AQUATIC EFFECTS TECHNOLOGY EVALUATION (AETE) PROGRAM

1997 Field Program
Final Report
Mattabi Mine Site,
Ontario

AETE Project 4.1.3

September 1998
Revised as of March 1999

1997 FIELD PROGRAM - AETE
MATTABI MINE

SITE REPORT

Report prepared for:

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AQUATIC EFFECTS TECHNOLOGY EVALUATION PROGRAM

Notice to Readers

1997 Field Program

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.

Phases II and III are the focus of this report. The objective of the 1997 Field Program is NOT to determine the extent and magnitude of effects of mining at the sites but rather to test a series of hypotheses under field conditions and evaluate monitoring methods for assessing aquatic effects.

In Phase I, the AETE Technical Committee selected seven candidates mine sites for the 1996 field surveys: Myra Falls, Westmin Resources (British Columbia); Sullivan, Cominco (British Columbia); Lupin, Contwoyto Lake, Echo Bay (Northwest Territories); Dome, Placer Dome Canada (Ontario); Levack/Onaping, Inco and Falconbridge (Ontario); Gaspé Division, Noranda Mining and Exploration Inc. (Québec); 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.

A summary of the results and comparisons of tools at all the four mine sites studied in 1997 are provided in a separate document which evaluate the cost-effectiveness of each monitoring tool (AETE Report #4.1.3, *Summary and Cost-effectiveness Evaluation of Aquatic Effects Monitoring Technologies Applied in the 1997 AETE Field Evaluation Program,* Beak International Incorporated and Golder Associates Ltd, September 1998)

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*.

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

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

Avis aux lecteurs

Études de terrain - 1997

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 II et III. L'objectif du projet N'EST PAS de déterminer l'étendue ou l'ampleur des effets des effluents miniers dans les sites. Le projet vise à vérifier une série d'hypothèses sur le terrain et à évaluer et comparer un ensemble choisi de méthodes de surveillance.

À l'étape I, le comité technique ÉTIMA a sélectionné sept sites miniers candidats aux fins des évaluations sur le terrain:Myra Falls, Westmin Resources (Colombie-Britannique); Sullivan, Cominco (Colombie-Britannique); Lupin, lac Contwoyto, Echo Bay (Territoires du Nord-Ouest); Levack/Onaping, Inco et Falconbridge (Ontario); Dome, Placer Dome Mine (Ontario); Division Gaspé, Noranda Mining and Exploration Inc.(Québec); 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.

Un résumé des résultats obtenus aux quatre sites miniers en 1997, la comparaison et l'évaluation des techniques dans une perspective coût-efficacité sont présentés dans un autre document (Rapport ÉTIMA #4.1.3, *Summary and Cost-effectiveness Evaluation of Aquatic Effects Monitoring Technologies Applied in the 1997 AETE Field Evaluation Program,* Beak International Incorporated and Golder Associates Ltd, September 1998).

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*.

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

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EXECUTIVE SUMMARY

The Mattabi Mine (Ontario) study is one of four field evaluations carried out in 1997 under the Aquatic Effects Technology Evaluation (AETE) Program, a joint government-industry program to evaluate the cost-effectiveness of technologies for the assessment of mining-related impacts in the aquatic environment. The other three mines studied were Dome (Ontario), Myra Falls (British Columbia) and Heath Steele (New Brunswick). Results of all four studies are summarized and evaluated in a separate summary report.

Mattabi Mines of Noranda Inc. operated a copper-lead-zinc open pit and underground mining operation and concentrator complex 80 km northeast of Ignace in northwestern Ontario. The mine was closed in 1991 and is undergoing rehabilitation; however, site runoff and seepages continue to be collected, treated and discharged to control impacts from acid rock drainage (ARD) and metal leaching. Effluent is treated with lime, polished and discharged to Bell Creek, which flows into Sturgeon Lake. Sturgeon Lake and other smaller lakes (including No Name Lake) were historically affected by ARD and loadings of zinc and other metals, and sediments in these waters are enriched with metals.

The objectives of the 1997 field program were to test 13 hypotheses formulated under four guiding questions:

1. are contaminants getting into the system (and to what degree and in which compartments)?
2. are contaminants bioavailable?
3. is there a measurable (biological) response? and
4. are contaminants causing the responses?

The hypotheses are more specific questions about the ability or relative ability of different monitoring tools to answer these four general questions about mine effect. The evaluation of tools included: sediment monitoring (sediment toxicity tests); fish monitoring (tissue metallothionein and metal analyses, and population/community indicators), and; integration of tools (relationships between exposure and biological responses and use of effluent sublethal toxicity).

Of the 13 hypotheses, 12 were tested at Mattabi as outlined in Table 1.1. The remaining hypothesis not tested at Mattabi relates to effluent chronic toxicity and its linkage to benthic and fish effects (H13). This hypothesis was deleted to optimize the field work plan (for project budget).

The sediment quality triad was used as an additional means of evaluating the linkages between sediment toxicity, sediment chemistry and benthic community response (H10 and H11) in a sediment quality gradient in No Name Lake and Mine Creek Bay (Sturgeon Lake). The triad provides a more holistic means of evaluating the tools.

Study Design

The study design at Mattabi was based on lake sampling for benthos, sediment chemistry and sediment toxicity using a gradient design, including five exposure areas having different sediment zinc concentrations (No Name Lake, Mine Creek Bay) and two reference areas (Tag Lake and Peterson Cove-Sturgeon Lake). Three stations were sampled for sediment quality, toxicity and benthos within each of the seven areas.

Sampling in Bell Creek followed a reference-exposure (Control-Impact) design, and allowed for testing of fish-related hypotheses. The reference area for fish collection was located in generally similar habitat nearby in a separate watershed (English River). Four stations were sampled for fish in each of the two areas, providing replicates for testing of hypotheses relating to fish populations and communities (H5 and H6).

Sampling Program

The field survey at Mattabi was completed in mid-October 1997, and included:

- water sampling at each of seven sediment/benthic sampling areas (one each) and each of two fish sampling areas (four per area). Only Bell Creek and English River data were used in hypothesis testing;

- surficial sediment sampling at each of 21 sampling stations (7 areas x 3 stations) using a petite Ponar, for determination of "total" metal concentration, partial metal concentration (i.e., the Fe and Mn oxide-bound fraction) and concentrations of acid volatile sulphide (AVS) and simultaneously extracted metals (SEM);

- surficial sediment sampling at the same 21 stations for benthic macroinvertebrate community analysis and for sediment toxicity testing (*Hyalella azteca* - survival and growth, *Chironomus riparius* - survival and growth, *Tubifex tubifex* - survival and growth);

- sampling of the fish community by gillnet (at least two sets per station) at each of four exposure stations and four reference stations for determination of fish community and population parameters, and to provide specimens of white sucker and northern pike for tissue analysis; and

- sampling of 83 white sucker and 85 northern pike total from the two sampling areas for analysis of metals and metallothionein (MT) in muscle (metals only), liver, kidney and gill.

Data Overview

Water Quality

Mattabi effluent was enriched in zinc, calcium and sulphate. Bell Creek water contained elevated concentrations of zinc, copper, cadmium and lead relative to the English River, with zinc concentrations greater than Canadian Water Quality Guidelines downstream of the mine.

Concentrations of zinc were also elevated in water in No Name Lake and to a much lesser degree in Mine Creek Bay relative to the lake reference areas. Water quality guidelines were exceeded only in No Name Lake, with zinc concentration nearly two orders of magnitude above the guideline.

Dissolved and total metal concentrations showed similar spatial patterns for key metals (Zn, Cu, Cd, Pb), with dissolved and total values similar in magnitude in most cases except for Pb in No Name Lake (dissolved Pb < total Pb).

Sediment Quality

All sediments were organic-rich and sandy, with total organic carbon contents of 20 to 30%. Concentrations of total Zn, Pb, Cd, Cu, As, Ni and Hg exceeded Canadian Interim Sediment Quality Assessment Values at most exposure stations, with maximum values for zinc as high as two orders of magnitude above Probable Effect Levels (PELs). Metal concentrations followed a declining concentration gradient across the range of exposure areas sampled.

Partial metal concentration gradients were weaker than those for total metals, implying that the largest fraction of metals present is relatively strongly bound to sediment particles.

The SEM/AVS ratios showed no distinct spatial patterns, although SEM and AVS values were much greater in the exposure gradient than at reference areas. The results imply some potential for sediment toxicity, although ratios were relatively low (≤1.5) in most exposure areas (except No Name Lake where higher ratios occurred). A ratio above one implies some potential for sediment toxicity, especially when SEM values are high.

Sediment Toxicity

Sediment toxicity (lethal and sublethal effects) showed little or no response in any test species to the sediment quality gradient at Mattabi. Although mortality occurred both in *Chironomus* and *Hyalella*, responses appeared similar regardless of location (reference vs exposure).

Benthic Macroinvertebrates

Benthic community trends were apparent in the sediment quality gradient, with reduced numbers of taxa in the most effected sediments. Hydracarina (water mites), *Caenis* (mayfly) and *Pisidium* (pea clam) in particular were reduced in abundance at the most affected locations.

Fish

Catches-per-unit-effort for all fish species combined were not distinctly different between reference and exposure areas. White sucker appeared more abundant in the exposure area and northern pike more abundant in the reference area. In white sucker, growth, liver size, gonad size and fecundity were comparable in reference and exposure fish. In pike, fish size at age, organ sizes and fecundity were distinctly greater in exposed (Bell Creek) fish relative to the reference area. When adjusted for body weight, organ sizes remained greater in exposed pike.

Tissue metal concentrations showed some reference-exposure differences, with differences most pronounced for selenium in all tissues and both species. This could be mine-related as selenium was detected in Mattabi effluent, but not in any other water sample.

The only metallothionein response measured was in gill and kidney of northern pike. No metallothionein responses occurred in sucker.

Hypothesis Testing

Hypothesis testing results are summarized in Table 5.2. Results of testing indicate that some of the contaminants (metals) are bioavailable, that some biological responses occurred and that contaminants appear to cause some of these responses.

Technology Evaluation

Some of the tools evaluated demonstrated a mine effect at Mattabi, whereas others did not (Table 6.2). Monitoring tools demonstrating effects or partially demonstrating effects included most water and sediment chemistry tools (except SEM/AVS), most benthic macroinvertebrate tools, and some of the fish tissue and metallothionein tools (depending on metal, tissue type and fish species). Tools that did not show responses consistent with impact included several in the fish health, fish population/community and sediment toxicity tool boxes. The limited effectiveness of some of these tools may be due to low metal bioavailability, possibly combined with the effects of natural variation. Of the monitoring tools in the same “tool box” demonstrating effects (e.g., total vs partial metals in sediments; metals vs metallothionein in tissues, etc.), major differences in tool effectiveness were not apparent at Mattabi (Table 6.3).

Overall, the relatively subdued impacts of metals at Mattabi are unexpected and noteworthy. This general condition contrasts with the greater bioavailability of metals and impact at Heath Steele and Myra Falls. This is particularly unusual because metal concentrations in Mattabi sediments are greater than observed at any of the other mines studied in the AETE program.

Conclusions on the cost-effectiveness of the tools based on results from all four mine sites studied in 1997 are found in a separate document “Summary and Cost-Effectiveness Evaluation of Aquatic Effects Monitoring Technologies Applied in the 1997 AETE Field Evaluation Program”.

SOMMAIRE

L'étude du site de la mine Mattabi (Ontario) est l'une des quatre évaluations sur le terrain effectuées en 1997 dans le cadre du Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ETIMA), programme conjoint gouvernement-industrie destiné à évaluer le rapport coût-efficacité des technologies d'évaluation des impacts liés aux activités minières dans le milieu aquatique. Les trois autres sites miniers étudiés étaient ceux de Dome (Ontario), de Myra Falls (Colombie-Britannique) et de Heath Steele (Nouveau-Brunswick). On présente un résumé et une évaluation des résultats de ces quatre études dans un rapport sommaire distinct.

La mine Mattabi de Noranda Inc. exploitait une mine à ciel ouvert de cuivre, de plomb et de zinc combinée à une mine souterraine et à une installation de concentration à 80 km au nord-est d'Ignace, dans le nord-ouest de l'Ontario. Cette mine a été fermée en 1991 et on y effectue actuellement des travaux de restauration; toutefois, on continue à recueillir des eaux de ruissellement et d'infiltration, qui sont traitées avant leur rejet afin de limiter l'impact des eaux d'exhaure des roches acides et de la lixiviation des métaux. On traite les effluents avec de la chaux, on les purifie et on les rejette dans le ruisseau Bell, qui se déverse dans le lac Sturgeon. Au cours des années passées, on a noté dans ce lac et dans d'autres lacs plus petits (notamment le lac No Name) des effets d'eaux d'exhaure acides, de charges de zinc et d'autres métaux, ainsi que de sédiments enrichis en métaux.

Les objectifs du programme sur le terrain de 1997 étaient de vérifier 13 hypothèses formulées pour tenter de répondre à quatre questions principales :

1. Est-ce que les contaminants pénètrent dans le réseau aquatique (et dans l'affirmative, dans quelle mesure et dans quels compartiments)?
2. Les contaminants sont-ils biodisponibles?
3. La réponse (biologique) est-elle mesurable?
4. Les contaminants sont-ils la cause de ces réponses?

Ces hypothèses représentent des questions plus spécifiques concernant la capacité (relative) des différents outils de surveillance de répondre à ces quatre questions générales sur les effets des activités minières. L'évaluation des outils prévoyait notamment la surveillance des sédiments (tests de toxicité des sédiments), la surveillance des poissons (dosage de la métallothionéine et des métaux dans les tissus et détermination des indicateurs des populations/communautés) et, enfin, l'intégration des outils (rapports entre l'exposition et les réponses biologiques, et utilisation de la toxicité sublétale des effluents).

On a vérifié 12 des 13 hypothèses au site de la mine Mattabi (voir le tableau 1.1). Les hypothèses non vérifiées à ce site concernent la toxicité chronique des effluents et ses liens avec les effets benthiques et les effets sur les poissons (H13). On a retiré cette hypothèse de la liste afin d'optimiser le plan de travail sur le terrain (pour le budget du projet).

On a utilisé les trois paramètres de la qualité des sédiments comme outil supplémentaire pour l'évaluation des liens entre la toxicité des sédiments, la chimie des sédiments et la réponse de

la communauté benthique (H10 et H11) dans un gradient de qualité des sédiments du lac No Name et de la baie Mine Creek (lac Sturgeon). Ces trois paramètres donnent une vue plus générale pour l'évaluation des outils.

Plan de l'étude

Le plan de l'étude à la mine de Mattabi était basé sur l'échantillonnage des lacs pour l'étude du benthos, ainsi que de la chimie et de la toxicité des sédiments selon un gradient, et notamment dans cinq zones d'exposition dont les sédiments présentaient différentes concentrations de zinc (lac No Name, baie Mine Creek) et dans deux zones de référence (lac Tag et anse Peterson - lac Sturgeon). On a prélevé des échantillons dans trois stations de chacune de ces sept zones pour déterminer la qualité et la toxicité des sédiments, ainsi que pour l'étude du benthos.

Dans le ruisseau Bell, l'échantillonnage suivait un modèle zone de référence (témoin) - zone d'exposition (impact), qui permettait de vérifier des hypothèses liées aux poissons. La zone de référence pour le collecte des poissons était située dans un habitat à peu près semblable dans un bassin hydrographique voisin, mais distinct (rivière English). On a prélevé des échantillons de poissons dans quatre stations de chacune des deux zones, de façon à obtenir des exemplaires multiples pour vérifier les hypothèses concernant les populations et les communautés de poissons (H5 et H6).

Programme d'échantillonnage

On a terminé les relevés sur le terrain à Mattabi vers la mi-octobre 1997, et notamment :

- l'échantillonnage de l'eau dans chacune des sept zones d'échantillonnage pour les sédiments ou les organismes benthiques (un pour chaque zone) et dans chacune des deux zones d'échantillonnage pour les poissons (quatre par zone). On n'a utilisé que les données du ruisseau Bell et de la rivière English pour la vérification des hypothèses;

- l'échantillonnage des sédiments de surface à chacune des 21 stations d'échantillonnage (7 zones x 3 stations) à l'aide d'un échantillonneur « Petite Ponar » pour la détermination de la concentration « totale » des métaux, de la concentration partielle des métaux (c.-à-d. la fraction liée aux oxydes de Fe et de Mn), ainsi que des concentrations de sulfure volatil en milieu acide et des métaux extractibles simultanément;

- l'échantillonnage des sédiments de surface à ces 21 stations pour l'analyse de la communauté des macroinvertébrés benthiques et pour des tests de toxicité des sédiments (survie et croissance d'*Hyalella azteca*, de *Chironomus riparius* et de *Tubifex tubifex*);

- l'échantillonnage des communautés de poissons à l'aide de filets maillants (au moins deux échantillons par station) à chacune des quatre stations d'exposition et à quatre stations de référence pour la détermination des paramètres des communautés et des populations de poissons, ainsi que pour obtenir des spécimens de meunier noir et de grand brochet pour des analyses de tissus;

- l'échantillonnage d'un nombre total de 83 meuniers noirs et de 85 grands brochets de deux zones d'échantillonnage pour le dosage des métaux et de la métallothionéine (MT) des muscles (métaux seulement), du foie, des reins et des branchies.

Aperçu des données

Qualité de l'eau

Les effluents du Mattabi étaient enrichis en zinc, en calcium et en sulfate. L'eau du ruisseau Bell contenait des fortes concentrations de zinc, de cuivre, de cadmium et de plomb par rapport à celles de la rivière English, ainsi que des concentrations de zinc dépassant les limites des Recommandations pour la qualité des eaux au Canada en aval de la mine.

De plus, les concentrations de zinc étaient élevées dans l'eau du lac No Name, ainsi que dans la baie Mine Creek (mais beaucoup moins dans celle-ci) par rapport aux zones de référence du lac. Les limites des Recommandations n'étaient dépassées que dans les eaux du lac No Name, où l'on observait un dépassement de presque deux ordres de grandeur pour le zinc.

Pour les concentrations de principaux métaux dissous et totaux (Zn, Cu, Cd, Pb), on observait, dans la plupart des cas, des profils de distribution spatiale semblables, avec des valeurs du même ordre pour les métaux dissous et totaux, sauf pour le Pb du lac No Name (Pb dissous plus faible que le Pb total).

Qualité des sédiments

Tous les sédiments étaient riches en matières organiques et sableux, avec des teneurs en carbone organique total de 20 à 30 %. Les concentrations de Zn, Pb, Cd, Cu, As, Ni et Hg totaux dépassaient les valeurs de l'évaluation intérimaire canadienne de la qualité des sédiments (Canadian Interim Sediment Quality Assessment Values) à la plupart des stations d'exposition, avec des valeurs maximales pour le zinc dépassant de jusqu'à deux ordres de grandeur les teneurs à effets probables. Les concentrations des métaux suivaient un gradient de concentration décroissant sur la plage des valeurs observées dans les zones d'exposition échantillonnées.

Les gradients des concentrations partielles des métaux étaient plus faibles que ceux des concentrations totales des métaux, ce qui indique que la fraction la plus importante des métaux est liée de façon relativement forte aux particules de sédiments.

Les rapports des concentrations des sulfures volatils en milieu acide et de celles des métaux extractibles simultanément ne correspondaient à aucun profil distinct de distribution spatiale, même si dans le gradient d'exposition, les valeurs de ces concentrations étaient très supérieures à celles observées dans les zones de référence. Ces résultats indiquent une certaine possibilité de toxicité des sédiments, bien que les valeurs de ces rapports soient relativement faibles (inférieures ou égales à 1,5) dans la plupart des zones d'exposition (sauf dans le lac No Name, où l'on a observé des valeurs de rapports plus élevées). Une valeur de rapport supérieure à l'unité indique une certaine possibilité de toxicité des sédiments, surtout avec des valeurs élevées de métaux extractibles simultanément.

Toxicité des sédiments

Au site Mattabi, la toxicité des sédiments (effets létaux et sublétaux) correspondait à une réponse faible à nulle du gradient de qualité des sédiments pour toutes les espèces testées. Malgré la mortalité observée chez *Chironomus* et *Hyalella*, les réponses paraissaient semblables quel que soit l'emplacement (comparaison entre la zone de référence et la zone d'exposition).

Macroinvertébrés benthiques

On notait certaines tendances des communautés benthiques dans le gradient de qualité des sédiments, avec des nombres réduits de taxons dans la plupart des sédiments touchés. À ces endroits, on observait notamment des réductions d'abondance chez *Hydracarina* (hydrachnidés), *Caenis* (éphémères) et *Pisidium* (pisidies).

Poissons

Pour toutes les espèces de poissons combinées, on n'observait pas de différences marquées entre les prises par unité d'effort de la zone de référence et celles de la zone d'exposition. On notait une plus grande abondance apparente de meunier noir dans la zone d'exposition, et de grand brochet dans la zone de référence. Pour le meunier noir, la croissance, la taille du foie et des gonades et la fécondité étaient comparables chez les poissons de la zone de référence et de la zone d'exposition. Pour le brochet, les valeurs de taille des poissons selon l'âge, ainsi que celles de la taille des organes et de la fécondité, étaient beaucoup plus grandes chez les poissons exposés (ruisseau Bell) que chez ceux de la zone de référence. Après un ajustement pour tenir compte du poids corporel, les valeurs de taille des organes restaient plus élevées chez les brochets exposés.

Les concentrations de métaux dans les tissus mesurées dans la zone de référence présentaient certaines différences par rapport à celles de la zone d'exposition, et ces différences étaient le plus prononcées pour le sélénium dans tous les tissus chez ces deux espèces. Cet effet pourrait être lié aux activités minières, étant donné qu'on a détecté la présence de sélénium dans les effluents de la mine Mattabi, mais dans aucun autre échantillon d'eau.

On n'a noté une réponse de la métallothionéine que pour les branchies et les reins du grand brochet, et non pour le meunier noir.

Vérification des hypothèses

Les résultats des vérifications des hypothèses sont résumés au tableau 5.2; ils indiquent que certains contaminants (métaux) sont biodisponibles, qu'on observe certaines réponses biologiques et que les contaminants peuvent être à l'origine de certaines de ces réponses.

Évaluation des techniques

Avec certains des outils évalués, on notait un effet dû aux activités de la mine Mattabi, ce qui n'était pas le cas pour d'autres (tableau 6.2). Les outils de surveillance indiquant des effets, même partiels, étaient notamment la plupart des outils de chimie de l'eau et des sédiments (sauf pour le rapport des concentrations des sulfures volatils en milieu acide et de celles des métaux extractibles simultanément), la plupart des outils d'étude des macroinvertébrés benthiques et certains outils d'analyse des tissus des poissons et de la réponse de métallothionéine (selon le métal, le type de tissu et l'espèce de poisson). Les outils avec lesquels on n'obtenait pas de réponse cohérente en fonction de l'impact étaient notamment plusieurs trousses d'outils pour la détermination de la santé des poissons, des paramètres des populations ou des communautés de poissons et de la toxicité des sédiments. L'efficacité limitée de certains de ces outils pourrait être due à une faible biodisponibilité des métaux, peut-être combinée aux effets des variation naturelles. Au site Mattabi, on n'a pas observé de différences importantes concernant l'efficacité des outils de surveillance de la même « trousse d'outils », avec lesquels on notait des effets (p. ex. concentrations totales par rapport aux concentrations partielles de métaux dans les sédiments; métaux par rapport à la métallothionéine dans les tissus, etc.) (tableau 6.3).

Dans l'ensemble, les impacts relativement modestes des métaux de la mine Mattabi sont inattendus et remarquables, car les conditions générales sont très différentes des conditions de plus grande biodisponibilité des métaux et d'impact aux sites Heath Steele et Myra Falls. Cela est d'autant plus difficile à expliquer que les concentrations de métaux dans les sédiments du site Mattabi sont plus élevées que celles observées à tous les autres sites miniers étudiés dans le cadre du programme ETIMA.

Un document distinct, « Summary and Cost-Effectiveness Evaluation of Aquatic Effects Monitoring Technologies Applied in the 1997 AETE Evaluation Program », présente les conclusions sur le rapport coût-efficacité de ces outils, qui sont basées sur les résultats obtenus pour les quatre sites miniers étudiés en 1997.

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1.0 INTRODUCTION

The Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN), initiated in 1993, evaluated the effectiveness of Canada's *Metal Mining Liquid Effluent Regulations* (MMLER). One of the key recommendations of the 1996 AQUAMIN Final Report is that a revised MMLER include a requirement that metal mines conduct Environmental Effects Monitoring (EEM), to evaluate the effects of mining activity on the aquatic environment, including fish, fish habitat and the use of fisheries resources.

In parallel, the Canada Centre for Mineral and Energy Technology (CANMET) is coordinating a cooperative government-industry program, the Aquatic Effects Technology Evaluation (AETE) program, to review and evaluate technologies for the assessment of mining-related impacts in the aquatic environment. The intention of the AETE program is to evaluate and identify cost-effective technologies to meet environmental monitoring requirements at mines in Canada. The program is focused on evaluation of environmental monitoring tools that may be used for a national mining EEM program, baseline assessments or general impact studies.

The three principal components of the AETE program are lethal and sublethal toxicity testing of water/effluents and sediments, biological monitoring in receiving waters, and water and sediment chemistry assessments. The program includes both literature-based technical evaluations and comparative field programs at candidate sites. The AETE program is presently at the stage of evaluating selected monitoring methods at four case study sites across Canada.

An AETE Pilot Field Study was carried out in the Val d'Or region of Quebec in 1995 to evaluate a large number of environmental monitoring methods and to reduce the list of monitoring technologies for further evaluation at a cross-section of mine sites across Canada (BEAK, 1996). In 1996, a field evaluation program was initiated and involved preliminary sampling at seven candidate mine sites with the objective of identifying a short-list of mines that had suitable conditions for further detailed monitoring and testing of hypotheses relating to the AETE program. Preliminary study designs were developed for four sites that were deemed to be most suitable for hypotheses testing in 1997 (EVS *et al.*, 1997). The sites selected were Heath Steele, New Brunswick; Lupin, Northwest Territories; Dome Mine, Ontario; and Westmin Resources (now Boliden-Westmin), British Columbia. Lupin was subsequently dropped based on a 1997 reconnaissance survey and replaced with the Mattabi

Mines Ltd. site in northwestern Ontario (BEAK and GOLDER, 1998a). This report documents the results of the 1997 Field Evaluation at the Mattabi Mine site.

The 1996 Field Evaluation constituted Phase I of the Field Evaluation Program. The 1997 Field Evaluation consists of Phases II and III of the Program. Phase II includes the review of necessary background information, finalization of a study design and implementation of the field studies. Phase III includes the compilation, interpretation and reporting of results. Mattabi was not studied in Phase II, but sufficient background information was available to quickly develop and finalize a study design for this site as an alternate to the Lupin Mine.

1.1 Study Objectives

The overall goal of the AETE Program is to identify cost-effective methods and technologies that are suitable for assessing aquatic environmental effects caused by mining activity. An effect is defined as "a measurable difference in an environmental variable (chemical, physical or biological) between a point downstream (or exposed to mining) in the receiving environment and an adequate reference point (either spatial or temporal)". Based on this definition, the AETE Technical Committee developed a series of hypotheses to be tested under field conditions at a number of mine sites in Canada. The Committee agreed that specific hypotheses should be articulated in order to clarify the purpose of the program elements. For the formulation of the hypotheses, the definition of an effect was refined by the AETE Committee to distinguish between effects or responses as measured in biological variables as opposed to effects reflected in physical or chemical changes.

The questions used in developing the hypotheses to be tested in the 1997 Field Evaluation Program were:

1. Are contaminants getting into the system (and to what degree, and in which compartments)? This question relates to the presence of elevated concentrations of metals in environmental media (e.g., water, sediments), and requires an understanding of metal dispersal mechanisms, chemical reactions in sediment and water, and aquatic habitat features which influence exposure of biological communities.

2. Are contaminants bioavailable? This question relates to the presence of metals in biota or to indicators of bioaccumulation such as the induction of metallothionein (MT) in fish. Only if contaminants are bioavailable can a biological effect from chemical contaminants occur.

3. Is there a measurable response? Biological responses may occur only if contaminants are entering the environment and occur in bioavailable forms. These responses may occur at various levels of biological organization, including sub-organism levels (e.g., histopathological effects), at the organism level (e.g., as measured in toxicity testing), or at population and community levels (as measured in resident benthos and fish communities).

4. Are contaminants causing the responses? This question is difficult to measure in field studies directly, as cause-effect mechanisms are difficult to assess under variable conditions prevailing in nature. However, correlations between measures of exposure, chemical bioavailability and response may be used to develop evidence useful in evaluating this question.

The AETE Technical Committee developed a study framework, using the above questions and the three components (water and sediment monitoring, biological monitoring in receiving waters and toxicity testing). The following eight areas of work were identified to finalize the work plan, develop the hypotheses, prioritize issues and identify field work requirements:

1. Chemical presence;
2. The overlap between communities and chemistry testing to determine whether biological responses are related to a chemical presence (bioavailability of contaminants);
3. Biological response in the laboratory;
4. Biological response in the field;
5. Chemical characteristics of the water and sediments used to predict biological responses in the field (contaminants causing a response);
6. The overlap between biological communities responses and bioassay responses to evaluate whether wild community changes are predicted by bioassay responses;

7. The overlap between chemistry and bioassay responses to evaluate whether chemicals are responsible for bioassay responses; and
8. The overlap between the chemical, the exposure and the effects in the laboratory and the effects in the field.

The core objective, however, is to **test the 13 hypotheses, developed by the AETE Committee, at as many of the four selected mine sites as possible (Table 1.1)** The hypotheses are more specific questions about the ability or relative ability of different monitoring tools to answer the four general questions (above) about mine effects.

These 13 hypotheses can be categorized as follows:

- ***Sediment Monitoring***: evaluation of sediment toxicity testing tools (test types) as to their relative ability to detect linkages between mine exposure and sediment toxicity (H1);

- ***Biological Monitoring (in Fish)***: evaluation of tissue biomonitoring tools (measurement types) as to their ability to detect linkages between mine exposure and tissue contamination (H2 to H4); and evaluation of population/community biomonitoring tools (measurement types) as to their ability to detect linkages between mine exposure and ecological response (H5 to H8); and

- ***Integration of Tools***: evaluation of various monitoring tools as to their relative ability to detect relationships between specific measures of mine exposure and specific biological response measures, or between sediment toxicity and benthic community response measures (H9 to H12); and evaluation of effluent toxicity testing tools (test types) as to their ability to detect relationships between effluent toxicity and population/community response measures (H13).

Twelve of the 13 hypotheses (all except H13) were tested at the Mattabi Mine site. In addition, it was desired to evaluate an overall "sediment quality triad" hypothesis, that addresses whether mine-related contaminants appear to be causing biological responses.

TABLE 1.1: HYPOTHESES TESTED IN 1997. AETE FIELD PROGRAM
(Hypotheses in bold print were tested at Mattabi)

Sediment Monitoring

H1. Sediment Toxicity:

H: ***The strength of the relationship between sediment toxicity responses and any exposure indicator is not influenced by the use of different sediment toxicity tests or combinations of toxicity tests.***

Biological Monitoring - Fish

H2. Metals in Fish Tissues (bioavailability of metals):

H: ***There is no difference in metal concentrations observed in fish liver, kidney, gills, muscle or viscera.***

H3. Metallothionein in Fish Tissues:

H: ***There is no difference in metallothionein concentration observed in liver, kidney, gills, viscera***

H4. Metal vs. Metallothionein in Fish Tissues:

H: ***The choice of metallothionein concentration vs. metal concentrations in fish tissues does not influence the ability to detect environmental exposure of fish to metals.***

H5. Fish - CPUE:

H: ***There is no environmental effect in observed CPUE (catch per unit effort) of fish.***

H6. Fish (or Benthic) - Community:

H: ***There is no environmental effect in observed fish (or benthic) community structure.***

H7: Fish - Growth:

H: ***There is no environmental effect in observed fish growth.***

H8. Fish - Organ/Fish Size:

H: ***There is no environmental effect in observed organ size (or fish size, etc.).***

Integration of Tools

H9.* Relationship between Water Quality and Biological Components:

H: ***The strength of the relationship between biological variables and metal chemistry in water is not influenced by the choice of total vs. dissolved analysis of metals concentration.***

H10. Relationship Between Sediment Chemistry and Biological Responses:

H: ***The strength of the relationship between biological variables and sediment characteristics is not influenced by the analysis of total metals in sediments vs. either metals associated with iron and manganese oxyhydroxides or with acid volatile sulphides.***

H11. Relationship Between Sediment Toxicity and Benthic Invertebrates:

H: ***The strength of the relationship between sediment toxicity responses and in situ benthic macroinvertebrate community characteristics is not influenced by the use of different sediment toxicity tests, or combinations of toxicity tests.***

H12.* Metals or Metallothionein vs. Chemistry (receiving water):

H: ***The strength of the relationship between the concentration of metals in the environment (water) and metal concentration in fish tissues is not different from the relationship between metal concentration in the environment and metallothionein concentration in fish tissues.***

H13. Chronic Toxicity - Linkage with Fish and Benthos Monitoring Results:

H: *The suite of sublethal toxicity tests cannot predict environmental effects to resident fish performance indicators or benthic macroinvertebrate community structure.*

* Results of H9 and H12 to be interpreted with caution at Mattabi, owing to study design limitations.

1.2 Site Description

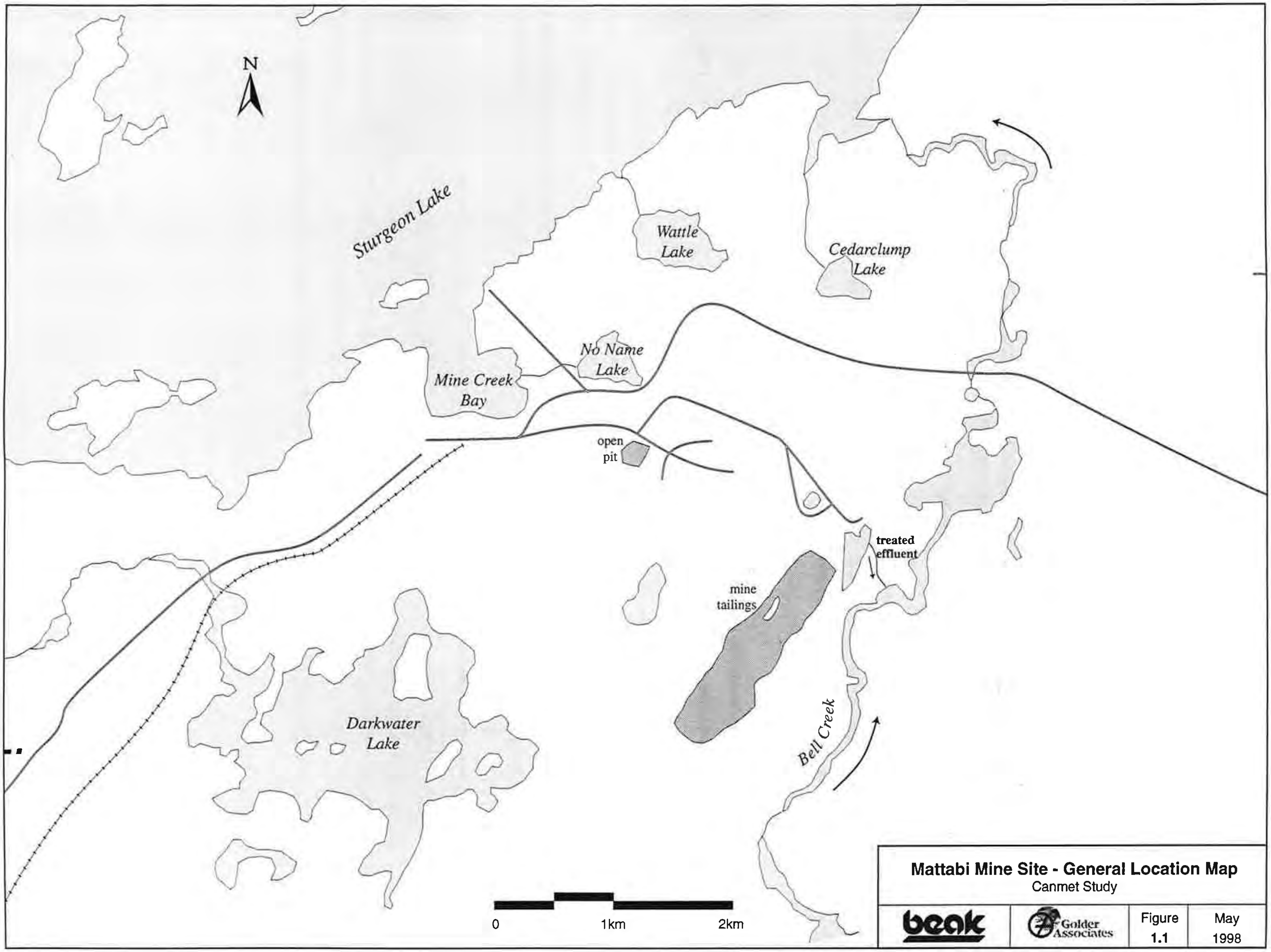
Mattabi Mines Ltd. (Mattabi) operated a copper-lead-zinc open pit and underground mining operation and concentrator complex between 1972 and 1991, approximately 80 km northeast of Ignace. As illustrated in Figure 1.1, the mine site is located in northwestern Ontario, between Sturgeon Lake and Bell Lake. The mine was developed between 1970 and 1972 and produced ore between 1972 and 1988. Milling operations continued until 1991. Operations also included mining at the F-Group open pit (development 1979-1980, production 1980-1984) 9 km west of the Mattabi Mine site and the Lyon Lake Mine (Lyon Lake Division; development 1974-1980 production 1980-1991), about 13 km east of the site. Ore from Lyon Lake and F-Group was milled at the Mattabi concentrator.

Rehabilitation activities continue at Mattabi, and effluent continues to be generated from runoff and acid rock drainage (ARD), and is treated with lime addition, polished and discharged to the environment (Bell Creek).

Various studies have been undertaken to document environmental conditions around the Mattabi Mine site, principally by the Noranda Technology Centre (NTC) and Beak Consultants Limited (NTC and BEAK, 1993).

The most recent study by the NTC, completed in 1989, provides an extensive evaluation of physical, chemical and biological conditions in Bell Creek, Bell Creek Bay, Mine Creek, Mine Creek Bay and various inland water bodies potentially affected by Mattabi operations (NTC and BEAK, 1993). The 1989 NTC study also summarizes the results of previous studies carried out by NTC between 1971 and 1987. Limited (fish) data were collected by NTC in 1989 and were reported in the NTC and BEAK study (1993). Conclusions of the 1989 study included the following (among several others):

- The impact of the tailings and polishing pond area on Bell Creek water, sediments and benthos was significant, primarily within the reach extending 6 km downstream of the polishing pond discharge, and some recovery was evident upstream of the mouth of Bell Creek into Bell Creek Bay (Sturgeon Lake). The principal contaminants were zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd).



Mattabi Mine Site - General Location Map

Canmet Study

beak

Golder Associates

Figure **1.1**

May 1998

- The impact of the Mattabi Mine on Mine Creek Bay (Sturgeon Lake) sediment metal concentrations (Zn, Cu, Pb and Cd) was limited to an approximate 400 m radius from the outlet of Mine Creek. The benthic community within this area showed some impairment from contamination.

- Sediments in No Name Lake were more contaminated with heavy metals than any of the other lakes and streams affected by the Mattabi Mine, owing to the effects of runoff and seepages affected by ARD.

NTC and BEAK (1993) undertook supplementary environmental work in 1991 and 1992 to fill some information gaps remaining after the 1989 study, and to collect additional information for the purposes of modelling the environmental improvements resulting from reclamation of the Mattabi Mine site.

Water quality conditions showed that concentrations of zinc (Zn) and iron (Fe) were elevated in Bell Creek downstream of the Mattabi site. Metal concentrations in sediments of Bell Creek, No Name Lake and Mine Creek Bay in 1991-92 were consistent with those reported in 1989, with contamination extending to a depth of about 10 cm below the sediment surface. The most contaminated sediments were found in No Name Lake. Of the five sediment samples tested by BEAK for toxicity, none tested positively for toxicity to amphipods (*Hyalella*), but the most contaminated sediments from No Name Lake and Mine Creek Bay caused lethal and sublethal effects in midge (*Chironomus*) larvae.

The 1991-92 benthic community characteristics were similar to those reported by the NTC in 1989. Benthic densities and diversities were reduced in Bell Creek downstream of Mattabi relative to the upstream reference sites. The greatest degree of impairment was observed in Mine Creek Bay and No Name Lake.

Fish sampling demonstrated that suckers and minnows successfully spawn in Bell Creek (NTC and BEAK, 1993). Fish catch records provided by NTC indicated that white sucker were relatively abundant in Bell Creek downstream of the Mattabi site in the 1989 study.

Discussions with Mr. Al Scott of Mattabi Mines prior to the AETE field survey indicated that total zinc concentrations measured downstream of the mine site in Bell Creek remained about 0.15 to 0.2 mg/L in the fall of 1997, and continues to remain elevated and is representative of average levels reported in 1990 and 1991.

Mattabi discharges treated effluent into Bell Creek, a slow-flowing, low gradient stream flowing northward from Bell Lake to Sturgeon lake. Rapids occur in the creek downstream of Bell Lake and upstream of Sturgeon Lake, and may act to discourage regular movement of fish from the reach adjacent to Mattabi to either of the lakes. The creek widens to 1 km downstream of the mine and conditions are more lacustrine than riverine, with mean depths of up to 4 m (but typically $\leq$2 m). Bell Creek sediments are soft and metal-enriched downstream of Mattabi.

2.0 STUDY DESIGN

2.1 General Background

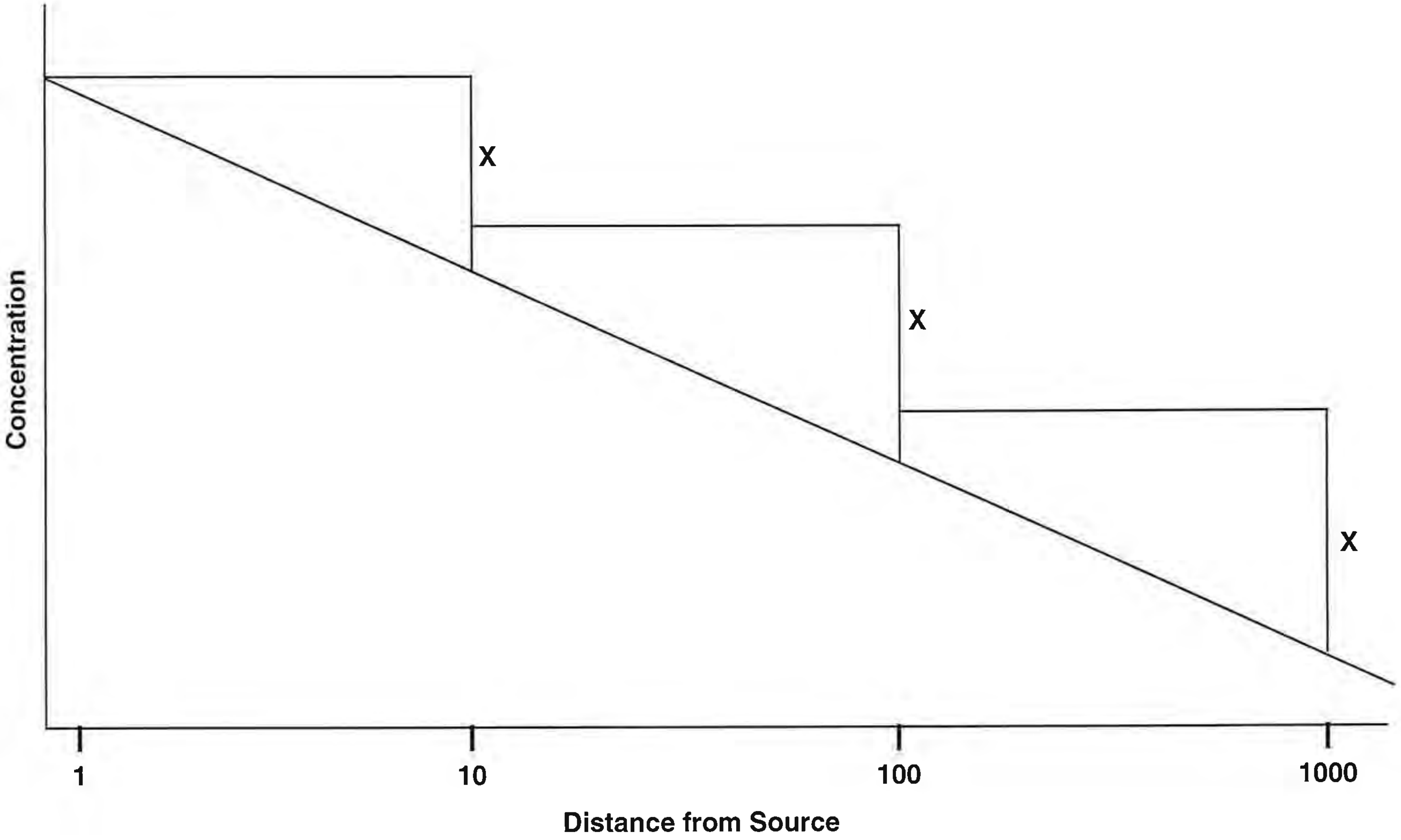
No preliminary study design was developed by EVS *et al.* (1997) for the Mattabi Mine site, as this mine was not originally considered for the 1997 AETE field program. This is in part because the original site selection for the field program considered only operating mines. However, the continued production of treated effluent, combined with the occurrence of nearby sediments enriched in metals and populations of large fish in metal-enriched Bell Creek, afforded good conditions for testing of several AETE hypotheses.

All 13 AETE hypotheses appeared testable at the Mattabi Mine site. However, in light of the fact that H13 (effluent toxicity) was tested at the three other 1997 field sites, effluent toxicity was not studied at Mattabi. This decision was made to allow for sufficient project budget to test the 12 remaining hypotheses.

2.2 General Considerations

In general, sampling is carried out in relation to a point source discharge in order to permit testing of hypotheses about the environmental effect of the discharge. Sampling is carried out both above and below the source (Control versus Exposed). To the extent possible, it is desirable to space the "below discharge" samples at exponentially increasing distances, because most dilution/mixing models assume exponential decay models. That is, a contaminant will decrease in concentration by a given amount over each order of magnitude increase in distance from the discharge (see Figure 2.1). When monitoring mine discharges, the nature of the receiving stream will often cause this ideal to be impossible to achieve, especially where tributary streams produce a stepwise dilution of effluent, or when dilution occurs rapidly (e.g., a stream discharging into a large lake). This latter condition prevails in Bell Creek.

There are many possible field study designs for monitoring of mining discharges and testing of the hypotheses, which can be put into three basic categories (Figure 2.2, Types A, B, C). The difference between the first two (Type A versus Type B or C) is driven by site differences (e.g., stepwise (Type A) versus more continuous dilution patterns (Types B and C)), whereas the difference between the Type B and Type C is



Idealized Effluent Dilution Model Downstream of a Mine Discharge

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Figure
2.1

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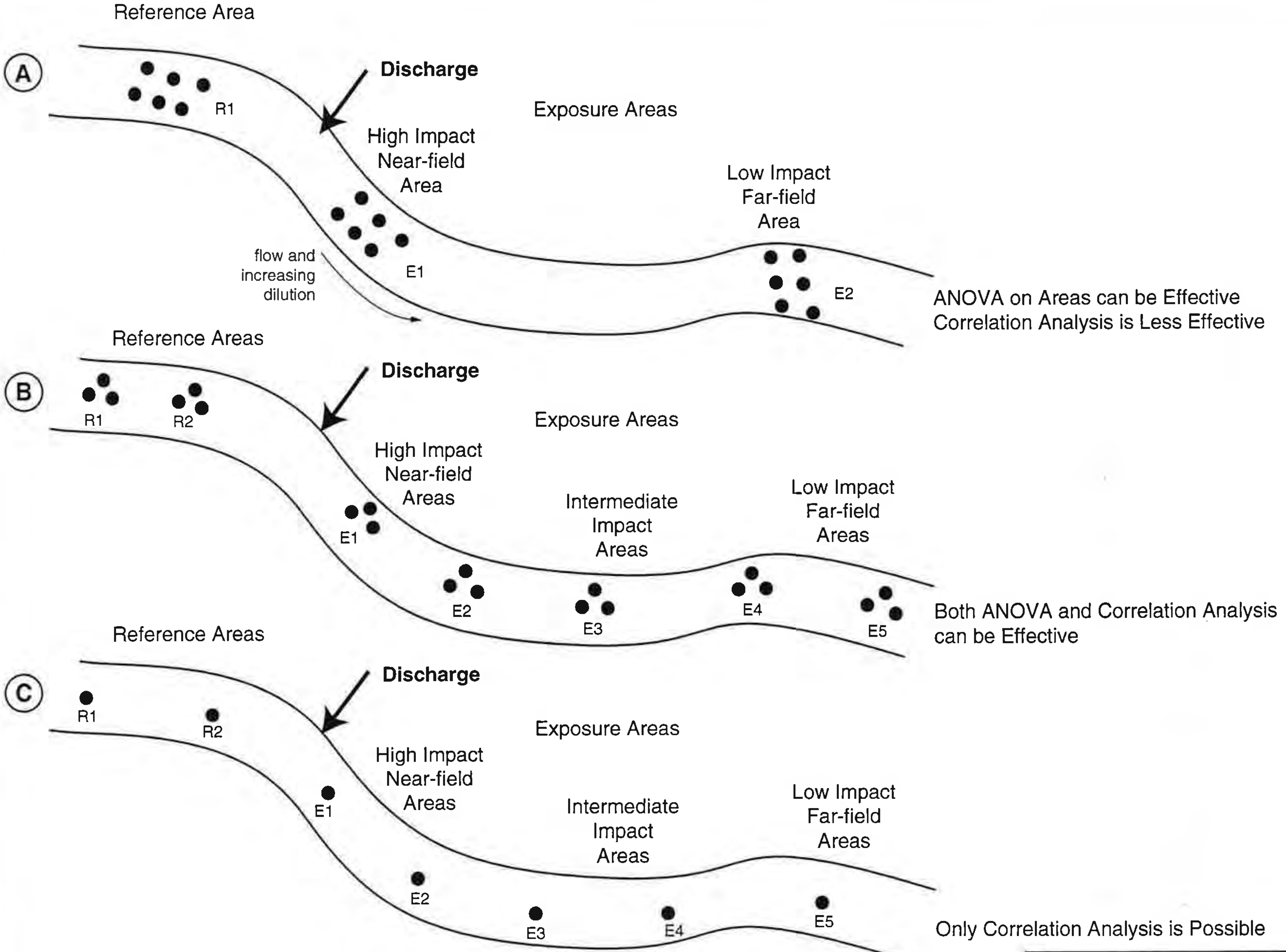


Representative Sampling Designs Downstream of Effluent Discharges (dots represent sampling stations)

beak	beak international incorporated	Figure **2.2**	May 1998

driven by the biota being sampled. For example, because of the sessile nature of some benthos and the limited mobility of some forage fish, allow for replicate sampling in a small area (Type B) with the primary design constraints being hydrology and habitat. For larger more mobile fish, sampling would be carried out over a larger area to ensure the groups of fish are not mixing and are distinct from one another, possibly necessitating a Type C design. Alternatively, a Type A design might be used for large fish, using individual fish rather than stations as replicates.

The ideal situation for testing hypotheses for the 1997 field evaluation is a Type B study design which is a combination of easy-to-sample biota and a site which can be sampled with a gradient design approximating that described above. This provides for:

- a gradient design permitting regression/correlation analysis of the impact pattern along the stream below the discharge, and of possible cause-effect relationships between chemical and biological variables; and
- replication at locations so that testing in an Analysis of Variance (ANOVA) design is possible.

Due to the natural site characteristics at Mattabi, the Type B study design could be implemented for benthos and sediment sampling, but not for large fish sampling.

The other two types of study design (Types A and C) sacrifice either one or the other of the above two attributes (i.e., a gradient design with replication at each location). For Type A, the nature of the site precludes a gradient design (e.g., Bell Creek for water-related exposures). Replicate samples are taken at an "above" = "Control" location, and at a "near-field" = "High Impact" and at a "far-field" = "Low Impact" location. This does not allow one to model the pattern of impact below the discharge, but an ANOVA for testing impact-related hypotheses is easily done. In some cases, two levels of exposure (near- and far-field) cannot both be reasonably sampled due to site conditions, and the Type A configuration is simplified to a reference/exposure (R/E) or control/impact (C/I) design. The C/I design is necessary for testing of fish-related hypotheses in Bell Creek, owing to a general absence of a downstream water quality gradient in Bell Creek (no significant downstream dilution sources entering the creek) and to the mobility of large fish.

For a Type C study design (i.e., gradient design with no replication), one can model the pattern of impact below the discharge but the only possible hypothesis testing is that associated with simple regression analysis. However, there still needs to be a gradient in contaminant levels for this type of design. This type of study design was not used at any of the mine sites used for the 1997 field evaluation program.

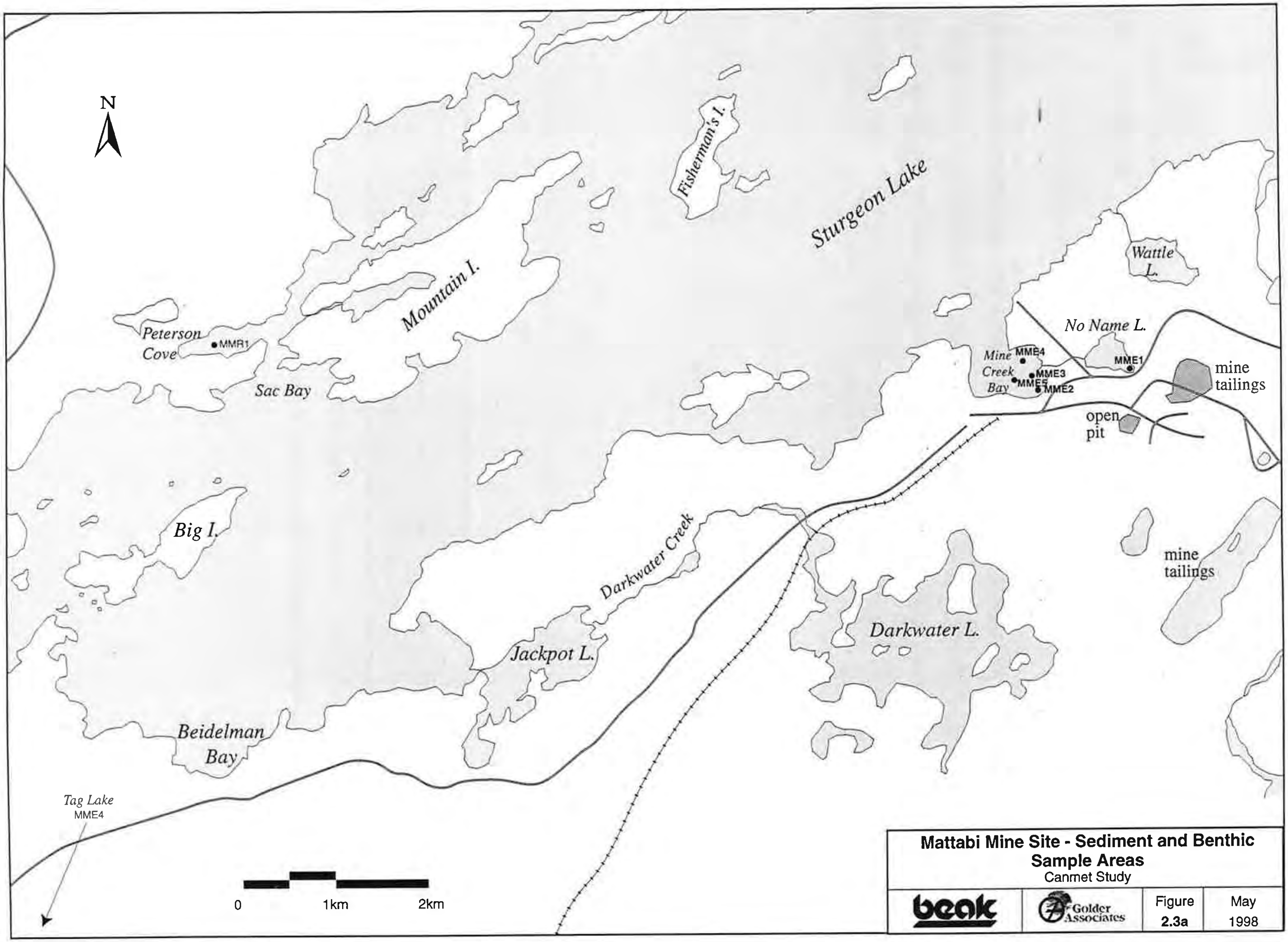
Finally, it is necessary to select an appropriate sampling effort and (apart from the above "basic types of design" considerations) to allocate the effort appropriately to above versus below discharge areas, to locations within areas, and to replicates within locations. For the AETE program, it was determined by the AETE Committee that a total sampling effort per mine site of 20 to 25 field samples provided a reasonable balance between feasibility and cost and statistical power and robustness (EVS *et al.,* 1997). The following is based on that total effort allocated to Mattabi.

2.3 Design at Mattabi

Sampling Areas

Much of the study design at Mattabi is of the second type in Figure 2.2 (Type B). This is based on the existence of a sediment chemistry gradient between No Name Lake and central Mine Creek Bay, all within a generally similar benthic habitat type (shallow depth, soft, organic-rich sediments). This gradient is believed to be attributed to the effects of ARD in the drainages of these watersheds. The study design for Mattabi allowed for the collection of sediments for chemical and toxicity testing, as well as for benthic community characterization, at three stations within each of seven areas (Figures 2.3a and 2.3b). This includes five areas along the sediment chemistry gradient and two reference areas - one in Tag Lake (Figure 2.3b), a small unimpacted waterbody similar in other characteristics to No Name Lake, and Peterson Cove, a Sturgeon Lake embayment remote from Mattabi but otherwise similar to Mine Creek Bay (Figure 2.3a). All stations were located at water depths of about 1.0 to 2.0 m.

The exposure gradient in Bell Creek is not clearly defined and waterborne metal concentrations change little with distance downstream of the mine. Exposure and reference sites for collection of fish included a downstream exposure area (Figure 2.4a), whereas a reference area was chosen on the English River (Figure 2.4b). A reference area separate from Bell Creek was chosen because large fish upstream of Mattabi in Bell Creek (e.g.,



Mattabi Mine Site - Sediment and Benthic Sample Areas

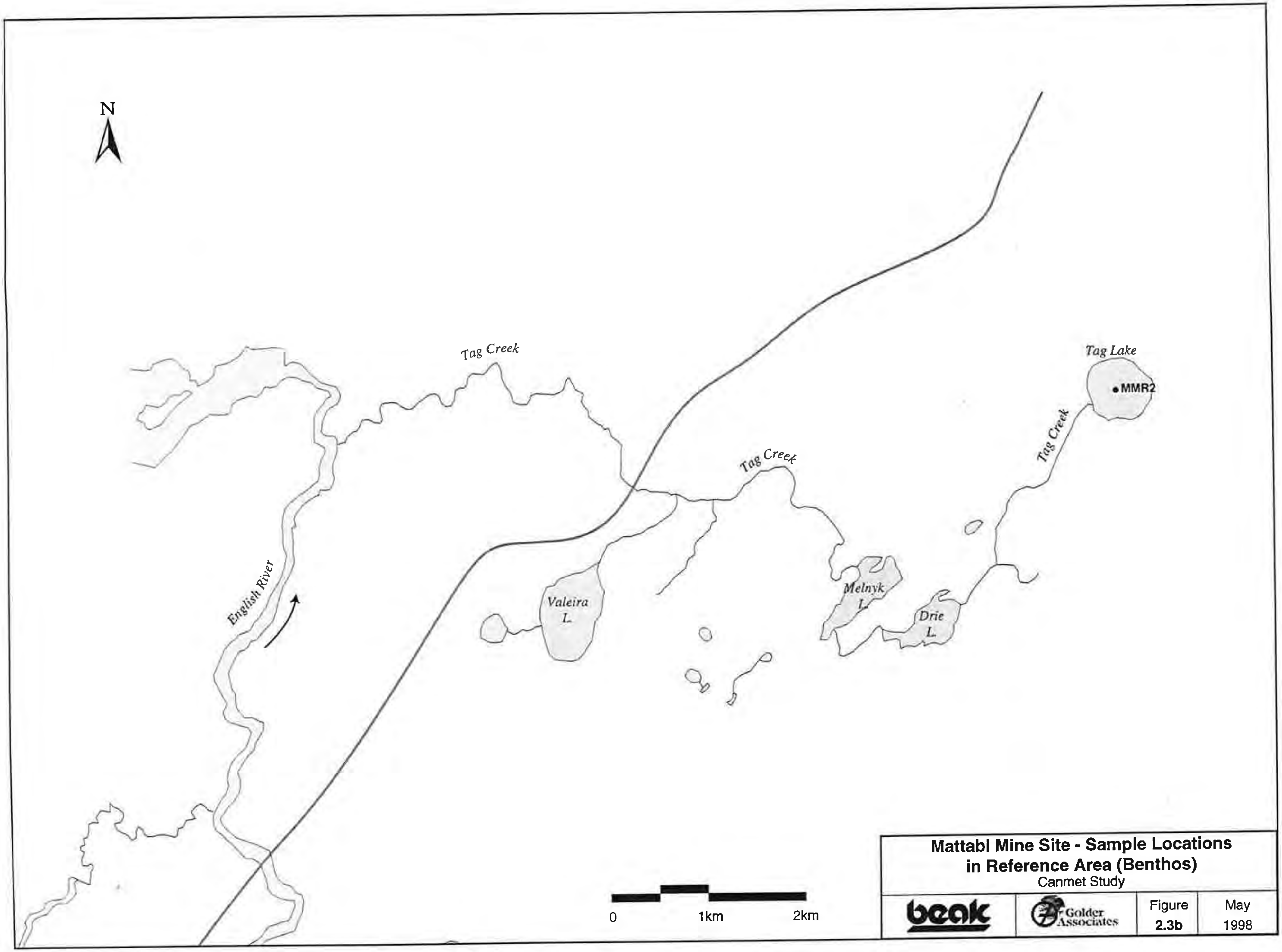
Canmet Study

beak

Golder Associates

Figure 2.3a

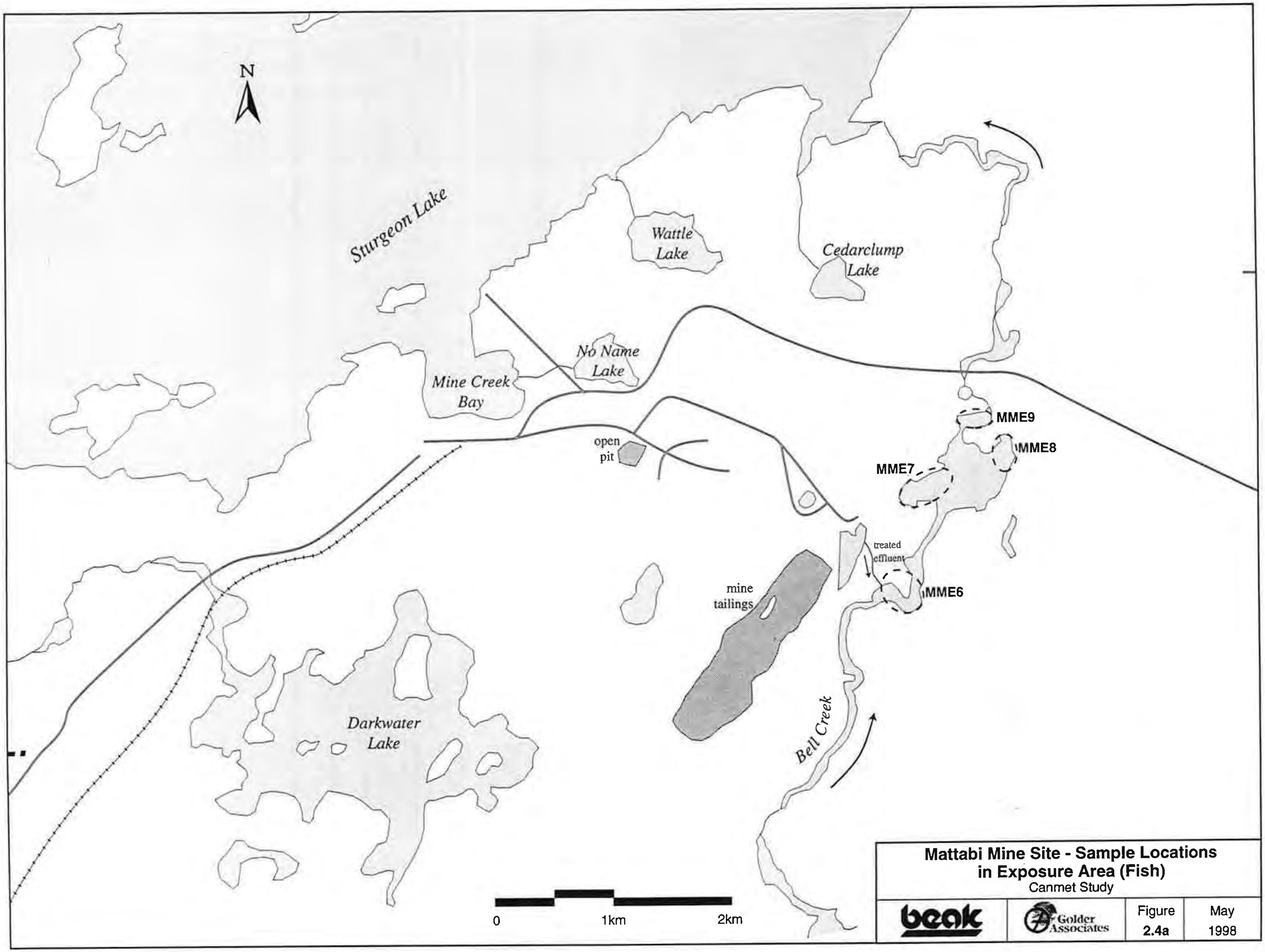
May 1998



Mattabi Mine Site - Sample Locations in Reference Area (Benthos)

Canmet Study

beak	Golder Associates	Figure 2.3b	May 1998



Mattabi Mine Site - Sample Locations in Exposure Area (Fish)

Canmet Study

Figure 2.4a

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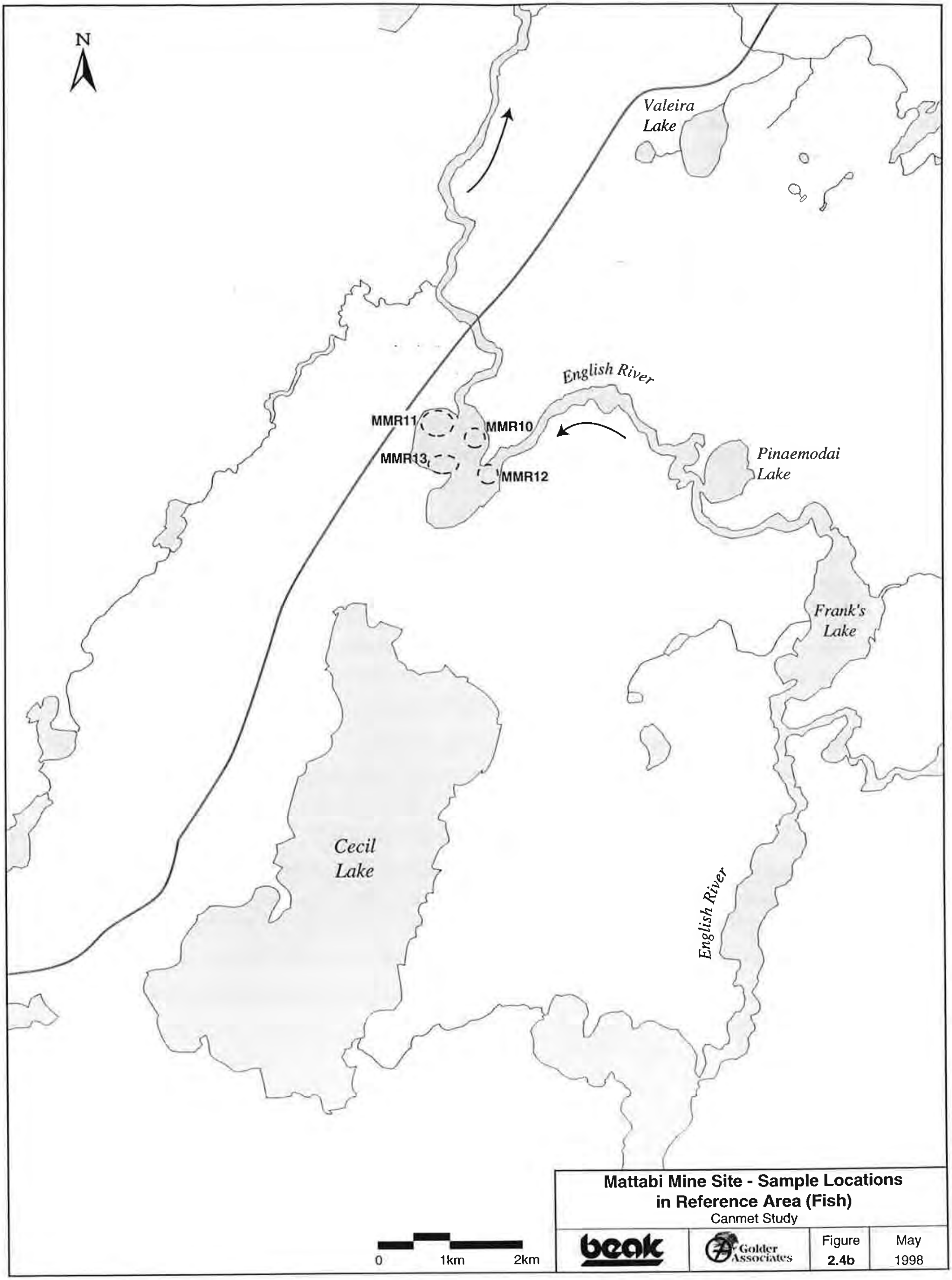


Mattabi Mine Site - Sample Locations in Reference Area (Fish)

Canmet Study

beak

Golder Associates

Figure **2.4b**

May 1998

northern pike, white sucker) are able to freely move downstream and their exposure history would be uncertain. This reference area was selected after consultation with local Ministry of Natural Resources (MNR) biologists and examination of candidate areas at the beginning of the field program.

Water samples were collected at each fish sampling station and each benthic sampling area for chemical characterization.

2.4 Statistical Power

The statistical power of the study design was evaluated using the Borenstein and Cohen (1988) computer code for power analysis. In Bell Creek and the English River (H2, H3 and H4), the total sampling effort of 30 fish distributed equally among two groups (reference and exposure areas) is sufficient to expect that an effect size (average difference between groups) of two within-group standard deviations could be detected with a power of 0.8 or better (i.e., chance of false-negative conclusion (beta) less than 0.2) using a significance criterion based on a chance of false-positive conclusion (alpha) less than 0.05. The total sampling effort of 40 fish (H7, H8, H9) distributed equally among two groups (reference and exposure areas) is sufficient to expect that an effect size (average difference between groups) of one within-group standard deviation could be detected with a power of 0.8 or better using a significance criterion based on an alpha of less than 0.05. The total sampling effort of 8 sampling stations for fish (H5) distributed equally among two groups (reference and exposure areas) is sufficient to expect that an effect size (average difference between groups) of three within-group standard deviations could be detected with a power of 0.8 or better using a significance criterion based on an alpha of less than 0.05.

In the lake habitat, the total sampling effort of 21 sampling stations for benthos, sediment chemistry and toxicity (H1 and H6) equally distributed among seven groups (two reference, 5 exposure) is sufficient to expect that an effect size of two within-group standard deviations could be detected with a power of 0.8 or better using an alpha less than 0.05.

The absolute difference indicated by the one to three standard deviations will vary from one monitoring parameter (effect measure) to another.

For H9 and H12, with a total of eight stations (reference and exposure), it should be possible to detect strong chemistry-biology-toxicity correlations (those that exceed r=0.7; power=0.8). For H10 and H11, with a total of 15 stations (using only exposure stations), it should be possible to detect strong chemistry-biology-toxicity correlations (those that exceed r=0.7; power=0.8).

3.0 FIELD AND LABORATORY METHODS

3.1 Sampling Time and Crew

The field survey was conducted at Mattabi from 15 to 23 October 1997. The field crew consisted of Robert Eakins and Alan Burt of Beak International Inc., and Don Sinclair and Ryan Benson of Golder Associates Ltd.

3.2 Sampling Station Characterization

Sampling stations for the Mattabi program are illustrated in Figures 2.3a and 2.3b, and Figures 2.4a and 2.4b. Habitat information and station coordinates are provided in Appendix 2.

Sampling areas included five exposure sediment/benthic sampling areas (MME1 to MME5) downgradient of Mattabi in No Name Lake and Mine Creek Bay. Reference areas for these exposure areas consisted of MMR1 in Peterson Cove (Sturgeon Lake), and MMR2 in Tag Lake south of Mattabi. These reference areas were representative of habitat conditions in Mine Creek Bay and No Name Lake, respectively. Three stations were sited within 20 m of a marker buoy located in each area, providing three replicates within each area. Global Positioning System (GPS) coordinates were recorded for each station.

Four fish exposure area stations were sampled in the middle reach of Bell Creek. Each was located in the zone of historical influence from the mine, including elevated levels of metals in water and sediment. Overall, these stations are all exposed to mining effects to similar degrees, and are sufficiently close to one another such that large fish may be expected to move freely among all exposure stations. Although exposed fish may move upstream and vice versa, most of the habitat freely used by fish is affected, with partial habitat barriers (rapids) further upstream and downstream discouraging routine movement of large fish further upstream and downstream (i.e., to Bell Lake on Sturgeon Lake).

The four fisheries reference stations were located in similar proximity to one another in the English River in an area of habitat similar to Bell Creek. Habitat in both fish sampling locations was characterized as wide, slow-moving, soft-bottomed streams, with depths of typically ≤2 m.

3.3 Sampling Effort

The numbers and distribution of each type of sample collected at Mattabi are summarized in Table 3.1. Variable numbers of fish collected at each station reflect the presence/absence and abundances of white sucker and northern pike.

3.4 Water Chemistry

Detailed field sampling procedures, including water quality sampling procedures, are outlined in Annex 1 (provided as a separate document) and summarized in this section.

3.4.1 Field

Most of the 15 water quality samples (with one exception) were collected on 23 October 1997. Samples from the reference site in Peterson Cove were collected on 22 October 1997. An additional sample was collected from the treated effluent discharge channel. Sampling was conducted under dry weather conditions and without significant rainfall during the previous three days. Samples were collected for laboratory analysis of:

- total and dissolved metals (Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Sr, Ta, Sn, U, V, B and Zn); Zn, Cu, Pb, and Cd are most relevant at Mattabi;
- nutrients (nitrate, nitrite, ammonia, P);
- major ions (including sulphate and ion balance);
- acidity, alkalinity, hardness, specific conductance;
- pH;
- colour;
- dissolved organic and inorganic carbon;
- solids (total suspended and dissolved); and
- turbidity.

In addition to samples collected for laboratory analysis, field determinations were made of specific conductance, water quality, pH and dissolved oxygen, with results recorded in field records. All field measurements were made on-site using calibrated meters.

TABLE 3.1: SUMMARY OF SAMPLES OBTAINED AT MATTABI

	Type of Sample					
Sampling Locations	Chronic Toxicity	Sediment Benthos Toxicity	Water	Fish for Tissue Analysis	Fish Community	Fish for Measurement
Each of 2 Reference Lake Areas*	--	3 stations	2	--	--	--
Each of 5 Exposure Lake Areas**	--	3 stations	5	--	--	--
Bell Creek	--	--	4 stations	15 northern pike 15 white sucker	4 stations	sucker - 20 males, 21 females pike - 15 males, 20 females
English River (Reference)	--	--	4 stations	16 northern pike 16 white sucker	4 stations	sucker - 21 males, 21 females pike - 21 males, 29 females
Total No. of Samples	--	21[1]	15[2]	62[3]	8[4]	168[5]

[1] Each benthic sample is a composite of five grabs; water conductivity and pH measured at each station.

[2] Water sampling stations correspond to sediment sampling areas and fish sampling stations.

[3] White sucker and northern pike in Bell Creek and English River (reference). Tissues analyzed include gill, kidney, liver (metallothionein and metals) and muscle (metals only) for each fish.

[4] These collections produce the fish for analysis and measurement as well as CPUE (catch-per-unit-effort) and taxa for the station.

[5] Fish measurements included fork length, weight, liver weight, gonad weight and fecundity.

* Reference areas include Tag Lake and Peterson Cove (Sturgeon Lake).

**Exposure areas include No Name Lake (highest exposure) plus four above-background areas in Mine Creek Bay.

All samples were placed on ice in coolers immediately after collection, and were transferred to a refrigerator prior to field processing. All samples requiring analysis without chemical preservation were kept chilled until delivery to the laboratory.

Sample containers, filtration and sample preservation procedures are identified in Annex 1, and include use of high density polyethylene containers confirmed free of measurable metal contamination, ultrapure nitric acid and de-ionized distilled water also confirmed by the lab to be free of measurable metal contamination (for field, trip and filter blanks), and a filtration procedure using polypropylene-stoppered syringes with 0.45 micron syringe-filters. All sample preparation was carried out in a clean indoor work space.

Quality assurance/quality control procedures followed in the field included collection of sample duplicates and preparation of trip blanks (Appendix 1). Unfortunately, field blanks and filter blanks for Mattabi were prepared but not analyzed owing to miscommunication with the chemistry laboratory.

3.4.2 Laboratory

All water samples were forwarded to the analytical laboratory (Philip Analytical Services Corporation, Burlington and Mississauga, Ontario) within four days of collection. Procedures used for laboratory analysis are summarized in Table 3.2.

Results of QA/QC analyses indicated no apparent contamination of samples with key metals, based on data from field duplicates and the trip blank. Dissolved and total metal results for field samples did not indicate any significant contamination by dissolved metal sample preparation (i.e., dissolved metals were generally ≤ total metals), although field and filter blanks were unavailable and thus could not be used to support this conclusion. Data quality appeared adequate for the testing of hypotheses at Mattabi.

3.5 Sediment Chemistry

Annex 1 provides more detail on procedures followed in the field for the collection and handling of sediment samples, which are summarized below.

At each station, samples for benthos were collected prior to sampling for sediment chemistry and toxicity to prevent disruption of the benthic community. For both chemistry and benthic

Table 3.2: LABORATORY METHODS AND BOTTLE/PRESERVATIVE PROCEDURES USED IN WATER SAMPLE ANALYSIS

(as provided by Philip Analytical Services)

Parameters	Method	Bottle Requirement	Preservative Type	Max. Holding Time
Acidity	Standard Methods (17th ed.) No. 2310B U.S. EPA Method No. 305.1	250 ml Bottle Glass	no preservative	14 days
Alkalinity	Standard Methods (17th ed.) No. 2320	250 ml Bottle Glass	no preservative	14 days
RCAP Calculations Total Dissolved Solids(Calculated) Hardness(as $CaCO_3$) Bicarbonate(as $CaCO_3$, calculated) Carbonate(as $CaCO_3$, calculated) Cation Sum Anion Sum Ion Balance	MDS Internal Reference Method			
Colour	U.S. EPA Method No. 110.3(Modified) (Reference-Std Methods(17th)2120CMod)	100 ml Bottle Glass	no preservative	48 hours
Specific Conductance	U.S EPA Method No. 120.1	100 ml Bottle Glass	no preservative	28 days
Manual Conventionals for RCP(pH,Turb,Conduct,Color)	U.S. EPA Method No. 150.1, 120.1, 180.1 and 110.3	250 ml Bottle HDPE	no preservative	
Hardness	U.S. EPA Method No. 130.2	250 ml Bottle Glass	no preservative	6 months
Ion Balance		250 ml Bottle HDPE	HNO_3 to pH < 2	14 days
pH, Hydrogen Ion Activity	U.S. EPA Method No. 150.1	100 ml Bottle Glass	no preservative	
Total dissolved Solids	U.S. EPA Method No. 160.1	1 L Bottle Glass	no preservative	7 days
Total Suspended Solids	U.S. EPA Method No. 160.2	500 ml Bottle Glass	no preservative	7 days
Turbidity, UltraViolet	U.S. EPA Method No. 180.1	100 ml Bottle Glass	no preservative	48 hours
RCAP MS Package, 8 Element ICPAES Scan B, Fe, P, Zn, Ca, Mg, K, Na	U.S. EPA Method No. 200.7	125 ml Bottle HDPE 250 ml Bottle HDPE	HNO_3 to pH < 2 no preservative	
ICP-MS 25 Element Scan, Clean Water Package Al, Sb, As, Ba, Be, Bi, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Se, As, Sr, Th, Sn, Ti, U, V, B, Fe, Zn	U.S. EPA Method No. 200.8(Modification)	250 ml Bottle HDPE 125 ml Bottle HDPE	no preservative HNO_3 to pH < 2	
Alkalinity for RCAP Packages 30, 50 and MS	U.S. EPA Method No. 310.2	250 ml Bottle HDPE	no preservative	14 days
Anions for RCAP 50 and MS(Cl,NO_2,NO_3,o-PO_4 & SO_4)	U.S. EPA Method No. 300.0 or U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.	250 ml Bottle HDPE	no preservative	48 hours
Dissolved Organic Carbon, as Carbon for RCAP	MOE Method No. ROM - 102ACE(Modified)	100 ml Bottle Glass	no preservative	3 days
Ammonia for RCAP Packages 30, 50 and MS	ASTM Method No. D1426-79 C Refer - Method No. 1100106 Issue 122289	100 ml Bottle Glass 250 ml Bottle HDPE	H_2SO_4 to pH < 2 no preservative	28 days
Organic Nitrogen(TKN - NH_3)	U.S. EPA Method No. 350.1 U.S. EPA Method No. 351.1	250 ml Bottle Glass	H_2SO_4 to pH < 2	28 days
Mercury, Cold Vapour AA	U.S. EPA SW846 Method No. 7470A Standard Methods(18th ed.) No. 3112B	100 ml Bottle Glass	HNO_3 to pH < 2 + 5% $K_2Cr_2$07	7 days

sampling, the boat (or sampling personnel) were re-positioned between sediment grabs to minimize any potential for sampling of disturbed sediments. Finally, sediment areas were sampled in a sequence from areas identified to be less impacted to more impacted to minimize the potential of cross-contamination between sites.

Sediment samples were collected from three stations in each of seven areas along the sediment chemistry gradient. Samples were collected manually using a standard stainless steel petite Ponar grab. Sediments were collected from depths ranging from 1 to 2 m. Ten to fifteen grab samples were collected at each station depending on the quantity of material retrieved in each grab. Sediment pH and redox potential were measured from several minimally disturbed sediment grabs at each station as the composite samples were collected.

Upon retrieval of the grab, surface water was allowed to run off before the sediment was placed into a plastic tub. The top 2 to 3 cm of sediment was collected using a stainless steel spoon and placed into a 20-L bucket with a polyethylene liner. This procedure was repeated with each grab and new material was thoroughly mixed with the previous material until at least eight litres of sediment per station had been collected. Subsamples of the homogenized sediment sample were dispensed into appropriate sample containers.

Three different types of sediment samples were collected for analysis from each site:

- a sample for "total" metals analysis, based on a nitric acid/hydrogen peroxide extraction procedure;
- a sample for "partial" metals analysis using a hydroxylamine hydrochloride procedure which is designed to solubilize amorphous Fe and Mn oxyhydroxides, along with their associated trace metals; and
- a sample for analysis of Acid Volatile Sulphide (AVS) and Simultaneously-Extracted Metals (SEM).

In addition, two field duplicate samples were collected from selected locations for total metals determination using extraction with aqua regia, to confirm the comparability of results using aqua regia and nitric acid/hydrogen peroxide extractions. Subsamples for partial metal extraction were collected by filling half a 500-mL sample bottle with sediment, which was then topped with a layer of site water. These samples were frozen at the end of each sampling day. Subsamples for SEM/AVS analyses were placed into a

250 mL whirl-pak bag, and then into a 1-L jar once the air had been removed from the bag. The 1-L jar was then filled with sediment so that the whirl-pak bag was surrounded by sediment which prevented exposure to air.

Samples for chemical analysis were forwarded to Philip Analytical Services Corporation. Analyses included metals (total and partial), moisture, bulk density, Munsell colour, total organic carbon (TOC), loss-on-ignition (LOI), grain size and SEM and AVS. Munsell colour, bulk density and percent moisture were done by BEAK staff.

Quality assurance/quality control procedures in addition to routine lab QA/QC included collection of hidden duplicate samples for metal analysis.

3.6 Sediment Toxicity

Sediment samples for toxicity testing were collected from the five exposure areas and two reference areas. A minimum of seven litres of sediment was collected from each of the three stations located within each of the seven areas described in the previous subsection, and were placed in 20-L plastic food-grade buckets with polyethylene bag liners.

Toxicity tests conducted on each sample included: *Hyalella azteca* survival and growth (Environment Canada, 1996 Draft Method); *Chironomus riparius* survival and growth (Environment Canada, 1997 Draft Method); and *Tubifex tubifex* survival and reproduction (ASTM E1384-94A, 1995). *Chironomus* and *Hyalella* tests were conducted at BEAK's toxicity testing laboratory in Dorval, Quebec, whereas the *Tubifex* tests were completed at the National Water Research Institute, Environment Canada, in Burlington, Ontario.

3.7 Benthic Invertebrates

3.7.1 Field

Benthic invertebrates samples were collected from each of three stations in each of seven sediment sampling areas. At each station, five petite Ponar grab samples were collected from water depths of 1 to 2 m and pooled to produce one sample. Each of the five grab samples was sieved using a 250 μm mesh screen prior to preservation to a minimum level of 10% buffered formalin. All samples were collected by the same two field crew members.

3.7.2 Laboratory

All samples were processed jointly by the BEAK Benthic Ecology Laboratory and by Zaranko Environmental Assessment Services (ZEAS), Guelph, Ontario. Both laboratories followed the same laboratory protocols summarized below.

In the laboratory, samples were inspected to insure that they were adequately preserved and correctly labelled. Samples were then stained to improve the sorting recovery.

Prior to detailed sorting, the samples were washed free of formalin in a 250 μm sieve under ventilated conditions. The benthic fauna and associated debris were then elutriated free of any sand and gravel. The remaining sand and gravel fraction was closely inspected for any of the denser organisms, such as Pelecypoda, Gastropoda and Trichoptera with stone cases that may not have all been washed from this fraction. The remaining debris and benthic fauna after elutriation were washed through 500 μm and 250 μm sieves to standardize the size of the debris being sorted and facilitate a minimum of 95% recovery of benthic fauna.

All benthic samples were processed with the aid of stereomicroscopes. A magnification of at least 10X was used for macrobenthos (invertebrates >500 μm) and 20X for meioinvertebrates (invertebrate size >250 to <500 μm). Benthos was sorted from the debris, enumerated into the major taxonomic groups, usually order and family levels and placed in vials for more detailed taxonomic analysis.

Benthic invertebrates were most commonly identified to the lowest practical level, genus or species for most groups. The level to which each group was identified and the taxonomic keys that the identification were based on are provided in Appendix 5.

To assess benthic data quality, subsampling error was determined for both density and number of taxa in 10% of the samples that were subsampled. Ten percent of sorted samples were also resorted by an independent taxonomist to ensure 95% recovery of all invertebrates.

A voucher collection or reference collection of benthic invertebrate specimens was compiled. This is a collection of representative specimens for each taxon so that there can be continuity in taxonomic identifications if different taxonomists process future samples. The voucher collection will be maintained at BEAK. The BEAK and ZEAS Benthic Ecology

Laboratories also maintain master reference collections of all taxa which have been identified by the labs.

The specimens selected for the voucher collection were preserved such that they will remain intact for many years. Chironomids and oligochaetes remain on the initial slides and representatives of each taxon were circled with a permanent marker and labelled. All other species were preserved in 80% ethanol in separately labelled vials. Each vial contains a 3% solution of glycerol to prevent spoilage of the fauna if the vials accidentally dry out.

3.7.3 Chironomid Deformities

In the last decade there has been considerable attention paid towards the use of chironomid mouth part deformities to monitor contaminant effects. Previous studies have shown that the incidence of chironomid deformities (especially in *Chironomus*) can be associated with contaminated sediments.

For the 1997 study, all mounted chironomid specimens from each site were scored for mandible and mentum abnormalities. These data were not used in the testing of specific hypotheses, but are discussed briefly in Section 4.0.

3.8 Fish

3.8.1 Collection and Sample Processing

Fish were collected at each of the four Bell Creek and four English River (reference) stations using experimental monofilament gillnets, consisting of 150-foot panels with mesh sizes 1.5, 2, 2.5, 3, 4 and 5 inch stretch mesh. A minimum of two overnight sets was completed at each station.

All fish captured were identified and enumerated, and measurements were taken of total length, fork length and body weight. Live specimens of species other than northern pike and white sucker were released after these measurements were taken. Once the target numbers of northern pike and white sucker were obtained (20 males and 20 females), only non-viable specimens of these species were retained. Viable excess catch of sentinel species were released.

Records of catch-per-unit-effort (numbers - CPUE, biomass - BPUE) were maintained for each gillnet set by accounting for numbers and biomass of fish, as well as the duration of gillnet sets.

Viable northern pike and white sucker for tissue metallothionein and metal analysis were maintained alive (requirement for MT analysis) in plastic garbage pails containing site water and were transported to shore for processing. Fish processed for tissue analyses were first processed for biological measurements including fork length, total length, body weight, age, liver weight, gonad weight and fecundity. Dead northern pike and white sucker specimens were processed for biological measurements only.

Samples for tissue analysis were dissected from freshly euthanized northern pike and white sucker specimens. These dissections included removal of the entire liver, kidney and gills (including gill arches) from each specimen and placement (after liver weight determination) in labelled, plastic bags in direct contact with dry ice. A small (generally ≤50 g) boneless, skinless dorsal fillet of muscle tissue was also collected from each specimen sampled for tissue analysis. All fish tissues were kept on dry ice throughout the field program and during shipment to the Department of Fisheries and Oceans laboratory (Dr. J. Klaverkamp) in Winnipeg.

Biological measurements on fish were carried out according to procedures outlined in Table 3.3. Detailed protocols for these determinations are available in Annex 1.

3.8.2 Tissue Metallothionein and Metal Analyses

All analyses of Mattabi fish tissues were carried out at the Department of Fisheries and Oceans, Freshwater Institute, under the direction of Dr. J. Klaverkamp. Analyses were completed on tissues from 15 to 16 northern pike and white sucker from each of the two sampling areas. Laboratory procedures are as documented by Dr. J. Klaverkamp (Annex 1).

TABLE 3.3: BIOLOGICAL DETERMINATIONS MADE IN NORTHERN PIKE AND WHITE SUCKER SPECIMENS

Measurement	Procedure
Fork Length, Total Length	Fish measuring boards, to nearest 1 mm.
Fish Weight	Calibrated spring scales, to nearest 5 g.
Liver Weight, Gonad Weight	Calibrated electronic balance, to nearest 0.1 g (based on fresh weight).
Fecundity	Measurement of volume (by water displacement) of predetermined number of preserved eggs (formaldehyde), and measurement of preserved ovary volumes, to nearest mL.
Age	Examination of annuli on cleithra (northern pike) and in sections of first large left pectoral fin rays (white sucker), to nearest year.

4.0 DATA OVERVIEW

This section summarizes the major trends for each of the data components (water, sediment, sediment toxicity, benthos and fish), whereas results of hypotheses testing based on the data are presented in Section 5.2.

4.1 Water Chemistry

Selected water chemistry data for Mattabi are summarized in Table 4.1 (total metals and general chemistry) and Table 4.2 (comparing total versus dissolved metals). Detailed data for all parameters and samples are presented in Appendix 3.

Effluent chemistry was sampled during the water chemistry sampling program at Mattabi, with results presented in Appendix 3 ("discharge" sample). Results show the effluent to be enriched with zinc, calcium and sulphate in particular. Mean effluent quality conditions for October 1997 at Mattabi, as provided by Mr. Al Scott (Mattabi Mines) (pers. comm.), are as follows:

- pH: 8.79
- TSS: 3 mg/L
- As: 0.042 mg/L
- Cu: 0.010 mg/L
- Fe: 0.304 mg/L
- Pb: 0.025 mg/L
- Ni: 0.020 mg/L
- Zn: 0.32 mg/L

QA/QC data associated with water chemistry analyses are provided in Appendix 1. Results of the QA/QC program indicate that the quality of Mattabi water chemistry data are adequate for testing of hypotheses, with data quality objectives for replicate samples met for key metals.

Concentrations of zinc, copper, cadmium and lead in water were elevated in Bell Creek (exposure) samples downstream of Mattabi relative to conditions in the English River (reference). Of these, only zinc occurred at concentrations greater than *Canadian Water Quality Guidelines* (CWQGs), with concentrations of 0.031 to 0.061 mg/L for total zinc.

Table 4.1: Selected Water Quality Results at the Mattabi Mine Site, October 1997. Total Metals and General Chemistry.

				MINE DISCHARGE	REFERENCE STATIONS (LAKE)		EXPOSURE STATIONS (LAKE)					REFERENCE STATIONS (RIVER)				EXPOSURE STATIONS (RIVER)			
Parameter	**Units**	**LOQ[1]**	**CWQG[2]**		MMR1	MMR2	MME1	MME2	MME3	MME4	MME5	MMR10	MMR11	MMR12	MMR13	MME6	MME7	MME8	MME9
Total Metals																			
Aluminum	mg/L	0.005	0.1	0.098	0.005	0.028	0.102	0.006	0.008	0.006	0.005	0.043	0.052	0.043	0.044	0.026	0.038	0.036	0.036
Cadmium	mg/L	0.00005	See below[3]	0.00151	nd[7]	nd	0.00185	nd	0.00005	nd	nd	nd	nd	nd	nd	0.00005	0.00006	0.00009	0.00006
Calcium	mg/L	0.1	na[4]	831	13.7	7.9	71.5	13.9	13.9	14	13.9	4.8	5	4.9	4.8	8.2	22.3	25.8	24.6
Cobalt	mg/L	0.0002	na	0.0021	nd	nd	0.0031	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0003	0.0003	0.0002
Copper	mg/L	0.0003	See below[5]	0.0154	0.002	nd	0.0199	0.0016	0.0019	0.0016	0.0015	0.0005	0.0006	0.0005	0.0005	0.0014	0.0019	0.0019	0.002
Iron	mg/L	0.02	0.3	0.21	0.05	0.13	0.23	0.05	0.05	0.06	0.05	0.32	0.35	0.3	0.31	0.08	0.1	0.11	0.1
Lead	mg/L	0.0001	See below[6]	0.0002	nd	0.0003	0.0058	0.0001	0.0001	0.0001	nd	nd	nd	nd	nd	nd	0.0009	0.0008	0.0009
Selenium	mg/L	0.002	0.001	0.004	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	mg/L	0.001	0.03	0.206	0.006	0.001	2.61	0.014	0.02	0.018	0.012	nd	nd	0.001	nd	0.031	0.057	0.059	0.061
General Chemistry																			
Sulphate	mg/L	2	na	2600	21	nd	233	21	21	21	20	nd	nd	nd	nd	13	52	65	64
Alkalinity(as $CaCO_3$)	mg/L	1	na	30	28	27	34	29	29	29	28	11	16	16	16	24	21	20	20
Conductivity - @25øC	us/cm	1	na	3520	112	58	655	106	107	106	105	40	40	40	40	78	177	213	206
Dissolved Organic Carbon(DOC)	mg/L	0.5	na	1.5	5.3	11.9	5.5	4.9	4.8	5	4.7	7.5	8	7.7	8.2	6.2	6.6	7	6.6
Hardness(as $CaCO_3$)	mg/L	0.1	na	2910	48.4	27.5	285	47	45.4	45.7	45.3	17.3	17.1	17.2	17.1	33.7	77.7	87.7	90.6
Field pH	Units	0.1	6.5 - 9.0	-	7.37	7.36	7.42	7.43	7.46	7.39	7.39	7.22	7.16	7.15	7.15	7.23	7.19	7.18	7.19
Total Dissolved Solids(Calculated)	mg/L	1	na	3690	61	32	400	60	60	60	59	23	26	26	26	44	97	113	113
Total Suspended Solids	mg/L	1	na	8	nd	7	3	nd	nd	nd	nd	2	2	nd	2	nd	nd	1	1

[1] LOQ - Limit of Quantitation - lowest level of the parameter that can be quantified with confidence

[2] CWQG - Canadian Water Quality Guidelines (CCREM, 1987)

[3] Cadmium Guideline values - 0.0002 mg/L (Hardness 0-60), 0.0008 mg/L (Hardness 60-120), 0.0018 mg/L (Hardness >180)

[4] na - Guideline values not available

[5] Copper Guideline values - 0.002 mg/L (Hardness 0-120), 0.004 mg/L (Hardness >180)

[6] Lead Guideline values - 0.001 mg/L (Hardness 0-60), 0.002 mg/L (Hardness 60-120), 0.007 mg/L (Hardness >180)

[7] nd - Parameter not detected

▨ - Denotes values that exceed the guideline

Table 4.2: Concentration of Total Metal Concentrations versus Dissolved Metal Concentrations Detected in Water Samples Collected at Mattabi Mine Site, October 1997.

			MINE DISCHARGE		REFERENCE STATIONS (LAKE)				EXPOSURE STATIONS (LAKE)									
					MMR1	MMR1	MMR2	MMR2	MME1	MME1	MME2	MME2	MME3	MME3	MME4	MME4	MME5	MME5
Parameters	Units	LOQ[1]	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum	mg/L	0.005	0.098	0.052	0.005	nd	0.028	0.014	0.102	0.033	0.006	nd	0.008	nd	0.006	nd	0.005	0.005
Cadmium	mg/L	0.00005	0.00151	0.00119	nd[2]	nd	nd	nd	0.00185	0.00183	nd	nd	0.00005	nd	nd	nd	nd	nd
Calcium	mg/L	0.1	831	868	13.7	15.3	7.9	8.2	71.5	73.3	13.9	14.8	13.9	14.2	14	14.3	13.9	14.2
Cobalt	mg/L	0.0002	0.0021	0.0018	nd	nd	nd	nd	0.0031	0.0034	nd	nd	nd	nd	nd	nd	nd	nd
Copper	mg/L	0.0003	0.0154	0.0128	0.002	0.0008	nd	0.0008	0.0199	0.0133	0.0016	0.0019	0.0019	0.002	0.0016	0.0021	0.0015	0.0017
Iron	mg/L	0.02	0.21	0.1	0.05	nd	0.13	0.03	0.23	0.08	0.05	nd	0.05	nd	0.06	nd	0.05	nd
Lead	mg/L	0.0001	0.0002	0.0002	nd	0.0002	0.0003	nd	0.0058	0.0021	0.0001	nd	0.0001	nd	0.0001	0.0002	nd	nd
Selenium	mg/L	0.002	0.004	0.004	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	mg/L	0.001	0.206	0.094	0.006	0.008	0.001	0.002	2.61	2.61	0.014	0.013	0.02	0.016	0.018	0.018	0.012	0.011

			REFERENCE STATIONS (RIVER)								EXPOSURE STATIONS (RIVER)							
			MMR10	MMR10	MMR11	MMR11	MMR12	MMR12	MMR13	MMR13	MME6	MME6	MME7	MME7	MME8	MME8	MME9	MME9
Parameters	Units	LOQ[1]	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum	mg/L	0.005	0.043	0.023	0.052	0.026	0.043	0.023	0.044	0.031	0.026	0.017	0.038	0.027	0.036	0.025	0.036	0.025
Cadmium	mg/L	0.00005	nd[2]	nd	nd	nd	nd	nd	nd	nd	0.00005	nd	0.00006	nd	0.00009	nd	0.00006	nd
Calcium	mg/L	0.1	4.8	5	5	4.9	4.9	4.9	4.8	4.9	8.2	8.7	22.3	22.1	25.8	24.8	24.6	25.6
Cobalt	mg/L	0.0002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0003	0.0002	0.0003	0.0003	0.0002	0.0002
Copper	mg/L	0.0003	0.0005	0.0006	0.0006	0.0009	0.0005	0.0008	0.0005	0.0006	0.0014	0.0017	0.0019	0.0022	0.0019	0.0021	0.002	0.0022
Iron	mg/L	0.02	0.32	0.2	0.35	0.18	0.3	0.21	0.31	0.2	0.08	0.04	0.1	0.07	0.11	0.07	0.1	0.07
Lead	mg/L	0.0001	nd	0.0004	nd	0.0001	nd	0.0001	nd	0.0002	nd	0.0001	0.0009	0.0008	0.0008	0.0007	0.0009	0.0007
Selenium	mg/L	0.002	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	mg/L	0.001	nd	nd	nd	0.001	0.001	0.001	nd	0.002	0.031	0.029	0.057	0.055	0.059	0.06	0.061	0.059

[1] LOQ - Limit of Quantitation = lowest level of the parameter that can be quantified with confidence

[2] nd - Parameter not detected

The sample from Station MME6 in Bell Creek showed lower metal concentrations than those from further downstream, apparently owing to less complete mixing of Mattabi effluent in the creek at the more upstream site relative to downstream (i.e., MME6 was located immediately offshore of the effluent discharge point). Water hardness, calcium concentration and conductivity were also greater in Bell Creek than at the reference site (or in Sturgeon Lake), reflecting the effects of lime addition at the Mattabi treatment plant.

In addition to the metals noted above, selenium and cobalt concentrations were detectable in treated Mattabi effluent but were lower in concentration in Bell Creek (Se was not detected in river samples; Appendix 3). This indicates that the mine may also be a source of these two metals. Hypotheses relating to water quality effects were tested based on conditions measured in Bell Creek and the English River.

Metal concentrations (total and dissolved Al, Zn, Cu, Pb, Cd) were elevated in No Name Lake (MME1) relative to exposure areas in Mine Creek Bay (Sturgeon Lake; MME2 to MME5), where metal levels were much less elevated relative to reference sites. Of these metals, all except Pb occurred in excess of their respective Canadian Water Quality Guidelines for the protection of aquatic life (Table 4.1). No Name Lake water quality is affected by ARD, whereas ARD sources to Mine Creek Bay have been largely eliminated through site rehabilitation activities. Also, any residual ARD sources to Mine Creek Bay are dispersed owing to the large assimilative capacity of Sturgeon Lake. Accordingly, metal concentrations in Mine Creek Bay were found to meet the Canadian guidelines. These substantially greater metal concentrations in No Name Lake relative to Mine Creek Bay indicate that sediment-related hypotheses, tested using the sediment chemistry gradient from MME1 (No Name Lake) to MME5 (Mine Creek Bay), may be confounded by effects from elevated aqueous metal concentrations at MME1. In particular, zinc concentrations of 2.61 mg/L are close to levels known to be acutely toxic to invertebrates (e.g., LC50 value for *Daphnia magna* about 2.8 mg/L in hard water; U.S. EPA, 1987). The high metal concentrations at MME1 are accompanied by hard water conditions (hardness = 285 mg/L) which may act to modify metal effects relative to those which may occur at water hardness levels of about 45 mg/L in Mine Creek Bay.

The total and dissolved concentrations of selected metals are provided in Table 4.2 and in Figure 4.1, with a complete data set provided in Appendix 3. Dissolved metal concentrations were similar to those for the corresponding total metals for most key metals. Dissolved lead levels were, however, substantially less than total lead levels in the most

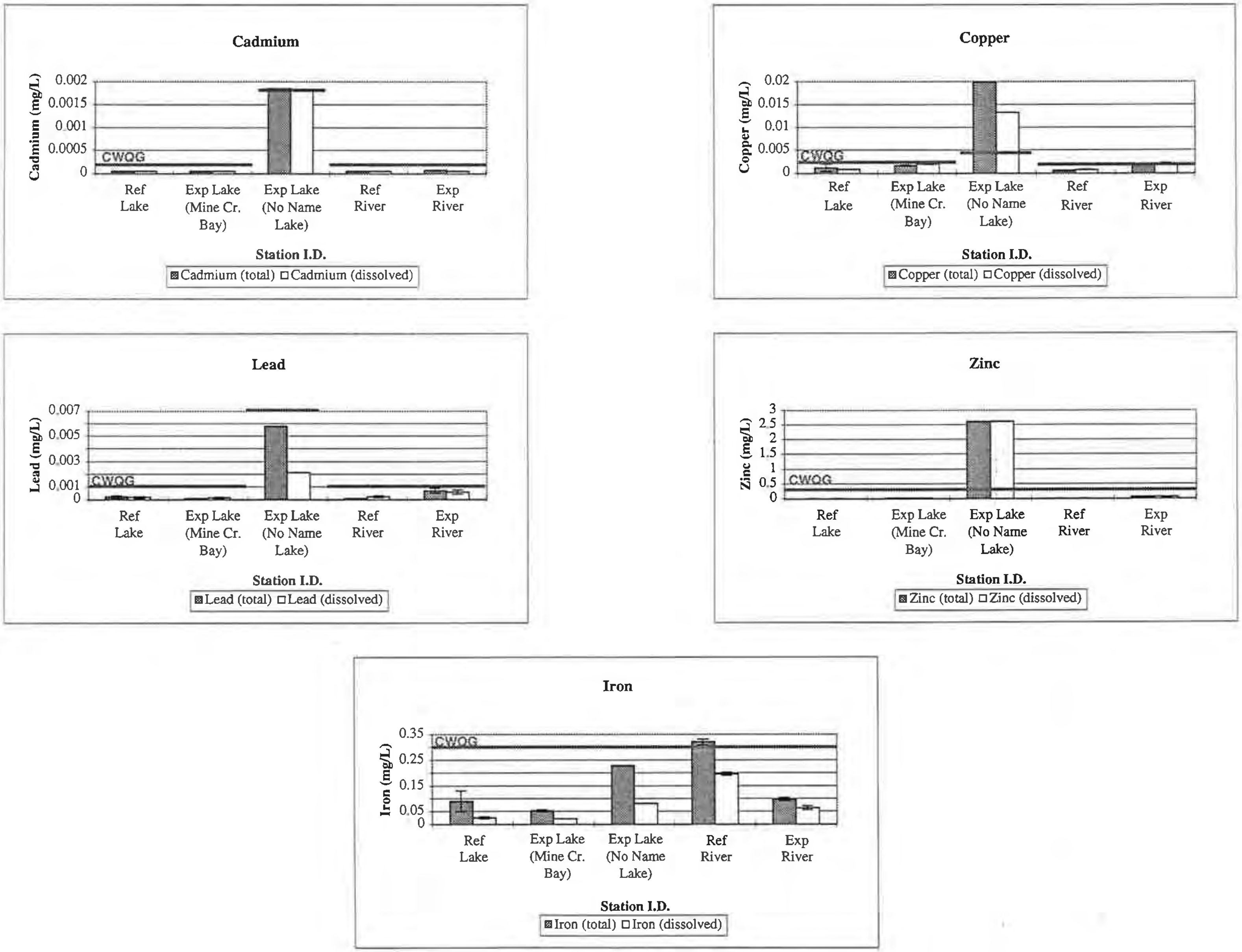


Figure 4.1: Mean Total and Dissolved Metal Concentrations in Water at Reference and Exposure Areas, Mattabi Mine, October 1997. Reach Means (±1 S.E.) Based on Data in Appendix 3. CWQG = Canadian Water Quality Guideline
(note: due to high hardness (285) and metals values, No Name Lake is presented separately)

metal-enriched sample (e.g., No Name Lake). The lower dissolved lead relative to total lead concentrations at MME1 may reflect lead precipitation or coprecipitation with iron hydroxide, as suggested by the substantial total iron concentration in the water (Table 4.2).

4.2 Sediment Chemistry

Fine-grained sediments are present both at stream and lake sampling stations; however, sediments were collected for hypothesis testing only at lake stations. Historical sediment quality data for Bell Creek indicate high but spatially heterogeneous metal concentrations in Bell Creek sediments, whereas those in Mine Creek Bay show a more systematic spatial gradient, facilitating a more effective study design in the latter area. Nonetheless, any biological effects observed in fish in Bell Creek may be attributed to either or both sediment metals and aqueous metals.

Sediment chemistry data are summarized in Table 4.3 (total metals), Table 4.4 (partial metals and Table 4.5 (acid volatile sulphide/simultaneously extracted metals). All raw data are provided in Appendix 4. The total metal concentrations are compared with Canadian Interim Sediment Quality Assessment Values (CISQAV) (Environment Canada, 1995). The TEL (threshold effect level) refers to the concentration below which an adverse effect is likely to rarely occur, while the PEL (probable effect level) refers to the concentration above which one could frequently expect adverse effects. All sediment QA/QC data are provided in Appendix 1.

Total Metal Concentrations and Physical Sediment Characteristics

All sediments were characterized as organic-rich and sandy, although reference area MMR1 in Sturgeon Lake tended to be somewhat coarser in grain size than other areas. Organic (TOC) concentrations were typically 20 to 30%. Sediment colour was classified as black in the exposure gradient, but somewhat different in colour at the reference sites (Table 4.3).

Concentrations of total zinc, lead, cadmium, copper, arsenic, nickel and mercury in sediments exceeded PEL levels at most exposure site stations, with maximum values as much as two orders of magnitude greater than PELs for zinc (Table 4.3 and Figure 4.2). There was a general decreasing trend in concentration from MME1 to MME5 although, for some metals other than zinc, concentrations were greater at MME5 than at MME4. Total

Table 4.3: Selected Sediment Quality Results at Mattabi Mine Site, October 1997. Metals Results Represent Total Metals Analyses.

Parameter	Units	MDL[1]	CISQAV[2]		REFERENCE STATIONS						EXPOSURE STATIONS														
			TEL[3]	PEL[4]	MMR1-1	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3	MME1-1	MME1-2	MME1-3	MME2-1	MME2-2	MME2-3	MME3-1	MME3-2	MME3-3	MME4-1	MME4-2	MME4-3	MME5-1	MME5-2	MME5-3
TOC (Solid)	%	0.1	na[5]	na	26	27	28	34	36	26	20	19	19	23	24	21	28	26	21	23	23	26	25	26	25
Aluminum	mg/kg	1	na	na	5200	3900	3700	2700	3000	3000	5000	11000	12000	6300	6200	6600	6000	6400	5900	5500	4900	6000	6600	6100	4900
Arsenic	mg/kg	0.5	5.9	17	3.5	3.9	3.4	5.4	7.2	7.1	67	150	160	41	32	43	19	26	24	16	4.5	13	14	20	18
Cadmium	mg/kg	0.05	0.596	3.53	1.8	1.6	1.6	0.94	1.2	1.2	60	100	140	43	32	63	36	56	39	18	5	12	13	14	21
Calcium	mg/kg	20	na	na	8680	9020	8856	9563	10010	8956	4187.5	9315	9075	11262.5	11050	10425	11332.5	10752.5	10465	11470	11967.2	11115	11335	11387.5	-
Cobalt	mg/kg	0.2	na	na	3.1	2.7	2.5	3.1	3.2	3.6	36	62	67	36	29	49	20	31	23	14	6.1	8.7	10	11	11
Copper	mg/kg	0.2	35.7	196.6	51	43	42	7.9	8.5	13	1100	2300	2500	1600	1200	1700	930	1300	1100	750	160	530	620	980	850
Iron	mg/kg	20	na	na	6100	4700	4400	3600	4300	3800	15000	33000	36000	16000	14000	17000	13000	15000	13000	12000	10000	10000	12000	13000	12000
Lead	mg/kg	0.1	35	91.3	25	26	24	29	27	36	760	1300	1700	870	600	990	490	670	490	300	55	280	340	540	560
Mercury	mg/kg	0.04	0.174	0.486	0.08	0.09	0.08	0.1	0.09	0.1	1.3	1.3	1.5	0.78	0.53	0.77	0.45	0.59	0.51	0.33	0.12	0.29	0.38	0.46	0.51
Nickel	mg/kg	0.5	18	35.9	19	18	17	5.1	5.6	5.9	39	81	86	50	48	56	34	45	35	37	26	25	24	24	27
Selenium	mg/kg	1	na	na	2.3	3.2	3.2	1.7	2.4	2.2	7	17	17	23	21	24	8.8	16	12	12	2.9	5	4.1	6.2	5.8
Zinc	mg/kg	1	123.1	314.8	450	330	360	78	90	97	20000	42000	45000	15000	15000	20000	10000	18000	13000	9000	2800	2700	2600	3400	4000
Grain Size Analysis[6]																									
Gravel (>2.0 mm - 4.8 mm)	(%)	0.1	na	na	0.2	4.9	3.5	3.4	0.2	2.6	1.1	1.2	0.2	4.1	1.3	4.2	7	6.6	6.6	2.2	2.8	3.1	3.7	6.2	6
Sand (2.0 mm - 0.050 mm)	(%)	0.1	na	na	94.3	88.4	80.9	89.3	4.5	66.5	55.1	68.1	61	66.3	75.6	73.4	70	60.7	78.9	56.2	72	75.7	73.5	57.8	80.9
V. Fine Sand, Silt, Clay (<0.10 mm)	(%)	0.1	na	na	5	7.8	16	7.7	95	31	44	31	39	31	23	22	23	34	15	42	26	22	23	36	13
Silt (0.002-0.050mm)	(%)	0.1	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clay (<0.002mm)	(%)	0.1	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eh	mV		na	na	-98	-80	-80	-11	-18	-11	-180	-165	-150	-151	-90	-137	-180	-132	-76	-163	-106	-90	-125	-130	-132
Bulk Density	g/mL		na	na	0.043	0.040	0.038	0.025	0.023	0.024	0.068	0.067	0.065	0.059	0.061	0.063	0.044	0.048	0.048	0.056	0.049	0.041	0.051	0.054	0.053
Sediment Moisture	%		na	na	95.9	96.1	96.3	97.5	97.8	97.6	93.3	93.4	93.6	94.14	94.22	94.0	95.6	95.2	95.2	94.4	95.3	96.0	95.0	94.8	94.7

[1] MDL - Method detection limit - lowest level of the parameter that can be detected with confidence

[2] CISQAV - Canadian Interim Sediment Quality Assessment Values (Freshwater) (Environment Canada, 1995)

[3] CISQAV - Threshold Effect Level (TEL)

[4] CISQAV - Probable Effect Level (PEL)

[5] na - Guideline values not available

[6] Silt and clay size fractions could not be readily distinguished owing to sediment consistency (Philip Analytical Services, Personal Communication).

▨ - Denotes values that exceed the Threshold Effect Level (TEL)

■ - Denotes values that exceed the Probable Effect Level (PEL)

Table 4.4: Selected Sediment Quality Results at Mattabi Mine Site, October 1997. Metals Results Based on Partial Extraction.

Component	Units	MDL[1]	REFERENCE STATIONS						EXPOSURE STATIONS														
			MMR1-1	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3	MME1-1	MME1-2	MME1-3	MME2-1	MME2-2	MME2-3	MME3-1	MME3-2	MME3-3	MME4-1	MME4-2	MME4-3	MME5-1	MME5-2	MME5-3
Aluminum	mg/kg	1	510	470	480	360	360	420	1800	1900	2300	710	730	780	590	540	630	830	640	680	600	630	630
Arsenic	mg/kg	0.5	1	1.2	1.1	0.9	1.4	1.6	3.8	2.6	2.7	0.8	0.5	<	1	0.5	0.7	1.3	0.8	2.4	2.7	3.2	2.4
Cadmium	mg/kg	0.05	0.81	0.84	0.71	0.3	0.39	0.54	0.2	0.13	0.2	0.12	0.07	0.09	0.2	0.12	0.16	0.19	0.59	2.7	2.5	3.9	1.2
Calcium	mg/kg	20	4546	4684	4660	4490	5288	5202	4700	5156	4814	6276	6248	6610	6812	5050	6206	6570	5910	4326	6492	6654	7870
Cobalt	mg/kg	0.2	0.3	0.3	0.3	<	<	<	14	9.6	9.9	4.6	3.7	6.7	2	2.1	2.2	2	1	1	0.8	1	1.3
Copper	mg/kg	0.2	1.2	1.1	1.1	<	<	<	0.2	0.2	0.2	0.2	<	<	0.2	<	0.3	0.4	0.3	2.1	1.7	4.1	1.7
Iron	mg/kg	20	530	520	510	760	900	800	3600	3200	3700	1600	1500	1800	1400	1200	1400	1400	1300	880	1200	1200	1400
Lead	mg/kg	0.1	5.3	5.4	5.3	2.4	2.1	4.2	34	19	30	19	14	14	18	17	18	28	8	38	39	92	70
Nickel	mg/kg	0.5	1.7	1.7	1.5	<	2.8	<	18	19	20	6.1	6	7.4	3.3	4	3.8	5.4	2.2	2.4	1.7	2.7	2.4
Selenium	mg/kg	1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Zinc	mg/kg	1	170	180	140	26	25	31	3500	3200	3800	1600	1700	1800	1500	1300	1500	1800	1000	670	740	750	1300
Molar Fraction [2]	-	-	0.279	0.301	0.240	0.031	0.025	0.035	0.833	0.856	0.880	0.858	0.971	0.856	0.919	0.929	0.919	1.104	0.659	0.666	0.538	0.559	0.808

[1] MDL -Method detection limit - lowest level of the parameter that can be detected with confidence

[2] Molar Fraction - molar concentration of (cadmium + copper + lead + zinc)/ iron

Table 4.5: Acid Volatile Sulphide (AVS) and Simultaneously Extracted Metals (SEM) Results and Ratios of Sediment Samples from Mattabi Mine Site, October 1997.

Component	Units	MDL[1]	REFERENCE STATIONS						EXPOSURE STATIONS														
			MMR1-1	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3	MME1-1	MME1-2	MME1-3	MME2-1	MME2-2	MME2-3	MME3-1	MME3-2	MME3-3	MME4-1	MME4-2	MME4-3	MME5-1	MME5-2	MME5-3
Aluminum	umol/g	2	459.7	217.4	121.7	109.4	130.6	121.5	455.9	457.4	556.0	409.3	248.1	203.4	277.4	236.8	186.1	218.9	215.7	165.5	255.6	294.6	252.9
Cadmium	umol/g	0.05	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Calcium	umol/g	7	928.4	476.1	262.1	368.1	567.0	436.3	386.5	361.0	411.7	581.7	386.3	273.9	509.2	380.1	323.6	402.7	475.2	336.5	530.5	578.3	471.5
Cobalt	umol/g	0.2	<	<	<	<	<	<	1.7	1.2	1.3	<	<	0.6	<	<	<	<	<	<	<	<	<
Copper	umol/g	0.1	3.4	1.4	0.9	<	<	<	20.8	24.1	0.5	17.4	9.9	11.9	11.8	13.1	9.2	6.1	2.2	3.5	6.9	9.7	11.6
Iron	umol/g	0.2	211.2	100.1	54.1	85.2	110.0	90.1	351.1	327.9	376.3	252.9	150.0	129.1	158.5	149.7	112.5	119.9	132.7	79.2	144.2	166.2	141.1
Lead	umol/g	0.4	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Nickel	umol/g	0.2	<	<	<	<	<	<	1.9	1.3	1.7	<	1.0	0.6	<	<	<	<	<	<	<	<	<
Zinc	umol/g	0.1	28.4	11.9	8.0	2.0	2.6	2.3	975.2	1106.1	1223.2	431.5	294.3	304.2	239.2	330.6	211.1	180.6	64.7	33.4	45.7	58.7	88.3
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			31.9	13.3	8.9	2.0	2.6	2.3	997.9	1131.5	1225.5	448.9	305.2	316.7	251.0	343.8	220.3	186.7	67.0	36.9	52.6	68.4	99.9
AV Sulphide		0.1	23.9	43.5	6.7	1.0	<0.1	<0.1	1416.0	1350.0	185.0	359.0	163.0	282.0	164.0	426.0	94.5	156.0	78.7	112.0	61.9	68.0	42.1
SEM/AVS Ratio			1.3	0.3	1.3	2.0	>2.6	>2.3	0.7	0.8	6.6	1.3	1.9	1.1	1.5	0.8	2.3	1.2	0.9	0.3	0.8	1.0	2.4

1 MDL - Method detection limit - lowest level that the parameter can be detected with confidence

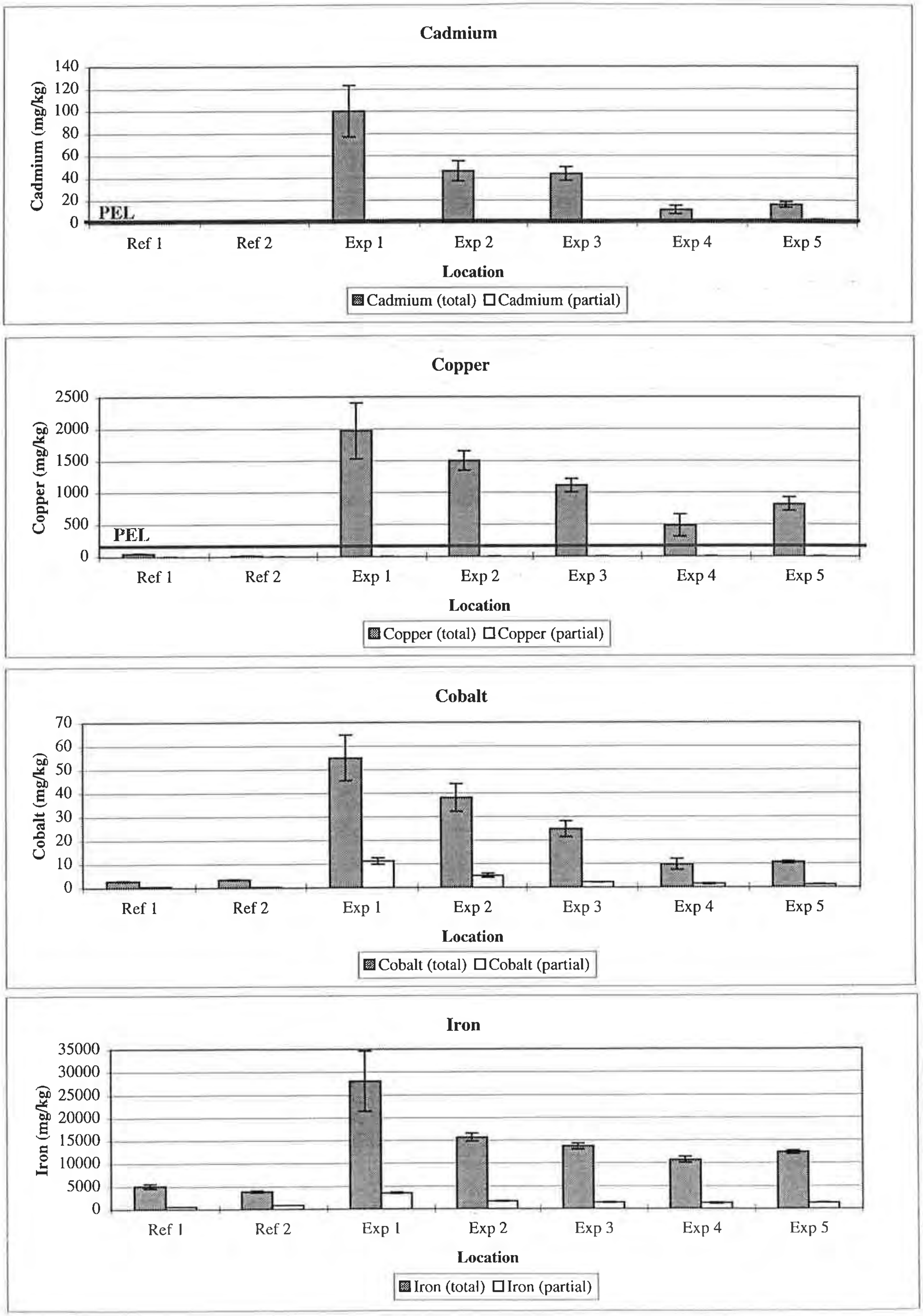


Figure 4.2: Mean Total and Partial Metals Concentrations in Sediments, Mattabi Mine, October 1997.
Area Means (± 1 S.E.) Based on Data in Appendix 4.

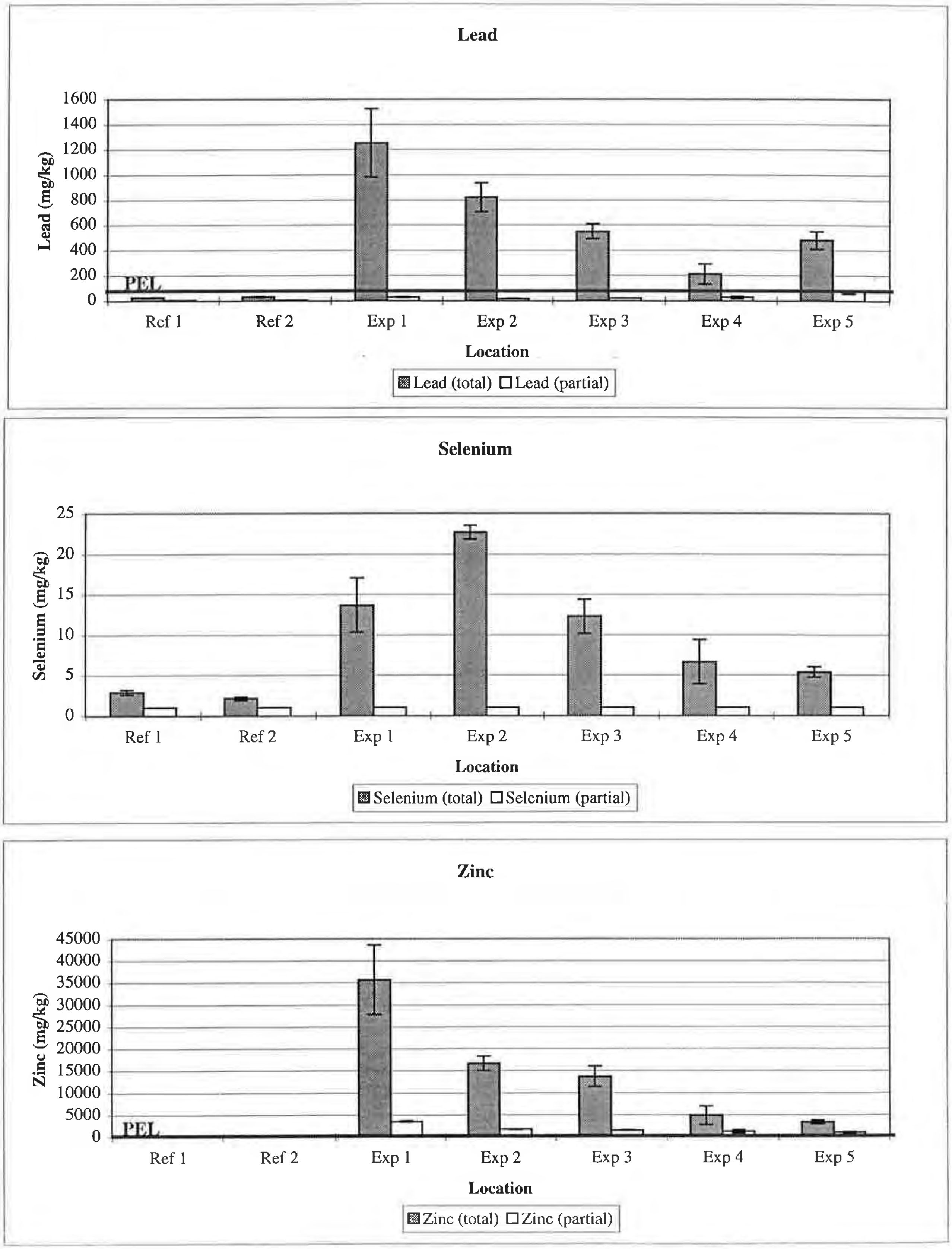


Figure 4.2: Mean Total and Partial Metals Concentrations in Sediments, Mattabi Mine, October 1997.
Area Means (± 1 S.E.) Based on Data in Appendix 4.

metal concentrations were greater at all exposure areas than at either of the two reference areas.

Generally, similar results were obtained in duplicate samples extracted using the hydrogen peroxide/nitric acid leach and conventional aqua regia (Appendix 1).

Geochemical Fractions

Partial metal extractions and ratios of acid volatile sulphide and simultaneously extracted metals may potentially be useful indicators of sediment metal bioavailability or sediment toxicity. Thus, these measurements may be of greater value than total sediment metal concentrations as tools to predict biological impact.

Partial Metals

At Mattabi, partial metals represented small fractions of total metals for zinc, copper, cadmium and lead (Table 4.4; Figure 4.2). In the most contaminated sediments, these fractions were about 10% for zinc and <1% for some of the other metals (Cu, Cd). The partial iron fraction was about 10% of total iron found in exposure sediments, indicating that iron hydroxide-bound forms may account for the partial fractions for most metals (i.e., those having partial metal fractions of ≤10%).

Partial metal concentration gradients were weaker than those for total metals or not evident for key metals from MME1 to MME5. This implies that most of the metals present in Mattabi sediments require a more aggressive leach than hydroxylamine hydrochloride to produce dissolution, and that the largest fractions of these metals are not controlled by iron hydroxide coprecipitation or by more readily dissociated particle-metal forms.

Acid Volatile Sulphide (AVS) and Simultaneously Extracted Metals (SEM)

In general, SEM/AVS ratios <1 may reflect non-toxic sediment conditions because some of the key metals (e.g., Ni, Pb, Cu, Cd, Zn) which are often associated with sediment toxicity will be in sulphide forms which reduces their bioavailability. However, it is possible that sediments with SEM/AVS ratios <1 will still be toxic due to the presence of other metals (e.g., arsenic, mercury) which are not included in the SEM analysis.

SEM/AVS ratios >1 often reflect sediments that may be toxic because there is insufficient sulphide to react with the bioavailable metals to make them less toxic. Again, SEM/AVS ratios >1 do not always accurately predict that sediments will be toxic because other factors, such as organic material or clay, will also bind metals, thereby reducing their toxicity.

The SEM/AVS ratio was developed to predict acute sediment toxicity and not necessarily for predicting chronic effects, including effects on the benthic community. However, it is not unreasonable to expect that, if sediments are acutely toxic, there would be some change in the benthic community structure that reflects this toxicity. Therefore, there may be a correlation between SEM/AVS ratios >1 and effects observed on benthic communities. This correlation is investigated in this report.

SEM/AVS ratios calculated for Mattabi sediments are presented in Table 4.5 and summarized in Figure 4.3. The data indicate spatially variable results, with ratios averaging above 1 for most sampling areas including one of the reference areas. With the exception of one of the three No Name Lake (MME1) sediment samples, there is no clear difference in mean SEM/AVS ratios between reference and exposure areas. At MME1, however, the ratios were more variable among the three sediment samples, with one value greater than at other sites.

***Aqua Regia* versus Nitric Acid/Hydrogen Peroxide Extraction Method**

Two samples (MMR1-1 and MME1-2) were analyzed for total metals after extraction by *aqua regia* to compare with results obtained by analysis using the nitric acid/hydrogen peroxide leach used for total metals analysis throughout this study (Appendix 1). There was relatively little variation in results between the two methods, with Cu, Cd and Pb results differing by ≤12% between the two extraction procedures.

4.3 Sediment Toxicity

Toxicity tests were carried out on the 15 sediment samples collected along the sediment quality gradient (three at each of MME1 to MME5) and from the six reference sediment samples (three each in the two reference areas). The tests included *Chironomus riparius* survival and growth, *Hyalella azteca* survival and growth, and *Tubifex tubifex* survival and reproduction. The principal endpoints in the *Tubifex* test are sublethal reproductive

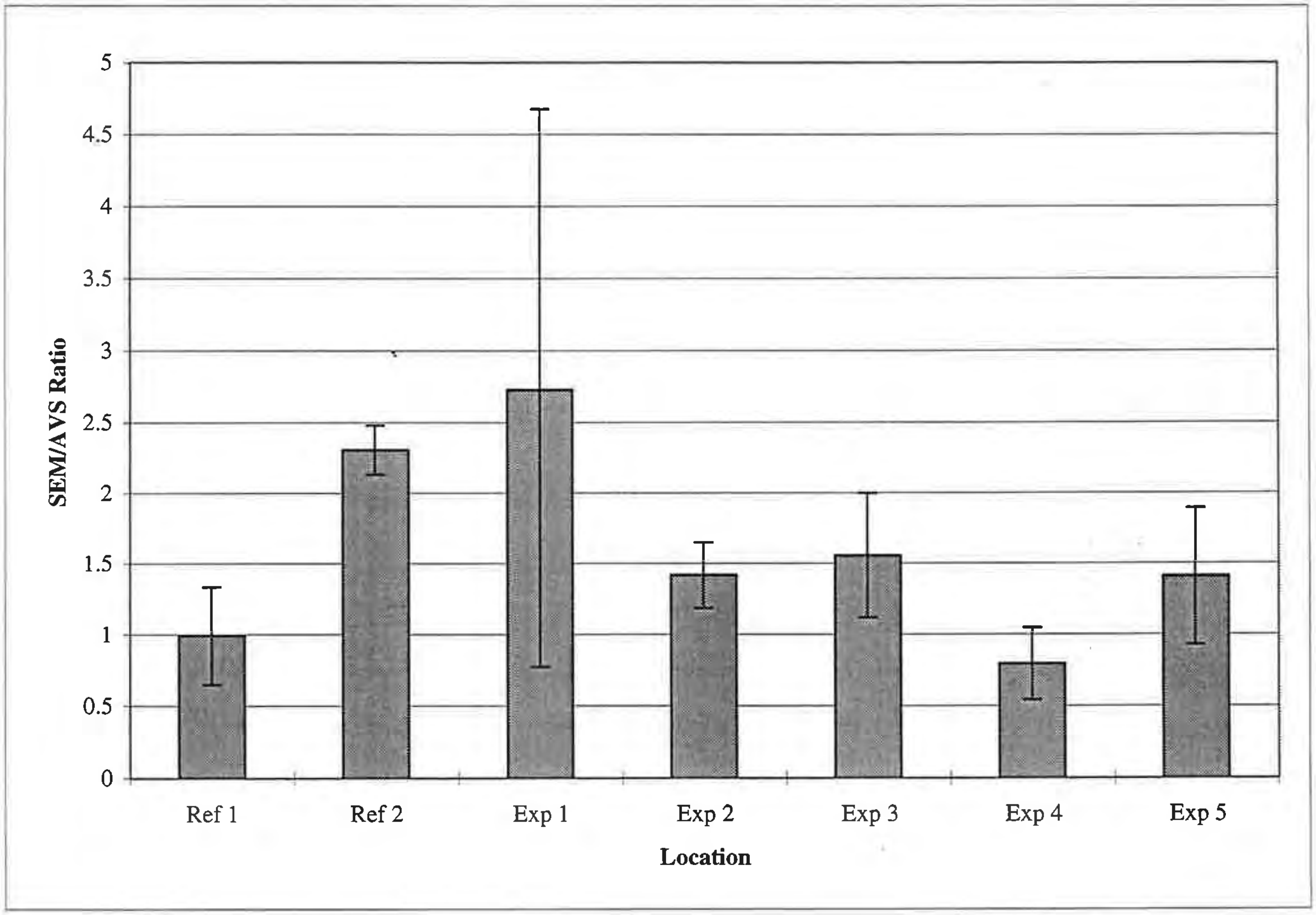
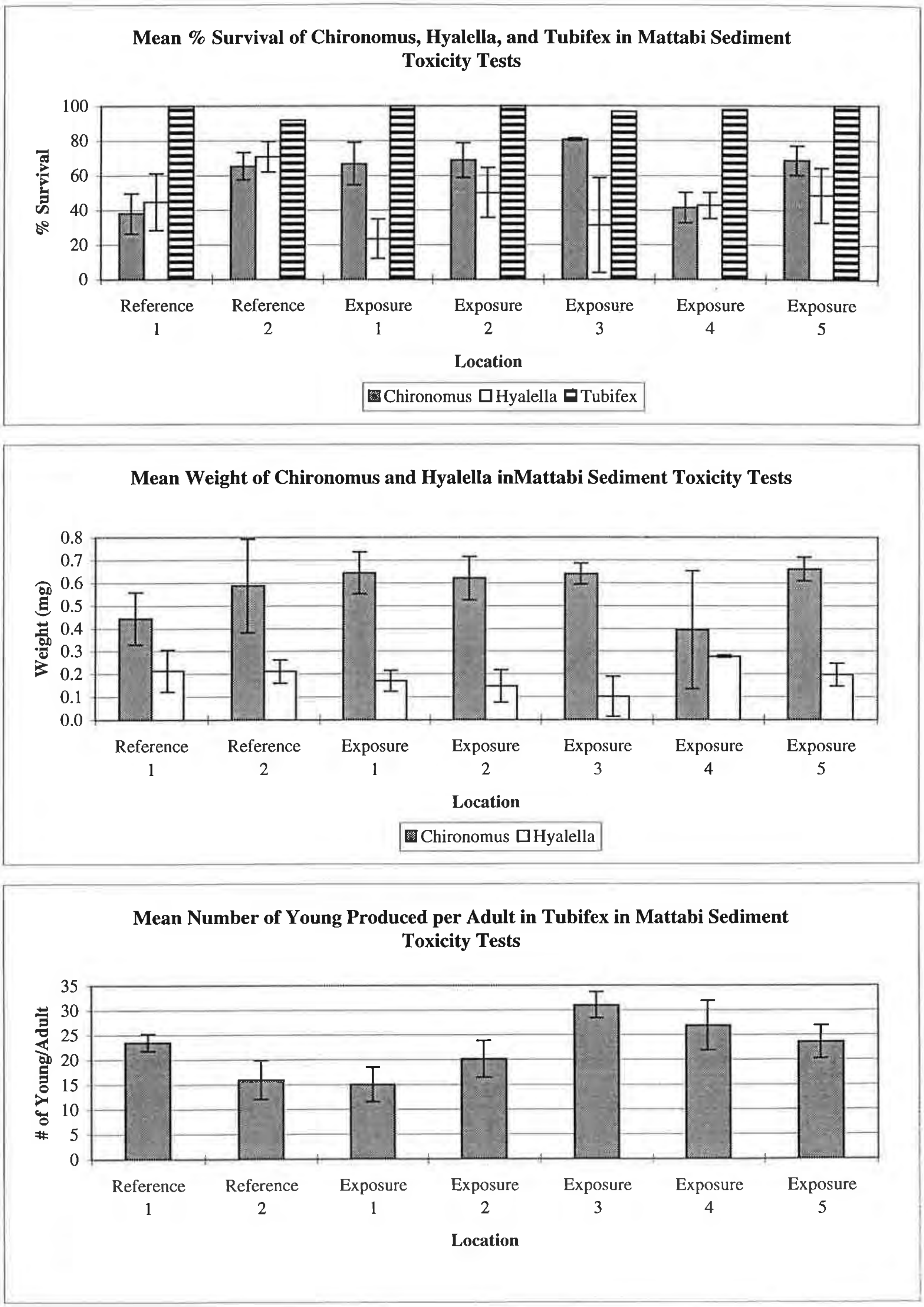


Figure 4.3: **Mean SEM/AVS Molar Concentration Ratio by Area, Mattabi Mine, October 1997.**
(SEM values for Cd, Cu, Ni, Pb and Zn).
Area Means (± 1 S.E.)



Mean % Survival of Chironomus, Hyalella, and Tubifex in Mattabi Sediment Toxicity Tests

Mean Weight of Chironomus and Hyalella inMattabi Sediment Toxicity Tests

Mean Number of Young Produced per Adult in Tubifex in Mattabi Sediment Toxicity Tests

Figure 4.4: Mean Sediment Toxicity Test Results (± 1 S.E.), Mattabi Mine, October 1997.

Table 4.6: Sediment Toxicity Results, Mattabi Mine, October 1997

Station	*Chironomus riparius*		*Hyalella azteca*		*Tubifex tubifex*	
	Survival ± S.D. (%)	Mean Dry Weight/Organism ± S.D. (mg)	Survival ± S.D. (%)	Mean Dry Weight/Organism ± S.D. (mg)	Survival ± S.D. (%)	Mean Young Produced per Adult
MMR1-1	56* ± 6	0.56* ± 0.05	64 ± 6	0.16* ± 0.06	100	25.20 ± 5.33
MMR1-2	16* ± 9	0.33* ± 0.04	12* ± 16	0.16 ± 0.13	100	21.75 ± 5.32
MMR1-3	42* ± 4	0.44* ± 0.06	58* ± 11	0.32* ± 0.02	100	23.65 ± 0.76
MMR2-1	50* ± 0	0.35* ± 0.11	88 ± 13	0.24 ± 0.08	95 ± 11.2	20.44 ± 5.22
MMR2-2	72 ± 19	0.69 ± 0.06	64* ± 9	0.15* ± 0.04	90 ± 13.7	13.42 ± 4.31
MMR2-3	74 ± 9	0.72 ± 0.08	60* ± 7	0.24 ± 0.05	90 ± 13.7	13.85 ± 4.33
MME1-1	86 ± 6	0.72 ± 0.05	46* ± 9	0.13 ± 0.05	100	18.95 ± 5.38
MME1-2	44* ± 6	0.67 ± 0.17	12* ± 16	0.16 ± 0.02	100	12.22 ± 6.83
MME1-3	70 ± 7	0.54 ± 0.11	12* ± 8	0.22 ± 0.23	100	13.80 ± 1.63
MME2-1	64 ± 6	0.72 ± 0.09	70 ± 12	0.21 ± 0.05	100	19.25 ± 4.38
MME2-2	88 ± 8	0.53 ± 0.09	58* ± 4	0.07* ± 0.04	100	24.25 ± 5.10
MME2-3	54* ± 6	0.61* ± 0.07	22* ± 25	0.16* ± 0.04	100	16.88 ± 2.57
MME3-1	80 ± 10	0.6 ± 0.16	86 ± 11	0.16 ± 0.03	95 ± 11.2	31.66 ± 4.18
MME3-2	80 ± 10	0.69 ± 0.07	8* ± 13	0.14* ± 0.04	95 ± 11.2	28.14 ± 5.98
MME3-3	82 ± 11	0.63 ± 0.06	0*	-	100	33.25 ±3.82
MME4-1	58* ± 4	0.21* ± 0.06	56* ± 9	0.28* ± 0.05	100	24.75 ± 3.60
MME4-2	38* ± 4	0.28* ± 0.11	42* ± 8	0.28 ± 0.05	93.75 ± 12.5	23.21 ± 2.83
MME4-3	28* ± 18	0.69 ± 0.2	30* ± 27	0.27* ± 0.04	100	32.60 ± 3.44
MME5-1	76 ± 9	0.72 ± 0.06	58* ± 8	0.20 ± 0.09	100	25.30 ± 3.83
MME5-2	52* ± 8	0.63* ± 0.05	18* ± 4	0.23 ± 0.14	100	25.75 ± 2.93
MME5-3	78 ± 11	0.63 ± 0.07	70 ± 10	0.19 ± 0.06	100	19.70 ± 3.55

* Indicates that the growth or survival was significantly less than the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test)

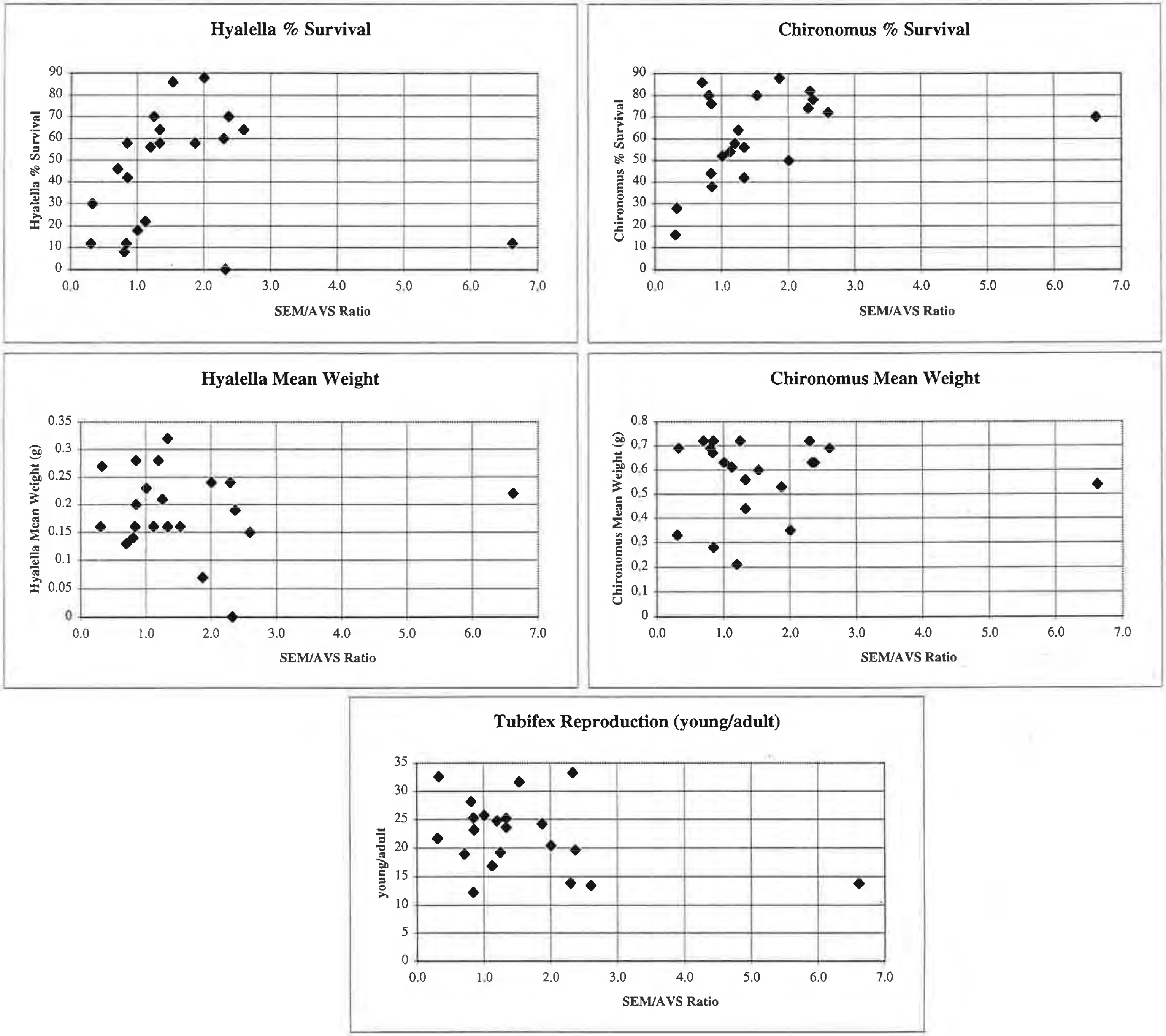
endpoints, because this species is recognized as insensitive in terms of its mortality response to many toxicants. Laboratory report summaries are presented in Appendix 4, with full reports provided in Annex 1.

Survival of all three species showed little apparent response to the sediment quality gradient (Figure 4.4; Table 4.6). Mortality responses occurred in both *Chironomus* and *Hyalella* in both reference and exposure area sediments. The data suggest a greater response in *Hyalella* in the most contaminated sediments (MME1) than at most other locations. This contrasts with sediment toxicity results obtained in 1991-1992, which showed no effects on *Hyalella* but some lethal and sublethal effects in *Chironomus*.

At the sublethal level, reference-exposure differences were similarly absent or at best weakly apparent. Production of young in *Tubifex* appeared to be slightly reduced in MME1 sediments relative to most sediments, but MMR2 reference sediments produced a similar response, suggesting this was not a mine exposure effect. *Hyalella* growth was lowest at MME3 and *Chironomus* growth lowest at MME4 on average, although growth in these sediments was variable within each of the two areas and mean sizes were not substantially different than growth observed in some of the reference sediments.

Toxicity of sediments did not appear to be related to the SEM/AVS ratio, despite the fact that ratio values fell both above and below 1.0 in the dataset (Figure 4.5). Indeed, the fact that significant levels of *Hyalella* and *Chironomus* mortality occurred at SEM/AVS ratios below 1.0 suggest that the SEM/AVS model was ineffective in this instance.

Sediment toxicity also did not appear related to the sum of molar Cd, Cu, Pb and Zn (partial extractions), expressed as fraction of the molar concentration of iron in the partial extractions (Table 4.4; Figure 4.6). A possible relationship here could be that toxicity occurs when heavy metals are present in excess of the molar concentration of Fe, because the excess portions are not coprecipitated with iron. This possible model is somewhat analogous to the model that states that SEM in excess of AVS concentrations can cause toxicity.



Hyalella % Survival

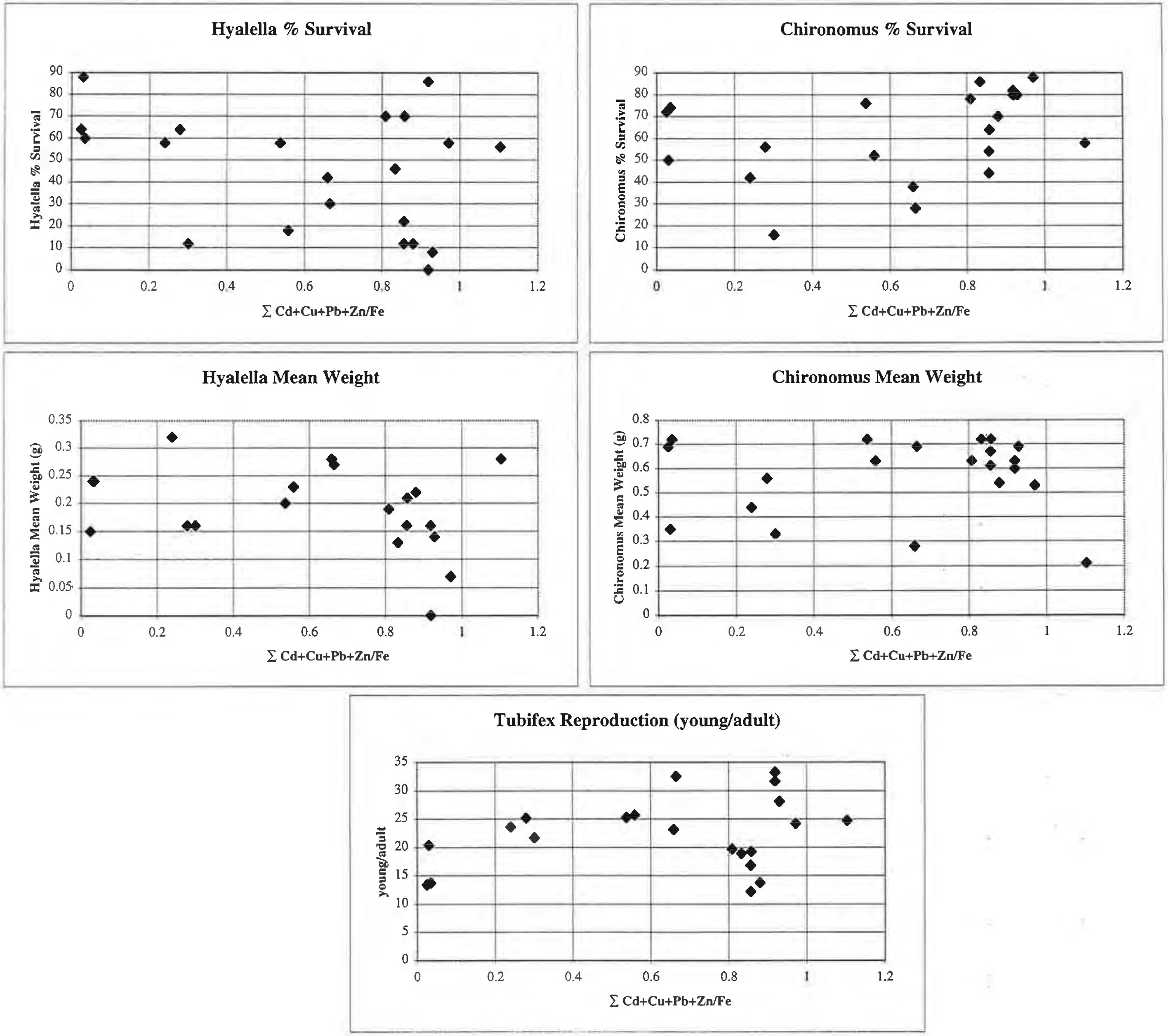
Chironomus % Survival

Hyalella Mean Weight

Chironomus Mean Weight

Tubifex Reproduction (young/adult)

Figure 4.5: Sediment Toxicity versus Ratio of Simultaneously Extracted Metals (Cd+Cu+Ni+Pb+Zn)/Acid Volatile Sulphide, Mattabi Mine, October 1997.



Hyalella % Survival

Chironomus % Survival

Hyalella Mean Weight

Chironomus Mean Weight

Tubifex Reproduction (young/adult)

Figure 4.6: Sediment Toxicity versus Ratio of Molar Concentrations of Cd, Cu, Pb and Zn in Partial Extractions/Iron in Partial Extractions, Mattabi Mine, October 1997.

4.4 Benthic Invertebrates

Benthic invertebrate data are provided in Appendix 5. Associated QA/QC data are provided in Appendix 1. Data summaries are provided in Table 4.7 and Figure 4.7.

Benthic community trends are apparent in the sediment chemistry gradient, with reduced numbers of taxa in the most exposed stations, as well as changes in the abundances of possible indicator taxa. Common or abundant taxa included Harpacticoida and chironomids, with certain common taxa conspicuously absent or abundant at the most impacted stations. The sensitive taxa included Hydracarina (mites), *Caenis* (mayfly) and *Pisidium* (mollusc), whereas the chironomid *Psectrocladius* was abundant and dominant uniquely at MME1 (No Name Lake) stations. These trends do not appear to be attributed to variations in sediment texture or organic content, as all sediments generally appeared similar in the field (No Name Lake similar to Tag Lake, Mine Creek Bay similar to Peterson Cove). To further illustrate this point, the greatest differences in sediment texture were observed between the two reference areas (coarsest and finest) and yet the benthic trends noted above correspond with reference-exposure area differences.

Data on mouth-part deformities and abnormalities in chironomid larvae are presented in Appendix 5. The data suggest no reference-exposure differences in the incidence of anomalies.

4.5 Fish

4.5.1 Fish Health and Community

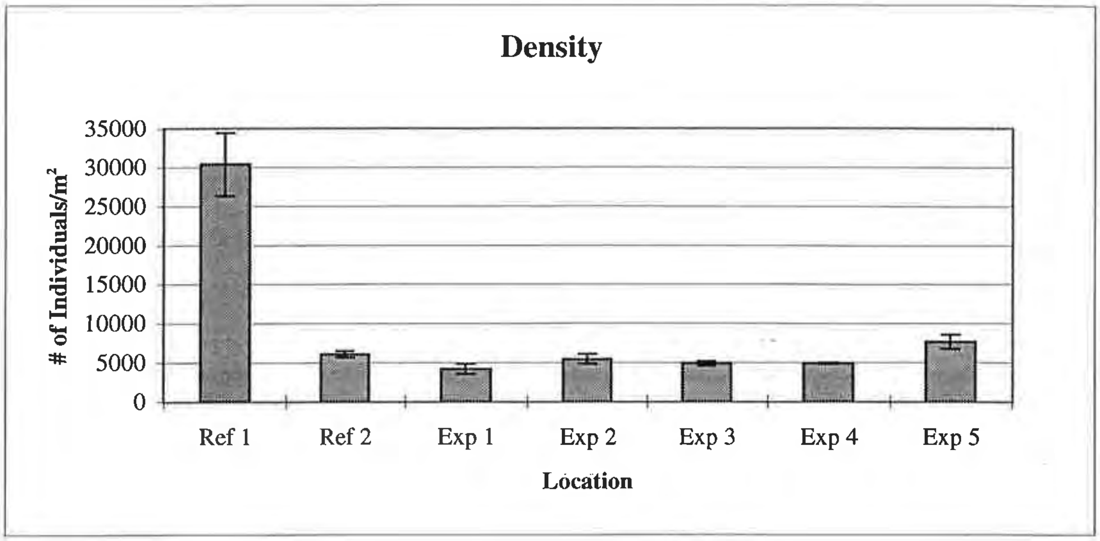
Detailed biological measurements on all fish captured in the Mattabi survey are presented in Appendix 6.

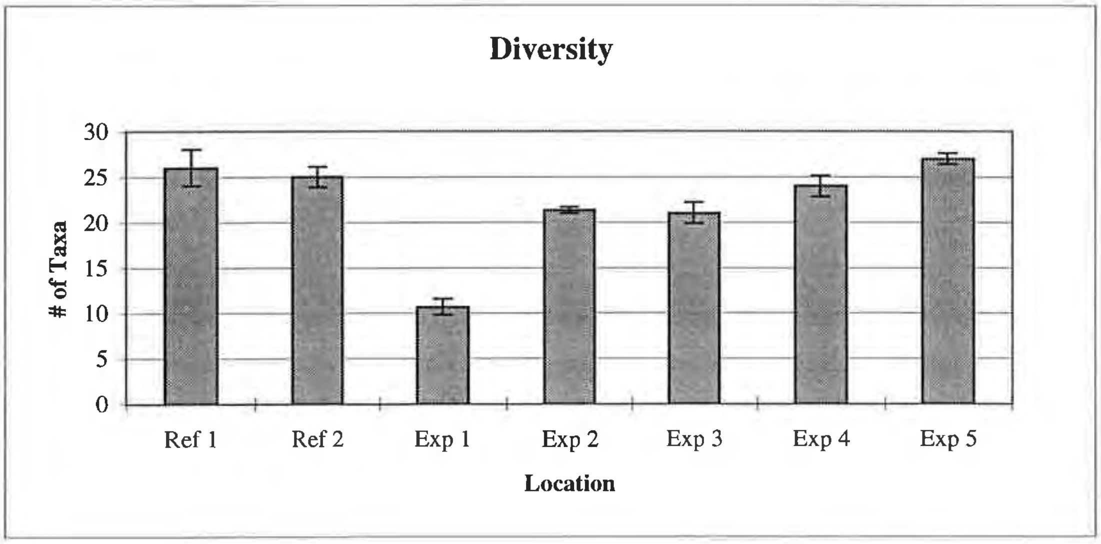
Several species of fish were captured in Bell Creek (exposure area) and the English River (reference area) (Table 4.8). The two sentinel species (northern pike and white sucker) were relatively abundant in each area, although pike appeared to be more abundant in the reference area and sucker more abundant in the exposure area. Catch-per-unit-effort in terms of numbers and biomass for all fish species combined were not distinctly different between the reference and exposure areas (Table 4.8; Figure 4.8). The principal difference in the fish community between the two areas is the presence of lake whitefish in the English

Table 4.7: Benthic Community Indices, Based on Petite Ponar Sampler Collections, Mattabi Mine, October 1997.

Station	Number of Individuals [1]	Number of Taxa	Hydracarina (%)	Caenis (%)	Chironomus (%)	Procladius (%)	Tanypodinae (%)	Chironiminae (%)	Pisidium (%)
MME1-1	5442	12	0.00	0.00	4.01	6.69	11.04	9.03	0.00
MME1-2	3240	9	0.00	0.00	0.00	10.13	15.17	11.24	0.00
MME1-3	3813	11	0.47	0.00	1.44	9.55	12.65	4.77	0.00
MME2-1	6006	21	1.82	4.25	10.91	12.13	12.12	41.21	2.42
MME2-2	6152	22	3.55	2.96	7.11	9.47	11.83	51.48	1.18
MME2-3	4222	21	0.85	9.48	6.04	18.98	24.14	45.69	1.72
MME3-1	4659	21	3.14	5.48	16.41	10.16	12.50	35.16	3.13
MME3-2	5387	23	3.38	8.11	10.81	12.16	14.86	32.43	2.70
MME3-3	4623	19	3.94	3.16	11.81	13.39	15.75	32.28	3.15
MME4-1	4950	22	4.40	34.20	7.35	24.63	25.74	16.54	2.21
MME4-2	5041	26	10.13	19.52	7.23	24.20	26.71	17.69	2.53
MME4-3	4805	24	3.42	9.10	17.06	19.70	21.97	26.89	4.17
MME5-1	8199	27	3.55	3.55	11.99	11.99	15.09	54.16	6.22
MME5-2	5824	26	4.38	4.38	10.63	16.25	20.00	41.25	10.00
MME5-3	8919	28	1.64	2.04	6.53	3.68	11.02	49.80	8.98
MMR1-1	22277	30	2.29	0.82	0.00	2.78	2.78	54.25	1.96
MMR1-2	35090	24	3.63	1.87	0.00	2.80	2.80	34.54	1.04
MMR1-3	33734	24	4.99	1.48	0.00	2.62	2.62	31.02	1.08
MMR2-1	6425	23	6.52	3.69	0.00	22.38	22.38	24.93	2.83
MMR2-2	5244	25	6.25	3.13	0.00	12.49	12.50	30.56	4.86
MMR2-3	6497	27	5.88	1.96	0.00	19.62	19.61	24.93	6.72

[1] Number of individuals per m^2 composite sample from a Petite Ponar.





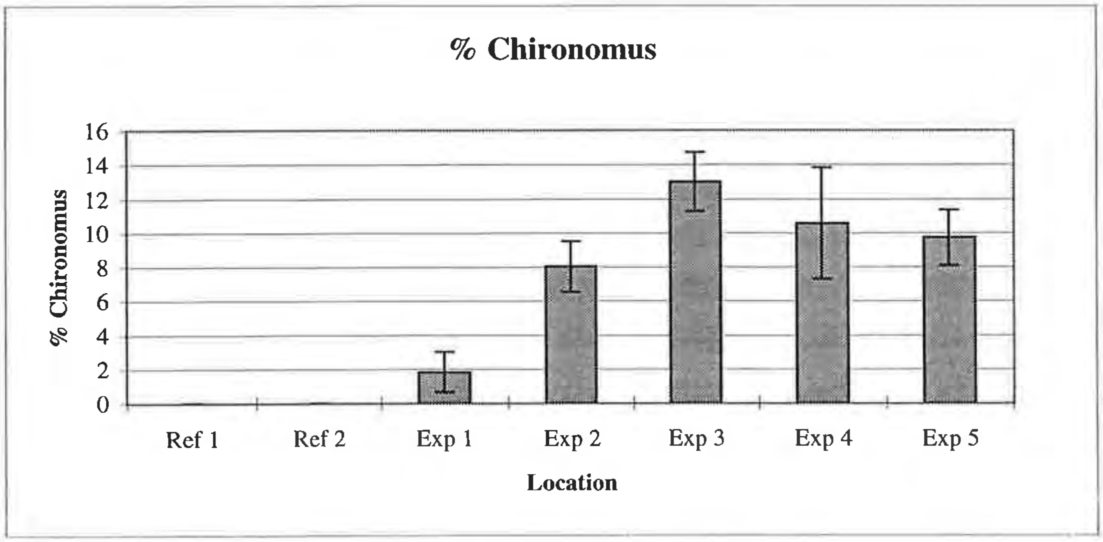
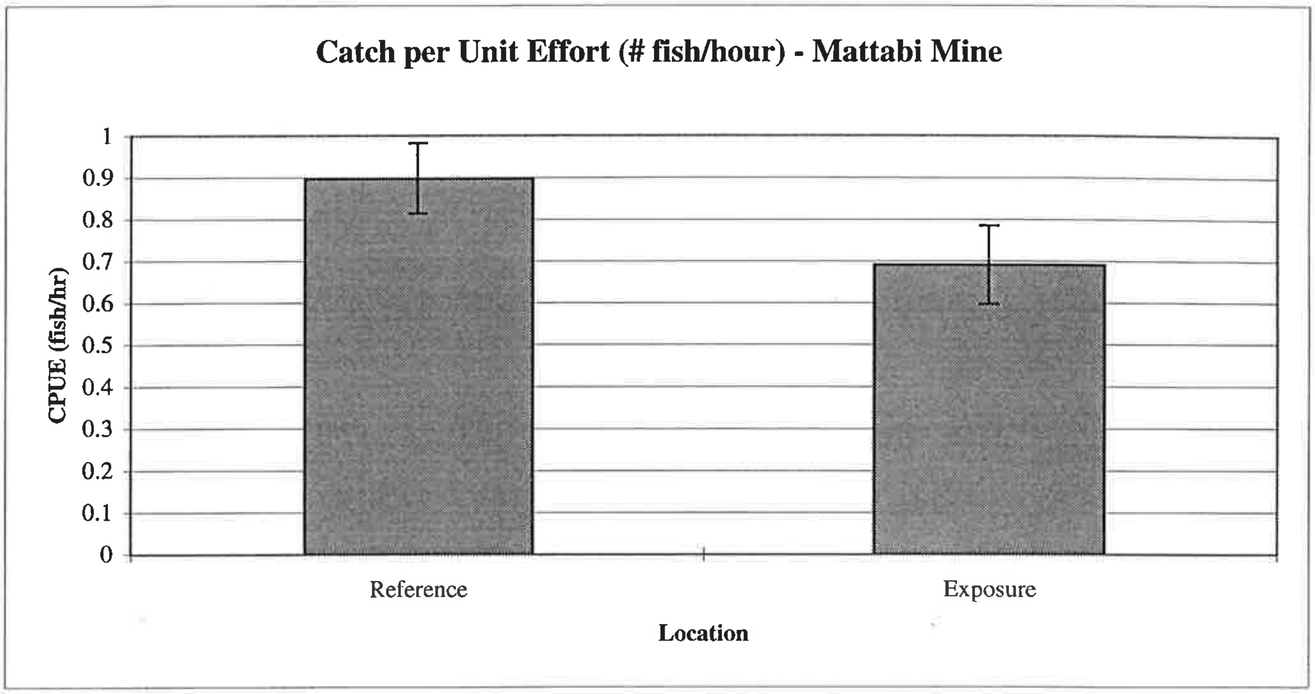


Figure 4.7: Mean Values for Selected Benthic Indices at Mattabi Mine, October 1997.
Area Means (± 1 S.E.) Based on Data in Table 4.7.

Table 4.8: Catch per Unit Effort in the Reference and Exposure Areas. Mattabi Mine, October 1997.

Area	Station	Date/Time Set	Date/Time Lift	Fishing Time (hrs)	Northern Pike (fish/hr)	White Sucker (fish/hr)	Walleye (fish/hr)	Yellow Perch (fish/hr)	Sauger (fish/hr)	Shorthead Redhorse (fish/hr)	Lake Whitefish (fish/hr)	Lake Herring (fish/hr)	All Fish (fish/hr)
Exposure	MM6	10/15/97 15:50	10/16/97 11:20	19.5	0.359	0.359	0.000	0.103	0.000	0.000	0.000	0.000	0.821
		10/17/97 15:15	10/18/97 11:50	20.6	0.049	0.243	0.049	0.049	0.000	0.049	0.000	0.000	0.437
		10/18/97 12:25	10/19/97 10:50	22.4	0.134	0.357	0.000	0.045	0.000	0.045	0.000	0.000	0.580
		10/18/97 12:15	10/19/97 11:25	23.2	0.086	0.129	0.000	0.086	0.000	0.043	0.000	0.000	0.345
			Mean	**21.4**	**0.157**	**0.272**	**0.012**	**0.071**	**0.000**	**0.034**	**0.000**	**0.000**	**0.546**
	MM7	10/15/97 16:20	10/16/97 12:30	20.2	0.099	0.397	0.099	0.149	0.000	0.000	0.000	0.000	0.744
		10/16/97 13:25	10/17/97 14:45	25.3	0.395	0.395	0.000	0.039	0.000	0.039	0.000	0.000	0.868
			Mean	**22.8**	**0.247**	**0.396**	**0.050**	**0.094**	**0.000**	**0.020**	**0.000**	**0.000**	**0.806**
	MM8	10/17/97 14:10	10/18/97 11:05	20.9	0.335	0.478	0.048	0.048	0.000	0.096	0.000	0.000	1.004
		10/18/97 11:00	10/19/97 10:00	23.0	0.087	0.652	0.000	0.043	0.000	0.000	0.000	0.000	0.783
			Mean	**22.0**	**0.211**	**0.565**	**0.024**	**0.046**	**0.000**	**0.048**	**0.000**	**0.000**	**0.893**
	MM9	10/16/97 13:30	10/17/97 9:45	20.3	0.247	0.198	0.099	0.000	0.000	0.049	0.000	0.000	0.593
		10/18/97 10:50	10/19/97 9:30	22.7	0.088	0.309	0.044	0.000	0.000	0.000	0.000	0.000	0.441
			Mean	**21.5**	**0.168**	**0.253**	**0.071**	**0.000**	**0.000**	**0.025**	**0.000**	**0.000**	**0.517**
	All		**Mean**	**21.8**	**0.188**	**0.352**	**0.034**	**0.056**	**0.000**	**0.032**	**0.000**	**0.000**	**0.662**
Reference	MM10	10/19/97 14:05	10/20/97 10:30	20.4	0.490	0.196	0.049	0.000	0.000	0.098	0.098	0.000	0.931
		10/21/97 11:35	10/22/97 10:15	22.7	0.618	0.176	0.132	0.044	0.000	0.000	0.176	0.000	1.147
			Mean	**21.5**	**0.554**	**0.186**	**0.091**	**0.022**	**0.000**	**0.049**	**0.137**	**0.000**	**1.039**
	MM11	10/19/97 14:20	10/20/97 11:10	20.8	0.336	0.240	0.096	0.000	0.000	0.048	0.288	0.000	1.008
		10/21/97 11:20	10/22/97 9:40	22.3	0.313	0.090	0.000	0.045	0.000	0.000	0.313	0.000	0.761
			Mean	**21.6**	**0.325**	**0.165**	**0.048**	**0.022**	**0.000**	**0.024**	**0.301**	**0.000**	**0.885**
	MM12	10/20/97 9:45	10/21/97 11:50	26.1	0.230	0.192	0.422	0.153	0.077	0.000	0.000	0.000	1.073
		10/22/97 11:20	10/23/97 9:55	22.6	0.000	0.443	0.221	0.177	0.089	0.000	0.000	0.000	0.930
			Mean	**24.3**	**0.115**	**0.317**	**0.322**	**0.165**	**0.083**	**0.000**	**0.000**	**0.000**	**1.002**
	MM13	10/20/97 10:10	10/21/97 12:30	26.3	0.304	0.038	0.000	0.000	0.000	0.000	0.076	0.000	0.418
		10/22/97 11:30	10/23/97 10:30	23.0	0.217	0.087	0.217	0.043	0.043	0.000	0.261	0.043	0.913
			Mean	**24.7**	**0.261**	**0.062**	**0.109**	**0.022**	**0.022**	**0.000**	**0.168**	**0.022**	**0.665**
	All		**Mean**	**23.0**	**0.314**	**0.183**	**0.142**	**0.058**	**0.026**	**0.018**	**0.152**	**0.005**	**0.898**



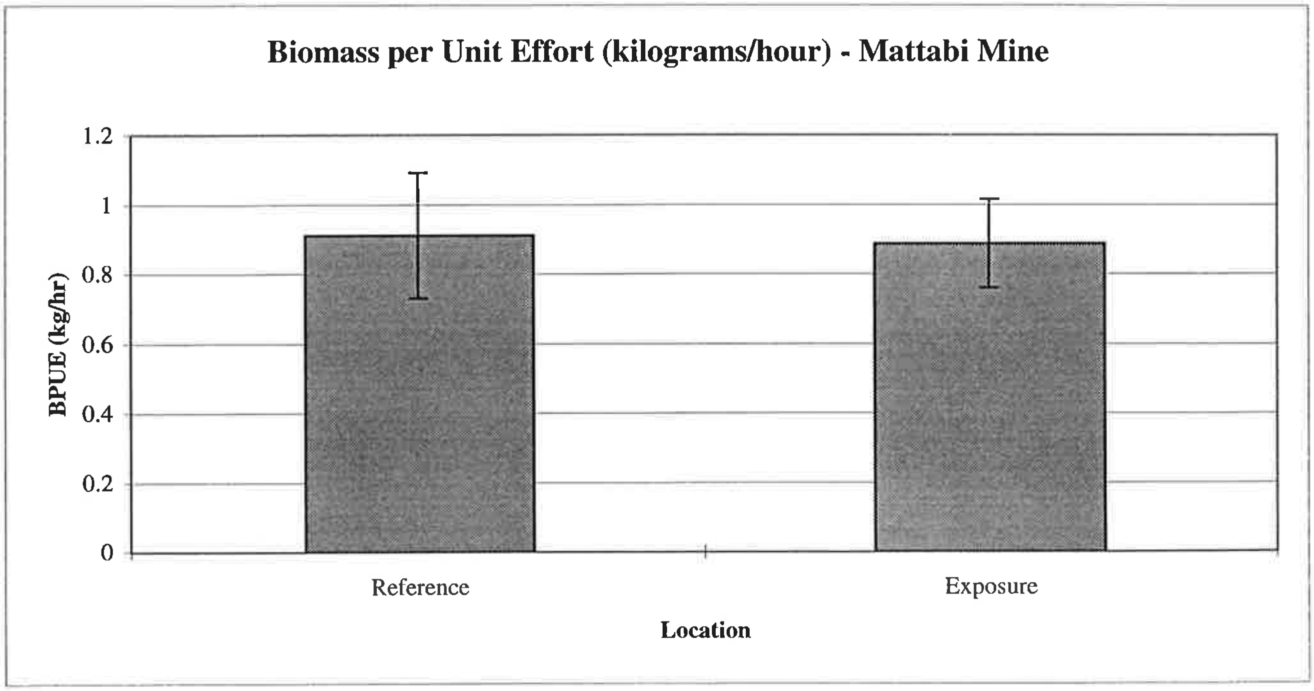


Figure 4.8: Mean Catch and Biomass Per-Unit-Effort by Gill Net (all species) at Mattabi Mine, October 1997. Means (±1 S.E.) Based on Data in Table 4.8.

River but not in Bell Creek; this probably represents an effect of habitat differences between Bell Creek and the English River. That is, the English River is a much larger river in general than Bell Creek, and thereby provides suitable habitat for lake whitefish. This habitat difference was less apparent at the local level, because all sampling areas were in wide (generally 100 to 1,000 m in width) reaches having relatively shallow mean depths. Deeper water suitable for whitefish, however, is present near reference areas, whereas habitat barriers (shallow riffles) probably prevent the seasonal movement of whitefish from Sturgeon Lake or Bell Lake into exposure areas in Bell Creek.

Size at age graphs show little apparent differences in growth of white sucker between reference and exposure areas (Figure 4.9; Table 4.9). However, northern pike showed greater growth in the Bell Creek exposure area than in the English River.

Similarly, liver size, gonad size (Figure 4.10; Table 4.9) and fecundity (numbers of eggs) (Figure 4.11) appeared greater at age for northern pike and similar for white sucker in Bell Creek relative to English River fish.

4.5.2 Fish Tissues

Tissue metal and metallothionein concentrations are provided in detail in Appendix 6. Data summaries are presented in Figures 4.12 to 4.14 for metals, Figure 4.15 for metallothionein (MT), and in Table 4.10 for both metals and MT.

Metal analyses showed some apparent reference-exposure area differences for a few metals in some tissues. Tissues accumulating the highest metal concentrations were kidney for cadmium (both species) and liver for copper (both species). Zinc was accumulated most by liver in sucker and kidney in pike. In white sucker, lead was higher in gills of exposed fish, whereas there was less difference between areas for lead in liver and kidney. In pike, lead was higher in gills and kidney in exposed fish, and there were no area differences in liver or muscle lead levels. Zinc in pike appeared more elevated in reference fish gill than in gill from exposed fish. Selenium was, on average, greater in exposed sucker and pike than in reference fish for all tissue types, and among all metals showed the most consistent reference-exposure difference. Water chemistry data show trace levels of selenium in the treated effluent (0.004 mg/L) but undetectable concentrations in all samples from the environment (<0.002 mg/L), suggesting that the observed reference-exposure difference in tissue selenium could be mine-related (refer to Appendix 3).

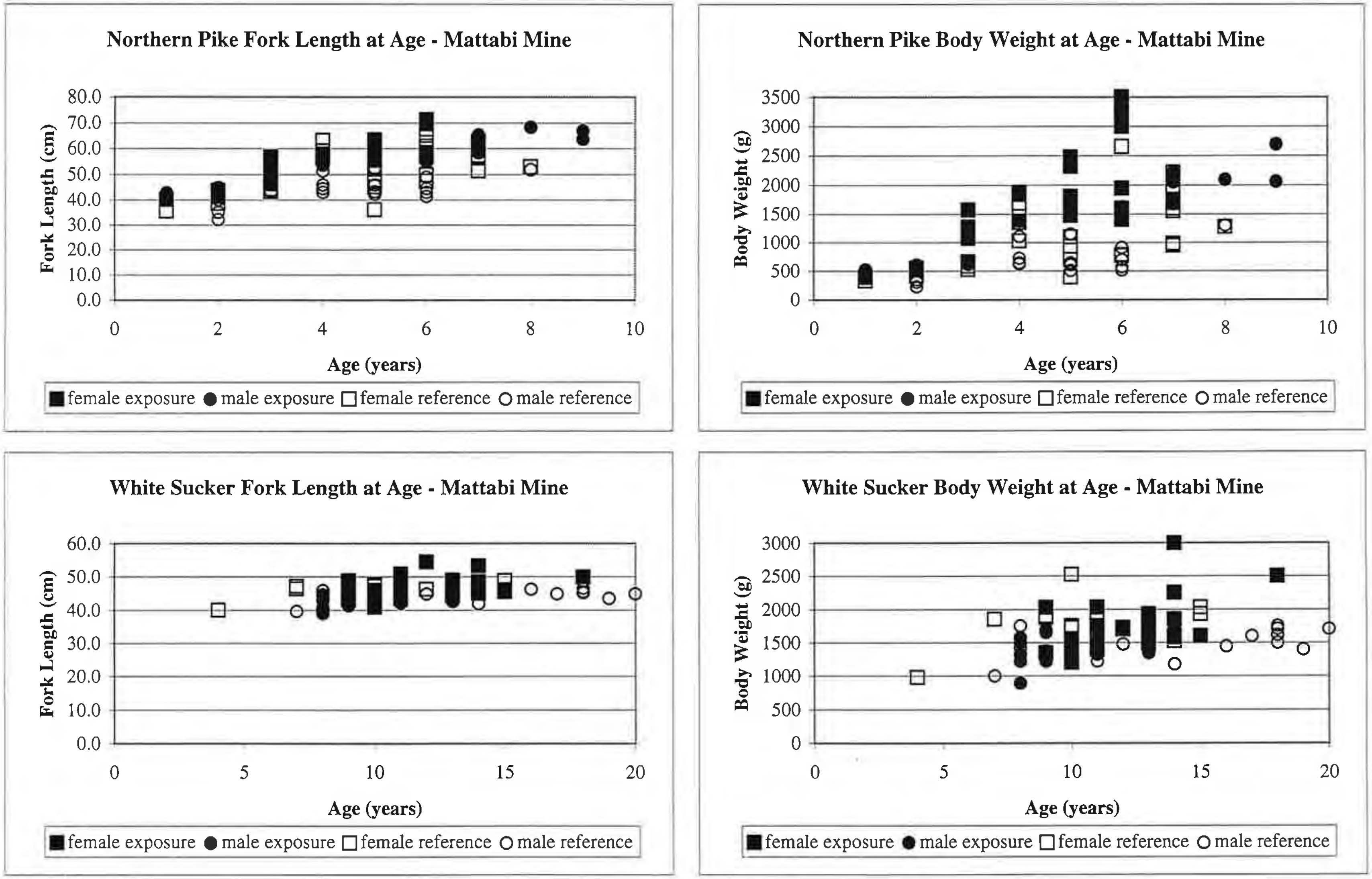


Figure 4.9: Fork Length at Age and Body Weight at Age of Northern Pike and White Sucker Collected at Mattabi Mine, October 1997.

Table 4.9: Summary of Biological Characteristics of Northern Pike and White Sucker, Mattabi Mine (values are mean ± 1 S.E.).

Biological Measurement	Reference Areas				Exposure Areas			
	Northern Pike		White Sucker		Northern Pike		White Sucker	
	Females	Males	Females	Males	Females	Males	Females	Males
Sample Size	29	21	21	21	20	16	21	21
Mean Age (yrs)	5 ± 0.3	4 ± 0.4	10 ± 0.6	14 ± 1.0	4 ± 0.4	5 ± 0.7	12 ± 0.5	10 ± 0.4
Mean Fork Length (cm)	53.6 ± 1.59	44.1 ± 1.24	45.9 ± 0.419	44.2 ± 0.448	57.0 ± 1.96	55.7 ± 2.62	46.0 ± 1.15	43.2 ± 0.479
Mean Total Length (cm)	57.3 ± 1.66	47.2 ± 1.31	50.4 ± 0.348	48.1 ± 0.482	60.7 ± 2.07	59.5 ± 2.80	50.0 ± 1.25	46.8 ± 0.536
Mean Weight (g)	1329 ± 130	693.3 ± 65.9	1707 ± 66.5	1480 ± 43.4	1723 ± 197	1535 ± 181	1714 ± 115	1412 ± 45.5
Mean Gonad Weight (g)	22.5 ± 2.86	7.69 ± 1.31	105 ± 6.89	65.8 ± 3.02	42.3 ± 5.12	16.9 ± 2.05	92.0 ± 8.46	54.7 ± 2.21
Mean Liver Weight (g)	14.6 ± 1.64	6.27 ± 0.789	28.3 ± 1.14	17.3 ± 0.849	21.6 ± 2.25	12.7 ± 1.55	27.6 ± 2.26	18.8 ± 0.707
Mean Fecundity (eggs/female	8998 ± 945	not applicable	19866 ± 1199	not applicable	14276 ± 1496	not applicable	20476 ± 1679	not applicable

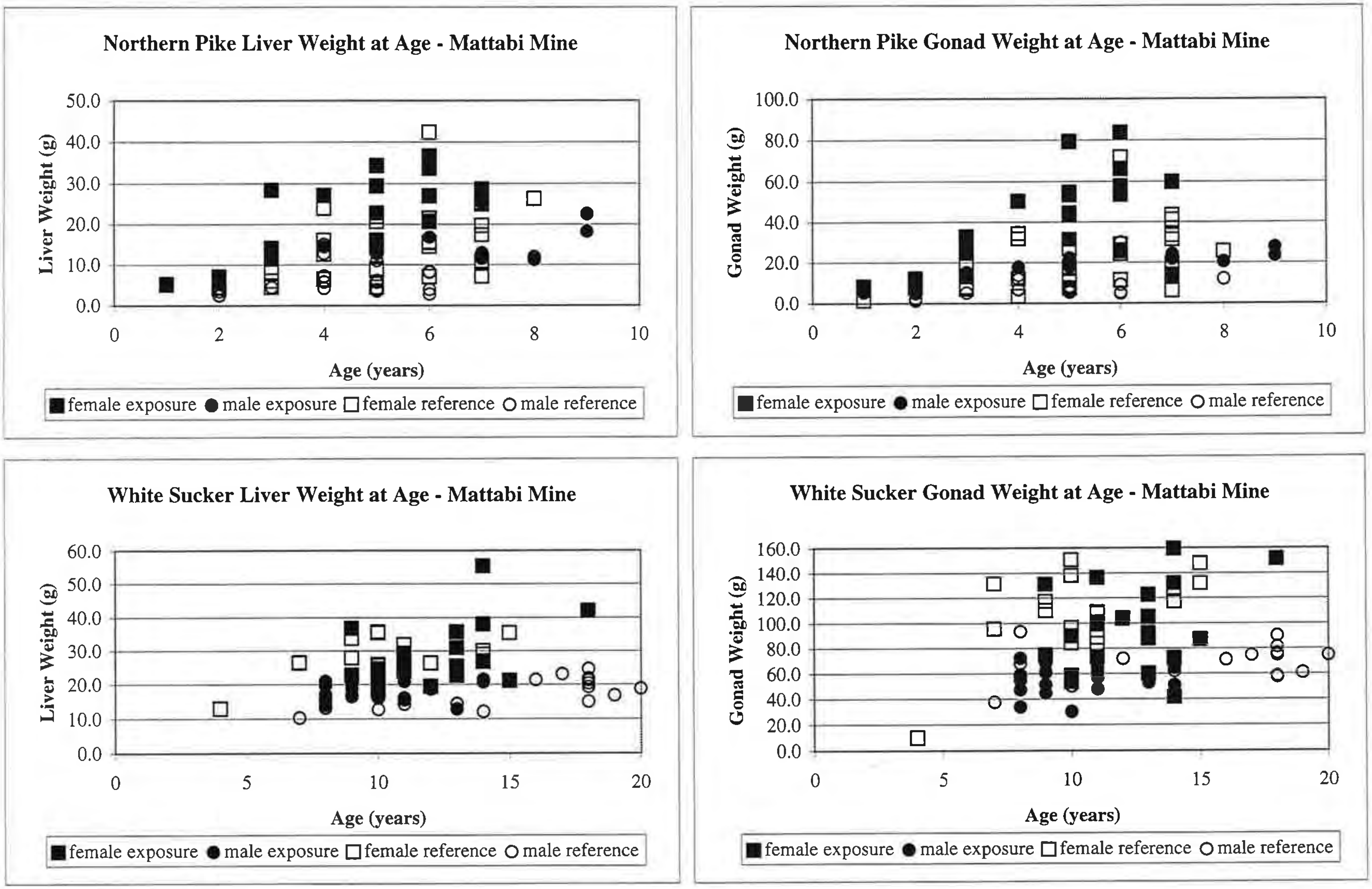


Figure 4.10: Liver Weight at Age and Gonad Weight at Age of Northern Pike and White Sucker Collected at Mattabi Mine, October 1997.

Table 4.10: Summary of Tissue Metallothionein and Selected Metal Concentrations, µg/g fresh weight, Mattabi Mine (values are mean ± 1 S.E.).

Component	Reference Areas							
	Northern Pike				White Sucker			
	Liver	Kidney	Gill	Muscle	Liver	Kidney	Gill	Muscle
Metallothionein	290 ± 34.7	99.1 ± 6.52	2.54 ± 0.256	not applicable	409 ± 59.9	105 ± 8.29	34.3 ± 2.47	not applicable
Cadmium	0.088 ± 0.015	0.269 ± 0.041	0.007 ± 0.0003	0.0195 ± 0.0004	0.266 ± 0.027	1.78 ± 0.231	0.0142 ± 0.0016	0.020 ± 0.0004
Cobalt	0.036 ± 0.004	0.126 ± 0.009	0.0121 ± 0.0014	0.005 ± 2.12E-11	0.028 ± 0.0016	0.177 ± 0.023	0.0352 ± 0.0031	0.005 ± 2.12E-11
Copper	11.9 ± 1.78	1.02 ± 0.026	0.686 ± 0.033	0.270 ± 0.016	13.7 ± 2.23	1.59 ± 0.074	0.779 ± 0.030	0.401 ± 0.027
Lead	0.232 ± 0.008	0.286 ± 0.009	0.041 ± 0.013	0.005 ± 2.12E-11	0.234 ± 0.007	0.292 ± 0.012	0.0258 ± 0.0035	0.005 ± 2.12E-11
Mercury	1.25 ± 0.301	0.482 ± 0.064	0.143 ± 0.028	0.590 ± 0.053	0.142 ± 0.016	0.119 ± 0.016	0.0278 ± 0.0023	0.300 ± 0.023
Selenium	1.14 ± 0.059	1.04 ± 0.048	0.126 ± 0.022	0.160 ± 0.006	0.742 ± 0.034	0.788 ± 0.037	0.076 ± 0.004	0.207 ± 0.0116
Zinc	31.7 ± 1.83	114 ± 6.06	59.4 ± 12.0	3.36 ± 0.107	27.2 ± 1.21	19.5 ± 0.567	11.8 ± 0.195	2.74 ± 0.100

Component	Exposure Areas							
	Northern Pike				White Sucker			
	Liver	Kidney	Gill	Muscle	Liver	Kidney	Gill	Muscle
Metallothionein	274 ± 38.5	148 ± 11.7	3.96 ± 0.57	not applicable	386 ± 51.1	97.8 ± 5.23	23.4 ± 1.98	not applicable
Cadmium	0.093 ± 0.0237	0.208 ± 0.017	0.093 ± 0.0013	0.0216 ± 0.0004	0.159 ± 0.0126	1.20 ± 0.148	0.0075 ± 0.0002	0.019 ± 0.0011
Cobalt	0.044 ± 0.005	0.203 ± 0.021	0.044 ± 0.009	0.005 ± 2.27E-11	0.0284 ± 0.0028	0.136 ± 0.0102	0.042 ± 0.0042	0.005 ± 2.27E-11
Copper	11.2 ± 1.79	1.10 ± 0.122	11.2 ± 0.108	0.265 ± 0.014	13.8 ± 1.93	1.71 ± 0.0376	0.827 ± 0.0405	0.349 ± 0.017
Lead	0.241 ± 0.0100	0.365 ± 0.019	0.241 ± 0.051	0.005 ± 2.27E-11	0.274 ± 0.0123	0.327 ± 0.010	0.101 ± 0.014	0.005 ± 2.27E-11
Mercury	0.303 ± 0.149	0.0728 ± 0.020	0.303 ± 0.016	0.163 ± 0.040	0.0156 ± 0.0021	0.0184 ± 0.003	0.0148 ± 0.0026	0.059 ± 0.0094
Selenium	3.80 ± 0.213	3.48 ± 0.353	3.80 ± 0.099	1.87 ± 0.157	2.79 ± 0.147	2.99 ± 0.180	0.334 ± 0.016	1.46 ± 0.119
Zinc	27.3 ± 1.78	118 ± 11.5	27.3 ± 11.3	4.11 ± 0.139	26.3 ± 1.65	21.1 ± 0.765	13.7 ± 0.268	2.93 ± 0.123

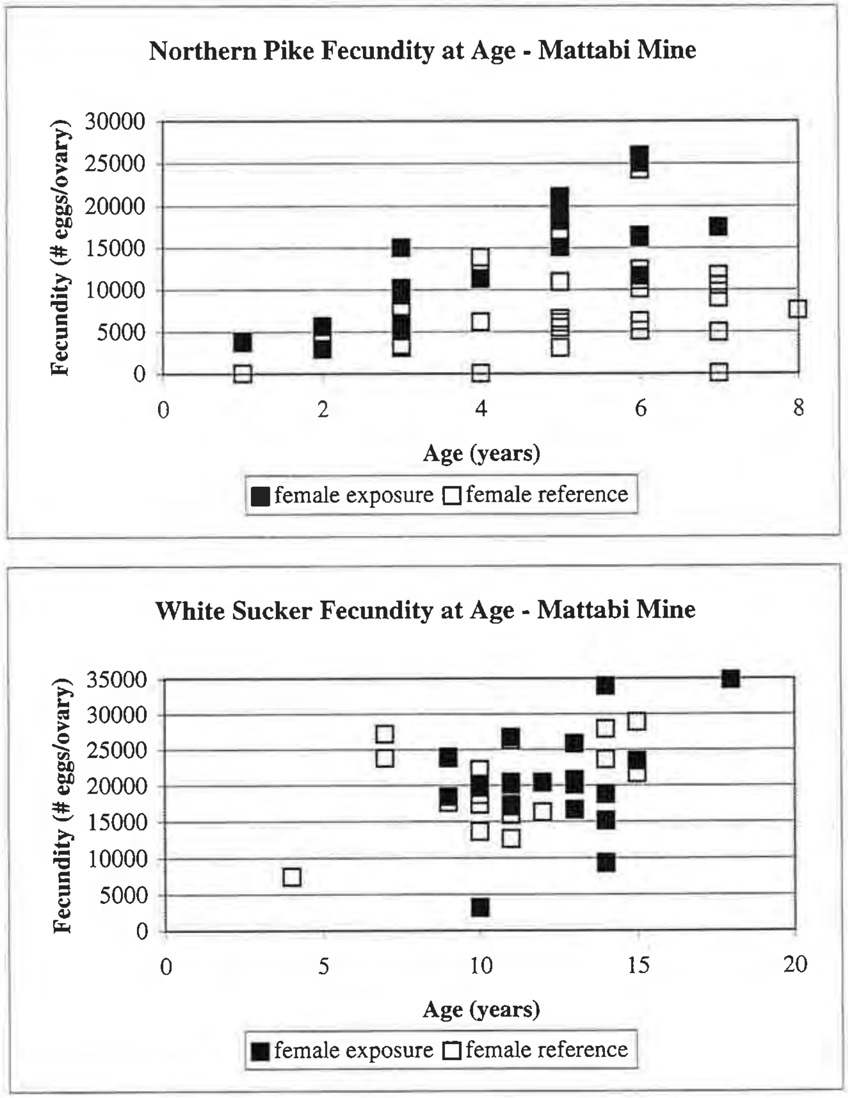


Figure 4.11: Fecundity at Age of Northern Pike and White Sucker Collected at Mattabi Mine, October 1997.

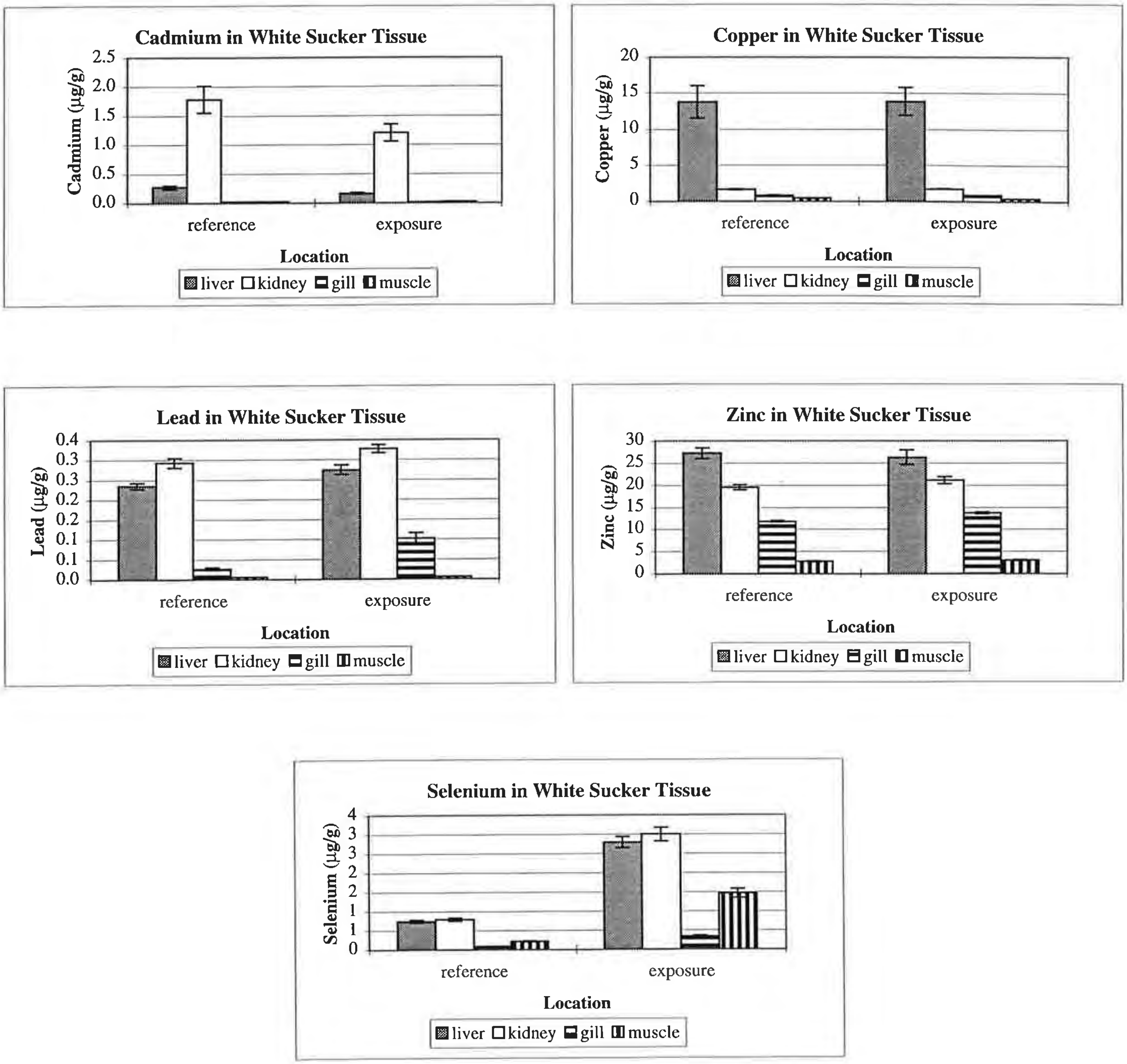


Figure 4.12: Mean Concentration of Cadmium, Copper, Lead, Zinc and Selenium in White Sucker Tissue, Mattabi Mine, October 1997
Area means (± 1 S.E.).

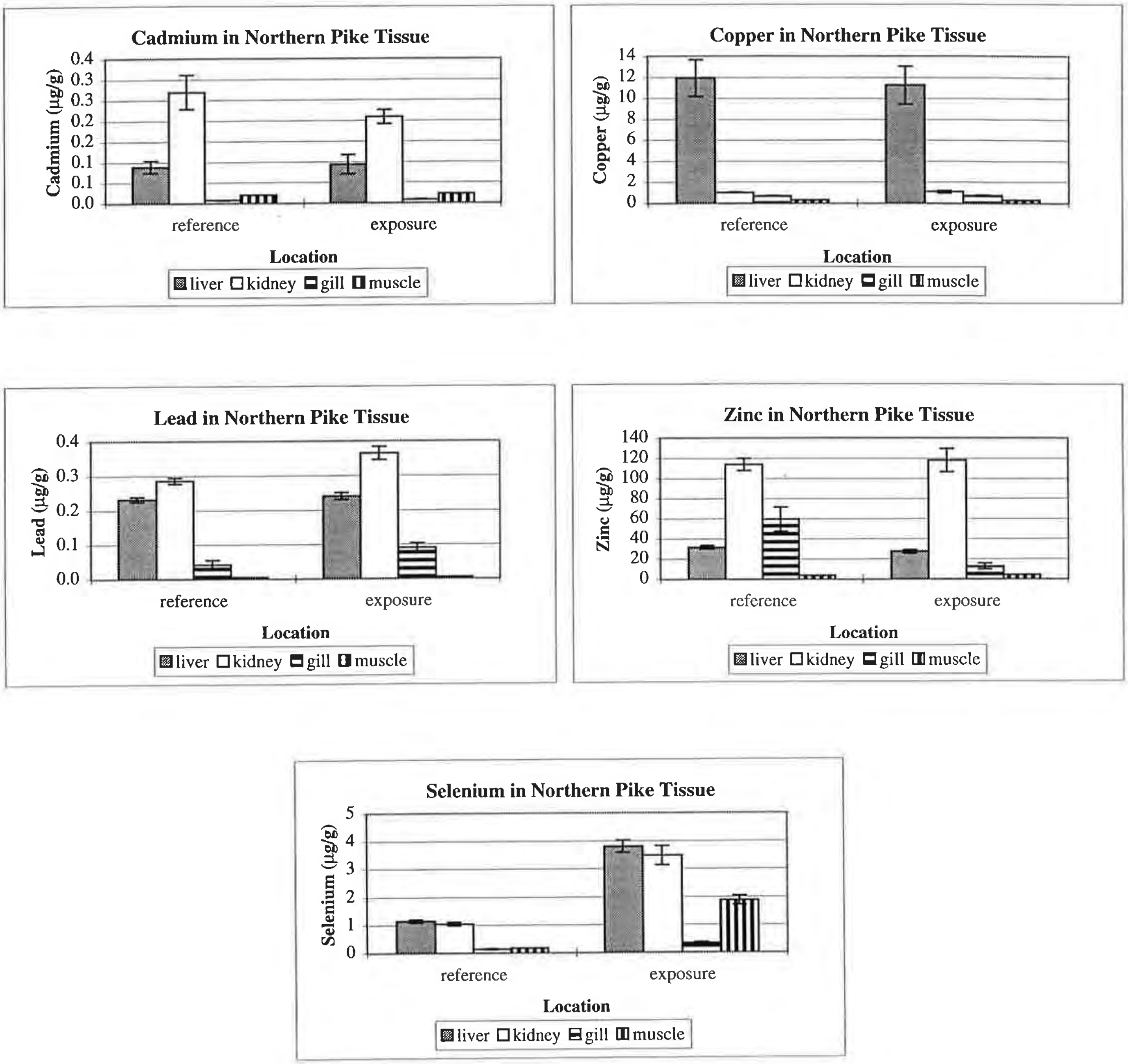


Figure 4.13: Mean Concentration of Cadmium, Copper, Lead, Zinc and Selenium in Northern Pike Tissue, Mattabi Mine, October 1997
Area means (± 1 S.E.).

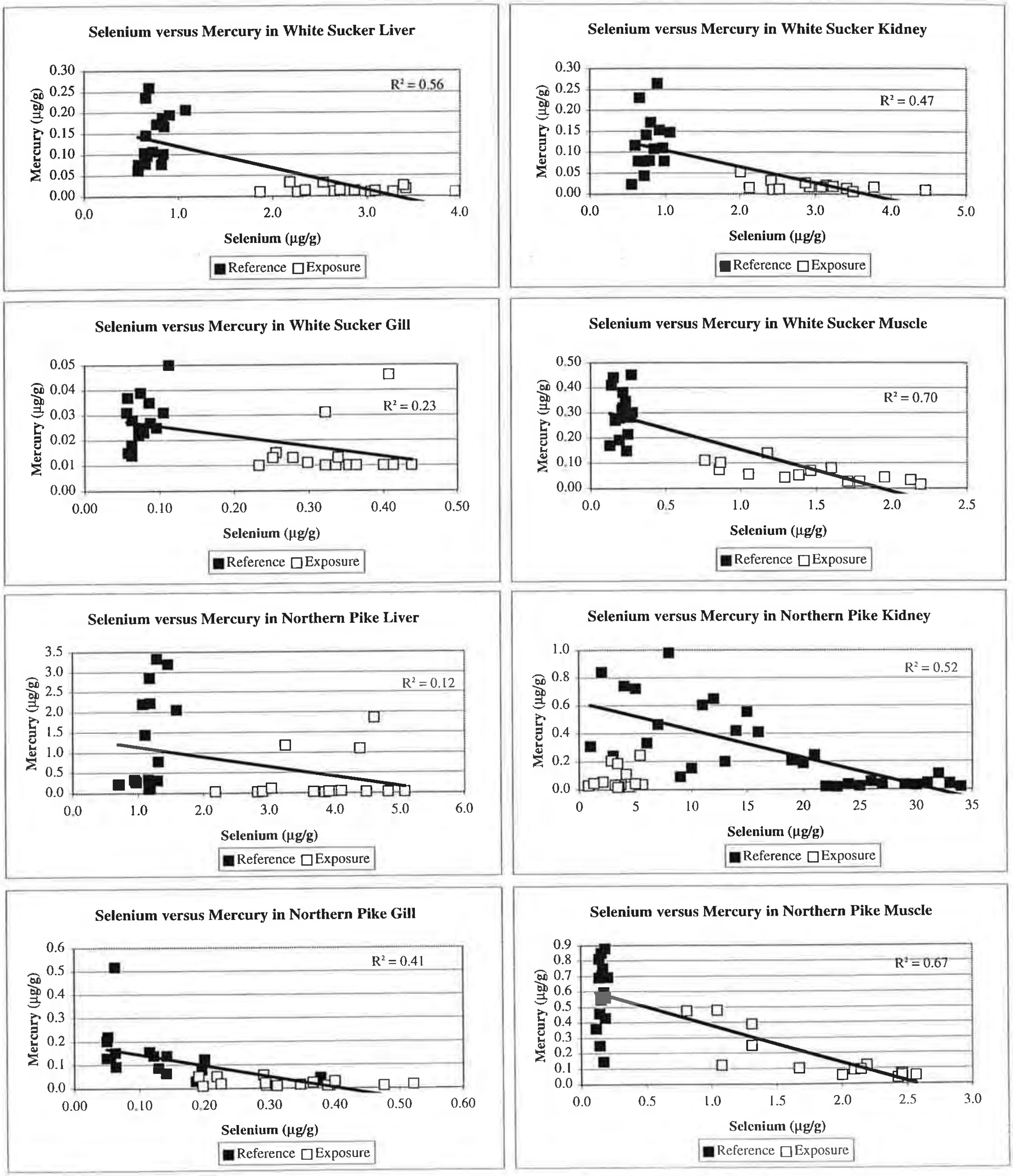
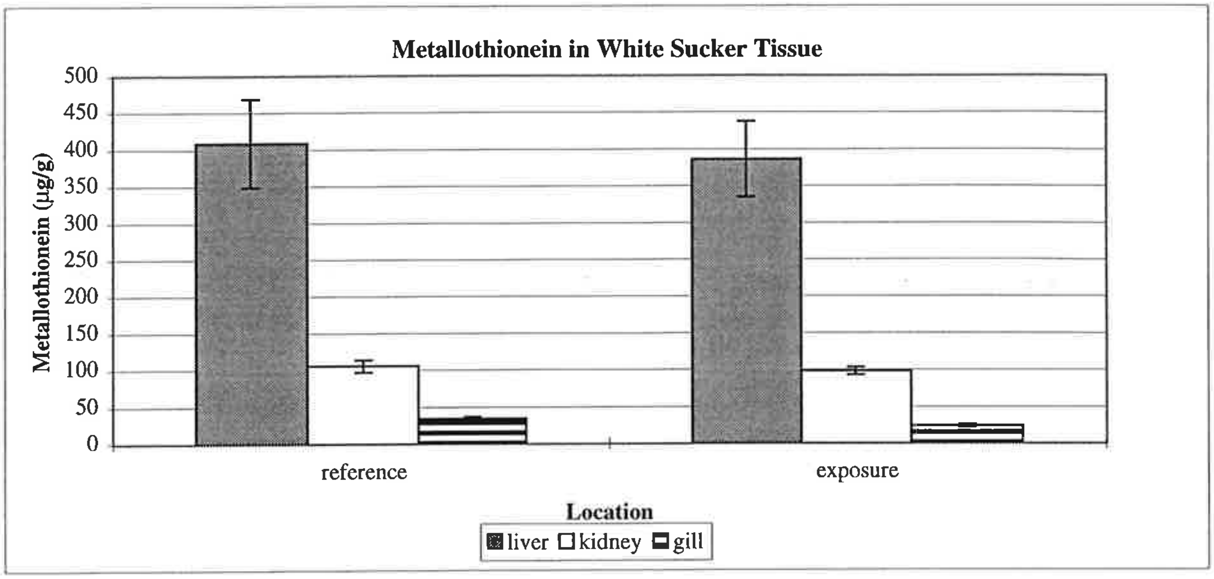


Figure 4.14: Concentration of Selenium versus Mercury in White Sucker and Northern Pike Tissue, Mattabi Mine, October 1997.



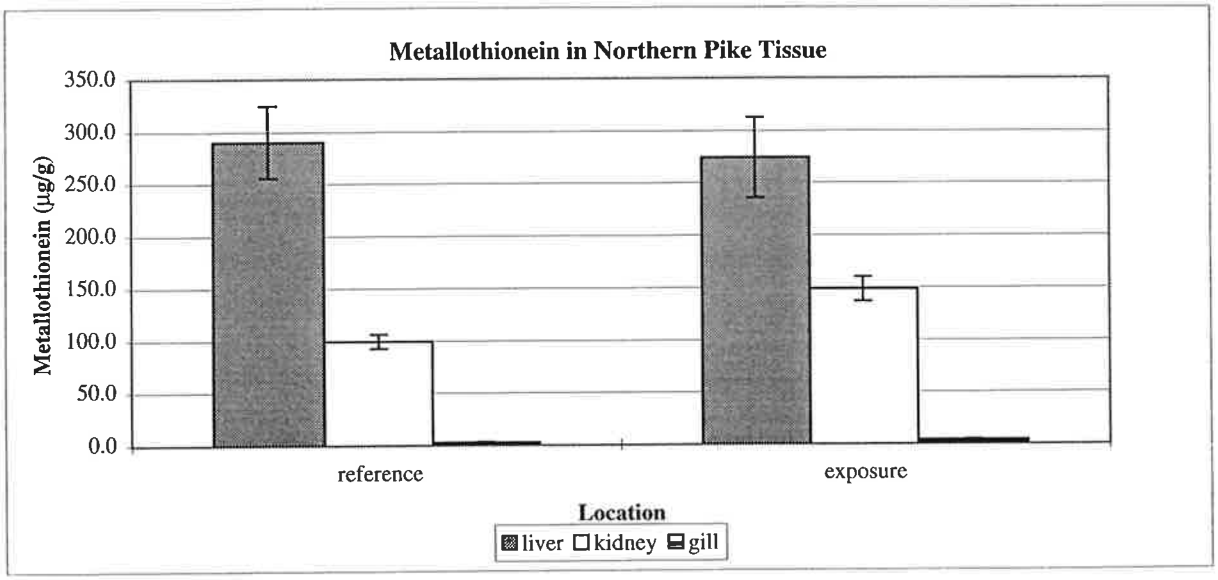


Figure 4.15: Mean Concentration of Metallothionein in White Sucker and Northern Pike Tissue, Mattabi Mine, October 1997
Area means (± 1 S.E.).

Recent studies have shown an ameliorative effect of tissue selenium concentrations on the bioaccumulation of mercury (Jack Klaverkamp, Freshwater Institute, pers. comm.). That is, selenium may inhibit the accumulation of mercury in fish tissues (Turner and Swick, 1983). In order to explore this relationship with the Mattabi data, plots of mercury against selenium were done for each tissue type from each species (Figure 4.14). This relationship appears to apply to muscle tissue in both white sucker and northern pike and less so in the other tissues, although the relationship was evident in white sucker liver and northern pike kidney.

As illustrated in Figure 4.15, tissue MT concentrations showed no obvious substantial reference-exposure difference for any tissue in either species. Concentrations of MT were highest in liver and lowest in gill in both species.

Correlation analysis of metals in tissues versus metallothionein in tissues indicates some apparent relationships (Tables 4.11a and 4.11b). The strongest relationship occurs between copper and MT in pike liver, although the molar sum of Cd, Cu and Zn and MT in northern pike liver also shows a strong relationship. The occurrence of significant relationships within tissues, for reference and exposure areas combined, coupled with an apparent lack of area differences in most tissue metals and MT in fish (Figures 4.13 and 4.15), implies a cause-effect linkage between metals and MT but that the tissue responses were unrelated to a mine effect. All significant correlations for liver are positive in both species, whereas significant correlations for gill and kidney are usually negative. Many of the significant correlations, other than those noted above for pike liver, may be spurious.

Table 4.11a: Correlation Matrix for Tissue Metal and Metallothionein Concentration at Mattabi Mines

White Sucker

	MT			Probabilities (1-tailed test)			
	Gill	Kidney	Liver	Gill	Kidney	Liver	N
CdCuZn_Gill	-0.2647			0.0787			30
CdCuZn_Kidney		-0.2245			0.1165		30
CdCuZn_Liver			0.4532			0.0052	31
Aluminum_Gill	-0.1070			0.2833			31
Aluminum_Kidney		0.0510			0.3945		30
Aluminum_Liver			-0.0789			0.3366	31
Arsenic_Gill	-0.0116			0.4754			31
Arsenic_Kidney		0.1097			0.2819		30
Arsenic_Liver			0.5341			0.0010	31
Chromium_Gill	-0.1285			0.2454			31
Chromium_Kidney		0.1238			0.2573		30
Chromium_Liver			0.0368			0.4221	31
Nickel_Gill	0.0041			0.4913			31
Nickel_Kidney		-0.1474			0.2186		30
Nickel_Liver			0.0273			0.4420	31
Lead_Gill	-0.4581			0.0048			31
Lead_Kidney		-0.0040			0.4916		30
Lead_Liver			0.0471			0.4006	31
Selenium_Gill	-0.6122			0.0001			31
Selenium_Kidney		-0.1027			0.2946		30
Selenium_Liver			0.0571			0.3801	31
Zinc_Gill	-0.2707			0.0704			31
Zinc_Kidney		-0.3427			0.0319		30
Zinc_Liver			0.4905			0.0025	31

▨ significant correlation with $\alpha = 0.05$

Note: all tissue metal concentrations are log transformed

CdCuZn = Σ Cd, Cu and Zn in μmol/gram fresh weight

Table 4.11b: Correlation Matrix for Tissue Metal and Metallothionein Concentration at Mattabi Mines

Northern Pike

	MT			Probabilities (1-tailed test)			
	Gill	Kidney	Liver	Gill	Kidney	Liver	N
CdCuZn_Gill	-0.4094			0.0123			30
CdCuZn_Kidney		-0.2052			0.1341		31
CdCuZn_Liver			0.8028			2.76E-08	31
Aluminum_Gill	0.2815			0.0625			31
Aluminum_Kidney		-0.5593			0.0005		31
Aluminum_Liver			0.3778			0.0181	31
Arsenic_Kidney		-0.3487			0.0474		24
Arsenic_Liver			-0.0241			0.4487	31
Cadmium_Gill	0.2616			0.0776			31
Cadmium_Kidney		-0.4168			0.0098		31
Cadmium_Liver			0.4956			0.0023	31
Chromium_Gill	0.0529			0.3888			31
Chromium_Kidney		-0.1682			0.1829		31
Chromium_Liver			0.2641			0.0756	31
Copper_Gill	-0.1410			0.2247			31
Copper_Kidney		0.1358			0.2333		31
Copper_Liver			0.9060			5.43E-11	31
Iron_Gill	0.3624			0.0226			31
Iron_Kidney		-0.1864			0.1577		31
Iron_Liver			0.3988			0.0131	31
Mercury_Gill	-0.3444			0.0289			31
Mercury_Kidney		-0.4242			0.0087		31
Mercury_Liver			0.4454			0.0060	31
Nickel_Gill	-0.1674			0.1840			31
Nickel_Kidney		-0.1797			0.1667		31
Nickel_Liver			0.2085			0.1302	31
Lead_Gill	-0.0167			0.4645			31
Lead_Kidney		0.4533			0.0052		31
Lead_Liver			0.0929			0.3096	31
Selenium_Gill	0.2522			0.0855			31
Selenium_Kidney		0.2460			0.1233		24
Selenium_Liver			-0.0043			0.4909	31
Zinc_Gill	-0.3690			0.0205			31
Zinc_Kidney		-0.2052			0.1341		31
Zinc_Liver			0.5581			0.0006	31

▨ significant correlation with $\alpha = 0.05$

Note: all tissue metal concentrations are log transformed

CdCuZn = Σ Cd, Cu and Zn in μmol/gram fresh weight

5.0 HYPOTHESIS TESTING

5.1 Methods

The 12 hypotheses tested at Mattabi are listed in Table 5.1, along with a more specific listing of the "effect" (response) and "exposure" (predictor) variables to be examined under each hypothesis. The general reasoning behind all of these hypotheses is that a mine "effect" is a measurable difference between reference and exposure locations, and/or a trend between locations that are exposed to different degrees of contamination. The hypotheses address either the ability of a particular monitoring tool to detect such an effect (and, in aggregate, whether an effect exists), or the **relative** ability of two different monitoring tools, that are being compared to one another, to detect such an effect. H5 through H8 are of the first type, whereas H1 through H4 are of the second type. H9 through H12 address the **relative** ability of two monitoring tools to detect a correlation between specific predictor and response variables.

These different types of hypotheses require different methods of statistical analysis. The following subsections describe the statistical approach in each category. In all cases, appropriate data transformations were applied prior to statistical analysis, such as log transformation for chemical concentrations or other parameters that span a wide range, and arcsine square root transformations for percent response variables. A significance criterion was used for all the statistical analyses, and use of the term 'significant" implies that this criterion was met.

It should be recognized that the term "predictor" variable is not intended to mean that the measure of exposure used (e.g., metal concentration in water) can be used to "predict" a specific biological response at all mine sites or in other surveys at this mine site. Nor does it imply that the predictor is necessarily the cause of a biological effect. Rather, the predictive ability is only suggested by correlation between effect and exposure measures.

5.1.1 H1 - Comparison of Sediment Toxicity Tests

Hypothesis H1 addresses the **relative** ability of three sediment toxicity test tools (response measures) to detect a mine effect. In particular, the *Hyalella azteca*, *Chironomus riparius* and *Tubifex tubifex* tests were compared to determine whether these tools differ in their ability to detect a mine effect (i.e., a reference versus exposure area difference, or a trend

TABLE 5.1 VARIABLES AND HYPOTHESES AT MATTABI

Hypothesis	Y variables	X variables	Test (Ho)	Comment
H1	Sediment Toxicity Response i Sediment Toxicity Response j	Lake Area Identifier	no trend or area x tool interaction by ANOVA	*Hyalella, Chironomus* and *Tubifex* tests are the monitoring tools of interest.
H2	Metal i in Tissue i Metal i in Tissue j	Creek Identifier	no R/E tool interaction	Tissues for white sucker and northern pike done separately by sex, as required.
H3	MT in Tissue i MT in Tissue j	Creek Identifier	no R/E tool interaction	Tissues for white sucker and northern pike done separately by sex, as required.
H4	Metal i in Tissue j MT in Tissue j	Creek Identifier	no R/E tool interaction	Tissues for white sucker and northern pike done separately by sex, as required.
H5	CPUE for sucker, pike and all fish	Creek Identifier	no R/E difference by ANOVA	CPUE by species and for all fish in Bell Creek and reference creek using gill net.
H6	BPUE, No. of Fish Taxa	Creek Identifier	no R/E difference by ANOVA	CPUE by species and for all fish in Bell Creek and reference creek using gill net.
H6 (benthos)	No. of Taxa Benthic Density Indicator Taxa	Area Number in Order of Decreasing Sediment Metal Concentration	no trend or R/E difference by ANOVA	Collections at 3 stations per area, 5 exposure areas and 2 reference areas.
H7	Length at age Weight at age Weight at length	Creek Identifier	no R/E difference by ANOVA	Analysis done separately for males and females (pike and sucker). Used age as a covariate as appropriate.
H8	Liver weight, gonad weight by sex, at age. Fecundity at age (females).	Creek Identifier	no R/E difference by ANOVA	Mature white sucker and northern pike.
H9*	No. of Fish Taxa Length and Weight at age Gonad and Liver wt at age and weight Fecundity	Dissolved Metal in Water (Tool 1) Total Metal in Water (Tool 2)	same correlation	Water quality in Bell Creek reflects mine influence.
H10	Benthic Density No. of Benthic Taxa Indicator Taxa Sediment Toxicity Endpoints	Partial Metal i in Sediment (1) Total Metal i in Sediment (2) SEM/AVS Ratio	same correlation	Use various sediment chemistry results.
H11	Benthic Density No. of Benthic Taxa Indicator Taxa	Sediment Toxicity Results	same correlation	Use various toxicity endpoints (*Hyalella, Chironomus, Tubifex* tests).
H12*	Metal i in Tissue j MT in Tissue j	Metal i in Water (dissolved and total)	same correlations	Tissues for white sucker and northern pike done separately by sex, as required.
Sediment Triad Hypotheses	Benthic PCs Sediment Toxicity Endpoints Sediment Chemistry PCs	Benthic Variables (B) Toxicity Variables (T) Chemistry Variables (C)	no correlation C-B, C-T and B-T	Sphericity test Mantel's test

Definitions:
MT = metallothionein
R/E = reference/exposure
CPUE = catch-per-unit-effort (number of fish caught per unit fishing effort)
BPUE = biomass-per-unit-effort (mass of fish caught per unit fishing effort)

* H9 and H12 are C/I comparisons with reference stations included in the correlations. Results to be interpreted cautiously.

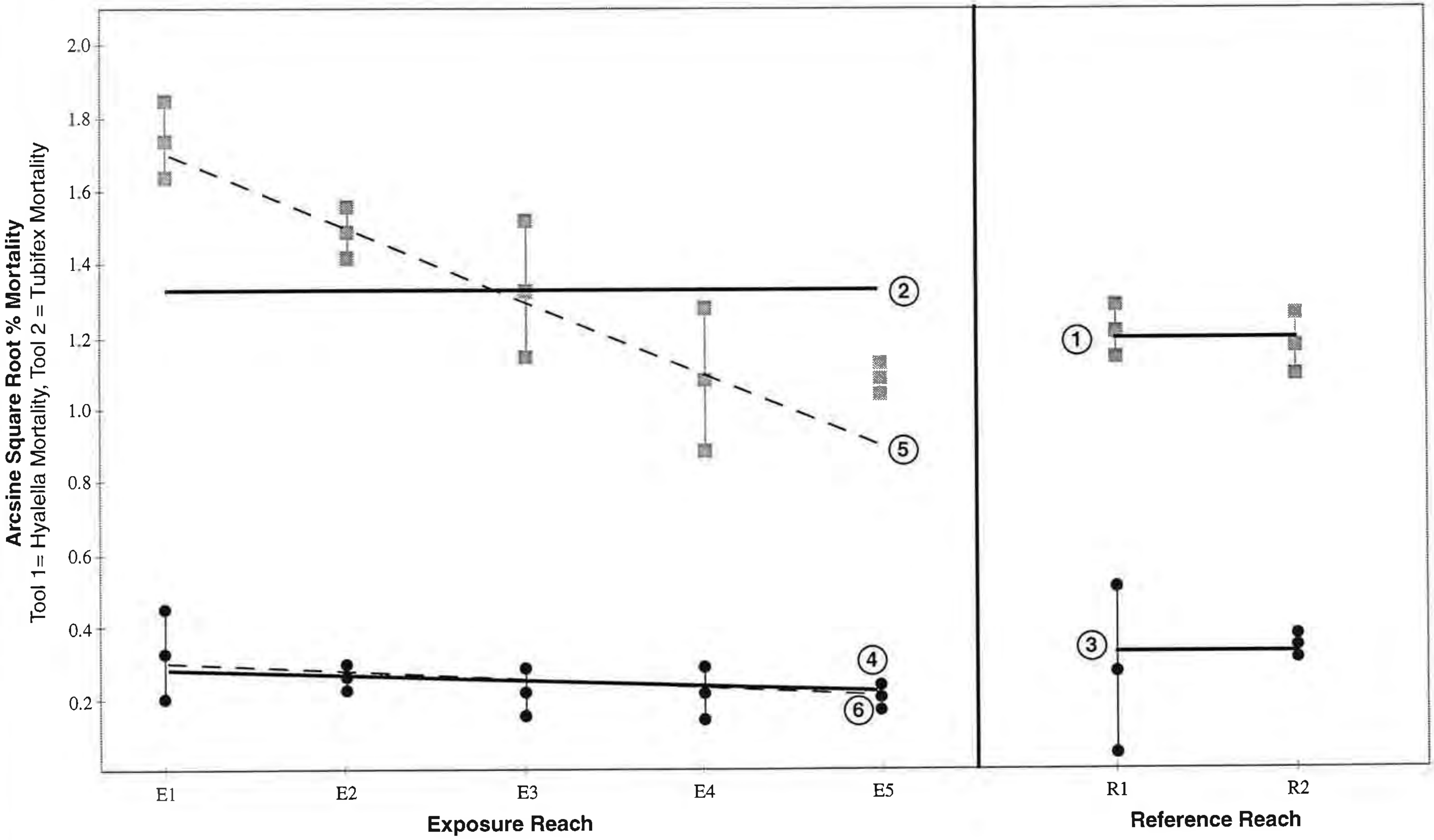
with degree of exposure within the exposure area). An area identifier, ordered within the exposure area to reflect distance from the mine site (i.e., MME1 to MME5), was used as a surrogate for degree of exposure to mine-related contaminants, based on the fact that with increased distance there is an attenuation in contaminant levels. The use of direct measures of exposure in evaluating sediment toxicity test results is included within the context of the overall Sediment Quality Triad hypothesis (Section 2.3.5). Analysis of variance (ANOVA) was used to address this hypothesis, as described below.

Essentially, the ANOVA is used to compare tool effectiveness in two ways:

- by determining if there is a reference area - exposure area difference in mean values for each tool (a larger difference indicates greater effectiveness); and
- by determining if there is a linear trend or gradient in response within the exposure area (a significant trend and greater slope indicates greater effectiveness).

The ANOVA partitions overall variance in the response measure into a number of terms, representing effects of particular interest. These include:

- A "Ref vs Exp x Tool" term which indicates whether the Reference versus Exposure difference is similar for both tools being compared (e.g., for *Hyalella* toxicity and *Tubifex* toxicity). It measures how much the spread between Line 1 and Line 2 differs from the spread between Line 3 and Line 4 in Figure 5.1. Lines 1 to 4 represent the means of the response measures for each tool in the reference or exposure area. This term also indicates how much the Line 1 to Line 3 spread differs from the Line 2 to Line 4 spread, or the degree of difference between the slopes of the two lines shown in Figure 5.2. A larger difference between the reference and exposure means for one tool relative to the other would indicate a greater effectiveness for the tool with the greater difference. For this example, the absolute reference-exposure difference for each tool is small, but the differences are in opposite directions. This produces a significant Ref vs Exp x Tool interaction, which implies that Tool 1 (*Hyalella* growth) is more effective than Tool 2 (*Tubifex* reproduction). The interaction is also illustrated in Figure 5.2.



Legend

▨ tool 1 responses for 3 stations per reach

● tool 2 responses for 3 stations per reach

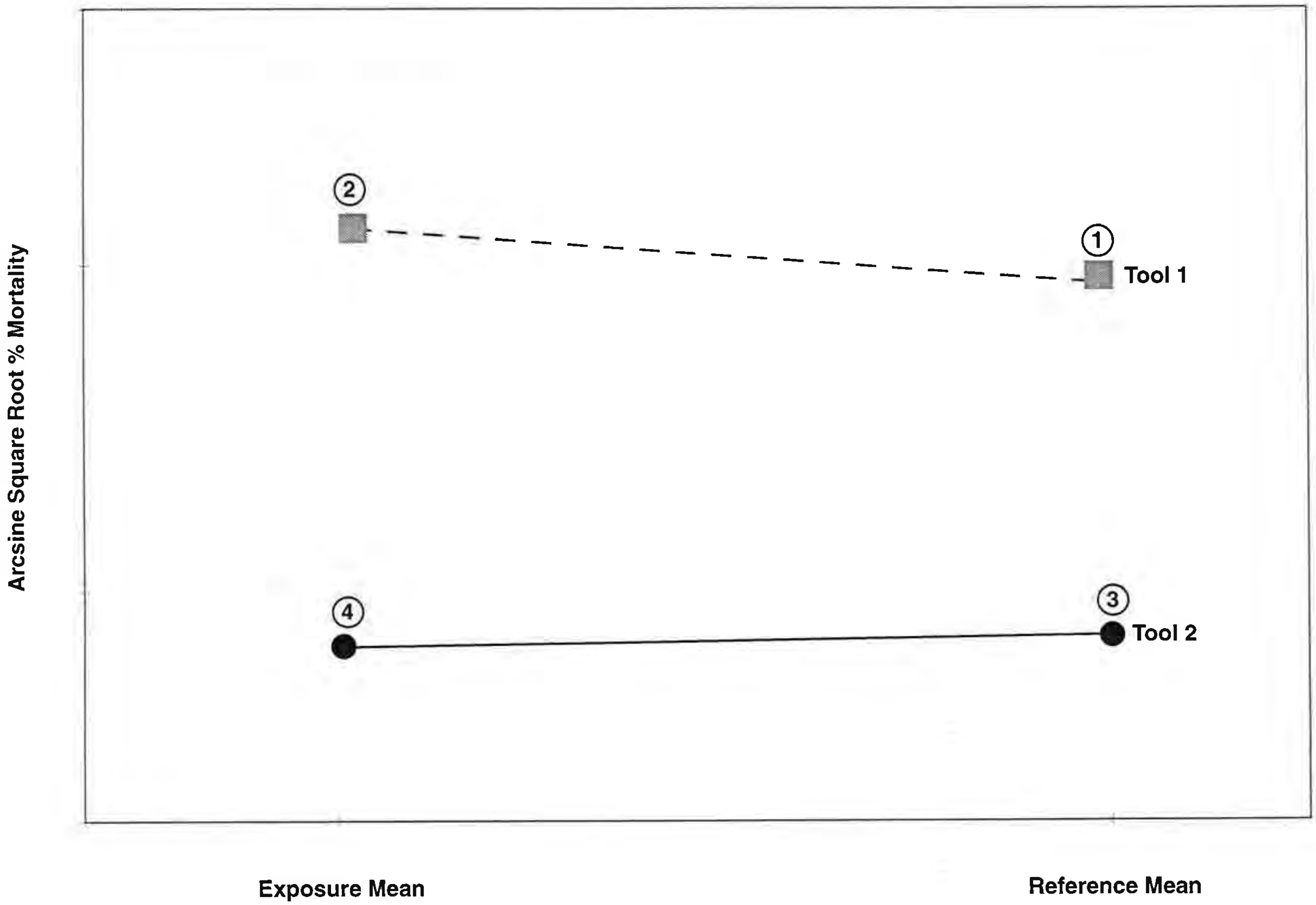
+ mean value of 3 stations per reach

—— reference or exposure mean

– – – – line fit to exposure reach means

Hypothetical Example Approach to Testing H1 Based on Hyalella Mortality and Tubifex Mortality

beak international incorporated	Figure 5.1	May 1998



The Reference versus Exposure by Tool Interaction (based on Fig. 5.1)

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Figure
5.2

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- A "Linear Trend x Tool" term which indicates whether the linear trend in the Exposure area (e.g., from near-field to far-field) is similar for both tools. It measures how much the Line 2 to Line 5 spread differs from the Line 4 to Line 6 spread in Figure 5.1. This term also indicates the degree of difference between the Line 5 and Line 6 slopes. A greater slope in the Line 5 (Tool 1) than in Line 6 (Tool 2) indicates a greater effectiveness of Tool 1 in this example.

In all cases, to test whether the spread described in either of the above two "effect" terms is significant, each is compared to the spread of the exposure means for each reach around Lines 5 and 6 (i.e., to a lack of fit "error" term). If the "effect" variance is large relative to the "error" variance, then the effect is considered to be present, and the tool is concluded to be responsive to mine exposure.

The "lack of fit" spread is compared in turn to the overall "within reach" spread (i.e., between stations in a particular reach), in order to test whether there may be any other (i.e., non-linear) trend among the exposure means, that is whether a straight line can be drawn through response measures for all exposure reaches. If "lack of fit" is significant, the nature of the trend is examined and, if appropriate, the analysis is repeated using a non-linear (second order) trend term instead of a linear trend term. This would appear in Figure 5.1 as curved lines rather than the straight Lines 5 and 6.

The response measures for H1 (*Hyalella* or *Tubifex* toxicity) were standardized prior to statistical analysis, in order to make them equally variable within a reach, since homogeneity of variance is an assumption of the ANOVA procedure. The standardization procedure involves dividing the *Hyalella* growth values by the pooled within-reach standard deviation for *Hyalella* growth, and dividing the *Tubifex* young production values by the pooled within-reach standard deviation for *Tubifex* production of young.

5.1.2 H2 through H4 - Fish Tissue Metals and Metallothionein

These hypotheses also test the relative ability of related exposure tools in fish to detect a mine effect. However, unlike Hypothesis H1, for Hypotheses H2 to H4 there is only a single level of exposure and mine effects are identified only by detection of reference-exposure differences using ANOVA. A test of "trend" is simply by comparison of responses at the reference and exposure areas. A significant interaction between the two tools being compared suggests a greater effectiveness in the tool with the larger difference between exposure area response and reference area response. Figure 5.3 illustrates this approach.

5.1.3 H5 through H8 - Fish Community and Fish Health

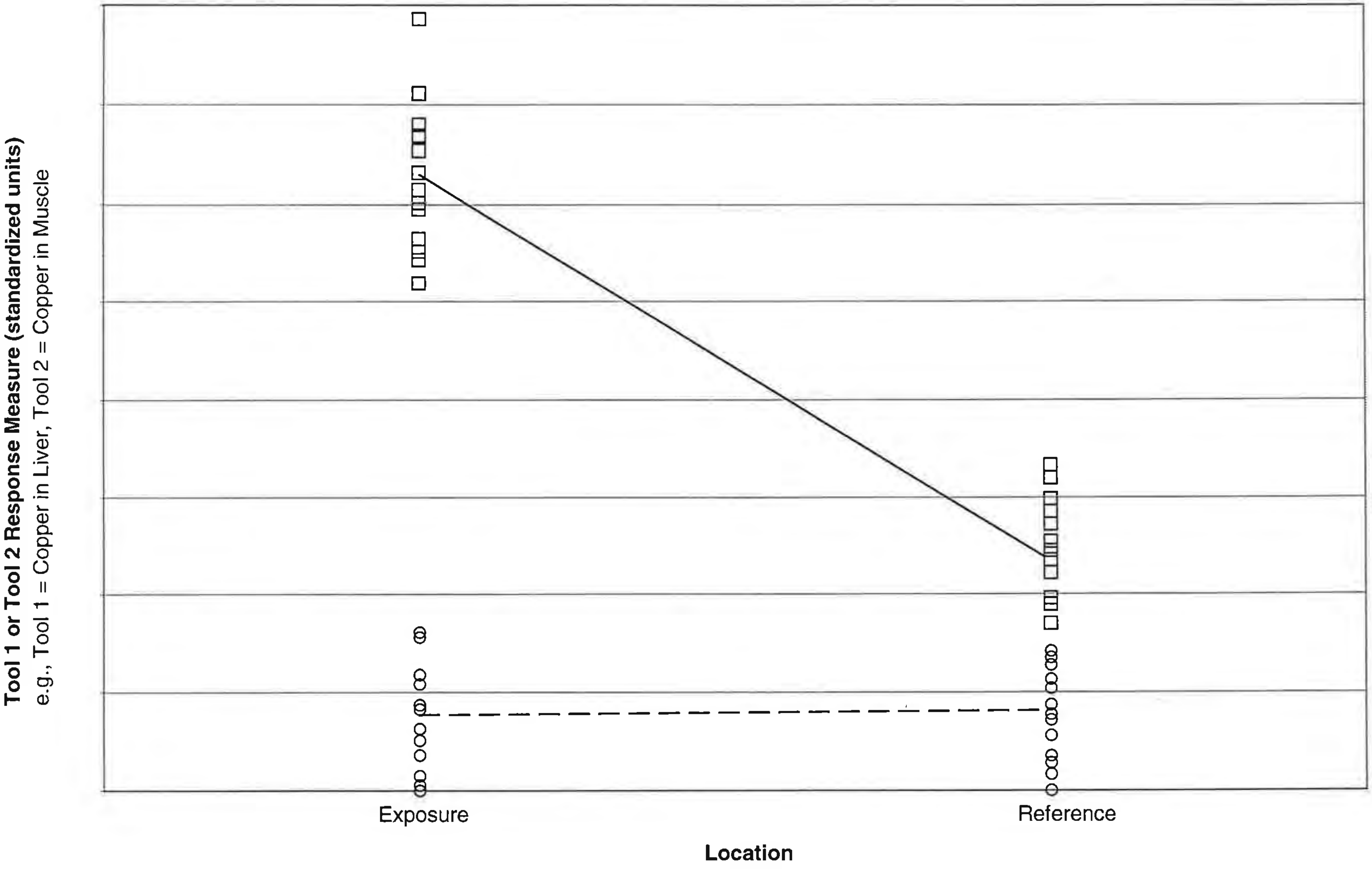
These hypotheses test the ability of individual monitoring tools to detect a mine effect (fish catch-per-unit-effort, fish growth, etc.). To determine if a fish monitoring index can detect a mine effect, a simple ANOVA test is used to determine whether the index varies more between areas than it does within areas. If so, then the pattern of differences between areas is examined to confirm that the response is consistent with a mine effect.

Figure 5.4 illustrates the approach. The patterns on the top graph are consistent with a mine effect (decreased fish catch near the mine). The bottom graph illustrates effects not typically consistent with a deleterious mine effect. However, judgement is always needed in interpretation of response patterns. For example, an increased fish catch near the mine could represent a mine effect if the mine caused nutrient enrichment rather than toxicity.

For both northern pike and sucker, fish growth and organ size were examined at age because the response measures can vary with fish age. Therefore, an age covariate was added to the ANOVA model to adjust all fish to a common age. To address the situation where fish grow at different rates in different areas, the analysis was also carried out with body weight as a covariate (Environment Canada, 1998). In addition, growth and organ size differed by sex for both species. Therefore, all analyses for H7 and H8 were carried out by sex.

5.1.4 H6 - Benthic Community Structure

Hypothesis H6, when considered with respect to the No Name Lake-Mine Creek Bay benthic communities, was tested across reference and exposure areas to assess reference-exposure differences, and within the exposure area for trends within the gradient. An area identifier, ordered within the exposure area to reflect relative position within the sediment quality gradient (E1 = highest metal concentrations, E5 = lowest concentrations), was used as a measure of mine exposure. ANOVA was used to address this hypothesis, as described below.



Legend

⊟——⊟ Copper in Northern Pike Liver (Tool 1)

○– – –○ Copper in Northern Pike Muscle (Tool 2)

Examples of Lake Area x Tool Interaction with Tool 1 Superior (H2)

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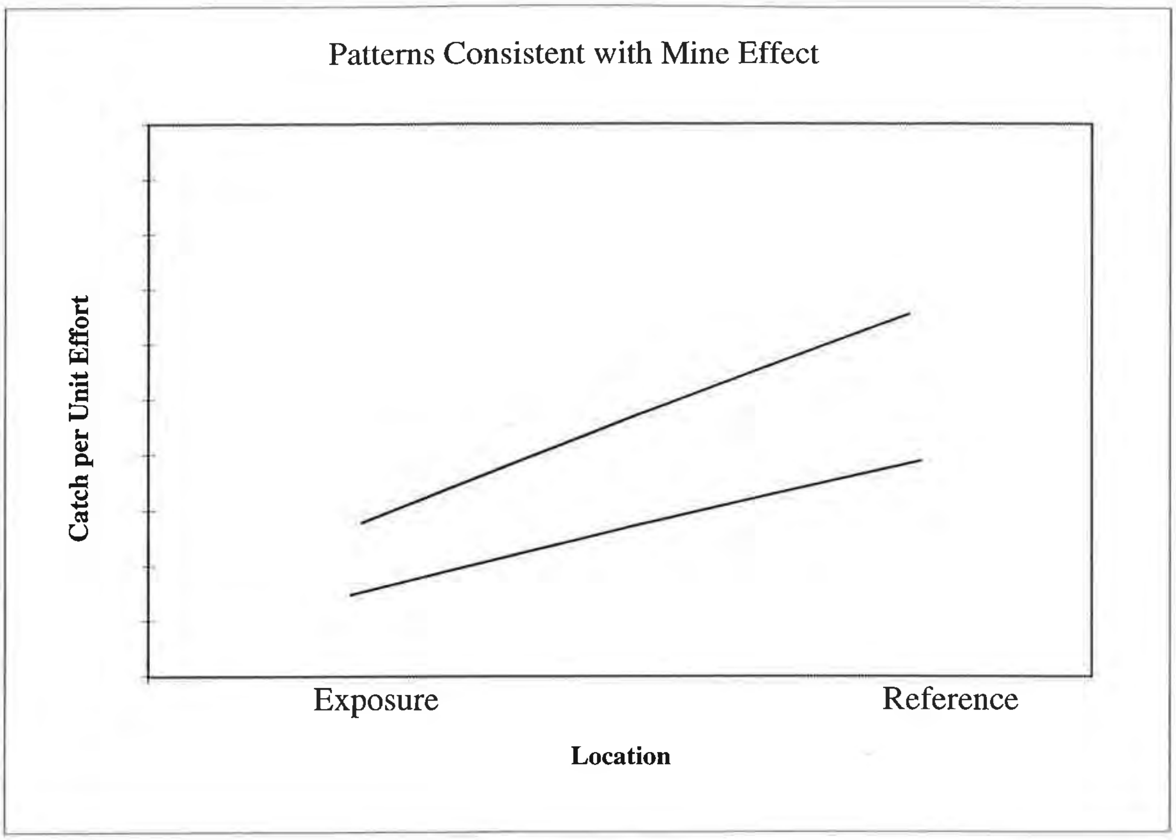
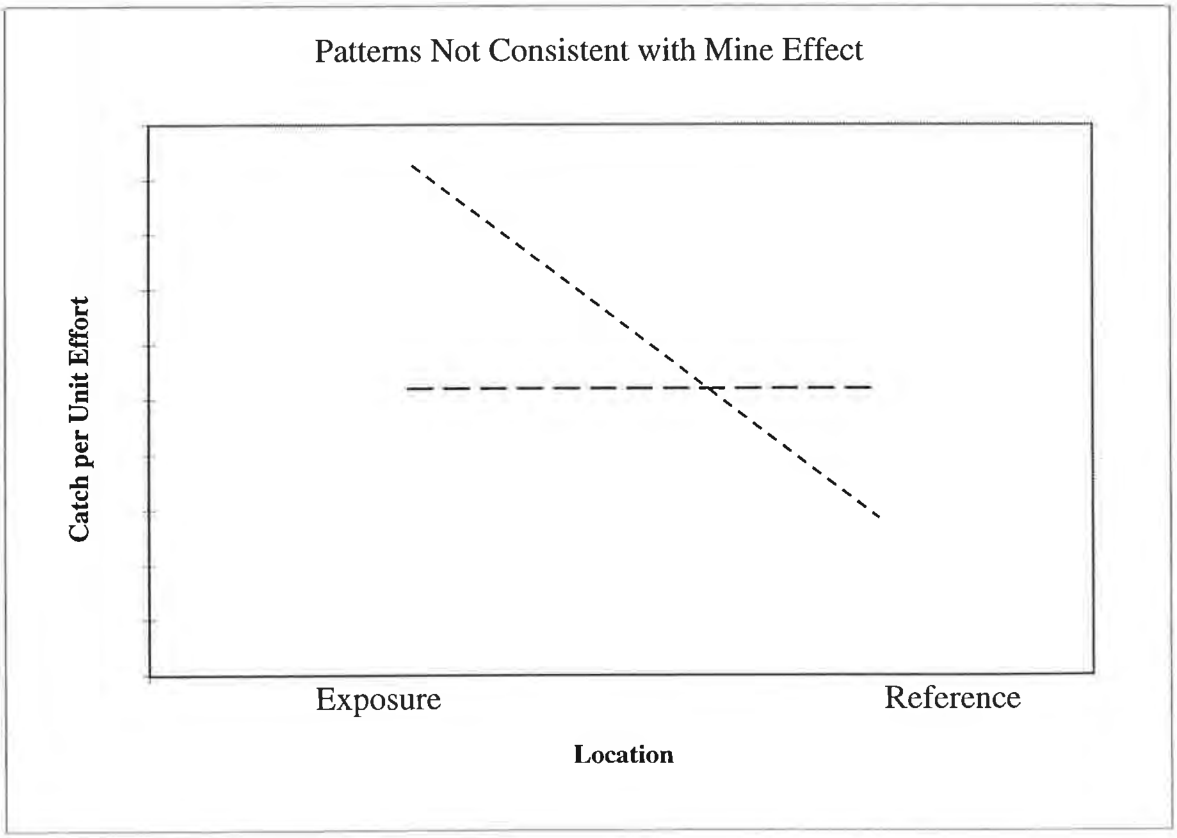


Patterns Consistent with Mine Effect



Patterns Not Consistent with Mine Effect

Legend

——— patterns consistent with mine effect
- - - - - - - patterns not consistent with mine effect
— — — — no pattern (no difference among areas)

Examples of Response Patterns Consistent (or not) with Mine Effects (H5)

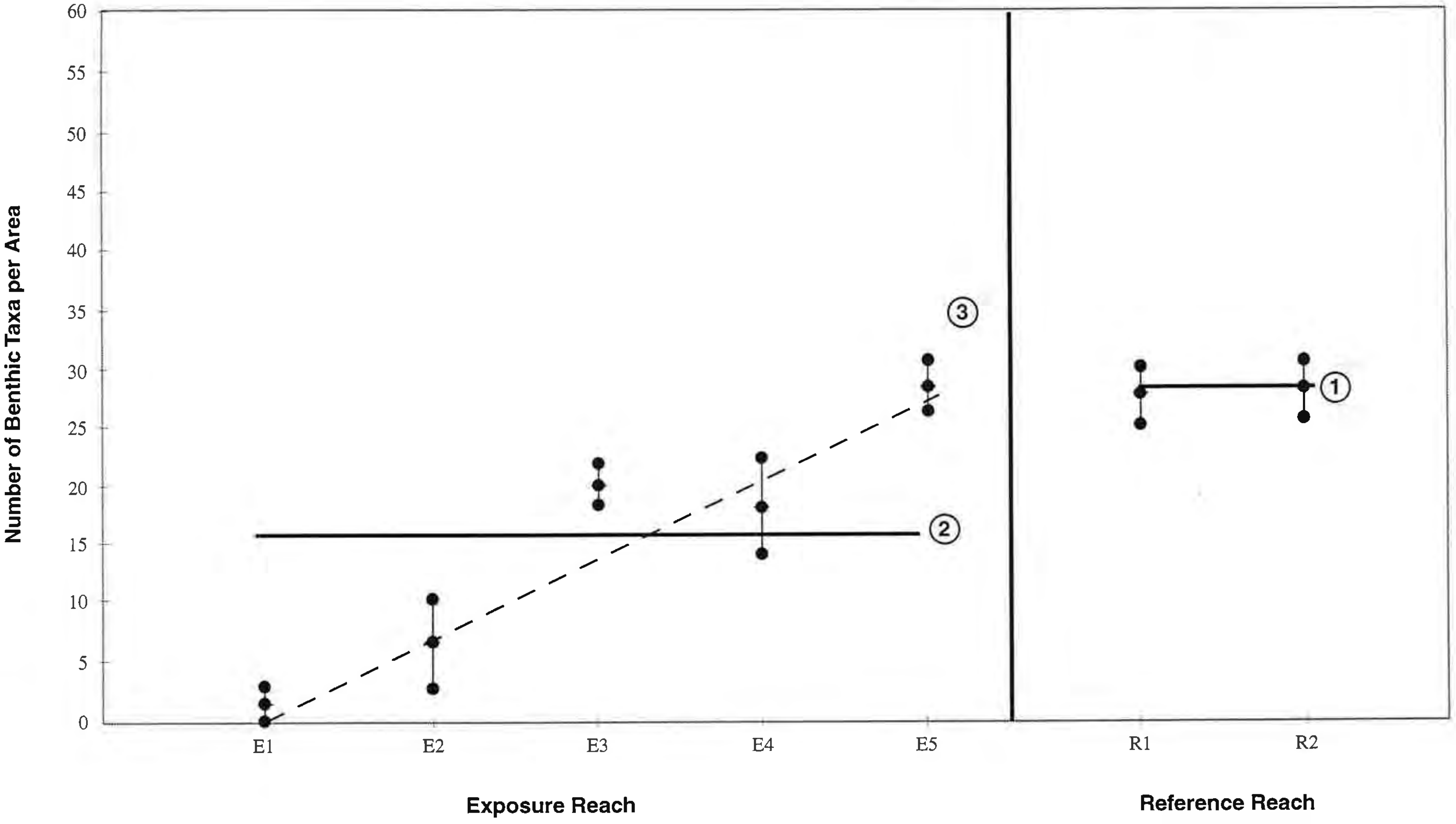
beak beak international incorporated	Figure 5.4	May 1998

The ANOVA partitions overall variance in the response measure into a number of terms representing effects of particular interest. These include:

- An "Among Reference" term which indicates whether the Reference reaches are similar to each other. It measures the spread of reference means around Line 1 in Figure 5.5 (i.e., around the grand reference mean represented by the solid line). This term is quantified in order to indicate whether reference reaches are differentially influenced by some factor that may also be confounding effects in the exposure area.
- A "Ref vs Exp" term which indicates whether the Reference and Exposure reaches are similar to each other. It measures the spread between Line 1 (reference mean) and Line 2 (exposure mean) in Figure 5.5 (i.e., between reference and exposure means). A reference-exposure difference is generally indicative of tool effectiveness, assuming that the direction of the difference is consistent with impact.
- A "Linear Trend" term which indicates whether there is a linear trend in the Exposure area (e.g., from near-field to far-field). It measures the spread between Line 2 and Line 3 (the exposure trend line) in Figure 5.5 (i.e., the difference in slopes). A significant linear trend, i.e., a near-field to far-field gradient is indicative of tool effectiveness, assuming that its direction is consistent with impact.

In all cases, to test whether the spread is significant, as described in any of the above three "effect" terms, each is compared to the spread of exposure reach means around Line 3 (i.e., to a "lack of fit" error term). This "lack of fit" error term accounts for the residual variability in the data after the above three terms are subtracted from the total among-reach variability. If an "effect" term is large relative to the "lack of fit" error, then the effect is more likely to be significant.

The "lack of fit" spread is compared in turn to the overall "within reach" spread (i.e., between stations within a reach), in order to test whether there may be any other (i.e., non-linear) trend among the exposure means, that is whether a straight line is the best description of the trend. If "lack of fit" is significant, the nature of the trend is examined and, if appropriate, the analysis is repeated using a non-linear (second order) trend term instead of a linear trend term. This would appear in Figure 5.4 as a curved line rather than straight Line 3.



Legend

● responses for 3 stations per reach

+ mean value of 3 stations per reach

—— reference or exposure mean

– – – – line fit to exposure reach means

Example Approach to Testing H6
Based on Number of Benthic Taxa

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Figure
5.5

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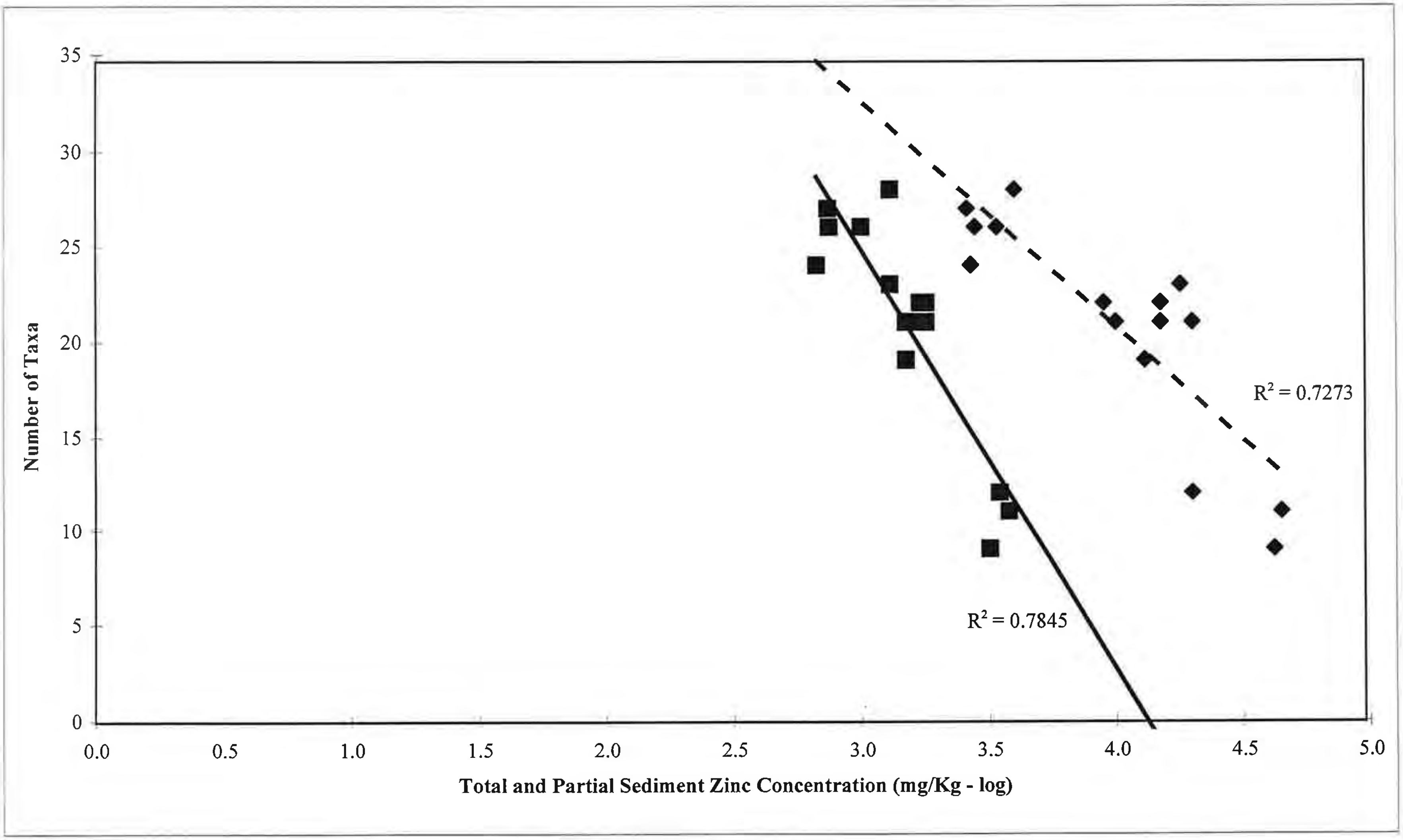
In the example, the data points in Figure 5.5 represent numbers of benthic taxa in each area and station. The ANOVA shows a significant "Ref vs Exp" effect, because there is a substantial difference between Lines 1 and 2. The ANOVA also shows that there is a significant "Linear Trend" effect, because numbers of taxa are lowest near the mine (Reach E1) and increase as we move further away (i.e., slope of Line 3). The interpretation would be that benthic species richness is responding to mine exposure.

5.1.5 H9 through H12 - Tool Integration Hypotheses

Hypotheses H9 to H12 address the **relative** ability of two monitoring tools to detect a mine effect. For example, in H10, partial metal in sediment was compared to total metal in sediment, for each of the key metals, to determine whether these two monitoring tools differ in their ability to detect a mine effect (i.e., a correlation between a biological response measure, such as fish CPUE, and the metal predictor variable). Correlation analysis was used to address this hypothesis, as described below.

The squared coefficient of correlation (r^2) between the response measure (Y) and each predictor variable (X1 or X2) indicates the proportion of variance in the response measure that is explained by the predictor (Figure 5.6). The best predictor, for each pair compared, is the one which explains the highest proportion of variance (i.e., has the highest r). No statistical test was performed to determine whether r_1 differs significantly from r_2, because the two r values are based on the same Y data set and are not independent. However, the individual r values were tested for statistical significance. Two r values were compared, to draw inferences about which monitoring tool is better, only when at least one of the r values was of the correct sign (negative or positive) to suggest a mine effect, and statistically distinguishable from zero based on a one-tailed test.

When differences between r values are small (e.g., ≤ 0.1), even though one or both r values may be statistically significant, a judgement is generally not made that the tool with the slightly higher r value is better able to detect an effect. Also, the correlations are generally calculated for many exposure measures (metals), so that judgements with respect to which exposure measure tool (e.g., total versus dissolved metal concentration in water) is more strongly correlated with biological response are made by the weight-of-evidence based on all r values for each tool. The exposure and response measures selected for inclusion in this analysis were those which showed an apparent spatial relationship to the



Examples of Approach to Testing H10 at Mattabi Mine

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Figure 5.6

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mine site (i.e., trend among exposure reaches or difference between reference and exposure reaches).

These correlations can be computed in two ways - including and excluding reference stations. Response tools correlated with causal agents when reference sites are excluded are considered more effective than those showing correlations when reference sites are included. This is because correlations seen within the exposure gradient are clearly associated with mine impact. The inclusion of data from the two references areas could potentially impose spurious correlations by producing clusters of data points at low exposure concentrations.

For H9 and H12, which involve correlations between responses in fish and water quality, samples were collected from four exposure stations within a larger exposure area and at another four stations in a reference area. Aqueous metal concentrations in the exposure area showed some variation among stations, with the principal difference occurring between MME6 and the other stations owing to effluent mixing patterns. Thus, the study design for these hypotheses can be considered either a control/impact (C/I) design or a control/impact/impact (C/I/I) design, depending on whether large fish range throughout the exposure area on the time scale of fish response and fish movement. For example, MT concentrations in fish could conceivably respond relatively quickly to exposure concentrations (as observed at Heath Steele, BEAK, 1998), although a measurable growth response to a specific exposure level in large fish would probably require that fish be relatively sedentary and not range throughout the exposure area at Mattabi. To address the possibility that fish are able to respond to exposure conditions at a relatively local level, H9 and H12 are tested by correlation analysis. In so doing, it is recognized that the results of the analyses must be interpreted with caution because the large fish sampled are likely to range freely throughout the exposure area and to be exposed to spatially averaged conditions. Also, reference station data are included in the analysis to offset the very limited variation in exposure conditions measured at exposure stations.

For H10 and H11, which are sediment-related hypotheses, correlation analysis can be reasonably completed using only data from the five exposure areas sampled. Thus, H10 and H11 are tested without the use of reference site data.

Hypothesis H9

At Mattabi, H9 (relationship between water chemistry and biological variables) is tested both using fish health and community tools. This hypothesis compares the effectiveness of dissolved versus total metals in water as predictors of biological response. As noted above, this analysis is of limited value because it cannot reasonably be done exclusive of reference stations and because of the limitations imposed by the C/I design. Some of the biological responses observed in H5 through H8 did not appear to be in response to metal exposure (e.g., greater growth, organ size, etc.). However, because the underlying nature of dose-response patterns in the natural environment is uncertain, H9 has been tested under the general assumption that the response could be *potentially* attributed either directly or indirectly to mining effects.

Hypothesis H9 is not tested using benthic community tools. This is because most of the exposure areas for benthos are located in Mine Creek Bay, where water-borne metal concentrations are greatly diluted by Sturgeon Lake. Water quality variations from station to station here are small and concentrations low relative to Canadian surface water guidelines. Thus, it is unlikely that benthic effects would be attributed to water quality, with the possible exception of effects in No Name Lake (area HE1).

Hypothesis H10

Hypothesis H10 tests both benthic index versus sediment chemistry correlations and sediment toxicity versus sediment chemistry correlations. The sediment chemistry tools include total metal concentrations (hydrogen peroxide/nitric acid extraction), partial metal concentrations (hydroxylamine extraction) and the ratio of the molar sum of simultaneously extracted metals (SEM) and acid volatile sulphide (AVS). Metals included in the SEM value are Cd, Cu, Ni, Pb and Zn. These are the metals often contributing to toxicity and potentially rendered non-bioavailable by the formation of metal monosulphides.

Hypothesis H11

Hypothesis H11 examines the remaining component of the "sediment quality triad" - the correlation between benthic indices and sediment toxicity. The toxicity tests include amphipod (*Hyalella azteca*), chironomid (*Chironomus riparius*) and oligochaete (*Tubifex tubifex*) tests on sediment samples from each lake station.

Hypothesis H12

H12 (relationship between water and fish tissue chemistry response) is tested using total metal concentration in water, and metallothionein and metals in fish tissues. As noted previously, H12 cannot be rigorously tested due to limitations imposed by the C/I design.

5.1.6 Triad Hypotheses

The "triad" hypothesis addresses the issue of whether chemical contaminants may be responsible for biological "effects" that are apparent in the study area. This hypothesis has not been articulated explicitly in the set of 13 hypotheses that were developed by the AETE (Section 1.0); however, it is consistent with the interest in H9 through H12 about the ability or relative ability of monitoring tools to detect correlations or relationships between chemical, toxicological and biological parameters. The basic approach to evaluation of the triad hypothesis is to simultaneously examine three types of correlations: chemical-toxicological (C-T), toxicological-biological (T-B) and chemical-biological (C-B). These are the three "arms" of the triad that would support an interpretation that chemical contaminants are responsible for biological effects. There should be significant correlations on all three arms before the hypothesis that chemical contaminants are the cause of the effect is accepted.

Statistical approaches to triad evaluation follow Green and Montagna (1996) and Chapman (1996). One approach is to examine the three bivariate correlations (C-T, T-B, C-B) for different sets of chemistry, toxicity and biology monitoring tools. Then, the overall evaluation of the triad hypothesis is based on "weight-of-evidence" considerations (i.e., are there sets of parameters showing significant C-T, T-B **and** C-B correlations, how many sets are there that meet this criterion, and how strong are the correlations in general?). This approach is simple, but rather tedious when there are many different chemistry, toxicity and biology monitoring tools to be paired in different ways.

A more holistic approach was applied using principal components analysis (PCA) to reduce the large number of variables to one or two dominant principal components (PCs) representing the mine effect gradient in chemistry (based on the original chemical variables), one or two representing the gradient in toxicity, and one or two representing the gradient in biology. Then multiple correlation coefficients (R) are computed using the PC variables to represent the dominant C-T, T-B and C-B correlations (if any) on each arm of the triad. Mantel's test was used to produce a single measure of concordance on each arm of the triad, equivalent to R^2 (e.g., Figure 5.7). Finally, Bartlett's test of sphericity was applied to determine if there is a significant overall concordance across the three arms of the triad.

5.2 Results

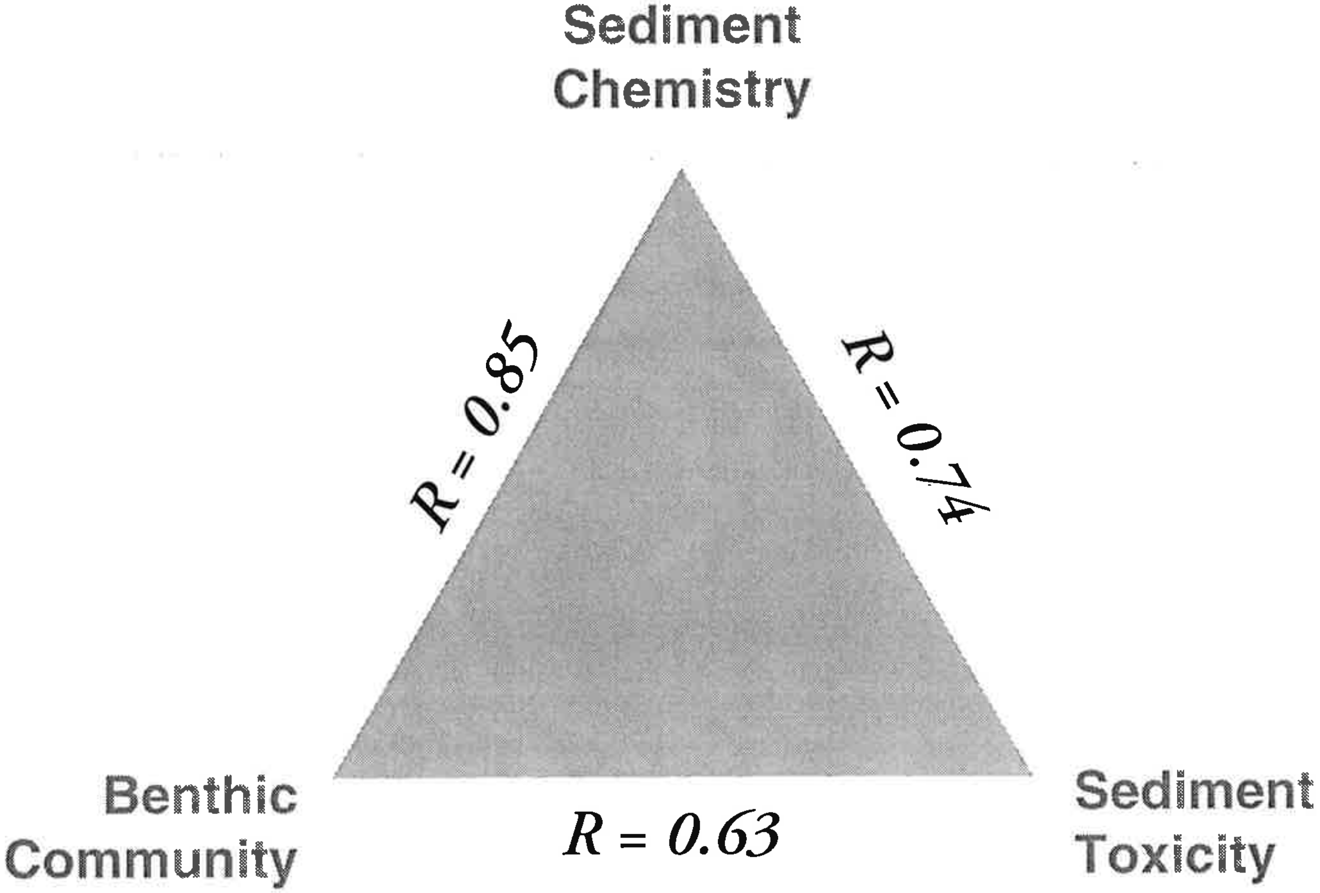
The general conclusions with respect to hypothesis testing at Mattabi are summarized in Table 5.2. The following sections present the findings in more detail, based on the statistical tables and figures presented in Appendix 7. The discussion is focused on results that meet the significance criterion of $p \leq 0.05$. Use of the term "significant" implies that this criterion was met, although "suggested" results may be mentioned as such when the criterion is approached but not achieved. The reader is reminded that tool effectiveness discussed herein pertains to the specific Mattabi dataset produced in this study, and conclusions should not necessarily be considered generally applicable at other mine sites.

5.2.1 H1 - Sediment Toxicity as a Response to Exposure

None of the *Tubifex, Hyalella* or *Chironomus* lethal or sublethal responses (arcsine square root of %) showed a trend that can be related to a mining effect (reference-exposure difference or exposure area trend). Significant differences in responses for *Chironomus* growth and *Tubifex* production of cocoons and young were evident among areas, but these differences did not occur between reference and exposure area groups. The lack of toxicity response to mine exposure is perhaps surprising, given the extreme sediment metal concentrations present. The small partial metals fraction may reflect this low bioavailability and low toxicity associated with sediment metals.

5.2.2 H2 - Comparison of Fish Tissues for Metal Concentration

This hypothesis was tested metal by metal in a two step process. First, ANOVA was used to identify whether a reference-exposure difference exists for each tissue (liver, gill, kidney, muscle) and metal. Effects of age and sex on metal concentration were also evaluated at this stage. Second, tissues were compared in a pair-wise fashion to identify significant area x



Approach to Evaluation of the Sediment Quality Triad

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TABLE 5.2: SUMMARY AND GENERAL CONCLUSIONS OF HYPOTHESES TESTED AT MATTABI

Hypothesis	Y variables	X variables	Test (Ho)	Comment
H1	Sediment Toxicity Response i Sediment Toxicity Response j	Lake Area Identifier	no trend or area x tool interaction by ANOVA	All tests showed no significant reference-exposure differences or trends in the exposure area. Thus, no discernible difference in effectiveness. Area effects unrelated to exposure were evident for sublethal responses in *Chironomus* and *Tubifex*.
H2	Metal i in Tissue i Metal i in Tissue j	Creek Identifier	no R/E x tool interaction	White sucker tissue concentrations of Pb and Zn showed exposure area elevation only in gill. Se was higher in exposed sucker muscle and kidney relative to reference suckers. These metals were also elevated in other tissues of exposed sucker, but only for one sex. Northern pike Cd and Zn in muscle, Pb and Co in gill/kidney, and Se in muscle, gill and liver showed exposure area elevation. The most effective tissue for monitoring of tissue metals depends on metal. Linkage of Se and Co to Mattabi is weak.
H3	MT in Tissue i MT in Tissue j	Creek Identifier	no R/E x tool interaction	MT response only significant for pike gill and kidney. These tissues were equally effective.
H4	Metal i in Tissue j MT in Tissue j	Creek Identifier	no R/E x tool interaction	MT and Pb, Se and Co elevated in northern pike gill/ kidney. MT and some metals (Pb, Co) were equally effective in showing mine-related exposure. Se was more elevated in the exposure area than MT for pike gill.
H5	CPUE for sucker, pike and all fish	Creek Identifier	no R/E difference by ANOVA	No significant effect of mine exposure on fish abundance.
H6	BPUE, No. of Fish Taxa	Creek Identifier	no R/E difference by ANOVA	Significant decrease in number of fish species in exposure area, probably due to habitat factors. No significant effect of mine exposure on fish biomass.
H6 (benthos)	No. of Taxa Benthic Density Indicator Taxa	Area Number in Order of Decreasing Sediment Metal Concentration	no trend or R/E difference by ANOVA	Significant decrease in exposure area, and exposure area trends in density, number of taxa and indicator taxa.
H7	Weight at age Length at age	Creek Identifier	no R/E difference by ANOVA	No significant differences in growth of white sucker. Significantly larger pike in exposure area. "Effects" of exposure beneficial and probably related to habitat.
H8	Liver weight, gonad weight by sex, at age. Fecundity at age (females).	Creek Identifier	no R/E difference by ANOVA	White sucker liver significantly larger in exposure fish. Gonad weight (body-weight adjusted) slightly smaller in exposed male sucker. Liver and gonad weight and fecundity in pike all significantly higher in exposed fish. "Effects" of exposure in pike not consistent with adverse impact.
H9*	No. of Fish Taxa Length and Weight at age Gonad and Liver wt at age (pike), Fecundity	Dissolved Metal in Water (Tool 1) Total Metal in Water (Tool 2)	same correlation	Similar correlations for dissolved and total metals. Better correlations with total Pb versus dissolved. H9 to be interpreted with caution due to study design limitations.

TABLE 5.2: SUMMARY AND GENERAL CONCLUSIONS OF HYPOTHESES TESTED AT MATTABI

Hypothesis	Y variables	X variables	Test (Ho)	Comment
H10	Benthic Density No. of Benthic Taxa Indicator Taxa Sediment Toxicity Endpoints	Partial Metal i in Sediment (1) Total Metal i in Sediment (2) SEM/AVS Ratio	same correlation	Similar correlations for total and partial metals with benthic community effects and sediment toxicity results (*Chironomus* and *Tubifex* sublethal endpoints). Total metals slightly better correlated than partial metals. No correlation of SEM/AVS ratios with benthos or toxicity results. SEM/AVS ratio did not correlate with observed toxicity results.
H11	Benthic Density No. of Benthic Taxa Indicator Taxa	Sediment Toxicity Results	same correlation	*Tubifex* reproduction showed strongest correlations with benthic metrics supporting cause-effect linkages. *Chironomus* growth showed some linkage with benthos but the direction of the correlation is inconsistent with impact.
H12*	Metal i in Tissue j MT in Tissue j	Metal i in Water (dissolved and total)	same correlations	In sucker, only Pb and Zn in gill were correlated with aqueous metal concentrations. MT concentrations in sucker tissues were unrelated to exposure concentrations. In pike, Pb in kidney and gill, and Zn in muscle, were correlated with aqueous concentrations of the same metals. Pike MT levels in kidney and gill were correlated with Cd, Pb and Zn in water. These metals in tissue showed similar correlations with corresponding metals in water.
Sediment Triad Hypotheses	Benthic PCs Sediment Toxicity Endpoints Sediment Chemistry PCs	Benthic Variables (B) Toxicity Variables (T) Chemistry Variables (C)	no correlation C-B, C-T and B-T	The sediment quality triad was significant using either partial or total metals, although the benthos/chemistry correlation was stronger using partial metals. The chemistry/toxicity and benthos/toxicity arms of the triad were not significant.

* H9 and H12 are C/I comparisons with reference stations included in the correlations. Results to be interpreted cautiously.

tissue (tool) interaction, which would indicate a greater degree of response (i.e., effectiveness) in one of the two tissues. This second comparison was made only if two or more tissues showed a significantly greater concentration in the exposure area for any metal.

In female white sucker, for example, the levels of selenium in kidney and liver exhibited similar relative degrees of difference between the reference and exposure areas, as indicated by the reach*tool term which was not statistically different (p = 0.660; see Hypothesis H2 in Appendix 7). However, for selenium in kidney and muscle in female white sucker, there was a significant reach*tool term (p = 5.41E-04), indicating that the relative differences between the reference and exposure for these two tissues were not similar. To identify which tissue demonstrated the larger gradient of difference, the plot provided (following the ANOVAs for H2 in Appendix 7) indicates a greater slope for the selenium in liver relative to selenium in muscle.

Also in Appendix 7 are tables identifying the cases where reference-exposure differences occurred for each metal, and showing the directions of the differences (whether exposure or reference fish were higher in concentration). On balance, for Cd, Co, Se, Ni, Zn, Pb, most (but not all) reference-exposure differences showed higher concentrations in the exposure area in at least one tissue or species. This provides a degree of confidence that the effects observed are mining-related.

White Sucker

For white sucker, significantly higher concentrations in exposure fish were found for Pb and Zn in gill, and for Se. The Se elevation was greater in muscle than in kidney for female sucker, but greater in kidney than in muscle for male suckers. In addition, there were some exposure area elevations observed in only one sex, e.g., Pb in female livers, Se in male gills. Gill displays a greater elevation of Pb and Zn in the exposure area than does muscle, liver or kidney tissue.

Kidneys display a greater elevation of Se in the exposure area than do muscle tissues for female white sucker; however, for males, there is a greater elevation in the muscle. Livers display a greater elevation of Se in the exposure area than do muscle tissues for female white sucker. Muscle displays a greater elevation of Se in the exposure area than does gill tissue for male white sucker.

Northern Pike

In northern pike, significantly higher concentrations were found in the exposure area for Cd and Zn in muscle, Pb and Co in gill and kidney, and Se in muscle, gill and liver. In addition, there were some exposure area elevations that were observed in only one sex, e.g., Se in female kidneys, Cr in female muscle and in male kidneys. Water chemistry results do not suggest a Cr source from Mattabi.

Muscle displays a greater elevation of Cd and Zn in the exposure area than does gill, liver or kidney tissue. Gill and kidney display a greater elevation of Pb and Co in the exposure area than do liver or muscle. Gill tissue displays a greater elevation of Fe in the exposure area than does muscle, liver or kidney.

Muscle displays a greater elevation of Se in the exposure area than does gill tissue, and gill tissues display a greater elevation than liver.

5.2.3 H3 - Comparison of Fish Tissues for Metallothionein Concentration

This hypothesis was tested by identifying whether a reference-exposure difference exists for each tissue (liver, kidney, gill). Effects of age and sex on MT concentration were also evaluated at this stage.

As shown in Appendix 7, the only significant MT response occurred in gill and kidney of northern pike (both sexes combined). There was no significant interaction between tissue (gill and kidney) or exposure effects on MT response, indicating similar responses for these two tissues. However, higher levels of MT were measured in the kidney making it a more reliable tool compared to the very low levels measured in gill.

5.2.4 H4 - Metallothionein vs Metal in Fish Tissues as a Response to Exposure

The only fish tissues showing both MT and metal responses were northern pike gill and kidney. Northern pike gill and kidney showed elevated MT, Pb, Se and Co in the exposure area relative to the reference area. ANOVAs for gill and for kidney showed no significant interaction between tool (MT, metal) and exposure effects, for either Pb or Co, indicating similar effectiveness of MT and metal. However, Se showed a stronger elevation in the exposure area than MT for pike gills.

5.2.5 H5, H6 - Fish CPUE, Fish Community as Responses to Exposure

Fish CPUE

The ANOVAs for CPUE for individual species and for all fish (numbers of individuals) showed no significant difference in CPUE between reference and exposure areas. The white sucker CPUE difference was insignificant (p = 0.072), because of only a slightly greater abundance of sucker in the exposure area (Bell Creek) catches (Appendix 7). These results indicate no effect of mine exposure on fish abundance.

Fish BPUE

ANOVAs of biomass-per-unit-effort (BPUE) for individual fish taxa and for all fish showed no differences between areas (Appendix 7). As stated for CPUE, these results indicate no effect of mine exposure on fish abundance.

Fish Species

The ANOVA for numbers of fish species present indicates a significant reference-exposure area difference (Appendix 7). The differences are related to the presence of sauger, lake whitefish and lake herring in the reference area but not in the exposure area. This fish community difference can probably be related to the presence of accessible deepwater habitat near sampling areas in the English River, rather than to any mining-related effect.

5.2.6 H6 - Benthic Community Measures as Responses to Exposure

ANOVAs demonstrated several reference exposure area differences and/or exposure area trends in the benthic community which are consistent with mining-related effects (Appendix 7). Reference-exposure area differences were found for log total density and log (and arcsine square root %) *Chironomus* (midge) density, whereas exposure area trends were significant for log total abundance, % Hydracarina (water mite), *Pisidium* (pea clam) abundance and numbers of benthic taxa. Nearly significant (p = 0.053) trends were found for arcsine square root % *Chironomus* (exposure area trend) and log Hydracarina abundance (exposure area trend, p = 0.051; and reference-exposure difference, p = 0.054). The directions of these differences were consistent with mining-related effects (e.g., reduced taxa, total abundance, *Pisidium* and Hydracarina abundances; increased *Chironomus* abundance). As outlined in Section 3.1, other benthic effects were apparent but not tested, including *Psectrocladius* abundance which was extreme at MME1, with none present elsewhere (rendering statistical testing difficult but unnecessary). As discussed previously (Section 3.1.4), benthic community responses appear more likely associated with mine-related effects than with variations in benthic habitat among areas.

5.2.7 H7 - Fish Growth and Condition as a Response to Exposure

Figure 4.9 shows size-age and weight-length relationships for white sucker and northern pike. The ANOVA tables showing trends in age-adjusted lengths and weights and length-adjusted weights are presented in Appendix 7.

White Sucker

White sucker differ by sex in their growth characteristics, with males being generally smaller than females. ANCOVAs are provided for both males and females using age adjusted data to account for the effects of age on fish size (Appendix 7). The ANOVAs show no significant growth differences in male or female white sucker between the reference and exposure areas. That is, suckers have comparable sizes at age and weights at length (condition).

Northern Pike

Northern pike, like white sucker, also differ in their growth characteristics by sex, with males being generally smaller than females. ANCOVAs are provided for males and females in Appendix 7. Unlike white suckers, however, northern pike were substantially different in size at age between areas. Both males and females were substantially larger at age in the exposure area than in the reference. Fish condition (length-adjusted weight) was similar in both areas. Thus, a fish of a given length had a comparable weight in both reference and exposure areas, but a specimen from the exposure area would tend to be younger. Reasons for the enhanced growth in pike in the exposure area are unclear, but appear inconsistent with a mining impact or possible reduced food base.

5.2.8 H8 - Organ Size as a Response to Exposure

Summaries of data on liver weight, gonad weight and fecundity (numbers of eggs) are presented along with ANOVAs in Appendix 7 for both northern pike and white sucker. Males and females are treated separately for all measurements, and results are adjusted for fish age or fish size.

White Sucker

In white sucker, both body weight and age-adjusted liver weight in males showed significant reference-exposure differences. In this case, mean liver weight at age and at body weight was greater in exposed fish than in reference fish. This could potentially be construed as an increase in liver energy storage, which may be inconsistent with a mine effect. The opposite response for gonad weight (slightly and statistically smaller gonads) occurred in exposed males, when the data were adjusted for body weight.

Northern Pike

In northern pike, all three parameters showed significant reference-exposure differences. Liver weight, gonad weight (both sexes) and fecundity were greater in Bell Creek northern pike (applies to age and/or body-weight adjusted data). These findings are consistent with the greater size of male and female northern pike at age - that is, larger fish have larger organs. However, the fact that females retain these organ size differences after body weight adjustment indicates that the responses are relatively strong. Overall, these responses appear to indicate more robust fish in Bell Creek. This may not be consistent with an obvious mine effect.

5.2.9 H9 - Dissolved vs Total Metal in Water as a Predictor of Biological Response in Fish

Hypotheses 9 through 12 involve examination of correlation coefficients between measured parameters. The correlations for H9 were computed using all reference and exposure area CPUE, BPUE, fish growth and organ size/fecundity measurements from Hypotheses H5 to H8 with emphasis on metals that showed significant area differences. The correlation matrix is shown in Appendix 7. The most relevant correlations are those for dependent variables (responses) showing reference-exposure differences consistent with a mining effect. However, as discussed for H5 to H8, it is suspected that the fish "effects" observed (increased growth and organ size in some cases) may be unrelated to metal exposure. Only the decreased body-weight adjusted organ size in female pike and male sucker appear consistent with a metal exposure impact.

For the most part, correlation coefficients were similar for dissolved and total metal fractions for some metals (Cu, Fe, Mg, Zn), but were higher for total lead than for dissolved lead.

These data should, however, be interpreted very cautiously because, as noted above, most of these correlations may not reflect cause-effect relationships. Also, as noted previously, the mobility of fish within the localized exposure zone gradient and the inclusion of reference site data in the analysis limit the validity of any conclusions that can be drawn.

5.2.10 H10 - Metals in Sediment as Predictors of Biological Response

For H10 and H11, correlations were computed excluding the reference station data. As noted previously, it is appropriate to exclude the reference stations as the correlations more clearly reflect relationships within the mine exposure gradient, and are not potentially skewed by the extreme low values on the x-axis driven by the six reference area stations. Thus, a result producing a high correlation coefficient when tested with exposure station data only is more effective than one producing high values when reference station data are included.

For tool comparison, no statistical tests are performed to compare the correlations generated by two measurement tools. However, differences of 0.1 or more between coefficients are considered worthy of discussion, as long as at least one of the coefficients is statistically distinguishable from zero.

Tables showing correlation coefficients between sediment measurements (total, partial, SEM/AVS ratio) and benthic and sediment toxicity testing results are presented in Appendix 7.

Total and Partial Metals and SEM/AVS Ratios as Predictors of Benthic Community and Toxicity Response

Both total and partial metals were correlated with the benthic community responses identified in H6. Significant correlations were seen with many metals including As, Cd, Cu, Fe, Pb, Ni, Se and Zn. Neither the total nor the partial metal measurements were greatly superior in terms of the numbers of significant correlations or strength of the correlations, although total metals were slightly superior in terms of exhibiting the appropriate sign for the correlations and a slightly greater number of significant correlations. This observation is consistent with the fact that sediment chemistry trends were stronger for total metals. Both total and partial metals were more effective than the SEM/AVS ratio, which did not correlate with any benthic response.

Sediment toxicity correlations are evaluated using sediment toxicity endpoints, with a focus on *Chironomus* growth and *Tubifex* reproduction which showed significant among area differences in H1 (regardless of these differences being unrelated to exposure), as well as other sediment toxicity test results. As observed with benthic responses, significant correlations were found with both total and partial metals. Neither total nor partial metals was clearly superior as the independent variable group. The significant positive correlations between total metals and *Chironomus* growth appear unusual, but are consistent with the increased growth measured in sediment toxicity tests completed at Mattabi in the early 1990s (NTC and BEAK, 1993) and may indicate an unexplained but real effect of metal exposure in this case.

Overall, H10 results suggest that benthic community responses are slightly better correlated with total metals than with partial metals. This result is consistent with the observed exposure-related trends seen in H6 and in terms of the stronger spatial responses observed in total metals relative to partial metals. H10 results for sediment toxicity may be less conclusive in terms of distinguishing greater effectiveness in total or partial metals. However, if the positive correlations between total metals and *Chironomus* growth reflect a metal exposure response, then total metals could be considered more effective than partial metals in this case. The SEM/AVS ratio was not correlated in a meaningful way with any benthic or sediment toxicity responses.

5.2.11 H11 - Sediment Toxicity as a Predictor of Benthic Community Response

Tables showing correlation coefficients between toxicity endpoints (*Chironomus* growth, *Tubifex* numbers of cocoons and young) and benthic indices (total density, numbers of taxa, % indicator taxa) are presented in Appendix 7. The toxicity parameters chosen for testing here include those showing significant among station differences in H1, even though these differences did not occur between reference and exposure areas. Other toxicity parameters were also considered including *Hyalella* results, and the correlation analysis broadened to consider dependent variables of interest that may not have been considered in H6. In particular, the analysis includes an examination of correlations between toxicity response in the laboratory and the abundance of the same or related organisms in the benthic community (e.g., is there a link between *Hyalella* survival and *Hyalella* density in the environment?).

Regardless of the lack of mining-related sediment toxicity effects in H1, several significant correlations occurred between sediment toxicity and benthic response. Correlations were strongest between the *Tubifex* reproduction endpoints and benthic endpoints. Thus, based on these comparisons, *Tubifex* reproduction responses appear to provide better indicators of benthic effects than *Chironomus* growth or other toxicity test results. It is interesting to observe the absence of correlations between *Hyalella, Chironomus* and *Tubifex* results and the relative abundances of these same taxa in the benthic community.

5.2.12 H12 - Total vs Dissolved Metals in Water as Predictors of Metal and Metallothionein in Fish

Tables showing correlation matrices between total and dissolved concentrations in water and fish tissue metal concentrations are presented in Appendix 7. Emphasis is placed on those metals and tissues showing significant mining exposure-related responses in H2 and H3.

Correlations could not be done for cobalt and selenium which showed significant exposure-reference area differences in tissue levels because aqueous selenium and cobalt were below detection limits in water at most stations. However, the possibility that cobalt and selenium concentrations in fish tissues could be affected by the mine cannot be discounted because, although these metals showed little or no evidence of elevation in the exposure area, they were detected in the effluent.

The only significant responses in white sucker were for Pb and Zn in gill (both sexes) and for Pb in liver (females only). The correlation coefficients indicate a comparable linkage between metal in tissue and water for both total and dissolved forms. This conclusion is relatively weak, however, as it is based on a C/I design that precludes rigorous dose-response evaluation.

In northern pike, significant tissue-water correlations were found for MT in kidney and gill with aqueous Cd, Pb and Zn. Significant tissue-water correlations were found for Pb in kidney and gill, and Zn in muscle.

For most metals examined in this hypothesis, dissolved and total metals produced similar correlation coefficients. For cadmium, significant correlations could be identified only for total metal results, owing to the dissolved metals values falling below detection limits.

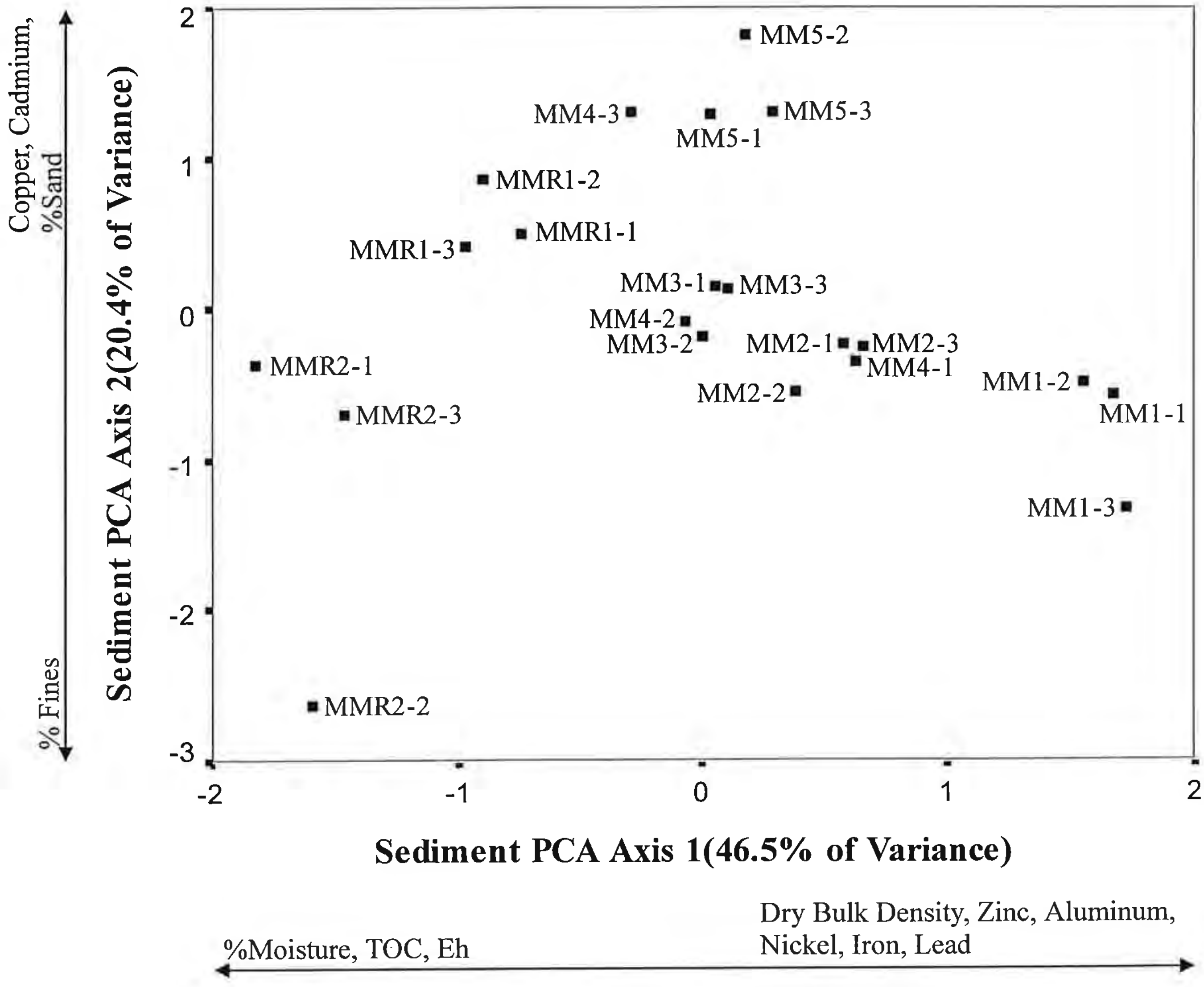
5.2.13 Triad Hypothesis

There are a number of chemistry (C), toxicity (T) and biology (B) monitoring tools that show significant bivariate correlations on all three arms of the "triad". For zinc, the correlations involving total metals were similar to those involving partial metals. However, for other metals, notably copper and cadmium, the correlations involving total metals were quite different than those involving partial metals. Spatial patterns of partial metals (except for zinc) did not follow those of total metals and were not clearly mine-related.

A more holistic evaluation of the sediment quality triad, involving multivariate analysis, is presented in Appendix 7. The many sediment chemistry variables were reduced by principal components analysis (PCA) to two sediment principal components (SPCs) representing sediment chemistry gradients. This PCA used both total metals and partial metals but not SEM/AVS results. Only partial and total metals appeared effective in hypothesis testing.

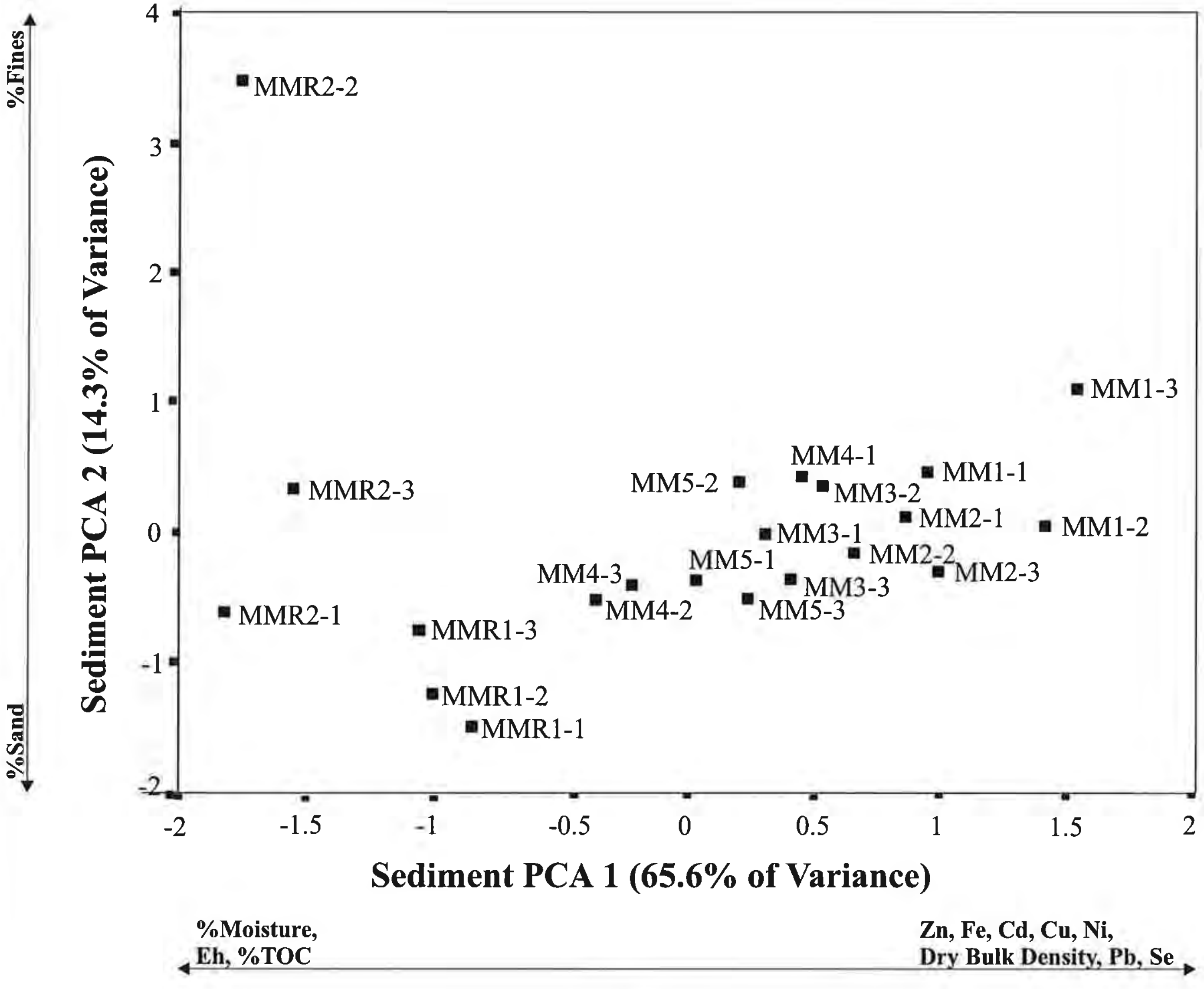
For partial metals, the dominant SPC1 (accounting for most (47%) of the overall variation in sediment quality) represents a mining-related gradient (Figure 5.8). Sediments influenced by mining tend to have a higher metal content, higher density, less moisture and less organic content than reference sediments. The subdominant SPC2 (accounting for 20% of the variation in sediment quality) represents variation in grain size, with more fine sediments at one end, versus sand at the other. The large lake stations (Mine Creek Bay and Peterson Cove) tend to contain more sand. Partial copper and cadmium tend to associate with sandy sediments rather than following the mining-related gradient in total metals.

For total metals, SPC1 accounts for 66% of the overall variation in sediment chemistry (Figure 5.9). SPC1 represents a mining-related gradient. As for partial metals, sediments influenced by mining tend to have a higher metal content, higher density, less moisture and less organic content than reference sediments. The dominant SPC2 represents mainly a grain size gradient, and explains only 14% of the overall sediment quality variation. It primarily separates Station MMR2-2 from all the others, based on fine texture. However, other reference stations and Mine Creek Bay stations tend to have more sand than No Name Lake stations.



Sediment (Partial Metals) PCA Results
Mattabi Mines Lake Stations

beak	beak international incorporated	Figure 5.8	May 1998



Sediment (Total Metals) PCA Results
Mattabi Mines Lake Stations

beak international incorporated	Figure 5.9	May 1998

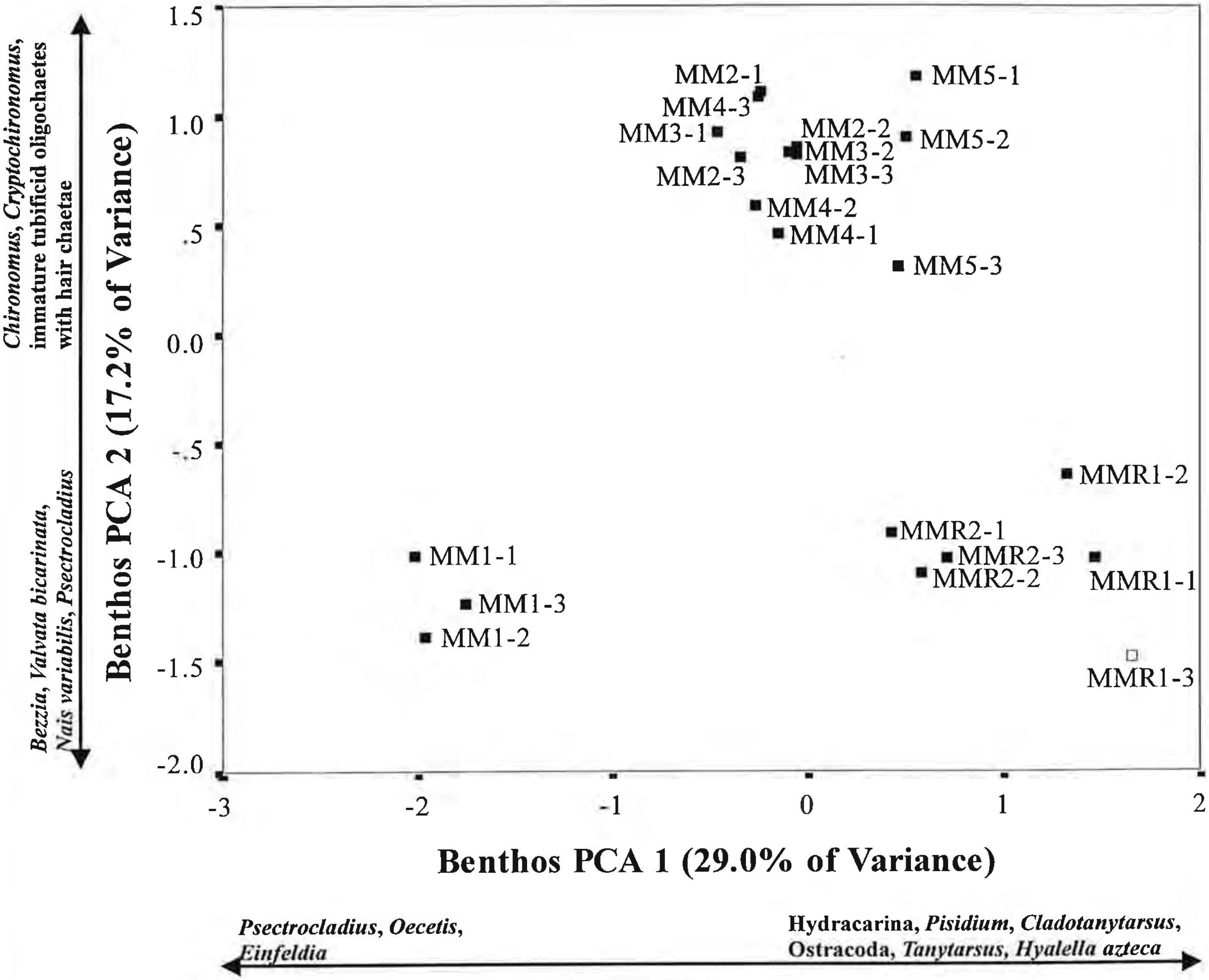
The many benthic community variables were reduced by PCA to two benthic BPCs representing gradients in the biological make-up of the community. The dominant BPC1, accounting for 29% of the overall variation in species composition, primarily represents Hydracarina, Pisidium, Tanytarsini chironomids, ostracods and *Hyalella* (pollution sensitive taxa) as well as the chironomid *Psectrocladius* (pollution tolerant taxa) (Figure 5.10). Tolerant species dominate at No Name Lake, while sensitive species characterize the reference stations. The subdominant BPC2, accounting for 17% of the variation in species composition, represents *Chironomus* primarily, and separates Mine Creek Bay stations from all others.

The dominant partial metal gradient (SPC1) was significantly correlated with BPC1 (multiple $R = 0.81$, $p < 0.001$; Figure 5.11). This mine-related gradient (SPC1) was not significantly correlated with sediment toxicity, although SPC2 for partial metals was significantly correlated with *Chironomus* growth and *Tubifex* production of cocoons and young (multiple $R = 0.66$, $p = 0.019$). The large lake sediments (e.g., Mine Creek Bay and Peterson Cove), which group together on SPC2, tend to provide for better *Tubifex* reproduction than either No Name Lake or Tag Lake sediments. However, "toxicity" does not appear to be driven by mine-related sediment features.

The dominant benthic community gradient, BPC1, representing sensitive vs tolerant species, was not significantly correlated with sediment toxicity, but toxicity was significantly correlated with BPC2, representing Mine Creek Bay species (i.e., better growth in Mine Creek Bay). The dominant benthic community gradient, BPC1, was related to the dominant sediment quality gradient (SPC1) which represents mine influence. Thus, the sediment features that drive toxicity (growth of test species) are different from those that drive benthic community composition. As noted in hypothesis testing (H1), relatively little toxicity was measured at Mattabi.

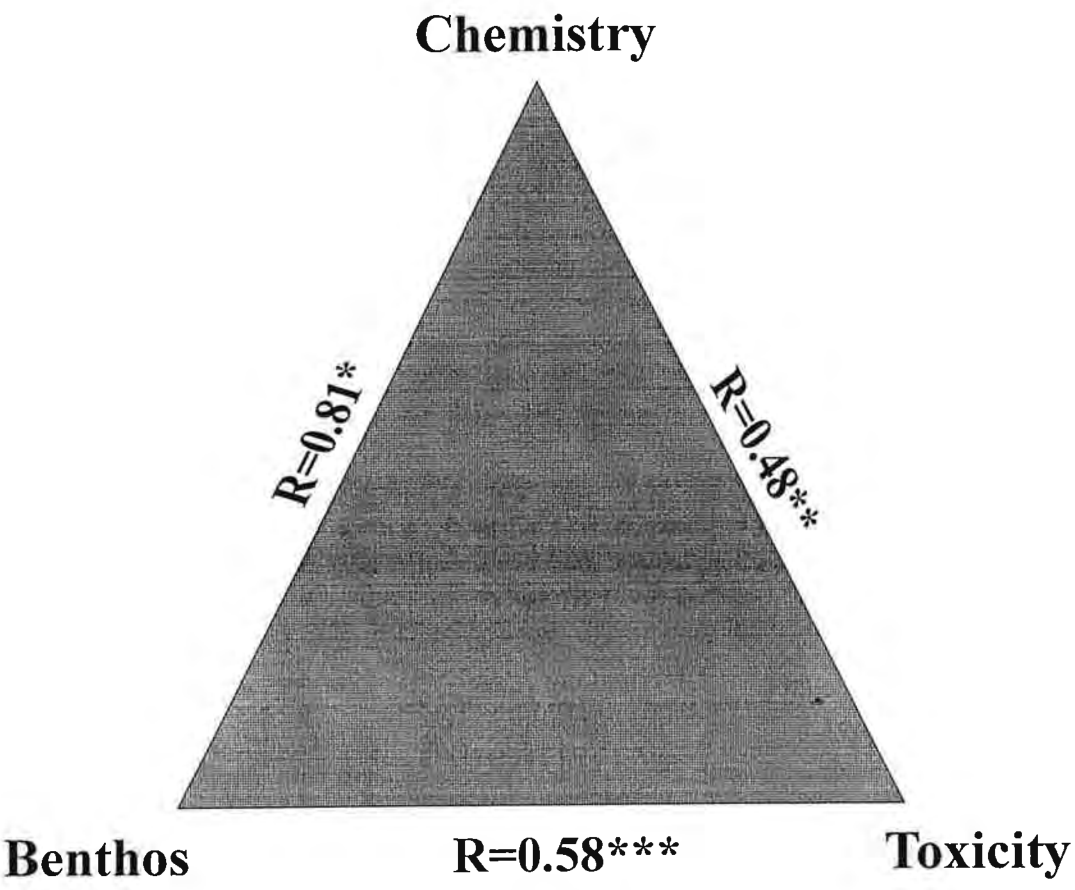
Based on Bartlett's sphericity test, and using only the dominant (mine-related) sediment quality and benthic community gradients, the sediment quality triad overall was significant. This demonstrates that chemistry, benthic and toxicity tools are linked, despite the weakness of the benthos-toxicity and chemistry-toxicity arms of the triad.

When the triad analysis was repeated using total rather than partial metals, the sediment-benthos arm of the triad was weakened and the other arms were not substantially altered relative to the partial metal triad (Figure 5.12). Results of this analysis are provided in



Benthic Macroinvertebrate PCA Results
Mattabi Mines Lake Stations

beak international incorporated	Figure 5.10	May 1998



Bartlett Sphericity Test = 28.8 (p<0.001)

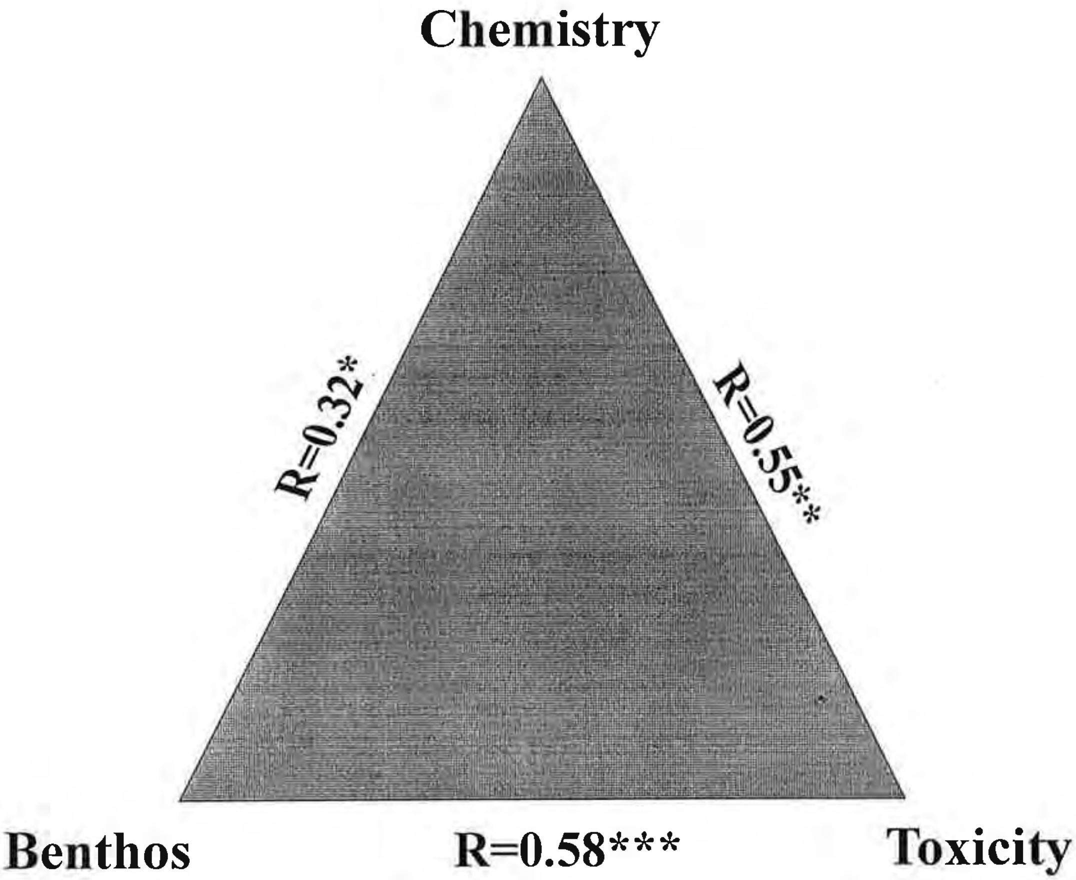
*** the relationship between sediment chemistry PCA Axis 1 and benthic PCA Axis 1 is statistically significant. Sediment PC 1 represents a gradient in metals (zinc, aluminum, nickel, iron and lead), dry bulk density, %moisture, %TOC and Eh. Benthic PC1 represents a gradient of sensitive to more tolerant organisms running from the high to low end of the axis.**

**** the relationship between sediment chemistry PCA Axis 1 and the toxicity tests (*Chironomus growth, Tubifex* young/adult and *Tubifex* %cocoons/adult) is not statistically significant. Sediment PCA 1 represents a gradient in metals (zinc, aluminum, nickel, iron and lead), dry bulk density, %moisture, %TOC and Eh.**

***** the relationship between benthic PCA Axis 1 and the toxicity tests (*Chironomus growth, Tubifex* young/adult and *Tubifex* %cocoons/adult) is not statistically significant.**

Triad Approach to Evaluate Mattabi Mine
Sediment Quality using Partial Metals

beak international incorporated	Figure 5.11	May 1998



Bartlett Sphericity Test = 13.5 (p<0.01)

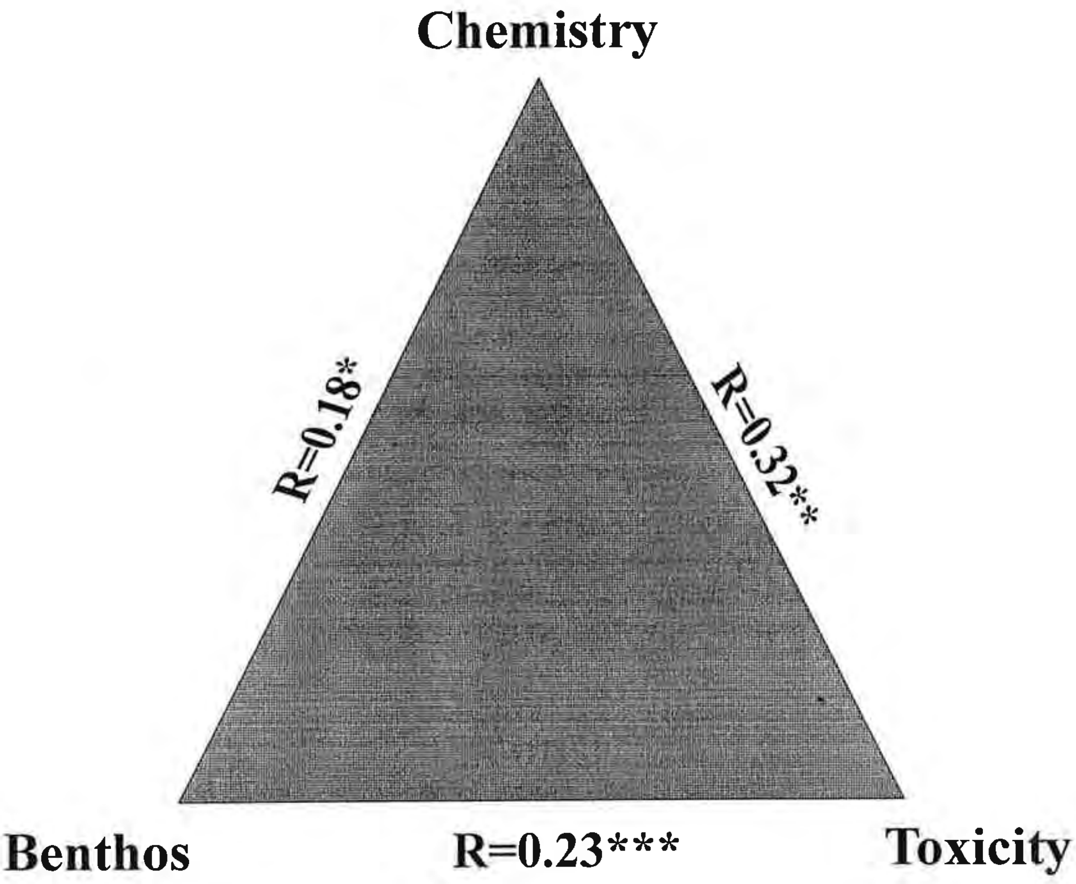
*** the relationship between sediment chemistry PCA Axis 1 and benthic PCA Axis 1 is not statistically significant. Sediment PCA 1 represents a gradient in metals (Zn, Fe, Cd, Cu, Ni, dry bulk density, Pb and Se), %moisture, %TOC and Eh. Benthic PC1 represents a gradient of sensitive to more tolerant organisms running from the high to low end of the axis.**

**** the relationship between sediment chemistry PCA Axis 1 and the toxicity tests (*Chironomus growth, Tubifex* young/adult and *Tubifex* %cocoons/adult) is not statistically significant. Sediment PCA 1 represents a gradient in metals (Zn, Fe, Cd, Cu, Ni, dry bulk density, Pb and Se), %moisture, %TOC and Eh.**

***** the relationship between benthic PCA Axis 1 and the toxicity tests (*Chironomus growth, Tubifex* young/adult and *Tubifex* %cocoons/adult) is not statistically significant.**

Triad Approach to Evaluate Mattabi Mine Sediment Quality using Total Metals

beak beak international incorporated	Figure 5.12	May 1998



Bartlett Sphericity Test = 3.19 ($p>0.05$)

*** the relationship between sediment (total) chemistry and the benthic community is not statistically significant.**

**** the relationship between sediment (total) chemistry and the toxicity tests is not statistically significant.**

***** the relationship between the benthic community and the toxicity tests is not statistically significant.**

Note: the 'R' as used here is equal to the $\sqrt{Z_M}$ presented in the table of Mantel results (Appendix 4), each Z_M is based on concordance of two euclidean distance matrices.

Triad Approach Using Mantel's Test to Evaluate Mattabi Mine Sediment (Total) Quality

beak international incorporated

Figure 5.13

May 1998

Appendix 7. The sediment quality triad with total metals overall was significant despite the fact that none of the arms using the major PC axes were significant.

To illustrate an alternate approach, Mantel's test was performed in parallel with the previous analysis. Results are illustrated in Figure 5.13. For each of the benthic community, sediment chemistry (total metals) and sediment toxicity datasets (appropriately transformed), euclidean distance matrices were derived indicating overall similarities between pairs of stations. Concordance between the three pairs of distance matrices (benthos-chemistry, benthos-toxicity and chemistry-toxicity) was tested using Mantel's test (10,000 iterations). Overall, results indicated that none of the associations across each of the arms of the triad (B-C, B-T, C-T) was statistically significant, and the Bartlett's Sphericity Test was not statistically significant ($p > 0.05$). This solution supports the conclusion that the triad is relatively weak at Mattabi.

6.0 EVALUATION OF AQUATIC EFFECTS TECHNOLOGIES

6.1 Introduction

The Mattabi Field Evaluation program evaluated several of the aquatic effects monitoring "tools" considered by the AETE program. These tools were evaluated through testing twelve of the thirteen hypotheses pertinent to the 1997 field program, as well as by examination of other tool performance indicators other than those specific to these hypotheses (e.g., sediment quality triad, chironomid deformities, other cause-effect relationships, practical aspects). To avoid repetition, the cost-effectiveness aspects of the monitoring technologies are considered collectively in a summary report on all four of the 1997 field sites, because costs for each specific technology were approximately equal at the four sites (BEAK and GOLDER, 1998b). The summary report also evaluates the overall effectiveness of each monitoring tool, based on the results of all four sites.

Monitoring tools may be organized within "tool boxes" under the four guiding questions formulated under the AETE program to develop the hypotheses tested (from Section 1.1):

1. Are contaminants getting into the system?
2. Are contaminants bioavailable?
3. Is there a measurable (biological) response? and
4. Are contaminants causing the response?

Tool boxes and monitoring tools may be categorized under these four questions. Some tools may logically fit under more than one question; for example, toxicity testing tools may fit under Questions 1, 2 or 3. Table 6.1 provides a reasonable framework for organization of these tools, although alternate frameworks may be equally valid.

The fourth question cannot be answered by the application of individual tools, unlike the first three questions. Rather, the fourth question can be answered only by integrating the use of tools between and among tool boxes through testing for statistical linkages between potential cause and effect variables (e.g., do chemical concentrations and biological measurements correlate with one another?). The most effective tools are clearly those used in combinations that provide a yes answer to Question No. 4. The sediment quality triad represents a means of addressing Question No. 4.

TABLE 6.1: GUIDING QUESTIONS, TOOL BOXES AND TOOLS CONSIDERED IN THE 1997 FIELD PROGRAM. TOOL BOXES AND TOOLS IN BOLD PRINT ARE SPECIFICALLY CONSIDERED AT MATTABI

Question	Tool Boxes	Tools
Are contaminants getting into the system?	**Water chemistry**	• **total metal concentrations** • **dissolved metal concentrations**
	Sediment chemistry	• **total metal concentrations** • **partial metal concentrations** • **acid volatile sulphide and sequentially extracted metals**
Are contaminants bioavailable?	**Fish tissues**	• **organ/tissue metal concentration** • **organ/tissue metallothionein concentration**
Is there a measurable response?	Effluent chronic toxicity[1]	• fathead minnow survival and growth test • *Ceriodaphnia dubia* (microcrustacean) survival and reproduction test • *Selenastrum capricornutum* (algae) growth test • *Lemna minor* (duckweed) growth test
	Sediment toxicity	• ***Chironomus riparius*** **(larval insect) survival and growth test** • ***Hyalella azteca*** **(crustacean) survival and growth test** • ***Tubifex tubifex*** **(aquatic worm) survival and reproduction test**
	Fish health indicators	• **fish growth (length, weight and age)** • **fish organ size, fecundity**
	Fish population/community health indicators	• **fish catch-per-unit-effort (CPUE - by species and total)** • **fish biomass-per-unit-effort (BPUE - by species and total)**
	Benthic community health indicators	• **densities of benthic invertebrates** • **numbers of benthic invertebrates** • **benthic community indices (e.g., EPT index)** • **frequency of chironomid deformity**
	Periphyton community health indicators	• periphyton community biomass • numbers of periphyton taxa
Are contaminants causing the response?	**Pair-wise combinations of the above tool boxes**	• **chemistry x biology tool correlations** • **toxicity x biology tool correlations** • **chemistry x toxicity tool correlations** • **Sediment Quality Triad**

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[1] Effluent chronic toxicity measured in the laboratory may also be categorized under Questions 1 or 2 (Are contaminants getting into the system?,or, Are contaminants bioavailable?).

The hypotheses are formulated to answer two general types of questions:

- Is the tool effective in measuring a mine effect (i.e., is there a reference - exposure difference or an exposure area gradient)?; and
- Is one tool more effective than another in measuring an effect?

The "effectiveness" of monitoring tools as discussed herein is specific to the Mattabi dataset. Mattabi represents one of four mine sites considered in the AETE 1997 Field Program, and only one of dozens of mine sites across Canada. A tool that is found to be of little value at Mattabi for detecting mine effects may be very useful at other sites and vice versa. Therefore, the reader is cautioned not to assume that the conclusions drawn from the Mattabi data will necessarily be broadly valid at mines across Canada. As shown in the AETE 1997 Field Program Summary Report (BEAK and GOLDER, 1998b), monitoring tools can respond very differently from site to site. Also, the presence or absence of a particular mine-related effect may simply reflect exposure level or bioavailability at the site. In the latter case, the absence of an effect may simply indicate that the tool was suitable for showing no effect.

6.2 Are Contaminants Getting Into the System?

6.2.1 Water Chemistry Tool Box

Hypothesis Testing Aspects

At Mattabi, water chemistry sampling in Bell Creek showed that metals were "getting into the system". This was demonstrated by elevated downstream concentrations in total and dissolved concentrations of several metals (e.g., zinc, copper, lead, cadmium, aluminum), and with increased selenium and cobalt concentrations measured in the effluent. In No Name Lake and Mine Creek Bay, sediment concentrations of cadmium, copper, lead and zinc clearly demonstrated that metals were getting into the system.

In testing of Hypotheses H9, elevated aqueous metal concentrations measured in Bell Creek were associated with enhanced fish size and fecundity at age. However, the effects observed for the most part were not consistent with an adverse impact, and the correlations may be a result of the C/I design and the responses more related to natural differences between reference and exposure areas. A few correlations were also observed between metal concentrations in water and tissue response (H12), with these responses more consistent with an exposure effect than noted for H9.

Other Considerations

The collection of dissolved metal samples according to the methods described in Annex 1 (provided under a separate cover) was not onerous, but required approximately five technician hours (additional relative to total metal samples) to filter and preserve the 18 samples (15 plus field duplicates and effluent samples).

The syringe and filter apparatus required, based on recommendations by chemists with the Geological Survey of Canada (GSC), were difficult to procure in Canada. Importation of the syringes from the U.S. required over one month due to delays at Canada Customs; thus, syringes were borrowed from GSC until delivery of our order. Availability of similar filtration materials necessary for ultra-trace metal work may be problematic in the future, requiring careful planning.

The commercial laboratory used required very specific instruction to provide sampling containers and filtration materials consistent with the specifications provided by GSC. For example, commercial laboratories often provide low density rather than high density polyethylene containers for metal samples, and may also provide containers with coloured lids such as "Falcon" tubes to consultants or mining companies. GSC has shown that such containers can contribute low levels of metals to water samples, and thus may not be suitable in aquatic effects monitoring where metal concentrations of interest are equal to or often below surface water quality guidelines.

The filtration procedure involved squeezing the water through a syringe-mounted filter, and was somewhat difficult and time-consuming due to the slow rate of filtration, rinsing requirements, etc. Also, where suspended solids levels are higher, filters became quickly clogged and required replacement.

Sample contamination was generally not apparent in the dissolved metal results, as dissolved metal concentrations were generally less than or equal to total metal concentrations (with exceptions occurring mainly at low concentrations near the detection limits).

To conclude, water chemistry (metal concentration) measurements were effective predictors of exposure at Mattabi. Neither total nor dissolved metal concentrations were more effective predictors of impacts in fish.

6.2.2 Sediment Chemistry Tool Box

Hypothesis Testing Aspects

In the exposure areas of No Name Lake and Mine Creek Bay, sediment concentrations of most metals demonstrated that contaminants were getting into the system. The gradients were most strongly demonstrated for total metals. The sediment chemistry tools of total metals, partial metals and SEM/AVS were evaluated through Hypotheses H10 by identifying reference versus exposure differences or concentration trends within the exposure gradient, and by examination of sediment metal correlations with biological responses (both benthic indices and sediment toxicity).

In general, reference-exposure differences and exposure area trends were observed for Zn, Cd, Cu, Pb, Ni and to a lesser degree for Hg and As.

Total metal and partial metal concentrations provided value in predicting biological effects in benthic communities or sediment toxicity. Neither total nor partial metals showed substantially better correlations with benthic community responses or toxicity, although correlations with total metals tended to be slightly superior in terms of the overall numbers of significant correlations. The SEM/AVS results did not show any significant correlation with the benthic metrics. There was only one weak correlation with a sublethal sediment toxicity response, but in the wrong direction, indicating that this sediment tool was not effective in predicting effects at Mattabi.

Other Considerations

Total metals and partial metals were similar in effectiveness in predicting biological effects, although the overall sediment quality triad was stronger when calculated with partial metals. The use of partial metals requires that the field crew have access to a freezer or dry ice since the samples have to be frozen after collection. The samples must also be kept frozen during transport to the analytical laboratory. In some field situations, this could increase the cost of sample collection, further decreasing the cost-effectiveness of this tool.

Sediment metal analyses may be more effective than aqueous metal analyses situations where aqueous metal concentrations are affected only sporadically (e.g., only in response to runoff or to intermittent effluent discharge), with concentrations approaching natural background between these impact events. This is because sediments will act to integrate metal loadings gradually over time while the water column may flush more rapidly.

The ineffectiveness of AVS and SEM determinations is perhaps not surprising, given the underlying assumptions in the SEM/AVS model. The SEM/AVS model relates the molar concentration ratio of potentially toxic simultaneously extracted metals (Cd, Cu, Pb, Ni, Zn) to the molar concentration of amorphous solid metal sulphide (predominantly FeS; Allen *et al.*, 1993). Where the SEM/AVS ratio is >1.0, some of the metals are not rendered unavailable by formation of metal sulphides and toxicity may occur (e.g., Long *et al.*, 1998). At lower ratio values, toxicity should not occur. In many mining-impacted sediments, including those in No Name Lake and Mine Creek Bay, metals are often introduced to the environment in complex metal sulphide minerals in tailings or other solids, and may not be controlled in their mobility by simple monosulphide forms. The potentially large fraction of sulphide mineral present and the uncertain behaviour of minerals such as pyrite (iron sulphide), sphaleride (zinc sulphide), chalcopyrite (copper sulphide) and galena (lead sulphide) in the extraction potentially introduces a major uncertainty relating to the assumptions associated with the SEM/AVS model.

6.3 Are Contaminants Bioavailable?

This question is answered through the measurement of metal bioaccumulation or biochemical responses to metal bioaccumulation (i.e., MT). Overall, the Mattabi results suggest that metals from the mine are sparingly bioavailable to fish in Bell Creek.

6.3.1 Tissue Metal Concentrations

Hypothesis Testing Aspects

The effectiveness of tissue metal concentrations as indicators of metal bioaccumulation is determined by the identification of differences between exposure and reference areas, with higher values in the exposure area indicating effectiveness. Tissues showing greater exposure-reference differences are considered more effective than those showing smaller differences for the same metal.

The relative affinities of metals for specific tissues tended to be the same in the two species. For example, copper accumulated principally in liver, cadmium and lead in kidney, and selenium in both liver and kidney in both species.

Reference-exposure area differences in tissue metal concentrations in sucker were evident only for Pb and Zn, and only in gill among the key metals associated with Mattabi (Zn, Cu, Pb, Cd). The degree of difference for Zn, in particular, is very small (<10% difference in area means; refer to Table 4.10). These results suggest that the principal metals from Mattabi are low in bioavailability (or are efficiently excreted) in white sucker. Selenium, however, was more concentrated in all tissues in exposed sucker (but not always in both sexes) and appeared to respond more effectively than any other metals; however, the connection of a selenium source with the mine is somewhat tenuous.

As in white sucker, the principal metals from Mattabi showed limited bioavailability in northern pike, with slightly greater tissue concentrations evident in the exposure area for Cd (muscle), Pb (gill and kidney) and Zn (muscle). As noted for sucker, Se and Co also appeared to respond, although for both metals a source linkage with Mattabi is not in strong evidence. Thus, tissue metal concentrations were apparently responsive to exposure in Mattabi pike, but only weakly so for the key metals. In neither species was a response in tissue copper observed.

Hypothesis 12, which compares correlations between metals in water and metals in fish tissues, showed significant correlations for Pb in liver of female sucker, and for Pb and Zn variously in gill, kidney and muscle of sucker and/or pike. These correlations are consistent with exposure-reference differences in H2. Hypothesis 12, however, is probably less effective in testing tissue metal tools for Pb than is H2, because of the large number of non-detect lead and chromium concentrations in the water quality data set. Correlations of tissue concentrations of Co and Se with waterborne levels could not be determined in H12 because these metals were below detection limits at most sites.

Other Considerations

From a practical standpoint, collection of tissues for metal analysis was not problematic, although more effort was required for fish collection and dissection than was necessary for small fish viscera at other mine sites in the 1997 AETE Field Program. The cold water conditions in October 1997 were conducive to maintaining viable fish for dissection, although viability was necessary for MT rather than for metals.

The correlations observed between concentrations of some metals in tissues and MT in tissues were good in some cases, especially in northern pike liver for Cu and the molar sum of Cd + Zn + Cu. These correlations imply cause-effect relationships within the tissues. The correlations between tissue metals and tissue MT in both species, especially in liver, imply metals and MT in liver effectively respond to accumulated metals, although the accumulation is not clearly connected with a mine effect as indicated previously.

6.3.2 Tissue Metallothionein Concentrations

Hypothesis Testing Aspects

The effectiveness of tissue MT concentrations as indicators of exposure to bioavailable metals from mine exposure is determined by identification of differences between exposure and reference areas, with higher values in the exposure area indicating effectiveness. Where more than one tissue type (gill, kidney, liver) shows a significantly elevated exposure area response, the tissue(s) having larger exposure-reference differences are identified as more effective.

At Mattabi, significant MT responses were found in northern pike only, with responses observed in gill and kidney. No response was identified for pike liver. This limited response in MT at Mattabi appears consistent with the limited metal bioaccumulation measured in Mattabi fish.

Other Considerations

The collection of tissues for MT analysis was not problematic, although the effort required for sample collection was greater than for fish viscera for other 1997 AETE field sites. The cold water conditions of October 1997 were conducive to maintaining fish viability until dissection, as required for MT. Maintenance of a dry ice supply was logistically difficult and expensive, with the supply delivered every three days by bus from Winnipeg to Ignace, and by taxi from Ignace to field headquarters.

Liver MT levels were strongly correlated with liver metal levels for Cu and the molar sum of Cd + Cu + Zn in northern pike. Similar correlations were not seen for other tissues.

This result implies a more effective MT response in liver than in other tissues once metal bioaccumulation occurs, although the metal source appears unrelated to Mattabi (i.e., liver Cd, Cu and Zn concentrations did not show a reference-exposure difference).

6.4 Is There A Measurable Effect?

The answer to this question is evaluated through Hypotheses H1, and H5 through H12. The hypotheses tested at Mattabi are based on a measurable effect in fish and benthos (H5 through H8) and on the integration of tools hypotheses (H9 through H11) which look for correlations between the measurable effect and the possible causal agents. Overall, the results suggest that the benthic community is affected by exposure, but that measurable sediment toxicity, as tested in H1, is not. Reasons for this paradox are unclear.

6.4.1 Sediment Toxicity

Hypothesis Testing Aspects

The effectiveness of sediment toxicity as an indicator of metal bioavailability is determined by the identification of differences in toxicity between reference and exposure areas and/or the occurrence of trends within the exposure areas (near-field to far-field). Effectiveness is also determined by the strength of correlations between possible causal agents (metals in sediment) and sediment toxicity and between sediment toxicity and the benthic community.

Sediment toxicity was evident in all three test species, including mortality and growth impairment in *Hyalella* and *Chironomus*, and reproductive impairment in *Tubifex*. However, none of these responses could be related to a mining effect in H1. Additionally, toxicity was not strongly correlated with sediment chemistry or associated with the SEM/AVS ratio. These results suggest that metals in exposure area sediments, although high in concentration, were low in bioavailability. Despite the general lack of strong linkages with sediment chemistry or with exposure to mine effects, some correlations were found between toxicity, especially *Tubifex* reproduction, and benthic response. These correlations may be spurious, as they are inconsistent with any toxicity-benthos linkage in the triad analysis, or with any other evidence. Overall, sediment toxicity generally responded poorly or not at all to sediment contamination at Mattabi.

These results underscore the importance of analyzing field reference sediments in evaluating sediment toxicity, because field references proved toxic in some cases.

Other Considerations

From a practical standpoint, sediment toxicity was readily assessed at Mattabi. *Hyalella* and *Chironomus* showed reduced survival in some sediments, while *Tubifex* showed no significant lethality response. *Tubifex* testing is not currently widely available from commercial laboratories. Commercial testing capability is widely available for sediment testing with *Chironomus* and *Hyalella*.

6.4.2 Benthic Community Health Indicators

Hypothesis Testing Aspects

Monitoring of benthic community parameters was effective in identifying response to mining effects in the exposure areas at Mattabi, with effects on total density, total numbers of taxa and on specific sensitive and tolerant indicator species. This effectiveness was evident in terms of reference-exposure differences and with respect to correlations with sediment metal concentrations in H10 and in the triad. No associations were seen between benthic indices and SEM/AVS results, suggesting that this is not an effective tool in predicting benthic effects at Mattabi.

Other Considerations

The collection of benthos for analysis at Mattabi was accomplished readily and required routine effort.

The incidence of chironomid deformity and abnormality, based on examination of mouth parts in mounted specimens, was low throughout the reference and exposure areas (Appendix 5), indicating that this tool would be ineffective in measuring biological responses to metals at Mattabi.

6.4.3 Fish Health Indicators

Hypothesis Testing Aspects

Fish health indicators, including community level indicators (catch/biomass-per-unit-effort, number of taxa) and population/individual level indicators (growth, organ size) were not rigorously tested at Mattabi owing to the limitations imposed by the C/I design.

Nonetheless, most of the fish health indicator evidence shows little negative impact of mine exposure on fish abundance or biomass, and effects on numbers of taxa are likely related to reference-exposure area habitat differences. When reference-exposure differences in fish growth were evident (northern pike), the differences did not support a metal impact conclusion (i.e., exposed fish grow faster). Similarly, liver weight, gonad weight and fecundity responses, which occurred in both species, did not support an adverse mine impact conclusion (i.e., exposed fish tended to have larger livers and gonads when adjusted for age and/or body weight).

Overall, the general absence of "negative" impacts on fish health, such as reduced abundance, growth or reproductive performance, are consistent with the results of fish tissue analyses. That is, tissue analyses imply that key metals from Mattabi are low in bioavailability, as measured by determination of tissue metal or MT concentration; accordingly, little deleterious impact should be expected.

Other Considerations

Fish measurements were readily taken and dissections readily performed in the field. The skill sets used here are the same as required in support of the adult fish survey of environmental effects monitoring programs for the pulp and paper industry.

Given that significant differences occurred in fish health indicators between the Mattabi reference and exposure areas, and that the differences do not support a mine impact conclusion, this indicates some important aspects with respect to the interpretation of these data. If the differences observed were exposure-related, then exposure to metals at non-toxic concentrations can potentially produce more robust fish. If the differences are unrelated to metal exposure and are simply in response to the sampling of distinct fish populations, then the probability is high at other sites of declaring a mine impact when the causes of the response differences are more likely associated with other (natural) factors. The probability is particularly high within a C/I study design framework such as implemented for fish at Mattabi.

6.5 Are Contaminants Causing the Responses?

As indicated previously, this question is not answered directly through the application of specific monitoring tools evaluated in this study, or through any of the hypotheses tested. Rather, the question is evaluated only by a weight-of-evidence provided by affirmative responses to the first three questions, and particularly by the strength of correlations between exposure indicators (chemical concentrations) and biological responses in hypotheses H9 through H12. Strong linkages between sediment chemistry, sediment toxicity and benthic community characteristics in the sediment quality triad would provide further support that contaminants cause the responses.

At Mattabi, evidence indicates that contaminants (metals) are getting into the system. However, analyses of fish tissues for metals and MT suggest that metals in Bell Creek are sparingly bioavailable. The biological responses observed in fish (growth, reproductive indicators, organ size) are generally not indicative of an adverse effect, a result that is consistent with low metal bioavailability.

If sediment toxicity can be considered to reflect bioavailability of metals in sediment, sediment metals at Mattabi are low in bioavailability (i.e., sediment toxicity was not strongly related to metal concentrations). This absence of strong metal-related toxicity is unusual, given the very high concentrations of metals such as zinc in the sediments.

Benthic community responses are evident and are associated with proximity to mine sources and with metal concentrations in sediments. This result implies that benthic responses are associated with contaminants and that benthic community responses can be more sensitive than sediment toxicity responses.

The sediment quality triad produced either weak or insignificant linkages between sediment chemistry, sediment toxicity and sediment biota, depending on the statistical solution and datasets used. The strongest linkage was found between partial metal concentrations and benthos. These results provide limited support for cause-effect relationships between chemistry and biota, chemistry and toxicity, and toxicity and biota. One may conclude that sediment metals are relatively low in bioavailability, to such an extent that other factors (e.g., minor grain size differences, natural "toxicants", etc.) tend to mask any impacts of sediment-associated metals.

Based on the above considerations, the Mattabi example serves to illustrate that metals released to the environment from mining activities can in some cases produce little impact, despite the presence of high concentrations in sediments and water. Hypotheses tested here also show that tools thought to better measure bioavailable metals (e.g., dissolved metals in water, partial metals in sediment) are not necessarily more effective than total water and sediment analyses.

6.6 Section Summary

Table 6.2 provides a summary of the effectiveness rankings of the aquatic monitoring tools evaluated at Mattabi. Table 6.3 compares the effectiveness of alternate tools that may be used to measure metal concentrations, metal bioavailability or biological response.

Some of the tools evaluated demonstrated a mine effect at Mattabi whereas others did not. Tools demonstrating or partially demonstrating effects at Mattabi included most in the water and sediment chemistry tool boxes (with the exception of SEM/AVS), most in the benthic community tool box, and some of the fish tissue and MT tools (i.e., all tissues were effective, but for few metals and with differences between species and sexes). Tools that did not demonstrate effects included several in the fish health, fish population/community, and sediment toxicity tool boxes. The limited effectiveness of some of these tools may be due to low metal bioavailability, possibly combined with small differences in habitat, food abundance, etc. Of the tools in the same tool box ranked as demonstrating effects, major differences in effectiveness were not evident at Mattabi. This indicates that cost-effectiveness will be important in evaluation of these tools. Cost-effectiveness is assessed in a separate summary report on the four 1997 field sites (Heath Steele, Myra Falls, Dome and Mattabi) (BEAK and GOLDER, 1998a).

A tool was considered to partially demonstrate an effect if it occurred with a limited number of endpoints, if the response was minimal, or if the response was in a direction inconsistent with adverse impact. For example, total and dissolved metals in water showed a partial effect in that they were unrelated to any adverse health impacts in fish, but did correspond with some fish tissue metal responses. Fish tissue metal concentrations were affected but in many cases not in terms of the key metals from the mine; thus, the effects were partially demonstrated. Liver weights adjusted for age were greater in exposed sucker and pike - an effect not clearly consistent with adverse impact and therefore considered a partial effect.

TABLE 6.2: EFFECTIVENESS OF MONITORING TOOLS TESTED AT MATTABI

		Effectiveness			
Tool Boxes	Tools	Effect Demonstrated	Effect Partially Demonstrated	Effect Not Demonstrated	Comment
Water Chemistry	Total Metals		√		Increased concentrations of Zn, Cu, Pb and Cd in exposure area. Se and Co source implied by effluent sample analysis. Increased concentrations appeared unrelated to any adverse effects on fish growth, community structure or organ size, but did show some relationships with tissue metal levels in fish.
	Dissolved Metals		√		
Sediment Chemistry	Total Metals	√			Gradients in exposure area evident, particularly for total Zn, Cu, Cd and Pb, but were weaker for partial metals. The corresponding correlations between partial metals and benthic responses were slightly weaker than those for total metals. Correlations occurred between sediment metals and the benthic community.
	Partial Metals		√		
	SEM/AVS			√	SEM/AVS was not correlated to biological impact or toxicity. Chemical determination may be confused by the abundance of complex metal sulphide minerals in sediments.
Sediment Toxicity	*Hyalella azteca, Chironomus riparius, Tubifex tubifex*			√	No response to mine-related effects. Mortality and growth responses occurred in *Hyalella* and *Chironomus*, and reproductive responses occurred in *Tubifex*, although effects were unrelated to Mattabi
Fish Tissues	**White Sucker**				
	Metals:				
	• Muscle		√		Unresponsive to mine exposure, except for Se. Evidence for a Se source in effluent is weak.
	• Liver		√		Unresponsive to mine exposure except for Se in females; weak correlations between liver MT and liver Zn, liver MT and liver Cu+Zu+Cu.
	• Gill	√			Responsive with respect to Pb, Zn and molar sum of Cd+Cu+Zn. No positive gill metal correlations with gill MT were found.
	• Kidney		√		Unresponsive to mine exposure, except for Se. No positive kidney metal correlations with kidney MT were found.

TABLE 6.2: EFFECTIVENESS OF MONITORING TOOLS TESTED AT MATTABI (cont'd)

		Effectiveness			
Tool Boxes	Tools	Effect Demonstrated	Effect Partially Demonstrated	Effect Not Demonstrated	Comment
Fish Tissues (cont'd)	**Northern Pike**				
	Metals:				
	• Muscle	√			Responsive for Cd, Zn, Se (both sexes). Evidence for a Se source at mine is weak.
	• Liver		√		Unresponsive to mine exposure except for Se. Liver MT strongly correlated with liver metals for Cu and Cd+Cu+Zn.
	• Gill	√			Responsive for Pb, Co and Se. Meaningful correlations between liver MT and liver metals were not evident.
	• Kidney	√			Responsive for Pb, Co (both sexes) and Se (females only). Evidence for Se and Co source at mine is weak. Weak correlation between kidney MT and kidney lead.
	White Sucker MT				
	• Liver			√	Liver MT unresponsive to mine exposure. Correlated with hepatic Zn and Cu+Zn+Cd.
	• Gill			√	Gill and kidney unresponsive to mine exposure. No positive correlations between gill/kidney MT and gill/kidney metals.
	• Kidney			√	
	Northern Pike MT				
	• Liver			√	Hepatic MT unresponsive to exposure. Strong correlations between hepatic metals (Cu, Cd+Cu+Zn) and MT.
	• Gill	√			Gill and kidney responsive to mine exposure. Positive correlations between gill/kidney MT and tissue metals were absent or weak.
	• Kidney	√			

TABLE 6.2: EFFECTIVENESS OF MONITORING TOOLS TESTED AT MATTABI (cont'd)

		Effectiveness			
Tool Boxes	Tools	Effect Demonstrated	Effect Partially Demonstrated	Effect Not Demonstrated	Comment
Fish Health Indicators	**Body Size and Age (Growth)**				
	• White sucker			√	No difference in weight at age for reference and exposure fish.
	• Northern pike			√	Exposed fish not negatively affected, but much larger at age. Fish condition (weight at length) unaffected.
	Liver Weight				
	• White sucker		√		Liver weight (adjusted for age or body weight) greater for male exposure fish. Nature of "effect" not clearly mine-related.
	• Northern pike		√		Larger liver weights (at age or body weight) in exposed females, and males (at age only). Nature of effect not clearly mine-related.
	Gonad Weight				
	• White sucker		√		Body weight-adjusted gonad weight slightly reduced in exposed males (potential mine-related effect).
	• Northern pike			√	Larger gonad weights for exposed fish. Effects not clearly mine-related.
	Fecundity				
	• White sucker			√	No difference in fecundity at age or body weight.
	• Northern pike			√	Greater fecundity at age but not at body weight. Effects not clearly mine-related.
Fish Population/ Community Health Indicators	**CPUE**				
	• White sucker			√	CPUE was slightly (but not significantly) greater in exposure area. Effect not clearly related to exposure.
	• Northern pike			√	CPUE for pike was comparable in reference and exposure areas.
	• All fish species			√	CPUE for all fish was comparable in reference and exposure areas.

TABLE 6.2: EFFECTIVENESS OF MONITORING TOOLS TESTED AT MATTABI (cont'd)

Tool Boxes	Tools	Effectiveness			Comment
		Effect Demonstrated	Effect Partially Demonstrated	Effect Not Demonstrated	
	BPUE				
	• White sucker			√	BPUE was comparable in reference and exposure areas for sentinel species and all fish.
	• Northern pike			√	
	• All fish species			√	
	Number of species			√	Numbers of species in catches were greater in reference area than exposure, owing to presence of coregonids exclusively in the reference. This is believed to be due to a habitat effect unrelated to exposure.
Benthic Community Health Indicators	Benthic Density	√			Exposure-reference difference and exposure area trend observed.
	No. of Taxa		√		Exposure area trend observed, but no reference-exposure area difference.
	Abundances of Indicator Species	√			Reference-exposure differences and exposure area trends evident in *Chironomus*, *Pisidium* and Hydracarina abundances.

TABLE 6.3: COMPARATIVE EFFECTIVENESS OF MONITORING TOOLS AT MATTABI

Tools	Comparison
Total Metals vs Dissolved Metals in Water	Total and dissolved metal concentrations approximately equal in reflecting elevated metal concentrations. Concentrations of both appeared unrelated to most biological effects, although some correlations occurred between metal concentrations and tissue response.
Total Metals, Partial Metals and SEM/AVS in Sediment	Total and partial metals were, on average, similar in reflecting benthic effects, with total metals slightly better correlated than partial metals. Total metals also better reflected mine gradients (showing "contaminants getting into the system"). The SEM/AVS ratio was unrelated to benthic effects or sediment toxicity.
Sediment Toxicity Tests	None of the tests indicated mine-related impact (i.e., reference-exposure differences or exposure area gradients). *Tubifex* was not effective as a survival test. Absence of mine-related sediment toxicity precluded more rigorous evaluation of tests.
Benthic Community Health Indicators (density, no. of taxa, indicator taxa)	Several indices indicated mine-related impact including total density, no. of taxa, and abundance of Hydracarina, *Chironomus* and *Pisidium*. Of these indicators, number of taxa and % Hydracarina were most strongly correlated with sediment metal concentrations.
Fish Tissues - Metals	In sucker and pike, no tissue was clearly superior in responding to mine exposure overall. In sucker, gill was the only tissue responding to any of the major Mattabi metals. In pike, gill, kidney and muscle all responded in terms of some of the major metals. Liver responded effectively to bioaccumulated Cu+Cd+Zn and Cu in pike, but metal source in liver unrelated to mine exposure.
Fish Tissues - Metallothionein	In sucker, MT levels did not respond to mine exposure in any tissues. In pike, gill and kidney were responsive to exposure. Pike liver from all reference-exposure fish responded to accumulated metals (Cu, Cd+Cu+Zn) but response unrelated to mine exposure.
Fish Tissues - Metals vs Metallothionein	In the only tissues where MT and metals both responded to exposure (gill and kidney in pike), MT and tissue metals responded similarly. For MT and tissue metals overall, effects were more often demonstrated for metals than for MT.
Fish Health Indicators	Among the responses observed (growth, condition, liver weight, gonad weight, fecundity), most were inconsistent with adverse mine effects. A small reduction in gonad size in exposed male sucker could be construed as a mine effect. Liver weight increases in both male sucker and in pike, gonad weight increases in pike and increased somatic growth in pike are all less obviously related to mine exposure.
Fish Population/Community Health Indicators	Neither CPUE, BPUE nor numbers of fish taxa were responsive to mine exposure.

Overall, the relatively subdued impacts of metals in the environment near Mattabi are unexpected and noteworthy. This result contrasts with the greater bioavailability and impact observed at the two other base metal mines studied in this program (Heath Steele, Myra Falls). This is particularly unusual considering that metal concentrations in sediments (e.g., Zn) at Mattabi are at higher concentrations than measured at other locations.

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APPENDIX 1

Quality Assurance/Quality Control

BEAK MEMO

To: **Paul McKee, Project Manager**
Dennis Farara, Project Manager

From: Pierre Stecko, QA Officer

Ref: **AETE 1997 - Mattabi Mine Data QA Report**

Date: May 29, 1998

We have reviewed the 1997 AETE data collected from the Mattabi mine and have conducted a data quality assessment (DQA) in comparison to the data quality objectives (DQO) outlined in the Quality Management Plan (QMP). A summary of the results of the data quality assessment is presented below, categorized by study.

Water Chemistry - Conventional and Aggregate Parameters (Table A1.1)

Trip blanks (there were no field blanks taken at Mattabi) met DQOs in all cases. There were no DQOs set for laboratory precision for water chemistry. However, we assessed the data for parameters with >50% difference between replicates and duplicates (as a percentage of the mean). **NO FLAGS.**

Water Chemistry - Metals and Nutrients (Table A1.1)

Trip blanks (there were no field blanks taken at Mattabi) met specified DQOs. However, very low, but detectable concentrations of total zinc occurred in the trip blank (up to 4 μg/L), suggesting that some contribution from the deionized water, the fixing or analysis reagents, or the sample jars (or lids) may have occurred. No nutrients, and only one metal exhibited differences greater than 50% between laboratory replicates or field duplicates. **FLAG:** Dissolved lead at MMR1 was flagged for variability between field duplicates. It should be noted that this flag occurs near the limit of quantitation, where further resolution is low.

Sediment

a) Total Metals (Table A1.2)

Recovery of total metals in matrix spikes varied from 78 to 120%, while the DQO for laboratory accuracy was 10% (i.e., 90 to 110% recovery). DQOs for laboratory precision were not exceeded for the key metals considered in this study. **FLAGS:** Recovery of barium (MMS5-1 [78%]; MMSR1-2 [120%]; MMS1-3 [71%]), beryllium (MMSR1-2; 120%), boron (MMSR1-2 [87%]; MMS1-3 [89%]), cadmium (MMS1-3; 120%), lead (MMSR1-2; 120%) and silver (MMS5-1 [89%]; MMS1-3 [82%]). In addition, DQOs for laboratory precision between replicates (10%) was exceeded for bismuth, boron and tin in the MMS5-1 field duplicate; calcium and magnesium at MMS5-2; for antimony and tin at MMSR1-2; and for beryllium and boron at MMS1-2. In addition, we assessed the data for parameters with >50% difference between field duplicates (as a percentage of the mean). Based on this assessment, particle size and tin are flagged at MMS5-1; and particle size and beryllium are flagged at MMS1-3.

b) Partial Extraction (Table A1.3)

Recovery of metals extracted with NH_2OH-HCl in 25% (v/v) acetic acid in matrix spikes varied from 89 to 120%, while the DQO for laboratory accuracy was 10% (i.e., 90 to 110% recovery). There are no flags for laboratory accuracy for the key metals considered in this study. **FLAGS:** Barium (MMS5-1; 89%), beryllium (120% at MMS5-1 and MMS1-3), and selenium (120% at MMS5-1 and MMS1-3).

In addition, precision was assessed with laboratory duplicates (i.e., samples that were split and digested separately in the laboratory). There are no DQOs for laboratory duplicates, however, we assessed the data for parameters with > 50% difference between laboratory duplicates. The only flag from this assessment was for titanium at MMS1-3.

c) Simultaneously Extracted Metals (Table A1.4)

The concentration of metals extracted with the acid volatile sulphides was assessed for laboratory precision in two laboratory duplicates (i.e., samples that were split and digested separately in the laboratory). Although no DQO was specified for precision among laboratory duplicates, the data was assessed for variability of greater than 50%. None of the key metals (cadmium, copper, nickel, lead and zinc) are flagged. **FLAG.** Boron at MMS5-2.

d) Comparisons of Metal Concentrations in Different Extracts

The amount of metal mobilized by the different extractants was checked for discrepancies. Total metals were assessed using a nitric acid and peroxide mix. To determine the comparability to Canadian Sediment Quality Guidelines (which are developed for metals extracted with aqua regia), some samples were extracted with aqua regia for comparison. The two methods compared well, although some significant differences were flagged for beryllium and molybdenum (Table A1.5). Concentrations removed by the partial extraction were always lower than those removed by the aqua regia and total extraction, consistent with the weaker nature of the extractant used. There were some inconsistencies in the comparison of simultaneously extracted metals and total metals (i.e., SEM were often greater than total metals; Table A1.6). These inconsistencies may be due to the wet extraction, whereby errors can be introduced in sub-sampling for the estimate of the wet/dry ratio (i.e., if a particularly wet sub-sample is taken, metals concentration of a dry weight basis will be overestimated).

Sediment Toxicity (Table A1.7)

Control mortality was always below the specified DQO of 30%. In addition, we reviewed coefficients of variation for the controls, variation between initial test and re-tests and the reference toxicant results (control charts). **FLAGS:** Variability between re-tests for *Chironomus riparius* exceeded 50% for survival and growth at MMS4-3, and for growth at MMS3-2 and MMSR1-3. Variability between re-tests for *Hyalella azteca* exceeded 50% for growth and survival at MMS4-3.

Table A1.1: Mattabi Water Chemistry QA/QC

Analysis of Water			EXPOSURE STATIONS					
Parameter	LOQ	Units	MM2 Total	MM2 Total Field Dup	**DQA (% diff) vs. FD**	MM2 Dissolved	MM2 Dissolved Field Dup	**DQA (% diff) vs. FD**
Acidity(as CaCO3)	1	mg/L	4	4	**0.00**	-	-	-
Alkalinity(as CaCO3)	1	mg/L	29	27	**7.14**	-	-	-
Aluminum	0.005	mg/L	0.006	0.006	**0.00**	nd	nd	-
Ammonia(as N)	0.05	mg/L	nd	0.05	-	-	-	-
Anion Sum	na	meq/L	1.04	0.998	**4.12**	-	-	-
Antimony	0.0005	mg/L	nd	nd	-	nd	nd	-
Arsenic	0.002	mg/L	nd	nd	-	nd	nd	-
Barium	0.005	mg/L	0.009	0.009	**0.00**	0.007	0.007	**0.00**
Beryllium	0.005	mg/L	nd	nd	-	nd	nd	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	29	27	**7.14**	-	-	-
Bismuth	0.002	mg/L	nd	nd	-	nd	nd	-
Boron	0.005	mg/L	0.04	0.029	**31.88**	nd	nd	-
Cadmium	0.00005	mg/L	nd	nd	-	nd	nd	-
Calcium	0.1	mg/L	13.9	14.9	**6.94**	14.8	14.5	**2.05**
Carbonate(as CaCO3, calculated)	1	mg/L	nd	nd	-	-	-	-
Cation Sum	na	meq/L	1.03	1.01	**1.96**	-	-	-
Chloride	1	mg/L	nd	nd	-	-	-	-
Chromium	0.0005	mg/L	nd	nd	-	nd	nd	-
Cobalt	0.0002	mg/L	nd	nd	-	nd	nd	-
Colour	5	TCU	8	8	**0.00**	-	-	-
Conductivity - @25øC	1	us/cm	106	106	**0.00**	-	-	-
Copper	0.0003	mg/L	0.0016	0.0018	**11.76**	0.0019	0.002	**5.13**
Dissolved Inorganic Carbon(as C)	0.2	mg/L	-	-	-	5.8	6.2	**6.67**
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	-	4.9	5.5	**11.54**
Hardness(as CaCO3)	0.1	mg/L	47	46.3	**1.50**	-	-	-
Ion Balance	0.01	%	0.62	0.77	**21.58**	-	-	-
Iron	0.02	mg/L	0.05	0.06	**18.18**	nd	nd	-
Langelier Index at 20øC	na	na	-0.907	-0.894	**1.44**	-	-	-
Langelier Index at 4øC	na	na	-1.31	-1.29	**1.54**	-	-	-
Lead	0.0001	mg/L	0.0001	0.0001	**0.00**	nd	0.0001	-
Magnesium	0.1	mg/L	2.3	2.4	**4.26**	2.5	2.4	**4.08**
Manganese	0.0005	mg/L	0.0049	0.0046	**6.32**	0.001	0.0008	**22.22**
Mercury (total)	0.0001	mg/L	nd	nd	-	-	-	-
Mercury (dissolved)	0.0001	mg/L	-	-	-	nd	nd	-
Molybdenum	0.0001	mg/L	nd	nd	-	nd	nd	-
Nickel	0.001	mg/L	nd	nd	-	nd	nd	-
Nitrate(as N)	0.05	mg/L	nd	nd	-	-	-	-
Nitrite(as N)	0.01	mg/L	nd	nd	-	-	-	-
Orthophosphate(as P)	0.01	mg/L	nd	nd	-	-	-	-
pH	0.1	Units	7.9	7.9	**0.00**	-	-	-
Phosphorus	0.1	mg/L	nd	nd	-	nd	nd	-
Phosphorus, Total	0.01	mg/L	nd	nd	-	-	-	-
Potassium	0.5	mg/L	0.5	nd	-	nd	nd	-
Reactive Silica(SiO2)	0.5	mg/L	1.5	1.5	**0.00**	-	-	-
Saturation pH at 20øC	na	units	8.8	8.83	**0.34**	-	-	-
Saturation pH at 4øC	na	units	9.2	9.23	**0.33**	-	-	-
Selenium	0.002	mg/L	nd	nd	-	nd	nd	-
Silver	0.00005	mg/L	nd	nd	-	nd	nd	-
Sodium	0.1	mg/L	2.1	1.9	**10.00**	2	1.9	**5.13**
Strontium	0.005	mg/L	0.028	0.027	**3.64**	0.027	0.027	**0.00**
Sulphate	2	mg/L	21	21	**0.00**	-	-	-
Thallium	0.0001	mg/L	nd	nd	-	nd	nd	-
Tin	0.002	mg/L	nd	nd	-	nd	nd	-
Titanium	0.002	mg/L	nd	nd	-	nd	nd	-
Total Dissolved Solids(Calculated)	1	mg/L	-	-	-	60	58	**3.39**
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.22	0.18	**20.00**	-	-	-
Total Suspended Solids	1	mg/L	nd	nd	-	-	-	-
Turbidity	0.1	NTU	0.3	0.3	**0.00**	-	-	-
Uranium	0.0001	mg/L	nd	nd	-	nd	nd	-
Vanadium	0.002	mg/L	nd	nd	-	nd	nd	-
Zinc	0.001	mg/L	0.014	0.016	**13.33**	0.013	0.014	**7.41**
Fluoride	0.02	mg/L	nd	nd	-	-	-	-

Table A1.1: Mattabi Water Chemistry QA/QC

Analysis of Water			REFERENCE STATIONS								
Parameter	LOQ	Units	MMR1 Total	MMR1 Total Lab Rep	**DQA (% diff) vs. LR**	MMR1 Total Field Dup	**DQA (% diff) vs. FD**	**DQA (% diff) LR vs. FD**	MMR1 Total Field Dup2	**DQA (% diff) vs. FD2**	**DQA (% diff) FD vs. FD2**
Acidity(as CaCO3)	1	mg/L	2	na	-	2	**0.00**	-	-	-	-
Alkalinity(as CaCO3)	1	mg/L	28	29	**3.51**	29	**3.51**	**0.00**	-	-	-
Aluminum	0.005	mg/L	0.005	-	-	0.005	**0.00**	-	-	-	-
Ammonia(as N)	0.05	mg/L	nd	nd	-	nd	-	-	-	-	-
Anion Sum	na	meq/L	1.03	-	-	1.04	**0.97**	-	-	-	-
Antimony	0.0005	mg/L	nd	-	-	nd	-	-	-	-	-
Arsenic	0.002	mg/L	nd	-	-	nd	-	-	-	-	-
Barium	0.005	mg/L	0.007	-	-	0.008	**13.33**	-	-	-	-
Beryllium	0.005	mg/L	nd	-	-	nd	-	-	-	-	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	28	-	-	29	**3.51**	-	-	-	-
Bismuth	0.002	mg/L	nd	-	-	nd	-	-	-	-	-
Boron	0.005	mg/L	0.015	-	-	0.01	**40.00**	-	0.008	**60.87**	**22.22**
Cadmium	0.00005	mg/L	nd	-	-	nd	-	-	-		-
Calcium	0.1	mg/L	13.7	-	-	13.8	**0.73**	-	13.9	**1.45**	**0.72**
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	-	nd	-	-	-	-	-
Cation Sum	na	meq/L	1.05	-	-	1.05	**0.00**	-	-	-	-
Chloride	1	mg/L	nd	nd	-	nd	-	-	-	-	-
Chromium	0.0005	mg/L	nd	-	-	nd	-	-	-	-	-
Cobalt	0.0002	mg/L	nd	-	-	nd	-	-	-	-	-
Colour	5	TCU	16	16	**0.00**	12	**28.57**	**28.57**	-	-	-
Conductivity - @25øC	1	us/cm	112	na	-	105	**6.45**	-	-	-	-
Copper	0.0003	mg/L	0.002	-	-	0.0013	**42.42**	-	-	-	-
Dissolved Inorganic Carbon(as C)	0.2	mg/L	-	-	-	-	-	-	-	-	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	-	-	-	-	-	-	-
Hardness(as CaCO3)	0.1	mg/L	48.4	-	-	48.5	**0.21**	-	-	-	-
Ion Balance	0.01	%	0.92	-	-	0.76	**19.05**	-	-	-	-
Iron	0.02	mg/L	0.05	-	-	0.05	**0.00**	-	-	-	-
Langelier Index at 20øC	na	na	-1.24	-	-	-1.23	**0.81**	-	-	-	-
Langelier Index at 4øC	na	na	-1.64	-	-	-1.63	**0.61**	-	-	-	-
Lead	0.0001	mg/L	nd	-	-	nd	-	-	-	-	-
Magnesium	0.1	mg/L	2.3	-	-	2.3	**0.00**	-	2.3	**0.00**	**0.00**
Manganese	0.0005	mg/L	0.0026	-	-	0.0026	**0.00**	-	-	-	-
Mercury (total)	0.0001	mg/L	nd	-	-	nd	-	-	-	-	-
Mercury (dissolved)	0.0001	mg/L	-	-	-	-	-	-	-	-	-
Molybdenum	0.0001	mg/L	nd	-	-	nd	-	-	-	-	-
Nickel	0.001	mg/L	nd	-	-	nd	-	-	-	-	-
Nitrate(as N)	0.05	mg/L	nd	nd	-	nd	-	-	-	-	-
Nitrite(as N)	0.01	mg/L	nd	nd	-	nd	-	-	-	-	-
Orthophosphate(as P)	0.01	mg/L	nd	nd	-	nd	-	-	-	-	-
pH	0.1	Units	7.6	na	-	7.6	**0.00**	-	-	-	-
Phosphorus	0.1	mg/L	nd	-	-	nd	-	-	nd	-	-
Phosphorus, Total	0.01	mg/L	-	-	-	-	-	-	-	-	-
Potassium	0.5	mg/L	0.8	-	-	0.8	**0.00**	-	0.6	**28.57**	**28.57**
Reactive Silica(SiO2)	0.5	mg/L	1.6	1.5	**6.45**	1.6	**0.00**	**6.45**	-	-	-
Saturation pH at 20øC	na	units	8.8	-	-	8.78	**0.23**	-	-	-	-
Saturation pH at 4øC	na	units	9.2	-	-	9.18	**0.22**	-	-	-	-
Selenium	0.002	mg/L	nd	-	-	nd	-	-	-	-	-
Silver	0.00005	mg/L	nd	-	-	nd	-	-	-	-	-
Sodium	0.1	mg/L	2	-	-	2	**0.00**	-	2	**0.00**	**0.00**
Strontium	0.005	mg/L	0.027	-	-	0.028	**3.64**	-	-	-	-
Sulphate	2	mg/L	21	21	**0.00**	21	**0.00**	**0.00**	-	-	-
Thallium	0.0001	mg/L	nd	-	-	nd	-	-	-	-	-
Tin	0.002	mg/L	nd	-	-	nd	-	-	-		-
Titanium	0.002	mg/L	nd	-	-	nd	-	-	-	-	-
Total Dissolved Solids(Calculated)	1	mg/L	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.18	0.2	**10.53**	0.21	**15.38**	**4.88**	-	-	-
Total Suspended Solids	1	mg/L	nd	nd	-	nd	-	-	-	-	-
Turbidity	0.1	NTU	0.5	0.4	**22.22**	0.3	**50.00**	**28.57**	-	-	-
Uranium	0.0001	mg/L	nd	-	-	nd	-	-	-	-	-
Vanadium	0.002	mg/L	nd	-	-	nd	-	-	-	-	-
Zinc	0.001	mg/L	0.006	-	-	0.006	**0.00**	-	-	-	-
Fluoride	0.02	mg/L	nd	nd	-	nd	-	-	-	-	-

Table A1.1: Mattabi Water Chemistry QA/QC

Analysis of Water			REFERENCE STATIONS				
Parameter	LOQ	Units	MMR1 Dissolved	MMR1 Dissolved Lab Rep	DQA (% diff) vs. LR	MMR1 Dissolved Field Dup	DQA (% diff) vs. FD
Acidity(as CaCO3)	1	mg/L	-	-	-	-	-
Alkalinity(as CaCO3)	1	mg/L	-	-	-	-	-
Aluminum	0.005	mg/L	nd	-	-	nd	-
Ammonia(as N)	0.05	mg/L	-	-	-	-	-
Anion Sum	na	meq/L	-	-	-	-	-
Antimony	0.0005	mg/L	nd	-	-	nd	-
Arsenic	0.002	mg/L	nd	-	-	nd	-
Barium	0.005	mg/L	0.007	-	-	0.007	**0.00**
Beryllium	0.005	mg/L	nd	-	-	nd	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	-	-	-	-
Bismuth	0.002	mg/L	nd	-	-	nd	-
Boron	0.005	mg/L	nd	nd	-	nd	-
Cadmium	0.00005	mg/L	nd	-	-	nd	-
Calcium	0.1	mg/L	15.3	15	**1.98**	15.3	**0.00**
Carbonate(as CaCO3, calculated)	1	mg/L	-	-	-	-	-
Cation Sum	na	meq/L	-	-	-	-	-
Chloride	1	mg/L	-	-	-	-	-
Chromium	0.0005	mg/L	nd	-	-	nd	-
Cobalt	0.0002	mg/L	nd	-	-	nd	-
Colour	5	TCU	-	-	-	-	-
Conductivity - @25øC	1	us/cm	-	-	-	-	-
Copper	0.0003	mg/L	0.0008	-	-	0.0011	**31.58**
Dissolved Inorganic Carbon(as C)	0.2	mg/L	5.9	5.9	**0.00**	6	**1.68**
Dissolved Organic Carbon(DOC)	0.5	mg/L	5.3	4.9	**7.84**	5.1	**3.85**
Hardness(as CaCO3)	0.1	mg/L	-	-	-	-	-
Ion Balance	0.01	%	-	-	-	-	-
Iron	0.02	mg/L	nd	-	-	nd	-
Langelier Index at 20øC	na	na	-	-	-	-	-
Langelier Index at 4øC	na	na	-	-	-	-	-
Lead	0.0001	mg/L	0.0002	-	-	0.0001	**66.67**
Magnesium	0.1	mg/L	2.5	2.5	**0.00**	2.5	**0.00**
Manganese	0.0005	mg/L	nd	-	-	nd	-
Mercury (total)	0.0001	mg/L	-	-	-	-	-
Mercury (dissolved)	0.0001	mg/L	nd	nd	-	nd	-
Molybdenum	0.0001	mg/L	nd	-	-	nd	-
Nickel	0.001	mg/L	nd	-	-	nd	-
Nitrate(as N)	0.05	mg/L	-	-	-	-	-
Nitrite(as N)	0.01	mg/L	-	-	-	-	-
Orthophosphate(as P)	0.01	mg/L	-	-	-	-	-
pH	0.1	Units	-	-	-	-	-
Phosphorus	0.1	mg/L	nd	nd	-	nd	-
Phosphorus, Total	0.01	mg/L	0.01	nd	-	nd	-
Potassium	0.5	mg/L	nd	nd	-	nd	-
Reactive Silica(SiO2)	0.5	mg/L	-	-	-	-	-
Saturation pH at 20øC	na	units	-	-	-	-	-
Saturation pH at 4øC	na	units	-	-	-	-	-
Selenium	0.002	mg/L	nd	-	-	nd	-
Silver	0.00005	mg/L	nd	-	-	nd	-
Sodium	0.1	mg/L	1.9	2	**5.13**	1.9	**0.00**
Strontium	0.005	mg/L	0.026	-	-	0.027	**3.77**
Sulphate	2	mg/L	-	-	-	-	-
Thallium	0.0001	mg/L	nd	-	-	nd	-
Tin	0.002	mg/L	nd	-	-	nd	-
Titanium	0.002	mg/L	nd	-	-	nd	-
Total Dissolved Solids(Calculated)	1	mg/L	61	-	-	60	**1.65**
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	-	-	-
Total Suspended Solids	1	mg/L	-	-	-	-	-
Turbidity	0.1	NTU	-	-	-	-	-
Uranium	0.0001	mg/L	nd	-	-	nd	-
Vanadium	0.002	mg/L	nd	-	-	nd	-
Zinc	0.001	mg/L	0.008	-	-	0.006	**28.57**
Fluoride	0.02	mg/L	-	-	-	-	-

Table A1.1: Mattabi Water Chemistry QA/QC

Analysis of Water			REFERENCE STATIONS						BLANKS	
Parameter	LOQ	Units	MMR2 Total	MMR2 Total Lab Rep	**DQA (% diff) vs. LR**	MMR2 Dissolved	MMR2 Dissolved Lab Rep	**DQA (% diff) vs. LR**	Trip Blank Total	Trip Blank Dissolved
Acidity(as CaCO3)	1	mg/L	4	4	**0.00**	-	-	-	2	-
Alkalinity(as CaCO3)	1	mg/L	27	27	**0.00**	-	-	-	1	-
Aluminum	0.005	mg/L	0.028	0.028	**0.00**	0.014	0.014	0.00	nd	nd
Ammonia(as N)	0.05	mg/L	nd	nd	-	-	-	-	0.07	-
Anion Sum	na	meq/L	0.566	-	-	-	-	-	0.034	-
Antimony	0.0005	mg/L	nd	nd	-	nd	nd	-	nd	nd
Arsenic	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Barium	0.005	mg/L	0.007	0.007	**0.00**	0.006	0.006	0.00	nd	nd
Beryllium	0.005	mg/L	nd	nd	-	nd	nd	-	nd	nd
Bicarbonate(as CaCO3, calculated)	1	mg/L	27	-	-	-	-	-	1	-
Bismuth	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Boron	0.005	mg/L	nd	nd	-	nd	nd	-	0.006	nd
Cadmium	0.00005	mg/L	nd	nd	-	nd	nd	-	nd	nd
Calcium	0.1	mg/L	7.9	8.1	**2.50**	8.2	9.4	**13.64**	0.7	nd
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	-	-	-	-	nd	-
Cation Sum	na	meq/L	0.615	-	-	-	-	-	0.011	-
Chloride	1	mg/L	nd	nd	-	-	-	-	nd	-
Chromium	0.0005	mg/L	0.0005	0.0005	**0.00**	nd	nd	-	nd	nd
Cobalt	0.0002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Colour	5	TCU	32	32	**0.00**	-	-	-	nd	-
Conductivity - @25øC	1	us/cm	58	ns	-	-	-	-	7	-
Copper	0.0003	mg/L	nd	nd	-	0.0008	0.0007	**13.33**	nd	0.0005
Dissolved Inorganic Carbon(as C)	0.2	mg/L	-	-	-	5.1	5.2	**1.94**	-	nd
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	-	-	11.9	11.9	**0.00**	-	nd
Hardness(as CaCO3)	0.1	mg/L	27.5	-	-	-	-	-	nd	-
Ion Balance	0.01	%	4.15	-	-	-	-	-	49.7	-
Iron	0.02	mg/L	0.13	0.13	0.00	0.03	0.02	**40.00**	nd	nd
Langelier Index at 20øC	na	na	-1.51	-	-	-	-	-	-6.39	-
Langelier Index at 4øC	na	na	-1.91	-	-	-	-	-	-6.79	-
Lead	0.0001	mg/L	0.0003	0.0002	**40.00**	nd	nd	-	nd	nd
Magnesium	0.1	mg/L	1.6	1.7	**6.06**	1.7	1.9	**11.11**	nd	nd
Manganese	0.0005	mg/L	0.025	0.0254	**1.59**	0.0009	0.0009	**0.00**	nd	nd
Mercury (total)	0.0001	mg/L	nd	nd	-	-	-	-	nd	-
Mercury (dissolved)	0.0001	mg/L	-	-	-	nd	nd	-	-	nd
Molybdenum	0.0001	mg/L	nd	nd	-	nd	nd	-	nd	nd
Nickel	0.001	mg/L	nd	nd	-	nd	nd	-	nd	nd
Nitrate(as N)	0.05	mg/L	nd	nd	-	-	-	-	nd	-
Nitrite(as N)	0.01	mg/L	nd	nd	-	-	-	-	nd	-
Orthophosphate(as P)	0.01	mg/L	nd	nd	-	-	-	-	nd	-
pH	0.1	Units	7.6	7.8	**2.60**	-	-	-	6.3	-
Phosphorus	0.1	mg/L	nd	nd	-	nd	nd	-	nd	nd
Phosphorus, Total	0.01	mg/L	0.03	0.03	**0.00**	-	-	-	-	nd
Potassium	0.5	mg/L	nd	nd	-	nd	nd	-	nd	nd
Reactive Silica(SiO2)	0.5	mg/L	2.6	2.8	**7.41**	-	-	-	nd	-
Saturation pH at 20øC	na	units	9.07	-	-	-	-	-	12.7	-
Saturation pH at 4øC	na	units	9.47	-	-	-	-	-	13.1	-
Selenium	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Silver	0.00005	mg/L	nd	nd	-	nd	nd	-	nd	nd
Sodium	0.1	mg/L	1	1.1	**9.52**	1.2	1.3	**8.00**	nd	nd
Strontium	0.005	mg/L	0.018	0.018	**0.00**	0.017	0.018	**5.71**	nd	nd
Sulphate	2	mg/L	nd	nd	-	-	-	-	nd	-
Thallium	0.0001	mg/L	nd	nd	-	nd	nd	-	nd	nd
Tin	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Titanium	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Total Dissolved Solids(Calculated)	1	mg/L	-	-	-	32	-	-	-	1
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	1.44	1.39	**3.53**	-	-	-	0.06	-
Total Suspended Solids	1	mg/L	7	8	**13.33**	-	-	-	nd	-
Turbidity	0.1	NTU	1.9	1.9	**0.00**	-	-	-	0.2	-
Uranium	0.0001	mg/L	nd	nd	-	nd	nd	-	nd	nd
Vanadium	0.002	mg/L	nd	nd	-	nd	nd	-	nd	nd
Zinc	0.001	mg/L	0.001	0.001	**0.00**	0.002	0.002	0.00	0.004	nd
Fluoride	0.02	mg/L	nd	nd	-	-	-	-	nd	-

Table A1.2: Mattabi Sediment QA/QC - Total Metals

Component	MDL	Units	MMS2-1	MMS2-1 Replicate	DQA (% diff) vs. R	MMS5-1	MMS5-1 Replicate	DQA (% diff) vs. R	MMS5-1 M. Spike	MMS5-1 MS % Rec.	MMS5-1 Field Dup	DQA (% diff) vs. FD	MMS5-1 LR of FD	DQA (% diff) vs. LR of FD
Aluminum	1	mg/kg	6300	-	-	6600	-	-	-	-	5300	**21.85**	5600	**16.39**
Antimony	0.2	mg/kg	16	-	-	5.9	-	-	-	-	6.2	**4.96**	6.3	**6.56**
Arsenic	0.5	mg/kg	41	-	-	14	-	-	-	-	14	**0.00**	14	**0.00**
Barium	0.5	mg/kg	56	-	-	59	-	-	-	-	63	**6.56**	64	**8.13**
Beryllium	0.2	mg/kg	0.7	-	-	1.2	-	-	-	-	<	-	<	-
Bismuth	0.5	mg/kg	2.8	-	-	1.3	-	-	-	-	1.3	**0.00**	1.5	**14.29**
Boron	2.5	mg/kg	10	-	-	11	-	-	-	-	9.2	**17.82**	8	**31.58**
Cadmium	0.05	mg/kg	43	-	-	13	-	-	-	-	14	**7.41**	14	**7.41**
Chromium	0.6	mg/kg	14	-	-	15	-	-	-	-	13	**14.29**	14	**6.90**
Cobalt	0.2	mg/kg	36	-	-	10	-	-	-	-	9.1	**9.42**	9.1	**9.42**
Copper	0.2	mg/kg	1600	-	-	620	-	-	-	-	600	**3.28**	590	**4.96**
Iron	20	mg/kg	16000	-	-	12000	-	-	-	-	11000	**8.70**	11000	**8.70**
Lead	0.1	mg/kg	870	-	-	340	-	-	-	-	350	**2.90**	360	**5.71**
Manganese	1	mg/kg	540	-	-	230	-	-	-	-	210	**9.09**	210	**9.09**
Molybdenum	0.2	mg/kg	6.2	-	-	1.3	-	-	-	-	1.5	**14.29**	1.4	**7.41**
Nickel	0.5	mg/kg	50	-	-	24	-	-	-	-	21	**13.33**	22	**8.70**
Selenium	1	mg/kg	23	-	-	4.1	-	-	-	-	5.1	**21.74**	5.3	**25.53**
Silver	0.05	mg/kg	13	-	-	7.1	-	-	-	-	7.4	**4.14**	8	**11.92**
Strontium	0.5	mg/kg	21	-	-	22	-	-	-	-	24	**8.70**	25	**12.77**
Thallium	0.2	mg/kg	1.2	-	-	0.2	-	-	-	-	0.2	**0.00**	0.2	**0.00**
Tin	0.2	mg/kg	2.2	-	-	4.6	-	-	-	-	3.7	**21.69**	2.7	**52.05**
Titanium	0.3	mg/kg	200	-	-	230	-	-	-	-	180	**24.39**	190	**19.05**
Vanadium	1	mg/kg	13	-	-	13	-	-	-	-	11	**16.67**	11	**16.67**
Zinc	1	mg/kg	15000	-	-	2600	-	-	-	-	2100	**21.28**	2100	**21.28**
Calcium	20	mg/kg	11262.5	-	-	11335	-	-	-	-	11630	**2.57**	11710	**3.25**
Magnesium	20	mg/kg	3360	-	-	3010	-	-	-	-	2942.5	**2.27**	2945	**2.18**
Loss on Ignition	0.1	(%)	48	49	**2.06**	51	-	-	-	-	51	**0.00**	52	**1.94**
Coarse Gravel (>4.8mm)	0.1	(%)	<	-	-	<	-	-	-	-	<	-	-	-
Fine Gravel (2.0-4.8mm)	0.1	(%)	4	-	-	3.6	-	-	-	-	3	**18.18**	-	-
V. Coarse Sand (1.0-2.0mm)	0.1	(%)	1.3	-	-	1.5	-	-	-	-	1.7	**12.50**	-	-
Coarse Sand (0.50-1.0mm)	0.1	(%)	21	-	-	22	-	-	-	-	31	**33.96**	-	-
Med. Sand (0.25-0.50mm)	0.1	(%)	22	-	-	26	-	-	-	-	15	**53.66**	-	-
Fine Sand (0.10-0.25mm)	0.1	(%)	22	-	-	24	-	-	-	-	2.8	**158.21**	-	-
V. Fine Sand (0.050-0.10mm)	0.1	(%)									0.9	-	-	-
Silt (0.002-0.050mm)	0.1	(%)									34	-	-	-
Clay (<0.002mm)	0.1	(%)									11	-	-	-
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	(%)	31	-	-	23	-	-	-	-	-	-		-
Mercury	0.04	mg/kg	0.78	-	-	0.38	0.36	**5.41**	1.3	93	0.28	**30.30**	-	-
TOC (Solid)	0.1	(%)	23	-	-	25	-	-	-	-	24	**4.08**	-	-

Table A1.2: Mattabi Sediment QA/QC - Total Metals

Component	MDL	Units	DQA (% diff) FD vs. LR of FD	MMS5-1 FD M. Spike	MMS5-1 FD MS % Rec.	MMS5-2	MMS5-2 Replicate	DQA (% diff) vs. R	MMSR1-2	MMSR1-2 Replicate	DQA (% diff) vs. R	MMSR1-2 M. Spike	MMSR1-2 MS % Rec.
Aluminum	1	mg/kg	**5.50**	NA	<	6100	-	-	3900	4300	**9.76**	NA	<
Antimony	0.2	mg/kg	**1.60**	57	100	8.5	-	-	0.9	0.5	**57.14**	55	110
Arsenic	0.5	mg/kg	**0.00**	490	96	20	-	-	3.9	3.6	**8.00**	57	110
Barium	0.5	mg/kg	**1.57**	100	78	53	-	-	44	43	**2.30**	110	120
Beryllium	0.2	mg/kg	-	480	96	0.2	-	-	<	<	-	48	96
Bismuth	0.5	mg/kg	**14.29**	52	100	1.9	-	-	<	<	-	54	110
Boron	2.5	mg/kg	**13.95**	460	90	8.3	-	-	7.1	6.8	**4.32**	51	87
Cadmium	0.05	mg/kg	**0.00**	63	99	14	-	-	1.6	1.5	**6.45**	30	110
Chromium	0.6	mg/kg	**7.41**	470	92	14	-	-	11	11	**0.00**	58	94
Cobalt	0.2	mg/kg	**0.00**	480	94	11	-	-	2.7	2.7	**0.00**	50	94
Copper	0.2	mg/kg	**1.68**	1100	97	980	-	-	43	42	**2.35**	94	100
Iron	20	mg/kg	**0.00**	NA	<	13000	-	-	4700	5000	**6.19**	NA	<
Lead	0.1	mg/kg	**2.82**	NA	<	540	-	-	26	25	**3.92**	84	120
Manganese	1	mg/kg	**0.00**	700	99	250	-	-	56	59	**5.22**	110	110
Molybdenum	0.2	mg/kg	**6.90**	52	100	1.2	-	-	1.6	1.5	**6.45**	57	110
Nickel	0.5	mg/kg	**4.65**	500	96	24	-	-	18	18	**0.00**	67	97
Selenium	1	mg/kg	**3.85**	490	96	6.2	-	-	3.2	3.1	**3.17**	57	110
Silver	0.05	mg/kg	**7.79**	30	89	11	-	-	0.16	0.15	**6.45**	NA	<
Strontium	0.5	mg/kg	**4.08**	76	100	20	-	-	11	11	**0.00**	70	120
Thallium	0.2	mg/kg	**0.00**	50	100	0.2	-	-	<	<	-	53	110
Tin	0.2	mg/kg	**31.25**	53	100	1.4	-	-	0.7	0.8	**13.33**	55	110
Titanium	0.3	mg/kg	**5.41**	660	94	210	-	-	110	120	**8.70**	170	110
Vanadium	1	mg/kg	**0.00**	470	91	12	-	-	6.5	7	**7.41**	53	92
Zinc	1	mg/kg	**0.00**	3100	100	3400	-	-	330	320	**3.08**	NA	<
Calcium	20	mg/kg	**0.69**	-	-	11387.5	9197.5	**21.28**	9020	-	-	-	-
Magnesium	20	mg/kg	**0.08**	-	-	3092.5	2565	**18.65**	2920	-	-	-	-
Loss on Ignition	0.1	(%)	**1.94**	-	-	50	52	**3.92**	60	-	-	-	-
Coarse Gravel (>4.8mm)	0.1	(%)	-	-	-	<	-	-	<	-	-	-	-
Fine Gravel (2.0-4.8mm)	0.1	(%)	-	-	-	6.1	-	-	4.8	-	-	-	-
V. Coarse Sand (1.0-2.0mm)	0.1	(%)	-	-	-	1.8	-	-	3.4	-	-	-	-
Coarse Sand (0.50-1.0mm)	0.1	(%)	-	-	-	18	-	-	26	-	-	-	-
Med. Sand (0.25-0.50mm)	0.1	(%)	-	-	-	20	-	-	33	-	-	-	-
Fine Sand (0.10-0.25mm)	0.1	(%)	-	-	-	18	-	-	26	-	-	-	-
V. Fine Sand (0.050-0.10mm)	0.1	(%)	-	-	-								
Silt (0.002-0.050mm)	0.1	(%)	-	-	-								
Clay (<0.002mm)	0.1	(%)	-	-	-			-			-		
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	(%)	-			36	-	-	7.8	-	-	-	-
Mercury	0.04	mg/kg	-	-	-	0.46	-	-	0.09	-	-	-	-
TOC (Solid)	0.1	(%)	-	-	-	26	-	-	27	-	-	-	-

Table A1.2: Mattabi Sediment QA/QC - Total Metals

Component	MDL	Units	MMS1-2	MMS1-2 Replicate	DQA (% diff) vs. R	MMS1-2 M. Spike	MMS1-2 MS % Rec.	MMS1-3	MMS1-3 Replicate	DQA (% diff) vs. R	MMS1-3 M. Spike	MMS1-3 MS % Rec.	MMS1-3 Field Dup	DQA (% diff) vs. FD
Aluminum	1	mg/kg	11000	11000	0.00	NA	<	12000	NA	-	NA	<	11000	8.70
Antimony	0.2	mg/kg	15	16	6.45	66	100	20	NA	-	67	94	19	5.13
Arsenic	0.5	mg/kg	150	150	0.00	620	95	160	NA	-	640	98	160	0.00
Barium	0.5	mg/kg	55	56	1.80	100	98	69	NA	-	100	71	64	7.52
Beryllium	0.2	mg/kg	0.5	0.4	22.22	480	95	0.4	NA	-	460	93	0.7	54.55
Bismuth	0.5	mg/kg	4.1	4	2.47	50	92	5.8	NA	-	52	93	5.2	10.91
Boron	2.5	mg/kg	13	10	26.09	470	91	11	NA	-	450	89	12	8.70
Cadmium	0.05	mg/kg	100	110	9.52	150	97	140	NA	-	160	120	130	7.41
Chromium	0.6	mg/kg	16	16	0.00	480	93	17	NA	-	480	92	16	6.06
Cobalt	0.2	mg/kg	62	64	3.17	530	93	67	NA	-	540	96	64	4.58
Copper	0.2	mg/kg	2300	2300	0.00	2800	89	2500	NA	-	NA	<	2500	0.00
Iron	20	mg/kg	33000	33000	0.00	NA	<	36000	NA	-	NA	<	35000	2.82
Lead	0.1	mg/kg	1300	1300	0.00	NA	<	1700	NA	-	NA	<	1700	0.00
Manganese	1	mg/kg	2000	2000	0.00	2500	98	1600	NA	-	2200	100	1600	0.00
Molybdenum	0.2	mg/kg	1.8	1.8	0.00	52	100	2.3	NA	-	52	100	2	13.95
Nickel	0.5	mg/kg	81	82	1.23	560	95	86	NA	-	570	96	83	3.55
Selenium	1	mg/kg	17	16	6.06	500	97	17	NA	-	510	98	16	6.06
Silver	0.05	mg/kg	17	17	0.00	39	90	13	NA	-	33	82	19	37.50
Strontium	0.5	mg/kg	19	19	0.00	74	110	23	NA	-	73	100	22	4.44
Thallium	0.2	mg/kg	1.1	1.1	0.00	48	93	1.4	NA	-	49	94	1.4	0.00
Tin	0.2	mg/kg	4.6	3.7	21.69	54	100	6.8	NA	-	55	96	5	30.51
Titanium	0.3	mg/kg	190	190	0.00	670	96	220	NA	-	700	96	210	4.65
Vanadium	1	mg/kg	18	18	0.00	480	93	20	NA	-	480	92	19	5.13
Zinc	1	mg/kg	42000	43000	2.35	NA	<	45000	NA	-	NA	<	40000	11.76
Calcium	20	mg/kg	9315	8952.5	3.97	-	-	9075	8690	4.33	-	-	8350	8.32
Magnesium	20	mg/kg	4890	4665	4.71	-	-	4985	4590	8.25	-	-	4590	8.25
Loss on Ignition	0.1	(%)	39	-	-	-	-	38	38	0.00	-	-	39	2.60
Coarse Gravel (>4.8mm)	0.1	(%)	<	-	-	-	-	<	-	-	-	-	<	-
Fine Gravel (2.0-4.8mm)	0.1	(%)	1.1	-	-	-	-	<	-	-	-	-	1.3	-
V. Coarse Sand (1.0-2.0mm)	0.1	(%)	2.1	-	-	-	-	<	-	-	-	-	1.3	-
Coarse Sand (0.50-1.0mm)	0.1	(%)	19	-	-	-	-	21	-	-	-	-	11	62.50
Med. Sand (0.25-0.50mm)	0.1	(%)	22	-	-	-	-	19	-	-	-	-	6	104.00
Fine Sand (0.10-0.25mm)	0.1	(%)	25	-	-	-	-	21	-	-	-	-	2.5	157.45
V. Fine Sand (0.050-0.10mm)	0.1	(%)											22	100.00
Silt (0.002-0.050mm)	0.1	(%)											45	100.00
Clay (<0.002mm)	0.1	(%)											11	100.00
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	(%)	31	-	-	-	-	39	-	-	-	-		100.00
Mercury	0.04	mg/kg	1.3	-	-	-	-	1.5	1.5	0.00	-	-	1.4	6.90
			-1		100.00									
TOC (Solid)	0.1	(%)	19	-	-	-	-	19	-	-	-	-	20	5.13

Table A1.3: Mattabi Sediment QA/QC - Partially Extracted Metals

Component	**MDL**	**Units**	MMS5-1	MMS5-1 Lab Duplicate	**DQA (% diff) vs. LD**	MMS5-1 M. Spike	MMS5-1 MS % Rec.	MMS1-3	MMS1-3 Lab Duplicate	**DQA (% diff) vs. LD**	MMS1-3 M. Spike	MMS1-3 MS % Rec.
Aluminum (ext.)	1	mg/kg	600	610	**1.65**	NA	NA	2300	2100	**9.09**	NA	NA
Antimony (ext.)	0.2	mg/kg	<	<	**-**	21	110	<	<	**-**	22	110
Arsenic (ext.)	0.5	mg/kg	2.7	2.6	**3.77**	110	110	2.7	2	**29.79**	110	110
Barium (ext.)	0.5	mg/kg	22	20	**9.52**	39	89	27	21	**25.00**	42	93
Beryllium (ext.)	0.2	mg/kg	<	<	**-**	120	120	0.2	0.2	**0.00**	120	120
Bismuth (ext.)	0.5	mg/kg	<	<	**-**	22	110	<	<	**-**	22	110
Cadmium (ext.)	0.05	mg/kg	2.5	2.3	**8.33**	23	100	0.2	0.13	**42.42**	21	100
Chromium (ext.)	0.6	mg/kg	2.2	2.2	**0.00**	98	96	3.9	3.6	**8.00**	99	95
Cobalt (ext.)	0.2	mg/kg	0.8	0.8	**0.00**	94	94	9.9	8.5	**15.22**	100	93
Copper (ext.)	0.2	mg/kg	1.7	2.8	**48.89**	96	93	0.2	0.2	**0.00**	93	93
Iron (ext.)	20	mg/kg	1200	1200	**0.00**	NA	NA	3700	3200	**14.49**	NA	NA
Lead (ext.)	0.1	mg/kg	39	32	**19.72**	54	95	30	19	**44.90**	46	100
Manganese (ext.)	1	mg/kg	140	140	**0.00**	NA	NA	890	820	**8.19**	NA	NA
Molybdenum (ext.)	0.2	mg/kg	<	<	**-**	21	100	<	<	**-**	20	100
Nickel (ext.)	0.5	mg/kg	1.7	1.7	**0.00**	96	94	20	18	**10.53**	110	92
Selenium (ext.)	1	mg/kg	<	<	**-**	120	120	<	<	**-**	120	120
Silver (ext.)	0.05	mg/kg	<	<	**-**	9.4	94	<	<	**-**	5.5	110
Strontium (ext.)	0.5	mg/kg	11	10	**9.52**	31	100	10	8.4	**17.39**	30	100
Thallium (ext.)	0.2	mg/kg	<	<	**-**	22	110	<	<	**-**	22	110
Tin (ext.)	0.2	mg/kg	<	<	**-**	20	100	<	<	**-**	19	97
Titanium (ext.)	0.3	mg/kg	0.6	0.4	**40.00**	97	97	0.7	0.4	**54.55**	96	95
Vanadium (ext.)	1	mg/kg	4.5	4.5	**0.00**	99	95	8.3	7.8	**6.21**	100	93
Zinc (ext.)	1	mg/kg	740	760	**2.67**	NA	NA	3800	3000	**23.53**	NA	NA
Calcium	20	mg/kg	6492	6362	**2.02**	-	-	4814	4610	**4.33**	-	-
Magnesium	20	mg/kg	834	829	**0.60**	-	-	1200	1138	**5.32**	-	-

Table A1.4: Mattabi Sediment QA/QC - Simultaneously Extracted Metals

Component	MDL	Units	MMS5-2	MMS5-2 Lab Duplicate	DQA (% diff) vs. LD	MMS1-1	MMS1-1 Lab Duplicate	DQA (% diff) vs. LD
Aluminum	2	umol/g	294.6	319.1		455.9	540.3	**16.95**
Barium	0.1	umol/g	0.7	0.8	**6.45**	0.7	0.9	**16.67**
Beryllium	0.1	umol/g	<	<	-	<	<	-
Boron	1	umol/g	12.9	50.2	**118.45**	12.2	17.3	**34.29**
Cadmium	0.05	umol/g	<	<	-	<	<	-
Calcium	7	umol/g	578.3	561.8	**2.90**	386.5	466.0	**18.67**
Chromium	0.1	umol/g	<	<	-	<	<	-
Cobalt	0.2	umol/g	<	<	-	1.7	1.9	**12.77**
Copper	0.1	umol/g	9.7	9.6	**1.08**	20.8	19.4	**7.14**
Iron	0.2	umol/g	166.2	178.0	**6.90**	351.1	432.7	**20.83**
Lead	0.4	umol/g	<	<	-	<	<	-
Magnesium	3	umol/g	152.2	157.1	**3.17**	155.4	185.7	**17.82**
Manganese	0.1	umol/g	9.2	9.2	**0.00**	107.9	132.8	**20.69**
Molybdenum	0.1	umol/g	<	<	-	<	<	-
Nickel	0.2	umol/g	<	<	-	1.9	1.8	**4.26**
Potassium	10	umol/g	<	<	-	<	<	-
Silver	0.1	umol/g	<	<	-	<	<	-
Sodium	6	umol/g	<	46.1	-	39.6	49.5	**22.22**
Strontium	0.1	umol/g	0.4	0.5	**11.97**	0.3	0.4	**23.45**
Sulphur	3	umol/g	33.0	35.1	**6.06**	46.8	49.7	**5.88**
Thallium	0.5	umol/g	<	<	-	<	<	-
Tin	0.5	umol/g	<	<	-	<	<	-
Titanium	0.3	umol/g	6.6	7.2	**8.00**	3.5	3.9	**10.26**
Vanadium	0.1	umol/g	<	<	-	0.5	0.5	**5.22**
Zinc	0.1	umol/g	58.7	58.7	**0.00**	975.2	1184.2	**19.35**
Zirconium	0.5	umol/g	<	<	-	<	<	-
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			68.4	68.3	**0.15**	997.9	1205.4	**18.83**
AV Sulphide	0.1		68.0	67.0	**1.48**	1416.0	1556.0	**9.42**
SEM/AVS Ratio			1.0	1.0	**1.33**	0.7	0.8	**9.45**

Table A1.5: Mattabi Sediment - Comparison of Aqua Regia Metals to Total Metals

Component	MDL	Units	MMSR1-1 Tot	MMSR1-1 AR	% difference	MMS1-2 Tot	MMS1-2 AR	% difference	MMS1-2 AR Lab Rep	MMS1-2 AR M. Spike	MMS1-2 AR MS % Rec.
Aluminum	30	mg/kg	5200	4500	**14.43**	11000	9700	**12.56**	9800	11000	690
Barium	0.2	"	43	40	**7.23**	55	55	**0.00**	55	160	110
Beryllium	0.1	"	0.2	0.1	**66.67**	0.5	0.3	**50.00**	0.3	52	100
Boron	10	"	9.1	<	-	13	11	**16.67**	11	110	99
Cadmium	0.2	"	1.8	1.7	**5.71**	100	97	**3.05**	97	150	110
Calcium	20	"	-	9200	-	-	8500	-	8200	9600	130
Chromium	5	"	12	12	**0.00**	16	15	**6.45**	16	120	110
Cobalt	5	"	3.1	<	-	62	60	**3.28**	61	170	110
Copper	5	"	51	52	**1.94**	2300	2600	**12.24**	2500	2700	130
Iron	5	"	6100	6200	**1.63**	33000	34000	**2.99**	34000	37000	220
Lead	10	"	25	22	**12.77**	1300	1300	**0.00**	1300	1400	130
Magnesium	40	"	-	2400	-	-	4100	-	4000	5700	150
Manganese	5	"	62	63	**1.60**	2000	2100	**4.88**	2000	2200	170
Molybdenum	1	"	1.5	2	**28.57**	1.8	19	**165.38**	18	68	99
Nickel	5	"	19	17	**11.11**	81	82	**1.23**	84	140	100
Phosphorus	50	"	-	1700	-	-	1200	-	1200	1700	94
Potassium	100	"	-	890	-	-	950	-	960	2100	110
Silicon	10	"	-	730	-	-	790	-	860	1100	290
Silver	0.5	"	0.26	<	-	17	19	**11.11**	18	71	100
Sodium	50	"	-	140	-	-	370	-	350	1400	110
Strontium	0.1	"	13	14	**7.41**	19	19	**0.00**	19	73	110
Sulphur	10	"	-	6700	-	-	47000	-	47000	48000	1500
Thallium	20	"	<	<	-	1.1	<	-	<	110	100
Tin	5	"	0.4	<	-	4.6	<	-	<	96	92
Titanium	5	"	170	200	**16.22**	190	210	**10.00**	200	330	130
Vanadium	10	"	8.3	<	-	18	19	**5.41**	19	72	110
Zinc	5	"	450	430	**4.55**	42000	39000	**7.41**	39000	40000	450
Zirconium	5	"	-	<	-	-	<	-	<	18	17

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	MDL	Units	MMS2-1 SEM	MMS2-1 Tot	MMS2-2 SEM	MMS2-2 Tot	MMS2-3 SEM	MMS2-3 Tot
Aluminum	2	mg/kg	11044	6300	6695	6200	5489	6600
Barium	0.1	mg/kg	117	56	75	44	58	58
Beryllium	0.1	mg/kg	<	0.7	<	0.2	<	0.2
Boron	1	mg/kg	245	10	109	8.6	72	7
Cadmium	0.05	mg/kg	<	43	<	32	<	63
Chromium	0.1	mg/kg	<	14	<	13	<	14
Cobalt	0.2	mg/kg	<	36	<	29	38	49
Copper	0.1	mg/kg	1104	1600	628	1200	755	1700
Iron	0.2	mg/kg	14122	16000	8375	14000	7210	17000
Lead	0.4	mg/kg	<	870	<	600	<	990
Manganese	0.1	mg/kg	1166	540	628	430	584	540
Molybdenum	0.1	mg/kg	<	6.2	<	4.9	<	6.1
Nickel	0.2	mg/kg	<	50	59	48	34	56
Silver	0.1	mg/kg	<	13	<	8.4	<	10
Strontium	0.1	mg/kg	44	21	28	17	20	21
Thallium	0.5	mg/kg	<	1.2	<	0.8	<	1.3
Tin	0.5	mg/kg	<	2.2	<	1.4	<	1.5
Titanium	0.3	mg/kg	387	200	230	190	182	200
Vanadium	0.1	mg/kg	<	13	<	12	<	12
Zinc	0.1	mg/kg	28212	15000	19241	15000	19891	20000

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	MDL	Units	MMS3-1 SEM	MMS3-1 Tot	MMS3-2 SEM	MMS3-2 Tot	MMS3-3 SEM	MMS3-3 Tot
Aluminum	2	mg/kg	7483	6000	6389	6400	5021	5900
Barium	0.1	mg/kg	82	56	69	55	59	47
Beryllium	0.1	mg/kg	<	0.2	<	0.2	<	0.2
Boron	1	mg/kg	<	8.1	79	8.4	46	7.6
Cadmium	0.05	mg/kg	<	36	<	56	<	39
Chromium	0.1	mg/kg	<	14	<	14	<	13
Cobalt	0.2	mg/kg	<	20	<	31	<	23
Copper	0.1	mg/kg	748	930	835	1300	586	1100
Iron	0.2	mg/kg	8851	13000	8361	15000	6281	13000
Lead	0.4	mg/kg	<	490	<	670	<	490
Manganese	0.1	mg/kg	354	220	305	240	222	190
Molybdenum	0.1	mg/kg	<	2.2	<	2.9	<	1.8
Nickel	0.2	mg/kg	<	34	<	45	<	35
Silver	0.1	mg/kg	<	10	<	11	<	11
Strontium	0.1	mg/kg	35	24	28	24	25	20
Thallium	0.5	mg/kg	<	0.6	<	0.9	<	0.6
Tin	0.5	mg/kg	<	1.4	<	1.9	<	2.5
Titanium	0.3	mg/kg	272	180	221	180	184	190
Vanadium	0.1	mg/kg	<	11	<	11	<	10
Zinc	0.1	mg/kg	15641	10000	21615	18000	13803	13000

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	**MDL**	**Units**	MMS4-1 SEM	MMS4-1 Tot	MMS4-2 SEM	MMS4-2 Tot	MMS4-3 SEM	MMS4-3 Tot
Aluminum	2	mg/kg	5905.8	5500	5820.4	4900	4465.4	6000
Barium	0.1	mg/kg	63.0	49	79.4	52	51.2	54
Beryllium	0.1	mg/kg	<	0.2	<	0.2	<	0.2
Boron	1	mg/kg	74.8	7.5	185.2	8.7	69.8	8.3
Cadmium	0.05	mg/kg	<	18	<	5	<	12
Chromium	0.1	mg/kg	<	14	<	13	<	13
Cobalt	0.2	mg/kg	<	14	<	6.1	<	8.7
Copper	0.1	mg/kg	389.8	750	142.9	160	223.3	530
Iron	0.2	mg/kg	6698.6	12000	7413.6	10000	4422.3	10000
Lead	0.4	mg/kg	<	300	<	55	<	280
Manganese	0.1	mg/kg	512.2	350	455.3	260	167.6	160
Molybdenum	0.1	mg/kg	<	4.3	<	2.5	<	1.9
Nickel	0.2	mg/kg	<	37	<	26	<	25
Silver	0.1	mg/kg	<	7.6	<	1.1	<	5.5
Strontium	0.1	mg/kg	37.4	28	49.7	32	24.7	25
Thallium	0.5	mg/kg	<	0.4	<	<	<	0.2
Tin	0.5	mg/kg	<	1.4	<	1.4	<	2.6
Titanium	0.3	mg/kg	263.8	230	322.8	230	186.0	190
Vanadium	0.1	mg/kg	<	11	<	9.7	<	11
Zinc	0.1	mg/kg	11807.4	9000	4231.5	2800	2185.4	2700

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	MDL	Units	MMS5-1 SEM	MMS5-1 Tot	MMS5-2 SEM	MMS5-2 Tot	MMS5-3	MMS5-3 SEM	MMS5-3 Tot
Aluminum	2	mg/kg	6896.9	6600	7947.5	6100	252.9	6825	4900
Barium	0.1	mg/kg	86.2	59	99.3	53	0.7	94	54
Beryllium	0.1	mg/kg	<	1.2	<	0.2	<	<	<
Boron	1	mg/kg	120.7	11	139.1	8.3	9.7	105	7.6
Cadmium	0.05	mg/kg	<	13	<	14	<	<	21
Chromium	0.1	mg/kg	<	15	<	14	<	<	11
Cobalt	0.2	mg/kg	<	10	<	11	<	<	11
Copper	0.1	mg/kg	436.8	620	616.0	980	11.6	735	850
Iron	0.2	mg/kg	8052.8	12000	9279.3	13000	141.1	7881	12000
Lead	0.4	mg/kg	<	340	<	540	<	<	560
Manganese	0.1	mg/kg	396.8	230	503.7	250	8.8	483	220
Molybdenum	0.1	mg/kg	<	1.3	<	1.2	<	<	1.3
Nickel	0.2	mg/kg	<	24	<	24	<	<	27
Silver	0.1	mg/kg	<	7.1	<	11	<	<	11
Strontium	0.1	mg/kg	32.2	22	36.4	20	0.4	32	18
Thallium	0.5	mg/kg	<	0.2	<	0.2	<	<	0.2
Tin	0.5	mg/kg	<	4.6	<	1.4	<	<	1.9
Titanium	0.3	mg/kg	281.6	230	317.9	210	5.5	262	180
Vanadium	0.1	mg/kg	<	13	<	12	<	<	9.1
Zinc	0.1	mg/kg	2987.6	2600	3839.9	3400	88.3	5773	4000

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	MDL	Units	MMSR1-1 SEM	MMSR1-1 Tot	MMSR1-2 SEM	MMSR1-2 Tot	MMSR1-3 SEM	MMSR1-3 Tot
Aluminum	2	mg/kg	12404	5200	5866	3900	3282.5	3700
Barium	0.1	mg/kg	202	43	78	44	38.9	39
Beryllium	0.1	mg/kg	<	0.2	<	<	<	<
Boron	1	mg/kg	217	9.1	99	7.1	56.9	5.9
Cadmium	0.05	mg/kg	<	1.8	<	1.6	<	1.6
Chromium	0.1	mg/kg	<	12	<	11	<	11
Cobalt	0.2	mg/kg	<	3.1	<	2.7	<	2.5
Copper	0.1	mg/kg	217	51	92	43	56.9	42
Iron	0.2	mg/kg	11793	6100	5588	4700	3022.2	4400
Lead	0.4	mg/kg	<	25	<	26	<	24
Manganese	0.1	mg/kg	248	62	113	56	56.9	47
Molybdenum	0.1	mg/kg	<	1.5	<	1.6	<	1.5
Nickel	0.2	mg/kg	<	19	<	18	<	17
Silver	0.1	mg/kg	<	0.26	<	0.16	<	0.15
Strontium	0.1	mg/kg	53	13	23	11	13.1	11
Thallium	0.5	mg/kg	<	<	<	<	<	<
Tin	0.5	mg/kg	<	0.4	<	0.7	<	0.7
Titanium	0.3	mg/kg	512	170	247	110	140.0	110
Vanadium	0.1	mg/kg	<	8.3	<	6.5	<	6.1
Zinc	0.1	mg/kg	1860	450	777	330	525.0	360

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	MDL	Units	MMSR2-1 SEM	MMSR2-1 Tot	MMSR2-2 SEM	MMSR2-2 Tot	MMSR2-3 SEM	MMSR2-3 Tot
Aluminum	2	mg/kg	2951.0	2700	3522.9	3000	3278.9	3000
Barium	0.1	mg/kg	122.9	85	181.8	110	142.1	94
Beryllium	0.1	mg/kg	<	<	<	<	<	<
Boron	1	mg/kg	<	6	<	6.6	<	5.8
Cadmium	0.05	mg/kg	<	0.94	<	1.2	<	1.2
Chromium	0.1	mg/kg	<	5.8	<	6.8	<	6.9
Cobalt	0.2	mg/kg	<	3.1	<	3.2	<	3.6
Copper	0.1	mg/kg	<	7.9	<	8.5	<	13
Iron	0.2	mg/kg	4758.1	3600	6141.5	4300	5031.6	3800
Lead	0.4	mg/kg	<	29	<	27	<	36
Manganese	0.1	mg/kg	123.0	76	170.6	95	131.2	87
Molybdenum	0.1	mg/kg	<	1.4	<	1.9	<	1.6
Nickel	0.2	mg/kg	<	5.1	<	5.6	<	5.9
Silver	0.1	mg/kg	<	0.07	<	1.5	<	0.09
Strontium	0.1	mg/kg	30.3	23	47.7	29	38.3	26
Thallium	0.5	mg/kg	<	<	<	<	<	<
Tin	0.5	mg/kg	<	1	<	1.3	<	1.2
Titanium	0.3	mg/kg	<	45	<	48	<	45
Vanadium	0.1	mg/kg	<	10	<	13	<	12
Zinc	0.1	mg/kg	131.1	78	170.4	90	153.0	97

Table A1.6: Comparison of Simultaneously Extracted Metals to Total Metals - Mattabi Sediments

Component	**MDL**	**Units**	MMS1-1 SEM	MMS1-1 Tot	MMS1-2 SEM	MMS1-2 Tot	MMS1-3 SEM	MMS1-3 Tot
Aluminum	2	mg/kg	12301	5000	12341	11000	15001	12000
Barium	0.1	mg/kg	100	36	89	55	95	69
Beryllium	0.1	mg/kg	<	0.2	<	0.5	<	0.4
Boron	1	mg/kg	132	5.1	51	13	125	11
Cadmium	0.05	mg/kg	<	60	<	100	<	140
Chromium	0.1	mg/kg	<	7	<	16	<	17
Cobalt	0.2	mg/kg	100	36	72	62	75	67
Copper	0.1	mg/kg	1321	1100	1532	2300	33	2500
Iron	0.2	mg/kg	19606	15000	18313	33000	21018	36000
Lead	0.4	mg/kg	<	760	<	1300	<	1700
Manganese	0.1	mg/kg	5927	1500	3364	2000	3102	1600
Molybdenum	0.1	mg/kg	<	1	<	1.8	<	2.3
Nickel	0.2	mg/kg	109	39	77	81	100	86
Silver	0.1	mg/kg	<	4.4	<	17	<	13
Strontium	0.1	mg/kg	29	11	29	19	33	23
Thallium	0.5	mg/kg	<	0.6	<	1.1	<	1.4
Tin	0.5	mg/kg	<	2.2	<	4.6	<	6.8
Titanium	0.3	mg/kg	169	91	162	190	200	220
Vanadium	0.1	mg/kg	26	8.3	26	18	30	20
Zinc	0.1	mg/kg	63762	20000	72318	42000	79976	45000

PERCENTAGE RECOVERY OF BENTHIC INVERTEBRATES FROM SAMPLES FOR MATTABI

Station	Number of Animals	Number of Animals in Re-	Percent Recovery
MMBR2-1	353	16	95.7
MMB4-1	264	0	100

CALCULATION OF SUBSAMPLING ERROR FOR BENTHIC INVERTEBRATE SAMPLES FOR MATTABI

Station	Number of Animals in	Number of Animals in	Standard Deviation	Coefficient of Variation
MMB3-2	156	124	22.63	16.16
MMB5-3	246	223	16.26	6.94

SAMPLES THAT REQUIRED SUBSAMPLING FOR MATTABI

Station	Fraction Sorted
MMBR1-1	1/4
MMBR1-2	1/4
MMBR1-3	1/5
MMBR2-1	1/2
MMBR2-2	1/2
MMBR2-3	1/2
MMB1-1	1/2
MMB1-2	1/2
MMB2-1	1/4
MMB2-2	1/4
MMB2-3	1/4
MMB3-1	1/4
MMB3-2	1/4*
MMB3-3	1/4
MMB4-1	1/2
MMB4-2	1/2
MMB4-3	1/2
MMB5-1	1/4
MMB5-2	1/4
MMB5-3	1/4*

*Additional 1/4 sorted for subsampling error

Table A1.7: Mattabi Sediment Toxicity QA/QC

Control Statistics

Organism	Control Mortality (%)	Control CV (%)
Chironomus riparius	6 - 14	6 - 11
Hyalella azteca	2 - 20	0 - 11

Chironomus riparius Re-Tests

	MMS4-3	MMS4-3 re-test	DQA (%)	MMS4-3 re-test 2	DQA (%)	MMS3-2	MMS3-2 re-test	DQA (%)	MMSR1-3	MMSR1-3 re-test	DQA (%)
Survival ± SD	28 ± 18	46 ± 6	**48.65**	66 ± 6	**80.85**	80 ± 10	48 ± 4	**50.00**	42 ± 4	54 ± 6	**25.00**
CV (%)	64	12		8		12	9		11	10	
Mean dw/org ± SD (mg)	0.69 ± 0 2	0.20 ± 0.12	**110.11**	0.44 ± 0.16	**44.25**	0.69 ± 0.07	0.20 ± 0.08	**110.11**	0.44 ± 0.06	0.23 ± 0.09	**62.69**
CV (%)	29	59		35		10	38		14	41	

Hyalella azteca Re-Tests

	MMS4-3	MMS4-3 re-test	DQA (%)	MMS3-1	MMS3-1 re-test	DQA (%)
Survival ± SD	30 ± 27	16 ± 26	**60.87**	86 ± 11	92 ± 13	**6.74**
CV (%)	91	163		13	14	
Mean dw/org ± SD (mg)	0 27 ± 0.04	0.09 ± 0.02	**100.00**	0.16 ± 0.03	0.23 ± 0.03	**35.90**
CV (%)	16	22		22	15	

CERTIFICATE OF ACCREDITATION

CERTIFICAT D'ACCRÉDITATION

Zenon Environmental Inc.

ZENON ENVIRONMENTAL LABORATORIES INC. – BURLINGTON

5555 North Service Road, Burlington, ON

having been assessed by the Canadian Association for Environmental Analytical Laboratories (CAEAL) Inc., under the authority of the Standards Council of Canada (SCC), and found to comply with the requirements of the ISO/IEC Guide 25, the conditions established by the SCC and the CAEAL proficiency testing program, is hereby recognized as an

ACCREDITED ENVIRONMENTAL LABORATORY

for specific tests or types of tests listed in the scope of accreditation approved by the Standards Council of Canada.

ACLAE

CAEAL

ayant été soumis à une évaluation par l'Association canadienne des laboratoires d'analyse environnementale (ACLAE) Inc., sous l'autorité du Conseil canadien des normes (CCN), et ayant été trouvé conforme aux prescriptions du Guide ISO/CEI 25, aux conditions établies par le CCN et au programme d'essais d'aptitude de l'ACLAE, est de fait reconnu comme

LABORATOIRE DE L'ENVIRONNEMENT ACCRÉDITÉ

pour des essais ou types d'essais déterminés inscrits dans la portée d'accréditation approuvée par le Conseil canadien des normes.

Accredited Laboratory No.
No de laboratoire accrédité : 197

Accreditation Date
Date d'accréditation: 1995-03-06

Issued on
Émis ce : 1995-03-06

Expiry date
Date d'expiration : 1998-03-06

Richard Lafontaine

President, SCC / Président, CCN

Assessment performed according to the *General Requirements for the Accreditation of Calibration and Testing Laboratories*, CAN-P-4 (ISO/IEC Guide 25), *Requirements for the Competence of Environmental Analytical Laboratories*, CAN/CSA-Z753 and the *Conditions for the Accreditation of Calibration and Testing Laboratories*, CAN-P-1515. The scope of accreditation is available from the accredited laboratory or SCC.

Évaluation effectuée conformément aux *Prescriptions générales concernant la compétence des laboratoires d'étalonnage et d'essais*, CAN-P-4 (Guide ISO/CEI 25), aux *Exigences visant les compétences des laboratoires de l'environnement*, CAN/CSA-Z753 et aux *Conditions d'accréditation des laboratoires d'étalonnage et d'essais*, CAN-P-1515. La portée d'accréditation est disponible auprès du laboratoire accrédité ou du CCN.

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CERTIFICATE OF ACCREDITATION

CERTIFICAT D'ACCRÉDITATION

CAEAL
1996
ACLAE

CAEAL
1997
ACLAE

Beak Consultants Ltd.
ECOTOXICOLOGY LABORATORY

455 Boul. Fenelon, Suite 104, Dorval, Québec

having been assessed by the Canadian Association for Environmental Analytical Laboratories (CAEAL) Inc., under the authority of the Standards Council of Canada (SCC), and found to comply with the requirements of the ISO/IEC Guide 25, the conditions established by the SCC and the CAEAL proficiency testing program, is hereby recognized as an

ACCREDITED ENVIRONMENTAL LABORATORY

for specific tests or types of tests listed in the scope of accreditation approved by the Standards Council of Canada.

ayant été soumis à une évaluation par l'Association canadienne des laboratoires d'analyse environnementale (ACLAE) Inc., sous l'autorité du Conseil canadien des normes (CCN), et ayant été trouvé conforme aux prescriptions du Guide ISO/CEI 25, aux conditions établies par le CCN et au programme d'essais d'aptitude de l'ACLAE, est de fait reconnu comme

LABORATOIRE DE L'ENVIRONNEMENT ACCRÉDITÉ

pour des essais ou types d'essais déterminés inscrits dans la portée d'accréditation approuvée par le Conseil canadien des normes.

Accredited Laboratory No.
No de laboratoire accrédité : 227

Accreditation Date
Date d'accréditation: 1996-02-15

Issued on
Émis ce : 1996-02-15

Expiry date
Date d'expiration : 2000-02-15

President, SCC / Président, CCN

Assessment performed according to the *General Requirements for the Accreditation of Calibration and Testing Laboratories*, CAN-P-4 (ISO/IEC Guide 25), *Requirements for the Competence of Environmental Analytical Laboratories*, CAN/CSA-Z753 and the *Conditions for the Accreditation of Calibration and Testing Laboratories*, CAN-P-1515.
The scope of accreditation is available from the accredited laboratory or SCC.

Évaluation effectuée conformément aux *Prescriptions générales concernant la compétence des laboratoires d'étalonnage et d'essais*, CAN-P-4 (Guide ISO/CEI 25), *Exigences visant les compétences des laboratoires de l'environnement*, CAN/CSA-Z753 et les *Conditions d'accréditation des laboratoires d'étalonnage et d'essais*, CAN-P-1515.
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ENVIRONNEMENT
ET FAUNE
QUÉBEC

N° 108

CERTIFICAT D'ACCRÉDITATION
DE LABORATOIRE D'ANALYSE ENVIRONNEMENTALE

Champ d'accréditation : Toxicologie de l'eau

Détenteur : LES CONSULTANTS BEAK LTÉE

Adresse : 455, boulevard Fénelon, bureau 104
Dorval (Québec) H9S 5T8

N° de laboratoire : 428

Service à la clientèle externe Oui ☒ Non ☐

Selon les dispositions de l'article 118.6 de la Loi sur la qualité de l'environnement (L.R.Q., chap. Q-2) et conformément aux normes et exigences d'accréditation incluant celles du Guide ISO/CEI 25, le détenteur de ce certificat est habilité à réaliser les analyses déterminées dans les domaines ci-dessous :

Domaine	Date d'entrée en vigueur	Date d'échéance
191	1997-07-02	1998-07-01

Le présent certificat, valide pour la période indiquée, est soumis aux règles et procédures établies et demeure la propriété du ministère de l'Environnement et de la Faune.

Québec, le 7 août 19 97

Le ministre de l'Environnement et de la Faune

Québec

APPENDIX 2

Field Notes

Table A2.1: Station Coordinates and Field Chemistry Measurements, Mattabi MineSite

Station I.D.	Latitude [1]	Longitude [2]	Temperature (°C)	D.O. (mg/L)	pH (units)	Eh (mV)	Conductivity (µs/cm)
MMR1-1	49°52'57.6"	91°06'52.2"	6.0	11.15	7.37	-98	122
MMR1-2	49°52'58.2"	91°06'54"	6.0	11.15	7.37	-80	122
MMR1-3	49°52'57.6"	91°06'53.4"	6.0	11.15	7.37	-80	122
MMR2-1	49°38'57"	91°14'46.8"	7.0	13.3	7.36	-11	50.2
MMR2-2	49°38'58.8"	91°14'51"	7.0	13.3	7.36	-18	50.2
MMR2-3	49°38'58.8"	91°14'48.6"	7.0	13.3	7.36	-11	50.2
MME1-1	49°52'58.2"	90°58'27.6"	9.0	11.6	7.42	-180	627
MME1-2	49°52'58.2"	90°58'28.2"	9.0	11.6	7.42	-165	627
MME1-3	49°52'56.4"	90°58'29.4"	9.0	11.6	7.42	-150	627
MME2-1	49°52'48.6"	90°59'22.2"	9.0	10.2	7.43/7.46	-151	103/101
MME2-2	49°52'50.4"	90°59'25.8"	9.0	10.2	7.43/7.46	-90	103/101
MME2-3	49°52'49.2"	90°59'22.2"	9.0	10.2	7.43/7.46	-137	103/101
MME3-1	49°52'51.6"	90°59'25.2"	9.0	10.2	7.46	-180	103
MME3-2	49°52'51.6"	90°59'27"	9.0	10.2	7.46	-132	103
MME3-3	49°52'51.6"	90°59'24"	9.0	10.2	7.46	-76	103
MME4-1	49°52'54"	90°59'30"	9.0	10.2	7.39	-163	102
MME4-2	49°52'52.8"	90°59'31.2"	9.0	10.2	7.39	-106	102
MME4-3	49°52'54"	90°59'27.6"	9.0	10.2	7.39	-90	102
MME5-1	49°52'52.2"	90°59'37.8"	9.0	10.3	7.39	-125	101
MME5-2	49°52'51"	90°59'35.4"	9.0	10.3	7.39	-130	101
MME5-3	49°52'51.6"	90°59'36.6"	9.0	10.3	7.39	-132	101

[1] Latitude - measurements are in degrees North

[2] Longitude - measurements are in degrees West

APPENDIX 3

Water Chemistry

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	Discharge Total	Discharge Dissolved	MME1 Total	MME1 Dissolved	MME2 Total	MME2 Total	MME2 Total
Date Sampled >			97/10/23	97/10/23	97/10/23	97/10/23	97/10/22	field dup	Replicate
Acidity(as CaCO3)	1	mg/L	2	-	10	-	4	4	-
Alkalinity(as CaCO3)	1	mg/L	30	-	34	-	29	27	-
Aluminum	0.005	mg/L	0.098	0.052	0.102	0.033	0.006	0.006	-
Ammonia(as N)	0.05	mg/L	0.64	-	nd	-	nd	0.05	-
Anion Sum	na	meq/L	54.8	-	6.28	-	1.04	0.998	-
Antimony	0.0005	mg/L	nd	nd	0.0006	0.0006	nd	nd	-
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd	nd	-
Barium	0.005	mg/L	0.01	0.009	0.022	0.021	0.009	0.009	-
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	30	-	34	-	29	27	-
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd	nd	-
Boron	0.005	mg/L	nd	0.007	nd	0.006	0.04	0.029	-
Cadmium	0.00005	mg/L	0.00151	0.00119	0.00185	0.00183	nd	nd	-
Calcium	0.1	mg/L	831	868	71.5	73.3	13.9	14.9	-
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	nd	-	nd	nd	-
Cation Sum	na	meq/L	59	-	6.59	-	1.03	1.01	-
Chloride	1	mg/L	6	-	27	-	nd	nd	-
Chromium	0.0005	mg/L	nd	nd	0.0006	nd	nd	nd	-
Cobalt	0.0002	mg/L	0.0021	0.0018	0.0031	0.0034	nd	nd	-
Colour	5	TCU	20	-	12	-	8	8	-
Conductivity - @25øC	1	us/cm	3520	-	655	-	106	106	-
Copper	0.0003	mg/L	0.0154	0.0128	0.0199	0.0133	0.0016	0.0018	-
Dissolved Inorganic Carbon(as C)	0.2	mg/L	-	5.7	-	6.8	-	-	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	1.5	-	5.5	-	-	-
Hardness(as CaCO3)	0.1	mg/L	2910	-	285	-	47	46.3	-
Ion Balance	0.01	%	3.71	-	2.42	-	0.62	0.77	-
Iron	0.02	mg/L	0.21	0.1	0.23	0.08	0.05	0.06	-
Langelier Index at 20øC	na	na	0.471	-	-0.826	-	-0.907	-0.894	-
Langelier Index at 4øC	na	na	0.071	-	-1.23	-	-1.31	-1.29	-
Lead	0.0001	mg/L	0.0002	0.0002	0.0058	0.0021	0.0001	0.0001	-
Magnesium	0.1	mg/L	171	179	23.7	24.8	2.3	2.4	-
Manganese	0.0005	mg/L	0.965	1	0.327	0.327	0.0049	0.0046	-
Mercury	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Molybdenum	0.0001	mg/L	0.0002	0.0002	nd	nd	nd	nd	-
Nickel	0.001	mg/L	0.032	0.032	0.013	0.014	nd	nd	-
Nitrate(as N)	0.05	mg/L	nd	-	nd	-	nd	nd	-
Nitrite(as N)	0.01	mg/L	nd	-	nd	-	nd	nd	-
Orthophosphate(as P)	0.01	mg/L	nd	-	nd	-	nd	nd	-
pH	0.1	Units	7.7	-	7.3	-	7.9	7.9	-
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd	nd	-
Phosphorus, Total	0.01	mg/L	-	nd	-	0.02	-	-	-
Potassium	0.5	mg/L	3.7	nd	1.5	1.5	0.5	nd	-
Reactive Silica(SiO2)	0.5	mg/L	0.9	-	0.6	-	1.5	1.5	-
Saturation pH at 20øC	na	units	7.21	-	8.09	-	8.8	8.83	-
Saturation pH at 4øC	na	units	7.61	-	8.49	-	9.2	9.23	-
Selenium	0.002	mg/L	0.004	0.004	nd	nd	nd	nd	-
Silver	0.00005	mg/L	nd	nd	nd	nd	nd	nd	-
Sodium	0.1	mg/L	20.2	21.4	19.3	19.6	2.1	1.9	-
Strontium	0.005	mg/L	0.872	0.91	0.119	0.121	0.028	0.027	-
Sulphate	2	mg/L	2600	-	233	-	21	21	-
Thallium	0.0001	mg/L	0.0004	0.0004	nd	nd	nd	nd	-
Tin	0.002	mg/L	nd	nd	nd	nd	nd	nd	-
Titanium	0.002	mg/L	0.043	0.041	0.004	0.004	nd	nd	-
Total Dissolved Solids(Calculated)	1	mg/L	-	3690	-	400	-	-	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.92	-	0.36	-	0.22	0.18	-
Total Suspended Solids	1	mg/L	8	-	3	-	nd	nd	-
Turbidity	0.1	NTU	1.5	-	1.2	-	0.3	0.3	-
Uranium	0.0001	mg/L	nd	0.0001	nd	nd	nd	nd	-
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd	nd	-
Zinc	0.001	mg/L	0.206	0.094	2.61	2.61	0.014	0.016	-
Fluoride	0.02	mg/L	2	-	0.35	-	nd	nd	-

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	MME2 Dissolved	MME2 Dissolved	MME3 Total	MME3 Dissolved	MME4 Total	MME4 Dissolved	MME5 Total
Date Sampled >			97/10/22	field dup	97/10/23	97/10/23	97/10/23	97/10/23	97/10/23
Acidity(as CaCO3)	1	mg/L	-	-	2	-	2	-	4
Alkalinity(as CaCO3)	1	mg/L	-	-	29	-	29	-	28
Aluminum	0.005	mg/L	nd	nd	0.008	nd	0.006	nd	0.005
Ammonia(as N)	0.05	mg/L	-	-	0.07	-	nd	-	nd
Anion Sum	na	meq/L	-	-	1.04	-	1.03	-	1.01
Antimony	0.0005	mg/L	nd	nd	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.007	0.007	0.009	0.007	0.007	0.007	0.008
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	-	29	-	29	-	28
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Boron	0.005	mg/L	nd	nd	nd	nd	0.007	0.005	0.008
Cadmium	0.00005	mg/L	nd	nd	0.00005	nd	nd	nd	nd
Calcium	0.1	mg/L	14.8	14.5	13.9	14.2	14	14.3	13.9
Carbonate(as CaCO3, calculated)	1	mg/L	-	-	nd	-	nd	-	nd
Cation Sum	na	meq/L	-	-	1.01	-	1.02	-	1.01
Chloride	1	mg/L	-	-	1	-	nd	-	nd
Chromium	0.0005	mg/L	nd	nd	0.0006	nd	0.0007	nd	0.0006
Cobalt	0.0002	mg/L	nd	nd	nd	nd	nd	nd	nd
Colour	5	TCU	-	-	10	-	6	-	10
Conductivity - @25øC	1	us/cm	-	-	107	-	106	-	105
Copper	0.0003	mg/L	0.0019	0.002	0.0019	0.002	0.0016	0.0021	0.0015
Dissolved Inorganic Carbon(as C)	0.2	mg/L	5.8	6.2	-	5.6	-	5.7	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	4.9	5.5	-	4.8	-	5	-
Hardness(as CaCO3)	0.1	mg/L	-	-	45.4	-	45.7	-	45.3
Ion Balance	0.01	%	-	-	1.67	-	0.64	-	0.16
Iron	0.02	mg/L	nd	nd	0.05	nd	0.06	nd	0.05
Langelier Index at 20øC	na	na	-	-	-0.622	-	-0.75	-	-0.898
Langelier Index at 4øC	na	na	-	-	-1.02	-	-1.15	-	-1.3
Lead	0.0001	mg/L	nd	0.0001	0.0001	nd	0.0001	0.0002	nd
Magnesium	0.1	mg/L	2.5	2.4	2.3	2.4	2.3	2.4	2.3
Manganese	0.0005	mg/L	0.001	0.0008	0.0159	0.0011	0.0035	0.0011	0.0033
Mercury	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Molybdenum	0.0001	mg/L	nd	nd	nd	0.0001	nd	nd	nd
Nickel	0.001	mg/L	nd	nd	0.002	nd	nd	nd	nd
Nitrate(as N)	0.05	mg/L	-	-	nd	-	nd	-	nd
Nitrite(as N)	0.01	mg/L	-	-	nd	-	nd	-	nd
Orthophosphate(as P)	0.01	mg/L	-	-	nd	-	nd	-	nd
pH	0.1	Units	-	-	8.2	-	8.1	-	7.9
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd
Phosphorus, Total	0.01	mg/L	nd	nd	-	0.01	-	0.01	-
Potassium	0.5	mg/L	nd	nd	0.6	nd	nd	nd	nd
Reactive Silica(SiO2)	0.5	mg/L	-	-	1.5	-	1.5	-	1.5
Saturation pH at 20øC	na	units	-	-	8.81	-	8.81	-	8.83
Saturation pH at 4øC	na	units	-	-	9.21	-	9.21	-	9.23
Selenium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Silver	0.00005	mg/L	nd	nd	nd	nd	nd	nd	nd
Sodium	0.1	mg/L	2	1.9	2	2.1	2	2.1	2
Strontium	0.005	mg/L	0.027	0.027	0.027	0.027	0.028	0.027	0.028
Sulphate	2	mg/L	-	-	21	-	21	-	20
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Total Dissolved Solids(Calculated)	1	mg/L	60	58	-	60	-	60	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	0.15	-	0.21	-	0.15
Total Suspended Solids	1	mg/L	-	-	nd	-	nd	-	nd
Turbidity	0.1	NTU	-	-	0.3	-	0.3	-	0.3
Uranium	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Zinc	0.001	mg/L	0.013	0.014	0.02	0.016	0.018	0.018	0.012
Fluoride	0.02	mg/L	-	-	nd	-	nd	-	nd

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	MME5 Dissolved	MME6 Total	MME6 Dissolved	MME7 Total	MME7 Dissolved	MME8 Total	MME8 Dissolved
Date Sampled >			97/10/23	97/10/23	97/10/23	97/10/23	97/10/23	97/10/23	97/10/23
Acidity(as CaCO3)	1	mg/L	-	4	-	6	-	4	-
Alkalinity(as CaCO3)	1	mg/L	-	24	-	21	-	20	-
Aluminum	0.005	mg/L	0.005	0.026	0.017	0.038	0.027	0.036	0.025
Ammonia(as N)	0.05	mg/L	-	nd	-	nd	-	nd	-
Anion Sum	na	meq/L	-	0.769	-	1.51	-	1.77	-
Antimony	0.0005	mg/L	nd	nd	nd	0.0005	nd	0.0005	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.007	0.009	0.006	0.008	0.007	0.007	0.007
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	24	-	21	-	20	-
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Boron	0.005	mg/L	nd	nd	nd	0.005	nd	nd	nd
Cadmium	0.00005	mg/L	nd	0.00005	nd	0.00006	nd	0.00009	nd
Calcium	0.1	mg/L	14.2	8.2	8.7	22.3	22.1	25.8	24.8
Carbonate(as CaCO3, calculated)	1	mg/L	-	nd	-	nd	-	nd	-
Cation Sum	na	meq/L	-	0.74	-	1.64	-	1.84	-
Chloride	1	mg/L	-	nd	-	nd	-	nd	-
Chromium	0.0005	mg/L	nd	0.0006	0.0006	0.0005	nd	nd	nd
Cobalt	0.0002	mg/L	nd	nd	nd	0.0003	0.0002	0.0003	0.0003
Colour	5	TCU	-	30	-	44	-	36	-
Conductivity - @25øC	1	us/cm	-	78	-	177	-	213	-
Copper	0.0003	mg/L	0.0017	0.0014	0.0017	0.0019	0.0022	0.0019	0.0021
Dissolved Inorganic Carbon(as C)	0.2	mg/L	5.7	-	4.8	-	4	-	3.8
Dissolved Organic Carbon(DOC)	0.5	mg/L	4.7	-	6.2	-	6.6	-	7
Hardness(as CaCO3)	0.1	mg/L	-	33.7	-	77.7	-	87.7	-
Ion Balance	0.01	%	-	1.91	-	4.1	-	1.88	-
Iron	0.02	mg/L	nd	0.08	0.04	0.1	0.07	0.11	0.07
Langelier Index at 20øC	na	na	-	-1.17	-	-1.09	-	-0.906	-
Langelier Index at 4øC	na	na	-	-1.57	-	-1.49	-	-1.31	-
Lead	0.0001	mg/L	nd	nd	0.0001	0.0009	0.0008	0.0008	0.0007
Magnesium	0.1	mg/L	2.4	3.5	2.9	5.5	5.5	6.5	6.3
Manganese	0.0005	mg/L	0.0006	0.0159	0.0127	0.0238	0.0211	0.0231	0.0211
Mercury	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Molybdenum	0.0001	mg/L	nd	nd	nd	0.0002	0.0001	0.0002	0.0001
Nickel	0.001	mg/L	nd	nd	nd	0.001	0.001	0.001	0.001
Nitrate(as N)	0.05	mg/L	-	nd	-	nd	-	nd	-
Nitrite(as N)	0.01	mg/L	-	0.01	-	nd	-	nd	-
Orthophosphate(as P)	0.01	mg/L	-	nd	-	nd	-	nd	-
pH	0.1	Units	-	7.9	-	7.7	-	7.8	-
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd
Phosphorus, Total	0.01	mg/L	nd	-	nd	-	nd	-	nd
Potassium	0.5	mg/L	nd	nd	nd	nd	0.7	nd	nd
Reactive Silica(SiO2)	0.5	mg/L	-	2.1	-	2.5	-	2.4	-
Saturation pH at 20øC	na	units	-	9.11	-	8.77	-	8.75	-
Saturation pH at 4øC	na	units	-	9.51	-	9.17	-	9.15	-
Selenium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Silver	0.00005	mg/L	nd	nd	nd	nd	nd	nd	nd
Sodium	0.1	mg/L	2.1	1.2	1.4	1.6	1.7	1.7	1.7
Strontium	0.005	mg/L	0.027	0.03	0.03	0.04	0.04	0.043	0.043
Sulphate	2	mg/L	-	13	-	52	-	65	-
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Total Dissolved Solids(Calculated)	1	mg/L	59	-	44	-	97	-	113
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	0.2	-	0.22	-	0.24	-
Total Suspended Solids	1	mg/L	-	nd	-	nd	-	1	-
Turbidity	0.1	NTU	-	0.4	-	0.5	-	0.5	-
Uranium	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Zinc	0.001	mg/L	0.011	0.031	0.029	0.057	0.055	0.059	0.06
Fluoride	0.02	mg/L	-	0.02	-	0.04	-	nd	-

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	MME9 Total	MME9 Dissolved	MME10 Total	MME10 Dissolved	MME11 Total	MME11 Dissolved	MME12 Total
Date Sampled >			97/10/23	97/10/23	97/10/23	97/10/23	97/10/23	97/10/23	97/10/23
Acidity(as CaCO3)	1	mg/L	6	-	4	-	6	-	2
Alkalinity(as CaCO3)	1	mg/L	20	-	11	-	16	-	16
Aluminum	0.005	mg/L	0.036	0.025	0.043	0.023	0.052	0.026	0.043
Ammonia(as N)	0.05	mg/L	nd	-	nd	-	nd	-	0.05
Anion Sum	na	meq/L	1.74	-	0.273	-	0.372	-	0.372
Antimony	0.0005	mg/L	nd	nd	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.007	0.007	nd	nd	nd	nd	0.005
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd
Bicarbonate(as CaCO3, calculated)	1	mg/L	20	-	11	-	16	-	16
Bismuth	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Boron	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd
Cadmium	0.00005	mg/L	0.00006	nd	nd	nd	nd	nd	nd
Calcium	0.1	mg/L	24.6	25.6	4.8	5	5	4.9	4.9
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-	nd	-	nd	-	nd
Cation Sum	na	meq/L	1.9	-	0.407	-	0.394	-	0.403
Chloride	1	mg/L	nd	-	nd	-	nd	-	nd
Chromium	0.0005	mg/L	0.0006	nd	0.0006	nd	nd	nd	nd
Cobalt	0.0002	mg/L	0.0002	0.0002	nd	nd	nd	nd	nd
Colour	5	TCU	36	-	68	-	70	-	72
Conductivity - @25øC	1	us/cm	206	-	40	-	40	-	40
Copper	0.0003	mg/L	0.002	0.0022	0.0005	0.0006	0.0006	0.0009	0.0005
Dissolved Inorganic Carbon(as C)	0.2	mg/L	-	4.2	-	2.6	-	2.7	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	-	6.6	-	7.5	-	8	-
Hardness(as CaCO3)	0.1	mg/L	90.6	-	17.3	-	17.1	-	17.2
Ion Balance	0.01	%	4.43	-	19.7	-	2.99	-	3.98
Iron	0.02	mg/L	0.1	0.07	0.32	0.2	0.35	0.18	0.3
Langelier Index at 20øC	na	na	-0.972	-	-1.86	-	-1.91	-	-1.99
Langelier Index at 4øC	na	na	-1.37	-	-2.26	-	-2.31	-	-2.39
Lead	0.0001	mg/L	0.0009	0.0007	nd	0.0004	nd	0.0001	nd
Magnesium	0.1	mg/L	6.1	6.5	1.2	1.2	1.2	1.2	1.2
Manganese	0.0005	mg/L	0.023	0.0213	0.0112	0.0031	0.0177	0.004	0.0153
Mercury	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Molybdenum	0.0001	mg/L	0.0001	0.0001	0.0001	nd	0.0001	0.0002	0.0001
Nickel	0.001	mg/L	0.001	0.001	nd	nd	nd	nd	nd
Nitrate(as N)	0.05	mg/L	nd	-	nd	-	nd	-	nd
Nitrite(as N)	0.01	mg/L	nd	-	nd	-	nd	-	nd
Orthophosphate(as P)	0.01	mg/L	nd	-	nd	-	nd	-	nd
pH	0.1	Units	7.8	-	7.8	-	7.6	-	7.5
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd
Phosphorus, Total	0.01	mg/L	-	nd	-	0.01	-	0.01	-
Potassium	0.5	mg/L	nd	0.6	nd	nd	0.8	nd	nd
Reactive Silica(SiO2)	0.5	mg/L	2.4	-	6.6	-	6.5	-	6.6
Saturation pH at 20øC	na	units	8.73	-	9.68	-	9.52	-	9.52
Saturation pH at 4øC	na	units	9.13	-	10.1	-	9.92	-	9.92
Selenium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Silver	0.00005	mg/L	nd	nd	nd	nd	nd	nd	nd
Sodium	0.1	mg/L	1.6	1.8	1.2	1.3	1.2	1.2	1.2
Strontium	0.005	mg/L	0.045	0.044	0.015	0.015	0.015	0.015	0.016
Sulphate	2	mg/L	64	-	nd	-	nd	-	nd
Thallium	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Total Dissolved Solids(Calculated)	1	mg/L	-	113	-	23	-	26	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	0.28	-	0.23	-	0.22	-	0.24
Total Suspended Solids	1	mg/L	1	-	2	-	2	-	nd
Turbidity	0.1	NTU	0.5	-	0.9	-	0.8	-	2.2
Uranium	0.0001	mg/L	nd	nd	0.0002	0.0002	0.0002	0.0002	0.0002
Vanadium	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd
Zinc	0.001	mg/L	0.061	0.059	nd	nd	nd	0.001	0.001
Fluoride	0.02	mg/L	0.02	-	nd	-	nd	-	0.02

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	MME12 Dissolved	MME13 Total	MME13 Dissolved	MMR1 Total	MMR1 Total	MMR1 Total	MMR1 Total field dup
Date Sampled >			97/10/23	97/10/23	97/10/23	97/10/22	Replicate	field dup	Replicate
Acidity(as CaCO3)	1	mg/L	-	6	-	2	ns	2	-
Alkalinity(as CaCO3)	1	mg/L	-	16	-	28	29	29	-
Aluminum	0.005	mg/L	0.023	0.044	0.031	0.005	-	0.005	-
Ammonia(as N)	0.05	mg/L	-	0.06	-	nd	nd	nd	-
Anion Sum	na	meq/L	-	0.371	-	1.03	-	1.04	-
Antimony	0.0005	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	0.007	-	0.008	-
Beryllium	0.005	mg/L	nd	nd	nd	nd	-	nd	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	16	-	28	-	29	-
Bismuth	0.002	mg/L	nd	nd	nd	nd	-	nd	-
Boron	0.005	mg/L	nd	nd	nd	0.015	-	0.01	0.008
Cadmium	0.00005	mg/L	nd	nd	nd	nd	-	nd	-
Calcium	0.1	mg/L	4.9	4.8	4.9	13.7	-	13.8	13.9
Carbonate(as CaCO3, calculated)	1	mg/L	-	nd	-	nd	-	nd	-
Cation Sum	na	meq/L	-	0.412	-	1.05	-	1.05	-
Chloride	1	mg/L	-	nd	-	nd	nd	nd	-
Chromium	0.0005	mg/L	nd	nd	nd	nd	-	nd	-
Cobalt	0.0002	mg/L	nd	nd	nd	nd	-	nd	-
Colour	5	TCU	-	74	-	16	16	12	-
Conductivity - @25øC	1	us/cm	-	40	-	112	ns	105	-
Copper	0.0003	mg/L	0.0008	0.0005	0.0006	0.002	-	0.0013	-
Dissolved Inorganic Carbon(as C)	0.2	mg/L	3	-	3	-	-	-	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	7.7	-	8.2	-	-	-	-
Hardness(as CaCO3)	0.1	mg/L	-	17.1	-	48.4	-	48.5	-
Ion Balance	0.01	%	-	5.28	-	0.92	-	0.76	-
Iron	0.02	mg/L	0.21	0.31	0.2	0.05	-	0.05	-
Langelier Index at 20øC	na	na	-	-1.79	-	-1.24	-	-1.23	-
Langelier Index at 4øC	na	na	-	-2.19	-	-1.64	-	-1.63	-
Lead	0.0001	mg/L	0.0001	nd	0.0002	nd	-	nd	-
Magnesium	0.1	mg/L	1.2	1.2	1.2	2.3	-	2.3	2.3
Manganese	0.0005	mg/L	0.0031	0.0152	0.0028	0.0026	-	0.0026	-
Mercury	0.0001	mg/L	nd	nd	nd	nd	-	nd	-
Molybdenum	0.0001	mg/L	0.0002	0.0001	0.0001	nd	-	nd	-
Nickel	0.001	mg/L	nd	nd	nd	nd	-	nd	-
Nitrate(as N)	0.05	mg/L	-	nd	-	nd	nd	nd	-
Nitrite(as N)	0.01	mg/L	-	nd	-	nd	nd	nd	-
Orthophosphate(as P)	0.01	mg/L	-	nd	-	nd	nd	nd	-
pH	0.1	Units	-	7.7	-	7.6	na	7.6	-
Phosphorus	0.1	mg/L	nd	nd	nd	nd	-	nd	nd
Phosphorus, Total	0.01	mg/L	nd	-	0.01	-	-	-	-
Potassium	0.5	mg/L	nd	0.7	nd	0.8	-	0.8	0.6
Reactive Silica(SiO2)	0.5	mg/L	-	6.5	-	1.6	1.5	1.6	-
Saturation pH at 20øC	na	units	-	9.52	-	8.8	-	8.78	-
Saturation pH at 4øC	na	units	-	9.92	-	9.2	-	9.18	-
Selenium	0.002	mg/L	nd	nd	nd	nd	-	nd	-
Silver	0.00005	mg/L	nd	nd	nd	nd	-	nd	-
Sodium	0.1	mg/L	1.3	1.2	1.3	2	-	2	2
Strontium	0.005	mg/L	0.015	0.015	0.015	0.027	-	0.028	-
Sulphate	2	mg/L	-	nd	-	21	21	21	-
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	-
Total Dissolved Solids(Calculated)	1	mg/L	26	-	26	-	-	-	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	0.27	-	0.18	0.2	0.21	-
Total Suspended Solids	1	mg/L	-	2	-	nd	nd	nd	-
Turbidity	0.1	NTU	-	2.2	-	0.5	0.4	0.3	-
Uranium	0.0001	mg/L	0.0002	0.0002	0.0002	nd	-	nd	-
Vanadium	0.002	mg/L	nd	nd	nd	nd	-	nd	-
Zinc	0.001	mg/L	0.001	nd	0.002	0.006	-	0.006	-
Fluoride	0.02	mg/L	-	nd	-	nd	nd	nd	-

Table A3.1: Water Quality at Mattabi Mine Site

Parameter	LOQ	Units	MMR1 Dissolved	MMR1 Dissolved	MMR1 Dissolved	MMR2 Total	MMR2 Total	MMR2 Dissolved	MMR2 Dissolved
Date Sampled >			97/10/22	Replicate	field dup	97/10/23	Replicate	97/10/23	Replicate
Acidity(as CaCO3)	1	mg/L	-	-	-	4	4	-	-
Alkalinity(as CaCO3)	1	mg/L	-	-	-	27	27	-	-
Aluminum	0.005	mg/L	nd	-	nd	0.028	0.028	0.014	0.014
Ammonia(as N)	0.05	mg/L	-	-	-	nd	nd	-	-
Anion Sum	na	meq/L	-	-	-	0.566	-	-	-
Antimony	0.0005	mg/L	nd	-	nd	nd	nd	nd	nd
Arsenic	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Barium	0.005	mg/L	0.007	-	0.007	0.007	0.007	0.006	0.006
Beryllium	0.005	mg/L	nd	-	nd	nd	nd	nd	nd
Bicarbonate(as CaCO3, calculated)	1	mg/L	-	-	-	27	-	-	-
Bismuth	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Boron	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd
Cadmium	0.00005	mg/L	nd	-	nd	nd	nd	nd	nd
Calcium	0.1	mg/L	15.3	15	15.3	7.9	8.1	8.2	9.4
Carbonate(as CaCO3, calculated)	1	mg/L	-	-	-	nd	-	-	-
Cation Sum	na	meq/L	-	-	-	0.615	-	-	-
Chloride	1	mg/L	-	-	-	nd	nd	-	-
Chromium	0.0005	mg/L	nd	-	nd	0.0005	0.0005	nd	nd
Cobalt	0.0002	mg/L	nd	-	nd	nd	nd	nd	nd
Colour	5	TCU	-	-	-	32	32	-	-
Conductivity - @25øC	1	us/cm	-	-	-	58	ns	-	-
Copper	0.0003	mg/L	0.0008	-	0.0011	nd	nd	0.0008	0.0007
Dissolved Inorganic Carbon(as C)	0.2	mg/L	5.9	5.9	6	-	-	5.1	5.2
Dissolved Organic Carbon(DOC)	0.5	mg/L	5.3	4.9	5.1	-	-	11.9	11.9
Hardness(as CaCO3)	0.1	mg/L	-	-	-	27.5	-	-	-
Ion Balance	0.01	%	-	-	-	4.15	-	-	-
Iron	0.02	mg/L	nd	-	nd	0.13	0.13	0.03	0.02
Langelier Index at 20øC	na	na	-	-	-	-1.51	-	-	-
Langelier Index at 4øC	na	na	-	-	-	-1.91	-	-	-
Lead	0.0001	mg/L	0.0002	-	0.0001	0.0003	0.0002	nd	nd
Magnesium	0.1	mg/L	2.5	2.5	2.5	1.6	1.7	1.7	1.9
Manganese	0.0005	mg/L	nd	-	nd	0.025	0.0254	0.0009	0.0009
Mercury	0.0001	mg/L	nd	nd	nd	nd	nd	nd	nd
Molybdenum	0.0001	mg/L	nd	-	nd	nd	nd	nd	nd
Nickel	0.001	mg/L	nd	-	nd	nd	nd	nd	nd
Nitrate(as N)	0.05	mg/L	-	-	-	nd	nd	-	-
Nitrite(as N)	0.01	mg/L	-	-	-	nd	nd	-	-
Orthophosphate(as P)	0.01	mg/L	-	-	-	nd	nd	-	-
pH	0.1	Units	-	-	-	7.6	7.8	-	-
Phosphorus	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd
Phosphorus, Total	0.01	mg/L	0.01	nd	nd	-	-	0.03	0.03
Potassium	0.5	mg/L	nd	nd	nd	nd	nd	nd	nd
Reactive Silica(SiO2)	0.5	mg/L	-	-	-	2.6	2.8	-	-
Saturation pH at 20øC	na	units	-	-	-	9.07	-	-	-
Saturation pH at 4øC	na	units	-	-	-	9.47	-	-	-
Selenium	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Silver	0.00005	mg/L	nd	-	nd	nd	nd	nd	nd
Sodium	0.1	mg/L	1.9	2	1.9	1	1.1	1.2	1.3
Strontium	0.005	mg/L	0.026	-	0.027	0.018	0.018	0.017	0.018
Sulphate	2	mg/L	-	-	-	nd	nd	-	-
Thallium	0.0001	mg/L	nd	-	nd	nd	nd	nd	nd
Tin	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Titanium	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Total Dissolved Solids(Calculated)	1	mg/L	61	-	60	-	-	32	-
Total Kjeldahl Nitrogen(as N)	0.05	mg/L	-	-	-	1.44	1.39	-	-
Total Suspended Solids	1	mg/L	-	-	-	7	8	-	-
Turbidity	0.1	NTU	-	-	-	1.9	1.9	-	-
Uranium	0.0001	mg/L	nd	-	nd	nd	nd	nd	nd
Vanadium	0.002	mg/L	nd	-	nd	nd	nd	nd	nd
Zinc	0.001	mg/L	0.008	-	0.006	0.001	0.001	0.002	0.002
Fluoride	0.02	mg/L	-	-	-	nd	nd	-	-

APPENDIX 4

Sediment Chemistry and Toxicity

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

		Client ID:	MME2-1	MME2-1	MME2-2	MME2-3	MME3-1	MME3-2
Component	**MDL**	**Units**		Duplicate				
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	6300	-	6200	6600	6000	6400
Antimony	0.2	"	16	-	10	14	8.8	12
Arsenic	0.5	"	41	-	32	43	19	26
Barium	0.5	"	56	-	44	58	56	55
Beryllium	0.2	"	0.7	-	0.2	0.2	0.2	0.2
Bismuth	0.5	"	2.8	-	2	2.8	1.6	2
Boron	2.5	"	10	-	8.6	7	8.1	8.4
Cadmium	0.05	"	43	-	32	63	36	56
Chromium	0.6	"	14	-	13	14	14	14
Cobalt	0.2	"	36	-	29	49	20	31
Copper	0.2	"	1600	-	1200	1700	930	1300
Iron	20	"	16000	-	14000	17000	13000	15000
Lead	0.1	"	870	-	600	990	490	670
Manganese	1	"	540	-	430	540	220	240
Molybdenum	0.2	"	6.2	-	4.9	6.1	2.2	2.9
Nickel	0.5	"	50	-	48	56	34	45
Selenium	1	"	23	-	21	24	8.8	16
Silver	0.05	"	13	-	8.4	10	10	11
Strontium	0.5	"	21	-	17	21	24	24
Thallium	0.2	"	1.2	-	0.8	1.3	0.6	0.9
Tin	0.2	"	2.2	-	1.4	1.5	1.4	1.9
Titanium	0.3	"	200	-	190	200	180	180
Vanadium	1	"	13	-	12	12	11	11
Zinc	1	"	15000	-	15000	20000	10000	18000
Calcium	20	mg/kg	11262.5	-	11050	10425	11332.5	10752.5
Magnesium	20	"	3360	-	3250	3225	3087.5	3020
Loss on Ignition	0.1	(%)	48	49	49	46	55	56
Coarse Gravel (>4.8mm)	0.1	(%)	<	-	<	<	<	<
Fine Gravel (2.0-4.8mm)	0.1	"	4	-	1.2	4.1	6.9	6.5
V. Coarse Sand (1.0-2.0mm)	0.1	"	1.3	-	1.6	1.4	2	0.7
Coarse Sand (0.50-1.0mm)	0.1	"	21	-	25	29	21	18
Med. Sand (0.25-0.50mm)	0.1	"	22	-	24	26	27	22
Fine Sand (0.10-0.25mm)	0.1	"	22	-	25	17	20	20
V. Fine Sand (0.050-0.10mm)	0.1							
Silt (0.002-0.050mm)	0.1							
Clay (<0.002mm)	0.1							
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	31	-	23	22	23	34
Mercury	0.04	mg/kg	0.78	-	0.53	0.77	0.45	0.59
TOC (Solid)	0.1	(%)	23	-	24	21	28	26
Bulk Density (g/mL)			0.059		0.061	0.063	0.044	0.048
Sediment Mositure (%)			94.14		94.22	94.0	95.6	95.2
Munsell Number			5Y 2.5/1		5Y 2.5/1	5Y 2.5/1	5Y 2.5/1	5Y 2.5/1
Munsell Colour			Black		Black	Black	Black	Black

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

		Client ID:	MME3-3	MME4-1	MME4-2	MME4-3	MME5-1	MME5-1
Component	**MDL**	**Units**						Duplicate
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	5900	5500	4900	6000	6600	-
Antimony	0.2	"	8.7	7	0.9	4.7	5.9	-
Arsenic	0.5	"	24	16	4.5	13	14	-
Barium	0.5	"	47	49	52	54	59	-
Beryllium	0.2	"	0.2	0.2	0.2	0.2	1.2	-
Bismuth	0.5	"	1.6	1.1	<	1.2	1.3	-
Boron	2.5	"	7.6	7.5	8.7	8.3	11	-
Cadmium	0.05	"	39	18	5	12	13	-
Chromium	0.6	"	13	14	13	13	15	-
Cobalt	0.2	"	23	14	6.1	8.7	10	-
Copper	0.2	"	1100	750	160	530	620	-
Iron	20	"	13000	12000	10000	10000	12000	-
Lead	0.1	"	490	300	55	280	340	-
Manganese	1	"	190	350	260	160	230	-
Molybdenum	0.2	"	1.8	4.3	2.5	1.9	1.3	-
Nickel	0.5	"	35	37	26	25	24	-
Selenium	1	"	12	12	2.9	5	4.1	-
Silver	0.05	"	11	7.6	1.1	5.5	7.1	-
Strontium	0.5	"	20	28	32	25	22	-
Thallium	0.2	"	0.6	0.4	<	0.2	0.2	-
Tin	0.2	"	2.5	1.4	1.4	2.6	4.6	-
Titanium	0.3	"	190	230	230	190	230	-
Vanadium	1	"	10	11	9.7	11	13	-
Zinc	1	"	13000	9000	2800	2700	2600	-
Calcium	20	mg/kg	10465	11470	11967.2	11115	11335	-
Magnesium	20	"	2922.5	3197.5	3046.4	2942.5	3010	-
Loss on Ignition	0.1	(%)	56	45	46	56	51	-
Coarse Gravel (>4.8mm)	0.1	(%)	<	<	<	<	<	-
Fine Gravel (2.0-4.8mm)	0.1	"	6.5	2.1	2.7	3	3.6	-
V. Coarse Sand (1.0-2.0mm)	0.1	"	1.9	1.2	4	1.7	1.5	-
Coarse Sand (0.50-1.0mm)	0.1	"	32	12	20	30	22	-
Med. Sand (0.25-0.50mm)	0.1	"	26	21	22	28	26	-
Fine Sand (0.10-0.25mm)	0.1	"	19	22	26	16	24	-
V. Fine Sand (0.050-0.10mm)	0.1							
Silt (0.002-0.050mm)	0.1							
Clay (<0.002mm)	0.1							
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	15	42	26	22	23	-
Mercury	0.04	mg/kg	0.51	0.33	0.12	0.29	0.38	0.36
TOC (Solid)	0.1	(%)	21	23	23	26	25	-
Bulk Density (g/mL)			0.048	0.056	0.049	0.041	0.051	
Sediment Mositure (%)			95.2	94.4	95.3	96.0	95.0	
Munsell Number			5Y 2.5/1	10YR 2/1	10YR 2/1	10YR 2/1	5Y 2.5/1	
Munsell Colour			Black	Black	Black	Black	Black	

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

	Client ID:		MME5-1	MME5-1	MME8-1 field dup of MME5-1	MME8-1 field dup of MME5-1	MME8-1 field dup of MME5-1	MME8-1 field dup of MME5-1
Component	**MDL**	**Units**	M. Spike	MS % Rec.		Duplicate	M. Spike	MS % Rec.
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	-	-	5300	5600	NA	<
Antimony	0.2	"	-	-	6.2	6.3	57	100
Arsenic	0.5	"	-	-	14	14	490	96
Barium	0.5	"	-	-	63	64	100	78
Beryllium	0.2	"	-	-	<	<	480	96
Bismuth	0.5	"	-	-	1.3	1.5	52	100
Boron	2.5	"	-	-	9.2	8	460	90
Cadmium	0.05	"	-	-	14	14	63	99
Chromium	0.6	"	-	-	13	14	470	92
Cobalt	0.2	"	-	-	9.1	9.1	480	94
Copper	0.2	"	-	-	600	590	1100	97
Iron	20	"	-	-	11000	11000	NA	<
Lead	0.1	"	-	-	350	360	NA	<
Manganese	1	"	-	-	210	210	700	99
Molybdenum	0.2	"	-	-	1.5	1.4	52	100
Nickel	0.5	"	-	-	21	22	500	96
Selenium	1	"	-	-	5.1	5.3	490	96
Silver	0.05	"	-	-	7.4	8	30	89
Strontium	0.5	"	-	-	24	25	76	100
Thallium	0.2	"	-	-	0.2	0.2	50	100
Tin	0.2	"	-	-	3.7	2.7	53	100
Titanium	0.3	"	-	-	180	190	660	94
Vanadium	1	"	-	-	11	11	470	91
Zinc	1	"	-	-	2100	2100	3100	100
Calcium	20	mg/kg	-	-	11630	11710	-	-
Magnesium	20	"	-	-	2942.5	2945	-	-
Loss on Ignition	0.1	(%)	-	-	51	52	-	-
Coarse Gravel (>4.8mm)	0.1	(%)	-	-	<	-	-	-
Fine Gravel (2.0-4.8mm)	0.1	"	-	-	3	-	-	-
V. Coarse Sand (1.0-2.0mm)	0.1	"	-	-	1.7	-	-	-
Coarse Sand (0.50-1.0mm)	0.1	"	-	-	31	-	-	-
Med. Sand (0.25-0.50mm)	0.1	"	-	-	15	-	-	-
Fine Sand (0.10-0.25mm)	0.1	"	-	-	2.8	-	-	-
V. Fine Sand (0.050-0.10mm)	0.1				0.9	-	-	-
Silt (0.002-0.050mm)	0.1				34	-	-	-
Clay (<0.002mm)	0.1				11	-	-	-
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	-	-				
Mercury	0.04	mg/kg	1.3	93	0.28	-	-	-
TOC (Solid)	0.1	(%)	-	-	24	-	-	-
Bulk Density (g/mL)								
Sediment Mositure (%)								
Munsell Number								
Munsell Colour								

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

		Client ID:	MME5-2	MME5-2	MME5-3	MMR1-1	MMR1-2	MMR1-2
Component	**MDL**	**Units**		Duplicate				Duplicate
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	6100	-	4900	5200	3900	4300
Antimony	0.2	"	8.5	-	8.1	0.5	0.9	0.5
Arsenic	0.5	"	20	-	18	3.5	3.9	3.6
Barium	0.5	"	53	-	54	43	44	43
Beryllium	0.2	"	0.2	-	<	0.2	<	<
Bismuth	0.5	"	1.9	-	2.1	<	<	<
Boron	2.5	"	8.3	-	7.6	9.1	7.1	6.8
Cadmium	0.05	"	14	-	21	1.8	1.6	1.5
Chromium	0.6	"	14	-	11	12	11	11
Cobalt	0.2	"	11	-	11	3.1	2.7	2.7
Copper	0.2	"	980	-	850	51	43	42
Iron	20	"	13000	-	12000	6100	4700	5000
Lead	0.1	"	540	-	560	25	26	25
Manganese	1	"	250	-	220	62	56	59
Molybdenum	0.2	"	1.2	-	1.3	1.5	1.6	1.5
Nickel	0.5	"	24	-	27	19	18	18
Selenium	1	"	6.2	-	5.8	2.3	3.2	3.1
Silver	0.05	"	11	-	11	0.26	0.16	0.15
Strontium	0.5	"	20	-	18	13	11	11
Thallium	0.2	"	0.2	-	0.2	<	<	<
Tin	0.2	"	1.4	-	1.9	0.4	0.7	0.8
Titanium	0.3	"	210	-	180	170	110	120
Vanadium	1	"	12	-	9.1	8.3	6.5	7
Zinc	1	"	3400	-	4000	450	330	320
Calcium	20	mg/kg	11387.5	9197.5	-	8680	9020	-
Magnesium	20	"	3092.5	2565	-	2855	2920	-
Loss on Ignition	0.1	(%)	50	52	51	59	60	-
Coarse Gravel (>4.8mm)	0.1	(%)	<	-	<	<	<	-
Fine Gravel (2.0-4.8mm)	0.1	"	6.1	-	5.9	<	4.8	-
V. Coarse Sand (1.0-2.0mm)	0.1	"	1.8	-	3.9	1.3	3.4	-
Coarse Sand (0.50-1.0mm)	0.1	"	18	-	32	30	26	-
Med. Sand (0.25-0.50mm)	0.1	"	20	-	27	35	33	-
Fine Sand (0.10-0.25mm)	0.1	"	18	-	18	28	26	-
V. Fine Sand (0.050-0.10mm)	0.1							
Silt (0.002-0.050mm)	0.1							
Clay (<0.002mm)	0.1							
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	36	-	13	5	7.8	-
Mercury	0.04	mg/kg	0.46	-	0.51	0.08	0.09	-
TOC (Solid)	0.1	(%)	26	-	25	26	27	-
Bulk Density (g/mL)			0.054		0.053	0.043	0.040	
Sediment Mositure (%)			94.8		94.7	95.9	96.1	
Munsell Number			5Y 2.5/1		5Y 2.5/1	5Y 4/3	5Y 4/3	
Munsell Colour			Black		Black	Olive	Olive	

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

	Client ID:		MMR1-2	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3
Component	**MDL**	**Units**	M. Spike	MS % Rec.				
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	NA	<	3700	2700	3000	3000
Antimony	0.2	"	55	110	0.6	0.4	0.5	0.4
Arsenic	0.5	"	57	110	3.4	5.4	7.2	7.1
Barium	0.5	"	110	120	39	85	110	94
Beryllium	0.2	"	48	96	<	<	<	<
Bismuth	0.5	"	54	110	<	<	<	<
Boron	2.5	"	51	87	5.9	6	6.6	5.8
Cadmium	0.05	"	30	110	1.6	0.94	1.2	1.2
Chromium	0.6	"	58	94	11	5.8	6.8	6.9
Cobalt	0.2	"	50	94	2.5	3.1	3.2	3.6
Copper	0.2	"	94	100	42	7.9	8.5	13
Iron	20	"	NA	<	4400	3600	4300	3800
Lead	0.1	"	84	120	24	29	27	36
Manganese	1	"	110	110	47	76	95	87
Molybdenum	0.2	"	57	110	1.5	1.4	1.9	1.6
Nickel	0.5	"	67	97	17	5.1	5.6	5.9
Selenium	1	"	57	110	3.2	1.7	2.4	2.2
Silver	0.05	"	NA	<	0.15	0.07	1.5	0.09
Strontium	0.5	"	70	120	11	23	29	26
Thallium	0.2	"	53	110	<	<	<	<
Tin	0.2	"	55	110	0.7	1	1.3	1.2
Titanium	0.3	"	170	110	110	45	48	45
Vanadium	1	"	53	92	6.1	10	13	12
Zinc	1	"	NA	<	360	78	90	97
Calcium	20	mg/kg	-	-	8856	9563	10010	8956
Magnesium	20	"	-	-	3145	3102	3050	2675
Loss on Ignition	0.1	(%)	-	-	60	73	75	72
Coarse Gravel (>4.8mm)	0.1	(%)	-	-	<	<	<	<
Fine Gravel (2.0-4.8mm)	0.1	"	-	-	3.4	3.3	0.1	2.5
V. Coarse Sand (1.0-2.0mm)	0.1	"	-	-	1.9	6.3	0.1	2.5
Coarse Sand (0.50-1.0mm)	0.1	"	-	-	30	30	1.2	22
Med. Sand (0.25-0.50mm)	0.1	"	-	-	29	27	1.6	20
Fine Sand (0.10-0.25mm)	0.1	"	-	-	20	26	1.6	22
V. Fine Sand (0.050-0.10mm)	0.1							
Silt (0.002-0.050mm)	0.1							
Clay (<0.002mm)	0.1							
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	-	-	16	7.7	95	31
Mercury	0.04	mg/kg	-	-	0.08	0.1	0.09	0.1
TOC (Solid)	0.1	(%)	-	-	28	34	36	26
Bulk Density (g/mL)					0.038	0.025	0.023	0.024
Sediment Mositure (%)					96.3	97.5	97.8	97.6
Munsell Number					5Y 4/3	10YR 3/4	10YR 3/4	10YR 3/4
Munsell Colour					Olive	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

	Client ID:		MME1-1	MME1-2	MME1-2	MME1-2	MME1-2	MME1-3
Component	**MDL**	**Units**			Duplicate	M. Spike	MS % Rec.	
ICP/MS - HNO3-H2O2								
Aluminum	1	mg/kg	5000	11000	11000	NA	<	12000
Antimony	0.2	"	8.7	15	16	66	100	20
Arsenic	0.5	"	67	150	150	620	95	160
Barium	0.5	"	36	55	56	100	98	69
Beryllium	0.2	"	0.2	0.5	0.4	480	95	0.4
Bismuth	0.5	"	2.4	4.1	4	50	92	5.8
Boron	2.5	"	5.1	13	10	470	91	11
Cadmium	0.05	"	60	100	110	150	97	140
Chromium	0.6	"	7	16	16	480	93	17
Cobalt	0.2	"	36	62	64	530	93	67
Copper	0.2	"	1100	2300	2300	2800	89	2500
Iron	20	"	15000	33000	33000	NA	<	36000
Lead	0.1	"	760	1300	1300	NA	<	1700
Manganese	1	"	1500	2000	2000	2500	98	1600
Molybdenum	0.2	"	1	1.8	1.8	52	100	2.3
Nickel	0.5	"	39	81	82	560	95	86
Selenium	1	"	7	17	16	500	97	17
Silver	0.05	"	4.4	17	17	39	90	13
Strontium	0.5	"	11	19	19	74	110	23
Thallium	0.2	"	0.6	1.1	1.1	48	93	1.4
Tin	0.2	"	2.2	4.6	3.7	54	100	6.8
Titanium	0.3	"	91	190	190	670	96	220
Vanadium	1	"	8.3	18	18	480	93	20
Zinc	1	"	20000	42000	43000	NA	<	45000
Calcium	20	mg/kg	4187.5	9315	8952.5	-	-	9075
Magnesium	20	"	2118.25	4890	4665	-	-	4985
Loss on Ignition	0.1	(%)	40	39	-	-	-	38
Coarse Gravel (>4.8mm)	0.1	(%)	<	<	-	-	-	<
Fine Gravel (2.0-4.8mm)	0.1	"	1	1.1	-	-	-	<
V. Coarse Sand (1.0-2.0mm)	0.1	"	0.1	2.1	-	-	-	<
Coarse Sand (0.50-1.0mm)	0.1	"	15	19	-	-	-	21
Med. Sand (0.25-0.50mm)	0.1	"	20	22	-	-	-	19
Fine Sand (0.10-0.25mm)	0.1	"	20	25	-	-	-	21
V. Fine Sand (0.050-0.10mm)	0.1							
Silt (0.002-0.050mm)	0.1							
Clay (<0.002mm)	0.1							
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	44	31	-	-	-	39
Mercury	0.04	mg/kg	1.3	1.3 -1	-	-	-	1.5
TOC (Solid)	0.1	(%)	20	19	-	-	-	19
Bulk Density (g/mL)			0.068	0.067				0.065
Sediment Mositure (%)			93.3	93.4				93.6
Munsell Number			2.5Y 2.5/1	2.5Y 2.5/1				2.5Y 2.5/1
Munsell Colour			Black	Black				Black

Table A4.1: Total Metals in Sediment Samples from Mattabi Mine Site

	Client ID:		MME1-3	MME1-3	MME1-3	MME8-3 field dup of MME1-3
Component	**MDL**	**Units**	Duplicate	M. Spike	MS % Rec.	
ICP/MS - HNO3-H2O2						
Aluminum	1	mg/kg	NA	NA	<	11000
Antimony	0.2	"	NA	67	94	19
Arsenic	0.5	"	NA	640	98	160
Barium	0.5	"	NA	100	71	64
Beryllium	0.2	"	NA	460	93	0.7
Bismuth	0.5	"	NA	52	93	5.2
Boron	2.5	"	NA	450	89	12
Cadmium	0.05	"	NA	160	120	130
Chromium	0.6	"	NA	480	92	16
Cobalt	0.2	"	NA	540	96	64
Copper	0.2	"	NA	NA	<	2500
Iron	20	"	NA	NA	<	35000
Lead	0.1	"	NA	NA	<	1700
Manganese	1	"	NA	2200	100	1600
Molybdenum	0.2	"	NA	52	100	2
Nickel	0.5	"	NA	570	96	83
Selenium	1	"	NA	510	98	16
Silver	0.05	"	NA	33	82	19
Strontium	0.5	"	NA	73	100	22
Thallium	0.2	"	NA	49	94	1.4
Tin	0.2	"	NA	55	96	5
Titanium	0.3	"	NA	700	96	210
Vanadium	1	"	NA	480	92	19
Zinc	1	"	NA	NA	<	40000
Calcium	20	mg/kg	8690	-	-	8350
Magnesium	20	"	4590	-	-	4590
Loss on Ignition	0.1	(%)	38	-	-	39
Coarse Gravel (>4.8mm)	0.1	(%)	-	-	-	<
Fine Gravel (2.0-4.8mm)	0.1	"	-	-	-	1.3
V. Coarse Sand (1.0-2.0mm)	0.1	"	-	-	-	1.3
Coarse Sand (0.50-1.0mm)	0.1	"	-	-	-	11
Med. Sand (0.25-0.50mm)	0.1	"	-	-	-	6
Fine Sand (0.10-0.25mm)	0.1	"	-	-	-	2.5
V. Fine Sand (0.050-0.10mm)	0.1					22
Silt (0.002-0.050mm)	0.1					45
Clay (<0.002mm)	0.1					11
V. Fine Sand, Silt, Clay (<0.10 mm)	0.1	"	-	-	-	
Mercury	0.04	mg/kg	1.5	-	-	1.4
TOC (Solid)	0.1	(%)	-	-	-	20
Bulk Density (g/mL)						
Sediment Mositure (%)						
Munsell Number						
Munsell Colour						

Table A4.2: Results of Partial Extraction Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME1-1	MME1-2	MME1-3	MME1-3 Lab Duplicate	MME2-1	MME2-2
Component	**MDL**	**Units**						
NH2OH-HCl								
Aluminum (ext.)	1	mg/kg	1800	1900	2300	2100	710	730
Antimony (ext.)	0.2	"	<	<	<	<	0.2	<
Arsenic (ext.)	0.5	"	3.8	2.6	2.7	2	0.8	0.5
Barium (ext.)	0.5	"	28	24	27	21	27	24
Beryllium (ext.)	0.2	"	0.2	0.2	0.2	0.2	0.3	<
Bismuth (ext.)	0.5	"	<	<	<	<	<	<
Cadmium (ext.)	0.05	"	0.2	0.13	0.2	0.13	0.12	0.07
Chromium (ext.)	0.6	"	2.9	3	3.9	3.6	2.3	2.3
Cobalt (ext.)	0.2	"	14	9.6	9.9	8.5	4.6	3.7
Copper (ext.)	0.2	"	0.2	0.2	0.2	0.2	0.2	<
Iron (ext.)	20	"	3600	3200	3700	3200	1600	1500
Lead (ext.)	0.1	"	34	19	30	19	19	14
Manganese (ext.)	1	"	1700	1100	890	820	300	240
Molybdenum (ext.)	0.2	"	<	<	<	<	<	<
Nickel (ext.)	0.5	"	18	19	20	18	6.1	6
Selenium (ext.)	1	"	<	<	<	<	<	<
Silver (ext.)	0.05	"	<	<	<	<	<	<
Strontium (ext.)	0.5	"	9.2	8.9	10	8.4	12	12
Thallium (ext.)	0.2	"	<	<	<	<	<	<
Tin (ext.)	0.2	"	<	<	<	<	<	<
Titanium (ext.)	0.3	"	0.3	0.3	0.7	0.4	0.4	0.3
Vanadium (ext.)	1	"	6.2	6.6	8.3	7.8	4.6	4.5
Zinc (ext.)	1	"	3500	3200	3800	3000	1600	1700
Calcium	20	mg/kg	4700	5156	4814	4610	6276	6248
Magnesium	20	"	1051	1179	1200	1138	923	940

Table A4.2: Results of Partial Extraction Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME2-3	MME3-1	MME3-2	MME3-3	MME4-1	MME4-2
Component	**MDL**	**Units**						
NH2OH-HCl								
Aluminum (ext.)	1	mg/kg	780	590	540	630	830	640
Antimony (ext.)	0.2	"	<	<	<	<	<	<
Arsenic (ext.)	0.5	"	<	1	0.5	0.7	1.3	0.8
Barium (ext.)	0.5	"	29	24	20	22	23	21
Beryllium (ext.)	0.2	"	<	<	<	<	<	<
Bismuth (ext.)	0.5	"	<	<	<	<	<	<
Cadmium (ext.)	0.05	"	0.09	0.2	0.12	0.16	0.19	0.59
Chromium (ext.)	0.6	"	2.2	2	2	2.3	2.9	2.7
Cobalt (ext.)	0.2	"	6.7	2	2.1	2.2	2	1
Copper (ext.)	0.2	"	<	0.2	<	0.3	0.4	0.3
Iron (ext.)	20	"	1800	1400	1200	1400	1400	1300
Lead (ext.)	0.1	"	14	18	17	18	28	8
Manganese (ext.)	1	"	310	110	70	90	230	160
Molybdenum (ext.)	0.2	"	<	<	<	<	<	<
Nickel (ext.)	0.5	"	7.4	3.3	4	3.8	5.4	2.2
Selenium (ext.)	1	"	<	<	<	<	<	<
Silver (ext.)	0.05	"	<	<	<	<	<	<
Strontium (ext.)	0.5	"	13	14	11	12	17	15
Thallium (ext.)	0.2	"	<	<	<	<	<	<
Tin (ext.)	0.2	"	<	<	<	<	<	<
Titanium (ext.)	0.3	"	0.4	0.4	0.4	0.4	0.7	0.7
Vanadium (ext.)	1	"	4.4	3.9	3.7	4.5	5.8	5.8
Zinc (ext.)	1	"	1800	1500	1300	1500	1800	1000
Calcium	20	mg/kg	6610	6812	5050	6206	6570	5910
Magnesium	20	"	1000	932	762	880	1061	891

Table A4.2: Results of Partial Extraction Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME4-3	MME5-1	MME5-1 Lab Duplicate	MME5-2	MME5-3	MMR1-1
Component	**MDL**	**Units**						
NH2OH-HCl								
Aluminum (ext.)	1	mg/kg	680	600	610	630	630	510
Antimony (ext.)	0.2	"	<	<	<	0.2	<	<
Arsenic (ext.)	0.5	"	2.4	2.7	2.6	3.2	2.4	1
Barium (ext.)	0.5	"	17	22	20	20	27	15
Beryllium (ext.)	0.2	"	<	<	<	0.2	0.2	<
Bismuth (ext.)	0.5	"	<	<	<	<	<	<
Cadmium (ext.)	0.05	"	2.7	2.5	2.3	3.9	1.2	0.81
Chromium (ext.)	0.6	"	3.3	2.2	2.2	2.5	2.4	2.5
Cobalt (ext.)	0.2	"	1	0.8	0.8	1	1.3	0.3
Copper (ext.)	0.2	"	2.1	1.7	2.8	4.1	1.7	1.2
Iron (ext.)	20	"	880	1200	1200	1200	1400	530
Lead (ext.)	0.1	"	38	39	32	92	70	5.3
Manganese (ext.)	1	"	60	140	140	130	180	16
Molybdenum (ext.)	0.2	"	<	<	<	<	<	<
Nickel (ext.)	0.5	"	2.4	1.7	1.7	2.7	2.4	1.7
Selenium (ext.)	1	"	<	<	<	<	<	<
Silver (ext.)	0.05	"	<	<	<	<	<	<
Strontium (ext.)	0.5	"	9.5	11	10	9.7	11	5.3
Thallium (ext.)	0.2	"	<	<	<	<	<	<
Tin (ext.)	0.2	"	<	<	<	<	<	<
Titanium (ext.)	0.3	"	0.7	0.6	0.4	0.6	0.4	0.7
Vanadium (ext.)	1	"	6.8	4.5	4.5	5.3	4.9	4.7
Zinc (ext.)	1	"	670	740	760	750	1300	170
Calcium	20	mg/kg	4326	6492	6362	6654	7870	4546
Magnesium	20	"	625	834	829	884	1030	806

Table A4.2: Results of Partial Extraction Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3
Component	**MDL**	**Units**					
NH2OH-HCl							
Aluminum (ext.)	1	mg/kg	470	480	360	360	420
Antimony (ext.)	0.2	"	<	<	<	<	<
Arsenic (ext.)	0.5	"	1.2	1.1	0.9	1.4	1.6
Barium (ext.)	0.5	"	16	16	28	35	39
Beryllium (ext.)	0.2	"	<	<	<	<	<
Bismuth (ext.)	0.5	"	<	<	<	<	<
Cadmium (ext.)	0.05	"	0.84	0.71	0.3	0.39	0.54
Chromium (ext.)	0.6	"	2.3	2.3	1.4	1.6	1.4
Cobalt (ext.)	0.2	"	0.3	0.3	<	<	<
Copper (ext.)	0.2	"	1.1	1.1	<	<	<
Iron (ext.)	20	"	520	510	760	900	800
Lead (ext.)	0.1	"	5.4	5.3	2.4	2.1	4.2
Manganese (ext.)	1	"	16	18	32	38	34
Molybdenum (ext.)	0.2	"	<	<	<	<	<
Nickel (ext.)	0.5	"	1.7	1.5	<	2.8	<
Selenium (ext.)	1	"	<	<	<	<	<
Silver (ext.)	0.05	"	<	<	<	<	<
Strontium (ext.)	0.5	"	5.7	5	9.2	11	13
Thallium (ext.)	0.2	"	<	<	<	<	<
Tin (ext.)	0.2	"	<	<	<	<	<
Titanium (ext.)	0.3	"	0.8	0.8	<	<	<
Vanadium (ext.)	1	"	4.3	4.3	3.9	4.2	3.9
Zinc (ext.)	1	"	180	140	26	25	31
Calcium	20	mg/kg	4684	4660	4490	5288	5202
Magnesium	20	"	821	796	820	370	520

Table A4.3: Results of AVS/SEM Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME1-1	MME1-1 Lab Duplicate	MME1-2	MME1-3	MME2-1	MME2-2
Component	**MDL**	**Units**						
Aluminum	2	umol/g	455.9	540.3	457.4	556.0	409.3	248.1
Barium	0.1	umol/g	0.7	0.9	0.7	0.7	0.8	0.5
Beryllium	0.1	umol/g	<	<	<	<	<	<
Boron	1	umol/g	12.2	17.3	4.7	11.6	22.7	10.1
Cadmium	0.05	umol/g	<	<	<	<	<	<
Calcium	7	umol/g	386.5	466.0	361.0	411.7	581.7	386.3
Chromium	0.1	umol/g	<	<	<	<	<	<
Cobalt	0.2	umol/g	1.7	1.9	1.2	1.3	<	<
Copper	0.1	umol/g	20.8	19.4	24.1	0.5	17.4	9.9
Iron	0.2	umol/g	351.1	432.7	327.9	376.3	252.9	150.0
Lead	0.4	umol/g	<	<	<	<	<	<
Magnesium	3	umol/g	155.4	185.7	156.1	185.3	193.3	122.5
Manganese	0.1	umol/g	107.9	132.8	61.2	56.5	21.2	11.4
Molybdenum	0.1	umol/g	<	<	<	<	<	<
Nickel	0.2	umol/g	1.9	1.8	1.3	1.7	<	1.0
Potassium	10	umol/g	<	<	<	<	<	<
Silver	0.1	umol/g	<	<	<	<	<	<
Sodium	6	umol/g	39.6	49.5	33.3	41.3	42.7	21.8
Strontium	0.1	umol/g	0.3	0.4	0.3	0.4	0.5	0.3
Sulphur	3	umol/g	46.8	49.7	47.7	119.9	40.1	39.1
Thallium	0.5	umol/g	<	<	<	<	<	<
Tin	0.5	umol/g	<	<	<	<	<	<
Titanium	0.3	umol/g	3.5	3.9	3.4	4.2	8.1	4.8
Vanadium	0.1	umol/g	0.5	0.5	0.5	0.6	<	<
Zinc	0.1	umol/g	975.2	1184.2	1106.1	1223.2	431.5	294.3
Zirconium	0.5	umol/g	<	<	<	<	<	<
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			997.9	1205.4	1131.5	1225.5	448.9	305.2
AV Sulphide	0.1		1416.0	1556.0	1350.0	185.0	359.0	163.0
SEM/AVS Ratio			0.7	0.8	0.8	6.6	1.3	1.9

Table A4.3: Results of AVS/SEM Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME2-3	MME3-1	MME3-2	MME3-3	MME4-1	MME4-2
Component	**MDL**	**Units**						
Aluminum	2	umol/g	203.4	277.4	236.8	186.1	218.9	215.7
Barium	0.1	umol/g	0.4	0.6	0.5	0.4	0.5	0.6
Beryllium	0.1	umol/g	<	<	<	<	<	<
Boron	1	umol/g	6.7	<	7.3	4.3	6.9	17.1
Cadmium	0.05	umol/g	<	<	<	<	<	<
Calcium	7	umol/g	273.9	509.2	380.1	323.6	402.7	475.2
Chromium	0.1	umol/g	<	<	<	<	<	<
Cobalt	0.2	umol/g	0.6	<	<	<	<	<
Copper	0.1	umol/g	11.9	11.8	13.1	9.2	6.1	2.2
Iron	0.2	umol/g	129.1	158.5	149.7	112.5	119.9	132.7
Lead	0.4	umol/g	<	<	<	<	<	<
Magnesium	3	umol/g	91.5	138.7	116.6	97.7	124.0	133.4
Manganese	0.1	umol/g	10.6	6.4	5.5	4.0	9.3	8.3
Molybdenum	0.1	umol/g	<	<	<	<	<	<
Nickel	0.2	umol/g	0.6	<	<	<	<	<
Potassium	10	umol/g	<	<	<	<	<	<
Silver	0.1	umol/g	<	<	<	<	<	<
Sodium	6	umol/g	14.9	<	<	20.0	25.7	27.6
Strontium	0.1	umol/g	0.2	0.4	0.3	0.3	0.4	0.6
Sulphur	3	umol/g	21.4	42.4	30.6	31.3	27.0	24.7
Thallium	0.5	umol/g	<	<	<	<	<	<
Tin	0.5	umol/g	<	<	<	<	<	<
Titanium	0.3	umol/g	3.8	5.7	4.6	3.8	5.5	6.7
Vanadium	0.1	umol/g	<	<	<	<	<	<
Zinc	0.1	umol/g	304.2	239.2	330.6	211.1	180.6	64.7
Zirconium	0.5	umol/g	<	<	<	<	<	<
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			316.7	251.0	343.8	220.3	186.7	67.0
AV Sulphide	0.1		282.0	164.0	426.0	94.5	156.0	78.7
SEM/AVS Ratio			1.1	1.5	0.8	2.3	1.2	0.9

Table A4.3: Results of AVS/SEM Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MME4-3	MME5-1	MME5-2	MME5-2 Lab Duplicate	MME5-3	MMR1-1
Component	**MDL**	**Units**						
Aluminum	2	umol/g	165.5	255.6	294.6	319.1	252.9	459.7
Barium	0.1	umol/g	0.4	0.6	0.7	0.8	0.7	1.5
Beryllium	0.1	umol/g	<	<	<	<	<	<
Boron	1	umol/g	6.5	11.2	12.9	50.2	9.7	20.1
Cadmium	0.05	umol/g	<	<	<	<	<	<
Calcium	7	umol/g	336.5	530.5	578.3	561.8	471.5	928.4
Chromium	0.1	umol/g	<	<	<	<	<	<
Cobalt	0.2	umol/g	<	<	<	<	<	<
Copper	0.1	umol/g	3.5	6.9	9.7	9.6	11.6	3.4
Iron	0.2	umol/g	79.2	144.2	166.2	178.0	141.1	211.2
Lead	0.4	umol/g	<	<	<	<	<	<
Magnesium	3	umol/g	89.6	138.5	152.2	157.1	132.3	298.8
Manganese	0.1	umol/g	3.0	7.2	9.2	9.2	8.8	4.5
Molybdenum	0.1	umol/g	<	<	<	<	<	<
Nickel	0.2	umol/g	<	<	<	<	<	<
Potassium	10	umol/g	<	<	<	<	<	<
Silver	0.1	umol/g	<	<	<	<	<	<
Sodium	6	umol/g	<	<	<	46.1	<	<
Strontium	0.1	umol/g	0.3	0.4	0.4	0.5	0.4	0.6
Sulphur	3	umol/g	18.8	26.9	33.0	35.1	26.2	62.8
Thallium	0.5	umol/g	<	<	<	<	<	<
Tin	0.5	umol/g	<	<	<	<	<	<
Titanium	0.3	umol/g	3.9	5.9	6.6	7.2	5.5	10.7
Vanadium	0.1	umol/g	<	<	<	<	<	<
Zinc	0.1	umol/g	33.4	45.7	58.7	58.7	88.3	28.4
Zirconium	0.5	umol/g	<	<	<	<	<	<
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			36.9	52.6	68.4	68.3	99.9	31.9
AV Sulphide	0.1		112.0	61.9	68.0	67.0	42.1	23.9
SEM/AVS Ratio			0.3	0.8	1.0	1.0	2.4	1.3

Table A4.3: Results of AVS/SEM Analysis Conducted on Sediment Samples from Mattabi Mine Site

	Client ID:		MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3
Component	**MDL**	**Units**					
Aluminum	2	umol/g	217.4	121.7	109.4	130.6	121.5
Barium	0.1	umol/g	0.6	0.3	0.9	1.3	1.0
Beryllium	0.1	umol/g	<	<	<	<	<
Boron	1	umol/g	9.2	5.3	<	<	<
Cadmium	0.05	umol/g	<	<	<	<	<
Calcium	7	umol/g	476.1	262.1	368.1	567.0	436.3
Chromium	0.1	umol/g	<	<	<	<	<
Cobalt	0.2	umol/g	<	<	<	<	<
Copper	0.1	umol/g	1.4	0.9	<	<	<
Iron	0.2	umol/g	100.1	54.1	85.2	110.0	90.1
Lead	0.4	umol/g	<	<	<	<	<
Magnesium	3	umol/g	146.7	82.7	48.6	59.0	52.7
Manganese	0.1	umol/g	2.1	1.0	2.2	3.1	2.4
Molybdenum	0.1	umol/g	<	<	<	<	<
Nickel	0.2	umol/g	<	<	<	<	<
Potassium	10	umol/g	<	<	<	<	<
Silver	0.1	umol/g	<	<	<	<	<
Sodium	6	umol/g	<	<	<	<	<
Strontium	0.1	umol/g	0.3	0.1	0.3	0.5	0.4
Sulphur	3	umol/g	30.8	19.1	16.1	<	<
Thallium	0.5	umol/g	<	<	<	<	<
Tin	0.5	umol/g	<	<	<	<	<
Titanium	0.3	umol/g	5.2	2.9	<	<	<
Vanadium	0.1	umol/g	<	<	<	<	<
Zinc	0.1	umol/g	11.9	8.0	2.0	2.6	2.3
Zirconium	0.5	umol/g	<	<	<	<	<
Sum of SEM (Cd/Cu/Ni/Pb/Zn)			13.3	8.9	2.0	2.6	2.3
AV Sulphide	0.1		43.5	6.7	1.0	<0.1	<0.1
SEM/AVS Ratio			0.3	1.3	2.0	>2.6	>2.3

Adult Survivorship: MATTABI MINE

	SITE	Mean	SD	CV	Classification
AETE 7a	MMSR1-1	100	0.00	0.00	NON TOXIC
	MMSR1-2	100	0.00	0.00	NON TOXIC
	MMSR1-3	100	0.00	0.00	NON TOXIC
	MMSR2-1	95	11.20	11.80	NON TOXIC
	MMSR2-2	90	13.70	15.20	NON TOXIC
	MMSR2-3	90	13.70	15.20	NON TOXIC
	Mean	91.66666667	0.00	0.00	NON TOXIC
AETE 7b	MMS1-1	100	0.00	0.00	NON TOXIC
	MMS1-2	100	0.00	0.00	NON TOXIC
	MMS1-3	100	0.00	0.00	NON TOXIC
	LAB CONTROL	100	0.00	0.00	NON TOXIC
AETE 8	MMS3-1	95	11.2	11.8	NON TOXIC
	MMS3-2	95	11.2	11.8	NON TOXIC
	MMS3-3	100	0	0	NON TOXIC
		96.66666667	0	0	NON TOXIC
	MMS4-1	100			
	MMS4-2	93.75	12.5	13.3	NON TOXIC
	MMS4-3	100	0	0	NON TOXIC
	LAB CONTROL	97.91666667	0	0	NON TOXIC
AETE 9	MMS2-1	100	0	0	NON TOXIC
	MMS2-2	100	0	0	NON TOXIC
	MMS2-3	100	0	0	NON TOXIC
	MMS5-1	100	0	0	NON TOXIC
	MMS5-2	100	0	0	NON TOXIC
	MMS5-3	100	0	0	NON TOXIC
	LAB CONTROL	100	0	0	NON TOXIC

Mean CV 3.16

CV Range 0 - 15.20

Cocoons/Adult: MATTABI MINE

	SITE	Mean	SD	CV	Classification
AETE 7a	MMSR1-1	9.05	1.35	14.93	NON TOXIC
	MMSR1-2	9.00	1.55	17.24	NON TOXIC
	MMSR1-3	9.25	0.92	9.93	NON TOXIC
	MMSR2-1	8.16	1.11	13.62	NON TOXIC
	MMSR2-2	5.39	0.94	17.53	**TOXIC**
	MMSR2-3	6.97	1.27	18.23	**POT. TOXIC**
	LAB CONTROL	10.80	0.98	9.03	NON TOXIC
AETE 7b	MMS1-1	11.35	1.07	9.42	NON TOXIC
	MMS1-2	10.94	0.82	7.53	NON TOXIC
	MMS1-3	11.20	0.33	2.91	NON TOXIC
	LAB CONTROL	11.00	0.73	6.63	NON TOXIC
AETE 8	MMS3-1	9.94	1.27	12.82	NON TOXIC
	MMS3-2	9.14	1.39	15.18	NON TOXIC
	MMS3-3	11.00	0.98	8.95	NON TOXIC
	MMS4-1	9.90	0.42	4.23	NON TOXIC
	MMS4-2	8.30	0.53	6.37	NON TOXIC
	MMS4-3	8.65	0.86	9.93	NON TOXIC
	LAB CONTROL	11.05	0.51	4.64	NON TOXIC
AETE 9	MMS2-1	9.50	1.16	12.20	NON TOXIC
	MMS2-2	9.25	0.64	6.89	NON TOXIC
	MMS2-3	9.13	0.52	5.70	NON TOXIC
	MMS5-1	9.20	1.34	14.56	NON TOXIC
	MMS5-2	8.70	1.04	11.92	NON TOXIC
	MMS5-3	8.20	0.91	11.08	NON TOXIC
	LAB CONTROL	9.80	0.89	9.09	NON TOXIC

Mean CV 10.42

CV Range 2.91 - 18.23

% Cocoons Hatched: MATTABI MINE

	SITE	Mean	SD	CV	Classification
AETE 7a	MMSR1-1	49.99	4.78	9.55	NON TOXIC
	MMSR1-2	49.42	6.70	13.55	NON TOXIC
	MMSR1-3	46.14	5.44	11.80	NON TOXIC
	MMSR2-1	51.20	9.56	18.67	NON TOXIC
	MMSR2-2	63.75	14.42	22.62	NON TOXIC
	MMSR2-3	50.47	3.81	7.54	NON TOXIC
	LAB CONTROL	57.49	4.74	8.24	NON TOXIC
AETE 7b	MMS1-1	51.00	4.77	9.35	NON TOXIC
	MMS1-2	44.77	7.12	15.90	NON TOXIC
	MMS1-3	47.31	2.37	5.00	NON TOXIC
	LAB CONTROL	58.20	4.00	6.87	NON TOXIC
AETE 8	MMS3-1	55.01	6.76	12.30	NON TOXIC
	MMS3-2	51.97	4.98	9.58	NON TOXIC
	MMS3-3	51.31	2.03	3.95	NON TOXIC
	MMS4-1	41.87	3.21	7.67	NON TOXIC
	MMS4-2	48.54	3.48	7.16	NON TOXIC
	MMS4-3	53.28	4.56	8.56	NON TOXIC
	LAB CONTROL	55.61	2.66	4.78	NON TOXIC
AETE 9	MMS2-1	48.81	4.50	9.22	NON TOXIC
	MMS2-2	49.15	4.58	9.32	NON TOXIC
	MMS2-3	46.54	1.91	4.10	NON TOXIC
	MMS5-1	50.06	6.50	12.97	NON TOXIC
	MMS5-2	53.55	8.78	16.40	NON TOXIC
	MMS5-3	57.70	5.96	10.34	NON TOXIC
	LAB CONTROL	50.13	5.45	10.87	NON TOXIC

Mean CV 10.25

CV Range 3.95 - 22.62

Young/Adult: MATTABI MINE

	SITE	Mean	SD	CV	Classification
AETE 7a	MMSR1-1	25.20	5.33	21.15	NON TOXIC
	MMSR1-2	21.75	5.32	24.45	NON TOXIC
	MMSR1-3	23.65	0.76	3.22	NON TOXIC
	mean	23.53			
		1.73			
	MMSR2-1	20.44	5.22	25.52	NON TOXIC
	MMSR2-2	13.42	4.31	32.14	NON TOXIC
	MMSR2-3	13.85	4.33	31.23	NON TOXIC
	Mean	15.90	4.40	14.75	NON TOXIC
		3.93			
	MMS1-1	18.95	5.38	28.41	NON TOXIC
	MMS1-2	12.22	6.83	55.88	NON TOXIC
	MMS1-3	13.80	1.63	11.84	NON TOXIC
	Mean	14.99	1.43	4.20	NON TOXIC
		3.52			
	MMS3-1	31.66	4.18	13.20	NON TOXIC
	MMS3-2	28.14	5.98	21.30	NON TOXIC
	MMS3-3	33.25	3.82	11.50	NON TOXIC
	Mean	31.02	3.60	14.60	NON TOXIC
		2.62			
	MMS4-1	24.75			
	MMS4-2	23.21	2.83	12.20	NON TOXIC
	MMS4-3	32.60	3.44	10.60	NON TOXIC
	Mean	26.85	4.06	13.50	NON TOXIC
		5.04			
	MMS2-1	19.25	4.38	22.74	NON TOXIC
	MMS2-2	24.25	5.10	21.04	NON TOXIC
	MMS2-3	16.88	2.57	15.23	NON TOXIC
	Mean	20.13	3.83	15.15	NON TOXIC
		3.762397285	2.93	11.36	NON TOXIC
	MMS5-1	25.30			
	MMS5-2	25.75			
	MMS5-3	19.70	3.55	18.00	NON TOXIC
	Mean	23.58	4.36	16.72	NON TOXIC
		3.37			
	Mean CV	18.80			
	CV Range	3.22 - 55.88			

Sample	Received[1]	Characteristics	Treatment	Beginning of test	End of test
D4-1-S	10/10/97	Silt / clay composition	Homogeneisation	25/10/97[2] 29/10/97[3]	08/11/97[2] 08/11/97[3]
D4-2-S	16/10/97	Silt / clay composition	Homogeneisation	25/10/97[2] 29/10/97[3]	08/11/97[2] 08/11/97[3]
D4-5-S	16/10/97	Silt / clay composition	Homogeneisation	25/10/97[2] 01/11/97[3]	08/11/97[2] 11/11/97[3]
D4-6-S	16/10/97	Silt / clay composition	Homogeneisation	25/10/97[2] 01/11/97[3]	08/11/97[2] 11/11/97[3]
D4-7-S	16/10/97	Silt / clay composition	Homogeneisation	25/10/97[2] 01/11/97[3]	08/11/97[2] 11/11/97[3]
MMS4-3	29/10/97	Silt / clay composition	Homogeneisation	05/11/97[2] 01/11/97[3]	19/11/97[2] 11/11/97[3]
MMS1-2	29/10/97	silt / clay composition, organic matter	Homogeneisation	30/10/97[2] 31/11/97[3]	13/11/97[2] 10/11/97[3]
MMSR2-1	29/10/97	silt / clay composition, organic matter	Homogeneisation	30/10/97[2] 31/11/97[3]	13/11/97[2] 10/11/97[3]
MMS1-3	29/10/97	silt / clay composition	Homogeneisation	30/10/97[2] 31/11/97[3]	13/11/97[2] 10/11/97[3]
MMS3-1	29/10/97	silt / clay composition, organic matter	Homogeneisation	05/11/97[2] 31/10/97[3]	19/10/97[2] 10/11/97[3]
MMS3-2	29/10/97	silt / clay composition, organic matter	Homogeneisation	05/11/97[2] 06/11/97[3]	19/11/97[2] 16/11/97[3]
MMSR1-3	29/10/97	silt / clay composition, organic matter	Homogeneisation	05/11/97[2] 06/11/97[3]	19/11/97[2] 16/11/97[3]
MMS4-1	29/10/97	silt / clay composition, organic matter	Homogeneisation	05/11/97[2] 06/11/97[3]	19/11/97[2] 16/11/97[3]
MMS4-2	29/10/97	silt / clay composition, organic matter	Homogeneisation	19/11/97[2] 06/11/97[3]	03/11/97[2] 16/11/97[3]
MMSR1-1	29/10/97	silt / clay composition, organic matter	Homogeneisation	19/11/97[2] 07/11/97[3]	03/11/97[2] 17/11/97[3]
MMS2-1	29/10/97	silt / clay composition, organic matter	Homogeneisation	19/11/97[2] 07/11/97[3]	03/11/97[2] 17/11/97[3]
MMS2-2	29/10/97	silt / clay composition, organic matter	Homogeneisation	30/10/97[2] 31/11/97[3]	13/11/97[2] 10/11/97[3]

Sample	Received[1]	Characteristics	Treatment	Beginning of test	End of test
MMS2-3	29/10/97	silt / clay composition, organic matter	Homogeneisation	19/11/97[2] 07/11/97[3]	03/11/97[2] 17/11/97[3]
MMS1-1	29/10/97	silt / clay composition	Homogeneisation	20/11/97[2] 07/11/97[3]	04/11/97[2] 17/11/97[3]
MMS5-1	29/10/97	silt / clay composition	Homogeneisation	20/11/97[2] 07/11/97[3]	04/11/97[2] 17/11/97[3]
MMS5-2	29/10/97	silt / clay composition	Homogeneisation	20/11/97[2] 07/11/97[3]	04/11/97[2] 17/11/97[3]
MMSR2-2	29/10/97	silt / clay composition, organic matter	Homogeneisation	20/11/97[2] 14/11/97[3]	04/11/97[2] 24/11/97[3]

1: Upon reception , samples were preserved 4°C until testing.
2: Survival and growth with *H. azteca.*
3: Survival and growth with *C. tentans.*

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CERTIFICATE OF ANALYSIS

Client: BEAK (Brampton)
Adresse: 14 Abacus rd
Brampton, On L6T 5B7

Contact: D. Farara/P. McKee
Project N° : 20776.230
Type of sample: Sediment
Collected by: BEAK (Brampton)
Method of transport: Federal Express

Final Test Results: Growth and Survival using the freshwater amphipod *Hyalella azteca*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V.[3] (%)	Date of test (1997)
MMS4-3	0492HASD	30* ± 27	91	0.27* ± 0.04	16	5 Nov.
MMS1-2	0493HASD	12* ± 16	137	0.16 ± 0.02	15	30 Oct.
MMSR2-1	0494HASD	88 ± 13	15	0.24 ± 0.08	32	30 Oct.
MMS1-3	0495HASD	12* ± 8	70	0.22 ± 0.23	101	30 Oct.
MMS3-1	0496HASD	86 ± 11	13	0.16 ± 0.03	22	30 Oct.
MMS3-2	0497HASD	8* ± 13	163	0.14* ± 0.04	30	5 Nov.
MMSR1-3	0498HASD	58* ± 11	19	0.32* ± 0.02	7	5 Nov.
MMS4-1	0499HASD	56* ± 9	16	0.28* ± 0.05	16	5 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, December 1996.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels many-one rank, Kruskall Wallis or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

19-jan-98

Approved by:

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater amphipod *Hyalella azteca*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V. [3] (%)	Date of test (1997)
MMS4-2	0500HASD	42* ± 8	20	0.28 ± 0.05	18	19 Nov.
MMSR1-1	0501HASD	64 ± 6	9	0.16* ± 0.06	39	19 Nov.
MMS2-1	0502HASD	70 ± 12	18	0.21 ± 0.05	22	19 Nov.
MMS2-2	0503HASD	58* ± 4	8	0.07* ± 0.04	58	30 Oct.
MMS2-3	0504HASD	22* ± 25	113	0.16* ± 0.04	26	19 Nov.
MMS1-1	0505HASD	46* ± 9	19	0.13 ± 0.05	41	20 Nov.
MMS5-1	0506HASD	58* ± 8	14	0.20 ± 0.09	48	20 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, December 1996.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels many-one rank, Kruskall Wallis or Student T test (when there was 0 variance). The computer programs used were Toxstat® 3.4 and excel 4.0.

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater amphipod *Hyalella azteca*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V. [3] (%)	Date of test (1997)
MMS5-2	0507HASD	18* ± 4	25	0.23 ± 0.14	59	20 Nov.
MMSR1-2	0508HASD	12* ± 16	137	0.16 ± 0.13	81	20 Nov.
MMS3-3	0509HASD	0*	–	—	–	20 Nov.
MMS5-3	0510HASD	70 ± 10	14	0.19 ± 0.06	29	21 Nov.
mmSR 2-3 ← MMSR~~3-2~~	0511HASD	60* ± 7	12	0.24 ± 0.05	21	21 Nov.
MMSR2-2	0512HASD	64* ± 9	14	0.15* ± 0.04	25	21 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, December 1996.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater amphipod *Hyalella azteca*

BEAK sample number	Survival ± s. d^1 (%)	C.V.^{2} (%)	Mean dry weight/org ± s.d^1 (mg)	C.V. ^{3} (%)	Date of test (1997)
Biological control	96 ± 6	6	0.25 ± 0.04	14	12 Sept.
Biological control	88 ± 8	10	0.26 ± 0.02	9	19 Sept.
Biological control	98 ± 4	5	0.26 ± 0.06	25	25 Sept.
Biological control	92 ± 8	9	0.24 ± 0.04	16	15 Oct.
Biological control	88 ± 8	10	0.26 ± 0.02	8	17 Oct.
Biological control	86 ± 6	6	0.26 ± 0.01	4	25 Oct.
Biological control	80 ± 0	0	0.3 ± 0.12	41	30 Oct.
Biological control	98 ± 11	11	0.41 ± 0.06	15	5 Nov.
Biological control	84 ± 6	6	0.28 ± 0.02	7	19 Nov.
Biological control	88 ± 4	5	0.25 ± 0.04	15	20 Nov.
Biological control	80 ± 0	0	0.25 ± 0.04	16	21 Nov.
Biological control (QAQC test)	80 ± 0	0	0.25 ± 0.02	7	28 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, December 1996.

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Conditions and procedures for whole sediment testing with the freshwater amphipod *Hyalella azteca*

Conditions and procedures	Env. Canada 1996[1]	BEAK International inc.
Test	14 days, static or twice daily renewal	14 days, static
Water renewal	Static: none, except if evaporation occurs	Static: none, except if evaporation occurs
Surface water	Dechlorinated culture water, uncontaminated ground water	Culture water originating from the city of Dorval aquaduct, and dechlorinated by a system devised by BEAK Dorval. Overlying surface water is aerated for 24 hrs prior to the start of tests.
Control sediment	Natural sediment exempt from natural or artifical contaminants, previously tested to ensure adequate growth and survival .	Natural sediment collected from Long Point (Lake Erie, ON) exempt from contaminants, provided by CCIW, Burlington, ON.
Organisms	*Hyalella azteca*, 2-9 days	*Hyalella azteca*, 2-9 days
Test beakers	300 mL glass beakers, with covers	300 mL glass beakers, with covers
Volume of sediment (wet)	100 mL	100 mL
Volume of overlying water	175 mL	175 mL
Number of replicates	A minimum of 5 field replicates, and 1 to 5 replicates for each field replicate	5 replicates per sample
Temperature	daily average: 23±1°C instant: 23±3°C	23±1°C: Temperature of water bath taken daily, temperature of 1 replicate from each sample taken 3 times/wk
Lighting and photoperiod	• fluorescent tubes that provide 500-1000 lux • photoperiode: 16 h light-8 h dark	• fluorescent tubes that provide 630-1000 lux • photoperiode: 16 h light-8 h dark
Aeration	static: continuous aeration (2 - 3 bubbles /sec in all beakers)	static: continuous aeration (2 - 3 bubbles /sec in all beakers)

1: Test conditions and procedures recommended by: Environnement Canada. December 1996. Test for growth and survival in sediment using larvae of freshwater amphipod (*Hyalella azteca*)-Preview to Final Manuscript. Environmental protection series biological test method. Method Development and Application Section, Environmental Technology Centre, Environment Canada, Ottawa. 102p.

Conditions and procedures	Env. Canada 1996[1]	BEAK International inc.
Feeding regime	Fish food flakes (Tetrafin™ or Nutrafin™ : 4 times/week, 15 mg (dry weight) in a 3.75 ml suspension/beaker or daily with 6.0 mg (dry weight) in a 1.5 ml suspension/beaker .	Fish food flakes (Nutrafin™) : 4 times/week, 15 mg (dry weight) in a 3.75 ml suspension/beaker.
Observations	Optional: number of organisms observed at the sediment surface, general behaviour (daily or less frequently).	Daily observations of each beaker, if organisms are observed, it is noted..
Parameters: overlying water	• DO and temperature: ≥3 timestimes/week for each sample • pH, hardness or alkalinity, conductivity and ammonia: Day 0 and Day 14 in at least one replicate for each sample.	• DO and temperature: 3 timestimes/week for each sample • pH, hardness or alkalinity, conductivity and ammonia: Day 0 and Day 14 in at least one replicate for each sample.
Test endpoint	Growth and survival: mean % survival and mean dry weight/organism for each sample.	Growth and survival: mean % survival and mean dry weight/organism for each sample.
Test validity	Test invalid if the mean survival in the controls is less than 80%, or if the mean individual dry weight of the test organisms is less than 0.2 mg.	Test invalid if the mean survival in the controls is less than 80%, or if the mean individual dry weight of the test organisms is less than 0.2 mg.
Reference toxicant	Water only 96 hr test using $CuSO_4$, $CdCl_2$, KCl or NaCl . Minimum of five concentrations and a control, with 3 replicates.	Water only 96 hr test using $CuSO_4$ Five concentrations and a control, with 3 replicates. Test performed monthly. • reference toxicant: $CuSO_4$ • Geometric mean and standard deviation: CL_{50}: 0,31 ppm (0,06) *Coefficient of variation: 22%

1: Test conditions and procedures recommended by: Environnement Canada. December 1996. Test for growth and survival in sediment using larvae of freshwater amphipod (*Hyalella azteca*)-Preview to Final Manuscript. Environmental protection series biological test method. Method Development and Application Section, Environmental Technology Centre, Environment Canada, Ottawa. 102p.

Quality Control Test Results: Growth and Survival using the freshwater amphipod *Hyalella azteca*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V. [3] (%)	Date of test (1997)
MF6-S	0447HASD	24* ± 15	63	0.16* ± 0.05	34	19 Sept.
D1B-2-S	0467HASD	84 ± 15	18	0.14* ± 0.03	24	15 Oct.
D3-1-S	0473HASD	52* ± 31	60	0.10* ± 0.01	11	15 Oct.
MMS4-3	0492HASD	30* ± 27	91	0.27* ± 0.04	16	5 Nov.
MMS3-1	0496HASD	86 ± 11	13	0.16 ± 0.03	22	30 Oct.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, December 1996.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

Quality control:

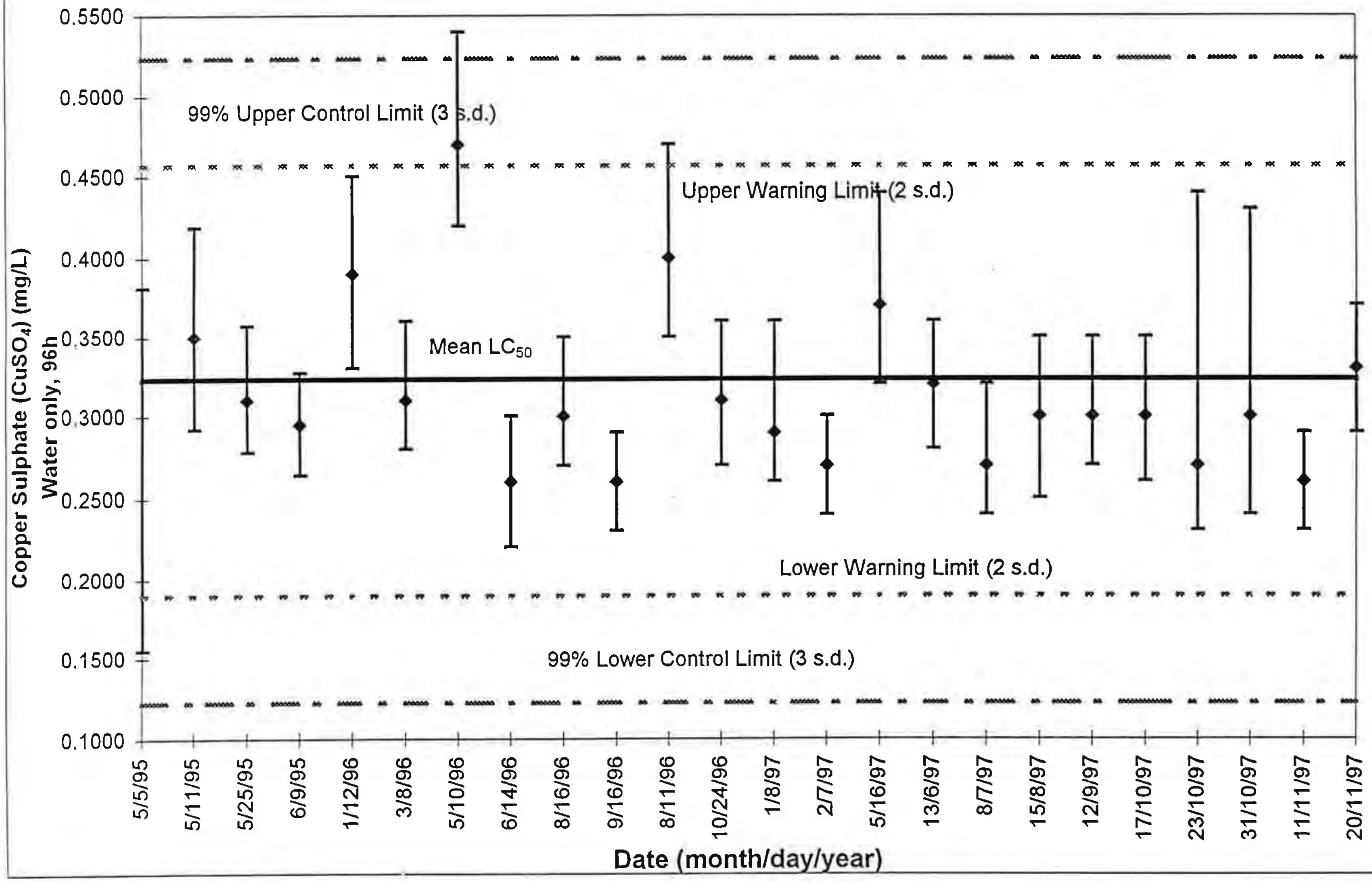
Sample **MF6-S** was re-tested on the 28 November 1997 (duplicate):
Survival (%): 22* ± 20, C.V.(%): 93
Growth (mg/organism): 0.14* ± 0.03, C.V. (%): 18

Sample **D1B-2-S** was re-tested on the 28 November 1997 (duplicate):
Survival (%): 74 ± 6, C.V.(%): 7
Growth (mg/organism): 0.14* ± 0.02, C.V. (%): 17

Sample **D3-1-S** was re-tested on the 28 November 1997 (duplicate):
Survival (%): 42* ± 16, C.V.(%): 39
Growth (mg/organism): 0.09* ± 0.01, C.V. (%): 16

Sample **MMS4-3** was re-tested on the 28 November 1997 (duplicate):
Survival (%): 16* ± 26, C.V.(%): 163
Growth (mg/organism): 0.09* ± 0.02, C.V. (%): 22

For the sample **MMS3-1**, a test was performed the 05 November 1997, but there was contamination (fungus observed on surface of sediment), so it was re-tested on the 28 November 1997:
Survival (%): 92 ± 13, C.V.(%): 14
Growth (mg/organism): 0.23 ± 0.03, C.V. (%): 15



BEAK International
Control Chart: *Hyalella azteca*

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater midgefly larvae *Chironomus riparius*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V. [3] (%)	Date of test (1997)
MMS4-3	0492CRSD	28* ± 18	64	0.69 ± 0.2	29	1 Nov.
MMS1-2	0493CRSD	44* ± 6	12	0.67 ± 0.17	25	31 Oct.
MMSR2-1	0494CRSD	50* ± 0	0	0.35* ± 0.11	31	31 Oct.
MMS1-3	0495CRSD	70 ± 7	10	0.54 ± 0.11	21	31 Oct.
MMS3-1	0496CRSD	80 ± 10	12	0.6 ± 0.16	27	31 Oct.
MMS3-2	0497CRSD	80 ± 10	12	0.69 ± 0.07	10	1 Nov.
MMSR1-3	0498CRSD	42* ± 4	11	0.44* ± 0.06	14	1 Nov.
MMS4-1	0499CRSD	58* ± 4	8	0.21* ± 0.06	28	6 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, January 1997.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels Many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater midgefly larvae *Chironomus riparius*

Client sample number	BEAK sample number	Survival ± s. d^{1} (%)	C.V.^{2} (%)	Mean dry weight/org ± s.d^{1} (mg)	C.V.^{3} (%)	Date of test (1997)
MMS4-2	0500CRSD	38* ± 4	12	0.28* ± 0.11	40	6 Nov.
MMSR1-1	0501CRSD	56* ± 6	10	0.56* ± 0.05	9	7 Nov.
MMS2-1	0502CRSD	64 ± 6	9	0.72 ± 0.09	12	7 Nov.
MMS2-2	0503CRSD	88 ± 8	10	0.53 ± 0.09	17	31 Oct.
MMS2-3	0504CRSD	54* ± 6	10	0.61* ± 0.07	12	7 Nov.
MMS1-1	0505CRSD	86 ± 6	6	0.72 ± 0.05	8	7 Nov.
MMS5-1	0506CRSD	76 ± 9	12	0.72 ± 0.06	8	7 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, January 1997.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels Many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Fianl Test Results: Growth and Survival using the freshwater midgefly larvae *Chironomus riparius*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V.[3] (%)	Date of test (1997)
MMS5-2	0507CRSD	52* ± 8	16	0.63* ± 0.05	8	7 Nov.
MMSR1-2	0508CRSD	16* ± 9	56	0.33* ± 0.04	12	14 Nov.
MMS3-3	0509CRSD	82 ± 11	13	0.63 ± 0.06	9	14 Nov.
MMS5-3	0510CRSD	78 ± 11	14	0.63 ± 0.07	11	14 Nov.
mmSR 2-3 ← MMSR3-2	0511CRSD	74 ± 9	12	0.72 ± 0.08	11	14 Nov.
MMSR2-2	0512CRSD	72 ± 19	27	0.69 ± 0.06	8	14 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, January 1997.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels Many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

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CERTIFICATE OF ANALYSIS

Client:	BEAK (Brampton)
Adresse:	14 Abacus rd Brampton, On L6T 5B7
Contact:	D. Farara/P. McKee
Project N° :	20776.230
Type of sample:	Sediment
Collected by:	BEAK (Brampton)
Method of transport:	Federal Express

Final Test Results: Growth and Survival using the freshwater midgefly larvae *Chironomus riparius*

BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V.[3] (%)	Date of test (1997)
Biological control	76 ± 6	7	0.85 ± 0.05	6	4 Oct.
Biological control	78 ± 4	6	0.97 ± 0.09	9	22 Oct.
Biological control	90 ± 10	11	0.8 ± 0.11	14	23 Oct.
Biological control	84 ± 6	6	0.98 ± 0.08	8	29 Oct.
Biological control	84 ± 6	6	0.63 ± 0.12	19	31 Oct.
Biological control	76 ± 5	7	0.82 ± 0.09	11	1 Nov.
Biological control	78 ± 4	6	1.07 ± 0.12	11	5 Nov.
Biological control	90 ± 0	0	0.67 ± 0.05	7	6 Nov.
Biological control	76 ± 6	7	0.78 ± 0.03	4	7 Nov.
Biological control	94 ± 9	10	0.75 ± 0.05	6	14 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, January 1997.

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Conditions and procedures for whole sediment testing with the freshwater midgefly larvae *Chironomus riparius*

Conditions and procedures	Env. Canada 1997[1]	BEAK International inc.
Test type	14 days, static or twice daily renewal	14 days, static
Water renewal	Static: none, except if evaporation occurs.	Static: none, except if evaporation occurs.
Overlying water	Dechlorinated culture water, uncontaminated ground water	Culture water originating from the city of Dorval aquaduct, and dechlorinated by a system devised by BEAK Dorval. Overlying surface water is aerated for 24 hrs prior to the start of tests.
Control sediment	Natural sediment exempt from natural or artifical contaminants, previously tested to ensure adequate growth and survival.	Natural sediment collected from Long Point (Lake Erie, ON) exempt from contaminants, provided by CCIW, Burlington, ON
Organisms	*Chironomus riparius*, ≤48hrs old, 10 organisms per beaker	*Chironomus riparius*, ≤48hrs old, 10 organisms per beaker
Test beakers	300 mL glass beakers, with covers	300 mL glass beakers, with covers
Volume of sediment (wet)	100 mL	100 mL
Volume of overlying water	175 mL	175 mL
Number of replicates	A minimum of 5 field replicates, and 1 to 5 replicates for each field replicate	5 replicates per sample
Temperature	daily average: 23±1°C instant: 23±3°C	23±1°C: Temperature of water bath taken daily, temperature of 1 replicate from each sample taken 3 times/wk
Lighting and photoperiod	• fluorescent tubes that provide 500-1000 lux • photoperiode: 16 h light-8 h dark	• fluorescent tubes that provide 630-1000 lux • photoperiode: 16 h light-8 h dark

1: Conditions and procedures recommended by: Environment Canada. January 1997. Test for growth and survival in sediment using larvae of freshwater midges (*Chironomus tentans* or *Chironomus riparius*)-Preview to Final Manuscript. Environmental protection series biological test method. Method Development and Application Section, Environmental Technology Centre, Environment Canada, Ottawa. 102p.

Conditions and procedures	Env. Canada 1997[1]	BEAK International inc.
Aeration	static: continuous aeration (2 - 3 bubbles /sec in all beakers)	static: continuous aeration (2 - 3 bubbles /sec in all beakers)
Feeding regime	Fish food flakes (Tetrafin™ or Nutrafin™ : 4 times/week, 15 mg (dry weight) in a 3.75 mL suspension/beaker or daily with 6.0 mg (dry weight) in a 1.5 mL suspension/beaker .	Fish food flakes (Nutrafin™) : 4 times/week, 15 mg (dry weight) in a 3.75 mL suspension/beaker.
Observations	Optional: number of organisms observed at the sediment surface, general behaviour (daily or less frequently).	Daily observations of each beaker, if organisms are observed, it is noted.
Parameters: overlying water	• DO and temperature: ≥3 times/week for each sample • pH, hardness or alkalinity, conductivity and ammonia: Day 0 and Day 14 in at least one replicate for each sample	• DO and temperature: 3 times/week for each sample • pH, hardness or alkalinity, conductivity and ammonia: Day 0 and Day 14 in at least one replicate for each sample
Test endpoint	Growth and survival: mean % survival and mean dry weight/organism for each sample	Growth and survival: mean % survival and mean dry weight/organism for each sample
Test validity	Test invalid if the mean survival in the control is less than 70% and/or if the mean dry weight per organisms is less than 0.5 mg.	Test invalid if the mean survival in the control is less than 70% and/or if the mean dry weight per organisms is less than 0.5 mg.
Reference toxicant	Water only 96 hrs test using $CuSO_4$, $CdCl_2$, KCl or NaCl . Minimum of five concentrations and a control, with 3 replicates.	Water only 96 hrs test using $CuSO_4$, $CdCl_2$, KCl or NaCl . Minimum of five concentrations and a control, with 3 replicates. • Reference toxicant: $CuSO_4$ • Geometric mean and standard deviation: CL_{50}: 0,19 ppm (0.04) Coefficient of variation: 22%

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[1] Test conditions and prodedures recommended by Environment Canada. January 1997. Test for growth and survival in sediment using larvae of freshwater midges (*Chironomus tentans* or *Chironomus riparius*)- Preview to Final Manuscript. Environmental protection series biological test method. Method Development and Application Section, Environmental Technology Centre, Environment Canada, Ottawa. 102p.

Quality Control Test Results: Growth and Survival using the freshwater midgefly larvae *Chironomus riparius*

Client sample number	BEAK sample number	Survival ± s. d[1] (%)	C.V.[2] (%)	Mean dry weight/org ± s.d[1] (mg)	C.V.[3] (%)	Date of test (1997)
D3-2-S	0474CRSD	80 ± 12	15	0.75 ± 0.19	26	29 Oct.
MMS4-3	0492CRSD	28* ± 18	64	0.69 ± 0.2	29	1 Nov.
MMS3-2	0497CRSD	80 ± 10	12	0.69 ± 0.07	10	1 Nov.
MMSR1-3	0498CRSD	42* ± 4	11	0.44* ± 0.06	14	1 Nov.

1. s.d. Standard deviation
2. C.V. Coefficient of variation: survival
3. C.V. Coefficient of variation: growth

Protocol: EPS1/RM/xx, January 1997.

*: indicates that the growth or survival was significantly less that the growth or survival of the biological control ($p<0.05$ or $p<0.01$ for the Student T test).

The statistical analyses were performed using the Tukey, Steels Many-one rank or Student T test (when there was 0 variance). The computer programs used were Toxstat®3.4 and excel 4.0.

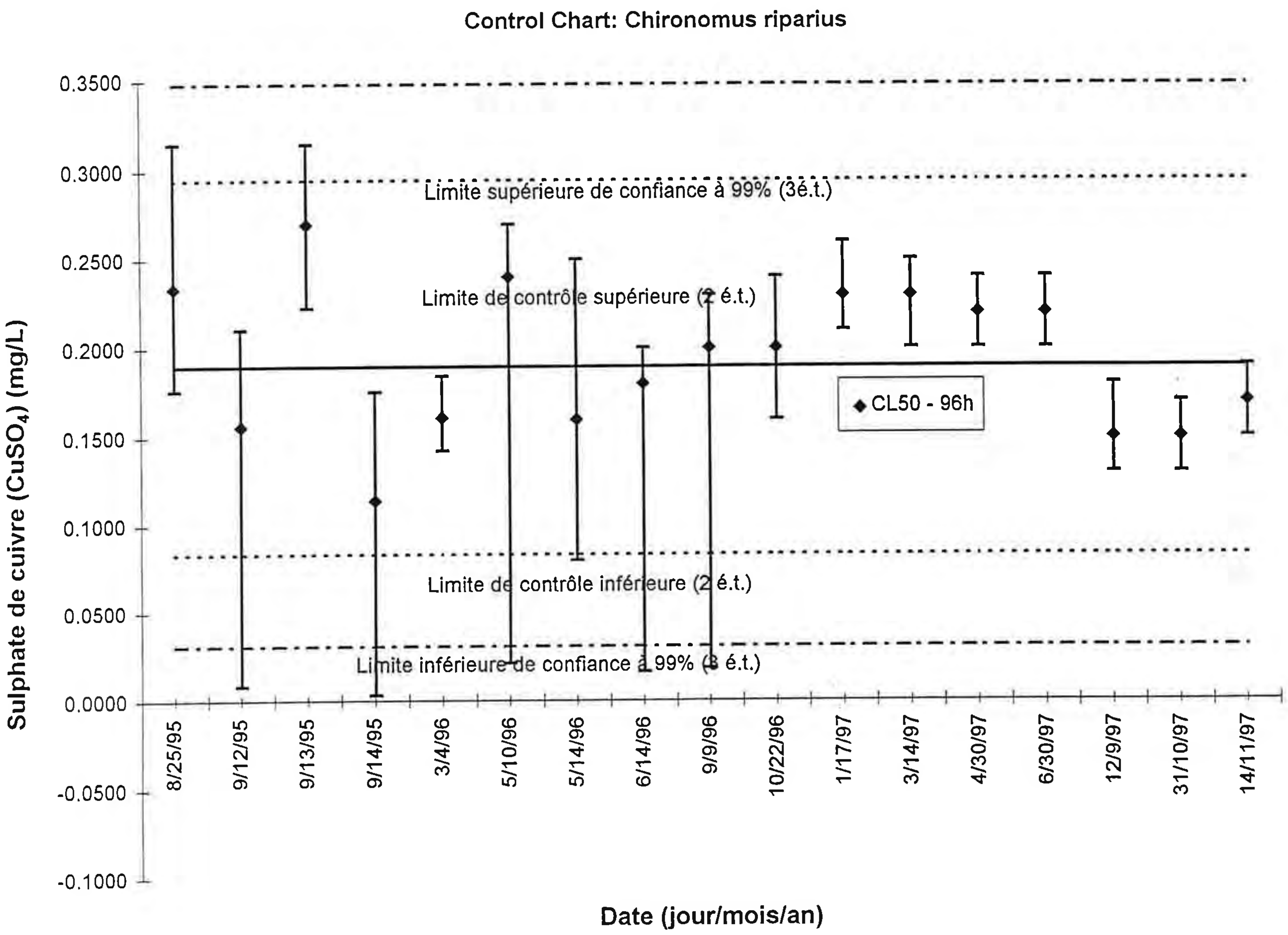
Quality control:

Sample **D3-2-S** was re-tested on the 14 Novemberr 1997 (duplicate):
Survival (%): 84 ± 11, C.V.(%): 14
Growth (mg/organism): 0.65 ± 0.04, C.V. (%): 7

Sample **MMS4-3** was re-tested on the 06 November and 14 November 1997 (triplicate):
Survival (%): 46* ± 6, C.V.(%): 12
Growth (mg/organism): 0.20* ± 0.12, C.V. (%): 59
Survival (%): 66* ± 6, C.V.(%): 8
Growth (mg/organism): 0.44*± 0.16, C.V. (%): 35
Quality control results were variable, results for this sample should be interpreted with caution.

Sample **MMSR1-3** was re-tested on the 14 November 1997):
Survival (%): 54* ± 6, C.V.(%): 10
Growth (mg/organism): 0.23*± 0.09, C.V. (%): 41

Sample **MMS3-2** was re-tested on the 06 November 1997
Survival (%): 48* ± 4, C.V.(%): 9
Growth (mg/organism): 0.20* ± 0.08, C.V.(%): 38
Quality control results were variable, results for this sample should be interpreted with caution.


Control Chart: Chironomus riparius
Sulphate de cuivre ($CuSO_4$) (mg/L)
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
-0.0500
-0.1000
Limite supérieure de confiance à 99% (3é.t.)
Limite de contrôle supérieure (2 é.t.)
Limite de contrôle inférieure (2 é.t.)
Limite inférieure de confiance à 99% (3 é.t.)
◆ CL50 - 96h
8/25/95
9/12/95
9/13/95
9/14/95
3/4/96
5/10/96
5/14/96
6/14/96
9/9/96
10/22/96
1/17/97
3/14/97
4/30/97
6/30/97
12/9/97
31/10/97
14/11/97
Date (jour/mois/an)

APPENDIX 5

Detailed Benthic Data and Chironomid Deformity Data

Table A5.1: Benthic Macroinvertebrates collected at Mattabi Mine Site (densities expressed per m²)

Station	MMR1-1	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3	MM1-1	MM1-2	MM1-3	MM2-1
P. Nematoda	36	-	137	200	73	18	-	-	-	-
P. Platyhelminthes										
Cl. Turbellaria										
O. Neorhabdocoela	-	-	-	-	-	-	-	-	-	-
O. Tricladida	73	73	46	-	-	-	-	-	-	-
P. Annelida										
Cl. Oligochaeta										
F. Naididae										
Arcteonais lomondi	-	-	46	-	-	18	-	-	-	-
Dero nivea	-	-	-	-	-	-	55	-	-	-
Nais pseudobtusa	36	-	-	-	-	-	-	-	-	-
Nais simplex	109	-	-	-	-	-	-	-	-	-
Nais variabilis	-	73	46	-	73	36	-	-	-	-
Pristina sp.	-	-	-	-	-	-	-	-	-	-
Pristina leidyi	-	-	-	-	-	-	-	-	-	-
Slavina appendiculata	36	-	46	-	-	-	-	-	-	-
Specaria josinae	-	-	-	-	-	-	-	-	-	-
Vejdovskyella comata	-	-	-	55	-	-	-	-	-	-
F. Tubificidae										
Ilyodrilus templetoni	-	-	-	-	-	-	18	-	-	-
immatures with hair chaetae	-	-	-	-	-	18	382	309	9	36
Cl. Hirudinae										
F. Glossiphoniidae										
Helobdella stagnalis	-	-	46	-	-	-	-	-	-	-
F. Erpobdellidae										
indeterminate	-	-	-	-	-	18	-	-	-	-
Erpobdella punctata	-	-	-	-	-	-	-	-	-	-
F. Piscicolidae										
Piscicola	-	-	46	-	-	-	-	-	-	-
P. Arthropoda										
Cl. Arachnoidea										
Hydracarina	510	1274	1684	419	328	382	-	-	18	109
Cl. Copepoda										
O. Harpacticoida	5533	16162	15334	-	-	-	-	-	-	-
Cl. Ostracoda	1602	2839	1684	1347	874	1547	-	-	-	2184
Cl. Malacostraca										
O. Amphipoda										
F. Crangonyctidae										
Crangonyx	-	-	-	-	-	18	-	-	-	-
F. Hyalellidae										
Hyalella azteca	291	182	1092	109	73	127	-	-	-	-
Cl. Insecta										
O. Collembola	-	-	-	-	-	-	-	-	-	-
O. Ephemeroptera										
F. Baetidae										
Callibaetis	36	-	-	-	-	-	-	-	-	-
F. Caenidae										
Caenis	182	655	501	237	164	127	-	-	-	255
F. Ephemerellidae										
indeterminate	-	-	-	-	-	-	-	-	-	-
Eurylophella	-	-	-	-	-	-	-	-	-	-
F. Leptophlebiidae										
indeterminate	-	-	-	-	-	-	-	-	-	-
O. Trichoptera										
F. Hydroptilidae										
Oxyethira	73	-	-	-	-	-	-	-	-	-
F. Leptoceridae										
Oecetis	-	-	-	18	-	-	55	18	36	-
F. Polycentropodidae										
Polycentropus	-	-	-	-	-	-	-	-	-	-
O. Diptera										
F. Ceratopogonidae										
Bezzia	-	-	-	127	55	73	55	36	9	-
Probezzia	-	-	-	-	-	-	-	-	-	-
Serromyia	-	-	-	-	-	-	-	-	-	36
Sphaeromias	-	-	-	-	-	-	-	-	-	36

Table A5.1: Benthic Macroinvertebrates collected at Mattabi Mine Site (densities expressed per m²)

Station	MMR1-1	MMR1-2	MMR1-3	MMR2-1	MMR2-2	MMR2-3	MM1-1	MM1-2	MM1-3	MM2-1
F. Chaoboridae										
Chaoborus albatus	-	-	-	528	819	582	-	-	-	-
Chaoborus punctipennis	36	36	-	-	-	18	-	-	-	-
F. Chironomidae										
Chironomid pupae	-	-	-	-	-	-	-	-	-	-
S.F. Chironominae										
Chironomus	-	-	-	-	-	-	218	-	55	655
Cladopelma	73	109	-	-	109	18	-	-	-	146
Cladotanytarsus	2293	3385	4095	564	564	419	-	-	-	437
Cryptochironomus	36	73	-	36	-	-	-	-	-	73
Dicrotendipes	73	109	137	73	18	36	-	-	-	218
Einfeldia	-	-	-	-	-	-	164	346	109	182
Endochironomus	-	-	-	18	18	-	-	-	-	-
Lauterborniella	364	473	819	73	55	18	-	-	-	-
Nilothauma	-	36	-	-	-	-	-	-	-	-
Pagastiella	109	36	-	419	309	473	73	18	18	36
Parachironomus	109	-	137	18	18	73	-	-	-	-
Paratanytarsus	655	-	-	73	164	36	-	-	-	-
Paratendipes	-	-	-	-	-	-	-	-	-	36
Polypedilum	36	36	46	146	73	164	-	-	-	218
Stempellina	-	-	-	-	-	-	-	-	-	73
Stempellinella	-	73	-	182	164	218	-	-	-	328
Tanytarsus	8336	7790	5233	-	109	164	-	-	-	36
Tribelos	-	-	-	-	-	-	36	-	-	36
S.F. Orthocladiinae										
Corynoneura	-	-	-	-	55	-	-	-	-	-
Cricotopus	-	-	-	-	73	-	-	-	-	-
Parakiefferiella	-	-	-	-	-	-	-	-	-	-
Psectrocladius	-	-	-	18	-	-	3786	2020	3076	-
Thienemanniella	-	-	-	-	55	-	-	-	-	-
Zalutschia	73	182	137	-	-	-	-	-	-	-
S.F. Tanypodinae										
indeterminate	-	-	-	-	-	-	-	-	-	-
Ablabesmyia	-	-	-	-	-	-	237	109	109	-
Guttipelopia	-	-	-	-	-	-	-	55	9	-
Procladius	619	983	883	1438	655	1274	364	328	364	728
P. Mollusca										
Cl. Gastropoda										
F. Hydrobiidae										
Amnicola sp.	73	36	956	-	-	-	-	-	-	-
F. Lymnaeidae										
Fossaria	73	-	-	-	-	-	-	-	-	-
F. Planorbidae										
Gyraulus	255	73	137	-	-	36	-	-	-	-
F. Valvatidae										
Valvata bicarinata	-	-	91	146	91	146	-	-	-	-
Valvata sincera	109	36	-	-	-	-	-	-	-	-
Cl. Pelecypoda										
F. Sphaeriidae										
Pisidium	437	364	364	182	255	437	-	-	-	146
TOTAL NUMBER OF ORGANISMS	22277	35090	33734	6425	5242	6497	5442	3240	3813	6006
TOTAL NUMBER OF TAXA	30	24	24	23	25	27	12	9	11	21

Table A5.1: Benthic Macroinvertebrates collected at Mattabi Mine Site (densities expressed per m²)

Station	MM2-2	MM2-3	MM3-1	MM3-2	MM3-3	MM4-1	MM4-2	MM4-3	MM5-1	MM5-2	MM5-3
P. Nematoda	36	-	36	-	36	-	36	18	109	109	-
P. Platyhelminthes											
Cl. Turbellaria											
O. Neorhabdocoela	-	-	-	-	-	-	18	-	-	-	-
O. Tricladida	36	-	-	-	-	36	-	-	-	-	73
P. Annelida											
Cl. Oligochaeta											
F. Naididae											
Arcteonais lomondi	-	-	-	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-	-	-	-
Nais pseudobtusa	-	-	-	-	-	-	-	-	-	-	-
Nais simplex	-	-	-	-	-	-	-	-	-	-	-
Nais variabilis	-	-	-	-	-	-	-	-	-	-	-
Pristina sp.	-	-	36	-	-	-	-	-	-	36	-
Pristina leidyi	-	-	-	73	-	-	-	-	-	-	73
Slavina appendiculata	-	-	-	-	-	-	-	-	-	-	36
Specaria josinae	36	-	-	36	-	18	127	36	-	109	-
Vejdovskyella comata	-	-	-	-	-	-	18	-	36	-	36
F. Tubificidae											
Ilyodrilus templetoni	-	-	109	109	-	-	-	36	-	-	-
immatures with hair chaetae	36	36	837	728	983	237	364	255	218	109	328
Cl. Hirudinae											
F. Glossiphoniidae											
Helobdella stagnalis	-	-	-	-	-	-	-	-	73	255	218
F. Erpobdellidae											
indeterminate	-	-	-	-	-	-	-	-	-	-	-
Erpobdella punctata	-	-	-	-	-	-	-	-	9	-	-
F. Piscicolidae											
Piscicola	-	-	-	-	-	-	-	-	-	-	-
P. Arthropoda											
Cl. Arachnoidea											
Hydracarina	218	36	146	182	182	218	510	164	291	255	146
Cl. Copepoda											
O. Harpacticoida	-	-	-	-	-	-	18	-	73	-	-
Cl. Ostracoda	1602	619	764	946	801	419	546	1238	764	146	582
Cl. Malacostraca											
O. Amphipoda											
F. Crangonyctidae											
Crangonyx	-	-	-	-	-	-	-	-	-	-	-
F. Hyalellidae											
Hyalella azteca	36	36	-	73	-	18	18	-	73	291	619
Cl. Insecta											
O. Collembola	-	-	-	-	-	18	-	-	-	-	-
O. Ephemeroptera											
F. Baetidae											
Callibaetis	-	-	-	-	-	-	-	-	-	-	-
F. Caenidae											
Caenis	182	400	255	437	146	1693	983	437	291	255	182
F. Ephemerellidae											
indeterminate	-	-	-	-	-	-	-	18	-	-	36
Eurylophella	-	-	-	-	-	-	-	18	-	-	-
F. Leptophlebiidae											
indeterminate	-	-	-	-	-	-	18	-	-	-	-
O. Trichoptera											
F. Hydroptilidae											
Oxyethira	-	-	-	-	-	-	-	-	36	36	146
F. Leptoceridae											
Oecetis	-	-	36	-	-	55	-	-	-	-	-
F. Polycentropodidae											
Polycentropus	-	-	-	-	-	-	-	-	-	-	36
O. Diptera											
F. Ceratopogonidae											
Bezzia	-	-	-	-	-	-	-	-	-	-	-
Probezzia	-	-	-	-	-	-	18	-	-	-	36
Serromyia	-	-	-	-	-	-	-	-	-	-	-
Sphaeromias	-	73	73	-	36	-	-	18	-	-	-

Table A5.1: Benthic Macroinvertebrates collected at Mattabi Mine Site (densities expressed per m²)

Station	MM2-2	MM2-3	MM3-1	MM3-2	MM3-3	MM4-1	MM4-2	MM4-3	MM5-1	MM5-2	MM5-3
F. Chaoboridae											
Chaoborus albatus	-	-	-	-	-	-	-	-	-	-	-
Chaoborus punctipennis	-	-	-	-	-	36	-	18	-	36	-
F. Chironomidae											
Chironomid pupae	-	-	-	36	-	-	-	-	-	-	36
S.F. Chironominae											
Chironomus	437	255	764	582	546	364	364	819	983	619	582
Cladopelma	109	146	255	109	109	-	36	36	146	73	-
Cladotanytarsus	437	400	-	328	73	18	18	18	182	146	546
Cryptochironomus	109	36	36	109	-	36	36	91	36	73	36
Dicrotendipes	837	328	73	109	109	73	18	18	1638	510	1784
Einfeldia	764	291	-	109	-	-	164	36	73	-	-
Endochironomus	-	-	-	-	-	-	-	18	146	36	-
Lauterborniella	-	-	182	146	73	-	18	-	109	-	-
Nilothauma	-	-	-	-	-	-	-	-	-	-	-
Pagastiella	255	109	-	36	-	73	91	-	-	-	-
Parachironomus	-	109	36	-	-	-	-	-	-	-	-
Paratanytarsus	-	-	-	-	-	-	-	-	-	36	182
Paratendipes	36	36	36	-	-	-	-	-	-	-	-
Polypedilum	36	109	182	73	218	55	36	109	400	36	874
Stempellina	36	-	-	-	73	18	-	-	36	-	-
Stempellinella	-	73	73	109	218	127	109	127	473	655	-
Tanytarsus	109	-	-	36	73	55	-	18	218	218	437
Tribelos	-	36	-	-	-	-	-	-	-	-	-
S.F. Orthocladiinae											
Corynoneura	-	-	-	-	-	-	-	-	-	-	-
Cricotopus	-	-	-	-	-	-	-	-	-	-	-
Parakiefferiella	-	-	-	-	-	-	-	-	-	-	36
Psectrocladius	-	-	-	-	-	-	-	-	-	-	36
Thienemanniella	-	-	-	-	-	-	-	-	-	-	-
Zalutschia	-	-	-	-	-	-	-	-	-	-	-
S.F. Tanypodinae											
indeterminate	-	-	-	-	-	-	-	-	-	109	36
Ablabesmyia	146	218	109	146	109	55	109	109	255	109	619
Guttipelopia	-	-	-	-	-	-	18	-	-	-	-
Procladius	582	801	473	655	619	1219	1219	946	983	946	328
P. Mollusca											
Cl. Gastropoda											
F. Hydrobiidae											
Amnicola sp.	-	-	-	-	-	-	-	-	-	-	-
F. Lymnaeidae											
Fossaria	-	-	-	-	-	-	-	-	-	-	-
F. Planorbidae											
Gyraulus	-	-	-	73	73	-	-	-	36	36	36
F. Valvatidae											
Valvata bicarinata	-	-	-	-	-	-	-	-	-	-	-
Valvata sincera	-	-	-	-	-	-	-	-	-	-	-
Cl. Pelecypoda											
F. Sphaeriidae											
Pisidium	73	73	146	146	146	109	127	200	510	582	801
TOTAL NUMBER OF ORGANISMS	6152	4222	4659	5387	4623	4950	5041	4805	8199	5824	8918
TOTAL NUMBER OF TAXA	22	21	21	23	19	22	26	24	27	26	28

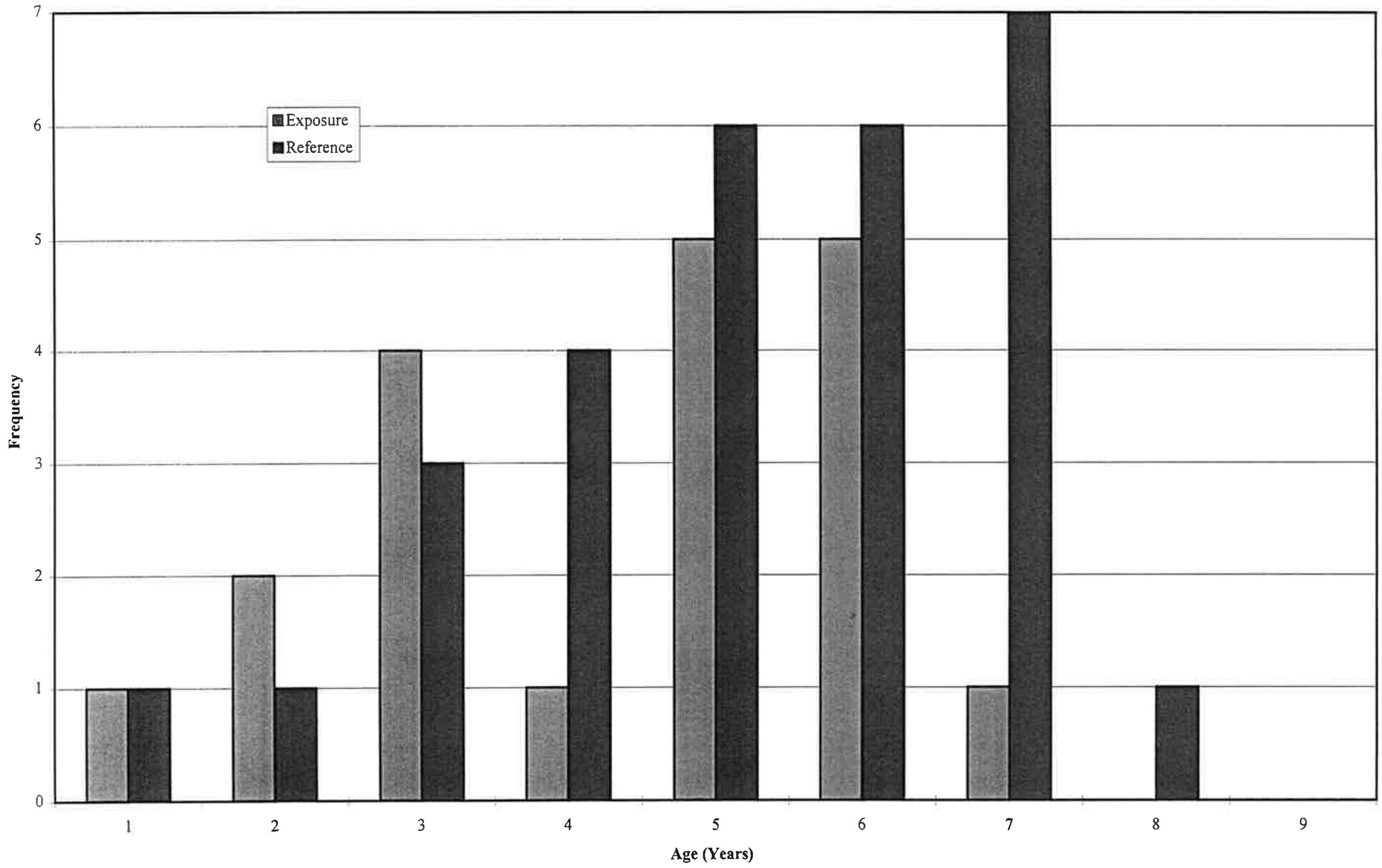
TABLE A5.2: Summary of Chironomid Abnormalities, Mattabi Mine Site

Station	No. Chironomids per sample fraction	Number examined	% Showing abnormalities	Genus showing abnormality	Noted abnormality
MMBR1-1	227	33	0	none	
MMBR1-2	200	29	0	none	
MMBR1-3	162	25	4	*Procladius*	middle and inner right tooth of ligula fused
MMBR2-1	66	15	0	none	
MMBR2-2	41	16	6	*Endochironomus*	apical left tooth of mandible broken
MMBR2-3	75	20	10	*Procladius* *Procladius*	right outer tooth of ligula smaller than left right inner tooth of ligula larger than left
MMB1-1	72	28	0	none	
MMB1-2	55	27	0	none	
MMB1-3	179	34	0	none	
MMB2-1	32	22	0	none	
MMB2-2	48	22	14	*Procladius* *Einfeldia* *Einfeldia*	chipped right inner tooth on ligula broken centre tooth broken centre tooth
MMB2-3	34	19	11	*Chironomus* *Cryptochironomus*	right 1st lateral of mentum worn left side of mentum with 2 broken outer teeth
MMB3-1	37	12	25	*Chironomus* *Chironomus* *Chironomus*	left outer 3 teeth of mentum worn 2nd right lateral worn 1st and 2nd lateral teeth fused; only 5 pairs of lateral teeth instead of 6
MMB3-2	43	20	5	*Chironomus*	6 lateral teeth on right, 5 on the left; 2nd lateral on left missing
MMB3-3	38	18	11	*Chironomus* *Polypedilum*	left apical mandibular tooth chipped left mandibular tooth chipped
MMB4-1	80	20	0	none	
MMB4-2	102	25	12	*Chironomus* *Chironomus* *Polypedilum*	2nd lateral teeth of mentum fused to first middle tooth broken;left toothlet of mentum missing right centre tooth of mentum smaller than left
MMB4-3	110	24	0	none	
MMB5-1	62	25	0	none	
MMB5-2	40	15	7	*Endochironomus*	centre teeth of mentum worn
MMB5-3	61	23	0	none	

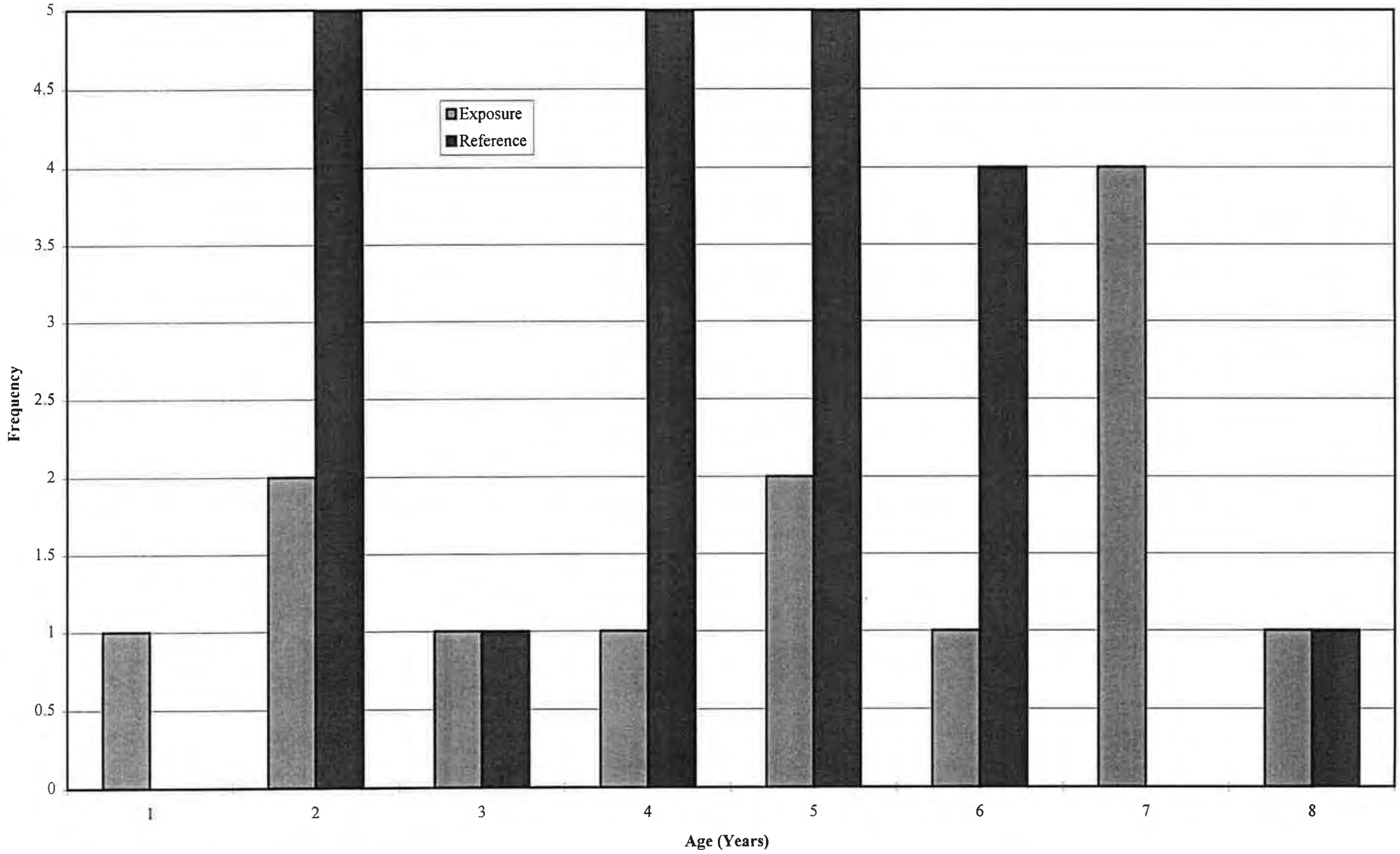
APPENDIX 6

Fish Data

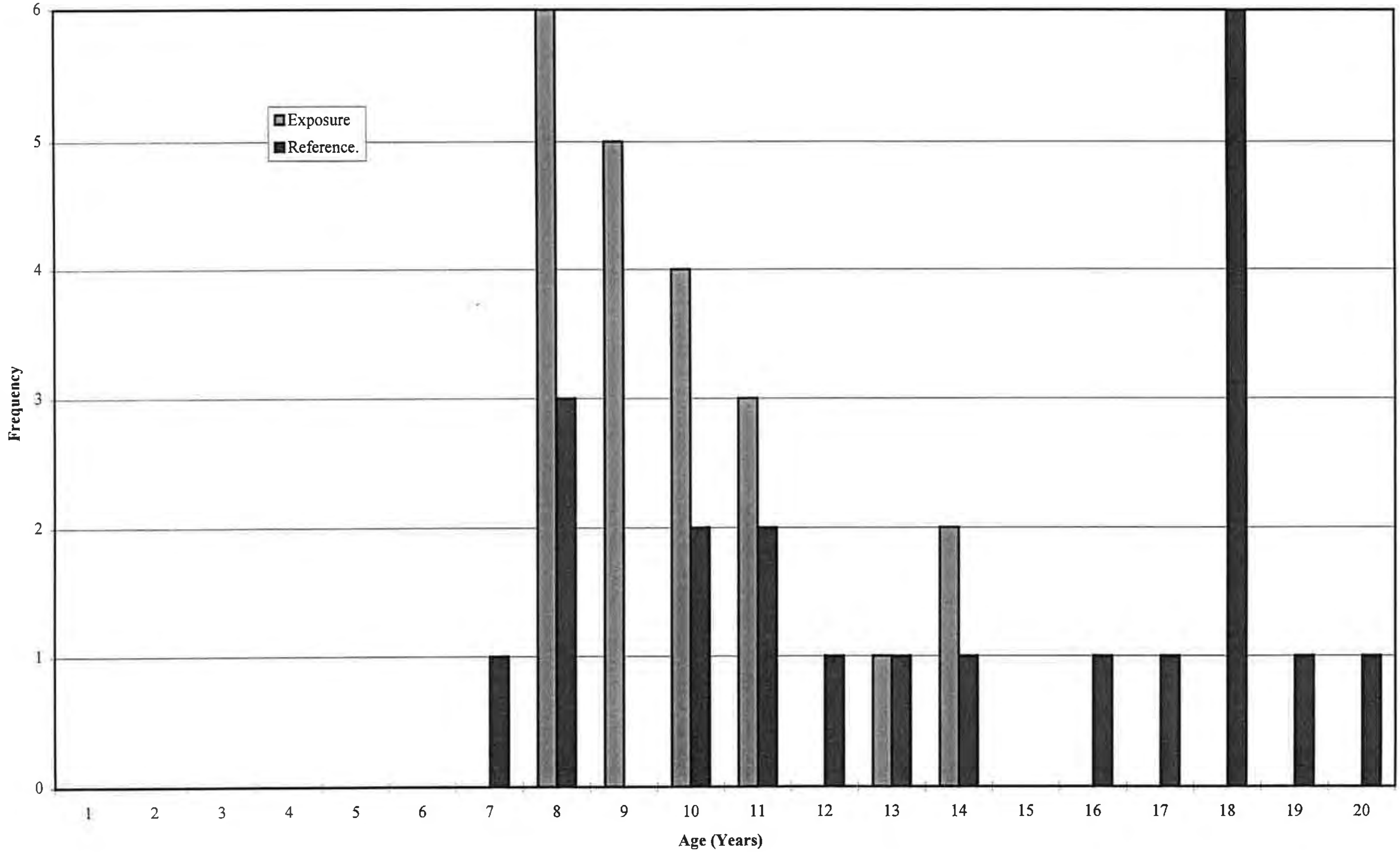
Age Distribution for Female Northern Pike Caught at Mattabi Mines, 1997



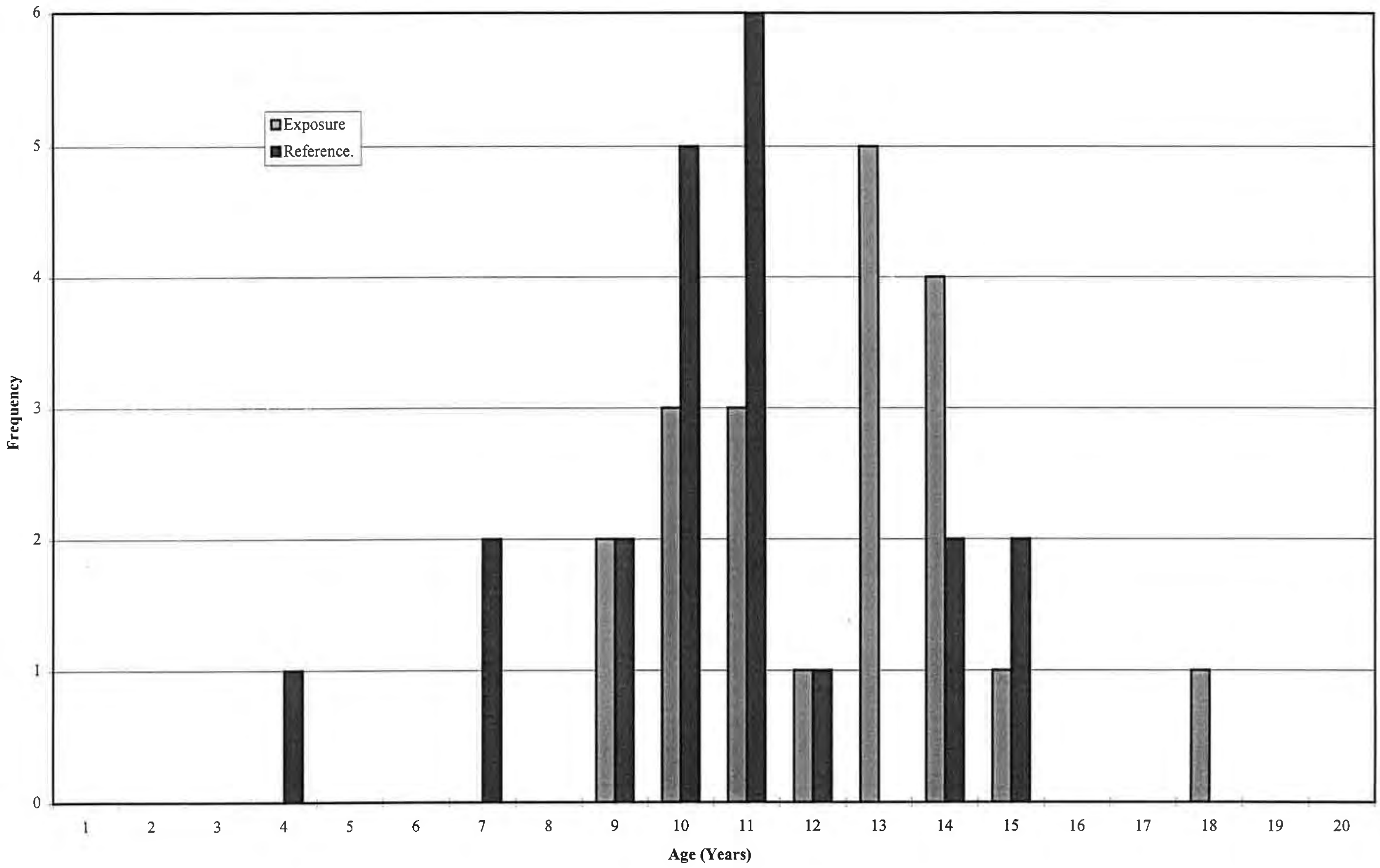
Age Distribution for Male Northern Pike Caught at Mattabi Mines, 1997



Age Distribution for Male White Sucker Caught at Mattabi Mines, 1997



Age Distribution for Female White Sucker Caught at Mattabi Mines, 1997



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Mattabi Mines (20776·1)

FISH AGING TALLY FORM

SAM	Station EFF	DATE	SPC	FISH	T LEN	WT.	SEX	AGEMT	NCA	EDGE	CONF	AGEA	COMMENTS
#12	MM6	16·10 97	W.S.	MME-WS1	52.5	1850	F	FR	13	H	(6-7)	13H	Poor edge - 1st almost gone
#13	"	"	"	MME-WS2	48.8	1510	F	"	10	H	(7)	10H	
#14	"	"	"	MME-WS 3	57.5	3000	F	"	14	H	(5)	14H	Poor after ≅ 7 to 8 - False checking?
#15	"	"	"	MME-WS 6	54.6	2500	F	"	18	+	(6)	18+	18+0
#16	"	"	"	MME-WS 7	52.8	2250	F	"	14	H	(7)	14H	
#18	"	? "	"	MME-WS34	49.4	1725	M	"	14	+	(7)	14+	
#19	"	"	"	MMEWS 4	44.4	1225	M	"	10	+	(7)	10+	1st ?
#30	MM7	16/10/97	WS	MMEWS12	46.5	1350	F	FR	9	H	(6 to 7)	9H	
#31	"	"	"	MMEWS13	53.4	2025	F	"	9	+	(6)	9+	FC1-2; Lots of FC's ±1
#32	"	"	"	MMEWS14	49.8	1750	F	"	11	H	(7)	11H	
#39	"	"	"	MMEWS 10	46.9	1325	M	"	10	H	(7)	10H	
#40	"	"	"	MMEWS 11	50.1	1650	M	"	9	H	(6 to 7)	9H	
#41	"	"	"	MMEWS15	48.4	1575	M	"	8	H	(7)	8H	FC0-1
#44	"	"	"	MMEWS 8	45.4	1325	M	"	8	H	"	8H	"
#45	"	"	"	MMEWS 9	46.8	1225	M	"	9	+	(6)	9+	Poor edge - 1st?
#56	MM8	?	"	MMEWS 30	50.6	1650	F	FR	13	+	(7)	13+	1st almost gone
#57	"	"	"	MMEWS 31	47.1	1450	F	"	11	+	(7)	11+	
#58	"	"	"	MMEWS 32	49.9	1575	F	"	14	+	(5 to 6)	14+	Poss-13+
#59	"	"	"	MMEWS 33	52.3	1925	F	"	13	+	(6)	13+	1st almost gone - FC's throughout
#60	"	"	"	MMEWS 27	44.1	1225	M	"	8	H	(6)	8H	FC0-1; 1-2; 2-3; 8-E - Poss-9H
#61	"	"	"	MMEWS 28	51.3	1700	M	"	14	+	(7)	14+	±1
#62	"	"	"	MMEWS29	45.0	1375	M	"	9	H	(7)	9H	1st gone in 2 cuts
#63	"	"	"	MMEWS 35	49.3	1600	M	"	14	H	(7)	14H	1st ass. as gone
#64	"	"	"	MMEWS 36	47.2	1525	M	"	10	H	(6 to 7)	10H	" " "
#65	"	"	"	MMEWS 37	48.8	1700	M	"	11	H	"	11H	1st? maybe gone
#66	"	"	"	MMEWS 38	50.5	1525	M	"	11	H	(6)	11H	1st assd as missing
#67	"	"	"	MMEWS 39	44.0	1225	M	"	8	H	(8)	8H	
#68	"	"	"	MMEWS 40	45.1	1375	M	"	9	H	(7)	9H	Some FC's
#69	"	"	"	MMEWS 41	44.6	1275	M	"	9	H	(6)	10H	1st ass. as missing
#70	"	"	"	MMEWS42	42.3	895	M	"	7	H	(6)	8H	Poss-7H FC6-7 1st as gone?

Note: FC = false check

Some fish assessed @ the 1st annulus assumed missing.

This occurs if the rays are removed to far out from the body. (Some appeared to be) during preparation

J -02

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Mattabi Mines (20776-1

FISH AGING TALLY FORM

SAM	Station EFF	DATE	SPC	FISH	TLEN	W.T.	SEX	AGEMT	NCA	EDGE	CONF	AGEA	COMMENTS
# 97	MM10	?16.09.97	WS	MMRWS 25	48.3	980	F	FR	4	++	(7)	4++	FCo-1
# 98	"	"	"	MMRWS 26	50.4	1570	F	"	11	+	(6)	11+	4th? Poor edge
# 99	"	"	"	MMRWS 27	52.3	1725	F	"	10	++	(7)	10++	
# 103	"	"	"	MMAWS 24	49.8	1450	M	"	16	+	(4 to 5)	16+	Good to 10 - Main ray, damaged
# 121	MM11	?	WS	MMRWS 28	49.3	1500	M	FR	18	+	(5 to 6)	18+	±1
# 122	"	"	"	MMAWS 29	46.0	1225	M	"	11	++	(7)	11++	1st almost gone
# 129	MM12	?	WS	MMRWS 14	49.0	1575	F	FR	10	+	(7)	11+	1st is gone
# 130	"	"	"	MMAWS 35	50.6	1750	F	"	10	+	(6)	10+	FC's - especially @ 8-E
# 131	"	"	"	MMRWS 36	50.0	1900	F	"	10	++	(6 to 7)	11++	" - 1st annulus missing
# 132	"	"	"	MMAWS 38	47.4	1500	F	"	11	++	(6)	11++	1st? Lots of FC's
# 133	"	"	"	MMAWS 39	49.7	1550	F	"	10	+	(7)	10+	
# 134	"	"	"	MMRWS 10	49.4	1710	M	"	20	+	(6)	20+	maybe overaging
# 135	"	"	"	MMRWS 11	47.7	1425	M	"	10	++	(7)	10++	
# 136	"	"	"	MMAWS 12	49.2	1750	M	"	8	++	(7)	8++	
# 137	"	"	"	MMAWS 13	46.9	1450	M	"	13	++	(5 to 6)	13++	±1
# 138	"	"	"	MMAWS 37	47.1	1425	M	"	8	+	(5)	8+	Tough zonation
# 139	"	"	"	MMAWS 40	43.1	1000	M	"	7	++	(7)	7++	slow #2; 6-7
# 140	"	"	"	MMRWS 41	46.0	1300	M	"	10	++	(6)	10++	FC's
# 141	"	"	"	MMAWS 42	45.7	1360	M	"	11	++	(7)	11++	1st goes fast.
# 157	MM13	?	WS	MMRWS 19	48.9	1360	F	FR	10	++	(6)	10++	1st may be gone
# 158	"	"	"	MMRWS 20	53.5	1925	F	"	15	+	(6)	15+	±1
# 159	"	"	"	MMRWS 21	52.2	1600	F	"	14	+	(5)	14+	±1 Poor - tough zonation
# 160	"	"	"	MMRWS 22	50.8	1525	F	"	14	+	(5)	14+	" " " "
# 161	"	"	"	MMRWS 23	50.0	1400	F	"	11	++	(7)	11++	
# 162	"	"	"	MNRWS 34	47.9	1740	F	"	11	++	(6)	11++	2nd?
# 163	"	"	"	MMRWS 15	49.5	1710	M	"	18	+	(7)	18+	Poss. 19+
# 164	"	"	"	MMAWS 16	46.1	1175	M	"	14	++	"	14++	1st almost gone
# 165	"	"	"	MMRWS 17	50.4	1500	M	"	18	+	(6 to 7)	18+	±1
# 166	"	"	"	MMRWS 18	52.7	1615	M	"	18	+	(6)	18+	"
# 167	"	"	"	MMRWS 30	47.2	1400	M	"	19	+	(6)	19+	±2 Stocking effect ??
# 168	"	"	"	MMRWS 31	48.4	1475	M	"	12	++	(6)	12++	
# 169	"	"	"	MMRWS 32	49.0	1600	M	"	17	+	(6)	17+	±1
# 170	"	"	"	MMAWS 33	50.8	1750	M	"	18	+	"	18+	intense stocking

Mattabi Mines - N. Pike (second shipment)

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(25 SENT LATE)

FISH AGING TALLY FORM

SAM	Station EFF	DATE	SPC	FISH	TLEN	W.T.	SEX	AGEMT	NCA	EDGE	CONF	AGEA	COMMENTS	
# 20	MM7	?	NP	MMENP 17	54.6	1075	F	CI	3	H	(6)	3H	Lots of FC's	
# 21	"	"	"	MMENP 18	62.3	1625	F	"	5	H	(6)	5H	2-4 slow.	
# 22	"	"	"	MMENP 19	45.5	555	F	"	2	H	(6to7)	2H		
# 26	"	"	"	MMENP 14	62.0	1675	M	"	7	+	(6)	7+	5-7 @ outsides	
# 27	"	"	"	MMENP 15	69.2	2050	M	"	7	H	(8)	7H		
# 28	"	"	"	MMENP 16	63.7	1800	M	"	5	+	(7)	5+		
# 71	MM9	?	NP	MMENP 12	74.6	3000	F	CI	6	H	(7)	6H		
# 72	"	"	"	MMENP 9	57.6	1275	F	"	3	+	(7)	3+		
# 73	"	"	"	MMENP 10	66.9	2100	M	"	7	+	(5)	7+	FC's	* check
# 74	"	"	"	MMENP 11	71.4	2700	M	"	9	+	(5)	4+		x "
# 75	"	"	"	MMENP 13	54.9	1175	M	"	3	H	(8)	3H		
# 79	MM10	?	NP	MMRNP 10	50.3	770	F	CI	6	H	(7)	6H		
# 83	"	"	"	MMRNP 4	60.8	1950	F	"	7	H	(6to7)	7H		
# 86	"	"	"	MMRNP 5	48.7	700	F	"	5	+	"	5+	5th near edge	
# 87	"	"	"	MMRNP 6	70.6	3200	F	"	6	H	(7)	6H		
# 88	"	"	"	MMRNP 7	64.6	2215	F	"	7	H	(6)	7H	1st may be false	
# 89	"	"	"	MMRNP 11	37.6	360	M	"	2	H	(7)	2H	1st ring close	
# 91	"	"	"	MMRNP 3	45.3	510	M	"	5	H	"	5H		
# 95	"	"	"	MMRNP 8	44.7	520	M	"	6	H	(6)	6H	5-6 slow	
# 96	"	"	"	MMRNP 9	44.8	560	M	"	2	H	(7)	2H	FC check.	
# 105	MM11	?	NP	MMRNP 12	63.7	1550	F	CI	5	H	(6)	5H		
# 106	"	"	"	MMRNP 13	51.2	925	F	"	5	H	(6)	5H	4-5 slow	
# 107	"	"	"	MMRNP 14	55.1	945	F	"	7	+	(5)	7+	still drying Poss 8+	
# 108	"	"	"	MMRNP 2	69.9	2650	F	"	6	H	(5)	6H	True annuli?	
# 112	"	"	"	MMRNP 1	46.3	695	M	"	6	+	(6to7)	6+	2-3 slow - 6th @ edge	

FISH AGING TALLY FORM

SAM	station EFF	DATE	SPC	FISH #	T. TLEN	Wt. W.T.	SEX	AGEMT	NCA	EDGE	CONF	AGEA	COMMENTS
#1	MM6	15.10.97	NP	MME-NP1	63.4	1750	F	Cl.	7	H	(6)	7H	
2	"	16.10.97	"	MME-NP2	59.9	1575	F	"	3	H	(7)	3H	
3	"	"	"	MME-NP25	74.0	3500	F	"	6	H	(7)	6H	
4	"	"	"	MMENP31	62.8	1950	F	"	6	H	(6)	6H	5-6 slow
5	"	"	"	MMENP5	61.8	1400	F	"	6	+	(5)	6+	Poor zonation
6	"	"	"	MMENP29	43.8	550	M	"	2	H	(7)	2H	
7	"	"	"	MMENP3	67.2	1775	M	"	5	H	(7)	5H	
8	"	"	"	MMENP30	73.6	2100	M	"	8	+	(6)	8+	
9	"	"	"	MMENP32	67.0	2225	M	"	7	+	(6to7)	7+	
10	"	"	"	MMENP 4	67.8	2060	M	"	9	H	(6)	9H	2nd ? poor edge
11	"	"	"	MMENP 6	45.7	530	—	"	1	H	(7)	1H	
23	MM7	"	NP	MMENP33	43.0	390	F	Cl	1	H	"	1H	FCo-1
24	"	"	"	MMENP34	46.6	520	F	"	2	H	"	2H	FCC edge
25	"	"	"	MMENP 7	49.5	660	F	"	3	+	(6)	3+	3rd ?
46	MM8	?	NP	MMENP20	65.4	2025	F	Cl	unable to age 1Cl. - deformed				
47	"	"	"	MMENP21	59.3	1475	F	"	5	H	(6)	5H	1st may be false
48	"	"	"	MMENP22	63.6	2325	F	"	5	+	(7)	5+	
49	"	"	"	MMENP27	67.7	2450	F	"	5	+	(4)	5+	Deformed - 1Cl.
50	"	"	"	MMENP28	75.5	3250	F	"	6	+	(5)	6+	thick - poor zonation
51	"	"	"	MMENP35	61.1	1875	F	"	4	+	(6)	4+	1Cl.
52	"	"	"	MMENP36	66.2	1800	F	"	5	H	(7)	5H	
53	"	"	"	MMENP23	58.5	1625	M	"	6	+	(6)	6+	
54	"	"	"	MMENP24	48.0	610	M	"	2	H	(7)	2H	
55	"	"	"	MMENP26	57.3	1375	M	"	4	+	(7)	4+	
80	MM10	?	NP	MMRNP30	47.3	580	F	Cl	3	H	(6)	3H	Weak annuli
81	"	"	"	MMRNP33	55.7	1100	F	"	5	+	(6)	5+	3 stacked @ edge (visible @ wheel
82	"	"	"	MMRNP39	59.6	1025	F	"	4	H	(5to6)	4H	Weak
84	"	"	"	MMRNP41	60.5	980	F	"	7	H	(6)	7H	
85	"	"	"	MMRNP43	60.6	1350	F	"	4	H	(5)	4H	Poor zonation
90	"	"	"	MMRNP28	47.6	575	M	"	1	H	(6)	1H	
92	"	"	"	MMRNP32	52.8	910	M	"	6	+	(5to6)	6+	" "
93	"	"	"	MMRNP40	49.4	720	M	"	4	+	(6)	4+	FCo-1?
94	"	"	"	MMRNP42	46.3	645	M	"	4	H	(7)	4H	

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FISH AGING TALLY FORM

SAM	STATN EFF	DATE	SPC	FISH	TLEN	W.T.	SEX	AGEMT	NCA	EDGE	CONF	AGEA	COMMENTS
109	MM11	?	NP	MMRNP34	66.2	1600	F	Cl	6	H	(6to7)	6H	
110	"	"	"	MMRNP36	53.2	785	F	"	6	H	(6)	6H	
111	"	"	"	MMRNP44	67.0	1610	F	"	4	H	(5)	4H	Poor zonation - Poss. older
113	"	"	"	MMRNP35	42.9	510	M	"	2	H	(7)	2H	
114	"	"	"	MMRNP37	37.9	310	M	"	2	H	(8)	2H	
115	"	"	"	MMRNP45	34.7	230	M	"	2	H	(6)	2H	1st ?
123	MM12	?	NP	MMRNP18	55.4	1225	F	Cl	3	H	(6)	3H	
124	"	"	"	MMRNP19	41.9	420	F	"	2	H	(7)	2H	
125	"	"	"	MMRNP20	63.1	1690	F	"	4	+	(6)	4+	4th ? 1Cl.
126	"	"	"	MMRNP24	60.9	1600	F	"	7	+	(5)	7+	True annuli ?
127	"	"	"	MMRNP17	46.5	640	M	"	5	+	(5)	5+	" "
128	"	"	"	MMRNP23	55.2	1300	M	"	8	+	(5)	8+	" "
142	MM13	?	NP	MMRNP15	60.8	1415	F	Cl	6	+	(6to7)	6+	
143	"	"	"	MMRNP16	67.1	2475	F	"	5	H	(7)	5H	
144	"	"	"	MMRNP21	39.0	395	F	"	5	+	(6)	5+	Poss. 4+
145	"	"	"	MMRNP26	56.0	1275	F	"	8	+	(6)	8+	Slow growth
146	"	"	"	MMRNP29	60.6	1700	F	"	7	+	(5)	7+	
147	"	"	"	MMRNP31	66.9	1550	F	"	7	H	(5)	7H	1Cl. Zon. poor
148	"	"	"	MMRNP46	46.5	530	F	"	3	H	(5)	3H	" "
149	"	"	"	MMRNP48	38.2	330	F	"	1	H	(8)	1H	
150	"	"	"	MMRNP22	48.0	610	M	"	5	H	(7)	5H	Slow growth - 4-5 Slow
151	"	"	"	MMRNP25	57.5	1325	M	"	4	H	(6)	4H	FCO-1 - Poss 5H
152	"	"	"	MMRNP27	47.4	625	M	"	4	H	(7)	4H	1st in close
153	"	"	"	MMRNP38	46.4	620	M	"	3	H	(6)	3H	FCO
154	"	"	"	MMRNP44	54.6	1110	M	"	4	H	(5)	4H	1st ? May be missing it
155	"	"	"	MMRNP45	49.1	635	M	"	5	+	(5)	5+	4-5 low FCO-1
156	"	"	"	MMRNP47	56.3	1150	M	"	5	H	(6)	5H	

Table A6.1: Results of Metallothionein and Metals Analyses conducted on Liver Tissue collected at Mattabi Mine Site

Station	Fish Number	Species	ug MT/g	Hg ug/G wet wt	Cd ug/G wet wt	Cu ug/G wet wt	Zn ug/G wet wt	Pb ug/G wet wt	Ni ug/G wet wt	Cr ug/G wet wt	Co ug/G wet wt	Al ug/G wet wt	Ba ug/G wet wt	Fe ug/G wet wt	Mo ug/G wet wt	V ug/G wet wt	As ug/G wet wt	Se ug/G wet wt
Liver																		
MM10	MMRWS 6	White Sucker	114.6	0.235	0.32	10.7	27	0.26	0.026	0.059	0.032	1.11	< 0.012	96	<0.03	0.09	<0.05	0.65
MM10	MMRWS 7	White Sucker	593.8	0.101	0.13	9.3	26	0.26	0.026	0.055	0.035	2.81	0.017	75	<0.03	0.08	<0.05	0.84
MM10	MMRWS 8	White Sucker	172.7	0.195	0.38	5.1	22	0.27	<0.025	0.066	0.029	0.72	< 0.012	38	<0.03	0.11	<0.05	0.90
MM10	MMRWS 9	White Sucker	439.5	0.106	0.35	16.9	32	0.19	0.026	0.042	0.028	1.32	< 0.012	401	<0.03	0.12	<0.05	0.72
MM11	MMRWS 1	White Sucker	300.8	0.187	0.41	8.5	25	0.22	0.100	0.037	0.034	1.45	< 0.012	80	<0.03	0.16	<0.05	0.83
MM11	MMRWS 2	White Sucker	387.0	0.259	0.29	39.2	39	0.23	0.025	0.050	0.024	5.65	0.047	223	<0.03	0.13	<0.05	0.68
MM11	MMRWS 3	White Sucker	116.2	0.103	0.33	13.2	26	0.20	< 0.025	0.047	0.021	8.61	0.069	226	<0.03	0.11	<0.05	0.64
MM11	MMRWS 4	White Sucker	296.1	0.167	0.17	10.3	27	0.21	0.035	0.059	0.023	1.03	< 0.012	175	<0.03	0.07	<0.05	0.85
MM11	MMRWS 5	White Sucker	386.6	0.076	0.10	5.0	20	0.25	0.053	0.053	0.021	0.71	< 0.012	207	<0.03	0.06	<0.05	0.57
MM12	MMRWS 10	White Sucker	292.8	0.097	0.37	6.5	22	0.27	0.038	0.057	0.034	1.70	< 0.012	55	<0.03	0.09	<0.05	0.67
MM12	MMR WS 11	White Sucker	843.9	0.078	0.21	11.8	28	0.27	< 0.025	0.054	0.023	0.93	< 0.012	200	<0.03	0.06	0.13	0.64
MM12	MMRWS 12	White Sucker	446.4	0.172	0.28	9.9	25	0.23	0.042	0.045	0.026	2.41	< 0.012	47	<0.03	0.13	0.14	0.76
MM12	MMRWS 13	White Sucker	272.2	0.076	0.22	29.4	34	0.23	0.054	0.088	0.038	6.01	0.066	346	<0.03	0.16	0.14	0.82
MM12	MMRWS 14	White Sucker	417.7	0.062	0.06	15.0	28	0.19	< 0.025	0.039	< 0.015	4.64	0.033	115	<0.03	0.06	0.16	0.57
MM13	MMRWS 15	White Sucker	998.7	0.206	0.36	14.9	28	0.20	0.044	0.051	0.032	5.21	0.038	395	<0.03	0.15	0.15	1.08
MM13	MMRWS 16	White Sucker	461.1	0.146	0.27	14.0	27	0.27	0.030	0.048	0.032	1.65	0.024	274	<0.03	0.09	0.08	0.65
MM7	MMEWS 19	White Sucker	180.0	0.032	0.22	9.8	25	0.32	0.086	0.064	0.027	1.86	0.022	111	<0.03	0.02	0.06	2.54
MM7	MMEWS 20	White Sucker	524.8	0.011	0.10	19.0	30	0.31	0.030	0.061	0.045	1.03	0.029	99	<0.03	0.01	0.10	2.29
MM7	MMEWS 21	White Sucker	267.4	0.010	0.09	6.9	18	0.25	< 0.025	0.033	0.032	0.94	0.015	199	<0.03	0.02	0.11	2.26
MM7	MMEWS 22	White Sucker	547.8	0.034	0.20	15.3	35	0.33	0.085	0.068	0.023	0.94	0.024	35	<0.03	0.04	0.12	2.18
MM7	MMEWS 23	White Sucker	522.0	0.014	0.17	16.3	29	0.27	0.030	0.059	0.030	0.77	0.022	94	<0.03	0.01	0.06	2.35
MM7	MMEWS 24	White Sucker	395.7	0.017	0.17	24.8	32	0.37	0.025	0.074	0.037	1.07	0.017	323	<0.03	0.02	0.13	3.42
MM7	MMEWS 25	White Sucker	834.0	< 0.010	0.17	32.2	35	0.26	0.029	0.054	0.015	1.03	0.026	97	<0.03	0.02	0.13	3.28
MM7	MMEWS 26	White Sucker	217.0	< 0.010	0.13	9.3	21	0.23	< 0.025	0.047	0.015	0.85	0.029	278	<0.03	0.02	0.12	1.87
MM8	MMEWS 27	White Sucker	378.2	< 0.010	0.20	8.7	27	0.24	< 0.025	0.046	0.032	1.05	0.018	31	<0.03	0.02	0.11	3.04
MM8	MMEWS 28	White Sucker	195.6	0.012	0.22	4.8	18	0.23	0.050	0.041	0.017	1.19	0.018	368	<0.03	0.02	<0.05	3.08
MM8	MMEWS 29	White Sucker	191.8	0.013	0.14	10.9	19	0.25	0.033	0.036	0.019	2.95	0.057	196	<0.03	0.03	<0.05	2.87
MM8	MMEWS 42	White Sucker	250.3	0.011	0.10	9.5	18	0.21	0.034	0.041	0.054	1.59	0.023	118	<0.03	0.02	<0.05	2.66
MM9	MMEWS 16	White Sucker	191.5	0.014	0.09	6.7	23	0.31	< 0.025	0.051	0.024	1.50	0.027	130	<0.03	0.02	<0.05	2.71
MM9	MMEWS 17	White Sucker	455.3	0.025	0.23	16.6	34	0.31	0.027	0.060	0.029	1.89	0.025	83	<0.03	0.02	0.06	3.39
MM9	MMEWS 18	White Sucker	639.1	0.010	0.15	16.9	31	0.22	0.028	0.043	0.026	1.45	0.030	305	<0.03	0.02	0.08	3.95
MM10	MMRNP 3	Northern Pike	216.6	2.201	0.11	8.0	26	0.19	< 0.025	0.056	0.039	1.53	0.015	300	<0.03	0.29	0.06	1.07
MM10	MMRNP 4	Northern Pike	302.1	2.848	0.08	8.8	32	0.24	< 0.025	0.070	0.027	1.80	0.017	20	<0.03	0.17	0.09	1.17
MM10	MMRNP 5	Northern Pike	231.2	0.208	0.04	9.7	28	0.26	< 0.025	0.055	0.029	1.03	0.018	102	<0.03	0.11	0.11	0.71
MM10	MMRNP 6	Northern Pike	136.3	0.321	0.06	4.6	22	0.24	< 0.025	0.049	< 0.015	1.08	0.017	15	<0.03	0.04	0.11	0.95
MM10	MMRNP 7	Northern Pike	153.9	2.056	0.07	5.2	29	0.25	< 0.025	0.047	0.018	0.69	< 0.012	23	<0.03	0.07	0.10	1.59
MM10	MMRNP 28	Northern Pike	387.1	0.313	0.06	15.8	46	0.20	0.354	1.188	0.061	0.75	< 0.012	152	<0.03	0.14	0.10	1.29
MM11	MMRNP 1	Northern Pike	183.0	0.218	0.06	6.5	21	0.18	0.046	0.045	0.024	1.75	0.016	105	<0.03	0.10	<0.05	0.69
MM11	MMRNP 2	Northern Pike	328.6	1.441	0.07	15.7	33	0.26	< 0.025	0.052	0.038	0.95	0.014	50	<0.03	0.13	0.07	1.10
MM11	MMRNP 35	Northern Pike	85.3	0.098	0.05	5.7	27	0.22	0.028	0.061	0.046	0.53	< 0.012	26	<0.03	0.10	<0.05	1.16
MM11	MMRNP 37	Northern Pike	140.1	0.130	0.03	5.7	31	0.25	< 0.025	0.056	0.026	1.29	< 0.012	24	<0.03	0.04	<0.05	1.18
MM12	MMRNP 17	Northern Pike	476.1	3.201	0.13	30.7	46	0.20	< 0.025	0.080	0.056	1.79	< 0.012	405	<0.03	0.41	0.14	1.46
MM13	MMRNP 15	Northern Pike	570.7	3.331	0.12	20.6	37	0.26	0.030	0.095	0.048	2.00	0.019	162	<0.03	0.08	<0.05	1.28
MM13	MMRNP 16	Northern Pike	251.4	0.263	0.04	7.7	36	0.27	0.025	0.071	0.019	1.06	< 0.012	18	<0.03	0.13	0.10	0.96
MM13	MMRNP 31	Northern Pike	438.0	2.229	0.05	16.2	37	0.27	0.026	0.057	0.027	0.63	< 0.012	18	<0.03	0.14	<0.05	1.18
MM13	MMRNP 44	Northern Pike	346.1	0.787	0.19	12.4	29	0.19	< 0.025	0.072	0.044	2.68	< 0.012	82	<0.03	0.45	<0.05	1.30
MM13	MMRNP 45	Northern Pike	398.0	0.340	0.25	17.2	26	0.22	0.033	0.092	0.054	2.10	< 0.012	195	<0.03	0.39	0.07	1.15
MM7	MMENP 14	Northern Pike	281.4	1.092	0.07	12.7	41	0.24	0.034	0.179	0.047	2.34	< 0.012	104	<0.03	0.15	<0.05	4.38
MM7	MMENP 15	Northern Pike	176.0	1.169	0.16	7.4	24	0.22	< 0.025	0.097	0.050	1.44	< 0.012	377	<0.03	0.11	<0.05	3.25
MM7	MMENP 16	Northern Pike	699.7	1.861	0.19	27.1	28	0.19	0.052	0.149	0.076	2.41	< 0.012	475	<0.03	0.17	0.10	4.60
MM7	MMENP 17	Northern Pike	179.5	0.020	0.04	3.4	31	0.27	0.025	0.064	0.033	0.56	< 0.012	91	<0.03	0.03	0.13	2.82
MM7	MMENP 18	Northern Pike	318.5	0.016	0.04	8.4	29	0.28	< 0.025	0.092	0.029	0.46	< 0.012	17	<0.03	0.03	0.08	3.85
MM8	MMENP 20	Northern Pike	207.4	0.033	0.06	10.4	30	0.27	0.058	0.083	0.037	0.67	< 0.012	46	<0.03	0.03	0.05	2.18
MM8	MMENP 21	Northern Pike	293.6	0.027	0.09	17.4	22	0.29	0.028	0.081	0.043	1.16	< 0.012	21	<0.03	0.06	<0.05	5.07
MM8	MMENP 22	Northern Pike	190.0	0.035	0.04	6.4	21	0.23	< 0.025	0.061	0.021	0.42	< 0.012	16	<0.03	0.03	<0.05	2.89
MM8	MMENP 23	Northern Pike	178.2	0.025	0.06	7.5	21	0.18	0.028	0.078	0.034	2.04	< 0.012	108	<0.03	0.03	0.07	4.82
MM8	MMENP 35	Northern Pike	144.9	0.036	0.04	5.7	20	0.26	< 0.025	0.076	0.031	1.39	< 0.012	15	<0.03	0.01	0.19	3.96
MM9	MMENP 9	Northern Pike	315.6	0.026	0.05	11.7	29	0.29	< 0.025	0.063	0.037	0.45	< 0.012	22	<0.03	0.03	0.06	3.67
MM9	MMENP 10	Northern Pike	285.2	0.042	0.08	12.4	22	0.19	0.040	0.073	0.050	3.09	< 0.012	172	<0.03	0.07	0.07	4.09
MM9	MMENP 11	Northern Pike	405.5	0.110	0.38	23.3	41	0.26	0.042	0.182	0.098	3.94	0.030	216	<0.03	0.23	0.08	3.03
MM9	MMENP 12	Northern Pike	373.6	0.033	0.07	12.5	30	0.27	0.055	0.062	0.051	1.37	< 0.012	106	<0.03	0.07	0.06	3.91
MM9	MMENP 13	Northern Pike	66.0	0.019	0.03	2.2	21	0.19	0.030	0.042	0.031	0.97	< 0.012	62	<0.03	0.01	0.09	4.48

Table A6.2: Results of Metallothionein and Metals Analyses conducted on Kidney Tissue collected at Mattabi Mine Site

Station	Fish Number	Species	ug MT/g	Hg ug/G wet wt	Cd ug/G wet wt	Cu ug/G wet wt	Zn ug/G wet wt	Pb ug/G wet wt	Ni ug/G wet wt	Cr ug/G wet wt	Co ug/G wet wt	Al ug/G wet wt	Ba ug/G wet wt	Fe ug/G wet wt	Mo ug/G wet wt	V ug/G wet wt	As ug/G wet wt	Se ug/G wet wt
Kidney																		
MM10	MMRWS 6	White Sucker	79.8	0.264	2.10	1.4	19	0.32	0.15	0.045	0.113	0.91	0.022	79	0.17	0.35	<0.05	0.90
MM10	MMRWS 7	White Sucker	148.7	0.078	1.63	1.4	19	0.24	0.06	0.045	0.202	0.43	0.018	72	0.12	0.16	<0.05	0.69
MM10	MMRWS 8	White Sucker	143.0	0.141	3.04	1.4	19	0.23	0.13	0.048	0.212	1.22	0.028	63	0.16	0.42	<0.05	0.75
MM10	MMRWS 9	White Sucker	85.9	0.077	1.44	1.3	17	0.32	0.07	0.047	0.106	0.86	0.019	85	0.16	0.12	<0.05	0.72
MM11	MMRWS 1	White Sucker	170.0	0.110	3.32	2.3	19	0.34	0.23	0.072	0.402	1.82	0.033	93	0.15	0.32	0.11	0.97
MM11	MMRWS 2	White Sucker	113.1	0.153	1.43	1.8	21	0.34	0.15	0.046	0.132	0.93	0.031	72	0.17	0.29	<0.05	0.92
MM11	MMRWS 3	White Sucker	83.1	0.080	1.00	1.5	20	0.34	0.14	0.050	0.200	0.57	0.032	81	0.18	0.23	<0.05	0.79
MM11	MMRWS 4	White Sucker	112.2	0.171	3.39	1.6	20	0.33	0.19	0.047	0.134	1.22	0.030	73	0.19	0.39	<0.05	0.81
MM11	MMRWS 5	White Sucker	122.2	0.108	1.35	1.9	21	0.35	0.14	0.047	0.134	<0.25	0.020	60	0.20	0.27	<0.05	0.85
MM12	MMRWS 10	White Sucker	63.0	0.230	1.51	1.4	18	0.30	0.11	0.068	0.150	0.95	0.028	68	0.11	0.30	<0.05	0.66
MM12	MMR WS 11	White Sucker	92.8	0.043	0.88	1.5	20	0.23	0.08	0.046	0.359	0.70	0.027	86	0.13	0.17	<0.05	0.72
MM12	MMRWS 12	White Sucker	100.8	0.023	0.29	1.2	17	0.21	0.04	0.044	0.089	1.20	0.021	91	0.09	0.11	<0.05	0.55
MM12	MMRWS 13	White Sucker	97.2	0.147	2.71	2.1	24	0.31	0.24	0.044	0.228	0.98	0.028	101	0.17	0.27	<0.05	1.06
MM12	MMRWS 14	White Sucker	51.8	0.079	0.76	1.4	24	0.32	0.23	0.042	0.139	1.14	0.032	122	0.09	0.27	<0.05	0.99
MM13	MMRWS 15	White Sucker	142.9	0.116	1.98	1.7	16	0.27	0.06	0.042	0.086	1.01	0.025	61	0.13	0.20	<0.05	0.60
MM13	MMRWS 16	White Sucker	77.3	0.079	1.65	1.4	19	0.22	0.08	0.047	0.143	0.74	0.029	104	0.16	0.13	<0.05	0.64
MM7	MMEWS 19	White Sucker	141.0	0.031	2.73	1.6	20	0.40	0.07	0.048	0.077	1.30	0.026	76	0.19	<0.05	<0.05	2.42
MM7	MMEWS 20	White Sucker	107.4	0.010	0.84	1.7	21	0.34	0.07	0.040	0.100	1.16	0.035	67	0.15	<0.05	<0.05	2.44
MM7	MMEWS 21	White Sucker	91.5	0.010	0.74	1.8	19	0.33	0.09	0.036	0.103	0.90	0.018	78	0.18	<0.05	0.08	2.52
MM7	MMEWS 22	White Sucker	104.9	0.052	1.72	1.7	17	0.33	0.10	0.042	0.161	0.85	0.018	55	0.18	0.11	<0.05	2.01
MM7	MMEWS 23	White Sucker	N/S	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
MM7	MMEWS 24	White Sucker	78.3	0.020	1.25	1.9	28	0.36	0.12	0.044	0.115	1.15	0.035	70	0.24	<0.05	<0.05	3.15
MM7	MMEWS 25	White Sucker	111.4	0.016	0.87	1.9	22	0.35	0.07	0.043	0.228	0.97	0.025	98	0.18	<0.05	<0.05	3.78
MM7	MMEWS 26	White Sucker	98.9	0.014	1.03	1.7	21	0.33	0.07	0.042	0.147	1.02	0.058	79	0.22	<0.05	<0.05	2.13
MM8	MMEWS 27	White Sucker	123.6	0.010	0.99	1.7	19	0.31	0.05	0.036	0.153	1.17	0.023	81	0.18	<0.05	0.22	4.46
MM8	MMEWS 28	White Sucker	86.4	0.013	1.08	1.6	18	0.33	0.09	0.038	0.155	1.19	0.043	107	0.13	0.07	0.07	3.42
MM8	MMEWS 29	White Sucker	99.8	0.016	0.99	1.7	20	0.31	0.06	0.039	0.123	0.66	0.030	84	0.21	<0.05	0.70	2.92
MM8	MMEWS 42	White Sucker	97.2	0.025	0.72	1.8	25	0.31	0.07	0.041	0.167	1.21	0.027	90	0.16	0.05	<0.05	2.87
MM9	MMEWS 16	White Sucker	81.2	0.017	0.90	1.5	20	0.22	0.05	0.046	0.129	0.91	< 0.012	68	0.20	0.06	<0.05	3.08
MM9	MMEWS 17	White Sucker	82.6	0.006	1.05	1.5	21	0.32	0.07	0.038	0.148	1.28	0.051	96	0.17	<0.05	<0.05	3.50
MM9	MMEWS 18	White Sucker	65.3	0.017	1.88	1.8	23	0.34	0.18	0.043	0.097	1.05	0.050	65	0.20	<0.05	<0.05	3.23
MM10	MMRNP 3	Northern Pike	85.8	0.309	0.16	1.0	100	0.32	0.05	0.174	0.113	5.03	0.136	55	0.07	0.25	n/s	n/s
MM10	MMRNP 4	Northern Pike	96.0	0.842	0.28	1.0	113	0.30	0.08	0.169	0.161	23.0	0.170	66	0.07	0.19	<0.05	0.83
MM10	MMRNP 5	Northern Pike	69.3	0.241	0.18	1.0	121	0.31	0.07	0.115	0.151	3.68	0.063	52	0.07	0.16	0.13	1.07
MM10	MMRNP 6	Northern Pike	118.0	0.741	0.34	1.2	99	0.23	0.05	0.120	0.113	2.11	0.049	49	0.05	0.06	0.08	0.93
MM10	MMRNP 7	Northern Pike	106.0	0.722	0.27	1.0	143	0.33	0.04	0.114	0.101	2.66	0.079	59	0.07	0.09	<0.05	0.96
MM10	MMRNP 28	Northern Pike	99.5	0.331	0.17	1.1	95	0.27	0.05	0.136	0.117	2.56	0.031	105	0.07	0.08	n/s	n/s
MM11	MMRNP 1	Northern Pike	119.1	0.464	0.26	1.1	118	0.27	0.08	0.141	0.137	5.84	0.117	80	0.07	0.22	n/s	n/s
MM11	MMRNP 2	Northern Pike	130.5	0.981	0.23	1.1	165	0.33	0.07	0.108	0.115	3.26	0.088	53	0.06	0.09	<0.05	0.88
MM11	MMRNP 35	Northern Pike	87.5	0.092	0.15	1.0	88	0.27	0.05	0.061	0.090	1.56	0.079	53	0.05	0.12	n/s	n/s
MM11	MMRNP 37	Northern Pike	126.5	0.151	0.12	1.0	99	0.22	0.04	0.044	0.068	1.86	0.020	62	0.06	<0.05	n/s	n/s
MM12	MMRNP 17	Northern Pike	121.2	0.604	0.50	1.1	118	0.29	0.08	0.140	0.162	4.40	0.211	103	0.07	0.38	n/s	n/s
MM13	MMRNP 15	Northern Pike	70.1	0.649	0.29	1.1	159	0.23	0.10	0.252	0.171	8.53	0.240	79	0.09	0.45	0.08	1.22
MM13	MMRNP 16	Northern Pike	89.5	0.201	0.10	1.0	97	0.33	0.05	0.126	0.092	1.88	0.048	46	0.04	0.10	<0.05	0.90
MM13	MMRNP 31	Northern Pike	145.0	0.420	0.12	0.8	110	0.29	0.04	0.091	0.078	1.63	0.054	51	0.06	0.09	0.08	1.13
MM13	MMRNP 44	Northern Pike	62.6	0.553	0.40	0.8	117	0.28	0.10	0.218	0.188	4.28	0.173	107	0.08	0.49	0.17	1.43
MM13	MMRNP 45	Northern Pike	59.2	0.410	0.72	1.1	80	0.29	0.09	0.212	0.167	5.22	0.207	91	0.09	0.40	n/s	n/s
MM7	MMENP 14	Northern Pike	146.4	0.207	0.21	1.0	108	0.33	0.09	0.618	0.215	1.68	0.202	82	0.10	0.10	<0.05	2.85
MM7	MMENP 15	Northern Pike	136.8	0.187	0.19	0.8	212	0.27	0.05	0.199	0.112	0.96	0.104	99	0.05	0.05	<0.05	3.39
MM7	MMENP 16	Northern Pike	83.5	0.244	0.30	1.0	92	0.30	0.12	0.617	0.208	1.38	0.093	99	0.08	0.09	0.12	5.39
MM7	MMENP 17	Northern Pike	147.3	0.019	0.11	1.0	73	0.43	0.04	0.152	0.163	0.71	0.022	56	0.06	<0.05	0.09	4.39
MM7	MMENP 18	Northern Pike	230.3	0.015	0.18	1.0	96	0.38	0.04	0.103	0.118	0.53	0.020	41	0.07	<0.05	<0.05	3.54
MM8	MMENP 20	Northern Pike	103.6	0.036	0.17	0.9	130	0.32	0.06	0.150	0.223	1.17	0.031	71	0.05	<0.05	<0.05	3.67
MM8	MMENP 21	Northern Pike	138.1	0.023	0.28	2.7	153	0.49	0.22	0.155	0.207	0.82	0.034	71	0.05	<0.05	<0.05	3.51
MM8	MMENP 22	Northern Pike	139.1	0.056	0.16	1.0	65	0.30	0.04	0.179	0.119	1.13	0.039	57	0.06	<0.05	<0.05	2.07
MM8	MMENP 23	Northern Pike	150.9	0.034	0.28	1.2	111	0.38	0.10	0.224	0.327	1.37	0.067	85	0.06	0.06	<0.05	5.59
MM8	MMENP 35	Northern Pike	157.1	0.034	0.20	1.2	97	0.32	0.05	0.097	0.149	0.89	0.027	60	0.06	<0.05	<0.05	3.16
MM9	MMENP 9	Northern Pike	151.6	0.029	0.24	1.1	106	0.34	0.05	0.136	0.119	1.67	0.026	62	0.06	<0.05	0.10	0.79
MM9	MMENP 10	Northern Pike	192.8	0.044	0.13	0.6	136	0.54	0.13	0.295	0.263	2.66	0.073	118	0.03	0.08	0.11	1.29
MM9	MMENP 11	Northern Pike	61.8	0.108	0.24	0.7	206	0.35	0.11	0.450	0.352	3.16	0.130	96	0.05	0.13	0.08	4.16
MM9	MMENP 12	Northern Pike	158.1	0.042	0.32	1.1	118	0.38	0.08	0.259	0.322	1.63	0.052	63	0.08	<0.05	0.09	4.96
MM9	MMENP 13	Northern Pike	224.8	0.016	0.12	1.1	67	0.35	0.04	0.171	0.149	1.01	0.044	84	0.07	<0.05	0.08	3.42

Table A6.3: Results of Metallothionein and Metals Analyses conducted on Gill Tissue collected at Mattabi Mine Site

Station	Fish Number	Species	ug MT/g	Hg ug/G wet wt	Cd ug/G wet wt	Cu ug/G wet wt	Zn ug/G wet wt	Pb ug/G wet wt	Ni ug/G wet wt	Cr ug/G wet wt	Co ug/G wet wt	Al ug/G wet wt	Ba ug/G wet wt	Fe ug/G wet wt	Mo ug/G wet wt	V ug/G wet wt	As ug/G wet wt	Se ug/G wet wt
Gill																		
MM10	MMRWS 6	White Sucker	25.7	0.031	0.016	0.83	10	0.036	0.04	0.089	0.021	2.21	1.27	27	<0.03	<.05	<.05	0.06
MM10	MMRWS 7	White Sucker	51.8	0.025	0.020	0.74	12	0.012	0.04	0.049	0.021	0.70	0.93	28	<0.03	<.05	<.05	0.10
MM10	MMRWS 8	White Sucker	28.7	0.050	0.020	0.65	13	0.024	0.03	0.053	0.053	3.49	1.16	35	<0.03	<.05	<.05	0.11
MM10	MMRWS 9	White Sucker	27.3	0.024	0.019	0.90	12	0.047	0.04	0.075	0.019	3.22	2.62	38	<0.03	<.05	<.05	0.07
MM11	MMRWS 1	White Sucker	30.3	0.014	0.019	0.70	12	0.014	0.03	0.065	0.047	1.11	1.47	31	<0.03	<.05	<.05	0.06
MM11	MMRWS 2	White Sucker	34.0	0.039	0.006	0.77	12	0.016	0.05	0.052	0.031	1.11	1.87	30	<0.03	<.05	<.05	0.07
MM11	MMRWS 3	White Sucker	23.6	0.022	0.006	0.56	11	0.013	0.03	0.119	0.035	21.33	1.09	72	<0.03	0.10	<.05	0.07
MM11	MMRWS 4	White Sucker	32.6	0.025	0.018	0.66	11	0.013	0.04	0.082	0.059	0.94	1.45	30	<0.03	<.05	<.05	0.08
MM11	MMRWS 5	White Sucker	39.7	0.018	0.019	0.91	13	0.038	0.05	0.062	0.029	3.48	0.89	48	<0.03	<.05	<.05	0.06
MM12	MMRWS 10	White Sucker	40.8	0.028	0.020	0.97	13	0.022	0.03	0.062	0.031	2.65	1.39	39	<0.03	<.05	<.05	0.06
MM12	MMR WS 11	White Sucker	50.8	0.023	0.018	0.79	12	0.022	0.04	0.079	0.038	2.60	1.11	30	<0.03	<.05	<.05	0.08
MM12	MMRWS 12	White Sucker	52.8	0.037	0.019	0.81	12	0.014	0.04	0.067	0.044	4.93	1.84	34	<0.03	0.05	<.05	0.06
MM12	MMRWS 13	White Sucker	29.8	0.035	0.007	0.92	12	0.043	0.03	0.092	0.021	3.80	1.36	42	<0.03	<.05	<.05	0.09
MM12	MMRWS 14	White Sucker	28.3	0.015	0.006	0.86	12	0.054	0.04	0.109	0.051	15.20	0.96	69	<0.03	0.08	<.05	0.06
MM13	MMRWS 15	White Sucker	25.9	0.031	0.007	0.79	12	0.033	0.03	0.077	0.031	6.34	2.73	60	<0.03	0.07	<.05	0.11
MM13	MMRWS 16	White Sucker	26.6	0.027	0.006	0.61	11	0.012	0.04	0.059	0.031	3.24	0.62	35	<0.03	<.05	<.05	0.09
MM7	MMEWS 19	White Sucker	36.5	0.013	0.009	0.85	13	0.169	0.05	0.055	0.037	3.42	0.93	37	<0.03	<.05	<.05	0.28
MM7	MMEWS 20	White Sucker	17.0	0.031	0.008	0.83	15	0.202	0.05	0.081	0.049	3.56	2.59	52	<0.03	<.05	<.05	0.32
MM7	MMEWS 21	White Sucker	16.0	0.011	0.007	1.15	14	0.223	0.05	0.078	0.064	6.34	0.83	50	<0.03	<.05	<.05	0.30
MM7	MMEWS 22	White Sucker	19.8	0.015	0.007	0.68	13	0.082	0.04	0.054	0.040	2.64	1.16	35	<0.03	<.05	<.05	0.26
MM7	MMEWS 23	White Sucker	29.8	0.013	0.006	0.67	13	0.060	0.04	0.043	0.029	1.75	0.89	38	<0.03	<.05	<.05	0.25
MM7	MMEWS 24	White Sucker	18.3	< 0.010	0.007	0.72	14	0.093	0.03	0.068	0.040	1.88	1.01	33	<0.03	<.05	<.05	0.34
MM7	MMEWS 25	White Sucker	24.5	< 0.010	0.007	1.01	12	0.096	0.04	0.079	0.039	3.65	0.93	36	<0.03	<.05	<.05	0.32
MM7	MMEWS 26	White Sucker	36.0	< 0.010	0.009	0.91	16	0.100	0.04	0.074	0.026	2.07	0.64	39	<0.03	<.05	<.05	0.23
MM8	MMEWS 27	White Sucker	18.2	< 0.010	0.007	0.70	12	0.046	0.05	0.103	0.053	0.87	0.93	36	<0.03	<.05	<.05	0.35
MM8	MMEWS 28	White Sucker	13.4	0.010	0.007	0.79	14	0.075	0.04	0.054	0.086	3.37	3.63	43	<0.03	<.05	<.05	0.40
MM8	MMEWS 29	White Sucker	16.6	< 0.010	0.007	0.73	14	0.049	0.03	0.042	0.029	2.11	1.18	36	<0.03	<.05	<.05	0.41
MM8	MMEWS 42	White Sucker	20.3	0.046	0.008	0.78	14	0.090	0.04	0.062	0.036	1.10	1.14	36	<0.03	<.05	<.05	0.41
MM9	MMEWS 16	White Sucker	26.1	0.010	0.008	1.12	15	0.108	0.12	0.109	0.034	4.45	0.89	75	<0.03	<.05	<.05	0.36
MM9	MMEWS 17	White Sucker	23.8	0.013	0.008	0.67	14	0.042	0.05	0.112	0.022	2.81	1.02	40	<0.03	<.05	<.05	0.34
MM9	MMEWS 18	White Sucker	34.7	< 0.010	0.008	0.79	13	0.087	0.06	0.063	0.044	3.09	0.94	51	<0.03	<.05	<.05	0.44
MM10	MMRNP 3	Northern Pike	1.5	0.138	0.006	0.83	92	0.029	0.18	0.173	0.008	2.69	0.12	27	<0.03	<.05	<.05	0.14
MM10	MMRNP 4	Northern Pike	1.3	0.220	0.007	0.62	10	0.009	0.01	0.178	0.010	0.79	0.42	29	<0.03	<.05	<.05	0.05
MM10	MMRNP 5	Northern Pike	3.2	0.078	0.008	0.52	105	0.016	< 0.01	0.224	0.010	2.19	0.41	30	<0.03	<.05	<.05	0.20
MM10	MMRNP 6	Northern Pike	2.9	0.151	0.007	0.67	9	< 0.005	0.02	0.170	0.006	0.81	0.34	23	<0.03	<.05	<.05	0.06
MM10	MMRNP 7	Northern Pike	2.8	0.128	0.007	0.67	12	0.007	0.01	0.151	0.009	1.01	0.35	24	<0.03	<.05	<.05	0.05
MM10	MMRNP 28	Northern Pike	2.8	0.063	0.005	0.60	99	0.053	0.09	4.250	0.025	1.76	0.30	65	<0.03	<.05	<.05	0.14
MM11	MMRNP 1	Northern Pike	3.2	0.138	0.006	0.89	141	0.028	0.06	0.796	0.010	2.58	0.14	38	<0.03	<.05	<.05	0.12
MM11	MMRNP 2	Northern Pike	1.9	0.517	0.008	0.79	9	0.026	0.03	0.205	0.012	1.44	1.23	25	<0.03	<.05	<.05	0.06
MM11	MMRNP 35	Northern Pike	2.4	0.029	0.005	0.58	65	0.044	< 0.01	0.085	0.012	3.12	0.15	38	<0.03	<.05	0.07	0.19
MM11	MMRNP 37	Northern Pike	1.3	0.045	0.009	1.00	130	0.172	0.02	0.039	0.010	3.42	0.24	28	<0.03	<.05	0.13	0.38
MM12	MMRNP 17	Northern Pike	1.5	0.123	0.006	0.54	89	0.011	0.02	0.163	0.008	1.82	0.25	29	<0.03	<.05	<.05	0.20
MM13	MMRNP 15	Northern Pike	5.3	0.201	0.007	0.65	13	0.026	0.01	0.269	0.017	3.43	0.96	32	<0.03	<.05	<.05	< 0.05
MM13	MMRNP 16	Northern Pike	3.7	0.092	0.007	0.65	11	0.007	0.02	0.428	0.008	1.32	0.60	26	<0.03	<.05	<.05	0.06
MM13	MMRNP 31	Northern Pike	2.3	0.128	0.009	0.70	12	0.036	0.01	0.153	0.010	1.51	0.76	22	<0.03	<.05	<.05	0.06
MM13	MMRNP 44	Northern Pike	2.2	0.156	0.007	0.55	69	0.031	0.01	0.189	0.016	1.67	0.52	41	<0.03	<.05	<.05	0.12
MM13	MMRNP 45	Northern Pike	2.2	0.086	0.009	0.70	84	0.159	0.02	0.198	0.023	8.00	0.31	54	<0.03	<.05	<.05	0.13
MM7	MMENP 14	Northern Pike	4.1	0.049	0.007	0.75	13	0.103	< 0.01	0.385	0.010	3.66	0.32	38	<0.03	<.05	<.05	0.19
MM7	MMENP 15	Northern Pike	2.4	0.056	0.007	1.04	9	0.095	0.05	0.258	0.017	8.37	0.39	46	<0.03	<.05	<.05	0.29
MM7	MMENP 16	Northern Pike	2.3	0.049	0.007	0.90	11	0.158	0.02	0.342	0.021	4.73	0.30	44	<0.03	<.05	<.05	0.22
MM7	MMENP 17	Northern Pike	2.7	< 0.010	0.008	0.62	8	0.139	0.02	0.184	0.014	4.87	0.12	34	<0.03	<.05	<.05	0.39
MM7	MMENP 18	Northern Pike	5.1	< 0.010	0.009	0.63	11	0.124	< 0.01	0.154	0.022	2.12	0.17	50	<0.03	<.05	<.05	0.39
MM8	MMENP 20	Northern Pike	3.8	0.012	0.011	0.70	9	0.056	0.01	0.204	0.032	7.95	0.15	59	<0.03	<.05	<.05	0.30
MM8	MMENP 21	Northern Pike	2.6	< 0.010	0.008	0.74	10	0.153	0.02	0.167	0.030	5.18	0.15	54	<0.03	<.05	<.05	0.31
MM8	MMENP 22	Northern Pike	2.2	< 0.010	0.007	0.65	12	0.132	0.04	0.268	0.016	2.05	0.09	33	<0.03	<.05	<.05	0.48
MM8	MMENP 23	Northern Pike	4.8	0.020	0.007	0.71	11	0.032	0.04	0.272	0.016	3.19	0.19	43	<0.03	<.05	<.05	0.23
MM8	MMENP 35	Northern Pike	1.9	0.016	0.007	0.68	7	0.024	0.03	0.213	0.014	1.69	0.38	40	<0.03	<.05	<.05	0.35
MM9	MMENP 9	Northern Pike	10.5	0.010	0.008	0.69	9	0.037	0.02	0.156	0.016	2.53	0.12	34	<0.03	<.05	<.05	0.20
MM9	MMENP 10	Northern Pike	4.6	0.029	0.010	0.70	10	0.062	0.04	0.199	0.038	6.30	0.26	77	<0.03	<.05	<.05	0.40
MM9	MMENP 11	Northern Pike	3.0	0.022	0.008	0.67	53	0.075	0.04	0.315	0.035	7.63	0.28	96	<0.03	<.05	<.05	0.29
MM9	MMENP 12	Northern Pike	3.3	0.023	0.009	0.68	8	< 0.005	0.05	0.218	0.038	7.98	0.23	100	<0.03	<.05	<.05	0.37
MM9	MMENP 13	Northern Pike	6.1	0.015	0.007	0.74	9	0.141	0.04	0.147	0.023	10.98	0.11	112	<0.03	<.05	<.05	0.52

Table A6.4: Results of Metallothionein and Metal Analyses conducted on Muscle Tissue collected at Mattabi Mine Site

Station	Fish Number	Species	Hg ug/G wet wt	Cd ug/G wet wt	Cu ug/G wet wt	Zn ug/G wet wt	Pb ug/G wet wt	Ni ug/G wet wt	Cr ug/G wet wt	Co ug/G wet wt	Al ug/G wet wt	Ba ug/G wet wt	Fe ug/G wet wt	Mo ug/G wet wt	V ug/G wet wt	As ug/G wet wt	Se ug/G wet wt
Muscle																	
MM10	MMRWS 6	White Sucker	0.452	0.019	0.26	2.8	<0.005	< 0.01	0.031	<0.005	0.16	<0.005	1.94	<0.03	<0.05	<0.05	0.27
MM10	MMRWS 7	White Sucker	0.269	0.022	0.55	3.0	<0.005	0.01	0.041	<0.005	0.11	<0.005	4.36	<0.03	<0.05	<0.05	0.16
MM10	MMRWS 8	White Sucker	0.321	0.020	0.23	2.3	<0.005	0.22	0.033	<0.005	0.33	<0.005	1.78	<0.03	<0.05	<0.05	0.21
MM10	MMRWS 9	White Sucker	0.310	0.020	0.35	2.4	<0.005	0.03	0.050	<0.005	0.19	<0.005	1.46	<0.03	<0.05	<0.05	0.21
MM11	MMRWS 1	White Sucker	0.346	0.021	0.57	2.6	<0.005	0.05	0.037	<0.005	0.52	0.009	1.89	<0.03	<0.05	<0.05	0.23
MM11	MMRWS 2	White Sucker	0.215	0.019	0.56	3.5	<0.005	0.02	0.035	0.005	0.18	<0.005	4.43	<0.03	<0.05	<0.05	0.25
MM11	MMRWS 3	White Sucker	0.191	0.022	0.36	3.0	<0.005	0.01	0.043	<0.005	0.24	<0.005	3.49	<0.03	<0.05	<0.05	0.19
MM11	MMRWS 4	White Sucker	0.441	0.019	0.53	3.4	<0.005	0.02	0.049	<0.005	0.20	0.006	6.06	<0.03	<0.05	<0.05	0.15
MM11	MMRWS 5	White Sucker	0.284	0.021	0.51	2.9	<0.005	0.04	0.045	<0.005	0.18	0.014	1.20	<0.03	<0.05	<0.05	0.21
MM12	MMRWS 10	White Sucker	0.411	0.017	0.30	2.7	<0.005	0.01	0.030	<0.005	0.18	<0.005	1.98	<0.03	<0.05	<0.05	0.14
MM12	MMR WS 11	White Sucker	0.149	0.024	0.34	2.4	<0.005	0.02	0.042	<0.005	0.14	<0.005	1.97	<0.03	<0.05	<0.05	0.23
MM12	MMRWS 12	White Sucker	0.170	0.019	0.37	2.5	<0.005	0.02	0.032	<0.005	0.13	<0.005	1.83	<0.03	<0.05	0.09	0.12
MM12	MMRWS 13	White Sucker	0.301	0.018	0.34	2.2	<0.005	0.01	0.038	<0.005	0.12	<0.005	2.77	<0.03	<0.05	0.14	0.27
MM12	MMRWS 14	White Sucker	0.283	0.020	0.32	2.7	<0.005	0.01	0.038	<0.005	0.14	<0.005	3.27	<0.03	<0.05	0.11	0.26
MM13	MMRWS 15	White Sucker	0.383	0.020	0.40	3.2	<0.005	0.01	0.046	<0.005	0.12	<0.005	4.75	<0.03	<0.05	0.13	0.21
MM13	MMRWS 16	White Sucker	0.278	0.022	0.41	2.3	<0.005	0.04	0.052	<0.005	0.15	<0.005	1.94	<0.03	<0.05	0.11	0.19
MM7	MMEWS 19	White Sucker	0.139	0.015	0.49	3.1	<0.005	0.04	0.047	<0.005	0.17	0.017	2.08	<0.03	<0.05	<0.05	1.18
MM7	MMEWS 20	White Sucker	0.056	0.024	0.44	3.1	<0.005	0.05	0.055	<0.005	0.19	0.016	1.92	<0.03	<0.05	<0.05	1.05
MM7	MMEWS 21	White Sucker	0.027	0.022	0.30	2.8	<0.005	0.03	0.042	<0.005	0.23	0.012	2.63	<0.03	<0.05	<0.05	1.79
MM7	MMEWS 22	White Sucker	0.111	0.019	0.32	2.3	<0.005	0.03	0.035	<0.005	0.12	<0.005	1.83	<0.03	<0.05	<0.05	0.76
MM7	MMEWS 23	White Sucker	0.073	0.022	0.22	2.7	<0.005	0.19	0.041	<0.005	0.13	0.016	1.45	<0.03	<0.05	<0.05	0.86
MM7	MMEWS 24	White Sucker	0.020	0.026	0.36	3.8	<0.005	0.05	0.052	<0.005	0.22	0.021	2.24	<0.03	<0.05	<0.05	1.72
MM7	MMEWS 25	White Sucker	0.032	0.022	0.37	2.9	<0.005	0.03	0.049	<0.005	0.11	0.013	1.59	<0.03	<0.05	0.13	2.12
MM7	MMEWS 26	White Sucker	0.042	0.022	0.38	2.7	<0.005	0.03	0.040	<0.005	0.13	<0.005	1.96	<0.03	<0.05	0.07	1.29
MM8	MMEWS 27	White Sucker	0.043	0.014	0.30	2.6	<0.005	0.02	0.038	<0.005	0.26	<0.005	1.64	<0.03	<0.05	<0.05	1.95
MM8	MMEWS 28	White Sucker	0.015	0.014	0.29	2.3	<0.005	0.04	0.035	<0.005	0.19	0.030	2.33	<0.03	<0.05	<0.05	2.19
MM8	MMEWS 29	White Sucker	0.052	0.016	0.34	3.2	<0.005	0.02	0.035	<0.005	0.10	0.009	1.89	<0.03	<0.05	<0.05	1.38
MM8	MMEWS 42	White Sucker	0.069	0.015	0.38	3.3	<0.005	0.04	0.045	<0.005	0.54	0.009	2.92	<0.03	<0.05	<0.05	1.46
MM9	MMEWS 16	White Sucker	0.080	0.023	0.33	3.0	<0.005	0.03	0.052	<0.005	0.11	0.021	1.53	<0.03	<0.05	<0.05	1.60
MM9	MMEWS 17	White Sucker	0.101	0.022	0.32	3.9	<0.005	0.03	0.046	<0.005	0.21	0.023	3.17	<0.03	<0.05	<0.05	0.86
MM9	MMEWS 18	White Sucker	0.027	0.015	0.41	2.6	<0.005	0.02	0.041	<0.005	0.11	<0.005	1.75	<0.03	<0.05	0.09	1.71
MM10	MMRNP 3	Northern Pike	0.549	0.022	0.24	3.4	<0.005	0.02	0.038	<0.005	0.15	0.072	1.54	<0.03	<0.05	<0.05	0.15
MM10	MMRNP 4	Northern Pike	0.813	0.018	0.18	2.8	<0.005	0.02	0.033	<0.005	0.15	<0.005	0.77	<0.03	<0.05	0.06	0.14
MM10	MMRNP 5	Northern Pike	0.459	0.022	0.41	3.3	<0.005	0.04	0.035	<0.005	0.12	0.083	0.98	<0.03	<0.05	<0.05	0.14
MM10	MMRNP 6	Northern Pike	0.706	0.017	0.32	4.1	<0.005	0.04	0.036	<0.005	0.70	0.014	0.98	<0.03	<0.05	0.09	0.16
MM10	MMRNP 7	Northern Pike	0.690	0.019	0.21	3.3	<0.005	0.02	0.033	<0.005	< 0.1	<0.005	0.73	<0.03	<0.05	0.09	0.14
MM10	MMRNP 28	Northern Pike	0.429	0.019	0.25	3.2	<0.005	0.02	0.090	<0.005	0.15	0.015	2.47	<0.03	<0.05	<0.05	0.18
MM11	MMRNP 1	Northern Pike	0.562	0.020	0.20	4.3	<0.005	0.02	0.034	<0.005	0.17	0.092	1.96	<0.03	<0.05	<0.05	0.19
MM11	MMRNP 2	Northern Pike	0.879	0.019	0.33	3.1	<0.005	0.04	0.036	<0.005	0.11	0.067	0.82	<0.03	<0.05	<0.05	0.18
MM11	MMRNP 35	Northern Pike	0.144	0.021	0.30	3.1	<0.005	0.01	0.033	<0.005	< 0.1	0.077	1.14	<0.03	<0.05	<0.05	0.17
MM11	MMRNP 37	Northern Pike	0.251	0.019	0.29	3.8	<0.005	0.02	0.033	<0.005	0.22	0.037	1.28	<0.03	<0.05	<0.05	0.14
MM12	MMRNP 17	Northern Pike	0.596	0.018	0.28	3.6	<0.005	0.03	0.033	<0.005	0.32	0.183	1.74	<0.03	<0.05	<0.05	0.17
MM13	MMRNP 15	Northern Pike	0.852	0.020	0.21	2.7	<0.005	0.03	0.034	<0.005	0.12	0.016	1.30	<0.03	<0.05	0.12	0.15
MM13	MMRNP 16	Northern Pike	0.361	0.017	0.27	2.9	<0.005	0.03	0.032	<0.005	< 0.1	0.010	1.06	<0.03	<0.05	0.08	0.11
MM13	MMRNP 31	Northern Pike	0.752	0.021	0.23	3.4	<0.005	0.02	0.044	<0.005	0.29	0.068	0.86	<0.03	<0.05	<0.05	0.17
MM13	MMRNP 44	Northern Pike	0.695	0.020	0.26	3.3	<0.005	0.02	0.034	<0.005	< 0.1	0.105	2.34	<0.03	<0.05	<0.05	0.20
MM13	MMRNP 45	Northern Pike	0.698	0.020	0.36	3.5	<0.005	0.03	0.037	<0.005	0.12	0.159	1.66	<0.03	<0.05	<0.05	0.16
MM7	MMENP 14	Northern Pike	0.478	0.022	0.34	4.9	<0.005	0.02	0.055	<0.005	0.15	<0.005	2.70	<0.03	<0.05	<0.05	1.05
MM7	MMENP 15	Northern Pike	0.476	0.019	0.34	4.8	<0.005	0.03	0.060	<0.005	< 0.1	0.091	2.19	<0.03	<0.05	0.07	0.81
MM7	MMENP 16	Northern Pike	0.389	0.020	0.24	4.1	<0.005	0.01	0.054	<0.005	< 0.1	0.085	1.77	<0.03	<0.05	<0.05	1.31
MM7	MMENP 17	Northern Pike	0.055	0.023	0.23	4.4	<0.005	0.02	0.051	<0.005	0.11	0.032	0.97	<0.03	<0.05	<0.05	2.00
MM7	MMENP 18	Northern Pike	0.039	0.023	0.24	3.9	<0.005	0.02	0.047	<0.005	< 0.1	0.028	0.95	<0.03	<0.05	<0.05	2.43
MM8	MMENP 20	Northern Pike	0.090	0.021	0.19	3.4	<0.005	0.02	0.047	<0.005	< 0.1	0.021	1.37	<0.03	<0.05	0.07	2.09
MM8	MMENP 21	Northern Pike	0.064	0.023	0.28	4.0	<0.005	0.02	0.044	<0.005	< 0.1	0.037	1.07	<0.03	<0.05	0.07	2.45
MM8	MMENP 22	Northern Pike	0.121	0.018	0.22	4.0	<0.005	0.03	0.048	<0.005	< 0.1	0.193	0.91	<0.03	<0.05	<0.05	1.08
MM8	MMENP 23	Northern Pike	0.067	0.020	0.24	5.0	<0.005	0.03	0.046	<0.005	0.10	0.036	1.58	<0.03	<0.05	0.05	2.46
MM8	MMENP 35	Northern Pike	0.101	0.023	0.23	4.1	<0.005	0.08	0.038	<0.005	0.12	0.020	1.06	<0.03	<0.05	0.06	1.67
MM9	MMENP 9	Northern Pike	0.054	0.021	0.37	4.3	<0.005	0.02	0.039	<0.005	< 0.1	0.020	1.44	<0.03	<0.05	<0.05	2.46
MM9	MMENP 10	Northern Pike	0.119	0.022	0.31	4.0	<0.005	0.02	0.036	<0.005	< 0.1	0.065	1.91	<0.03	<0.05	<0.05	2.19
MM9	MMENP 11	Northern Pike	0.249	0.023	0.29	4.2	<0.005	0.02	0.039	<0.005	0.12	0.056	1.83	<0.03	<0.05	<0.05	1.31
MM9	MMENP 12	Northern Pike	0.092	0.023	0.21	3.0	<0.005	0.02	0.040	<0.005	0.15	<0.005	1.39	<0.03	<0.05	<0.05	2.14
MM9	MMENP 13	Northern Pike	0.051	0.022	0.26	3.6	<0.005	0.01	0.046	<0.005	< 0.1	0.010	1.48	<0.03	<0.05	0.06	2.57

Table A6.5: Raw Biological Data on Fish Sampled at Mattabi Mine Site

Station	Fish Number	Species	Sex	Age	Fork Length (cm)	Total Length (cm)	Whole Weight (g)	Gonad Weight (g)	Gonad Volume (ml)	Egg Volume (ml)	Liver Weight (g)	Age Structure	Fecundity (Fish)	Comments
MM6	MMENP1	Northern Pike	F	7	60.1	63.4	1750	59.7	56.0	56.0	28.6	C	17476	
MM6	MMENP2	Northern Pike	F	3	56.5	59.9	1575	32.9	30.5	30.5	28.3	C	14994	
MM6	MMENP3	Northern Pike	M	5	62.8	67.2	1775	22.3	---	---	12.6	C		
MM6	MMENP4	Northern Pike	M	9	63.7	67.8	2060	23.4	---	---	18.3	C		
MM6	MMENP5	Northern Pike	F	6	58.2	61.8	1400	25.3	22.0	22.0	20.6	C	11652	
MM6	MMENP6	Northern Pike	M	1	42.8	45.7	530	5.4	---	---	5.5	C		
MM6	MMENP25	Northern Pike	F	6	69.6	74.0	3500	83.8	80.0	80.0	33.7	C	25975	
MM6	MMENP29	Northern Pike	M	2	41.0	43.8	550	6.3	---	---	5.5	C		Burbot in stomach
MM6	MMENP30	Northern Pike	M	8	68.3	73.6	2100	20.4	---	---	11.2	C		
MM6	MMENP31	Northern Pike	F	6	58.4	62.8	1950	57.6	56.0	56.0	34.0	C	16214	
MM6	MMENP32	Northern Pike	M	7	63.0	67.0	2225	22.1	---	---	12.9	C		
MM6	MMEWS1	White Sucker	F	13	48.4	52.5	1850	122.3	115.0	63.0	35.7	P,S	20669	Part of liver appears dead - sclerosis??
MM6	MMEWS2	White Sucker	F	10	45.0	48.8	1510	89.9	84.0	84.0	24.3	P,S	19733	
MM6	MMEWS3	White Sucker	F	14	53.2	57.5	3000	159.4	148.0	68.0	55.4	P,S	33944	Lower lobe of liver is partly black
MM6	MMEWS4	White Sucker	M	10	41.0	44.4	1225	30.4	---	---	16.1	P,S		Viscera with *Ligula intestinalis* 54.5g, >1 m long
MM6	MMEWS5	White Sucker	IF		28.4	30.5	305	1.4	---	---	3.7	P,S		Still immature
MM6	MMEWS6	White Sucker	F	18	49.9	54.6	2500	151.3	146.0	78.0	41.9	P,S	34838	
MM6	MMEWS7	White Sucker	F	14	48.5	52.8	2250	132.0	123.0	65.0	37.9	P,S	18709	
MM6	MMEWS34	White Sucker	M	14	45.3	49.4	1725	64.3	---	---	20.8	P,S		
MM7	MMENP7	Northern Pike	F	3	46.3	49.5	660	12.9	13.0	13.0	11.3	C	5627	
MM7	MMENP8	Northern Pike	IM		33.0	35.2	220	1.2	---	---	1.8	C		Black Spot
MM7	MMENP14	Northern Pike	M	7	58.3	62.0	1675	21.6	---	---	12.4	C		
MM7	MMENP15	Northern Pike	M	7	65.4	69.2	2050	13.6	---	---	11.5	C		
MM7	MMENP16	Northern Pike	M	5	59.2	63.7	1800	17.8	---	---	12.8	C		
MM7	MMENP17	Northern Pike	F	3	50.9	54.6	1075	31.4	29.0	29.0	14.0	C	10192	
MM7	MMENP18	Northern Pike	F	5	58.4	62.3	1625	43.4	40.0	40.0	16.1	C	15114	
MM7	MMENP19	Northern Pike	F	2	42.8	45.5	555	12.0	12.0	12.0	7.0	C	5553	
MM7	MMENP33	Northern Pike	F	1	40.2	43.0	390	8.1	8.0	8.0	5.2	C	3730	
MM7	MMENP34	Northern Pike	F	2	43.7	46.6	520	7.6	7.0	7.0	6.6	C	2903	
MM7	MMEWS8	White Sucker	M	8	42.8	45.4	1325	54.8	---	---	17.2	P,S		
MM7	MMEWS9	White Sucker	M	9	42.7	46.8	1225	44.8	---	---	16.6	P,S		
MM7	MMEWS10	White Sucker	M	10	43.2	46.9	1325	57.2	---	---	21.5	P,S		
MM7	MMEWS11	White Sucker	M	9	46.4	50.1	1650	68.1	---	---	21.4	P,S		
MM7	MMEWS12	White Sucker	F	9	43.2	46.5	1350	74.8	70.0	70.0	22.8	P,S	18427	Black lower liver lobe
MM7	MMEWS13	White Sucker	F	9	48.8	53.4	2025	131.0	122.0	60.0	36.7	P,S	23912	
MM7	MMEWS14	White Sucker	F	11	46.2	49.8	1750	100.5	93.0	46.0	29.3	P,S	17361	
MM7	MMEWS15	White Sucker	M	8	44.7	48.4	1575	58.7	---	---	19.8	P,S		
MM7	MMEWS19	White Sucker	F	11	50.8	55.0	2025	136.4	126.0	66.0	29.0	P,S	26733	
MM7	MMEWS20	White Sucker	F	10	43.0	46.8	1475	56.8	44.0	44.0	21.3	P,S	3087	
MM7	MMEWS21	White Sucker	F	12	54.5	58.3	1700	103.5	81.0	42.0	19.5	P,S	20341	
MM7	MMEWS22	White Sucker	F	14	46.9	51.5	1850	72.2	68.0	68.0	26.8	P,S	15092	Black liver lobe
MM7	MMEWS23	White Sucker	F	10	40.9	44.5	1200	53.4	50.0	50.0	18.0	P,S		
MM7	MMEWS24	White Sucker	F	15	45.4	49.2	1600	86.8	81.0	36.0	21.1	P,S	23400	
MM7	MMEWS25	White Sucker	M	11	42.1	45.4	1325	57.3	---	---	15.4	P,S		
MM7	MMEWS26	White Sucker	M	8	43.0	46.6	1500	72.2	---	---	20.9	P,S		
MM8	MMENP20	Northern Pike	F	ND	61.7	65.4	2025	57.6	44.0	44.0	21.8	C	14514	
MM8	MMENP21	Northern Pike	F	5	55.6	59.3	1475	31.3	31.0	31.0	14.7	C	19283	Common shiner in gut
MM8	MMENP22	Northern Pike	F	5	60.0	63.6	2325	53.3	51.0	51.0	34.3	C	20874	
MM8	MMENP23	Northern Pike	M	6	55.0	58.5	1625	25.9	---	---	16.8	C		
MM8	MMENP24	Northern Pike	M	2	44.9	48.0	610	6.2	---	---	6.1	C		
MM8	MMENP26	Northern Pike	M	4	53.7	57.3	1375	17.6	---	---	14.4	C		
MM8	MMENP27	Northern Pike	F	5	63.0	67.7	2450	79.3	73.0	73.0	29.4	C	21070	
MM8	MMENP28	Northern Pike	F	6	71.3	75.5	3250	53.6	51.0	51.0	26.9	C	25024	
MM8	MMENP35	Northern Pike	F	4	57.7	61.1	1875	50.2	47.0	47.0	27.1	C	11340	
MM8	MMENP36	Northern Pike	F	5	62.3	66.2	1800	54.5	52.0	52.0	22.7	---	18200	
MM8	MMEWS27	White Sucker	M	8	40.0	44.1	1225	47.5	---	---	13.9	P,S		
MM8	MMEWS28	White Sucker	M	9	46.5	51.3	1700	51.5	---	---	18.9	P,S		
MM8	MMEWS29	White Sucker	M	9	41.4	45.0	1375	61.0	---	---	16.9	P,S		
MM8	MMEWS30	White Sucker	F	13	46.4	50.6	1650	60.1	54.0	54.0	25.4	P,S	20098	
MM8	MMEWS31	White Sucker	F	11	43.3	47.1	1450	73.0	70.0	39.0	26.8	P,S	20322	
MM8	MMEWS32	White Sucker	F	14	45.0	49.9	1575	41.6	39.0	39.0	26.9	P,S	9288	
MM8	MMEWS33	White Sucker	F	13	49.0	52.3	1925	104.7	98.0	49.0	30.9	P,S	25788	
MM8	MMEWS35	White Sucker	M	14	45.5	49.3	1600	51.2	---	---	21.6	P,S		
MM8	MMEWS36	White Sucker	M	10	44.4	47.2	1525	55.1	---	---	24.7	P,S		
MM8	MMEWS37	White Sucker	M	11	45.3	48.8	1700	65.3	---	---	21.0	P,S		
MM8	MMEWS38	White Sucker	M	11	46.6	50.5	1525	48.1	---	---	23.8	P,S		Darkened end of liver lobe
MM8	MMEWS39	White Sucker	M	8	40.7	44.0	1225	57.5	---	---	15.8	P,S		
MM8	MMEWS40	White Sucker	M	9	41.6	45.1	1375	61.5	---	---	20.3	P,S		
MM8	MMEWS41	White Sucker	M	10	42.8	44.6	1275	55.9	---	---	20.2	P,S		
MM8	MMEWS42	White Sucker	M	8	39.1	42.3	895	33.8	---	---	15.5	P,S		

Table A6.5: Raw Biological Data on Fish Sampled at Mattabi Mine Site

Station	Fish Number	Species	Sex	Age	Fork Length (cm)	Total Length (cm)	Whole Weight (g)	Gonad Weight (g)	Gonad Volume (ml)	Egg Volume (ml)	Liver Weight (g)	Age Structure	Fecundity (Fish)	Comments
MM9	MMENP9	Northern Pike	F	3	54.2	57.6	1275	24.5	24.0	24.0	13.2	C	9345	
MM9	MMENP10	Northern Pike	M	7	62.3	66.9	2100	24.3	---	---	25.3	C		
MM9	MMENP11	Northern Pike	M	9	67.0	71.4	2700	27.8	---	---	22.5	C		
MM9	MMENP12	Northern Pike	F	6	70.0	74.6	3000	66.0	61.0	61.0	36.6	C	16440	
MM9	MMENP13	Northern Pike	M	3	51.3	54.9	1175	15.1	---	---	13.0	C		
MM9	MMEWS 16	White Sucker	F	13	45.2	49.0	1525	92.1	85.0	34.0	23.9	P,S	20680	
MM9	MMEWS17	White Sucker	F	13	44.3	48.7	1475	87.9	82.0	42.0	22.7	P,S	16630	
MM9	MMEWS18	White Sucker	M	13	42.8	46.4	1350	53.2	---	---	12.8	P,S		
MM10	MMRNP3	Northern Pike	M	5	42.2	45.3	510	5.9	---	---	3.6	C		Black liver lobe
MM10	MMRNP4	Northern Pike	F	7	57.2	60.8	1950	41.0	39.0	39.0	17.4	C	10539	
MM10	MMRNP5	Northern Pike	F	5	45.2	48.7	700	13.8	15.0	15.0	8.5	C	5463	
MM10	MMRNP6	Northern Pike	F	6	66.2	70.6	3200	71.8	68.0	68.0	42.4	C	24276	Black Spot
MM10	MMRNP7	Northern Pike	F	7	61.0	64.6	2215	43.3	42.0	42.0	24.9	C	11721	
MM10	MMRNP8	Northern Pike	M	6	41.5	44.7	520	4.9	---	---	4.0	C		
MM10	MMRNP9	Northern Pike	M	2	42.0	44.8	560	4.9	---	---	4.4	C		
MM10	MMRNP10	Northern Pike	F	6	47.4	50.3	770	23.9	23.0	23.0	15.5	C	5022	
MM10	MMRNP11	Northern Pike	M	2	35.1	37.6	360	2.4	---	---	3.4	C		
MM10	MMRNP28	Northern Pike	M	6	44.4	47.6	575	30.0	---	---	2.8	C		
MM10	MMRNP30	Northern Pike	F	3	44.3	47.3	580	7.0	8.0	8.0	4.5	C	3355	
MM10	MMRNP32	Northern Pike	M	6	48.9	52.8	910	9.1	---	---	8.1	C		
MM10	MMRNP33	Northern Pike	F	5	52.1	55.7	1100	16.8	16.0	16.0	8.9	C	6070	
MM10	MMRNP39	Northern Pike	F	4	56.4	59.6	1025	12.1	12.0	12.0	6.4	C	6143	
MM10	MMRNP40	Northern Pike	M	4	45.9	49.4	720	6.7	---	---	7.2	C		
MM10	MMRNP41	Northern Pike	F	7	56.4	60.5	980	6.0	6.0	6.0	7.2	C	0	Fish was emaciated
MM10	MMRNP42	Northern Pike	M	4	43.0	46.3	645	6.6	---	---	5.8	C		
MM10	MMRNP43	Northern Pike	F	4	57.2	60.6	1350	31.6	30.0	30.0	16.1	C	11831	
MM10	MMRWS6	White Sucker	F	9	46.7	51.1	1900	117.2	109.0	55.0	27.8	P,S	17561	Black liver lobe
MM10	MMRWS7	White Sucker	M	8	43.0	46.5	1500	59.0	---	---	13.1	P,S		
MM10	MMRWS8	White Sucker	F	10	47.1	51.7	2525	150.6	139.0	67.0	35.6	P,S	22124	
MM10	MMRWS9	White Sucker	F	9	48.0	52.5	1875	109.7	102.0	47.0	33.6	P,S	23786	
MM10	MMRWS24	White Sucker	M	16	46.2	49.8	1450	71.1	---	---	21.4	P,S		
MM10	MMRWS25	White Sucker	F	4	40.0	48.3	980	9.8	10.0	10.0	12.8	P,S	7373	Imamatrue ovaries (relatively)
MM10	MMRWS26	White Sucker	F	11	46.8	50.4	1570	94.2	88.0	46.0	27.5	P,S	17089	
MM10	MMRWS27	White Sucker	F	10	47.8	52.3	1725	138.1	127.0	62.0	35.4	P,S	20052	
MM11	MMRNP1	Northern Pike	M	6	43.1	46.3	695	5.3	---	---	8.3	C		
MM11	MMRNP2	Northern Pike	F	6	65.2	69.9	2650	29.0	29.0	29.0	21.4	C	12430	
MM11	MMRNP12	Northern Pike	F	5	59.6	63.7	1550	26.6	26.0	26.0	21.8	C	10934	
MM11	MMRNP13	Northern Pike	F	5	47.8	51.2	925	17.5	17.0	17.0	14.2	C	6534	
MM11	MMRNP14	Northern Pike	F	7	51.4	55.1	945	13.8	14.0	14.0	10.9	C	4877	
MM11	MMRNP34	Northern Pike	F	6	62.3	66.2	1600	26.1	25.0	25.0	15.3	C	10076	
MM11	MMRNP35	Northern Pike	M	2	40.0	42.9	510	5.1	---	---	4.1	C		
MM11	MMRNP36	Northern Pike	F	6	49.7	53.2	785	11.3	11.0	11.0	7.0	C	6213	
MM11	MMRNP37	Northern Pike	M	2	35.2	37.9	310	2.4	---	---	2.6	C		
MM11	MMRNP44	Northern Pike	F	4	63.0	67.0	1610	34.1	33.0	33.0	23.8	C	13857	
MM11	MMRNP45	Northern Pike	M	2	32.2	34.7	230	1.3	---	---	2.4	C		
MM11	MMRWS1	White Sucker	M	18	45.3	50.2	1750	81.2	---	---	21.2	P,S		
MM11	MMRWS2	White Sucker	F	7	46.4	50.6	1850	95.6	90.0	40.0	26.5	P,S	23722	
MM11	MMRWS3	White Sucker	F	15	46.0	49.8	2025.0	147.7	147	75	35.4	P,S	21634	
MM11	MMRWS4	White Sucker	F	7	47.2	51.9	1850	131.3	124.0	61.0	26.3	P,S	27166	Black liver lobe
MM11	MMRWS5	White Sucker	F	12	46.2	50.0	1725	103.5	98.0	52.0	26.4	P,S	16276	
MM11	MMRWS28	White Sucker	M	18	45.5	49.3	1500	76.4	---	---	24.6	P,S		Black liver lobe
MM11	MMRWS29	White Sucker	M	11	42.4	46.0	1225	48.2	---	---	16.1	P,S		
MM12	MMRNP17	Northern Pike	M	5	43.3	46.5	640	8.2	---	---	4.0	C		Sand Shiner in gut
MM12	MMRNP18	Northern Pike	F	3	50.8	54.4	1225	18.6	18.0	18.0	8.2	C	7924	
MM12	MMRNP19	Northern Pike	F	2	38.5	41.9	420	8.6	9	9	4.2	C	3691	
MM12	MMRNP20	Northern Pike	F	4	58.9	63.1	1690	3.4	4.0	4.0	12.5	C	0	Immature gonads - no eggs
MM12	MMRNP23	Northern Pike	M	8	51.8	55.2	1300	12.0	---	---	11.8	C		
MM12	MMRNP24	Northern Pike	F	7	57.4	60.9	1600	33.3	32.0	32.0	25.2	C	11700	
MM12	MMRWS10	White Sucker	M	20	44.8	49.4	1710	74.7	---	---	18.9	P,S		
MM12	MMRWS11	White Sucker	M	10	43.4	47.7	1425	50.1	---	---	12.7	P,S		
MM12	MMRWS12	White Sucker	M	8	45.9	49.2	1750	93.6	---	---	17.0	P,S		
MM12	MMRWS13	White Sucker	M	13	42.6	46.9	1450	56.9	---	---	14.4	P,S		Black liver lobe
MM12	MMRWS14	White Sucker	F	11	44.8	49.0	1575	83.5	77.0	55.0	24.0	P,S	12604	
MM12	MMRWS35	White Sucker	F	10	45.9	50.6	1750	96.5	90.0	90.0	25.9	P,S	17313	
MM12	MMRWS36	White Sucker	F	11	45.5	50.0	1900	107.7	101.0	101.0	26.3	P,S	20049	Black lobe - liver
MM12	MMRWS37	White Sucker	M	8	43.2	47.1	1425	68.0	---	---	15.2	P,S		
MM12	MMRWS38	White Sucker	F	11	43.4	47.4	1500	88.4	82.0	82.0	27.7	P,S	15909	
MM12	MMRWS39	White Sucker	F	10	45.4	49.7	1550	84.0	79.0	79.0	25.5	P,S	18667	
MM12	MMRWS40	White Sucker	M	7	39.6	43.1	1000	37.4	---	---	10.3	P,S		
MM12	MMRWS41	White Sucker	M	10	42.9	46.0	1300	53.7	---	---	16.1	P,S		Black Liver
MM12	MMRWS42	White Sucker	M	11	42.2	45.7	1360	61.6	---	---	14.2	P,S		

Table A6.5: Raw Biological Data on Fish Sampled at Mattabi Mine Site

Station	Fish Number	Species	Sex	Age	Fork Length (cm)	Total Length (cm)	Whole Weight (g)	Gonad Weight (g)	Gonad Volume (ml)	Egg Volume (ml)	Liver Weight (g)	Age Structure	Fecundity (Fish)	Comments
MM13	MMRNP15	Northern Pike	F	6	57.0	60.8	1415	25.5	26.0	26.0	14.4	C	11117	
MM13	MMRNP16	Northern Pike	F	5	63.2	67.1	2475	44.4	44.0	44.0	20.6	C	17099	
MM13	MMRNP21	Northern Pike	F	5	36.1	39.0	395	7.3	8.0	8.0	4.5	C	3084	
MM13	MMRNP22	Northern Pike	M	5	45.9	48.0	610	5.4	---	---	5.7	C		
MM13	MMRNP25	Northern Pike	M	4	53.8	57.5	1325	13.8	---	---	15.0	C		
MM13	MMRNP26	Northern Pike	F	8	52.8	56.0	1275	25.6	26.0	26.0	26.2	C	7520	
MM13	MMRNP27	Northern Pike	M	4	44.5	47.4	625	7.0	---	---	4.2	C		
MM13	MMRNP29	Northern Pike	F	7	57.1	60.6	1700	31.5	30.0	30.0	19.6	C	10483	
MM13	MMRNP31	Northern Pike	F	7	62.6	66.9	1550	19.5	19.0	19.0	10.2	C	8964	
MM13	MMRNP38	Northern Pike	M	3	43.3	46.4	620	5.1	---	---	4.5	C		
MM13	MMRNP44	Northern Pike	M	4	51.4	54.6	1110	11.7	---	---	12.7	C		
MM13	MMRNP45	Northern Pike	M	5	46.0	49.1	635	6.3	---	---	6.1	C		
MM13	MMRNP46	Northern Pike	F	3	43.3	46.5	530	7.9	9.0	9.0	6	C	3029	
MM13	MMRNP47	Northern Pike	M	5	52.5	56.3	1150	7.3	---	---	11.0	C		
MM13	MMRNP48	Northern Pike	F	1	35.6	38.2	330	1.4	2.0	2.0	5.1	C	0	Imature Gonads
MM13	MMRWS15	White Sucker	M	18	45.1	49.5	1710	57.4	---	---	15.0	P,S		
MM13	MMRWS16	White Sucker	M	14	42.0	46.1	1175	61.9	---	---	12.1	P,S		
MM13	MMRWS17	White Sucker	M	18	46.5	50.4	1500	74.6	---	---	20.3	P,S		
MM13	MMRWS18	White Sucker	M	18	48.7	52.7	1615	90.1	---	---	21.9	P,S		
MM13	MMRWS19	White Sucker	F	10	44.3	48.9	1360	58.3	55.0	55.0	24.6	P,S	13557	
MM13	MMRWS20	White Sucker	F	15	48.9	53.5	1925	131.9	124.0	54.0	35.3	P,S	28825	
MM13	MMRWS21	White Sucker	F	14	47.0	52.2	1600	117.2	110.0	60.0	28.9	P,S	23553	
MM13	MMRWS22	White Sucker	F	14	46.7	50.8	1525	126.5	118.0	68.0	30.0	P,S	27815	
MM13	MMRWS23	White Sucker	F	11	45.8	50.0	1400	108.7	102.0	55.0	27.4	P,S	15890	
MM13	MMRWS30	White Sucker	M	19	43.4	47.2	1400	61.0	---	---	16.9	P,S		
MM13	MMRWS31	White Sucker	M	12	44.8	48.4	1475	72.0	---	---	18.6	P,S		
MM13	MMRWS32	White Sucker	M	17	44.9	49.0	1600	74.7	---	---	23.1	P, S		
MM13	MMRWS33	White Sucker	M	18	46.6	50.8	1750	58.5	---	---	19.3	P,S		
MM13	MMRWS34	White Sucker	F	11	43.7	47.9	1740	100.4	95.0	95.0	31.9	P,S	26232	

APPENDIX 7

Figures and Tables Illustrating Hypothesis Testing Results

Mattabi Mines: Hypothesis 1

Sediment Toxicity: significance of endpoints as tools

Chironomus Mortality

Source	SS	df	MS	F Ratio	P
Among Area	0.652	6	0.109	2.050	0.126
Among Reference	0.092	1	0.092	1.100	0.371
Reference vs Exposure	0.270	1	0.270	3.229	0.170
Linear Trend	0.039	1	0.039	0.468	0.543
Lack of Fit	0.251	3	0.084	1.578	0.239
Error (Within Area)	0.742	14	0.053		

Hyalella Mortality

Source	SS	df	MS	F Ratio	P
Among Area	0.951	6	0.159	0.905	0.519
Among Reference	0.330	1	0.330	4.457	0.125
Reference vs Exposure	0.317	1	0.317	4.282	0.130
Linear Trend	0.082	1	0.082	1.106	0.370
Lack of Fit	0.222	3	0.074	0.423	0.740
Error (Within Area)	2.453	14	0.175		

Tubifex Mortality was not examined due to very low level of mortality

Chironomus Growth

Source	SS	df	MS	F Ratio	P
Among Area	0.630	6	0.105	6.309	**0.002**
Among Reference	0.093	1	0.093	0.592	0.522
Reference vs Exposure	0.051	1	0.051	0.324	0.627
2° Trend	0.174	2	0.087	0.555	0.643
Lack of Fit	0.313	2	0.156	9.403	**0.003**
Error (Within Area)	0.233	14	0.017		

Hyalella Growth

Source	SS	df	MS	F Ratio	P
Among Area	0.537	6	0.090	2.457	0.078
Among Reference	0.031	1	0.031	0.398	0.573
Reference vs Exposure	0.053	1	0.053	0.687	0.468
Linear Trend	0.222	1	0.222	2.879	0.188
Lack of Fit	0.231	3	0.077	2.117	0.144
Error (Within Area)	0.510	14	0.036		

Tubifex Cocoons/Adult

Source	SS	df	MS	F Ratio	P
Among Area	0.140	6	0.023	4.127	**0.014**
Among Reference	0.020	1	0.020	0.609	0.517
Reference vs Exposure	0.004	1	0.004	0.127	0.756
2° Trend	0.051	2	0.025	0.772	0.564
Lack of Fit	0.065	2	0.033	5.787	**0.015**
Error (Within Area)	0.079	14	0.006		

Tubifex #Young/Adult

Source	SS	df	MS	F Ratio	P
Among Area	0.795	6	0.133	8.876	**4.08E-04**
Among Reference	0.098	1	0.098	4.050	0.182
Reference vs Exposure	0.093	1	0.093	3.826	0.190
2° Trend	0.556	2	0.278	11.488	0.080
Lack of Fit	0.048	2	0.024	1.621	0.233
Error (Within Area)	0.209	14	0.015		

Mattabi Mines - Hypothesis 2

Summary of Analysis of Metals in White Sucker Tissue

All Fish Included							Separated by Sex	
			Covariates		Interactions			
Metal	Tissue	Reference vs Exposure	Age	Sex	Exposure*Age	Exposure*Sex	Female	Male
CdCuZn	Muscle	E	-	-	-	-		
	Gill	*1	-	-	-	-		
	Liver	E	-	-	-	-		
	Kidney	E	-	-	-	-		
Cadmium	Muscle	E	-	-	-	-		
	Gill	E	-	-	-	-		
	Liver	*2	-	-	-	-		
	Kidney	*2	-	-	-	-		
Chromium	Muscle	E	-	-	-	-		
	Gill	E	-	-	-	-		
	Liver	E	-	-	-	-		
	Kidney	E	-	-	-	-		
Cobalt	Muscle	<D.L.						
	Gill	1	-	-	-	-		
	Liver	E	-	-	-	-		
	Kidney	2	-	-	-	-		
Copper	Muscle	(2)						
	Gill	(2)						
	Liver	(2)						
	Kidney	(2)						
Mercury	Muscle	(2)						
	Gill	(2)						
	Liver	(2)						
	Kidney	(2)						
Nickel	Muscle	E	-	-	-	-		
	Gill	1	-	-	-	-		
	Liver	E	-	-	-	-		
	Kidney		*	-	-	*	2	2
Lead	Muscle	**< D.L.**						
	Gill	*1	-	*	-	-		
	Liver		-	-	-	*	*1	2
	Kidney	1	-	*	-	-		
Selenium	Muscle		-	*	-	*	*1	*1
	Gill		-	*	-	*	1	*1
	Liver		*	*	*	*	*1	[1]
	Kidney		-	-	-	*	*1	*1
Zinc	Muscle	E	-	-	-	-		
	Gill	*1	-	-	-	-		
	Liver		-	-	*	-	E	2
	Kidney	1	-	-	-	-		

- not significant at $\alpha = 0.05$
* significant at $\alpha = 0.05$
E - Equal in exposure and reference areas, not statistically different
1 - higher in Exposure, not statistically significant
2 - higher in reference, not statistically significant
*1 - higher in Exposure, statistically significant
*2 - higher in reference, statistically significant
(2) - all tissues had higher metal levels in the reference, therefore not mine related and not tested
- for other metals, at least one tissue had elevated levels in exposure, therefore all tissues tested
[1] Results indicated significant Exposure*Age interaction for males, therefore not tested
<D.L. = Less than analytical detection limit
Note: In comparisons with significant interaction term(s), results divided by sex

Mattabi Mines - Hypothesis 2

Summary of Analysis of Metals in Northern Pike Tissue

		All Fish Included					Separated by Sex	
			Covariates		Interactions			
Metal	Tissue	Reference vs Exposure	Age	Sex	Exposure*Age	Exposure*Sex	Female	Male
CdCuZn	Muscle	*1	-	*	-	-		
	Gill		-	*	-	*	*2	*2
	Liver	2	*	-	-	-		
	Kidney	2	*	-	-	-		
Cadmium	Muscle	*1	-	-	-	-		
	Gill	E	-	-	-	-		
	Liver	E	-	*	-	-		
	Kidney	2	-	-	-	-		
Cobalt	Muscle	**All <D.L.**						
	Gill	*1	-	-	-	-		
	Liver	1	-	*	-	-		
	Kidney	*1	-	-	-	-		
Chromium	Muscle		-	*	*	-	*1	1
	Gill		-	-	*	-	2	2
	Liver	2	-	-	-	-		
	Kidney		-	*	-	*	1	*1
Copper	Muscle	E	-	-	-	-		
	Gill	1	-	-	-	-		
	Liver	2	*	-	-	-		
	Kidney	2	-	-	-	-		
Iron	Muscle	E	*	*	-	-		
	Gill	*1	-	*	-	-		
	Liver		*	*	*	-	2	1
	Kidney	E	-	*	-	-		
Mercury	Muscle	(2)						
	Gill	(2)						
	Liver	(2)						
	Kidney	(2)						
Nickel	Muscle	E						
	Gill		-	*	*	-	1	2
	Liver		-	*	*	-	1	2
	Kidney	1	-	-	-	-		
Lead	Muscle	**All <D.L.**						
	Gill	*1	-	-	-	-		
	Liver	E	-	-	-	-		
	Kidney	*1	-	-	-	-		
Selenium	Muscle	*1	-	-	-	-		
	Gill	*1	*	-	-	-		
	Liver	*1	-	-	-	-		
	Kidney		-	*	*	-	*1	[1]
Zinc	Muscle	*1	-	*	-	-		
	Gill		-	*	-	*	2	*2
	Liver	E	-	-	-	-		
	Kidney	E	-	-	-	-		

- not significant at $\alpha = 0.05$

* significant at $\alpha = 0.05$

E - Equal in exposure and reference areas, not statistically different

1 - higher in Exposure, not statistically significant

2 - higher in reference, not statistically significant

*1 - higher in Exposure, statistically significant

*2 - higher in reference, statistically significant

(2) - all tissues had higher metal levels in the reference, therefore not mine related and not tested

- for other metals, at least one tissue had elevated levels in exposure, therefore all tissues tested

[1] Results indicated significant Exposure*Age interaction for males, therefore not tested

<D.L. = Less than analytical detection limit

Note: In comparisons with significant interaction term(s), results divided by sex

Mattabi Mines - Hypothesis 2

Comparison of organ tissues for concentrations of metals

White sucker - Female

Tool: selenium in Kidney and Liver

Source	SS	df	MS	F Ratio	P
Among Reach	381.925	1	381.925	382.211	**1.06E-10**
Among Tools	5.253	1	5.253	5.257	**0.030**
Reach*Tool	0.197	1	0.197	0.197	0.660
Within Reach (Error)	26.980	27	0.999		

Tool: selenium in Kidney and Muscle

Source	SS	df	MS	F Ratio	P
Among Reach	246.698	1	246.698	246.682	**1.06E-10**
Among Tools	253.420	1	253.420	253.403	**1.06E-10**
Reach*Tool	11.507	1	11.507	11.506	**0.002**
Within Reach (Error)	27.002	27	1.000		

Tool: selenium in Muscle and Liver

Source	SS	df	MS	F Ratio	P
Among Reach	270.161	1	270.161	270.396	**6.66E-16**
Among Tools	192.336	1	192.336	192.503	**4.51E-14**
Reach*Tool	15.243	1	15.243	15.256	**5.41E-04**
Within Reach (Error)	27.976	28	0.999		

White sucker - Male

Tool: selenium in Kidney and Gill

Source	SS	df	MS	F Ratio	P
Among Reach	292.785	1	292.785	292.757	**1.22E-15**
Among Tools	27.526	1	27.526	27.524	**1.76E-05**
Reach*Tool	0.023	1	0.023	0.023	0.880
Within Reach (Error)	26.002	26	1.000		

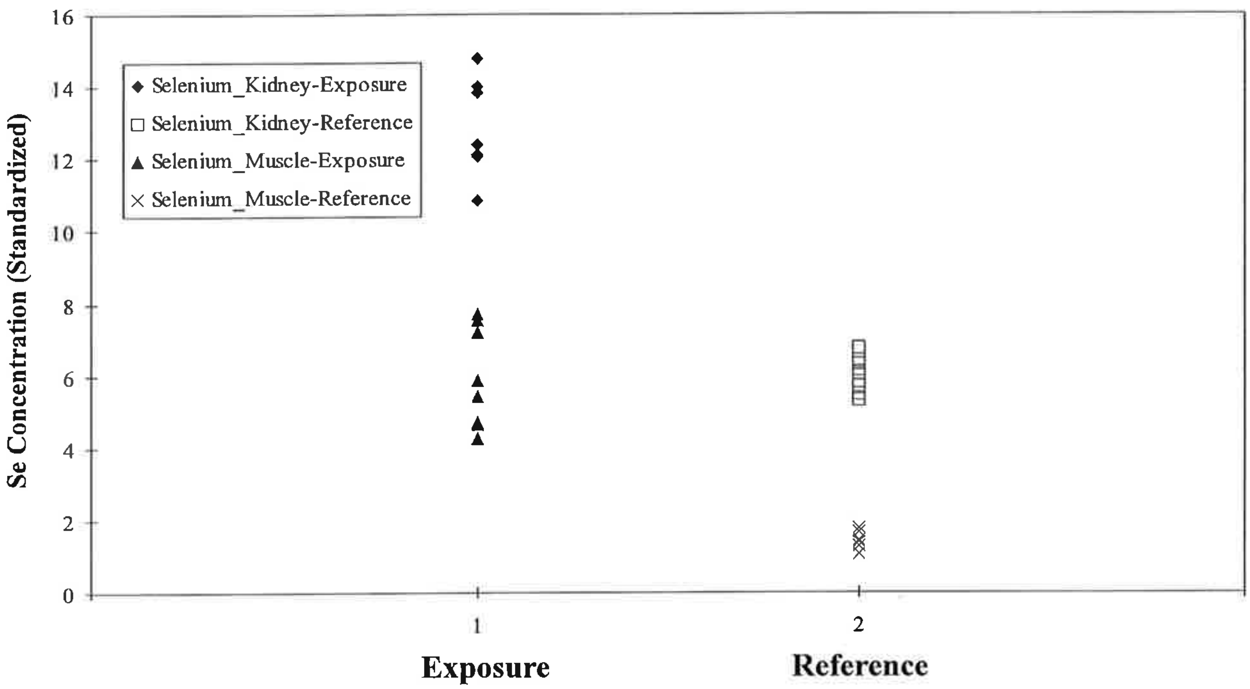
Tool: selenium in Kidney and Muscle

Source	SS	df	MS	F Ratio	P
Among Reach	409.125	1	409.125	409.135	**1.97E-17**
Among Tools	6.821	1	6.821	6.821	**0.015**
Reach*Tool	8.781	1	8.781	8.781	**0.006**
Within Reach (Error)	25.999	26	1.000		

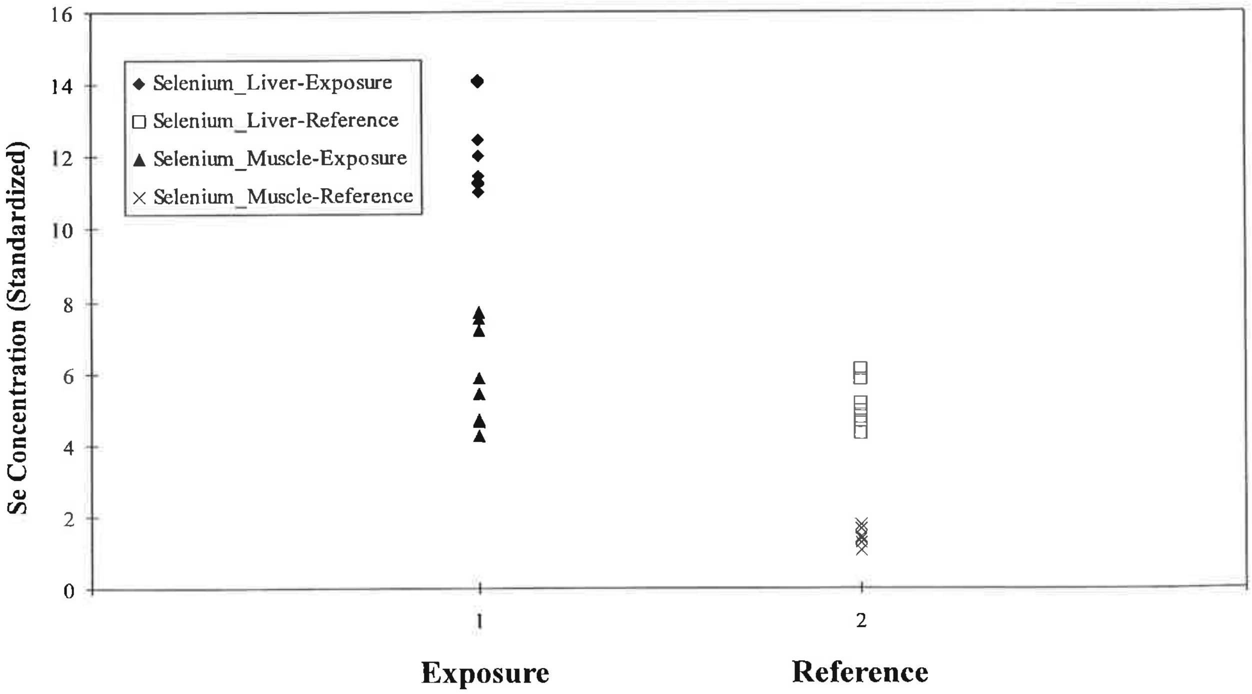
Tool: selenium in Muscle and Gill

Source	SS	df	MS	F Ratio	P
Among Reach	402.976	1	402.976	402.995	**2.37E-17**
Among Tools	6.943	1	6.943	6.943	**0.014**
Reach*Tool	9.709	1	9.709	9.709	**0.004**
Within Reach (Error)	25.999	26	1.000		

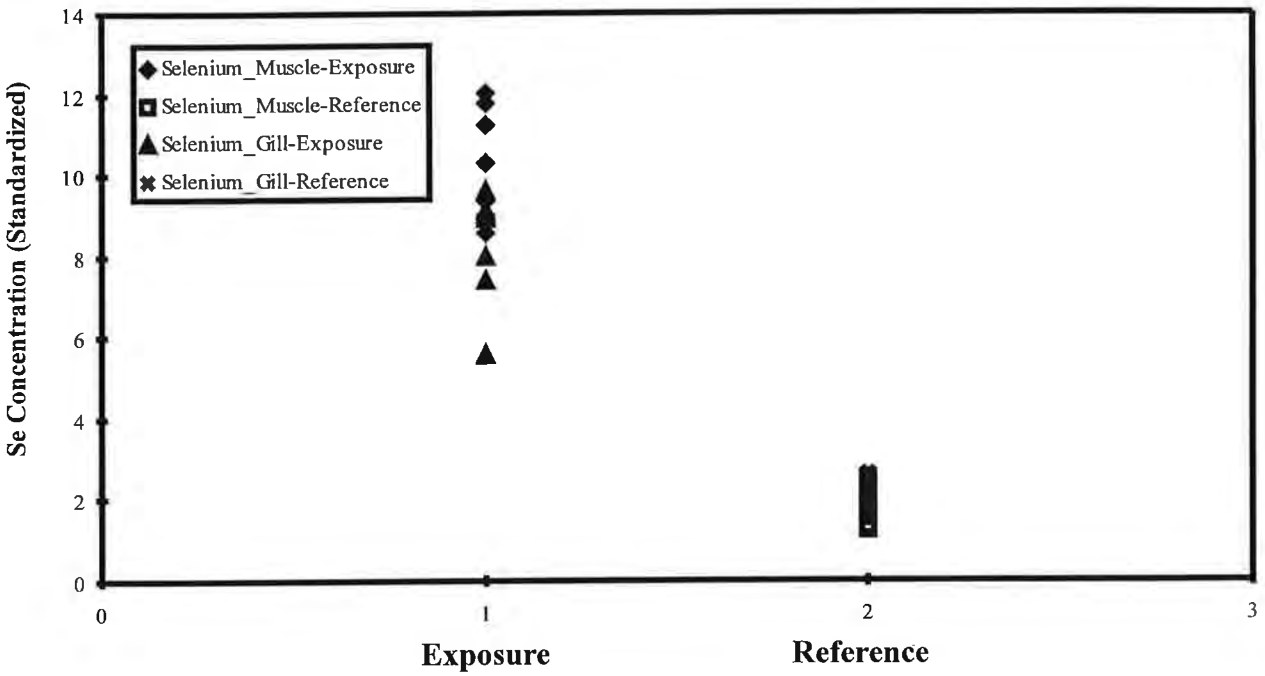
Mattabi Mines - Selenium in Female White sucker Kidney and Muscle Tissues



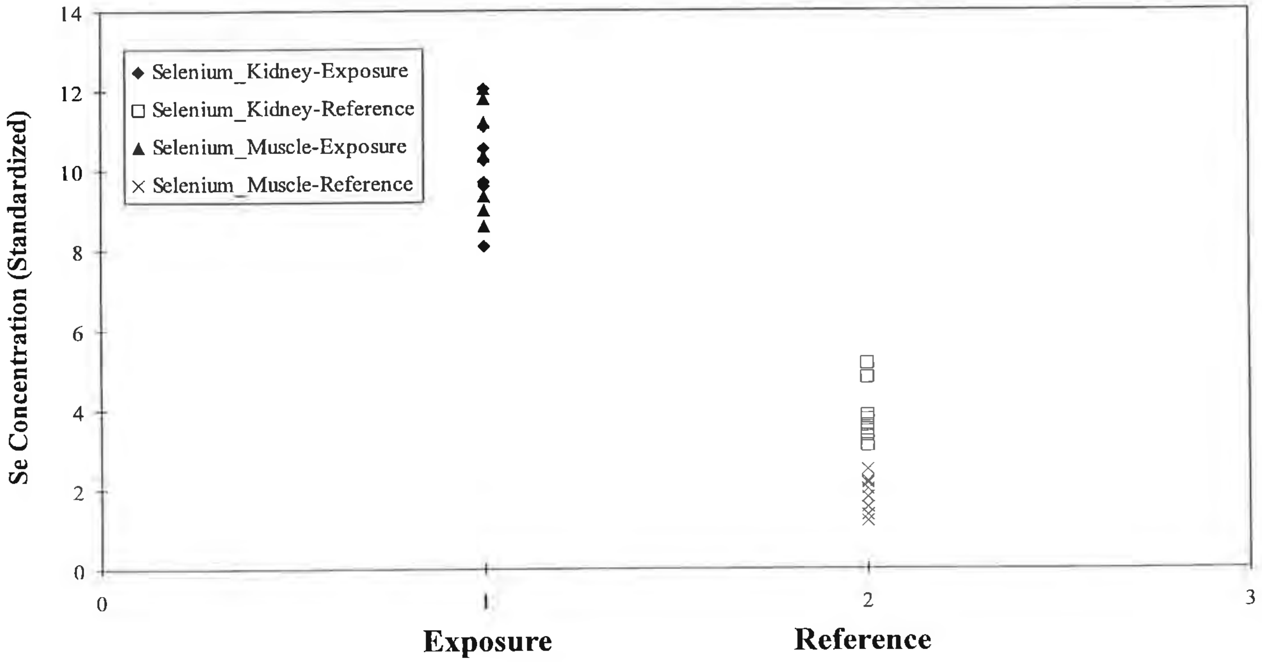
Mattabi Mines - Selenium in Female White sucker Liver and Muscle Tissues



Mattabi Mines - Selenium in Male White sucker Muscle and Gill Tissues



Mattabi Mines - Selenium in Male White sucker Kidney and Muscle Tissues



Mattabi Mines - Hypothesis 2

Comparison of organ tissues for concentrations of metals

Northern Pike - All Fish

Tool: lead in Gill and Kidney

Source	SS	df	MS	F Ratio	P
Among Reach	21.667	1	21.667	21.666	**1.93E-05**
Among Tools	449.945	1	449.945	449.917	**5.19E-29**
Reach*Tool	0.798	1	0.798	0.798	0.375
Within Reach (Error)	58.004	58	1.000		

Tool: cobalt in Gill and Kidney

Source	SS	df	MS	F Ratio	P
Among Reach	27.022	1	27.022	27.019	**2.74E-06**
Among Tools	5.614	1	5.614	5.613	**0.021**
Reach*Tool	0.110	1	0.110	0.110	0.741
Within Reach (Error)	58.007	58	1.000		

Tool: selenium in Muscle and Gill

Source	SS	df	MS	F Ratio	P
Among Reach	239.075	1	239.075	239.066	**3.09E-22**
Among Tools	10.874	1	10.874	10.874	**1.67E-03**
Reach*Tool	39.705	1	39.705	39.704	**4.09E-08**
Within Reach (Error)	58.002	58	1.000		

Tool: selenium in Muscle and Liver

Source	SS	df	MS	F Ratio	P
Among Reach	456.411	1	456.411	456.418	**3.59E-29**
Among Tools	248.223	1	248.223	248.226	**1.28E-22**
Reach*Tool	0.160	1	0.160	0.160	0.691
Within Reach (Error)	57.999	58	1.000		

Tool: selenium in Gill and Liver

Source	SS	df	MS	F Ratio	P
Among Reach	226.882	1	226.882	226.887	**1.05E-21**
Among Tools	155.188	1	155.188	155.192	**4.89E-18**
Reach*Tool	34.830	1	34.830	34.831	**1.96E-07**
Within Reach (Error)	57.999	58	1.000		

Northern Pike - Female

Tool: selenium in Kidney and Muscle

Source	SS	df	MS	F Ratio	P
Among Reach	216.850	1	216.850	216.845	**1.02E-14**
Among Tools	12.353	1	12.353	12.353	**1.52E-03**
Reach*Tool	54.810	1	54.810	54.809	**4.61E-08**
Within Reach (Error)	28.001	28	1.000		

Tool: selenium in Kidney and Gill

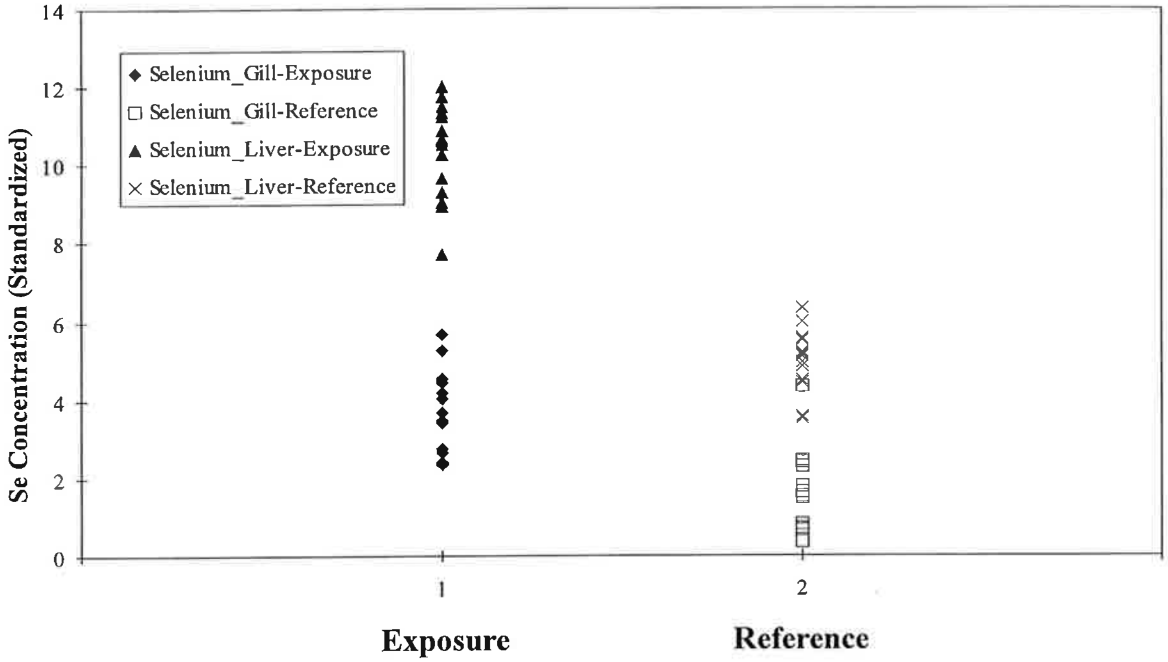
Source	SS	df	MS	F Ratio	P
Among Reach	59.395	1	59.395	59.398	**2.14E-08**
Among Tools	4.348	1	4.348	4.348	**0.046**
Reach*Tool	0.148	1	0.148	0.148	0.704
Within Reach (Error)	27.999	28	1.000		

Tool: selenium in Kidney and Liver

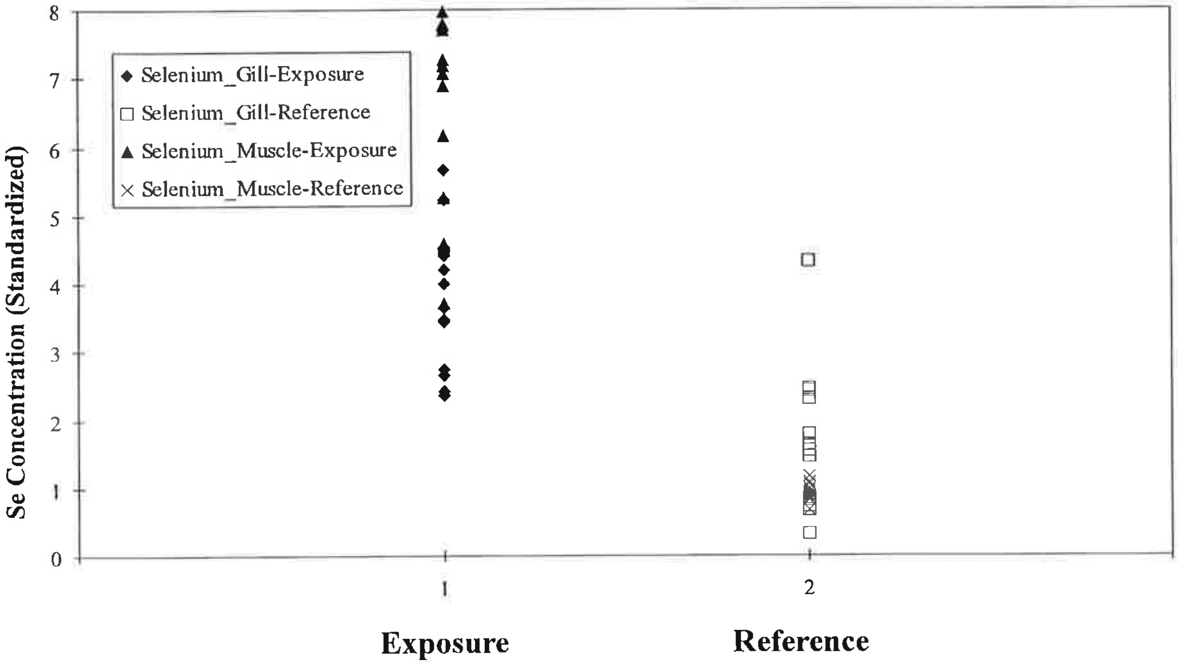
Source	SS	df	MS	F Ratio	P
Among Reach	101.281	1	101.281	101.291	**8.35E-11**
Among Tools	68.966	1	68.966	68.973	**4.90E-09**
Reach*Tool	7.515	1	7.515	7.516	**0.011**
Within Reach (Error)	27.997	28	1.000		

Note: metal concentrationn is significantly greater ($p<0.05$) in both tissues indicated in the exposure area

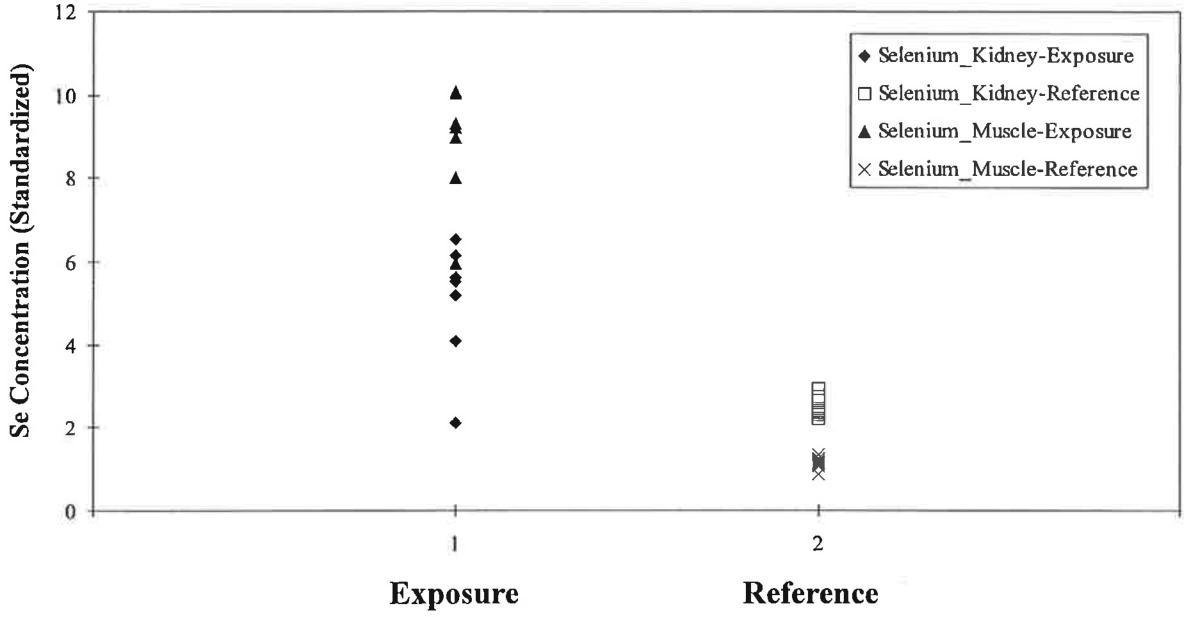
Mattabi Mines - Selenium in Northern Pike Gill and Liver Tissues



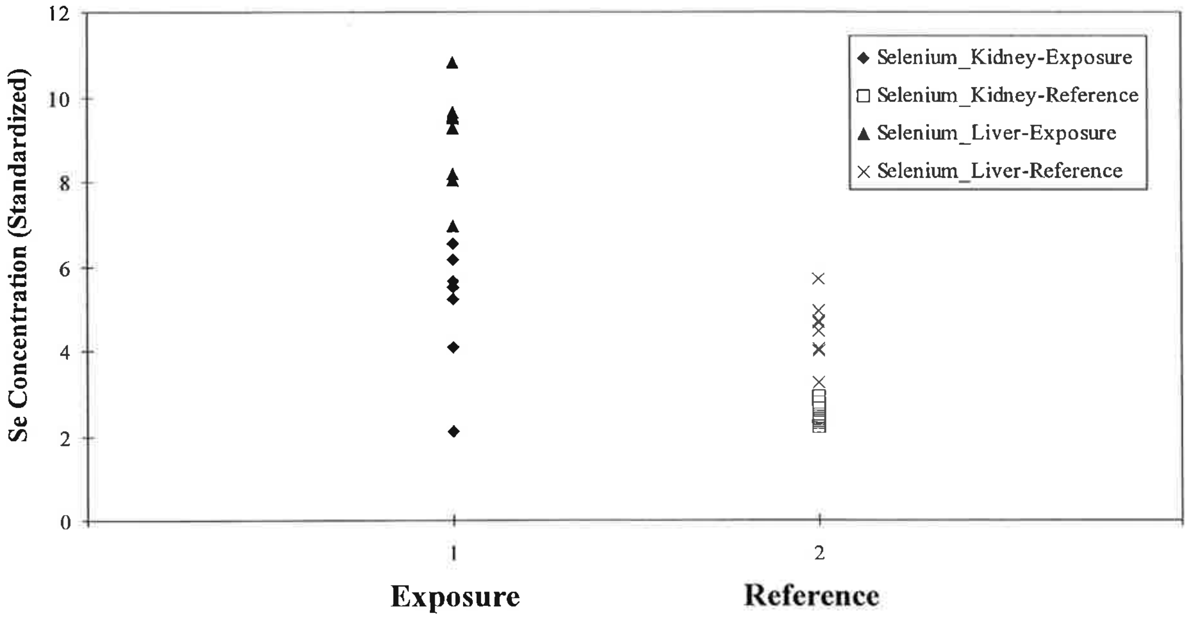
Mattabi Mines - Selenium in Northern Pike Muscle and Gill Tissues



Mattabi Mines - Selenium in Female Northern Pike Kidney and Muscle Tissues



Mattabi Mines - Selenium in Female Northern Pike Kidney and Liver Tissues



Mattabi Mines - Hypothesis 3

Comparison of metallothionein in different organ tissues of Northern pike

Tool: metallotheinein in Gills and Kidneys of Northern pike

Source	SS	df	MS	F Ratio	P
Among Reach	18.879	1	18.879	18.877	**5.68E-05**
Among Tools	2546.937	1	2546.937	2546.692	**1.28E-49**
Reach*Tool	0.313	1	0.313	0.313	0.578
Within Reach (Error)	58.006	58	1.000		

Note: metallothionein is significantly greater ($p<0.05$) in both tissues in the exposure area
Metallothionein was not significantly elevated in White sucker tissues

Mattabi Mines - Hypothesis 4

Comparison of metals and metallothionein in Northern pike tissues

All Fish

Tool: cobalt/metallothionein in Gills

Source	SS	df	MS	F Ratio	P
Among Reach	21.697	1	21.697	21.694	**1.91E-05**
Among Tools	0.696	1	0.696	0.696	0.408
Reach*Tool	0.762	1	0.762	0.761	0.386
Within Reach (Error)	58.008	58	1.000		

Tool: cobalt/metallothionein in Kidneys

Source	SS	df	MS	F Ratio	P
Among Reach	23.867	1	23.867	23.865	**8.51E-06**
Among Tools	2394.347	1	2394.347	2394.169	**7.34E-49**
Reach*Tool	3.77E-04	1	3.77E-04	3.77E-04	0.985
Within Reach (Error)	58.004	58	1.000		

Tool: lead/metallothionein in Gills

Source	SS	df	MS	F Ratio	P
Among Reach	14.238	1	14.238	14.237	**3.81E-04**
Among Tools	22.335	1	22.335	22.334	**1.5E-05**
Reach*Tool	1.45E-04	1	1.45E-04	1.45E-04	0.990
Within Reach (Error)	58.001	58	1.000		

Tool: lead/metallothionein in Kidneys

Source	SS	df	MS	F Ratio	P
Among Reach	27.317	1	27.317	27.313	**2.47E-06**
Among Tools	1154.724	1	1154.724	1154.557	**5.50E-40**
Reach*Tool	0.104	1	0.104	0.104	0.749
Within Reach (Error)	58.008	58	1.000		

Tool: selenium/metallothionein in Gills

Source	SS	df	MS	F Ratio	P
Among Reach	39.790	1	39.790	39.784	**3.99E-08**
Among Tools	0.338	1	0.338	0.338	0.563
Reach*Tool	6.364	1	6.364	6.363	**0.014**
Within Reach (Error)	58.009	58	1.000		

Note: metal and metallothionein exhibited significantly greater (p<0.05) concentrations in exposure fish

Females

Tool: selenium/metallothionein in Kidneys

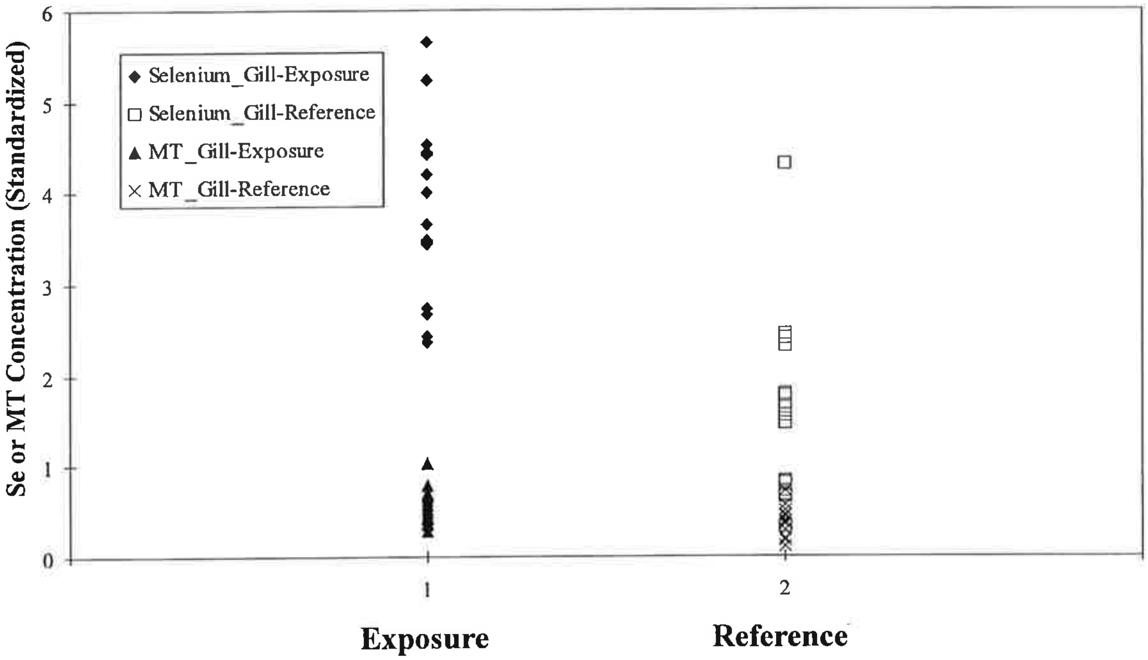
Source	SS	df	MS	F Ratio	P
Among Reach	27.700	1	27.700	36.875	**1.51E-06**
Among Tools	1144.443	1	1144.443	1523.481	**5.86E-26**
Reach*Tool	2.436	1	2.436	3.243	0.083
Within Reach (Error)	21.034	28	0.751		

Males

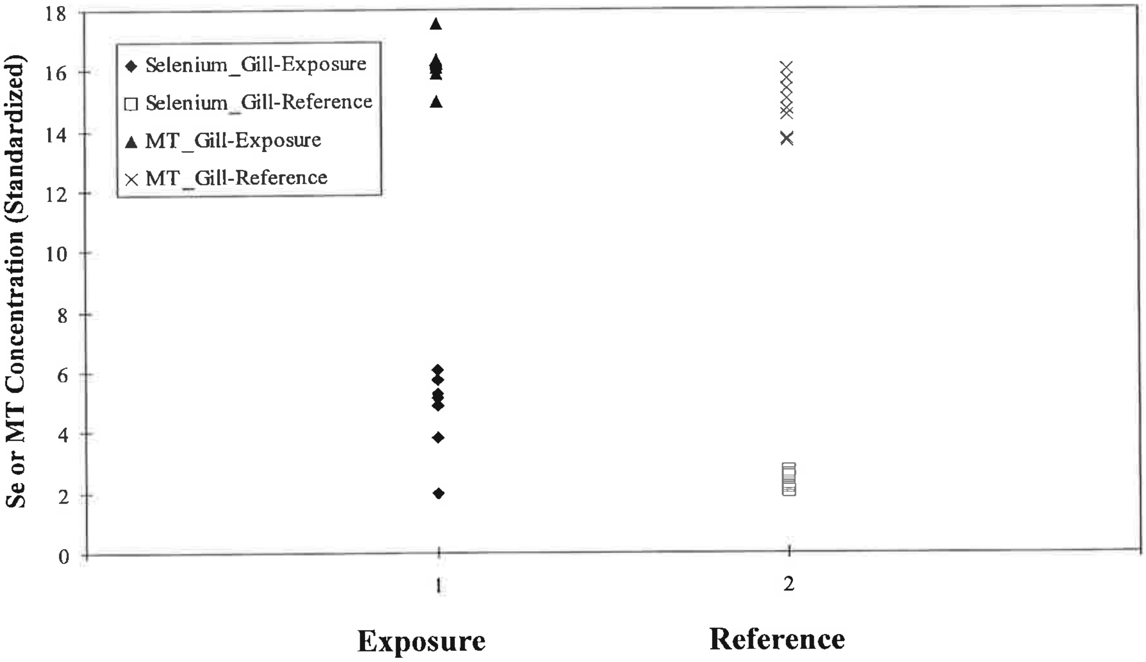
Tool: chromium/metallothionein in Kidneys

Source	SS	df	MS	F Ratio	P
Among Reach	16.662	1	16.662	12.599	**0.001**
Among Tools	1236.903	1	1236.903	935.347	**6.50E-22**
Reach*Tool	0.854	1	0.854	0.645	0.429
Within Reach (Error)	34.382	26	1.322		

Mattabi Mines - Selenium and Metallothionein in Northern Pike Gill Tissue



Mattabi Mines - Selenium and Metallothionein in Female Northern Pike Kidney Tissue



Mattabi Mines - Hypothesis 5

Fish Catch Per Unit Effort

White Sucker

Source	SS	df	MS	F	P
Among Areas	0.008	1	0.008	4.737	0.072
Within Areas (Error)	0.010	6	0.002		

Northern Pike

Source	SS	df	MS	F	P
Among Areas	0.003	1	0.003	1.523	0.263
Within Areas (Error)	0.011	6	0.002		

Walleye

Source	SS	df	MS	F	P
Among Areas	0.003	1	0.003	2.936	0.137
Within Areas (Error)	0.006	6	0.001		

Yellow Perch

Source	SS	df	MS	F	P
Among Areas	5.79E-06	1	5.79E-06	0.011	0.921
Within Areas (Error)	0.003	6	0.001		

Shorthead Redhorse

Source	SS	df	MS	F	P
Among Areas	6.53E-05	1	6.53E-05	1.040	0.347
Within Areas (Error)	3.77E-04	6	6.28E-05		

All Fish

Source	SS	df	MS	F	P
Among Areas	0.005	1	0.005	2.658	0.154
Within Areas (Error)	0.012	6	0.002		

Mattabi Mines - Hypothesis 6

Fish Biomass Per Unit Effort and Number of Taxa

White Sucker

Source	SS	df	MS	F	P
Among Exposure	0.010	1	0.010	4.217	0.086
Within Exposure (Error)	0.014	6	0.002		

Northern Pike

Source	SS	df	MS	F	P
Among Exposure	6.15E-05	1	6.15E-05	0.018	0.897
Within Exposure (Error)	0.020	6	0.003		

Walleye

Source	SS	df	MS	F	P
Among Exposure	3.68E-04	1	3.68E-04	2.355	0.176
Within Exposure (Error)	9.37E-04	6	1.56E-04		

Yellow Perch

Source	SS	df	MS	F	P
Among Exposure	2.26E-06	1	2.26E-06	0.295	0.607
Within Exposure (Error)	4.6E-05	6	7.66E-06		

Shorthead Redhorse

Source	SS	df	MS	F	P
Among Exposure	3.31E-05	1	3.31E-05	0.101	0.762
Within Exposure (Error)	0.002	6	3.28E-04		

All Fish

Source	SS	df	MS	F	P
Among Exposure	1.52E-05	1	1.52E-05	0.003	0.958
Within Exposure (Error)	0.030	6	0.005		

Number of Fish Taxa

Source	SS	df	MS	F	P
Among Exposure	3.125	1	3.125	6.818	**0.040**
Within Exposure (Error)	2.75	6	0.458		

Mattabi Mines - Hypothesis 6

Fish Biomass Per Unit Effort and Number of Taxa

White Sucker

Source	SS	df	MS	F	P
Among Exposure	0.010	1	0.010	4.217	0.086
Within Exposure (Error)	0.014	6	0.002		

Northern Pike

Source	SS	df	MS	F	P
Among Exposure	6.15E-05	1	6.15E-05	0.018	0.897
Within Exposure (Error)	0.020	6	0.003		

Walleye

Source	SS	df	MS	F	P
Among Exposure	3.68E-04	1	3.68E-04	2.355	0.176
Within Exposure (Error)	9.37E-04	6	1.56E-04		

Yellow Perch

Source	SS	df	MS	F	P
Among Exposure	2.26E-06	1	2.26E-06	0.295	0.607
Within Exposure (Error)	4.6E-05	6	7.66E-06		

Shorthead Redhorse

Source	SS	df	MS	F	P
Among Exposure	3.31E-05	1	3.31E-05	0.101	0.762
Within Exposure (Error)	0.002	6	3.28E-04		

All Fish

Source	SS	df	MS	F	P
Among Exposure	1.52E-05	1	1.52E-05	0.003	0.958
Within Exposure (Error)	0.030	6	0.005		

Number of Fish Taxa

Source	SS	df	MS	F	P
Among Exposure	3.125	1	3.125	6.818	**0.040**
Within Exposure (Error)	2.75	6	0.458		

Mattabi Mines Benthos - Hypothesis #6

Total Abundance (log)

Source	SS	DF	MS	F	P	Test Against
Reach	1.549	6	0.258	38.050	**6.98E-08**	Within Reach
Among Reference	0.722	1	0.722	52.637	**0.005**	Lack of Fit
Ref vs Exp	0.712	1	0.712	51.908	**0.006**	Lack of Fit
Linear Trend	0.074	1	0.074	5.384	0.103	Lack of Fit
Lack of Fit	0.041	3	0.014	2.022	0.157	Within Reach
Within Reach	0.095	14	0.007			

Taxa

Source	SS	DF	MS	F	P	Test Against
Reach	551.238	6	91.873	23.245	**1.60E-06**	Within Reach
Among Reference	1.5	1	1.500	0.056	0.828	Lack of Fit
Ref vs Exp	94.671	1	94.671	3.527	0.157	Lack of Fit
Linear Trend	374.533	1	374.533	13.952	**0.033**	Lack of Fit
Lack of Fit	80.534	3	26.845	6.792	**0.005**	Within Reach
Within Reach	5.53E+01	14	3.952			

Hydracarina (log)

Source	SS	DF	MS	F	P	Test Against
Reach	12.132	6	2.022	16.335	**1.36E-05**	Within Reach
Among Reference	0.289	1	0.289	1.383	0.361	Lack of Fit
Ref vs Exp	3.566	1	3.566	17.062	0.054	Lack of Fit
2° Trend	7.859	2	3.930	18.801	0.051	Lack of Fit
Lack of Fit	0.418	2	0.209	1.688	0.220	Within Reach
Within Reach	1.733	14	0.124			

Caenis (log)

Source	SS	DF	MS	F	P	Test Against
Reach	16.997	6	2.833	68.973	**1.36E-09**	Within Reach
Among Reference	0.194	1	0.194	0.075	0.802	Lack of Fit
Ref vs Exp	0.622	1	0.622	0.239	0.658	Lack of Fit
Linear Trend	8.386	1	8.386	3.227	0.170	Lack of Fit
Lack of Fit	7.795	3	2.598	63.264	**2.20E-08**	Within Reach
Within Reach	0.575	14	0.041			

Chironomus (log)

Source	SS	DF	MS	F	P	Test Against
Reach	30.61	6	5.102	22.524	**1.95E-06**	Within Reach
Among Reference	0	1	0.000	0.000	1.000	Lack of Fit
Ref vs Exp	25.980	1	25.980	41.635	**0.008**	Lack of Fit
Linear Trend	2.758	1	2.758	4.420	0.126	Lack of Fit
Lack of Fit	1.872	3	0.624	2.755	0.082	Within Reach
Within Reach	3.171	14	0.227			

Procladius (log)

Source	SS	DF	MS	F	P	Test Against
Reach	0.524	6	0.087	4.596	**8.81E-03**	Within Reach
Among Reference	2.03E-02	1	0.020	0.284	0.631	Lack of Fit
Ref vs Exp	0.113	1	0.113	1.586	0.297	Lack of Fit
Linear Trend	0.177	1	0.177	2.484	0.213	Lack of Fit
Lack of Fit	0.214	3	0.071	3.750	**0.036**	Within Reach
Within Reach	0.266	14	0.019			

Pisidium (log)

Source	SS	DF	MS	F	P	Test Against
Reach	15.649	6	2.608	188.218	**1.45E-12**	Within Reach
Among Reference	3.43E-02	1	0.034	0.038	0.863	Lack of Fit
Ref vs Exp	2.083	1	2.083	2.328	0.267	Lack of Fit
2° Trend	11.742	2	5.871	6.561	0.132	Lack of Fit
Lack of Fit	1.790	2	0.895	64.575	**8.56E-08**	Within Reach
Within Reach	0.194	14	0.014			

%Hydracarina (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.105	6	0.018	9.665	**2.61E-04**	Within Reach
Among Reference	5.83E-03	1	0.006	4.726	0.162	Lack of Fit
Ref vs Exp	0.020	1	0.020	15.867	0.058	Lack of Fit
2° Trend	0.077	2	0.039	31.248	**0.031**	Lack of Fit
Lack of Fit	0.002	2	0.001	0.681	0.522	Within Reach
Within Reach	2.54E-02	14	0.002			

%*Caenis* (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.358	6	0.060	11.543	**9.96E-05**	Within Reach
Among Reference	4.35E-03	1	0.004	0.103	0.778	Lack of Fit
Ref vs Exp	0.026	1	0.026	0.626	0.512	Lack of Fit
2° Trend	0.243	2	0.122	2.884	0.257	Lack of Fit
Lack of Fit	0.084	2	0.042	8.150	**4.50E-03**	Within Reach
Within Reach	0.072	14	0.005			

%*Chironomus* (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.457	6	0.076	21.735	**2.43E-06**	Within Reach
Among Reference	0	1	0.000	0.000	1.000	Lack of Fit
Ref vs Exp	0.335	1	0.335	102.761	**0.010**	Lack of Fit
2° Trend	0.115	2	0.058	17.712	0.053	Lack of Fit
Lack of Fit	0.007	2	0.003	0.930	0.418	Within Reach
Within Reach	0.049	14	0.004			

%*Procladius* (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.202	6	0.034	9.186	**3.41E-04**	Within Reach
Among Reference	0.111	1	0.111	5.583	0.142	Lack of Fit
Ref vs Exp	0.019	1	0.019	0.961	0.430	Lack of Fit
2° Trend	0.032	2	0.016	0.808	0.553	Lack of Fit
Lack of Fit	0.040	2	0.020	5.425	**0.018**	Within Reach
Within Reach	0.051	14	0.004			

%Tanypodinae (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.211	6	0.035	12.598	**6.11E-05**	Within Reach
Among Reference	1.11E-01	1	0.111	8.076	0.105	Lack of Fit
Ref vs Exp	0.057	1	0.057	4.122	0.179	Lack of Fit
2° Trend	0.016	2	0.008	0.577	0.634	Lack of Fit
Lack of Fit	0.027	2	0.014	4.924	**0.024**	Within Reach
Within Reach	0.039	14	0.003			

%Chironominae (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.521	6	0.087	18.125	**7.32E-06**	Within Reach
Among Reference	2.88E-02	1	0.029	0.248	0.652	Lack of Fit
Ref vs Exp	0.006	1	0.006	0.048	0.841	Lack of Fit
Linear Trend	0.139	1	0.139	1.199	0.354	Lack of Fit
Lack of Fit	0.348	3	0.116	24.192	**8.42E-06**	Within Reach
Within Reach	0.067	14	0.005			

%Pisidium (arcsine square root)

Source	SS	DF	MS	F	P	Test Against
Reach	0.149	6	0.025	31.664	**2.28E-07**	Within Reach
Among Reference	1.57E-02	1	0.016	3.025	0.180	Lack of Fit
Ref vs Exp	0.001	1	0.001	0.132	0.740	Lack of Fit
Linear Trend	0.117	1	0.117	22.512	**0.018**	Lack of Fit
Lack of Fit	0.016	3	0.005	6.627	**5.16E-03**	Within Reach
Within Reach	0.011	14	0.001			

Mattabi Mines - Individual Fish Metrics

			White Sucker	**Northern Pike**								
			Male	Female					Male			
Station	Area	Ftaxa	Liver Wgt	Fork Length	Weight	Gonad Wgt	Liver Wgt	Fecundity	Fork Length	Weight	Gonad Wgt	Liver Wgt
MMR10	1	6	11.3	37.6	335	3.7	3.3	327	33.6	268.3	2.7	2.5
MMR11	2	6	12.1	39.1	354	3.6	3.9	821	31.7	234.7	1.6	2.5
MMR12	3	5	10.2	38.9	421	3.3	3.8	140	33.1	289.4	2.6	2.7
MMR13	4	7	10.4	35.1	281	2.7	3.1	264	37.9	385.7	3.2	4.1
MM6	5	5	12.3	41.6	510	8.1	7.3	1554	41.6	509.5	4.8	4.7
MM7	6	5	14.0	39.1	378	6.6	4.8	1975	43.0	599.7	4.8	5.0
MM8	7	5	13.8	44.1	649	10.7	7.4	2257	40.9	547.1	6.2	6.5
MM9	8	4	8.3	45.7	673	9.7	7.3	1842	42.2	614.9	5.9	8.0
Mean												
Reference		6.0	11.0	37.7	347	3.3	3.5	388	34.1	294.5	2.5	3.0
Exposure		4.8	12.1	42.6	552	8.8	6.7	1907	41.9	567.8	5.4	6.0

Mattabi Mines - Hypothesis 7

Fish Biomass Length and Weight @Age

White Sucker

Females

Fork Length@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	2.01E-05	1	2.01E-05	0.034	0.855
Age Covariate	0.004	1	0.004	6.576	**0.014**
Within Exposure (Error)	0.023	38	0.001		

Weight@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.001	1	0.001	0.163	0.689
Age Covariate	0.053	1	0.053	8.114	**0.007**
Within Exposure (Error)	0.249	38	0.007		

Weight@Fork Length (Log)

Source	SS	df	MS	F	P
Among Exposure	0.002	1	0.002	0.644	0.427
Fork Length Covariate	0.690	1	0.690	200.532	**1.11E-16**
Within Exposure (Error)	0.134	39	0.003		

Males

Fork Length@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	6.87E-05	1	6.87E-05	0.203	0.655
Age Covariate	0.005	1	0.005	13.971	**5.95E-04**
Within Exposure (Error)	0.013	39	0.000		

Weight@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.001	1	0.001	0.407	0.527
Age Covariate	0.034	1	0.034	9.618	**0.004**
Within Exposure (Error)	0.136	39	0.003		

Weight@Fork Length (Log)

Source	SS	df	MS	F	P
Among Exposure	2.55E-04	1	2.55E-04	0.208	0.651
Fork Length Covariate	0.122	1	0.122	99.105	**1.11E-16**
Within Exposure (Error)	0.048	39	1.23E-03		

Northern Pike

Females

Fork Length@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.027	1	0.027	8.897	**4.60E-03**
Age Covariate	0.113	1	0.113	37.797	**1.79E-07**
Within Exposure (Error)	0.134	45	0.003		

Weight@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.386	1	0.386	10.269	**2.49E-03**
Age Covariate	1.426	1	1.426	37.905	**1.73E-07**
Within Exposure (Error)	1.693	45	0.038		

Weight@Fork Length (Log)

Source	SS	df	MS	F	P
Among Exposure	0.003	1	0.003	0.626	0.433
Fork Length Covariate	2.916	1	2.916	603.381	**4.36E-28**
Within Exposure (Error)	0.222	46	0.005		

Males

Fork Length@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.056	1	0.056	34.940	**1.23E-06**
Age Covariate	0.086	1	0.086	53.232	**6.13E-09**
Within Exposure (Error)	0.053	33	0.002		

Weight@Age (Log)

Source	SS	df	MS	F	P
Among Exposure	0.592	1	0.592	32.594	**2.3E-06**
Age Covariate	0.883	1	0.883	48.627	**2.56E-08**
Within Exposure (Error)	0.600	33	0.018		

Weight@Fork Length (Log)

Source	SS	df	MS	F	P
Among Exposure	3.51E-04	1	3.51E-04	0.151	0.700
Fork Length Covariate	2.035	1	2.035	872.465	**2.22E-16**
Within Exposure (Error)	0.079	34	0.002		

Mattabi Mines - Hypothesis 8

Fish Liver Weight, Gonad Weight and Fecundity

White Sucker

Females

Liver Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.015	1	0.015	1.672	0.204
Age Covariate	0.119	1	0.119	13.238	**8.12E-04**
Within Exposure (Error)	0.343	38	0.009		

Liver Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.003	1	0.003	0.985	0.327
Body Weight Covariate	0.339	1	0.339	104.871	**1.11E-16**
Within Exposure (Error)	0.123	38	0.003		

Gonad Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.081	1	0.081	2.364	0.132
Age Covariate	0.396	1	0.396	11.556	**1.60E-03**
Within Exposure (Error)	1.303	38	0.034		

Gonad Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.026	1	0.026	1.412	0.242
Body Weight Covariate	0.995	1	0.995	53.688	**2.79E-09**
Within Exposure (Error)	0.704	38	0.019		

Fecundity@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.033	1	0.033	1.068	0.308
Age Covariate	0.178	1	0.178	5.811	**0.021**
Within Exposure (Error)	1.134	37	0.031		

Fecundity@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.015	1	0.015	0.653	0.424
Age Covariate	0.442	1	0.442	18.787	**1.08E-04**
Within Exposure (Error)	0.871	37	0.024		

Males

Liver Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.076	1	0.076	13.006	**8.70E-04**
Age Covariate	0.093	1	0.093	15.943	**2.80E-04**
Within Exposure (Error)	0.229	39	0.006		

Liver Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.037	1	0.037	7.236	**0.010**
Body Weight Covariate	0.124	1	0.124	24.274	**1.58E-05**
Within Exposure (Error)	0.199	39	0.005		

Gonad Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.015	1	0.015	1.860	0.180
Age Covariate	0.033	1	0.033	4.162	**0.048**
Within Exposure (Error)	0.312	39	0.008		

Gonad Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.035	1	0.035	7.298	**0.010**
Body Weight Covariate	0.159	1	0.159	33.365	**1.06E-06**
Within Exposure (Error)	0.186	39	0.005		

Northern Pike

Females

Liver Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.813	1	0.813	20.418	**4.48E-05**
Age Covariate	1.525	1	1.525	38.324	**1.53E-07**
Within Exposure (Error)	1.791	45	0.040		

Liver Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.087	1	0.087	5.728	**0.021**
Body Weight Covariate	2.620	1	2.620	172.061	**3.74E-17**
Within Exposure (Error)	0.701	46	0.015		

Gonad Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	1.806	1	1.806	25.711	**7.30E-06**
Age Covariate	2.547	1	2.547	36.247	**2.83E-07**
Within Exposure (Error)	3.162	45	0.070		

Gonad Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.369	1	0.369	9.788	**3.05E-03**
Body Weight Covariate	4.028	1	4.028	106.949	**1.38E-13**
Within Exposure (Error)	1.733	46	0.038		

Fecundity@Age (log)

Source	SS	df	MS	F	P
Among Areas	6.069	1	6.069	7.008	**0.011**
Age Covariate	4.579	1	4.579	5.288	**0.026**
Within Exposure (Error)	38.971	45	0.866		

Fecundity@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	2.255	1	2.255	2.759	0.103
Age Covariate	5.972	1	5.972	7.309	**0.010**
Within Exposure (Error)	37.584	46	0.817		

Males

Liver Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.629	1	0.629	19.203	**1.12E-04**
Age Covariate	0.562	1	0.562	17.153	**2.25E-04**
Within Exposure (Error)	1.081	33	0.033		

Liver Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	6.12E-05	1	6.12E-05	0.006	0.940
Body Weight Covariate	1.931	1	1.931	181.885	**2.22E-16**
Within Exposure (Error)	0.361	34	0.011		

Gonad Weight@Age (log)

Source	SS	df	MS	F	P
Among Areas	0.757	1	0.757	19.882	**8.99E-05**
Age Covariate	1.183	1	1.183	31.092	**3.44E-06**
Within Exposure (Error)	1.256	33	0.038		

Gonad Weight@Body Weight (log)

Source	SS	df	MS	F	P
Among Areas	0.001	1	0.001	0.056	0.814
Body Weight Covariate	2.778	1	2.778	110.999	**2.22E-16**
Within Exposure (Error)	0.851	34	0.025		

Mattabi Mines - Hypothesis 9

Fish Community Metrics vs Water Quality Data

Matrix of Pearson Correlations

	Northern Pike											White Sucker		
	Number of Fish Taxa	Female Fecundity @age	Female Fork Length @age	Female Gonad Weight @age	Female Liver Weight @age	Female Weight @age	Female Gonad Weight @Body Weight	Female Liver Weight @Body Weight	Male Fork Length @age	Male Gonad Weight @age	Male Liver Weight @age	Male Weight @age	Male Liver Weight @age	Male Gonad Weight @Body Weight	Male Liver Weight @Body Weight
Copper_Diss	-0.7538	0.8988	0.7981	0.9337	0.8714	0.7704	0.7840	0.4358	0.8448	0.8385	0.8570	0.8906	0.2146	-0.2513	0.0760
Copper_Total	-0.7327	0.8967	0.7918	0.9382	0.8600	0.7676	0.8046	0.4062	0.8716	0.8777	0.8932	0.9140	0.1831	-0.2136	0.0493
Iron_Diss	0.7227	-0.9113	-0.7464	-0.9340	-0.9135	-0.7277	-0.8990	-0.6178	-0.8706	-0.8282	-0.8075	-0.8720	-0.2815	0.5283	-0.1706
Iron_Total	0.7254	-0.8286	-0.7318	-0.9228	-0.8931	-0.7441	-0.8237	-0.5436	-0.9224	-0.9121	-0.8566	-0.9353	-0.2040	0.4882	-0.0345
Magnesium-Diss	-0.7004	0.8715	0.7924	0.9333	0.8474	0.7773	0.7863	0.3470	0.8663	0.8952	0.9046	0.9144	0.1673	-0.1800	0.0258
Magnesium_Total	-0.6982	0.8862	0.7935	0.9500	0.8749	0.7835	0.8207	0.3987	0.8826	0.9054	0.9001	0.9229	0.2080	-0.2663	0.0629
Manganese_Diss	-0.7042	0.8839	0.7747	0.9232	0.8313	0.7511	0.7824	0.3771	0.8563	0.8703	0.8819	0.9032	0.2052	-0.1768	0.0627
Manganese_Total	-0.5398	0.7811	0.6506	0.7266	0.6571	0.6098	0.5403	0.2876	0.6754	0.6377	0.7763	0.7484	0.1880	0.0710	0.1468
Lead_Diss	-0.4802	0.6362	0.4923	0.6459	0.4392	0.4541	0.5382	0.1044	0.6498	0.7073	0.6830	0.6988	0.1507	0.2174	-0.0181
Lead_Total	-0.6002	0.7345	0.6512	0.7541	0.6135	0.6164	0.5652	0.1628	0.7238	0.7562	0.8059	0.7946	0.0961	0.1639	-0.0370
Zinc_Diss	-0.6766	0.8650	0.7769	0.9213	0.8299	0.7629	0.7738	0.3392	0.8624	0.8909	0.9030	0.9119	0.1799	-0.1611	0.0399
Zinc_Total	-0.7037	0.8676	0.7802	0.9245	0.8351	0.7635	0.7752	0.3543	0.8665	0.8900	0.8988	0.9148	0.1714	-0.1701	0.0257
Probabilities (1-tailed test)															
Copper_Diss	0.0154	0.0012	0.0088	0.0003	0.0024	0.0126	0.0106	0.1402	0.0041	0.0046	0.0033	0.0015	0.3049	0.2741	0.4290
Copper_Total	0.0193	0.0013	0.0096	0.0003	0.0031	0.0131	0.0080	0.1590	0.0024	0.0021	0.0014	0.0007	0.3321	0.3058	0.4539
Iron_Diss	0.0214	0.0008	0.0167	0.0003	0.0008	0.0204	0.0012	0.0513	0.0025	0.0056	0.0077	0.0024	0.2497	0.0891	0.3432
Iron_Total	0.0208	0.0055	0.0195	0.0005	0.0014	0.0171	0.0060	0.0819	0.0006	0.0008	0.0033	0.0003	0.3140	0.1099	0.4677
Magnesium-Diss	0.0265	0.0024	0.0095	0.0004	0.0039	0.0116	0.0103	0.1999	0.0027	0.0013	0.0010	0.0007	0.3460	0.3348	0.4758
Magnesium_Total	0.0270	0.0017	0.0094	0.0002	0.0022	0.0107	0.0063	0.1640	0.0018	0.0010	0.0012	0.0005	0.3106	0.2619	0.4412
Manganese_Diss	0.0256	0.0018	0.0120	0.0005	0.0053	0.0159	0.0109	0.1786	0.0033	0.0025	0.0019	0.0011	0.3129	0.3376	0.4413
Manganese_Total	0.0837	0.0111	0.0403	0.0206	0.0383	0.0542	0.0834	0.2449	0.0330	0.0445	0.0118	0.0163	0.3278	0.4336	0.3644
Lead_Diss	0.1142	0.0450	0.1076	0.0418	0.1381	0.1292	0.0844	0.4028	0.0406	0.0249	0.0310	0.0269	0.3608	0.3025	0.4830
Lead_Total	0.0578	0.0190	0.0401	0.0153	0.0529	0.0518	0.0721	0.3500	0.0212	0.0150	0.0079	0.0092	0.4105	0.3491	0.4653
Zinc_Diss	0.0327	0.0028	0.0117	0.0006	0.0054	0.0138	0.0121	0.2056	0.0029	0.0015	0.0011	0.0008	0.3349	0.3516	0.4626
Zinc_Total	0.0257	0.0026	0.0112	0.0005	0.0049	0.0137	0.0119	0.1946	0.0027	0.0015	0.0012	0.0007	0.3424	0.3435	0.4759

▨ significant correlation at p = 0.05

Notes:

- cell frequency = 8 for all tests
- Degrees of Freedom = 6 for all tests
- all chemistry data log transformed
- all fish data (except fish taxa), log transformed

Mattabi Mines - Hypothesis 10

Benthic Community and Toxicity Endpoints vs Metal Concentrations in Sediment
Excluding Reference Stations

Matrix of Pearson Correlations

	Benthic Macroinvertebrate Community												Toxicity					
	Total Density (log)	Number of Taxa	%Hydracarina (Asin sqrt)	%*Chironomus* (Asin sqrt)	%*Pisidium* (Asin sqrt)	*Caenis* Density (log)	%*Caenis* (Asin sqrt)	*Hyalella* Density (log)	%*Hyalella* (Asin sqrt)	%Tanypodinae (Asin sqrt)	Tubificidae Density (log)	%Tubificidae (Asin sqrt)	*Chironomus* Mortality (Asin sqrt)	*Chironomus* Growth (Asin sqrt)	*Hyalella* Mortality (Asin sqrt)	*Hyalella* Growth (Asin sqrt)	Tubifex #Cocoons/Adult	Tubifex #Young/Adult
Arsenic_Total	-0.495	-0.866	-0.887	-0.715	-0.716	-0.841	0.364	-0.424	-0.247	0.446	-0.447	0.011	-0.213	0.625	0.275	-0.413	-0.382	-0.718
Cadmium_Total	-0.512	-0.810	-0.808	-0.570	-0.694	-0.709	0.339	-0.430	-0.283	0.504	-0.310	0.206	-0.321	0.624	0.266	-0.567	-0.355	-0.596
Copper_Total	-0.352	-0.639	-0.760	-0.461	-0.447	-0.572	0.432	-0.250	-0.065	0.614	-0.422	0.090	-0.298	0.658	0.234	-0.523	-0.155	-0.454
Iron_Total	-0.600	-0.822	-0.723	-0.802	-0.702	-0.788	0.253	-0.371	-0.259	0.351	-0.478	-0.084	0.047	0.516	0.325	-0.217	-0.486	-0.787
Lead_Total	-0.271	-0.621	-0.820	-0.455	-0.418	-0.626	0.402	-0.221	0.004	0.638	-0.427	0.095	-0.358	0.708	0.179	-0.497	-0.066	-0.477
Nickel_Total	-0.647	-0.803	-0.654	-0.720	-0.804	-0.620	0.433	-0.429	-0.408	0.373	-0.498	-0.117	-0.015	0.383	0.265	-0.431	-0.578	-0.730
Selenium_Total	-0.417	-0.486	-0.450	-0.330	-0.477	-0.222	0.613	-0.240	-0.235	0.533	-0.466	-0.072	-0.170	0.339	0.184	-0.591	-0.291	-0.330
Zinc_Total	-0.624	-0.853	-0.700	-0.642	-0.818	-0.656	0.387	-0.477	-0.426	0.384	-0.316	0.128	-0.210	0.452	0.282	-0.560	-0.550	-0.639
Aluminum_Partial	-0.552	-0.900	-0.774	-0.836	-0.836	-0.914	0.052	-0.501	-0.394	-0.011	-0.376	-0.160	0.011	0.267	0.243	-0.105	-0.626	-0.854
Arsenic_Partial	0.119	-0.239	-0.403	-0.286	-0.022	-0.555	-0.343	-0.059	0.168	-0.195	0.012	-0.015	-0.024	0.193	0.003	0.315	0.027	-0.281
Cadmium_Partial	0.452	0.560	0.318	0.389	0.700	0.258	-0.375	0.415	0.503	-0.233	0.077	-0.182	0.177	-0.127	-0.007	0.538	0.528	0.415
Copper_Partial	0.476	0.546	0.259	0.348	0.744	0.246	-0.370	0.466	0.611	-0.200	0.072	-0.152	0.185	-0.107	-0.010	0.514	0.575	0.395
Iron_Partial	-0.472	-0.894	-0.811	-0.838	-0.835	-0.909	0.187	-0.439	-0.329	0.215	-0.346	-0.006	-0.129	0.425	0.151	-0.175	-0.525	-0.877
Lead_Partial	0.440	0.192	-0.190	0.091	0.467	-0.122	-0.307	0.343	0.604	0.004	-0.029	-0.009	-0.119	0.131	-0.043	0.261	0.463	0.096
Nickel_Partial	-0.610	-0.942	-0.821	-0.801	-0.904	-0.846	0.288	-0.518	-0.439	0.182	-0.401	-0.067	-0.111	0.356	0.249	-0.348	-0.632	-0.828
Zinc_Partial	-0.521	-0.886	-0.750	-0.765	-0.871	-0.772	0.230	-0.477	-0.402	0.212	-0.282	0.065	-0.177	0.329	0.107	-0.387	-0.593	-0.789
SEM/AVS	-0.197	-0.371	-0.216	-0.345	-0.303	-0.432	-0.071	-0.170	-0.046	0.183	-0.334	-0.244	-0.082	0.145	0.145	0.057	-0.140	-0.365
Probabilities (1-tailed test)																		
Arsenic_Total	0.030	1.52E-05	5.27E-06	0.001	0.001	0.000	0.091	0.058	0.188	0.048	0.047	0.485	0.223	0.006	0.160	0.071	0.080	0.001
Cadmium_Total	0.025	1.25E-04	1.34E-04	0.013	0.002	0.002	0.108	0.055	0.153	0.028	0.131	0.231	0.121	0.006	0.169	0.017	0.097	0.010
Copper_Total	0.099	0.005	0.001	0.042	0.047	0.013	0.054	0.184	0.408	0.007	0.059	0.375	0.140	0.004	0.201	0.028	0.290	0.044
Iron_Total	0.009	8.56E-05	0.001	1.59E-04	0.002	0.000	0.181	0.086	0.176	0.100	0.036	0.383	0.434	0.025	0.118	0.228	0.033	2.52E-04
Lead_Total	0.164	0.007	9.21E-05	0.044	0.061	0.006	0.069	0.215	0.494	0.005	0.056	0.368	0.095	0.002	0.261	0.035	0.407	0.036
Nickel_Total	0.005	1.58E-04	0.004	0.001	1.49E-04	0.007	0.053	0.055	0.066	0.085	0.029	0.339	0.479	0.080	0.170	0.062	0.012	0.001
Selenium_Total	0.061	0.033	0.046	0.115	0.036	0.214	0.008	0.194	0.200	0.020	0.040	0.400	0.272	0.108	0.256	0.013	0.147	0.115
Zinc_Total	0.006	2.67E-05	0.002	0.005	9.61E-05	0.004	0.077	0.036	0.057	0.079	0.125	0.325	0.227	0.045	0.155	0.019	0.017	0.005
Aluminum_Partial	0.017	2.46E-06	3.50E-04	5.08E-05	5.15E-05	0.000	0.427	0.028	0.073	0.484	0.084	0.284	0.484	0.168	0.191	0.361	0.006	2.57E-05
Arsenic_Partial	0.337	0.196	0.068	0.150	0.469	0.016	0.106	0.418	0.275	0.243	0.483	0.479	0.467	0.245	0.495	0.136	0.462	0.155
Cadmium_Partial	0.045	0.015	0.124	0.076	0.002	0.176	0.084	0.062	0.028	0.202	0.393	0.259	0.264	0.325	0.490	0.024	0.021	0.062
Copper_Partial	0.037	0.018	0.176	0.102	0.001	0.188	0.087	0.040	0.008	0.237	0.399	0.294	0.254	0.352	0.486	0.030	0.012	0.072
Iron_Partial	0.038	3.44E-06	1.22E-04	4.84E-05	5.35E-05	0.000	0.252	0.051	0.116	0.221	0.103	0.491	0.324	0.057	0.296	0.275	0.022	9.04E-06
Lead_Partial	0.050	0.247	0.249	0.373	0.039	0.332	0.133	0.105	0.009	0.494	0.459	0.487	0.336	0.321	0.439	0.184	0.041	0.367
Nickel_Partial	0.008	7.43E-08	8.73E-05	1.66E-04	1.86E-06	0.000	0.149	0.024	0.051	0.258	0.069	0.406	0.347	0.097	0.185	0.111	0.006	6.95E-05
Zinc_Partial	0.023	5.59E-06	0.001	4.48E-04	1.18E-05	0.000	0.204	0.036	0.069	0.225	0.154	0.409	0.265	0.116	0.353	0.086	0.010	2.37E-04
SEM/AVS	0.240	0.087	0.219	0.104	0.136	0.054	0.401	0.273	0.435	0.257	0.020	0.190	0.386	0.303	0.304	0.424	0.309	0.090

▨ significant correlation at p = 0.05

Notes:

- cell frequency = 15 for all tests
- Degrees of Freedom = 13 for all tests
- all chemistry data log transformed, except SEM/AVS (no transformation)

Mattabi Mines - Hypothesis 11

Benthic Community vs Toxicity Endpoints Excluding Reference Stations

Matrix of Pearson Correlations

	Toxicity					
	Chironomus Mortality (Asin sqrt)	*Chironomus* Growth (Asin sqrt)	*Hyalella* Mortality (Asin sqrt)	*Hyalella* Growth (Asin sqrt)	Tubifex #Cocoons/Adult	Tubifex #Young/Adult
Total Density (log)	-0.404	0.001	-0.481	0.194	0.752	0.416
Number of Taxa	0.083	-0.411	-0.323	0.352	0.682	0.709
Caenis (log)	0.200	-0.577	-0.238	0.195	0.375	0.736
%*Caenis*¹	-0.247	0.444	-0.256	-0.294	0.096	-0.204
%*Chironomus*¹	-0.235	-0.245	-0.278	0.039	0.551	0.917
Hyalella (log)	0.030	-0.195	-0.101	0.237	0.547	0.225
%*Hyalella*¹	-0.031	0.059	-0.127	0.225	0.736	0.173
%Hydracarina¹	0.266	-0.633	-0.097	0.402	0.244	0.717
%Tanypodinae¹	-0.558	0.769	-0.196	-0.413	0.409	-0.147
%*Pisdium*¹	0.104	-0.201	-0.214	0.398	0.780	0.718
Tubificidae (log)	-0.057	-0.060	0.004	-0.111	0.076	0.445
%Tubificidae¹	-0.433	0.423	0.080	-0.442	0.128	0.242
Probabilities (1-tailed test)						
Total Density (log)	0.068	0.498	0.035	0.253	0.001	0.061
Number of Taxa	0.384	0.064	0.120	0.109	0.003	0.002
Caenis (log)	0.237	0.012	0.197	0.252	0.084	0.001
%*Caenis*¹	0.187	0.049	0.179	0.154	0.367	0.233
%*Chironomus*¹	0.200	0.190	0.158	0.448	0.017	7.66E-07
Hyalella (log)	0.457	0.243	0.361	0.208	0.017	0.210
%*Hyalella*¹	0.456	0.417	0.326	0.219	0.001	0.269
%Hydracarina¹	0.169	0.006	0.365	0.077	0.191	0.001
%Tanypodinae¹	0.015	4.05E-04	0.242	0.071	0.065	0.301
%*Pisdium*¹	0.356	0.237	0.222	0.080	3.02E-04	0.001
Tubificidae (log)	0.420	0.416	0.494	0.352	0.393	0.048
%Tubificidae¹	0.054	0.058	0.388	0.057	0.325	0.192

▨ significant correlation at p = 0.05

Notes:

- cell frequency = 15 for all tests
- Degrees of Freedom = 13 for all tests

¹ Arcsine square root transformed

Mattabi Mines - Hypothesis 12

Matrix of Pearson Correlations

White Sucker

	All Fish			All Fish			All Fish			Females		All Fish	
	Gill			Kidney			Liver			Liver		Muscle	
	Zinc	Lead	MT	Zinc	Lead	MT	Zinc	Lead	MT	Lead	MT	Cadmium	Zinc
Cadmium_Total	-	-	-0.860	-	-	-0.172	-	-	-0.360	-	0.310	-0.689	-
Lead_Total	-	0.900	-0.678	-	0.499	-0.313	-	0.715	-0.178	0.946	0.310	-	-
Lead_Diss	-	0.894	-0.702	-	0.420	-0.143	-	0.740	-0.225	0.958	0.063	-	-
Zinc_Total	0.970	-	-0.707	0.681	-	-0.318	-0.322	-	-0.209	-	0.302	-	0.499
Zinc_Diss	0.965	-	-0.729	0.668	-	-0.306	-0.350	-	-0.211	-	0.301	-	0.494
Probabilties (1-tailed test)													
Cadmium_Total	-	-	0.007	-	-	0.356	-	-	0.214	-	0.306	0.043	-
Lead_Total	-	0.003	0.047	-	0.127	0.247	-	0.036	0.351	0.008	0.306	-	-
Lead_Diss	-	0.003	0.039	-	0.174	0.380	-	0.029	0.314	0.005	0.460	-	-
Zinc_Total	1.43E-04	-	0.038	0.046	-	0.243	0.241	-	0.327	-	0.311	-	0.127
Zinc_Diss	2.15E-04	-	0.032	0.051	-	0.252	0.221	-	0.325	-	0.312	-	0.130

Cell frequency = 7 for all except Females - Liver and -MT where cf = 5

Degrees of Freedom = 5 for all except Females - Liver and -MT where df = 3

▨ significant correlation at p = 0.05

Notes:

- all chemistry data log transformed
- all fish tissue data log transformed

Mattabi Mines - Hypothesis 12

Matrix of Pearson Correlations

Northern Pike

	Muscle		Females	**Gill**			**Kidney**		Males
	Cadmium	Zinc	Chromium	MT	CdCuZn[1]	Lead	MT	Lead	Chromium
Cadmium_Total	0.4989	-	-	0.5760	-0.5755	-	0.5940	-	-
Chromium_Total	-	-	0.1539	0.3224	-	-	0.1643	-	0.4689
Lead_Dissolved	-	-	-	0.6764	-	0.5894	0.5605	0.7267	-
Lead_Total	-	-	-	0.6340	-	0.6527	0.6526	0.7633	-
Zinc_Dissolved	-	0.8200	-	0.6411	-0.6035	-	0.6424	-	-
Zinc_Total	-	0.8212	-	0.6381	-0.5994	-	0.6513	-	-
Probabilities (1-tailed test)									
Cadmium_Total	0.0494	-	-	0.0250	0.0251		0.0208	-	-
Chromium_Total	-	-	0.4024	0.1534			0.3050	-	0.1443
Lead_Dissolved	-	-	-	0.0079		0.0219	0.0290	0.0037	-
Lead_Total	-	-	-	0.0134		0.0107	0.0107	0.0019	-
Zinc_Dissolved	-	0.0005	-	0.0123	0.0189		0.0121	-	-
Zinc_Total	-	0.0005	-	0.0128	0.0197		0.0109	-	-

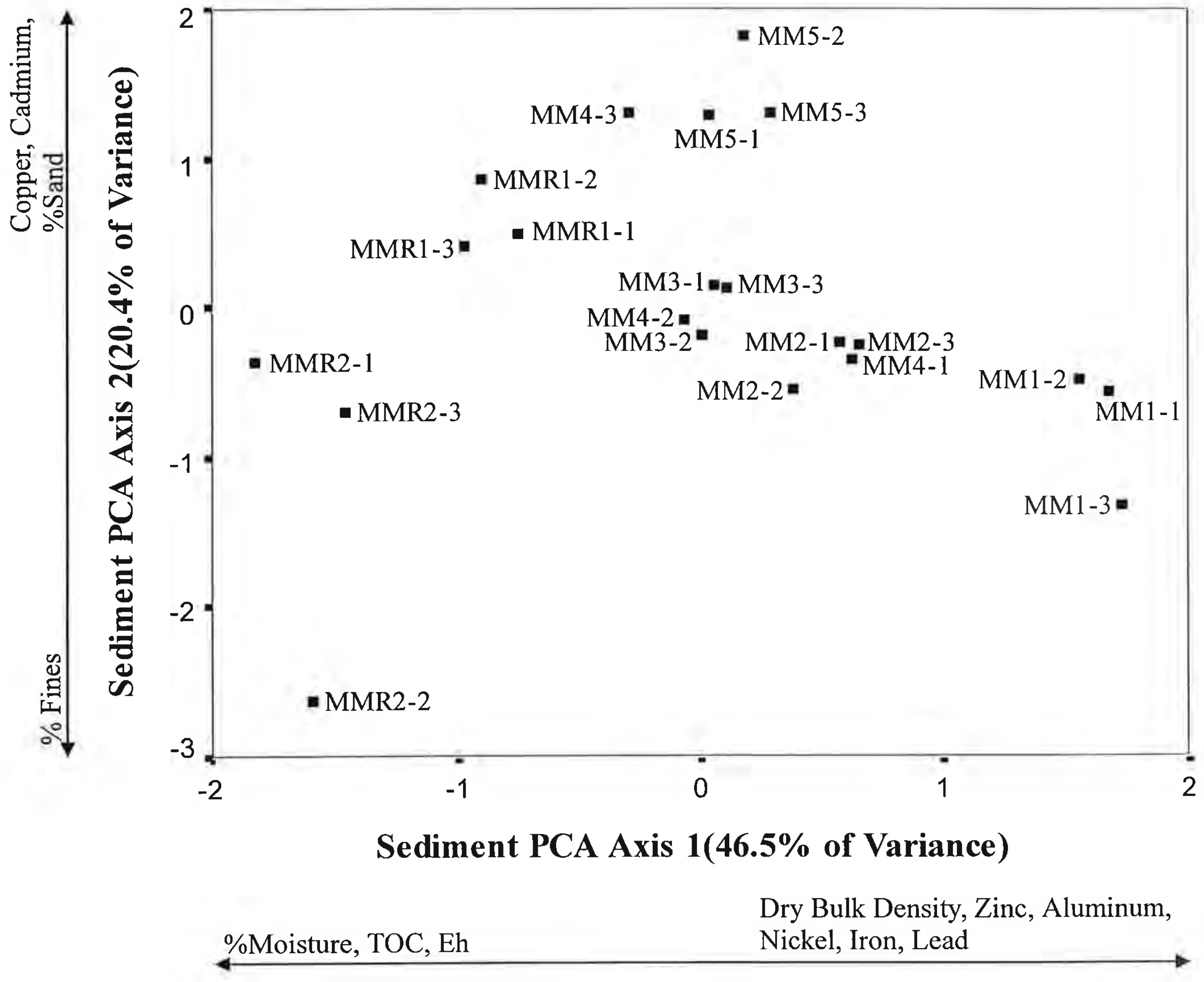
▨ significant correlation at p = 0.05

Notes:

- cell frequency = 7 for all tests
- degrees of freedom = 5 for all tests
- all chemistry data log transformed
- all fish tissue data log transformed
- Dissolved cadmium and chromium not shown as all below detection limits

TRIAD HYPOTHESIS

Sediment (Partial Metals) PCA Results
Mattabi Mines Lake Stations

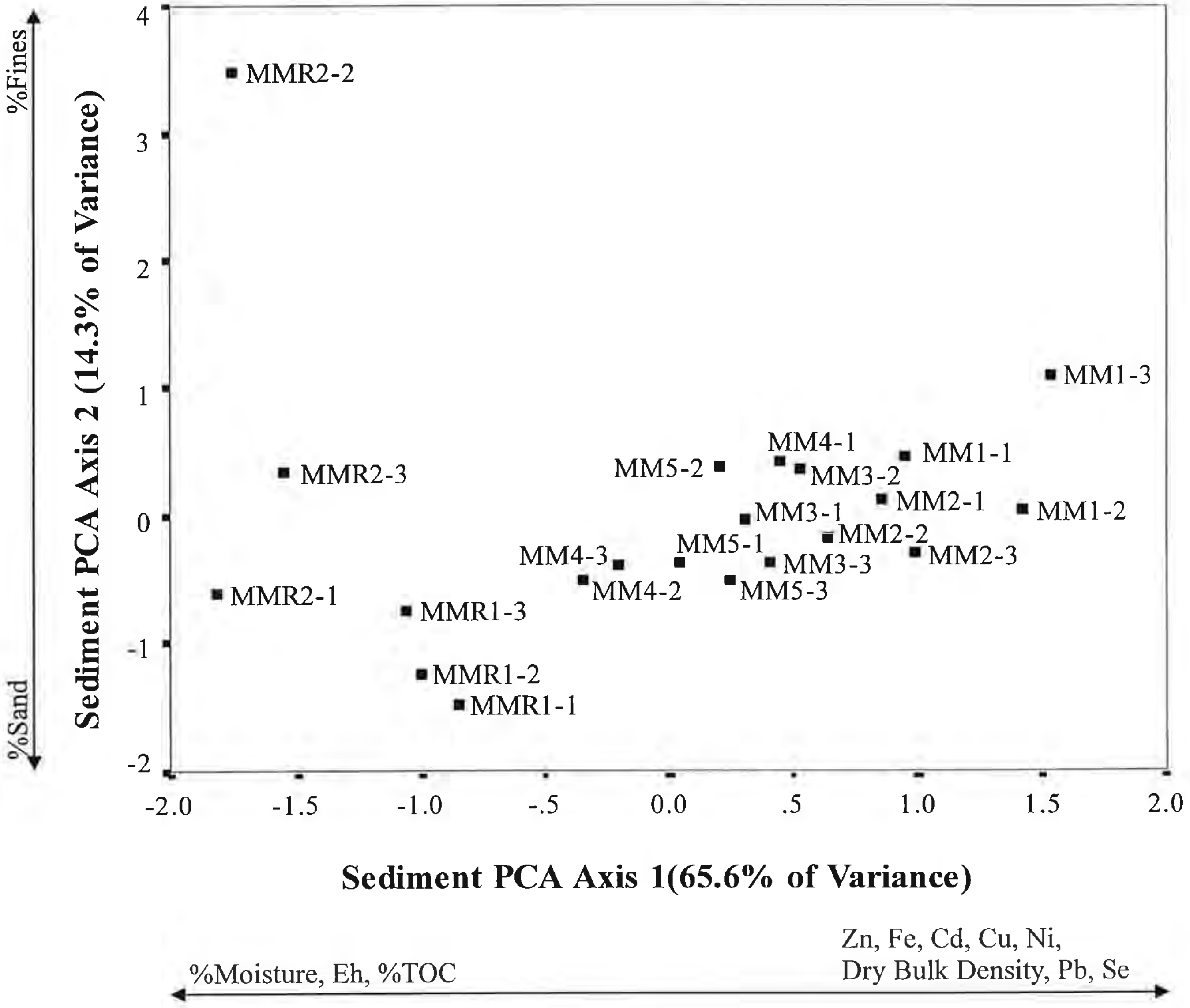


Relative Contributions of Physical-Chemical Variables to Sediment Principal Components at Mattabi Mines

(Partial Metal Extraction Technique)

	Principal Components			
	1	2	3	4
%Variance Explained	46.5	20.4	14.4	7.6
Dry Bulk Density	0.96139	0.11162	-0.11917	-0.02452
%Moisture	-0.95615	-0.16934	0.12694	0.03958
Zinc_Partial	0.94022	0.17222	-0.15508	-0.15993
Aluminum_Partial	0.92584	-0.15633	0.09671	0.26909
Nickel_Partial	0.91043	-0.32338	0.03835	-0.02224
Iron_Partial	0.89347	-0.29681	0.08482	-0.02314
TOC	-0.87174	-0.09015	0.22121	-0.19629
Eh	-0.86377	-0.21372	0.04008	0.24306
Lead_Partial	0.72316	0.53059	0.28207	-0.15291
Copper_Partial	-0.09248	0.82653	0.48618	0.08634
Cadmium_Partial	-0.21629	0.72920	0.60640	0.08155
%Very Fine Sand, Silt, Clay	0.06692	-0.66665	0.62974	-0.37468
%Gravel	-0.09884	0.56832	-0.25741	-0.56248
Arsenic_Partial	0.32657	0.21972	0.78433	0.30123
%Sand	-0.05707	0.62517	-0.62728	0.44812
SEM/AVS	0.15758	-0.47496	0.13695	0.47773

Sediment (Total Metals)
PCA Results
Mattabi Mines Lake Stations

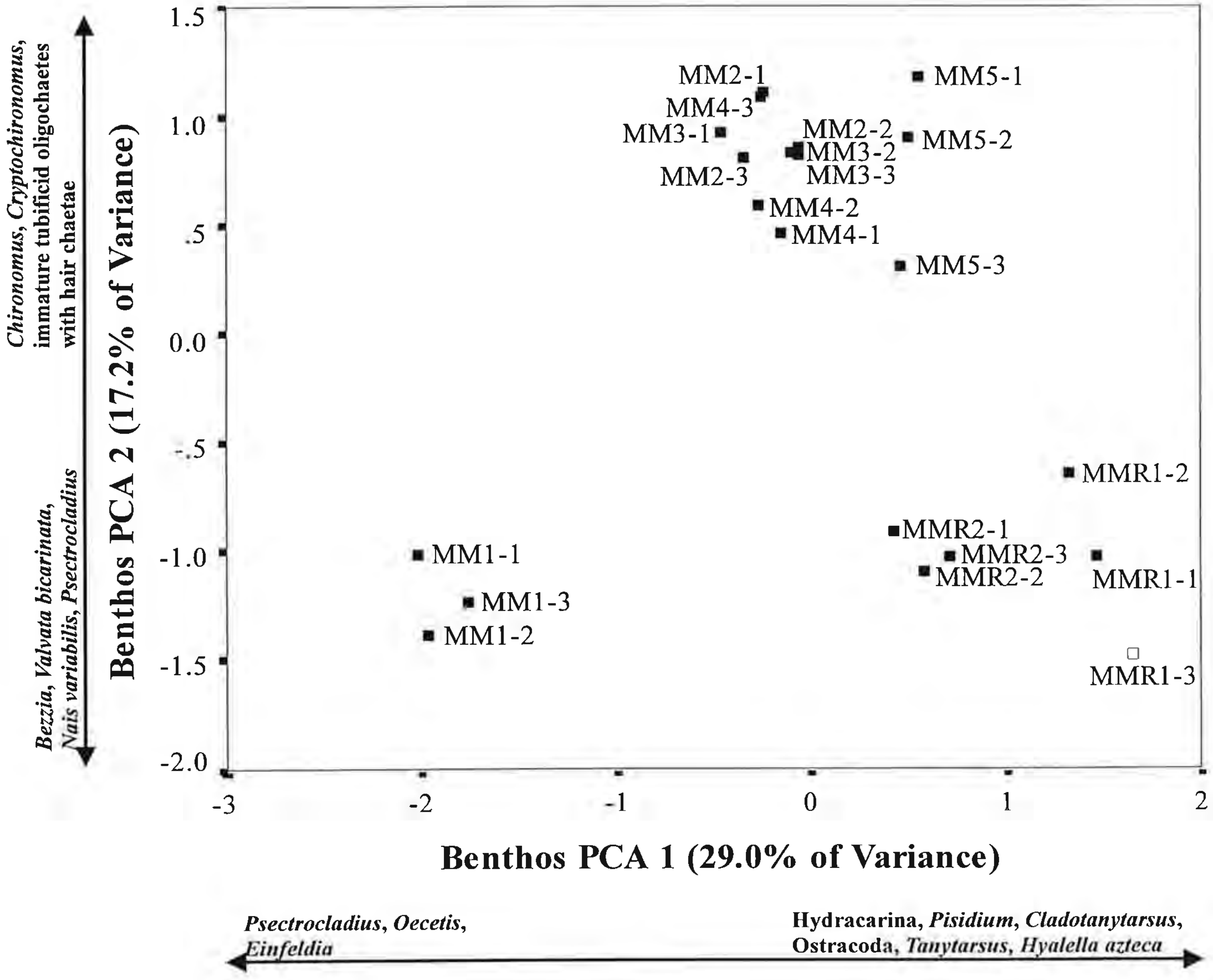


Relative Contributions of Physical-Chemical Variables to Sediment Principal Components at Mattabi Mines

(Total Metal Extraction Technique)

	Principal Components		
	1	2	3
%Variance Explained	65.5	14.3	10.1
Zinc_Total	0.9858	-0.0047	-0.0586
Iron_Total	0.9730	0.0900	0.0763
Cadmium_Total	0.9711	0.1120	-0.0076
Copper_Total	0.9698	-0.0571	-0.1074
Nickel_Total	0.9628	-0.1344	0.0297
Dry Bulk Density	0.9489	-0.1100	-0.0304
Lead_Total	0.9443	0.1241	-0.0744
Selenium_Total	0.8962	0.0965	-0.0876
Arsenic_Total	0.8899	0.2882	0.0815
SEM/AVS	0.1355	0.3999	0.8263
%Gravel	0.1137	-0.0620	0.9030
%Sand	-0.0015	-0.9691	0.1687
%Fines	-0.0039	0.9670	-0.1225
%TOC	-0.8436	0.2221	-0.1259
Eh	-0.8524	0.0937	0.1366
%Moisture	-0.9503	0.1476	0.0348

Benthic Macroinvertebrate PCA Results
Mattabi Mines Lake Stations



Relative Contributions of Benthic Macroinvertebate Taxa to Benthic Principal Components at Mattabi Mines , October 1997

	Principal Components										
	1	2	3	4	5	6	7	8	9	10	11
% Variance Explained	29.0	17.2	11.3	8.6	5.6	4.9	3.8	3.4	2.9	2.5	2.2
Hydracarina	0.9000	0.1831	0.1360	-0.0213	-0.1773	-0.0170	-0.0807	0.1471	-0.1322	-0.0512	-0.0504
Pisidium	0.8938	0.3755	0.1079	0.1270	0.0513	-0.0370	0.0972	0.0191	-0.0299	-0.0536	0.0021
Cladotanytarsus	0.8826	-0.0120	0.0280	-0.0954	0.1670	0.2949	-0.0970	-0.0831	0.1093	-0.0944	0.1187
Cl. Ostracoda	0.8258	0.3998	0.2490	-0.1872	0.0588	0.0493	0.0100	0.1262	-0.0910	-0.0928	-0.0386
Tanytarsus	0.8221	-0.0914	-0.3747	-0.0738	-0.0723	0.0472	0.0256	-0.3426	-0.0209	-0.1069	-0.0137
Hyalella azteca	0.8071	-0.1781	-0.1411	0.2745	0.0412	0.2545	0.0397	0.1390	0.1320	-0.0996	0.2173
Caenis	0.7404	0.5221	0.1721	-0.1022	-0.1433	0.0773	0.0437	0.2106	-0.1578	-0.0026	0.0855
Gyraulus	0.6774	-0.0863	-0.4353	0.0701	-0.0369	-0.2492	0.0009	-0.2465	0.1059	-0.2004	0.0150
Dicrotendipes	0.6610	0.5926	-0.1220	0.1124	0.3007	0.1688	-0.0687	-0.0021	-0.0579	-0.0231	0.0525
Polypedilum	0.6444	0.5572	0.2190	0.1243	0.3249	-0.0787	0.0408	0.0456	-0.1933	-0.1035	-0.0026
Lauterborniella	0.6393	-0.2244	0.0716	-0.1725	-0.0953	-0.4795	-0.2039	0.2058	0.0357	-0.0574	-0.1427
O. Harpacticoida	0.6329	-0.3343	-0.4172	-0.2956	-0.1942	-0.0846	-0.2610	0.0801	0.1010	0.2382	-0.0171
Zalutschia	0.6139	-0.4356	-0.4113	-0.4187	-0.1561	-0.0700	-0.0661	0.0335	0.0486	0.1886	0.0117
Amnicola sp.	0.6046	-0.4581	-0.4184	-0.3712	-0.0622	-0.1460	-0.1312	0.1132	0.0187	0.1573	0.0982
Procladius	0.5610	0.1870	0.5072	0.0305	-0.3998	0.1463	-0.1145	0.0709	-0.1185	0.2600	0.1788
Nais variabilis	0.5271	-0.5209	0.2363	-0.2185	-0.1130	-0.1079	-0.0849	-0.2263	0.0017	-0.2149	0.2706
O. Tricladida	0.5229	-0.1874	-0.5898	-0.1772	-0.0092	0.3393	0.1365	0.1075	-0.3154	-0.0444	-0.0621
P. Nematoda	0.5063	0.0173	0.3120	0.3229	-0.0309	-0.3273	-0.2568	0.1690	0.1138	0.1239	-0.2322
Slavina appendiculata	0.5018	-0.3140	-0.6043	0.0581	0.3519	-0.0375	0.0946	0.2190	-0.0413	-0.0517	-0.0044
Paratanytarsus	0.4687	-0.3331	0.1052	0.4715	0.2825	0.1582	0.4210	-0.0370	0.1791	-0.0416	-0.2955
Parachironomus	0.4437	-0.3839	0.2829	-0.2535	0.3930	-0.1982	0.1851	0.2834	0.1524	0.0977	-0.0208
Valvata bicarinata	0.4108	-0.5554	0.5840	0.1606	0.1514	-0.0873	-0.0772	0.0863	-0.1080	-0.1048	0.2144
Chaoborus punctipennis	0.4026	-0.0308	-0.0866	-0.0287	-0.5313	0.1321	0.5389	-0.3121	-0.0255	0.2611	-0.0887
Oxyethira	0.3704	0.1364	-0.5289	0.5565	0.2543	0.0696	0.1721	-0.1199	0.2164	0.1448	-0.2143
Helobdella stagnalis	0.3599	0.1538	-0.4665	0.5937	0.2045	-0.1072	-0.1131	-0.1176	0.0565	0.0975	0.3050
Cladopelma	0.3114	0.5913	0.2368	-0.3401	-0.0183	-0.1297	-0.0396	-0.1762	0.4523	-0.0953	-0.2747
Cryptochironomus	0.2816	0.6885	-0.0947	-0.0316	-0.1471	0.3425	0.1978	0.2987	0.1258	0.2307	-0.0492
Stempellinella	0.2523	0.5310	0.6294	0.1040	-0.2262	-0.1480	-0.0098	-0.2369	-0.0158	0.1426	0.0771
Chaoborus albatus	0.2405	-0.4227	0.7912	0.2804	0.1262	0.0548	0.0974	-0.0386	-0.0205	-0.1428	-0.0183
Endochironomus	0.2166	0.2035	0.3027	0.6135	-0.0945	-0.1547	-0.1629	-0.1769	0.2565	0.3985	0.0439
Vejdovskyella comata	0.1602	0.1185	0.0343	0.6647	0.1962	0.1407	-0.3254	0.3877	-0.1277	0.1405	-0.0203
Stempellina	-0.0015	0.5065	0.0140	-0.1392	0.1281	0.1743	-0.4152	-0.4041	-0.4186	0.0017	-0.2321
Specaria josinae	-0.0219	0.4998	-0.0293	0.1751	-0.6366	0.2365	0.1008	0.2204	0.1511	-0.1627	0.1053
Pagastiella	-0.0589	-0.3712	0.5092	-0.2130	-0.0546	0.6410	0.0988	0.1130	0.0965	-0.1177	-0.1036
Paratendipes	-0.1428	0.4545	0.1550	-0.5421	0.4678	0.1765	0.0014	0.1632	0.0694	0.0732	-0.0972
Sphaeromias	-0.1608	0.5290	0.2089	-0.4813	0.3713	-0.3488	0.0920	-0.0391	-0.0387	0.1558	-0.0873
Ilyodrilus templetoni	-0.2849	0.2817	0.0260	-0.1710	-0.1253	-0.5175	0.4158	0.3058	0.1599	-0.1144	0.2000
Bezzia	-0.3215	-0.6855	0.5327	0.2810	0.1031	0.0344	0.0557	-0.0810	0.0235	-0.0257	0.0346
Chironomus	-0.3335	0.8703	-0.1923	0.0898	0.0522	-0.0412	0.0366	0.0038	-0.0654	-0.0182	0.1191
Tribelos	-0.3641	0.1248	0.0875	-0.4083	0.4693	0.2427	0.0385	-0.1795	0.1811	0.2960	0.3650
immatures with hair chaetae	-0.5422	0.6280	-0.1841	0.1774	-0.0649	-0.2395	0.0797	-0.0023	-0.1142	-0.2455	0.0528
Guttipelopia	-0.5573	-0.2939	-0.1319	0.1118	-0.2967	0.0738	-0.3592	0.1971	0.1179	-0.1010	-0.2566
Ablabesmyia	-0.5765	0.5170	-0.3820	0.2957	0.0034	-0.0819	0.0164	0.1166	0.0412	-0.1478	0.0850
Einfeldia	-0.6395	0.2367	-0.0711	-0.1966	-0.0027	0.3363	-0.3818	0.1096	0.3758	-0.0503	0.1054
Oecetis	-0.6445	-0.3067	0.0381	0.0505	-0.0569	-0.1109	0.2261	0.1986	-0.4225	0.3243	-0.0496
Psectrocladius	-0.7389	-0.5245	-0.2459	0.2324	0.1214	0.0356	-0.0082	-0.0163	-0.0185	0.0833	0.0450

Mattabi Mines
Sediment Quality Triad Correlations for Lakes
(Partial metals used in sediment chemistry)

x variable	y variable(s)	R	p
Sediment Chemistry x Benthos			
SPC1	BPC1	0.814	<0.001
SPC1	BPC2	0.177	0.443
SPC2	BPC1	0.343	0.128
SPC2	BPC2	0.455	0.038
Sediment Chemistry x Toxicity			
SPC1	*Chironomus Growth, Tubifex* Young, *Tubifex* %Cocoons	0.476	0.214
SPC2	*Chironomus Growth, Tubifex* Young, *Tubifex* %Cocoons	0.660	0.019
Benthos x Toxicity			
BPC1	*Chironomus Growth, Tubifex* Young, *Tubifex* %Cocoons	0.576	0.07
BPC2	*Chironomus Growth, Tubifex* Young, *Tubifex* %Cocoons	0.787	0.001

▨ - statistically significant at p=0.05

Mattabi Mines
Sediment Quality Triad Correlations for Lakes
(Total metals used in sediment chemistry)

x variable	y variable(s)	R	p
Sediment Chemistry x Benthos			
SPC1	BPC1	0.316	0.163
SPC1	BPC2	0.263	0.250
SPC2	BPC1	0.226	0.324
SPC2	BPC2	0.437	0.048
Sediment Chemistry x Toxicity			
SPC1	*Chironomus Growth, Tubifex* #Young, *Tubifex* %Cocoons	0.547	0.102
SPC2	*Chironomus Growth, Tubifex* #Young, *Tubifex* %Cocoons	0.531	0.122
Benthos x Toxicity			
BPC1	*Chironomus Growth, Tubifex* #Young, *Tubifex* %Cocoons	0.576	0.070
BPC2	*Chironomus Growth, Tubifex* #Young, *Tubifex* %Cocoons	0.787	0.001

▨ - statistically significant at p=0.05

Mattabi
Sediment Quality Triad - Mantel's Tests
Comparison of Euclidean Distance Matrices

Matrix 1	Matrix 2	Z_M	p
Sediment Chemistry[1]	Benthic Community	0.182	0.409
Sediment Chemistry[1]	Sediment Toxicity[2]	0.316	0.222
Benthic Community	Sediment Toxicity[2]	0.234	0.314

Results based on 10,000 Iterations

▨ - statistically significant at p=0.05

[1] based on total extraction results

[2] based on *Chironomus* and *Hyalella* %mortality and growth and *Tubifex* cocoons and #adults

MATTABI
SEDIMENT QUALITY TRIAD
BENTHIC COMMUNITY - EUCLIDEAN DISTANCE MATRIX

	Lake Sampling Station																				
Case	R1-1	R1-2	R1-3	R2-1	R2-2	R2-3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1	5-2	5-3
R1-1	0.00000																				
R1-2	0.10621	0.00000																			
R1-3	0.07416	0.00000	0.00000																		
R2-1	0.63431	0.64750	0.59299	0.00000																	
R2-2	0.61379	0.61100	0.55628	0.23605	0.00000																
R2-3	0.56029	0.57507	0.52945	0.16321	0.22533	0.00000															
1-1	0.59434	0.62270	0.56811	0.37873	0.44324	0.31704	0.00000														
1-2	0.61442	0.63611	0.59570	0.31936	0.26329	0.28065	0.33566	0.00000													
1-3	0.62253	0.61823	0.56976	0.26900	0.35191	0.33580	0.23833	0.25986	0.00000												
2-1	0.55723	0.56554	0.50130	0.30860	0.26796	0.32889	0.36741	0.29476	0.28808	0.00000											
2-2	0.57733	0.55181	0.51064	0.34696	0.26911	0.28636	0.35194	0.23498	0.32648	0.28185	0.00000										
2-3	0.56990	0.58262	0.52854	0.27280	0.29834	0.28343	0.24571	0.23425	0.23499	0.23939	0.23750	0.00000									
3-1	0.76406	0.76086	0.71357	0.38806	0.36354	0.41351	0.43560	0.30958	0.25222	0.41409	0.34458	0.34209	0.00000								
3-2	0.75915	0.75580	0.70062	0.47126	0.41611	0.46085	0.46748	0.36708	0.36392	0.35794	0.41130	0.32191	0.27550	0.00000							
3-3	0.77662	0.77810	0.73043	0.60811	0.51163	0.57114	0.64493	0.48710	0.52456	0.48739	0.57812	0.54443	0.46656	0.40821	0.00000						
4-1	0.98574	0.94390	0.90750	0.73070	0.65704	0.72283	0.79036	0.67310	0.68714	0.68455	0.71942	0.75283	0.64800	0.66802	0.69443	0.00000					
4-2	0.94213	0.89690	0.85538	0.59345	0.58120	0.63862	0.71509	0.54476	0.57810	0.55370	0.60861	0.63959	0.54695	0.62080	0.71446	0.33362	0.00000				
4-3	1.00000	0.95105	0.91047	0.77192	0.70294	0.75841	0.79614	0.70615	0.67342	0.71317	0.73302	0.77477	0.63036	0.71181	0.72014	0.42099	0.35675	0.00000			
5-1	0.71613	0.67604	0.63455	0.53507	0.54079	0.49697	0.56054	0.54139	0.54480	0.48057	0.47893	0.54683	0.55507	0.56763	0.66663	0.65862	0.62915	0.66073	0.00000		
5-2	0.79005	0.74445	0.71033	0.54221	0.55375	0.53411	0.60870	0.55561	0.52378	0.54534	0.55172	0.56897	0.58501	0.56853	0.72318	0.62323	0.56809	0.63002	0.24039	0.00000	
5-3	0.76106	0.71615	0.69629	0.50567	0.52493	0.48671	0.57641	0.48202	0.45760	0.46056	0.51838	0.53233	0.55719	0.52000	0.65627	0.57508	0.51509	0.56142	0.24707	0.18322	0.00000

MATTABI
SEDIMENT QUALITY TRIAD
SEDIMENT TOXICITY - EUCLIDEAN DISTANCE MATRIX

	Lake Sampling Station																				
Case	R1-1	R1-2	R1-3	R2-1	R2-2	R2-3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1	5-2	5-3
R1-1	0.00000																				
R1-2	0.96291	0.00000																			
R1-3	0.39313	0.67800	0.00000																		
R2-1	0.62108	1.29337	0.70843	0.00000																	
R2-2	0.51054	1.14940	0.71472	0.73627	0.00000																
R2-3	0.65460	1.18445	0.67423	0.77231	0.52558	0.00000															
1-1	0.69765	1.33398	0.91586	1.14353	0.64645	0.77799	0.00000														
1-2	0.93035	0.83993	0.88437	1.36272	0.84758	0.90713	0.90641	0.00000													
1-3	0.83596	0.90627	0.76438	1.27731	0.79485	0.73043	0.66398	0.46894	0.00000												
2-1	0.35528	1.18581	0.60410	0.63956	0.38320	0.42591	0.63323	0.98060	0.84164	0.00000											
2-2	0.57260	1.34826	0.91822	1.05066	0.72682	1.02245	0.54301	1.13250	1.02389	0.65723	0.00000										
2-3	0.56766	0.70266	0.54271	1.09566	0.64963	0.76033	0.65615	0.50051	0.39489	0.69009	0.78520	0.00000									
3-1	0.69773	1.62277	1.06825	0.81578	0.82825	1.06170	0.96546	1.47176	1.41205	0.66833	0.61288	1.17586	0.00000								
3-2	0.90267	1.11578	0.99694	1.50807	1.05364	1.19117	0.69223	0.89158	0.73409	1.01513	0.73976	0.59099	1.29775	0.00000							
3-3	1.41359	1.37539	1.50583	2.00583	1.57433	1.82607	1.31479	1.25846	1.32093	1.60971	1.18155	1.12106	1.71618	0.73789	0.00000						
4-1	0.49047	0.72509	0.25934	0.78307	0.85519	0.85838	0.95199	1.02202	0.85513	0.75502	0.92476	0.63793	1.12814	0.99752	1.47623	0.00000					
4-2	0.77439	0.71559	0.41845	0.89004	0.98379	0.78158	1.21393	1.08061	0.91488	0.86858	1.28966	0.80621	1.39522	1.26296	1.79494	0.53070	0.00000				
4-3	0.55702	0.72348	0.49091	1.08198	0.90199	0.95356	0.89187	0.93414	0.78761	0.76870	0.80394	0.48471	1.12673	0.65559	1.15039	0.51629	0.71546	0.00000			
5-1	0.49318	1.23436	0.70008	0.91853	0.66479	0.63940	0.59398	1.06361	0.83948	0.36506	0.60415	0.69439	0.76773	0.82154	1.47288	0.80396	0.93162	0.63980	0.00000		
5-2	0.76820	0.82412	0.63849	1.20252	0.94213	0.82859	0.97654	0.90272	0.70888	0.79683	1.05677	0.57353	1.31490	0.81529	1.39626	0.77411	0.65621	0.44727	0.65052	0.00000	
5-3	0.42185	1.21592	0.64957	0.59999	0.39764	0.52510	0.73810	1.09445	0.94736	0.20660	0.70046	0.76594	0.66600	1.08938	1.67003	0.78412	0.87486	0.79726	0.43346	0.82689	0.00000

MATTABI
SEDIMENT QUALITY TRIAD
SEDIMENT CHEMISTRY - EUCLIDEAN DISTANCE MATRIX

	Lake Sampling Station																				
Case	R1-1	R1-2	R1-3	R2-1	R2-2	R2-3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1	5-2	5-3
R1-1	0.00000																				
R1-2	0.26317	0.00000																			
R1-3	0.27217	0.00000	0.00000																		
R2-1	0.40976	0.25427	0.23915	0.00000																	
R2-2	0.58581	0.46571	0.42427	0.36759	0.00000																
R2-3	0.39740	0.23346	0.21211	0.13522	0.29969	0.00000															
1-1	0.63736	0.58671	0.59804	0.81530	0.82761	0.73902	0.00000														
1-2	0.74730	0.70565	0.72134	0.93095	0.95892	0.85933	0.15576	0.00000													
1-3	0.70997	0.78328	0.79585	0.98821	1.00000	0.91565	0.32864	0.26028	0.00000												
2-1	0.61631	0.55134	0.56273	0.77798	0.80967	0.71103	0.14372	0.15495	0.32700	0.00000											
2-2	0.56827	0.49186	0.50578	0.71181	0.76988	0.65146	0.21385	0.22838	0.37142	0.07890	0.00000										
2-3	0.64067	0.58092	0.59621	0.81055	0.86011	0.74389	0.15545	0.12495	0.31219	0.02648	0.08026	0.00000									
3-1	0.50316	0.42466	0.42964	0.63222	0.68615	0.58474	0.24780	0.32916	0.44805	0.17762	0.20559	0.22803	0.00000								
3-2	0.56690	0.49084	0.49555	0.69662	0.71911	0.63247	0.20889	0.24942	0.37829	0.08655	0.10698	0.13457	0.09784	0.00000							
3-3	0.51226	0.42826	0.44276	0.63764	0.72034	0.56665	0.25892	0.29472	0.41538	0.16527	0.09831	0.16524	0.18817	0.12522	0.00000						
4-1	0.50892	0.43013	0.43587	0.67221	0.68783	0.59727	0.16385	0.28132	0.41325	0.12069	0.15216	0.17258	0.13079	0.11606	0.17714	0.00000					
4-2	0.31600	0.18294	0.19191	0.44353	0.54060	0.37769	0.39753	0.52465	0.61631	0.38933	0.34451	0.41740	0.28507	0.33621	0.28334	0.25254	0.00000				
4-3	0.38383	0.26234	0.26912	0.46069	0.55498	0.40126	0.34885	0.44593	0.54050	0.29297	0.24257	0.32622	0.17015	0.21080	0.16194	0.20717	0.15130	0.00000			
5-1	0.40606	0.30878	0.32066	0.53166	0.61479	0.47489	0.26248	0.38290	0.49306	0.24234	0.21428	0.27588	0.14138	0.19339	0.16735	0.14437	0.14868	0.07063	0.00000		
5-2	0.47119	0.38319	0.38882	0.59359	0.62495	0.52858	0.21104	0.33337	0.44859	0.18267	0.17468	0.23004	0.12343	0.13860	0.16790	0.09354	0.22144	0.12611	0.05439	0.00000	
5-3	0.45084	0.36551	0.38135	0.58704	0.68440	0.53806	0.22906	0.32831	0.45151	0.18593	0.16147	0.21247	0.11106	0.15217	0.12813	0.13436	0.21746	0.11248	0.03719	0.06831	0.00000