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RECEIVING WATER AND CONTAMINANT PATHWAY MONITORING IN THE KENO VALLEY, 2003

SPECIAL PROJECTS #2

Prepared for

Nacho Nyak Dun Development Corporation

Prepared by

Laberge Environmental Services
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EXECUTIVE SUMMARY

In 2003 the various mines, infrastructure and treatment facilities formerly known as United Keno Hill Mines was deemed to be abandoned under the Yukon Waters Act. The Government of Yukon assumed care and maintenance duties. One of the components of the care and maintenance contract was a special project to examine ambient receiving water quality and the fate and transport of metals along selected contaminant pathways.

To address the concern about potential environmental degradation to the South McQuesten River resulting from high metal-laden discharges from several abandoned mines, Laberge Environmental Services (LES) conducted a sampling program targeting the receiving waters as well as the major inputs.

Forty-six sites were sampled in the Keno Valley area in August 2003 and analyzed for a variety of water quality parameters. Four of these sites were sampled under low flow conditions in February and March 2004. Most of the watercourses sampled in the study area flow in a northerly direction over terrain that is underlain by discontinuous permafrost.

The data indicates that zinc is the contaminant of concern in the study area. Concentrations ranged from <0.001 ppm in receiving waters to 60.2 ppm in mine drainage. The lowest concentrations were generally documented in the South McQuesten River and the Flat Creek watersheds. Discharges from most of the adits and old mine workings had the greatest concentrations of metals.

Based on the August 2003 data set there appeared to be no overall impact on the South McQuesten River water quality. The downstream site displayed excellent water quality and even surpassed that of the upstream control site. An examination of historic receiving water quality data collected sporadically over the past seven years showed very little change in the South McQuesten River. Flat Creek water quality appears to be improving over time, however Christal Creek waters are showing a deteriorating trend. In the early winter of 2003, the established flow pathway from Galkeno 300 was altered. Fugitive flow from Galkeno 300 began to report to Christal Creek across the Keno Highway. Monitoring in February and March 2004 showed a significant impact to Christal Creek water quality. Effects were also noted within the South McQuesten River.

Removal of the aqueous transport of zinc appears to be occurring naturally at several locations within the study area. Metals were significantly reduced downstream of the Silver King Mine discharge. Sequential leach analysis was performed to determine the metal removal processes transpiring in this area. Most metals were removed with iron and manganese oxides and appear to be securely bound in the muskeg sediments. Similar metal removal processes appear to be involved in zinc reduction throughout No Cash Creek. The wetlands in the valley appear to aid in metal removal as well. Investigations throughout Flat Creek suggest that the wetland below the tailings impoundment plays a role in removing metals from Flat Creek.

Remediation of contaminated discharges will likely be required in some areas to safeguard the health of the local ecosystem. Exploring natural metal attenuation methods is suggested as an option for long term treatment for some of these areas.

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1.0 INTRODUCTION

1.1 Background

A great deal of information exists on the history of the various mining properties situated within the study area. This historical information is provided in several documents including environmental assessment and decommissioning reports, and details will not be reproduced here. For the purposes of this report, the following brief summary on the background of the study area will suffice.

The Elsa Keno mining district was a major silver producer in Canada for 70 years, consisting of several underground and open pit silver/lead/zinc mines. Although the mill has not operated since 1989, mine water has continued to flow into the environment. Lime-treated discharge from the tailings pond system and from Galkeno 900 adit, and discharges from several adits comprise the most significant on-going metal laden flows. Recently (March 2004), flow from the Galkeno 300 adit was directed through a lime treatment system because metal laden water from this portal was reporting across the highway to Christal Creek.

1.2 Scope of Work

The ambient water quality and discharge in the receiving environment in the Elsa Keno area had not been examined for several years. Awareness of the current water quality conditions and metal loadings from discharge points, and within the receiving environment, aid in appropriate management decisions and mitigation measures.

As a component of the Operation and Maintenance of Environmental Control Facilities of the Keno Hill Properties, Elsa, Yukon, Laberge Environmental Services was contracted by Nacho Nyak Dun Development Corporation under Contribution Agreement # 2003, to complete Special Projects #2.

The objectives of Special Projects #2 are as follows:

- Update understanding of current environmental effects by surveying the ambient water quality and rate of flow in the receiving environment

- Increase knowledge and update fate and transport mechanisms along key pathways so that appropriate decisions can be made regarding treatment alternatives such as passive methods

The objectives were realized through the completion of the following tasks:

- Review past network data, design a monitoring program, and prepare for implementation,
- Conduct intensive sampling of receiving environment pathways below key mine discharges,
- Follow standard QA/QC and field practice to obtain comprehensive and defensible data,
- Carry out data management to meet data quality objectives and to ensure compatibility with future data management plans,
- Review initial results with Technical Manger and Project Team, conduct follow up monitoring as required,
- Prepare a report presenting all data from the 2003 monitoring program, including some historic summaries for the receiving water sites.

2.0 STUDY AREA

The study area is located in central Yukon, situated on the Silver Trail approximately 50 kilometres northeast of Mayo in the vicinity of the small communities Elsa and Keno. The study area lies within the Yukon Plateau North ecoregion with the terrain consisting of rolling upland plateaus and small mountain groups. The Tintina Trench traverses the ecoregion from southeast to northwest.

The ecoregion is characterized by long cold winters (mean temperature of -20°C) and warm summers (mean temperature of 10.5°C). The extreme cold causes extensive areas of permafrost. Mean annual precipitation ranges from 300 mm in the major valleys up to 600 in the mountains to the northeast. Within the study area, maximum precipitation occurs in July and minimum precipitation occurs in April.

Sedge or sphagnum tussocks are common in wetlands and in black spruce stands. Extensive shrub lands occur at mid-elevations and on valley bottoms due to cold air drainage. Northern boreal forests exist at elevations up to 1500 m asl. White spruce in a matrix of dwarf willow, birch, ericaceous shrubs, and, occasionally, lodgepole pine forms extensive open forests. Black spruce, scrub willow, birch, and mosses are found on poorly drained sites. Turbic Cryosolic and Eutric Brunisolic soils predominate.

A total of 46 sampling stations were established in the study area (see Figure 2.1). Some of these sites have been monitored off and on since the 1970s. Laberge Environmental Services established many of the sites in 1994 when intensive sampling was carried out over a two-year period. A few additional sites were established in 2003. As such, some sites have had several site designations over time. Sample site designations, locations and descriptions are presented in Table 2.1.

Table 2.1 SITE NUMBERING AND LOCATION

Sample #	LES Site #	UKHM[1] Site #	UKHM[2] Site #	Site Description	UTM (NAD 83)
1	LES 01	S-21	UK1	S.McQuesten River u/s Christal Creek	08 V 0474043 7092848
2	LES 01B			S.McQuesten River d/s Christal Creek	08 V 0474470 7091903
3	LES 02	S-10	UK2	S.McQuesten River at Pumphouse Pond	08 V 0472086 7090028
4	LES 03		UK5	S.McQuesten River u/s Flat Creek	08 V 0465834 7088478
5	LES 04	S-11	UK3	S.McQuesten River 300 m d/s Flat Creek	08 V 0465619 7088333
6	LES 05			S.McQuesten River 9 km d/s Flat Creek	08 V 0460686 7088869
7	LES 06	S-18	UK6	Christal Creek @ Keno Hwy	
8	LES 07	S-19	UK7	Christal Creek 100 m u/s Hanson Rd X-ing	08 V 0478789 7092460
9	LES 07B		UK8	Christal Creek @ Mouth	08 V 0474607 7091926
10	LES 08			Flat Creek @ Keno Hwy	
11	LES 09	S-9	UK9	Flat Creek u/s South McQuesten River	08V 0465861 7088396
12	LES 11			Galena Creek u/s Silver King and the Keno Hwy	
13	LES 11B			Galena Creek d/s Silver King	08 V 0471894 7086081
14	LES 12	S-13	UK14	Silver King Decant	08 V 0471825 7085845
15	LES 14	S-17	UK15	Husky Southwest	08 V 0473854 7086579
16	LES 18	S-3	UK24	Bermingham Adit	
17	LES 19	S-15	UK17	Ruby Adit	
18	LES 20	S-4	UK25	No Cash 500	
19	LES 21			No Cash just u/s highway	08 V 0477460 7088829
20	LES 31	S-5	UK20	Galkeno 900	
21	LES 32		UK27	Galkeno 300	
22	LES 37		UK11	Lightning Creek u/s Hope Gulch	08 V 0490329 7087789
23	LES 38	S-6	UK21	Keno 700	
24	LES 40	S-8	UK19	Onek	
25	LES 41		UK12	Lightning Creek @ Keno u/s bridge	08 V 0485434 7086769
26	LES 46			Flat Ck u/s Porcupine Ditch	08 V 0474723 7087970
27	LES 47		UK10	Porcupine Creek Diversion Ditch	
28	LES 48			Hope Gulch u/s Lightning Creek	08 V 0490231 7087800
29	LES 57			Galena Creek @ mouth	08 V 0471008 7087031
30	LES 69			Flat Creek d/s Tailings, u/s Husky SW	08 V 0473741 7087889
31	LES 71			Flat Creek d/s Galena Creek	08 V 0470703 7087096
32	LES 72	S-1	UK13	Tailings Decant	08 V 0474305 7088263
33	LES 77			Husky	08 V 0474979 7087155
34	STN 06			Christal Creek d/s Paddy Mine	08 V 0480746 7091630
35	STN 25			Flat Creek u/s Galena Creek	
36	Stn 37			Charity Gulch u/s Lightning	08 V 0488981 7087516
37	Stn 38			Lightning Creek u/s Thunder Gulch	08 V 0487480 7087239
38	Stn 44			Bermingham Pit	
39	SKT1			Silver King Transect #1	08 V 0471818 7085864
40	SKT2			Silver King Transect #2	08 V 0471798 7085898
41	SKT3			Silver King 130 m d/s decant	08 V 0471767 7085968
42	NCC1			No Cash Creek 35 md/s Hwy, #1	08 V 0477458 7088828
43	NCC2			No Cash Creek 500 m d/s Hwy, #2	08 V 0477016 7088974
44	NCC3			No Cash Creek in wetland, 800 m d/s Hwy	08 V 0476718 7089025
45	NCC4			No Cash Creek just u/s Ditch, 1.4 km d/s Hwy	08 V 0476200 7089230
46	Ditch			Ditch u/s of No Cash Creek	

[1] Water Licence # QZ94-002
[2] Water Licence # QZ96-001

3.0 METHODS

The bulk of the field work was carried out in August 2003. Some additional receiving water samples were collected in February and March 2004 as part of the monitoring of the fugitive flow from the Galkeno 300 adit.

3.1 Water Quality

Water quality samples were collected from 46 discreet sites over two time periods in August 2003; August 1 to 4, and August 22 to 24. In-situ measurements of water temperature, pH, conductivity, and dissolved oxygen were collected from each site. Water quality samples were collected from three to four sites in February 18^{th} to 20^{th} and March 22^{nd} to 24^{th}, 2004.

Samples for routine analysis such as alkalinity, anions, and nutrients, were collected in new one litre plastic bottles. Samples to be analyzed for total and dissolved metals were collected in new 250 mL plastic bottles. Dissolved metals samples were filtered using dedicated filtration apparatus every evening at the "lab house". For the late August sample set, Norwest Labs filtered the samples for dissolved metals. All samples were kept cool, shipped by air in coolers to Vancouver, BC and analyzed by Norwest Labs in Surrey, BC.

3.2 Hydrology

Spot flow measurements were taken at all sites where possible, with a "Price" meter and wading rod. An area with a uniform cross section was chosen and the velocity and depth were measured using either a AA Price or Price mini meter. Ten or more readings were taken across the profile of the stream. Total discharge was calculated as the sum of these individual discharges. For those sites that had minimal discharges, the timed-bucket method was employed. Using a stopwatch, the flow was timed to fill a known volume. The average of three trials was reported as the discharge. Low flow measurements were obtained using the salt dilution technique.

In 1994, staff gauges were constructed and installed at six sites; Lightning Creek upstream Hope Gulch, Lightning Creek upstream of the bridge at Keno City, the Porcupine Diversion, Flat Creek upstream of the South McQuesten River, Christal Creek at the Keno Highway, and Christal Creek at the Hanson Lake Road Crossing. All sites were inspected in 2003, with the intention of rehabilitating Christal Creek at the Hanson Lake Road Crossing only. A chart-pac data logger with pressure transducer was installed at this site on August 4, 2003.

3.3 Multi-media sampling at Contaminant Flow Paths

The flow paths from Silver King and No Cash 500 were examined in greater detail. Along with water samples, sediment and vegetation samples were collected for metal content.

Five sites along two transects at 10 m and 50 m below the discharge from the Silver King settling ponds were set up (see Figure 3.1). A further set of samples was collected 130 m downstream just prior to the flow permanently going to ground. At each site a small hand dug pit was excavated. A representative sample of the organic layer and one of the mineral layer was collected at each pit using a stainless steel trowel and placed in new zip-lock plastic bags. A subsample of each layer was bagged separately and sent to Microbial Technologies Inc. At each transect, willow (*Salix richardsonii*) leaves, and the most recent year's twig growth, were placed separately in new zip-lock plastic bags. The sediment and willow samples were kept cool and shipped to Norwest Labs in Surrey, BC for metals analyses.

Five sites along the flow path of No Cash Creek were sampled for water and stream sediments. Richardson willow (*Salix richardsonii*) leaves and the most recent year's twig growth were collected adjacent to each site. A sediment sample consisting of the organic layer and of the mineral layer were collected from the small wetland located adjacent to No Cash Creek approximately 800m downstream of the highway.

3.4 Sequential Extraction Analysis - Silver King

Microbial Technologies Inc performed sequential extraction analysis on four of the samples collected, to determine zinc distribution in soils exposed to Silver King mine waters. Details on the extraction methodologies are included in Appendix A.

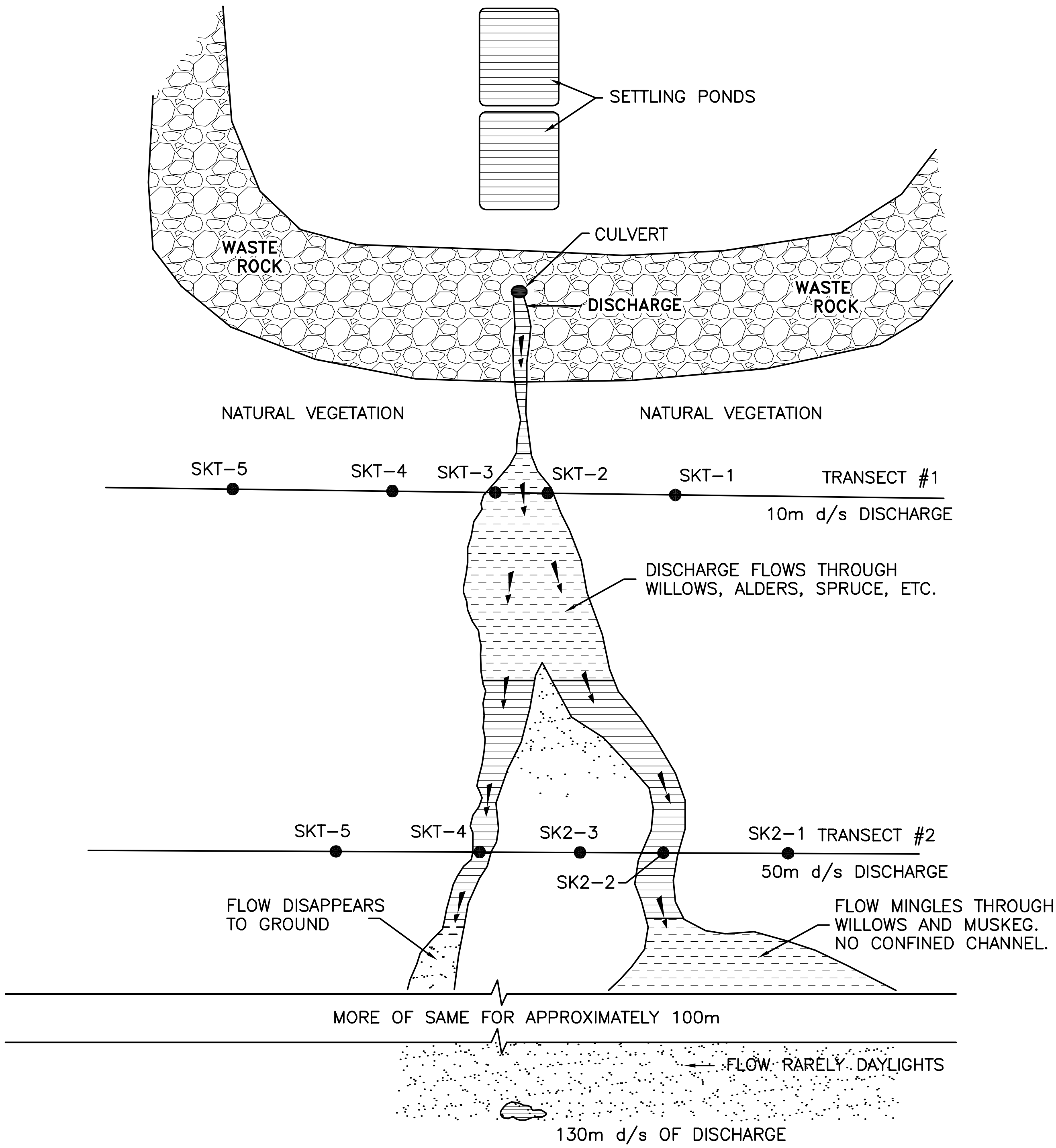

Figure 3.1 Contaminant Flow Path Sample Sites
At Silver King, August 23, 2003
(Not To Scale)

4.0 RESULTS AND DISCUSSION

4.1 Water Quality

During the month of August 2003, 46 sites were sampled in the Keno Valley area encompassing numerous discharges and receiving waters. In-situ measurements were taken at each site, water temperature, pH, and conductivity. Samples were collected and analyzed for a variety of parameters. The analytical lab sheets are included in Appendix B.

To interpret this large set of data, fifteen parameters were examined in detail; water temperature, pH, flow, sulphate, alkalinity, hardness, total suspended solids and eight metals (Table 4.1). The temperature generally reflected the seasonal and diurnal timing of the surface water sampling. Some of the very low temperatures recorded at some of the adits indicate that they drain permafrost areas.

The majority of the waters sampled were near neutral, except for the acidic flow at Husky Mine (2.83) and the alkaline flow at the tailings decant (9.73). Of all the adits sampled, it appears that only Husky Mine has acid rock drainage potential. The pH of the drainage was 2.83. Alkalinity was not detected here indicating that there is little in the way of buffering capacity within this drainage.

Instantaneous discharge measurements were made where possible. The South McQuesten River had the greatest flow. Most of the adits had minimal flows.

Sulphate concentrations fluctuated throughout. Natural levels of sulphate in surface waters range from 10 to 80 mg/L (CCREM, 1987). The high sulphate values documented at the majority of the sites indicate that the sampled waters are in close proximity to an ore body or are receiving waters for adit discharges.

Most of the waters sampled were clear. Lightning Creek below Thunder Gulch, Galena Creek upstream Flat Creek and several of the adits had turbid flows.

Metals in the dissolved state tend to be more bioavailable to aquatic life than other forms,

TABLE 4.1 DATA SORTED BY ASCENDING INDEX, AUGUST 2003

Station Name	Site #	Date	Temp °C	pH	Flow cms	SO4 mg/L	TSS mg/L	Alkalinity mg/L as CaCO3	Hardness mg/L as CaCO3	Cadmium-d mg/L	Copper-d mg/L	Iron-d mg/L	Lead-d mg/L	Selenium-t mg/L	Zinc-d mg/L	Zinc-t mg/L	Arsenic-t mg/L	Index
Galena u/s Flat Cr	29	Aug 23/03				222.0	60	164	392	<0.0006	0.002	0.037	<0.005	<0.02	0.002	0.020	<0.02	0
Silver King discharge 130 m d/s	41	Aug 23/03	6.0	6.78		421.0	20	92	533	<0.0006	<0.001	0.132	<0.005	<0.02	0.051	<0.001	<0.02	1
Lightning Cr u/s Hope Cr.	22	Aug.4/03	4.8	7.88	0.4237	26.6	<1	31	56	<0.0006	0.007	0.019	<0.005	<0.02	0.023	0.004	<0.02	1
Charity Gulch	36	Aug.4/03	1.8	8.22	0.0008	137.0	<1	41	160	<0.0006	0.008	<0.002	<0.005	<0.02	0.011	0.008	<0.02	1
Ditch u/s No Cash Cr	46	Aug 24/03	4.3	6.62		12.8	<5	64	101	<0.0006	0.003	0.164	<0.005	<0.02	0.011	0.011	<0.02	1
S. McQuesten 9 km d/s Flat Cr.	6	Aug.2/03	13.7	8.33	4.7276	64.6	<1	115	185	<0.0006	0.010	0.016	<0.005	<0.02	0.019	0.017	<0.02	1
Galena Cr u/s Silver King	12	Aug.3/03	6.0	7.9		58.4	<1	197	273	<0.0006	0.008	<0.002	<0.005	<0.02	0.019	0.018	<0.02	1
S. McQuesten d/s Flat Cr.	5	Aug.2/03	13.8	8.08		70.2	<1	113	184	<0.0006	0.010	0.007	<0.005	<0.02	0.021	0.025	<0.02	1
Flat Cr. @ Keno Hwy	10	Aug.3/03	2.6	7.66		59.6	<1	206	256	<0.0006	0.008	<0.002	<0.005	0.07	0.010	0.011	<0.02	2
Flat Cr. u/s Porcupine Ditch	26	Aug.3/03	4.5	8.32	0.0283	217.0	<1	203	380	<0.0006	0.010	<0.002	<0.005	0.06	0.021	0.014	<0.02	2
S. McQuesten u/s Flat Cr.	4	Aug.2/03	13.7	8.41	4.6117	69.6	<1	109	176	<0.0006	0.010	0.016	<0.005	0.04	0.020	0.022	<0.02	2
S. McQuesten @ pumphouse	3	Aug.2/03	14.3		4.7974	67.8	1	106	169	<0.0006	0.011	0.030	<0.005	0.08	0.021	0.025	<0.02	2
S. McQuesten u/s Christal Cr.	1	Aug.3/03	14.1	8.43	4.8718	65.7	<1	97	140	<0.0006	0.013	0.007	<0.005	0.08	0.020	0.026	<0.02	2
Christal Cr d/s Paddy Mine	34	Aug 24/03	5.0	8.07	0.4321	163.0	22	106	275	0.0013	0.001	0.038	<0.005	<0.02	0.281	0.321	<0.02	2
Lightning Cr. @ Keno Hwy	25	Aug.3/03	6.8	7.88	0.6414	40.9	52	43	83	<0.0006	0.009	0.068	<0.005	<0.02	0.019	0.582	<0.02	2
Tailings Decant	32	Aug.3/03	16.0	9.73	0.0014	252.0	2	47	283	<0.0006	0.011	0.005	0.010	0.09	0.012	0.009	<0.02	3
S. McQuesten d/s Christal Cr.	2	Aug.3/03	13.8	8.42		77.9	<1	99	163	<0.0006	0.012	0.011	<0.005	0.10	0.030	0.035	<0.02	3
Lightning Cr u/s Thunder Gulch	37	Aug.4/03	5.1	7.8	0.6514	38.6	<1	37	69	<0.0006	0.005	0.003	<0.005	<0.02	0.037	0.036	<0.02	3
Flat Cr. u/s S. McQuesten River	11	Aug.2/03	8.2	8.12	0.1092	201.0	2	197	384	<0.0006	0.010	<0.002	<0.005	<0.02	0.044	0.036	<0.02	3
Berminton Pit water	38	Aug.2/03	10.8	7.46		14.0	<1	8	24	0.0028	0.007	0.004	<0.005	<0.02	0.053	0.051	<0.02	3
Flat Cr u/s Galena Cr	35	Aug 23/03				195.0	<2	162	332	<0.0006	0.002	0.057	<0.005	0.07	0.056	0.057	<0.02	3
Galkeno 900 Decant	20	Aug.2/03	7.6	8.68	0.0027	1040.0	34	109	1421	<0.0006	0.009	0.010	<0.005	0.04	0.020	0.091	<0.02	3
Flat Cr d/s Galena Cr	31	Aug 23/03				197.0	29	166	347	<0.0006	0.002	0.041	<0.005	<0.02	0.036	0.112	0.03	3
Flat Cr. d/s Porcupine Ditch	30	Aug.3/03	6.3	8.31		406.0	<1	203	655	0.0016	0.010	<0.002	<0.005	<0.02	0.216	0.222	<0.02	3
No Cash Creek in wetland	44	Aug 24/03	4.2	7.48		317.0	28	129	399	0.0063	0.002	0.028	<0.005	<0.02	0.913	0.922	<0.02	3
No Cash Creek d/s Hwy Transect #1	42	Aug 24/03	3.6	8.05		290.0	4	104	348	0.0221	0.002	0.009	<0.005	<0.02	2.440	2.472	<0.02	3
No Cash 500 @ Hwy	19	Aug.3/03	5.2	7.88		377.0	<1	148	572	<0.0006	0.009	<0.002	<0.005	<0.02	2.99	3.14	<0.02	3
Galena Cr d/s Silver King	13	Aug.3/03	5.6	7.56	0.0006	197.0	<1	177	369	0.0012	0.009	<0.002	<0.005	0.03	0.146	0.140	<0.02	4
Porcupine Diversion	27	Aug.3/03	5.6	8.26	0.031	408.0	2	206	707	0.0024	0.010	<0.002	<0.005	0.03	0.252	0.248	<0.02	4
Christal Cr. @ mouth	9	Aug.3/03	8.2	8.38		290.0	<1	143	407	0.0012	0.009	<0.002	<0.005	0.03	0.259	0.256	<0.02	4
Christal Cr. @ Hanson Road	8	Aug.3/03	6.3	8.5	0.1657	292.0	<1	146	399	0.0006	0.010	<0.002	<0.005	0.11	0.298	0.312	<0.02	4
Hope Gulch	28	Aug.4/03	4.9	8.25	0.0295	77.0	<1	51	117	0.0043	0.007	<0.002	<0.005	<0.02	0.407	0.382	0.02	4
No Cash Creek u/s Ditch	45	Aug 24/03	6.2	7.77		261.0	28	120	360	0.0031	0.003	0.064	<0.005	<0.02	0.520	0.520	0.22	4
Silver King discharge Transect #2	40	Aug 23/03	6.1	7.29		426.0	34	97	470	0.0052	<0.001	<0.002	<0.005	<0.02	0.543	0.872	0.03	4
Christal Cr. @ Keno Hwy	7	Aug.2/03	9.9	8.09		467.0	98	132	601	0.0010	0.010	0.020	<0.005	0.06	0.774	0.900	<0.02	4
No Cash Creek d/s Hwy Transect #2	43	Aug 24/03	3.7	8.00		323.0	15	130	406	0.0151	0.002	0.003	<0.005	<0.02	1.640	1.662	0.02	4
Silver King discharge Transect #1	39	Aug 23/03		6.94		417.0	26	97	496	0.0056	<0.001	<0.002	<0.005	0.10	0.653	0.763	0.04	5
Silver King decant	14	Aug.3/03	4.2	6.79	0.0042	437.0	25	101	720	0.0089	0.009	2.695	<0.006	<0.02	0.777	0.873	<0.02	5
Husky SW Adit	15	Aug.1/03	4.4	7.5	0.0001	545.0	74	285	930	0.0177	0.010	0.008	<0.005	<0.02	1.727	1.911	0.10	5
Keno 700 Adit	23	Aug.2/03	0.8	7.84	0.0016	129.0	<1	185	285	0.0065	0.009	<0.002	<0.005	0.10	0.828	0.832	0.02	6
Ruby Adit	17	Aug.2/03	2.7	7.83	0.0007	128.0	10	133	259	0.0054	0.007	<0.002	<0.005	0.06	0.653	0.931	0.04	6
Berminton Adit	16	Aug.2/03	3.0	7.38	0.0005	50.4	<1	103	142	0.1628	0.008	0.003	<0.005	0.13	4.10	4.43	0.06	6
No Cash 500 Adit	18	Aug.2/03	1.7	7.81	0.0027	507.0	7	154	706	0.1009	0.010	<0.002	<0.005	0.08	12.87	13.11	0.03	6
Onek Adit	24	Aug.2/03	2.0	7.91	0.0003	542.0	155	206	634	0.8000	0.010	<0.002	0.033	<0.02	70.1	60.2	0.23	6
Husky Mine	33	Aug.1/03	14.0	2.83	0.0002	1150.0	24	<5	638	0.0675	0.664	89.1	0.109	0.10	7.72	7.52	0.24	8
Galkeno 300 Adit	21	Aug.2/03	3.2	6.61	0.0039	1110.0	45	37	315	0.0336	0.209	8.93	0.054	0.33	62.4	40.4	0.23	8
CCME Guideline for Freshwater Aquatic Life										0.0050	0.002	0.300	0.001	0.001	0.030	0.030	0.005	
Detection limit							1	5	1	0.0006	0.001	0.002	0.005	0.02	0.001	0.001	0.02	

Index : Number of times the sample exceeds the CCME Aquatic limit. Less than values were omitted even if the detection limit exceeds the guideline.

Sample exceeds the guideline

Guideline below the detection limit

dissolved cadmium, copper, iron, lead and zinc were tabulated. Norwest Labs of Surrey BC completed all the lab analyses and advised that dissolved selenium data tends to be unreliable (personal communication, Bill Warning, Oct 6, 2003) consequently total selenium values rather than dissolved selenium values were included. Total zinc and total arsenic were also included to provide for the samples with higher suspended solids that may contain precipitated metals.

The data were compared to the CCME (1999) guidelines for the protection of freshwater aquatic life. (Note that the guidelines do not distinguish between dissolved and total metals.) These guidelines tend to be quite restrictive and the detection limit for some of the parameters exceeded the recommended guideline. In these cases, it is not known whether that particular sample did or did not meet the guideline. The individual cells where the *reported* data exceeded the guideline are highlighted in yellow in the tables.

The data was then analyzed according to the CCME Water Quality Index. For each sample, the number of yellow cells was counted to give a number from 0 to 8. This value is displayed in the column labeled 'Index'. The sites with a high index value indicate that more guidelines were exceeded than sites with a low index. This approach does not differentiate between samples that barely exceed the guidelines and those that grossly exceed the guideline. Sites with a high index signify those that are more contaminated than sites with a low index.

In Table 4.1, the data has been sorted by index and displays the sites arranged from cleanest water (index of zero) to most contaminated water (index of eight). As expected, the adit drainage sites appear at the bottom of the table. The least contaminated sites, with an index from 0 to 2, were generally upstream sites and most of the South McQuesten River sites. Galena Creek upstream Flat Creek was the only site in the study area to have an index of zero. The tailings decant is also of fairly good quality with an index of 3. Note that zinc was not one of the guidelines exceeded in the tailings decant. Most of the Christal Creek sites had an index of 4 or 5. The exception to this was Christal Creek downstream of the Paddy Mine, which only had an index of 2. The most grossly contaminated sites where all of the metals guidelines were exceeded, were the Husky Mine and Galkeno 300 adit discharges.

Cadmium appears to be associated with high concentrations of zinc only. The recommended guideline for cadmium was exceeded at the adit sites.

Copper was ubiquitous throughout the study area and appeared to be a reflection of the geochemistry of the area. It was detected at most of the sites and ranged very little in concentration. The guideline was exceeded at all of the sites with the exception of Galena Creek upstream of Flat Creek, Flat Creek downstream of Galena Creek, Flat Creek upstream of Galena Creek, Christal Creek downstream of the Paddy Mine, in the Silver King drainage downstream of the adit and downstream on No Cash Creek below the highway. Generally concentrations of copper were low, just slightly exceeding the guideline in most cases. Higher copper levels were documented in the Husky Mine and Galkeno 300 discharges but concentrations were under 1 ppm.

The guideline for iron was met at all of the sites with the exception of the Silver King decant, Husky Mine and Galkeno 300 adit. These sites also contained obvious iron precipitates and red staining.

Lead was not detected at most of the sites, however the detection limit slightly exceeds the guideline so it is unknown whether the guideline was met at the non-detected sites. The guideline for lead was definitely exceeded at the tailings decant, Onek adit, Husky Mine and Galkeno 300 adit.

The detection limit for selenium exceeds the guideline. Selenium was detected, and therefore exceeded the limit at approximately half of the sites. The greatest concentration was documented at Onek adit (0.33 mg/L). It is suspected that the selenium guideline may be exceeded at several of the other sites as well. If selenium is deemed to be a metal of concern at the Keno Valley study area, selenium should be analyzed to ultra trace detection limits in future sampling programs. However, it should be recognized, that by the lab′s own admission, the generated selenium results are not entirely reliable. They have stated that the most reliable data that can be generated is the analysis for total selenium using the ICP-MS method. This method should be employed in all future samples if selenium is regarded as a metal of concern for the study area.

The guideline for zinc was generally exceeded at those sites where the index was 3 or greater.

The detection limit for arsenic exceeds the guideline. Arsenic was detected and thus exceeded the recommended guideline at the adits sites, at Flat Creek downstream of Galena Creek and at Hope Gulch.

To further interpret the data, the contaminants of concern were reduced to three; cadmium, copper and zinc. The data was ranked in ascending index and sites grouped per index value (Table 4.2). Each index value was colour coded. The colour was assigned to the site, which was then plotted on Figure 4.1. There are a few differences from this table and Table 4.1 when only three parameters are examined. There now are two sites with an index of zero (blue), the Silver King discharge at 130 m downstream and Galena Creek just upstream of Flat Creek. There are 15 sites with an index of one (green). These sites are located along the South McQuesten River, several sites on Flat Creek and the upstream section of Lightning Creek. Generally the guideline exceeded at these sites was copper. Twenty sites have an index of two (orange). These include most of the sites on Christal Creek and No Cash Creek, lower Lightning Creek and some sites in the Silver King / Galena Creek area. The Birmingham Pit and discharge from the settling pond at Galkeno 900 also had an index of two. The remaining 9 sites had an index of 3 (red) and all were adit discharges.

Zinc has generally been accepted as the contaminant of the most concern in the Keno Valley study area. Total zinc concentrations ranged from below the method detection limit of 0.001 ppm at 130 m d/s of the Silver King discharge to 60.2 ppm at Onek adit.

The sites have been examined with respect to their concentrations of zinc documented in August 2003. As indicated by the total suspended solids data, most of the waters sampled were clear. After comparing the total and dissolved zinc concentrations, it appears that the majority of zinc in the samples is in the dissolved state. However, some of the dissolved zinc values exceeded the total zinc values, especially in those samples with high concentrations of zinc. Both the lab and a water chemist (Gerry Whitley) have indicated that this typically occurs on occasion. With these issues in mind, total zinc values were used to generate Table 4.3 displaying the data sorted by ascending zinc concentrations. Note that the sites are not arranged in the same order as when they were sorted by ascending index. For example, the tailings decant has an index of 3 (Table 4.1) yet has the fourth lowest zinc concentration in the study area. To visually examine the data, the total zinc concentrations were grouped in five ranges, colour coded (Table 4.4) and plotted on Figure 4.2. Sites where the zinc concentration met the guideline for aquatic life (0.03 ppm) and the target guideline (0.5 ppm) were colour coded blue and green respectively. From the map it can easily be

Table 4.2 SAMPLE SITES RANKED ACCORDING TO INCREASING INDEX VALUES, AUGUST 2003

Station Name	Site #	Date	Cadmium-d mg/L	Copper-d mg/L	Zinc-t mg/L	Index
Silver King discharge 130 m d/s	41	Aug 23/03	<0.0006	<0.001	<0.001	0
Galena u/s Flat Cr	29	Aug 23/03	<0.0006	0.002	0.020	0
Lightning Cr u/s Hope Cr.	22	Aug.4/03	<0.0006	0.007	0.004	1
Charity Gulch	36	Aug.4/03	<0.0006	0.008	0.008	1
Tailings Decant	32	Aug.3/03	<0.0006	0.011	0.009	1
Ditch u/s No Cash Cr	46	Aug 24/03	<0.0006	0.003	0.011	1
Flat Cr. @ Keno Hwy	10	Aug.3/03	<0.0006	0.008	0.011	1
Flat Cr. u/s Porcupine Ditch	26	Aug.3/03	<0.0006	0.010	0.014	1
S. McQuesten 9 km ds Flat Cr.	6	Aug.2/03	<0.0006	0.010	0.017	1
Galena Cr u/s Silver King	12	Aug.3/03	<0.0006	0.008	0.018	1
S. McQuesten u/s Flat Cr.	4	Aug.2/03	<0.0006	0.010	0.022	1
S. McQuesten d/s Flat Cr.	5	Aug.2/03	<0.0006	0.010	0.025	1
S. McQuesten @ pumphouse	3	Aug.2/03	<0.0006	0.011	0.025	1
S. McQuesten u/s Christal Cr.	1	Aug.3/03	<0.0006	0.013	0.026	1
Flat Cr u/s Galena Cr	35	Aug 23/03	<0.0006	0.002	0.057	1
Flat Cr d/s Galena Cr	31	Aug 23/03	<0.0006	0.002	0.112	1
Christal Cr d/s Paddy Mine	34	Aug 24/03	0.0013	0.001	0.321	1
S. McQuesten d/s Christal Cr.	2	Aug.3/03	<0.0006	0.012	0.035	2
Lightning Cr u/s Thunder Gulch	37	Aug.4/03	<0.0006	0.005	0.036	2
Flat Cr. u/s S. McQuesten River	11	Aug.2/03	<0.0006	0.010	0.036	2
Berminton Pit water	38	Aug.2/03	0.0028	0.007	0.051	2
Galkeno 900 Decant	20	Aug.2/03	<0.0006	0.009	0.091	2
Galena Cr d/s Silver King	13	Aug.3/03	0.0012	0.009	0.140	2
Flat Cr. d/s Porcupine Ditch	30	Aug.3/03	0.0016	0.010	0.222	2
Porcupine Diversion	27	Aug.3/03	0.0024	0.010	0.248	2
Christal Cr. @ mouth	9	Aug.3/03	0.0012	0.009	0.256	2
Christal Cr. @ Hanson Road	8	Aug.3/03	0.0006	0.010	0.312	2
Hope Gulch	28	Aug.4/03	0.0043	0.007	0.382	2
No Cash Creek u/s Ditch	45	Aug 24/03	0.0031	0.003	0.520	2
Lightning Cr. @ Keno Hwy	25	Aug.3/03	<0.0006	0.009	0.582	2
Silver King discharge, Transect #1	39	Aug 23/03	0.0056	<0.001	0.763	2
Silver King discharge, Transect #2	40	Aug 23/03	0.0052	<0.001	0.872	2
Christal Cr. @ Keno Hwy	7	Aug.2/03	0.0010	0.010	0.900	2
No Cash Creek in wetland	44	Aug 24/03	0.0063	0.002	0.922	2
No Cash Creek d/s Hwy Transect #2	43	Aug 24/03	0.0151	0.002	1.662	2
No Cash Creek d/s Hwy Transect #1	42	Aug 24/03	0.0221	0.002	2.472	2
No Cash 500 @ Hwy	19	Aug.3/03	<0.0006	0.009	3.14	2
Keno 700 Adit	23	Aug.2/03	0.0065	0.009	0.832	3
Silver King decant	14	Aug.3/03	0.0089	0.009	0.873	3
Ruby Adit	17	Aug.2/03	0.0054	0.007	0.931	3
Husky SW Adit	15	Aug.1/03	0.0177	0.010	1.911	3
Berminton Adit	16	Aug.2/03	0.1628	0.008	4.43	3
Husky Mine	33	Aug.1/03	0.0675	0.664	7.52	3
No Cash 500 Adit	18	Aug.2/03	0.1009	0.010	13.11	3
Galkeno 300 Adit	21	Aug.2/03	0.0336	0.209	40.4	3
Onek Adit	24	Aug.2/03	0.8000	0.010	60.2	3
CCME Guideline for Freshwater Aquatic Life			0.0050	0.002	0.030	
Detection limit			0.0006	0.001	0.001	

Index: Number of times the sample exceeds the CCME Aquatic limit. Less than values were omitted even if the detection limit exceeds the guideline.

Sample exceeds the guideline

ABOUT THIS MAP

One way to interpret a large volume of water quality data is to create a water quality index. The index is based on the number of parameters that exceed the CCME recommended guideline for the protection of freshwater aquatic life (CCME, 1999) in a particular sample. For the purposes of this map, three metals were chosen; cadmium (dissolved), copper (dissolved) and zinc (total).

Sample sites were ranked with an index from 0 to 3 depending on the number of the three metals that exceeded the guideline. For example, a site with an index of 3 indicates that the applicable guideline for cadmium, copper and zinc were all exceeded. Note that the index does not differentiate between samples that barely exceed the guideline and those that grossly exceed the guideline. See Map #2 for detailed zinc ranking.

There were only two sites that had an index of 0; the discharge 130 m downstream from Silver King and the mouth of Galena Creek. The majority of the sites on the South McQuesten River and Flat Creek had an index of 1. Most drainages below adits and on Christal Creek had an index of 2. All of the adit discharges had an index of 3.

Legend

- Index of 0
- Index of 1
- Index of 2
- Index of 3
- Watercourse
- Topographical Contours
- Main Road
- Dirt Road
- Trails
- Open Pit
- Waste Rock Dump
- Tailings
- Lake

0 1 2 4 6 km

1:40,000

Figure 4.1
Sample Sites Ranked According to Index, August 2003

Drawn by: PI Checked by: RLM

Date: April 22, 2003

Our File: D:\Project\NND-03-02\GIS\mxd\Laberge_4-1.mxd

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Table 4.4 SAMPLE SITES RANKED ACCORDING TO INCREASING ZINC CONCENTRATIONS (mg/L), AUGUST 2003

Station Name	Site #	Zinc-t mg/L	Colour Description
Silver King discharge 130 m d/s	41	<0.001	Meets CCME guideline of 0.030 mg/L
Lightning Cr us Hope Cr.	22	0.004	
Charity Gulch	36	0.008	
Tailings Decant	32	0.009	
Ditch u/s No Cash Cr	46	0.011	
Flat Cr. @ Keno Hwy	10	0.011	
Flat Cr. u/s Porcupine Ditch	26	0.014	
S. McQuesten 9 km d/s Flat Cr.	6	0.017	
Galena Cr u/s Silver King	12	0.018	
Galena u/s Flat Cr	29	0.020	
S. McQuesten u/s Flat Cr.	4	0.022	
S. McQuesten d/s Flat Cr.	5	0.025	
S. McQuesten @ pumphouse	3	0.025	
S. McQuesten u/s Christal Cr.	1	0.026	
S. McQuesten ds Christal Cr.	2	0.035	Meets target level of 0.50 mg/L
Lightning Cr u/s Thunder Gulch	37	0.036	
Flat Cr. u/s S. McQuesten River	11	0.036	
Berminton Pit water	38	0.051	
Flat Cr u/s Galena Cr	35	0.057	
Galkeno 900 Decant	21	0.091	
Flat Cr d/s Galena Cr	31	0.112	
Galena Cr d/s Silver King	13	0.140	
Flat Cr. d/s Porcupine Ditch	30	0.222	
Porcupine Diversion	27	0.248	
Christal Cr. @ mouth	9	0.256	
Christal Cr. @ Hanson Road	8	0.312	
Christal Cr d/s Paddy Mine	34	0.321	
Hope Gulch	28	0.382	
No Cash Creek u/s Ditch	45	0.520	Slightly exceeds target level
Lightning Cr. @ Keno Hwy	25	0.582	
Silver King discharge Transect #1	39	0.763	
Keno 700 Adit	23	0.832	
Silver King discharge Transect #2	40	0.872	
Silver King decant	14	0.873	
Christal Cr. @ Keno Hwy	7	0.900	
No Cash Creek in wetland	44	0.922	
Ruby Adit	17	0.931	
Husky SW Adit	15	1.911	Significantly exceeds target level
No Cash Creek d/s Hwy Transect #2	43	1.662	
No Cash Creek d/s Hwy Transect #1	42	2.472	
No Cash 500 @ Hwy	19	3.14	
Berminton Adit	16	4.43	
Husky Mine	33	7.52	
No Cash 500 Adit	18	13.11	Grossly exceeds target level
Galkeno 300 Adit	21	40.4	
Onek Adit	24	60.2	

Figure 4.2
Zinc levels in the discharges and receiving waters
Keno Valley
August 2003

Drawn by: PI Checked by: RLM

Date: April 22, 2003

Our File: D:\Project\NND-03-02\GIS\mxd\Laberge_4-2.mxd

Legend

- Zinc concentration meets CCME guidelines of 0.030 mg/L (<0.001 to 0.030mg/L)
- Zinc concentration meets the target level of 0.500 mg/L (0.030 to 0.500mg/L)
- Zinc concentration slightly exceeds the target level (0.510 to 0.990mg/L)
- Zinc concentration significantly exceeds the target level (1.000 to 10.0mg/L)
- Zinc concentration grossly exceeds the target level (>10.0mg/L)

Watercourse
Topographical Contours
Main Road
Dirt Road
Trails

Open Pit
Waste Rock Dump
Tailings
Lake

0 1 2 4 6 km

1:40,000

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seen that the South McQuesten River sites are blue and the sites on Christal Creek and Flat Creek are green. So, although there were inputs that moderately (pink) and grossly (red) exceeded these guidelines, the receiving waters had very low concentrations of zinc.

4.1.1 Effluent Discharge Data

Most mining in the study area has taken place on the north slopes of Galena Hill and Keno Hill. Elevated levels of zinc, manganese and occasionally cadmium are common in the drainages from many of these workings. Due to the high costs of ore transportation from the Keno Valley district, most mining operations in the early days selected the richest ore for shipment. Consequently, large amounts of mineralized waste rock were deposited near portals and open pits. Elevated metal concentrations near these areas may also be a result of leaching of the mineralized waste rock.

Effluent and drainage data from several of the adits and tailings ponds have been summarized in Table 4.5. The highest concentrations of metals in the study area were found at most of these sites.

In attempts to determine which drainages had the potential to create the most adverse impacts on the receiving environment, zinc loading calculations were performed (Table 4.6). Loadings ranged from 0.0005 kg of zinc per day at Charity Gulch to almost 14 kg of zinc per day at Galkeno 300. Similar loadings were grouped and are displayed in Figure 4.3 as various sized circles.

The largest circles tend to be located on Galena Hill. Although Husky Mine had one of the highest zinc concentrations, 7.5 mg/L, due to the low discharge the loading was relatively minor. Onek Adit had one of the lowest discharges measured, however it also contained the highest concentration of zinc in the study area, 60.2 mg/L. This resulted in a fairly high loading, however it was almost ten times lower than the loading from Galkeno 300.

Table 4.5 SUMMARIZED DATA FOR ADITS AND DECANTS, AUGUST 2003

Station name	Site #	Date	Temp °C	pH	Flow cms	SO4 mg/L	TSS mg/L	Alkalinity mg/L as CaCO3	Hardness mg/L as CaCO3	Cadmium-d mg/L	Copper-d mg/L	Iron-d mg/L	Lead-d mg/L	Selenium-t mg/L	Zinc-d mg/L	Zinc-t mg/L	Arsenic-t mg/L	Index
Galena Hill discharges:																		
Berminton Adit	16	Aug.2/03	3.0	7.38	0.0005	50.4	<1	103	142	0.1628	0.008	0.003	<0.005	0.13	4.10	4.43	0.06	6
Berminton Pit water	38	Aug.2/03	10.8	7.46		14.0	<1	8	24	0.0028	0.007	0.004	<0.005	<0.02	0.053	0.051	<0.02	3
Ruby Adit	17	Aug.2/03	2.7	7.83	0.0007	128.0	10	133	259	0.0054	0.007	<0.002	<0.005	0.06	0.653	0.931	0.04	6
No Cash 500 Adit	18	Aug.2/03	1.7	7.81		507.0	7	154	706	0.1009	0.010	<0.002	<0.005	0.08	12.87	13.11	0.03	6
Galkeno 300 Adit	21	Aug.2/03	3.2	6.61	0.0039	1110.0	45	37	315	0.0336	0.209	8.93	0.054	0.33	62.4	40.4	0.23	8
Galkeno 900 Decant	20	Aug.2/03	7.6	8.68	0.0027	1040.0	34	109	1421	<0.0006	0.009	0.010	<0.005	0.04	0.020	0.091	<0.02	3
Keno Hill discharges:																		
S. McQuesten Watershed																		
Onek Adit	24	Aug.2/03	2.0	7.91	0.0003	542.0	155	206	634	0.8000	0.010	<0.002	0.033	<0.02	70.1	60.2	0.23	6
Duncan Creek Watershed																		
Keno 700 Adit	23	Aug.2/03	0.8	7.84	0.0016	129.0	<1	185	285	0.0065	0.009	<0.002	<0.005	0.10	0.828	0.832	0.02	6
Hope Gulch	28	Aug.4/03	4.9	8.25	0.0295	77.0	<1	51	117	0.0043	0.007	<0.002	<0.005	<0.02	0.407	0.382	0.02	4
Charity Gulch	36	Aug.4/03	1.8	8.22	0.0008	137.0	<1	41	160	<0.0006	0.008	<0.002	<0.005	<0.02	0.011	0.008	<0.02	1
Southwest of Elsa:																		
Silver King decant	14	Aug.3/03	4.2	6.79	0.0042	437.0	25	101	720	0.0089	0.009	2.695	<0.006	<0.02	0.777	0.873	<0.02	5
Husky Mine	33	Aug.1/03	14.0	2.83	0.0002	1150.0	24	<5	638	0.0675	0.664	89.1	0.109	0.10	7.72	7.52	0.24	8
Husky SW Adit	15	Aug.1/03	4.4	7.5	0.0001	545.0	74	285	930	0.0177	0.010	0.008	<0.005	<0.02	1.727	1.911	0.10	5
Tailings Pond Area:																		
Ditch u/s No Cash Cr	46	Aug 24/03	4.3	6.62		12.8	<5	64	101	<0.0006	0.003	0.164	<0.005	<0.02	0.011	0.011	<0.02	1
Tailings Decant	32	Aug.3/03	16.0	9.73	0.0014	252.0	2	47	283	<0.0006	0.011	0.005	0.010	0.09	0.012	0.009	<0.02	3
Porcupine Diversion	27	Aug.3/03	5.6	8.26	0.031	408.0	2	206	707	0.0024	0.010	<0.002	<0.005	0.03	0.252	0.248	<0.02	4
CCME Guideline for Freshwater Aquatic Life										0.0050	0.002	0.300	0.001	0.001	0.030	0.030	0.005	
Detection limit							1	5	1	0.001	0.002	0.005	0.02	0.001	0.001	0.02		

Index: Number of times the sample exceeds the CCME Aquatic limit. Less than values were omitted even if the detection limit exceeds the guideline.

Sample exceeds the guideline

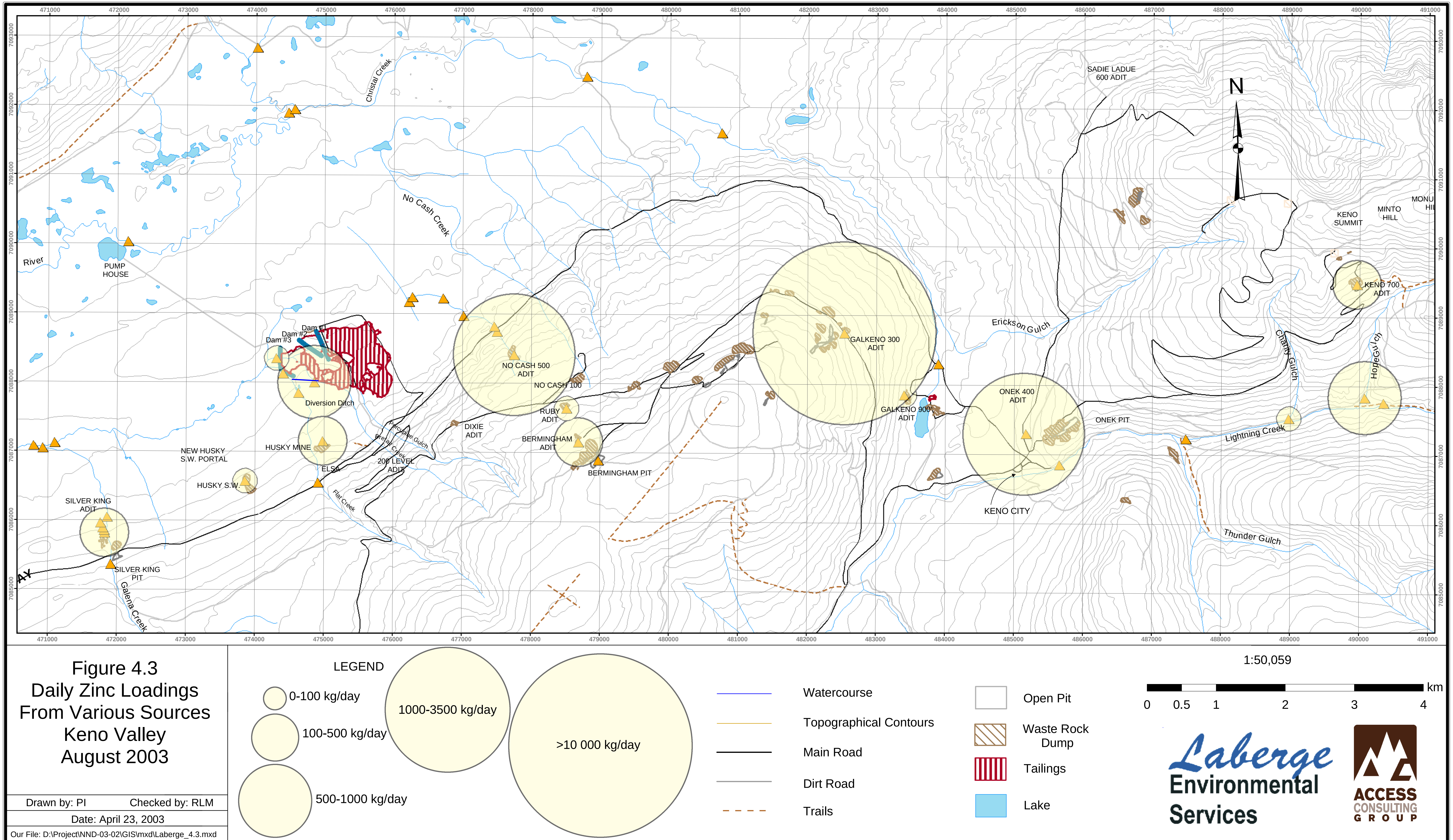


Figure 4.3
Daily Zinc Loadings
From Various Sources
Keno Valley
August 2003

Drawn by: PI Checked by: RLM
Date: April 23, 2003
Our File: D:\Project\NND-03-02\GIS\mxd\Laberge_4.3.mxd

Table 4.6 ZINC LOADINGS (kg/day) FROM VARIOUS SOURCES, AUGUST 2003

Station Name	Site #	Date	Flow cms	Zinc-t mg/L	Index	Loading kg/day
Charity Gulch	36	Aug.4/03	0.0008	0.008	1	0.0005
Tailings Decant	32	Aug.3/03	0.0014	0.009	3	0.001
Husky SW Adit	15	Aug.1/03	0.0001	1.911	5	0.02
Galkeno 900 Decant	20	Aug.2/03	0.0027	0.091	3	0.02
Ruby Adit	17	Aug.2/03	0.0007	0.931	6	0.06
Keno 700 Adit	23	Aug.2/03	0.0016	0.832	6	0.12
Husky Mine	33	Aug.1/03	0.0002	7.52	8	0.13
Berminton Adit	16	Aug.2/03	0.0005	4.43	6	0.19
Silver King decant	14	Aug.3/03	0.0042	0.873	5	0.32
Porcupine Diversion	27	Aug.3/03	0.031	0.248	4	0.66
Hope Gulch	28	Aug.4/03	0.0295	0.382	4	0.97
Onek Adit	24	Aug.2/03	0.0003	60.2	6	1.6
No Cash 500 Adit	18	Aug.2/03	0.0027	13.11	6	3.1
Galkeno 300 Adit	21	Aug.2/03	0.0039	40.4	8	13.6
Sample exceeds the guideline						

4.1.2 Receiving Water Data

For the majority of the flows and inputs, the South McQuesten River is the ultimate receiving water. Two main tributaries, Christal Creek and Flat Creek, receive contaminated water from various sources in the Keno Valley. Lightning Creek receives inputs from the south side of Keno Hill and the north facing slope of Sourdough Hill. Lightning Creek flows into Duncan Creek, a tributary of the Mayo River. Both the McQuesten and Mayo Rivers drain into the Stewart River.

4.1.2.1 South McQuesten River

The South McQuesten River′s headwaters originate in McQuesten Lake. The uppermost site on the South McQuesten River was established approximately 2 km upstream of the mouth of Christal Creek. Five additional sites were sampled along the South McQuesten River spanning a total distance of approximately 31 km. Summarized August 2003 data is presented in Table 4.7.

Although Christal Creek and Flat Creek enter the South McQuesten River, the measured discharge remains relatively constant at the six sites measured. This may indicate that portions of the South McQuesten River are exfluent (flowing in and below the substrate).

Table 4.7 SUMMARIZED DATA FOR THE SOUTH MCQUESTEN RIVER, AUGUST 2003

	S. McQuesten u/s Christal Cr	S. McQuesten d/s Christal Cr	S. McQuesten @ pumphouse	S. McQuesten u/s Flat Cr.	S. McQuesten d/s Flat Cr.	S. McQuesten 9 km d/s Flat Cr.	CCME Guideline	Detection limit
Site #	1	2	3	4	5	6		
Date	Aug.3/03	Aug.3/03	Aug.2/03	Aug.2/03	Aug.2/03	Aug.2/03		
Temp °C	14.1	13.8	14.3	13.7	13.8	13.7		
pH	8.43	8.42		8.41	8.08	8.33		
Flow cms	4.8718		4.7974	4.6117		4.7276		
Cadmium-d	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0050	0.0006
Copper-d	0.013	0.012	0.011	0.010	0.010	0.010	0.002	0.001
Iron-d	0.007	0.011	0.030	0.016	0.007	0.016	0.300	0.002
Lead-d	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.001	0.005
Selenium-t	0.08	0.10	0.08	0.04	<0.02	<0.02	0.001	0.02
Arsenic-t	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.005	0.001
Zinc-d	0.020	0.030	0.021	0.020	0.021	0.019	0.030	0.02
Zinc-t	0.026	0.035	0.025	0.022	0.025	0.017	0.030	0.001
SO4	65.7	77.9	67.8	69.6	70.2	64.6		
TSS	<1	<1	1	<1	<1	<1		
Alkalinity	97	99	106	109	113	115		
Hardness	140	163	169	176	184	185		
Index	2	3	2	2	1	1		

NOTE: The CCME guideline refers to the guidelines for freshwater aquatic life (CCME, 1999).
Index: Number of times the sample exceeds the CCME Aquatic limit.
Less than values were omitted even if the detection limit exceeds the guideline.
Sample exceeds the guideline

The clear, slightly alkaline waters were moderately hard. Cadmium, lead and arsenic were not detected in the South McQuesten River. Selenium was detected only at the upstream sites. There was a slight increase in zinc downstream of the confluence with Christal Creek. Zinc levels remained relatively consistent from the pumphouse to 9 km downstream of Flat Creek and were very similar in concentration, and often lower, than the levels documented at the background upstream site.

Sulphate levels were fairly consistent throughout the watershed. The index at the background and upstream sites was two, and three just below Christal Creek. Downstream of all inputs, the water quality of the South McQuesten River had actually improved and had an index of one.

Based on the August 2003 data set, there appeared to be a slight impact on the South McQuesten River from Christal Creek but no observable impact from Flat Creek. There appeared to be no overall impact on the South McQuesten River as evidenced by the good quality water documented at the downstream sites (overall better quality than the background unaffected upstream site).

Low flow samples were collected from two sites on the South McQuesten River in February and March of 2004. These samples represent results of an impact study assessing the fugitive flow from Galkeno 300 (see separate report prepared by Access Consulting Group) and would not reflect typical low flow geochemistry of the South McQuesten River downstream of Christal Creek. Summarized data is presented below in Table 4.8. The analytical data is included in Appendix B.

The fugitive flow from Galkeno 300 is impacting the South McQuesten River via Christal Creek. The zinc concentrations documented at the pumphouse are an order of magnitude greater than those reported upstream of Christal Creek. These data may not be representative of the receiving water conditions after treatment was initiated due to a lag time effect.

Table 4.8 South McQuesten River Low Flow Data, 2004

Parameter and Date (2004)		S. McQuesten R u/s Christal Creek	S. McQuesten River at Pumphouse
Flow (cms)	Feb 19 March 23	1.45 0.44	1.49 0.43
Conductivity (field) (uS/cm)	Feb 19 March 23	389 406	421 433
Cadmium (mg/L) (dissolved)	Feb 19 March 23	<0.0006 0.0022	<0.0006 <0.0006
Copper (mg/L) (dissolved)	Feb 19 March 23	<0.001 0.003	<0.001 <0.001
Iron (mg/L) (dissolved)	Feb 19 March 23	0.038 0.033	0.010 0.047
Lead (mg/L) (dissolved)	Feb 19 March 23	0.044 0.032	0.044 <0.01
Zinc (mg/L) (dissolved)	Feb 19 March 23	0.013 0.026	0.139 0.204
Zinc (mg/L) (total)	Feb 19 March 23	0.013 0.027	0.142 0.206

4.1.2.2 Christal Creek

Christal Creek flows northwest from Christal Lake for approximately 13 km and empties into the South McQuesten River. Christal Creek receives metal laden inputs from Galkeno 900 (lime treated), Galkeno 300 (lime treatment commenced in March 2004) and seepages (surface and groundwater) from workings on the west face of Keno Hill. Christal Lake, a long term receptor for tailings and wastewater from Galkeno 900 and Mackeno, would contribute to loading as well.

Four sites were established on Christal Creek; just downstream of the Keno Highway, downstream of the Paddy Mine, 100 m upstream of the Hanson Lake Road, and at the mouth. Selected parameters from the August 2003 data set have been summarized in Table 4.9.

The site downstream of the Paddy Mine was sampled three weeks following the sampling of the other sites. Christal Creek was recovering from a rain event and a much higher flow was measured here at that time.

TABLE 4.9 SUMMARIZED DATA FOR CHRISTAL CREEK, AUGUST 2003

	Christal Cr. @ Keno Hwy	Christal Cr d/s Paddy Mine	Christal Cr. @ Hanson Rd	Christal Cr. @ mouth	CCME Guideline	Detection limit
Site #	7	34	8	9		
Date	Aug.2/03	Aug 24/03	Aug.3/03	Aug.3/03		
Temp °C	9.9	5.0	6.3	8.2		
pH	8.09	8.07	8.5	8.38		
Flow cms		0.4321	0.1657			
Cadmium-d	0.0010	0.0013	0.0006	0.0012	0.0050	0.0006
Copper-d	0.010	0.001	0.010	0.009	0.002	0.001
Iron-d	0.020	0.038	<0.002	<0.002	0.300	0.002
Lead-d	<0.005	<0.005	<0.005	<0.005	0.001	0.005
Selenium-t	0.06	<0.02	0.11	0.03	0.001	0.02
Arsenic-t	<0.02	<0.02	<0.02	<0.02	0.005	0.02
Zinc-d	0.774	0.281	0.298	0.259	0.030	0.001
Zinc-t	0.900	0.321	0.312	0.256	0.030	0.001
SO4	467.0	163.0	292.0	290.0		
TSS	98	22	<1	<1		1
Alkalinity	132	106	146	143		5
Hardness	601	275	399	407		1
Index	4	2	4	4		

NOTE: The CCME guideline refers to the guidelines for freshwater aquatic life (CCME, 1999).
Index: Number of times the sample exceeds the CCME Aquatic limit.
Less than values were omitted even if the detection limit exceeds the guideline.
Sample exceeds the guideline

The slightly alkaline waters of Christal Creek were clear and very hard. Cadmium and iron met the respective recommended guidelines. Selenium was detected at most of the sites. Zinc exceeded the guideline at all sites, decreasing in concentration progressively downstream. Although the aquatic life guideline was exceeded at all sites, the working target guideline of 0.5 mg/L was met throughout Christal Creek with the exception of the site located just below the Keno Highway (refer to Figure 4.2).

Sulphate levels were high at the upstream site, decreased considerably near the Paddy Mine (which was sampled 3 weeks later and may be due to dilution from rain), increased by the Hanson Road Crossing and remained consistent to the mouth.

All sites on Christal Creek had an index of 4, indicating water of questionable quality, except near the Paddy Mine where an index of 2 was reported.

Low flow samples were collected from Christal Creek in February and March of 2004. These samples represent results of an impact study assessing the fugitive flow from Galkeno 300 (see separate report prepared by Access Consulting Group) and would not reflect typical low flow geochemistry of the Christal Creek system. Summarized data is presented below in Table 4.10. The analytical data is included in Appendix B.

Table 4.10 Christal Creek Low Flow Data, 2004

Parameter and Date (2004)		Christal Creek u/s of the Hanson Lake Road	Christal Creek at the mouth
Flow (cms)	Feb 19 March 23	0.18 0.15	
Conductivity (field) (uS/cm)	Feb 19 March 23	714 726	
Cadmium (mg/L) (dissolved)	Feb 19 March	<0.0006 0.0044	 0.0033
Copper (mg/L) (dissolved)	Feb 19 March	<0.001 0.003	 0.007
Iron (mg/L) (dissolved)	Feb 19 March	<0.002 <0.002	 <0.002
Lead (mg/L) (dissolved)	Feb 19 March	0.033 0.011	 <0.01
Zinc (mg/L) (dissolved)	Feb 19 March	2.10 2.53	 1.89
Zinc (mg/L) (total)	Feb 19 March	2.14 2.56	 1.91

Christal Creek was impacted by the fugitive discharge from Galkeno 300 in February and March. Zinc concentrations at both sites were almost a magnitude greater than concentrations reported at these sites during the August 2003 survey. Lead was not detected in the Christal watershed during August 2003 but elevated levels were reported upstream of the Hanson Lake Road crossing in February and March 2004.

4.1.2.3 Flat Creek

Flat Creek originates on Galena Hill and flows north downslope to the broad valley below the tailings impoundment. It then flows westward 5 km through a sedge / horsetail wetland with black spruce and willows dominating the shrub/tree community (Laberge Environmental Services, 1994). The remainder of Flat Creek flows northwest mainly through mature forest to its confluence with the South McQuesten River.

Flat Creek is the receiving water for mine effluent from the tailings facility and indirectly, from some of the adit discharges on Galena Hill. Past records indicate that the tailings pond washed out during spring freshet in 1961 and a dam breach occurred in 1978 (Access Mining Consultants, 1996). This would have resulted in tailings disposition within Flat Creek.

Six sites were sampled on Flat Creek from upstream of the Keno Highway to the mouth at the South McQuesten River. The sites upstream and downstream of the confluence with Galena Creek were sampled three weeks after the other sites. Summarized August 2003 data are presented in Table 4.11.

The very hard waters of Flat Creek were near neutral to slightly alkaline. Cadmium, lead and arsenic were not detected in Flat Creek. The guideline for copper was exceeded at all the sites except near Galena Creek. Selenium was detected in the upstream sites. Zinc concentrations increased in Flat Creek by an order of magnitude downstream of the confluence with the Porcupine Ditch. Zinc levels decreased considerably from here to just above the confluence of Galena Creek. This reach of Flat Creek flows through the aforementioned wetland, which may be contributing to metal removal. Zinc levels did increase downstream of Galena Creek, but this appears to be due to the suspended solids in the water column. The dissolved zinc concentration decreased downstream of Galena Creek where it slightly exceeded the recommended guideline. Zinc levels in Galena Creek were below the guideline. The CCME guideline for zinc was met at the two upstream sites on Flat Creek only. All sites however, met the working target guideline of 0.5 ppm.

Sulphate levels also markedly increased from the influence of the Porcupine Ditch. Sulphate concentrations leveled off near Galena Creek and remained consistent to the mouth.

Table 4.11 SUMMARIZED DATA FOR FLAT CREEK, AUGUST 2003

	Flat Cr. @ Keno Hwy	Flat Cr u/s Porcupine Ditch	Flat Cr d/s Porcupine Ditch	Flat Cr u/s Galena Cr	Flat Cr d/s Galena Cr	Flat Cr u/s S. McQuesten R	CCME Guideline	Detection limit
Site #	10	26	30	35	31	11		
Date	Aug.3/03	Aug.3/03	Aug.3/03	Aug 23/03	Aug 23/03	Aug.2/03		
Temp °C	2.6	4.5	6.3			8.2		
pH	7.66	8.32	8.31			8.12		
Flow cms		0.0283				0.1092		
Cadmium-d	<0.0006	<0.0006	0.0016	<0.0006	<0.0006	<0.0006	0.0050	0.0006
Copper-d	0.008	0.010	0.010	0.002	0.002	0.010	0.002	0.001
Iron-d	<0.002	<0.002	<0.002	0.057	0.041	<0.002	0.300	0.002
Lead-d	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.001	0.005
Selenium-t	0.07	0.06	<0.02	0.07	<0.02	<0.02	0.001	0.02
Arsenic-t	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	0.005	0.02
Zinc-d	0.010	0.021	0.216	0.056	0.036	0.044	0.030	0.001
Zinc-t	0.011	0.014	0.222	0.057	0.112	0.036	0.030	0.001
SO4	59.6	217.0	406.0	195.0	197.0	201.0		
TSS	<1	<1	<1	<2	29	2		1
Alkalinity	206	203	203	162	166	197		5
Hardness	256	380	655	332	347	384		1
Index	2	2	3	2	2	3		

NOTE: The CCME guideline refers to the guidelines for freshwater aquatic life (CCME, 1999).
Index: Number of times the sample exceeds the CCME Aquatic limit.
Less than values were omitted even if the detection limit exceeds the guideline.
Sample exceeds the guideline

Flat Creek was generally clear but initially became turbid after the confluence with Galena Creek. The sites on Flat Creek had an index of 2 or 3 indicating relatively good water quality.

4.1.2.4 Lightning Creek

Lightning Creek is situated in a steep sided valley. Three sites on Lightning Creek were sampled spanning a distance of approximately 5 km, from upstream of Hope Gulch to just upstream of the bridge at Keno City. Mine adit drainages from Keno 700 and the Onek decline portal located on the south side of Keno Hill, and Bellekeno 600 on the north side of Sourdough Hill, eventually report to Lightning Creek. The water chemistry in Thunder Gulch, a main tributary, is dominated by placer mining activity, creating a large impact on Lightning Creek. Contributions of metals from Bellekeno 600 to Lightning Creek via Thunder Gulch are negligible. There is no direct discharge to the receiving environment from the treatment ponds, however a small seep has been documented on the slope below the ponds, which flows into Thunder Gulch. It has not been determined whether the source of the seep is the treatment pond. The seep has been regularly monitored in 2003 and contains zinc concentrations of 1 to 2 ppm. No discernable impacts have been documented in downstream sampling (Travis Ritchie, personal communication).

Summarized August 2003 data are presented in Table 4.12. The waters of Lightning Creek were soft with low alkalinity indicating a low buffering capacity of the creek. Sulphate levels reflect natural concentrations. Cadmium, lead, selenium and arsenic were not detected in Lightning Creek. Copper slightly exceed the guideline at all sites. Zinc concentrations increased downstream of Hope Gulch. Hope Gulch, with a documented concentration of 0.407 ppm (refer to Table 4.3), contributed to the zinc levels in Lightning Creek. The zinc levels in Lightning Creek by Keno City were mostly in the suspended state. Total zinc exceeded the guideline whereas dissolved zinc met the guideline. Placer operations on Thunder Gulch were active during the August sampling, significantly contributing to the sediment load in Lightning Creek.

The loadings from the old UKHM sites to Lightning Creek can be considered marginal compared with the sediment and metals loadings from placer activities.

Table 4.12 SUMMARIZED DATA FOR LIGHTNING CREEK, AUGUST 2003

	Lightning Cr u/s Hope Cr.	Lightning Cr u/s Thunder Gulch	Lightning Cr. @ Keno Hwy	CCME Guideline	Detection Limit
Site #	22	37	25		
Date	Aug.4/03	Aug.4/03	Aug.3/03		
Temp °C	4.8	5.1	6.8		
pH	7.88	7.8	7.88		
Flow cms	0.4237	0.6514	0.6414		
Cadmium-d	<0.0006	<0.0006	<0.0006	0.0050	0.0006
Copper-d	0.007	0.005	0.009	0.002	0.001
Iron-d	0.019	0.003	0.068	0.300	0.002
Lead-d	<0.005	<0.005	<0.005	0.001	0.005
Selenium-t	<0.02	<0.02	<0.02	0.001	0.02
Arsenic-t	<0.02	<0.02	<0.02	0.005	0.02
Zinc-d	0.023	0.037	0.019	0.030	0.001
Zinc-t	0.004	0.036	0.582	0.030	0.001
SO4	26.6	38.6	40.9		
TSS	<1	<1	52		1
Alkalinity	31	37	43		5
Hardness	56	69	83		1
Index	1	3	2		

NOTE: The CCME guideline refers to the guidelines for freshwater aquatic life (CCME, 1999).
Index: Number of times the sample exceeds the CCME Aquatic limit.
Less than values were omitted even if the detection limit exceeds the guideline.
Sample exceeds the guideline

4.2 Hydrology

The study area streams usually present peak flow in June and low flow in March or April. Significant flood events occur due to rainstorms in the summer and/or fall. Mining companies, government agencies and consultants have collected stream flow data sporadically over the years. Stream flow variation and extreme event forecasts were most recently compiled by Access Mining Consultants Ltd for the UKHM water licence application in 1997. At that time, a form of regional analysis was done, augmented with various partial records and instantaneous discharge measurements. The results were reproduced in *The Keno Valley / Dublin Gulch Environmental Baseline Assessment*, by Environmental Services, Public Works and Government Services, March 2000. By comparing Water Survey of Canada median elevations and mean annual runoff (MAR), a correlation was established for the Keno Valley area. Seasonal runoff distribution was predicted for several sub basins in the study area. The results compared favourably with the instantaneous discharge measurements.

In the current study, discharge measurements were made at the majority of the water quality stations. At sites where water level gauges existed, these were surveyed relative to assumed datums so that rating curves may be re-established for these sites in the future.

Results of instantaneous discharge measurements are included in Table 4.1 with the water quality data. Basin characteristics are presented in Table 4.13.

Table 4.13 Basin Characteristics for the Gauged Sites

Station	Drainage Area (km^2)	Median Elevation (m)	MAR (mm)
Christal Cr @ Keno Hwy	7.7	990	240
Christal Cr @ Hanson L. Rd	43.5	870	230
Lightning @ Keno City			
Lightning Cr u/s Hope Gulch			
Porcupine Diversion	3.7	1200	900
Flat Cr u/s S. McQuesten R	31.2	700	170
MAR = mean annual runoff			

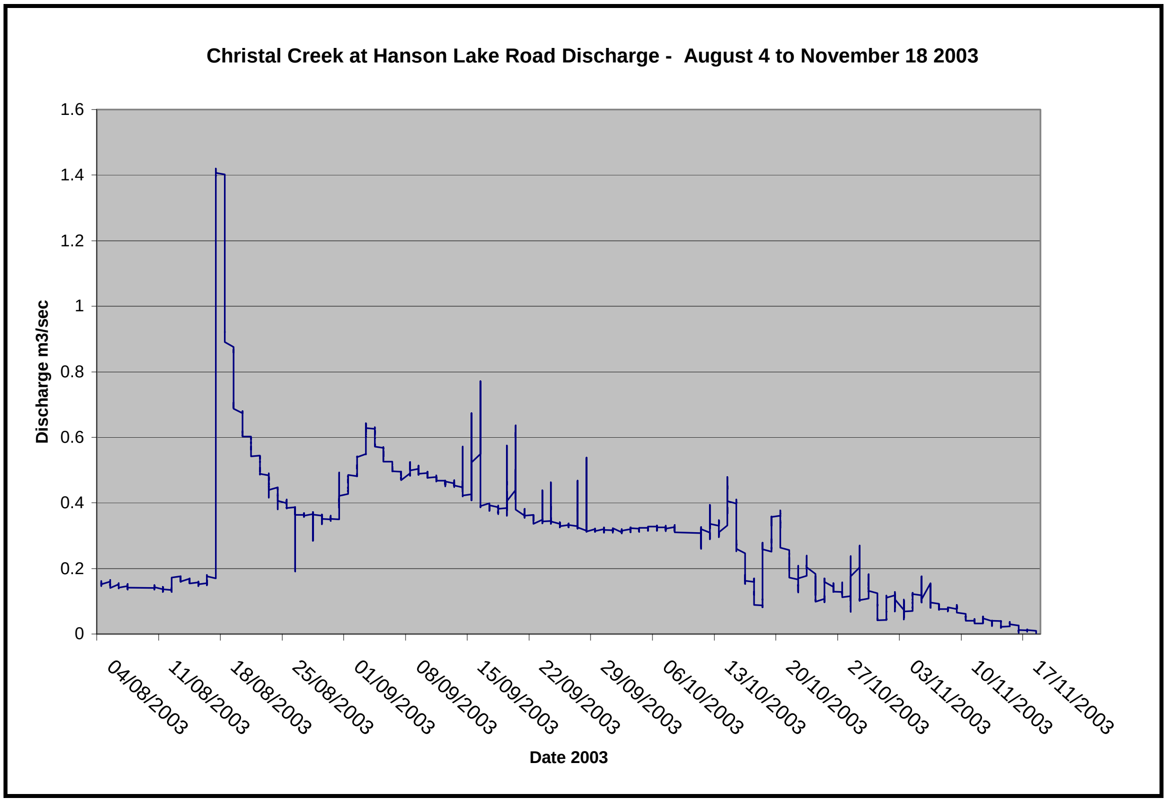
A brief discussion of the gauge sites follows. Photographs of the sites are included in Appendix C.

4.2.1 Christal Creek upstream Hanson Lake Road

The staff gauge was found to be in good condition in 2003, and was surveyed relative to bench marks. The recorder shelter was in poor condition. Christal Creek at the Hanson Lake road crossing is the only site with a continuous stage record. A Chart Pac data logger and PS9000 pressure transducer were installed in early August and operated until November 18th, 2003 when it failed due to a power supply fault. Flow variation over the period of record is illustrated in the hydrograph (Figure 4.4). Christal Creek experienced a rainfall event flood around the 18th of August, 2003, when the creek overtopped its banks and presented a discharge of about 1.4 m^3/sec.

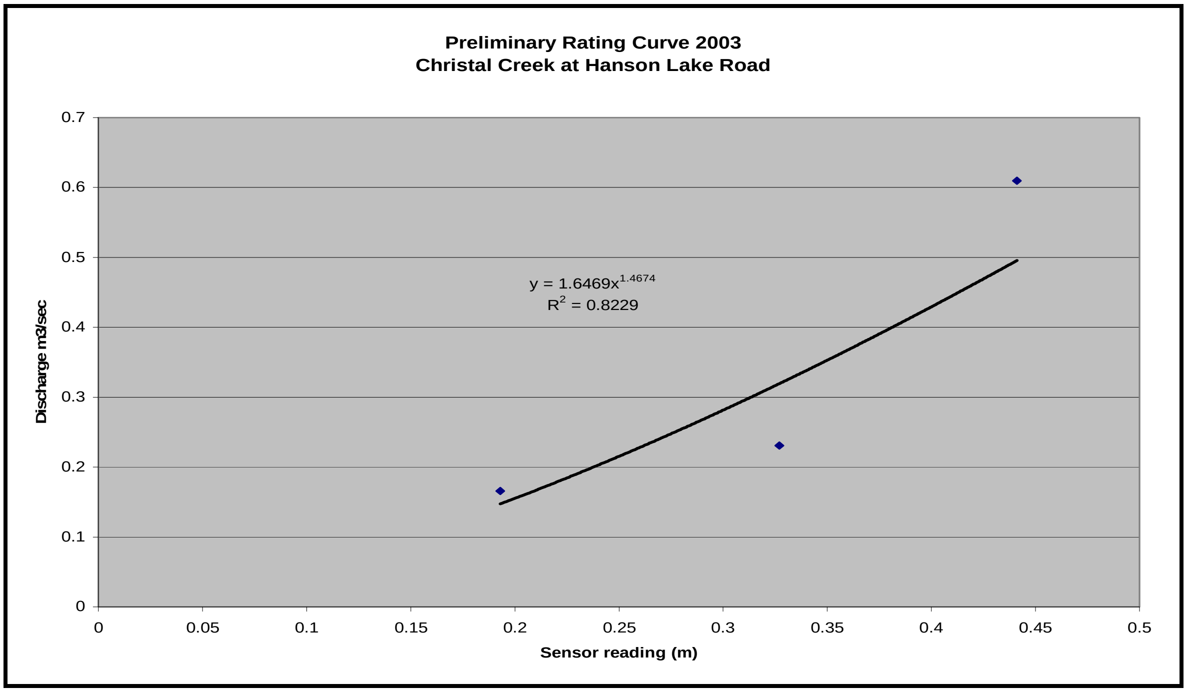
Low flow, represented by the last days of the record, and by spot measurements in February and March, 2004 was in the order of 0.1 m^3/sec.

Figure 4.4 Christal Creek Hydrograph 2003



Christal Creek at the Hanson Lake road is the only site with a partial continuous stage record. The instantaneous spot measurements and staff gauge readings have been plotted in Figure 4.5 to provide a preliminary rating curve for Christal Creek.

Figure 4.5 Christal Creek Rating Curve



4.2.2 Flat Creek upstream South McQuesten River

A staff gauge was installed initially at the Shanghai Road Crossing in 1994, but this location proved to be unreliable. A new installation was completed near the mouth of Flat Creek in 1996. In 2003 the gauge was found to be in good condition, although the temporary bench mark could not be located.

4.2.3 Porcupine Creek Diversion Ditch

A staff gauge was installed in the diversion ditch near the 3rd dam in 1995. In 2003 this gauge was found to be in good condition, and was surveyed relative to bench marks.

4.2.4 Lightning Creek at Keno City

This gauge was installed in 1994, and was destroyed by aufice and flooding in 1995, and refurbished in 1996. In 2003 the gauge was found to be in good condition, and was surveyed relative to bench marks.

4.2.5 Lightning Creek upstream Hope Gulch

This gauge was installed in 1994 and last visited in 1998. Since that time beaver activity had altered the flow in this reach and the gauge is no longer useful. Discharge was measured upstream of the gauge where the channel of Lightning Creek was confined. No attempts were made to survey the bench marks.

4.2.6 Christal Creek downstream of the Keno Highway

This gauge was installed in 1994 and was last inspected by Laberge Environmental Services in 1997. Since that time sedimentation in Christal Creek below the highway had occurred, burying most of the gauge. This reach of the creek appears to be fairly dynamic and a future gauge should be installed further downstream in a stable confined region.

4.3 Multi-media Sampling Results

4.3.1 Silver King

The discharge from Silver King adit is treated in two settling ponds prior to decanting to the environment. The use of lime as further treatment was discontinued in November 2001. The flow from the settling ponds does not enter Galena Creek but flows through the bush directly below the impoundment, where within 200 meters it disappears to ground. There is a height of land separating the flow path from Silver King and Galena Creek. The higher metals levels currently documented in Galena Creek downstream of the mine site area (see Section 4.1), are a result of contact with the waste rock pile from Silver King and not as a result of the discharge.

The flow fans outs out at 10 m below the discharge and forms two unconfined channels by 50 m downstream (refer to Figure 3.1). The flow in the east channel (left hand channel facing upstream) goes to ground just beyond Transect #2. The flow in the west channel becomes totally unconfined and disperses through the willows creating a swamp-like environment. The saturated area was followed to a point 130 m downstream where the flow last daylighted (site SKT3). Similar conductivity values throughout indicated that the flow path is from the same source. The area below SKT3 to Flat Creek, a distance of 1.5 km, was carefully examined on foot, revealing no further daylighting whatsoever.

Although water quality has already been discussed in Section 4.1, a few parameters have been examined in detail in Table 4.14. The concentrations of cadmium, copper, zinc, iron and manganese are greatly reduced at the site 130 meters downstream of the discharge. Substantial levels of iron and manganese are reported in the flow up to 50 m downstream of the discharge point. As explained in the following section (4.4), metals are precipitated out of the water column as iron and manganese oxides. The colouration of the water was reddish/orange indicating iron content. All of the iron in the water is in the form of suspended matter as the dissolved values were below detection (see Appendix B). Values for conductivity, pH, calcium and sulphate were similar throughout the flow path. Lead was not detected at any of the sites.

Table 4.14 Summarized Data in the Silver King Flow Path

Parameter	**Decant**	**SKT1 10 m d/s**	**SKT2 50 m d/s**	**SKT3 130 m d/s**
Conductivity	923	992	979	963
pH	6.79	6.94	6.61	6.78
Cd (T) mg/L	0.0094	0.0071	0.0092	<0.0006
Cu (T) mg/L	0.039	0.024	0.028	0.001
Pb (T) mg/L	<0.006	<0.006	<0.006	<0.006
Zn (T) mg/L	0.873	0.763	0.872	<0.001
Fe (T) mg/L	11.0	10.7	12.4	0.199
Mn (T) mg/L	2.53	2.22	2.25	0.0138
Ca (T) mg/L	159	141	152	151
SO4 mg/L	437	417	426	421

Zinc concentrations in the dissolved and total phases have been graphed in Figure 4.6. There is a slight decrease in zinc concentrations 50 m downstream of the discharge, however, after flowing through the willows and muskeg, concentrations were greatly reduced as documented at SKT3. The concentration of total zinc was below the method detection limit of 0.001 mg/L at this location,

Table 4.15 Zinc Concentrations in Various Media in the Silver King Pathway, August 2003

Site Location	Zinc ppm					
	Water		Vegetation		Sediment	
	Dissolved	Total	Twigs	Leaves	Mineral	Organic
Silver King Discharge	0.777	0.873				
Silver King Transect #1 (10 m d/s)	0.653	0.763	628	1220	3980	7760
Silver King Transect #2 (50 m d/s)	0.543	0.872	467	1260	387	3250
Silver King Transect #3 (130 m d/s)	0.051	<0.001	314	442	62.4	446
Silver King Control Site			209	207	59.2	112

Silver King Discharge
Silver King 10 m d/s
Silver King 50 m d/s
Silver King 130 m d/s

Figure 4.6 Zinc concentrations in water along the Silver King flow zone

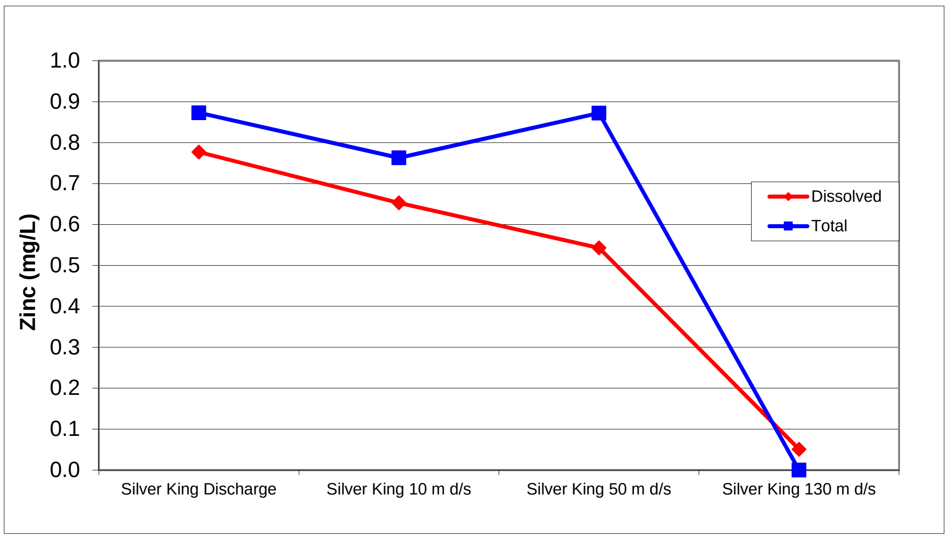
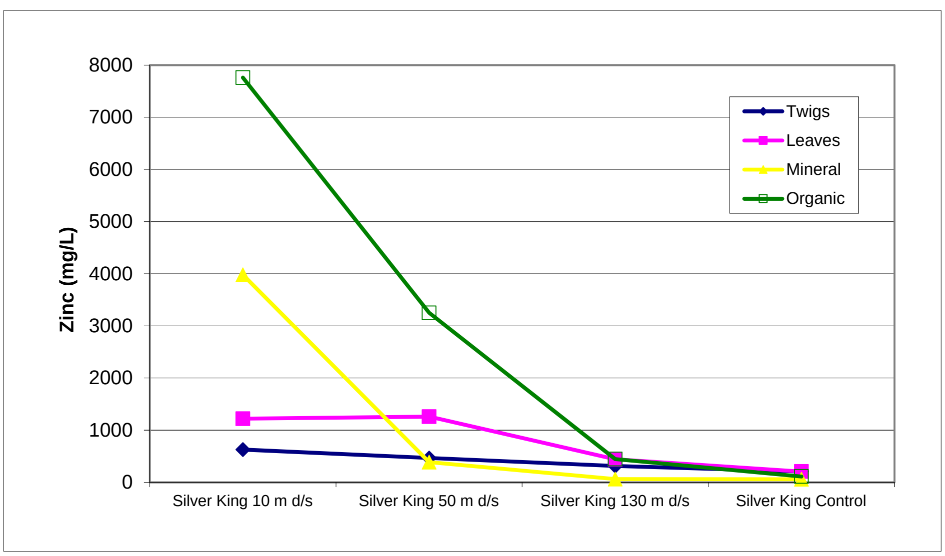


Figure 4.7 Zinc concentrations in tissues and sediments along the Silver King flow zone



the only site in the study area where this occurred. The detected dissolved zinc value reported here was probably due to field contamination or to lab error.

Although the immediate discharge area is aesthetically displeasing (a locked gate to the Silver King area prevents public access), it appears that the environmental conditions below Silver King are satisfactorily removing metals from the water column.

For economic purposes, analyses were completed on selected sediment samples with the remainder being archived. The organic and mineral layers of sediment were analyzed from sites SKT1-2, SKT2-4, SKT3, and the control sample collected from SKT2-1. These data are included in Appendix D.

The zinc concentrations in the sediments of the organic layer were significantly higher than concentrations in the mineral layer, including the site 130 m downstream (see Table 4.15). The organic layer was heavily stained with orange precipitate at the two upstream sites, and to a much lesser degree at the lower site (see Photograph in Appendix C). The organic layer would also include decomposing leaves and other organic debris that had been deposited in previous years. Concentrations in both layers decreased significantly as one moved progressively downstream.

The concentration of zinc in the mineral layer at SKT3 was very similar to the concentration in the mineral layer at the control site. The zinc concentration in the organic layer at SKT3 was approximately four times greater than the concentration in the organic layer at the control site.

This northeast facing slope is predominantly a black spruce forest. Black spruce along with white spruce and paper birch form the tree cover. Willows (blue-green willow and Richardson's willow are the most widespread), dwarf birch, shrubby cinquefoil and ericaceous shrubs (Labrador tea and bog blueberry being the most common) form the shrub layer. Feathermoss and sphagnum moss dominate the ground cover. Forbs are not abundant. Dense stands of mountain alder colonize disturbed sites. See Appendix E for a complete listing of the vegetation.

Twigs and leaves were collected from plants (*Salix richardsonii*) along each transect and the control samples were collected beyond the zone of impact near SKT3. Zinc concentrations were tabulated (Table 4.15) and graphed in Figure 4.7. The concentration in the twigs was lower than the concentration in the leaves, considerably so at SKT1 and SKT2. The values reported at SKT3 approached those documented at the control site. There was virtually no difference in the concentration of zinc in the twigs and in the leaves from the control site. The analytical results for the tissues are presented in Appendix D.

4.3.2 No Cash Creek

The discharge from the No Cash 500 adit flows into No Cash Creek upstream of the Keno Highway, forming the majority of the flow. No Cash Creek flows in a confined, well established channel down the slope to the valley floor where it passes through a small wetland and a willow swamp prior to its confluence with the interceptor ditch.

Water samples were collected of the adit as well as five points along the length of No Cash Creek. There is considerable reduction in zinc concentration along the pathway flow from 13 mg/L at the adit to 0.5 mg/L at the mouth of No Cash Creek (Table 4.16, Figure 4.8). The creek is very clear and the dissolved and total zinc concentrations were very similar at each site.

Several studies by Kwong and various associates have been conducted on the metal removal mechanisms involved in this system. The dissolved zinc introduced by mine water is dissipated downstream but the relative constant sulphate concentrations suggest that dilution is not the cause. Aqueous transport of metal contaminants are apparently attenuated along the stream. Precipitation and/or sorption of metallic ions onto solid matter along the stream bed and banks are probably predominant (Kwong, Roots and Kettley, 1994).

No-Cash Creek drains northeast through predominantly black spruce forest. Black spruce along with white spruce and paper birch form the tree cover. Willows (blue-green willow and Richardson’s willow are the most widespread), dwarf birch, shrubby cinquefoil and ericaceous shrubs (Labrador tea and bog blueberry being the most common) form the shrub layer. Feathermoss and sphagnum moss dominate the ground cover. Forbs are not abundant. Dense stands of mountain alder colonize disturbed sites.

Table 4.16 Zinc Concentrations in Various Media in the No Cash Pathway, August 2003

Site	Zinc ppm						
	Water		Vegetation		Sediment		
	Dissolved	Total	Twigs	Leaves	Stream	Mineral	Organic
No Cash 500	12.87	13.11					
No Cash @ Highway	2.99	3.14					
No Cash Creek #1 (NCC!)	2.44	2.47	558	2150	2780		
No Cash Creek #2 (NCC2)	1.64	1.66	364	1730	5740		
No Cash Creek in Wetland (NCC3)	0.913	0.922	418	1580	622	3360	3250
No Cash Creek u/s Ditch (NCC4)	0.520	0.541	270	992			
No Cash Control Site			191	203			

Figure 4.8 Zinc concentration in water along the No Cash flow zone

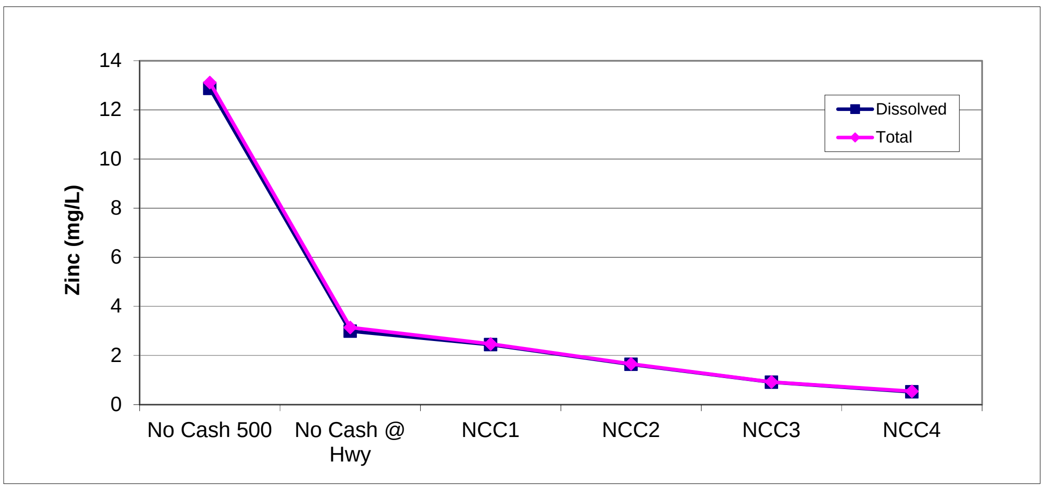
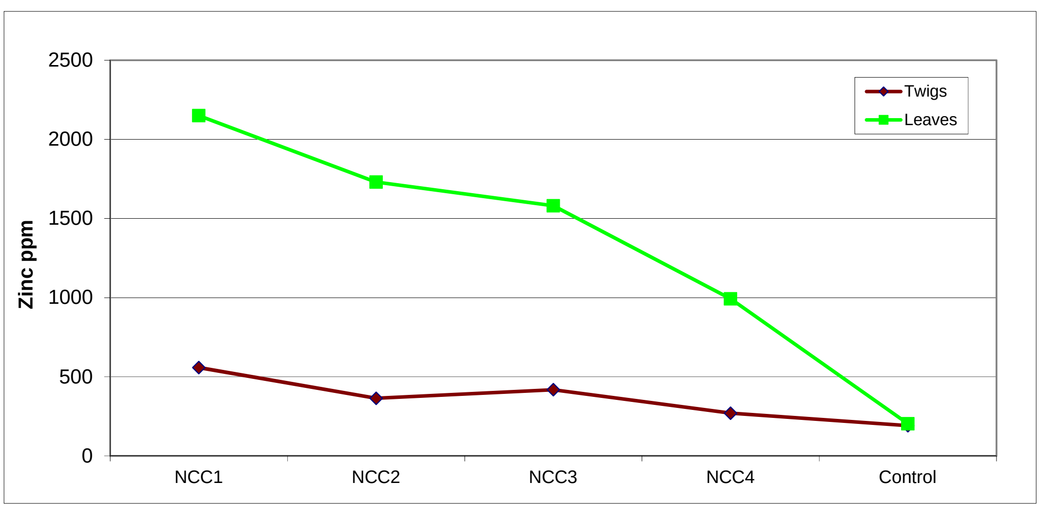


Figure 4.9 Zinc concentrations in tissues along the No Cash flow zone



The narrow strip of riparian vegetation along the creek is mostly willows (little-tree willow, Scouler's willow, Bebb's willow, Barclay's willow and Richardson's willow) mountain alder and balsam poplar. Water sedge, blue-joint reed grass and horsetail grow in and along the creeks.

Willow leaves and twigs (*Salix richardsonii*) were analyzed for metals. The zinc concentration in the twigs was relatively consistent at the sites, but somewhat higher than at the control site (Table 4.16, Figure 4.9). The concentration of zinc in the leaves was considerably higher than in the twigs, although levels gradually decreased along the system. The concentration in the twigs and leaves at the control site were similar to each other, and also similar to the concentrations in the vegetation at the control site at Silver King.

Since No Cash Creek consists of a confined flow, stream sediment samples were collected. Zinc concentrations were high at the upstream sites but significantly lower in the wetland area.

A sediment sample within the wetland was collected and the organic and mineral layers analyzed individually. Both the organic and mineral layers had similar concentrations of zinc in the No Cash wetland. This natural wetland has been in existence for a long time and has likely been removing metals for an undetermined period.

4.4 Metal Removal at Silver King

The sequential extraction analyses performed by Microbial Technologies Inc indicated that the discharge from the Silver King Mine is effectively treated by the muskeg below the decant. The treatment is mostly provided by iron and manganese oxides that precipitate within the muskeg and scavenge metals.

Cadmium and zinc were strongly correlated (behaved identically geochemically) and were mostly adsorbed onto or co-precipitated with iron and manganese oxides. Calcium was extracted in the exchangeable/carbonate fraction, and likely existed as a carbonate in the muskeg. Copper and nickel were present in minor amounts. Copper likely formed insoluble sulphides as indicated in the AVS sequential leach analysis. Copper was also adsorbed onto iron/manganese oxides. Nickel was predominately adsorbed onto oxides. Lead was also present in minor amounts and was almost entirely removed within 50 m of the discharge point. Few metals were released in the water-soluble fraction indicating that metals were strongly bound, in some form, within the muskeg samples.

Complete details of the findings are outlined in Appendix A.

Similar sequential extraction results were documented on sediments from nine different sites in the Keno Hill mining district in 1993. Kwong *et al* found that the majority of zinc in the sediments is associated with two fractions, carbonate – bound (about 42%) and co-precipitated with iron plus manganese oxides (approximately 30%) (Kwong *et al*, 1997). They found that the organics in the sediments played a significant role in attenuating aqueous transport of copper in the water courses in the study. Due to the extreme climatic conditions of the area, especially in the presence of discontinuous permafrost, it is unlikely that the organic matter occurring in the sediments can be readily oxidized to release the bound copper.

Since fine-grained sediments usually dominate water-mineral interaction occurring at a natural site, only the –180 µm portion of the collected samples was subjected to analysis (Kwong *et al*, 1997).

Cryogenic precipitation accounts for the removal of some metal ions in the winter months, however, depending on the precipitate, for example hydrozincite, they are likely to re-dissolve during spring freshet (Kwong *et al*, 1997).

Ferrous iron sorbed onto sediment particles along the streambed undergoes oxidation to precipitate ferric hydroxide, especially under open water conditions (Kwong *et al*, 1997). Extensive iron oxide coatings are evident immediately below the No Cash 500 and Silver King discharge areas. Iron oxide is an efficient scavenger for many dissolved metals. Sorption onto precipitating ferric hydroxides is an important metal attenuation mechanism. Metal ions strongly sorbed onto precipitating ferric hydroxide are not readily re-mobilized. The destruction of oxides occurs under highly reducing conditions or in a highly acidic environment (pH<3), conditions that are not naturally prevalent in the Silver King or No Cash areas.

5.0 DISCUSSION

5.1 Receiving Water Compilation

Although a large volume of data exists for many of the receiving water sites, only data from recent years were examined. This would more readily reflect the conditions under non-operational and abandoned conditions. Generally during this time period, annual treatment of the tailings during freshet, and on-going treatment at Galkeno 900 took place.

Sporadic sampling of the receiving waters has occurred over the past several years by various agencies, companies and consultants. Zinc concentrations were tabulated (Table 5.1) to determine if any trends were evident.

Prior to the impacts of the fugitive flow from Galkeno 300 (early 2004), it appears that there has been little change in the quality of the South McQuesten River in the past seven years, based on the limited collected data. In general, higher concentrations tended to coincide with the typical timing of freshet (May).

The quality of Flat Creek appears to be improving over time. The highest concentrations occurred during freshet (May 1996 and May 1997) and during low flow conditions in February 2001.

The quality of Christal Creek appears to be deteriorating over time, prior to the impact of the fugitive flow from Galkeno 300. Zinc concentrations near Hanson Road were relatively constant with a gradual increasing trend. Zinc concentrations at Keno Highway and at the mouth tended to fluctuate to a greater extent. High zinc values were documented at the mouth in early 2003 by DIAND, possibly denoting low flow conditions when ionic constituents are more concentrated. Monitoring of Christal Creek in late winter and early spring of 2004 shows that the quality of Christal Creek has significantly deteriorated due to impacts from the fugitive flow from Galkeno 300 (see Section 4.1.2.2).

The elevated zinc level in Lightning Creek documented in August 2003 is indicative of the high

Table 5.1 RECENT TOTAL ZINC CONCENTRATIONS (mg/L) AT VARIOUS RECEIVING WATER SITES

Date	Sampler	S. McQuesten u/s Christal	S. McQuesten @ Pumphouse	S McQuesten u/s Flat Cr	S. McQuesten d/s Flat Cr	S. McQuesten 9 km d/s Flat	Flat Cr u/s S. McQuesten	Christal Cr d/s Keno Hwy	Christal Cr @ Hanson Rd	Christal Cr @ mouth	Lightning Cr @ Keno
Feb 7, 1996	DIAND										0.012
May 8, 1996	DIAND				0.227		0.363				
July 18, 1996	EP								0.242		
Sept 24, 1996	DIAND				0.110		0.143				0.007
May 21-22, 1997	EP	0.034	0.069	0.067	0.120	0.67	0.165	0.265	0.273	0.377	
May 27, 1997	DIAND						0.224				
Apr 6-8, 1998	EP	0.012	0.031	0.04	0.032		0.029	0.262	0.131	0.161	
May 23, 1998	DIAND							1.170			
June 9-11, 1998	EP	0.046							0.167	0.278	
Apr 4-5, 2000	EP		0.059					0.299	0.160		
Feb 2, 2001	AMT		0.0308	0.0314	0.0340		0.253		0.150		0.0247
Apr 18, 2001	EP							0.613	0.202		
May 24, 2001	DIAND							1.05			
July 10-11, 2001	DIAND	0.065	0.059	0.057	0.067		0.099	0.540		0.273	
Oct 30, 2001	DIAND									0.300	
Nov 8, 2001	AMT		0.032	0.028	0.033		0.025		0.226		
Apr 25, 2002	DIAND					0.017					
Sept 3-4, 2002	EP							0.807	0.356		
Sept 30, 2002	DIAND						0.053				
Jan 7, 2003	DIAND									0.666	
Feb 26, 2003	DIAND									0.772	
April 18, 2003	EP							1.787			
May 6, 2003	DIAND			0.051	0.059		0.071*	1.59		0.67	
July 8, 2003	EDI					0.015	0.044		0.344		
July 22, 2003	DIAND										0.025
Aug 3-5, 2003	LES	0.026	0.025	0.022	0.025	0.017	0.036	0.900	0.312	0.256	0.582
Oct 7, 2003	DIAND						0.035	0.621		0.363	
Feb 19, 2004	LES	0.013	0.142						2.14		
March 23, 2004	LES	0.027	0.206						2.56	1.91	

* = average of daily samples from May 6 to May 28

DIAND = Department of Indian and Northern Development, Water Resources Division. After devolution, April 2001, this department became Water Resources, Environment, of the Yukon Territorial Government.

EP = Environmental Protection, Environment Canada

AMT = Advanced Minerals Technology

EDI = Environmental Dynamics Inc

LES = Laberge Environmental Services

6.0 CONCLUSIONS

Several conclusions can be made following the examination of the data collected during this study.

- Zinc is the primary contaminant of concern. Elevated levels were found in the discharges of several of the abandoned mines in the Keno Valley study area. Treating the zinc problem will also tend to treat the secondary metals of concern (notably cadmium).

- Removal of zinc from the water column appears to be occurring naturally at several locations within the study area. A 96% reduction in zinc concentration occurred in No Cash Creek from the adit discharge of No Cash 500 to the confluence with the interceptor ditch. Zinc was removed from the water column downstream of the Silver King discharge to below the detection limit (0.001 ppm). The muskeg is providing a medium where iron and manganese can precipitate as oxides and remove metals from the mine drainage. Zinc concentrations were significantly reduced in Flat Creek after flowing through the wetland.

- There was no discernable impact on the South McQuesten River downstream of all inputs during the August 2003 survey. The downstream site displayed excellent water quality and even surpassed that of the upstream control site.

- The site contributing the greatest concentrations of contaminants to the receiving environment is the Galkeno 300 adit, located on Galena Hill. Based on the August 2003 data, the daily loading of zinc was calculated at over 13,000 kg. During early winter the established flow pathway from Galkeno 300 was altered. Fugitive flow from Galkeno 300 began to report to Christal Creek across the Keno Highway. Follow up monitoring determined a significant impact to the water quality of Christal Creek. Effects were also noted within the South McQuesten River.

7.0 RECOMMENDATIONS

This report has utilized a variety of ways to illustrate the contaminant data. There would be some advantages to adopting one of the methods for future water quality reports so that the general reader could compare results between reports.

Monitoring of the receiving waters should continue on a regular basis. In light of the recent development with the fugitive flow from Galkeno 300, it is even more imperative to continue to assess the receiving waters. At a minimum the following sites should be monitored biannually, during low flow (March or April) and during typical open water conditions (July).

- South McQuesten River upstream Christal Creek
- South McQuesten River at Pumphouse
- South McQuesten River upstream Flat Creek
- South McQuesten River 300 m downstream Flat Creek
- South McQuesten River 9 km downstream Flat Creek
- Christal Creek at Keno Highway
- Christal Creek upstream Hanson Lake Road Crossing
- Christal Creek at mouth
- Flat Creek at mouth
- Lightning Creek upstream Hope Gulch
- Lightning Creek upstream Thunder Gulch
- Lightning Creek upstream Keno City Bridge

To fully characterize the health of the receiving environment, monitoring of other matrices should also take place. This would encompass assessing stream sediment characteristics and biotic populations (invertebrate and vertebrate).

Analyzing stream sediments provides information on metal mobilization occurring within the streambed. Stream sediments are usually monitored in the context of understanding the fate and transport of some contaminant and are conducted to determine the impacts on the receiving waters from the discharge of a point source of pollution. Suspended particles eventually settle out and often adsorb onto the bottom sediments. Dissolved ions may precipitate out of the water column and settle to the bottom. The bottom sediments then become a “sink” for contaminants. Bedload movements can transport the contaminated sediment downstream far from the source. The substrate also provides habitat for benthic organisms and contaminated stream sediments can have substantial effects on biological activity.

The benthic macroinvertebrate community is typically the most biologically productive part of a stream or river and can indicate a great deal about the ecological health of a water body. Whereas a water quality sample will only give an indication of the characteristics of the water at the instant of time of sampling, the benthic community can indicate prevailing conditions.

Benthic macroinvertebrates have been studied extensively, and have been used as biological indicators on the health of the aquatic environment. They have proven to be useful organisms to study because:

- They are common in most aquatic environments;
- Many are sensitive to physical and chemical changes in their habitat;
- Many live in the water for over a year (unlike zooplankton that have relatively short life cycles);
- They are relatively sedentary and remain in their general area (unlike fish that can readily move to another area to avoid a pollutant);
- They are easily collected in many streams and rivers.

Benthic macroinvertebrate studies have been undertaken in the 1980s and 1990s in some of the receiving waters in the Keno Valley. The last biological monitoring program was conducted by LES in 1994. Annual monitoring of several sites on the South McQuesten River, Christal Creek, Flat Creek and Lightning Creek is recommended.

White Mountain Environmental Consulting conducted an in-depth fish resources study in the Keno Valley in 1994. Fish habitat was assessed and the utilization of this habitat was monitored. Fish tissue samples were also collected for metal analysis. A similar study is recommended for 2004. The anomalous zinc loading experienced by Christal Creek and the

South McQuesten River could have an impact on the fisheries. Grayling spawn in the South McQuesten River and rear in Christal Creek, as far upstream as the Hanson Lake bridge (WMEC, 1995). The South McQuesten River is also home for salmon spawners. Studies should be initiated in May, spawning time for grayling, in June to record the emergence of grayling and salmon fry, in mid summer to document all species utilization and also in the fall.

In summary the following is recommended:

- Instigate a regular receiving water monitoring program as outlined above. Sites would be monitored on an increased basis in response to mitigating circumstances.

- Develop a consistent method of illustrating collected data to allow comparisons between future studies and reports.

- Conduct a benthic marcroinvertebrate monitoring program at selected sites on the South McQuesten River, Christal Creek, Flat Creek and Lightning Creek. Similar methodology should be employed (i.e. artificial substrate samplers, etc) as in the past to allow for comparisons.

- Conduct a fisheries assessment complete with tissue analysis for metals using similar reach configurations and methodologies as utilized during the 1994 study.

- Conduct a stream sediment monitoring program at the receiving water sites.

- Continue spot discharge measurements at Christal Creek upstream of the Hanson Lake Road crossing, and continue with the maintenance and operation of the data logger.

- Construct or rehabilitate staff gauges at all six sites and, install data loggers at Lightning Creek at Keno City, Flat Creek at the mouth and South McQuesten at the pumphouse pond. This would include re-establishing rating curves for each site.

- Proceed with caution in using mechanical means in the immediate vicinity of the adit discharge zones. As indicated in water quality studies, metals are removed rapidly immediately below the adits. Generally the metals are precipitated out as iron or manganese oxides, as a result of cryogenic precipitation, and/or sorbed onto sediment particles. As such, physical disturbance of these deposition areas has the potential to redistribute the metals further downstream, exacerbating the problem.

- Explore in greater detail the natural metal attenuation mechanisms evident downstream various discharge areas. Exploit these to develop remediation options.

- Have on-site personnel maintain a wildlife log; species of animals sighted, when, where, and what species (if possible) of vegetation they were eating.

- Conduct vegetation tissue sampling for metal analysis for a variety of species that are known, or observed, to form the major portion of the diet of various animals (moose, caribou, grouse, etc)

- Consideration should be given regarding the recovery of zinc from the Galkeno 300 discharge (technology permitting) as an alternative to the expense of treatment.

- Determine the fate of flows into the South McQuesten wetlands, update maps, and conduct sampling to determine the fate of contaminants.

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APPENDIX A

EVALUATION OF METAL REMOVAL IN MUSKEG BELOW THE SILVER KING MINE

By
Microbial Technologies, Inc
December 2003

Evaluation of metal removal in muskeg below the Silver King Mine

A Project Report submitted to:

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December 2003

Executive Summary

Microbial Technologies, Inc. was contracted by Laberge Environmental to analyze muskeg samples collected below the Silver King Mine, Elsa, Yukon. Contaminated mine water drains from the mine, but the contaminants have been shown to be removed as the water flows over muskeg below. The objective of our analyses was to determine what might account for this cleansing property of muskeg.

Four samples were selected for analysis. These samples were taken in the flowpath of the drainage, ten and fifty metres below the discharge point. They were subjected to a chemical leach analysis that reveals the geochemistry of metals in the muskeg. Ten of the most abundant metals was examined in detail.

Iron and manganese were the two most abundant metals in the muskeg. They were found predominantly as amorphous and crystalline oxides. Calcium was extracted in the exchangeable/carbonate fraction, and likely existed as a carbonate in the muskeg. Its large quantities will insure that soils remain buffered. Cadmium and zinc concentrations were strongly correlated (e.g., behaved identically, geochemically), and they were mostly adsorbed onto or coprecipitated with iron and manganese oxides. Copper and nickel were present in minor amounts. Copper likely formed insoluble sulphides, as well as being adsorbed onto iron/manganese oxides, whereas nickel was predominantly adsorbed onto oxides. Lead, also present in minor amount, was entirely removed within 50 metres of the Silver King discharge point. Aluminum resisted extraction, indicating that it is in a chemically-inert form.

These results indicate that muskeg provides a medium where iron and manganese can precipitate as oxides and remove metals from mine drainage. This is comparable to the situation at the Galkeno 300 adit. Given these similarities, and the metals loadings in the Silver King discharge, it is predicted that the capacity to retain metals of muskeg below Silver King is still very large.

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Introduction

The adit from the Silver King Mine releases contaminated water containing 1-2 mg/L zinc. Until 2001, this zinc was removed by adding lime to mine water and allowing it to precipitate in settling ponds below the adit. In Fall 2001, lime addition was discontinued and mine water was allowed to flow over the muskeg. Monitoring data showed that zinc was effectively removed by the muskeg, even in the dead of winter.

What causes zinc to be removed is unknown. It is important to understand the metal-removal processes operating at Silver King because we must know if a) treatment will be brief or prolonged, and b) if metals will be stably retained in the muskeg, or if they will eventually be remobilized. The answer to each of these questions have different management consequences.

Investigations of zinc-contaminated water being treated by muskeg below the Galkeno 300 adit may hold clues about this process (MacGregor, 2000). In this study, zinc was predominantly associated with iron and manganese oxide fractions, with lesser amounts being retained on the "organic" fraction[1]. However, there were significant differences between the water chemistries of these adits. For instance, zinc concentrations are two orders of magnitude higher in the Galkeno 300 water compared with the Silver King water.

Microbial Technologies, Inc. was requested to investigate muskeg collected below the Silver King adit to identify metal removal processes. We used a diagnostic sequential leach analysis to identify these processes. This analysis is performed by leaching samples with reagents of increasing strength and correlating metals in leachate with fractions that are solubilized. Each leach step is designed to be selective for a given geochemically-significant fraction. For example, a dithionite-citrate leach is expected to liberate metals associated with amorphous iron oxides. If iron is, in fact, dissolved in this leach step, then any metal also leached in this step is arguably associated with amorphous iron oxides. This argument is valid *only* if no other form of iron or other geochemically-significant fraction is simultaneously leached.

The sequential leach analysis identifies the processes responsible for metal removal in muskeg. With this information, one can answer the above questions about the longevity and stability of the treatment process. These topics from the objectives of the study presented herein.

[1] These fractions are "operationally-defined", meaning that they are defined in relation to the specific sequence of chemicals used to extract them. In fact, zinc in the "organic" fraction could equally well be associated with iron/manganese oxides or sulphides that are specifically extracted by these same chemicals, depending on the specific procedure used by MacGregor (2000).

Sampling

Samples were collected below the Silver King Mine by Laberge Environmental on August 23, 2003. They were collected along transects perpendicular to the mine water flowpath, at 10, 50, and 130 m from the discharge point (Figure 1). For each sampling point, a surface (organic) and subsurface (mineral) sub-sample was collected[2]. The samples were packed tightly in WhirlPak bags to exclude air, tagged, cooled and shipped to our laboratory for further analysis.

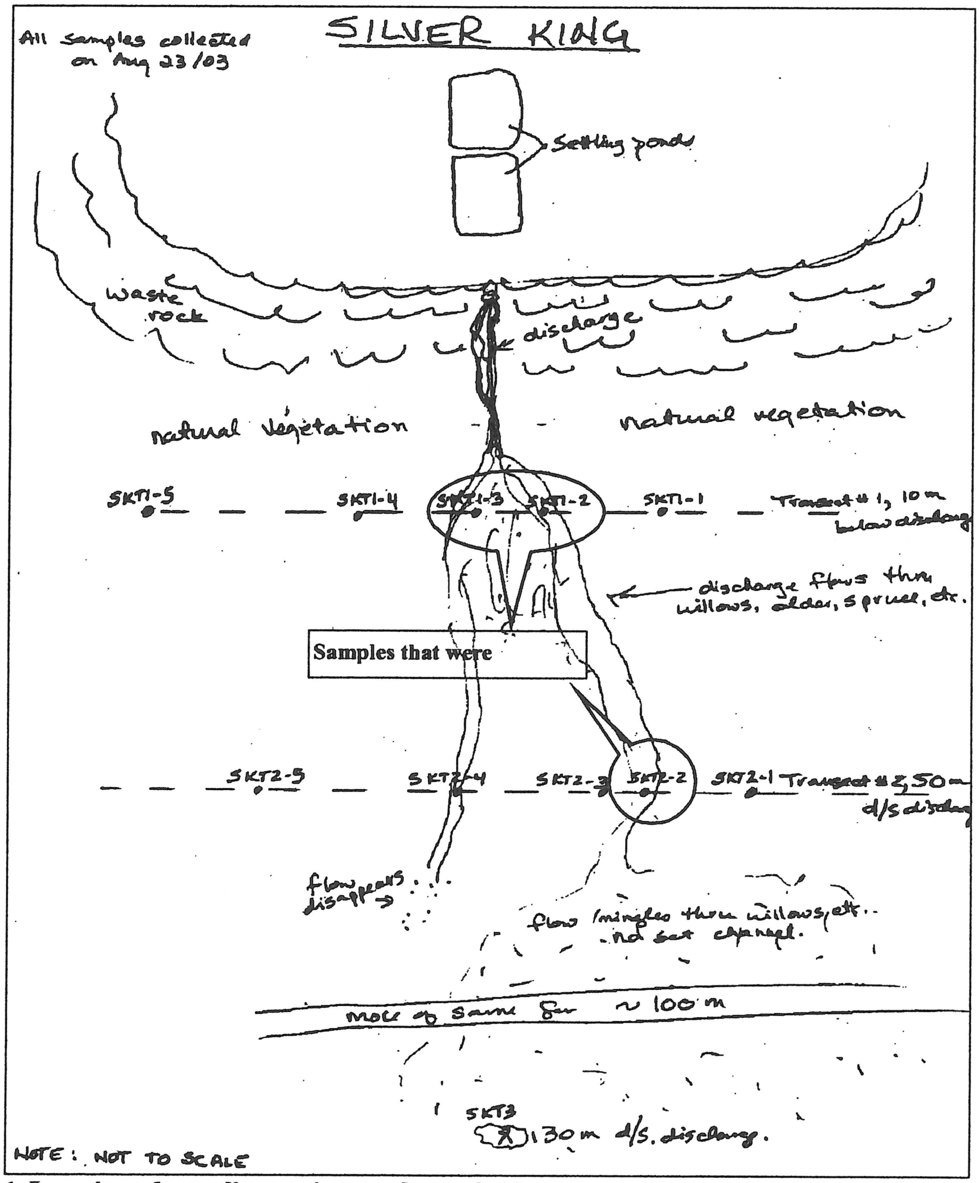

Figure 1. Location of sampling stations and sample identification. Reproduced from field notes taken by Laberge Environmental during sampling trip.

[2] Their depths were not recorded.

Materials and Methods

Four samples were tested to determine zinc distribution in soils exposed to Silver King mine waters. These samples were: T1-2,3A; T1-2,3B; T2-2A; and T2-2B. Two of the above samples were composites. T1-2,3A was a composite of T1-2A and T1-3A while T1-2,3B was a composite of T1-2B and T1-3B.

Two replicates of each sample (see Table 1) were taken and put through the lab procedures outlined in Table 2. The samples generated from these laboratory procedures are shown in Table 3. Each of these samples came from combining the products of the two replicates.

The raw data from these analyses are presented in Appendix A.

Table 1. Wet and dry weight of samples tested in the laboratory study.

Sample	Wet Weight (g)	Dry Weight (g)	Combined Dry Weights (g)
T1-2,3A-R1*	11.507	3.969	7.945
T1-2,3A-R2	11.529	3.976	
T1-2,3B-R1	6.953	4.167	8.167
T1-2,3B-R2	6.674	4.000	
T1-2A-R1	7.964	4.101	8.159
T1-2A-R2	7.881	4.058	
T1-2B-R1	8.042	3.763	7.548
T1-2B-R2	8.090	3.785	

* R1 = replicate 1; R2 = replicate 2.

Table 2. Lab Procedures used to analysis soils exposed to Silver King mine waters.

Step	Procedure
1	Send sub-samples of samples to analytical lab for "Total Metals in Solids" analysis.
2	Use 4 g of sample per centrifuge tube, 2 tubes per sample.
3	Mix sample with RO water (20 ml/4g). Place on shaker in the hot room for 2 hours. Centrifuge. Save supernatant and acidify with 1 mL nitric acid. Send supernatant to analytical lab for "Total Metals in Filtrates" analysis.
4	Add 1M, pH 5.0, Acetic Acid/Sodium Acetate (20 ml/4g). Place on shaker in the hot room for 16 hours. Centrifuge. Save supernatant and acidify with 1 mL nitric acid. Send supernatant to analytical lab for "Total Metals in Filtrates" analysis.

5	Mix sample with RO water (20 ml/4g). Place on shaker in the hot room for 20 minutes. Centrifuge and discard supernatant.
6	Do CBD extraction (see Table 4).
7	Repeat Step 5.
8	Do AVS extraction (see Table 5).
9	Repeat Step 5.
10	Take sample residue to analytical lab for "Total Metals in Solids" analysis.

Table 3. Samples generated from laboratory procedures.

Step	Samples Generated	Analysis
1	T1-2,3A-S1; T1-2,3B-S1; T2-A2-S1; T2-B2-S1.	Total Metals in Solids
3	T1-2,3A-S3; T1-2,3B-S3; T2-A2-S3; T2-B2-S3.	Total Metals in Filtrates
4	T1-2,3A-S4; T1-2,3B-S4; T2-A2-S4; T2-B2-S4.	Total Metals in Filtrates
6	T1-2,3A-S6; T1-2,3B-S6; T2-A2-S6; T2-B2-S6.	Total Metals in Filtrates
8	T1-2,3A-S8-HCl; T1-2,3B-S8-HCl; T2-A2-S8-HCl; T2-B2-S8-HCl.	Total Metals in Filtrates
8	T1-2,3A-S8-GAS; T1-2,3B-S8-GAS; T2-A2-S8-GAS; T2-B2-S8-GAS.	Sulphide
10	T1-2,3A-S10; T1-2,3B-S10; T2-A2-S10; T2-B2-S10.	Total Metals in Solids

Table 4. CBD Extraction Method Used To Remove Free And Loosely Bound Fe/Si/Al-Oxides.

Ingredients

- 88 g/L sodium-citrate dihydrate
- 84 g/L sodium bicarbonate
- solid sodium dithionite

Methods

- 4 g sample in 40 mL centrifuge tube.
- Add 20 mL citrate.
- Add 2.7 mL bicarbonate.

- Mix and place on rotator in incubator.
- Heat to 75 C.
- Add 1g dithionite, stir for 1 minute.
- Add 2nd 1g of dithionite, stir, and react for 60 minutes.
- Add 5.5 mL saturated NaCl to promote flocculation.
- Mix at 75-80 C for 6 hours.
- Centrifuge to remove suspended silicates.
- Save supernatant and acidify with 1 mL nitric acid.
- Send supernatant to analytical lab for "Total Metals in Filtrates" analysis.

Table 5. AVS Extraction

Methods

- 4 g sample in 40 mL centrifuge tube.
- React with 20 ml of 4 N HCl for one hour in the absence of oxygen by sparing with nitrogen gas.
- Trap hydrogen sulphide with 20 ml of a pH 14.25 anti-oxidant buffer.
- Combine like samples and preserve trapped hydrogen sulphide with 1 ml of 2 N zinc acetate.
- Centrifuge tube with sample and HCl.
- Save supernatant.
- Send supernatant to analytical lab for "Total Metals in Filtrates" analysis.

Alkaline Anti-oxidant Buffer

- Put 300 ml RO water in a 750 mL flask.
- Add 40 g KOH.
- Add 7.5 g ascorbic acid
- Swirl to dissolve
- Dilute to 500 ml with RO water

Table 6. Laboratory observations.

Step	Sample	Observation
4	T2-2A-R2	There was leakage from this sample. Would effect results for sample T2-A2-S4.
6	T2-2A-R2	Received 3ml bicarbonate instead of 2.7 ml. This should not effect test results.

6	T2-2A-R1 T2-2A-R2	Small amount of liquid leaked out while samples were spinning in the incubator.
6	T1-2,3B-R1	Major leakage. Will effect test results for T1-2,3B-S6.
8	T1-2,3A-R1	Sample was lost.
8	T1-2,3A-R2	Used 25 drops of Zn acetate to preserve hydrogen sulphide trapped in 20 ml of anti-oxidant buffer.
8	T1-2,3B-R1	Rubber stopper, through which nitrogen gas was delivered and oxygen was keep out, would not stay in. Soapy looking foam developed from the anti-oxidant buffer. The foam flowed over the side of the container.
8	T2-2A-R2	Strong bubbling occurred when HCl was added. Carried some of sample through air hose causing slight contamination of the anti-oxidant buffer (sample T2-2A-S8-GAS).
8	T2-2B-R1	Strong bubbling occurred when HCl was added. Soapy looking foam developed from the anti-oxidant buffer. The foam flowed over the side of the container.
8	T2-2B-R2	Bubbling occurred when HCl was added.
8	T2-2A-R1	Noted unreacted gray sample material at the bottom of centrifuge tube after step 8 was completed. Shook sample and it reacted strongly with the HCl in the tube. Means sample T2-A2-S8-GAS, will give inaccurate reading for sulphide (less than what it should be).

Table 7. Theoretical amounts of supernatant found in the samples collected.

Sample collected	Theoretical Amount of Supernatant
T1-2,3A-S3; T1-2,3B-S3; T2-A2-S3; T2-B2-S3.	40 ml R.O. Water
T1-2,3A-S4; T1-2,3B-S4; T2-A2-S4; T2-B2-S4.	40 ml Acetic Acid/ Na Acetate
T1-2,3A-S6; T2-B2-S6.	56.4 ml of various chemicals (see Table 4)
T2-A2-S6	56.7 ml of various chemicals (see Table 4)
T1-2,3B-S6	Unknown due too large loss of supernatant.
T1-2,3A-S8-HCl; T2-A2-S8-HCl; T2-B2-S8-HCl.	40 ml HCl
T1-2,3B-S8-HCl	50 ml HCl*
T1-2,3B-S8-GAS; T2-A2-S8-GAS; T2-B2-S8-GAS.	40 ml Anti-Oxidant Buffer
T1-2,3A-S8-GAS	20 ml Anti-Oxidant Buffer

* 10 additional ml of HCl was accidentally added to this sample.

Table 8. Potential sources of error associated with the various samples collected.

Sample collected	Potential error
T2-A2-S4	May be inaccurate due to a small loss of supernatant.
T1-2,3B-S6	Will be inaccurate due to a large loss of supernatant.
T2-2A-S6	May be inaccurate due to the loss of some supernatant.
T1-2,3B-S8-GAS; T2-2B-S8-GAS	Sulphide may have been lost because (1) the tube was not sealed immediately after HCl was added and (2) foam escaped the container which held the anti-oxidant buffer.
T2-A2-S8-GAS	Sulphide may have been lost because not all the sample in the centrifuge tube had reacted with the HCl.
T2-2A-S8-GAS	Sample contaminated? See Table 6.

Results and Discussion

Characteristics of samples tested

Four samples were selected for further analysis. These are:

- Composite samples SKT1-2 and SKT1-3, fractions A and B (i.e., organic and mineral fractions)
- Sample SKT2-2, fractions A and B (i.e., organic and mineral fractions)

These samples were collected in the flowpath of the mine drainage, 10 and 50 m below the discharge point, respectively (Figure 1). All these samples were visibly orange-stained (Figure 2), indicative of iron oxides and oxyhydroxides[3]. These samples were analyzed for metal content (Table 9).

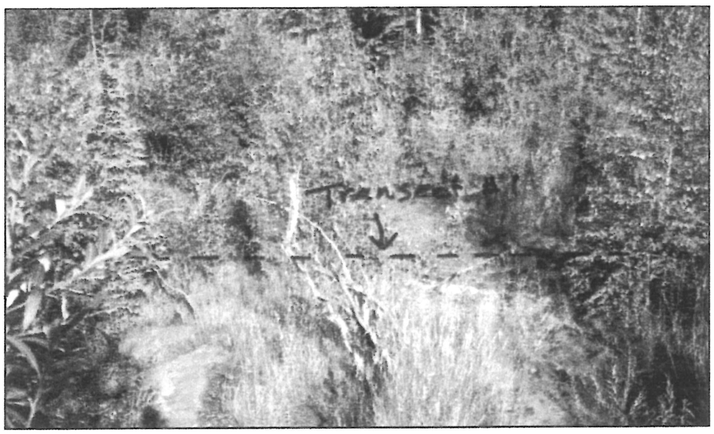

Figure 2. Sampling sites for SKTi-2,3 (left) and SKT2-2 (right). Note orange iron staining.

Table 9. Total metal content (mg/dry kg) of muskeg samples used in the study*.

Sample ID	T1-2,3A	T1-2,3B	T2-2A	T2-2B	Sample ID	T1-2,3A	T1-2,3B	T2-2A	T2-2B
Aluminum	5,930	5,540	2,480	2,210	Magnesium	1,990	2,570	2,600	1,900
Antimony	294	172	597	238	Manganese	61,300	32,100	156,000	47,600
Arsenic	640	280	730	380	Molybdenum	10.9	5.4	18.4	6.9
Barium	215	111	285	115	Nickel	952	404	1,880	459
Cadmium	134	67.3	263	86.1	Phosphorus	738	333	570	215
Calcium	12,200	14,500	54,500	94,800	Potassium	1,170	620	470	390
Chromium	12.3	9.6	7.2	5.2	Silver	71.4	22.0	14.7	6.0
Cobalt	348	179	682	206	Strontium	59.6	33.8	109	93.1
Copper	378	143	460	110	Titanium	40.6	277	6.6	31.3
Iron	195,000	110,000	278,000	107,000	Zinc	8,910	4,900	19,300	5,770
Lead	524	163	<100	<50					

* Only metals in detectable quantities are shown.

[3] Various species of iron can precipitate in an oxic environments, including iron oxides (Fe_2O_3), oxyhydroxides ($FeOOH$), and iron hydroxides ($Fe(OH)_3$). These species exist in various degree of crystallization, from fully amorphous to fully crystalline. For simplicity, they will all be referred to as iron oxides.

There is a large variability in the metal content of these samples, so only the strongest patterns can be considered valid. Lead is effectively removed within the first 10 metres of the discharge point, since it is not detected by 50 m. Silver is also mostly removed within the first 50 m. Both metals are preferentially found in the organic layer, consistent with their strong affinity to organic matter. Other metals seemed to be enriched in the organic layer of soil (samples A) compared with the mineral layer (samples B) .

Statistical analyses of metal concentrations reveal that some metals are highly correlated with iron (Fe) and manganese (Mn), particularly arsenic, antimony, copper, cobalt, nickel and zinc with iron, and antimony, cobalt, nickel and zinc with manganese (Table 10). Immediately, this suggests that arsenic is associated with iron (it typically co-precipitates with iron oxides), antimony and zinc are associated with manganese (it is strongly sorbed onto manganese oxides), and nickel is associated with both iron and manganese (it is sorbed onto both iron and manganese oxides.

Table 10. Correlations between metal concentrations in muskeg samples.

Metal pair	Correlation coefficient (r^2)	Metal pair	Correlation coefficient (r^2)
As-Fe	0.947	As-Mn	0.830
Sb-Fe	0.944	Sb-Mn	0.999
Cu-Fe	0.971	Cu-Mn	0.822
Co-Fe	0.978	Co-Mn	0.988
Pb-Fe	0.0933	Pb-Mn	-0.266
Mn-Fe	0.934	Mn-Fe	0.934
Ni-Fe	0.986	Ni-Mn	0.980
Zn-Fe	0.962	Zn-Mn	0.995

Sequential leach analysis

The following fractions were identified by the sequential leach analysis:

1. Water-soluble fraction (water leach)
2. Exchangeable and carbonate fraction (1M acetate pH 5.0 leach)
3. Amorphous iron and manganese oxides (Citrate-Bicarbonate-Dithionite, CBD leach)
4. Crystalline iron and manganese oxides, metal sulphides (4M HCl, AVS leach)
5. Residual fraction (organic matter, acid-resistant sulphides, occluded)

Each of these fractions arises from specific geochemical processes responsible for the retention of metals in muskeg. The results of these extractions reveal the distribution pattern of each metal in these fractions and allows a deduction of their geochemistry in the muskeg environment (Table 12).

The results of this analysis are presented in two sections, first focusing on each fraction solubilized by the leach steps, then by the distribution of individual metals in the leached fractions.

Analysis of fractions obtained in each leach step

Few metals were released in the water-soluble fraction, indicating that metals were bound in some form within the muskeg samples.

The (acetate) leach step released substantial amounts of calcium and magnesium, as well as some zinc. A portion of the first two metals was undoubtedly held as exchangeable cations. However, some of the calcium released may also have been contributed from calcium carbonate[4]. Samples from the first transect (T1-2,3A and B) released 60 and 80% of their calcium, respectively, in this fraction, whereas the other sample released only 20% of its calcium in that fraction. Clearly, calcium is in different forms in these different samples, with one form being far more labile, or pH-sensitive, than the other.

The zinc in the exchangeable and carbonate fraction of these same samples amounts approximately to 16% and 6% of the total released during the sequential leach (Table 12)

Large amounts of iron and manganese were released in the CBD extraction. This is as expected, since the extraction is designed to solubilized amorphous iron and manganese oxides. The proportion of iron solubilized was 36%, 61% and 50% of all the leachable iron for samples T1-2,3A, T1-2,3B, and T2-2B, respectively. Less amorphous manganese was released in these samples, representing 20%, 33% and 26%, respectively, of all the leachable manganese.

A substantial proportion of toxic metals was solubilized as well in this leach step, including cobalt, nickel, and zinc. Evidently, these metals were either adsorbed or co-precipitated with the amorphous iron and manganese oxides.

The hydrochloric acid (AVS) extraction was somewhat unspecific in this test, because both crystalline iron and manganese oxides and acid-soluble sulphides will be solubilized. However, both volatilized hydrogen sulphide and solubilized iron and manganese were measured, so that it was possible to determine the relative contribution of these species to the total amount of metal solubilized in this leach step.

This leach step also solubilized a large proportion of iron and manganese. Iron accounted for 64%, 38% and 50% of all the leachable iron for samples T1-2,3A, T1-2,3B, and T2-2B, respectively. For manganese, the proportions were 79%, 67%, and 74%, respectively. For both metals, this leach step solubilized 0.1-0.7 g/4 (wet) g samples, which are very large amounts.

In contrast, very little hydrogen sulphide was recovered during this leach step (Table 11), indicating that formation of (acid-soluble) metal sulphides was not significant. Even so, the strong reactivity of some metals towards hydrogen sulphide suggests that they will preferably form insoluble sulphides at low sulphide concentrations (Table 13).

Table 11. Mass of hydrogen sulphide extracted during AVS leach step (as mg S).

T1-2,3A	T1-2,3B	T2-2A	T2-2B
0.0312	0.1016	0.1062	0.089

[4] This is consistent with its known propensity to form calcium carbonate minerals, such as calcite or aragonite.

Table 12. Concentrations of various metals in fractions identified by the sequential leach analysis.

	T1-2,3A				T1-2,3B			
	Water	Acetate	CBD	AVS	Water	Acetate	CBD	AVS
Aluminum	0.00	0.00	0.90	10.68	0.00	0.00	1.98	5.12
Cadmium	0.00	0.16	0.05	0.59	0.00	0.04	0.01	0.33
Calcium	4.28	51.60	8.98	21.16	3.50	58.40	8.05	2.98
Chromium	0.00	D.L.	D.L.	0.02	0.00	D.L.	D.L.	0.02
Cobalt	0.00	D.L.	1.50	0.75	0.00	D.L.	0.85	0.24
Copper	0.00	0.04	0.25	1.64	0.00	0.03	0.03	0.62
Iron	0.16	0.11	377.99	684.00	0.00	0.64	292.10	182.40
Lead	0.00	0.02	0.03	2.96	0.00	0.02	0.02	1.25
Magnesium	0.76	4.40	1.17	2.48	0.47	3.12	0.47	1.48
Manganese	0.01	2.24	62.15	244.80	0.00	0.12	52.44	104.40
Nickel	0.00	0.24	3.03	2.44	0.00	0.09	1.64	0.66
Zinc	0.02	9.36	12.88	31.64	0.01	4.36	8.60	14.40
	T2-2A				T2-2B			
Aluminum	0.00	0.00	0.79	1.00	0.00	0.00	1.13	5.28
Cadmium	0.00	0.03	0.07	0.79	0.00	0.03	0.01	0.50
Calcium	4.92	141.20	3.35	72.00	4.04	190.00	6.33	740.00
Chromium	0.00	D.L.	D.L.	0.07	0.00	D.L.	D.L.	0.02
Cobalt	0.00	D.L.	1.72	0.62	0.00	D.L.	0.90	0.29
Copper	0.00	0.01	0.40	1.10	0.00	0.00	0.01	0.62
Iron	0.00	0.01	338.44	544.00	0.00	0.01	385.33	384.80
Lead	0.00	0.02	0.03	0.10	0.00	0.02	0.03	0.10
Magnesium	0.68	4.84	0.80	3.72	0.54	4.84	1.00	7.76
Manganese	0.00	0.04	100.01	356.00	0.00	0.03	59.89	168.00
Nickel	0.00	0.05	4.60	2.51	0.00	0.02	0.56	1.81
Zinc	0.00	2.88	23.39	42.40	0.00	2.28	1.32	33.32

[1] Water-soluble fraction
[2] Exchangeable metals and carbonates
[3] Metals adsorbed onto amorphous iron oxides and manganese oxides
[4] Metals adsorbed onto crystalline iron oxides and manganese oxides, and acid-labile metal sulphides

Table 13. Solubilities of some metal sulphides at 25 °C.

Metal Sulphide	log K_{sp}	Metal Sulphide	Log K_{sp}
Ag_2S	-50.1	FeS	-18.1
Bi_2S_3	-100.0	HgS	-52.7
CdS	-25.8	MnS	-10.5
CoS	-21.3	NiS	-19.4
CuS	-36.1	PbS	-27.5
Cu_2S	-47.7	ZnS	-24.7

Several toxic metals were also solubilized extensively in that leach step, including cadmium, copper, nickel and zinc. Copper has the highest affinity for sulphide and would be expected to preferentially form insoluble sulphides. This is supported by the finding that copper is almost completely absent from the amorphous iron/manganese oxide fraction, yet is present in the AVS fraction. Cadmium, nickel and zinc would be expected to be adsorbed or coprecipitate with the iron and manganese oxides, and become solubilized as these compounds are solubilized.

Distribution of individual metals in extracted fractions

Copper

Copper was present in small amounts in all the muskeg samples tested, with concentrations ranging from 110-460 mg/dry kg (Table 9). It was enriched approximately 3X in the upper organic layer, suggesting some affinity for organic matter.

Most of the copper in muskeg was retained in the AVS fraction (Figure 3). Minor amounts were also extracted in the exchangeable/carbonate and amorphous iron/manganese oxide fractions. Given its strong affinity for sulphide, it is expected that most of the copper was retained in the muskeg as an insoluble sulphide. Additionally, minor amounts were also retained on amorphous iron/manganese oxides, almost exclusively in the top (organic) portion of the soil samples. However, this is deceptive because both iron and manganese oxides were almost more abundant in the top layer of soil (See Figure 7 and Figure 9), and this apparent enrichment of copper may simply reflect an association with iron and manganese.

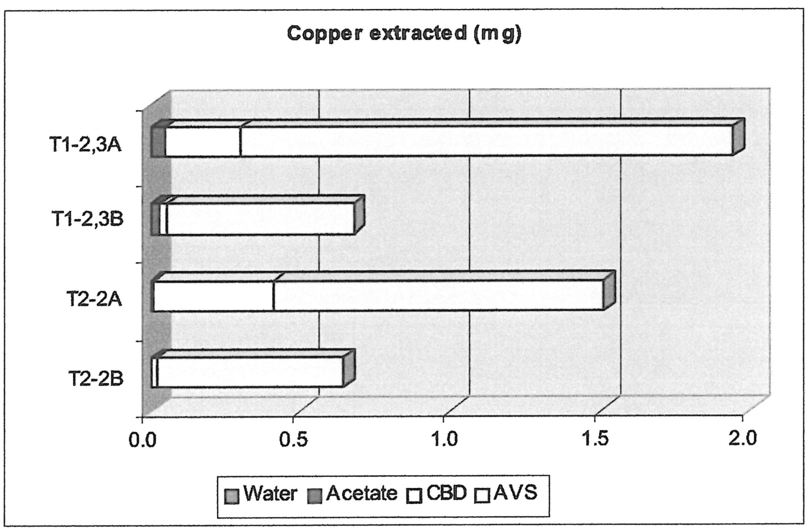

Figure 3. Copper distribution in all the fraction extracted during the leach test.

Cadmium and zinc

Cadmium is known to behave geochemically like zinc, so it is expected that cadmium will be found in the same form as zinc. In fact, these metals are perfectly correlated in the entire data set (r^2=1.000). Given that zinc concentrations are much higher than those for cadmium, this analysis focuses on zinc.

Zinc was one of the most abundant toxic metals in the muskeg, present in concentrations ranging from 4.9-19 g/dry kg. Most of this zinc could be solubilized during the sequential leach (Table 14).

Table 14. Total mass of zinc initially present in muskeg and extracted during the sequential leach.

	Total mass initially present (mg)				Total mass extracted (mg)		
Sample ID	T1-2,3A	T1-2,3B	T2-2A	T2-2B	T1-2,3A	T1-2,3B	T2-2B
Zinc	127	32.1	275	38.8	108	29.5	31.7

Zinc was solubilized in all the fractions that were extracted. It was to be most abundant in the AVS fraction (Figure 4). However, this appears to reflect an association with crystalline iron and manganese oxides. In fact, zinc appears to have a strong affinity to both amorphous and crystalline oxides, since it is strongly correlated with both iron (r^2=0.995) and manganese (r^2=0.977) solubilized during the test. As with copper, the association with amorphous iron/manganese oxides predominated in the upper (organic) layer of soil samples.

The finding of a strong affinity of zinc for iron and manganese oxides is similar to that reported by MacGregor (2000) and is consistent with reports of its geochemical behaviour in wetlands (Sobolewski, 1999). This is not surprising, given the similarity in chemistry of the mine drainage.

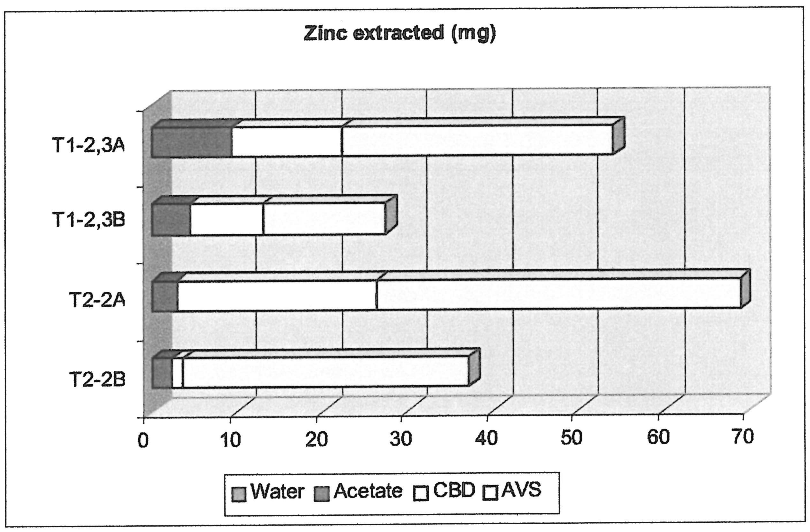

Figure 4. Zinc distribution in all the fraction extracted during the leach test.

Calcium

Calcium was one of the most abundant metals retained in the muskeg. Unlike other metals, calcium was predominantly extracted in the exchangeable/carbonate fraction, except for sample T2-2B, which appears to be anomalous (Figure 5). In the latter, most of the calcium was extracted in the AVS leach. For the former samples, calcium is very likely to have been present as a carbonate. It is also suspected of being a carbonate in sample T2-2B, since addition of HCl in this sample caused considerable foaming, which could only come from the rapid release of carbon dioxide.

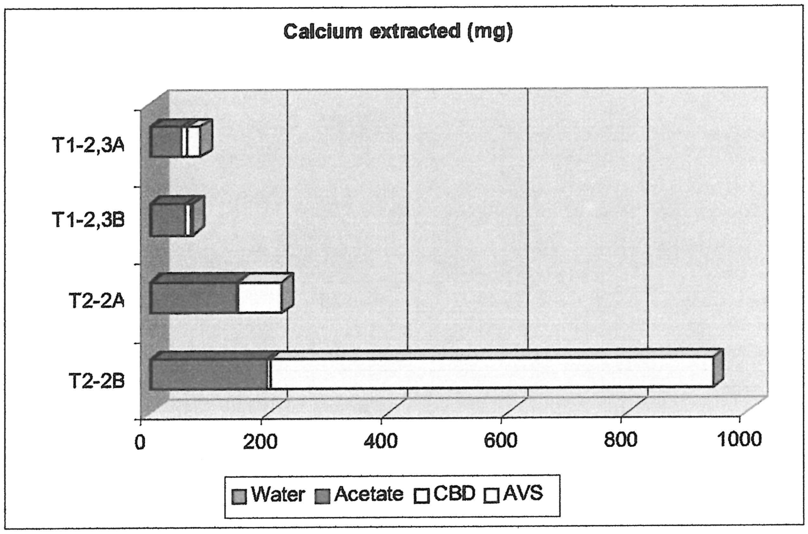

Figure 5. Calcium distribution in all the fraction extracted during the leach test.

Cobalt

Like copper, cobalt was present in very small amounts in muskeg. It was predominantly associated with iron and manganese oxides, since it was almost entirely extracted in the CBD and AVS leach steps. It was enriched in the top (organic) layer of soil, but this seems to reflect the association with iron and manganese oxides.

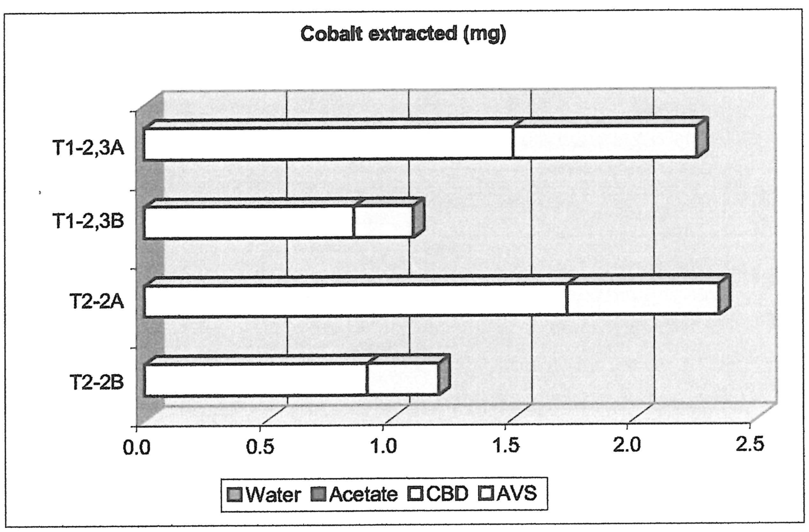

Figure 6. Cobalt distribution in all the fraction extracted during the leach test.

Iron

Iron was the most abundant metal retained in muskeg, with over 1g extracted in the 4 g (ww) sample T1-2,3A. Strikingly, all the iron was extracted in the CBD and AVS leaches (Figure 7), indicating that it was present entirely as an oxide, in various degrees of crystallinity. Iron (and manganese) would not have been present as insoluble sulphides in the AVS fraction because they are relatively soluble (Table 13).

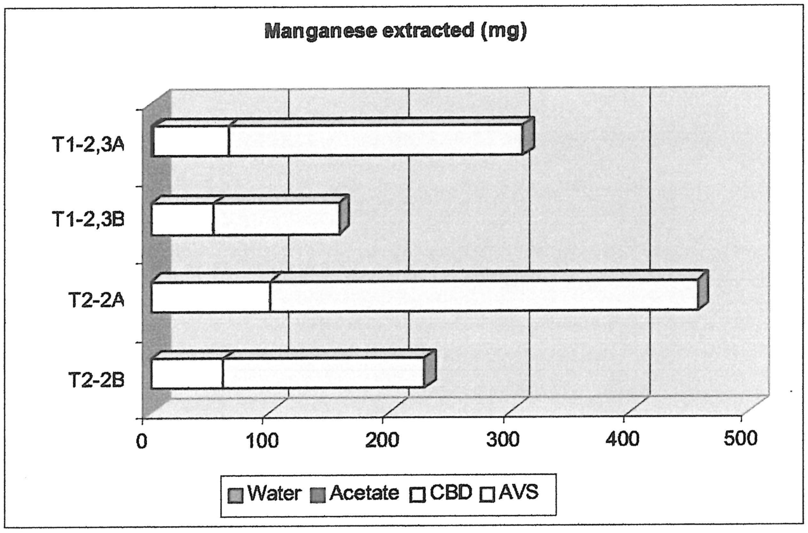

Figure 9. Manganese distribution in all the fraction extracted during the leach test.

Nickel

Nickel was present in small amounts in muskeg. Nickel was predominantly associated with iron and manganese oxides, since it was almost entirely extracted in the CBD and AVS leach steps. It was enriched in the top (organic) layer of soil, but this could also reflect the association with iron and manganese oxides.

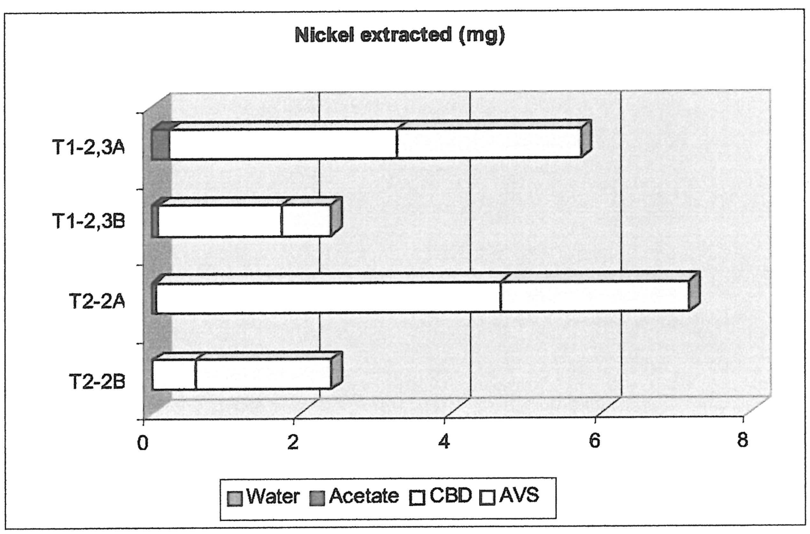

Figure 10. Nickel distribution in all the fraction extracted during the leach test.

Conclusions and Recommendations

The discharge from the Silver King mine is effectively treated by the muskeg below the adit. The present study reveals that treatment is mostly provided by iron and manganese oxides that precipitate within the muskeg and scavenge toxic metals. This would explain the fact that year-round metal removal has been documented, since treatment through biological processes would be expected to decrease or stop altogether during the winter.

Although zinc is the contaminant of greatest concern in the Silver King discharge, other metals were removed by the muskeg. Thus, natural metal attenuation by muskeg may be important at other mine sites, where other contaminants than zinc are found. However, this will only occur if water is similarly neutral, iron and manganese concentrations are high, and biological activity is low enough that reducing conditions do not develop in the muskeg to dissolve iron and manganese oxides.

MacGregor (2000) demonstrated that the Galkeno 300 discharge is effectively treated in the muskeg downstream from the adit. This natural attenuation of zinc-contaminated water was very impressive, with zinc concentrations decreasing from over 150 mg/l to approximately 1.5 mg/L. Zinc removal was also reported to be due mainly to the formation of iron and manganese oxides, and there was a similar enrichment of zinc in the surface, organic layer of soil, compared with the mineral layer below[5]. Given the high reported zinc loadings and the high sustained degree of attenuation by the muskeg, this would suggest that the Silver King adit discharge will also be treated for a long time by the muskeg below. Conversely, the Galkeno 300 adit discharge can reasonably be expected to be treated year-round, as has been observed for the Silver King adit discharge.

[5] However, the available information cannot preclude that this enrichment is due to the preferential precipitation of iron and manganese oxides at the soil surface.

References

MacGregor, D., 2000. Possible Mechanisms of Natural Attenuation of Metal-Bearing Waters in Soils in Northern Climates. Mine Environmental Research Group (MERG) Report 2000-6, March 2000.

Sobolewski, A. 1999. A review of processes responsible for metal removal in wetlands treating contaminated mine drainage. International J. Phytoremediation *1*: 19-51.

Appendix A

Raw data for chemical analyses

Sample ID	T2-2A-S1	T2-2B-S1	T1-2,3A-S1	T1-2,3B-S1	T1-2,3A-S3	T1-2,3B-S3	T2-2A-S3	T2-2B-S3	T1-2,3A-S4	T1-2,3B-S4	T2-2A-S4	T2-2B-S4	T1-2,3A-S6	T1-2,3B-S6	T2-2A-S6	T2-2B-S6	T1-2,3A-S8	T1-2,3B-S8	T2-2A-S8	T2-2B-S8	T1-2,3A-S10	T1-2,3B-S10	T2-2B-S10	T1-2,3A-S8 Gas	T1-2,3B-S8 Gas	T2-2A-S8 Gas	T2-2B-S8 Gas
ALS Sample No.	21	22	23	24	17	18	19	20	1	2	3	4	13	14	15	16	5	6	7	8	25	26	28	9	10	11	12
Total Metals																											
Aluminum	2480	2210	5930	5540	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	16	43	14	20	267	128	162	132	7440	9190	4420	-	-	-	-
Antimony	597	238	294	172	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	<10	<10	10	<10	<20	<20	29	25	337	63	398	-	-	-	-
Arsenic	730	380	640	280	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	<10	<10	<10	<10	69	<20	49	40	110	<100	330	-	-	-	-
Barium	285	115	215	111	0.021	<0.010	<0.010	<0.010	0.33	<0.20	<0.20	<0.20	0.67	<0.50	<0.50	<0.50	4.7	3.1	1.8	5.9	169	63.1	260	-	-	-	-
Beryllium	<1.0	<0.50	0.85	<0.50	<0.0050	<0.0050	<0.0050	<0.0050	<0.10	<0.10	<0.10	<0.10	<0.25	<0.25	<0.25	<0.25	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<2.0	-	-	-	-
Bismuth	<40	<20	<20	<20	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	<10	<10	<10	<10	<20	<20	<20	<20	<20	<20	<60	-	-	-	-
Boron	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<2.0	<2.0	<2.0	<2.0	<5.0	<5.0	<5.0	<5.0	<10	<10	<10	<10	-	-	-	-	-	-	-
Cadmium	263	86.1	134	67.3	<0.010	<0.010	<0.010	<0.010	3.93	0.97	0.74	0.85	0.85	<0.50	1.17	<0.50	14.8	8.2	19.8	12.5	14.5	2.6	8.4	-	-	-	-
Calcium	54500	94800	12200	14500	107	87.5	123	101	1290	1460	3530	4750	159	175	59.3	112	529	74.6	1800	18500	5740	3410	7640	-	-	-	-
Chromium	7.2	5.2	12.3	9.6	<0.010	<0.010	<0.010	<0.010	<0.20	<0.20	<0.20	<0.20	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	1.7	<1.0	15.0	14.4	20.2	-	-	-	-
Cobalt	682	206	348	179	<0.010	<0.010	<0.010	<0.010	<0.20	<0.20	<0.20	<0.20	26.6	18.5	30.5	16.0	18.8	6.1	15.5	7.3	15.7	4.7	12.0	-	-	-	-
Copper	460	110	378	143	0.014	<0.010	<0.010	<0.010	1.08	0.69	0.27	<0.20	4.51	0.57	7.10	<0.50	41.0	15.6	27.4	15.6	90.4	20.9	87.5	-	-	-	-
Iron	278000	107000	195000	110000	4.12	<0.030	<0.030	<0.030	2.86	15.9	<0.60	<0.60	6690	6350	5990	6820	17100	4560	13600	9620	20800	11000	19500	-	-	-	-
Lead	<100	<50	524	163	<0.050	<0.050	<0.050	<0.050	<1.0	<1.0	<1.0	<1.0	<2.5	<2.5	<2.5	<2.5	73.9	31.3	<5.0	<5.0	127	2940	<200	-	-	-	-
Lithium	<4.0	4.5	4.5	6.5	0.040	0.018	0.040	0.020	<0.20	<0.20	0.21	<0.20	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	<1.0	<1.0	6.1	8.7	<6.0	-	-	-	-
Magnesium	2600	1900	1990	2570	18.9	11.7	16.9	13.5	110	78.1	121	121	20.7	10.2	14.1	17.7	62	37	93	194	1280	3640	1330	-	-	-	-
Manganese	156000	47600	61300	32100	0.363	<0.0050	<0.0050	<0.0050	55.9	2.88	0.99	0.73	1100	1140	1770	1060	6120	2610	8900	4200	4510	430	1780	-	-	-	-
Molybdenum	18.4	6.9	10.9	5.4	<0.030	<0.030	<0.030	<0.030	<0.60	<0.60	<0.60	<0.60	<1.5	<1.5	<1.5	<1.5	<3.0	<3.0	<3.0	<3.0	<4.0	<4.0	<20	-	-	-	-
Nickel	1880	459	952	404	<0.050	<0.050	<0.050	<0.050	6.1	2.3	1.2	<1.0	53.6	35.6	81.5	9.9	61.1	16.5	62.7	45.2	76.5	19.0	179	-	-	-	-
Phosphorus	570	215	738	333	<0.30	<0.30	<0.30	<0.30	<6.0	<6.0	<6.0	<6.0	<15	<15	<15	<15	81	36	46	<30	257	56	310	-	-	-	-
Potassium	470	390	1170	620	6.8	<2.0	2.8	<2.0	<40	<40	<40	<40	<100	<100	<100	<100	<200	<200	<200	<200	1440	890	790	-	-	-	-
Selenium	<100	<50	<50	<50	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	<10	<10	<10	<10	<20	<20	<20	<20	<50	<50	<200	-	-	-	-
Silicon	-	-	-	-	5.64	3.64	4.58	3.58	58.3	63.7	41.6	36.3	49.5	103	51.7	86.4	322	59.7	277	187	-	-	-	-	-	-	-
Silver	14.7	6.0	71.4	22.0	<0.010	<0.010	<0.010	<0.010	<0.20	<0.20	<0.20	<0.20	<0.50	<0.50	<0.50	<0.50	6.6	1.6	<1.0	<1.0	50.3	27.9	9.9	-	-	-	-
Sodium	-	-	-	-	2.1	<2.0	<2.0	<2.0	10500	12800	10900	12300	32200	36800	33600	33300	7630	2130	5180	3090	-	-	-	-	-	-	-
Strontium	109	93.1	59.6	33.8	0.212	0.139	0.204	0.159	3.37	2.95	4.73	4.77	0.97	0.86	0.43	0.59	2.69	<0.50	3.65	13.1	21.1	12.0	14.3	-	-	-	-
Thallium	<100	<50	<50	<50	<0.20	<0.20	<0.20	<0.20	<4.0	<4.0	<4.0	<4.0	<10	<10	<10	<10	<20	<20	<20	<20	<50	<50	<200	-	-	-	-
Tin	<20	<10	<10	<10	<0.030	<0.030	<0.030	<0.030	<0.60	<0.60	<0.60	<0.60	<1.5	<1.5	<1.5	<1.5	<3.0	<3.0	<3.0	<3.0	<10	<10	<30	-	-	-	-
Titanium	6.6	31.3	40.6	277	<0.010	<0.010	<0.010	<0.010	<0.20	<0.20	<0.20	<0.20	<0.50	2.64	<0.50	<0.50	1.3	9.7	<1.0	<1.0	105	731	126	-	-	-	-
Vanadium	<4.0	<2.0	<2.0	30.0	<0.030	<0.030	<0.030	<0.030	<0.60	<0.60	<0.60	<0.60	<1.5	<1.5	<1.5	<1.5	<3.0	<3.0	<3.0	<3.0	13.8	33.9	16.9	-	-	-	-
Zinc	19300	5770	8910	4900	0.384	0.263	0.0779	0.0468	234	109	72.0	56.9	228	187	414	23.3	791	360	1060	833	1310	178	497	-	-	-	-
Inorganic																											

Parameters																											
Sulphide S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.56	5.08	5.31	4.45

Evaluation of metal removal in muskeg below the Silver King Mine – Addendum

A Project Report submitted to:

Laberge Environmental

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Executive Summary

Microbial Technologies, Inc. was contracted by Laberge Environmental to analyze muskeg samples collected below the Silver King Mine, Elsa, Yukon. These samples (T2-1A and T2-1B) were collected outside the presumed flowpath of the Silver King discharge, to compare their metal concentrations and distribution with those of muskeg samples collected within the flowpath (T1-2,3 and T2-2 samples).

For metals present in the Silver King discharge, samples T2-1A and T2-1B had between 10-100 lower concentrations than samples collected in the flowpath. For other metals, all samples had comparable concentrations.

Key metals had different distributions in samples T2-1A and T2-1B compared with the other muskeg samples. In particular, copper, lead and zinc were almost entirely in the acid-volatile sulphide (AVS) fraction in the former samples, whereas they were distributed among iron/manganese oxides and sulphides in the latter samples. The release of hydrogen sulphide during the AVS leach of T2-1A, but not T2-1B, suggests that these metals were held as insoluble sulphides in that sample. The distribution of zinc was poorly correlated with that of iron and manganese in the T2-1A and T2-1B samples, whereas it was very strongly correlated with them in the T1-2,3 and T2-2 samples.

The additional study confirms the conclusions of the original study, and shows that metals are retained differently in muskeg outside the flowpath of the Silver King Mine discharge.

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Introduction

Water discharged from the Silver King Mine adit contains 1-2 mg/L zinc. This water is allowed to flow over muskeg downstream from the discharge point, where it is removed very effectively, even in the dead of winter. A previous study by Microbial Technologies, Inc. demonstrated that much of this zinc, as well as other metals, was removed by iron and manganese oxides that form within the surface peat. This was determined through a diagnostic sequential leach analysis, which identified the geochemical fraction that effect metal removal.

A concern arose that some of the samples analyzed in the above study had abnormally high calcium concentrations, possibly arising from the presence of lime that was previously deposited in the vicinity. This may have skewed the results of the study, and it was felt that an additional set of control samples ought to be analyzed by the same method to determine if metals behaved differently. The results of this new set of analyses are presented below.

Materials and Methods

The sequential leach analysis was conducted following the procedures exactly as described in the previous report[1], and they will not be repeated here. Briefly, four grams of the organic layer and the mineral layer of sample T2-1 were exposed to a sequence of leaches:

1. Water leach, for water-soluble fraction
2. 1 Molar acetate (pH 5) leach, for exchangeable and carbonate fractions
3. Citrate-bicarbonate-dithionite leach at 75 ºC, for iron and manganese oxide fractions
4. 1 M HCl leach, for acid-volatile sulphide fraction
5. Residual analysis by total solid digest

After each of the above extraction, a water rinse was performed to remove residual reagent. The leaches were carried out in 45 mL glass centrifuge tubes, facilitating the separation of solids from liquids for each extraction. All the leachates were preserved with nitric acid and, together with the residual solids, were shipped to ALS Analytical services Labs, Inc. for metal analysis by ICP scan.

[1] Sobolewski, A. 2003. Evaluation of metal removal in muskeg below the Silver King Mine. Report prepared for Laberge Environmental Services. 25 pp. + Appendices.

Results and Discussion

Characteristics of samples tested

Sample SKT2-1, fractions A and B (i.e., organic and mineral fractions) was chosen for the additional sequential leach analysis, as it was located to the East of the visible flowpath for the Silver King discharge, 50 m below the discharge point. These samples were peaty in appearance and devoid of obvious iron oxide/oxyhydroxide precipitates. They were analyzed for metals (Table 1), and these concentrations are compared with those from two nearby samples located in the flowpath of the Silver King discharge (in light blue).

Table 1. Total metal content (mg/dry kg) of muskeg samples analyzed in this and previous study.

Sample ID	T2-1A	T2-1B	T2-2A	T2-2B	Sample ID	T2-1A	T2-1B	T2-2A	T2-2B
Aluminum	1,190	10,400	2,480	2,210	Magnesium	1,380	5,690	2,600	1,900
Antimony	<20	<20	597	238	Manganese	279	574	156,000	47,600
Arsenic	<100	<100	730	380	Molybdenum	<4.0	<4.0	18.4	6.9
Barium	128	161	285	115	Nickel	6.5	17.8	1,880	459
Cadmium	<2.0	<2.0	263	86.1	Phosphorus	609	399	570	215
Calcium	14,400	5,650	54,500	94,800	Potassium	960	730	470	390
Chromium	<2.0	18.1	7.2	5.2	Silver	<2.0	<2.0	14.7	6.0
Cobalt	<2.0	6.4	682	206	Strontium	32	18.7	109	93.1
Copper	7.1	18	460	110	Titanium	62.8	358	6.6	31.3
Iron	1,850	22,300	278,000	107,000	Zinc	82.6	51	19,300	5,770
Lead	<50	<50	<100	<50					

Metals concentrations in the T2-1 samples are strikingly lower compared with T2-2 samples, notably calcium, cobalt, copper, iron, manganese, nickel and zinc. Except for calcium, these metals were more abundant in the organic layer of sample T2-2 by factors ranging from 65-560. The enrichments were less dramatic in the mineral layer, ranging from 26-113. Without a doubt, these enrichments reflect the contribution of metals from the Silver King discharge and their retention in the muskeg.

Sequential leach analysis

The following fractions were identified by the sequential leach analysis:

1. Water-soluble fraction (water leach)
2. Exchangeable and carbonate fraction (1M acetate pH 5.0 leach)
3. Iron and manganese oxides (Citrate-Bicarbonate-Dithionite, “CBD” leach)
4. Amorphos metal sulphides (1M HCl, “AVS” leach)
5. Residual fraction (organic matter, acid-resistant sulphides, occluded)

Each of these fractions reflects specific geochemical processes responsible for the retention of metals in muskeg. These fractions shown in Table 2, and will be compared with those of sample T2-2.

Table 2. Metal concentrations in fractions from control samples (T2-1A and B) determined by sequential leach analysis.

	T2-1A					T2-1B				
	Water	Acetate	CBD	AVS	SUM	Water	Acetate	CBD	AVS	SUM
Aluminum	0.00	0.00	0.00	0.07	0.07	0.01	0.00	2.74	2.07	4.82
Barium	0.00	0.01	0.02	0.01	0.04	0.00	0.06	0.18	0.19	0.43
Calcium	0.44	4.52	2.99	0.63	8.57	0.52	6.95	5.58	2.68	15.7
Copper	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.04	0.29	0.33
Iron	0.01	0.00	0.89	34.9	35.8	0.05	0.02	22.0	7.80	29.9
Lead	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.09	0.09
Magnesium	0.08	0.47	0.19	0.03	0.77	0.08	0.83	0.40	0.93	2.33
Manganese	0.00	0.07	0.18	0.60	0.86	0.00	0.03	1.23	0.15	1.41
Phosphorus	0.00	0.10	0.00	0.02	0.12	0.00	0.00	0.00	0.56	0.56
Potassium	0.15	0.55	0.00	0.00	0.70	0.00	0.00	0.00	0.13	0.13
Strontium	0.00	0.01	0.01	0.00	0.02	0.00	0.01	0.02	0.01	0.04
Zinc	0.02	0.03	0.07	0.24	0.36	0.01	0.01	0.05	0.40	0.47

Table 3. Metal concentrations in fractions from original samples (T2-2A and B) determined by sequential leach analysis.

	T2-2A					T2-2B				
	Water	Acetate	CBD	AVS	SUM	Water	Acetate	CBD	AVS	SUM
Aluminum	0.00	0.00	0.79	1.00	1.79	0.00	0.00	1.13	5.28	6.41
Cadmium	0.00	0.03	0.07	0.79	0.89	0.00	0.03	0.01	0.50	0.55
Calcium	4.92	141	3.35	72.0	221	4.04	190	6.33	740	940
Copper	0.00	0.01	0.40	1.10	1.51	0.00	0.00	0.01	0.62	0.64
Iron	0.00	0.01	338	544	882	0.00	0.01	385	385	770
Lead	0.00	0.02	0.03	0.10	0.15	0.00	0.02	0.03	0.10	0.15
Magnesium	0.68	4.84	0.80	3.72	10.0	0.54	4.84	1.00	7.76	14.14
Manganese	0.00	0.04	100	356	456	0.00	0.03	59.9	168	228
Phosphorus	-	-	-	-	-	-	-	-	-	-
Potassium	-	-	-	-	-	-	-	-	-	-
Strontium	-	-	-	-	-	-	-	-	-	-
Zinc	0.00	2.88	23.4	42.4	68.7	0.00	2.28	1.32	33.3	36.9

The initial water leach did not release metals in any of the samples (Table 2). Some calcium, magnesium and potassium were released, much as for the T2-2 samples.

The acetate leach released most of the calcium and magnesium in both T2-1 samples, much like the T2-2 samples (Table 2 vs Table 3). However, compared to T2-2, the amounts released by the T2-1 samples are a thirtieth (1/30) for calcium and a tenth (1/10) for magnesium. In both cases, these elements were likely held as exchangeable cations or as carbonates.

The CBD leachate (which leaches iron and manganese oxides) released both iron and manganese from the T2-1 samples, but there were difference between the upper (organic) and lower (mineral) portions of this sample. The upper, organic fraction (T2-1A) released only 2.5% of its iron content in the CBD leach, whereas the lower, mineral fraction (T2-1B) released 74%. T2-1A released 21% of its manganese content in the CBD leach, compared with 87% for T2-1B. Thus, iron and manganese oxides accumulated in the mineral layer of sample T2-1.

The above contrasts with the large amounts of iron and manganese released in the same fraction from the T2-2 samples: 400-500 times more released from T2-2A and 20-50 times more released from T2-2B. Clearly, T2-2 was exposed to, and retained much more iron and manganese than T2-1.

Unlike for the T2-2 samples, little of the toxic metals (copper, lead, zinc) held in the T2-1 samples were solubilized in the CBD leachate. This result indicates that copper, lead, and zinc were not associated with iron and manganese oxides in the T2-1 samples. This view is corroborated by the fact that these metals did not accumulate more in T2-1B than in T2-1A, despite its greater concentrations of iron and manganese oxides.

Substantial amounts of calcium were released in the CBD leach of sample T2-1. Proportionally, much more calcium was released from that fraction than for the T2-2 samples: 35% for T2-1, compared with 1% for T2-2.

Most of the toxic metals (copper, lead, zinc) held in the T2-1 samples were solubilized in the hydrochloric acid (AVS) leach. However, their amounts were a fraction of the amount released in sample T2-2. Most of the aluminum, iron, and manganese held in T2-1 were solubilized by the HCl leach in T2-1A, but not in T2-1B.

Surprisingly more hydrogen sulphide was recovered in T2-1A than in T2-1B, or in the T2-2 samples (Table 4). Considering that most of copper, iron, lead and zinc were also released during the AVS leach of T2-1A, this result suggests that they were probably held as insoluble, acid-soluble sulphides.

Table 4. Mass of hydrogen sulphide extracted during AVS leach step (as mg S).

T2-1A	T2-1B	T2-2A	T2-2B
14.2	0.073	0.1062	0.089

Distribution of selected metals in extracted fractions

The distribution of calcium, iron, manganese, and zinc in the fractions extracted during the sequential leach of the T2-1 samples is presented below. Their distribution is compared with that of the corresponding metals in the original samples (T1-2,3; T2-2). All the results for the T2-1 samples are plotted at one-tenth the scale of the original samples, which gives a good idea of the differences between these samples. This is slightly awkward for metals that are at low concentrations in the T2-1 samples, but it helps to appreciate differences with the original samples.

Calcium

Calcium was predominantly extracted in the acetate leach in the T2-1 samples (Figure 1), indicating that it was mostly present as an exchangeable cation or as a carbonate. However, large amounts were also extracted in the CBD leach. This distribution contrasts with that for the T1-2,3 and T2-2A samples, in which calcium was much more abundant in the acetate leach than the CBD leach (Figure 2). In these samples, it was present at approximately 10X higher concentrations than in the T2-1 samples.

Sample T2-2B was markedly different, having much higher calcium concentrations than all the other samples. The fact that most of the calcium was extracted in the acid (AVS) leach appears to reflect this: high calcium carbonate concentrations would have neutralized the leach solution pH in the acetate extraction step, preventing its thorough extraction. The unextracted calcium would be solubilized in an acid leach, as observed (Figure 2).

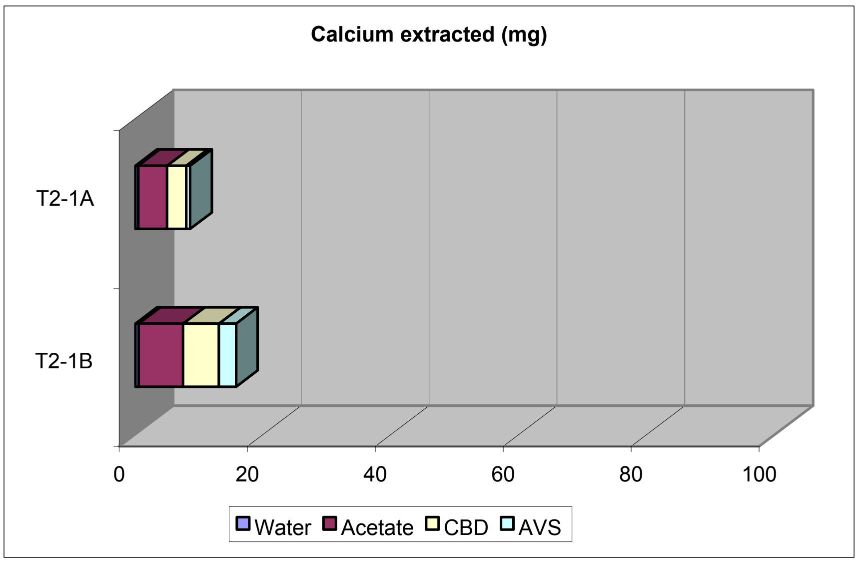

Figure 1. Calcium extracted from the control samples during the leach test.

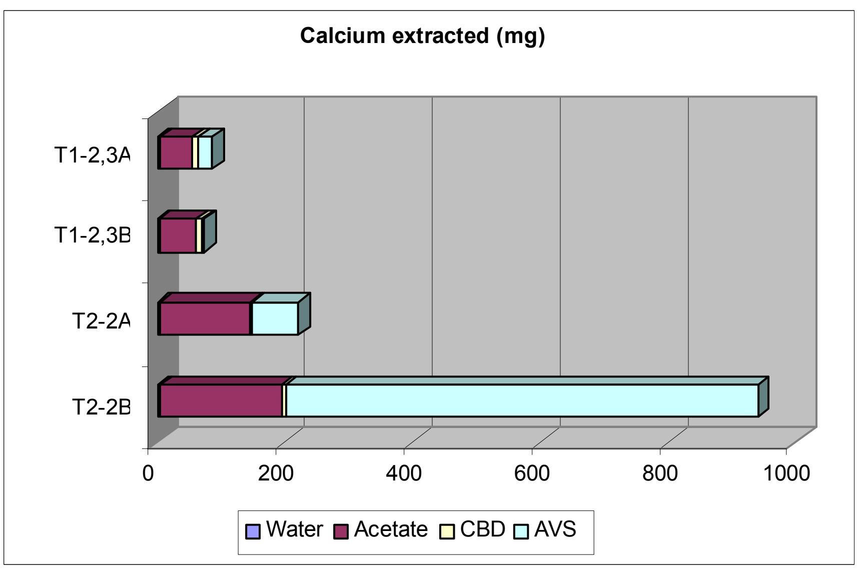

Figure 2. Calcium extracted from the original samples during the leach test.

Iron

Iron concentrations in the T2-1 samples were one order of magnitude lower than in the T1-2,3 and T2-2 samples. Its distribution was also distinctly different: most of the iron in T2-1A was in the AVS fraction, and in the CBD fraction in T2-1B (Figure 3). In contrast, iron was evenly distributed between the CBD and AVS fractions in the T1-2,3 and T2-2 samples (Figure 4).

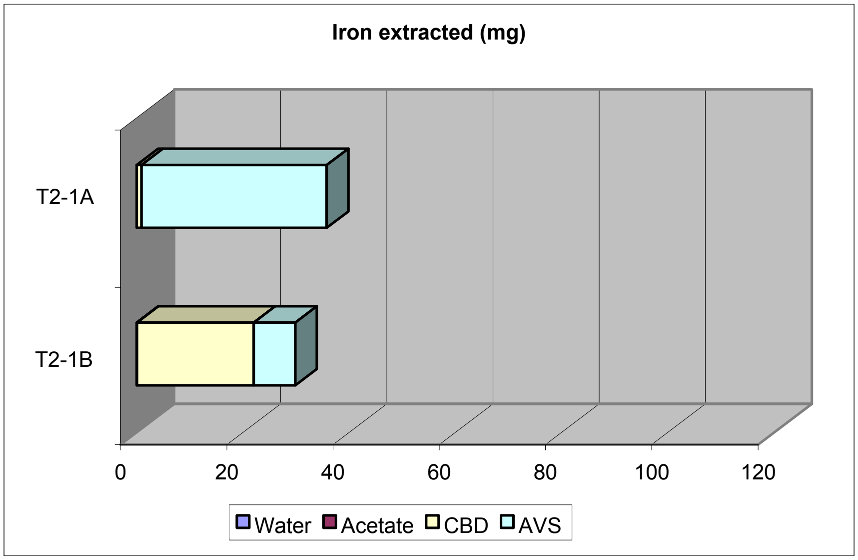

Figure 3. Iron extracted from the control samples during the leach test.

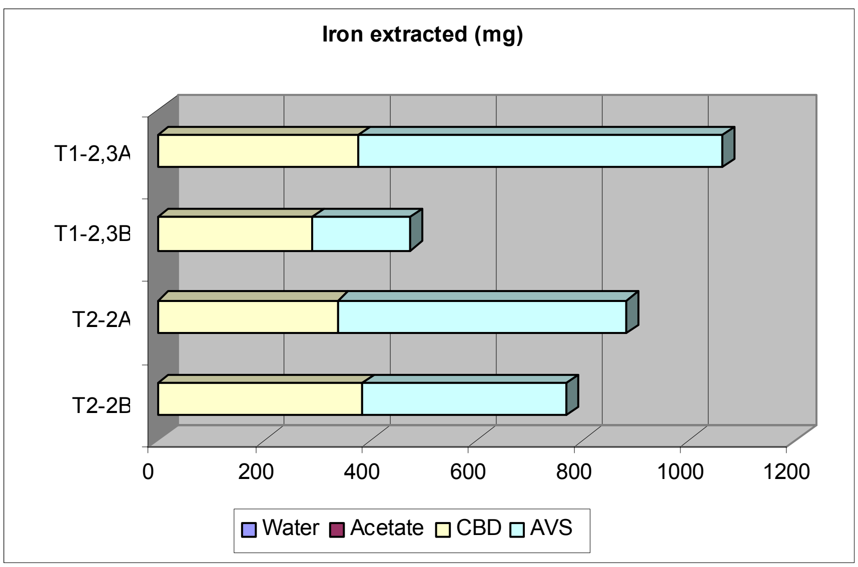

Figure 4. Iron extracted from the original samples during the leach test.

Manganese

Manganese concentrations in the T2-1 samples were two orders of magnitude lower than in the T1-2,3 and T2-2 samples. Its distribution in these samples was similar to that of iron: most of the manganese in T2-1A was in the AVS fraction, and in the CBD fraction in T2-1B (Figure 5). As with iron, manganese was distributed more evenly in the T1-2,3 and T2-2 samples, although it was more predominant in the

AVS fraction than in the CBD fraction (Figure 6). Thus, both iron and manganese concentrations and distribution were distinctly different between the T2-1 samples and the T1-2,3 and T2-2 samples.

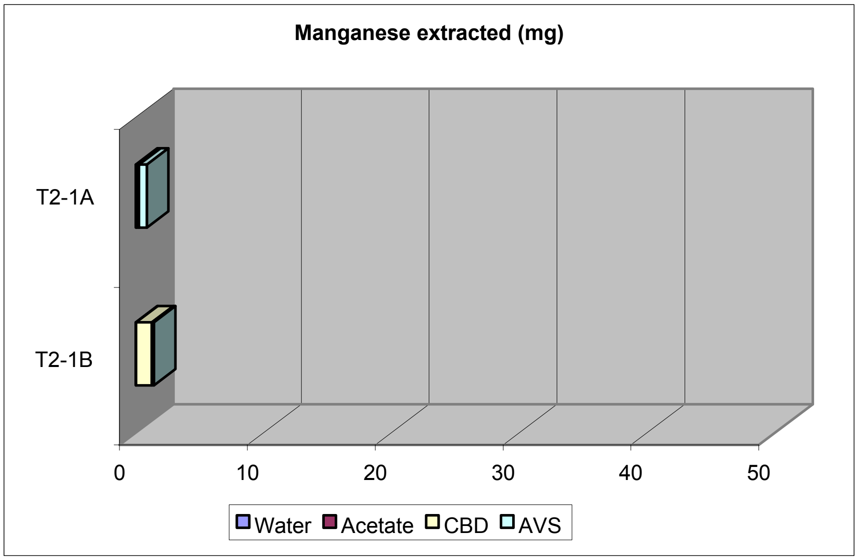

Figure 5. Manganese extracted from the control samples during the leach test.

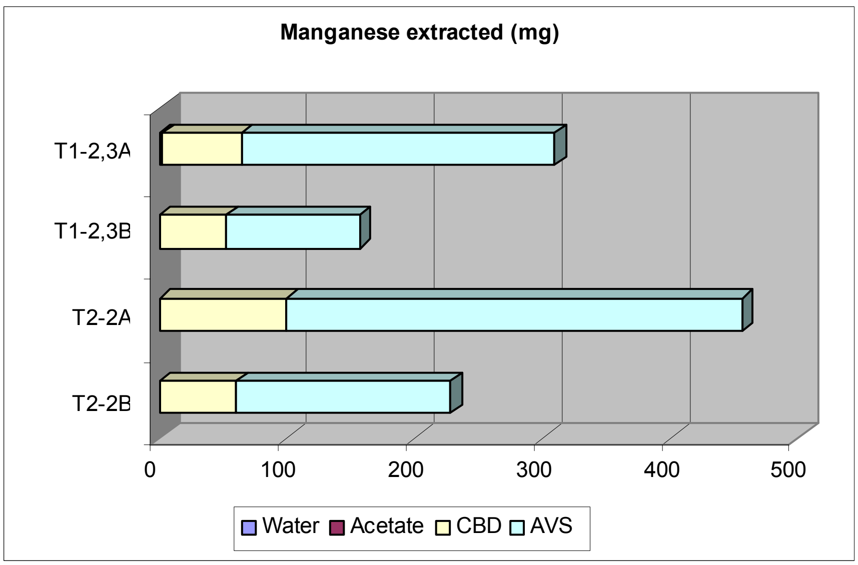

Figure 6. Manganese extracted from the original samples during the leach test.

Zinc

Zinc was almost entirely in the AVS fraction in the T2-1 samples (Figure 7). It was more evenly distributed in the other fractions in T1-2,3 and T2-2 samples, although it was mainly in the AVS fraction as well (Figure 8). Its concentrations in these samples were at least one order of magnitude higher than in the T2-1 samples.

Zinc in the T2-1 samples was not correlated with either iron (r^2=0.44) or manganese (r^2=0.099). This contrasts with the T1-2,3 and T2-2 samples, in which it appeared to have a strong affinity to both iron and manganese oxides, being strongly correlated with iron (r^2=0.995) and manganese (r^2=0.977) solubilized during the test.

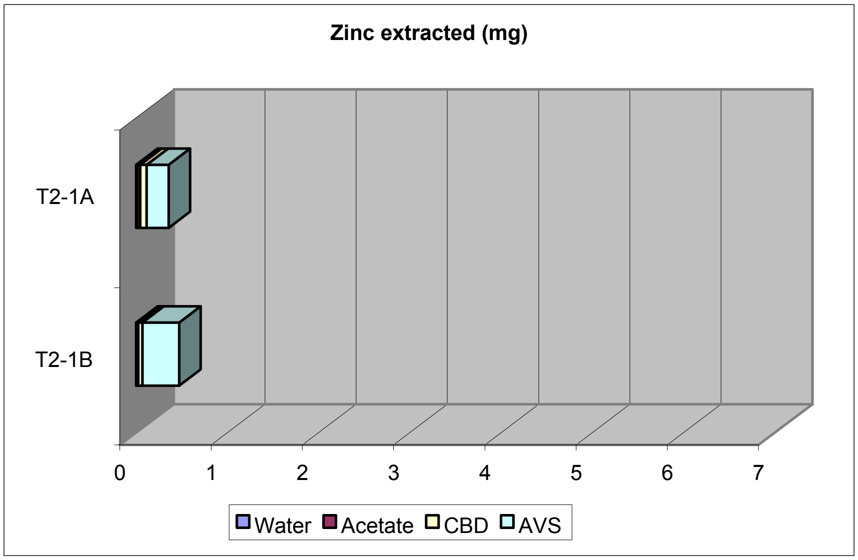

Figure 7. Zinc extracted from the control samples during the leach test

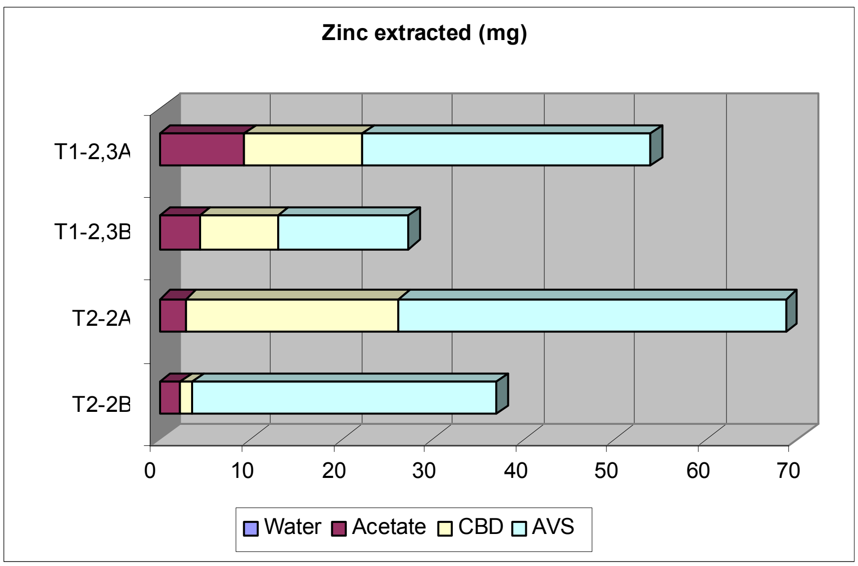

Figure 8. Zinc extracted from the original samples during the leach test.

Conclusions

Upon review of the original study, a concern was expressed that muskeg samples were collected from an area where lime had been applied. This was thought to possibly skew metal distributions and invalidate the study results. Indeed, sample T2-2B has very high calcium concentrations, and its predominance in the acetate and AVS fractions may reflect a high lime content, as discussed earlier. This may have affected zinc distribution in that sample, since zinc was mostly present in the AVS fraction, rather than being distributed between that and the CBD fraction, as with all other samples (T1-2,3A/B, T2-2A).

Aside from that anomalous sample (T2-2B), the original samples (T1-2,3A/B, T2-2A) had consistently similar metal distributions. The present sequential leach analysis shows that they had 10X higher metal concentrations than the T2-1A/B samples, at least for metals present in the Silver King discharge (e.g., cadmium, copper, iron, lead, manganese, nickel, and zinc)[2]. Their distributions were similar among samples T1-2,3A/B, T2-2A, and they were significantly different from those in T2-1A/B. This suggests that the same factors governed the retention of metals in the original muskeg samples, and that they were significantly different from those acting in the T2-1A/B samples.

Given the strong correlation between iron, manganese and zinc in samples T1-2,3 and T2-2, it was concluded that, to a large degree, zinc was retained on the surface of iron and manganese oxides in these samples. In contrast, zinc was poorly correlated with either of these metals in the T2-1 samples, indicating that it was retained differently. Its predominance in the AVS fraction in the T2-1 samples suggests that it was present as an insoluble sulphide, an idea supported for sample T2-1A, which produced large amounts of hydrogen sulphide during the AVS extraction. For the other sample, as for the T2-2 samples, the lack of hydrogen sulphide recovered during the AVS extraction indicates that zinc was retained in another form.

In summary, metal concentrations in the T2-1 samples were much lower than in the T1-2,3A/B, T2-2A/B samples analyzed in the original study. In addition, the distribution of key metals, such as iron, manganese and zinc, was different, indicating that they were governed by different geochemical factors. Finally, the consistency of metal distributions in samples T1-2,3A/B, T2-2A indicates that the geochemical factors were acting similarly for muskeg in the flowpath of the Silver King Mine discharge.

[2] In addition, metals not expected in the Silver King Mine discharge, like aluminum, barium or titanium, were present in comparable concentrations in all the muskeg samples analyzed in both studies.

APPENDIX B

WATER QUALITY ANALYTICAL DATA, 2003 AND 2004

Norwest Labs

NORWEST LABS

INFORMATION SHEET WATERS

CONTROL NUMBER W 51488

RESULTS & INVOICE TO:	COPY OF RESULTS TO:	WORK ORDER NO. / DATE STAMP
COMPANY: ACG	COMPANY: LES	
ADDRESS: 204D Strickland St. Whitehorse	ADDRESS:	
CITY/TOWN:	CITY/TOWN:	
PROVINCE: Y.T.	PROVINCE:	
POSTAL CODE: Y1A 2J8	POSTAL CODE:	
ATTENTION: DAN CORNETT	ATTENTION: KEN NORDIN	
PHONE: 867 668 6463	PHONE:	
FAX:	FAX:	
CELL: dan@accessconsulting.ca	CELL: Laberge@internorth.com	

PURCHASE ORDER NO.:	PROJECT REF.:	REF./QUOTE NO.:
	G300 FUGITIVE FLOW INVESTIGATION	

DATE SAMPLED D 23 M 03 Y 04 NUMBER OF SAMPLES WATER 12 LIQ WASTE OTHER (SPECIFY)

SPECIAL INSTRUCTIONS (SEE OVER FOR IMPORTANT SAMPLE INFORMATION INSTRUCTIONS AND ANALYSIS CODES)

- metals samples field filtered and preserved.
- Bioassay under seperate cover

QA REPORT ✓

RUSH
(UPON FILLING IN THIS SECTION THE CLIENT ACCEPTS THAT SURCHARGES WILL BE ATTACHED TO THE ANALYSIS)
NORWEST AUTHORIZATION
NAME DATE
RUSH DATE REQUIRED D M Y
TIME HR. MIN.

CLIENT NO.
LP
COMPLETION DATE D M Y

SAMPLE CUSTODY	SAMPLED BY	RECEIVED BY	RELINQUISHED BY	RECEIVED BY
	K. NORDIN		K. NORDIN	Donna
COMPANY	LES		LES	297577
DATE	23/24 03/04		25/03/04	MAR26/04

	SITE I.D.	SAMPLE DESCRIPTION	OTHER	ANALYSIS PACKAGE CODES (USE CODES LISTED ON THE REVERSE OF THIS SHEET)	LAB CODING
1	KV1	South McQuesten u/s Christal		TOTAL & DISSOLVED METALS,	
2	KV2	South McQuesten @ Pump House Pond		ALK, SO4, pH, COND,	
3	KV7	Christal Creek @ Hanson L Road		TSS, HARDNESS	
4	KV7B	Christal Creek @ mouth	–		
5	Site (A)	Christal Creek site A	–		
6	Site (C)	~~CD~~ Fugitive Flow @ C	–		
7	Site (D)	Christal Creek site D	–		
8	ACGWQ5	Christal Creek u/s Hwy	–		
9	Culvert #4	G300 Fugitive Flow Culvert #4			
10	G300 Adit	Galkeno 300 Adit flow	–		
11	GK300 EFF.	POND EFFLUENT GK300	–		
12	DUPLICATE		–		
13			–		
14					
15					

AGRI-FOOD ENVIRONMENTAL

EDMONTON PH. (403) 438-5522 FAX (403) 434-8586
CALGARY PH. (403) 291-2022 FAX (403) 291-2021
LANGLEY PH. (604) 530-4344 FAX (604) 534-9996
LETHBRIDGE PH. (403) 329-9266 FAX (403) 327-8527
WINNIPEG PH. (204) 982-8630 FAX (204) 275-6019

ENERGY RESOURCE

EDMONTON PH. (403) 454-1504 FAX (403) 451-4022
CALGARY PH. (403) 291-3024 FAX (403) 250-2819
GRANDE PRAIRIE PH. (403) 532-8709 FAX (403) 539-0611
FORT ST. JOHN PH. (250) 785-2731 FAX (250) 785-7092
ESTEVAN PH. (306) 634-7218 FAX (306) 634-4101

NOTE: Please complete this form in its entirety to ensure correct testing and reporting requirements.

ACCREDITED BY THE STANDARDS COUNCIL OF CANADA FOR SPECIFIC TESTS.

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Report Transmission Cover Page

Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

Copies	Contact	Company		Address				
1	Dan Cornett	Access Mining Consultants Ltd.		204D Strickland Street	Fax	x	Post	x
				Whitehorse, YT	Email	x	Pickup	
				Y1A 2J8	Custom Email		Courier	
			Phone:	(867) 668-6463	Web		Hand	
			Fax:	(867) 667-6680	Email Notification			
			Email:	dan@accessconsulting.ca				

________ # OF PAGES IN THIS TRANSMISSION

Report Transmission Notes

Agreement Notes

Lot Notes

Sample Notes:

Notes to Clients

Lot Notes:

Due to instrument difficulties at NWL-Surrey, reported ICP results were obtained by NWL-Edmonton low-level ICP analysis. [KR Apr-7-04]
NWL-Edmonton ICP analysis does not include element Thorium; therefore reported results do not list "Th". [KR Apr-7-04]

Sample Notes:

Batch Notes:

Method Notes:

Method Result Notes:

Reports associated with this Lot

Id/Format/Reported Date	Id/Format/Reported Date	Id/Format/Reported Date
530573 Envir2QC 3 Smp & DL 7-Apr-04		

Comment:
See Methodology and Notes page of Analytical Report for all comments pertaining to this report.

If this report transmission is not satisfactory, please send report requirements to the address at the top of this page.

NORWEST LABS

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Sample Custody

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Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

Sample Disposal Date: May 07, 2004

All samples will be stored until this date unless other instructions are received. Please indicate other requirements below and return this form to the address or fax number on the upper right of this page.

__________ **Extend Sample Storage Until** _______________ **(MM/DD/YY)**

The following charges apply to extended sample storage:

Storage for 1 to 5 samples per month	$ 10.00
Storage for 6 to 20 samples per month	$ 15.00
Storage for 21 to 50 samples per month	$ 30.00
Storage for 51 to 200 samples per month	$ 60.00
Storage for more than 200 samples per month	$ 110.00

__________ **Return Sample, collect, to the address below via:**

________ Greyhound
________ Loomis
________ Purolator
________ Other (Specify) _______________

Name: ____________________
Company: ____________________
Address: ____________________
____
Phone: ____________________
Fax: ____________________
Signature: ____________________

If no other arrangements have been made, samples will be disposed of on May 07, 2004.

NORWEST LABS

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Surrey, BC. V3S 8P8
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Fax: (604) 514-3323

Analytical Report

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204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

		NWL Number	297577-1	297577-2	297577-3	
		Sample Description	KV 1 - South McQuesten u/s Christal / 23 & 24 - Mar-04	KV 2 - South McQuesten @ Pump House Pond / 23 & 24 - Mar-04	KV 7 - Christal Creek @ Hanson L. Road / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Dissolved (Trace)						
Aluminum	Dissolved	mg/L	<0.01	<0.01	0.03	0.01
Antimony	Dissolved	mg/L	<0.02	<0.02	<0.02	0.02
Arsenic	Dissolved	mg/L	<0.04	<0.04	<0.04	0.04
Barium	Dissolved	mg/L	0.0770	0.0880	0.0506	0.0005
Beryllium	Dissolved	mg/L	<0.0006	0.0044	0.0011	0.0005
Bismuth	Dissolved	mg/L	<0.02	<0.02	0.07	0.02
Cadmium	Dissolved	mg/L	0.0022	<0.0006	0.0044	0.0005
Calcium	Dissolved	mg/L	59.2	66.0	123	0.01
Chromium	Dissolved	mg/L	<0.001	0.001	<0.001	0.001
Cobalt	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Copper	Dissolved	mg/L	0.003	<0.001	0.003	0.001
Iron	Dissolved	mg/L	0.033	0.047	<0.002	0.002
Lead	Dissolved	mg/L	0.032	<0.01	0.011	0.01
Lithium	Dissolved	mg/L	<0.007	<0.007	0.023	0.006
Magnesium	Dissolved	mg/L	19.6	20.8	24.3	0.01
Manganese	Dissolved	mg/L	0.0297	0.212	3.08	0.0005
Molybdenum	Dissolved	mg/L	<0.01	<0.01	<0.01	0.01
Nickel	Dissolved	mg/L	<0.002	0.002	0.012	0.002
Phosphorus	Dissolved	mg/L	0.11	0.08	0.18	0.05
Potassium	Dissolved	mg/L	<1	<1	<1	1
Selenium	Dissolved	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Dissolved	mg/L	3.4	3.4	4.0	0.05
Silver	Dissolved	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Dissolved	mg/L	3.15	2.90	1.45	0.05
Strontium	Dissolved	mg/L	0.252	0.241	0.267	0.005
Sulphur	Dissolved	mg/L	30.3	36.7	106	1
Tin	Dissolved	mg/L	<0.01	<0.01	0.029	0.01
Titanium	Dissolved	mg/L	<0.004	<0.004	<0.004	0.004
Uranium	Dissolved	mg/L	<0.06	<0.06	<0.06	0.06
Vanadium	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Dissolved	mg/L	0.026	0.204	2.53	0.001
Zirconium	Dissolved	mg/L	<0.005	<0.005	<0.005	0.005
Metals Total (Trace)						
Aluminum	Total	mg/L	0.08	<0.01	0.03	0.01

Norwest Labs
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Fax: (604) 514-3323

Analytical Report

Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

		NWL Number	297577-1	297577-2	297577-3	
		Sample Description	KV 1 - South McQuesten u/s Christal / 23 & 24 - Mar-04	KV 2 - South McQuesten @ Pump House Pond / 23 & 24 - Mar-04	KV 7 - Christal Creek @ Hanson L. Road / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Total (Trace) - Continued						
Antimony	Total	mg/L	<0.02	<0.02	<0.02	0.02
Arsenic	Total	mg/L	<0.04	<0.04	0.06	0.04
Barium	Total	mg/L	0.0833	0.0922	0.0511	0.0005
Beryllium	Total	mg/L	<0.0006	0.0067	0.0022	0.0005
Bismuth	Total	mg/L	0.09	0.02	0.07	0.02
Cadmium	Total	mg/L	0.0033	0.0011	0.0044	0.0005
Calcium	Total	mg/L	59.8	66.7	124	0.01
Chromium	Total	mg/L	<0.001	0.008	<0.001	0.001
Cobalt	Total	mg/L	<0.001	<0.001	0.001	0.001
Copper	Total	mg/L	0.006	0.003	0.003	0.001
Iron	Total	mg/L	0.261	0.161	0.111	0.002
Lead	Total	mg/L	0.037	0.051	0.011	0.01
Lithium	Total	mg/L	<0.007	<0.007	0.027	0.006
Magnesium	Total	mg/L	19.8	21.0	24.6	0.01
Manganese	Total	mg/L	0.0411	0.227	3.11	0.0005
Molybdenum	Total	mg/L	<0.01	0.02	<0.01	0.01
Nickel	Total	mg/L	0.007	0.004	0.012	0.002
Phosphorus	Total	mg/L	0.12	0.08	0.18	0.05
Potassium	Total	mg/L	<1	<1	<1	1
Selenium	Total	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Total	mg/L	3.4	3.5	4.0	0.05
Silver	Total	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Total	mg/L	3.19	2.93	1.53	0.05
Strontium	Total	mg/L	0.254	0.243	0.270	0.005
Sulphur	Total	mg/L	32.2	38.0	108	1
Tin	Total	mg/L	<0.01	0.013	0.041	0.01
Titanium	Total	mg/L	0.013	<0.004	<0.004	0.004
Uranium	Total	mg/L	<0.07	<0.07	<0.07	0.06
Vanadium	Total	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Total	mg/L	0.027	0.206	2.56	0.001
Zirconium	Total	mg/L	<0.006	<0.006	<0.006	0.005
Physical and Aggregate Properties						
Temp. of observed pH and EC		°C	20.4	20.4	20.8	
Solids	Total Suspended	mg/L	<3	<3	<3	1

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Sampled By: K. Nordin
Company: LES

Project
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Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
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		NWL Number	297577-1	297577-2	297577-3	
		Sample Description	KV 1 - South McQuesten u/s Christal / 23 & 24 - Mar-04	KV 2 - South McQuesten @ Pump House Pond / 23 & 24 - Mar-04	KV 7 - Christal Creek @ Hanson L. Road / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Routine Water						
pH			7.72	7.73	7.84	
Electrical Conductivity		µS/cm at 25C	451	477	796	1
Calcium	Dissolved	mg/L	60.8	66.5	136	0.2
Magnesium	Dissolved	mg/L	20.8	21.0	26.5	0.2
Sulphate (SO4)	Dissolved	mg/L	83.2	96.1	296	0.2
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	193	190	186	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	158	156	152	5
Hardness	Dissolved as CaCO3	mg/L	238	252	448	

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NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

		NWL Number	297577-4	297577-5	297577-6	
		Sample Description	KV 7B - Christal Creek @ Mouth / 23 & 24 - Mar-04	Site A - Christal Creek site A / 23 & 24 - Mar-04	Site C - Fugitive Flow @ C / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Dissolved (Trace)						
Aluminum	Dissolved	mg/L	<0.01	<0.01	<0.01	0.01
Antimony	Dissolved	mg/L	<0.02	<0.02	<0.02	0.02
Arsenic	Dissolved	mg/L	<0.04	<0.04	<0.04	0.04
Barium	Dissolved	mg/L	0.0517	0.0462	0.0352	0.0005
Beryllium	Dissolved	mg/L	0.0011	0.0011	0.0033	0.0005
Bismuth	Dissolved	mg/L	0.06	<0.02	<0.02	0.02
Cadmium	Dissolved	mg/L	0.0033	0.0077	0.0363	0.0005
Calcium	Dissolved	mg/L	125	151	294	0.01
Chromium	Dissolved	mg/L	0.002	<0.001	<0.001	0.001
Cobalt	Dissolved	mg/L	<0.001	0.001	<0.001	0.001
Copper	Dissolved	mg/L	0.007	<0.001	<0.001	0.001
Iron	Dissolved	mg/L	<0.002	0.011	<0.002	0.002
Lead	Dissolved	mg/L	<0.01	0.012	<0.01	0.01
Lithium	Dissolved	mg/L	<0.007	<0.007	0.022	0.006
Magnesium	Dissolved	mg/L	24.0	25.4	50.7	0.01
Manganese	Dissolved	mg/L	1.84	6.12	16.1	0.0005
Molybdenum	Dissolved	mg/L	<0.01	<0.01	0.035	0.01
Nickel	Dissolved	mg/L	0.005	0.020	0.076	0.002
Phosphorus	Dissolved	mg/L	0.24	0.17	0.20	0.05
Potassium	Dissolved	mg/L	<1	<1	<1	1
Selenium	Dissolved	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Dissolved	mg/L	4.0	4.4	5.5	0.05
Silver	Dissolved	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Dissolved	mg/L	1.43	1.38	1.79	0.05
Strontium	Dissolved	mg/L	0.267	0.279	0.618	0.005
Sulphur	Dissolved	mg/L	103	147	362	1
Tin	Dissolved	mg/L	<0.01	<0.01	<0.01	0.01
Titanium	Dissolved	mg/L	<0.004	<0.004	<0.004	0.004
Uranium	Dissolved	mg/L	<0.06	<0.06	<0.06	0.06
Vanadium	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Dissolved	mg/L	1.89	4.35	30.9	0.001
Zirconium	Dissolved	mg/L	<0.005	<0.005	<0.005	0.005
Metals Total (Trace)						
Aluminum	Total	mg/L	0.06	<0.01	<0.01	0.01
Antimony	Total	mg/L	<0.02	<0.02	0.04	0.02

NORWEST LABS

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		NWL Number	297577-4	297577-5	297577-6	
		Sample Description	KV 7B - Christal Creek @ Mouth / 23 & 24 - Mar-04	Site A - Christal Creek site A / 23 & 24 - Mar-04	Site C - Fugitive Flow @ C / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Total (Trace) - Continued						
Arsenic	Total	mg/L	0.06	<0.04	<0.04	0.04
Barium	Total	mg/L	0.0567	0.0467	0.0356	0.0005
Beryllium	Total	mg/L	0.0022	0.0011	0.0033	0.0005
Bismuth	Total	mg/L	0.12	0.12	<0.02	0.02
Cadmium	Total	mg/L	0.0056	0.0078	0.0367	0.0005
Calcium	Total	mg/L	126	153	29.7	0.01
Chromium	Total	mg/L	0.002	<0.001	<0.001	0.001
Cobalt	Total	mg/L	<0.001	0.001	<0.001	0.001
Copper	Total	mg/L	0.008	0.002	<0.001	0.001
Iron	Total	mg/L	0.056	0.233	<0.002	0.002
Lead	Total	mg/L	0.027	0.028	<0.01	0.01
Lithium	Total	mg/L	0.007	0.042	0.022	0.006
Magnesium	Total	mg/L	25.5	25.6	51.2	0.01
Manganese	Total	mg/L	1.86	6.19	16.3	0.0005
Molybdenum	Total	mg/L	<0.01	<0.01	0.04	0.01
Nickel	Total	mg/L	0.010	0.023	0.077	0.002
Phosphorus	Total	mg/L	0.31	0.22	0.20	0.05
Potassium	Total	mg/L	<1	<1	<1	1
Selenium	Total	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Total	mg/L	4.0	4.5	5.6	0.05
Silver	Total	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Total	mg/L	1.45	1.40	1.80	0.05
Strontium	Total	mg/L	0.270	0.283	0.624	0.005
Sulphur	Total	mg/L	104	148	366	1
Tin	Total	mg/L	<0.01	<0.01	0.013	0.01
Titanium	Total	mg/L	0.028	<0.004	<0.004	0.004
Uranium	Total	mg/L	<0.07	<0.07	<0.07	0.06
Vanadium	Total	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Total	mg/L	1.91	4.40	31.2	0.001
Zirconium	Total	mg/L	<0.006	<0.006	0.006	0.005
Physical and Aggregate Properties						
Temp. of observed pH and EC		°C	21.0	20.7	20.6	
Solids	Total Suspended	mg/L	<3	5	<2	1
Routine Water						
pH			7.69	7.42	6.93	

NORWEST LABS

Analytical Report

Norwest Labs
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Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

		NWL Number	297577-4	297577-5	297577-6	
		Sample Description	KV 7B - Christal Creek @ Mouth / 23 & 24 - Mar-04	Site A - Christal Creek site A / 23 & 24 - Mar-04	Site C - Fugitive Flow @ C / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Routine Water - Continued						
Electrical Conductivity		µS/cm at 25C	781	927	1740	1
Calcium	Dissolved	mg/L	133	166	349	0.2
Magnesium	Dissolved	mg/L	26.3	27.8	57.5	0.2
Sulphate (SO4)	Dissolved	mg/L	285	395	1130	0.2
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	181	163	44	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	149	134	36	5
Hardness	Dissolved as CaCO3	mg/L	440	528	1110	

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ID: G300 Fugitive Flow Investigati
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NWL Lot ID: 297577
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Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
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		NWL Number	297577-7	297577-8	297577-9	
		Sample Description	Site D - Christal Creek site D / 23 & 24 - Mar-04	ACG WQ5 - Christal Creek u/s Hwy / 23 & 24 - Mar-04	Culvert # 4 - G300 Fugitive Flow Culvert # 4 / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Dissolved (Trace)						
Aluminum	Dissolved	mg/L	0.01	<0.01	0.11	0.01
Antimony	Dissolved	mg/L	<0.02	<0.02	0.03	0.02
Arsenic	Dissolved	mg/L	<0.04	<0.04	0.04	0.04
Barium	Dissolved	mg/L	0.0517	0.0517	0.0176	0.0005
Beryllium	Dissolved	mg/L	0.0022	0.0011	0.0132	0.0005
Bismuth	Dissolved	mg/L	0.03	0.03	0.06	0.02
Cadmium	Dissolved	mg/L	0.0088	0.0011	0.117	0.0005
Calcium	Dissolved	mg/L	152	145	223	0.01
Chromium	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Cobalt	Dissolved	mg/L	<0.001	<0.001	0.010	0.001
Copper	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Iron	Dissolved	mg/L	0.012	0.021	<0.002	0.002
Lead	Dissolved	mg/L	0.012	<0.01	<0.01	0.01
Lithium	Dissolved	mg/L	<0.007	0.014	0.022	0.006
Magnesium	Dissolved	mg/L	26.6	25.0	42.8	0.01
Manganese	Dissolved	mg/L	7.57	1.17	94.1	0.0005
Molybdenum	Dissolved	mg/L	0.012	<0.01	0.10	0.01
Nickel	Dissolved	mg/L	0.025	0.004	0.284	0.002
Phosphorus	Dissolved	mg/L	0.16	0.06	0.23	0.05
Potassium	Dissolved	mg/L	<1	<1	<1	1
Selenium	Dissolved	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Dissolved	mg/L	4.4	4.3	4.7	0.05
Silver	Dissolved	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Dissolved	mg/L	1.56	1.36	1.26	0.05
Strontium	Dissolved	mg/L	0.288	0.250	0.386	0.005
Sulphur	Dissolved	mg/L	148	120	354	1
Tin	Dissolved	mg/L	<0.01	<0.01	<0.01	0.01
Titanium	Dissolved	mg/L	0.016	<0.004	<0.004	0.004
Uranium	Dissolved	mg/L	<0.06	<0.06	<0.06	0.06
Vanadium	Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Dissolved	mg/L	5.73	0.175	80.6	0.001
Zirconium	Dissolved	mg/L	<0.005	<0.005	<0.005	0.005
Metals Total (Trace)						
Aluminum	Total	mg/L	0.01	<0.01	0.13	0.01
Antimony	Total	mg/L	<0.02	<0.02	0.03	0.02

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204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

			NWL Number	297577-7	297577-8	297577-9	
			Sample Description	Site D - Christal Creek site D / 23 & 24 - Mar-04	ACG WQ5 - Christal Creek u/s Hwy / 23 & 24 - Mar-04	Culvert # 4 - G300 Fugitive Flow Culvert # 4 / 23 & 24 - Mar-04	
			Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**		**Results**	**Results**	**Results**	**Detection Limit**
Metals Total (Trace) - Continued							
Arsenic	Total	mg/L		0.05	<0.04	0.10	0.04
Barium	Total	mg/L		0.0522	0.0522	0.0211	0.0005
Beryllium	Total	mg/L		0.0022	0.0033	0.0178	0.0005
Bismuth	Total	mg/L		0.05	0.29	0.03	0.02
Cadmium	Total	mg/L		0.0089	0.0011	0.118	0.0005
Calcium	Total	mg/L		154	147	225	0.01
Chromium	Total	mg/L		<0.001	<0.001	<0.001	0.001
Cobalt	Total	mg/L		0.003	<0.001	0.011	0.001
Copper	Total	mg/L		0.010	0.010	<0.001	0.001
Iron	Total	mg/L		0.288	0.293	<0.002	0.002
Lead	Total	mg/L		0.028	<0.01	<0.01	0.01
Lithium	Total	mg/L		<0.007	0.014	0.023	0.006
Magnesium	Total	mg/L		26.8	25.3	43.8	0.01
Manganese	Total	mg/L		7.65	1.18	95.0	0.0005
Molybdenum	Total	mg/L		0.01	<0.01	0.11	0.01
Nickel	Total	mg/L		0.030	0.004	0.287	0.002
Phosphorus	Total	mg/L		0.16	0.06	0.23	0.05
Potassium	Total	mg/L		<1	<1	<1	1
Selenium	Total	mg/L		<0.1	<0.1	<0.1	0.1
Silicon	Total	mg/L		4.5	4.4	4.7	0.05
Silver	Total	mg/L		<0.002	<0.002	<0.002	0.002
Sodium	Total	mg/L		1.58	1.38	1.27	0.05
Strontium	Total	mg/L		0.291	0.252	0.390	0.005
Sulphur	Total	mg/L		156	126	357	1
Tin	Total	mg/L		<0.01	<0.01	<0.01	0.01
Titanium	Total	mg/L		0.017	<0.004	<0.004	0.004
Uranium	Total	mg/L		<0.07	<0.07	<0.07	0.06
Vanadium	Total	mg/L		<0.001	<0.001	<0.001	0.001
Zinc	Total	mg/L		5.79	0.177	81.4	0.001
Zirconium	Total	mg/L		<0.006	<0.006	<0.006	0.005
Physical and Aggregate Properties							
Temp. of observed pH and EC		°C		20.6	20.5	20.6	
Solids	Total Suspended	mg/L		8	<2	<2	1
Routine Water							
pH				7.45	7.44	6.46	

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204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
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Report Number: 530573

		NWL Number	297577-7	297577-8	297577-9	
		Sample Description	Site D - Christal Creek site D / 23 & 24 - Mar-04	ACG WQ5 - Christal Creek u/s Hwy / 23 & 24 - Mar-04	Culvert # 4 - G300 Fugitive Flow Culvert # 4 / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Routine Water - Continued						
Electrical Conductivity		µS/cm at 25C	950	850	1620	1
Calcium	Dissolved	mg/L	171	155	253	0.2
Magnesium	Dissolved	mg/L	29.0	26.4	47.0	0.2
Sulphate (SO4)	Dissolved	mg/L	418	343	1070	0.2
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	164	175	15	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	135	143	12	5
Hardness	Dissolved as CaCO3	mg/L	547	497	824	

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Project
ID: G300 Fugitive Flow Investigati
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NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
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		NWL Number	297577-10	297577-11		
		Sample Description	G300 Adit - Galkeno 300 Adit Flow / 23 & 24 - Mar-04	GK300 EFF - Pond Effluent GK300 / 23 & 24 - Mar-04		
		Matrix	Water - General	Water - General		
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Dissolved (Trace)						
Aluminum	Dissolved	mg/L	0.26	0.17		0.01
Antimony	Dissolved	mg/L	0.03	0.05		0.02
Arsenic	Dissolved	mg/L	0.16	0.06		0.04
Barium	Dissolved	mg/L	0.0066	<0.0006		0.0005
Beryllium	Dissolved	mg/L	0.0297	0.0242		0.0005
Bismuth	Dissolved	mg/L	0.07	0.06		0.02
Cadmium	Dissolved	mg/L	0.226	0.162		0.0005
Calcium	Dissolved	mg/L	172	245		0.01
Chromium	Dissolved	mg/L	<0.001	<0.001		0.001
Cobalt	Dissolved	mg/L	0.108	0.073		0.001
Copper	Dissolved	mg/L	<0.001	<0.001		0.001
Iron	Dissolved	mg/L	21.8	1.58		0.002
Lead	Dissolved	mg/L	<0.01	<0.01		0.01
Lithium	Dissolved	mg/L	<0.007	0.011		0.006
Magnesium	Dissolved	mg/L	37.0	35.3		0.01
Manganese	Dissolved	mg/L	163	135		0.0005
Molybdenum	Dissolved	mg/L	0.165	0.10		0.01
Nickel	Dissolved	mg/L	0.453	0.287		0.002
Phosphorus	Dissolved	mg/L	0.24	0.09		0.05
Potassium	Dissolved	mg/L	1.2	<1		1
Selenium	Dissolved	mg/L	<0.1	<0.1		0.1
Silicon	Dissolved	mg/L	4.9	2.9		0.05
Silver	Dissolved	mg/L	<0.002	<0.002		0.002
Sodium	Dissolved	mg/L	1.36	1.17		0.05
Strontium	Dissolved	mg/L	0.251	0.406		0.005
Sulphur	Dissolved	mg/L	352	342		1
Tin	Dissolved	mg/L	<0.01	<0.01		0.01
Titanium	Dissolved	mg/L	<0.004	<0.004		0.004
Uranium	Dissolved	mg/L	<0.06	<0.06		0.06
Vanadium	Dissolved	mg/L	<0.001	<0.001		0.001
Zinc	Dissolved	mg/L	132	69.1		0.001
Zirconium	Dissolved	mg/L	<0.005	<0.005		0.005
Physical and Aggregate Properties						
Temp. of observed pH and EC		°C	21.1	21.4		
Solids	Total Suspended	mg/L	15	14		1

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		NWL Number	297577-10	297577-11		
		Sample Description	G300 Adit - Galkeno 300 Adit Flow / 23 & 24 - Mar-04	GK300 EFF - Pond Effluent GK300 / 23 & 24 - Mar-04		
		Matrix	Water - General	Water - General		
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Routine Water						
pH			6.48	7.14		
Electrical Conductivity		µS/cm at 25C	1640	1670		1
Calcium	Dissolved	mg/L	187	261		0.2
Magnesium	Dissolved	mg/L	40.2	36.8		0.2
Sulphate (SO4)	Dissolved	mg/L	1030	1020		0.2
Hydroxide		mg/L	<5	<5		5
Carbonate		mg/L	<6	<6		6
Bicarbonate		mg/L	79	111		5
P-Alkalinity	as CaCO3	mg/L	<5	<5		5
T-Alkalinity	as CaCO3	mg/L	65	91		5
Hardness	Dissolved as CaCO3	mg/L	632	804		

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		NWL Number	297577-10	297577-11	297577-12	
		Sample Description	G300 Adit - Galkeno 300 Adit Flow / 23 & 24 - Mar-04	GK300 EFF - Pond Effluent GK300 / 23 & 24 - Mar-04	Duplicate / 23 & 24 - Mar-04	
		Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Total (Trace)						
Aluminum	Total	mg/L	0.27	0.17	<0.01	0.01
Antimony	Total	mg/L	0.04	0.09	<0.02	0.02
Arsenic	Total	mg/L	0.18	0.08	<0.04	0.04
Barium	Total	mg/L	0.0067	<0.0006	0.0644	0.0005
Beryllium	Total	mg/L	0.0300	0.0244	0.0033	0.0005
Bismuth	Total	mg/L	0.06	0.07	0.10	0.02
Cadmium	Total	mg/L	0.228	0.163	0.0011	0.0005
Calcium	Total	mg/L	174	248	148	0.01
Chromium	Total	mg/L	<0.001	<0.001	<0.001	0.001
Cobalt	Total	mg/L	0.109	0.078	<0.001	0.001
Copper	Total	mg/L	<0.001	<0.001	0.009	0.001
Iron	Total	mg/L	23.2	4.78	0.504	0.002
Lead	Total	mg/L	<0.01	<0.01	<0.01	0.01
Lithium	Total	mg/L	<0.007	0.011	<0.007	0.006
Magnesium	Total	mg/L	37.4	35.8	25.3	0.01
Manganese	Total	mg/L	165	136	1.40	0.0005
Molybdenum	Total	mg/L	0.17	0.10	<0.01	0.01
Nickel	Total	mg/L	0.458	0.290	0.008	0.002
Phosphorus	Total	mg/L	0.25	0.09	0.19	0.05
Potassium	Total	mg/L	1.5	1.8	1.8	1
Selenium	Total	mg/L	<0.1	<0.1	<0.1	0.1
Silicon	Total	mg/L	4.9	3.1	4.5	0.05
Silver	Total	mg/L	<0.002	<0.002	<0.002	0.002
Sodium	Total	mg/L	1.42	1.18	1.59	0.05
Strontium	Total	mg/L	0.253	0.410	0.256	0.005
Sulphur	Total	mg/L	370	348	125	1
Tin	Total	mg/L	<0.01	<0.01	<0.01	0.01
Titanium	Total	mg/L	<0.004	0.010	<0.004	0.004
Uranium	Total	mg/L	<0.07	<0.07	<0.07	0.06
Vanadium	Total	mg/L	<0.001	<0.001	<0.001	0.001
Zinc	Total	mg/L	133	74.8	0.270	0.001
Zirconium	Total	mg/L	<0.006	<0.006	<0.006	0.005

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Approved by:

Bill Warning, B.Sc.
Lab Operations Manager

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Quality Control

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Metals Dissolved

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Sulphur	mg/L	<0.05	0.08	-2.22	2.39	✓
Material Used: Edmonton Method Blank						
Date Acquired: Mar 30, 2004						
Acquired By: To Thong						

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Phosphorus	mg/L	50.0	50.0	35.0	65.0	✓
Silicon	mg/L	25.1	25.0	22.5	27.5	✓
Sulphur	mg/L	48.4	49.8	44.6	55.0	✓
Material Used: Metals High						
Date Acquired: Mar 30, 2004						
Acquired By: To Thong						
Phosphorus	mg/L	0.50	0.50	0.20	0.80	✓
Silicon	mg/L	0.49	0.50	0.45	0.55	✓
Sulphur	mg/L	0.93	1.02	0.81	1.23	✓
Material Used: Metals Low						
Date Acquired: Mar 30, 2004						
Acquired By: To Thong						

Physical and Aggregate Properties

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Solids	mg/L	107	110	10	15	✓
Material Used: Edmonton Duplicate						
Date Acquired: Mar 31, 2004						
Acquired By: Byul Sim						

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Solids	mg/L	191	200	180	220	✓
Material Used: Water High						
Date Acquired: Mar 31, 2004						
Acquired By: Byul Sim						
Solids	mg/L	21	20	18	22	✓
Material Used: Water Low						
Date Acquired: Mar 30, 2004						
Acquired By: Byul Sim						

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Quality Control

Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

Routine Water

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
pH		7.86	7.83	9.99	0.10	✓
Electrical Conductivity	dS/m at 25C	15.6	15.7	9.990	0.002	✓
Calcium	mg/L	28	29	10.0	0.6	✓
Magnesium	mg/L	20	21	10.0	0.2	✓
Sodium	mg/L	4650	4630	10.0	1.2	✓
Potassium	mg/L	47	46	10.0	1.2	✓
Iron	mg/L	0.86	0.82	9.99	0.01	✓
Hydroxide	mg/L	<5	<5	10		✓
Carbonate	mg/L	<6	<6	10		✓
Bicarbonate	mg/L	193	189	10		✓
P-Alkalinity	mg/L	<5	<5	10	5	✓
T-Alkalinity	mg/L	158	155	10	5	✓

Material Used: Edmonton Duplicate
Date Acquired: Mar 30, 2004
Acquired By: Amanda Mitchell

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Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Quality Control

Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

Routine Water (Continued...)

Control Sample		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Calcium		mg/L	246	251	237	265	✓
Magnesium		mg/L	97.4	102	95	109	✓
Sodium		mg/L	251	250	236	264	✓
Potassium		mg/L	248	251	234	268	✓
Iron		mg/L	9.79	9.73	9.26	10.20	✓
Manganese		mg/L	2.38	2.42	2.32	2.53	✓
Material Used:	Metals High						
Date Acquired:	Mar 30, 2004						
Acquired By:	To Thong						
Calcium		mg/L	4.9	4.8	4.3	5.3	✓
Magnesium		mg/L	1.8	1.9	1.6	2.1	✓
Sodium		mg/L	4.8	5.2	4.3	6.1	✓
Potassium		mg/L	4.8	5.0	4.5	5.4	✓
Iron		mg/L	0.19	0.20	0.15	0.24	✓
Manganese		mg/L	0.046	0.049	0.044	0.054	✓
Material Used:	Metals Low						
Date Acquired:	Mar 30, 2004						
Acquired By:	To Thong						
Electrical Conductivity		uS/cm	865	824	738	910	✓
Material Used:	S0020 - Cond						
Date Acquired:	Mar 29, 2004						
Acquired By:	Maria Gaborni						
Electrical Conductivity		uS/cm	435	430	385	475	✓
Material Used:	S0088 - Cond						
Date Acquired:	Mar 29, 2004						
Acquired By:	Maria Gaborni						
pH			9.16	9.23	9.11	9.35	✓
Electrical Conductivity		dS/m at 25C	2.71	2.73	2.61	2.85	✓
P-Alkalinity		mg/L	522	525	478	572	✓
T-Alkalinity		mg/L	1020	1005	972	1038	✓
Material Used:	Water High						
Date Acquired:	Mar 30, 2004						
Acquired By:	Amanda Mitchell						
pH			6.90	6.90	6.83	6.97	✓
Electrical Conductivity		dS/m at 25C	0.076	0.076	0.070	0.081	✓
P-Alkalinity		mg/L	47	61	43	78	✓
T-Alkalinity		mg/L	124	128	119	137	✓
Material Used:	Water Low						
Date Acquired:	Mar 30, 2004						
Acquired By:	Amanda Mitchell						

Norwest Labs
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Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Methodology and Notes

Bill to: Access Mining Consultants Ltd.
Report to: Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, YT, Canada
Y1A 2J8
Attn: Dan Cornett
Sampled By: K. Nordin
Company: LES

Project
ID: G300 Fugitive Flow Investigati
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 297577
Control Number: W 51488
Date Received: Mar 26, 2004
Date Reported: Apr 07, 2004
Report Number: 530573

Method of Analysis:

MethodName	Reference		Method	Date Analysis Started	Location
Alkalinity, pH, and EC in water	APHA	*	Conductivity - Laboratory Method, 2510 B	30-Mar-04	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Electrometric Method, 4500-H+ B	30-Mar-04	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Titration Method, 2320 B	30-Mar-04	Norwest Labs Edmonton
Metals SemiTrace (Dissolved) in water	US EPA		Metals & Trace Elements by Ultrasonic Nebulization ICP-AES, 200.15	7-Apr-04	Norwest Labs Surrey
Metals SemiTrace (Total) in water	US EPA		Metals & Trace Elements by Ultrasonic Nebulization ICP-AES, 200.15	7-Apr-04	Norwest Labs Surrey
Metals Trace (Dissolved) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	31-Mar-04	Norwest Labs Edmonton
Solids Suspended (Total, Fixed and Volatile)	APHA	*	Total Suspended Solids Dried at 103-105'C, 2540 D	30-Mar-04	Norwest Labs Edmonton
Solids Suspended (Total, Fixed and Volatile)	APHA	*	Total Suspended Solids Dried at 103-105'C, 2540 D	31-Mar-04	Norwest Labs Edmonton

* Norwest method(s) is based on reference method

References:

APHA	Standard Methods for the Examination of Water and Wastewater
US EPA	US Environmental Protection Agency Test Methods

Comments:

Due to instrument difficulties at NWL-Surrey, reported ICP results were obtained by NWL-Edmonton low-level ICP analysis. [KR Apr-7-04]

NWL-Edmonton ICP analysis does not include element Thorium; therefore reported results do not list "Th". [KR Apr-7-04]

APPENDIX C

PHOTOGRAPHS

The gauge in Flat Creek upstream of the South McQuesten River, August 2003.

Stained vegetation just upstream of SKT3, August 2003. Photographs of site SKT2 are included in Appendix A.

Lightning Creek at Keno City, August 2003

Gauge on Porcupine Creek Diversion Ditch, August 2003.

APPENDIX D

MULTI – MEDIA ANALYTICAL RESULTS

Norwest Labs

NORWEST LABS

INFORMATION SHEET WATERS

393

CONTROL NUMBER W 51499

RESULTS & INVOICE TO:	COPY OF RESULTS TO:	WORK ORDER NO.
Labuze Environmental Services		
COMPANY: PO Box 21072	COMPANY:	DATE STAMP
ADDRESS: Whitehorse YT	ADDRESS:	
CITY/TOWN: Y1A 6P7	CITY/TOWN:	
PROVINCE:	PROVINCE:	
POSTAL CODE:	POSTAL CODE:	
ATTENTION: B. Burns	ATTENTION:	
PHONE: 867-668-6838	PHONE:	
FAX: 867-667-6756	FAX:	
CELL: labuze@internorth.com	CELL:	

PURCHASE ORDER NO.:	PROJECT REF.:	REF./QUOTE NO.:

DATE SAMPLED D M Y NUMBER OF SAMPLES WATER LIQ WASTE OTHER (SPECIFY)

SPECIAL INSTRUCTIONS (SEE OVER FOR IMPORTANT SAMPLE INFORMATION INSTRUCTIONS AND ANALYSIS CODES)

Sediment Samples: For the stream sediment samples - NCC1, NCC2 + NCC3, please dry, sieve thru a 100 mesh screen then run ST33.

QA REPORT ☐

RUSH
(UPON FILLING IN THIS SECTION THE CLIENT ACCEPTS THAT SURCHARGES WILL BE ATTACHED TO THE ANALYSIS)

NORWEST AUTHORIZATION

NAME DATE

RUSH DATE REQUIRED D M Y

TIME HR. MIN.

CLIENT NO.

LP

COMPLETION DATE D M Y

SAMPLE CUSTODY	SAMPLED BY	RECEIVED BY	RELINQUISHED BY	RECEIVED BY
	COMPANY	COMPANY	COMPANY	COMPANY
	DATE	DATE	DATE	DATE

	SITE I.D.	SAMPLE DESCRIPTION	OTHER	ANALYSIS PACKAGE CODES (USE CODES LISTED ON THE REVERSE OF THIS SHEET)	LAB CODING
1	SKT3	- twigs	veg	ST 33	
2	SKT Control	- leaves	-		
3	SKT Control	- twigs	-		
1 / 4	NCC1	stream sediments	-	ST33 - solids, TOC	
2 / 5	NCC2	stream sediments	-	" "	
3 / 6	NCC3	stream sediments	-	" "	
4 / 7	NCC3A	- organics	-	" "	
5 / 8	NCC3B	- mineral	Sediment	" "	
6 / 9	SKT1-2A	- organics	-	" "	
7 / 10	SKT1-2B	- mineral	-	" "	
8 / 11	SKT2-4A	- organics	-	" "	
9 / 12	SKT2-4B	- mineral	-	" "	
10 / 13	SKT3-A	- organics	-	" "	
11 / 14	SKT3-B	- mineral	-	" "	
15			-		

AGRI-FOOD ENVIRONMENTAL			ENERGY RESOURCE		
EDMONTON	PH. (403) 438-5522	FAX (403) 434-8586	EDMONTON	PH. (403) 454-1504	FAX (403) 451-4022
CALGARY	PH. (403) 291-2022	FAX (403) 291-2021	CALGARY	PH. (403) 291-3024	FAX (403) 250-2819
LANGLEY	PH. (604) 530-4344	FAX (604) 534-9996	GRANDE PRAIRIE	PH. (403) 532-8709	FAX (403) 539-0611
LETHBRIDGE	PH. (403) 329-9266	FAX (403) 327-8527	FORT ST. JOHN	PH. (250) 785-2731	FAX (250) 785-7092
WINNIPEG	PH. (204) 982-8630	FAX (204) 275-6019	ESTEVAN	PH. (306) 634-7218	FAX (306) 634-4101

NOTE: Please complete this form in its entirety to ensure correct testing and reporting requirements.

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: **(604) 514-3322**
Fax: **(604) 514-3323**

Report Transmission Cover Page

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

Copies	Contact	Company		Address				
1	Bonnie Burns	Laberge Environmental Services		Box 21072, 1-405 Ogilvie Street	Fax		Post	x
				Whitehorse, YT	Email	x	Pickup	
				Y1A 6P7	Custom Email	x	Courier	
			Phone:	(867) 668-6838	Web		Hand	
			Fax:	(867) 667-6956	Email Notification			
			Email:	laberge@internorth.com				

_______ # OF PAGES IN THIS TRANSMISSION

Report Transmission Notes

Agreement Notes

Lot Notes

Sample Notes:

Notes to Clients

Agreement Notes

Lot Notes

Sample Notes:

Reports associated with this Lot

Id/Format/Reported Date	Id/Format/Reported Date	Id/Format/Reported Date
438006 Envir2 3 Smp & DL		

Comment:
See Methodology and Notes page of Analytical Report for all comments pertaining to this report.

If this report transmission is not satisfactory, please send report requirements to the address at the top of this page.

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Sample Custody

Bill to: Laberge Environmental Services
Report to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

Sample Disposal Date: Oct 05, 2003

All samples will be stored until this date unless other instructions are received. Please indicate other requirements below and return this form to the address or fax number on the upper right of this page.

__________ **Extend Sample Storage Until** _______________ **(MM/DD/YY)**

The following charges apply to extended sample storage:

Storage for 1 to 5 samples per month	$ 10.00
Storage for 6 to 20 samples per month	$ 15.00
Storage for 21 to 50 samples per month	$ 30.00
Storage for 51 to 200 samples per month	$ 60.00
Storage for more than 200 samples per month	$ 110.00

__________ **Return Sample, collect, to the address below via:**

_______ Greyhound
_______ Loomis
_______ Purolator
_______ Other (Specify) _______________

Name: ____________________
Company: ____________________
Address: ____________________
____
Phone: ____________________
Fax: ____________________
Signature: ____________________

If no other arrangements have been made, samples will be disposed of on Oct 05, 2003.

Analytical Report

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

		NWL Number	251669-1	251669-2	251669-3	
		Sample Date				
		Sample Description	NCC1 Stream Sediment	NCC2 Stream Sediment	NCC3 Stream Sediment	
		Matrix	Soil - general	Soil - general	Soil - general	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Classification						
Carbon	Total Organic	%	3.32	2.72	2.80	0.05
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	8780	8690	6720	1
Antimony	Strong Acid Extractable	ug/g	5.5	<1.0	<1.0	2
Arsenic	Strong Acid Extractable	ug/g	65.5	45.0	12.9	2
Barium	Strong Acid Extractable	ug/g	197	171	138	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.02	<0.02	0.15	0.05
Bismuth	Strong Acid Extractable	ug/g	<1.0	<1.0	<1.0	2
Cadmium	Strong Acid Extractable	ug/g	29.3	53.9	6.47	0.05
Calcium	Strong Acid Extractable	ug/g	7590	8540	5920	1
Chromium	Strong Acid Extractable	ug/g	15.4	16.0	12.9	0.1
Cobalt	Strong Acid Extractable	ug/g	10.4	12.5	5.47	0.1
Copper	Strong Acid Extractable	ug/g	38.7	49.5	24.9	0.1
Iron	Strong Acid Extractable	ug/g	20300	20000	14400	0.2
Lead	Strong Acid Extractable	ug/g	387	135	28.9	0.5
Lithium	Strong Acid Extractable	ug/g	10.9	11.5	9.45	0.5
Magnesium	Strong Acid Extractable	ug/g	4120	4700	3330	1
Manganese	Strong Acid Extractable	ug/g	3910	6140	617	0.05
Molybdenum	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	1
Nickel	Strong Acid Extractable	ug/g	25.8	38.0	16.9	0.1
Phosphorus	Strong Acid Extractable	ug/g	645	684	786	5
Potassium	Strong Acid Extractable	ug/g	397	400	348	30
Selenium	Strong Acid Extractable	ug/g	<2	<2	<2	4
Silicon	Strong Acid Extractable	ug/g	321	266	281	5
Silver	Strong Acid Extractable	ug/g	6.94	4.50	1.99	0.2
Sodium	Strong Acid Extractable	ug/g	54.6	59.9	49.8	5
Strontium	Strong Acid Extractable	ug/g	19.3	23.0	19.4	0.5
Sulphur	Strong Acid Extractable	ug/g	1640	734	572	20
Thorium	Strong Acid Extractable	ug/g	1.5	2.0	1.5	0.5
Tin	Strong Acid Extractable	ug/g	2.98	3.50	<0.2	0.5
Titanium	Strong Acid Extractable	ug/g	129	132	122	0.1
Uranium	Strong Acid Extractable	ug/g	<3	<3	<3	6
Vanadium	Strong Acid Extractable	ug/g	27.1	25.9	21.4	0.1
Zinc	Strong Acid Extractable	ug/g	2780	5740	622	0.05

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Analytical Report

Bill to:	Laberge Environmental Services	**Project**		**NWL Lot ID:**	**251669**
eport to:	Laberge Environmental Services	**ID:**	17654	Control Number:	W 51499
	Box 21072	**Name:**	ELSA - NND	Date Received:	Aug 27, 2003
	1-405 Ogilvie Street	**Location:**		Date Reported:	Sep 05, 2003
	Whitehorse, YT, Canada	**LSD:**		Report Number:	438006
	Y1A 6P7	**P.O.:**			
Attn:	Bonnie Burns	**Acct. Code:**			
Sampled By:					
Company:					

		NWL Number	251669-1	251669-2	251669-3	
		Sample Date				
		Sample Description	NCC1 Stream Sediment	NCC2 Stream Sediment	NCC3 Stream Sediment	
		Matrix	Soil - general	Soil - general	Soil - general	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Strong Acid Extractable - Continued						
Zirconium	Strong Acid Extractable	ug/g	1.4	1.3	2.4	0.5

Norwest Labs
#104, 19575-55 A Ave.
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Analytical Report

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

		NWL Number	251669-4	251669-5	251669-6	
		Sample Date				
		Sample Description	NCC3A Organics	NCC3B Mineral	SKT1-2A Organics	
		Matrix	Soil - general	Soil - general	Soil - general	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Classification						
Carbon	Total Organic	%	9.74	1.87	4.59	0.05
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	8510	6210	3530	1
Antimony	Strong Acid Extractable	ug/g	<1.0	20.4	112	2
Arsenic	Strong Acid Extractable	ug/g	46.8	110	373	2
Barium	Strong Acid Extractable	ug/g	240	75.0	147	0.05
Beryllium	Strong Acid Extractable	ug/g	0.100	<0.02	<0.02	0.05
Bismuth	Strong Acid Extractable	ug/g	<1.0	<1.0	<1.0	2
Cadmium	Strong Acid Extractable	ug/g	41.8	68.1	130	0.05
Calcium	Strong Acid Extractable	ug/g	11500	9840	8060	1
Chromium	Strong Acid Extractable	ug/g	15.4	12.4	7.46	0.1
Cobalt	Strong Acid Extractable	ug/g	9.45	10.9	313	0.1
Copper	Strong Acid Extractable	ug/g	71.1	71.1	289	0.1
Iron	Strong Acid Extractable	ug/g	25900	24400	84600	0.2
Lead	Strong Acid Extractable	ug/g	125	875	1350	0.5
Lithium	Strong Acid Extractable	ug/g	10.9	11.4	4.48	0.5
Magnesium	Strong Acid Extractable	ug/g	3930	6410	1730	1
Manganese	Strong Acid Extractable	ug/g	2560	3190	44900	0.05
Molybdenum	Strong Acid Extractable	ug/g	<0.5	<0.5	4.0	1
Nickel	Strong Acid Extractable	ug/g	34.3	25.8	1040	0.1
Phosphorus	Strong Acid Extractable	ug/g	756	666	532	5
Potassium	Strong Acid Extractable	ug/g	547	298	299	30
Selenium	Strong Acid Extractable	ug/g	<2	298	<2	4
Silicon	Strong Acid Extractable	ug/g	30.8	<2	<2	5
Silver	Strong Acid Extractable	ug/g	3.48	5.96	9.45	0.2
Sodium	Strong Acid Extractable	ug/g	49.8	25	29.9	5
Strontium	Strong Acid Extractable	ug/g	31.8	17.9	24.9	0.5
Sulphur	Strong Acid Extractable	ug/g	1130	4770	4430	20
Thorium	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.5
Tin	Strong Acid Extractable	ug/g	3.48	2.0	2.99	0.5
Titanium	Strong Acid Extractable	ug/g	96.5	49.5	4.48	0.1
Uranium	Strong Acid Extractable	ug/g	<3	<3	25	6
Vanadium	Strong Acid Extractable	ug/g	23.9	18.2	6.32	0.1
Zinc	Strong Acid Extractable	ug/g	3250	3360	7760	0.05
Zirconium	Strong Acid Extractable	ug/g	4.58	3.63	<0.2	0.5

Norwest Labs
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Analytical Report

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 251669
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

		NWL Number	251669-7	251669-8	251669-9	
		Sample Date				
		Sample Description	SKT1-2B Mineral	SKT2-4A Organics	SKT2-4B Mineral	
		Matrix	Soil - general	Soil - general	Soil - general	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Classification						
Carbon	Total Organic	%	1.15	3.35	2.53	0.05
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	3160	2360	7940	1
Antimony	Strong Acid Extractable	ug/g	159	37.0	<1.0	2
Arsenic	Strong Acid Extractable	ug/g	194	165	19.9	2
Barium	Strong Acid Extractable	ug/g	79.1	70.0	134	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.02	<0.03	<0.02	0.05
Bismuth	Strong Acid Extractable	ug/g	<1.0	<1.0	<1.0	2
Cadmium	Strong Acid Extractable	ug/g	60.2	41.0	3.97	0.05
Calcium	Strong Acid Extractable	ug/g	6920	210000	12900	1
Chromium	Strong Acid Extractable	ug/g	6.97	4.00	14.4	0.1
Cobalt	Strong Acid Extractable	ug/g	179	75.0	17.4	0.1
Copper	Strong Acid Extractable	ug/g	114	93.0	24.3	0.1
Iron	Strong Acid Extractable	ug/g	69700	32000	22800	0.2
Lead	Strong Acid Extractable	ug/g	191	605	22.3	0.5
Lithium	Strong Acid Extractable	ug/g	4.98	3.00	14.4	0.5
Magnesium	Strong Acid Extractable	ug/g	1720	3600	4270	1
Manganese	Strong Acid Extractable	ug/g	25900	11100	2280	0.05
Molybdenum	Strong Acid Extractable	ug/g	2.0	<0.5	<0.5	1
Nickel	Strong Acid Extractable	ug/g	423	270	69.5	0.1
Phosphorus	Strong Acid Extractable	ug/g	254	325	402	5
Potassium	Strong Acid Extractable	ug/g	150	150	248	30
Selenium	Strong Acid Extractable	ug/g	<2	<2	5.0	4
Silicon	Strong Acid Extractable	ug/g	2	<3	83.4	5
Silver	Strong Acid Extractable	ug/g	11.9	5.50	1.49	0.2
Sodium	Strong Acid Extractable	ug/g	15	35.0	25	5
Strontium	Strong Acid Extractable	ug/g	15.4	114	18.4	0.5
Sulphur	Strong Acid Extractable	ug/g	1170	5700	606	20
Thorium	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.5
Tin	Strong Acid Extractable	ug/g	3.48	4.00	<0.2	0.5
Titanium	Strong Acid Extractable	ug/g	106	7.65	101	0.1
Uranium	Strong Acid Extractable	ug/g	<3	<3	<3	6
Vanadium	Strong Acid Extractable	ug/g	17.7	0.700	25.4	0.1
Zinc	Strong Acid Extractable	ug/g	3980	3250	387	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.2	<0.2	0.30	0.5

NORWEST LABS

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Analytical Report

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 251669
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

		NWL Number	251669-10	251669-11		
		Sample Date				
		Sample Description	SKT3-A Organics	SKT3-B Mineral		
		Matrix	Soil - general	Soil - general		
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Classification						
Carbon	Total Organic	%	32.3	3.79		0.05
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	2660	8940		1
Antimony	Strong Acid Extractable	ug/g	23.8	<1.0		2
Arsenic	Strong Acid Extractable	ug/g	103	25.5		2
Barium	Strong Acid Extractable	ug/g	301	286		0.05
Beryllium	Strong Acid Extractable	ug/g	0.099	0.350		0.05
Bismuth	Strong Acid Extractable	ug/g	<1.0	<1.0		2
Cadmium	Strong Acid Extractable	ug/g	4.96	<0.02		0.05
Calcium	Strong Acid Extractable	ug/g	41700	7240		1
Chromium	Strong Acid Extractable	ug/g	3.47	17.0		0.1
Cobalt	Strong Acid Extractable	ug/g	1.98	5.99		0.1
Copper	Strong Acid Extractable	ug/g	42.2	35.0		0.1
Iron	Strong Acid Extractable	ug/g	31300	21000		0.2
Lead	Strong Acid Extractable	ug/g	46.6	11.5		0.5
Lithium	Strong Acid Extractable	ug/g	0.99	12.5		0.5
Magnesium	Strong Acid Extractable	ug/g	3080	3850		1
Manganese	Strong Acid Extractable	ug/g	630	130		0.05
Molybdenum	Strong Acid Extractable	ug/g	<0.5	<0.5		1
Nickel	Strong Acid Extractable	ug/g	11.9	20.0		0.1
Phosphorus	Strong Acid Extractable	ug/g	769	589		5
Potassium	Strong Acid Extractable	ug/g	298	400		30
Selenium	Strong Acid Extractable	ug/g	<2	<2		4
Silicon	Strong Acid Extractable	ug/g	<2	284		5
Silver	Strong Acid Extractable	ug/g	1.98	<0.10		0.2
Sodium	Strong Acid Extractable	ug/g	44.6	45.0		5
Strontium	Strong Acid Extractable	ug/g	63.5	22.5		0.5
Sulphur	Strong Acid Extractable	ug/g	5260	679		20
Thorium	Strong Acid Extractable	ug/g	<0.2	1.5		0.5
Tin	Strong Acid Extractable	ug/g	4.96	<0.2		0.5
Titanium	Strong Acid Extractable	ug/g	64.5	92.9		0.1
Uranium	Strong Acid Extractable	ug/g	<3	<3		6
Vanadium	Strong Acid Extractable	ug/g	4.86	30.0		0.1
Zinc	Strong Acid Extractable	ug/g	446	62.4		0.05
Zirconium	Strong Acid Extractable	ug/g	2.53	2.70		0.5

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Analytical Report

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

Approved by: Bill Warning, B.Sc.
Lab Operations Manager

NORWEST LABS

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Methodology and Notes

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251669**
Control Number: W 51499
Date Received: Aug 27, 2003
Date Reported: Sep 05, 2003
Report Number: 438006

Method of Analysis:

MethodName	Reference		Method	Date Analysis Completed	Location
Carbon, Nitrogen, Sulfur in soil	Agronomy No 9, Part 2	*	Total Carbon, Method Using High-Temperature Induction Furnace, 29-2.2.4	Sep 05, 2003	Norwest Labs Lethbridge
Metals SemiTrace (Strong Acid Leachable) in solids	US EPA		Metals & Trace Elements by Ultrasonic Nebulization ICP-AES, 200.15	Sep 03, 2003	Norwest Labs Surrey

* Norwest method(s) is based on reference method

References:

Agronomy No 9, Part 2	Methods Of Soil Analysis, Part 2
US EPA	US Environmental Protection Agency Test Methods

Comments:

NORWEST LABS

INFORMATION SHEET WATERS

2 8 3

CONTROL NUMBER W 51494

RESULTS & INVOICE TO:	COPY OF RESULTS TO:	WORK ORDER NO.
Laberge Environmental Services		
COMPANY:	COMPANY:	DATE STAMP
ADDRESS: PO Box 21072	ADDRESS:	
CITY/TOWN: Whitehorse	CITY/TOWN:	
PROVINCE: YT	PROVINCE:	
POSTAL CODE: Y1A 6P7	POSTAL CODE:	
ATTENTION: B. BURNS	ATTENTION:	
PHONE: 867-668-6838	PHONE:	
FAX: 867-667-6956	FAX:	
~~CELL:~~ laberge@internorth.com	~~CELL:~~	

PURCHASE ORDER NO.:	PROJECT REF.:	REF./QUOTE NO.:

DATE SAMPLED D M Y NUMBER OF SAMPLES WATER LIQ WASTE OTHER (SPECIFY) TISSUE-VEG

SPECIAL INSTRUCTIONS (SEE OVER FOR IMPORTANT SAMPLE INFORMATION INSTRUCTIONS AND ANALYSIS CODES)

QA REPORT ☐

RUSH
(UPON FILLING IN THIS SECTION THE CLIENT ACCEPTS THAT SURCHARGES WILL BE ATTACHED TO THE ANALYSIS)
NORWEST AUTHORIZATION
NAME DATE
RUSH DATE REQUIRED D M Y
TIME HR. MIN.

CLIENT NO.
LP
COMPLETION DATE D M Y

SAMPLE CUSTODY	SAMPLED BY	RECEIVED BY	RELINQUISHED BY	RECEIVED BY
	COMPANY	COMPANY	COMPANY	COMPANY
	DATE	DATE	DATE	DATE

	SITE I.D. / SAMPLE DESCRIPTION	OTHER	ANALYSIS PACKAGE CODES (USE CODES LISTED ON THE REVERSE OF THIS SHEET)	LAB CODING
1	NCC Control - leaves	–	ST33 - please rinse veg	
2	NCC1 - leaves	–	with DI first before drying - thanks	
3	NCC1 - twigs	–	" "	
4	NCC2 - leaves	–	" "	
5	NCC2 - twigs	–	" "	
6	NCC3 - leaves	–	" "	
7	NCC3 - twigs	–	" "	
8	NCC4 - leaves	–	" "	
9	NCC4 - twigs	–	" "	
10	NCC Control - twigs	–	" "	
11	SKT1 - leaves	–	" "	
12	SKT1 - twigs	–	" "	
13	SKT2 - leaves	–	" "	
14	SKT2 - twigs	–	" "	
15	SKT3 - leaves	–	" "	

AGRI-FOOD ENVIRONMENTAL			ENERGY RESOURCE		
EDMONTON	PH. (403) 438-5522	FAX (403) 434-8586	EDMONTON	PH. (403) 454-1504	FAX (403) 451-4022
CALGARY	PH. (403) 291-2022	FAX (403) 291-2021	CALGARY	PH. (403) 291-3024	FAX (403) 250-2819
LANGLEY	PH. (604) 530-4344	FAX (604) 534-9996	GRANDE PRAIRIE	PH. (403) 532-8709	FAX (403) 539-0611
LETHBRIDGE	PH. (403) 329-9266	FAX (403) 327-8527	FORT ST. JOHN	PH. (250) 785-2731	FAX (250) 785-7092
WINNIPEG	PH. (204) 982-8630	FAX (204) 275-6019	ESTEVAN	PH. (306) 634-7218	FAX (306) 634-4101

NOTE: Please complete this form in its entirety to ensure correct testing and reporting requirements.

NORWEST LABS

INFORMATION SHEET WATERS

393

CONTROL NUMBER W 51499

RESULTS & INVOICE TO:	COPY OF RESULTS TO:	WORK ORDER NO.
Labrge Environmental Services		
COMPANY: PO Box 21072	COMPANY:	DATE STAMP
ADDRESS: Whitehorse YT	ADDRESS:	
CITY/TOWN: Y1A 6P7	CITY/TOWN:	
PROVINCE:	PROVINCE:	
POSTAL CODE: B. Burns	POSTAL CODE:	
ATTENTION: 867-668-6838	ATTENTION:	
PHONE: 867-667-6756	PHONE:	
FAX: labrge@internorth.com	FAX:	
CELL:	CELL:	

PURCHASE ORDER NO.:	PROJECT REF.:	REF./QUOTE NO.:

DATE SAMPLED D M Y NUMBER OF SAMPLES WATER LIQ WASTE OTHER (SPECIFY)

SPECIAL INSTRUCTIONS (SEE OVER FOR IMPORTANT SAMPLE INFORMATION INSTRUCTIONS AND ANALYSIS CODES)

Sediment Samples: for the stream sediment samples - NCC1, NCC2 + NCC3, please dry, sieve thru a 100 mesh screen then run ST33.

QA REPORT ☐

RUSH

(UPON FILLING IN THIS SECTION THE CLIENT ACCEPTS THAT SURCHARGES WILL BE ATTACHED TO THE ANALYSIS)

NORWEST AUTHORIZATION

NAME DATE

RUSH DATE REQUIRED D M Y

TIME HR. MIN.

CLIENT NO.

LP

COMPLETION DATE D M Y

SAMPLE CUSTODY	SAMPLED BY	RECEIVED BY	RELINQUISHED BY	RECEIVED BY
	COMPANY	COMPANY	COMPANY	COMPANY
	DATE	DATE	DATE	DATE

	SITE I.D.	SAMPLE DESCRIPTION	OTHER	ANALYSIS PACKAGE CODES (USE CODES LISTED ON THE REVERSE OF THIS SHEET)	LAB CODING
1	SKT3	twigs	veg	ST 33	
2	SKT Control	leaves			
3	SKT Control	twigs	-		
4	NCC1	stream sediments	-	ST33 - solids, TOC	
5	NCC2	stream sediments	-	" "	
6	NCC3	stream sediments	-	" "	
7	NCC3A	organics	-	" "	
8	NCC3B	mineral	-	" "	
9	SKT1-2A	organics	-	" "	
10	SKT1-2B	mineral	-	" "	
11	SKT2-4A	organics	-	" "	
12	SKT2-4B	mineral	-	" "	
13	SKT3-A	organics	-	" "	
14	SKT3-B	mineral	-	" "	
15			-		

Sediment (samples 4–14)

AGRI-FOOD ENVIRONMENTAL			ENERGY RESOURCE		
EDMONTON	PH. (403) 438-5522	FAX (403) 434-8586	EDMONTON	PH. (403) 454-1504	FAX (403) 451-4022
CALGARY	PH. (403) 291-2022	FAX (403) 291-2021	CALGARY	PH. (403) 291-3024	FAX (403) 250-2819
LANGLEY	PH. (604) 530-4344	FAX (604) 534-9996	GRANDE PRAIRIE	PH. (403) 532-8709	FAX (403) 539-0611
LETHBRIDGE	PH. (403) 329-9266	FAX (403) 327-8527	FORT ST. JOHN	PH. (250) 785-2731	FAX (250) 785-7092
WINNIPEG	PH. (204) 982-8630	FAX (204) 275-6019	ESTEVAN	PH. (306) 634-7218	FAX (306) 634-4101

NOTE: Please complete this form in its entirety to ensure correct testing and reporting requirements.

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: **(604) 514-3322**
Fax: **(604) 514-3323**

Report Transmission Cover Page

Bill to: Laberge Environmental Services
eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251667**
Control Number: W 51494
Date Received: Aug 27, 2003
Date Reported: Sep 02, 2003
Report Number: 438000

Copies	Contact	Company	Address				
1	Bonnie Burns	Laberge Environmental Services	Box 21072, 1-405 Ogilvie Street	Fax		Post	x
			Whitehorse, YT	Email	x	Pickup	
			Y1A 6P7	Custom Email	x	Courier	
		Phone:	(867) 668-6838	Web		Hand	
		Fax:	(867) 667-6956	Email Notification			
		Email:	laberge@internorth.com				

_______ # OF PAGES IN THIS TRANSMISSION

Report Transmission Notes

Agreement Notes

Lot Notes

Sample Notes:

Notes to Clients

Agreement Notes

Lot Notes

Sample Notes:

Reports associated with this Lot

Id/Format/Reported Date	Id/Format/Reported Date	Id/Format/Reported Date
438000 Envir2 3 Smp & DL		

Comment:
See Methodology and Notes page of Analytical Report for all comments pertaining to this report.

If this report transmission is not satisfactory, please send report requirements to the address at the top of this page.

NORWEST LABS

Sample Custody

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Bill to: Laberge Environmental Services
Report to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **251667**
Control Number: W 51494
Date Received: Aug 27, 2003
Date Reported: Sep 02, 2003
Report Number: 438000

Sample Disposal Date: Oct 02, 2003

All samples will be stored until this date unless other instructions are received. Please indicate other requirements below and return this form to the address or fax number on the upper right of this page.

___________ **Extend Sample Storage Until** ________________ **(MM/DD/YY)**

The following charges apply to extended sample storage:

Storage for 1 to 5 samples per month	$ 10.00
Storage for 6 to 20 samples per month	$ 15.00
Storage for 21 to 50 samples per month	$ 30.00
Storage for 51 to 200 samples per month	$ 60.00
Storage for more than 200 samples per month	$ 110.00

___________ **Return Sample, collect, to the address below via:**

________ Greyhound
________ Loomis
________ Purolator
________ Other (Specify) ________________

Name: ______________________________
Company: ______________________________
Address: ______________________________
____
Phone: ______________________________
Fax: ______________________________
Signature: ______________________________

If no other arrangements have been made, samples will be disposed of on Oct 02, 2003.

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Analytical Report

Bill to:	Laberge Environmental Services	Project		NWL Lot ID:	251667
eport to:	Laberge Environmental Services Box 21072 1-405 Ogilvie Street Whitehorse, YT, Canada Y1A 6P7	ID:	17654	Control Number:	W 51494
		Name:	ELSA - NND	Date Received:	Aug 27, 2003
		Location:		Date Reported:	Sep 02, 2003
		LSD:		Report Number:	438000
Attn:	Bonnie Burns	P.O.:			
Sampled By:		Acct. Code:			
Company:					

Analyte		Units	251667-1	251667-2	251667-3	
		NWL Number	251667-1	251667-2	251667-3	
		Sample Date				
		Sample Description	NCC Control - Leaves	NCC Control - Twigs	NCC1 - Leaves	
		Matrix	Tissue	Tissue	Tissue	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	23.1	38.7	68.4	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	<2	2
Barium	Strong Acid Extractable	ug/g	20.6	11.0	5.52	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	<0.05	<0.05	35.4	0.05
Calcium	Strong Acid Extractable	ug/g	37600	10100	34300	1
Chromium	Strong Acid Extractable	ug/g	1.0	0.81	1.71	0.1
Cobalt	Strong Acid Extractable	ug/g	<0.1	<0.1	<0.1	0.1
Copper	Strong Acid Extractable	ug/g	2.01	3.67	4.53	0.1
Iron	Strong Acid Extractable	ug/g	42.9	65.9	73.5	0.2
Lead	Strong Acid Extractable	ug/g	<0.5	3.3	<0.5	0.5
Lithium	Strong Acid Extractable	ug/g	1.2	<0.5	1.2	0.5
Magnesium	Strong Acid Extractable	ug/g	8630	1420	4850	1
Manganese	Strong Acid Extractable	ug/g	96.5	82.0	55.6	0.05
Molybdenum	Strong Acid Extractable	ug/g	1.0	<1	<1	1
Nickel	Strong Acid Extractable	ug/g	0.30	0.51	2.11	0.1
Phosphorus	Strong Acid Extractable	ug/g	690	1070	928	5
Potassium	Strong Acid Extractable	ug/g	3990	3470	15300	30
Selenium	Strong Acid Extractable	ug/g	<4	<4	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	<5	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	6.0	12	27	5
Strontium	Strong Acid Extractable	ug/g	64.0	18.5	44.0	0.5
Sulphur	Strong Acid Extractable	ug/g	10400	896	8250	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	1.0	1.63	4.02	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.30	0.31	0.50	0.1
Zinc	Strong Acid Extractable	ug/g	203	191	2150	0.05
Zirconium	Strong Acid Extractable	ug/g	0.70	0.51	<0.5	0.5

Norwest Labs
#104, 19575-55 A Ave.
Surrey, BC. V3S 8P8
Phone: (604) 514-3322
Fax: (604) 514-3323

Analytical Report

Bill to:	Laberge Environmental Services	Project	NWL Lot ID: 251667
eport to:	Laberge Environmental Services Box 21072 1-405 Ogilvie Street Whitehorse, YT, Canada Y1A 6P7	ID: 17654 Name: ELSA - NND Location: LSD: P.O.:	Control Number: W 51494 Date Received: Aug 27, 2003 Date Reported: Sep 02, 2003 Report Number: 438000
Attn:	Bonnie Burns		
Sampled By:		Acct. Code:	
Company:			

Analyte		Units	NWL Number 251667-4 Sample Description NCC1 - Twigs Matrix Tissue Results	251667-5 NCC2 - Leaves Tissue Results	251667-6 NCC2 - Twigs Tissue Results	Detection Limit
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	50.5	25.2	17.8	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	<2	2
Barium	Strong Acid Extractable	ug/g	3.26	3.93	1.93	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	15.1	33.3	12.0	0.05
Calcium	Strong Acid Extractable	ug/g	7330	41200	6510	1
Chromium	Strong Acid Extractable	ug/g	1.82	1.31	1.19	0.1
Cobalt	Strong Acid Extractable	ug/g	<0.1	<0.1	<0.10	0.1
Copper	Strong Acid Extractable	ug/g	6.57	3.82	5.54	0.1
Iron	Strong Acid Extractable	ug/g	67.4	55.5	26.9	0.2
Lead	Strong Acid Extractable	ug/g	2.0	<0.5	0.59	0.5
Lithium	Strong Acid Extractable	ug/g	<0.5	1.3	<0.5	0.5
Magnesium	Strong Acid Extractable	ug/g	1160	6580	1000	1
Manganese	Strong Acid Extractable	ug/g	27.5	46.8	12.6	0.05
Molybdenum	Strong Acid Extractable	ug/g	<1	<1	<1.0	1
Nickel	Strong Acid Extractable	ug/g	1.31	1.31	0.69	0.1
Phosphorus	Strong Acid Extractable	ug/g	867	1190	873	5
Potassium	Strong Acid Extractable	ug/g	3290	13800	2950	30
Selenium	Strong Acid Extractable	ug/g	5.1	8.0	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	<5	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	16	17	9.9	5
Strontium	Strong Acid Extractable	ug/g	13.7	61.3	15.0	0.5
Sulphur	Strong Acid Extractable	ug/g	717	9260	653	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	2.83	1.81	1.39	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.30	0.50	0.20	0.1
Zinc	Strong Acid Extractable	ug/g	558	1730	364	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5

NORWEST LABS

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Analytical Report

Bill to:	Laberge Environmental Services	Project		NWL Lot ID:	251667
eport to:	Laberge Environmental Services	ID:	17654	Control Number:	W 51494
	Box 21072	Name:	ELSA - NND	Date Received:	Aug 27, 2003
	1-405 Ogilvie Street	Location:		Date Reported:	Sep 02, 2003
	Whitehorse, YT, Canada	LSD:		Report Number:	438000
	Y1A 6P7	P.O.:			
Attn:	Bonnie Burns	Acct. Code:			
Sampled By:					
Company:					

		NWL Number	251667-7	251667-8	251667-9	
		Sample Date				
		Sample Description	NCC3 - Leaves	NCC3 - Twigs	NCC4 - Leaves	
		Matrix	Tissue	Tissue	Tissue	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	29.5	22.8	26.8	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	<2	2
Barium	Strong Acid Extractable	ug/g	12.0	5.27	8.16	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	28.2	10.0	6.49	0.05
Calcium	Strong Acid Extractable	ug/g	39400	8030	32800	1
Chromium	Strong Acid Extractable	ug/g	1.12	1.49	0.89	0.1
Cobalt	Strong Acid Extractable	ug/g	<0.1	<0.10	<0.10	0.1
Copper	Strong Acid Extractable	ug/g	4.99	6.05	4.27	0.1
Iron	Strong Acid Extractable	ug/g	54.5	38.5	49.8	0.2
Lead	Strong Acid Extractable	ug/g	<0.5	1.2	<0.5	0.5
Lithium	Strong Acid Extractable	ug/g	1.3	<0.5	1.4	0.5
Magnesium	Strong Acid Extractable	ug/g	5720	721	4750	1
Manganese	Strong Acid Extractable	ug/g	116	48.0	136	0.05
Molybdenum	Strong Acid Extractable	ug/g	<1	<1.0	<1.0	1
Nickel	Strong Acid Extractable	ug/g	1.0	0.99	0.69	0.1
Phosphorus	Strong Acid Extractable	ug/g	1230	1000	965	5
Potassium	Strong Acid Extractable	ug/g	10900	3010	10500	30
Selenium	Strong Acid Extractable	ug/g	<4	<4	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	9.9	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	14	12	8.9	5
Strontium	Strong Acid Extractable	ug/g	61.6	15.6	50.0	0.5
Sulphur	Strong Acid Extractable	ug/g	14900	704	6650	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	1.43	1.79	1.29	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.31	0.30	0.40	0.1
Zinc	Strong Acid Extractable	ug/g	1580	418	992	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.5	0.69	<0.5	0.5

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eport to: Laberge Environmental Services
Box 21072
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Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 251667
Control Number: W 51494
Date Received: Aug 27, 2003
Date Reported: Sep 02, 2003
Report Number: 438000

	NWL Number	251667-10	251667-11	251667-12	
	Sample Date				
	Sample Description	NCC4 - Twigs	SKT1 - Leaves	SKT1 - Twigs	
	Matrix	Tissue	Tissue	Tissue	

Analyte		Units	Results	Results	Results	Detection Limit
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	15.9	24.1	222	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	<2	2
Barium	Strong Acid Extractable	ug/g	4.25	7.02	25.9	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	2.74	33.6	30.1	0.05
Calcium	Strong Acid Extractable	ug/g	7500	21400	9440	1
Chromium	Strong Acid Extractable	ug/g	1.09	0.50	1.72	0.1
Cobalt	Strong Acid Extractable	ug/g	<0.10	0.40	0.91	0.1
Copper	Strong Acid Extractable	ug/g	4.77	5.32	8.82	0.1
Iron	Strong Acid Extractable	ug/g	32.7	46.1	166	0.2
Lead	Strong Acid Extractable	ug/g	<0.5	<0.5	0.61	0.5
Lithium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Magnesium	Strong Acid Extractable	ug/g	637	3640	1080	1
Manganese	Strong Acid Extractable	ug/g	38.8	274	171	0.05
Molybdenum	Strong Acid Extractable	ug/g	<1.0	<1	<1	1
Nickel	Strong Acid Extractable	ug/g	1.29	6.22	4.77	0.1
Phosphorus	Strong Acid Extractable	ug/g	874	1640	1120	5
Potassium	Strong Acid Extractable	ug/g	2450	9920	4310	30
Selenium	Strong Acid Extractable	ug/g	<4	7.0	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	<5	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	7.0	10	82.2	5
Strontium	Strong Acid Extractable	ug/g	15.3	25.6	15.6	0.5
Sulphur	Strong Acid Extractable	ug/g	656	4700	791	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	0.99	1.51	27.2	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.30	0.40	0.61	0.1
Zinc	Strong Acid Extractable	ug/g	270	1220	628	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.5	<0.5	1.1	0.5

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eport to: Laberge Environmental Services
Box 21072
1-405 Ogilvie Street
Whitehorse, YT, Canada
Y1A 6P7
Attn: Bonnie Burns
Sampled By:
Company:

Project
ID: 17654
Name: ELSA - NND
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 251667
Control Number: W 51494
Date Received: Aug 27, 2003
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Report Number: 438000

		NWL Number	251667-13	251667-14	251667-15	
		Sample Date				
		Sample Description	SKT2 - Leaves	SKT2 - Twigs	SKT3 - Leaves	
		Matrix	Tissue	Tissue	Tissue	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	21.1	14.1	20.2	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	2.0	2
Barium	Strong Acid Extractable	ug/g	2.27	1.71	4.20	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	40.4	14.9	0.709	0.05
Calcium	Strong Acid Extractable	ug/g	33200	9460	15800	1
Chromium	Strong Acid Extractable	ug/g	0.70	0.70	0.40	0.1
Cobalt	Strong Acid Extractable	ug/g	0.30	0.1	0.1	0.1
Copper	Strong Acid Extractable	ug/g	5.72	6.74	2.73	0.1
Iron	Strong Acid Extractable	ug/g	56.4	28.8	41.5	0.2
Lead	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Lithium	Strong Acid Extractable	ug/g	<0.5	<0.5	0.51	0.5
Magnesium	Strong Acid Extractable	ug/g	3820	1360	4200	1
Manganese	Strong Acid Extractable	ug/g	54.9	37.7	118	0.05
Molybdenum	Strong Acid Extractable	ug/g	<1	<1	<1	1
Nickel	Strong Acid Extractable	ug/g	4.32	1.81	1.72	0.1
Phosphorus	Strong Acid Extractable	ug/g	1590	855	807	5
Potassium	Strong Acid Extractable	ug/g	12800	5050	11100	30
Selenium	Strong Acid Extractable	ug/g	4.0	<4	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	<5	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	8.0	7.0	6.1	5
Strontium	Strong Acid Extractable	ug/g	34.5	12.6	17.2	0.5
Sulphur	Strong Acid Extractable	ug/g	3450	644	3890	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	1.20	0.80	1.21	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.30	0.20	0.40	0.1
Zinc	Strong Acid Extractable	ug/g	1260	467	442	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5

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		NWL Number	251667-16	251667-17	251667-18	
		Sample Date				
		Sample Description	SKT3 - Twigs	SKT Control - Leaves	SKT Control - Twigs	
		Matrix	Tissue	Tissue	Tissue	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Strong Acid Extractable						
Aluminum	Strong Acid Extractable	ug/g	12.3	21.4	23.3	1
Antimony	Strong Acid Extractable	ug/g	<2	<2	<2	2
Arsenic	Strong Acid Extractable	ug/g	<2	<2	<2	2
Barium	Strong Acid Extractable	ug/g	5.32	22.3	16.0	0.05
Beryllium	Strong Acid Extractable	ug/g	<0.05	<0.05	<0.05	0.05
Bismuth	Strong Acid Extractable	ug/g	<2	<2	<2	2
Cadmium	Strong Acid Extractable	ug/g	0.941	<0.05	3.21	0.05
Calcium	Strong Acid Extractable	ug/g	5780	21700	7120	1
Chromium	Strong Acid Extractable	ug/g	1.0	0.41	1.21	0.1
Cobalt	Strong Acid Extractable	ug/g	0.1	<0.1	<0.1	0.1
Copper	Strong Acid Extractable	ug/g	4.50	2.55	5.26	0.1
Iron	Strong Acid Extractable	ug/g	79.8	38.3	46.4	0.2
Lead	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Lithium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Magnesium	Strong Acid Extractable	ug/g	1350	8140	1750	1
Manganese	Strong Acid Extractable	ug/g	80.0	222	160	0.05
Molybdenum	Strong Acid Extractable	ug/g	<1	<1	<1	1
Nickel	Strong Acid Extractable	ug/g	1.43	0.71	18.2	0.1
Phosphorus	Strong Acid Extractable	ug/g	818	634	795	5
Potassium	Strong Acid Extractable	ug/g	4950	2830	3510	30
Selenium	Strong Acid Extractable	ug/g	7.2	<4	<4	4
Silicon	Strong Acid Extractable	ug/g	<5	<5	<5	5
Silver	Strong Acid Extractable	ug/g	<0.2	<0.2	<0.2	0.2
Sodium	Strong Acid Extractable	ug/g	6.1	6.1	7.1	5
Strontium	Strong Acid Extractable	ug/g	10.1	23.9	9.92	0.5
Sulphur	Strong Acid Extractable	ug/g	644	3690	769	20
Thorium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Tin	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5
Titanium	Strong Acid Extractable	ug/g	0.82	1.22	1.21	0.1
Uranium	Strong Acid Extractable	ug/g	<6	<6	<6	6
Vanadium	Strong Acid Extractable	ug/g	0.20	0.41	0.20	0.1
Zinc	Strong Acid Extractable	ug/g	314	207	209	0.05
Zirconium	Strong Acid Extractable	ug/g	<0.5	<0.5	<0.5	0.5

Approved by: Bill Warning, B.Sc.
Lab Operations Manager

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Methodology and Notes

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Method of Analysis:

MethodName	Reference	Method	Date Analysis Completed	Location
Metals SemiTrace (Strong Acid Leachable) in solids	US EPA	Metals & Trace Elements by Ultrasonic Nebulization ICP-AES, 200.15	Sep 02, 2003	Norwest Labs Surrey

* Norwest method(s) is based on reference method

References:

US EPA — US Environmental Protection Agency Test Methods

Comments:

APPENDIX E

CONTAMINANT PATHWAY VEGETATION TYPES

Silver King Transect 1

Trees and Shrubs
Alnus crispa
Betula glandulosa
Betula payrifera
Empetrum nigrum
Ledum groenlandicum
Picea glauca
Ribes hudsonianum
Rosa acicularis
Rubus idaeus
Salix bebbiana
Salix glauca
Salix pseudomyrsinites
Salix scouleriana
Vaccinium vitis-idaea
Vaccinium uliginosum

Forbs
Achillea millefolium
Epilobium angustifolium
Geocaulon lividum
Lycopodium clavatum
Lycopodium sp.
Stellaria sp.

Graminoids
Agrostis scabra
Beckmannia syzigachne
Calamagrostis canadensis
Festuca altaica
Hordeum jubatum
Poa pratensis

Bryophytes
Pleurozium schreberi

Silver King Transect 2

Trees and Shrubs
Betula glandulosa
Betula occidentalis
Betula papyrifera
Empetrum nigrum
Ledum groenlandicum
Picea glauca
Picea mariana

Potentilla fruticosa
Rosa acicularis
Salix glauca
Salix richardsonii
Vaccinium uliginosum
Vaccinium vitis-idaea

Forbs
Epilobium angustifolium
Equisetum arvense
Equisetum scirpoides
Geocaulon lividum

Graminoids
Agrostis scabra
Beckmannia syzigachne
Calamagrostis canadensis
Carex sp.
Elymus sp.

Bryophytes
Pleurozium schreberi

No-Cash Creek Transect 1

Trees and Shrubs
Alnus crispa
Betula papyrifera
Picea glauca
Populus balsamifera
Salix arbusculoides
Salix bebbiana
Salix richardsonii
Salix scouleriana

Forbs
Achillea millefolium
Anemone richardsonii
Epilobium angustifolium
Equisetum arvense

No-Cash Creek Transect 2

Trees and Shrubs
Alnus crispa
Arctostaphylos rubra
Ledum groenlandicum
Picea mariana
Potentilla fruticosa
Salix arbusculoides
Salix glauca
Salix richardsonii
Vaccinium uliginosum
Vaccinium vitis-idaea

Forbs
Equisetum arvense

Graminoids
Carex sp.

Bryophytes
Pleurozium shreberi
Sphagnum sp.

No-Cash Creek Transect 3

Trees and Shrubs
Betula glandulosa
Kalmia polifolia
Picea glauca
Picea mariana
Potentilla fruticosa
Salix arbusculoides
Salix barclayi
Salix glauca
Salix richardsonii
Vaccinium uliginosum
Vaccinium vitis-idaea

Forbs
Equisetum arvense
Equisetum fluviatile

Graminoids
Carex aquatilis
Juncus sp.

Bryophytes
Pleurozium shreberi
Sphagnum sp.

No-Cash Creek Transect 4

Trees and Shrubs
Betula glandulosa
Betula papyrifera
Picea mariana
Populus balsamifera
Potentilla fruticosa
Salix arbusculoides
Salix barclayi
Salix bebbiana
Salix richardsonii
Salix scouleriana
Vaccnium uliginosum

Forbs
Equisetum arvense

Graminoids
Calamagrostis canadensis

Bryophytes
Pleurozium shreberi
Sphagnum sp.