample location: Creek

Sample year: Average 1991-1993

Parameters	Spring April	Summer July	Fall October	Winter December
Cu (mg/L)	2.11	2.26	1.46	2.88
Fe_{Tot} (mg/L)	7.98	8.47	9.36	11.97
Zn (mg/L)	2.00	1.79	1.45	2.26
SO_4 (mg/L)	427	737	718	877
Flowrate (L/s)	8.88	3.73	1.51	2.35
Acidity (mg/L) (as $CaCO_3$)	149.67	182.2	165.7	252.5
pH	3.65	3.47	3.62	3.38

Table A-IV-66 - Data for AMD stream S-3

Stream code: S-3 Mine type: Cu/Ag/Au

Region: British Columbia Mine status: Shut down

AMD stream description:
Seepage from tailings dam #1 (base of dam constructed from waste rock)

AMD stream source: Waste rock

Sample location: Dam #1 seepage Sample year: Average 1991-1993

Parameters	Spring April	Summer July	Fall October	Winter December
Cu (mg/L)	31.35	29.7	24.1	27.4
Fe_{Tot} (mg/L)	825.8	735.1	499.5	589.5
Zn (mg/L)	20.89	20.0	18.0	19.6
SO_4 (mg/L)	6,030	5,830	6,460	5,364
Flowrate (L/s)	9.91	4.50	3.95	3.29
Acidity (mg/L) (as $CaCO_3$)	4,097	3,767	2,990	3,324
pH	2.48	2.58	2.63	2.47

Table A-IV-67 - Data for AMD stream S-4

Stream code: S-4

Mine type: Cu/Ag/Au

Region: British Columbia

Mine status: Shut down

AMD stream description:
Seepage stream

AMD stream source: Waste rock dump

Sample location: Main waste dump

Sample year: Average 1991-1993

Parameters	Spring April	Summer July	Fall October	Winter December
Cu (mg/L)	300.0	239.7	209.3	341.7
$Fe_{Dissolved}$ (mg/L)	3,971.7	2,799.0	2,305.0	4,219.0
Zn (mg/L)	217.7	198.7	180.0	224.5
SO_4 (mg/L)	29,579	24,445	16,318	26,411
Flowrate (L/s)	7.53	3.27	2.30	3.33
Acidity (mg/L) (as $CaCO_3$)	20,793	16,811	14,693	23,082
pH	2.45	2.54	2.62	2.38

Table A-IV-68 - Data for AMD stream T-1

Stream code: T-1 Mine type: Cu

Region: British Columbia Mine status: Shut down (temporary)

AMD stream description:
Surface drainage collection pond

AMD stream source: AMD, natural runoff and leach system seepage (waste dumps leached with acid to recover Cu)

Sample location: Pond #6 Sample year: 1993

Parameters	Spring May	Summer August	Fall November	Winter February
Al (mg/L)	35.3	24.8	14.0	0.049
As (mg/L)				<0.20
Cd (mg/L)				<0.10
Co (mg/L)				0.146
Cr (mg/L)				<0.015
Cu (mg/L)	33.2	41.8	27.4	1.49
Fe_{Tot} (mg/L)	8.28	2.17	0.509	0.474
Mn (mg/L)				4.24
Mo (mg/L)	0.012	0.012	0.007	0.046
Ni (mg/L)				0.021
Pb (mg/L)				<0.05
Zn (mg/L)				0.349
SO_4 (mg/L)	1,020	1,450	1,340	954
Ca (mg/L)	183	376	360	247
Mg (mg/L)	65.5	81.9	75.6	69.4
Temperature (EC)	19	20	9	7

Table A-IV-68 (cont'd)

Parameters	Spring May	Summer August	Fall November	Winter February

Acidity (mg/L) (as $CaCO_3$)	243	222	116	13.9
pH	4.4	4.5	4.8	7.0
TSS[1] (mg/L)	23.0	7.0	5.0	9.0
Hardness (mg/L) (as $CaCO_3$)	727	1,280	1,210	889

[1] Total suspended solids

Table A-IV-69 - Data for AMD stream T-2

Stream code: T-2 Mine type: Cu

Region: British Columbia Mine status: Shut down (temporary)

AMD stream description:
Surface drainage collection pond

AMD stream source: Pond #6 and dump #1 seepage (waste dumps leached with acid to recover Cu)

Sample location: Pond #4 Sample year: 1993

Parameters	Spring May	Summer August	Fall	Winter February
Al (mg/L)	32.3	25.3	14.1	32.1
As (mg/L)				<0.20
Cd (mg/L)				<0.10
Co (mg/L)				0.498
Cr (mg/L)				<0.015
Cu (mg/L)	32.2	40.9	26.6	11.3
Fe_{Tot} (mg/L)	4.29	4.18	3.17	2.31
Mn (mg/L)				10.0
Mo (mg/L)	0.004	0.002	0.004	0.009
Ni (mg/L)				0.089
Pb (mg/L)				<0.05
Zn (mg/L)				0.954
SO_4 (mg/L)	951	1,260	1,290	1,310
Ca (mg/L)	175	308	386	231
Mg (mg/L)	59.3	75.3	76.2	83.8
Temperature (EC)	14.5	23	1	6

Table A-IV-69 (cont'd)

Parameters	Spring May	Summer August	Fall	Winter February

Acidity (mg/L) (as $CaCO_3$)	251	221	111	229
pH	4.30	4.20	4.50	5.70
TSS[1] (mg/L)	12.0	12.0	19.0	9.0
Hardness (mg/L) (as $CaCO_3$)	682	1,080	1,280	915

[1] Total suspended solids

Table A-IV-70 - Data for AMD stream U-1

Stream code: U-1 Mine type: Pb/Zn/Ag

Region: British Columbia Mine status: Operating

AMD stream description:
Combined stream of mine water and site drainage

AMD stream source: Underground mine drainage and waste rock dump seepage

Sample location: Mine drain pipeline outflow at tailings pond

Sample year: 1993-1994

Parameters	Spring Apr/94	Summer Jun/93	Fall Oct/93	Winter Feb/94
As (mg/L)	0.21	0.07	0.09	0.12
Cu (mg/L)	0.41	0.13	0.11	0.21
Fe_{Tot} (mg/L)	254	100	100	41
Mn (mg/L)	27			5.3
Pb (mg/L)	1.6	5.6	5.3	23
Zn (mg/L)	117	65	87	85
SO_4 (mg/L)	3,284	2,045	2,493	1,697
F (mg/L)	7.2	2.9	3.7	4.5
Flowrate (L/s)	77	71	55	49
Acidity (mg/L) (as $CaCO_3$ to pH 9.5)	2,221			1,263
pH	3.2	3.6	3.4	3.6
Ec[1] (µS/cm)	4,060	2,890	3,530	2,500
TSS[2] (mg/L)	338	943	659	320

[1] Electrical conductivity

[2] Total suspended solids

Table A-IV-71 - Data for AMD stream V-1

Stream code: V-1 | Mine type: Pb/Zn/Ag

Region: British Columbia | Mine status: Operating

AMD stream description:
Combined stream of tailings pond seepages

AMD stream source: Tailings

Sample location: Seepage pump station | Sample year: 1993-1994

Parameters	Spring Apr/94	Summer Jun/93	Fall Oct/93	Winter Feb/94
Cd (mg/L)	0.010	<0.005	0.005	0.005
Cu (mg/L)	0.020	0.005	<0.005	0.005
Fe_{Tot} (mg/L)	292	168	330	340
Mn (mg/L)	19	13	15	17
Pb (mg/L)	0.10	<0.01	0.10	<0.01
Zn (mg/L)	4.2	0.70	1.9	1.5
SO_4 (mg/L)	3,680	2,857	3,345	3,710
F (mg/L)	24	2.8	9.6	35
Flowrate (L/s)	68	41	48	33
Acidity (mg/L) (as $CaCO_3$ to pH 9.5)	972			2,380
pH	5.6	6.5	6.1	5.4
Ec[1] (µS/cm)	4,960	4,000	4,650	5,000
TSS[2] (mg/L)	59	3	72	44

[1] Electrical conductivity

[2] Total suspended solids

Table A-IV-72 - Data for AMD stream V-2

Stream code: V-2 Mine type: Pb/Zn/Ag

Region: British Columbia Mine status: Operating

AMD stream description:
Combined tailings effluent, tailings seepage and mine drainage

AMD stream source: Mine workings, waste rock and tailings

Sample location: Treatment plant feed Sample year: 1993-1994

Parameters	Spring Apr/94	Summer Jun/93	Fall Oct/93	Winter Feb/94
Cu (mg/L)	0.25	0.09	0.10	0.05
Fe_{Tot} (mg/L)	204	104	131	184
Pb (mg/L)	3.9	4.4	4.3	3.6
Zn (mg/L)	58	22	21	21
F (mg/L)	5.5	2.5	2.0	4.9
Flowrate (L/s)	258	233	233	292
Acidity (mg/L) (as $CaCO_3$ to pH 9.5)	12,295			14,873
pH	3.6	3.4	4.2	4.4
Ec[1] (µS/cm)	3,160	2,560	2,230	2,390
TSS[2] (mg/L)	10	6	10	37

[1] Electrical conductivity

[2] Total suspended solids

APPENDIX V

SITE INFORMATION

Table A-V-1 - Site information

Site Code: A

Acid generating materials

Quantities: 5 million tonnes waste rock
80,000 tonnes tailings

Chemical/mineralogical information: waste rock is acid generating

Information pertinent to acid generation at the site

AMD is collected and pumped to an open pit for temporary storage. The pit is pumped to a new water treatment plant at another site (8.5 km away) on a seasonal basis.

Site Code: B

Acid generating materials

Quantities: 67 million tonnes tailings
75 million tonnes ore (underground)

Chemical/mineralogical information: tailings are 70-75% pyrite
ore is 60-65% pyrite

Significant problems with AMD at the site

Must achieve <10 mg/L TSS to meet total Zn limit of 1.0 mg/L on a grab sample.

Success in dealing with AMD at the site

New treatment system can effectively buffer spring runoff.

Site Code: W

Acid generating materials

Quantities: 4.16 million tonnes tailings

Chemical/mineralogical information:

organic matter = 0.8 %	Zn = 1,55 ppm	S = 19.3%
P = 27 ppm	Cu = 864 ppm	Fe = 12%
Na = 70 ppm	Pb = 715 ppm	pH = 4.2
K = 12 ppm Mn = 424 ppm		
Mg = 471 ppm	Co = 59 ppm	

Ca = 4,792 ppm   Cr = 45 ppm

Information pertinent to acid generation at the site

Tailings pond covers 66 ha including 20 ha under water.

Significant problems with AMD at the site

Effluent water quality may affect receiving lake sediments.

Success in dealing with AMD at the site

Reclamation of the site is under way via construction of two dams to maintain an average 3-meter water cover.

Site Code: X

Acid generating materials

Chemical/mineralogical information: (units are %)

SiO_2 = 58 - 61.5	Pb = 0.004 - 0.017	FeS_2 = 6 - 11.7
Al_2O_3 = 13 - 18.5	Zn = 0.01 - 0.025	$Fe_{(1-x)}S$ = 0.7 - 2.6
CaO = 1.6 - 2.8	Cu = 0.01 - 0.04	
MgO = 1.2 - 2.8	As = <0.001	
K_2O = 1 - 5	S_{Tot} = 3 - 7.2	
CO_3 = 1.8 - 3.3		

Information pertinent to acid generation at the site

The only source of acid water is the underground pumping system (~30 L/s). The main contaminants are heavy metals (Zn, Cu and Fe); the acidity is elevated and pH < 3 before treatment.

Significant problems with AMD at the site

The cost of treatment (lime, construction of settling ponds), occasional "scaling" associated with the recycle water, and rusting of equipment and support systems.

Site Code: C

Acid generating materials

Quantities: two waste rock dumps, each 21 million tonnes

Chemical/mineralogical information: pyrite 3.5%
chalcopyrite (very little)

feldspar
chlorite
carbonates

Information pertinent to acid generation at the site

Ditches are used to recover the AMD for treatment at a high density sludge plant.

Significant problems with AMD at the site

The drainage area is very large resulting in an enormous quantity of water to treat (~3 million m^3/a). The quantities vary seasonally with the largest occurring in the spring.

Success in dealing with AMD at the site

All AMD is collected and treated. None of the norms have been exceeded in the final effluent for the past three years.

<u>Site Code: D</u>

Acid generating materials

Quantities: 13.8 million tonnes tailings
11.5 million tonnes waste rock

Chemical/mineralogical information: disseminated pyrite
low carbonate
S_{Tot} = 0.2-10% (areas 30-40%)
heavy metals: Cu and Zn

Information pertinent to acid generation at the site

All AMD is collected by a ditch system.

Significant problems with AMD at the site

Control of pH and Zn concentration.

Success in dealing with AMD at the site

Control of all metals (except Zn, occasionally) has been achieved. The collection system is simple but effective.

<u>Site Code: AA</u>

Acid generating materials

Chemical/mineralogical information: waste rock is not acid generating

Information pertinent to acid generation at the site

There is no treatment (active or passive) for the waste rock piles. Drainage ditches divert surface water to a ditch for pumping and treatment.

Significant problems with AMD at the site

Excessive levels of Fe, Zn and pH. However metal loadings entering receiving rivers are one to two orders of magnitude less than the natural levels.

Success in dealing with AMD at the site

Ponds are drained to the open pit. Contaminated tailings have been collected.

Site Code: BB

Acid generating materials

Quantities: 90 acre sulphide tailings dam (6 million tonnes)

Chemical/mineralogical information: ~15-25% sulphides (pyrite, pyrrhotite)

Information pertinent to acid generation at the site

Revegetation performed in 1970's and 1980's. Fresh water diversion projects along with seepage collection ditches and storage ponds constructed in 1970's.

Significant problems with AMD at the site

Residual AMD from tailings dam cannot be eliminated economically by known technology. Hence a water treatment plant (WTP) will be necessary for foreseeable future. While sludge disposal is currently not a major cost, it could become more expensive to dispose of in the long term.

Success in dealing with AMD at the site

Regulations are consistently met; there are no significant problems with AMD treatment via the high density sludge (HDS) treatment plant. Tailings areas have been reclaimed by direct seeding/clay covering. Seeding and water management appear to have reduced acid generation by 70-80% since the late 1970's. Contaminated flows into the environment have been eliminated since 1984 through capture of contaminated flows/seepages and construction of the AMD storage pond, HDS water treatment plant and sludge ponds.

Site Code: R

Acid generating materials

Quantities: 7.5 million m^3 tailings

Information pertinent to acid generation at the site

AMD from the site is intercepted via ditches, ponds, etc. and routed to an open pit. A pumping facility at the mine headframe is utilized to transfer the stored runoff from the pit to a newly constructed waste water treatment plant. The treated effluent is then discharged through a polishing pond into a creek and the generated sludge is pumped to sludge holding ponds. Some areas have been revegetated.

Significant problems with AMD at the site

AMD impact on vegetation and wildlife, fisheries, land use and water quality in receiving waters.

Success in dealing with AMD at the site

The successful identification of AMD streams, their collection, treatment and discharge to the environment at 100% compliance to provincial standards and regulations. Very good results are noticeable in areas which have been revegetated.

Site Code: Z

Acid generating materials

Quantities: 45.4 million tonnes tailings

Chemical/mineralogical information: 6.4-11.5% sulphide sulphur
NNP = -225 to -440 $CaCO_3$ t/1000 t
(strong acid generation potential)

Information pertinent to acid generation at the site

AMD is generated at the tailings area and from the underground mine, waste rock roads, plant site foundations, and mill concentrate spillage. Presently 5% of the tailings area is revegetated.

Significant problems with AMD at the site

The tailings area seepages are reasonably well contained and collected for treatment. The greatest loadings of heavy metal, with Zn as the primary aquatic detriment, come from the mill and plant site groundwater AMD. One creek immediately adjacent to the site suffers impairment to benthic communities. Precipitation of metals to sediments occurs relatively quickly and within a short distance downstream of the site.

The tailings area is of 1950/60's design. Several engineered clay core dams with grout curtains have already been constructed in recent years to contain and intercept discharges (seepages). Several other such dams are required along with associated seepage pump stations to control the remaining seepages.

The underground workings are acid generating and the long term closure plan requires perpetual dewatering of mine workings to prevent overflow into a nearby creek.

Waste rock used to construct roads and plant site foundations generates significant loadings of Zn in a dilute AMD form (i.e., 1-3 ppm Zn) as storm water runoff. This may necessitate the costly removal of all material.

Success in dealing with AMD at the site

Water treatment plant has been in 100% compliance with regulatory limits for the past 4.5 years. Closure planning has successfully identified sources and loadings of all AMD streams and seepages on site. Attempts will be made to mitigate the high impact streams.

Site Code: E

Acid generating materials

Quantities: 60 million tonnes in tailings management area one (TMA-1)
3 million tonnes in TMA-2

Chemical/mineralogical information: (units are %)

SiO_2 = 90	Rare earths = 0.05	Ti = 0.15
U_3O_8 = 0.003	Fe_{Tot} = 2.15	Cu = 0.01
ThO_2 = 0.007	S_{Tot} = 2.4	

Information pertinent to acid generation at the site

Mill tailings slurry is treated with limestone and lime prior to discharge into tailings basin. Most of TMA-1 was kept saturated by inflow of fresh tailings slurry during operating period. It is now effectively flooded under a water cover. Most of TMA-2 is not vegetated; it has not been used for tailings disposal since the late 1970's.

Success in dealing with AMD at the site

TMA-1: water cover to prevent further acid generation; use of low grade lime during dredge program to relocate high beach material to below water level at the other end of the basin.
TMA-2: raising water table and revegetating; batch treating surface runoff waters.

Site Code: F

Acid generating materials

Quantities: 6 million tonnes tailings

Chemical/mineralogical information: 6% FeS_2

Information pertinent to acid generation at the site

Runoff water from the inactive tailings management area is directed through the treatment plant; sludges are impounded and overflow water enters the local watershed. Revegetation has been undertaken to about 15% of the surface of the tailings management area.

Significant problems with AMD at the site

The perched tailings area (with porous dams) results in the flushing of AMD into streams based on rainfall/snowmelt. Hence, there are highly variable flows to treat and effective treatment is achieved during low flow periods.

Success in dealing with AMD at the site

Pump and treat.

Site Code: G

Acid generating materials

Chemical/mineralogical information: tailings spills are 3.5% S, 3.0% Fe
waste rock varies up to tailings content
(very minimal acid consumers present)

Information pertinent to acid generation at the site

Some site grading has been done.

Significant problems with AMD at the site

AMD from waste rock piles and tailings spills.

Site Code: H

Acid generating materials

Quantities: 46 million tonnes tailings

<1 million tonnes waste rock

Chemical/mineralogical information: tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

The main acid source is from the tailings basin where the tailings are above the water table. The main basin is currently being flooded. Lime treatment is occurring inside the basin to reduce the acid and precipitate loadings on the treatment plant and settling ponds. Other AMD sources are seepages/runoff from waste rock and/or the toe of tailings dams.

Significant problems with AMD at the site

Tailings stored above the water table.

Success in dealing with AMD at the site

One section of the tailings basin has been flooded continuously since October 1992. Surface waters on the flooded section are neutral (pH = 6.8-7.2, TDS = 130-150 mg/L, SO_4 = 50-70 mg/L, acidity = 5 mg/L, alkalinity = 7 mg/L).

Site Code: I

Acid generating materials

Quantities: 14 million tonnes tailings

Chemical/mineralogical information: tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

Decommissioning of this mine/mill site is currently underway via flooding of the tailings.

Significant problems with AMD at the site

Exposed tailings stored above the water table.

Success in dealing with AMD at the site

The partial flooding of one old tailings spill has successfully reduced AMD.

Site Code: J

Acid generating materials

Quantities: 2.7 million tonnes tailings

Chemical/mineralogical information: tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

All tailings revegetated (seeded) in 1978-1980.

Significant problems with AMD at the site

Tailings are at the high point of the watershed; high permeability dams were used.

Site Code: K

Acid generating materials

Quantities: 0.45 million tonnes tailings

Chemical/mineralogical information: tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

Tailings were placed in a small lake and are mostly submerged. Revegetation of exposed tailings was carried out in mid-1970's.

Significant problems with AMD at the site

Tailings deposited above the water line of the lake.

Site Code: L

Acid generating materials

Quantities: 12 million tonnes tailings
<1 million tonnes waste rock

Chemical/mineralogical information: tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

Revegetation (seeding) of the tailings areas performed in 1978-1980.

Significant problems with AMD at the site

Tailings deposit settling on sand/gravel deposits; high permeability tailings dams not designed to retain water.

Site Code: M

Acid generating materials

Quantities: 2.1 million tonnes U tailings
2.3 million tonnes Cu tailings

Chemical/mineralogical information: U tailings are 3.5% S, 3.0% Fe and 85-90% silica/silicates

Information pertinent to acid generation at the site

Revegetation (seeding) of the tailings areas was performed in 1978-1980. Deposition of lime waste (300,000 tonnes) commenced in 1981 at one major location adjacent to the untreated runoff water collection/holding pond.

Significant problems with AMD at the site

Surface stabilization - erosion causes continual exposure of new surfaces of tailings.

Site Code: N

Acid generating materials

Quantities: 20-40 million tons current tailings stockpile
5 million tons old tailings pond
20-40 million tons waste rock piles/roads

Chemical/mineralogical information: (units are %)

	Tailings slimes	Pyrrhotite tailings	Waste rock
S_{Tot}		1-1.5	33
0-1			
Ni	0.10	0.8	-
Cu	0.08	0.08	total
Fe	15	60	metals
Co	0.04	0.03	0-0.5

Sulphide minerals: chalcopyrite, pentlandite and pyrrhotite

Information pertinent to acid generation at the site

This site involves a very large watershed (9,000 acres) containing both operating and shut down mine/mill complexes. Limestone treatment was performed in a major receiving lake in 1968. AMD was intercepted in creeks to the mill in 1980-1982. A tailings site was covered with 5 feet of waste rock and sewage in mid-1980's. A treatment plant was converted to a liner in 1990 due to gradually elevated Ni levels in the major receiving lake. An intercept dam, pump house and pipeline were installed in 1991 to intercept all mine water and surface runoff from two of the mine sites. Since 1992, essentially 90% of AMD from the entire site is collected and treated in the treatment system.

Significant problems with AMD at the site

Natural runoff and seepage from old non-operational tailings site and old mine/mill site. Railbeds and many miles of roadbeds constructed of waste rock. AMD from exposed tailings beach area (200-250 acres) which has developed over 26 years of operations.

Success in dealing with AMD at the site

Nickel loadings to receiving streams reduced by ~90-95% by diversion and treatment methods. Waste rock and sewage cover on tailings area reduced AMD generation from this tailings site by ~75%.

Site Code: O

Acid generating materials

Quantities: <1,000 tonnes waste rock

Information pertinent to acid generation at the site

Waste rock dump associated with abandoned mine.

Significant problems with AMD at the site

Contributes small amount to stream/wetland loading; appearance.

Site Code: P

Acid generating materials

Quantities: ~2 million tonnes tailings
<0.5 million tonnes waste rock

Chemical/mineralogical information: contains Ni, Cu sulphides plus other base/heavy metal sulphides, pyrrhotite and pyrite in widely varying amounts.

Information pertinent to acid generation at the site

Materials are stored in a variety of ways (i.e., tailings stacks, tailings ponds); many materials are stored in sand/gravel soils located above the groundwater aquifer.

Significant problems with AMD at the site

Impact on groundwater; iron concentrations in final effluent; and the seepage is not totally collected by the effluent system.

Success in dealing with AMD at the site

Most of the AMD at the site is collected by the effluent system.

Site Code: Q

Acid generating materials

Quantities: ~20 million tonnes waste rock

Chemical/mineralogical information: 80% rhyolites with high silica content
~5% sulphides

Information pertinent to acid generation at the site

Progressive rehabilitation ongoing with some revegetation.

Significant problems with AMD at the site

Some low grade ore residual pads from previous years display some AMD; effects are limited and localized.

Success in dealing with AMD at the site

The current milling plan includes the use of all waste rock for backfill purposes within the mine.

Site Code: Y

Acid generating materials

Chemical/mineralogical information: sulphide tailings (pH 3.7-6.2)

feldspar	50%	pyroxenes	7%	magnetite	0.6%
amphiboles	20%	biotite	7%	pentlandite	0.5%
quartz	10%	pyrrhotite	5.6%	chalcopyrite	0.3%

Cu = 1 - 81 ppm	Ni = 1 - 87 ppm	Fe = 59 - 441 ppm

Information pertinent to acid generation at the site

Revegetation projects ongoing within watershed.

Significant problems with AMD at the site

Historical contamination includes: old processing areas, railbeds, tailings lines, contaminated soils with atmospheric input, and seepage from mill ponds.

Success in dealing with AMD at the site

Area is being revegetated (visual improvement). An evaluation has begun to measure improvements as various stages of reclamation and decommissioning are implemented. The watershed is being divided into smaller parcels for progressive action based on relative contributions to contaminant load.

<u>Site Code: CC</u>

Acid generating materials

Quantities: 5.4 million yd^3 waste rock (11 piles)
290.4 million yd^3 tailings (one site)
2.2 million yd^3 tailings (another site)

Chemical/mineralogical information: sulphide tailings (pH 3.7-6.2)

feldspar	50%	pyroxenes	7%	magnetite	0.6%
amphiboles	20%	biotite	7%	pentlandite	0.5%
quartz	10%	pyrrhotite	5.6%	chalcopyrite	0.3%
Cu = 1 - 81 ppm		Ni = 1 - 87 ppm		Fe = 59 - 441 ppm	

Information pertinent to acid generation at the site

Considerable revegetation initiative on tailings, barren land, etc.

Significant problems with AMD at the site

Tailings and process wastewaters.

Success in dealing with AMD at the site

Milling operations use ~100% recycled water; however, due to the large collection area involved, much more water is generated via precipitation than is used.

Site Code: DD

Acid generating materials

Quantities: ~51.1 million tonnes waste rock
~35.6 million tonnes tailings

Chemical/mineralogical information:

Tailings:	pyrite	43.5%	sphalerite	0.4% (0.23% Zn)
	pyrrhotite	9.5%	chalcopyrite	0.3% (0.09% Cu)
	silicates	46.0%		
Waste rock:	pyrite	7%	pyrrhotite	
	anhydrite	<5%	chalcopyrite	3%
			sphalerite	

Information pertinent to acid generation at the site

The majority of the tailings and waste rock is stockpiled above ground without water cover.

Significant problems with AMD at the site

The cost of treatment is high. There is also a significant repair and replacement cost associated with the corrosion of operating equipment due to contact with AMD materials.

Success in dealing with AMD at the site

The diversion and segregation of AMD streams away from cleaner recycle and fresh water streams has reduced the corrosion problems.

Site Code: S

Acid generating materials

Quantities: 85.4 million tonnes acid generating waste rock (three dumps)
33.7 million tonnes potentially acid generating tailings (tailings pond)

Chemical/mineralogical information: waste rock

sulphur (average 2.40%)	chalcopyrite	tetrahedrite
pyrite (average 4.53%)	pyrrhotite sphalerite	
arsenopyrite	galena	

heavy metals: Cu, Zn, Fe, Pb, Sb, As, Cd, Al

Information pertinent to acid generation at the site

Waste dumps are in the process of being resloped and covered with a compacted clay seal. Pits are filled with water to reduce AMD production from the walls. Tailings are covered with 1.5 m of water to stop oxidation of sulphides.

Significant problems with AMD at the site

The waste dumps generate large volumes of strong AMD which must be collected and treated. There are old seepages of AMD from waste rock dumps along the fractured bedrock base to the surrounding environment. The oxidation of plant site fill and portions of tailings dams results in high volumes of low contamination AMD that requires treatment. The sludge produced from treatment of AMD must be dealt with.

Success in dealing with AMD at the site

The collection system successfully collects AMD before it reaches the environment. The treatment plant successfully treats AMD so that water surpasses discharge criteria. Backfilling one of the open pits greatly reduced the rate of oxidation resulting in lower metal concentrations in the AMD from the pit. The effectiveness of compacted clay covers on the waste dumps in reducing infiltration of oxygen and water is being evaluated.

Site Code: T

Acid generating materials

Quantities: 310 million tons waste rock (five dumps)
280 million tons tailings (tailings pond)

Chemical/mineralogical information:

Tailings:	S = 0.83%	AP = 26 t/1,000 t	Ca = 8,158 ppm
	SO_4 = 0.04%	NP = 19 t/1,000 t	Mg = 8,900 ppm
	Fe = 26,734 ppm	NNP = -7 t/1,000 t	Cu = 924 ppm

Tailings do not show signs of acid generation although they are marginally acid generating by static tests.

Waste rock: dumps that are acid generating contain 1.5-3.0% pyrite and 0.10% Cu.
NP (occurs as carbonates) = 25 t/1,000 t

Information pertinent to acid generation at the site

AMD is difficult to monitor at the site as four out of five waste dumps are leached with sulphuric acid to recover copper. Seeps are checked annually to characterize flow on the property.

Significant problems with AMD at the site

When AMD occurred, a collection and treatment facility was installed. However, now that the dumps are being leached, AMD solutions are included with leach solutions which are picked up by a primary collection and pumping system. A secondary collection system is located downstream of this system to pick up any seepage or overflow from the primary collection system.

Success in dealing with AMD at the site

The double collection system for picking up AMD and leach solutions is very effective in minimizing environmental impact. There is some indication of near surface groundwater contamination that is being addressed through ditching.

Site Code: U

Acid generating materials

Quantities: 8.92 million tonnes waste rock (three dumps)

Chemical/mineralogical information:

Principal minerals: pyrrhotite, pyrite, calcite, quartz, mica, chlorite, feldspar, sphalerite, galena

	Oxidized		Unoxidized	
	Mean	Range	Mean	Range
Total S (%)	3.5	0.5 to 5.6	2.4	1.2 to 3.5
NP (kg $CaCO_3$/t)	-114	-10 to -201	27	23 to 31
Paste pH	4.1	2.8 to 5.7	8.3	8.1 to 8.5
Metals (µg/g)				
As	956	106 to 2,460		
Cd	7.6	0.5 to 18		
Cu	131	51 to 226		
Mn	497	65 to 895		
Ni	12	6 to 23		
Pb	4,035	966 to 8,594		
Zn	1,680	294 to 4,562		
Fe (%)	7.9	5.0 to 10.9		

Information pertinent to acid generation at the site

Mine drainage, waste dump seepage and groundwater contaminated by waste dump seepage are combined into one stream and transported by pipeline from the mine to the tailings pond located at the concentrator ~6 km from the mine.

Significant problems with AMD at the site

Problems in locating, intercepting and collecting contaminated ground water result in the discharge to various creeks of groundwater contaminated by waste dump seepage.

Success in dealing with AMD at the site

In 1979, the installation of a mine drainage collection and treatment system stopped direct discharge of mine drainage and waste dump seepage to a creek. In 1991, the construction of a diversion and seepage collection system in a valley between waste dumps stopped direct discharge of seepage from waste dumps to the creek. In 1994, dewatering pumps were installed to intercept and collect contaminated groundwater before entry into the creek.

Site Code: V

Acid generating materials

Quantities: 6.11 million tonnes waste rock
85.6 million tonnes tailings

Chemical/mineralogical information:

	Waste rock		Tailings		
	Old	New	Active	Siliceous	Iron
Total S (%)	2.78	1.07	19.2	7.3	33.5
NP (kg $CaCO_3$/t)	14	52	41	60	32
Paste pH	6.9	8.8	6.8	4.6	4.5
Metals (µg/g)					
As	4.0	6.0	196	201	
Cd	7.5	1.5	19.5	8.5	55
Cu	57	16	269	212	221
Mn	780	895	5,890	2,100	1,510
Ni	13	13	15	<3	<3
Pb	1,940	300	7,130	3,810	5,390
Zn	2,780	768	7,360	1,430	1,770
Fe (%)	6.08	2.95	27	23	54

Information pertinent to acid generation at the site

Seepage from five collection points (three for tailings ponds and two for gypsum ponds) is pumped to a central collection pond; it is then pumped to the tailings pond where it is combined with mine drainage, tailings effluent and surface drainage from tailings ponds

before being pumped to the treatment plant. Application of a dry cover system and revegetation has started on an abandoned section of the tailings pond.

Significant problems with AMD at the site

The volume of contaminated seepage exiting the tailings ponds needs to be reduced. The effectiveness of seepage and contaminated groundwater interception needs to be improved.

Success in dealing with AMD at the site

The tailings effluent and seepage collection and treatment system has been developed and implemented. The treatment plant discharges an effluent which is in compliance with permit 100% of the time. Low volumes of free draining sludge are also produced.
