WEST KITIKMEOT / SLAVE STUDY SOCIETY

Re: Investigation of Aquatic Impacts of On-Ice Exploratory Diamond Drilling

STUDY DIRECTOR RELEASE FORM

The above publication is the result of a project conducted under the West Kitikmeot / Slave Study. I have reviewed the report and advise that it has fulfilled the requirements of the approved proposal and can be subjected to independent expert review and be considered for release for public.

Study Director

September 19, 2000
Date

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer

November 1, 2000
Date

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer

December 7, 2000
Date

BOARD RELEASE FORM

The Study Board is satisfied that this final report has been reviewed for scientific content and approves it for release to the public.

Chair
West Kitikmeot/Slave Study Society

December 8, 2000
Date

ANNUAL REPORT TO THE WEST KITIKMEOT/SLAVE STUDY SOCIETY
Investigation of Aquatic Impacts of On-Ice Exploratory Diamond Drilling:

May 15, 1999
Submitted by Anne Wilson

SUMMARY

Work done under this funding is part of the third year of a three-year study which examines the impacts of exploratory drilling from ice. Diamond drills are used to extract rock core samples, generating return water which contains rock fines or solids, plus residues of any additives which may have been used. Disposal of this effluent is difficult at cold temperatures, so this research is being done to see what effects occur when the drilling waste is deposited on the lake bottom. Impacts of short holes involving limited discharges were measured in 1996/97 on Great Slave Lake, with ”before” and “after” samples collected for analysis and evaluation. A longer hole with higher quantities of effluent released was studied at Baton Lake; baseline measurements were done in 1997, and follow up work has been done for water quality and benthic samples. In winter of 1998, drilling in kimberlite geology was examined for two short holes at Lac de Gras, with follow up work done in March 1999.

This report presents the results of the 1998/99 work (except for 1999 sediment quality and benthic data which are not yet available) and reiterates the previous work reported for 1998. The 1999 field component consisted of winter followup done at Lac de Gras, with water quality results now available, and benthic community and sediment characterization results still to come from the analytical laboratories. Statistical workup of the data and final interpretation will be done once these data are received.

Baton Lake:
To conclude work at the Baton Lake site, benthic, sediment and water samples were collected in early 1998 at the discharge site and at reference sites for comparison to pre-drilling conditions. Benthic samples were identified taxonomically and the abundance of each group was determined. Statistical comparison showed no significant changes in numbers of individuals of the two dominant groups of organisms (cyclopoid copepods and nematode worms) but the overall diversity had dropped slightly in the other groups (from an average of four different types to 2.4 per sample). Particle size analysis was done on samples collected the summer after drilling, and one year later.

The clay fraction was elevated after drilling (compared to the reference site) but by February of 1998, had returned to pre-drilling levels, due to the lake's high natural sedimentation rate. Sediment chemistry data showned no clear trends or increases with effluent release, and values were generally comparable to those at the reference site.

Great Slave Lake:
Summer water quality measurements were taken using the Hydrolab Multiprobe to measure temperature, pH, conductivity, dissolved oxygen, and turbidity, and samples were collected for analyses of total suspended solids (TSS). For all sites, TSS were below detection limits, and turbidity ranged from 7.0 to 16.1 NTU. Dissolved oxygen levels were near saturation, ranging from 9.4 to 13.6 mg/L over the water column for all stations. Conductivity readings were consistently near 0.220 mS/cm, and pH values averaged from 7.5 to 8.0 for all profiles. Temperature readings indicated the water column was well mixed, with no stratification. Summer work confirmed that there was no resuspension of drilling fines. No winter followup work was done at this site.

Lac de Gras:
The Hydrolab Multiprobe was used to measure temperature, pH, conductivity, total dissolved solids, dissolved oxygen, and turbidity in August of 1998. Water quality showed conductivity readings of 0.010 mS/cm, pH ranging from 6.20 to 6.66, total dissolved solids below detection, and dissolved oxygen values ranging from 9.31 to 9.93 (all above 88% saturation). Turbidity readings were zero for all sites, and temperature measurements ranged from 11.82 to 12.51 at the three sites, indicating a well-mixed (unstratified) water column. Water samples were also collected for analysis of TSS and metals. All TSS measurements were below detection limits, and data for total metals in the water column showed values below or near detection, i.e. extremely low levels in line with background water quality. Sediment chemistry data are not yet available for 1999, but data for 1998 showed no dramatic changes after drilling. Benthic data for pre- and post- release show apparent drops in both numbers of individuals, and number of taxa present; statistical analysis of the data will be done when the 1999 data are available.

ACKNOWLEDGMENTS

The researcher would like to acknowledge the contribution of the West Kitikmeot/Slave Study Society for funding; Dr. Buster Welch and Kathleen Martin for scientific advice and providing lab equipment; Fisheries and Oceans for providing laboratory facilities; Royal Oak Mines Inc. and Diavik Diamond Mines Inc. for site access and logistical support including accommodation, meals, and transportation; Taiga Environmental Lab for analytical work; and Environment Canada for equipment, summer student support, and lab analyses. Ron Bujold, Thorben Bieger, Bart Blais, Frankie Nitsiza, and Dean Halifax spent long hours in equipment preparation, out on the ice sampling, and in the lab processing samples. Thanks to Steve Harbicht for assistance in the summer water quality work, and with the DGPS operation.

OBJECTIVES

The objective of this study is to evaluate impacts of on-ice drilling on water and sediment quality and on benthic life, and to continue to compile data on baseline conditions. The overall study seeks to answer the following main questions: 1. does first-stage exploration drilling significantly affect water clarity and sediment quality; and 2. is the benthic community significantly impacted in the immediate area of drilling when effluent is released to the lake bottom? This information will help with management of drilling waste disposal such that the least effects are caused.

DESCRIPTION

Background:

Work was initiated in early 1997 to examine the effects of first stage diamond drilling programs working from lake ice surfaces. Samples were taken to assess the changes in water quality and effects on benthic invertebrates for three sites: Baton Lake, where a fairly deep hole was drilled; Great Slave Lake, where 11 shallow holes were drilled; and Lac de Gras, where two short holes were drilled into kimberlite ore. Reference sites provided baseline data as well as points for comparison later in time. Water clarity and changes to the benthic communities are the main indicators examined to determine magnitude and duration of effects. Initial work dealt with non-kimberlite targets only because of the potential toxicity of kimberlite effluents; however, in 1998 a kimberlite target was examined using two shallow holes at the Diavik lease on Lac de Gras, with followup work done in March of 1999.

Study Area:

The lakes under study are in the Slave Geological Province, and include Baton Lake (at Colomac Mine), Great Slave Lake (Yellowknife Bay) and Lac de Gras (Diavik Diamond Mines Inc.). Great Slave Lake (Figure 1) and Lac de Gras (Figure 3) are both large lakes, and can be classified as oligotrophic and ultra-oligotrophic, respectively. The substrate in the area of drilling at Great Slave Lake consisted of a fine layer of organic material over clay and/or rocks; at Lac de Gras, the sediments were iron-rich, with silty consistency, and were poorly consolidated for the top 0.5 metre sampled. Baton Lake is a long narrow lake confined within a bedrock valley (Figure 2); the sediments consist of highly unconsolidated organic materials.

Methodology:

During the first stage at each study lake, baseline data were collected for water quality, sediment chemistry and benthic community composition. Discharge of drilling fines was done at five metres above lake bottom using a diffuser pipe for all sites except the Lac de Gras ones, where a one-inch hose was used following plugging problems with the diffuser. Great Slave Lake stations were set up at 0, 15, and 50 metres, in the direction of increasing depth from the discharge point at each drill hole. Sample stations for Baton Lake were set up in a grid pattern, with the discharge point at the centre, stations at the four compass points 15 m and 30 m away, and intermediate points 21 m away (see Figure 2). A similar pattern was used at Lac de Gras, except there were 8 stations 15 m from the discharge point, in the four compass directions plus NE, SE, NW and SW, and 4 stations 30 metres from discharge, at each of the compass points. Water quality measurements were done using a Hydrolab metre to measure water quality parameters. Water samples were collected using a van dorn type water sampler, and tested by Taiga Environmental Lab for total suspended solids, turbidity, and total metals. Analysis of variance was used to statistically evaluate changes in numbers for the dominant benthic taxa, and for sediment chemistry parameters for Baton Lake.

ACTIVITIES FOR THE YEAR

During the open water season, several trips were made to Great Slave Lake (near Yellowknife Bay) and Lac de Gras to collect water quality information. For the winter 1998 field season, researchers travelled to Baton Lake and collected water, sediment and benthic samples as followup to the work previously done. A new site with drilling into two kimberlite holes was examined at Diavik's Lac de Gras lease. There, researchers took baseline and post-impact water quality measurements, and collected sediment and benthic samples. Short-term measurements of drilling impacts were taken for this site following drilling, and summer water quality work done, with subsequent followup in March of 1999. Water quality results for Baton Lake and Lac de Gras are reported in the 1997 Final Annual report dated May 1998. All results are available except for benthic data and sediment chemistry for 1999.

RESULTS

Great Slave Lake: Summer followup was repeated as last year's results had shown inconsistently high turbidity readings, likely due to prolonged wind and wave action suspending fine natural clays from the substrate. Results are summarized on Table 1. For all Great Slave Lake stations, lake waters were well mixed with temperatures at all depths and stations between 10.3 and 13.9 degrees Celsius. pH values ranged from 7.44 to 8.02, and conductivity values ranged from 0.220 to 0.222 mS/cm. Total dissolved solids were very low (at 0.1Kmg/L) for all sites. Dissolved oxygen values were at or near saturation (minimum of 88%) for all readings. Turbidity varied somewhat between stations, ranging from 7.0 to 16.1 NTU, with most between 7 - 9 NTU. All samples measured for TSS were below the detection limit of 3 mg/L.

Baton Lake

Winter water quality results for 1998 were previously reported; no summer work was done at this site. Benthic results and particle size analysis data are summarized in Table 2 and Table 3, respectively. Sediment chemistry data are reported in Table 8.

Lac de Gras

Water quality results are shown on Table 4 (for measurements taken with the Hydrolab Multiprobe) and Table 5 (metals analyses). One effluent sample was analysed for metals (Table 6). Particle size analysis data for "before" sediment samples from A5-1 are listed in Table 7, and results for sediment chemistry are shown in Table 9. Benthic community taxa and counts were received for the samples collected prior to drilling at A5-1 and reference sites, and for after drilling at both A5-1 and A5-2. Total numbers of individuals and taxa in each sample are shown in Figures 4 and 5.

DISCUSSION / CONCLUSIONS

Great Slave Lake

Seventeen months after the release of effluent in the Great Slave Lake study area, no residual effects on water quality were observed. There was no evidence of resuspension of any drilling fines in the area. Because of the small volumes of rock fines released, the extremely limited dispersion of fines, and the low level of effects in the first year, it was concluded that sampling again in the second winter would not be useful.

Baton Lake

Benthic results were analysed for pre- and post-drilling differences in the two most abundant taxa, and in the number of taxa present. As shown on Table 2, using analysis of variance testing showed no significant differences in numbers of invertebrates present before and one year after release. Unfortunately, only limited baseline data were collected for benthic community samples (5 sites) so the test only utilizes data for stations C, E1, N1, S1 and W1. For those sites, there were sufficient numbers of individuals in two taxa (cyclopoid copepods and nematode worms) so these were used to perfomr the analysis. Because of the extremely small number of taxa inhabiting the sediments of Baton Lake, interpretation of a significant (at 5%) drop in numbers of taxa should be done with caution. Reference sites showed no observable difference in individuals or taxa from 1997 to 1998. Statistically significant increases in sediment aluminum and magnesium were seen, as well as a drop in total organic carbon, which is to be expected with the addition of the rock fines in the area of discharge.

Lac de Gras

Two holes were drilled at Lac de Gras, designated A5-1 and A5-2. The duration of drilling was shorter than anticipated at A5-1, as the core was out of the kimberlite early on, so drilling was ended and a second hole drilled about 150 metres to the southwest. The first hole went through considerable bedrock and drilled approximately 60 metres through kimberlite (the total depth was 239.5 m) while the second hole encountered kimberlite immediately and was drilled to 137 metres with interruptions due to problems with the mud-like consistency encountered in A5-2. Larger quantities of additives (viscosifiers) were required for the second hole. Interpretation of data from Lac de Gras will be subject to these differences between the two holes drilled, particularly for sediment chemistry and benthic community data. Volumes of fines released were 1.02 m^3 for A5-1 and 0.58 m^3 for A5-2. Summer water quality at both release sites was comparable tothe reference site, with a well-mixed water column and temperatures close to 12^o C. pH values were slightly acidic, ranging from 6.27 at the reference site, to 6.32 and 6.52 at the sample sites. Conductivity was extremely low (10.2 uS/cm) and total dissolved solids were all read as zero. Dissolved oxygen levels were near saturation (88 to 95.2%) ranging from 9.31 to 9.93 mg/L in the water column. No turbidity was detectable, and TSS levels were below detection limits in all water samples. Water chemistry results showed no differences between the reference site and A5-1 and A5-2, with most parameters below detection limits. Effluent chemistry was done for a sample from A5-2, and showed moderately high levels of total aluminum and magnesium. Particle size analysis was done for the A5-1 site prior to release, and showed most sites were low in clay (3-9%), predominantly silt (37-60%), and 32 to 60% sand. Sediment chemistry results for metals are available for 1998, and show slight post-drilling increases in some parameters such as chromium, calcium, magnesium, manganese, and nickel, as well as somewhat elevated ammonia-nitrogen. Statistical workup of the complete dataset will be done upon receipt of the 1999 data. Total hydrocarbons in the sediments after drilling were determined to be 223 ppm at the discharge point, (likely due to drilling lubricants), below detection limits 15 m to the east, and less than 30 ppm at 30 m to the east of discharge.

Benthic data are plotted on Figures 4 and 5. Values are consistently higher for numbers of individuals and number of taxa before as compared to after effluent release. Statistical analysis of the data will be done once the 1999 benthic data are received.

LINKS WITH PARALLEL STUDIES

There are no links with other studies on the effects of drilling waste release to lake beds; this is believed to be the only such work currently underway. Related information and research materials are being provided by industry, such as effluent samples for toxicity testing, results of effluent treatment technology advances, and any field measurements that companies may take.

TRAINING ACTIVITIES AND RESULTS

Local technicians were hired to assist with the field work, and received training on the sampling equipment, sample handling, use of the Hydrolab Multiprobe, recording and entering data, and preparing data for statistical analysis. This continued for the last field season this March.

EXPENDITURES AND SOURCE OF FUNDS

WKSS Funding:	$3500.00
Comprehensive Liability Insurance policy	$750.00
Technician/ technical help expenses:	$2000.00
Analytical Costs	$**
Misc. Equipment & Supplies	$801.85
Total:	**$3551.85**

**Amounts billed by DIAND for water analyses totalling $1498.50 were contributed.

Other resources included: from Environment Canada (EC), provision of staff and summer student help (estimated cost $3500); shipping of samples (about $600); analytical work done in-house ($6,000) and by Taiga Environmental Labs ($2500); and benthic analyses, contractor help, and miscellaneous costs for supplies totalling about $19000. Royal Oak provided logistic ground support and accommodation at Colomac Mine, for an estimated contribution of $2500. Diavik supplied site transportation and support (clearing, drilling of holes, and accommodation and meals) valued at approximately $3620 for the 1998 components, and an estimated $2500 for the winter 1999 work.

SCHEDULE AND REVISIONS

All field work has been completed for this study, and benthic data and sediment chemistry results will be available by early to mid-summer. These will be analysed statistically over the fall, and presented in a final report as soon as possible.

REFERENCES

(None for this report).

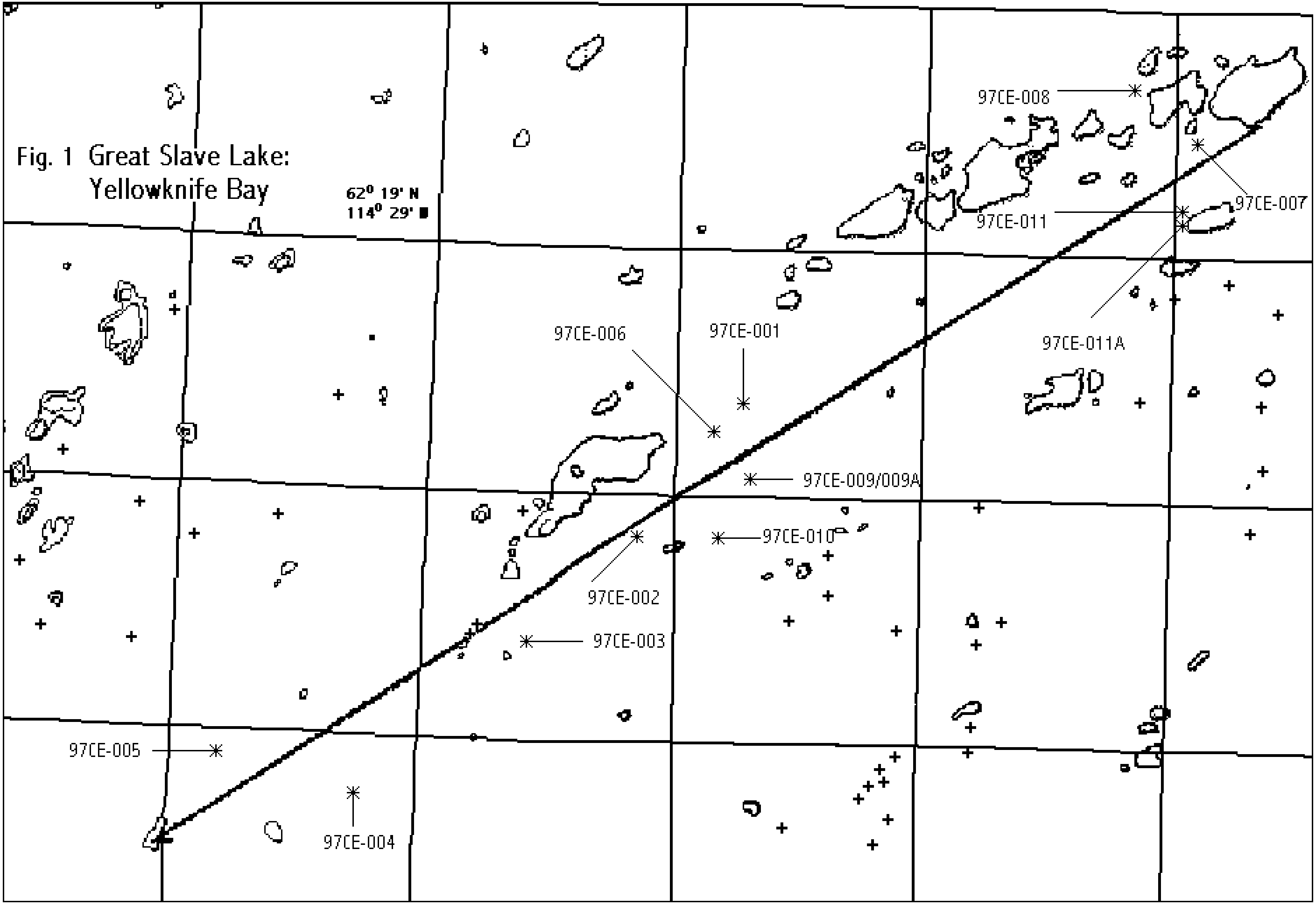
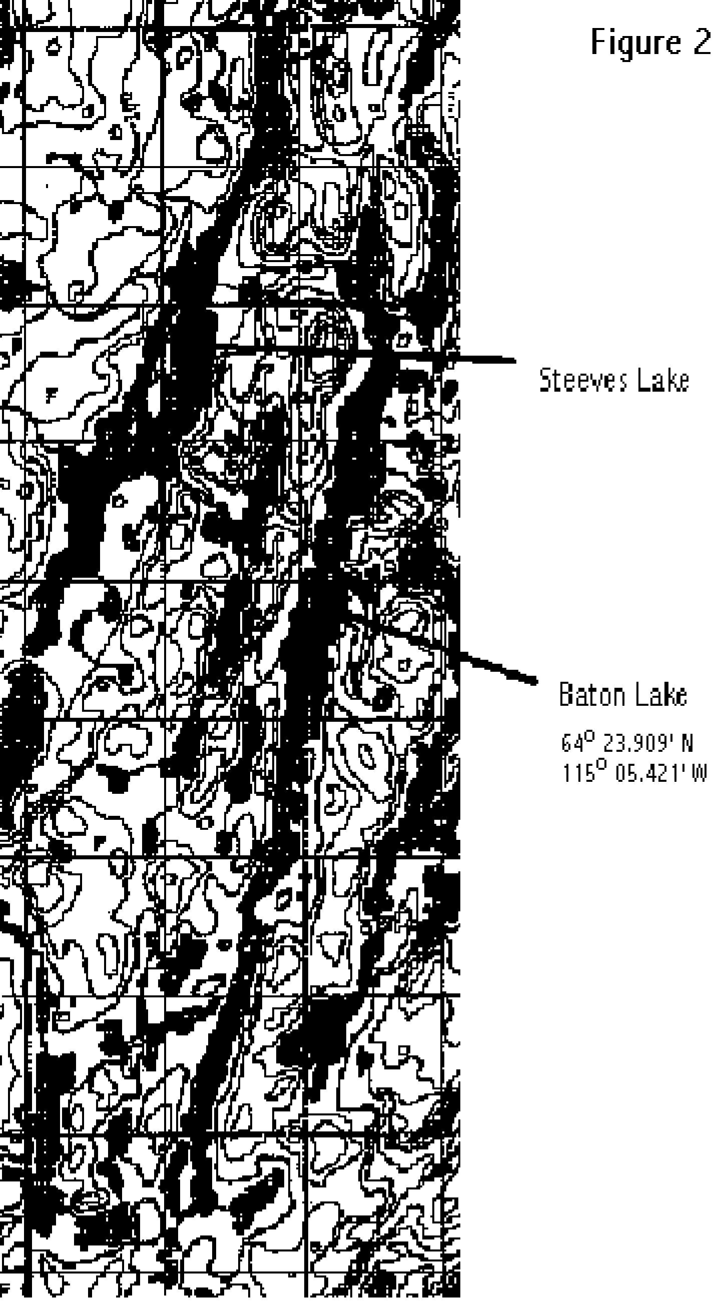


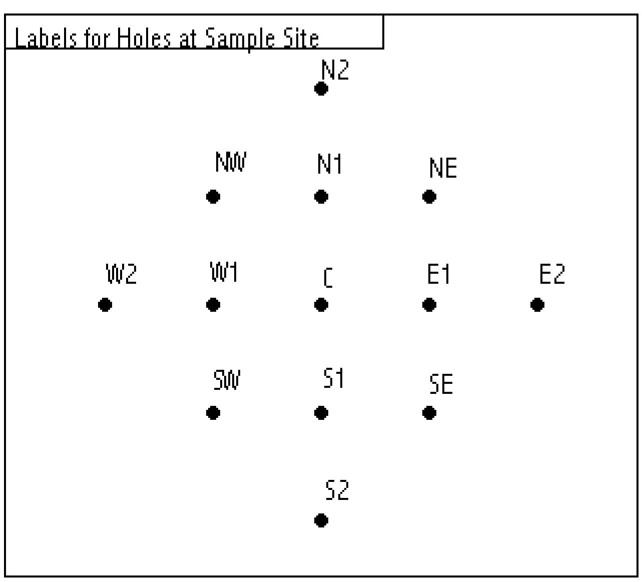
Fig. 1 Great Slave Lake: Yellowknife Bay

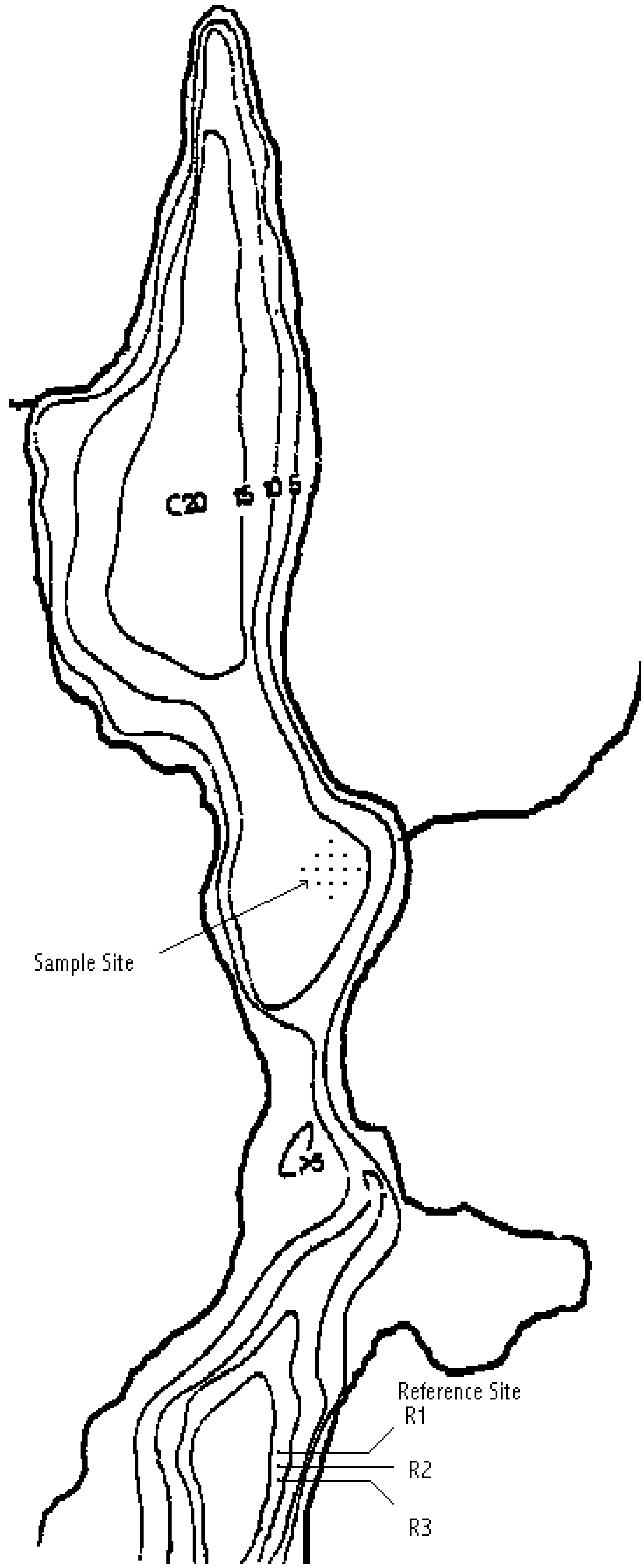
(NTS maps 85I/7 and 85I/8)

Figure 2. Baton Lake Sample Sites



(NTS map # 86B/6)





(After Beak, 1987)

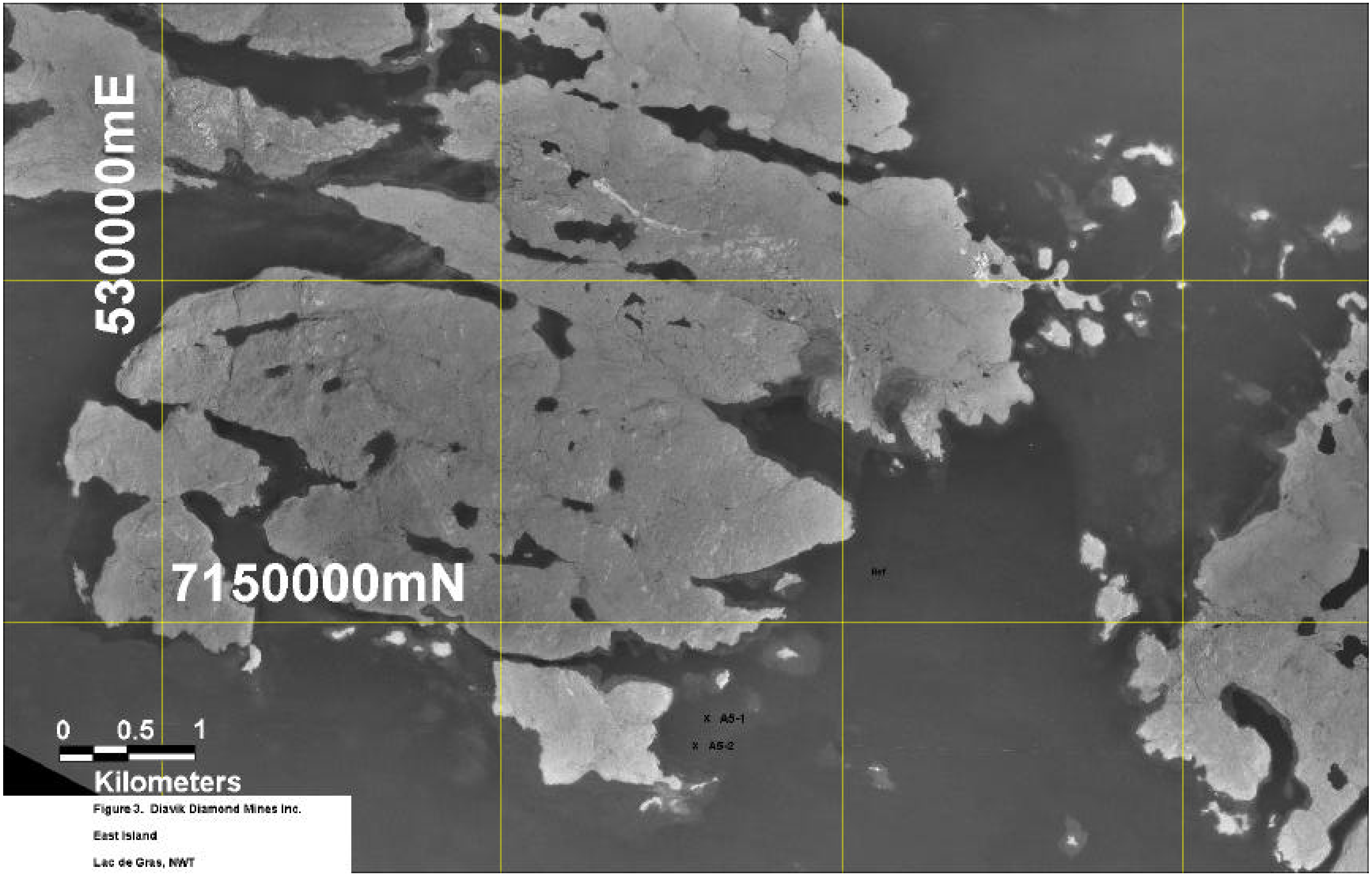


Figure 3. Diavik Diamond Mines Inc.

East Island

Lac de Gras, NWT

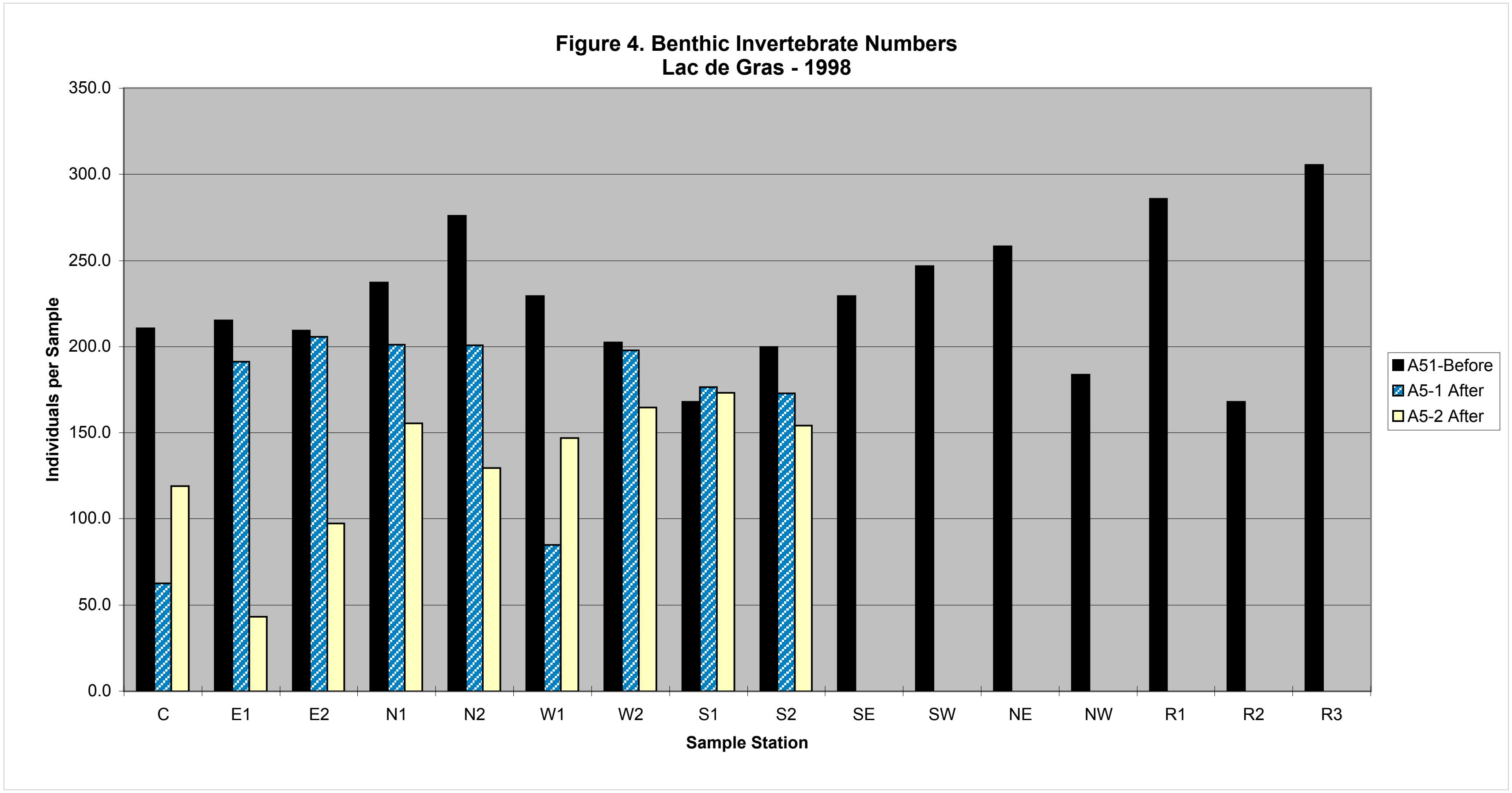


Figure 4. Benthic Invertebrate Numbers
Lac de Gras - 1998
Individuals per Sample
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
C
E1
E2
N1
N2
W1
W2
S1
S2
SE
SW
NE
NW
R1
R2
R3
Sample Station
A51-Before
A5-1 After
A5-2 After

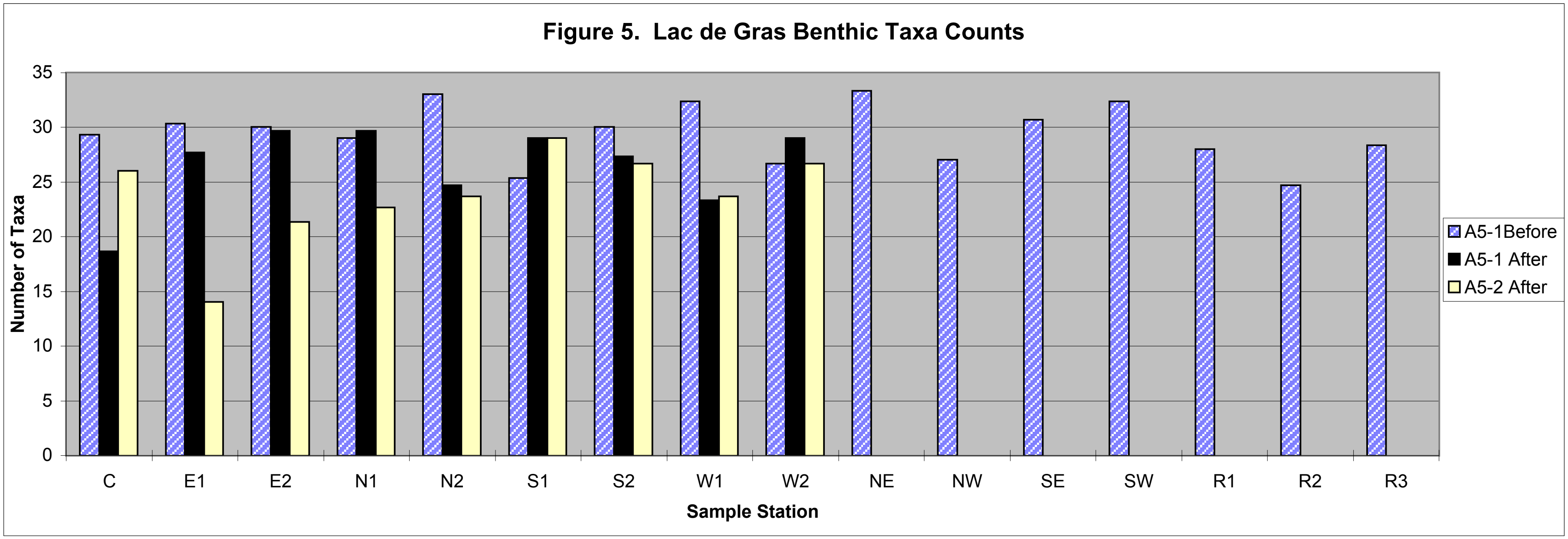


Figure 5. Lac de Gras Benthic Taxa Counts
Number of Taxa
0
5
10
15
20
25
30
35
C
E1
E2
N1
N2
S1
S2
W1
W2
NE
NW
SE
SW
R1
R2
R3
Sample Station
A5-1Before
A5-1 After
A5-2 After

Table 1. Great Slave Lake Water Quality - Hydrolab Readings - August 1998

Site	Temp	pH	SpCond	TDS	DO	DO	Turb
	degC	units	uS/cm	Kmg/l	%Sat	mg/l	NTU
G1							
Min	13.2	7.95	220	0.1	92.7	9.49	8.2
Max	13.8	8.01	221	0.1	98.7	9.99	9.3
Mean	13.6	7.99	220	0.1	96.1	9.76	8.5
Std. Dev.	0.2	0.02	0	0.0	1.9	0.15	0.4
G3							
Min	13.1	7.93	220	0.1	94.0	9.65	7.4
Max	13.6	8.00	221	0.1	96.3	9.78	9.0
Mean	13.4	7.98	220	0.1	94.9	9.68	7.9
Std. Dev.	0.2	0.02	0	0.0	0.8	0.05	0.5
G4							
Min	11.5	7.88	220	0.1	91.8	9.62	7.7
Max	13.6	8.01	222	0.1	95.8	9.78	12.3
Mean	12.7	7.95	221	0.1	93.6	9.71	9.7
Std. Dev.	0.8	0.05	0	0.0	1.3	0.06	1.8
G5							
Min	11.3	7.83	220	0.1	90.1	9.60	13.6
Max	13.6	7.98	221	0.1	133.9	13.61	16.1
Mean	12.9	7.93	221	0.1	97.5	10.05	14.5
Std. Dev.	0.8	0.05	0	0.0	11.4	1.10	0.8
G6							
Min	13.5	7.95	220	0.1	94.1	9.56	7.0
Max	13.8	8.02	220	0.1	95.2	9.64	8.3
Mean	13.7	8.00	220	0.1	94.8	9.62	7.5
Std. Dev.	0.1	0.03	0	0.0	0.4	0.03	0.4
G7							
Min	13.8	7.44	221	0.1	94.8	9.58	7.7
Max	13.9	7.56	221	0.1	95.1	9.60	7.8
Mean	13.9	7.50	221	0.1	95.0	9.59	7.8
Std. Dev.	0.0	0.08	0	0.0	0.2	0.01	0.0
G9							
Min	12.6	7.86	220	0.1	90.2	9.38	7.6
Max	13.8	8.00	221	0.1	101.5	10.51	12.8
Mean	13.5	7.95	220	0.1	97.4	9.92	8.9
Std. Dev.	0.4	0.05	0	0.0	3.1	0.29	1.5
G10							
Min	13.5	7.95	220	0.1	94.6	9.63	7.8
Max	13.6	8.00	221	0.1	95.2	9.67	8.7
Mean	13.6	7.98	220	0.1	94.9	9.65	8.2
Std. Dev.	0.0	0.02	0	0.0	0.3	0.02	0.4
G11							
Min	13.8	7.85	220	0.1	93.7	9.47	7.7
Max	13.9	7.98	221	0.1	94.6	9.56	8.5
Mean	13.8	7.94	220	0.1	94.0	9.50	8.2
Std. Dev.	0.0	0.04	0	0.0	0.3	0.03	0.2
Reference							
Min	10.3	7.74	220	0.1	88.3	9.59	7.9
Max	13.6	8.00	221	0.1	97.2	9.88	15.4
Mean	12.3	7.90	221	0.1	92.7	9.68	10.6
Std. Dev.	1.3	0.09	0	0.0	2.6	0.06	2.8

Table 2: ANOVA Summary of Results for One-Factor Randomized Complete Block Design for Testing for a Difference in Mean Levels Before and After Diamond Drilling

Response variable	Mean level before	Standard deviation before	Mean level after	Standard deviation after	F-ratio	P-value	
Organism data (based on 5 sites: C, E1, N1, S1,W1)							
Number of Diacyclops	2182.4	2836.2	1258.4	742.3	0.77	0.4289	
Number of Nematoda	43.0	64.3	9.8	9.9	1.26	0.3248	
Number of individuals	2231.6	2836.7	1269.2	740.9	0.84	0.4118	
Number of taxa	4.0	1.4	2.4	0.9	9.85	0.0349	**
Chemical data(based on 4 sites: C, E1, S1, W1)							
Aluminum, %	1.555	0.062	1.613	0.062	7.82	0.0681	*
Magnesium, ppm	7940.00	583.15	9700.00	832.83	32.91	0.0105	**
Manganese, ppm	901.75	268.27	1008.00	141.54	0.06	0.4945	
TOC %	16.75	0.50	15.75	1.26	6.00	0.0917	*
Organism log10 transformed data (based on 5 sites: C, E1, N1, S1,W1)							
Log10(Number of Diacyclops)	3.011	0.342	3.043	0.559	0.03	0.8813	
Log10(1 + Number of Nematoda)	0.834	0.534	1.283	0.611	1.60	0.2743	
Log10(Number of individuals)	3.017	0.340	3.061	0.553	0.05	0.8304	
Log10(Number of taxa)	0.346	0.208	0.582	0.146	9.08	0.0394	**
Chemical log10 transformed data(based on 4 sites: C, E1, S1, W1)							
Log10(Aluminum)	0.191	0.018	0.207	0.017	7.97	0.0665	*
Log10(Magnesium)	3.899	0.032	3.986	0.036	41.84	0.0075	***
Log10(Manganese)	2.941	0.128	3.000	0.057	0.92	0.4074	
Log10(TOC)	1.224	0.013	1.196	0.036	5.44	0.1020	
* Statistically significant at the 10% level.							
** Statsistically significant at the 5% level							
*** Statistically significant at the 1% level							

Table 3. Baton Lake - Particle Size Analysis (%)

	July 97			Feb. 1998		
Hole	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**
E-1				**0.6**	**17.8**	**81.6**
E-2				**4.0**	**52.2**	**43.8**
W-1				**2.7**	**36.8**	**60.7**
W-2				**2.8**	**37.4**	**59.8**
C	**21.3** **SD 20.6)**	**49.3** **(SD 8.5)**	**29.3** **(SD 17.5)**	**1.9**	**42.7**	**55.4**
S-1				**2.0**	**29.0**	**69.1**
S-2				**3.6**	**48.1**	**48.8**
N-1				**8.3**	**70.5**	**21.2**
N-2				**2.8**	**39.5**	**57.7**
SE				**4.3**	**49.8**	**45.9**
NW				**5.1**	**58.8**	**41.2**
SW				**4.2**	**52.2**	**43.6**
NE				**3.6**	**50.7**	**45.4**
R-1	**7** **(SD 1)**	**27.3** **(SD 1.5)**	**65.7** **(2.5)**	**6.0**	**52.4**	**41.7**
R-3				**8.9**	**59.0**	**32.1**

Note: No particle size data are available for winter 1997.

Table 4. Lac de Gras Water Quality - Hydrolab Readings - August 1998

Site	Temp.	pH	Sp.Cond.	TDS	DO	DO	Depth	Turbidity
21/08/98	degC	units	uS/cm	Kmg/l	%Sat	mg/l	meters	NTU
A5-1								
Min	**11.92**	**6.39**	**10.1**	**0.0**	**90.6**	**9.56**		**0.0**
Max	**12.47**	**6.66**	**10.3**	**0.0**	**95.2**	**9.93**	**18**	**0.0**
Mean	**12.14**	**6.52**	**10.2**	**0.0**	**92.4**	**9.70**		**0.0**
Std. Dev.	**0.18**	**0.06**	**0.07**	**0.0**	**1.17**	**0.09**		**0.0**
A5-2								
Min	**12.00**	**6.20**	**10.1**	**0.0**	**89.80**	**9.45**		**0.0**
Max	**12.51**	**6.41**	**10.2**	**0.0**	**91.10**	**9.48**	**12.10**	**0.0**
Mean	**12.25**	**6.32**	**10.19**	**0.0**	**90.33**	**9.46**		**0.0**
Std. Dev.	**0.14**	**0.06**	**0.03**	**0.0**	**0.40**	**0.01**		**0.0**
Reference								
Min	**11.82**	**6.12**	**10.1**	**0.0**	**88.00**	**9.31**		**0.0**
Max	**12.38**	**6.33**	**10.2**	**0.0**	**89.70**	**9.37**	**22.00**	**0.0**
Mean	**12.05**	**6.27**	**10.2**	**0.0**	**88.73**	**9.34**		**0.0**
Std. Dev.	**0.15**	**0.07**	**0.02**	**0.0**	**0.45**	**0.02**		**0.0**

Table 5. Lac de Gras Water Quality - Metals Analysis - August 21, 1998

	A5-1 mean	A5-2 mean	Ref mean
TSS (mg/L)	<3	<3	<3
Ag	<0.1	<0.1	<0.1
Al	<25	<25	<25
Ba	1.1	1.1	1.1
Be	<0.1	<0.1	<0.1
Bi	<0.1	<0.1	<0.1
Cd	<0.1	<0.1	<0.1
Cr	0.4	0.3	0.2
Fe (mg/L)	<0.02	<0.02	<0.02
Co	<0.1	<0.1	<0.1
Cs	<0.1	<0.1	<0.1
Cu	0.6	0.6	0.6
Li	1.1	1.1	1.0
Mn	1.7	1.7	1.6
Mo	0.0	<0.1	<0.1
Ni	0.3	0.3	0.3
Pb	1.6	1.8	1.0
Se	<1	<1	<1
Sb	0.5	0.5	0.5
Sr	5.0	5.0	5.0
Ti	0.1	<0.2	<0.2
Th	<0.1	<0.1	<0.1
U	<0.1	<0.1	<0.1
V	<0.1	<0.1	<0.1
Zn	<10	<10	<10

Table 6. Drilling Effluent - Lac de Gras

	Total (mg/L)	Extractable (mg/L)
Al	**974**	**160**
Ba	**51**	**29.5**
Be	**0.041**	**0.011**
Cd	**0.21**	**0.004**
Ca	**2250**	**1550**
Ch	**9.03**	**0.726**
Co	**3.15**	**0.061**
Cu	**1.09**	**0.065**
Fe	**1920**	**379**
Pb	**2.4**	**0.26**
Mg	**5570**	**1160**
Mn	**34.6**	**24**
Mb	**0.177**	**<0.005**
Ni	**27.8**	**3.76**
K	**259**	**33**
Na	**35.9**	**30.4**
Ti	**21.4**	**<0.002**
Va	**4.38**	**0.594**
Zn	**4.37**	**0.644**

Table 7. Particle Size Analysis - Lac de Gras - March 8, 1998 Sediment Samples

Hole	**Clay (%)**	**Silt (%)**	**Sand (%)**
E-2	**3.8**	**49.3**	**46.9**
W-1	**4.6**	**55.8**	**39.7**
W-2	**2.8**	**37.4**	**59.8**
C	**4.1**	**45.4**	**50.5**
C	**4.3**	**47.6**	**48.1**
S-1	**3.5**	**45.1**	**51.4**
S-2	**3.6**	**48.1**	**48.3**
N-2	**2.8**	**39.5**	**57.7**
SE	**4.3**	**50.5**	**45.2**
NW	**5.1**	**60.3**	**34.6**
SW	**4.2**	**47.9**	**47.9**
SW	**4.7**	**56.4**	**38.9**
NE	**3.8**	**50.7**	**45.5**
NE	**4.1**	**53.7**	**42.2**
R-1	**6.4**	**54.3**	**39.3**
R-1	**5.1**	**52.0**	**42.9**
R-3	**9.0**	**59.0**	**32.0**

Missing R2, N1 and E1 - not subsampled

Table 8. Baton Lake Sediment Chemistry

	Before (Release Site)				**After - 1997** (Release Site)				**Winter 1998** (Release Site)				**Reference Site - 1997**				**Reference Site - 1998**			
Parameter	Min	Max	**Mean**	Std.Dev.	Min	Max	**Mean**	Std.Dev.	Min	Max	**Mean**	Std.Dev.	Min	Max	**Mean**	Std.Dev.	Min	Max	**Mean**	Std.Dev.
Aluminum(%)	1.47	1.61	**1.56**	0.06	1.46	1.79	**1.59**	0.10	1.38	1.81	**1.54**	0.13	1.62	1.73	**1.67**	0.06	1.56	1.67	**1.62**	0.06
Arsenic	2.5	8.4	**5.2**	2.66	2.9	9.5	**5.95**	2.24					2.6	7.0	**4.9**	2.2				
Barium	102	124	**112.75**	9.07	90.1	159	**114.62**	17.20	82.00	133.97	**108.03**	15.29	115	127	**122**	6.2	100.86	106.72	**103.39**	3.01
Cadmium	0.50	0.80	**0.65**	0.13	0.6	1.1	**0.82**	0.19	B.D.	B.D.	**B.D.**	B.D.	0.40	1.00	**0.63**	0.32	B.D.	B.D.	**B.D.**	B.D.
Calcium(%)	1.24	1.29	**1.26**	0.02	1.18	1.42	**1.27**	0.07	0.94	1.15	**1.04**	0.07	1.09	1.18	**1.13**	0.05	0.83	0.92	**0.87**	0.05
Chromium	56.30	63.40	**59.65**	3.62	54.2	84.1	**65.22**	8.44	55.43	82.35	**66.17**	7.86	96.60	106.00	**101.20**	4.70	99.31	112.75	**104.09**	7.52
Cobalt	13.30	19.40	**16.18**	2.98	15.4	21.3	**18.12**	1.95	13.91	19.31	**17.33**	1.71	17.70	18.40	**17.97**	0.38	16.31	18.14	**17.21**	0.91
Copper	101.00	115.00	**105.75**	6.29	71.7	115	**97.98**	11.09	66.08	97.82	**87.86**	10.38	65.70	70.90	**67.97**	2.66	57.00	65.57	**62.61**	4.86
Iron(%)	1.85	2.68	**2.24**	0.42	2.02	3.27	**2.56**	0.39	2.29	3.14	**2.67**	0.30	2.66	3.59	**3.17**	0.47	2.48	3.34	**3.05**	0.49
Lead	10.00	13.00	**11.50**	1.29	9	15	**11.69**	2.25	14.67	23.31	**19.32**	2.97	7.00	8.00	**7.67**	0.58	16.10	19.49	**17.91**	1.70
Magnesium	7350	8540	**7940**	583.15	7420	10900	**9124.62**	1071.44	7340	9300	**8301**	693	10900	11300	**11167**	231	9520	10100	**9870**	308
Manganese	648.00	1240.00	**901.75**	268.27	536	1590	**947.69**	262.42	435.18	1250.00	**867.10**	247.22	538.00	921.00	**728.33**	191.51	524.48	937.29	**699.55**	213.42
Molybdenum	5.20	6.70	**5.85**	0.72	3.9	8.2	**5.51**	1.00	4.14	4.31	**4.23**	0.12	3.90	6.70	**5.17**	1.42	B.D.	B.D.	**B.D.**	B.D.
Nickel	45	49	**47**	1.83	42	69	**52.00**	7.23	41.88	61.16	**51.42**	5.66	58.00	64.00	**61.67**	3.21	54.73	64.21	**58.43**	5.07
Potassium	1400	1500	**1425**	50	1400	1800	**1500**	100	1300	1600	**1422**	97	1500	1600	**1533**	58	1400	1600	**1467**	115
Selenium	B.D.	B.D.	**B.D.**	B.D.	B.D.	30	**25**	7.07	B.D.	B.D.	B.D.	B.D.	B.D.	B.D.	**B.D.**	B.D.	B.D.	B.D.	**B.D.**	B.D.
Sodium	210	240	**220**	14	220	410	**270**	47.26	130.00	240.00	**162.50**	35.36	230	260	**240**	17.32	50.00	100.28	**83.43**	28.95
Vanadium	35.7	44.4	**40.1**	4.39	37.8	53.8	**43.86**	4.52	37.35	52.34	**41.05**	4.49	49.80	53.60	**52.27**	2.14	46.59	47.22	**47.00**	0.36
Zinc	123	142	**131.5**	8.1	119	170	**133.77**	14.62	109.31	172.03	**122.52**	19.20	157	165	**161**	4	141.30	142.35	**141.98**	0.59
NH_3 - N	78	160	**118.25**	42.73	48	274	**105.19**	59.19	35.50	221.00	**97.32**	56.54	32.80	46.20	**39.17**	6.72	31.40	137.00	**71.57**	57.15
NO_3 - N	1.40	2.70	**1.83**	0.75	B.D.	1.4	**1.25**	0.10	0.20	2.80	**1.49**	0.84	B.D.	B.D.	**B.D.**	B.D.	1.20	2.60	**1.80**	0.72
TKN(%)	1.63	1.73	**1.67**	0.04	1.43	1.76	**1.59**	0.09	1.29	1.67	**1.49**	0.11	1.14	1.28	**1.22**	0.07	1.02	1.08	**1.05**	0.03
TC(%)	17.00	21.00	**19.00**	1.63	16	22	**18.46**	1.98	15.30	17.90	**16.95**	0.92	15	15	**15**	0	12.0	13.9	**13.20**	1.02
TOC (%)	16.00	17.00	**16.75**	0.50	14	20	**16.69**	1.70	14.80	17.10	**16.02**	0.72	13	15	**14**	1	11.2	12.9	**12.10**	0.85
Beryllium	0.40	0.60	**0.48**	0.10	0.5	0.7	**0.55**	0.07	0.21	0.39	**0.31**	0.05	0.60	0.70	**0.63**	0.06	0.29	0.35	**0.32**	0.03
Titanium	486.0	602.0	**542.3**	61.2	534	695	**608.31**	44.56	557.5	652.2	**605.2**	30.2	709.0	798.0	**747.0**	45.9	717.4	723.8	**721.5**	3.5

*All units are parts per million except where indicated to be % by dry weight

NH_3-N - Ammonia Nitrogen NO_3.N - Nitrate Nitrogen   TKN - Total Kjeldhal Nitrogen

TC - Total Carbon   TOC - Total Organic Carbon   B.D. - Below Detection

Table 9. Lac de Gras Sediment Chemistry

		A51 "Before"				A51 "After"				A52 "After" 1998				Reference Site 1998			
		Min	Max	**Mean**	St.Dev.	Min	Max	**Mean**	Std. Dev.	Min	Max	**Mean**	Std. Dev.	Min	Max	**Mean**	Std. Dev.
Organic Carbon%	Total	1.17	2.09	**1.73**	0.28	0.95	2.41	**1.97**	0.43	0.56	2.20	**1.81**	0.48	1.05	1.67	**1.36**	0.44
Carbon%	Total	1.62	2.73	**2.16**	0.29	1.47	3.02	**2.44**	0.44	0.75	2.76	**2.30**	0.61	1.34	2.09	**1.72**	0.53
TKN	Total	1080	2550	**1746**	364	777	2440	**1863**	474	539	2120	**1624**	479	1165	1580	**1373**	293
Ammonia - Nitrogen,	Extractable	2.9	5.5	**4.0**	1.0	2.50	12.50	**7.08**	3.07	1.90	10.00	**5.01**	2.28	0.88	2.00	**1.44**	0.80
Nitrate - Nitrogen,	Extractable	0.3	5.1	**1.0**	1.4	0.10	1.60	**0.67**	0.53	0.20	12.40	**2.70**	4.77	0.30	0.75	**0.53**	0.32
Aluminum	Extractable	10000	11500	**10714**	570	11500	12700	**12189**	382	9710	15100	**12679**	1568	14200	14300	**14250**	71
Aluminum	Total	55400	62400	**59423**	1935	55500	64100	**59000**	2803	44700	66200	**59500**	6640	64950	65500	**65225**	389
Barium	Extractable	66	132	**95**	25	76	415	**155**	102	64	843	**176**	251	80	85	**83**	4
Barium	Total	353	478	**444**	36	421	677	**478**	77	393	1070	**515**	210	459	498	**479**	28
Beryllium	Extractable	0	0	**0**	0	0.3	0.35	**0.33**	0.02	0.2	0.6	**0.4**	0.1	0	0	**0**	0
Beryllium	Total	0	1	**1**	0	0.5	1.2	**0.7**	0.2	0.5	0.7	**0.7**	0.1	1	1	**1**	0
Cadmium	Extractable	B.D.	B.D.	**B.D.**	B.D.	B.D.	B.D.	**B.D.**	B.D.	B.D.	B.D.	**B.D.**	B.D.	B.D.	B.D.	**B.D.**	B.D.
Cadmium	Total	B.D.	B.D.	**B.D.**	B.D.	1	2	**1**	1	B.D.	B.D.	**B.D.**	B.D.	B.D.	B.D.	**B.D.**	B.D.
Calcium	Extractable	849	1210	**1045**	99	969	29400	**4463**	9362	918	23900	**4354**	7359	1155	1325	**1240**	120
Calcium	Total	8710	10000	**9307**	478	8440	30400	**11518**	7090	8400	25400	**11583**	5250	9140	9395	**9267**	180
Chromium	Extractable	32	36	**34**	1	33	63	**37**	10	28	98	**42**	21	41	42	**42**	1
Chromium	Total	40.2	49.6	**46.0**	3.0	44.8	152.0	**59.4**	34.8	35.7	306.7	**78.8**	85.8	53	60	**56**	5
Cobalt	Extractable	18	66	**40**	16	21	82	**51**	22	12	62	**30**	15	28	29	**28**	0
Cobalt	Total	20	70	**43**	17	24	91	**55**	24	14	65	**34**	15	28	31	**30**	2
Copper	Extractable	25	33	**28**	3	27	184	**46**	52	21	55	**31**	9	32	39	**36**	5
Copper	Total	26.6	32.4	**29.5**	2.1	26.2	164.0	**43.9**	45.1	22.5	69.2	**33.0**	13.9	32	38	**35**	4
Iron	Extractable	15900	44600	**28586**	9032	21200	44300	**29733**	6987	13600	35700	**23756**	7329	22850	29050	**25950**	4384
Iron	Total	20050	49900	**33295**	9372	25500	51900	**33900**	8290	16600	40400	**27911**	7099	26600	32150	**29375**	3924
Lead	Extractable	B.D.	B.D.	**B.D.**	B.D.	5	169	**24**	54	B.D.	B.D.	**B.D.**	B.D.	12	13	**12**	1
Lead	Total	6	32	**19**	9	8	254	**44**	79	13	74	**22**	20	31	33	**32**	1
Magnesium	Extractable	4580	5110	**4839**	199	4620	23600	**7127**	6181	4420	65200	**12059**	19955	6045	6220	**6133**	124
Magnesium	Total	6200	7060	**6590**	218	6140	23600	**8501**	5666	5830	68100	**13963**	20331	7735	7750	**7743**	11
Manganese	Extractable	785	19100	**7560**	5380	1780	21600	**13159**	6995	1390	27300	**11166**	9755	1190	2960	**2075**	1252
Manganese	Total	908	19200	**7863**	5469	1800	20500	**13669**	7291	1530	27700	**11276**	9729	1170	3075	**2123**	1347
Molybdenum	Extractable	B.D.	B.D.	**B.D.**	B.D.	5	8	**6**	2	2	6	**4**	2	B.D.	B.D.	**B.D.**	B.D.
Molybdenum	Total	B.D.	B.D.	**B.D.**	B.D.	3	7	**4**	1	1	9	**4**	2	3	3	**3**	0
Nickel	Extractable	27	115	**61**	32	34	131	**89**	35	25	438	**91**	132	44	55	**50**	8
Nickel	Total	32	119	**62**	29	36	137	**92**	36	27	462	**97**	138	46	58	**52**	9
Potassium	Extractable	2600	2900	**2741**	97	2800	5400	**3156**	844	2700	4200	**3067**	487	3250	3300	**3275**	35
Potassium	Total	18800	20900	**20027**	605	18500	22900	**19844**	1302	16300	22200	**20144**	1793	22100	23000	**22550**	636
Sodium	Extractable	100	150	**126**	17	130	290	**194**	56	120	280	**184**	53	145	160	**153**	11
Sodium	Total	18300	20800	**19500**	847	17300	22500	**19011**	1523	10600	22100	**18589**	3310	20200	20300	**20250**	71
Titanium	Extractable	587	683	**629**	32	601	845	**650**	75	408	737	**614**	95	772	776	**774**	3
Titanium	Total	1660	2100	**1985**	124	1880	2200	**2016**	99	1720	2430	**2152**	226	2235	2365	**2300**	92
Vanadium	Extractable	24	28	**27**	1	24	33	**26**	3	22	47	**29**	7	33	34	**34**	1
Vanadium	Total	38.5	48.6	**44.8**	2.7	42	49	**45**	2	38	93	**53**	16	52	57	**55**	4
Zinc	Extractable	42	69	**52**	10	44	130	**67**	25	34	90	**53**	16	60	61	**60**	1
Zinc	Total	48.5	72.7	**58.7**	9.2	50.8	153.0	**77.8**	30.1	41.7	105.7	**62.5**	18.2	66	67	**66**	1