AQUATIC EFFECTS TECHNOLOGY EVALUATION (AETE) PROGRAM

Field Evaluation of Aquatic Effects Monitoring

Recommendations for 1997 Sites

AETE Project 4.1.2

1996 Field Evaluation

AQUATIC EFFECTS MONITORING

RECOMMENDATIONS FOR 1997 SITES

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AQUATIC EFFECTS TECHNOLOGY EVALUATION PROGRAM

Notice to Readers

Aquatic Effects Monitoring
1996 Preliminary Field Surveys

The Aquatic Effects Technology Evaluation (AETE) program was established to review appropriate technologies for assessing the impacts of mine effluents on the aquatic environment. AETE is a cooperative program between the Canadian mining industry, several federal government departments and a number of provincial governments; it is coordinated by the Canada Centre for Mineral and Energy Technology (CANMET). The program is designed to be of direct benefit to the industry, and to government. Through technical evaluations and field evaluations, it will identify cost-effective technologies to meet environmental monitoring requirements. The program includes three main areas: acute and sublethal toxicity testing, biological monitoring in receiving waters, and water and sediment monitoring. The program includes literature-based technical evaluations and a comprehensive three year field program.

The program has the mandate to do a field evaluation of water, sediment and biological monitoring technologies to be used by the mining industry and regulatory agencies in assessing the impacts of mine effluents on the aquatic environment; and to provide guidance and to recommend specific methods or groups of methods that will permit accurate characterization of environmental impacts in the receiving waters in as cost-effective a manner as possible. A pilot field study was conducted in 1995 to fine-tune the study design.

A phased approach has been adopted to complete the field evaluation of selected monitoring methods as follows:

Phase I: 1996- Preliminary surveys at seven candidate mine sites, selection of sites for further work and preparation of study designs for detailed field evaluations.

Phase II: 1997-Detailed field and laboratory studies at selected sites.

Phase III: 1998- Data interpretation and comparative assessment of the monitoring methods: report preparation.

Phase I is the focus of this report. The overall objective of this project is to conduct a preliminary field/laboratory sampling to identify a short-list of mines suitable for further detailed monitoring, and recommend study designs. The objective is NOT to determine the detailed environmental effects of a particular contaminant or extent and magnitude of effects of mining at the sites.

In Phase I, the AETE Technical Committee has selected seven candidates mine sites for the 1996 field surveys:

1) Myra Falls, Westmin Resources (British Columbia)
2) Sullivan, Cominco (British Columbia)
3) Lupin, Contwoyto Lake, Echo Bay (Northwest Territories)
4) Levack/Onaping, Inco and Falconbridge (Ontario)
5) Dome, Placer Dome Canada (Ontario)
6) Gaspé Division, Noranda Mining and Exploration Inc. (Québec)
7) Heath Steele Division, Noranda Mining and Exploration Inc. (New-Brunswick)

Study designs were developed for four sites that were deemed to be most suitable for Phase II of the field evaluation of monitoring methods (Myra Falls, Dome, Heath Steele, Lupin). Lupin was subsequently dropped based on additional reconnaissance data collected in 1997. Mattabi Mine, (Ontario) was selected as a substitute site to complete the 1997 field surveys.

For more information on the monitoring techniques, the results from their field application and the final recommendations from the program, please consult the *AETE Synthesis Report* to be published in September 1998.

Any comments regarding the content of this report should be directed to:

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PROGRAMME D'ÉVALUATION DES TECHNIQUES DE MESURE D'IMPACTS EN MILIEU AQUATIQUE

Avis aux lecteurs

Surveillance des effets sur le milieu aquatique
Études préliminaires de terrain - 1996

Le Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ÉTIMA) vise à évaluer les différentes méthodes de surveillance des effets des effluents miniers sur les écosystèmes aquatiques. Il est le fruit d'une collaboration entre l'industrie minière du Canada, plusieurs ministères fédéraux et un certain nombre de ministères provinciaux. Sa coordination relève du Centre canadien de la technologie des minéraux et de l'énergie (CANMET). Le programme est conçu pour bénéficier directement aux entreprises minières ainsi qu'aux gouvernements. Par des évaluations techniques et des études de terrain, il permettra d'évaluer et de déterminer, dans une perspective coût-efficacité, les techniques qui permettent de respecter les exigences en matière de surveillance de l'environnement. Le programme comporte les trois grands volets suivants : évaluation de la toxicité aiguë et sublétale, surveillance des effets biologiques des effluents miniers en eaux réceptrices, et surveillance de la qualité de l'eau et des sédiments. Le programme prévoit également la réalisation d'une série d'évaluations techniques fondées sur la littérature et d'évaluation globale sur le terrain.

Le Programme ÉTIMA a pour mandat d'évaluer sur le terrain les techniques de surveillance de la qualité de l'eau et des sédiments et des effets biologiques qui sont susceptibles d'être utilisées par l'industrie minière et les organismes de réglementation aux fins de l'évaluation des impacts des effluents miniers sur les écosystèmes aquatiques; de fournir des conseils et de recommander des méthodes ou des ensembles de méthodes permettant, dans une perspective coût-efficacité, de caractériser de façon précise les effets environnementaux des activités minières en eaux réceptrices. Une étude-pilote réalisée sur le terrain en 1995 a permis d'affiner le plan de l'étude.

L'évaluation sur le terrain des méthodes de surveillance choisies s'est déroulée en trois étapes:

Étape I 1996 - Évaluation préliminaire sur le terrain des sept sites miniers candidats, sélection des sites où se poursuivront les évaluations et préparation des plans d'étude pour les évaluations sur le terrain.

Étape II 1997- Réalisation des travaux en laboratoire et sur le terrain aux sites choisis

Étape III 1998 -Interprétation des données, évaluation comparative des méthodes de surveillance; rédaction du rapport.

Ce rapport vise seulement les résultats de l'étape I. L'objectif du projet consiste à réaliser des échantillonnages préliminaires sur le terrain et en laboratoire afin d'identifier les sites présentant les caractéristiques nécessaires pour mener les évaluations globales des méthodes de surveillance en 1997 et de développer des plans d'études. Son objectif N'EST PAS de déterminer de façon détaillée les effets d'un contaminant particulier, ni l'étendue ou l'ampleur des effets des effluents miniers dans les sites.

À l'étape I, le comité technique ÉTIMA a sélectionné sept sites miniers candidats aux fins des évaluations sur le terrain:

1) Myra Falls, Westmin Resources (Colombie-Britannique)
2) Sullivan, Cominco (Colombie-Britannique)
3) Lupin, lac Contwoyto, Echo Bay (Territoires du Nord-Ouest)
4) Levack/Onaping, Inco et Falconbridge (Ontario)
5) Dome, Placer Dome Mine (Ontario)
6) Division Gaspé, Noranda Mining and Exploration Inc.(Québec)
7) Division Heath Steele Mine, Noranda Mining and Exploration Inc.(Nouveau-Brunswick)

Des plans d'études ont été élaborés pour les quatres sites présentant les caractéristiques les plus appropriées pour les travaux prévus d'évaluation des méthodes de surveillance dans le cadre de l'étape II (Myra Falls, Dome, Heath Steele, Lupin). Toutefois, une étude de reconnaissance supplémentaire au site minier de Lupin a révélé que ce site ne présentait pas les meilleures possibilités. Le site minier de Mattabi (Ontario) a été choisi comme site substitut pour compléter les évaluations de terrain en 1997.

Pour des renseignements sur l'ensemble des outils de surveillance, les résultats de leur application sur le terrain et les recommandations finales du programme, veuillez consulter le *Rapport de synthèse ÉTIMA* qui sera publié en septembre 1998.

Les personnes intéressées à faire des commentaires sur le contenu de ce rapport sont invitées à communiquer avec M^{me} Diane E. Campbell à l'adresse suivante :

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1.0
INTRODUCTION

The Aquatic Effects Technology Evaluation (AETE) Program was established to conduct field and laboratory evaluation and comparison of selected environmental effects monitoring technologies for assessing impacts of mine effluents on the aquatic environment. The focus of the Program is on robustness, costs, and the suitability of monitoring sites.

Building upon previous work, which includes literature reviews, technical evaluations, and pilot field studies (e.g., BAR 1996a,b; Beak, 1996; Couillard and St-Cyr, 1996; Taylor, 1996), the AETE Program sponsored, in 1996, preliminary evaluations of aquatic effects monitoring at seven candidate mine sites. Based on the results of these preliminary evaluations, some of these sites will be selected for further work in 1997.

This report provides recommendations regarding selection of sites for 1997 work. Separate reports provide detailed information on work conducted at each of the seven sites (EVS, ESP and JWEL, 1996a-g). A recommended study design for 1997 is provided in EVS, ESP and JWEL (1996h).

2.0
PURPOSE AND OBJECTIVE

The purpose of this draft report is to evaluate the seven sites surveyed in 1996 relative to a short-list of sites for detailed study in 1997. The objective of this report is, to the extent possible (given data and information availability), to compare the seven sites to specific criteria (cf. Section 4.0) and provide conclusions and recommendations.

3.0
RELEVANT SITE-SPECIFIC INFORMATION

Summary information for each of the seven sites is provided in Tables 1-7, beginning with Vancouver Island (Myra Falls) and proceeding eastward.

To provide additional information for future studies, the suite of parameters (field- and laboratory-measured) were evaluated for each mine. The evaluation was essentially a screening to weed out variables that are not worth including in subsequent studies. The only reason to include a relatively useless variable would be if the cost of measuring the variable is negligible (e.g., if the variable is part of a routine analysis package). A master list of variables was compiled from the individual mine reports. Variables were categorized into one of four types:

1. *Exposure* - those parameters indicative of exposure to mine effluent (e.g., metals or metallothionein).

2. *Other* - those parameters which may be exposure-related (e.g., pH), good modifying factors, or indicate differences between areas not related to mine activity. Differences between reference and exposure areas in these variables may be exposure-related (i.e., related to mine discharge) or indicate potential differences between areas that are not mine related. With one reference area it was difficult to distinguish between these two cases.

3. *Effects* - those parameters used to measure potential effects of exposure to mine effluent (e.g., effluent toxicity and benthic community structure). Ideally, these endpoints are sensitive to exposure to mine effluent and relatively easy to measure.

4. *Habitat* - those parameters which may be exposure-related, good modifying factors, or indicate differences between areas (e.g., sediment grain size or total organic carbon).

Evaluation criteria and evaluation results are presented in Table 8.

4.0
POSSIBLE APPROPRIATE SITES FOR 1997

The AETE Program anticipates selection of some of the seven mine sites surveyed in 1996 for further work in 1997. Work in 1997 will be based on hypotheses to be tested (Table 9).

Selection of sites for 1997 requires consideration of the following five criteria:

1. The presence of well defined water chemistry, sediment chemistry (where sediment is available) and biotic gradients of contamination and effects in the receiving environments.

2. Availability of adequate multiple reference and exposure stations for biota (fish and benthos).

3. Presence of suitable habitat for tests of methodology (e.g., unconsolidated sediments).

4. Accessability by road and boat.

5. Overall site suitability for testing AETE's hypotheses in the 1997 detailed field evaluations.

Comparisons relative to the above criteria are contained in Tables 1 - 7. The seven 1996 sites are further assessed using numbered scores based on these criteria in Table 10 (Summary data - detailed information for each site is provided in Appendix A). The overall suitability of each site to evaluate each of the 1997 hypotheses (Table 9) is assessed in Table 11. Based on Tables 1 - 7 and 10 and 11, our assessment of site suitability for detailed work in 1997 is provided below (Section 4.1).

4.1 SPECIFIC RECOMMENDATIONS FOR 1997 SITES

In determining which sites should be addressed in 1997 we considered both the site scores (from Table 10) and the hypotheses which can, either completely or partially, be addressed at each site. This information is summarized below:

Mine Site	Percentage Score (from Table 10)	Hypotheses Fully Addressed (a "Y" in Table 11)	Hypotheses Partially Addressed (a "P" in Table 11)	Hypotheses Not Addressed (a "N" in Table 11)
Dome	78%	10	2	1
Gaspe	69%	3	6	4
Heath Steele	67%	3	6	4
Lupin	63%	10	3	0
Myra Falls	61%	6	4	3
Onaping/Levack	61%	3	6	4
Sullivan	57%	2	8	3

Based simply on site scores, selection of 1997 sites is relatively easy. However, when hypotheses are also considered, the process becomes more difficult:

- The Dome site is clearly the primary candidate for 1997 studies based on both percentage scores (highest of all sites) and hypotheses which can be addressed (only exceeded by Lupin). Accordingly, we recommend this site for 1997 studies.

- The Gaspe and Heath Steele sites have very similar percentage scores (69% and 67%), and address a similar number of hypotheses. The main differences between these two sites are the sublethal toxicity and fish tissue results. Sublethal toxicity was more evident for the Heath Steele site, but the results of metal and metallothionein analyses were clearer for the Gaspe site. Because the two sites are so similar, we recommend that only one be used in 1997. Since a draft study design is already being reviewed by the AETE Committee for the Heath Steele site, we recommend this site for 1997 studies.

- The Lupin site has the next highest percentage score (63%) and addresses the most hypotheses of any site. Accordingly, we recommend this site for 1997 studies.

- If 1997 studies were only conducted at the above three sites, some hypotheses might not be adequately tested (i.e., at three sites). The next highest percentage score (61%) is shared by Myra Falls and Onaping\Levack. However, far more hypotheses can be tested at the former than the latter, as noted above. The final mine site, Sullivan, has the lowest percentage score (57%) and the lowest number of hypotheses which can be fully tested, as noted above. Accordingly, we recommend the Myra Falls site for 1997 studies.

The results of the above recommendations are examined below where hypotheses are matched against recommended mine sites. Sites names in parentheses indicate that the hypotheses are only partially testable (a "P" in Table 12). Comments are only provided where there are less than three sites where hypotheses can be fully tested. Note that hypothesis 9 (H9), which can be tested at all of the seven sites, is not included as it is not recommended for the 1997 field studies (EVS, ESP and JWEL, 1996h).

HYPOTHESIS	RECOMMENDED MINE SITES	COMMENTS (CF. TABLE 12)
H1	Dome, Lupin	No other sites possible
H2	Dome, Lupin, Myra Falls, (Heath Steele)	
H3	Lupin, Myra Falls, (Dome), (Heath Steele)	Only other "yes" is Onaping/Levack
H4	Dome, Lupin, Myra Falls, (Heath Steele)	
H5	Dome, Lupin, Heath Steele, (Myra Falls)	
H6	Dome, Lupin, (Myra Falls)	No other sites a "yes"
H7	Dome, Lupin, Heath Steele, (Myra Falls)	
H8	Dome, Lupin, (Heath Steele), (Myra Falls)	No other sites a "yes"
H10	Heath Steele, Myra Falls, (Dome), (Lupin)	Only other "yes" is Sullivan
H11	Dome, Lupin	No other sites possible
H12	Dome, Lupin	No other sites possible
H13	Myra Falls, (Lupin), (Heath Steele)	No other "yes" sites
H14	Dome, Heath Steele, Myra Falls, (Lupin)	

4.2 FUTURE STUDIES AND POWER ANALYSIS

This section outlines the use of power analysis for making study design decisions for future AETE monitoring programs. There is a difference in focus between the 1996 and 1997 AETE Monitoring Programs (i.e., there is a 1996 program focused on evaluating mines; the 1997 program will focus on comparative evaluation of monitoring tools). While not necessarily applicable for the 1997 Monitoring Program, the results of these power analyses will be useful for future programs evaluating impact assessment hypotheses (i.e., Is there a difference in parameter x between the exposure and reference areas?).

The general equation for power analysis is as follows (Sokal and Rohlf, 1981):

Equation 1

$$n = 2\ (t_\alpha + t_\beta)\ (\frac{s}{d})^2$$

where: n = Number of stations in each area (i.e., exposure and reference area)

t_α = Inverse of t distribution for α (one or two-tailed) and 2n-2 degrees of freedom (df)

t_β = Inverse of t distribution for β (one-tailed) and 2n-2 df

s = Pooled within group standard deviation

d = Effect size

As the equation is set up, calculating n is an iterative process because t_α and t_β are dependent on n (to determine df). One difficulty with this equation is that a relevant effect size, d, must be determined; selecting ecologically relevant effect sizes can be a source of great controversy. The equation can be rearranged to: (1) generate power curves (to examine relationships among parameters), (2) calculate d for a fixed n, or (3) retrospectively calculate statistical power (i.e., $1-\beta$) to detect predetermined effect sizes.

The general relationships among equation parameters are informative in determining what factors should be considered to optimize study designs. To this end, Section 4.2.1 explores several general issues relating to power analysis. The remaining sections deal with using power analysis to determine minimum sample size requirements (Section 4.2.2) for fixed effect sizes and to determine minimum detectable effect sizes for fixed sample sizes (Section 4.2.3). Because of the difficulties associated with recommending ecologically relevant effect sizes for each variable at this stage, use of power analysis to determine minimum sample sizes was limited to a few examples. Emphasis was placed on documenting minimum detectable effect sizes for various fixed sample sizes for each variable selected. While the generic power curves can be used for any mine, examples for calculating sampling effort for fixed effect sizes (i.e., Section 4.2.2) and effect sizes for fixed sampling efforts (i.e., Section 4.2.3) were limited to key variables from the Dome, Lupin and Heath Steele mines.

4.2.1 Generic Power Curves

The relationship among equation parameters was examined by generating generic power curves. An important consideration in power analysis is selecting appropriate α and β values. The value for α is usually set at 0.05 (i.e., the investigator has a 1 in 20 chance of detecting an effect when none exists [Type 1 error]). While β values set the probability of not detecting an effect when one in fact exists (i.e., Type II error), they are often ignored by investigators (Buhl-Mortensen, 1996). Since the consequences of committing a Type II error can be serious (i.e., missing a real effect), we recommend that β values be set equivalent to α (i.e., 0.05). To examine the influence of β on the relationship between effect size and sample size, power curves were generated for two β values: 0.05 and 0.2. The power curves were generated by rearranging Equation 1 as follows:

Equation 2

$$d = \frac{(t_\alpha + t_\beta)}{\sqrt{n}}$$

where: d = Effect size (in SD units)
t_α = Inverse of t distribution for α of 0.05, 2n-2 degrees of freedom (df), and 2 tails
t_β = Inverse of t distribution for β of 0.05 or 0.2, 2n-2 df, and 1 tail
n = Number of stations in each area (i.e., exposure and reference area)

Note that since *s* is omitted from the equation, the units for effect size become standard deviations. The equation was solved for *n* ranging from 2 to 50. The resulting two power curves (i.e., for β= 0.05 and 0.2) are provided in Figure 1. The results show that the greatest benefits (i.e., in terms of reducing the minimum detectable effect size) of increasing sampling effort occur between 2 and 10 samples per area and that after about 20 samples there is almost no benefit from further increases in sampling effort.

4.2.2 Calculation of Sampling Effort for Fixed Effect Sizes

Calculating sampling effort for fixed effect sizes depends on the investigators' ability to determine what constitutes an ecologically-relevant effect size. The following example using benthic invertebrate total abundance from the Lupin Mine demonstrates some of the difficulties with this process. The results from the 1996 AETE program at Lupin are shown in Table 12.

How many samples would it take to detect a difference between Reference and Exposure Areas? That can only be answered if we establish the minimum effect size we wish to detect. As previously discussed, determining relevant effect sizes is a challenging and often controversial task. One could arbitrarily state that a 33% or 66% reduction in the abundance of benthic invertebrates is ecologically significant in this case, but either approach is debatable. An alternative approach would be to generate a power curve for total abundance to examine the relationship between effect size and sampling effort. The latter is more informative and allows reviewers to make their own conclusions as to trade offs between detectable effect size and sampling effort. This exercise is often informative to those who believe that relevant effect sizes are on the order of 5 to 10 percent. The relationship between effect size and sampling effort for benthic invertebrate abundance at the Lupin Mine is shown in Figure 2. The power curve shows two lines because effect size is asymmetrical for log-transformed data (i.e., you can have a 500% increase in benthos, but a 500% decrease is impossible) (n.b., the scale of the bottom line has been changed 10-fold to facilitate use of the graph). In this case, a two-fold (i.e., 100% increase or 50% decrease) effect size is the smallest one could hope to measure regardless of sampling effort. After about 10 samples per area, the cost of increasing sampling effort is likely to outweigh any benefits of reducing effect size. This shows that increasing sample size is not necessarily the answer to achieve increased power; reducing variability (e.g., by compositing replicate benthos samples at each station) might provide a much higher pay off in terms of reducing minimum detectable effect sizes.

4.2.3 Calculation of Detectable Effect Size for Fixed Sampling Effort

The preceding example demonstrates some of the difficulties associated with specifying effect sizes. Most monitoring studies are limited by available financial resources, and consideration of this constraint is an important factor in the design of most studies. With this in mind, it is often useful to calculate the minimum detectable effect size for a fixed sampling effort (i.e., what can be managed within available budget). If the resulting effect size is not considered sufficiently small to detect "real" effects, then the study should not proceed as planned. Table 13 shows the minimum detectable effect sizes for fixed sampling efforts of 5, 10 and 30 stations per area for key variables for the Dome, Lupin, and Heath Steele mines. The effect sizes were calculated using the following formula (rearranged from Equation 1):

Equation 3

$$d = \frac{(t_\alpha + t_\beta)\, s}{\sqrt{n}} \qquad d = \frac{(t_\alpha + t_\beta)\, CV}{\sqrt{n}}$$

where:
- d = Effect Size
- t_α = Inverse of t distribution for α of 0.05, 2n-2 degrees of freedom (df), and 2 tails
- t_β = Inverse of t distribution for β of 0.05 or 0.2, 2n-2 df, and 1 tail
- n = Number of stations in each area (i.e., exposure and reference area)
- s = Pooled within group standard deviation (for log-transformed variables)
- CV = Pooled within group standard deviation/reference mean (for non-transformed variables)

Selection of key parameters for each mine was based on the following:

- Contaminants suspected of being associated with mine operations (water, sediment, fish tissue).

- Other exposure indicators (e.g., metallothionein) if appropriate data were available.

- Effects indicators if appropriate data were available.

5.0
CONCLUSIONS

We recommend the following four sites for the 1997 field studies:

- Dome
- Heath Steele
- Lupin
- Myra Falls

These recommendations are based on our review and analysis of all available technical information, as documented in this report, and comprise our best professional judgement. However, the final decision on the 1997 study sites rests with the AETE Committee, who also have to consider non-technical issues.

6.0
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FIGURES

Figure 1. Generic Power Curves for B=0.05 and B=0.2

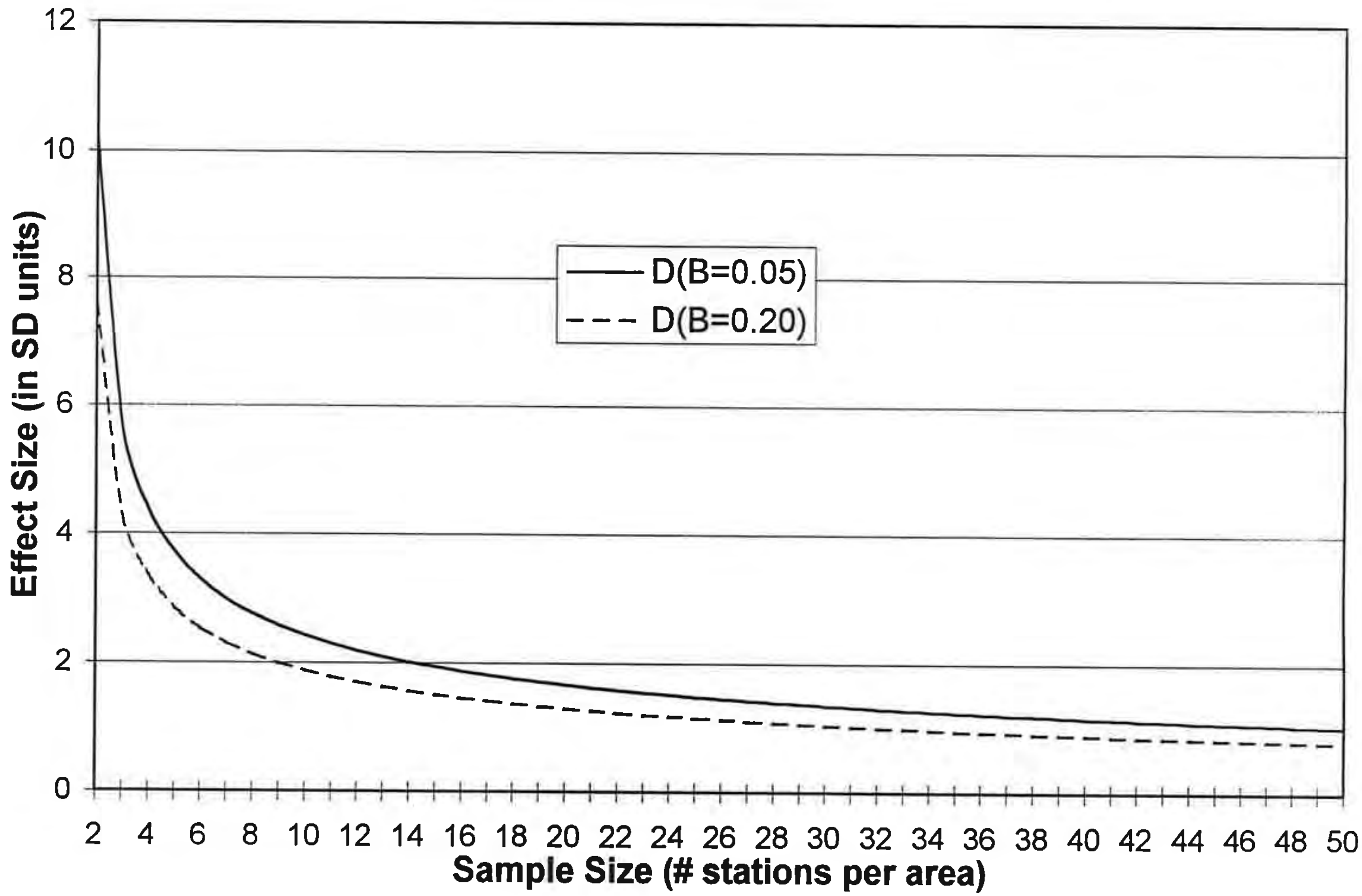
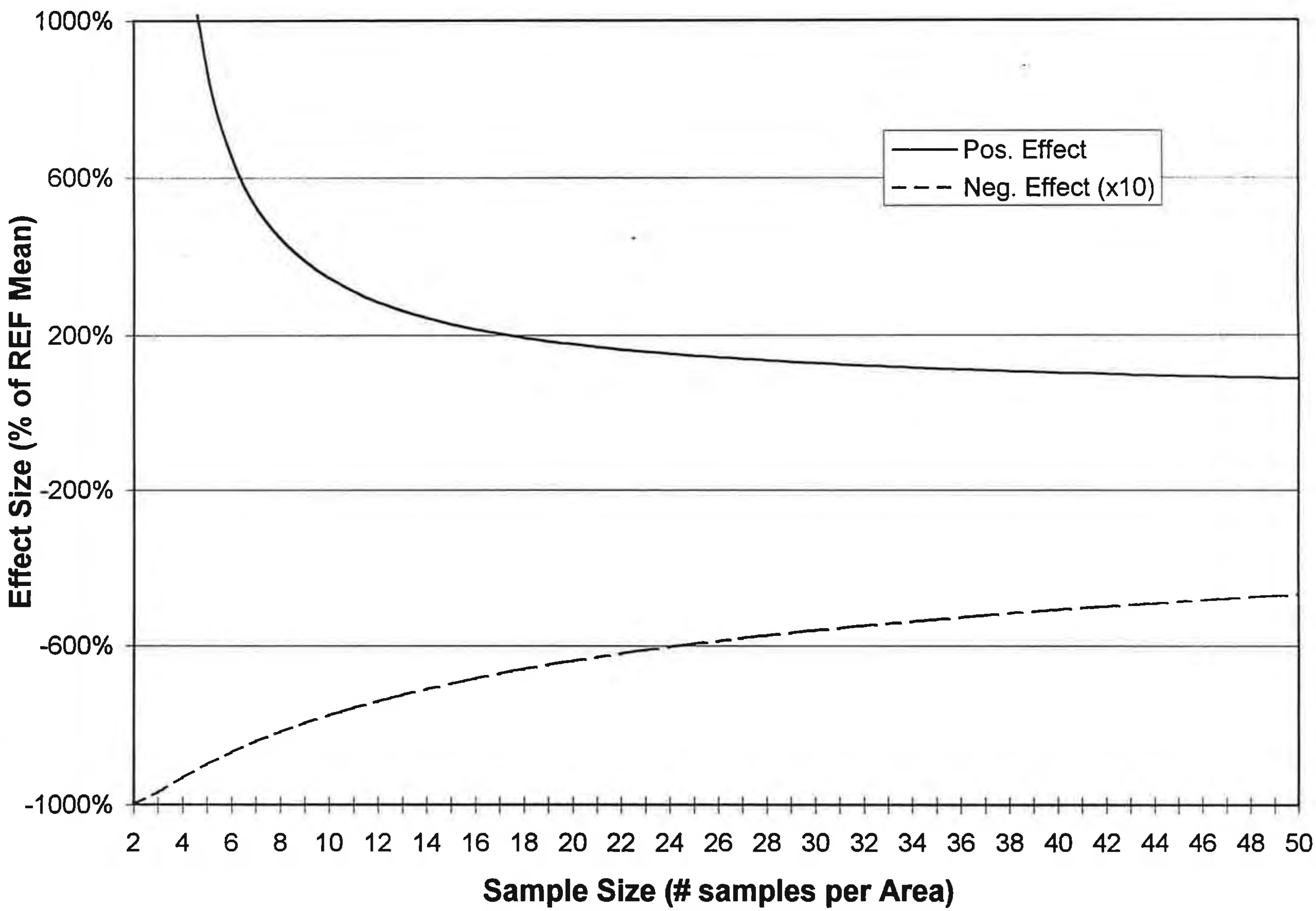


Figure 2. Benthos abundance - Lupin Mine: Power Curve (a = b = 0.05)



TABLES

Table 1. Summary information for specific study elements for the Myra Falls mine site (stream/lake discharge)

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	na	• Some rainbow trout and *Daphnia* toxicity in Buttle Lake, but results not consistent
1.2 Water Chemistry	na	• Monitoring data exist • Although inputs are well defined, delineation of mixing zone confounded by changing water level controlled by B.C. Hydro
1.3 Sediment Chemistry	na	• There are no historic data
1.4 Benthos	na	• Emphasis has been on plankton • Benthos changes observed below the mine
1.5 Fisheries 1.5.1 Population	na	• No trends apparent in historic data
1.5.2 Tissue	na	• Fish tissue and metallothionein studies indicate differences between reference and exposure areas but differences have decreased over time
2.0 Study Area 2.1 Site Access	na	• Boat launch within 20min boat ride of reference site; another boat launch within 60min boat ride of exposure site
2.2 Availability of Multiple Reference and Exposure Areas	na	• Multiple reference and exposure stations of relatively uniform habitat type available
2.3 Confounding Discharges	na	• None
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	na	• Effluent continuously discharged (easy access)
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Yes	• Survival and reproduction affected
3.2.2 Fathead Minnow	Yes	• Survival and growth affected
3.2.3 *Selenastrum capricornutum*	Yes	• Growth affected (most sensitive end-point of all tested)
3.2.4 *Lemna minor*	Yes	• Growth affected
3.2.5 Trout embryo	Yes	• No data; controls failed

Table 1 (continued)

Element	Sampled 1996	Summary/Comments
4.0 Habitats	Yes	• Main habitat difference between exposure and reference areas is finer sediments in former • Multiple reference and exposure stations of relataively uniform habitat type available
5.0 Water Chemistry	Yes	• Significant elevations in conventional parameters (e.g., pH, conductivity) and several metals at exposure compared to reference area
6.0 Sediments	Yes	• Difficult to find appropriate sediment at both exposure and reference areas • Increased level of effort would be required to find other depositional areas and these may not be representative (i.e., may only represent a small portion of the system) • Fluctuating water level exposes littoral sediment depositional areas
7.0 Benthic Invertebrates	Yes	• Buttle Lake steep-sided; shore drops off quickly • Littoral zone varies as water levels are altered • Zooplankton may be more useful in this system for determining effects; artificial substrates are another possibility
8.0 Fisheries 8.1 Communities	Yes	• Potential sentinel species are rainbow trout, cutthroat trout, Dolly Varden • Sentinel species available with reasonable effort • Size difference noted but may be an artifact of sampling methods
8.2 Tish Tissue	No	• Good historical data available

Table 2. Summary information for specific study elements for the Sullivan mine site (stream/river discharge).

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	na	• Trout died in historic *in situ* toxicity tests
1.2 Water Chemistry	na	• Elevated contaminant concentrations compared to reference sites
1.3 Sediment Chemistry	na	• Elevated contaminant concentrations compared to reference sites but large variations between years • Some historic stations outside study area
1.4 Benthos	na	• Differences between reference and exposure sites
1.5 Fisheries 1.5.1 Population	na	• Only limited information available
1.5.2 Tissue	na	• Higher zinc and iron in fish tissues downstream in 1981
2.0 Study Area 2.1 Site Access	na	• Access by wading possible but water fast and deep; boat recommended
2.2 Availability of Multiple Reference and Exposure Areas	na	• Multiple reference and exposure stations of relatively uniform habitat type available
2.3 Confounding Discharges	na	• Other point sources within exposure area
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	na	• Discharge is continuous; easy access
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Yes	• Survival and reproduction affected; latter was most sensitive sublethal toxicity endpoint (of all tests)
3.2.2 Fathead Minnow	Yes	• No effects
3.2.3 *Selenastrum capricornutum*	Yes	• Growth affected
3.2.4 *Lemna minor*	Yes	• Growth affected
3.2.5 Trout embryo	Yes	• No data; controls failed
4.0 Habitats	Yes	• Similar habitat in both reference and exposure areas • Primarily erosional habitat; little depositional habitat

Table 2 (continued)

Element	Sampled 1996	Summary/Comments
5.0 Water Chemistry	Yes	• Well defined stream channel • Significant differences between reference and exposure areas for several conventionals and metals
6.0 Sediments	Yes	• Primarily erosional habitat • Significant differences between reference and exposure areas for fines, TOC and loss on ignition • Metals elevated at exposure compared to reference, but findings confounded by substrate differences (exposure station primarily silt/clay; reference station primarily sand/gravel) • Metals analyses of periphyton could be useful
7.0 Benthic Invertebrates	Yes	• Good substrate for sampling with Hess • Water fast and deep in places making sampling difficult • Artificial substrates could be useful • No clear benthos gradient in the St. Mary River, though one may exist in Mark Creek
8.0 Fisheries 8.1 Communities	Yes	• Sentinel species available (e.g., large-scale sucker and mountain whitefish) • No physical barriers to migration in the St. Mary River; a natural barrier to fish movement in Mark Creek • Water fast and deep in places making efficient surveys difficult
8.2 Tish Tissue	Yes	• No differences in sculpin metallothionein or tissue metal levels between reference and exposure areas

Table 3. Summary information for specific study elements for the Lupin mine site (stream/lake discharge)

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	na	• Rainbow trout, *Daphnia magna* and Microtox indicate little or no acute toxicity • Historic process changes have improved effluent quality
1.2 Water Chemistry	na	• Baseline and pre-discharge monitoring data exist
1.3 Sediment Chemistry	na	• Baseline and pre-discharge monitoring data exist
1.4 Benthos	na	• Baseline and pre-discharge monitoring data exist
1.5 Fisheries 1.5.1 Population	na	• Some baseline data exist; pre-discharge monitoring not focused on fish populations
1.5.2 Tissue	na	• Historically arsenic has accumulated in fish tissues • No historic metallothionein data
2.0 Study Area 2.1 Site Access	na	• Access by boat from the Lupin mine to either the exposure (Sun Bay) or reference (South Bay) areas is about 1h, with about 2h travel time between areas • Winds can be high enough to preclude access by boat; program timing is limited to fair weather • Other access would be by foot (6-10km) or helicopter (expensive)
2.2 Availability of Multiple Reference and Exposure Areas	na	• Multiple reference and exposure stations of uniform habitat type available within bays surveyed; suitability of other reference areas unknown
2.3 Confounding Discharges	na	• None
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	na	• Effluent discharged annually in later summer over 2 weeks
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	No	• Mine not discharging
3.2.2 Fathead Minnow	No	• Mine not discharging
3.2.3 *Selenastrum capricornutum*	No	• Mine not discharging
3.2.4 *Lemna minor*	No	• Mine not discharging

Table 3 (continued)

Element	Sampled 1996	Summary/Comments
3.2.5 Trout embryo	No	• Mine not discharging
4.0 Habitats	Yes	• Multiple reference and exposure stations of uniform habitat type available within bays surveyed; suitability of other reference areas unknown • Significant differences between reference and exposure areas (depth, fines, TOC, loss on ignition) • Distance between reference and exposure areas substantial (approx. 2 h by boat)
5.0 Water Chemistry	Yes	• Reference area has elevated concentrations of some contaminants compared with the exposure area; it is presumed this would reverse during discharge • Effluent not being discharged so these data of limited utility but are comparable to historic data
6.0 Sediments	yes	• Good substrate for sampling sediments with Petite Ponar • Most contaminants in sediments elevated at the exposure stations compared with the reference stations; arsenic particularly elevated; results comparable to historic data • Well defined sediment chemistry gradient • Sediment suitable for toxicity testing; collection of sediments not difficult
7.0 Benthic Invertebrates	Yes	• No difference between reference and exposure areas for total abundance or species richness. • Habitat differences may confound differences in benthos • Some species specific to exposure or reference sites
8.0 Fisheries 8.1 Communities	Yes	• Sentinel species and large fish available in required numbers with what should be an acceptable level of effort (e.g., burbot, lake trout, round whitefish, lake cisco) • Not enough data to determine whether fish population gradients exist between reference and exposure areas • No physical barriers to migration
8.2 Tish Tissue	No	• Large fish are available but increased effort needed to attain sufficient numbers of sentinel species

Table 4. Summary information for specific study elements for the Dome mine site (stream/river discharge).

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	N/A	• Placer Dome has detailed effluent chemistry and toxicity data available
1.2 Water Chemistry	N/A	• 1989 data available from exposure area and just upstream of effluent discharge
1.3 Sediment Chemistry	N/A	• 1989 data available from exposure area and just upstream of effluent discharge
1.4 Benthos	N/A	• 1989 data available from exposure area and just upstream of effluent discharge
1.5 Fisheries 1.5.1 Population	N/A	• Quantitative numbers available on catch data but no population estimates
1.5.2 Tissue	N/A	• Some tissue data available for exposure area only; only muscle tissue sampled
2.0 Study Area 2.1 Site Access	N/A	• Site is accessible in both reference and exposure areas
2.2 Availability of Multiple Reference and Exposure Areas	N/A	• Multiple exposure areas are available but limited reference areas are available on this river system
2.3 Confounding Discharges	N/A	• Old inactive tailings areas influence water quality in this system
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	N/A	• Effluent is available June to October
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Y	• Not toxic in 1996 but effluent has displayed acute toxicity in the past
3.2.2 Fathead minnow	Y	• Not toxic in 1996 but effluent has displayed acute toxicity in the past
3.2.3 *Selenastrum capricornutum*	Y	• Toxic in 1996
3.2.4 *Lemna minor*	Y	• Toxic in 1996

Table 4 (continued)

Element	Sampled 1996	Summary/Comments
3.2.5 Trout embryo	Y	• Test invalid
4.0 Habitats	Y	• Reference and exposure areas very similar in habitat
5.0 Water Chemistry	Y	• Water chemical concentration is statistically greater in exposure area relative to reference area for several metals and for general chemistry parameters • A gradient likely exists in the exposure area as indicated by conductivity measurements recorded in the field and other unpublished data
6.0 Sediments	Y	• Sediments are available • Concentrations of metals (arsenic, copper, cobalt, nickel) are statistically greater in exposure area relative to reference area • A gradient is expected based on unpublished data
7.0 Benthic Invertebrates	Y	• Significant differences exist between the reference and exposure area with respect to density, pooled number of taxa and indicator species • A gradient is expected based on unpublished data and review of sediment chemistry
8.0 Fisheries 8.1 Communities	Y	• Pearl Dace, Northern Redbelly Dace were used in 1996 and were abundant • Potential to use yellow perch in 1997 if lakes used for reference and exposure areas • Insufficient data collected in 1996 to determine differences in fish communities and relative abundance between reference and exposure areas • Pearl dace from exposure area were significantly longer than those from reference area • Barriers to fish migration occur throughout the system
8.2 Fish Tissue	Y	• No-significant difference in metallothionein levels between reference and exposure areas • Significant difference in metals concentrations between reference and exposure areas

Table 5. Summary information for specific study elements for the Onaping mine site (stream/river discharge).

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	N/A	• Inco and Falconbrige both have detailed effluent chemistry data in background reports
1.2 Water Chemistry	N/A	• Good background water chemistry data available
1.3 Sediment Chemistry	N/A	• Limited sediment chemistry data due to erosional nature of the Onaping River
1.4 Benthos	N/A	• Good benthic data available back to the 1970s
1.5 Fisheries 1.5.1 Population	N/A	• Qualitative catch data available in several reports but no population estimates
1.5.2 Tissue	N/A	• No known tissue data available
2.0 Study Area 2.1 Site Access	N/A	• Site is readily accessible in exposure area, difficult access in reference area
2.2 Availability of Multiple Reference and Exposure Areas	N/A	• Multiple reference and exposure areas are available on this river system
2.3 Confounding Discharges	N/A	• Sewage treatment plant discharges immediately above mine effluents. Interpretation is confused by discharge from two mines to one receiving location
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	N/A	• Falconbridge effluent available year round. INCO discharge is not continuous
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Y	• Falconbridge and INCO effluent toxic in 1996
3.2.2 Fathead minnow	Y	• Falconbridge effluent not toxic in 1996 • INCO effluent toxic in 1996
3.2.3 *Selenastrum capricornutum*	Y	• Falconbridge and INCO effluent inhibited growth in 1996
3.2.4 *Lemna minor*	Y	• Falconbridge and INCO effluent inhibited growth in 1996
3.2.5 Trout embryo	Y	• Falconbridge and INCO effluent were not toxic

Table 5 (continued)

Element	Sampled 1996	Summary/Comments
4.0 Habitats	Y	• Reference and exposure areas very similar
5.0 Water Chemistry	Y	• Water concentrations statistically greater in exposure area relative to reference area for several metals and general chemistry
6.0 Sediments	Y	• Depositional sediments are present but not common in either exposure or reference area • Differences in sediment chemistry not pronounced
7.0 Benthic Invertebrates	Y	• Exposure area displayed more abundant and diverse benthic community compared with reference area
8.0 Fisheries 8.1 Communities	Y	• Insufficient data to compare fish communities in exposure and reference areas • Some sensitive species (e.g., rainbow trout) captured in exposure area
8.2 Tissues	Y	• Metal and metallothionein higher in white sucker in exposure area but small sample sizes precluded statistical analysis

Table 6. Summary information for specific study elements for the Gaspé Mine site (stream/river discharge).

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	N/A	• Extensive historical data exist
1.2 Water Chemistry	N/A	• Extensive historical data (25 years) exist for both reference and exposure areas
1.3 Sediment Chemistry	N/A	• Sediments collected historically show lack of depositional areas
1.4 Benthos	N/A	• Extensive historical data exist (500 μm mesh)
1.5 Fisheries 1.5.1 Population	N/A	• Much of the historical data focus on juvenile Atlantic salmon populations
1.5.2 Tissue	N/A	• Some studies on Cu concentrations in livers of juvenile Atlantic salmon. • Metallothionein data from one, and only study, inconclusive
2.0 Study Area 2.1 Site Access	N/A	• Site is easily accessible by road
2.2 Availability of Multiple Reference and Exposure Areas	N/A	• Reference areas available but should be located above Little York Lake. • Exposure area consists entirely of effluent from the reclaim basin
2.3 Confounding Discharges	N/A	• Reach B in the reference area differs from Reach A in some general chemistry parameters • Discharge of municipal sewage into the reclaim basin. Volume of discharge low in comparison to mine effluent discharge
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	N/A	• Effluent is discharged continuously
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Yes	• Some toxicity with IC25 @ 79.4 % v/v of effluent
3.2.2 Fathead minnow	Yes	• No toxicity
3.2.3 *Selenastrum capricornutum*	Yes	• No toxicity
3.2.4 *Lemna minor*	Yes	• Toxicity (IC25 @ 31.8 % v/v; IC50 @ 66.9 % v/v)

Table 6 (continued)

Element	Sampled 1996	Summary/Comments
3.2.5 Trout embryo	Yes	• Test invalid due to toxicity of receiving water
4.0 Habitats	Yes	• Habitats of uniform substrate composition • No significant differences in depth and velocity between reference and exposure areas
5.0 Water Chemistry	Yes	• Significant differences in nutrients, chloride, sulphate, conductivity, hardness, TDS and DIC between reference and exposure areas • Highly significant differences in total and dissolved Ca, Cu, Mg, Mn, Mo, K, Si, Na and Sr between reference and exposure areas • Gradient in alkalinity, sulphate, conductivity, hardness, K and Na in the exposure area
6.0 Sediments	No	• Suitable (>1.0 m^2), representative depositional areas not available
7.0 Benthic Invertebrates	Yes	• Significant differences in total species richness and richness of sensitive species between reference and exposure areas • Differences in total abundance between the reference and exposure area were not significant
8.0 Fisheries 8.1 Communities	Yes	• Juvenile Atlantic salmon and brook trout were present in both reference and exposure areas • Both sentinel species were available in both areas although salmon appeared to be more abundant • Differences in lengths, weights and condition of juvenile Atlantic salmon were apparent between reference and exposure areas. CPUE was slightly higher for salmon in the reference area
8.2 Fish Tissue	Yes	• Metallothionein was significantly higher in juvenile Atlantic salmon and brook trout from the exposure area • Metal concentrations were higher in fish tissues from the exposure area • Metal concentrations and metallothionein were related • No barrier exists and there is the potential for migration of species between reference and exposure areas

Table 7. Summary information for specific study elements for the Heath Steele Mine site (stream/river discharge).

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	N/A	• Extensive historical data exist
1.2 Water Chemistry	N/A	• Extensive historical data (25 years) exist for both reference and exposure areas
1.3 Sediment Chemistry	N/A	• Sediments collected historically show lack of depositional areas
1.4 Benthos	N/A	• Extensive historical data exist (500 µm mesh)
1.5 Fisheries 1.5.1 Population	N/A	• Several studies have been conducted to determine the presence and absence of species . Much of the historical data focus on juvenile Atlantic salmon populations
1.5.2 Tissue	N/A	• One study conducted in 1995 showed no difference between reference and exposure areas
2.0 Study Area 2.1 Site Access	N/A	• Site is accessible by road although a four wheel drive is recommended for access to the exposure area
2.2 Availability of Multiple Reference and Exposure Areas	N/A	• Reference areas available on Northwest Miramichi River and on Tomogonops River (BCL-4) • Exposure areas available on all branches of the Tomogonops River. The site is complex with point and non-point source discharges from the mine affecting different branches of the Tomogonops River
2.3 Confounding Discharges	N/A	• There are no confounding discharges
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	N/A	• Effluent is discharged continuously
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Yes	• Toxicity with IC25 @ 19.0 % v/v of effluent
3.2.2 Fathead minnow	Yes	• Toxicity with IC25 @ 23.0 % v/v of effluent
3.2.3 *Selenastrum capricornutum*	Yes	• Toxicity with IC25 @ 23.3 % v/v of effluent
3.2.4 *Lemna minor*	Yes	• Toxicity with IC 25 @ 47.3 % v/v of effluent

Table 7 (continued)

Element	Sampled 1996	Summary/Comments
3.2.5 Trout embryo	Yes	• Toxicity with EC50 @ 77.6 % v/v of effluent
4.0 Habitats	Yes	• Habitats of uniform substrate composition • Velocity slightly higher in the reference area compared to the exposure area
5.0 Water Chemistry	Yes	• Significant differences in chloride, sulphate, conductivity, hardness, TDS and DOC between reference and exposure areas • Significant differences in Ba, Ca, Cu, Mg, Mn, Na, Pb, Sr and Zn between reference and exposure areas • Strong gradient in metals and general chemistry is apparent in the South Branch Tomogonops based upon historical studies (1995 and 1996)
6.0 Sediments	No	• Suitable (>1.0 m^2), representative depositional areas not available
7.0 Benthic Invertebrates	Yes	• Significant differences in total species abundance and species richness and richness between reference and exposure areas • Differences in richness of sensitive species between the reference and exposure area were not significant
8.0 Fisheries 8.1 Communities	Yes	• Juvenile Atlantic salmon and lake chub were present in both reference and exposure areas • Both sentinel species were available in both areas. Qualitative sampling was conducted in 1996 • Some differences in CPUE, lengths and weights of juvenile Atlantic salmon were apparent between reference and exposure areas
8.2 Fish Tissue	Yes	• Metallothionein was significantly higher in juvenile Atlantic salmon from the exposure area metallothionein was also higher for lake chub in the exposure area compared to the reference area on the Northwest Miramichi River. However, metallothionein levels measured from the alternate reference area were the highest for all sites • Metal concentrations were inconclusive • Sample sizes were very small which complicates data interpretation • No barrier exists and there is the potential for migration of species between reference and exposure areas

Table 8. Variable evaluations for 1996 AETE monitoring program

PARAMETER TYPE	MEDIUM	PARAMETER	LUPIN	SULLIVAN	MYRA	DOME	LEVACK	GASPE	HEATH STEELE
EXPOSURE	WATER	Boron, Dissolved							
EXPOSURE	WATER	Boron, Total							
EXPOSURE	WATER	Calcium, Dissolved	•						
EXPOSURE	WATER	Calcium, Total	•						
EXPOSURE	WATER	Iron, Dissolved	•						•
EXPOSURE	WATER	Iron, Total	•						•
EXPOSURE	WATER	Magnesium, Dissolved	•						
EXPOSURE	WATER	Magnesium, Total	•						
EXPOSURE	WATER	Phosphorus, Dissolved							
EXPOSURE	WATER	Phosphorus, Total							
EXPOSURE	WATER	Potassium, Dissolved							
EXPOSURE	WATER	Potassium, Total							
EXPOSURE	WATER	Sodium, Dissolved	•						
EXPOSURE	WATER	Sodium, Total	•						
EXPOSURE	WATER	Zinc, Dissolved			•				
EXPOSURE	WATER	Zinc, Total			•				
EXPOSURE	WATER	Aluminum, Dissolved	•						
EXPOSURE	WATER	Aluminum, Total	•		•				
EXPOSURE	WATER	Antimony, Dissolved							
EXPOSURE	WATER	Antimony, Total							
EXPOSURE	WATER	Arsenic, Dissolved							
EXPOSURE	WATER	Arsenic, Total							
EXPOSURE	WATER	Barium, Dissolved							
EXPOSURE	WATER	Barium, Total						•	
EXPOSURE	WATER	Beryllium, Dissolved							
EXPOSURE	WATER	Beryllium, Total							
EXPOSURE	WATER	Bismuth, Dissolved							
EXPOSURE	WATER	Bismuth, Total							
EXPOSURE	WATER	Cadmium, Dissolved							
EXPOSURE	WATER	Cadmium, Total							
EXPOSURE	WATER	Chromium, Dissolved							
EXPOSURE	WATER	Chromium, Total							
EXPOSURE	WATER	Cobalt, Dissolved							
EXPOSURE	WATER	Cobalt, Total							
EXPOSURE	WATER	Copper, Dissolved							
EXPOSURE	WATER	Copper, Total							
EXPOSURE	WATER	Lead, Dissolved							
EXPOSURE	WATER	Lead, Total							
EXPOSURE	WATER	Manganese, Dissolved	•						
EXPOSURE	WATER	Manganese, Total	•						
EXPOSURE	WATER	Molybdenum, Dissolved							
EXPOSURE	WATER	Molybdenum, Total							
EXPOSURE	WATER	Nickel, Dissolved	•						
EXPOSURE	WATER	Nickel, Total	•						
EXPOSURE	WATER	Selenium, Dissolved							
EXPOSURE	WATER	Selenium, Total							
EXPOSURE	WATER	Silver, Dissolved							
EXPOSURE	WATER	Silver, Total							
EXPOSURE	WATER	Strontium, Dissolved	•						
EXPOSURE	WATER	Strontium, Total	•						
EXPOSURE	WATER	Thallium, Dissolved							
EXPOSURE	WATER	Thallium, Total							
EXPOSURE	WATER	Tin, Dissolved							
EXPOSURE	WATER	Tin, Total							
EXPOSURE	WATER	Titanium, Dissolved							
EXPOSURE	WATER	Titanium, Total							

Table 8 (continued)

PARAMETER TYPE	MEDIUM	PARAMETER	LUPIN	SULLIVAN	MYRA	DOME	LEVACK	GASPE	HEATH STEELE
EXPOSURE	WATER	Uranium, Dissolved							
EXPOSURE	WATER	Uranium, Total							
EXPOSURE	WATER	Vanadium, Dissolved							
EXPOSURE	WATER	Vanadium, Total							
EXPOSURE	WATER	Mercury, Total		NM				NM	NM
EXPOSURE	WATER	Cyanide, Free	NM	NM	NM			NM	NM
EXPOSURE	WATER	Cyanide, Total						NM	NM
EXPOSURE	SEDIMENT	Antimony		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Arsenic		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Barium		/[1]			*	/[1]	/[1]
EXPOSURE	SEDIMENT	Beryllium		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Cadmium		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Chromium		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Cobalt		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Copper		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Lead		/[1]			*	/[1]	/[1]
EXPOSURE	SEDIMENT	Mercury		/[1]	NM	NM	NM	/[1]	/[1]
EXPOSURE	SEDIMENT	Molybdenum		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Nickel		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Selenium		/[1]				/[1]	/[1]
EXPOSURE	SEDIMENT	Silver		/[1]			*	/[1]	/[1]
EXPOSURE	SEDIMENT	Vanadium		/[1]			*	/[1]	/[1]
EXPOSURE	SEDIMENT	Zinc		/[1]			*	/[1]	/[1]
EXPOSURE	FISH	Cadmium	/[2]	NA	/[2]	NA	NA	NA	NA
EXPOSURE	FISH	Copper	/[2]	NA	/[2]	NA	NA	NA	NA
EXPOSURE	FISH	Zinc	/[2]	NA	/[2]	NA	NA	NA	NA
EXPOSURE	FISH	Metallothionien [3]	/[2]		/[2]				
OTHER	WATER	Alkalinity(as CaCO3)							
OTHER	WATER	Chloride							
OTHER	WATER	Nitrate(as N)							
OTHER	WATER	Nitrite(as N)							
OTHER	WATER	Orthophosphate(as P)							
OTHER	WATER	Sulphate	*						
OTHER	WATER	Reactive Silica(SiO2)	*						*
OTHER	WATER	Anion Sum	*						
OTHER	WATER	Bicarbonate(as CaCO3, calculated)							
OTHER	WATER	Carbonate(as CaCO3, calculated)							
OTHER	WATER	Cation Sum	*						
OTHER	WATER	Colour	*					*	
OTHER	WATER	Conductivity - @25°C							
OTHER	WATER	Dissolved Oxygen			/[4]			*	
OTHER	WATER	Hardness(as CaCO3)	*						
OTHER	WATER	Ion Balance						*	
OTHER	WATER	Langelier Index at 20°C						NM	NM
OTHER	WATER	Langelier Index at 4°C						NM	NM
OTHER	WATER	pH							
OTHER	WATER	Saturation pH at 20°C						NM	NM
OTHER	WATER	Saturation pH at 4°C						NM	NM
OTHER	WATER	Temperature							
OTHER	WATER	Thiosalts	NM	NM	NM	NM	NM	NM	
OTHER	WATER	Total Dissolved Solids(Calculated)	*						
OTHER	WATER	Turbidity		/[4]					
OTHER	WATER	Ammonia(as N)							

Table 8 (continued)

PARAMETER TYPE	MEDIUM	PARAMETER	LUPIN	SULLIVAN	MYRA	DOME	LEVACK	GASPE	HEATH STEELE
OTHER	WATER	Total Kjeldahl Nitrogen(as N)							
OTHER	WATER	Dissolved Inorganic Carbon(as C)	NM						*
OTHER	WATER	Dissolved Organic Carbon(DOC)	*						
OTHER	WATER	Total Inorganic Carbon (TIC)		NM	NM	NM	NM	NM	NM
OTHER	WATER	Total Dissolved Solids	NM			NA	NA	NM	NM
OTHER	WATER	Total Suspended Solids							
EFFECTS	BENTHOS	Total Richness					*		
EFFECTS	BENTHOS	Richness of Ephemenoptera [5,6]	NM		NM		*		
EFFECTS	BENTHOS	Abundance of Ephemenoptera [6]	NM		NM	NM	NM	NM	NM
EFFECTS	BENTHOS	Total Abundance					*		
HABITAT	LAKE	Depth							
HABITAT	River/Strm	Flow	/[7]		/[7]				*
HABITAT	River/Strm	% Riffle	/[7]		/[7]	NA			
HABITAT	River/Strm	% Run [8]	/[7]		/[7]				
HABITAT	River/Strm	% Pools	/[7]		/[7]	NA			
HABITAT	SEDIMENT	% Fines		/[1]					
HABITAT	SEDIMENT	Total Organic Carbon		/[1]				/[1]	/[1]
HABITAT	SEDIMENT	Grain Size		/[1]				/[1]	/[1]
HABITAT	SEDIMENT	Loss on Ignition		/[1]				/[1]	/[1]
HABITAT	SEDIMENT	Moisture Content		/[1]				/[1]	/[1]

Legend	
	Not detected in reference or exposure area
/	Logistical difficulties associated with variable
	No significant difference between areas
	Sign. difference between areas; difference as expected (i.e., mine-related)
*	Sign. diff. between areas, but in wrong direction (mine discharging at time of study)
*	Sign. diff. between areas, but in wrong direction (mine NOT discharging at time of study)
NM	Not measured
NA	Not available

Notes:

1 Sediments not collected
2 For Lupin only: fish tissue for analysis not collected
3 For Heath Steele only: significant difference between reference (NW Miramichi River) and exposure (Tomogonops River) for salmon and lake chub. However, samples collected at a second reference site (B-CL-4) showed highest levels measured.
4 Not possible to collect due to equipment difficulties
5 For Heath Steele only: determined EPT index: significant difference for 500 µm size only.
6 For Lupin and Myra; no Ephemenopterans present in lake systems
7 Not relevant, as study conducted in lake system
8 For Sullivan only: Riffle and run were assessed together and reported as % riffle only.

Table 9. Hypotheses to be tested in 1997. Note changes in wording to H1, and deletion of H9 recommended in EVS, ESP and JWEL (1996h) are not included as these recommendations have not been reviewed or approved by the AETE Committee.

Sediment Monitoring
1. Sediment Toxicity: H: *The use of different sediment toxicity tests (or combinations of toxicity tests) does not influence the ability to detect environmental effect in sediment toxicity.*
Biological Monitoring - Fish
2. Metals in fish tissues: bioavailability of metals in tissue levels H: *There is no environmental difference in metal concentrations observed in fish liver, kidney, gills or muscle.*
3. Metallothionein in fish tissues: H: *There is no environmental difference in metallothionein concentrations observed in fish liver, kidney or gills.*
4. Metals vs. metallothionein in fish tissues: H: *The choice of metallothionein concentration vs. metal concentrations in tissues does not influence the ability to detect environmental exposure in fish.*
5. Fish - CPUE: H: *There is no environmental effect in observed CPUE (catch per unit effort) of fish.*
6. Fish - Community: H: *There is no environmental effect in observed fish community structure.*
7. Fish - Growth: H: *There is no environmental effect in observed fish growth.*
8. Fish - Organ/Fish Size: H: *There is no environmental effect in observed organ size (or fish size, etc.).*
Biological Monitoring - Benthos
9. Benthos - Sampler size influence on level of detection of differences: H: *The choice of sampler size does not influence the ability to detect environmental effects in benthic community characteristics.*
Integration of Tools
10. Relationship between water quality and biological components: H: *The strength of the relationship between biological parameters and metal chemistry in water is not influenced by the choice of total vs. dissolved analysis of metals concentrations.*
11. Relationship between sediment chemistry and biological responses: H: *The strength of the relationship between biological variable and sediment characteristics is not influenced by the analysis of total metals in sediments vs. either metals associated with iron and manganese oxyhydroxides or with acid volatile sulphides.*
12. Relationship between sediment toxicity and benthic invertebrates: H: *The strength of the relationship between sediment toxicity responses and in situ benthic macroinvertebrate community characteristics is not influenced by the use of different sediment toxicity tests or combinations of toxicity tests.*

Table 9 (continued)

13. Metals or metallothionein vs. chemistry (receiving water and sediment): H: *The strength of the relationship between the concentration of metals in the environment (water and sediment chemistry) and metal concentration in fish tissues is not different from the relationship between metal concentration in the environment and metallothionein concentration in fish tissues.*
14. Chronic Toxicity - Linkage with Fish and Benthos monitoring results: H: *The suite of sublethal toxicity tests cannot predict environmental effects to resident fish performance indicators or benthic macroinvertebrate community structure.*

Table 10. Summary site evaluation criteria scores for each mine site.

Site Evaluation Criteria	Maximum Criterion Score	Myra Falls	Sullivan	Lupin	Dome	Onaping\Levack	Gaspé	Heath Steele
1.0 Availability of Useful Historical Data (if yes, score 2 per subcriteria)								
1.1 Effluent Characterization	2	0	2	2	2	2	2	2
1.2 Water Chemistry	2	2	2	2	2	2	2	2
1.3 Sediment Chemistry	2	0	2	2	2	0	1	1
1.4 Benthos	2	2	2	2	2	2	2	2
1.5 Fisheries								
1.5.1 Population	1	1	1	1	1	1	1	1
1.5.2 Tissue	1	1	0.5	0.5	1	0	0.5	1
Total Criterion 1.0	10	6	9	9.5	10	8	8.5	10
2.0 Study Area								
2.1 Site Access								
2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	5	10	1	10	10	10	10
2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	4	5	2	5	2	5	5
2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	3	5	2	4	5	5	4
2.2 Are multiple reference and exposure areas available?	Score maximum of 5	2	5	5	4	5	5	5
2.3 Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	0	10	0	0	5	5
Total Criterion 2.0	35	24	25	20	23	22	30	29

Table 10 (continued)

Site Evaluation Criteria	Maximum Criterion Score	Myra Falls	Sullivan	Lupin	Dome	Onaping\Levack	Gaspé	Heath Steele
3.0 Effluent/Sublethal Toxicity								
3.1 Is effluent available year round?	Score maximum of 10	5	5	1	3	4	5	5
3.2 Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)								
3.2.1 *Ceriodaphnia dubia*	4	2	2	0	0	2	2	2
3.2.2 *Fathead minnow*	4	2	0	0	0	1	0	2
3.2.3 *Selenastrum capricornutum*	4	2	2	0	2	2	0	2
3.2.4 *Lemna minor*	4	2	2	0	2	2	2	2
3.2.5 Trout embryo test	4	0	0	0		0	0	2
Total Criterion 3.0	30	13	11	1	7	11	9	15
4.0 Habitats **Are habitats similar between the Reference and Exposure areas?**								
4.1 Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	3	5	3	5	5	5	5
4.2 Water depth	2.5	2	2.5	3	2	2.5	2.5	2.5
4.3 Water velocity	2.5	2.5	2.5	0	2	2.5	2.5	1.5
Total Criterion 4.0	10	7.5	10	6	9	10	10	9

Table 10 (continued)

Site Evaluation Criteria	Maximum Criterion Score	Myra Falls	Sullivan	Lupin	Dome	Onaping\Levack	Gaspé	Heath Steele
5.0 Water Chemistry **Are water chemical concentrations statistically greater in exposure area relative to reference area?**								
5.1 For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	0	5	5	5	5
5.2 For a minimum of two metals (dissolved or total)	10	5	10	0	10	10	10	10
Total Criterion 5.0	15	10	15	0	15	15	15	15
6.0 Sediments								
6.1 Are representative dispositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	5	5	10	10	5	0	0
6.2 Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	0	0	10	10	5	0	0
Total Criterion 6.0	20	5	5	20	20	10	0	0
7.0 Benthos **Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)**								
7.1 Total density	5	1	1	0	5	0	0	5
7.2 Total species richness	5	1	1	0	0	0	5	5
7.3 Richness of sensitive species (e.g. mayflies)	5	1	1	2	5	0	5	0
Total Criterion 7.0	15	3	3	2	10	0	10	10

Table 10 (continued)

Site Evaluation Criteria	Maximum Criterion Score	Myra Falls	Sullivan	Lupin	Dome	Onaping\Levack	Gaspé	Heath Steele
8.0 Fisheries								
8.1 Community								
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	5	5	3	5	5
8.1.2 Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	2	1	5	3	0	5	5
8.1.3 Are fish community differences apparent between the reference and exposure area which can be linked to the effluent? (if yes, score 5)	5	2	0	1	0	5	2.5	2.5
8.2 Fish Tissue and Histopathology								
8.2.1 Is there a difference in MT levels between reference and exposure fish?	5	0	0	0	0	5	5	2
8.2.2 Is there a difference in metals levels between reference and exposure fish?	5	0	0	0	5	3	5	2
8.2.3 Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	0	0	0	0	0

Table 10 (continued)

Site Evaluation Criteria	Maximum Criterion Score	Myra Falls	Sullivan	Lupin	Dome	Onaping\Levack	Gaspé	Heath Steele
8.2.4 Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	0	0	0	5	0	0	0
Total Criterion 8.0	35	9	6	11	18	16	22.5	12.5
Mine Score		77.5	84.5	69.5	112	92	105	104.5
Total Maximum Actual Score	155	128	148	110	143	150	153	155
Percent Actual		61	57	63	78	61	69	67

Table 11. Suitability of each site for testing the different hypotheses.

Hypotheses (Listed in Table 9)	Myra Falls	Sullivan	Lupin	Dome	Onaping	Gaspé	Heath Steele
1. Sediment Toxicity	N	N	Y	Y	N	N	N
2. Metals in fish tissues	Y	P	Y	Y	Y	P	P
3. Metallothionein in fish tissues	Y	P	Y	P	Y	P	P
4. Metals vs. metallothionein in fish tissues	Y	P	Y	Y	Y	P	P
5. Fish - CPUE	P	P	Y	Y	P	Y	Y
6. Fish - Community	P	P	Y	Y	P	N	N
7. Fish - Growth	P	P	Y	Y	P	Y	Y
8. Fish - Organ/Fish Size	P	P	Y	Y	P	P	P
(9. Benthos - Sampler Size)	(Y)	(Y)	(Y)	(Y)	(Y)	(Y)	(Y)
10. Water Quality and Biology	Y	Y	P	P	N	P	P
11. Sediment Chemistry and Biology	N	N	Y	Y	N	N	N
12. Sediment Toxicity and Benthos	N	N	Y	Y	N	N	N
13. Metals or Metallothionein vs. Chemistry	Y	P	P	N	P	P	P
14. Chronic Toxicity	Y	Y	P	Y	P	Y	Y

Y - yes; N - no; P - partial (either not certain based on 1996 and historical data or only part of the hypothesis testable - see footnotes); parentheses indicate hypothesis not recommended for testing (EVS, ESP and JWEL, 1996h).

1. Myra Falls

- H1 - Difficult to find sediments; recent studies have shown that sediment metals are not available.
- H2 - Historic data indicate differences between areas.
- H3 - As for H2.
- H4 - As for H3.
- H5 - Level of effort for collection may be acceptable but may not be able to clearly delineate CPUE due to limits in permitting.
- H6 - Excessive level of effort may be required to adequately delineate communities, and there are no barriers to movement between area; see H5.
- H7 - See H5 and H6.
- H8 - See H5 and H6.
- H9 - Possible but not recommended.
- H10 - Plankton in Buttle Lake are most appropriate to test this hypothesis; benthos gradient may be possible in Myra Creek; fish historically used for testing.
- H11 - See H1.
- H12 - See H1.
- H13 - Done historically.
- H14 - Qualitative comparisons possible.

Table 11 (continued)

2.	Sullivan	H1 -	Difficult to find sediments.
		H2 -	Sentinel species available, but no barrier between exposure and reference areas; caged fish may be appropriate.
		H3 -	See H2.
		H4 -	See H2.
		H5 -	Lack of barrier between exposure and reference area; alternative fish capture techniques (e.g., boat-mounted electro-shocker) should capture more fish.
		H6 -	See H5.
		H7 -	See H2.
		H8 -	See H2.
		H9 -	Not recommended; see H1.
		H10 -	Link receiving water quality to benthos, algae, or toxicity.
		H11 -	See H1.
		H12 -	See H1.
		H13 -	See H1; could test qualitatively; see H2.
		H14 -	Could use caged fish and field benthos.
3.	Lupin	H1 -	Sediment contamination gradient not measured, but predicted based on available information.
		H2 -	Fishing success in 1996 limited; demersal fish (burbot) recommended as sentinel species; few burbot caught, although alternative collection methods should improve catch.
		H3 -	See H2.
		H4 -	See H2.
		H5 -	Increased fishing effort should allow testing this hypothesis.
		H6 -	See H5.
		H7 -	See H2.
		H8 -	See H2.
		H9 -	Not recommended.
		H10 -	Short effluent discharge period limits our ability to link receiving water to biological responses. Recommend qualitatively addressing this issue by testing effluent toxicity and extrapolating results to the field.
		H11 -	Tested as part of sediment quality triad.
		H12 -	Tested as part of sediment quality triad.
		H13 -	Can be tested qualitatively using demersal fish and sediment chemistry.
		H14 -	Can be tested qualitatively with benthos, but not with fish since not sampled synoptically.
4.	Dome	H1 -	Sediments readily available. Clear metal concentration differences between reference and exposure areas.
		H2 -	1996 results show differences in two species of forage fish. Recommend using yellow perch in 1997.
		H3 -	1996 results do not show significant differences in metallothionein levels. Recommend using yellow perch in 1997 .
		H4 -	Use data from H2 and H3 to compare with water and/or sediment data from reference and exposure areas.
		H5 -	Intensive fishing required at two exposure and two reference sites.
		H6 -	As for H5.
		H7 -	As for H5.
		H8 -	As for H5 and yellow perch recommended for comparison of organ size.
		H9 -	Possible but not recommended.
		H10 -	Only benthic community suitable to test this hypothesis; cannot be assured of discrete fish samples along a well-defined gradient.

Table 11 (continued)

		H11 -	Site is suitable.
		H12 -	As for H11.
		H13 -	Cannot be assured of discrete fish samples along well-defined gradient.
		H14-	Results of sublethal toxicity can be qualitatively compared to fish and benthic indicators.
5.	Onaping	H1 -	Sediments not readily available.
		H2 -	1996 results suggest some higher metals in exposure but numbers of fish are limited.
		H3 -	1996 results show higher metallothionein, but small samples sizes. Greater fishing effort required.
		H4 -	Use data from H2 and H3.
		H5 -	Low fish numbers may preclude adequate testing of this hypothesis.
		H6 -	As for H5.
		H7 -	As for H5.
		H8 -	As for H5.
		H9 -	Possible but not recommended
		H10 -	1996 results show benthos did not respond as expected to elevated metals in exposure area.
		H11 -	As for H10; also, sediment metal levels not largely different between exposure and reference when corrected for percent fines.
		H12 -	As for H11.
		H12 -	Relationship between tissues and water chemistry possible, but tenuous for sediments as described in H11.
		H14 -	Two effluents show different toxicity.
6.	Gaspé	H1 -	Site not suitable; no suitable representative depositional areas exist.
		H2 -	Site partially suitable as sentinel species (juvenile Atlantic salmon) are too small for effective dissection of various tissues. Therefore, only measurements on whole fish are possible. Due to the absence of a barrier restricting migration of species between reference and exposure areas, caged fish would be a suitable alternative to evaluate exposure areas. Results of 1996 study showed significant differences in metals and metallothionein in sentinel species between reference and exposure areas.
		H3 -	Site partially suitable as per H2.
		H4 -	Site partially suitable as per H2.
		H5 -	Site suitable to test the hypothesis for juvenile Atlantic salmon based upon the results of the 1996 survey.
		H6 -	Site not suitable as species diversity was low in both the reference and exposure areas.
		H7 -	Site suitable but the population of the sentinel species are juveniles with a restricted range of age classes.
		H8 -	Partially suitable although fish are too small for organ dissection.
		H9 -	Possible but not recommended.
		H10 -	Site partially suitable for benthos and water chemistry. However, only a small gradient in general water chemistry exists in exposure area. Testing of this hypothesis requires a strong gradient in metals in the exposure area.
		H11 -	Site not suitable as per H1.
		H12 -	Site not suitable as per H1.
		H13 -	This hypothesis may only be testable in a qualitative sense and only for water chemistry.
		H14 -	Site partially suitable although results of 1996 survey showed limited sublethal toxicity. Could be tested with benthos qualitatively, but not with fish since not sampled synoptically.
7.	Heath Steele	H1 -	Site not suitable; no suitable representative depositional areas exist.
		H2 -	Site is partially suitable as sentinel species too small for effective dissection of various tissues. Whole fish measurements or measurements on viscera only are possible. Caged fish would be a suitable alternative to evaluate exposure area to avoid possibility of fish

Table 11 (continued)

	movement between exposure and reference areas. Results of 1996 study inconclusive due to small sample sizes.
H3 -	Site partially suitable as per H2.
H4 -	Site partially suitable as per H2.
H5 -	Site suitable to test the hypothesis for juvenile Atlantic salmon based upon the results of the 1996 survey.
H6 -	Site not suitable as species diversity was low in both the reference and exposure areas.
H7 -	Site suitable but the population of the sentinel species is composed only of juveniles (0 - 3y) (i.e., the range of the data are very narrow).
H8 -	Partially suitable although fish are too small for organ dissection.
H9 -	Possible but not recommended.
H10 -	Site partially suitable for benthos and water chemistry. Testing requires a strong gradient in exposure which can be found in the South Branch Tomogonops River.
H11 -	Site not suitable as per H1.
H12 -	Site not suitable as per H1.
H13 -	This hypothesis may only be testable in a qualitative sense and only for water chemistry.
H14 -	Site suitable, but can only be tested on benthic parameters because fish are not present in sufficient numbers where the gradient is located (South Branch Tomogonops).

Table 12. Sites at which hypotheses can be tested in 1997.

Sites[1]	Hypotheses
Dome, Lupin	**Sediment Monitoring** 1. Sediment Toxicity: H: *The use of different sediment toxicity tests (or combinations of toxicity tests) does not influence the ability to detect envisronmental effect in sediment toxicity.*
Dome, Lupin, Myra Falls, Onaping/Levack, (Sullivan), (Gaspé), (Heath Steele)	2. Metals in fish tissues: bioavailability of metals in tissue levesl H: *There is no environmental difference in metal concentrations observed in fish liver, kidney, gills or muscle.*
Lupin, Myra Falls, Onaping/Levack, (Sullivan), (Dome), (Gaspé), (Heath Steele)	3. Metallothionein in fish tissues: H: *There is no envisronmental difference in metallothionein concentrations observed in fish liver, kidney or gills.*
Dome, Lupin, Myra Falls, Onaping/Levack, (Sullivan), (Gaspé), (Heath Steele)	4. Metals vs. metallothionein in fish tissues: H: *The choice of metallothionein concentration vs. metal concentrations in tissues does not influence the ability to detect environmental exposure in fish.*
Dome, Lupin, Gaspé, Heath Steele, (Myra Falls), (Sullivan), (Onaping/Levack)	5. Fish - CPUE: H: *There is no environmental effect in observed CPUE (catch per unit effort) of fish.*
Dome, Lupin, (Myra Falls), (Sullivan), (Onaping/Levack)	6. Fish - Community: H: *There is no environmental effect in observed fish community structure.*
Dome, Lupin, Heath Steele, Gaspé, (Myra Falls), (Sullivan), (Onaping/Levack)	7. Fish - Growth: H: *There is no environmental effect in observed fish growth.*

Table 12 (continued)

Sites[1]	Hypotheses
Dome, Lupin, (Myra Falls), (Sullivan), (Onaping/Levack), (Gaspé), (Heath Steele)	8. Fish - Organ/Fish Size: H: *There is no environmental effect in observed organ size (or fish size, etc.).*
All, but testing not recommended - EVS, ESP and JWEL, 1996h	**Biological Monitoring - Benthos** 9. Benthos - Sampler size influence on level of detection of differences: H: *The choice of sampler size does not influence the ability to detect environmental effects in benthic community characteristics.*
Myra Falls, Sullivan, Heath Steele, (Lupin), (Dome), (Gaspé)	**Integration of Tools** 10. Relationship between water quality and biological components: H: *The strength of the relationship between biological parameters and metal chemistry in water is not influenced by the choice of total vs. dissolved analysis of metals concentrations.*
Dome, Lupin	11. Relationship between sediment chemistry and biological responses: H: *The strength of the relationship between biological variable and sediment characteristics is not influenced by the analysis of total metals in sediments vs. either metals associated with iron and manganese oxyhydroxides or with acid volatile sulphides.*
Dome, Lupin	12. Relationship between sediment toxicity and benthic invertebrates: H: *The strength of the relationship between sediment toxicity responses and in situ benthic macroinvertebrate community characteristics is not influenced by the use of different sediment toxicity tests or combinations of toxicity tests.*
Myra Falls, (Sullivan), (Lupin), (Onaping/Levack), (Gaspé), (Heath Steele)	13. Metals or metallothionein vs. chemistry (receiving water and sediment): H: *The strength of the relationship between the concentration of metals in the environment (water and sediment chemistry) and metal concentration in fish tissues is not different from the relationship between metal concentration in the environment and metallothionein concentration in fish tissues.*
Dome, Heath Steele, Myra Falls, Sullivan, Gaspé, (Lupin), (Onaping/Levack)	14. Chronic Toxicity - Linkage with Fish and Benthos monitoring results: H: *The suite of sublethal toxicity tests cannot predict environmental effects to resident fish performance indicators or benthic macroinvertebrate community structure.*

[1] Parentheses indicate uncertainty (i.e., a "partial" in Table 11).

Table 13. Benthic invertebrate total abundance - Lupin Mine 1996.

VARIABLE	REFERENCE AREA		EXPOSURE AREA		EFFECT	SIGNIFICANT
	MEAN[1]	SD[2]	MEAN[1]	SD[2]	SIZE[3]	DIFFERENCE?[4]
Total Abundance	626	±306	414	±290	-34%	No

1. Arithmetic means (i.e., not based on log-transformed data)
2. Standard deviation of untransformed data
3. Relative to Reference Area mean
4. Based on t-test of log-transformed data

Table 14. Estimates of minimum detectable effect sizes for key variables for three fixed samples sizes for Lupin, Dome and Heath Steele Mines.

Component	Key Variable	Units	REF Mean	EXP Mean	Effect Size	Sign.?	Var.	Type	Min. Effect Sizes for Sample Sizes					
									5		10		30	
						LUPIN								
Sediment	As (log)	mg/kg	5.83	28.25	384%	Yes	0.199	SD	451%	-82%	204%	-67%	85%	-46%
Sediment	Hg (log)	mg/kg	0.016	0.021	35%	No	0.121	SD	182%	-65%	97%	-49%	45%	-31%
Sediment	Ni (log)	mg/kg	13.34	26.61	100%	Yes	0.062	SD	70%	-41%	41%	-29%	21%	-17%
Sediment	CN (log)	mg/kg	0.16	0.98	505%	Yes	0.211	SD	511%	-84%	225%	-69%	92%	-48%
Benthos	S	# taxa	22.8	25.3	11%	No	17%	CV	65%	-65%	42%	-42%	23%	-23%
Benthos	N (log)	# org.s	556	343	-38%	No	0.266	SD	880%	-90%	342%	-77%	127%	-56%
						DOME								
Water	COND	us/cm	271	776	186%	Yes	13%	CV	48%	-48%	31%	-31%	17%	-17%
Water	S(log)	mg/L	7.6	239.0	3045%	Yes	0.014	SD	13%	-11%	8%	-8%	4%	-4%
Water	Cu(total)	mg/L	0.004	0.013	225%	Yes	50%	CV	186%	-186%	121%	-121%	67%	-67%
Water	Ni(total)	mg/L	0.002	0.029	1350%	Yes	100%	CV	373%	-373%	243%	-243%	134%	-134%
Sediment	As (log)	mg/kg	294	549	87%	Yes	0.102	SD	139%	-58%	76%	-43%	37%	-27%
Sediment	Co(log)	mg/kg	27.5	92.4	236%	Yes	0.109	SD	155%	-61%	84%	-46%	40%	-29%
Sediment	Cu(log)	mg/kg	380	1339	252%	Yes	0.078	SD	95%	-49%	55%	-35%	27%	-21%
Benthos	Density	#/sq.m	18130	6319	-65%	Yes	0.318	SD	1430%	-93%	491%	-83%	167%	-63%
Fish-P. Dace	F-Length	cm	7.1	8.5	20%	Yes	0.070	SD	82%	-45%	47%	-32%	24%	-19%
Fish-P. Dace	Weight	g	4.1	6.2	51%	No	0.220	SD	560%	-85%	242%	-71%	97%	-49%
Fish-N.R. Dace	F-Length	cm	5.3	5.6	6%	No	0.063	SD	71%	-42%	42%	-29%	21%	-18%
Fish-N.R. Dace	Weight	g	1.9	2.0	5%	No	0.201	SD	458%	-82%	206%	-67%	86%	-46%
Fish-P. Dace	MT(log)	ugMT/g	99	113	14%	No	0.231	SD	626%	-86%	263%	-72%	104%	-51%
Fish-P. Dace	Metal(log)	uM/g	0.840	1.870	123%	Yes	0.138	SD	225%	-69%	116%	-54%	53%	-35%
Fish-N.R. Dace	MT	ugMT/g	207	218	5%	No	50%	CV	187%	-187%	122%	-122%	67%	-67%
Fish-N.R. Dace	Metals	uM/g	0.78	1.45	86%	Yes	45%	CV	168%	-168%	110%	-110%	61%	-61%

Table 14 (continued)

Component	Key Variable	Units	REF Mean	EXP Mean	Effect Size	Sign.?	Var.	Type	Min. Effect Sizes for Sample Sizes 5		10		30	
					HEATH STEELE									
Chemistry	potassium	mg/L	1.76	2.63	49%	No	0.121	SD	182%	-65%	96%	-49%	45%	-31%
Chemistry	pH	pH	7.27	7.37	1%	No	0.084	SD	0.31	-0.31	0.20	-0.20	0.11	-0.11
Chemistry	Nitrate	mg/L	1.07	1.08	1%	No	0.027	SD	26%	-21%	16%	-14%	9%	-8%
Chemsitry	TKN	mg/L	1.44	1.50	4%	No	0.012	SD	11%	-10%	7%	-6%	4%	-4%
Fish	fishwt(log)	g	9.35	9.35	0%	No	0.100	SD	136%	-58%	75%	-43%	36%	-27%
Fish	fishlg(log)	mm	93.54	63.24	-32%	No	0.063	SD	72%	-42%	42%	-30%	21%	-18%
Benthos	abun500(log)	N	650	242	-63%	Yes	0.124	SD	189%	-65%	100%	-50%	47%	-32%
Benthos	rich500(log)	# taxa	41.70	25.38	-39%	Yes	0.092	SD	120%	-55%	67%	-40%	33%	-25%
Benthos	abun250(log)	# org.s	1386	636	-54%	Yes	0.121	SD	183%	-65%	97%	-49%	45%	-31%
Benthos	rich250(log)	# taxa	54.58	43.23	-21%	Yes	0.064	SD	73%	-42%	43%	-30%	22%	-18%
Benthos	EPT 500	# taxa	25.2	17.7	-30%	Yes	17%	CV	62%	-62%	40%	-40%	22%	-22%
Benthos	EPT 250	# taxa	27	22.2	-18%	Yes	17%	CV	64%	-64%	42%	-42%	23%	-23%

Notes: For log-transformed variables, area means are geometric (i.e., back-transformed from transformed means)
Effect size is the observed increase/decrease in the Exposure area relative to the Reference area;
two-tailed power analysis calculated, some predicted minimum effects sizes are obviously one way (e.g., increase in metals)
Significance (Sign.) - Was the observed difference between Reference and Exposure areas significant (i.e., in t-test)?
Measure of variability (Var.) is coefficient of variation (in percent; CV) for standard variables and standard deviation (in log unit for log-transformed variables)
Power analyses for fish variables from Heath Steele calculated using square root of mean square error from ANCOVA of length or weight on age
Effect size for pH reported in pH units (not percent relative to reference mean)

APPENDIX A

Detailed Individual Site Evaluations

APPENDIX A-1

Site Evaluation Criteria for
Myra Falls Mine Site

Appendix A-1 Site evaluation criteria for Myra Falls mine site (stream/lake discharge).

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Myra Falls	Comments
1.0 Availability of Useful Historical Data (if yes, score 2 per subcriteria)				
1.1 Effluent Characterization	2	2	0	- some rainbow trout and *Daphnia* toxicity in Buttle Lake, but results not consistent
1.2 Water Chemistry	2	2	2	
1.3 Sediment Chemistry	2	2	0	- 1980 data may be influenced by release of tailings which is no longer done
1.4 Benthos	2	2	2	
1.5 Fisheries				
1.5.1 Population	1	1	1	
1.5.2 Tissue	1	1	1	- metals and metallothionein
Total Criterion 1.0	10	10	6	
2.0 Study Area				
2.1 Site Access				
2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	5	- not directly accessible by road as need to take ferry to Vancouver Island - can also fly
2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	4	- takes about 15 min by road and 15-30 min by boat
2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	3	- takes 40 min by road plus 45 min by boat
2.2 Are multiple reference and exposure areas available?	Score maximum of 5	5	2	- lots of reference area available; exposure area fair size, but not all suitable for sediment studies

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Myra Falls	Comments
2.3 Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	10	- however, BC Hydro changing water levels
Total Criterion 2.0	35	35	24	
3.0 Effluent/Sublethal Toxicity				
3.1 Is effluent available year round?	Score maximum of 5	5	5	
3.2 Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)				- some rainbow trout and *Daphnia* toxicity in Buttle Lake, but results not consistent
3.2.1 *Ceriodaphnia dubia*	2	2	2	
3.2.2 *Fathead minnow*	2	2	2	
3.2.3 *Selenastrum capricornutum*	2	2	2	
3.2.4 *Lemna minor*	2	2	2	
3.2.5 Trout embryo test	2	0	0	
Total Criterion 3.0	15	13	13	
4.0 Habitats **Are habitats similar between the Reference and Exposure areas?**				
4.1 Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	3	- however, could have spent more time to find better habitat??? - habitat on creek similar - smaller riffle areas and more pools upstream than downstream; stations sampled were similar
4.2 Water depth	2.5	2.5	2	- same depth contour could probably be sampled; however we sampled reference first, and at exposure had to go deeper for sediment - depth on creek similar
4.3 Water velocity	2.5	2.5	2.5	- creek similar velocity

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Myra Falls	Comments
Total Criterion 4.0	10	10	7.5	
5.0 Water Chemistry **Are water chemical concentrations statistically greater in exposure area relative to reference area?**				
5.1 For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	- conductivity and pH significantly different
5.2 For a minimum of two metals (dissolved or total)	10	10	5	- data difficult to interpret, gradient may exist
Total Criterion 5.0	15	15	10	
6.0 Sediments				
6.1 Are representative depositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	5	
6.2 Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	0	0	
Total Criterion 6.0	20	10	5	
7.0 Benthos **Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)**				
7.1 Total density	5	5	1	} differences at single
7.2 Total species richness	5	5	1	} stations in Myra Creek;
7.3 Richness of sensitive species (e.g. mayflies)	5	5	1	} not in Buttle Lake
Total Criterion 7.0	15	15	3	
8.0 Fisheries				- permit limitations (e.g., no gillnet sets overnight) affected CPUE
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Myra Falls	Comments
8.1.2	Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	2	- need to test assumption that more effort would yield enough of two target sentinel species
8.1.3	Are fish community differences apparent between the reference and exposure area which can be linked to the effluent? (if yes, score 5)	5	5	2	- some differences in size (i.e., smaller at exposure), but may not be real (due to catch effort)
8.2 Fish Tissue and Histopathology					
8.2.1	Is there a difference in MT levels between reference and exposure fish?	5	0	0	- not sampled - historically trends between exposure and "reference"
8.2.2	Is there a difference in metals levels between reference and exposure fish?	5	0	0	- not sampled - historically trends between exposure and "reference"
8.2.3	Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	- not sampled - historically no data?
8.2.4	Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	- although different lakes they are connected
	Total Criterion 8.0	35	20	9	
Total Maximum Score		155	128	77.5	61%

APPENDIX A-2

Site Evaluation Criteria for
Sullivan Mine Site

Appendix A-2 Site evaluation criteria for Sullivan mine site (stream/river discharge).

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Sullivan	Comments
1.0	**Availability of Useful Historical Data (if yes, score 2 per subcriteria)**				
1.1	Effluent Characterization	2	2	2	- B. Duncan, Cominco, pers. comm.
1.2	Water Chemistry	2	2	2	
1.3	Sediment Chemistry	2	2	2	
1.4	Benthos	2	2	2	
1.5	Fisheries				
1.5.1	Population	1	1	1	- B. Duncan, Cominco, pers. comm.
1.5.2	Tissue	1	1	0.5	- metals only; no metallothionein
	Total Criterion 1.0	10	10	9.5	
2.0	**Study Area**				
2.1	Site Access				
2.1.1	Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	10	- about 8 h drive from Vancouver - can also fly
2.1.2	Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	- < 0.5 h; no boat needed - river may be a bit fast for some sampling; boat may be useful
2.1.3	Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	- < 0.5 h; no boat needed - river may be a bit fast for some sampling; boat may be useful
2.2	Are multiple reference and exposure areas available?	Score maximum of 5	5	5	- about 1 km of river for exposure - lots of comparable reference/upstream areas

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Sullivan	Comments
2.3 Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	0	- STP discharges just downstream of effluent discharge - Cow and Mark creek both contribute metals due to non-point source mine drainage
Total Criterion 2.0	35	35	25	
3.0 Effluent/Sublethal Toxicity				
3.1 Is effluent available year round?	Score maximum of 5	5	5	
3.2 Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)				- no historic chronic toxicity data available
3.2.1 *Ceriodaphnia dubia*	2	2	2	
3.2.2 *Fathead minnow*	2	2	0	
3.2.3 *Selenastrum capricornutum*	2	2	2	
3.2.4 *Lemna minor*	2	2	2	-
3.2.5 Trout embryo test	2	0	0	-
Total Criterion 3.0	15	13	11	
4.0 Habitats **Are habitats similar between the Reference and Exposure areas?**				
4.1 Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	5	
4.2 Water depth	2.5	2.5	2.5	
4.3 Water velocity	2.5	2.5	2.5	
Total Criterion 4.0	10	10	10	

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Sullivan	Comments
5.0 Water Chemistry **Are water chemical concentrations statistically greater in exposure area relative to reference area?**				
5.1 For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	
5.2 For a minimum of two metals (dissolved or total)	10	10	10	
Total Criterion 5.0	15	15	15	
6.0 Sediments				
6.1 Are representative depositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	5	- very little
6.2 Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	0	
Total Criterion 6.0	20	20	5	
7.0 Benthos **Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)**				
7.1 Total density	5	5	1	} possibly in Mark Creek; not in St. Mary River
7.2 Total species richness	5	5	1	}
7.3 Richness of sensitive species (e.g. mayflies)	5	5	1	}
Total Criterion 7.0	15	15	3	-
8.0 Fisheries				
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	- some found in this survey - historic and pers. comm. indicate present

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Sullivan	Comments
8.1.2	Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	1	- difficulties capturing fish because relatively large river (e.g., electroshocking difficult); didn't get enough fish to say sentinel spp. available in sufficient #s - historic data also poor
8.1.3	Are fish community differences apparent between the reference and exposure area which can be linked to the effluent? (if yes, score 5)	5	5	0	- nothing apparent; not enough data - not enough historic data
8.2 Fish Tissue and Histopathology					
8.2.1	Is there a difference in MT levels between reference and exposure fish?	5	5	0	- no difference
8.2.2	Is there a difference in metals levels between reference and exposure fish?	5	5	0	- no difference - historically downstream fish showed higher Fe and Zn
8.2.3	Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	- not sampled - no historic data
8.2.4	Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	
	Total Criterion 8.0	35	30	6	
Total Maximum Score		155	148	84.5	57%

APPENDIX A-3

Site Evaluation Criteria for Lupin Mine Site

Appendix A-3 Site evaluation criteria for Lupin minesite (stream/lake discharge).

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Lupin	Comments
1.0	**Availability of Useful Historical Data (if yes, score 2 per subcriteria)**				
	1.1 Effluent Characterization	2	2	2	- 1996 metals data - one report with summary of acute toxicity data - no sublethal toxicity
1.2	Water Chemistry	2	2	2	
1.3	Sediment Chemistry	2	2	2	
1.4	Benthos	2	2	2	
1.5	Fisheries				
	1.5.1 Population	1	1	1	
	1.5.2 Tissue	1	1	0.5	- no metallothionein
	Total Criterion 1.0	10	10	9.5	
2.0	**Study Area**				
2.1	Site Access				
	2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	1	- not accessible by road as need to fly up by company plane
	2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	2	- takes 1 hour by boat; if weather bad may need helicopter
	2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	2	- takes 1 hour by boat; if weather bad may need helicopter

	Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Lupin	Comments
2.2	Are multiple reference and exposure areas available?		Score maximum of 5	5	5	- lots of stations at exposure and reference area sampled; however, don't know about suitability of other reference areas
2.3	Are there "No" confounding point and non-point source discharges?		Score maximum of 10	10	10	
	Total Criterion 2.0		35	35	20	
3.0	**Effluent/Sublethal Toxicity**					
3.1	Is effluent available year round?		Score maximum of 5	5	1	- just two weeks
3.2	Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)					- no chronic toxicity data available; not tested in 1996 - historical acute toxicity data indicate no toxicity to rainbow trout, *Daphnia magna* or Microtox
	3.2.1	*Ceriodaphnia dubia*	2	0	0	
	3.2.2	*Fathead minnow*	2	0	0	
	3.2.3	*Selenastrum capricornutum*	2	0	0	
	3.2.4	*Lemna minor*	2	0	0	
	3.2.5	Trout embryo test	2	0	0	
	Total Criterion 3.0		15	5	1	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Lupin	Comments
4.0	**Habitats** **Are habitats similar between the Reference and Exposure areas?**				
4.1	Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	3	
4.2	Water depth	2.5	5	3	- average depth shallower at reference site, but some overlap; all depths < 10 m
4.3	Water velocity	2.5	n/a	0	- not applicable
	Total Criterion 4.0	10	10	6	
5.0	**Water Chemistry** **Are water chemical concentrations statistically greater in exposure area relative to reference area?**				
5.1	For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	0	0	- no discharge - historical difference in water chemistry at exposure area pre- versus post- discharge
5.2	For a minimum of two metals (dissolved or total)	10	0	0	- see 5.1 comments
	Total Criterion 5.0	15	0	0	
6.0	**Sediments**				
6.1	Are representative depositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	10	
6.2	Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	10	
	Total Criterion 6.0	20	20	20	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Lupin	Comments
7.0	**Benthos** **Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)**				
7.1	Total density	5	5	0	
7.2	Total species richness	5	5	0	
7.3	Richness of sensitive species (e.g. mayflies)	5	5	2	- some species present at ref and not at exp and visa versa - need to assess their significance (i.e., metal tolerant or intolerant?)
	Total Criterion 7.0	15	15	2	- could be higher depending on indicator species
8.0 Fisheries					
8.1	Community				
	8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	
	8.1.2 Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	5	
	8.1.3 Are fish community differences apparent between the reference and exposure area which can be linked to the effluent? (if yes, score 5)	5	5	1	- some differences but not consistent with historic; not enough fish caught/info available

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Lupin	Comments
8.2 Fish Tissue and Histopathology				
8.2.1 Is there a difference in MT levels between reference and exposure fish?	5	0	0	- not sampled - no historic data
8.2.2 Is there a difference in metals levels between reference and exposure fish?	5	0	0	- not sampled - historically arsenic shows difference.
8.2.3 Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	- not sampled - historically populations larger (in # not size) at ref, but no health information
8.2.4 Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	
Total Criterion 8.0	35	15	11	
Total Maximum Score	155	110	69.5	63%

APPENDIX A-4

Site Evaluation Criteria for Dome Mine Site

Appendix A-4 Site evaluation criteria for Dome mine site (stream/river discharge).

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Dome	Comments
1.0 Availability of Useful				
1.1 Effluent Characterization	2	2	2	
1.2 Water Chemistry	2	2	2	
1.3 Sediment Chemistry	2	2	2	
1.4 Benthos	2	2	2	
1.5 Fisheries				
1.5.1 Population	1	1	1	
1.5.2 Tissue	1	1	1	
Total Criterion 1.0	10	10	10	
2.0 Study Area				
2.1 Site Access				
2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	10	
2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	
2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	4	- road is very close although there is a steep embankment as the only access - canoe only
2.2 Are multiple reference and exposure areas available?	Score maximum of 5	5	4	- there are limited reference areas
2.3 Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	0	- many non-point discharges are contributing contamination to the system
Total Criterion 2.0	35	35	23	

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Dome	Comments
3.0 Effluent/Sublethal Toxicity				
3.1 Is effluent available year round?	Score maximum of 5	5	3	- effluent available June - October
3.2 Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)				
3.2.1 *Ceriodaphnia dubia*	2	2	0	
3.2.2 *Fathead minnow*	2	2	0	
3.2.3 *Selenastrum capricornutum*	2	2	2	
3.2.4 *Lemna minor*	2	2	2	
3.2.5 Trout embryo test	2	0		- test invalid - not included in total score
Total Criterion 3.0	15	13	7	
4.0 Habitats Are habitats similar between the Reference and Exposure areas?				
4.1 Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	5	
4.2 Water depth	2.5	2.5	2.0	- reference area slightly more shallow
4.3 Water velocity	2.5	2.5	2.0	- low flow in exposure area; very low flow in reference area
Total Criterion 4.0	10	10	9	
5.0 Water Chemistry Are water chemical concentrations statistically greater in exposure area relative to reference area?				
5.1 For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	
5.2 For a minimum of two metals (dissolved or total)	10	10	10	

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Dome	Comments
Total Criterion 5.0	15	15	15	
6.0 Sediments				
6.1 Are representative depositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	10	
6.2 Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	10	- significant difference when metals corrected for % fines
Total Criterion 6.0	20	20	20	
7.0 Benthos Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)				
7.1 Total density	5	5	5	
7.2 Total species richness	5	5	0	
7.3 Richness of sensitive species (e.g. mayflies)	5	5	5	- richness of indicator species is significantly different
Total Criterion 7.0	15	15	10	
8.0 Fisheries				
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	
8.1.2 Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	3	
8.1.3 Are fish community differences apparent between the reference and exposure area (if yes, score 5)	5	0	0	- insufficient data to assess community differences

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Dome	Comments
8.2 Fish Tissue and Histopathology				
8.2.1 Is there a difference in MT levels between reference and exposure fish?	5	5	0	
8.2.2 Is there a difference in metals levels between reference and exposure fish?	5	5	5	
8.2.3 Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	- fish health measurements not recorded
8.2.4 Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	5	
Total Criterion 8.0	35	25	18	
Total Maximum Score	155	143	112	78%

APPENDIX A-5

Site Evaluation for Onaping/Levack Mine Site

Appendix A-5 Site evaluation criteria for Onaping/Levack mine site (stream/river discharge).

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Onaping/ Levack	Comments
1.0 Availability of Useful Historical Data (if yes, score 2 per subcriteria)				
1.1 Effluent Characterization	2	2	2	
1.2 Water Chemistry	2	2	2	
1.3 Sediment Chemistry	2	2	1	
1.4 Benthos	2	2	2	
1.5 Fisheries				
1.5.1	1	1	1	
1.5.2 Tissue	1	1	0	
Total Criterion 1.0	10	10	8	
2.0 Study Area				
2.1 Site Access				
2.1.1 Is this site	10	10	10	
2.1.2 is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	2	- gravel road most of the way - to access river require ATV
2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	
2.2 Are multiple reference and exposure areas available?	Score maximum of 5	5	5	
2.3 Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	0	- point and possibly non-point discharges are contributing contamination to the system
Total Criterion 2.0	35	35	22	
3.0 Effluent/Sublethal Toxicity Falconbridge/Inco				N.B. There are two effluents at this site
3.1 Is effluent available year round?	Score maximum of 5	5	5/3	- Falconbridge effluent available year round; Inco not

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Onaping/ Levack	Comments
3.2 Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)					(results available for Falconbridge effluent only to date)
3.2.1	*Ceriodaphnia dubia*	2	2	2/2	
3.2.2	*Fathead minnow*	2	2	0/2	
3.2.3	*Selenastrum capricornutum*	2	2	2/2	
3.2.4	*Lemna minor*	2	2	2/2	
3.2.5	Trout embryo test	2	2	0/0	
Total Criterion 3.0		15	15	11	- Average of Falconbridge and Inco
4.0 Habitats Are habitats similar between the Reference and Exposure areas?					
4.1 Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)		5	5	5	
4.2 Water depth		2.5	2.5	2.5	
4.3 Water velocity		2.5	2.5	2.5	
Total Criterion 4.0		10	10	10	
5.0 Water Chemistry Are water chemical concentrations statistically greater in exposure area relative to reference area?					
5.1 For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)		5	5	5	
5.2 For a minimum of two metals (dissolved or total)		10	10	10	
Total Criterion 5.0		15	15	15	
6.0 Sediments					
6.1 Are representative depositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)		10	10	5	- depositional areas are present but not abundant

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Onaping/ Levack	Comments
6.2 Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	5	- significant difference for one metal only
Total Criterion 6.0	20	20	10	
7.0 Benthos Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)				- significant difference exists between exposure and reference areas, however exposure area displays a more diverse and abundant benthos community than reference area
7.1 Total density	5	5	0	
7.2 Total species richness	5	5	0	
7.3 Richness of sensitive species (e.g. mayflies)	5	5	0	
Total Criterion 7.0	15	15	0	
8.0 Fisheries				
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	3	- low numbers of fish available
8.1.2 Are suitable sentinel species abundant in reference and exposure areas?	5	5	0	- low numbers of fish available
8.1.3 Are fish community differences apparent between the reference and exposure area (if yes, score 5)	5	5	5	- based on limited data, fish community differences are apparent

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Onaping/ Levack	Comments
8.2 Fish Tissue and Histopathology					
8.2.1	Is there a difference in MT levels between reference and exposure fish?	5	5	5	- differences observed but low sample number
8.2.2	Is there a difference in metals levels between reference and exposure fish?	5	5	3	- some differences indicated but low sample numbers
8.2.3	Are there obvious differences in fish health between reference and exposure area fish?	5	0	0	- fish health measurements not recorded
8.2.4	Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	- no barriers to fish migration
Total Criterion 8.0		35	30	16	
Total Maximum Score		170	150	92	61%

APPENDIX A-6

Site Evaluation Criteria for Gaspé Mine Site

Appendix A-6 Site evaluation criteria for Gaspé mine site (stream/river discharge).

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Gaspé	Comments
1.0	Availability of Useful Historical Data (if yes, score 2 per subcriteria)				
	1.1 Effluent Characterization	2	2	2	
	1.2 Water Chemistry	2	2	2	- extensive historical data base
	1.3 Sediment Chemistry	2	2	1	- historical results show limitation of suitable, representative depositional areas
	1.4 Benthos	2	2	2	- extensive historical database
	1.5 Fisheries				
	1.5.1 Population	1	1	1	- mostly for juvenile Atlantic salmon
	1.5.2 Tissue	1	1	0.5	- some data exist for metal levels (Cu) in liver of salmon - inconclusive data for one metallothionein study
	Total Criterion 1.0	10	10	8.5	
2.0 Study Area					
2.1	Site Access				
	2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	10	
	2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Gaspé	Comments
2.1.3	Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	
2.2	Are multiple reference and exposure areas available?	Score maximum of 5	5	5	- reference areas should be located upstream of Little York Lake - exposure area consists almost entirely of effluent
2.3	Are there "No" confounding point and non-point source discharges?	Score maximum of 10	10	5	- small discharge of municipal sewage effluent into reclaim basin upstream of exposure area - general chemistry in reach B differs from reach A
	Total Criterion 2.0	35	35	30	
3.0 Effluent/Sublethal Toxicity					
3.1	Is effluent available year round?	Score maximum of 5	5	5	
3.2	Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)				
3.2.1	*Ceriodaphnia dubia*	2	2	2	- IC25 @ 79.4% v/v of effluent
3.2.2	*Fathead minnow*	2	2	0	
3.2.3	*Selenastrum capricornutum*	2	2	0	
3.2.4	*Lemna minor*	2	2	2	
3.2.5	Trout embryo test	2	0	0	- test invalid
	Total Criterion 3.0	15	13	9	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Gaspé	Comments
4.0 Habitats Are habitats similar between the Reference and Exposure areas?					
4.1	Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	5	
4.2	Water depth	2.5	2.5	2.5	
4.3	Water velocity	2.5	2.5	2.5	
	Total Criterion 4.0	10	10	10	
5.0 Water Chemistry Are water chemical concentrations statistically greater in exposure area relative to reference area?					
5.1	For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	- significant differences in TDS, DIC, hardness, conductivity, sulphate and chloride between reference and exposure areas
5.2	For a minimum of two metals (dissolved and total)	10	10	10	- significant differences in Ca, Cu, Mg, Mn, Ni, K, Si, Na, St and Mo between reference and exposure areas
	Total Criterion 5.0	15	15	15	
6.0 Sediments					
6.1	Are representative dispositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	0	- suitable, representative depositional areas not available
6.2	Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	0	- as per 6.1
	Total Criterion 6.0	20	20	0	

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Gaspé	Comments
7.0 Benthos Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)				
7.1 Total abundance	5	5	0	- no significant difference in total abundance between reference and exposure areas
7.2 Total species richness	5	5	5	- significant differences in total species richness
7.3 Richness of sensitive species (e.g. mayflies)	5	5	5	- significant differences in abundance of pollution sensitive taxa between reference and exposure areas
Total Criterion 7.0	15	15	10	
8.0 Fisheries				
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	- Juvenile Atlantic salmon and brook trout available in reference and exposure areas
8.1.2 Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	5	- both sentinel species abundant in reference and exposure areas
8.1.3 Are fish community differences apparent between the reference and exposure area? (if yes, score 5)	5	5	2.5	- some differences in length, weight and condition of juvenile Atlantic salmon between reference and exposure areas

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Gaspé	Comments
8.2 Fish Tissue and Histopathology					
8.2.1	Is there a difference in MT levels between reference and exposure fish?	5	5	5	- metallothionein higher in juvenile Atlantic salmon and brook trout from exposure area
8.2.2	Is there a difference in metals levels between reference and exposure fish?	5	5	5	- metals higher in tissues from fish sampled in exposure area.
8.2.3	Are there obvious differences in fish health between reference and exposure area fish?	5	5	0	- small fish size, thus whole fish sampled for tissue.
8.2.4	Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	- no barriers exist although reference and exposure areas distant spatially
Total Criterion 8.0		35	35	22.5	
Total Maximum Score		155	153	105	69%

APPENDIX A-7

Site Evaluation Criteria for
Heath Steele Mine Site

Appendix A-7 Site evaluation criteria for Heath Steele mine site (stream/river discharge).

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Heath Steele	Comments
1.0 Availability of Useful Historical Data (if yes, score 2 per subcriteria)				
1.1 Effluent Characterization	2	2	2	
1.2 Water Chemistry	2	2	2	• extensive historical data (25 years)
1.3 Sediment Chemistry	2	2	1	• historical results show limitation of suitable, representative depositional areas
1.4 Benthos	2	2	2	• extensive historical database
1.5 Fisheries				
1.5.1 Population	1	1	1	• several studies have been conducted
1.5.2 Tissue	1	1	1	• limited useful historical data available • liver analyses conducted in 1995 show no difference in metals or metallothionein between reference and exposure fish
Total Criterion 1.0	10	10	10	
2.0 Study Area				
2.1 Site Access				
2.1.1 Is this site accessible by road? (Score 1, 5 or 10 with 1 being most difficult)	10	10	10	
2.1.2 Is the reference area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	5	

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Heath Steele	Comments
	2.1.3 Is the exposure area accessible by road or boat? (Score 1-5 with 1 being most difficult)	5	5	4	• four-wheel drive required
2.2	Are multiple reference and exposure areas available?	Score maximum of 5	5	5	• reference areas available on Northwest Miramich River. Station also available on Tomogonops (BCL-4)
2.3	Are there "No" confounding point or non-point source discharges?	Score maximum of 10	10	5	• although the system is complex, with point and non-point source mine discharges affecting different branches, there are no other discharges which are not mine related.
	Total Criterion 2.0	35	35	29	
3.0 Effluent/Sublethal Toxicity					
3.1	Is effluent available year round?	Score maximum of 5	5	5	
3.2	Does effluent clearly exhibit chronic toxicity? (If yes, score 2 per subcriteria)				
	3.2.1 *Ceriodaphnia dubia*	2	2	2	• IC25 @ 19.0% v/v effluent
	3.2.2 *Fathead minnow*	2	2	2	• IC25 @ 23.0 % v/v effluent
	3.2.3 *Selenastrum capricornutum*	2	2	2	• IC25 @ 23.3% v/v effluent
	3.2.4 *Lemna minor*	2	2	2	• IC25 @ 47.3% v/v effluent
	3.2.5 Trout embryo test	2	2	2	• EC50 @ 77.6% v/v effluent
	Total Criterion 3.0	15	15	15	
4.0 Habitats	Are habitats similar between the Reference and Exposure areas?				

Site Evaluation Criteria		Maximum Possible Criterion Score	Maximum Actual Criterion Score	Heath Steele	Comments
4.1	Substrate (score 1-5, with 1 being most different, and 5 being as similar as you could expect from two field locations)	5	5	5	
4.2	Water depth	2.5	2.5	2.5	
4.3	Water velocity	2.5	2.5	1.5	• mean water velocity greater in reference area (3.79 m^3/s) compared to exposure area (1.35 m^3/s)
	Total Criterion 4.0	10	10	9	
5.0 Water Chemistry Are water chemical concentrations statistically greater in exposure area relative to reference area?					
5.1	For a minimum of two general water chemistry parameters (e.g. alkalinity, sulphate, conductivity, hardness, chloride)	5	5	5	• significant differences in TDS, DOC, hardness, conductivity, sulphate and chloride between reference and exposure areas
5.2	For a minimum of two metals (dissolved and total)	10	10	10	• significant differences in several metals including Cu, Pb, Mg, Mn, Sr and Zn between reference and exposure areas
	Total Criterion 5.0	15	15	15	
6.0 Sediments					
6.1	Are representative dispositional areas (>1 m^2) available? (no=0, somewhat=5, yes=10)	10	10	0	• suitable, representative depositional areas not available
6.2	Are concentrations of at least two metals in sediments greater in exposure area relative to reference area?	10	10	0	• as per 6.1
	Total Criterion 6.0	20	20	0	

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Heath Steele	Comments
7.0 Benthos Is there a significant difference between the reference and exposure areas? (no difference score 0; significant difference score 5 per subcriteria)				
7.1 Total abundance	5	5	5	• significantly greater abundance in reference area
7.2 Total species richness	5	5	5	• significantly greater species richness in reference area
7.3 Richness of sensitive species (e.g. mayflies)	5	5	0	• no significant difference in abundance of pollution sensitive taxa between reference and exposure area
Total Criterion 7.0	15	15	10	
8.0 Fisheries				
8.1 Community				
8.1.1 Are suitable sentinel species available in reference and exposure areas?	5	5	5	• Juvenile Atlantic salmon and lake chub available in reference and exposure areas
8.1.2 Are suitable sentinel species abundant in reference and exposure areas? (reasonable CPUE)	5	5	5	• both sentinel species abundant in reference and exposure areas
8.1.3 Are fish community differences apparent between the reference and exposure area? (if yes, score 5)	5	5	2.5	• some differences in CPUE, length and weight of juvenile Atlantic salmon between reference and exposure areas
8.2 Fish Tissue and Histopathology				
8.2.1 Is there a difference in MT levels between reference and exposure fish?	5	5	2	• Conflicting results but sample sizes small

Site Evaluation Criteria	Maximum Possible Criterion Score	Maximum Actual Criterion Score	Heath Steele	Comments
8.2.2 Is there a difference in metals levels between reference and exposure fish?	5	5	2	• conflicting results but sample sizes small
8.2.3 Are there obvious differences in fish health between reference and exposure area fish?	5	5	0	• small fish size thus whole fish sampled for tissue.
8.2.4 Do barriers to fish migration exist between the reference and exposure area? (if yes, score 5)	5	5	0	• no barriers exist although reference and exposure areas distant spatially
Total Criterion 8.0	35	35	12.5	
Total Maximum Score	155	155	104.5	67%