AQUATIC EFFECTS TECHNOLOGY EVALUATION (AETE) PROGRAM

1996 Preliminary Field Survey
Heath Steele Mine Site,
New Brunswick

AETE Project 4.1.2

1996 Preliminary Field Survey
Heath Steele Mine Site, New Brunswick

Sponsored by :

Canada Centre for Mineral and Energy Technology (CANMET)
Mining Association of Canada (MAC)

on Behalf of :

Aquatic Effects Technology Evaluation (AETE) Program

Prepared by :

Jacques Whitford Environment Ltd.
711 Woodstock Road
P.O. Box 1116
Fredericton, N.B.
E3B 5C2

in consortium with :

Ecological Services for Planning Ltd.
361 Southgate Drive
Guelph, Ontario
N1G 3M5

EVS Environment Consultants
195 Pemberton Avenue
North Vancouver, B.C.
V7P 2R4

December 1996

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:

Diane E. Campbell
Manager, Metals and the Environment Program
Mining and Mineral Sciences Laboratories - CANMET
Room 330, 555 Booth Street, Ottawa, Ontario, K1A 0G1
Tel.: (613) 947-4807 Fax: (613) 992-5172
E-mail: dicampbe@nrcan.gc.ca

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 :

Diane E. Campbell
Gestionnaire, Programme des métaux dans l'environnement
Laboratoires des mines et des sciences minérales - CANMET
Pièce 330, 555, rue Booth, Ottawa (Ontario), K1A 0G1
Tél.: (613) 947-4807 / Fax : (613) 992-5172
Courriel : dicampbe@nrcan.gc.ca

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS (continued)

Page No.

TABLE OF CONTENTS (continued)

APPENDICES

LIST OF TABLES

After Page

LIST OF TABLES (continued)

After Page

LIST OF TABLES (continued)

After Page

LIST OF FIGURES

EXECUTIVE SUMMARY

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. Field evaluations were conducted at seven mine sites in 1996 to determine which sites were suitable for further evaluation in 1997. This final field survey report provides detailed information on work conducted at the Heath Steele Mine site near the City of Miramichi, New Brunswick.

The 1996 field survey at the Heath Steele Mine involved the following study/field components:

- historical data review;
- sublethal toxicity testing;
- habitat characterization and classification;
- water chemistry sampling;
- benthic invertebrate sampling;
- fish population sampling; and
- fish tissue collection.

A summary of the results of the 1996 survey at the Heath Steele Mine are presented in the following executive summary table. The 1996 field survey results indicated that this site meets some of the suitability criteria for hypothesis testing in 1997. The evaluation of the suitability of this site is presented under separate cover.

An extensive historical database on effluent, water chemistry and benthic invertebrate community structure exists for the Heath Steele Mine. Fisheries population studies have also been conducted to determine the presence and absence of species and to monitor the recovery of populations in the Tomogonops and Northwest Miramichi Rivers. This historical data was valuable for assessing where reference and exposure areas should be located in the 1996 field survey. Results of the 1996 program were also compared to these historical data sets.

The Heath Steele Mine site was easily accessible and multiple reference and exposure areas of uniform habitat and substrate composition were available. There were no confounding discharges into the receiving environment which would affect result interpretation. The mine discharges both point (tailings discharge) and non-point (seepage) sources into the South Branch, and North and Little South Branches, of the Tomogonops River, respectively. To optimize sampling effort in the 1996 survey, the exposure area was located on the Tomogonops River below the confluence of the North and South Branches. This area is frequented by sentinel fish species and is exposed to the combined mine discharges (tailings effluent and seepage). The reference area was located on the Northwest Miramichi River at Payne's Bridge.

The exposure area, selected for the 1996 survey, had not been sampled historically. Exposure stations have typically been located on the North Branch, Little South Branch, South Branch or the Tomogonops River upstream of its confluence with the Northwest Miramichi River. Stations located on the different Branches are exposed to either mine seepage or mine effluent which differ in effluent composition and may affect aquatic biota differently. In addition, fish populations on these Branches are of limited abundance. The historical exposure station located on the Tomogonops River at the confluence with the Northwest Miramichi River (HS-20) was not an optimal station for the 1996 survey as fish and benthic communities have recovered at this station over the last several years. Therefore, the exposure area sampled in 1996 was located on the Tomogonops River below the confluence of the North and South Branches as this area is exposed to the combined mine discharges and provided for optimized sampling effort for water chemistry, benthic invertebrate communities and fish populations.

Effluent is discharged continuously at the Heath Steele Mine site from the tailings pond east overflow. Sublethal toxicity testing was conducted on the effluent and results clearly indicated toxicity to *Ceriodaphnia dubia* reproduction, juvenile fathead minnow survival and growth, *Selenastrum capricornatum* growth, *Lemna minor* growth, and trout embryo viability. It is recommended for future studies involving sublethal toxicity testing, that receiving (dilution) water be screened for toxicity to *C. dubia* and fathead minnow prior to effluent testing, that all sublethal tests be performed on effluent collected on the same day, and that sublethal tests be conducted on more than one occasion to obtain an estimate of testing variability.

Suitable representative depositional areas did not exist in either the reference or exposure area for sediment sampling. Due to the lack of sediments, the water column represents the main source of exposure of aquatic biota to metals discharged from the mine. As a result, water chemistry analyses should be used in future field programs to measure exposure. A significant difference in general water chemistry (chloride, sulphate, conductivity, hardness, TDS and DOC) and total and dissolved metals (Ba, Ca, Cu, Mg, MN, Na, Pb, Sr and Zn) existed between the reference and exposure areas.

Results from the benthic invertebrate sampling program showed significant differences in total species abundance and richness between the reference and exposure areas. Richness of sensitive species did not differ between areas. These results were consistent with historical results. Based upon the results of BEAK (1996c), it is recommended that a mesh size of 250 μm be retained for sample collection and composite Surber samples be collected at each sampling station.

Juvenile Atlantic salmon and lake chub were the dominant species found in both the reference and exposure areas and these species were abundant. Significant differences in lengths and weights of salmon occurred between these areas. Although sample sizes were small, juvenile salmon were larger and heavier in the reference area. Estimates of variability in condition did not differ between areas for either salmon or lake chub. However, size-at-age relationships significantly differed between areas for both species.

Tissues of lake chub and juvenile Atlantic salmon were sampled for metals and metallothionein (MT) analyses from the Northwest Miramichi River (HS-21) and the Tomogonops River (JW-E1). Although MT levels were significantly higher in both species from the exposure area, sample sizes were small, metals data did not support the MT results, and results from the alternate reference area (BCL-4) showed the highest MT levels in lake chub. Future studies of metals and metallothionein are possible at this mine site with two restrictions. Firstly, a barrier does not exist at the site to eliminate the possibility of fish migration between the reference and exposure areas. Thus, caged fish would be a suitable alternative for evaluating effluent exposure at this site. Secondly, as only small fish are available and abundant (juvenile Atlantic salmon and lake chub) in the reference and exposure areas, comparison of different tissue burdens could not be evaluated as the fish are too small for dissection.

Overall, the Heath Steele Mine site was suitable to sample all program components in 1996 with the exception of sediments. The sampling locations were accessible and a reasonable level of effort was required to complete the field survey.

Table 1: Summary information for specific study elements for the Heath Steele Mine site.

Element	Sampled 1996	Summary/Comments
1.0 Historical Data Review 1.1 Effluent Characterization	N/A	• Extensive historical data exists.
1.2 Water Chemistry	N/A	• Extensive historical data (25 years) exists 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 exists (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 focuses 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

Element	Sampled 1996	Summary/Comments
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 capricornatum*	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.
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 richness and richness of sensitive species between reference and exposure areas. • Differences in total abundance between the reference and exposure area were not significant.

Element	Sampled 1996	Summary/Comments
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	• MT was significantly higher in juvenile Atlantic salmon from the exposure area. MT was also higher for lake chub in the exposure area compared to the reference area on the Northwest Miramichi River. However, MT 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.

SOMMAIRE

Le Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ÉTIMA) a été créé dans le but d'évaluer et de comparer sur le terrain et en laboratoire certaines techniques de surveillance des effets environnementaux permettant de mesurer l'impact des effluents miniers sur le milieu aquatique. En 1996, on a procédé à des évaluations sur le terrain à sept mines afin de déterminer quels sites conviendraient à une évaluation ultérieure en 1997. Le présent rapport final d'étude sur le terrain fournit des renseignements détaillés sur les recherches menées à la mine Heath Steele près de la ville de Miramichi (Nouveau-Brunswick).

L'étude sur le terrain conduite en 1996 à la mine Heath Steele portait sur les éléments du terrain ou de l'étude énumérés ci-dessous.

- Revue des données historiques
- Tests de toxicité sublétale
- Caractérisation et classification des habitats
- Échantillonnage pour l'analyse chimique de l'eau
- Échantillonnage des invertébrés benthiques
- Échantillonnage des populations de poissons
- Prélèvement de tissus de poissons

Un sommaire des résultats de l'étude menée en 1996 à la mine Heath Steele est présenté dans le tableau récapitulatif ci-dessous. Selon les résultats, ce site satisferait certains critères de pertinence pour la vérification des hypothèses prévue en 1997. L'évaluation de la pertinence du site est présentée dans un document distinct.

Il existe une base de données historiques détaillées sur l'effluent, la chimie de l'eau et la structure des communautés d'invertébrés benthiques pour la mine Heath Steele. On a également mené des études de populations sur les lieux de pêche afin de déterminer quelles espèces sont présentes et de surveiller le rétablissement des populations dans la rivière Tomogonops et le bras nord-ouest de la rivière Miramichi. Les données historiques ont servi à déterminer les meilleurs emplacements pour les zones de référence et d'exposition aux fins de l'étude sur le terrain en 1996. Les résultats du programme de 1996 ont aussi été comparés aux ensembles de données historiques.

Le site de la mine Heath Steele était facilement accessible et renfermait plusieurs zones de référence et d'exposition présentant une certaine uniformité de l'habitat et de la composition du substrat. Aucun autre rejet au même endroit dans le milieu récepteur ne pouvait influer sur l'interprétation des résultats. Les rejets de la mine proviennent de sources ponctuelles (déversement de résidus) et de sources diffuses (percolation) dans le bras South, le bras North et le bras Little South de la rivière Tomogonops, respectivement. Pour optimiser l'effort d'échantillonnage lors de l'étude menée en 1996, on a établi une zone d'exposition sur la rivière Tomogonops en aval du confluent des bras North et South. Cette zone est fréquentée par des espèces de poissons indicatrices et exposée à des rejets miniers combinés (effluents de résidus et

percolation). La zone de référence était située sur le bras nord-ouest de la rivière Miramichi, à la hauteur du pont Payne's.

La zone d'exposition choisie pour l'étude de 1996 n'a pas fait l'objet d'échantillonnages antérieurs. Les postes de la zone d'exposition étaient pour la plupart situés sur les bras North, Little South et South de la rivière Tomogonops, en amont de son confluent avec le bras nord-ouest de la rivière Miramichi. Les postes installés sur les différents bras de la rivière reçoivent soit les eaux de percolation de la mine, soit l'effluent minier, qui n'ont pas la même composition et qui peuvent avoir des effets différents sur le biote aquatique. En outre, les populations de poissons ne sont pas très importantes dans ces bras de rivière. Le poste de la zone d'exposition antérieure, situé sur la rivière Tomogonops, au confluent avec le bras nord-ouest de la Miramichi ((HS-20), n'offrait pas des conditions optimales pour l'étude de 1996 parce que les communautés de poissons et d'invertébrés s'y étaient rétablies depuis plusieurs années. Par conséquent, la zone d'exposition échantillonnée en 1996 a été sélectionnée sur la rivière Tomogonops, en aval du confluent des bras North et South, car cet endroit reçoit les rejets combinés de la mine et offrait des conditions optimales de prélèvement d'échantillons pour l'étude de la chimie de l'eau, des communautés d'invertébrés benthiques et des populations de poissons.

La mine Heath Steele rejette de façon continue un effluent provenant du trop-plein est du bassin de décantation et de stockage des résidus et des boues. L'effluent a été soumis à des tests de toxicité sublétale, et les résultats indiquent clairement que l'effluent a un effet toxique sur la reproduction de *Ceriodaphnia dubia*, sur la croissance et la survie de la tête-de-boule au stade juvénile, sur la croissance de *Selenastrum capricornutum* et de *Lemna minor*, ainsi que sur la viabilité des embryons de truite. Lors d'études ultérieures comportant des tests de toxicité sublétale, il est recommandé de vérifier la toxicité des eaux réceptrices (eaux de dilution) pour *C. dubia* et la tête-de-boule avant de procéder aux essais sur l'effluent, de mener tous les tests de toxicité sublétale sur des échantillons d'effluent recueillis le même jour, et de faire ces tests plus d'une fois pour évaluer la variabilité des essais.

Il n'y a pas de zones de dépôt représentatives appropriées pour l'échantillonnage des sédiments, ni dans la zone de référence, ni dans la zone d'exposition. En raison de l'absence de sédiments, la colonne d'eau représente la principale source d'exposition du biote aquatique aux métaux rejetés par la mine. Par conséquent, lors des prochains programmes de recherche sur le terrain, on devrait faire des analyses chimiques de l'eau pour mesurer le degré d'exposition. Il existe une différence importante entre la zone de référence et la zone d'exposition relativement à la chimie générale de l'eau (chlorures, sulfates, conductivité, dureté, TSD et COD) et aux concentrations de métaux sous forme dissoute ou en concentrations totales (Ba, Ca, Cu, Mg, Mn, Na, Pb, Sr et Zn).

Les résultats du programme d'échantillonnage des invertébrés benthiques montrent des différences importantes entre la zone de référence et la zone d'exposition relativement à l'abondance et à la diversité des espèces en général. La diversité des espèces vulnérables est la même dans les deux zones. Les résultats sont compatibles avec les données historiques. D'après les résultats de BEAK (1996c), il est recommandé d'utiliser des mailles de 250 μm pour la récolte d'échantillons et de prélever des échantillons composites par filet Surber à chaque poste d'échantillonnage.

Le saumon atlantique juvénile et le méné de lac étaient les espèces dominantes, tant dans la zone de référence que dans la zone d'exposition, et on les trouvait en abondance. Des différences importantes dans la longueur et le poids des saumons ont été observées entre ces zones. Malgré la petite taille des échantillons, les saumons atlantiques juvéniles capturés dans la zone de référence étaient plus longs et plus lourds. Les estimations de la variabilité des conditions sont à peu près semblables entre ces zones dans le cas du saumon et du méné de lac. Cependant, le ratio taille-âge diffère considérablement entre ces zones relativement à ces deux espèces.

On a prélevé des tissus de méné de lac et de saumon atlantique juvénile provenant du bras nord-ouest de la rivière Miramichi (HS-21) et de la rivière Tomogonops (JW-E1) afin d'analyser leur teneur en métaux et en métallothionéine (MT). La teneur en MT était beaucoup plus élevée chez les deux espèces dans les échantillons de la zone d'exposition, mais les échantillons étaient de petite taille. Les données relatives aux métaux ne corroborent pas les résultats des analyses sur la métallothionéine, et les résultats obtenus pour l'autre zone de référence (BCL-4) montrent que les ménés de lac présentent les concentrations de MT les plus élevées. Il est possible de mener d'autres études sur les métaux et la métallothionéine à ce site minier en tenant compte de deux restrictions. Premièrement, il n'existe à cet endroit aucun obstacle permettant d'éliminer la possibilité de migration des poissons entre la zone de référence et la zone d'exposition. Par conséquent, l'emploi de cages à poissons à cet endroit serait une solution de rechange appropriée pour évaluer l'exposition à l'effluent. Deuxièmement, comme il n'y a que des petits poissons qui sont présents en abondance (saumon atlantique juvénile et méné de lac) dans les zones de référence et d'exposition, on ne peut comparer les différents dépôts tissulaires, car les poissons sont trop petits pour être disséqués.

Dans l'ensemble, le site de la mine Heath Steele convenait à l'échantillonnage de tous les éléments du programme en 1996, sauf en ce qui a trait aux sédiments. Les emplacements d'échantillonnage étaient accessibles et l'étude sur le terrain nécessitait une somme raisonnable d'efforts.

Tableau ES-1. Résumé de l'information concernant certains éléments de l'étude relative à la mine Heath Steele.

Élément	Échantillons prélevés en 1996	Sommaire/remarques
1.0 Revue des données historiques 1.1 Caractérisation de l'effluent	s.o.	• Il existe des données historiques détaillées.
1.2 Chimie de l'eau	s.o.	• Il existe des données historiques détaillées (25 ans) pour les zones de référence et d'exposition.
1.3 Chimie des sédiments	s.o.	• Les prélèvements de sédiments effectués dans le passé montrent l'absence de zones de dépôt.
1.4 Benthos	s.o.	• Il existe des données historiques détaillées (maille de 500 μm).
1.5 Pêches 1.5.1 Population	s.o.	• On a mené plusieurs études visant à déterminer quelles espèces sont présentes. Bien des données historiques sont axées sur les populations de saumons atlantiques juvéniles.
1.5.2 Tissus	s.o.	• D'après une étude menée en 1995, il n'y a pas de différences entre la zone de référence et la zone d'exposition.
2.0 Zone d'étude 2.1 Accès au site	s.o.	• Le site est accessible par la route bien qu'il soit recommandé d'utiliser un véhicule à quatre roues motrices pour se rendre dans la zone d'exposition.
2.2 Disponibilité de plusieurs zones de référence et d'exposition	s.o.	• Des zones de référence sont établies dans le bras nord-ouest de la rivière Miramichi et dans la rivière Tomogonops (BCL-4). • Des zones d'exposition sont accessibles sur tous les bras de la rivière Tomogonops. Ce site est complexe, car il y a des rejets de sources ponctuelles et diffuses provenant de la mine et touchant divers bras de la rivière Tomogonops.
2.3 Rejets au même endroit	s.o.	• Il n'y a pas d'autres rejets provenant d'ailleurs.
3.0 Effluent et toxicité sublétale 3.1 Fréquence des rejets d'effluent	s.o.	• L'effluent est rejeté de façon continue.
3.2 Toxicité sublétale 3.2.1 *Ceriodaphnia dubia*	Oui	• Toxicité à CI 25 à environ 19,0 % vol./vol. de l'effluent.
3.2.2 Tête-de-boule	Oui	• Toxicité à CI 25 à environ 23,0 % vol./vol. de l'effluent.
3.2.3 *Selenastrum capricornutum*	Oui	• Toxicité à CI 25 à environ 23,3 % vol./vol. de l'effluent.
3.2.4 *Lemna minor*	Oui	• Toxicité à CI 25 à environ 47,3 % vol./vol. de l'effluent.
3.2.5 Embryon de truite	Oui	• Toxicité à CE 50 à environ 77,6 % vol./vol. de l'effluent.
4.0 Habitats	Oui	• Composition du substrat uniforme dans les habitats. • Vélocité légèrement supérieure dans la zone de référence comparativement à la zone d'exposition.
5.0 Chimie de l'eau	Oui	• Différences importantes entre la zone de référence et la zone d'exposition concernant les concentrations de chlorures et de sulfates, la conductivité, la

Élément	Échantillons prélevés en 1996	Sommaire/remarques
		dureté, le TSD et le COD. • Différences importantes entre les zones de référence et d'exposition concernant les teneurs en Ba, Ca, Cu, Mg, Mn, Na, Pb, Sr et Zn. • D'après les études antérieures (1995 et 1996), il y aurait un fort gradient du point de vue des métaux et de la chimie générale dans le bras sud de la rivière Tomogonops.
6.0 Sédiments	Non	• Il n'y a pas de zones de dépôt représentatives appropriées (>1,0 m²).
7.0 Invertébrés benthiques	Oui	• Différences importantes entre les zones de référence et d'exposition relativement à la diversité spécifique totale et à la diversité des espèces vulnérables. • Différences négligeables entre la zone de référence et la zone d'exposition du point de vue de l'abondance de toutes les espèces.
8.0 Pêches 8.1 Communautés	Oui	• Présence de saumons atlantiques juvéniles et de ménés de lac dans les zones de référence et d'exposition. • Les deux espèces indicatrices étaient présentes dans les deux zones. Un échantillonnage qualitatif a eu lieu en 1996. • Certaines différences dans les prises par unité d'effort (PPUE), la longueur et le poids des saumons atlantiques juvéniles ont été observées dans les zones de référence et d'exposition.
8.2 Tissus de poissons	Oui	• La teneur en MT était nettement plus élevée chez le saumon atlantique juvénile dans la zone d'exposition. Elle était aussi plus élevée chez le méné de lac dans la zone d'exposition comparativement à celle mesurée chez le méné de la zone de référence située dans le bras nord-ouest de la rivière Miramichi. Cependant, les concentrations de MT mesurées chez les poissons de la zone de référence de remplacement étaient les plus élevées de tous les sites. • Les résultats relatifs aux concentrations de métaux ne sont pas concluants. • La taille des échantillons était très petite, ce qui complique l'interprétation des données. • Il n'y a aucun obstacle pouvant empêcher une éventuelle migration des poissons entre les zones de référence et d'exposition.

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, the AETE Program sponsored, in 1996, field evaluations of aquatic effects monitoring at seven candidate mine sites. Based on the results of these preliminary evaluations, some of these sites have been recommended for further work in 1997.

This final field survey report provides detailed information on work conducted at one of these seven sites. Separate reports are provided for each of the other six sites. Recommendations regarding selection of sites for 1997 work are provided under separate cover together with a field study design for each of the recommended sites.

2.0 SITE SPECIFIC BACKGROUND INFORMATION

2.1 Site Description

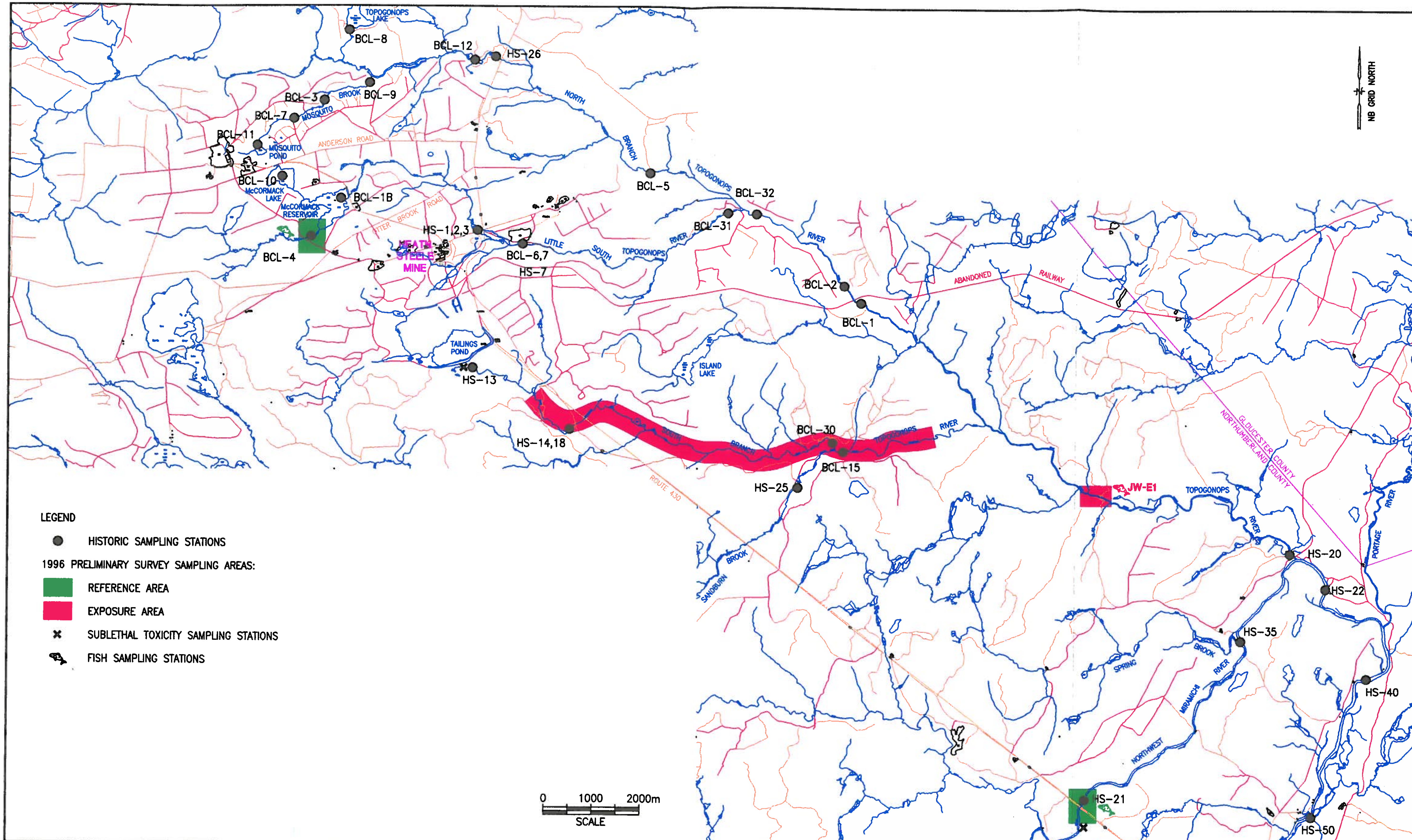
The Heath Steele Mine is a base metal mining and milling operation located in the Appalachian region of northeastern New Brunswick 50 km northwest of the city of Miramichi. There are two sites which currently exist on the property; the Heath Steele site and the Stratmat site. The location of these respective sites relative to one another is illustrated in Figure 2.1. Exploration of the Heath Steele site commenced in 1953 and resulted in the discovery of two major ore bodies (Heath Steele Mines Limited 1988). Development of open pit and underground shafts commenced in 1955 and the mill was brought into operation in 1956 with a capacity of approximately 1500 tonnes per day (Bailey 1988). In May 1958 operations ceased and all the workings were flooded due to low metal prices and difficulties in mining metallurgy. In 1960 the Heath Steele Mine site opened, treatment of mine drainage water commenced, and drainage control works were installed. Milling operations did not resume until 1962 and by 1972 the production rate had reached 3000 t/day. From 1983 to 1989, production again ceased due to depressed metal prices although some milling of gold-silver ores occurred (Bailey 1988; Heath Steele Mines Limited 1988). Shut-down periods for the Heath Steele Mine site also occurred from June 1993 to October 1994.

The Stratmat site is located 4.5 km northwest of the Heath Steele site. Although the site was explored in the 1950's, this site was not developed until 1987 and 1988 (Heath Steele Mines Limited 1988). In 1989 operations began and in 1993 the site was closed.

Currently, the Heath Steele site is in operation and produces zinc (52%), lead (38%), and copper (22-24%) flotation concentrates from complex massive sulphide ores at a rate of approximately 2700 tonnes per day (BEAK 1992). All effluent streams discharge into a 245 hectare tailings pond, expanded from 189 hectares in early 1996, for effluent treatment before release to the receiving environment (Mike Patterson, pers. comm.).

A summary of monthly mean effluent quality in 1995 and 1996, provided by Heath Steele Mines (Mike Patterson, pers. comm.), is illustrated in Table 2.1. The effluent from the Pond East overflow is characterized by high total dissolved solids, hardness, and conductivity. The effluent is often alkaline (mean pH in 1995 was 9.94). The Certificate of Approval from the Department of Environment in New Brunswick states that a minimum pH of 8.5 is required. The principal cations are the alkaline metals specifically calcium, magnesium, potassium, sodium and strontium. The corresponding anions are sulphate and to a lesser extent, chloride. The concentrations of heavy metals vary between species and season. The highest loadings of heavy metals come from zinc and lead, with minor inputs of copper, arsenic and cadmium (in descending order). In 1995, the mean monthly concentrations of zinc and lead in the effluent were 230 and 180 µg/L, respectively. Monthly averages of zinc ranged between 20 and 990 µg/L but these levels were not observed in the recordings for 1996. The highest inputs of lead and zinc occur in winter and early spring which are coincident with periods of elevated pH and high flows. Total thiosalts results were available only for 1996 and show levels ranging from 44.8 mg/L to 108.6 mg/L (Mike Patterson, pers. comm.).

FILE: HEATH



SITE LOCATION MAP
HEATH STEELE MINE
1997 STUDY DESIGN

Date:	Scale:
96 12 13	1 : 75 000
Job No.: 8128	Fig. No.: 2.1

Jacques Whitford Environment Limited

Table 2.1: Monthly Effluent Chemistry in 1995 and 1996 at Heath Steele Mine Sampled at HS-13, Tailings Pond East Overflow

Year	Month	Average Monthly Concentrations								Flow (L/min)	Average Monthly Loadings					
		pH (pH units)	Cu (mg/L)	Pb (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	TSS (mg/L)	Total Thiosalts (mg/L)		Cu (kg)	Pb (kg)	Zn (kg)	As (kg)	Cd (kg)	TSS (kg)
1995	January	10.92	0.01	0.20	0.55	0.003	0.0003	4.4		17,100	7.6	152.7	419.8	2.3	0.2	3,358.7
	February	10.80	0.01	0.18	0.99	0.003	0.0054	10.8		12,720	5.1	92.3	507.7	1.5	2.8	5,539.0
	March	11.40	0.01	0.49	0.34	0.003	0.0007	8.9		19,260	8.6	421.3	292.3	2.6	0.5	7,651.9
	April	10.65	0.02	0.08	0.32	0.004	0.0002	4.6		39,360	35.1	140.6	562.2	7.0	0.3	8,082.3
	May	10.56	0.01	0.02	0.14	0.003	0.0075	2.2		41,400	18.5	37.0	258.7	5.5	12.5	4,065.8
	June	8.06	0.02	0.41	0.13	0.003	0.0016	2.5		20,340	10.0	204.1	64.7	1.5	1.3	1,244.8
	July	7.98	0.01	0.50	0.09	0.003	0.0020	1.7		15,240	6.8	340.2	61.2	2.0	1.2	1,158.5
	August	9.34	0.01	0.17	0.03	0.003	0.0006	2.0		17,160	7.7	130.2	23.0	2.3	0.4	1,532.0
	September	9.03	0.01	0.06	0.04	0.008	0.0001	3.8		10,620	4.7	28.4	19.0	3.8	0.0	1,801.5
	October	9.76	0.01	0.06	0.07	0.006	0.0040	6.2		14,040	6.3	37.6	43.9	3.8	2.3	3,885.8
	November	9.70	0.01	0.02	0.05	0.006	0.0001	2.8		21,120	9.4	18.9	47.1	5.7	0.1	2,639.8
	December	9.90	0.01	0.01	0.02	0.005	0.0001	1.7		9,360	4.2	4.2	8.4	2.1	0.0	710.3
Average		9.84	0.01	0.18	0.23	0.004	0.0019	4.3	-----	19,810	10.3	134	192.3	3.3	1.8	3,472.4
Total Kilograms or M³										10,425,197	124	1607	2308	40.11	21.77	41668.63
1996	January	11.08	0.01	0.07	0.10	0.003		2.5	86.2	17,100	7.6	53.4	78.3	2.3	0.0	1,908.4
	February	10.97	0.01	0.01	0.23	0.003		2.9	108.6	20,280	8.2	8.2	188.1	2.5	0.0	2,371.3
	March	10.47	0.01	0.01	0.26			3.7	80.1	19,860	8.9	8.9	230.5	0.0	0.0	3,280.2
	April	11.11	0.01	0.02	0.04	0.003		3.3		32,040	14.3	28.6	57.2	4.3	0.0	4,719.9
	May	9.96	0.01	0.02	0.06	0.003		8.4	46.3	30,900	13.8	27.6	82.8	4.1	0.0	11,586.8
	June	10.19	0.01	0.03	0.01	0.003		1.6	53.8	33,900	8.3	24.9	8.3	2.5	0.0	1,327.8
	July	9.77	0.01	0.06	0.01	0.004		1.5	79.8	24,480	10.9	65.6	10.9	4.4	0.0	1,639.2
	August	9.53	0.01	0.02	0.01	0.003		1.3	100.1	11,520	5.1	10.3	5.1	1.5	0.0	668.5
	September	9.25	0.01	0.02	0.02	0.003		2.6	44.8	2,940	1.3	2.6	2.6	0.4	0.0	341.2
	October										0.0	0.0	0.0	0.0	0.0	0.0
	November										0.0	0.0	0.0	0.0	0.0	0.0
	December										0.0	0.0	0.0	0.0	0.0	0.0
Average		10.26	0.01	0.03	0.08	0.003	-----	3.1	75	21,447	6.5	19.2	55.2	1.8	0	2,320.3
Total Kilograms or M³										8,429,616	78	230	662	21.97	0	27,843.26

The Heath Steele Mine site is located in the northern Miramichi mineral zone which is underlain by highly deformed, regionally metamorphosed, volcanic and sedimentary rocks of the Tetagouche Group (BEAK 1992). This zone contains many copper, zinc, lead and pyrite deposits in the form of massive pyrite with spalerite, galena and chalcopyrite, or pyrrhotite-chalcopyrite in association with massive pyrite (Montreal Engineering Company Limited 1973).

The Heath Steele and Stratmat Mine sites are also situated near the headwaters of the Tomogonops River, a major tributary of the Northwest Miramichi River (Figure 2.1). The Tomogonops River consists of three branches; the North Branch, Little South Branch, and South Branch. The North Branch receives flows from several sources including Mosquito Pond, Mosquito Brook and Tomogonops Lake. The North Branch Tomogonops River, upstream of the mine site, served as a reference area until 1993 when it was discovered that acid mine drainage from the Stratmat Mine site was impacting water quality and biota. Since that time, mitigation efforts have reduced metal loadings significantly (Mike Patterson pers. comm.).

The Little South Branch of the Tomogonops River converges with the North Branch Tomogonops 6 km downstream of the Heath Steele Mine site. The upper Little South Branch receives flows from McCormack Lake and McCormack Reservoir (BCL-4). A reference area for this branch currently exists upstream of McCormack Reservoir. The lower Little South Branch has been affected by subsurface seepage from the north end of the Heath Steele tailings pond.

The South Branch Tomogonops River converges with the North Branch approximately 15 km below the tailings pond. All effluent streams originating from the mine are pumped to the tailings pond for treatment before release to the South Branch at a rate of 16.6 m^3/min.

The Tomogonops River joins the Northwest Miramichi River approximately 22 km downstream of the Heath Mines and mill site. The Northwest Miramichi River drains a watershed area of 3900 km^2 and joins the Southwest Miramichi River at Newcastle to form the Miramichi River (Bailey 1988). The Miramichi River Basin drains a watershed area of 11,700 km^2 and is important habitat for Atlantic salmon (*Salmo salar*).

2.2 Historical Data Review

An extensive historical data base exists for the Heath Steele Mine site because of monitoring programs conducted to satisfy regulatory requirements and those established to evaluate environmental affects associated with unexpected mine releases.

Environmental monitoring of water chemistry has been conducted since 1974 and Heath Steele Mines carries out a weekly and monthly water quality sampling program on the Tomogonops and Northwest Miramichi Rivers as required in the *New Brunswick Department of Environment Certificate of Approval (COA)* to operate (BEAK 1992, Mike Patterson pers. comm.). Benthic invertebrate populations in the Tomogonops and Northwest Miramichi Rivers have been studied since 1981 and benthos and water chemistry sampling are also monitored bi-annually as part of the mine's *COA* requirements. Heath Steele also conducts rainbow trout acute lethality testing of its treated effluent and receiving waters four times per year (Mike Patterson pers. comm.).

In 1958 when the mine was shut down due to low metal prices, all workings were flooded (Bailey 1988). In 1960, when the mine reopened, the shafts and pit were dewatered into the Little South Tomogonops River. This resulted in extremely high metal concentrations, primarily zinc and copper, in the Tomogonops River and Northwest Miramichi River systems. This release of mine water stimulated avoidance behavior of migrating Atlantic salmon populations and prompted a series of toxicological and fisheries behavior studies by Dr. John Sprague and the Fisheries Research Board (Bailey 1988, BEAK 1992). In the late 1960's, treatment of mine drainage water commenced, drainage control works were installed, and monitoring of effluent quality commenced. In 1981 an intensive, multi-component study was conducted on water and sediment chemistry, benthic invertebrate and fish populations to establish baseline conditions for monitoring the effect of plant process changes (Wood 1981). In 1988, a two year study conducted by Environment Canada evaluated the effects of three mines, including Heath Steele, on their respective receiving environments. In February 1991, a pipeline break resulted in a mine water release into the Little South Tomogonops River and elevated metal concentrations in the Tomogonops River and Northwest Miramichi River. To monitor the effects of this release on the receiving environment, studies on hydrology, water and sediment chemistry, toxicology, benthic fauna and fish populations were conducted by BEAK (1992; 1993; 1994b). In late 1993 and early 1994 elevated zinc concentrations in the North Branch Tomogonops River, resulting from acidic seepage from the Stratmat Mine site, were discovered. The North Branch was historically unaffected by the mine until that event. The effect of this seepage on toxicity, water and sediment chemistry, benthos and fish in the Tomogonops River system was investigated in June and October of 1994 (BEAK 1994a; 1995b).

A literature review for design of the 1996 Field Studies is summarized in Table 2.2. BEAK Consultants Limited (1992) summarized studies relevant to environmental monitoring at Health Steele. These were not reviewed for this program but are presented in Table 2.3. Wood (1981) also provided a bibliography of references regarding the status of the Tomogonops and Northwest Miramichi River systems.

Reference and exposure stations on the Tomogonops and Northwest Miramichi Rivers are available and have been sampled historically by Heath Steele Mines. The location of historical sampling stations are illustrated in Figure 2.1. Reference stations in the Tomogonops River system include BCL-4, BCL-10, BCL-13, BCL-8 and HS-25. BCL-4 has been the reference station for the North Branch and Little South Branch Tomogonops since 1994. Prior to 1994, HS-26 on the North Branch at Highway 430 served as a reference station until it was affected by acid mine drainage from the Stratmat Mine site. BCL-10, BCL-13 and BCL-8 are reference stations located in McCormack Lake, McCormack Reservoir and Tomogonops Lake,

Table 2.2: Summary of Studies on the Receiving Waters of the Heath Steele Mine

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Montreal Engineering Company Ltd. (1973)		+			+		From 1970 to 1972 a Federal-Provincial, Northeastern New Brunswick Mine Water Quality Program was conducted to summarize the important aspects of base metal mining waste management in Northeastern New Brunswick.
Wells *et. al* (1974)	+						The effectiveness of a 2-stage lime addition, flocculation, and clarification pilot plant mine drainage treatment system on reducing acute toxicity was evaluated in 1973 and 1974.
Montreal Engineering Company Ltd. (1979)		+					Hydrogeological investigations were carried out from May to June 1979 to identify the origins of metal contamination to the Little South Tomogonops River. Groundwater was highly contaminated with copper and zinc due to mine site seepage.
Wood (1981)		+	+	+	+		Environmental survey conducted in 1981 on the Tomogonops and Northwest Miramichi Rivers and included benthic and fish population surveys and water and sediment chemistry analyses. A significant gradient in water chemistry was apparent. Higher levels of lead and zinc found in all sediments (including controls) in the Tomogonops system compared to the Northwest Miramichi. Benthic invertebrate diversity and density decreased downstream of the mine. Salmon populations were affected in the Tomogonops River.
Bailey (1988)		+	+			+	In June 1984, the Water Quality Branch of Environment Canada sampled water, sediments and metals in fish tissue from the Tomogonops and Northwest Miramichi Rivers. Water chemistry gradients in copper, lead and zinc occurred. Sediments provided limited data. Forage fish (lake chub) collected in the Northwest Miramichi at Wayerton contained high body burdens of zinc.
Heath Steele Mines (1990)		+					1989 Environmental Report. Water chemistry gradient (Cu, Pb, Zn) in the Little South Tomogonops River.

Table 2.2 (continued)

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Heath Steele Mines (1991)		+		+	+		1990 Environmental Report. Water chemistry gradient (Cu, Pb, Zn) in the Little South, South Branch and Tomogonops Rivers. Acute lethality tests on rainbow trout showed mortality due to a pH effect. Benthic surveys showed a gradient in density and diversity. Electrofishing surveys indicated no aversion by salmon at the mouth of the Tomogonops River.
BEAK (1992)	+	+	+	+	+	+	Environmental surveys were conducted in 1991 in the Tomogonops and Northwest Miramichi Rivers following release of mine water from a broken pipeline. Effluent samples showed high zinc and copper concentrations. Mine water was acutely lethal to salmon embryos, Atlantic salmon, brook trout and rainbow trout fry. Zinc and copper concentrations were elevated in both rivers at the time of the discharge. Ambient water samples at nearfield stations were not lethal to fathead minnows but were lethal to *Ceriodaphnia dubia*. No effect was apparent in benthic communities. Fish mortality at nearfield sites and reduced CPUE. Metals analyses on fish fillet samples showed copper and zinc levels within safe levels for human consumption.
Heath Steele Mines (1992)	+	+		+			1991 Environmental Report. Water chemistry gradient (Cu, Pb, Zn) in the Little South, South Branch and Tomogonops Rivers. In February, June, and October 96 hour rainbow trout bioassays passed. In September some mortalities were reported in samples of the tailings effluent and from water sampled from the mouth of the Tomogonops River (HS-20). Benthic results reported in BEAK (1992).
BEAK (1993)					+		A fisheries survey conducted in August 1992 on the Northwest Miramichi River to identify residual affects of a 1991 ruptured pipeline on juvenile salmon. Results support BEAK (1992) which estimated losses of juvenile salmon due to the discharge.

Table 2.2 (continued)

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Hare (1993)				+			Benthic surveys conducted in June and October of 1992. Mining operations had a significant affect on benthic population densities and species abundance in the South Branch (HS-14) and Tomogonops (HS-20) Rivers.
Heath Steele Mines (1993)	+	+		+			1992 Environmental Report. Water chemistry gradient (Cu, Pb, Zn) in Little South, South Branch and Tomogonops Rivers. Quarterly toxicity tests showed 100% survival of rainbow trout in 96 hour static tests. Benthic results reported in Hare (1993).
BEAK (1994a)	+	+	+	+	+		Study conducted in June 1994 to assess the effect of seepage from the Stratmat mine site. Study included an electrofishing survey, fish habitat characterization, benthic community assessment, toxicity testing and water and sediment chemistry analyses in the Tomogonops River system. Zinc concentrations were elevated in the North Branch due to seepage from Stratmat Mine. Sediments were very limited but those sampled showed a gradient in zinc concentration downstream of Stratmat. Benthic and fish communities showed minor impairment. Water samples collected downstream of Stratmat were acutely lethal to rainbow trout.
BEAK (1994b)					+		Follow-up studies of juvenile Atlantic salmon populations conducted in 1992 and 1993 after release of mine water in 1991 (*see* BEAK 1994a). Population densities recovered in affected reaches.
BEAK (1995a)		+		+			Benthic surveys conducted in June and October of 1994 showed improvement in the South Branch Tomogonops River compared to 1992 and 1993 surveys. Densities and diversities at exposure stations show impairment compared to reference stations.

Table 2.2 (continued)

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
BEAK (1995b)	+	+	+	+			A benthic and sediment quality survey was carried out in dispositional areas of Mosquito Pond, lower Mosquito Brook, the North Branch and Upper Little South Branch of the Tomogonops River in October of 1994. Zinc, lead, and cadmium increased in the sediments but had low bioavailability based on porewater analyses and sequential extraction analyses. Sediments did not increase *Chironomus tentans* mortality or cause growth inhibition. Benthic communities downstream of Stratmat Mine showed minor impairment.
BEAK (1996a)		+		+			A water chemistry and benthic invertebrate survey was conducted in 1995 in the South Branch Tomogonops River (HS-18, BCL-15), Little South Branch (BCL-4, HS-7), Tomogonops River (HS-20), and Northwest Miramichi River (HS-35). High conductivity, hardness, sulphate and metal levels were evident in the Tomogonops system. Benthic invertebrate densities and diversities were reduced near the mine site but recovered downstream (HS-20).
BEAK (1996b)		+			+	+	Study conducted in conjunction with BEAK (1996a). Juvenile Atlantic salmon (fry and parr), and grilse occurred in the South Branch Tomogonops at Sandburn Brook, and at the Little South Branch - North Branch Tomogonops Rivers confluence. Metallothionein and liver metal levels did not differ between exposed and reference fish populations.

Table 2.3: Other Reference Material Relevant to Environmental Programs Conducted at Heath Steele Mine (after BEAK 1992).

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Sprague (1964a)	+						Avoidance of Copper-Zinc Solutions by Young Salmon in the Laboratory. Avoidance Threshold: 2.3 μg/L Cu, 53 μg/L Zn, or mixture 0.42 μg/L Cu, + 6.1 μg/L Zn.
Sprague (1964b)	+						Lethal Concentrations of Copper and Zinc for Young Atlantic Salmon. Incipient Lethal Levels: 48 μg/L Cu, 600 μg/L Zn.
Sprague *et al.* (1964)	+						Sublethal Copper-Zinc Pollution in a Salmon River - A Field and Laboratory Study. Avoidance by migrating adults; parr avoid less than one tenth incipient lethal levels.
Sprague and Ramsay (1965)	+						Lethal Levels of Mixed Copper-Zinc Solutions for Juvenile Salmon. Incipient lethal levels: 32 μg/L Cu, 420 μg/L Zn, in soft water at 17°C.
Sprague (1968)	+						Avoidance Reactions of Rainbow Trout to Zinc Sulphate Solutions. Avoidance Threshold: 5.6 μg/L, Lethal Threshold 570 μg/L.
Saunders (1969)				+			Contributions of Salmon from the Northwest Miramichi River, New Brunswick, to Various Fisheries. Tagged fish (smolts) from the Northwest Miramichi River showed that adult salmon substantially contributed to the commercial fishery within the region.
Fish. Res. Brd. of Can. (1970 & 1973)		+					Chemical Conditions in the Northwest Miramichi River During 1960 - 1968, 1970 and 1973. Eleven annual reports.

Table 2.3 (continued)

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Howarth and Sprague. (1978)		+					Copper Lethality to Rainbow Trout in waters of various hardness and pH. 96 hour LC50 for juveniles and subadults is 26.0 and 24.0 mg/L respectively.
Prairer (1984)				+			Status of Atlantic Salmon in the Northwest Miramichi River, New Brunswick. Main characteristics of the Northwest Miramichi, including the Tomogonops River. Provides an overview of salmon status (population, sport and commercial fishing, enhancement).
Wood (1984)				+			Biological Survey for Heath Steele Mines Limited May - August 1984.
Bradley and Sprague (1985)	+						The Influence of pH, Water Hardness, and Alkalinity on the Acute Lethality of Zinc to Rainbow Trout. Acute lethality of dissolved zinc significantly increases at higher pH and lower hardness levels.
Pedder and Maly (1985)	+						The Effect of Lethal Copper Solutions on the Behavior of Rainbow Trout. EC50 - 96 hour value for avoidance between 0.5 and 0.75 mg/L.
Cusimano, Brakke and Chapman (1986)	+						Effects of pH on the Toxicities of Cadmium, Copper, and Zinc to Steelhead Trout. 96-h LC50 value at pH 4.7, 5.7, 7.0 are: Zinc: 671, 97, 66 μg/L; Cu: 66.0, 4.2, 2.8 μg/L; Cad: 28.0, 0.7, <0.5 μg/L.
Randall *et al.* (1990)					+		Status of Atlantic Salmon in the Miramichi River During 1989. Electrofishing survey indicated an increase in average density of juvenile salmon in 1989 from 1988, however, returns of adult salmon were less in 1989 than the preceding year.

Table 2.3 (continued)

Source	Toxicity	Water Chemistry	Sediment Quality	Benthos	Fish		Summary
					Pop.	Tissue	
Wood (1990)					+		Status of the Juvenile Atlantic Salmon Population in the Northwest Miramichi River, 1990. Comparing 1987 and 1990 results, better spawning and rearing success in 1987.
Moore, Courtenay and Pickard (1991)					+		The Status of Atlantic Salmon in the Miramichi River During 1990. Electrofishing survey indicated an increase in average densities of juvenile salmon in 1990 campared to 1989.
Parker (1991)	+						An In-Situ Study of Acute Toxicity of the Tomogonops River System to Yearling Atlantic Salmon. Upstream of mine site: not acutely lethal; mine site: acutely lethal; Hwy. 430: acutely lethal; mouth: not acutely lethal; possible toxicity.

respectively. These three stations were sampled in 1994 to delineate the extent of seepage from Stratmat mine (BEAK 1994). HS-25 is a reference station located on Sandburn Brook, a tributary to the South Branch Tomogonops River.

Exposure stations on the North Branch Tomogonops River include BCL-11, BCL-7, BCL-3, BCL-9, BCL-12, HS-26 and BCL-5 (Figure 2.1). Again, many of these stations were established in 1994. Exposure stations on the Little South Branch Tomogonops include HS-1, HS-2, HS-3, BCL-6, BCL-7, HS-7 and BCL-31. HS-1, HS-2 and HS-3 are located on the mine site. Stations BCL-6, BCL-7 and HS-7 are located at or near the same location on the Little South Branch. BCL-32, BCL-2 and BCL-1 are exposure stations located on the Tomogonops River downstream of the confluence of the North Branch with the Little South Branch but upstream of the South Branch. HS-13, HS-14, HS-18, BCL-30 and BCL-15 are located on the South Branch Tomogonops downstream of the tailings pond. HS-13 is where the tailings overflow is sampled and HS-14 and HS-18 refer to the same station or closely related stations. HS-20 is located downstream of the confluence of the North, Little South and South Branches at the mouth of the Tomogonops River.

Reference stations on the Northwest Miramichi River include HS-21 and HS-35 (Figure 2.1). HS-21 is located at Payne's Bridge on Highway 430. HS-35 is a reference station located on the Northwest Miramichi River between HS-21 and the mouth of the Tomogonops River (Figure 2.1).

Exposure stations on the Northwest Miramichi River beginning downstream of the confluence with the Tomogonops River and moving south include HS-22, HS-40, HS-50, HS-24, HS-55, HS-60 and HS-80 (Figure 2.1). HS-40 is located downstream of the influence of the Portage River. HS-24 (not shown in Figure 2.1) is located at Wayerton Bridge. HS-60 (not shown in Figure 2.1) is located upstream of the confluence with the Big Serogie River. HS-80 (not shown in Figure 2.1) is located downstream of the confluence with the Big Serogie River.

Not all of these stations are sampled annually and many stations were established to serve short-term monitoring needs to characterize event specific effects (*i.e.*, 1991 mine water release, 1993/94 discovery of Stratmat seepage). Heath Steele monitors monthly water chemistry at HS-13 (effluent), HS-1, HS-2, HS-3 (Little South Branch), HS-14 (South Branch), HS-20 (Tomogonops mouth), HS-21 (Northwest Miramichi reference) and HS-24 (Northwest Miramichi at Wayerton). As part of Heath Steele's *COA*, benthic invertebrates and water chemistry are monitored bi-annually at HS-3 (Little South Branch), HS-18 (South Branch), HS-20 (Tomogonops mouth), HS-22 (Northwest Miramichi downstream of Tomogonops), HS-24 (Northwest Miramichi at Wayerton), HS-26 (reference site on North Branch Tomogonops until 1994), BCL-4 (reference site on Tomogonops established in 1994) and HS-21 (reference station on Northwest Miramichi).

3.0 METHODS

3.1 Study Area

The objective of the 1996 preliminary survey field program was to determine if significant differences occurred in various chemical and biological parameters between reference and exposure areas. As a result, sampling stations were selected in locations that would maximize the probability of detecting differences if they existed. Historical stations were used when feasible to provide additional data for comparison purposes. Sampling stations were located in areas of uniform habitat type to minimize other sources of variation. This increased the probability of detecting biological and chemical differences that resulted from metal inputs into the aquatic system. Sampling stations in the exposure area were selected over a spatial area which ensured a similar level of contaminant exposure. Various biological and chemical parameters from the exposure and reference areas were compared in a simple statistical test (*i.e*,. Student's t-test) to determine whether there was a significant difference between reference and exposure areas.

The Northwest Miramichi River, upstream and downstream of Payne's Bridge on Highway 430, was chosen as the reference area (Figure 2.1). The Northwest Miramichi River has been used as a reference station historically (HS-21) and is a station sampled routinely by Heath Steele Mines as a component of its regulatory monitoring requirements. Six water chemistry and benthic invertebrate sampling stations were established at this location. Fish were sampled qualitatively at this site as quantitative surveys have been previously conducted (*see* Section 2.0). A quantitative fish study was also conducted at a second reference site on McCormack Brook (BCL-4). This site has been sampled historically since 1994.

The exposure area was located in the Tomogonops River downstream of the confluence of the North, Little South and South Branches of the Tomogonops River and approximately 4.3 km upstream of the confluence of the Tomogonops River with the Northwest Miramichi River (Figure 2.1). This site was chosen because it is affected by both point source (effluent discharge from tailings pond into the South Branch Tomogonops) and non-point source (seepage into the North Branch and Little South Branch Tomogonops) discharges from Heath Steele Mines.

One possible disadvantage in using the Northwest Miramichi River as a reference area for the fish study was the possibility (especially in the case of salmon) of fish migration between this area and the exposure area in the Tomogonops River. Such migration would render meaningless any comparisons between the two populations. We therefore sampled a second reference site (BCL-4) on McCormack Brook for fish tissue sampling (Figure 2.1).

3.2 Effluent Characterization and Sublethal Toxicity

B.A.R. Environmental Inc. in Guelph, Ontario coordinated all sublethal toxicity testing which was conducted on the Heath Steele Mine effluent and receiving water as specified in *Project # 4.1.2a, Extrapolation Study (September 9, 1996)*. Sublethal toxicity tests performed by B.A.R. Environmental Inc. included: *Lemna minor* growth inhibition, *Ceriodaphnia dubia* survival and reproduction, juvenile fathead minnow *(Pimephales promelas)* survival and growth, and salmonid embryo tests. Eco-CNFS Inc. in Pointe Claire, Quebec conducted the *Selenastrum capricornutum* microplate growth inhibition test.

Receiving water samples were collected from the Northwest Miramichi River at historical station HS-21, upstream of the confluence with the Tomogonops River (Figure 2.1). A receiving water sample (40 litres) was collected by mine personnel at this site prior to commencement of the 1996 field program. This sample was necessary to determine if the receiving waters resulted in toxicity to *Ceriodaphnia dubia* or juvenile fathead minnow. If so, these organisms were acclimated to the receiving water before toxicity evaluations. On September 23, 1996, 420 litres (twenty one 20 litre pails) of receiving water were collected and shipped to B.A.R. Environmental Inc. One small bottle (200 ml) of receiving water was collected and shipped to Eco-CNFS.

Effluent samples were collected at the HS-13 at the tailings pond east overflow on September 23, 1996 (Figure 2.1). Seven 20 litre pails (140 litres) were shipped to B.A.R. Environmental Inc. and 200 ml were shipped to Eco-CNFS. All water and effluent samples were shipped via courier (Purolator Courier) and arrived at their respective destinations within 48 hours as required.

Effluent and receiving water samples were collected and analyzed for general chemistry (Total Suspended Solids (TSS), cations and anions, Dissolved Organic Carbon (DOC), Dissolved Inorganic Carbon (DIC), nutrients), dissolved metals and total metals.

3.3 Habitat Characterization, Classification and Sample Station Selection

The objective of the habitat characterization and classification was to describe existing habitats and substrate types in both reference and exposure areas. This information was necessary to select sample stations of uniform habitat type within each area and between areas.

Characterization of habitat and substrate was conducted on September 22, 1996 in the reference area and exposure area. Habitat in the reference area (Northwest Miramichi River) was characterized throughout one continuous reach, commencing approximately 290 m upstream of Payne's Bridge and ending approximately 315 m downstream of the bridge (Figure 2.1). Historical station HS-21 was included in the assessment. Habitat in the exposure area was characterized throughout one continuous reach of the Tomogonops River which was 800 m in length (Figure 2.1).

Habitat in the reference and exposure areas was characterized by visual assessment using the Department of Fisheries and Oceans (DFO) and the New Brunswick Department of Natural Resources and Energy (NBDNRE) *Stream Survey and Habitat Assessment Table* as a guide (DFO and NBDNRE 1994). The habitat surveyed was divided into discrete habitat units based on stream type (fall, run, riffle, pool). For each unit the length, average width, average depth, current velocity, substrate composition (percent bedrock, boulder, rock, rubble, gravel, sand and fines), embeddedness, percent undercut bank, percent over hanging bank vegetation, percent shade, percent stream bank vegetation and percent bank erosion were determined. Current velocity was measured in the middle of the stream and at 1/4 and 3/4 distances in the stream channel. Originally it was intended that a Geneq Inc. Global Flow Probe Model FP101 be used to measure current velocity at 0.6 m water depth. However, as this meter was not accurate under the lowest flow conditions, velocity was calculated as indicated in the habitat assessment table using the float duration of a whiffle ball. Based on the substrate types identified in the habitat characterization, the study area was classified into constituent habitats based on the habitat classification scheme of Cowardin *et al.* (1979) developed for the U.S. Fish and Wildlife Service.

Habitat within the reference and exposure areas was photographed, mapped and GPS (Global Positioning System) positions were recorded at the beginning and end of each habitat assessment, at significant reference points (*i.e.*, bridges, large beaver dams) and at sampling stations. Position data were collected using a Trimble GeoExplorer II™ Global Positioning System. Sample locations were recorded as point entities and reduced to an average geographic coordinate per sample location using base station data and the Trimble PFINDER™ software. This differential correction is a technique that uses an extra receiver, usually a base station, and calculations to increase the accuracy of each position (Trimble 1996). The accuracy of the data is on the order of three meters in the X and Y direction. The corrected sample location data points were adjusted to the appropriate datum and projection using Datumx, NT2v, and GSRUG coordinate conversion software. The converted points were entered onto the reference and base maps using a batch conversion process and were introduced into AutoCad as point features.

Six sampling stations were selected in both the reference and exposure areas. Station selection was based on habitat and substrate uniformity and correspondence of station locations with historical sampling locations. Each station represented a discrete sample point with no statistical replication to maintain a consistent statistical design with that proposed for the 1997 detailed field studies (Dr. Roger Green pers. comm.). The key to locating reference and exposure stations was to maximize the probability of detecting significant differences in water chemistry parameters and benthic invertebrate community structure between the two areas. The distance between sampling stations varied depending upon the habitat characterization as well as upon the size of the receiving environment and the influence of other effluent sources or tributaries.

3.4 Water Samples

Water chemistry samples were collected from the reference stations and exposure stations on September 22 and 23, 1996. One replicate water sample was collected from each of 12 sampling stations. Replication was reduced depending upon the distance between sampling stations. Grab water samples were collected at the surface from reference and exposure stations with bottles prepared by MDS Environmental Services Limited. The bottles used to collect samples, the sample preservatives and sample analyses are summarized in Table 3.1.

Clean sampling techniques were used at all times to minimize sources of contamination. Samples were collected in triplicate rinsed bottles which were then submerged and capped below the surface to avoid any surface contamination and minimize air space. Separate samples were collected for total and dissolved metals. Samples for dissolved metals were field-filtered by syringe through acid-washed cellulose acetate filters (0.45 μm) mounted in Swinex filter holders according to standard methods (APHA 1995 -Section 3030B). Prior to use, each filter and filter holder were washed with nitric acid (approximately 2%) and rinsed with distilled water. Both metals samples were acidified with ultra pure nitric acid (provided by laboratory) to a pH < 2. All samples, except for thiosalts, were cooled and shipped to MDS Environmental Services Limited in Mississauga, Ontario for analysis. Detailed analytical methods are presented in Appendix C. Thiosalt analyses were conducted on-site by Heath Steele Mines.

Field measurements of temperature, conductivity, dissolved oxygen, and pH were also taken at each station sampled using a Hydrolab H20 multiprobe. All field instruments were calibrated prior to use and values were recorded manually in the field.

Field Quality Assurance/Quality Control (QA/QC) protocols included collection and analysis of one transport or trip blank, one filter blank and one field replicate. These QA/QC samples were collected at the exposure station closest to the effluent discharge (HS-E1). The transport blank and filter blank water were provided by the analytical laboratory. Laboratory QA/QC protocols included the use of laboratory replicates to indicate precision, and certified reference materials and spiked samples to indicate analytical accuracy. A Quality Management Plan (QMP) for the 1996 field surveys is attached as Appendix A.

Receiving water chemistry was characterized to determine if there was a statistically significant difference in chemistry between reference and exposure sampling areas. Means and standard errors of parameters were calculated for reference and exposure areas. If the concentration of a particular parameter was below detection limits, this concentration was taken as half the detection limit for mean calculation. Comparison of water quality parameters between reference and exposure sites was completed using independent samples t-tests with SPSS/PC+ version 5.0. Statistical analyses were performed on selected general chemistry, total and dissolved metals parameters. Homogeneity of variances were assessed using Levene's test. When

Table 3.1: Summary of Bottles and Preservatives Used and Analyses Conducted on Water Chemistry Samples Collected at Each Sampling Station

Sample Bottle	Preservative	Analyses
1 - 500 mL HDPE	none	Total Suspended Solids (TSS)
1 - 500 mL HDPE	none	Thiosalts
1 - 500 mL HDPE	none	General Chemistry Cations and Anions *(Alkalinity as $CaCO_3$, Chloride, Sulphate, Anion Sum., Bicarbonate as $CaCO_3$, Carbonate as $CaCO_3$, Cation Sum., Colour, Conductivity, Hardness as $CaCO_3$, Ion Balance, Langelier Index at 20 °C, Langelier Index at 4 °C, pH, Saturation pH at 20 °C, Saturation pH at 4 °C, Total Dissolved Solids, Turbidity)*
1 - 100 mL glass	none	Dissolved Organic Carbon (DOC) Dissolved Inorganic Carbon (DIC)
1 - 250 mL glass	H_2SO_4	Nutrients *(Nitrate, Nitrite, Ammonia, Total Kjeldahl Nitrogen, Phosphorus, Orthophosphate)*
1 - 250 mL HDPE	HNO_3	Total Metals *(Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Chromium, Cobalt, Copper, Calcium, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Reactive Selenium, Silica (SiO_2), Silver, Sodium, Strontium, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc)*
1 - 250 mL HDPE	HNO_3	Dissolved Metals (as for total metals)

variances were equal, the pooled t-test results were used. When variances were unequal separate estimates were used. The two-tailed probability determined significance between means at α =0.05.

3.5 Sediment Samples

Suitable representative depositional areas (greater than 1.0 m^2) for sediment collection were not found in the reference and exposure areas. The Northwest Miramichi and Tomogonops Rivers are erosional with little available unconsolidated fine sediment. As sediments were not collected, detailed notes on each station were made and pictures taken to provide evidence that the substrate was not suitable (Appendix B).

3.6 Benthos Samples

3.6.1 Sample Collection

The benthic invertebrate community at the Heath Steele Mine site was characterized to determine if a statistically significant difference in species composition and abundance existed between reference and exposure areas. One benthic sample was collected at each of the six sampling stations in both the reference and exposure areas. Samples from each station were collected from similar habitat types using a quantitative Surber sampler (0.093 m^2) with a 250 µm mesh net. Large substrate within the sampler area was scrubbed clean with a stiff brush and the substrate was disturbed to a depth of 5 cm. Samples were sieved in the field through 500 µm and 250 µm sieves. Different sieved fractions were obtained so the objectives of the AETE Program could be met and these samples could be compared with historical data sets which had been sampled with a 500 µm mesh. Samples were preserved in 10% buffered formalin and shipped to Zaranko Environmental Assessment Services in Guelph, Ontario for analyses.

Mean and standard errors for total species abundance and richness were calculated for both the reference and exposure areas. Calculations were conducted separately for samples sieved in the field through 500 µm and 250 µm sieve fractions. Means for each area were compared with a students t-test after confirming homogeneity of variances with Levene's test. If assumptions were not met, data were $\log_{10}$ transformed before analysis. The two-tailed probability determined significance between means at α = 0.05.

Relative abundance of selected taxonomic groups was also determined for each area at both sieve sizes. Mean EPT and EPT/C indices (Ephemeroptera (E), Plecoptera (P), Trichoptera (T), Chironomids (C)) were also calculated and for each area and analysed statistically with t-tests as described above (Plafkin, *et al.* 1989)

3.6.2 Sorting and Taxonomy

In the laboratory, invertebrates in benthic samples were counted and identified to genus level. Details of the analytical methods are presented in Appendix D.

General QA/QC protocols for benthic invertebrate analyses included the following:

- all firms submitted benthic samples to Zaranko Environmental Assessment Services in Guelph, Ontario for analyses;
- a reference collection of identified organisms was created and maintained for both the receiving and reference environments;
- taxonomy was verified by an independent expert;
- sorting efficiency was estimated by recounts of the sorted material on 10% of the samples. If subsampling was deemed necessary, an estimate would have been made of the subsampling error;
- all unsorted and sorted fractions of the samples were retained until taxonomy and sorting efficiency are confirmed; and
- all data transcriptions were checked for accuracy.

QA/QC procedures are presented in the Quality Management Plan in Appendix A. The results of the benthic QA/QC program are presented in Appendix D.

3.7 Fisheries

3.7.1 Collection

Fish were collected at one reference area and one exposure area to determine whether a statistically significant difference in composition and abundance existed between these areas. A *License to Fish for Experimental, Scientific or Educational Purposes* was obtained from regional Fisheries and Oceans in New Brunswick (Licence number S-96-051). The reference site was located on the Northwest Miramichi River (HS-21). The exposure site was located on the Tomogonops River below the confluence of the North and South Tomogonops Branches (JW-E1). Qualitative electrofishing surveys were conducted at these sites. Quantitative fisheries studies have been conducted historically on the Northwest Miramichi River at reference Station HS-21 and on the Tomogonops River at exposure Stations HS-7, BCL-6, HS-14/18, BCL-5, BCL-31, BCL-32, BCL-2, BCL-1, BCL-30, BCL-15 and HS-20 (Figure 2.1).

A second reference site was sampled (BCL4 on McCormack Brook) to assess the availability of target sentinel species and to serve as a second control for assessment of effluent exposure. It was necessary to sample a second reference site to reduce the potential for migration of fish between the reference and exposure areas. A quantitative survey was conducted at this site and barrier nets were erected at the same locations downstream of the culvert as for previous historical surveys. Dense cover of alders had been trimmed back to the banks thus the survey area was well defined. Five sweeps of an area (209.6 m^2) were made along the enclosed reach.

All fish populations were assessed using Smith-Root Models 12 and 7 electrofishers which is considered to be the most effective means of capturing fish in shallow rivers. Quantitative methods were used to census the fish populations at the mine sites and qualitative methods were used for additional collections. Fish were collected at a time of day to ensure maximum abundance. All fish, not collected for tissue analysis, were returned unharmed to the river after measurements were obtained.

For both the quantitative and qualitative surveys, the two most abundant species were kept for morphological data recording and further chemical analysis. All fish captured were weighed to the nearest ± 0.01 g using a calibrated digital, electronic scale. Fork length, the length from the tip of the snout to the depth of the fork in the tail, was measured to the nearest ± 0.01 mm. All fish were examined externally for any anomalies and these were recorded on field data sheets. Scale samples were taken from a representative number of fish within obvious age groups. These samples were shipped to Mr. Jon Tost of North Shore Environmental Services in Thunder Bay, Ontario for age determinations.

Statistical analyses on fish measurements involved t-tests for comparison of means between reference and exposure areas. Residual plots on raw and $\log_{10}$ transformed data were examined to assess assumptions of homogeneity of variance. Probability plots were used to assess assumptions of data normality. Estimates of variability in size-at-age (log length vs age) and condition (body weight vs length) were completed by Analysis of Covariance (ANCOVA).

QA/QC protocols for aging of fish structures included all firms submitting samples to North Shore Environmental Services for aging, and verification of 10% of the structures by independent sources. Details of QA/QC protocols are attached in the QMP in Appendix A.

3.7.2 Tissue Processing for Metals and Metallothionein Analyses

At each of the seven mine sites an evaluation was conducted to determine if fish tissue would be collected for metals and metallothionein analyses. The evaluation was based upon the criteria listed in Table 3.2. When applying the selection criteria to a site, Criterion #1 was of primary importance, especially regarding sub-criteria "b" (*i.e.*, mobility) and "f" (*i.e.*, fish abundance). If these two sub-criteria were not met, then fish tissue was not collected. Of particular importance in Criterion #2, is sub-criterion "a". Specifically, if a mine

Table 3.2: Criteria Used for Determination of Site Suitability for Collection of Fish Tissue for Metals and Metallothionein Analyses

Criteria	Assessment
1) Presence of Suitable Sentinel Species	a) Are the fish species present benthic feeding? Benthic feeding fish are preferable as a sentinel species due to their greater exposure to metals. If however, no benthic species are present at a site, then the other feeding guilds (*e.g.*, insectivores) must be considered.
	b) Are the fish present relatively sedentary (*i.e.*, Are fish caught in reference and exposure areas species likely to spend most of their time in these areas?) If the selected sentinel species are not sedentary, then is there a barrier (*e.g.*, waterfall, dam, long distance) that physically isolates the reference population from the exposure area and vice versa?
	c) Is the sampling period (September and October) suitable for the selected species? Specifically, fish that are spawning, and therefore possibly moving in and out of reference and exposure areas may not be appropriate sentinel species for the 1996 field surveys. However, if the 1997 field studies occur during a different time period, these fish may be appropriate sentinel species.
	d) Do the fish species at a site have an intermediate life span? Long lived fish may have acclimated to metal exposure, and thus not be suitable for measuring metals in tissue.
	e) Are the fish present large enough to supply the tissue for metals and metallothionein? The approximate size of fish that would have large enough organs to be split is 15-20 cm. Fish larger than 20 cm are preferred. Fish smaller than 10 cm should be frozen whole.
	f) Are species present abundant enough to collect the number of fish needed (8 fish of 2 species/preferably 4 males and 4 females of each species) within a reasonable time limit?
	g) Are similar sentinel species found at the reference and exposure areas? If there is no possibility of collecting similar species at the two locations, it is not worthwhile to consider the site for sampling fish tissue this year.
2) Quality/Quantity of Historical Data and Logistics	a) Have the data been published in peer-reviewed literature (*i.e.*, scientific journal, government publication, consultant report)? If a site has fish tissue data that show a clear difference in metal levels, then further collection of tissue for metals and metallothionein analysis is not warranted.
	b) Is it feasible to maintain fish frozen at a site for the required amount of time? It is possible to maintain a 100 kg block of dry ice for a week depending on outside temperatures and how often the cooler is opened and closed.

site already had sufficient fish tissue data to provide enough information for planning the sampling element for fish collection for 1997 at the site, then no further destructive sampling occurred.

At the Heath Steele Mine site, juvenile Atlantic salmon and lake chub were selected as the sentinel species. Tissues of both species were collected for metals and metallothionein analyses as these species were abundant in both the reference and exposure areas during the sampling period and historical data on tissue analyses was limited. Although a barrier was not present at the site to physically separate populations in each area, a second reference area (BCL-4) was selected for comparison purposes.

At the reference station on the Northwest Miramichi River and at the exposure station (JW-E1), lake chub and juvenile Atlantic salmon were sampled. At the second reference site on McCormack Brook, lake chub were also sampled. Eight fish of each targeted sentinel species were collected for metals and metallothionein analyses. Collection of fish species from three stations would allow for a three way comparison of metal and metallothionein levels in lake chub (BCL-4 vs JW-E1 vs HS-21) and a two way comparison in juvenile Atlantic salmon (JW-E1 vs HS-35).

Details on sampling and processing methodologies are contained in the revised protocols outlined by Dr. J .F. Klaverkamp (*version August 29, 1996*) (Appendix E). Samples were shipped on dry ice to the Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6.

4.0 RESULTS

4.1 Date of Sample Collection and Analysis

The dates that samples were collected and analysed are presented in Table 4.1.

4.2 Effluent Characterization and Sublethal Toxicity

4.2.1 Chemistry

The results of the chemical analyses of the effluent and of the receiving water from the Northwest Miramichi River are summarized in Tables 4.2 and 4.3. As expected from previous monitoring studies (*see* Section 2), the effluent has high levels of alkali metals including calcium, magnesium, potassium, strontium and sodium (Table 4.2). The corresponding anion is primarily sulphate, and to a lesser extent, chloride (Table 4.3). Given the high concentration of these ions, it is not surprising that the conductivity, total dissolved solids and hardness of the effluent are considerably greater than those parameters in the receiving water from the Northwest Miramichi River (*e.g.* conductivity: 1950 vs. 47 μs/cm; Table 4.1). The pH of both water samples was identical (7.2). The waters from both sources were low in colour, DOC, DIC and suspended solids but elevated in TKN and nitrates. Trace metal concentrations in the effluent were consistently greater than those in the receiving water, although in most cases remain relatively low (Table 4.2). Elevated concentrations of trace metals in the effluent were noted for aluminum, antimony, barium, chromium, iron, lead, manganese, molybdenum, nickel, selenium, thallium and zinc. Total lead was especially elevated (22.5 μg/L) compared to the receiving water sample (0.4 μg/L).

4.2.2 Toxicity

The final results of the sublethal toxicity tests are presented in a separate report by B.A.R. Environmental Inc. which documents the results of the testing for the seven mine sites evaluated in the 1996 field survey. Raw data and statistical analyses for each test can be found in that report. A summary of these results is presented below for the Heath Steele Mine based upon preliminary results submitted by B.A.R. on October 11 and November 7, 1996.

Receiving water was collected from the Northwest Miramichi River (HS-21) and used as dilution and control water in all sublethal toxicity tests. Samples of the receiving water were collected by the mine before the effluent was collected so that the receiving water could be screened for its toxicity to fathead minnow and *Ceriodaphnia dubia*. Ceriodaphnids and fathead minnows were exposed to the full strength sample (100 percent v/v receiving water) and to laboratory water over a seven day period without prior acclimation. Receiving water was judged to be toxic if survival was less than 80 percent (*Ceriodaphnia dubia*, fathead minnow) and/or if mean reproduction was less than 15 young per female (*Ceriodaphnia dubia*). Although

Table 4.1: Date of Sample Collection and Analysis for the Heath Steele Mine Site

<table>
<tr><th colspan="2">Matrix</th><th>Date Collected</th><th>Status</th></tr>
<tr><td colspan="2">Effluent</td><td>September 23</td><td>Toxicity tests results received October 11. Revised results received on November 7. Final report pending.</td></tr>
<tr><td colspan="2">Receiving Water</td><td>September 22 and 23</td><td>Analytical chemistry and QA/QC results received on November 1.</td></tr>
<tr><td colspan="2">Sediment</td><td colspan="2">No sediment sampling was conducted.</td></tr>
<tr><td colspan="2">Benthos</td><td>September 22 and 23</td><td>Results and QA/QC submitted by Zaranko Environmental Assessment Services on November 25.</td></tr>
<tr><td rowspan="2">Fish</td><td>Tissue analysis</td><td rowspan="2">September 21, 22 and 23</td><td>Metallothionein results received November 8. Metal results received December 16.</td></tr>
<tr><td>Aging</td><td>Received from North Shore Environmental Services on November 19</td></tr>
</table>

Table 4.2: Dissolved and Total Metals (mg/L) in the Effluent and in Samples Collected From the Northwest Miramichi River (HS-R3) for Sublethal Toxicity Testing, September 23, 1996, Heath Steele Mine

Metal (mg/L)	LOQ	Effluent (HS-13)		Northwest Miramichi River (HS-R3)	
		Dissolved	Total	Dissolved	Total
Aluminum	0.01	0.49	0.48	nd	nd
Antimony	0.002	0.002	0.003	nd	nd
Arsenic	0.002	0.003	nd	nd	nd
Barium	0.005	0.049	0.050	nd	nd
Beryllium	0.005	nd	nd	nd	nd
Bismuth	0.002	nd	nd	nd	nd
Boron	0.005	nd	0.008	nd	nd
Cadmium	0.0005	nd	nd	nd	nd
Calcium	0.1	290	410	6.0	6.2
Chromium	0.002	0.003	0.003	nd	nd
Cobalt	0.001	nd	0.001	nd	nd
Copper	0.002	nd	nd	nd	nd
Iron	0.02	nd	0.12	0.05	0.07
Lead	0.0001	0.0004	0.0225	0.0002	nd
Magnesium	0.1	1.7	1.9	1.0	1.0
Manganese	0.002	0.069	0.090	0.003	0.005
Molybdenum	0.002	0.024	0.022	nd	nd
Nickel	0.002	0.010	0.011	nd	nd
Potassium	0.5	5.0	2.2	1.4	1.0
Reactive Silica	0.5	1.1	na	8.3	na
Selenium	0.002	0.014	0.009	nd	nd
Silver	0.0003	nd	nd	nd	nd
Sodium	0.1	109	115	1.9	1.9
Strontium	0.005	0.380	0.342	0.017	0.017
Thallium	0.0001	0.0018	0.0016	nd	nd
Tin	0.002	nd	nd	nd	nd
Titanium	0.002	nd	nd	nd	nd
Uranium	0.0001	nd	nd	0.0001	0.0001
Vanadium	0.002	nd	nd	nd	nd
Zinc	0.002	nd	0.019	nd	nd

LOQ = Limit of Quantification
nd = Parameter not detected at LOQ
na = Not available

Table 4.3: Water Chemistry Analyses of Effluent and Samples Collected From the Northwest Miramichi River (HS-R3) for Sublethal Toxicity Testing, September 23, 1996, Heath Steele Mine (all units in mg/L unless otherwise indicated)

Parameter	LOQ	Effluent (HS-13)	HS-R3 (Northwest Miramichi River)
Nitrate	0.05	0.33	0.21
Nitrite	0.01	0.07	nd
Ammonia	0.05	0.16	nd
TKN	0.05	0.59	0.48
Phosphorus	0.1	nd	nd
Orthophosphate	0.01	nd	nd
Alkalinity	1	16	21
Chloride	1	13	nd
Sulphate	2	1050	3
Bicarbonate	1	16	21
Carbonate	1	nd	nd
Colour (TCU)	5	nd	22
Conductivity (μS/cm)	1	1950	47
Hardness	0.1	731	19.1
Turbidity	0.1	0.5	0.1
Anion Sum (meq/L)	na	22.6	0.519
Cation Sum (meq/L)	na	19.5	0.499
Ion Balance	0.01	7.31	2.05
pH (units)	0.1	7.2	7.2
DIC	0.5	2.2	4.0
DOC	0.5	1.9	2.6
TDS	1	1480	36
TSS	5	nd	nd
Thiosalts	na	44.8 [1]	nd

[1] Thiosalts in the effluent measured 1097.6 mg/L. A sample collected on the same day by Heath Steele Mines, measured 44.8 mg/L. As Heath Steele has not had a measurement exceeding 110 mg/L in 1995 and 1996 (*see* Table 4.1), the 1996 survey result would appear to be an anomaly.

LOQ = Limit of Quantification
nd = Parameter not detected at LOQ
na = Not applicable/available
TKN = Total Kjeldahl Nitrogen
DIC = Dissolved Inorganic Carbon
DOC = Dissolved Organic Carbon
TDS = Total Dissolved Solids
TSS = Total Suspended Solids

survival (90 percent) and reproduction (16.1 young per female) of *Ceriodaphnia dubia* were decreased in the Heath Steele receiving water compared to laboratory control water exposures, the receiving water was not considered toxic. Only fathead minnow and *Ceriodaphnia dubia* were selected for the screening tests as these test methods allow an acclimation period before definitive effluent tests are conducted. These screening tests should be conducted for future testing programs to ensure the receiving (dilution) water is not toxic.

Results of the *C. dubia* test conducted on September 25, 1996 indicated a 25 percent inhibition of reproduction (IC25) at 19.0 percent effluent and a 50 percent inhibition of reproduction (IC50) at 25.0 percent effluent (Table 4.4).

The fathead minnow (*Pimephales promelas*) survival and growth inhibition test was also conducted on September 25, 1996 and indicated a 25 percent inhibition of survival at 23.0 percent effluent (Table 4.4). Complete mortality occurred in all test chambers at higher effluent concentrations (> 50 percent). As a result, growth end-points could not be effectively determined.

The results of freshwater alga *Selenastrum capricornatum* growth inhibition test conducted on September 26, 1996 indicated incremental toxicity with increasing effluent concentration (IC25 at 23.3 % v/v; IC50 at 42.1 % v/v) (Table 4.4).

For most of the sublethal tests on the duckweed, *Lemna minor*, the plants in the control exposures did not produce enough fronds to satisfy validity criteria established by the Saskatchewan Research Council . The plants begin the assay with three leaves per replicate and there must be an average of thirty by the end of the test (seven days). None of the controls produced this ten fold increase (Robert Roy, B.A.R., pers. comm.). Despite this, the data was considered acceptable since leaf production did increase eight-fold and growth in the controls was fairly consistent. The Heath Steele effluent, which was tested on September 25, 1996, was toxic to *Lemna minor* growth (Table 4.4).

The rainbow trout (*Oncorhynchus mykiss*) embryo tests conducted on September 25, 1996 indicated reduced embryo viability (EC50) at 77.6 percent effluent (Table 4.4). The test performed on the Heath Steele effluent was one of the few which was a valid test compared to results from the other six mine sites evaluated in the 1996 field surveys. In most cases, the test results were invalid due to poor quality of the eggs and/or milt used. For the Heath Steele test, egg viability was estimated to be "good".

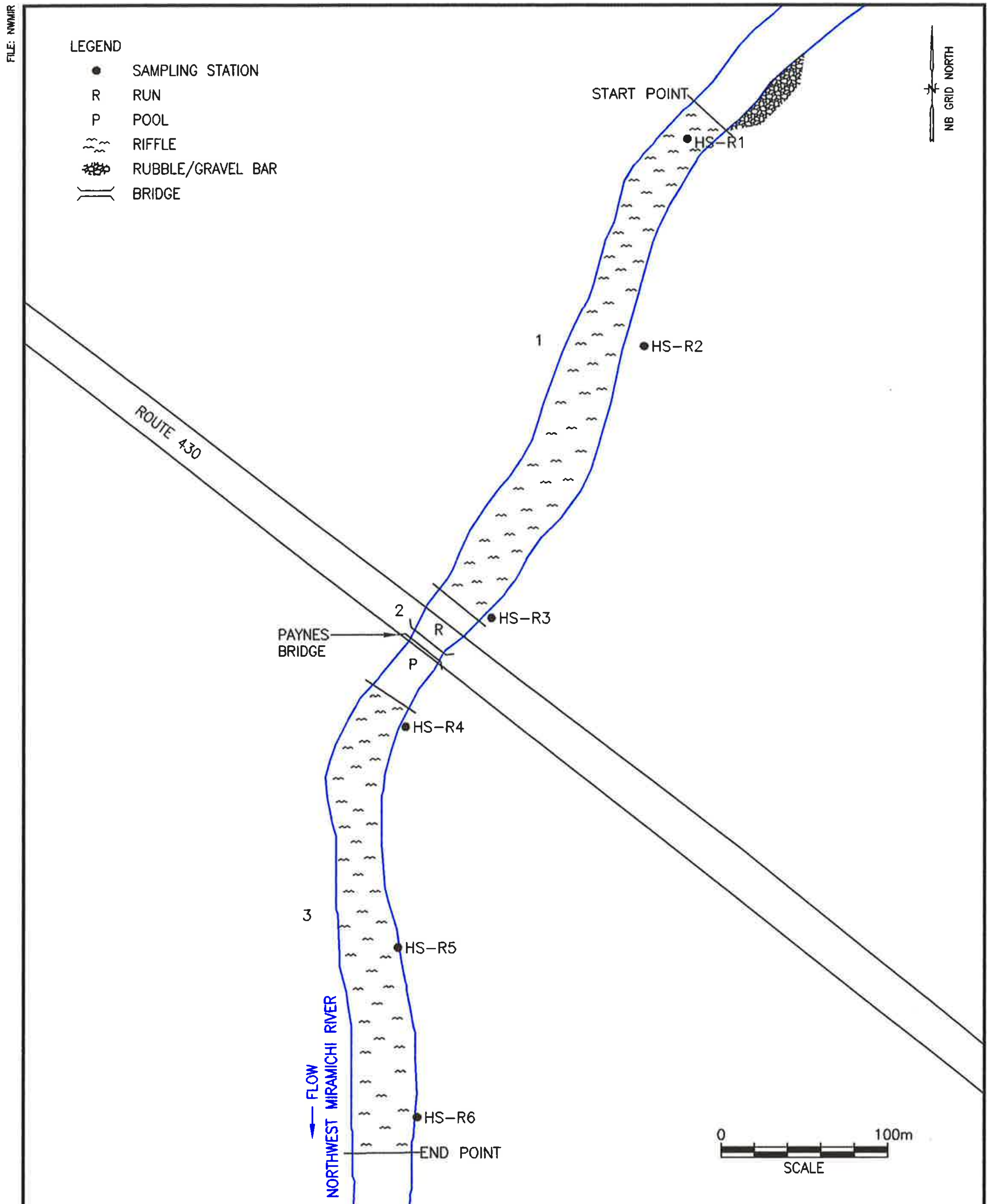
4.3 Habitat Characterization and Classification

A habitat assessment of the reference area was conducted on September 22, 1996 commencing 290 m upstream of Payne's Bridge (Highway 430) and ending 315 m downstream of the bridge (Figure 4.1). The reference area was divided into three habitat units. These are described in detail in Appendix A of the *Draft*

Table 4.4: Summary of Results of Bioassays Conducted with Heath Steele Mine Effluent. Toxicity Test Results are Expressed as % v/v of Effluent

Ceriodaphnia dubia		Fathead minnow			*Selenastrum capricornatum*		*Lemna minor*		Embryo trout
IC25 (95% CI)	IC50 (95% CI)	Survival	Growth		IC25 (95% CI)	IC50 (95% CI)	IC25 (95% CI)	IC50 (95% CI)	EC50 (95% CI)
		IC25 (95% CI)	IC25 (95% CI)	IC50 (95% CI)					
19.0 (16.6 - 21.7)	25.0 (21.7 - 33.0)	23.0 (12.4 - 96.1)	>50[a]	>50[a]	23.3 (10.9 - 35.7)	42.1 (29.7 - 54.4)	47.3 (37.8 - 55.5)	76.5 (68.1 - 83.1)	77.6 (68.6 - 87.7)

[a] complete mortality at higher effluent concentrations



NORTHWEST MIRAMICHI RIVER HABITAT ASSESSMENT REFERENCE AREA, SEPTEMBER 22, 1996 HEATH STEELE MINES	DATE: 96 12 20	SCALE: 1 : 3000	Jacques Whitford Environment Limited
	JOB No. 8128	FIGURE No. 4.1	

Preliminary Survey Report dated October 25, 1996 and are summarized in Section 4.3.1 below. Selected site photographs are provided in Appendix B.

A habitat assessment of the exposure area was conducted on September 22, 1996. A full assessment of the area was conducted commencing 417 m upstream of the access road and ending 163 m downstream of the access road (Figure 4.2). The exposure area was divided into eight habitat units as described in detail in Appendix A of the *Draft Preliminary Survey Report* dated October 25, 1996 and are summarized in Section 4.3.2 below. Selected site photographs are provided in Appendix B.

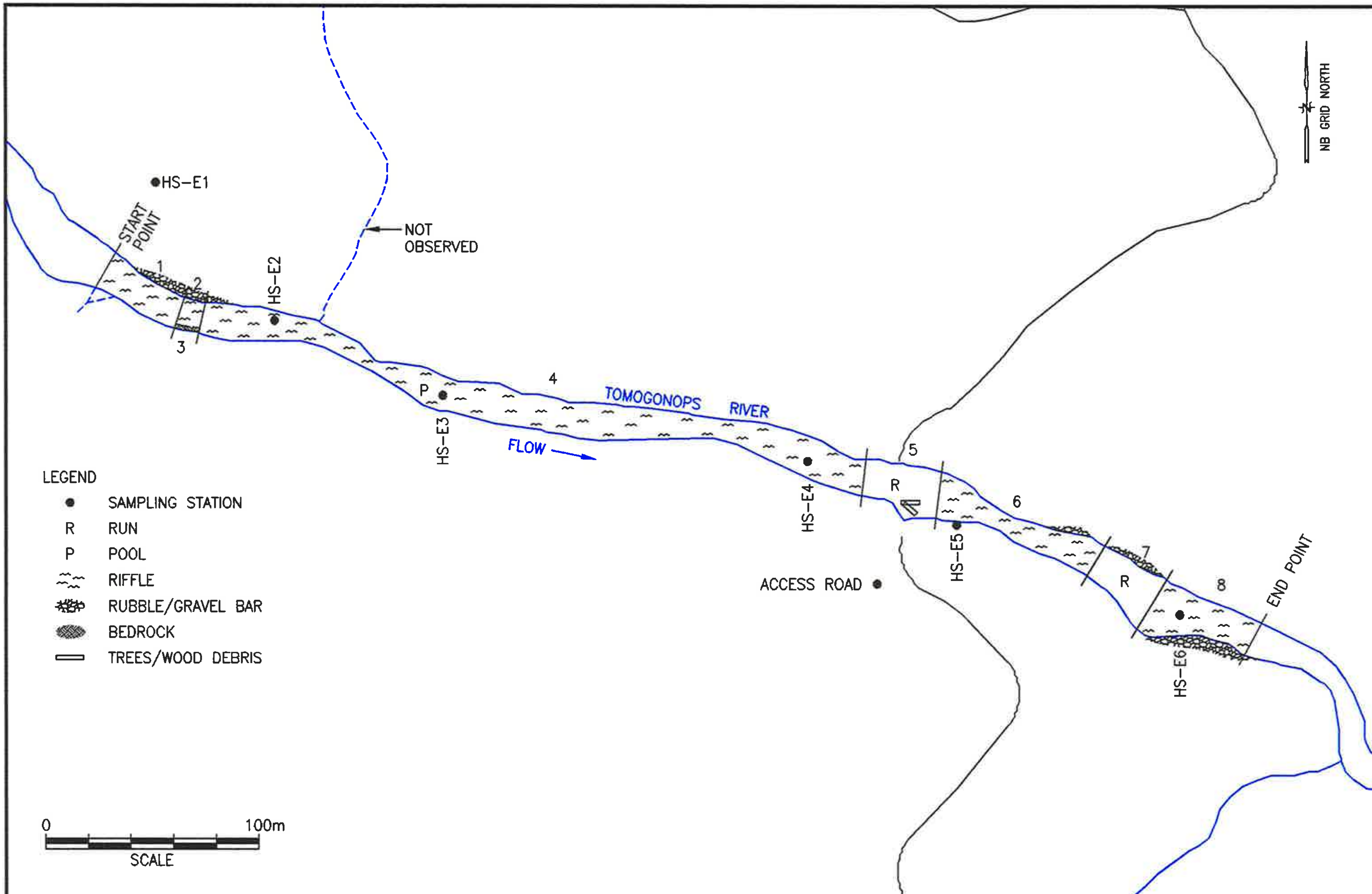
4.3.1 Reference Area - Northwest Miramichi River

The area of the Northwest Miramichi River that was surveyed (605 m) consisted of 0.4 percent pool habitat, 12 percent run habitat, and 87.6 percent riffle habitat (Figure 4.1). The overall substrate was composed of 4 percent boulder, 23 percent rock, 42 percent rubble, 24 percent gravel, 6 percent sand, and 1 percent fine material. Of this, 27 percent was rock or larger, and 73 percent was smaller than rock. Small eddy pools were associated with boulders located in the stream. Gravel and some fine material ($<1.0\ m^2$) occurred along the margins of the river and in small patches behind large rocks and boulders. Less than 30 percent of the substrate was covered by persistent emergents, trees, shrubs, or emergent mosses. The area was not under tidal influence and was a freshwater river. In accordance with Cowardin *et al.* (1979), the surveyed section of the Northwest Miramichi River is a riverine system, in the upper perennial subsystem. The substrate had less than 30 percent vegetative cover, and at least 25 percent of the substrate was smaller than rock placing the area in the class unconsolidated bottom, and subclass cobble (rubble).

4.3.2 Exposure Area - Tomogonops River

The 580 m section of the Tomogonops River surveyed consisted of 2 percent pool habitat, 12 percent run habitat, and 86 percent riffle habitat (Figure 4.2). Small eddy pools were associated with boulders located in the stream. The overall substrate was composed of 1 percent bedrock, 9 percent boulder, 28 percent rock, 36 percent rubble, 16 percent gravel, 5 percent sand, and 5 percent fine material. This means that 38 percent of the substrate was rock or larger, and that 62 percent of the substrate consisted of particles smaller than rocks. Gravel and some fine material ($<1.0\ m^2$) occurred along the margins of the river and in small clumps behind large rocks and boulders. Less than 30 percent of the substrate was covered by persistent emergents, trees, shrubs, or emergent mosses. The area was not under tidal influence and was a freshwater river. In accordance with Cowardin *et al.* (1979), the surveyed section of the Tomogonops River is a riverine system, in the upper perennial subsystem. The substrate had less than 30 percent vegetative cover, and at least 25 percent of the substrate was smaller than rock placing the area in the class unconsolidated bottom, and subclass cobble (rubble).

FILE: TOMOGONO



TOMOGONOPS RIVER HABITAT ASSESSMENT EXPOSURE AREA, SEPTEMBER 22, 1996 HEATH STEELE MINES	Date: 96 12 20	Scale: 1 : 2000
	Job No.: 8128	Fig. No.: 4.2

Jacques Whitford Environment Limited

4.3.3 Summary

Overall, habitat in the reference and exposure areas was similar with respect to proportion of pools, runs and riffles. Suitable areas of uniform habitat type and substrate existed for selection of multiple reference and exposure sampling stations.

No major point or non-point source discharges, other than that related to the Heath Steele Mine, were present in the reference or exposure areas.

4.4 Sample Station Selection

Six sampling stations were selected in both the reference (HS - R1, R2, R3, R4, R5 and R6) and exposure (HS-R1, R2, R3, R4, R5 and R6) areas as indicated in Figure 2.1. Sample station HS-R3 in the Northwest Miramichi River corresponded with historical sampling station HS-21. The exposure stations were located in an area which had not been sampled historically. This area was chosen as it is exposed to the combined effects of acidic seepage which discharge into the North and Little South Branches of the Tomogonops River and the effects of the tailings effluent which is discharged into the South Branch Tomogonops River. Historical exposure sampling stations exist upstream of this site and on each of the respective Branches, and have been sampled extensively. A historical station (HS-20), which receives the combined effects of the three Branches is located downstream of this station was not considered suitable for the 1996 surveys as improvements in water chemistry and benthic community structure have been documented in the last few years. Sampling stations for water chemistry and benthos were selected in uniform habitat types based upon study design recommendations provided by Dr. Roger Green (pers. comm.).

The map and GPS units for each sampling station and corresponding habitat unit are presented in Table 4.5 below.

4.5 Water

4.5.1 QA/QC

The results from the field quality control samples are presented in Appendix C. The field replicate and the field blank suggest that contamination in the field was not significant and that sample heterogeneity is insignificant and/or precision is adequate. A slightly elevated value of TKN in the field blank is probably the result of contamination by ammonia from the air. DOC was also slightly elevated in the blank. The results of the filter blank showed no contamination due to filtering for all dissolved metals with the exception of potassium. Potassium concentration in the filter blank was 0.6 mg/L. The laboratory replicate on one of the

Table 4.5: Location of Reference and Exposure Stations, Heath Steele Mine

Station		MAP UNITS		GPS UNITS		Corresponding Habitat Unit
		NB Stereographic (ATS77)		Geographic (WGS84)		
		Northing	Easting	Latitude	Longitude	
Reference Area Figure 4.1	HS-R1	876249	345895	47° 11' 03.8"	65° 53' 39.8"	Unit 1
	HS-R2	876350	345883	47° 11' 07.0"	65° 53' 40.4"	Unit 1
	HS-R3	876480	345888	47° 11' 11.3"	65° 53' 40.1"	Unit 1
	HS-R4	876545	345939	47° 11' 13.3"	65° 53' 37.6"	Unit 3
	HS-R5	876705	346030	47° 11' 18.5"	65° 53' 33.2"	Unit 3
	HS-R6	876828	346056	47° 11' 22.5"	65° 53' 32.0"	Unit 3
Exposure Area Figure 4.2	HS-E1	883096	345928	47° 14' 45.5"	65° 53' 35.8"	Unit 4
	HS-E2	883031	345983	47° 14' 43.4"	65° 53' 33.1"	Unit 4
	HS-E3	882996	346062	47° 14' 42.2"	65° 53' 29.4"	Unit 4
	HS-E4	882964	346233	47° 14' 41.2"	65° 53' 21.3"	Unit 4
	HS-E5	882934	346303	47° 14' 40.2"	65° 53' 18.0"	Unit 6
	HS-E6	882892	346408	47° 14' 38.8"	65° 53' 13.0"	Unit 8

samples from the exposure area (HS-R1; Appendix C) suggests that analytical precision has been maintained in the laboratory.

4.5.2 Chemistry

Results of the water chemistry analyses on samples from the exposure (Tomogonops River) and reference (Northwest Miramichi River) areas are summarized in Tables 4.6-4.9. Detailed results from each station are presented in Appendix C. Sample stations selected within the reference and exposure areas were approximately 100 m apart. As a result, it was not necessary to collect water chemistry samples at each of the six stations within each area. In the reference area samples were collected at four stations (HS-R1, HS-R2, HS-R3, and HS-R6). In the exposure area samples were collected at three stations (HS-E1, HS-E3, and HS-E6).

Table 4.6 summarizes the physio-chemical measurements collected at each station in the field with the Hydrolab. Mean conductivity in the exposure area (420.3 μS/cm) was 10 fold higher than in the reference area (43.8 μS/cm). The conductivity in the effluent measured at HS-13 was 1950 μS/cm (Table 4.2, Section 4.2.1). Differences in conductivity were statistically significant ($p<0.001$). Flows also significantly differed between the reference and exposure areas with higher flows recorded in the Northwest Miramichi River. There were also slight, but significant differences, in temperature and dissolved oxygen between the two areas (Table 4.6).

A students t-test was used to compare selected chemical parameters between the reference and exposure areas (Tables 4.7-4.9). Tests revealed that the water samples from the exposure area were significantly greater in concentrations of anions (chloride and sulphate), conductivity, hardness, DOC and TDS (Table 4.7). There was a significant difference in DIC between areas although concentrations were greater in the reference area than the exposure area.

Dissolved (Table 4.8) and total (Table 4.9) barium, calcium, lead, magnesium, manganese, sodium, strontium and zinc were significantly higher in the exposure area compared to the reference area. Dissolved copper and aluminum were also significantly higher in the exposure area. Total copper was not significantly different between areas due to a high concentration measured at HS-R6 (0.012 mg/L; Appendix C). This measurement is most probably an anomaly considering all other samples for total copper were below detection limits. Dissolved and total iron were significantly different between areas although concentrations were greater in the reference area compared to the exposure area.

Assuming that sodium is a conservative element, when the mean sodium concentration in the exposure area (Table 4.8) was compared to sodium concentrations in the effluent (Table 4.2, Section 4.2.1), the effluent concentration was approximately 15% in the exposure area.

Table 4.6 Summary of Field Data ($\bar{x} \pm 1$ SE) at Reference and Exposure Stations, Heath Steele Mine

Parameter	Reference			Exposure			t[1]	p[2]
	$\bar{x}$	SE	n	$\bar{x}$	SE	n		
pH (units)	6.92	0.035	4	6.93	0.018	3	-0.21	0.845
conductivity (μS/cm)	43.75	4.987	4	420.30	0.882	3	-18.55**	<0.001*
temperature (°C)	10.43	0.568	4	10.90	0.082	3	-3.21	0.024*
dissolved oxygen (mg/L)	10.50	0.042	4	10.08	0.047	3	7.65	0.001*
depth (cm)	22.00	0.645	6	21.00	2.00	6	1.84	0.11
flow (m^3/s)	3.79	0.338	6	1.35	0.231	6	6.63	<0.001*

* Statistically significant difference between reference and exposure stations ($p<0.05$)
[1] Students t-statistic
** Denotes data were $\log_{10}$ transformed
[2] Probability value

Table 4.7 Summary of General Chemistry Data ($\bar{x} \pm 1$ SE) at Reference and Exposure Stations, Heath Steele Mine

Parameter	Reference			Exposure		n	t[1]	p[2]
	$\bar{x}$	SE	n	$\bar{x}$	SE			
Nitrate (mg/L)	0.08	0.045	4	0.083	0.01	3	-0.11	0.917
TKN (mg/L)	0.447	0.014	4	2.003	1.498	3	-1.17**	0.363
Chloride (mg/L)	nd	na	4	4	0.000	3	na	na
Sulphate (mg/L)	3	0.000	4	178.667	1.202	3	-609.05**	<0.001*
Conductivity (μS/cm)	47.33	0.629	4	427.333	1.667	3	-240.45	<0.001*
Hardness (mg/L)	19.08	0.085	4	189	1.00	3	-332.91	<0.001*
pH (units)	7.27	0.05	4	7.37	0.03	3	-1.78	0.134
DIC (mg/L)	3.867	0.111	4	3.467	0.033	3	3.42	0.019*
DOC (mg/L)	2.833	0.108	4	3.433	0.088	3	-4.29	0.008*
TDS (mg/L)	34.75	0.478	4	290.667	1.667	3	-125.69**	<0.001*

* Statistically significant difference between reference and exposure stations ($p<0.05$)
[1] Students t-statistic
** Denotes data were $\log_{10}$ transformed
[2] Probability value

Table 4.8 Summary of Dissolved Metals Data ($\bar{x} \pm 1$ SE) at Reference and Exposure Stations, Heath Steele Mine

Metal (mg/L)	Reference			Exposure		n	t[1]	p[2]
	$\bar{x}$	SE	n	$\bar{x}$	SE			
Aluminum	nd	na	4	0.02	0.000	3	na	na*
Barium	nd	na	4	0.012	0.000	3	na	na*
Calcium	6.0	0.025	4	72.2	0.351	3	-390.77**	<0.001*
Copper	0.002	0.001	4	0.004	0.000	3	-4.23	0.008*
Iron	0.05	0.000	4	0.03	0.000	3	-	-*
Lead	0.0002	0.000	4	0.0004	0.000	3	-2.86	0.035*
Magnesium	1.0	0.000	4	2.03	0.033	3	-37.05	0.001*
Manganese	0.003	0.000	4	0.164	0.002	3	-45.94**	<0.001*
Potassium	0.725	0.286	4	1.333	0.167	3	-1.66	0.157
Sodium	1.9	0.025	4	15.3	0.100	3	-128.60	<0.001*
Strontium	0.017	0.000	4	0.078	0.000	3	-353.21**	<0.001*
Zinc	nd	na	4	0.053	0.001	3	na	na*

* Statistically significant difference between reference and exposure stations ($p<0.05$)
[1] Students t-statistic
** Denotes data were $\log_{10}$ transformed
[2] Probability value

Table 4.9 Summary of Total Metals Data ($\bar{x} \pm 1$ SE) for Reference and Exposure Stations, Heath Steele Mine

Metal (mg/L)	Reference			Exposure			t[1]	p[2]
	$\bar{x}$	SE	n	$\bar{x}$	SE	n		
Aluminum	0.01	0.000	4	0.02	0.000	3	2.54	0.052
Barium	nd	na	4	0.012	0.000	3	na	na*
Calcium	6.4	0.175	4	75.6	2.534	3	-58.01**	<0.001*
Copper	0.004	0.003	4	0.005	0.000	3	0.33	0.717
Iron	0.07	0.004	4	0.047	0.003	3	-4.18	0.008*
Lead	nd	na	4	0.0005	0.000	3	na	na*
Magnesium	1.0	0.000	4	2.2	0.100	3	-16.88**	0.003*
Manganese	0.006	0.001	4	0.156	0.002	3	88.13	<0.001*
Potassium	0.812	0.249	4	1.7	0.451	3	1.86	0.123
Sodium	2.0	0.050	4	15.7	0.584	3	-47.94	0.002*
Strontium	0.017	0.000	4	0.074	0.000	3	140.41	<0.001*
Zinc	0.003	0.001	4	0.057	0.003	3	19.24	<0.001*

* Statistically significant difference between reference and exposure stations ($p<0.05$)
[1] Students t-statistic
** Denotes data were $\log_{10}$ transformed
[2] Probability value

4.6 Sediment

Sediments were not collected at the Heath Steele Mine site in either the reference or exposure areas. This is because the Northwest Miramichi and Tomogonops Rivers are erosional with little to no fine unconsolidated sediments. In the reference area the substrate consisted of only one percent fine material (Section 4.3.1). The substrate in the exposure area consisted of five percent fine material (Section 4.3.2). Photographs in Appendix B illustrate substrate commonly found during the habitat surveys. Substrate in all areas was dominated by material larger than gravel.

4.7 Benthic

4.7.1 QA/QC

The results of the benthic QA/QC are presented in Appendix D. QA/QC included calculation of subsampling error and percent recovery (sorting efficiency) of benthic invertebrates from samples. Coefficients of variation were calculated to determine subsampling error. For both samples tested, coefficients were less than 4 percent. Sorting efficiency was greater than 98 percent.

4.7.2 Community Structure

Tables in Appendix D present the abundance of each taxon identified in the benthic samples at the two mesh sizes (500 μm and 250 μm, respectively). Abundance is expressed per area of an individual Surber sample representing 0.09 m^2. Table 4.10 summarizes the mean abundance and richness (number of taxa) at the reference and exposure areas. The reference area had a significantly greater abundance of benthic organisms (1457 vs. 647 in the 250 μm sieve) and richness or number of taxa (55.0 vs. 43.7 in the 250 μm sieve). Figures 4.3 and 4.4 indicate graphically the relationship between abundance and richness for both mesh sizes and sampling areas. At both sieve sizes, samples from the reference area and the exposure area fall into distinctly different sample assemblages.

Differences in the relative distribution of taxa between the reference and exposure areas indicated that the exposure areas had been affected by mine effluent, although the impacts observed were somewhat unexpected. Table 4.11 compares the relative abundance of important taxa (Ephemeroptera, Plecoptera, Trichoptera, Chironomids) and the indices EPT and EPT/C in the reference and exposure areas. Between 86 percent and 91 percent of all the organisms in the samples fall into these four taxonomic groups. At the smaller mesh size (250μm), the mean EPT index (Plafkin *et al.* 1989), summarizing the taxa richness within the insect groups that are considered pollution sensitive (Ephemeroptera, Plecoptera, Trichoptera), was higher in the reference area (27.0 vs. 22.2) but the difference was not statistically significant. The relative numbers of Ephemeroptera and Trichoptera were not significantly different between the two areas although the proportion of Ephemeroptera decreased in the exposure area and many taxa, including the pollution

Table 4.10 Abundance and Richness of Benthic Communities at Heath Steele in the Reference and Exposure Areas at Two Sieve Sizes

Parameter	Reference ($\bar{x}$ ± SE)	Exposure ($\bar{x}$ ±SE)	t[1]	p[2]
Abundance (500 μm)	669 ± 72	251 ± 30	5.38	0.000*
Richness (500 μm)	42.2 ± 2.8	26.0 ± 2.3	4.46	0.001*
Abundance (250 μm)	1457 ± 214	647 ± 53	3.67	0.004*
Richness (250 μm)	55.0 ± 3.0	43.7 ± 2.8	2.79	0.019*

* Statistically significant difference between the reference and exposure stations ($p< 0.05$).
[1] Students t-statistic
[2] Probability value

Table 4.11 Relative Abundance of Selected Taxonomic Groups, EPT and EPT/C at Heath Steele Mine in the Reference and Exposure Areas at Two Sieve Sizes

Parameter	Reference ($\bar{x} \pm$ SE)	Exposure ($\bar{x} \pm$SE)	t[1]	p[2]
Sieve Size: 500 μm				
% Ephemeroptera	44.6 ± 3.2	38.1 ± 3.8	1.3	0.224
% Plecoptera	8.2 ± 1.1	21.2 ± 1.7	-6.5	0.000*
%Trichoptera	27.6 ± 3.0	27.8 ± 3.1	-0.4	0.969
%Chironomids	10.3 ± 2.0	2.3 ± 0.8	3.72	0.004*
EPT	25.2 ± 1.9	17.7± 1.5.	3.04	0.012*
EPT/C	9.8 ± 2.4	59.6 ± 27.1	-3.36**	0.008*
Sieve Size 250 μm				
% Ephemeroptera	44.1 ± 4.7	40.5 ± 4.0	0.59	0.566
% Plecoptera	6.9 ± 1.1	16.7 ± 1.3	-5.92	0.000*
%Trichoptera	14.9 ± 1.7	14.0 ± 1.8	0.36	0.726
%Chironomids	20.0 ± 4.3	16.2 ± 2.6	0.75	0.471
EPT	27.0 ± 2.0	22.2 ± 1.8	1.82	0.098
EPT/C	4.62 ± 1.58	5.37 ± 1.29	-0.37	0.721

* Statistically significant difference between the exposed and reference stations ($p < 0.05$).

[1] Students t-statistic

** Students t calculated on log transformed data

[2] Probability value

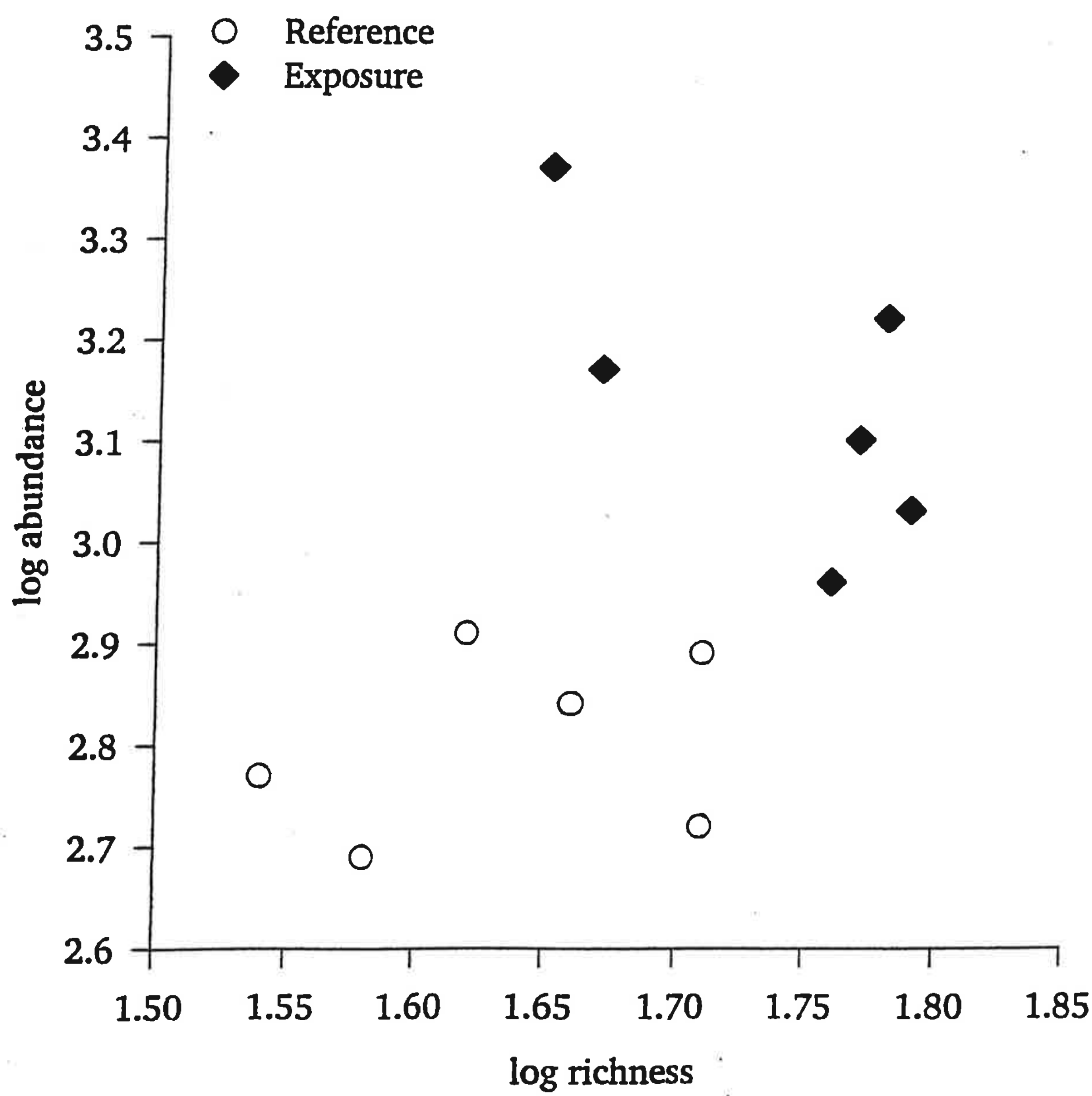


Figure 4.3: Bivariate Plot of Abundance vs Richness (250 μm sieve)

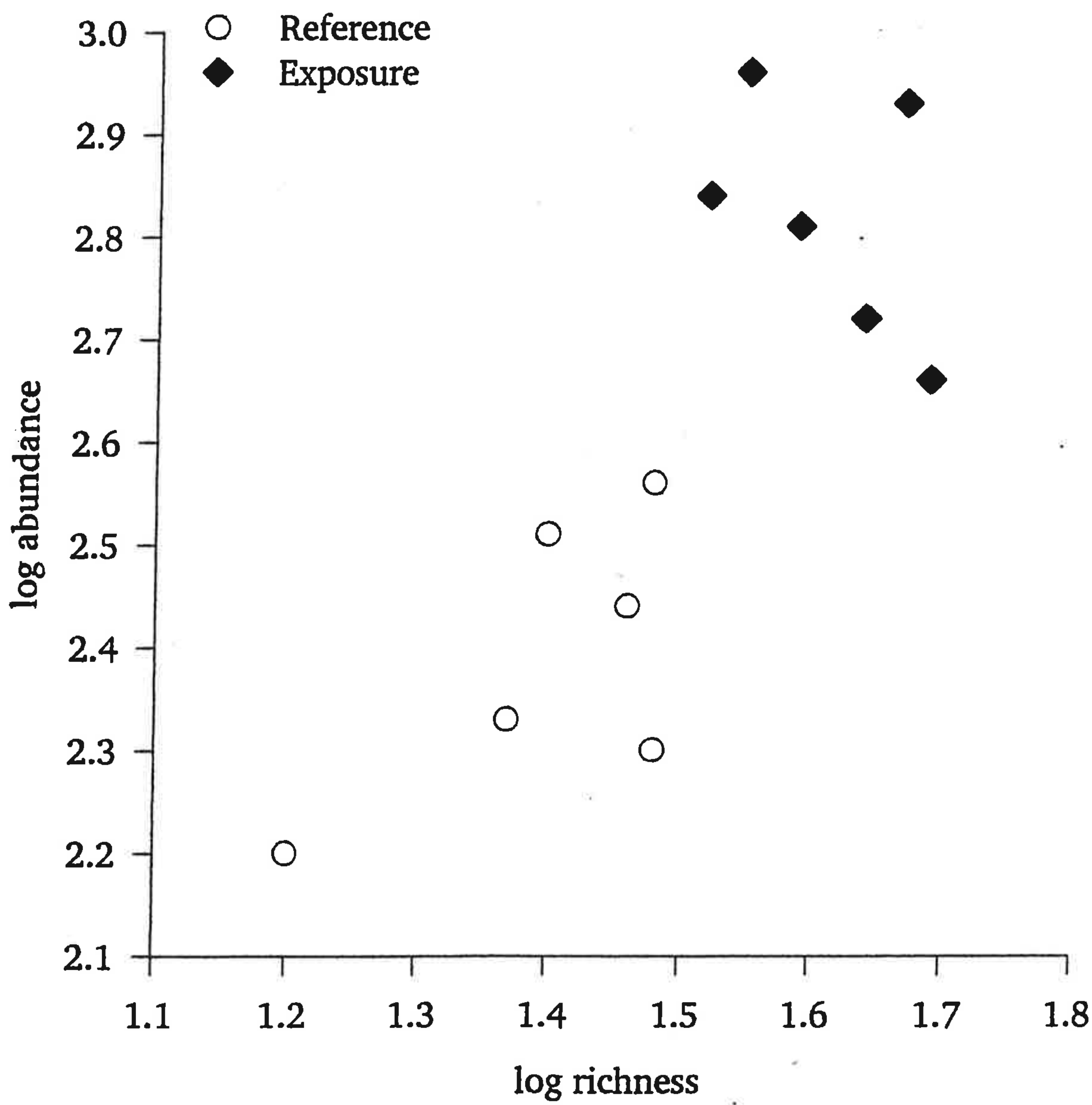


Figure 4.4: Bivariate Plot of Abundance vs Richness (500 μm sieve)

intolerant Ephemerellidae and Heptageniidae (*e.g.* Ephemerella, Heptagenia), were poorly represented there. Plecopterans were significantly greater in relative number in the exposed areas (16.7% vs. 6.9%). Surprisingly, Chironomids in the reference area included a large number of small, relatively pollution-intolerant Chironominae such as *Rheotanytarsis* and *Micropspectra*. The decrease in proportion of chironomids and increase in Plecoptera in the exposure samples resulted in an unexpected increase in the ratio of EPT/C in the exposure area.

At the larger mesh size (500 μm), all the trends seen at 250 μm were apparent but a larger number of these were statistically significant (Table 4.11). In addition to a significantly greater proportion of Plecoptera in the exposure area, there was also a significant decrease in the proportion of Chironomids and EPT and a significant increase in the ratio EPT/C.

Sieve size had a substantial effect on abundance and species richness in both the exposure and reference areas. Within the reference area, for example, the 250 μm sieve caught 2.2 times the number of organisms and 1.3 times the mean number of distinct taxa compared to the 500 μm sieve (Table 4.10). Sieve size also had a substantial effect on the species distribution in the two areas and on the statistical differences between the population parameters (Table 4.11). A much larger number of the smaller chironomid taxa present were caught on the finer screen. This resulted in much larger proportion of chironomids in the 250 μm sieve (16.2% vs. 2.3% in the exposure area) and a substantial reduction in the EPT/C ratio (5.37 vs. 59.6).

Despite these differences, both mesh sizes detected significant differences in abundance and richness between the exposure and reference areas and the same trends in population structure were observed, even if fewer of the population parameters were statistically significant at 250 μm. Similar findings were observed in the previous AETE study (BEAK 1996c), in which mesh size was compared in its ability to detect mine related effects. This study also found that the smaller mesh sizes caught a larger number of organisms and number of taxa. The ability to detect a difference between the exposure and reference areas was best at the smallest mesh size (200 μm) but significant power to detect these differences was still evident at larger mesh sizes especially when effects were severe.

4.8 Fisheries

4.8.1 Communities

Qualitative electrofishing surveys were conducted at both the reference and exposure stations. Four fish species were found at the exposure station (JW-E1) in the Tomogonops River and included Atlantic salmon, lake chub, white sucker and slimy sculpin. Salmon and lake chub were the most abundant species. Spotcheck electrofishing at the reference station on the Northwest Miramichi River (HS-21) produced Atlantic salmon, lake chub and white sucker. Salmon and lake chub were the most abundant species at this station. Summary data on the size and weight of fish captured by electrofishing are presented in Table 4.12. Electrofishing field records are presented in Appendix E.

At the reference station (HS-21), 11 juvenile Atlantic salmon were captured compared to 13 in the exposure area (Table 4.12). These relative abundances indicated that densities of salmon were similar in both areas. However, only qualitative surveys were conducted. More detailed quantitative surveys are required before differences in densities between areas can be determined. Of the 11 salmon caught from the reference station, only three were between 100 and 150 mm, and no fish greater than 150 mm were observed. Salmon from the exposure station were all less than 100 mm in fork length. Statistical t-tests on salmon length and weight data showed a significant difference at α=0.05 between the exposure and reference stations.

A greater number of lake chub were captured at the exposure station compared to the reference station, due to lower water velocities which facilitated the qualitative electrofishing survey. Mean values for lake chub length and weights are shown in Table 4.12. Fork lengths of captured fish were all under 100 mm with the exception of one specimen from the exposure station. The average length of an adult lake chub is 102 mm (Scott and Crossman 1973). Colouration of the fish and their smaller size indicated that the populations sampled during the field survey consisted predominantly of juveniles. Although significant differences in lengths and weights of lake chub occurred between the reference and exposure areas, differences were not highly significant.

Frequency histograms of salmon fork length are presented in Figure 4.5. Fish from the reference area had a peak in fork length at 85 mm. Two peaks in frequency appeared for fish from the exposure station at lengths of 61.5 mm and 64.5 mm. Histograms of weight showed dual peaks indicating two age classes of fish at both the reference and exposure areas.

Histograms of lake chub fork length showed a single peak at 57.5 mm for the Northwest Miramichi River reference station and two peaks at the exposure station on the Tomogonops River (Figure 4.6). The second peak at this station represented a young-of-the-year (Y-O-Y) age class which was not observed at the reference station. Histograms of weights showed a similar pattern with a peak at 2.5 g. The exposure station had two peaks, one representing Y-O-Y lake chub (Figure 4.7).

Data on catch per unit effort (CPUE) on salmon and lake chub at both study areas are presented in Table 4.13. CPUE was similar between the reference and exposure stations both for salmon and lake chub.

Estimates of variability in condition (log body weight vs log length) for juvenile Atlantic salmon showed that a significant relationship existed between body weight and fish length but this relationship did not differ between the reference and exposure areas (Figure 4.8a). ANCOVA results are presented in Table 4.14. Analysis of size-at-age showed a difference between sampling areas for lake chub (Figure 4.8b).

Table 4.12: Summary of Lengths and Weights of Sentinel Fish Species from the Reference and Exposure Stations, Heath Steele Mine

Fish Species	Measurements	Reference (HS-21)		Exposure (JW-E1)		t[1]	p[2]
		$\bar{x} \pm SE$	n	$\bar{x} \pm SE$	n		
Atlantic juvenile salmon	length (mm)	94.91 ± 5.17	11	63.62 ± 2.04	13	-6.909**	0.000*
	weight (g)	10.72 ± 1.89	11	3.14 ± 0.38	13	-6.625**	0.000*
lake chub	length (mm)	61.50 ± 2.03	8	52.06 ± 5.29	18	-2.261**	0.0352*
	weight (g)	2.87 ± 0.26	8	2.99 ± 1.04	18	-2.149**	0.0447*

** Statistically significant difference between reference and exposure stations ($p<0.05$).
[1] Students t-statistic
** Denotes data was $\log_{10}$ transformed
[2] Probability value

Figure 4.5: Frequency Histograms of Atlantic Salmon Lengths and Weights for the Reference and Exposure Sites - Heath Steele Mines

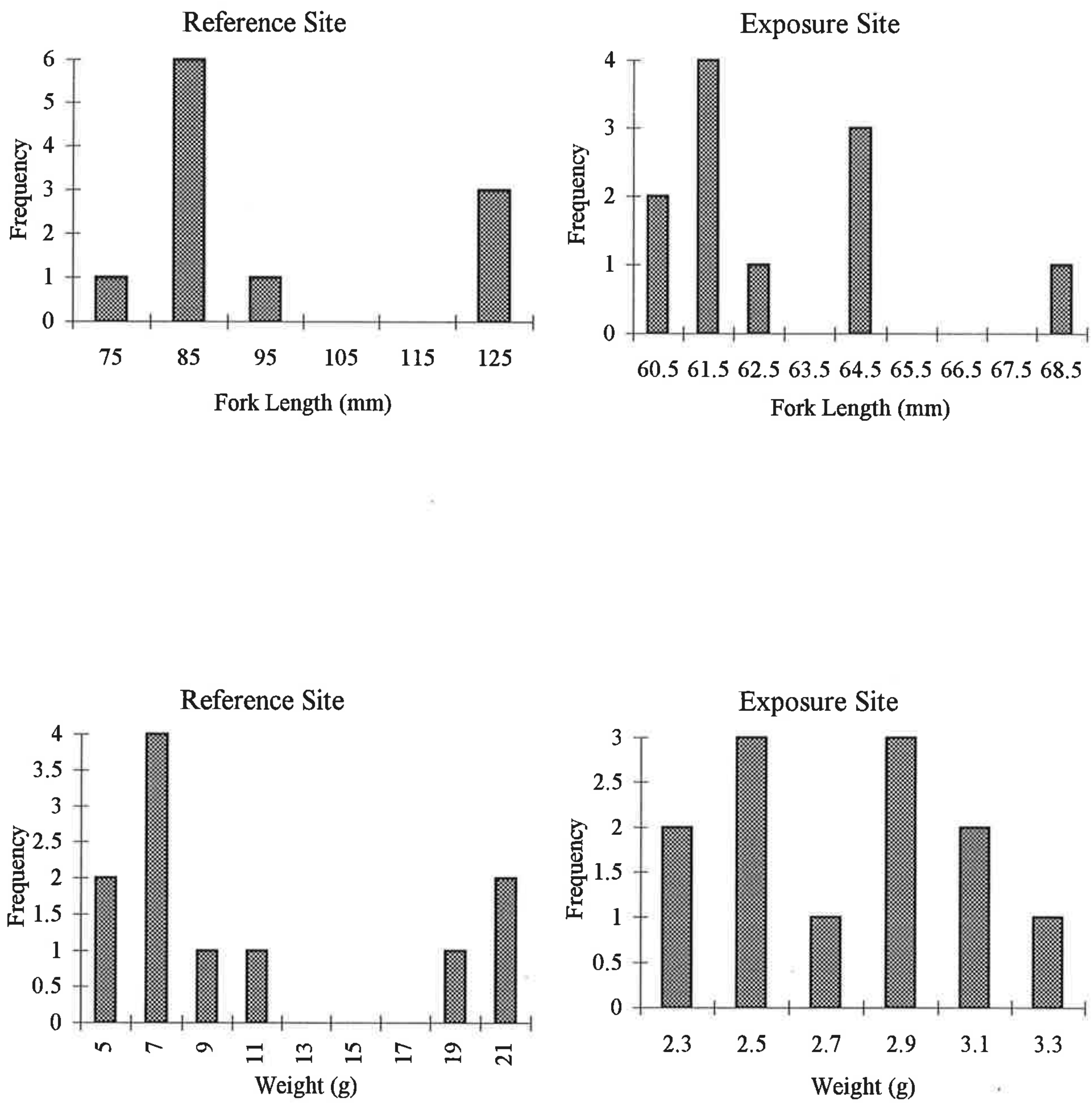


Figure 4.6: Frequency Histograms of Lake Chub Lengths for the Reference and Exposure Sites - Heath Steele Mines

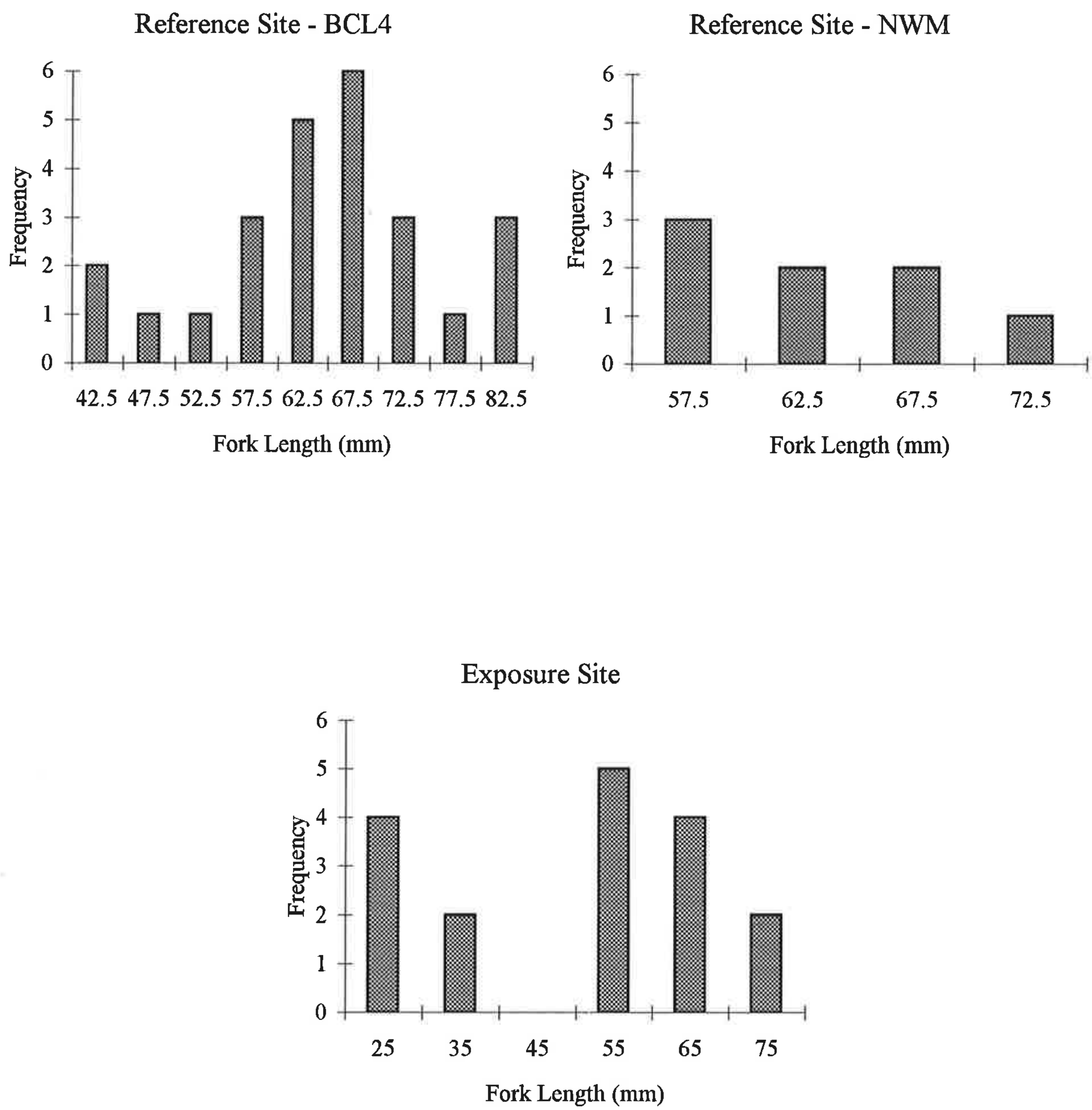
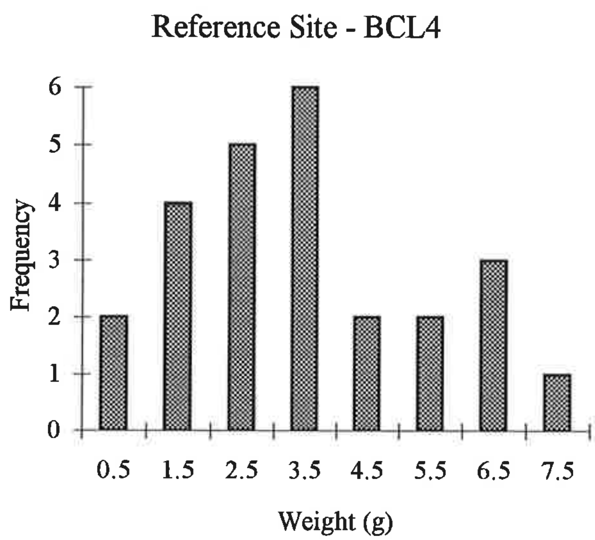
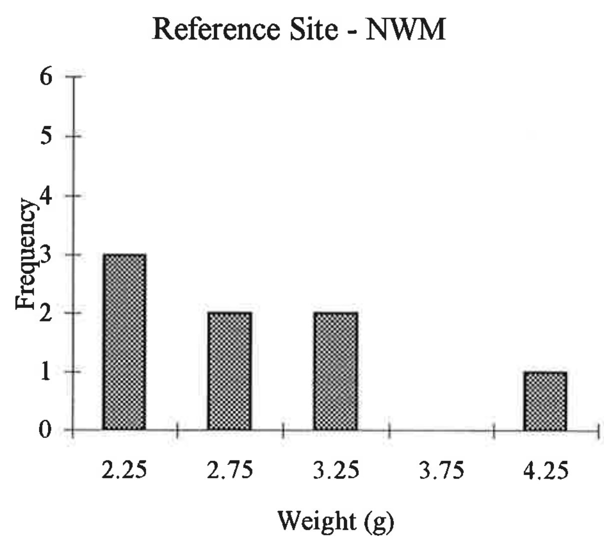


Figure 4.7: Frequency Histograms of Lake Chub Weights for the Reference and Exposure Sites - Heath Steele Mines





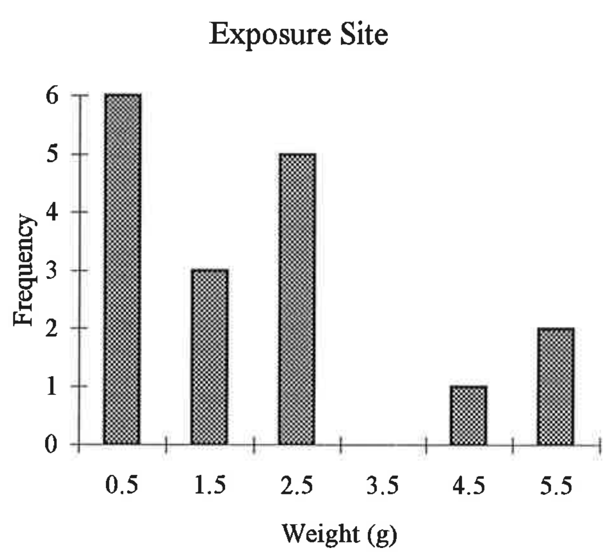


Table 4.13: Catch Per Unit Effort (CPUE) of Sentinel Fish Species From the Reference and Exposure Stations, Heath Steele Mine

Fish Species	Reference Site	Exposure Site
juvenile Atlantic salmon	0.85 fish/min	0.98 fish/min
brook trout	0.61 fish/min	0.60 fish/min

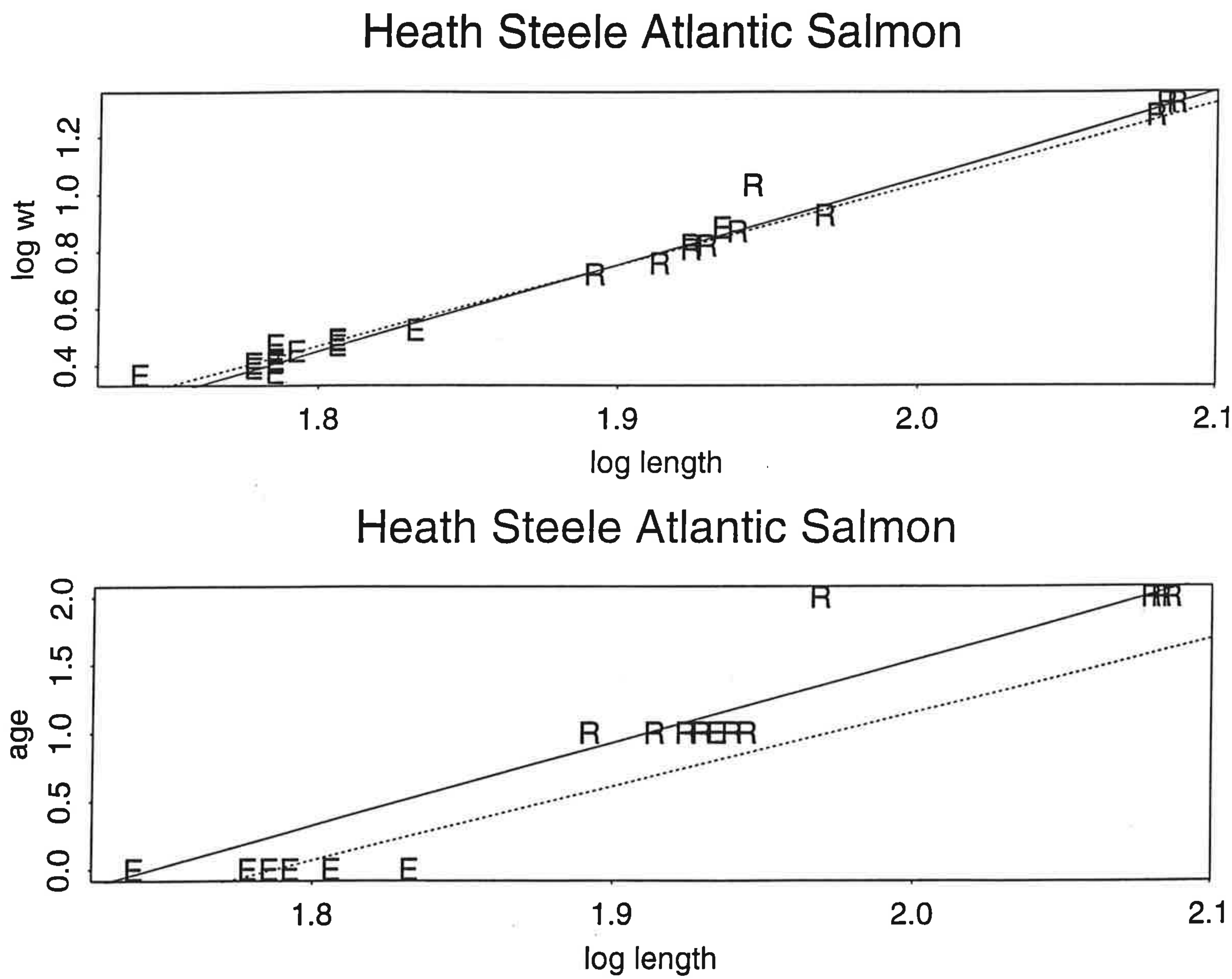


Figure 4.8: Relationship of A) length vs weight and B) length vs age of Juvenile Atlantic Salmon from Reference (-) and Exposure (----) Areas, Heath Steele Mine

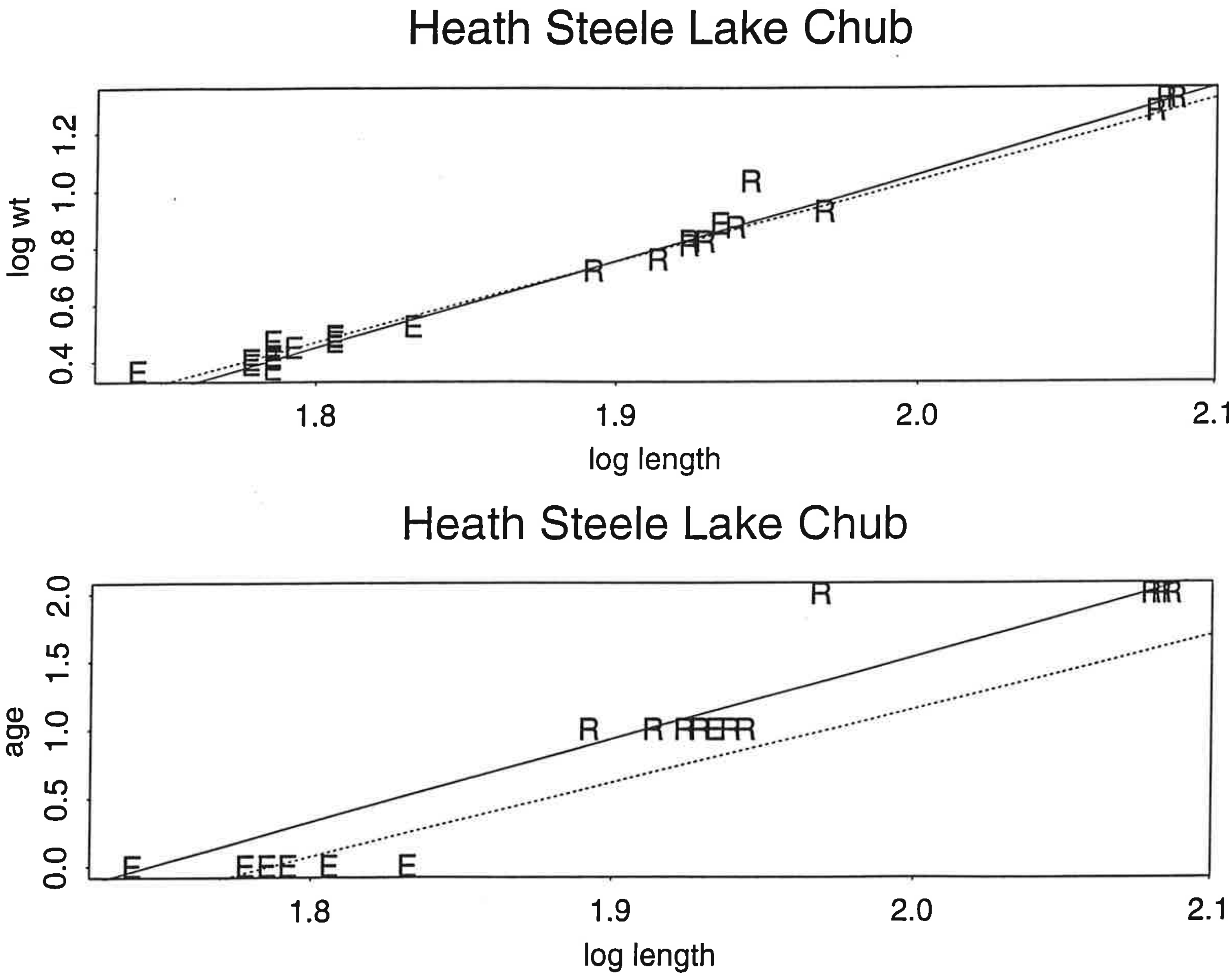


Figure 4.9: Relationship of A) length vs weight and B) length vs age of Lake Chub from Reference (-) and Exposure (----) Areas, Heath Steele Mine

Table 4.14: Estimates of Variability in Condition and Size-at-Age Using Analysis of Covariance, Heath Steele Mine

Species	Statistic	Condition	Size-at-Age
juvenile Atlantic salmon	Regression Line	y=-4.82+2.94x	y=-10.16+5.84x Ref. y=-10.45+5.84x Exp.
	t-value	35.470	-2.117
	p-value	0.0001	0.0464
lake chub	Regression Line	y=-4.97+3.04x	y=-4.8+2.9x Ref. y=-4.94+2.9x Exp.
	t-value	41.135	-2.435
	p-value	0.0001	0.0235

Estimates of variability in condition (log body weight vs log length) for lake chub showed a similar result as that described for salmon. Although a significant relationship between length and weight existed, the relationship did not differ with sampling area (Figure 4.9a). Analyses site-at-age for lake chub showed a significant relationship existed and this relationship differed between the reference and exposure area (Figure 4.9b)

4.8.2 Tissue Analysis

Tissues of lake chub and juvenile Atlantic salmon were sampled for metals and metallothionein analyses from the Northwest Miramichi River (HS-21) and the Tomogonops River (JW-E1). Lake chub were also sampled from a second reference site on McCormack Brook (BCL-4). Eight fish of each targeted sentinel species were collected. Because of the small size of the lake chub, the fish were pooled into three samples for stations HS-21 and JW-E1 and pooled into two samples for Site BCL4. Samples were also pooled for juvenile Atlantic salmon. The eight samples from the exposure station were pooled into three samples. For the reference station, two of the salmon samples consisted of two pooled fish, the remaining four samples consisted of single fish.

Results of the metals and metallothionein analyses are not clear. Although tissues of juvenile Atlantic salmon from the exposure area contained significantly higher ($p = 0.006$) metallothionein concentrations compared to reference concentrations, concentrations of metals (Zn + Cu + Cd) were higher in tissues from reference fish collected from the Northwest Miramichi River (Table 4.15).

Metallothionein levels in lake chub were significantly different between the three stations sampled (Northwest Miramichi River, McCormack Brook and Tomogonops River) (ANOVA on $\log_{10}$ transformed data; $p = 0.039$) (Table 4.15). A Duncan's Multiple Range Test showed that each station was significantly different from the other. Metallothionein was significantly higher in lake chub from the exposure station compared to tissues from the Northwest Miramichi River. Metals concentrations did not differ between these stations. It was expected that tissue samples from the second reference station (BCL-4) would contain the lowest metallothionein and metal concentrations. However, lake chub from this site contained the highest metallothionein concentrations (159.5 μgMT/g) and the lowest metal levels (3.5 μm/g). The anomalous results found for the metallothionein and metals data from the Heath Steele Mine may be a result of small sample sizes. The hard data files for the analyses are presented in Appendix E.

4.9 Estimated Level of Effort

One important criterion when considering the suitability of a mine site for evaluation of hypothesis in 1997, is the level of effort which was required at that site. The estimated level of effort for conducting each

Table 4.15: Metals and Metallothionein Levels ($\bar{x}$ ± 1SD) in Juvenile Atlantic Salmon and Lake Chub Collected from Reference and Exposure Areas, Heath Steele Mine

Species	Parameter	Reference Area (McCormack Brook - BCL4)		Reference Area (NW Miramichi River - HS-21)		Exposure Area (Tomogonops River - JW-E1)	
		$\bar{x}$ ± 1SD	n	$\bar{x}$ ± 1SD	n	$\bar{x}$ ± 1SD	n
Juvenile Atlantic salmon	MT (µg MT/g)	not sampled		39.7 ± 2.2	6	64.4 ± 8.8	3
	(Zn + Cu + Cd) (µm/g)			5.9 ± 1.0	6	4.5 ± 0.1	3
	Length (cm)			8.5 ± 0.6	6	6.7 ± 0.8	3
	Weight (g)			7.2 ± 1.7	6	4.0 ± 1.6	3
Lake chub	MT (µg MT/g)	159.5 ± 10.6	2	50.3 ± 10.5	3	81.5 ± 4.6	3
	(Zn + Cu + Cd) (µm/g)	3.5 ± 0.6	2	4.0 ± 0.2	3	4.0 ± 0.5	3
	Length (cm)	6.0 ± 0.1	2	5.9 ± 0.4	3	6.5 ± 0.8	3
	Weight (g)	2.6 ± 0.1	2	2.7 ± 0.6	3	3.3 ± 0.7	3

program element in the 1996 field survey is presented in Table 4.16. Level of effort was allocated by tasks which were predetermined by the consulting consortium upon commencement of this project.

The level of effort allocated to sampling sublethal toxicity samples, water chemistry and benthic invertebrate community structure was determined by sample collection time per reference and exposure area and other site specific logistics (*e.g.*, access to collection sites). The level of effort allocated to characterizing fish abundance, and community structure was determined by catch per unit effort and other site-specific logistics. Overall, the Heath Steele Mine site required a reasonable level of effort to complete each program element. Both the reference and exposure areas were accessible by road which minimized travel and field reconnaissance time. Some delays in data analyses and interpretation occurred because of the consortium's decision to submit samples to the same analytical laboratory (*i.e.*, chemical analyses to MDS, benthos to Zarenko Environmental). However, the benefits of improved analyses consistency and QA/QC out-weighed the disadvantages of the delays. The levels of effort summarized in Table 4.16 do not include time spent reviewing the suitability of the Heath Steele site for testing hypotheses in 1997, ranking the site against selection criteria, or completing the 1997 study design.

Expenses and disbursements for the field survey at the Heath Steele Mine are presented in Table 4.17. Excessive costs were incurred for shipping of effluent samples for sublethal toxicity testing. Large effluent volumes were required for the trout embryo test. Considering the low success rate for this test for the overall project at all seven mine sites, the costs incurred for conducting the tests should be evaluated against the value of the data obtained if future testing is considered.

Table 4.16: Estimated Level of Effort for Each Program Element at the Heath Steele Mine Site

Task			Level of Effort (person hours)
Project Initiation Meeting			9
Literature Review and 1996 Study Design			38
Field Surveys	Planning and Prep. of Field Logistics		66
	Site Reconnaissance, Habitat Characterization and Station Selection		33
	Sublethal Toxicity Sample Collection		6
	Water Chemistry		10
	Sediment Chemistry		samples not collected
	Benthos		15.5
	Fish	Population	33.5
		Tissue Processing	6
Data Analysis and Interpretation			93
Preliminary Surveys and Recommendation Report			97
Final Survey Report			77
Progress Reports			11
Conference Calls			14

Table 4.17: Expenses and Disbursements for the Preliminary Field Survey at the Heath Steele Site

Expense	Sublethal Toxicity Sample Collection	Water Chemistry	Sediment Chemistry	Benthos	Fish
Travel			$1882.00		
Accommodations			$748.00		
Meals			$808.00		
Miscellaneous Supplies			$1740.00		
Shipping			$1690.00		
Analyses	na	$2020.00	ns	$2400.00	$120.00

na = not applicable
ns = not sampled

5.0 DISCUSSION

5.1 Comparison of Results with Historical Data

Water Chemistry

The water quality parameters at the exposure and reference station have been compared in Table 5.1 with those measured in June of 1994 (BEAK 1994). There is no direct comparison between JW-E1 and any historical sampling station. The closest station is HS-20 at the mouth of the Tomogonops River. Like JW-E1, HS-20 receives effluent from both the North and South Branches of the Tomogonops River. However, it is also diluted by a number of tributaries downstream of JW-E1. The effects of this dilution can be seen in Table 5.1. The conductivity, hardness, sulphate and concentration of alkali metals (Na, K, Ca) are significantly less at HS-20 than at JW-E1. This trend was less evident with the trace metals which exhibited considerable variability. Some were greater at JW-E1 (zinc) and other were marginally less (lead). Comparisons are difficult since detection limits were different between the two studies.

Water chemistry samples collected from the Northwest Miramichi River at reference station HS-21 were compared to samples collected historically at HS-35 (Figure 2.1). Table 5.1 indicates that the two reference samples were close in conductivity, pH, hardness, calcium and sodium. As with the exposure stations, the levels of trace metals are more variable, with low concentrations found in both reference samples.

Benthic Invertebrates

The abundance (total number of organisms) and richness (total number of taxa) of the benthic samples from the exposure (JW-E1) and reference area (HS -21) are compared in Table 5.2 with historic data from Stations HS-20, HS-14/18 and reference station HS-35 (Figure 2.1). Comparisons between the 1996 samples taken in late September with previous samples taken in October were considered most meaningful. Data from samples taken in June have also been included in Table 5.2 to indicate the significant differences in richness and abundance that occur with season.

Table 5.2 indicates that the benthic community at HS-14/18, located on the South Branch Tomogonops River, has been significantly impaired relative to that at the reference station HS-35, although it has shown considerable recovery since 1992 and 1993. The South Branch Tomogonops receives direct discharge from the tailings pond and station HS-14/18 is subjected to conditions of low pH (due apparently to thiosalts), high conductivity and high zinc concentrations (*e.g.* October 1995; BEAK 1996). The benthic community at HS-20, located at the mouth of the Tomogonops, has also shown considerable improvement from conditions observed in 1992 and 1993. In 1995, little or no impairment was evident at HS-20 although mayflies were absent in the October samples (BEAK 1996).

Table 5.1: **Comparison of Water Quality Parameters in the Tomogonops River Exposure Area (JW-E1) and the Northwest Miramichi Reference Area (HS-21) with Historical Data (HS-20 and HS-35)[1].**

Parameter	HS-20 (exposure area) (BEAK 1994)		JW-E1 (exposure area) (JWEL 1996)[2]		HS-35 (reference area) (BEAK 1994)		HS-21 (reference area) (JWEL 1996)[2]	
Cond. (μS/cm)	295		427.3		37		47.3	
pH	7.18		6.93		6.5		6.92	
Hardness	126.6		189		20.3		19.1	
Sulphate	125		179		5.2		3	
Zn	0.044	**0.034**	0.06	**0.053**	0	**0.001**	0.003	**0.001**
Cu	0.01	**0.01**	0	**0.004**	0	**0.0009**	0.004	**0.002**
Pb	0	**0**	0	**0**	0	**0.0003**	nd	**0**
Ni	0	**0**	0	**nd**	nd	**nd**	nd	**nd**
As	0	**0**	nd	**nd**	0	**0.0008**	nd	**nd**
Cr	nd	**nd**	nd	**nd**	nd	**nd**	nd	**nd**
Ca	48.9	**46.8**	75.6	**72.2**	7.05	**7.19**	6.375	**6.025**
Na	3.28	**3.1**	15.7	**15.3**	1.26	**1.33**	1.95	**1.925**
K	0.648	**0.593**	1.7	**1.333**	0.33	**0.323**	0.812	**0.725**

[1] Dissolved values in bold. All values in mg/L unless otherwise indicated.

[2] Average of all the stations

Table 5.2: Comparison of Abundance and Richness of Benthic Invertebrates with Historical Data (HS-20, HS-14 and HS-35)[1]. First Values Represent Samples Taken in October. Second Values Represent Samples taken in June. Mesh size 500 μm.

Year	JW-E1 (exposure area)		HS-20 (exposure area)		HS-14 (exposure area)		HS-21 (reference area)		HS-35 (reference area)	
	Richness	No./m²	Richness	No./m²	Richness	No./m²	Richness	No./m²	Richness	No./m²
1996 (This study)	26	2,789					42.2	7433		
1995			39/38.5	795/1,405	8.5	140			46/35.5	4,995/ 2,657
1994			32.5/35	752/1,147	10.5	550			31/32.5	1,822/ 6,123
1993			14/5	190/36	0	0			32/30	1,000/ 674
1992			9/10	289/120	6	474			33/33	1,079/ 1,183
1991			/18	/171					/46	/5,269
1988			25	417						
1987			31	509	12	70				
1984										
1981			/10		4	49				

[1] Data from BEAK (1996)

Since JW-E1 is a new station, it cannot be compared directly to results obtained at any one of the stations sampled in previous studies. Like HS-20, JW-E1 receives effluent from the South Branch and non-point source seepage from the Little South and North Branches. However, dilution at JW-E1 is less than that at HS-20 due to a closer proximity to the mine. Logically, JW-E1 should represent conditions that are intermediate to the impairment observed at HS-14/18 and the relatively unimpaired conditions at HS-20. The richness or number of taxa at JW-E1 observed in this study (26) was indeed intermediate between that at HS-14/18 (8.5) and HS-20 (39) observed in 1995 and considerably less than the richness at reference station HS-21 (42.2) (Table 5.2). The density of organisms at JW-E1 in 1996 (2789/m^2) was, as expected, greater than that observed at HS-14/18 in 1995 (140/m^2) but, unexpectedly, also greater than that at HS-20 (795/m^2). The higher densities of benthic organisms at JW-E1 relative to HS-20 may be related the fact that the comparisons are between two different years. The reference area in 1996 (HS-21) was similar in both richness and abundance to historical reference area (HS-35).

Fisheries

Historical fisheries data exist for reference station HS-21 on the Northwest Miramichi River. Table 5.3 contains historical data for Atlantic salmon. The data shows that all age classes are well represented from year to year. Qualitative electrofishing in 1996 revealed a high population of salmon of various sizes. Histograms of fish length showed that the majority of the salmon were less than 100 mm and none were greater than 150 mm which is similar to the findings of the electrofishing conducted in 1981 and 1996 (Wood 1981; BEAK 1992, 1993, 1994b).

No historical fisheries data from the Tomogonops River exposure station (JW-E1) exists for direct comparison with the 1996 survey. Qualitative electrofishing undertaken at this station in 1996 indicated a wide range in parr age classes. Fishery surveys conducted in 1994 and 1995 in the North Branch Tomogonops (BCL-1, BCL-2) showed that Atlantic salmon populations are recovering compared to earlier years (BEAK 1994a, 1996b).

Historical studies conducted in the Northwest Miramichi River and Branches of the Tomogonops River show that juvenile Atlantic salmon are the most abundant species present overall. This supports the results of the 1996 survey. Historical studies (BEAK 1996b) also show that overall species abundance and CPUE are typically higher at reference station HS-35 and these parameters decrease at the exposure stations. Sample sizes in the 1996 survey did not show a similar pattern although sample sizes were small.

Population data on lake chub were not collected regularly during previous studies at Station HS-21 on the Northwest Miramichi River, thus results from the 1996 survey can only be compared with a 1994 study (BEAK 1994 a). In 1993, lake chub density at Station HS-21 was 1.3/100m^2. The qualitative electrofishing in 1996 produced a considerably higher number of fish in a similar area.

Table 5.3: Summary of Juvenile Salmon Population Estimates (N/100 m^2) (Moran and Zippin method) by Age Structure for the Northwest Miramichi River From 1987 to 1993.[1]

Age Class	1987	1990	1991	1992	1993
0+	48.77	29.67	47.9	25.1	67.1
1+	47.87	5.65	25.9	36.6	22.5
2+	11.9	0.57	3.7	8.8	6.3

[1] Data from BEAK (1990; 1992; 1993; 1994)

Historical data on lake chub at exposure station JW-E1 does not exist. The nearest stations studied in previous work are BCL-1 and BCL-2 (Figure 2.1) and insufficient numbers of lake chub were captured at these sites for comparison. BEAK (1994a) appears to be the only report which notes population estimates for lake chub at reference station BCL-4. The population estimate for lake chub at BCL-4 in 1994 was 37.7 fish/100 m^2. The population estimate in 1996 was calculated at 11.8 fish/100 m^2.

In 1995, MT analysis was conducted on livers from Atlantic salmon parr collected from two exposure stations (nearfield and farfield) on the Tomogonops River and one on the Northwest Miramichi River (BEAK 1996b). Statistical analysis showed a minor difference between the reference area and the farfield area but both of these sites did not different significantly from the near field station. The results were determined to be inconclusive. Metal analyses did not show a difference between stations. The 1996 survey showed a difference in MT levels in salmon between the reference and exposure areas. However, metal results did not support the MT data at these stations.

5.2 Comparison of Reference Versus Exposure Areas

Habitat

Habitat between the reference and exposure areas was similar although flows in the reference area were higher compared to the exposure area. Although all reaches contained varied habitat (*i.e.*, runs, riffles, pools), suitable areas of uniform habitat were available for selection of multiple reference and exposure stations.

Water Chemistry

Significantly greater levels of conductivity, hardness, TDS, DIC, alkali metals and many of the trace metals at JW-E1 relative to the Northwest Miramichi River, suggest that JW-E1 has been significantly exposed to mine effluent. Situated downstream of the confluence of the South and North Branches of the Tomogonops but upstream of most tributaries, this station is exposed to both seepage and direct effluent discharge before extensive dilution occurs. In addition, the water quality was similar at all the stations along the length of this reach, which implies that this area is exposed uniformly to effluent. Water quality in the reference area reflects background concentrations of the measured parameters.

Benthic Invertebrates

Results from the benthic invertebrate sampling program showed significant differences in total species abundance and richness between the reference and exposure areas. Although there were differences in the composition of "sensitive species" between the areas, these differences were not significant.

Fisheries

Juvenile Atlantic salmon and lake chub were the most abundant fish species in the reference and exposure areas. Area differences were apparent for juvenile salmon showing significantly greater lengths and weights in the reference area compared to the exposure area. Although differences in CPUE and abundance were not apparent in 1996 for the two selected sentinel species, differences have been observed historically. Estimates of variability in condition did not differ between areas for either salmon or lake chub. However, size-at-age relationships differed between areas for both species.

Although MT levels were significantly higher in tissues of lake chub and juvenile Atlantic salmon collected from the exposure area (JW-E1) compared to the reference area (HS-21), sample sizes were small. In addition, metals data did not support the MT results, and results from an alternate reference area (BCL-4) showed the highest MT levels in lake chub which confounded result interpretation.

6.0 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE SAMPLING

An evaluation of the suitability of the Heath Steele Mine site for testing hypotheses in 1997 has been presented in a separate document. In that document, the site specific characteristics of the Heath Steele Mine site are summarized and the site is evaluated against specific selection criteria relative to the other six mine sites surveyed in the 1996 field program.

The 1996 field survey results indicated that the Heath Steele Mine site meets some of the suitability criteria for hypothesis testing in 1997. An extensive historical database of effluent and water chemistry data, benthic invertebrate community data and fisheries population data exists for sampling stations located in both the reference and exposure areas. Less extensive historical data exists on sediment and fish tissue chemistry. The results of the 1996 field program were compared to historical data sets to confirm the presence or absence of well defined differences between reference and exposure areas. Historical sediment chemistry data were valuable to confirm the limitation of suitable, representative depositional areas.

Effluent is discharged continuously from the tailings pond and this location of the discharge is easily accessible for collection of effluent for sublethal toxicity testing. Sublethal toxicity tests clearly indicated effluent toxicity to all species tested. It is recommended for future studies involving sublethal toxicity testing, that receiving (dilution) water be screened for toxicity to *C. dubia* and fathead minnow prior to effluent testing, that all sublethal tests be performed on effluent collected on the same day for quality control, and that tests be conducted on more than one occasion to obtain an estimate of testing variability.

The Heath Steele Mine site and the reference and exposure areas were easily accessible by road from the town of Newcastle or Bathurst. The habitat characterization and classification determined that multiple reference and exposure stations of uniform habitat type were available in each area. The habitat survey also confirmed that fine-grained sediments within the reference and exposure areas were limited. Although some sediments have been collected and analysed historically for metal content, these sediments are limited to small areas (< 1 m^2) along stream margins and behind large boulders. Based on these observations sediment quantity is not sufficient for testing of sediment chemistry and toxicity. More importantly, these sediments are not representative of the sediments in the reference and exposure area and do not represent the main pathway of metal exposure to aquatic biota in the exposure area. Thus, sediments should not be sampled in future field programs. In this system, water chemistry sampling is more appropriate to determine exposure.

There are no known confounding point or non-point source discharges in either the reference or exposure area. However, the Heath Steele Mine site is complex due to different point and non-point source discharges, which originate from the mine, and influence different Branches of the Tomogonops River. To optimize the sampling effort in the 1996 survey, the exposure area was located below the confluence of the North and South Branches of the Tomogonops River. This area is frequented by sentinel fish species and receives the combined effects of the seepage into the North and Little South Branches and the tailings effluent discharge into the South Branch. The exposure area, selected for the 1996 survey, had not been sampled historically. Exposure stations have typically been located on the North Branch, Little South Branch, South Branch or the Tomogonops River upstream of its confluence with the Northwest Miramichi River. Stations located on the different Branches are exposed to either mine seepage or mine effluent which differ in effluent composition and may affect aquatic biota differently. In addition, fish populations on these Branches are of limited abundance. The historical exposure station located on the Tomogonops River at the confluence with the Northwest Miramichi River (HS-20) was not an optimal station for the 1996 survey as fish and benthic communities have recovered at this station over the last several years. Therefore, the exposure area sampled in 1996 was exposed to the combined mine discharges and provided for optimized sampling effort for water chemistry, benthic invertebrate communities and fish populations. This site should be sampled for fisheries assessments in future sampling programs as sentinel species are abundant, are exposed to both mine discharges, and the habitat at this site is comparable to habitat in the Northwest Miramichi River. In addition, this site contains sufficient area for location of multiple exposure stations.

Observations from the water chemistry survey indicated that a significant difference in general water chemistry and metals existed between reference and exposure areas which is consistent with historical data. Chemical parameters which are recommended for future monitoring programs are presented in Table 6.1. These are parameters which were significantly higher in the exposure area, were not significantly different but were detectable, and/or were measured in the effluent.

Results from the benthic invertebrate sampling program were consistent with historical data showing affected communities (decreased abundance and species richness) in the exposure area compared to the reference area. Based upon the results of BEAK (1996c), it is recommended that a mesh size of 250 µm be retained for sample collection and composite Surber samples be collected at each sampling station.

Juvenile Atlantic salmon and lake chub were the dominant species in both the reference and exposure areas and these species were abundant. It is recommended that juvenile Atlantic salmon be considered a sentinel species for future studies as it is most abundant and has been studied historically. Although CPUE did not differ between areas in the 1996 survey, historical data suggests this parameter may be useful to assess differences in fish populations between areas. Significant differences in lengths and weights of salmon occurred between areas. Although sample sizes were small, juvenile salmon were larger and heavier in the reference area. Size-at-age relationships for juvenile salmon also differed between areas. Based on these results, future population studies on these species are feasible. However, because there are only juveniles in the reference and exposure areas, size-at-age determinations would be restricted to the limited age classes present.

Tissues of lake chub and juvenile Atlantic salmon were sampled for metals and metallothionein (MT) analyses from the Northwest Miramichi River (HS-21) and the Tomogonops River (JW-E1). Although MT levels

Table 6.1: Water (and Effluent) Chemistry Parameters Recommended for Future Studies at the Heath Steele Mine Site

Metals (total and dissolved)	General Chemistry
Aluminum[1]	Alkalinity[2]
Barium[1]	Anion Sum[1]
Calcium[1]	Bicarbonate[2]
Copper[1]	Cation Sum[1]
Lead[1]	Chloride[1]
Magnesium[1]	Colour[2]
Manganese[1]	Conductivity[1]
Molybdenum[3]	Dissolved Organic Carbon[2]
Nickel[2]	Hardness[1]
Potassium[2]	Ion Balance[2]
Selenium[2]	Kjeldahl Nitrogen[2]
Sodium[1]	Nitrate[2]
Strontium[1]	pH[2]
Thallium[3]	Sulphate[1]
Uranium[1]	Thiosalts[3]
Zinc[1]	Total Dissolved Solids[1]
	Turbidity[2]

[1] Parameter significantly higher in exposure area in 1996 field survey.
[2] Parameter was detectable in the 1996 field survey but not statistically different between reference and exposure areas.
[3] Parameter only detected in effluent.

were significantly higher in both species from the exposure area, sample sizes were small, metals data did not support the MT results, and results from the alternate reference area (BCL-4) showed the highest MT levels in lake chub. Future studies of metals and metallothionein are possible at this mine site with two restrictions. Firstly, a barrier does not exist at the site to eliminate the possibility of fish migration between the reference and exposure areas. Thus, caged fish would be a suitable alternative for evaluating effluent exposure at this site. Secondly, as only small fish are available and abundant (juvenile Atlantic salmon and lake chub) in the reference and exposure areas, comparison of different tissue burdens could not be evaluated as the fish are too small for dissection.

Overall, the Heath Steele Mine site was suitable to sample all program components in 1996 with the exception of sediments. The sampling locations were accessible and a reasonable level of effort was required to complete the field survey.

7.0 REFERENCES

American Public Health Association (APHA). 1995. *Standard Methods for the Examination of Water and Waste Water*. American Public Health Association. Washington, D.C.

Bailey, Harold S. 1988. *A Heavy Metal Study of Three River Basins in Atlantic Canada Influenced by Mining Activities*. Environmental Canada, Water Quality Branch, Atlantic Region, Moncton, New Brunswick 1W/L - AR - WQB - 88 - 138. 69pp.

BEAK Consultants Ltd. 1992. *Environmental Surveys of the Northwest Miramichi River System Following a Discharge by Heath Steele Mines, 1991.* Report Prepared for Heath Steele Mines, Newcastle, New Brunswick. BEAK Consultants Ltd., Brampton ON, Report No. 3105.1. 118 pp. plus Appendices.

BEAK Consultants Ltd. 1993. *Surveys of Juvenile Atlantic Salmon in the Northwest Miramichi River, 1992*. A Report Prepared for Heath Steele Mines Ltd., Newcastle, New Brunswick. BEAK Ref. 2742.1. 19 pp. plus Appendices.

BEAK Consultants Ltd. 1994a. *Environmental Survey of the Tomogonops River, 1994.* Report prepared for Heath Steele Mines, Newcastle, New Brunswick. BEAK Ref. 20065.1. 32 pp. plus Appendices.

BEAK Consultants Ltd. 1994b. *Environmental Studies of the Northwest Miramichi River, 1991-1993, Following a Mine Water Discharge*. Report prepared for Heath Steele Mines, Newcastle, New Brunswick. BEAK Ref. 2912.1. 29 pp. plus Appendices.

BEAK Consultants Ltd. 1995a. *Benthic Survey of the Tomogonops River and Northwest Miramichi River, 1994*. Report prepared for Heath Steele Mines, Division of Brunswick Mining and Smelting Limited: BEAK Ref. 20066.1. 7 pp. plus Appendices.

BEAK Consultants Ltd. 1995b. *Sediment Quality and Benthic Community Conditions in Mosquito Pond, Mosquito Brook and the North Branch Tomogonops River 1994 (Draft)* Report prepared for Heath Steele Mines, Division of Brunswick Mining and Smelting Limited. BEAK Ref. 20066.3. 15 pp. plus Appendices.

BEAK Consultants Ltd. 1996a. *Benthic Survey of the Tomogonops River and Northwest Miramichi River, 1995*. Report prepared for Heath Steele Mines, Noranda Ming and Exploration Limited. BEAK Ref. 20278.1. 8 pp. plus Appendices.

BEAK Consultants Ltd. 1996b. *Fisheries Reconnaissance of the Tomogonops River - October 1995*. Report prepared for Heath Steele Division, Noranda Mining and Exploration Inc. BEAK Ref. 20278.2. 10 pp. plus Appendices.

BEAK Consultants Ltd. 1996c. *1996 Field Evaluation of Aquatic Effects Monitoring Methods*. Reports prepared for Natural Resources Canada, CANMET. BEAK Ref. 20303.1.

Bradley R.W. and J.B. Sprague. 1985. *The Influence of pH, Water Hardness, and Alkalinity on the Acute Lethality of Zinc to Rainbow Trout (Salmo gairdneri)*. Can J. Fish. Aquatic Sci. 42:731-736.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. *Classification of Wetlands and Deep Water Habitat of the United States*. U.S. Department of the Interior, Washington, D.C., FWS/OB5 - 79/31.103 pp.

Cusimano, R.F., D.F. Brakke and G.S. Chapman. 1986. *Effects of pH on the Toxicities of Cadmium, Copper and Zinc to Steelhead Trout (Salmo Gairdneri)*. Can J. Fish Aquat. Sci. 43:1497-1503.

Department of Fisheries and Oceans (DFO) and the New Brunswick Department of Natural Resources and Energy (NBDNRE). 1994. *Stream Survey and Habitat Assessment Table*, Fredericton, New Brunswick

Hare Fisheries and Environmental Consultants Inc. 1993. *Benthic Survey of the Tomogonops River System and the Northwest Miramichi River - 1992*. Report prepared for Heath Steele Mines Limited. 18 pp. plus Appendices.

Heath Steele Mines Limited. 1988. *Heath Steele - Stratmat Closure Plan (Draft)*. Heath Steele Mines, Newcastle, New Brunswick.

Heath Steele Mines. 1990. *Heath Steele Mines 1989 Annual Report - Surface Water Monitoring*. A Report Prepared by Heath Steele Mines, Newcastle, New Brunswick 27 pp.

Heath Steele Mines. 1991. *Heath Steele Mines Environmental Report 1990*. A Report Prepared by Heath Steele Mines, Newcastle, New Brunswick. 7 pp. plus Appendices.

Heath Steele Mines. 1992. *Heath Steele Mines Environmental Report 1991*. A Report Prepared by Heath Steele Mines, Newcastle, New Brunswick. 23 pp.

Heath Steele Mines. 1993. *Heath Steele Mines Environmental Report 1992*. A Report Prepared by Heath Steele Mines, Newcastle, New Brunswick. 21 pp. plus Appendices.

Howarth, R.S. and J.B. Sprague. 1978. *Copper Lethality to Rainbow Trout in Waters of Various Hardness and pH.* Water Research 12:455-462.

Montreal Engineering Company, Ltd. 1973. *Base Metal Mine Waste Management in Northeastern New Brunswick.* A Synopsis Based on Findings of the Northeastern New Brunswick Mine Water Quality Program. Report prepared for the Water Pollution Control Directorate, Environmental Protection Service. Report No. EPS 8 - WP - 73 - 1. 55p.

Montreal Engineering Company, Ltd. 1979. *Report to Heath Steele Mines Limited Concerning Investigations into the sources of Contamination Entering the Little South Tomogonops River.* Montreal Engineering Company Ltd., Fredericton, New Brunswick.

Moore, D.J., S. Courtney and P.R. Pickard. 1991. *Status of Atlantic Salmon in the Miramichi River During 1989.* Dept. of Fisheries and Oceans, Science Branch, Moncton, New Brunswick CAFSAC Research Document 91/8.

Moran, P. A. P. 1951. *A Mathematical Theory of Animal Trapping*. Biometrika. 38:307-311.

Parker, R.W. 1991. *An In-Situ Study of the Acute Toxicity of the Tomogonops River System to Yearling Atlantic Salmon*. Environment Canada Environment Control Branch Conservation and Protection: 13 p.

Pedder, S.C.J. and E.J. Maley. 1985. *The Effect of Lethal Copper Solutions on the Behaviour of Rainbow Trout, Salmo gairdneri*. Arch. Environ. Contam. Toxicol. 14, 504-507.

Plafkin, J.L., Michael T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers - Benthic Macroinvertebrates and Fish*. United States Environmental Protection Agency. EPA/ 444/ 4-89-001.

Prairie, R. 1984. *Status of Atlantic Salmon in the Northwest Miramichi River, New Brunswick*. Centre de Recherche Noranda. Technical Memorandum No. 192.

QAMS. 1986. Development of data quality objectives. Description of Stages I and II (draft). Quality Assurance Management Staff. Environmental Protection Agency, Washington, D.C.

QAMS. 1990. *Proposed Glossary of Quality Assurance Related Trms.* Quality Assurance Management Staff. Environmental Protection Agency, Washington, D.C.

Randall, R.G., D.M. Moore and P.R. Pickard. 1990. *Status of Atlantic Salmon in the Miramichi River during 1989.* Department of Fisheries and Oceans. CAFSAC Research Document 90/4.

Saunders, R.L. 1969. *Contributions of Salmon from the Northwest Miramichi River, New Brunswick, to Various Fisheries.* J. Fish. Res. Board Canada. 26:269-278.

Scott, W.B. and E.J. Crossman. 1973. *Freshwater fishes of Canada.* Fish. Res. Bd. 184. 966 pp.

Sprague, J.B. 1964a *Avoidance of Copper-Zinc Solution by Young Salmon in the Laboratory.* J. Water Pollution Control Federation, 36(8):999-1004.

Sprague, J.B. 1964b *Lethal Concentrations of Copper and Zinc for Young Atlantic Salmon.* J. Fish. Res. Board Canada, 21(10):17-26.

Sprague, J.B. 1968. *Avoidance Reactions of Rainbow Trout to Zinc Sulphate Solutions.* Water Research Pergamon Press, Vol. 2:367-372.

Sprague, J.B., P.F. Elson and R.L. Saunders. 1964. *Sublethal Copper-Zinc Pollution in a Salmon River - a Field and Laboratory Study.* Int. J. Air Wat. Pollution 9:531-543.

Sprague, J.B and B.A. Ramsay. 1965. *Lethal Levels of Mixed Copper-Zinc Solutions for Juvenile Salmon.* J. Fish. Res. Board Canada, 22(2):425-432.

Wells, P.G., E. Pessah and W.R. Parker. 1974. *The Toxicity of Raw and Treated Drainage from Heath Steele Mines, New Brunswick, During Period of September - October, 1974.* Toxicity Evaluation Section, Surveillance and Analysis Division, Environmental Protection Service, Atlantic Region Report No. EPS - 5 - AR - 74 - 14. 27 p.

Wood, C.S. 1981. *Baseline Ecological Survey for Heath Steele Mines Limited August - October 1981.* Internal Report No. 410, Ecology Section, Department of Environmental Technology, Centre de Recherche Noranda, Pointe Claire, Quebec. N - 8121 - 10 - T. 27 pp.

Wood, C.S. 1981. *Baseline Ecological Survey for Heath Steele Mines Limited, August-October 1981.* Ecology Section, Department of Environmental Technology, Centre de Recherche Noranda.

Wood, C. 1984. *Biological Survey for Heath Steele, May-August 1984*. Centre de Recherche Noranda. Technical Memorandum No. 185.

Wood, C. 1990. *Centre de Technologie Noranda, Status of the Juvenile Atlantic Salmon Population in the Northwest Miramichi River*, 1990. Report File No. EN1-0301-022.

Zippin, C. 1956. *An Evaluation of the Removal Method of Estimating Animal Populations*. Biometrics. 12:163-189.

APPENDICES

APPENDIX A

Quality Management Plan (QMP)

INTRODUCTION

Appropriate quality assurance and quality control (QA/QC) protocols are essential to ensure that environmental data achieve a high level of quality commensurate with the intended use of the data. This quality management plan (QMP) served as a general set of protocols covering both laboratory and field operations to be used by all members of the EVS-ESP-JWEL consortium. Use of this QMP ensured both a high quality of data as well as uniformity and comparability in the data generated at each study site.

DATA QUALITY OBJECTIVES

For all field and laboratory measurements, data quality objectives (DQOs) have been set where applicable. Data quality objectives are defined by the US EPA as "qualitative and quantitative statements of the level of uncertainty that a decision maker is willing to accept in decisions made with environmental data" (QUAMS; 1986, 1990). The DQOs define the degree to which the total error in the results derived from the data must be controlled to achieve an acceptable confidence in a decision that will be made with the data. In terms of this project, the AETE committee has already stipulated that analytical measurements will achieve a detection limit of 1/10 that of the CCME guidelines for protection of the aquatic environment. The quality control officer ensured that the required detection limits were made known to the analytical laboratory well in advance. In this way, the correct methodology, volume of samples and methods of preservation were established before the field work was underway. Detection limits for field instruments (Hydrolab, YSI etc.) and the gravimetric measurements for biological analyses (e.g. fish organ weights) were also sent to each team.

QUALITY CONTROL OFFICER

The quality control officer (QCO) for the project (Ms. Monique Dubé) has the following responsibilities:

- to ensure that all data quality objectives are known to both field personnel and the chosen analytical laboratory
- to ensure that standard operating procedures (SOPs) are followed for each field component at each study site
- to ensure that both the toxicity and analytical laboratories follow established SOPs for each analysis
- to ensure the all analyses were under statistical control during each analytical run. This requires that the quality control data for each analysis be reviewed and compared with historic control

limits to be requested from the analytical and toxicity laboratories. The QC data will include percent recoveries of spiked samples, and results for blanks, replicates and certified reference materials. Logical checks of the data will also be conducted, especially for toxicity.

The quality control officer (QCO) has authority for requiring corrective actions (e.g., repetition of the analysis) if the SOPs were not followed or the analytical systems were not under control. The QCO will also be made aware of all outliers.

FIELD PROTOCOLS FOR WATER, SEDIMENT AND BENTHIC SAMPLING

RESPONSIBILITIES AND TRAINING

For each field team, a team leader was chosen with authority to make decisions in the field related to implementation of the study plan. The team leader was responsible for ensuring that all field personnel were trained and competent in use of each field instrument, that all SOPs were followed and that adequate heath and safety measures were followed.

STANDARD OPERATING PROCEDURES

Whenever feasible, water, sediment and benthic samples were taken at the same sampling stations. The location of each station was recorded either as a GPS reading or with reference to a large scale map and known landmarks. The location of each station was known to the nearest 20 m. At each station the field information to be reported included:

- station location
- date and time
- field crew members
- habitat descriptions
- sampling methods
- depth
- wind and climatic conditions
- water temperature
- substrate type (sand/gravel/cobble/silt/clay)
- water velocity (rivers)

This information was recorded on field data sheets.

BENTHIC SAMPLING

Benthic collections were made by Eckman, standard (or petite) ponar grab, Hess sampler, Surber sampler or hand-inserted core tubes depending on substrate type. The Eckman is used primarily on soft sediments in deep water (>2 m), although a pole mounted version can be used in harder substrates and shallower waters. The ponar grab is used for substrates consisting of hard and soft sediments such as clay, hard pan, sand, gravel and mud where penetration of the substrate by the sampler is possible. The standard ponar is set with a spring loaded pin, lowered to the bottom and allowed to penetrate the substrate. When the ponar penetrates the sediment, the pin is released and the jaws are allowed to close on the sediment sample when the sampler is withdrawn. The ponar (plus sample) is then pulled through the water column and placed in a plastic basin on the bottom of the boat. Because of the weight of the standard ponar a frame and electrically driven winch should be used to raise and lower the grab. After the sample has been removed and whenever the ponar is not being used, the safety pin must be inserted into the lever bar to prevent the bar from closing on the operator. Care must also be taken when using the winch to avoid catching hands and clothes. The petit ponar is considerably lighter, safer and easier to use. A winch may not be necessary under most conditions.

Both the Eckman and ponar samplers were made of stainless steel rather than brass. The choice of using an Eckman or ponar sampler depends on the nature of the sediment and the depth of the water column. In hard sediments, use of the Eckman sampler is limited as penetration is poor. The pole mounted Eckman is able to penetrate some hard substrate, but its use is limited to shallow depths. If sediments are very soft, the Eckman may be preferable to the ponar because the latter tends to fill entirely with sediments, thereby obliterating the sediment-water interface. At depths greater than 20 m the ponar may be more successful because of its greater weight and stability in the water column. If both samplers are available, a certain amount of trial and error may be required to determine the most appropriate sampler.

The Surber sampler was used in shallow (<32 cm), flowing waters on rocky substrates where a grab sample cannot be taken. The Surber sampler consists of two square frames hinged together; one frame rests on the surface while the other remains upright and holds a nylon collecting net and bucket. A base extension is used when sampling areas of fine, loose sediments or rubble. The base frame fits into the base extension which is pushed into the sediments to decrease the lateral movement of invertebrates out of the area to be sampled. The sampler is positioned with its net mouth open facing upstream. When in use, the two frames are locked at right angles, the base frame (and base extension) marking off the area of substrate to be sampled and the other frame supporting a net to strain out organisms washed into it from the sample area.

The Hess sampler is especially useful for sampling gravel and cobble bottoms in streams. The Hess sampler consists of a stainless steel cylinder with two large windows and a pair of handles for pushing the cylinder while rotating it into the gravel or cobble. Penetration depths of 75 or 150 mm can be varied by attaching the handles to either end of the sampler. Water flows in through the upstream window of the Hess sampler and out through the downstream window and into the collecting net and bucket.

General operating procedures for the Surber and Hess samplers were as follows:

- Position the sampler securely to the bottom substrate, parallel to the water flow with the net pointing downstream.
- The sampler is brought down quickly to reduce the escape of rapidly-moving organisms.
- There should be no gaps under the edges of the frame that would allow for washing of water under the net and loss of benthic organisms. Eliminate gaps that may occur along the edge of the Hess/Surber sampler frame by shifting of rocks and gravel along the outside edge of the sampler.
- To avoid excessive drift into the sampler from outside the sample area, the substrate upstream from the sampler should not be disturbed.
- Once the sampler is positioned on the stream bottom, it should be maintained in position during sampling so that the area delineated remains constant.
- Hold the sampler with one hand or brace with the knees from behind.
- Heavy gloves should be required when handling dangerous debris; for example, glass or other sharp objects present in the sediment.
- Turn over and examine carefully all rocks and large stones and rub carefully in front of the net with the hands or a soft brush to dislodge the organisms and pupal cases, etc., clinging to them before discarding.
- Wash larger components of the substrate within the enclosure with stream water; water flowing through the sampler should carry dislodged organisms into the net.
- Stir the remaining gravel and sand vigorously with the hands to a depth of 5-10 cm where applicable, depending upon the substrate, to dislodge bottom-dwelling organisms.
- It may be necessary to hand pick some of the heavier mussels and snails that are not carried into the net by the current.
- Remove the sample by washing out the sample bucket, if applicable, into the sample container (wide-mouthed jar) with 10% buffered formalin fixative.

- Examine the net carefully for small organisms clinging to the mesh, and remove them (preferably with forceps to avoid damage) for inclusion in the sample.

- Rinse the sampler net after each use.

In the case of soft sediments at shallow depths, plastic core tubes (2.5 " ID) can be inserted by hand into the sediments. Stoppers are placed at each end as the tube is withdrawn.

Sieving of Benthic Samples

Samples were sieved in the field using a mesh size of 250 µm, and preserved with sufficient buffered formalin to produce a 10 % concentration. If further sieving was required (e.g., 500 µm sieve) to allow for data collected to be comparable across studies, then this additional step was done in the field, and both sized fractions were preserved and identified.

Quality Control Protocols for Benthic Identification

Invertebrate samples were sorted on a low power microscope and keyed to the generic level. A reference collection of identified organisms will be maintained for both the receiving and reference environments. Taxonomy will be verified by an independent expert. Sorting efficiency will be estimated by recounts of the sorted material on 10% of the samples. If subsampling is deemed necessary, an estimate will be made of the subsampling error. All unsorted and sorted fractions of the samples will be retained until taxonomy and sorting efficiency are confirmed. All data transcriptions will be checked for accuracy.

WATER CHEMISTRY

As indicated in the study plan, water quality samples were taken as grab samples at 12 sampling stations plus the effluent. In shallow receiving environments (<2m) 1 grab sample was collected at the surface from each station with clean bottles prepared by the analytical laboratory. Samples were collected by removing the cap below the surface (approximately 15 cm depth) to avoid any surface contamination. Latex (or nitryl) gloves were used during this procedure to avoid all contamination. In deeper receiving environments (> 2 m), one sub-surface grab were collected at each station using a Van Dorn-type sampler. Separate samples will be collected for total and dissolved metals. The dissolved sample will be field filtered according to standard methods (APHA 1995 -Section 3030B). Both metals samples (total and dissolved) were acidified with ultrapure HNO_3 (provided by the analytical laboratory) to a pH <2. Samples were also taken in separate bottles for analysis of other water quality parameters.

Field measurements of temperature, conductivity, dissolved oxygen and pH were also taken at each station using a Hydrolab H_20 or YSI meters. The analytical methods for calibration and use of each field instrument were those outlined in each respective instruction manual. A log was kept of each field instrument indicating its usage and any problems encountered. In using an oxygen electrode, care was taken to change the membrane on a regular basis, or if it became dried out, torn or damaged in any way. Certain chemicals found in effluent discharge can interfere with oxygen measurements. Conductivity was used where appropriate to characterize mixing zones and exposure zones. All values including calibration readings were recorded on the field sheets.

Quality Control Protocols for Water Chemistry

At each mine site quality control samples for water chemistry included collection and analysis of one transport or trip blank, one filter blank and one field replicate (collected at the exposure station). If subsurface samples were collected using a Van Dorn-type sampler, then a sampler blank were also collected. The transport blank and filter blank water were provided by the analytical laboratory. The transport blank consisted of a sample bottle filled with distilled deionized water in the laboratory. The transport blank was brought to the field, opened, then shut immediately. A filter blank consisted of a field-filtered sample of distilled, deionized water provided by the analytical laboratory. When a van Dorn type bottle was used to collect samples, a sampler blank was also taken in which distilled, deionized water was poured into the sampler and then taken as a normal sample. One field replicate from a station in the affected area was taken using a separate bottle and separate filtration. These field QC samples were excusive of those analysed routinely in the laboratory as part of normal laboratory QC.

QC Requirements for Choice of an Analytical Laboratory

A common analytical laboratory was selected for all three regions (West, Ontario, East). The laboratory was certified by CAEAL and the project QCO ensured that the laboratory followed these quality control practices :

- Written (or referenced) SOPs for each analytical system
- Instrument calibration and maintenance records
- Clearly enunciated responsibilities of Q/A officer
- Adequate and training of personnel
- Good Laboratory Practices (GLPs)
- Sample preservation and storage protocols
- Sample tracking system (e.g., LIMS system)
- Use of QC samples to ensure control of precision and accuracy (Blanks, replicates, spikes, certified reference materials (minimum effort should be 15-20%)
- Maintenance of control charts and control limits on each QC sample
- Data handling and reporting (blanks, replicates, spike recovery, significant figures)
- Policy for reporting low level data (e.g., ASTM L,W)
- Participation in external audits and round robbins.

The QCO requested that all QC data (including control limits) be contained in the analytical reports and ensured that all analytical runs were under statistical control at the time of analysis. The QCO also ensured that the analytical laboratory attained the required detection limits or had a valid technical reason when these limits were not attained. These values were flagged in the analytical report. The QCO examined all outliers and can request repeat analysis if the data are questionable.

SEDIMENT SAMPLING

Sediment samples were collected only if a station had an area > 1 m^2 of depositional habitat. If not, detailed notes on the site were made and pictures taken to provide evidence that the station was not suitable for sediment collection (This information is important to indicate the occurrence or the non-occurrence of depositional sediments for the sediment toxicity testing in the 1997 field program). The sampling device to be used (Eckman or ponar samplers) depended on the nature of the substrate and depth of water (see benthic sampling). Again, all sampling devices were of stainless steel construction. Only the upper two cm of the sediment column were used and the sampler penetration was a minimum of 4-5 cm depth to ensure the upper two cm was not disturbed. One composite sediment sample, consisting of five grab samples was collected per station. The upper two cm of substrate from each of the 5 grabs were placed in a glass or plastic mixing bowl. The composite sample was then homogenized in the bowl with a plastic spoon. Sample jars provided by the laboratory (i.e., pre-cleaned glass with teflon-lined lids) were filled to the top to minimize air space. Duplicate jars were collected at all stations in case of breakage and suspected contamination.

Quality Control Protocols for Sediment Sampling

The following guidelines were used to determine the acceptability of a grab sample: a) the sampler is not over-filled, b) overlying water is present indicating minimal leakage, c) overlying water is not excessively turbid indicating minimal disturbance, d) the desired penetration depth is achieved (i.e., 4-5 cm for a 2 cm deep surficial sample). If any of the above criteria were not met, the sample was rejected. The samples were placed in sample jars provided by the analytical laboratory (precleaned glass, teflon lined lids). The grab samplers were cleaned between stations using a phosphate-free detergent wash and a rinse with deionized water. The plastic utensils and bowls were cleaned between sampling stations using the following protocol: 1) a water rinse, 2) a phosphate-free soap wash, 3) a deionized water rinse, 4) a 5% HNO_3 rinse and 5) a final rinse in deionized water. Three swipe blanks were collected, each in the reference and affected areas, to determine the effectiveness of field decontamination procedures. The swipes consisted of acid-wetted, ashless filter paper wiped along the inside of the sampler and mixing bowl/spoon surfaces that are likely to contact sample media. These samples were placed in whirl-pack bags and sent to the analytical laboratory for extraction and metals analysis. One of the duplicate samples taken at each station was analyzed as a field replicate.

All samples were cooled and shipped to the designated laboratory for analysis. Each sample was analyzed for site specific metals, total organic carbon (TOC), particle size and loss on ignition. The quality control procedures to be followed by the analytical laboratory and the review of the quality of the data were the same as outlined above for the water quality parameters.

Toxicity Samples

The laboratory (B.A.R.) has already been chosen for the sublethal toxicity analyses. The samples were taken with sample pails provided by the laboratory. The procedures for effluent sampling followed those outlined in the document *Aquatic Effects Technology Evaluation Program Project #4.1.2a Extrapolation Study*. B.A.R. is expected to comply with the following QA/QC protocols:

- Written or referenced SOPs for each test
- Adequate training of personnel
- Appropriate instrument calibration and maintenance
- GLPs
- Dilution water controls
- Test record sheets
- Dose selection
- Reference toxicants
- Control charts
- Adequate data handling and reporting procedures.

The QCO will review all the reports and determine whether the reference toxicants fall within control limits, control mortality is limited etc.

Fish Samples

Metallothionein and metals analysis were, where possible and appropriate, conducted on a minimum of 8 fish of 2 species at both the reference and exposure areas (total of 32 fish for each mine site). Where possible, 4 females and 4 males of each species were collected. Only fish collected for metallothionein and metals analysis were sacrificed in the study and all measurements were conducted on these fish. No field splitting of organs for metallothionein and metals analysis (kidney, gill, liver) was done with whole tissue samples forwarded to Dr. Klaverkamp's laboratory for processing and handling. Where fish larger than 20 cm were not available, whole fish (i.e., 10-15 cm length) were used for analyses with no dissection of fish attempted. Fish smaller than 10 cm were not targetted for metallothionein and metals analysis. Tissue and whole fish samples were frozen on dry ice and forwarded to the laboratory for analysis.

Standard operating procedures for gill netting, trap netting and backpack electrofishing are presented below. The maximum effort to be expended on electrofishing was 1 full day per station (reference and exposed; total 2 days). The maximum fishing effort for gill netting was 2 days per station (reference and exposed; total 4 days). Gill nets were checked frequently to collect living fish.

Protocol for Gill Netting

The protocol employed during gill netting was as follows:

1) Individual panels of various mesh sizes were assembled to comprise a gang of nets of required sizes. The order of assembly of sizes was the same for each gang. A bridle was attached to each end, and anchor/float lines were attached to the bridle appropriate for the water depth in which the nets were deployed. The section of rope between the anchor and the bridle was of sufficient length that the anchor could be placed on bottom before any netting is deployed.

2) Netting locations were selected that were free of major bottom irregularities or obstructions (steep drop-offs, tree stumps, etc). Upon selection of the preferred site, the net was deployed in a continuous fashion along the selected route. Care was taken to avoid tangles or twists of the net, and to ensure that marker buoys at each end were visible (i.e., above water) after setting. Water temperatures were taken on the bottom and at 2 m above the bottom at each end of the net if other than isothermal conditions were present. The location and orientation of the net relative to shoreline features were marked on an appropriate map and/or obtained by electronic positioning equipment (GPS). The above noted information, the water depth at each end of the net, the date, time of day and other relevant information (wind direction and weather conditions, wave height, etc) were recorded in the field book for each netting location.

3) Upon retrieval, the same information as noted above (as applicable) was recorded. All fish collected were identified and enumerated. Those fish not required for further testing/analysis were live released provided they were in good condition. The remaining fish were analyzed, packaged and preserved, or disposed of according to the requirements of the sampling program.

Protocol for Trap Netting

The protocol for trap netting was as follows:

1) Prior to use in the water, the net was spread out on land and examined for holes and signs of excessive wear (broken and/or frayed lines or attachment points) if the condition of the net could not be determined from previous users. The lead, wings, house and all attachment lines were examined, as well as the house access point opening. All damages were repaired, the house opening was secured and the net was repacked to facilitate ease of deployment.

2) Netting sites were selected that are relatively smooth bottomed, of a substrate suitable for anchoring (i.e. mud, sand, and/or gravel; smooth bedrock not suitable) and free of major irregularities (large boulders, tree stumps or snags, etc.). If water visibility permitted, the selected location was examined from above to confirm its suitability.

3) The net was set perpendicular to shore such that the lead was in shallow water near shore and the house was in deeper water offshore. The net was continuously deployed from the bow of the boat, while backing offshore, until all parts of the net and all anchors were in the water. Upon setting the house anchor, the net was then tensioned. The wing anchors were then lifted and repositioned such that the wings were aligned at a 45° angle to the lead, and lightly tensioned. The date, time of day, water temperature and other appropriate information were recorded in the field book.

4) When servicing the net, the house float was lifted and the boat was pulled under the anchor line between the house and the house anchor. The boat was then manually pulled sideways to the house of the net, which was then passed over the boat until all fish were concentrated at the near shore end of the house. The house access point was then opened and the fish were removed, identified and enumerated. The fish required for analysis were retained, while the remainder were released live. The catch and the ancillary environmental data (as above) were recorded in the field book. The house opening was then closed and the boat backed out from beneath the net. Anchors were lifted and reset to re-tension the net as required.

Protocols for Back-Pack Electrofishing

The operators of the electrofishing gear will follow procedures outlined in standard fisheries text books. Before the electrofishing operations began, the amount of effort, either by distance, time or desired sample size was agreed upon in order to calculate catch per unit effort.

Health and safely procedures were followed strictly. These are also outlined in standard text books.

Analysis of Fish

At least 8 (preferably adult) fish of each sentinel species were, where possible and appropriate, collected from the reference and exposure areas. The biological variables measured on large (i.e., >20 cm) fish included, where possible and appropriate:

- fork length
- fresh weight
- external/internal conditions
- sex
- age
- gonad weight
- kidney weight
- egg size and mass (if appropriate)
- liver weight

No internal variables were measured on fish of less than 20 cm in length. Information on each fish species were recorded on the data logging sheets provided.

Length was measured to the nearest ±2 mm. Fork length is the length from the tip of the snout to the depth of the fork in the tail. Fish were towel dried and weighed to the nearest 1 g or 5% of total body weight.

An external examination was conducted for lumps and bumps, secondary sexual characteristics, missing fins or eyes, opercular, fin or gill damage, external lesions, presence of parasites, and other anomalous features. All external lesions were recorded as to position, shape, size, colour, depth, appearance on cut surface and any other features of note. Photographs were taken of lesions to aid in their interpretation. The external conditions were assessed according to the health assessment index of Adams et al. (1993); or Goede (1993) on data logging sheets.

Age were determined by the appropriate structure (scales, otoliths, pectoral spines) following established protocols. A single person (John Tost; North Shore Environmental) will perform the age determinations on all the fish. Aging structures were archived for future reference. Fish age will be confirmed by a second expert (minimum 10%).

The body cavity were opened to expose the internal organs. The internal examination of each fish included the recording and/or photographing of evident tumors, neoplasms and lesions in major organs including the liver and skin. The internal conditions will be assessed according to the health assessment index of Adams et al. (1993) or Goede and Barton (1990) on data logging sheets.

All internal organs were examined for lumps, bumps or abnormal features. The lower intestine and oesophagus were cut to allow total removal of the gastrointestinal tract. The liver was removed and weighed on pre-weighed aluminum pans. The liver samples must be weighed immediately to avoid loss of water. Care was taken to avoid rupturing the gall bladder and to remove the spleen before weighing. If the liver tissue was diffuse, it was teased from the intestines starting from the posterior and proceeding anteriorly. The liver was weighed, divided in half and frozen in separate plastic bags for metals and metallothionein analysis (see latest protocols from AETE).

The gonads were removed from the dorsal wall of the body cavity from the anterior to the posterior and weighed on a pre-weighed pan to the nearest 0.01 g or ±1% of the total organ weight. Care was taken to remove external mesenteries and visceral lipid deposits before weighing the gonads; gonadal membranes, however, remained intact. Egg volume and mass were measured on fresh eggs. One hundred eggs were counted in a stereoscopic microscope and added to a small graduated cylinder containing a known volume of water. The cylinder was placed on a balance so that the mass of the 100 eggs could be measured. The volume of the eggs was then determined from the displacement of the water in the cylinder.

The kidneys were removed by making lengthwise incisions along each edge of the tissue and then detached using the spoon end of a stainless steel weighing spatula by applying firm but gentle pressure against the upper abdominal cavity wall (dorsal aorta). In this procedure the kidney was scraped away from the dorsal aorta and associated connective tissue. The kidney was divided in half, placed in separate whirlpack bags and frozen on dry ice for both metals and metallothionein analysis.

The gills arches and attached filaments were removed by severing the dorsal and ventral cartilaginous attachment of the arches to the surrounding oral cavity. The gill arches were placed in whirlpack bags and frozen on dry ice for metals and metallothionein analysis.

REFERENCES

Adams, S.M., A.M. Brown and R.W. Goede. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. Transactions of the American Fisheries Society. 122:63-73.

APHA (American Public Health Association). 1995. Standard methods for the examination of water and wastewater. APHA, American Water Works Association, Water Environment Federation.

Goede, R.W. 1993. Fish health/condition assessment procedures. Utah Division of Wildlife Resources, Fisheries Experiment Station, Logan, UT.

APPENDIX B

Selected Site Photographs

Photographs
Northwest Miramichi River
Reference Area
Heath Steele Mine

Photo 1: Starting Point of Habitat Assessment, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 2: Station HS-R1 in Habitat Unit 1, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 3: Substrate of Station HS-R1, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 4: Downstream of Station HS-R1, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 5: Station HS-R2 in Habitat Unit 1, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 6: Station HS-R3 in Habitat Unit 1 50 m Upstream of Payne Bridge, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

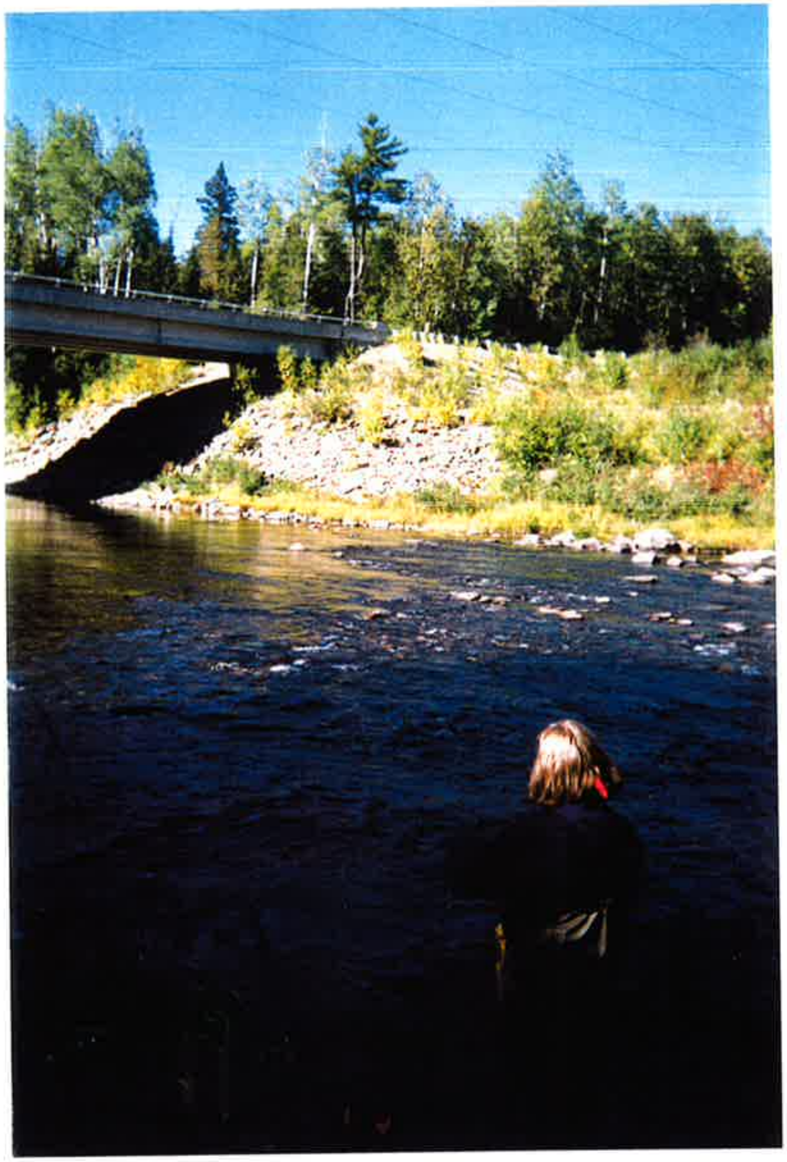


Photo 7: Station HS-R4 in Habitat Unit 3, 50 m Downstream of Payne Bridge, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 8: Station HS-R5 in Habitat Unit 3, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 9: Substrate at Station HS-R5, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 10: Downstream of Station HS-R5, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photo 11: Station HS-R6 in Habitat Unit 3, Northwest Miramichi River, Sept. 22, 1996, Reference Area, Heath Steele Mine

Photographs
Tomogonops River
Exposure Area
Heath Steele Mine

Photo 12: Station HS-E1 Facing Upstream, Tomogonops River, September 22, 1996, Exposure Area, Heath Steele Mine

Photo 13: Station HS-E1 Facing Downstream, Tomogonops River, September 22, 1996, Exposure Area, Heath Steele Mine

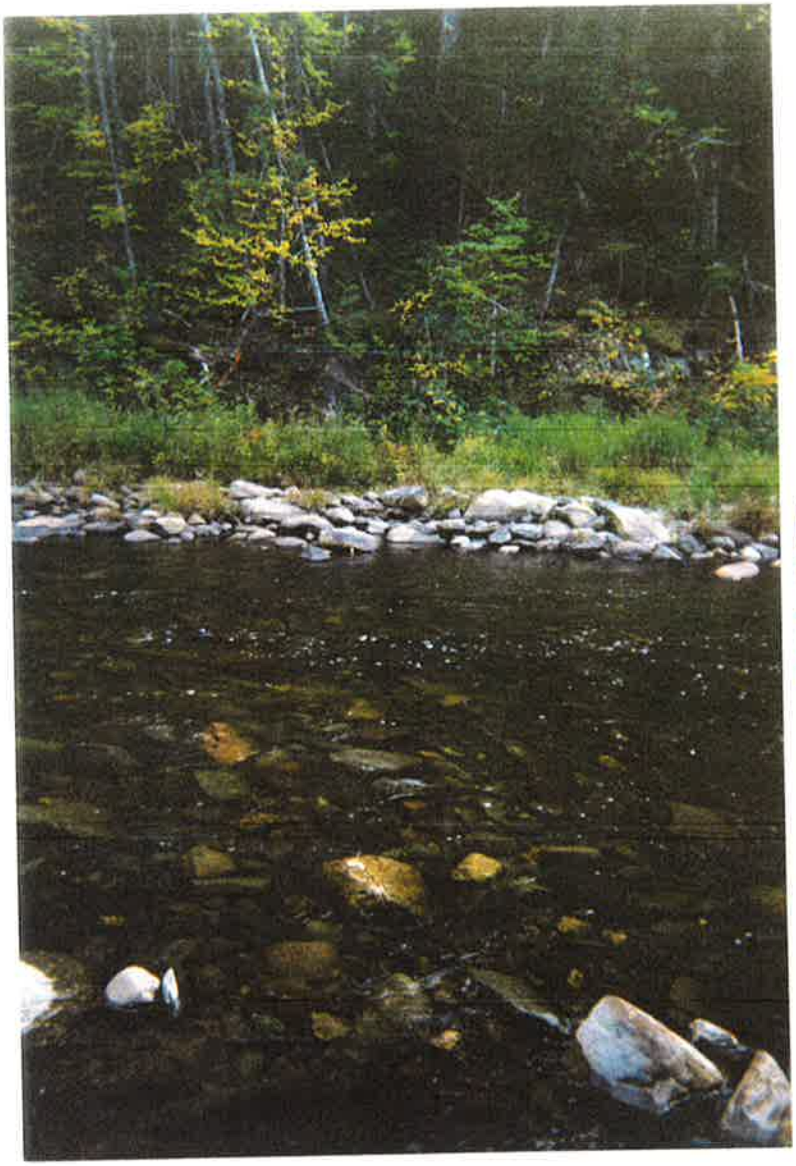


Photo 14: Station HS-E2 in Habitat Unit 4, Tomogonops River, September 22, 1996, Exposure Area, Heath Steele Mine

Photo 15 Station HS-E3 in Habitat Unit 4, Tomogonops River, September 22, 1996, Exposure Area, Heath Steele Mine

Photo 16: Downstream of Station HS-E3, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

Photo 17: Station HS-E4 in Habitat Unit 4, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

Photo 18: Substrate at Station HS-E4, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

Photo 19: Station HS-E5 in Habitat Unit 6, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

Photo 20: Substrate of Station HS-E5, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

Photo 21: Station HS-E6 in Habitat Unit 8, Tomogonops River, September 22, 1996, Exposure Area, Heath Steele Mine

Photo 22: Substrate at Station HS-E6, Tomogonops River
September 22, 1996, Exposure Area, Heath Steele Mine

APPENDIX C

Water Quality and Chemistry

C.1 Detailed Methods

MDS
Environmental Services Limited

Client:	Jacques Whitford Environment Ltd. P.O. Box 1116 711 Woodstock Road Fredericton, NB, CANADA E3B 5C2	Date Submitted: Date Reported: MDS Ref#: MDS Quote#:	September 25/96 November 1/96 966621 96-697-GS
Fax:	506-452-7652	Client Ref#: Sampled By:	Heath Steele Monique Dube
Attn:	Monique Dube		

Certificate of Analysis

Analysis Performed:

Alkalinity
Anions(Cl,NO2,NO3,o-PO4 & SO4)
RCAP MS Package, 8 Element ICPAES Scan
Reactive Silica
RCAP MS Package, 22 Element ICP-MS Scan
RCAP Calculations
Manual Conventionals(pH,Turbidity,Conductivity,Color)
Ammonia
Total Kjeldahl Nitrogen, Digestion Required
Dissolved Inorganic Carbon, as Carbon(Autoanalyzer)
Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Total Suspended Solids
Acid Digestion

Methodology:

1) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
2) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1,
365.1 and 375.4.

6850 Goreway Drive, Mississauga, Ontario, Canada

Client: Jacques Whitford Environment Ltd.
P.O. Box 1116
711 Woodstock Road
Fredericton, NB, CANADA
E3B 5C2
Fax: 506-452-7652

Attn: Monique Dube

Date Submitted: September 25/96
Date Reported: November 1/96
MDS Ref#: 966621
MDS Quote#: 96-697-GS

Client Ref#: Heath Steele
Sampled By: Monique Dube

Certificate of Analysis

Methodology: (Cont'd)

3) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
   U.S. EPA Method No. 200.7
4) Analysis of silicon in water by ICPAES and conversion to silica.
   Standard Methods(17th ed.) No. 4500-Si G
5) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
   U.S. EPA Method No. 200.8(Modification)
6) Determination of theoretical RCAP parameters by calculation.
   EPL Internal Reference Method
7) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
   U.S. EPA Method No. 150.1, 120.1, 180.1
   and 110.3
8) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
   ASTM Method No. D1426-79 C
   Refer - Method No. 1100106 Issue 122289

Client: Jacques Whitford Environment Ltd.
P.O. Box 1116
711 Woodstock Road
Fredericton, NB, CANADA
E3B 5C2
Fax: 506-452-7652

Attn: Monique Dube

Date Submitted:	September 25/96
Date Reported:	November 1/96
MDS Ref#:	966621
MDS Quote#:	96-697-GS
Client Ref#:	Heath Steele
Sampled By:	Monique Dube

Certificate of Analysis

Methodology: (Cont'd)

9) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
   ASTM Method No. D3590-84AFD
   Refer - Method No. 1100106 Issue 122289
10) The determination of dissolved inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
   MOE Method No. ROM - 102AC2.1
   (Refer Method No. 1102106 Issue 122989)
11) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
   MOE Method No. ROM - 102AC2
   Refer - Method No. 1102106 Issue 122989
12) The determination of Total Suspended Solids by weight.
   U.S. EPA Method No. 160.2
13) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
   U.S. EPA Method No. 3020

MDS
Environmental Services Limited

Client:	Jacques Whitford Environment Ltd. P.O. Box 1116 711 Woodstock Road Fredericton, NB, CANADA E3B 5C2	Date Submitted: Date Reported: MDS Ref#: MDS Quote#:	September 25/96 November 1/96 966621 96-697-GS
Fax:	506-452-7652	Client Ref#: Sampled By:	Heath Steele Monique Dube
Attn:	Monique Dube		

Certificate of Analysis

Instrumentation:

1) Cobas Fara Centrifugal Analyzer
2) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
3, 4) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
5) PE Sciex ELAN 6000 ICP-MS Spectrometer
6) Calculation from existing results; no instrumentation required.
7) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
8) Skalar Segmented Flow Analyzer, Model SA 20/40
9,10,11) Technicon Autoanalyzer
12) Precision Mechanical Convention Oven/Sartorius Basic Balance
13) Thermolyne Hotplate/Hot Block

Sample Description: Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

Results: Refer to REPORT of ANALYSIS attached.

Certified By
Samar Habash
Service Manager

Certified By
M. Hartwell, M.Sc.
Director, Laboratory Operations

C.2 QA/QC

MDS Environmental Services Limited.

Certificate of Quality Control

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Date Reported: November 1/96
MDS Ref # : 966621
MDS Quote#: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele Mine

Parameter	SAMPLE ID (spike)	LOQ	Units	Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
				Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	100	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	112	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	HS-R1	0.05	mg/L	nd(b)	0.1	yes	109	88	114	yes	0.33	0.30	0.18	0.42	yes	yes
Nitrite(as N)	na	0.01	mg/L	nd(b)	0.03	yes	84	80	116	yes	na	na	na	na	na	yes
Orthophosphate(as P)	HS-R1	0.01	mg/L	nd(b)	0.03	yes	103	90	110	yes	1.00	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	104	90	113	yes	na	na	na	na	na	yes
Boron	HS-E3 @Total.UNF	0.005	mg/L	nd(b)	0.02	yes	109	85	115	yes	1.04	1.00	0.60	1.40	yes	yes
Boron	HS-R1	0.005	mg/L	nd(b)	0.02	yes	108	85	115	yes	1.09	1.00	0.60	1.40	yes	yes
Calcium	HS-E3 @Total.UNF	0.1	mg/L	nd(b)	0.2	yes	110	85	115	yes	*	*	*	*	*	yes
Calcium	HS-R1	0.1	mg/L	nd(b)	0.2	yes	99	85	115	yes	1.3	1.0	0.2	1.8	yes	yes
Iron	HS-E3 @Total.UNF	0.02	mg/L	nd(b)	0.03	yes	109	85	115	yes	1.05	1.00	0.60	1.40	yes	yes
Iron	HS-R1	0.02	mg/L	nd(b)	0.03	yes	103	85	115	yes	1.07	1.00	0.60	1.40	yes	yes
Magnesium	HS-E3 @Total.UNF	0.1	mg/L	nd(b)	0.2	yes	109	85	115	yes	1.2	1.0	0.2	1.6	yes	yes
Magnesium	HS-R1	0.1	mg/L	nd(b)	0.2	yes	102	85	115	yes	1.2	1.0	0.2	1.6	yes	yes
Phosphorus	HS-E3 @Total.UNF	0.1	mg/L	nd(b)	0.2	yes	104	85	115	yes	1.0	1.0	0.4	1.6	yes	yes
Phosphorus	HS-R1	0.1	mg/L	nd(b)	0.2	yes	103	85	115	yes	1.0	1.0	0.4	1.6	yes	yes
Potassium	HS-E3 @Total.UNF	0.5	mg/L	nd(b)	1.0	yes	104	85	115	yes	5.4	5.0	1.0	8.0	yes	yes
Potassium	HS-R1	0.5	mg/L	nd(b)	1.0	yes	101	85	115	yes	6.6	5.0	1.0	8.0	yes	yes
Sodium	HS-E3 @Total.UNF	0.1	mg/L	nd(b)	0.2	yes	97	85	115	yes	0.6	1.0	0.2	1.6	yes	yes
Sodium	HS-R1	0.1	mg/L	nd(b)	0.2	yes	104	85	115	yes	1.3	1.0	0.2	1.6	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Date Reported: November 1/96
MDS Ref # : 966621
MDS Quote#: 96-697-GS

Client Ref#: Heath Steele Mine

Analysis of Water

Parameter	SAMPLE ID (spike)	LOQ	Units	Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
				Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
Zinc	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.02	yes	106	85	115	yes	1.04	1.00	0.60	1.40	yes	yes
Zinc	HS-R1	0.002	mg/L	nd(b)	0.02	yes	100	85	115	yes	1.08	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	99	80	120	yes	na	na	na	na	na	yes
Aluminum	HS-E3 @Total.UNF	0.01	mg/L	nd(b)	0.03	yes	103	85	115	yes	0.09	0.100	0.050	0.140	yes	yes
Aluminum	HS-R1	0.01	mg/L	nd(b)	0.03	yes	104	85	115	yes	0.10	0.100	0.050	0.140	yes	yes
Antimony	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	96	85	115	yes	0.095	0.100	0.050	0.140	yes	yes
Antimony	HS-R1	0.002	mg/L	nd(b)	0.004	yes	100	85	115	yes	0.097	0.100	0.050	0.140	yes	yes
Arsenic	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	97	85	115	yes	0.096	0.100	0.050	0.140	yes	yes
Arsenic	HS-R1	0.002	mg/L	nd(b)	0.004	yes	101	85	115	yes	0.119	0.100	0.050	0.140	yes	yes
Barium	HS-E3 @Total.UNF	0.005	mg/L	nd(b)	0.01	yes	97	85	115	yes	0.094	0.100	0.050	0.140	yes	yes
Barium	HS-R1	0.005	mg/L	nd(b)	0.01	yes	102	85	115	yes	0.099	0.100	0.050	0.140	yes	yes
Beryllium	HS-E3 @Total.UNF	0.005	mg/L	nd(b)	0.01	yes	89	85	115	yes	0.089	0.100	0.050	0.140	yes	yes
Beryllium	HS-R1	0.005	mg/L	nd(b)	0.01	yes	96	85	115	yes	0.124	0.100	0.050	0.140	yes	yes
Bismuth	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	95	85	115	yes	0.097	0.100	0.050	0.140	yes	yes
Bismuth	HS-R1	0.002	mg/L	nd(b)	0.004	yes	99	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Cadmium	HS-E3 @Total.UNF	0.0005	mg/L	nd(b)	0.0010	yes	95	85	115	yes	0.0941	0.100	0.050	0.140	yes	yes
Cadmium	HS-R1	0.0005	mg/L	nd(b)	0.0010	yes	101	85	115	yes	0.1020	0.100	0.050	0.140	yes	yes
Chromium	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	94	85	115	yes	0.093	0.100	0.050	0.140	yes	yes
Chromium	HS-R1	0.002	mg/L	nd(b)	0.004	yes	101	85	115	yes	0.101	0.100	0.050	0.140	yes	yes
Cobalt	HS-E3 @Total.UNF	0.001	mg/L	nd(b)	0.002	yes	94	85	115	yes	0.091	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Date Reported: November 1/96
MDS Ref # : 966621
MDS Quote#: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele Mine

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Cobalt	HS-R1	0.001	mg/L	nd(b)	0.002	yes	101	85	115	yes	0.103	0.100	0.050	0.140	yes	yes
Copper	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	93	85	115	yes	0.089	0.100	0.050	0.140	yes	yes
Copper	HS-R1	0.002	mg/L	nd(b)	0.004	yes	102	85	115	yes	0.102	0.100	0.050	0.140	yes	yes
Lead	HS-E3 @Total.UNF	0.0001	mg/L	0.0001(b)	0.002	yes	96	85	115	yes	0.0983	0.100	0.050	0.140	yes	yes
Lead	HS-R1	0.0001	mg/L	0.0002(b)	0.002	yes	101	85	115	yes	0.1080	0.100	0.050	0.140	yes	yes
Manganese	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	95	85	115	yes	0.093	0.100	0.050	0.140	yes	yes
Manganese	HS-R1	0.002	mg/L	nd(b)	0.004	yes	102	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Molybdenum	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	96	85	115	yes	0.097	0.100	0.050	0.140	yes	yes
Molybdenum	HS-R1	0.002	mg/L	nd(b)	0.004	yes	100	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Nickel	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	95	85	115	yes	0.089	0.100	0.050	0.140	yes	yes
Nickel	HS-R1	0.002	mg/L	nd(b)	0.004	yes	101	85	115	yes	0.101	0.100	0.050	0.140	yes	yes
Selenium	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	94	85	115	yes	0.093	0.100	0.050	0.140	yes	yes
Selenium	HS-R1	0.002	mg/L	nd(b)	0.004	yes	98	85	115	yes	0.118	0.100	0.050	0.140	yes	yes
Silver	HS-E3 @Total.UNF	0.0003	mg/L	nd(b)	0.0006	yes	100	85	115	yes	0.1100	0.100	0.050	0.140	yes	yes
Silver	HS-R1	0.0003	mg/L	nd(b)	0.0006	yes	103	85	115	yes	0.0941	0.100	0.050	0.140	yes	yes
Strontium	HS-E3 @Total.UNF	0.005	mg/L	nd(b)	0.01	yes	98	85	115	yes	0.098	0.100	0.050	0.140	yes	yes
Strontium	HS-R1	0.005	mg/L	nd(b)	0.01	yes	102	85	115	yes	0.083	0.100	0.050	0.140	yes	yes
Thallium	HS-E3 @Total.UNF	0.0001	mg/L	nd(b)	0.0002	yes	99	85	115	yes	0.0983	0.100	0.050	0.140	yes	yes
Thallium	HS-R1	0.0001	mg/L	nd(b)	0.0002	yes	102	85	115	yes	0.1060	0.100	0.050	0.140	yes	yes
Tin	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	94	85	115	yes	0.095	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Date Reported: November 1/96
MDS Ref # : 966621
MDS Quote#: 96-697-GS

Client Ref#: Heath Steele Mine

Analysis of Water

Parameter	SAMPLE ID (spike)	LOQ	Units	Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
				Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
Tin	HS-R1	0.002	mg/L	nd(b)	0.004	yes	99	85	115	yes	0.096	0.100	0.050	0.140	yes	yes
Titanium	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	94	85	115	yes	0.095	0.100	0.050	0.140	yes	yes
Titanium	HS-R1	0.002	mg/L	nd(b)	0.004	yes	99	85	115	yes	0.098	0.100	0.050	0.140	yes	yes
Uranium	HS-E3 @Total.UNF	0.0001	mg/L	nd(b)	0.0002	yes	96	85	115	yes	0.0974	0.100	0.050	0.140	yes	yes
Uranium	HS-R1	0.0001	mg/L	nd(b)	0.0002	yes	103	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Vanadium	HS-E3 @Total.UNF	0.002	mg/L	nd(b)	0.004	yes	94	85	115	yes	0.094	0.100	0.050	0.140	yes	yes
Vanadium	HS-R1	0.002	mg/L	nd(b)	0.004	yes	101	85	115	yes	0.103	0.100	0.050	0.140	yes	yes
Colour	na	5	TCU	na(b)	na	na	88	85	115	yes	na	na	na	na	na	yes
Conductivity - @25°C	na	1	us/cm	na(b)	na	na	97	91	109	yes	na	na	na	na	na	yes
pH	na	0.1	Units	na(b)	na	na	99	98	102	yes	na	na	na	na	na	yes
Turbidity	na	0.1	NTU	na(b)	na	na	96	81	129	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	104	79	119	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	98	77	122	yes	na	na	na	na	na	yes
Dissolved Inorganic Carbon(as C)	na	0.5	mg/L	nd	1.0	yes	na	na	na	na	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	104	80	116	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	98	82	118	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

C.3 Results

C.3.1 Summarized Tables

Table C1: Field Measurements Taken at Reference and Exposure Stations at Heath Steele Mine on September 23, 1996.

Measurement	Reference Stations						Exposure Stations					
	HS-R1	HS-R2	HS-R3	HS-R4	HS-R5	HS-R6	HS-E1	HS-E2	HS-E3	HS-E4	HS-E5	HS-E6
pH (units)	6.84	6.90	6.92	na	na	7.01	6.89	na	6.94	na	na	6.95
Conductivity (μS/cm)	58.7	38.6	38.4	na	na	39.3	422	na	419	na	na	420
Temperature (°C)	8.24	8.03	8.22	na	na	10.43	10.97	na	11.00	na	na	10.74
Dissolved Oxygen (mg/L)	10.50	10.67	10.61	na	na	10.50	10.14	na	9.99	na	na	10.12
Depth (cm)	25	24	23	24	23	22	23	24	23	22	18	17
Flow (m^3/s)	2.32	3.69	3.07	3.21	2.38	3.79	1.76	1.34	0.84	0.94	0.85	0.96

na = Not available

Table C2: Water Chemistry Analyses of Samples Collected From Reference and Exposure Stations at Heath Steele Mine on September 23, 1996 (all units in mg/L unless otherwise indicated).

Parameter	LOQ	Reference Stations					Exposure Stations				Field Blank
		HS-R1	Lab Replicate	HS-R2	HS-R3	HS-R6	HS-E1	Field Replicate	HS-E3	HS-E6	
Nitrate	0.05	nd	nd	nd	0.21	0.05	0.08	0.08	0.10	0.07	nd
Nitrite	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ammonia	0.05	0.05	na	nd	nd	nd	nd	nd	nd	nd	nd
TKN	0.05	0.42	na	0.42	0.48	0.44	0.50	0.50	0.45	0.56	0.50
Phosphorus	0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Orthophosphate	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Alkalinity (as $CaCO_3$)	1.0	21	21	21	21	20	20	19	19	20	nd
Chloride	1.0	nd	nd	nd	nd	nd	4	nd	4	4	nd
Sulphate	2.0	3	3	3	3	3	177	174	178	181	nd
Bicarbonate	1.0	21	21	21	21	20	20	19	19	20	nd
Carbonate	1.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Colour (TCU)	5	21	22	21	22	20	20	19	20	17	nd
Conductivity (μS/cm)	1.0	49	49	47	47	46	424	427	429	429	3
Hardness	0.1	19.0	21.6	18.9	19.1	19.3	188	189	188	191	nd
Turbidity	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	nd
Anion Sum (meq/L)	na	0.503	0.502	0.504	0.519	0.487	4.18	4.02	4.19	4.27	0.000
Cation Sum (meq/L)	na	0.494	NCALC	0.465	0.499	0.494	4.46	4.48	4.45	4.51	0.016
Ion Balance	0.01	0.84	NCALC	3.98	2.05	0.72	3.22	5.36	3.00	2.71	100
pH (units)	0.1	7.2	7.2	7.2	7.2	7.4	7.4	7.4	7.3	7.4	7.0
DIC	0.5	3.6	na	4.1	4.0	4.0	3.4	3.5	3.5	3.5	nd
DOC	0.5	3.1	na	2.7	2.6	2.8	3.3	3.9	3.4	3.6	0.7
TDS	1	35	NCALC	34	36	34	289	283	289	294	nd
TSS	5	nd	na	nd	nd	nd	nd	nd	nd	nd	na
Thiosalts	na	nd	na	nd	nd	nd	nd	nd	nd	nd	na

LOQ = Limit of Quantification
nd = Parameter not detected at LOQ
na = Not applicable\available
TKN = Total Kjeldahl Nitrogen
DIC = Dissolved Inorganic Carbon
DOC = Dissolved Organic Carbon
TDS = Total Dissolved Solids
TSS = Total Suspended Solids
NCALC = Not calculated

Table C3: Dissolved Metals (mg/L) in Water Chemistry Samples Collected from Reference and Exposure Stations at the Heath Steele Mine on September 23, 1996.

Metal (mg/L)	LOQ	Reference Stations					Exposure Stations				Field (Filter) Blank
		HS-R1	Lab Replicate	HS-R2	HS-R3	HS-R6	HS-E1	Replicate	HS-E3	HS-E6	
Aluminum	0.01	nd	nd	nd	nd	nd	0.02	0.02	0.02	0.02	nd
Antimony	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Arsenic	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Barium	0.005	nd	nd	nd	nd	nd	0.012	0.012	0.012	0.012	nd
Beryllium	0.005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bismuth	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Boron	0.005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cadmium	0.0005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Calcium	0.1	6.0	6.0	6.0	6.0	6.1	71.9	72.3	71.8	72.9	nd
Chromium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cobalt	0.001	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Copper	0.002	0.003	0.003	nd	nd	nd	0.004	0.004	0.004	0.004	nd
Iron	0.02	0.05	0.05	0.05	0.05	0.05	0.03	0.04	0.03	0.03	nd
Lead	0.0001	0.0003	0.0001	0.0001	0.0002	0.0001	0.0003	0.0004	0.0004	0.0004	nd
Magnesium	0.1	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.1	nd
Manganese	0.002	0.004	0.004	0.003	0.003	0.003	0.167	0.163	0.165	0.161	nd
Molybdenum	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nickel	0.002	0.002	0.002	nd	nd	nd	nd	0.004	nd	0.002	nd
Potassium	0.5	1.2	1.0	1.1	1.4	1.1	1.5	1.4	1.5	1.0	0.6
Reactive Silica	0.5	8.3	8	8.3	8.3	8.3	5.4	5.4	5.5	5.5	nd

Table C3 (continued)

Metal (mg/L)	LOQ	Reference Stations					Exposure Stations				Field (Filter) Blank
		HS-R1	Lab Replicate	HS-R2	HS-R3	HS-R6	HS-E1	Replicate	HS-E3	HS-E6	
Selenium	0.002	nd	nd	nd	nd	nd	0.002	0.003	nd	0.002	nd
Silver	0.0003	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sodium	0.1	1.9	1.9	1.9	1.9	1.9	15.2	15.4	15.2	15.5	nd
Strontium	0.005	0.017	0.018	0.017	0.017	0.017	0.077	0.078	0.078	0.078	nd
Thallium	0.0001	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tin	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Titanium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Uranium	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	nd	nd	nd	nd	nd
Vanadium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	0.002	nd	nd	nd	nd	nd	0.052	0.05	0.052	0.056	nd

LOQ = Limit of Quantification
nd = Parameter not detected at LOQ
na = Not available

Table C4: Total Metals (mg/L) in Water Chemistry Samples Collected from Reference and Exposure Stations at the Heath Steele Mine on September 23, 1996.

Metal (mg/L)	LOQ	Reference Stations				Exposure Stations					Field Blank
		HS-R1	HS-R2	HS-R3	HS-R6	HS-E1	Field Replicate	HS-E3	Lab Replicate	HS-E6	
Aluminum	0.01	nd	nd	nd	0.02	0.02	0.02	0.02	0.02	0.02	nd
Antimony	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Arsenic	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Barium	0.005	nd	nd	nd	nd	0.012	0.012	0.012	0.012	0.012	nd
Beryllium	0.005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bismuth	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Boron	0.005	nd	nd	nd	nd	nd	0.006	nd	nd	nd	nd
Cadmium	0.0005	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Calcium	0.1	6.0	6.0	6.0	6.1	70.5	76.5	78.0	74.5	78.2	nd
Chromium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cobalt	0.001	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Copper	0.002	nd	nd	nd	0.012	0.005	0.006	0.005	0.005	0.005	nd
Iron	0.02	0.07	0.06	0.07	0.08	0.04	0.05	0.05	0.05	0.05	nd
Lead	0.0001	nd	nd	nd	0.0002	0.0006	0.0004	0.0004	0.0005	0.0004	nd
Magnesium	0.1	1.0	1.0	1.0	1.0	2.0	2.2	2.3	2.1	2.3	nd
Manganese	0.002	0.006	0.005	0.005	0.009	0.157	0.154	0.158	0.157	0.153	nd
Molybdenum	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nickel	0.002	nd	nd	nd	nd	nd	nd	0.002	0.002	nd	nd
Potassium	0.5	0.6	1.4	1.0	nd	2.6	1.8	1.3	1.4	1.2	nd
Reactive Silica	0.5	na	na	na	na	na	na	na	na	na	na

Table C4 (continued)

Metal (mg/L)	LOQ	Reference Stations				Exposure Stations					Field Blank
		HS-R1	HS-R2	HS-R3	HS-R6	HS-E1	Field Replicate	HS-E3	Lab Replicate	HS-E6	
Selenium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Silver	0.0003	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sodium	0.1	1.9	1.9	1.9	2.1	14.5	16.0	16.3	15.4	16.2	nd
Strontium	0.005	0.017	0.017	0.017	0.018	0.074	0.071	0.074	0.075	0.075	nd
Thallium	0.0001	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tin	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Titanium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Uranium	0.0001	0.0001	0.0001	0.0001	0.0001	nd	nd	nd	nd	nd	nd
Vanadium	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	0.002	0.005	nd	nd	0.005	0.052	0.055	0.056	0.054	0.062	nd

LOQ = Limit of Quantification
nd = Parameter not detected at LOQ
na = Not available

C.3.2 Raw Data

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS @Effluent 96/09/23	HS(T.UNF) @Effluent 96/09/23	HS-E1 96/09/23	HS-E1 Replicate	HS-E1 @Blank 96/09/23
Alkalinity(as CaCO3)	1	mg/L	16	-	20	-	nd
Chloride	1	mg/L	13	-	4	-	nd
Nitrate(as N)	0.05	mg/L	0.33	-	0.08	-	nd
Nitrite(as N)	0.01	mg/L	0.07	-	nd	-	nd
Orthophosphate(as P)	0.01	mg/L	nd	-	nd	-	nd
Sulphate	2	mg/L	1050	-	177	-	nd
Boron	0.005	mg/L	nd	0.008	nd	-	nd
Calcium	0.1	mg/L	290	410	71.9	-	nd
Iron	0.02	mg/L	nd	0.12	0.03	-	nd
Magnesium	0.1	mg/L	1.7	1.9	2.0	-	nd
Phosphorus	0.1	mg/L	nd	nd	nd	-	nd
Potassium	0.5	mg/L	5.0	2.2	1.5	-	0.6
Reactive Silica(SiO2)	0.5	mg/L	1.1	-	5.4	-	nd
Sodium	0.1	mg/L	109	115	15.2	-	nd
Zinc	0.002	mg/L	nd	0.019	0.052	-	nd
Aluminum	0.01	mg/L	0.49	0.48	0.02	-	nd
Antimony	0.002	mg/L	0.002	0.003	nd	-	nd
Arsenic	0.002	mg/L	0.003	nd	nd	-	nd
Barium	0.005	mg/L	0.049	0.050	0.012	-	nd
Beryllium	0.005	mg/L	nd	nd	nd	-	nd
Bismuth	0.002	mg/L	nd	nd	nd	-	nd
Cadmium	0.0005	mg/L	nd	nd	nd	-	nd
Chromium	0.002	mg/L	0.003	0.003	nd	-	nd
Cobalt	0.001	mg/L	nd	0.001	nd	-	nd
Copper	0.002	mg/L	nd	nd	0.004	-	nd
Lead	0.0001	mg/L	0.0004	0.0225	0.0003	-	nd
Manganese	0.002	mg/L	0.069	0.090	0.167	-	nd

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS @Effluent 96/09/23	HS(T.UNF) @Effluent 96/09/23	HS-E1 96/09/23	HS-E1 Replicate	HS-E1 @Blank 96/09/23
Molybdenum	0.002	mg/L	0.024	0.022	nd	-	nd
Nickel	0.002	mg/L	0.010	0.011	nd	-	nd
Selenium	0.002	mg/L	0.014	0.009	0.002	-	nd
Silver	0.0003	mg/L	nd	nd	nd	-	nd
Strontium	0.005	mg/L	0.380	0.342	0.077	-	nd
Thallium	0.0001	mg/L	0.0018	0.0016	nd	-	nd
Tin	0.002	mg/L	nd	nd	nd	-	nd
Titanium	0.002	mg/L	nd	nd	nd	-	nd
Uranium	0.0001	mg/L	nd	nd	nd	-	nd
Vanadium	0.002	mg/L	nd	nd	nd	-	nd
Anion Sum	na	meq/L	22.6	-	4.18	-	0.000
Bicarbonate(as CaCO3, calculated)	1	mg/L	16	-	20	-	nd
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	nd	-	nd
Cation Sum	na	meq/L	19.5	-	4.46	-	0.016
Colour	5	TCU	nd	-	20	-	nd
Conductivity - @25°C	1	us/cm	1950	-	424	-	3
Hardness(as CaCO3)	0.1	mg/L	731	-	188	-	nd
Ion Balance	0.01	%	7.31	-	3.22	-	100
Langelier Index at 20°C	na	na	-0.686	-	-0.882	-	NCALC
Langelier Index at 4°C	na	na	-1.09	-	-1.28	-	NCALC
pH	0.1	Units	7.2	-	7.4	-	7.0
Saturation pH at 20°C	na	units	7.89	-	8.31	-	NCALC
Saturation pH at 4°C	na	units	8.29	-	8.71	-	NCALC
Total Dissolved Solids(Calculated)	1	mg/L	1480	-	289	-	nd
Turbidity	0.1	NTU	0.5	-	0.1	-	nd
Ammonia(as N)	0.05	mg/L	0.16	-	nd	-	nd
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.59	-	0.50	-	0.50

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
na = Not Applicable
NCALC = Not Calculated
nd = parameter not detected ! = LOQ higher than listed due to dilution () Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS @Effluent 96/09/23	HS(T.UNF) @Effluent 96/09/23	HS-E1 96/09/23	HS-E1 Replicate	HS-E1 @Blank 96/09/23
Dissolved Inorganic Carbon(as C)	0.5	mg/L	2.2	-	3.4	-	nd
Dissolved Organic Carbon(DOC)	0.5	mg/L	1.9	-	3.3	-	0.7
Total Suspended Solids	5	mg/L	nd	-	nd	-	-

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter Date Sampled >	LOQ	Units	HS-E1 @Replicate 96/09/23	HS-E1 @Total.UNF 96/09/23	HS-E1(T.UN F)@Blank 96/09/23	HS-E1(T.UN F@Replicat 96/09/23	HS-E3 96/09/23
Alkalinity(as CaCO3)	1	mg/L	19	-	-	-	19
Chloride	1	mg/L	nd	-	-	-	4
Nitrate(as N)	0.05	mg/L	0.08	-	-	-	0.10
Nitrite(as N)	0.01	mg/L	nd	-	-	-	nd
Orthophosphate(as P)	0.01	mg/L	nd	-	-	-	nd
Sulphate	2	mg/L	174	-	-	-	178
Boron	0.005	mg/L	nd	nd	nd	0.006	nd
Calcium	0.1	mg/L	72.3	70.5	nd	76.5	71.8
Iron	0.02	mg/L	0.04	0.04	nd	0.05	0.03
Magnesium	0.1	mg/L	2.0	2.0	nd	2.2	2.0
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd
Potassium	0.5	mg/L	1.4	2.6	nd	1.8	1.5
Reactive Silica(SiO2)	0.5	mg/L	5.4	-	-	-	5.5
Sodium	0.1	mg/L	15.4	14.5	nd	16.0	15.2
Zinc	0.002	mg/L	0.050	0.052	nd	0.055	0.052
Aluminum	0.01	mg/L	0.02	0.02	nd	0.02	0.02
Antimony	0.002	mg/L	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.012	0.012	nd	0.012	0.012
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd
Cadmium	0.0005	mg/L	nd	nd	nd	nd	nd
Chromium	0.002	mg/L	nd	nd	nd	nd	nd
Cobalt	0.001	mg/L	nd	nd	nd	nd	nd
Copper	0.002	mg/L	0.004	0.005	nd	0.006	0.004
Lead	0.0001	mg/L	0.0004	0.0006	nd	0.0004	0.0004
Manganese	0.002	mg/L	0.163	0.157	nd	0.154	0.165

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS-E1 @Replicate 96/09/23	HS-E1 @Total.UNF 96/09/23	HS-E1(T.UN F)@Blank 96/09/23	HS-E1(T.UN F@Replicat 96/09/23	HS-E3 96/09/23
Molybdenum	0.002	mg/L	nd	nd	nd	nd	nd
Nickel	0.002	mg/L	0.004	nd	nd	nd	nd
Selenium	0.002	mg/L	0.003	nd	nd	nd	nd
Silver	0.0003	mg/L	nd	nd	nd	nd	nd
Strontium	0.005	mg/L	0.078	0.074	nd	0.071	0.078
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd
Uranium	0.0001	mg/L	nd	nd	nd	nd	nd
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd
Anion Sum	na	meq/L	4.02	-	-	-	4.19
Bicarbonate(as CaCO3, calculated)	1	mg/L	19	-	-	-	19
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	-	-	nd
Cation Sum	na	meq/L	4.48	-	-	-	4.45
Colour	5	TCU	19	-	-	-	20
Conductivity - @25°C	1	us/cm	427	-	-	-	429
Hardness(as CaCO3)	0.1	mg/L	189	-	-	-	188
Ion Balance	0.01	%	5.36	-	-	-	3.00
Langelier Index at 20°C	na	na	-0.904	-	-	-	-1.00
Langelier Index at 4°C	na	na	-1.30	-	-	-	-1.40
pH	0.1	Units	7.4	-	-	-	7.3
Saturation pH at 20°C	na	units	8.32	-	-	-	8.33
Saturation pH at 4°C	na	units	8.72	-	-	-	8.73
Total Dissolved Solids(Calculated)	1	mg/L	283	-	-	-	289
Turbidity	0.1	NTU	0.1	-	-	-	0.1
Ammonia(as N)	0.05	mg/L	nd	-	-	-	nd
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.50	-	-	-	0.45

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
na = Not Applicable
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS-E1 @Replicate 96/09/23	HS-E1 @Total.UNF 96/09/23	HS-E1(T.UNF)@Blank 96/09/23	HS-E1(T.UNF@Replicat 96/09/23	HS-E3 96/09/23
Dissolved Inorganic Carbon(as C)	0.5	mg/L	3.5	-	-	-	3.5
Dissolved Organic Carbon(DOC)	0.5	mg/L	3.9	-	-	-	3.4
Total Suspended Solids	5	mg/L	nd	-	-	-	nd

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter / Date Sampled >	LOQ	Units	HS-E3 @Total.UNF 96/09/23	HS-E3 @Total.UNF Replicate	HS-E6 96/09/23	HS-E6 @Total.UNF 96/09/23	HS-R1 96/09/23
Alkalinity(as CaCO3)	1	mg/L	-	-	20	-	21
Chloride	1	mg/L	-	-	4	-	nd
Nitrate(as N)	0.05	mg/L	-	-	0.07	-	nd
Nitrite(as N)	0.01	mg/L	-	-	nd	-	nd
Orthophosphate(as P)	0.01	mg/L	-	-	nd	-	nd
Sulphate	2	mg/L	-	-	181	-	3
Boron	0.005	mg/L	nd	nd	nd	nd	nd
Calcium	0.1	mg/L	78.0	74.5	72.9	78.2	6.0
Iron	0.02	mg/L	0.05	0.05	0.03	0.05	0.05
Magnesium	0.1	mg/L	2.3	2.1	2.1	2.3	1.0
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd
Potassium	0.5	mg/L	1.3	1.4	1.0	1.2	1.2
Reactive Silica(SiO2)	0.5	mg/L	-	-	5.5	-	8.3
Sodium	0.1	mg/L	16.3	15.4	15.5	16.2	1.9
Zinc	0.002	mg/L	0.056	0.054	0.056	0.062	nd
Aluminum	0.01	mg/L	0.02	0.02	0.02	0.02	nd
Antimony	0.002	mg/L	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.012	0.012	0.012	0.012	nd
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd
Cadmium	0.0005	mg/L	nd	nd	nd	nd	nd
Chromium	0.002	mg/L	nd	nd	nd	nd	nd
Cobalt	0.001	mg/L	nd	nd	nd	nd	nd
Copper	0.002	mg/L	0.005	0.005	0.004	0.005	0.003
Lead	0.0001	mg/L	0.0004	0.0005	0.0004	0.0004	0.0003
Manganese	0.002	mg/L	0.158	0.157	0.161	0.153	0.004

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter Date Sampled >	LOQ	Units	HS-E3 @Total.UNF 96/09/23	HS-E3 @Total.UNF Replicate	HS-E6 96/09/23	HS-E6 @Total.UNF 96/09/23	HS-R1 96/09/23
Molybdenum	0.002	mg/L	nd	nd	nd	nd	nd
Nickel	0.002	mg/L	0.002	0.002	0.002	nd	0.002
Selenium	0.002	mg/L	nd	nd	0.002	nd	nd
Silver	0.0003	mg/L	nd	nd	nd	nd	nd
Strontium	0.005	mg/L	0.074	0.075	0.078	0.075	0.017
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd
Uranium	0.0001	mg/L	nd	nd	nd	nd	0.0002
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd
Anion Sum	na	meq/L	-	-	4.27	-	0.503
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	-	20	-	21
Carbonate(as CaCO3, calculated)	1	mg/L	-	-	nd	-	nd
Cation Sum	na	meq/L	-	-	4.51	-	0.494
Colour	5	TCU	-	-	17	-	21
Conductivity - @25°C	1	us/cm	-	-	429	-	49
Hardness(as CaCO3)	0.1	mg/L	-	-	191	-	19.0
Ion Balance	0.01	%	-	-	2.71	-	0.84
Langelier Index at 20°C	na	na	-	-	-0.896	-	-2.15
Langelier Index at 4°C	na	na	-	-	-1.30	-	-2.55
pH	0.1	Units	-	-	7.4	-	7.2
Saturation pH at 20°C	na	units	-	-	8.31	-	9.32
Saturation pH at 4°C	na	units	-	-	8.71	-	9.72
Total Dissolved Solids(Calculated)	1	mg/L	-	-	294	-	35
Turbidity	0.1	NTU	-	-	0.1	-	0.1
Ammonia(as N)	0.05	mg/L	-	-	nd	-	0.05
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	0.56	-	0.42

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
na = Not Applicable
nd = parameter not detected ! = LOQ higher than listed due to dilution () Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Client Ref#: Heath Steele

Analysis of Water

Parameter / Date Sampled >	LOQ	Units	HS-E3 @Total.UNF 96/09/23	HS-E3 @Total.UNF Replicate	HS-E6 96/09/23	HS-E6 @Total.UNF 96/09/23	HS-R1 96/09/23
Dissolved Inorganic Carbon(as C)	0.5	mg/L	-	-	3.5	-	3.6
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	3.6	-	3.1
Total Suspended Solids	5	mg/L	-	-	nd	-	nd

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution () Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R1 Replicate	HS-R1 @Total-Unf 96/09/23	HS-R2 96/09/23	HS-R2 @Total.UNF 96/09/23	HS-R3 96/09/23
Alkalinity(as CaCO3)	1	mg/L	21	-	21	-	21
Chloride	1	mg/L	nd	-	nd	-	nd
Nitrate(as N)	0.05	mg/L	nd	-	nd	-	0.21
Nitrite(as N)	0.01	mg/L	nd	-	nd	-	nd
Orthophosphate(as P)	0.01	mg/L	nd	-	nd	-	nd
Sulphate	2	mg/L	3	-	3	-	3
Boron	0.005	mg/L	nd	nd	nd	nd	nd
Calcium	0.1	mg/L	6.0	6.2	6.0	6.2	6.0
Iron	0.02	mg/L	0.05	0.07	0.05	0.06	0.05
Magnesium	0.1	mg/L	1.0	1.0	1.0	1.0	1.0
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd
Potassium	0.5	mg/L	1.0	0.6	nd	1.4	1.4
Reactive Silica(SiO2)	0.5	mg/L	8.0	-	8.3	-	8.3
Sodium	0.1	mg/L	1.9	1.9	1.9	1.9	1.9
Zinc	0.002	mg/L	nd	0.005	nd	nd	nd
Aluminum	0.01	mg/L	nd	nd	nd	nd	nd
Antimony	0.002	mg/L	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd
Barium	0.005	mg/L	nd	nd	nd	nd	nd
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd
Cadmium	0.0005	mg/L	nd	nd	nd	nd	nd
Chromium	0.002	mg/L	nd	nd	nd	nd	nd
Cobalt	0.001	mg/L	nd	nd	nd	nd	nd
Copper	0.002	mg/L	0.003	nd	nd	nd	nd
Lead	0.0001	mg/L	0.0001	nd	nd	nd	0.0002
Manganese	0.002	mg/L	0.004	0.006	0.003	0.005	0.003

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R1 Replicate	HS-R1 @Total-Unf 96/09/23	HS-R2 96/09/23	HS-R2 @Total.UNF 96/09/23	HS-R3 96/09/23
Molybdenum	0.002	mg/L	nd	nd	nd	nd	nd
Nickel	0.002	mg/L	0.002	nd	nd	nd	nd
Selenium	0.002	mg/L	nd	nd	nd	nd	nd
Silver	0.0003	mg/L	nd	nd	nd	nd	nd
Strontium	0.005	mg/L	0.018	0.017	0.017	0.017	0.017
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd
Uranium	0.0001	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd
Anion Sum	na	meq/L	0.502	-	0.504	-	0.519
Bicarbonate(as CaCO3, calculated)	1	mg/L	21	-	21	-	21
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	nd	-	nd
Cation Sum	na	meq/L	NCALC	-	0.465	-	0.499
Colour	5	TCU	22	-	21	-	22
Conductivity - @25°C	1	us/cm	49	-	47	-	47
Hardness(as CaCO3)	0.1	mg/L	21.6	-	18.9	-	19.1
Ion Balance	0.01	%	NCALC	-	3.98	-	2.05
Langelier Index at 20°C	na	na	NCALC	-	-2.11	-	-2.08
Langelier Index at 4°C	na	na	NCALC	-	-2.51	-	-2.48
pH	0.1	Units	7.2	-	7.2	-	7.2
Saturation pH at 20°C	na	units	NCALC	-	9.32	-	9.32
Saturation pH at 4°C	na	units	NCALC	-	9.72	-	9.72
Total Dissolved Solids(Calculated)	1	mg/L	NCALC	-	34	-	36
Turbidity	0.1	NTU	0.1	-	0.1	-	0.1
Ammonia(as N)	0.05	mg/L	-	-	nd	-	nd
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	0.42	-	0.48

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
na = Not Applicable
NCALC = Not Calculated
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R1 Replicate	HS-R1 @Total-Unf 96/09/23	HS-R2 96/09/23	HS-R2 @Total.UNF 96/09/23	HS-R3 96/09/23
Dissolved Inorganic Carbon(as C)	0.5	mg/L	-	-	4.1	-	4.0
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	2.7	-	2.6
Total Suspended Solids	5	mg/L	-	-	nd	-	nd

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R3 Replicate	HS-R3 @Total.UNF 96/09/23	HS-R6 96/09/23	HS-R6 @Total.UNF 96/09/23	
Alkalinity(as CaCO3)	1	mg/L	-	-	20	-	
Chloride	1	mg/L	-	-	nd	-	
Nitrate(as N)	0.05	mg/L	-	-	0.05	-	
Nitrite(as N)	0.01	mg/L	-	-	nd	-	
Orthophosphate(as P)	0.01	mg/L	-	-	nd	-	
Sulphate	2	mg/L	-	-	3	-	
Boron	0.005	mg/L	-	nd	nd	nd	
Calcium	0.1	mg/L	-	6.2	6.1	6.9	
Iron	0.02	mg/L	-	0.07	0.05	0.08	
Magnesium	0.1	mg/L	-	1.0	1.0	1.0	
Phosphorus	0.1	mg/L	-	nd	nd	nd	
Potassium	0.5	mg/L	-	1.0	1.1	nd	
Reactive Silica(SiO2)	0.5	mg/L	-	-	8.3	-	
Sodium	0.1	mg/L	-	1.9	1.9	2.1	
Zinc	0.002	mg/L	-	nd	nd	0.005	
Aluminum	0.01	mg/L	-	nd	nd	0.02	
Antimony	0.002	mg/L	-	nd	nd	nd	
Arsenic	0.002	mg/L	-	nd	nd	nd	
Barium	0.005	mg/L	-	nd	nd	nd	
Beryllium	0.005	mg/L	-	nd	nd	nd	
Bismuth	0.002	mg/L	-	nd	nd	nd	
Cadmium	0.0005	mg/L	-	nd	nd	nd	
Chromium	0.002	mg/L	-	nd	nd	nd	
Cobalt	0.001	mg/L	-	nd	nd	nd	
Copper	0.002	mg/L	-	nd	nd	0.012	
Lead	0.0001	mg/L	-	nd	0.0001	0.0002	
Manganese	0.002	mg/L	-	0.005	0.003	0.009	

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
\- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R3 Replicate	HS-R3 @Total.UNF 96/09/23	HS-R6 96/09/23	HS-R6 @Total.UNF 96/09/23	
Molybdenum	0.002	mg/L	-	nd	nd	nd	
Nickel	0.002	mg/L	-	nd	nd	nd	
Selenium	0.002	mg/L	-	nd	nd	nd	
Silver	0.0003	mg/L	-	nd	nd	nd	
Strontium	0.005	mg/L	-	0.017	0.017	0.018	
Thallium	0.0001	mg/L	-	nd	nd	nd	
Tin	0.002	mg/L	-	nd	nd	nd	
Titanium	0.002	mg/L	-	nd	nd	nd	
Uranium	0.0001	mg/L	-	0.0001	0.0001	0.0001	
Vanadium	0.002	mg/L	-	nd	nd	nd	
Anion Sum	na	meq/L	-	-	0.487	-	
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	-	20	-	
Carbonate(as CaCO3, calculated)	1	mg/L	-	-	nd	-	
Cation Sum	na	meq/L	-	-	0.494	-	
Colour	5	TCU	-	-	20	-	
Conductivity - @25°C	1	us/cm	-	-	46	-	
Hardness(as CaCO3)	0.1	mg/L	-	-	19.3	-	
Ion Balance	0.01	%	-	-	0.72	-	
Langelier Index at 20°C	na	na	-	-	-1.96	-	
Langelier Index at 4°C	na	na	-	-	-2.36	-	
pH	0.1	Units	-	-	7.4	-	
Saturation pH at 20°C	na	units	-	-	9.33	-	
Saturation pH at 4°C	na	units	-	-	9.73	-	
Total Dissolved Solids(Calculated)	1	mg/L	-	-	34	-	
Turbidity	0.1	NTU	-	-	0.1	-	
Ammonia(as N)	0.05	mg/L	-	-	nd	-	
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	0.44	-	

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
na = Not Applicable
nd = parameter not detected ! = LOQ higher than listed due to dilution () Adjusted LOQ

MDS Environmental Services Limited.

Report of Analysis

Client : Jacques Whitford Environment Ltd.
Contact: Monique Dube

Report Date: November 1/96
MDS Ref # : 966621
MDS Quote #: 96-697-GS

Analysis of Water

Client Ref#: Heath Steele

Parameter	LOQ	Units	HS-R3 Replicate	HS-R3 @Total.UNF 96/09/23	HS-R6 96/09/23	HS-R6 @Total.UNF 96/09/23	
Dissolved Inorganic Carbon(as C)	0.5	mg/L	-	-	4.0	-	
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	2.8	-	
Total Suspended Solids	5	mg/L	-	-	nd	-	

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.
- = Not Requested
nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

APPENDIX D

Benthic Invertebrate Community Structure

D.1 Detailed Methods

Sample Processing

All benthos samples were processed and analyzed by Zaranko Environmental Assessment Series (ZEAS), Guelph, ON.

Upon arrival, samples were immediately logged and inspected to ensure adequate preservation to a minimum level of 10% buffered formalin and correct labeling. No problems with preservative or labeling were identified. All benthic samples were sorted with the use of a stereomicroscope. A magnification of 10X was used for macrobenthos (invertebrates > 500 μm) and 20X for meiobenthos (invertebrate size from 200 to 500 μm). To expedite sorting, prior to processing, all samples were stained with a protein dye that is absorbed by aquatic organisms but not by organic material such as detritus and algae. The stain has proven to be extremely effective in increasing sorting accuracy and efficiency.

Prior to sorting, samples were washed free of formalin in a 250 μm sieve. Benthic invertebrates and associated debris were elutriated from any sand and gravel in the sample. Elutriation techniques effectively removed almost all organisms. The remaining sand and gravel fraction was closely inspected for the odd heavier organism such as Pelecypoda, Gastropoda, and Trichoptera with stone cases that may not have all been washed from this fraction. After elutriation, the remaining debris and benthic invertebrates were washed through a series of two sieves, 500μm and 250 μm respectively.

Subsampling

Benthic samples were sorted entirely (both 500 and 250 μm) except in the instance of large amounts of organic matter and high densities of organisms. Benthic samples containing large amount of organic matter or high densities of organisms can often take days to sort entirely. Thus sorting the whole sample may not be cost effective. In addition, with large quantities of organic matter there comes a point when additional sorting does not yield further ecological information. As such, the following subsampling techniques were employed.

Sample material was distributed evenly on the 500 μm and 250 μm sieves. One half of the material was removed and set aside while the remaining half was distributed evenly on each sieve and again divided in two. A minimum subsample volume of 25% was the criteria set for this study. The same fraction was sorted from the 500 μm and the 250 μm sieve. On average, each sample took between five and six hours to sort in which an average of 300 organisms were removed from the associated debris.

Benthic invertebrates were enumerated and sorted into major taxonomic groups, (i.e., order and family), placed in glass vials and represerved in 70% ethanol for more detailed taxonomic analysis by senior staff. Each vial was labeled with the survey name, date, station, and replicate number. For QA/QC evaluation, sorted sediments and debris were represerved and will be retained for up to a period of six months following the submission of the final report. For those samples that were subsampled, sorted and unsorted fractions were represerved separately.

Detailed Identification

All invertebrates were identified to the lowest practical level, usually genus, with the exception of bivalves (*Sphaerium*), and oligochaetes which were identified to species. Nematodes were identified to phylum, water mites and harpacticoids to order, and ostracods to class.

Chironomids and oligochaetes were mounted on glass slides in a clearing media prior to identification using a compound microscope. In samples with large numbers of oligochaetes, a random sample of no less than 20% of the picked individuals, up to a maximum of 50, were mounted on slides for identification. Similarly, in samples with a large number of chironomids, individuals that could be identified using a dissecting scope, (e.g., *Cryptochironomus, Chironomus, Monodiamesa, Procladius, Heterotrissocladius*), were enumerated and removed from the sample. The remaining individuals were sorted into sub-families and tribes. A random sample of no less than 20% of the individuals from each group were mounted on slides for identification, up to a maximum of 50 individuals.

Voucher Collection

The standard operating procedures for ZEAS's Benthic Ecology Laboratory requires the compilation of a voucher collection for all benthic invertebrate projects. Representative specimens for each taxon are placed in labeled glass vials. Mounted chironomids and oligochaetes remain on the initial slides and representatives of each taxon are circled with a permanent marker. A voucher collection is one way of ensuring continuity in taxonomic identifications if different taxonomists process future samples. The voucher collection is either maintained in our files indefinitely or returned to the client. ZEAS also maintains a master reference collection of all taxa which have been identified by the lab.

QUALITY ASSURANCE AND QUALITY CONTROL MEASURES

ZEAS incorporates the following QA/QC procedures for all benthic studies to ensure reliability of data:

- all samples were stained to facilitate accurate sorting;
- the most updated and widely used taxonomic keys are referenced;
- 10% of all sorted samples were resorted by a second taxonomist to ensure 95% recovery of all invertebrates;
- a voucher collection was compiled and will be kept indefinitely or returned to the client;
- both sorted and unsorted sample fractions were represerved in 10 % formalin and will be maintained for six months after submission of the final report;
- all tabulated benthic data were cross checked against bench sheets by a second person to ensure there have been no data entry errors or incorrect spelling of scientific nomenclature;
- subsampling error was calculated for 10% of the samples requiring subsampling.

REPORTING BENTHIC MACROINVERTEBRATE DATA

Following identification and enumeration, a detailed taxa list was prepared for each station summarizing the total organism density and total number of taxa. The taxa list was prepared using Excel 5.0.

D.2 QA/QC

TABLE 1. CALCULATION OF SUBSAMPLING ERROR FOR BENTHIC INVERTEBRATE SAMPLES FROM HEATH STEEL, NORANDA MINING AND EXPLORATION LTD (1996).

Station	Number of Animals in Fraction 1	Number of Animals in Fraction 2	Standard Deviation	Coefficient of Variation
HS-E1	150	142	5.65	3.9%
HS-E4	253	245	5.65	2.3%

TABLE 2: PERCENTAGE RECOVERY OF BENTHIC INVERTEBRATES FROM SAMPLES FOR HEATH STEEL, NORANDA MINING AND EXPLORATION LTD (1996).

Station	Number of Animals Recovered	Number of Animals in Re-sort	Percent Recovery
HS-R2	746	12	98.4%
HS-E5	695	7	99.0%

TABLE 3. SAMPLE FRACTIONS SORTED FOR HEATH STEEL, NORANDA MINING AND EXPLORATION LTD (1996).

Station	Fraction Sorted
HS-R1	1/4
HS-R2	1/2
HS-R3	WHOLE
HS-R4	1/2
HS-R5	WHOLE
HS-R6	WHOLE
HS-E1	1/2[a]
HS-E2	WHOLE
HS-E3	1/2
HS-E4	WHOLE[b]
HS-E5	WHOLE
HS-E6	WHOLE

[a] two quarters were sorted for subsampling error calculations

[b] two halves were sorted for subsampling error calculations

D.3 Results

Table D1: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (250 Micrometer Sieve)

Station	Reference						Exposed					
Replicate	1	2	3	4	5	6	1	2	3	4	5	6
FP. Coelenterata												
Hydra											1	
FP. Nematoda					1	4	12		6		16	3
FP. Platyhelminthes												
Cl. Turbellaria												
F. Tricladida			6	2	1	1						
FP. Nemertea												
Prostoma					1		2				1	
FP. Annelida												
Cl. Oligochaeta												
F. Enchytraeidae	8	13	2	12	1	5	6	5	10	2	4	6
F. Naididae												
Chaetogaster diastrophus								2				
Nais communis		9	6	32	13	21						
Pristina leidyi				3	2							
Pristinella jenkinae							2	1	2		8	1
Slavina appendiculata		31	3	3	5	10						
F. Lumbriculidae												
Lumbriculus variegatus	8	2	10		2	6						
FP. Arthropoda												
Cl. Arachnida												
O. Hydracarina	136	54	71	70	97	148	24	24	12	13	11	15
Cl. Ostracoda		2						3	2	1	1	2
Cl. Entognatha												
O. Collembola	4	2	1					15				
Cl. Insecta												
O. Coleoptera												
F. Elmidae												
Optioservus	1	4	5	8	12	26		16	28	7	30	18
Oulimnius latiusculus										1		
Promoresia					1							
Stenelmis												1
F. Staphylinidae								1				
O. Ephemeroptera												
indeterminate												
F. Ameletidae												
Ameletus				2		1		1				
F. Baetidae												
indeterminate		4										
Acerpenna	28	8	1	8	10	64		1				1
Acentrella			26	8	1	2	20	16	20	16	9	14
Baetis	4	30	57	8	2	1	186	65	246	230	264	267
F. Ephemeridae												
Ephemera	8		1									
F. Ephemerellidae												
Ephemerella	376	68	154	120	113	102		3	4			1
Eurylophella			3		1	1						
?Serratella		34	195	50	17	15	4	2	2	1		3
F. Heptageniidae												
indeterminate		26	67	28		52						
Epeorus	228	334	318	140	62	37	14	47	26	25	27	27

Table D1: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (250 Micrometer Sieve)

Station	Reference						Exposed					
Replicate	1	2	3	4	5	6	1	2	3	4	5	6
Hydroptila	8				1	2						
Oxyethira	4											
F. Lepidostomatidae												
Lepidostoma	136	134	65	138	112	62	10	39	14	8	3	11
F. Leptoceridae												
indeterminate												1
Oecetis	28		2	2	3	1		2			1	
F. Odontoceridae												
Psilotreta			1		3	1						
F. Philopotamidae												
Dolophilodes			6									
F. Polycentropodidae												
indeterminate										1		
Neureclipsis			3	2		2						
Polycentropus	12		12		9	13	4	9	10	1	6	4
F. Rhyacophilidae												
Rhyacophila			1	2		1			2			1
O. Diptera												
F. Athericidae												
Atherix						1				2		
F. Ceratopogonidae		2		2	1	6	6	5	14	6	8	5
F. Chironomidae												
Chironomid pupae	4	2	1		1	6	6	4	6		4	6
S.F. Chironominae												
Cryptochironomus						1						
Micropsectra	44	70	3	44	11	34					1	1
Microtendipes	60	36	10	6	18	57		7	2		1	1
Nilothauma	16	2	1	2	1	2						
Polypedilum	32	20	8	2	11	1	2	34	26	18	12	6
Rheotanytarsus	712	32	19	2	5	9	2					
Robackia				2								
Stempellina		10	2	44	11	9		1				
Stempellinella									2			
Tanytarsus		14		4		15	4	1	4			4
S.F. Diamesinae												
Diamesa											1	
Pagastia							2					
Potthastia	8			6	1	4						
S.F. Orthocladiinae												
Corynoneura		6	1	6		9	6	7	10	2		
Cricotopus/Orthocladius		2			1				2		3	1
Cricotopus			1	2	2							
Eukiefferiella			1					2	8	1		
Heleniella				2						4	3	
Lopescladius				8	1							
Nanocladius	4											
Orthocladius	4	68	19	50	55		70	28	12	7	10	2
Parametriocnemus			1		1		2	5	4		57	27
Synorthocladius	8			4		3	2	2			9	7
Thienemanniella			3	6	1		26	35	32	8	14	15
Tvetenia	4	12	6		1		2					1

Table D1: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (250 Micrometer Sieve)

Station	Reference						Exposed					
Replicate	1	2	3	4	5	6	1	2	3	4	5	6
Heptagenia	144	54	120	32	48	70		2	2			
Rhithrogena		2		8		1				3	2	2
Stenonema	4	2	14		2	7						1
F. Isonychiidae												
Isonychia			5	2	1							
F. Leptophlebiidae												
Paraleptophlebia	72	92	117	154	71	53	2	1		2	1	3
O. Megaloptera												
F. Corydalidae												
Nigronia	3		1									
O. Odonata												
F. Gomphidae												
Ophiogomphus	7	1	15									
indeterminate	8	34	2	32	29	23	4	12	26	9	4	16
O. Plecoptera												
F. Capniidae												
indeterminate				4		4	12	15	42		33	35
Paracapnia	40	28	19	28	11	11	24	34	64	72	24	59
F. Chloroperlidae												
indeterminate				6	4	3			6			4
?Haploperla				2								1
Sweltsa			1	8	1	1	2	1		5	1	2
F. Leuctridae												
Leuctra												1
F. Perlidae												
indeterminate	4	42	16	48	41	51	8	13	16	7	3	7
Acroneuria										1		1
Agnetina	5	15	12	5	7	2		1	2	2	1	1
F. Perlodidae												
indeterminate	48	2	13	26	14	4	28	16	14	1	9	16
Isogenoides				4		2				3	1	
F. Pteronarcyidae												
Pteronarcys	1	3		2	2	1				1		1
F. Taeniopterygidae												
indeterminate			2			2				10	9	5
Taeniopteryx		4					8	13	2		2	3
O. Trichoptera												
Trichoptera pupae				2				1				
F. Brachycentridae												
Brachycentrus	8	9	10		18	5	6	4	14	2	8	10
Micrasema	4	2	2					2				
F. Glossosomatidae												
Glossosoma		19		2			4	1		2	5	10
F. Helicopsychidae												
Helicopsyche			1			1						
F. Hydropsychidae												
indeterminate		2					26	8	32	3	14	33
Cheumatopsyche	40	42	53	10	22	1			4	1	4	1
Hydropsyche sparna				4			6			1		2
Hydropsyche	49	53	84	40	19	3	32	12	48	14	45	80
F. Hydroptilidae												

Table D1: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (250 Micrometer Sieve)

Station	Reference						Exposed					
Replicate	1	2	3	4	5	6	1	2	3	4	5	6
S.F. Tanypodinae												
Ablabesmyia	4			2	2	5						
Conchapelopia	12	8		2								
Helopelopia						7						
Labrudinia								1				
Rheopelopia	24	22	18	26	16	32			10		1	
Thienemannimyia complex		6	19		5	18		1	12		10	3
Trissopelopia								1				
F. Empididae												
indeterminate					1							
Chelifera	8							1			3	
Hemerodromia			9			2	8	5	12	1	11	8
F. Tipulidae												
indeterminate				2	2	4				2		
Antocha	16	2	1		1	12		1	2		1	1
Dicranota								1				
Hexatoma			2	1		1						
FP. Mollusca												
Cl. Gastropoda												
F. Physidae												
Physella								1				
Cl. Pelecypoda												
F. Sphaeriidae												
Pisidium						1						
TTOTAL NUMBER OF ORGANISMS	2386	1475	1628	1282	909	1062	584	531	814	496	697	758
TTOTAL NUMBER OF TAXA	45	47	60	58	57	63	35	51	41	38	46	51
FRELATIVE ABUNDANCE(%)												
Chironomidae	39.2	21	6.94	17.2	15.8	20	21.2	24.3	16	8.06	18.1	9.76
Ephemeroptera	36.2	44.3	66.2	43.7	36.1	38.2	38.7	26	36.9	55.8	43.5	42.1
Trichopera	12.1	17.7	14.7	15.8	20.6	8.66	15.1	14.7	15.2	6.65	12.3	20.2
Plecoptera	4.11	6.37	3.87	10.4	8.8	7.63	14	17.5	17.9	20.6	11.9	17.9
EEPT Index (uncorrected)	22	24	32	31	26	34	18	25	20	24	22	32
CCorrection for EPT	0	3	1	2	0	1	1	0	1	2	1	3
EEPT Index (corrected)	22	21	31	29	26	33	17	25	19	22	21	29
EEPT/C	1.34	3.25	12.2	4.07	4.13	2.73	3.19	2.4	4.38	10.3	3.75	8.22

Table D2: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (500 Micrometer Sieve)

Station	Reference						Exposed					
Replicate	1	2	3	4	5	6	1	2	3	4	5	6
P. Coelenterata												
Hydra												
P. Nematoda												
P. Platyhelminthes												
Cl. Turbellaria												
F. Tricladida			5	2	1							
P. Nemertea												
Prostoma												
P. Annelida												
Cl. Oligochaeta												
F. Enchytraeidae	8	10	2	6	1	5						4
F. Naididae												
Chaetogaster diastrophus												
Nais communis												
Pristina leidyi												
Pristinella jenkinae												
Slavina appendiculata												
F. Lumbriculidae												
Lumbriculus variegatus	8	2	9		2	6						
P. Arthropoda												
Cl. Arachnida												
O. Hydracarina	8	14	11	6	7	13	4	3	2	3		2
Cl. Ostracoda												
Cl. Entognatha												
O. Collembola												
Cl. Insecta												
O. Coleoptera												
F. Elmidae												
Optioservus	1	4	4	4	8	11		6	8	5	6	
Oulimnius latiusculus										1		
Promoresia												
Stenelmis												
F. Staphylinidae								1				
O. Ephemeroptera												
indeterminate												
F. Ameletidae												
Ameletus				2		1						
F. Baetidae												
indeterminate		2										
Acerpenna	4			4	8	7		1				1
Acentrella			22	8	1	2	20	16	20	15	9	14
Baetis		10	21	2	1	1	28	28	62	86	111	99
F. Ephemeridae												
Ephemera	8		1									
F. Ephemerellidae												
Ephemerella	252	54	121	110	100	60		3	4			1
Eurylophella			2		1	1						
?Serratella		10	86	18	7	7	2					1
F. Heptageniidae												
indeterminate												
Epeorus	36	66	60	32	11	6		13	8	4	8	10
Heptagenia	92	54	120	32	46	70		1	2			
Rhithrogena		2		8		1				2	1	2
Stenonema	4	2	14		2	7						1

Table D2: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (500 Micrometer Sieve)

F. Isonychiidae												
Isonychia			4	2	1							
F. Leptophlebiidae												
Paraleptophlebia	44	38	40	46	30	32					1	
O. Megaloptera												
F. Corydalidae												
Nigronia	3		1									
O. Odonata												
F. Gomphidae												
Ophiogomphus	7	1	15									
indeterminate	4	34	2	32	29	23	4	11	24	9	4	15
O. Plecoptera												
F. Capniidae												
indeterminate												
Paracapnia	24	26	17	28	11	11	24	31	62	40	23	56
F. Chloroperlidae												
indeterminate					2	2						2
?Haploperla				2								1
Sweltsa			1	8	1	1	2	1		5	1	2
F. Leuctridae												
Leuctra												1
F. Perlidae												
indeterminate	4	14	5	16	16	14	2	2	2	1	2	2
Acroneuria										1		1
Agnetina	5	15	12	5	7	2		1	2	2	1	1
F. Perlodidae												
indeterminate	20		5	12	10	1	10	3	4		6	7
Isogenoides				4		2				3	1	
F. Pteronarcyidae												
Pteronarcys	1	3		2	2	1				1		1
F. Taeniopterygidae												
indeterminate						1						
Taeniopteryx		2						2	2		2	3
O. Trichoptera												
Trichoptera pupae				2				1				
F. Brachycentridae												
Brachycentrus	8	9	10		18	5	6	4	14	2	8	10
Micrasema			1					1				
F. Glossosomatidae												
Glossosoma		19		2			2	1		2	5	10
F. Helicopsychidae												
Helicopsyche			1			1						
F. Hydropsychidae												
indeterminate												
Cheumatopsyche	40	42	53	10	20	1			4	1	4	
Hydropsyche sparna				4			6			1		2
Hydropsyche	49	53	77	40	19	3	32	12	48	14	45	79
F. Hydroptilidae												
Hydroptila	8				1	2						
Oxyethira	4											
F. Lepidostomatidae												
Lepidostoma	116	122	55	116	98	39	6	35	14	8	3	11
F. Leptoceridae												
indeterminate												
Oecetis	16		1		1							
F. Odontoceridae												
Psilotreta			1		3	1						
F. Philopotamidae												
Dolophilodes			6									
F. Polycentropodidae												
indeterminate												

Table D2: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (500 Micrometer Sieve)

Neureclipsis			3	2		2						
Polycentropus	12		11		7	11	4	7	10	1	5	2
F. Rhyacophilidae												
Rhyacophila			1	2		1						1
O. Diptera												
F. Athericidae												
Atherix						1				2		
F. Ceratopogonidae						3		1	6	1	3	2
F. Chironomidae												
Chironomid pupae	4	2	1		1	3	2	1	2		3	
S.F. Chironominae												
Cryptochironomus												
Micropsectra	8	26	1	24	5	5					1	1
Microtendipes	24	6	9		11	29					1	
Nilothauma	12	2	1	2	1	1						
Polypedilum												
Rheotanytarsus	16	4	1		1	1						
Robackia				2								
Stempellina		2	1	4	3	1		1				
Stempellinella												
Tanytarsus				4								
S.F. Diamesinae												
Diamesa											1	
Pagastia												
Potthastia						2						
S.F. Orthocladiinae												
Corynoneura				2								
Cricotopus/Orthocladius		2			1				2		3	
Cricotopus												
Eukiefferiella			1					1				
Heleniella												
Lopescladius												
Nanocladius												
Orthocladius	4		1	4	4			1	2			
Parametriocnemus			1		1						1	
Synorthocladius	4			2		1		1				
Thienemanniella								1	2		1	
Tvetenia												1
S.F. Tanypodinae												
Ablabesmyia												
Conchapelopia	12											
Helopelopia												
Labrudinia												
Rheopelopia	16	12	11	20	16	32			4		1	
Thienemannimyia complex			8		1	11			2			
Trissopelopia												
F. Empididae												
indeterminate					1							
Chelifera	4											
Hemerodromia			7			1	6	4	8	1	6	5
F. Tipulidae												
indeterminate												
Antocha	8	2			1	7		1				
Dicranota												
Hexatoma			2	1		1.						
P. Mollusca												
Cl. Gastropoda												
F. Physidae												
Physella								1				
Cl. Pelecypoda												
F. Sphaeriidae												

Table D2: Detailed Identification and Densities of Benthic Invertebrates from Heath Steele (500 Micrometer Sieve)

Pisidium						1						
TOTAL NUMBER OF ORGANISMS	898	666	845	634	519	454	160	197	320	211	267	351
TOTAL NUMBER OF TAXA	37	33	48	40	44	51	16	31	25	24	29	31
RELATIVE ABUNDANCE(%)												
Chironomidae	11.1	8.41	4.26	10.1	8.67	18.9	1.25	3.05	4.38	0	4.49	0.57
Ephemeroptera	49	35.7	58.1	41.6	40.1	43	31.3	31.5	30	50.7	48.7	36.8
Trichopera	28.2	36.8	26	28.1	32.2	14.5	35	31	28.1	13.7	26.2	32.8
Plecoptera	6.01	9.01	4.73	12.1	9.44	7.71	23.8	20.3	22.5	25.1	13.5	21.9
EPT Index uncorrected	20	19	28	27	26	31	13	19	15	18	18	26
Correction for EPT	0	0	0	0	0	0	0	0	0	0	0	0
EPT index corrected	20	19	28	27	26	31	13	19	15	18	18	26
EPT/C	7.47	9.7	20.9	8.11	9.42	3.44	72	27.2	18.4	ERR	19.7	161

APPENDIX E

Fisheries

E.1 Detailed Methods

Revised Protocol for Metallothionein Analyses
on fish collected during the field trip for the preliminary survey
(Version: August 29, 1996)

Part of the biological monitoring component of AETE program consists of metallothionein analyses of tissues from large fish, e.g., trout, pike, suckers. This protocol presents the on-site sampling requirements. If the contractor is not familiar with conducting preparation of fish, advices and/or training in the dissection and handling of tissues should be obtained from the Freshwater Institute.

Sample size and sampling effort

- Liver, kidney, gill filaments, and skeletal muscle should be dissected from the 8 to 10 (eigth to ten) individuals **living**fish from each of the two large species from a reference site and an exposed site. The two most abundant large fish species common to the sampling sites are targetted.
- The largest specimen from each species should be selected.
- When possible 4 males and 4 females from the same species should be collected. No additionnal sampling effort should be given to meet the above sex requirement for the Phase I of the field study.
- A minimum number of 6 fish from the same species is required with a reasonnable level of effort for sampling (the best judgment will be applied considering the overall time constraints for performing field work for other components). The sampling gear and method should not be destructive: gill nets should regularly verified to avoid overfishing and sacrifice fewer fish.
- The tissues from the same fish can be split to serve for metallothionein and metal analyses.
- These tissues should be placed in marked individual polyethylene ("Whirlpak") bags, frozen on dry ice, and submitted for metallothionein analyses.
- When fish capture is performed using a seine net, young-of-the-year fish should be collected as well. In this case no dissection is required (abdomina contents will be removed at the laboratory). Whole fish are placed in marked individual polyethylene ("Whirlpak") bags, frozen on dry ice and whole fish.

Other information required

Information should be obtained on fish sex, body length (±1 mm), body weight (±1.0 g), liver and gonadal weights (±0.1 g) and collection should be made of appropriate aging structures (scales, fin rays, operculum, cleithrum or otoliths, depending upon species). Fecundity (estimates of total egg counts) and egg sizes should also be estimated if the timing of the collections is appropriate for the dominant species. All fish should also be checked for external and internal anomalies (a useful guide can be found in Goede and Barton; Amer. Fish. Soc. Sympos. 8:93-108, 1990; other analogous methods can be used). These data should be analysed to provide information on average (with variability) parameters, growth (size at age), the relationship between body length and weight, and the relationships between body size and liver weight, gonad weight and fecundity. All analyses should be conducted separately for each sex.

On-site sampling requirements

1. It is essential to obtain tissue samples from fish that are alive after collection and immediately before tissue removal.

2. A sample numbering system must be designed and used to facilitate tracking of all tissue sub-samples taken from the same fish. All tissue samples must be appropriately labelled.

3. After capture, the following measurements should be obtained on each fish: total body weight (g), gutted carcass weight [g] after removal of viscera), gonad weight (g), liver weight (g), fork length (cm), sex; and appropriate structure(s) for determining fish age should be removed.

4. Sampling of fish tissues should begin immediately after the whole body measurements have been made. Fish should be euthanised via concussion, cervical dislocation or with an overdose of anesthesic.

5. Gill, liver and kidney from the same fish can be divided into a part used for metallothionein analyses and another part used for metal analyses. Work must progress quickly on the euthanised fish with tissue.

6. Dissection and preserving procedures

   a) **Gills**:

      Remove the gill arches and attached filaments by severing the dorsal and ventral cartilaginous attachment of the arches to the surrounding oral cavity. Place the gill arches in a polyethylene bag ("Whirlpak"), label and freeze on dry ice or in liquid nitrogen. Gill arches are to be removed from the fish and frozen as soon after death as possible.

   b) Open the fish ventrally to expose the abdominal contents by using scissors to cut from the anus to the base of the pectoral fins. Care should be taken not to cut into internal organs when opening the fish.

   c) **Liver**: Remove the liver using care not to rupture the gall bladder. Remove the gall bladder from liver using care to prevent bile leakage from contacting the liver. Weigh and record weight to the nearest 0.1 g, if possible. Place the part of the liver in a "Whirlpak", label and freeze on dry ice or in liquid nitrogen.

   d) **Kidney**:Remove the kidneys by making lengthwise incisions along each edge of the tissue and then detach using the "spoon" end of a stainless steel weighing spatula by applying firm, but gentle, pressure against the upper abdominal cavity wall (i.e., against the dorsal aorta). In this procedure, the kidney is scraped away from the dorsal aorta and all associated connective tissue. The kidney is then to be placed in a "Whirlpak", labelled and frozen in liquid nitrogen or dry ice. The kidney is to be removed from the fish and frozen as soon after death as possible.

Samples for metallothionein (on dry ice) should be sent to:

Dr. J.F. Klaverkamp
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
Phone: (204) 983-5003
Fax: (204) 984-6587

E.2 Population Survey Results

Table E.1: Electrofishing Results for the Northwest Miramichi River, Heath Steele Mine, September 1996

ID#	Length (mm)	Weight (g)	Age	ID#	Length (mm)	Weight (g)	Age
Lake Chub				Atlantic Salmon			
LCMR 1 *	62	2.70	0	SALMR 1 *	121	20.83	2
LCMR 2 *	70	4.43	1	SALMR 2	122	20.85	2
LCMR 3 *	60	2.83	0	SALMR 3	120	18.81	2
LCMR 4 *	65	3.33	1	SALMR 4 *	78	5.25	1
LCMR 5	68	3.05	1	SALMR 5	84	6.45	1
LCMR 6	55	2.19	0	SALMR 6	88	10.77	1
LCMR 7	56	2.25	0	SALMR 7 *	93	8.47	2
LCMR 8	56	2.21	0	SALMR 8 *	85	6.63	1
				SALMR 9 *	84	6.65	1
				SALMR 10 *	87	7.45	1
				SALMR 11	82	5.75	1

* scales taken for aging

Table E.2: Electrofishing Data for the Tomogonops River, Heath Steele Mine, September 1996

ID#	Length (mm)	Weight (g)	Age	ID#	Length (mm)	Weight (g)	Age
Lake Chub				Atlantic Salmon			
LCA1*	70	4.78	1	SALA1-1*	60	2.56	0
LCA2*	110	19.28	2	SALA1-2*	55	2.33	0
LCA3*	68	5.51	1	SALA1-3*	86	7.66	1
LCA4*	60	2.81	0	SALA1-4*	61	2.59	0
LCA5*	75	5.14	1	SALA1-5*	61	2.37	0
LCA6*	60	2.25	0	SALA1-6*	60	2.46	0
LCA7*	56	2.71	0	SALA1-7*	68	3.34	0
LCA8*	60	2.64	0	SALA1-8*	61	2.97	0
LCA9*	55	1.94	0	SALA1-9*	64	3.1	0
LCA10*	59	2.49	0	SALA1-10*	64	3.07	0
LCA11*	51	1.7	0	SALA1-11*	61	2.64	0
LCA12*	35	0.5	0	SALA1-12*	64	2.96	0
LCA13*	50	1.05	0	SALA1-13*	62	2.82	0
LCA14*	25	0.19	0				
LCA15*	32	0.35	0	White Sucker			
LCA16*	26	0.21	0		82	6.32	
LCA17*	20	0.12	0				
LCA18*	25	0.19	0	Slimy Sculpin			
					66	2.94	

* scales taken for aging

Table E.3: Electrofishing Results for McCormack Brook (BCL4), Heath Steele Mine, September 1996

Sweep No.1			Sweep No.2			Sweep No.3			Sweep No.4			Sweep No.5		
ID#	Length (mm)	Weight (g)	ID#	Length (mm)	Weight (g)	ID#	Length (mm)	Weight (g)	ID#	Length (mm)	Weight (g)	ID#	Length (mm)	Weight (g)
Lake Chub														
LCR 1 *	56	1.88	LCR 13	62	2.92	LCR 17	81	6.69	LCR 22	67	3.77	LCR 24	74	5.48
LCR 2 *	60	2.43	LCR 14	65	3.42	LCR 18	81	7.18	LCR 23	60	2.44	LCR 25	65	3.11
LCR 3 *	57	2.33	LCR 15	52	1.64	LCR 19	63	3.36				LCR 26	43	0.88
LCR 4 *	70	4.28				LCR 20	65	3.14						
LCR 5 *	63	2.88				LCR 21	40	0.89						
LCR 6 *	67	3.43												
LCR 7 *	55	1.76												
LCR 8 *	45	1.09												
LCR 9 *	74	4.85												
LCR 10 *	83	6.94												
LCR 11	79	6.75												
LCR 12	69	5.11												
White Sucker														
WS1 - H				72	4		75	4.63						
Brook Trout														
BTR1-H *	79	5.78	BTR 11	100	10.13	BTR 15	125	20.15	BTR 16	82	6.67	BTR 24	72	4.19
BTR2-H *	75	4.66	BTR 12	75	4.2				BTR 17	73	4.83	BTR 25	71	5.09
BTR3-H *	78	5.95	BTR 13	78	5.03				BTR 18	69	3.63			
BTR4-H *	76	4.75	BTR 14	69	3.38				BTR 19	74	4.21			
BTR5-H *	68	3.75							BTR 20	70	3.84			
BTR6-H *	64	3.09							BTR 21	60	2.59			
BTR7-H *	62	2.68							BTR 22	72	3.94			
BTR8-H *	61	2.27							BTR 23	64	3.05			
BTR9-H *	140	32.37												
BTR10-H *	115	16.32												

E.3 Tissue Results

December 16, 1996

To: Lise Trudel
FAX: (613) 992-5172

From: J. F. Klaverkamp
FAX: (204) 984-6587

Subject: Relationships of MT to Metal Concentrations

The following information provides an overview of comparisons between MT (expressed as *u*g MT/g) and metal (expressed as *u*M/g) concentrations (data are expressed as the mean ± S.E.M. with (n)) in fish tissues sent to us by the three environmental consulting firms. There are cases where, as would be expected, MT is elevated when metal concentrations are higher. In other cases, the relationship is not clear cut. Again, in my view, we have to remember that one of the major objectives of this exercise was to gain experience by field personnel in capturing and dissecting live fish, and in transporting the samples to an analytical laboratory.

Jacques Whitford:

Gaspe sites:

MT results for brook trout and salmon collected from the Gaspe sites are related to metal concentrations:

	Brook trout:	Salmon:
Gaspe reference:		
[MT]	184 ± 38 (5)	73 ± 14 (8)
[Zn + Cu + Cd]	1.1 ± 0.1 (5)	3.6 ± 0.4 (8)
Gaspe exposure:		
[MT]	383 ± 72 (8)	118 ± 13 (8)
[Zn + Cu + Cd]	2.2 ± 0.2 (8)	4.6 ± 0.3 (8)

Heath Steele sites:

As I indicated in my memo to you on November 8, 1996, this set of results is not straight-forward. For lake char, one of the reference sites (#1) has the highest MT concentration (160 *u*g MT/g ± 17), but the lowest [Zn + Cu + Cd] (3.5 *u*M/g ± 0.6). This data set has only an n of 2. In comparing the other two sites for lake char, metal concentrations are about the same, but the exposure site has slightly higher MT (82 *u*g MT/g ± 5 for the exposure site *versus* 50 *u*g MT/g ± 14 for the reference site (#2). For salmon, fish from the exposure site have slightly higher MT, but lower metal concentrations. These results could indicate that the slight MT induction observed is not due to Zn, Cu or Cd. We should also keep in mind that, overall, this data set is the weakest in terms of numbers of observations.

	Lake char:	Salmon:
Heath Steele reference:		
Site #1:		
[MT]	160 ± 17 (2)	40 ± 2 (6)
[Zn + Cu + Cd]	3.5 ± 0.6 (2)	5.9 ± 1.0 (6)
Site #2:		
[MT]	50 ± 14 (3)	------------
[Zn + Cu + Cd]	4.0 ± 0.2 (3)	------------
Heath Steele exposure:		
[MT]	82 ± 5 (3)	64 ± 9 (3)
[Zn + Cu + Cd]	4.0 ± 0.5 (3)	4.5 ± 0.1 (3)

reversed, see hard data

Ecological Services Group:

For the viscera of Pearl Dace and Redbelly Dace, the differences in MT concentrations between the reference and exposure sites are not significantly different. Metal concentrations, however, are higher in viscera of fish from the exposure site. These results indicate that [MT] in viscera from these dace species do not reflect concentrations of Zn, Cu and Cd. One could argue that while [Zn + Cu + Cd] were higher in exposed fish, they were not high enough to produce a response. On the other hand, analyses of white sucker liver and gill do demonstrate a direct relationship between MT and metal concentrations. [MT] in white sucker kidney are higher in the fish from the exposure site, although concentrations of Zn + Cu + Cd are about the same. More suckers should be analyzed to see if this trend holds because the numbers of white suckers collected range from only one to two fish per site.

	Pearl dace:	Redbelly dace:
Reference:		
[MT]	99 ± 27 (6)	207 ± 65 (5)
[Zn + Cu + Cd]	0.84 ± 0.11 (6)	0.78 ± 0.13 (5)
Exposure:		
[MT]	113 ± 19 (7)	218 ± 28 (5)
[Zn + Cu + Cd]	1.87 ± 0.21 (7)	1.45 ± 0.18 (5)

White sucker:

	Liver:	Kidney:	Gill:
Reference:			
[MT]	103 (1)	115 (1)	28.5 ± 0.8 (2)
[Zn + Cu + Cd]	0.39 (1)	0.66 (1)	0.24 ± 0.01 (2)
Exposure:			
[MT]	480 ± 193 (2)	406 (1)	49.7 ± 2.1 (2)
[Zn + Cu + Cd]	0.64 ± 0.04 (2)	0.62 (1)	0.35 ± 0.02 (2)

EVS:

Sullivan Mine:

Here the story is also straight-forward; there are no differences between the reference site and the exposure site in terms of metal and MT concentrations. This data set was the best in terms of numbers of fish analyzed.

	Sculpin:
Reference:	
[MT]	136 ± 14 (13)
[Zn + Cu + Cd]	2.3 ± 0.4 (13)
Exposure:	
[MT]	135 ± 13 (11)
[Zn + Cu + Cd]	2.9 ± 0.4 (11)

While I have not had the time to do thorough regression analyses on all the data, I am attaching a few figures of results for "Gaspe salmon" and "Gaspe brook trout". You will also find attached a Summary Table and all the raw data. With compliments from DFO.

Wishing all of you a very merry and peaceful Christmas,

Jack

J. F. Klaverkamp

cc Susan Belford
Peter Chapman
Barb Dowsley
Yves Couillard

Summary

Description	Sample ID	$\bar{x}$ MT µg/g	S.E.	n	$\bar{x}$ Σ(Mx) µmol/g	S.E.
Jacque Whitford						
Gaspe site reference	BTR	183.7	37.9	5	1.14	0.14
Gaspe site exposure	BTE	383.1	72.3	8	2.24	0.16
Gaspe site reference	SALR	73.0	13.8	8	3.63	0.35
Gaspe site exposure	SALE	117.7	13.3	8	4.64	0.27
Heath Steele exposure	LCA	81.5	4.59	3	3.95	0.50
Heath Steele reference site 1	LCRA	159.6	16.8	2	3.51	0.55
Heath Steele reference site 2	LCMR	50.3	13.5	3	4.01	0.23
Heath Steele exposure	SALE	64.4	8.77	3	4.47	0.05
Heath Steele reference	SALMR	39.7	2.21	8	5.85	0.99
Heath Steele reference	BTR	128.2	15.7	5	3.75	0.60
ECOLOGICAL SERVICES GROUP SOUTH PORCUPINE RIVER VISCERA						
Pearl Dace reference site	PDR	98.5	26.6	6	0.84	0.11
Pearl Dace exposure site	PDE	112.8	19.2	7	1.87	0.21
Redbelly Dace reference site	RDR	207.1	64.9	5	0.78	0.13
Redbelly Dace exposure site	RDE	218.2	28.0	5	1.45	0.18
EVS ENVIRONMENT CONSULT. SULLIVAN MINE						
Sculpin reference site	SURCC	136.4	13.9	13	2.28	0.40
Sculpin exposure site	SUECC	135.0	13.3	11	2.93	0.40

Description	Sample ID	Zn µg/g	Cu µg/g	Cd µg/g	MT µg/g	MT µmoles/g	Σ[Mx] µmoles/g
Jacque Whitford							
Gaspe site reference	BTR-1	47	15.7	0.68	146.1	0.0195	0.975
	BTR-2	38	7.8	0.40	86.7	0.0116	0.711
	BTR-3	68	8.4	0.65	142.7	0.0190	1.186
	BTR-4	73	12.9	0.82	291.3	0.0388	1.320
	BTR-5	48	47.0	0.21	251.8	0.0336	1.489
Gaspe site exposure	BTE-1	153	47.0	0.64	856.1	0.1141	3.086
	BTE-2	87	46.9	0.20	287.3	0.0383	2.217
	BTE-3	101	60.9	0.31	382.4	0.0510	2.505
	BTE-4	81	41.8	0.41	251.3	0.0335	1.896
	BTE-5	84	63.9	0.38	402.1	0.0536	2.129
	BTE-6	83	48.3	0.42	287.5	0.0383	1.995
	BTE-7	58	49.5	0.47	202.2	0.0270	1.668
	BTE-8	114	43.6	0.32	396.0	0.0528	2.427
Gaspe site reference	SALR1	165	10.5	0.49	44.7	0.0060	2.695
	SALR2	185	50.0	0.69	146.7	0.0196	3.616
	SALR3	263	49.3	0.30	74.0	0.0099	4.797
	SALR4	196	10.9	0.23	56.5	0.0075	3.164
	SALR5	224	24.8	0.38	60.5	0.0081	3.819
	SALR6	135	5.3	0.13	29.1	0.0039	2.150
	SALR7	241	3.7	0.41	56.4	0.0075	3.747
	SALR8	297	33.2	0.59	116.3	0.0155	5.066
Gaspe site exposure	SALE1	245	57.3	0.58	89.0	0.0119	4.667
	SALE2	259	100.8	0.64	125.1	0.0167	5.550
	SALE3	334	38.6	0.53	102.7	0.0137	5.724
	SALE4	141	86.3	0.78	174.7	0.0233	3.528
	SALE5	220	87.6	0.58	116.7	0.0156	4.742
	SALE6	160	82.2	0.44	169.1	0.0225	3.738
	SALE7	209	90.8	0.48	96.2	0.0128	4.694
	SALE8	199	94.7	0.48	68.2	0.0091	4.534
Heath Steele exposure	LCA1-A	74	166.1	0.81	89.3	0.0119	3.750
	LCA1-B	49	154.8	0.68	73.4	0.0098	3.198
	LCA1-C	110	203.0	0.95	81.9	0.0109	4.889
	SALEA-H	105	176.4	0.38	48.1	0.0064	4.323
	SALEB-H	123	169.2	0.32	66.8	0.0089	4.550
	SALEC-H	208	81.7	0.45	78.2	0.0104	4.477
Heath Steele reference	LCRA-H	71	188.4	0.65	142.8	0.0190	4.058
	LCRB-H	54	138.0	0.41	176.3	0.0235	2.987
Heath Steele reference	BTR-H-A	65	75.7	0.34	132.3	0.0176	2.181
	BTR-H-B	62	136.2	0.62	161.5	0.0215	3.100
	BTR-H-C	74	240.9	0.23	156.6	0.0209	4.928
	BTR3-H	57	146.3	0.17	115.5	0.0154	3.176
	BTR5-H	79	264.6	0.22	75.2	0.0100	5.370
	SALMRA-H	163	108.2	0.21	41.7	0.0066	4.200
	SALMRB-H	138	135.7	0.22	35.6	0.0047	4.245
	SALMR6-H	166	82.6	0.17	48.7	0.0065	3.668
	SALMR7-H	244	187.8	0.18	35.4	0.0047	6.690
	SALMR8-H	166	209.4	0.14	41.6	0.0055	5.830
	SALMR10-H	478	189.0	0.25	35.0	0.0047	10.262
	LCMRA-H	96	168.6	0.19	62.0	0.0083	4.444
	LCMRB-H	60	190.0	0.16	23.4	0.0031	3.913
	LCMRC-H	83	153.1	0.23	65.6	0.0087	3.684
	SALMR-2-G	25	33.1	0.01	13.3	0.0018	0.903
	SALE-2-G	57	53.4	0.01	14.6	0.0019	1.713
	ATLSALGRB-1	103	115.9	0.08	20.5	0.0027	3.413
	ATLSALGRB-2	107	73.2	0.05	56.0	0.0075	2.792
	ATLSALGRB-3	80	25.2	0.04	34.5	0.0046	1.626
	ATLSALGRB-4	97	37.9	0.36	25.4	0.0034	2.091
	ATLSALGRB-6	60	16.6	0.04	11.5	0.0015	1.492
	ATLSALGRB-A	38	14.5	0.05	55.5	0.0074	0.817