AQUATIC EFFECTS TECHNOLOGY EVALUATION (AETE) PROGRAM

1996 Preliminary Field Survey
Lupin Mine Site,
Northwest Territories

AETE Project 4.1.2

1996 Preliminary Field Survey
Lupin Mine Site, Northwest Territories

Sponsored by :

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

on Behalf of :

Aquatic Effects Technology Evaluation (AETE) Program

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AQUATIC EFFECTS TECHNOLOGY EVALUATION PROGRAM

Notice to Readers

Aquatic Effects Monitoring
1996 Preliminary Field Surveys

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

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

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

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

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

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

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

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

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

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

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

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

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

Avis aux lecteurs

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

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

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

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

Étape I	1996 - Évaluation préliminaire sur le terrain des sept sites miniers candidats, sélection des sites où se poursuivront les évaluations et préparation des plans d'étude pour les évaluations sur le terrain.
Étape II	1997- Réalisation des travaux en laboratoire et sur le terrain aux sites choisis
Étape III	1998 -Interprétation des données, évaluation comparative des méthodes de surveillance; rédaction du rapport.

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

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

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

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

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

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

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EXECUTIVE SUMMARY

As part of the Aquatic Effects Technology Evaluation (AETE) Program, a field survey was conducted of the Lupin Mine in the North West Territories. This site has been suggested as a candidate for detailed testing of monitoring tools in 1997 studies sponsored by the AETE Program. The purpose of this survey was to provide information on whether or not to include this site in 1997 and, if so, for what particular hypotheses.

As part of this field survey, available historical information was reviewed. Transitory changes in water quality (copper, zinc, arsenic concentrations) have occurred related to effluent discharges. Historic data provided evidence for metals accumulation in sediments but no clear relationship between contamination and biological effects. Metallothionein measurements have not been made. Lake trout have elevated arsenic concentrations in their livers apparently related to the effluent discharge, but again there is no evidence of adverse effects related to this contamination.

Effluent discharge only occurs over a two week period in the summer; because the field survey was conducted in September soon after the work was contracted, neither effluent quality nor water quality during discharge could be assessed. However, data from the mine indicate the effluent is not acutely toxic nor are Permit limits exceeded.

Field studies were conducted at an exposure area (Sun Bay) and a reference area (South Bay), both in Contwoyto Lake. Significant elevations in some parameters occurred at the reference area compared to the exposure area. Some parameters exceeded Canadian freshwater guidelines for the protection of aquatic life at both exposure and reference areas. However, no conclusions are possible relative to conditions during effluent discharge, since the mine was not discharging.

Sediments showed significant elevations in some metals at the exposure area compared to the reference area. Arsenic was identified as a contaminant of concern in both areas relative to Canadian interim sediment quality criteria; nickel was identified as such only in the exposure area. However, arsenic (and most other metals) concentrations in the reference area are comparable to pre-discharge concentrations.

There was no significant difference between reference and exposure areas for total abundance or species richness of the benthos. However, some species were specific to one area and not the other, and habitat differences between the two areas may have confounded the comparison.

Three fish species (lake trout, round whitefish, lake cisco) were collected in sufficient numbers to be considered potential sentinel species; an additional species, burbot, was collected in low numbers but in both areas. Overall, catches were not abundant, and neither tissue nor metallothionein analyses were conducted due to the relative paucity of the catches. Additional information regarding this site is provided in Table ES-1.

Overall, the exposure and reference areas were judged acceptable for 1997 studies by the AETE Program. Fish can be collected with reasonable effort; burbot is the preferred sentinel species (if adequate numbers can be collected using angling or trap nets). Sediments and historic water quality data show differences between reference (lower) and exposure areas (higher) for some parameters. Sediment quality triad-type studies can be conducted.

Table ES-1. Summary information for specific study elements for the Lupin mine site (stream/lake discharge).

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

Table ES-1. Continued.

ELEMENT	SAMPLED 1996	SUMMARY/COMMENTS
3.2.2 Fathead Minnow	No	Mine not discharging
3.2.3 *Selenastrum capricornutum*	No	Mine not discharging
3.2.4 *Lemna minor*	No	Mine not discharging
3.2.5 Trout embryo	No	Mine not discharging
4.0 Habitats	Yes	Multiple reference and exposure stations of uniform habitat type available within bays surveyed; suitability of other reference areas unknown Significant differences between reference and exposure areas (depth, fines, TOC, loss on ignition) Distance between reference and exposure areas substantial (approx. 2 h by boat)
5.0 Water Chemistry	Yes	Reference area has elevated concentrations of some contaminants compared with the exposure area; it is presumed this would reverse during discharge Effluent not being discharged so these data of limited utility but are comparable to historic data
6.0 Sediments	yes	Good substrate for sampling sediments with Petite Ponar Most contaminants in sediments elevated at the exposure stations compared with the reference stations; arsenic particularly elevated; results comparable to historic data Well defined sediment chemistry gradient Sediment suitable for toxicity testing; collection of sediments not difficult

Table ES-1. Continued.

ELEMENT	SAMPLED 1996	SUMMARY/COMMENTS
7.0 Benthic Invertebrates	Yes	No difference between reference and exposure areas for total abundance or species richness. Habitat differences may confound differences in benthos Some species specific to exposure or reference sites
8.0 Fisheries 8.1 Communities	Yes	Sentinel species and large fish available in required numbers with what should be an acceptable level of effort (e.g., burbot, lake trout, round whitefish, lake cisco) Not enough data to determine whether fish population gradients exist between reference and exposure areas No physical barriers to migration
8.2 Tish Tissue	No	Large fish are available but increased effort needed to attain sufficient numbers of sentinel species

SOMMAIRE

Dans le cadre du Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ÉTIMA), une étude sur le terrain a été menée à la mine Lupin dans les Territoires du Nord-Ouest. L'endroit a été proposé comme site possible pour l'essai détaillé d'outils de surveillance aux fins de recherches prévues pour 1997 dans le cadre du programme ÉTIMA. Le but de l'étude était de fournir des renseignements permettant de décider s'il fallait utiliser ou non ce site en 1997, et dans l'affirmative, pour la vérification de quelles hypothèses en particulier.

Au cours de cette étude sur le terrain, on a passé en revue les données historiques existantes. Des changements temporaires se sont produits dans la qualité de l'eau (concentrations de cuivre, de zinc et d'arsenic) qui étaient liés aux rejets d'effluent. Les données historiques prouvent que des métaux s'accumulent dans les sédiments, sans que l'on puisse établir de corrélation évidente entre la contamination et les effets biologiques. La teneur en métallothionéine n'a pas été mesurée. On a trouvé dans le foie du touladi des concentrations élevées d'arsenic qui semblent liées aux rejets d'effluents, mais là encore, l'existence d'effets néfastes imputables à cette contamination n'est pas prouvée.

Le rejet de l'effluent se limite à une période de deux semaines à la fin de l'été; comme l'étude sur le terrain a été réalisée en septembre, peu de temps après l'octroi du contrat, on n'a pu évaluer ni la qualité de l'effluent, ni la qualité de l'eau pendant la période de rejet de l'effluent. Selon les données provenant des responsables de la mine, l'effluent n'est cependant pas très toxique et les limites stipulées dans le permis sont respectées.

Les études sur le terrain ont été menées dans une zone d'exposition (baie Sun) et une zone de référence (baie South), toutes deux situées dans le lac Contwoyto. Pour certains paramètres, des élévations importantes ont été observées dans la zone de référence par rapport à la zone d'exposition. Certains paramètres excédaient les directives canadiennes relatives à la qualité des eaux douces pour la protection de la vie aquatique dans la zone d'exposition et dans la zone de référence. Toutefois, il est impossible de tirer des conclusions sur les conditions qui existent pendant le rejet de l'effluent, car la mine ne rejetait pas d'effluent au moment de l'étude.

En ce qui a trait aux sédiments, on a noté des augmentations importantes de la concentration de certains métaux dans la zone d'exposition comparativement aux teneurs dans la zone de référence. L'arsenic est considéré comme un contaminant préoccupant dans les deux zones par rapport aux critères provisoires du Canada relativement à la qualité des sédiments, mais le nickel n'est défini comme contaminant préoccupant que dans la zone d'exposition. Toutefois, les concentrations d'arsenic (et de la plupart des autres métaux) dans la zone de référence sont comparables aux teneurs observées avant la période de rejet.

Il n'y avait pas de différence importante entre les zones de référence et d'exposition quant à l'abondance et à la diversité des espèces dans le benthos. Néanmoins, certaines espèces ne se trouvaient que dans une seule des deux zones, et les différences entre les deux zones du point de vue de l'habitat peuvent constituer des facteurs d'erreur dans la comparaison des résultats.

Trois espèces de poissons (touladi, ménomini rond et cisco de lac) ont été capturées en nombre suffisant pour être considérées comme des espèces indicatrices possibles; une autre espèce, la lotte, a été récoltée en faible nombre dans les deux zones. Dans l'ensemble, les prises n'étaient pas abondantes, et l'on n'a pas fait d'analyses de tissus ni de métallothionéine à cause de la pauvreté relative des prises. On trouvera dans le tableau ES-1 d'autres informations sur cette mine.

Dans l'ensemble, les responsables du programme ÉTIMA ont jugé les zones d'exposition et de référence acceptables pour les études de 1997. On peut y prélever du poisson sans trop d'efforts; la lotte serait la meilleure espèce indicatrice (si l'on peut en capturer un nombre suffisant à l'aide de lignes à pêche ou de filets-pièges). Les données relatives aux sédiments et les données historiques sur la qualité de l'eau présentent certaines différences de concentrations entre la zone de référence (plus faibles) et la zone d'exposition (plus élevées) pour certains paramètres. On peut mener des études fondées sur des triades en ce qui concerne la qualité des sédiments.

Tableau ES-1. Résumé de l'information concernant certains éléments de l'étude relative à la mine Lupin (rejet dans le cours d'eau et le lac).

Élément	Échantillons prélevés en 1996	Sommaire/remarques
1.0 Revue des données historiques 1.1 Caractérisation de l'effluent	s.o.	Les essais sur la truite arc-en-ciel et *Daphnia magna* ainsi que les tests Microtox indiquent qu'il y a peu de toxicité aiguë, sinon aucune. Les changements apportés antérieurement au procédé ont amélioré la qualité de l'effluent.
1.2 Chimie de l'eau	s.o.	Des données de référence et des données de surveillance ont été recueillies avant les rejets.
1.3 Chimie des sédiments	s.o.	Des données de référence et des données de surveillance ont été recueillies avant les rejets.
1.4 Benthos	s.o.	Des données de référence et des données de surveillance ont été recueillies avant les rejets.
1.5 Pêches 1.5.1 Population	s.o.	Il existe certaines données de référence; les activités de surveillance menées avant les rejets n'étaient pas axées sur les populations de poissons.
1.5.2 Tissus	s.o.	D'après les données historiques, l'arsenic s'accumule dans les tissus des poissons. Il n'y a pas de données historiques sur la métallothionéine.
2.0 Zone d'étude 2.1 Accès au site	s.o.	Un trajet d'environ une heure en bateau permet de se rendre à la mine Lupin dans la zone d'exposition (baie Sun) ou dans la zone de référence (baie South), et le trajet entre ces deux sites dure approximativement deux heures. Les vents peuvent être assez forts pour empêcher l'accès par bateau; les recherches doivent être réalisées par beau temps. On pourrait aussi accéder aux sites à pied (6 à 10 km) ou par hélicoptère (coûteux).
2.2 Disponibilité de plusieurs zones de référence et d'exposition	s.o.	Plusieurs zones d'exposition et de référence présentant un type d'habitat uniforme sont accessibles dans les baies à l'étude; le caractère approprié d'autres zones de référence n'est pas connu.
2.3 Rejets au même endroit	s.o.	Aucun.

Tableau ES-1. Suite.

Élément	Échantillons prélevés en 1996	Sommaire/remarques
3.0 Effluent et toxicité sublétale 3.1 Fréquence des rejets d'effluent	s.o.	L'effluent est rejeté deux semaines par année, à la fin de l'été.
3.2 Toxicité sublétale 3.2.1 *Ceriodaphnia dubia*	Non	Pas de rejet d'effluent minier.
3.2.2 Tête-de-boule	Non	Pas de rejet d'effluent minier.
3.2.3 *Selenastrum capricornutum*	Non	Pas de rejet d'effluent minier.
3.2.4 *Lemna minor*	Non	Pas de rejet d'effluent minier.
3.2.5 Embryon de truite	Non	Pas de rejet d'effluent minier.
4.0 Habitats	Oui	Plusieurs sites présentant un type d'habitat uniforme sont accessibles dans les zones d'exposition et de référence dans les baies visées par l'étude; le caractère approprié d'autres zones de référence n'est pas connu. Différences importantes entre les zones de référence et d'exposition (profondeur, particules fines, COT, perte par calcination). Distance appréciable entre les zones de référence et d'exposition (environ 2 h de bateau).
5.0 Chimie de l'eau	Oui	Dans la zone de référence, on a noté des concentrations élevées de certains contaminants par rapport à la zone d'exposition; on suppose que cette situation serait inversée pendant la période de rejet de l'effluent. Comme il n'y avait pas de rejet d'effluent, ces données sont d'une utilité restreinte, mais elles sont comparables aux données historiques.
6.0 Sédiments	Oui	Substrat approprié pour l'échantillonnage des sédiments avec l'emploi d'un dispositif Pelite Ponar. Dans la plupart des cas, la concentration des contaminants est plus élevée dans la zone d'exposition que dans la zone de référence; les teneurs en arsenic sont particulièrement élevées; les résultats se comparent aux données historiques. Gradient bien défini en ce qui a trait à la chimie des sédiments. Les sédiments conviennent aux tests de toxicité et sont faciles à prélever.
7.0 Invertébrés benthiques	Oui	Il n'y a pas de différence entre la zone d'exposition

Tableau ES-1. Suite.

Élément	Échantillons prélevés en 1996	Sommaire/remarques
		et la zone de référence du point de vue de l'abondance ou de la diversité des espèces dans l'ensemble. Les différences dans l'habitat peuvent fausser les valeurs de la composition du benthos. Certaines espèces ne se retrouvent que dans la zone d'exposition ou la zone de référence.
8.0 Pêches 8.1 Communautés	Oui	On peut obtenir le nombre requis d'espèces indicatrices et de gros poissons en déployant un effort jugé acceptable (p. ex., lotte, touladi, ménomini rond, cisco de lac). Il n'y a pas assez de données pour déterminer s'il existe un gradient des populations de poissons entre la zone de référence et la zone d'exposition. Pas d'obstacles physiques aux migrations.
8.2 Tissus de poissons	Non	Il y a de gros poissons, mais il faut déployer plus d'efforts pour capturer un nombre suffisant d'individus des espèces indicatrices.

1.0
INTRODUCTION

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

Building upon previous work, which includes literature reviews, technical evaluations, and pilot field studies, the AETE Program sponsored, in 1996, preliminary evaluations of aquatic effects monitoring at seven candidate mine sites. Based on the results of these preliminary evaluations, some of these sites have been recommended for further work in 1997.

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

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2.0
SITE SPECIFIC BACKGROUND INFORMATION

2.1 SITE DESCRIPTION

Echo Bay's Lupin Mine is located on the western shore of Contwoyto Lake (65° 46′N and 111° 15′W; Murdoch and Sutherland, 1988) in the Northwest Territories approximately 375 km northeast of Yellowknife (Figure 2-1). Liquid and solid wastes were first discharged from the tailings pond in the autumn of 1985 over a period of a few weeks. Approximately four million cubic meters (m^3) of liquid effluent was discharged to Contwoyto Lake via Seep Creek and Unnamed Lake to Sun Bay (Murdoch and Sutherland, 1988). Effluent (675,000 m^3) is currently discharged for approximately two weeks annually during late summer/early autumn (Wilson, 1991). Water flows (from Inner Sun Bay to Outer Sun Bay) through a 25 m wide and 250 m long channel (Murdoch and Sutherland, 1988). Inner Sun Bay is relatively shallow with mean and maximum depths of 1.7 m and 6.5 m, respectively (Murdoch and Sutherland, 1988), while water depth in Outer Sun Bay is generally deeper than 10 m (Reid, Crowther and Partners, and R.L. and L., 1985).

In our 1996 field survey, Sun Bay served as the exposure site, while South Bay, southeast of Lupin Mine, served as the reference site. Water flows to the reference site in a southeasterly direction from Decant Creek through Test Lake and Shallow Bay before entering South Bay in Contwoyto Lake (Reid Crowther and Partners and R.L. and L., 1984).

2.2 HISTORICAL DATA REVIEW

Although the mine began operations in 1982, effluent discharge was unnecessary until 1985 when the tailings management area capacity was exceeded as a result of expanding mill operations. Effluent discharge is sporadic, occurring over a two week period from approximately mid-July to early-August each year. During an effluent discharge event, effluent from a tailings pond is decanted to Seep Creek which drains into Unnamed Lake and ultimately into Inner and Outer Sun Bay of the west basin.

Considerable historical data are available for Contwoyto Lake related to Lupin mine operations. Available information is summarized in Table 2-1. Studies of water, sediment, benthos, and fish were completed prior to the start of mine operations in 1982, and before and after the first effluent decant in 1985. Since 1985, monitoring has focused on sediment chemistry and benthic invertebrate community changes in the west basin. Additional water quality monitoring has been conducted in the west basin, but no additional water quality or

Figure 2-1. Site Location Map: Lupin Mine

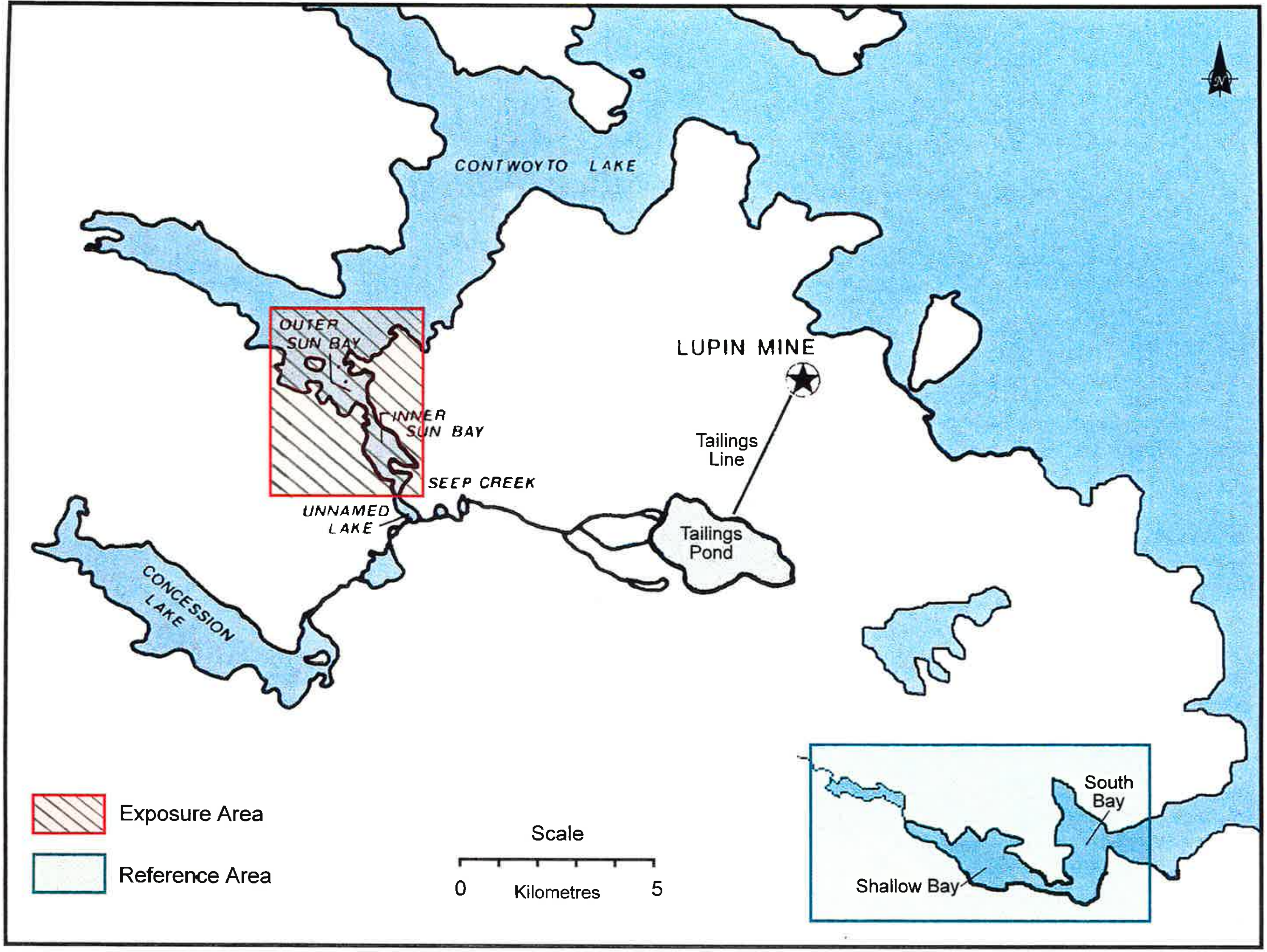

Table 2-1. Summary of the available historical information from Contwoyto Lake and various reference lakes, Lupin, NWT.

Source	Toxicity (Bioassays)	Water Quality	Sediment Quality	Plankton	Benthos	Fish	Summary
Moore, 1978		+		+	+	+	Pre-mine baseline survey (1975) in both reference and exposure areas on Contwoyto Lake indicated that the lake was comparable to other arctic lakes with respect to water quality and biological inventory.
Beak and Mary Collins, 1980		+		+	+	+	Pre-mine baseline monitoring (1980), showed good water quality with all contaminant parameters below criteria. Species inventory of plankton (phyto- and zoo-), benthic invertebrates and fish.
Reid Crowther and R.L.&L, 1984		+	+		+	+	Hydrological studies and a habitat survey were conducted. The objective was to determine environmental sensitivity of two drainages as potential receiving waters for mine tailings once current tailings drainages reach capacity.
Reid Crowther and R.L.&L, 1985						+	Results varied between species and sites. Arsenic was higher in all fish species except arctic grayling and trout over time, lead was higher in all species but arctic char. Copper, zinc and mercury showed increases in certain species over time. Lake trout results indicated significant differences between years for lead, mercury and zinc in Sun Bay, and for copper and mercury in Contwoyto Lake.
Roberge et al., 1986						+	Survey of commercial and sport-fishing potential of Contwoyto Lake. Fish were identified, tagged, and measured. Six fish species were found in the lake.
Duncan and Neil, 1987		+	+			+	Baseline monitoring in exposure sites (Sun Bay) to provide a database for future effects monitoring and develop a framework for EIA monitoring.

Table 2-1. continued.

SOURCE	TOXICITY (BIOASSAYS)	WATER QUALITY	SEDIMENT QUALITY	PLANKTON	BENTHOS	FISH	SUMMARY
Duncan et al., 1987					+		Use of clams as metal biomonitoring tool comparing conditions pre- and post- effluent discharge. Iron, zinc and lead increased in clam shells after effluent discharge. Clam soft tissues were also analysed using X-ray fluorometry, and high levels of iron, lead and zinc were incorporated. May be a better indicator than sediment and fish on short time scales.
Sutherland, 1988		+	+		+		Copper, zinc and arsenic exceeded water criteria for aquatic life protection in Inner Sun Bay. Arsenic was elevated in sediment cores. Benthic invertebrate communities were similar between reference and exposure sites.
Ash et al., 1991						+	Conducted analyses of metal concentrations in fish muscle and liver tissue. No major differences were noted between exposure and reference sites for almost all parameters, with the exception of arsenic which showed significant increases in the exposure sites compared with reference sites over time.
EVS, 1991					+		Increased species diversity and biomass over 1985 study.
Porter et al., 1991			+		+		Benthic invertebrate abundance was lower compared to 1985, although species richness doubled. No clear trends in sediment metal concentrations between study years.
EVS, 1992					+		Resident taxa did not suggest mine-related impacts to benthic communities.

fisheries work has been undertaken in the south basin following the start of effluent discharge.

Historic water quality data provide information on baseline conditions in the west and south basins of Contwoyto Lake, including seasonal and annual variability of metals in water and other conventional parameters, as well as changes in water chemistry before and during the 1985 effluent discharge (Table 2-2). The historic data also provide some understanding of flow patterns in the west basin and plume dispersal. However, available data from the first effluent decant in 1985 may not be representative of effluent discharges in later years as a result of process changes which have improved effluent quality. Moreover, control stations sampled in the west basin in previous monitoring studies appear to be situated within the exposure zone and as such are not appropriate controls. The historic data show that changes in water quality have occurred as a result of effluent discharges with water concentrations of copper, zinc and arsenic in Seep Creek, Unnamed Lake, and Inner and Outer Sun Bay measured during discharge events. Water quality conditions appear to rapidly (i.e., within weeks) return to background concentrations following completion of each discharge event.

Table 2-2. Summary of historic total metals in water (mg/L) in Contwoyto Lake (ranges are provided).

BAY	YEAR	MONTH	CONDUCTIVITY	AS	CU	NI	ZN
Shallow Bay[1]	1983	Jun - Sep	8 - 11	<0.001	0.0015 0.0026	<0.005 0.008	<0.01 0.016
Inner Sun Bay	1983	Jun - Sep	10 - 13	<0.001	0.001 0.0021	<0.005	<0.01 0.017
	1985	Aug[2]	12 - 15	<0.001	0.0007 0.0008	0.0008 0.0009	0.0005 0.0007
		Sep[3]	335 - 347	0.184 0.196	0.022 0.027	0.0082 0.0089	0.0386 0.0395

[1] data are not available for South Bay; Shallow Bay (which is upstream of South Bay) is used for comparison

[2] pre- (August) discharge data

[3] post-discharge data

Note: 1983 (Reid Crowther and R.L. & L., 1984)
1985 (Murdoch and Sutherland, 1988)

Sediment data have been collected in the west basin before and after the start of effluent discharge in conjunction with benthos sampling (Table 2-3). These data show that metals have accumulated in sediment between 1982-1984 to 1985 at stations in Inner and Outer Sun

Bay. However, sediment metal concentrations were not higher at Inner and Outer Sun Bay in 1985 after the first ever effluent discharge. There may have been a sample collection or analytical method change between 1982-84 and 1985, although none was noted in the reports we reviewed. Alternatively, there may have been other metal sources or seepage occurring prior to the first effluent discharge in 1985. Regardless, metal concentrations in sediment remained high in 1990 compared with 1982-84 (i.e., similar to 1985 levels). Sediment-metal concentrations exhibit some spatial variability with higher concentrations generally occurring at stations sampled in Outer Sun Bay. This trend appears to correspond to the depositional nature of stations further from the Seep Creek discharge. Sediments collected in Inner Sun Bay are generally coarser with finer sediments appearing at the outer extent of Inner Sun Bay and in Outer Sun Bay. The lack of fine sediments in the immediate near-field exposure area is a confounding factor, as elevated sediment-metal concentrations would be expected at stations in Seep Creek, Unnamed Lake and Inner Sun Bay.

Table 2-3. Summary of historic sediment chemistry (mg/kg) in Contwoyto Lake.

Bay	Year	Month	As	Cu	Pb	Ni	Zn
Inner Sun Bay	1983	Jun	6.5	28.3	1.8	28.2	55.7
		Aug	6.4	9.4	3.0	24.0	41.4
		Sep	7.3	29.3	3.9	22.6	47.6
	1985	Aug	19.6	15.7	22.4	18.3	52.1
		Sep	16.5	27.2	23.1	24.9	57.7
	1990	Aug	24.2	26.8	4.8	3.5	25.9
Outer Sun Bay	1983	Jun	7.4	52.6	1.5	26.9	62.9
		Aug	9.7	14.4	2.9	27.1	52.3
		Sep	7.0	45.3	6.9	25.2	50.7
	1985	Aug	43.4	24.8	17.8	22.9	61.1
		Sep	40.3	25.0	20.6	24.6	56.8
	1990	Aug	24.8	20.4	4.9	15.8	36.2
South Bay	1983	Jun	4.0	26.9	2.1	13.2	29.6
		Aug	3.7	20.0	3.5	16.3	34.4
		Sep	3.2	13.2	3.6	14.4	23.7

Benthos data from the west basin exposure area provide an ambiguous picture of the effect of effluent discharge on the benthic invertebrate community. Although benthos were collected prior to and after the start of effluent discharges, inconsistencies in sampling protocols, variation in sediment characteristics, and lack of appropriate control stations make it difficult to detect any changes in the benthic community attributable to the effluent discharge. For example, inconsistencies in taxonomy mean that benthic invertebrate community structure cannot be used to determine temporal changes in benthos. In addition, other sampling station characteristics such as water depth, confound any observed changes in the benthic community with effluent discharge. Also, water chemistry data suggest that both reference and exposure stations sampled in the west basin were exposed to effluent discharges; this suggests lack of suitable reference stations for comparisons. Although there is some evidence of benthic community change (i.e., reduction in sensitive species such as gastropods [snails] and increase in tolerant species such as aquatic mites and oligochaetes) in Inner Sun Bay, possibly resulting from impairment of water quality, similar changes have not been related to sediment-metal contamination.

Extensive fisheries work has been completed in Contwoyto Lake in the vicinity of the Lupin mine site with an emphasis on identification of fish habitat, fish species presence and utilization. Presence/absence studies demonstrated that lake trout are abundant in Contwoyto Lake with large numbers caught by gillnet in the west and south basins. Round whitefish, lake cisco, Arctic char, and Arctic grayling were also captured in smaller numbers in the west and south basins and at other reference locations in Contwoyto Lake northwest of the mine site. Studies undertaken in Seep Creek indicated that Arctic grayling use the creek for spawning, rearing, and feeding despite seasonal variation in flows and significantly reduced flows in late summer. Round whitefish and lake trout may also use the creek for rearing and feeding. Although the same species are present in both the west and south basins, habitat utilization appears to be higher in the south basin with large fish populations of all species compared with the west basin.

To assess metal concentrations in fish, fish tissue has been sampled before and after the start of effluent discharges. Clear trends in arsenic accumulations in liver tissues of lake trout have been observed (Table 2-4). Accumulations of metals do not seem to be a problem at this time (Ash et al., 1991).

Table 2-4. Comparison of mean metal content of lake trout muscle and liver tissue between years 1982 - 1990.

	Inner Sun Bay							Contwoyto Lake							Out Sun Bay						
	As	Cd	Cu	Pb	Hg	Ni	Zn	As	Cd	Cu	Pb	Hg	Ni	Zn	As	Cd	Cu	Pb	Hg	Ni	Zn
Muscle																					
1982-1984	0.103	0.063	2.276	0.103	0.891	0.272	20.123	0.069	0.046	3.543	0.191	0.735	0.599	26.807	nm	nm	nm	nm	nm	nm	nm
1985	0.097	<0.05	2.263	0.073	0.896	0.131	22.12	<0.05	>0.05	2.05	<0.05	0.728	0.325	22.6	nm	nm	nm	nm	nm	nm	nm
1988	0.207	<0.05	1.214	<0.05	0.963	<0.25	19.222	0.066	0.046	1.122	<0.05	1.121	<0.25	19.08	0.050	<0.05	1.063	0.062	0.947	<0.25	21.218
1990	0.156	0.060	1.512	0.132	0.901	0.130	20.123	0.114	0.27	1.282	<0.05	1.101	<0.25	17.9	0.075	<0.05	1.315	<0.05	1.085	<0.25	16.775
Probability	ns	ns	***	*	ns	***	ns	ns	ns	***	***	*	***	ns	ns	ns	ns	ns	ns	ns	ns
Liver																					
1982-1984	0.117	2.499	85.260	0.215	2.467	0.860	155.88	<0.05	2.396	54.514	0.187	1.781	0.734	140.71	nm	nm	nm	nm	nm	nm	nm
1985	0.129	1.940	99.80	<0.05	1.015	0.861	151.58	<0.05	2.190	51.96	<0.05	0.789	0.655	140.60	nm	nm	nm	nm	nm	nm	nm
1988	0.359	2.320	92.56	0.086	1.371	1.564	170.44	0.172	3.232	85.723	0.126	1.501	1.942	160.23	0.090	2.414	182.84	0.143	0.975	1.489	205.6
1990	0.445	1.917	80.833	0.095	1.494	1.077	156.5	<0.05	2.475	43.582	0.38	1.908	0.527	138.21	0.126	1.69	86.6	0.144	0.895	1.273	137.82
Probability	**	**	ns	***	**	ns	ns	**	ns	*	***	ns	***	ns	ns	ns	ns	ns	ns	ns	ns

Probability:
* $p<0.05$
** $p<0.01$
*** $p<0.001$

ns not significant
nm not measured

3.0
METHODS

3.1 STUDY AREA

The study area was located in Contwoyto Lake in bays adjacent to the Lupin Gold Mine, NWT (Figure 2-1; historic and 1996 sampling stations are detailed in Section 4.0, Figures 4-1 and 4-2). Sun Bay was selected as the exposure site as it receives tailings pond decant for a two week period each summer and was found to be somewhat affected by metal exposure in previous studies (e.g., Murdoch and Sutherland, 1988). South Bay was selected as the reference site because it had similar substrate to the exposure site based on previous studies (Reid, Crowther and Partners and R.L. and L., 1984). Although seepage from the tailings ponds to South Bay occurred in 1992, this site was selected because 1) no further seepage has occurred (David Honstein, Lupin Mine Environmental Manager, pers. comm.) and, 2) it has substrate that is more similar to the exposure site than alternative reference sites. Because the mine had already decanted the tailings ponds prior to our field survey, mine effluent was not characterized (e.g., for chemistry or toxicity).

3.2 EFFLUENT CHARACTERIZATION AND SUBLETHAL TOXICITY

Because the mine had ceased discharge for the year, effluent could neither be collected nor characterized during the September field survey. However, chemistry and acute toxicity data were provided for the 1996 discharge (Robert Martin Lupin Mine Environmental Coordinator, pers. comm.), and are summarized in Section 4.2

3.3 HABITAT CHARACTERIZATION, CLASSIFICATION AND SAMPLE STATION SELECTION

Selection of field sample station locations was based on information from past studies and field survey characterization efforts. Although the primary objective of this study was to detect differences between exposure and reference sites, the exposure stations were selected to represent a gradient from high exposure to relatively low exposure (yet within the 1% dilution zone) during periods of effluent discharge, because higher sediment contaminant concentrations have been observed further from the source than near. Murdoch and Sutherland (1988) and Porter et al. (1991) have suggested this difference is due to finer sediments being transported to Outer Sun Bay. Therefore, to ensure exposed sediments were sampled, stations located in Inner and Outer Sun Bay were selected. The primary determining factor for reference station selection was comparable habitat characteristics with exposure stations. The general locations for the exposure (i.e., Inner and Outer Sun Bay) and reference areas (i.e., South Bay) were selected prior to the field study, based on information from previous studies and personal communications with mine staff. Final station locations were determined in the field based on habitat characteristics (e.g., substrate type and station depth).

Positional information for field sampling stations was collected using a Trimble GeoExplorer global positioning system (GPS) receiver. Approximately 120 position readings were acquired for each station for differential post-processing. All GPS data collected in the field were downloaded to a personal computer for post-processing using Trimble Geo-PC software. Base station data were unavailable, and therefore these position readings were simply averaged (and not corrected). Expected accuracies using this method are between 30-40 m in the horizontal. Following averaging of all field collected positions, a visual check to determine possible anomalies in field collected and/or averaged data was conducted. This check involved comparing averaged data to uncorrected data, with additional information drawn from field log books. Following averaging and data inspection, any unexpected results were discussed with field personnel and positions within a file were averaged to provide a single positional solution for each station. All positions were then combined into a single file and output to the AutoCAD DXF file format for possible future incorporation into AutoCAD or GIS spatial files.

Habitat characterization (i.e., water depth and substrate type) was conducted at both the exposure and reference sites prior to station selection and sample collection. Approximately half a day was spent at each site to characterize habitat. Water depths were taken with a weighted survey tape. Sediment samples were collected using a Petite Ponar. Historical stations were inspected to confirm substrate type and water depth. Additional areas were inspected to locate stations of the desired characteristics (i.e., silty and 5 ± 2 m in depth). Sampling stations were selected based on these observations.

Water, sediment and benthos samples were collected September 10-12, 1996 in Contwoyto Lake. Two sites were investigated: Sun Bay (exposure site) and South Bay (reference site). Station maps are provided in Section 4.0 (Figures 4-1 and 4-2). Samples from six stations at each site were collected at Sun Bay September 10 and 11 and at South Bay September 11 and 12. Where possible we sampled at or near historic sampling locations. Based on previous data review, there were differences between some of the stations. These differences were not necessarily attributed to exposure effects, but could have been confounded by substrate type and/or water depth. Consequently, we attempted to sample in similar substrate (silty) and water depth (~ 5 m ± 2 m), which resulted in not always sampling at historic stations. Unfortunately the reference stations were much shallower and much closer together due to difficulties in finding deeper and silty areas at South Bay. Access to Shallow Bay was not possible due to shallow water depth.

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Based on previous review of the data, the exposure zone was estimated to extend into Outer Sun Bay, but not to the outer edge near a large island. Consequently, the Outer Sun Bay stations were confined to the inner portions of Outer Sun Bay. Since we found fairly similar substrate in both Inner and Outer Sun Bay, we allocated stations equally between the two areas (i.e., three in each). Stations at South Bay were shallower (i.e., 0.9 to 4.2 m) than at Sun Bay (e.g., 2.7 to 7.2 m). Although stations at the reference site tended to have more sand, most sites were silty.

3.4 WATER SAMPLES

Field measurements of temperature, conductivity, dissolved oxygen, and pH were taken at each station sampled using a Hydrolab H_20 multiprobe. Additional conductivity measurements were not taken to characterize mixing/exposure zones as the mine was not discharging. All field instruments were calibrated prior to use and values recorded manually in the field.

One grab sample was collected at the surface from each station because: 1) water depths were generally shallow (< 5 m), 2) water quality profiles did not show any stratification, and 3) effluent was not being discharged. Clean techniques were used at all times to minimize sources of contamination. Separate samples were collected for total and dissolved (i.e., operationally defined as water filtered through a 0.45 μm filter) metals. The sample for dissolved metals analysis was field-filtered according to standard methods (Section 3030B; APHA, 1995). Both metals samples (total and dissolved) were acidified with ultrapure HNO_3 (provided by the analytical laboratory) to a pH <2. The bottles used to collect samples, the sample preservatives and sample analyses are summarized in Table 3-1. All samples were cooled and shipped on ice to MDS Laboratories in Mississauga, Ontario for analysis of total and dissolved metals (an ICPMS low level metals scan), cations and anions, nutrients, hardness, alkalinity, dissolved organic and inorganic carbon, turbidity and total suspended solids. Analytical methods are provided in Appendix C. All pertinent information was included on the chain-of-custody (COC) sheets which accompanied the samples to the various laboratories. If any anomalies in sample submission had been detected (none were), they would have been immediately communicated to field personnel for clarification.

Quality assurance/quality control (QA/QC) of receiving water chemistry included, in addition to all three firms submitting samples to the same analytical laboratory, collection and analysis of one transport or trip blank (all parameters except dissolved metals), one filter blank (dissolved metals only), and one field replicate (collected at the exposure station closest to the site of effluent discharge). The transport blank water was provided by the analytical laboratory. Details of the QA/QC procedures followed are provided in the Quality Management Plan (QMP) in Appendix A.

The untransformed water chemistry data were first assessed for normality and then log transformed (log base 10) as required. All data were log transformed, prior to statistical analysis using SYSTAT for Windows Version 5 (SYSTAT, 1992) as a review of the data distribution showed the data violated assumptions of normality. Exposure and reference data were compared using Students *t*-test. Prior to *t*-test analysis, Bartlett's test for homogeneity of variances was conducted. Pooled variance *t*-test results were used when variances were homogeneous. Separate variance *t*-test results were used when variances were heterogenous. Means were considered to be significantly different when $p < 0.05$.

Table 3-1. Summary of bottles and preservatives used and analyses conducted on water chemistry samples collected at each sampling station.

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

3.5 SEDIMENT SAMPLES

Sediment samples for chemistry were collected using a 0.0225 m^2 (15 cm x 15 cm) stainless-steel Petite Ponar. Grabs were accepted for use based on several criteria (Environment Canada, 1995): 1) sediment was not extruded from the upper face of the sampler, 2) overlying water was present indicating minimal leakage, 3) overlying water was not excessively turbid and the sediment surface within the grab was relatively flat indicating minimal disturbance/winnowing, 4) the penetration depth was at least 4-5 cm. Samples not meeting these criteria were rejected.

Five field replicate grab samples were collected at each station to test sediment chemistry. Sampling for chemistry analyses involved using a pre-cleaned plastic spoon to deposit the top 2 cm of sediment collected from the centre of each Petite Ponar Grab into a pre-cleaned pyrex glass bowl. The Petite Ponar grab, mixing bowls and plastic utensils were cleaned between sampling stations using the following protocol: 1) water rinse, 2) phosphate-free soap wash, 3) deionized water rinse. Once five successful grabs were collected, the sediment (i.e., a composite of five grab samples) was thoroughly stirred until homogenous in colour and texture.

Homogenized samples were placed into two pre-cleaned 250-mL glass containers for chemical analysis. Sample containers were filled to capacity with minimal head space. Duplicate jars were collected at all stations in case of breakage during shipping. Between stations, the Petite Ponar grab was washed as noted above.

All sample jars were labeled, and sample collection information was entered onto a field data sheet. Sediment samples were stored and transported in coolers with ice packs. Samples were shipped to MDS Laboratories for analyses of metals, total organic carbon, particle size and loss on ignition. All pertinent information was included on the chain-of-custody (COC) sheets which accompanied the samples to the various laboratories. If any anomalies in sample submission had been detected (none were), they would have been immediately communicated to field personnel for clarification.

Quality assurance/quality control (QA/QC) for sediment sampling included, in addition to all three firms submitting samples to the same analytical laboratory: 1) a split sample from the exposure station, 2) a swipe blank collected to determine the effectiveness of field decontamination procedures (e.g., a deionized water-wetted, ashless filter paper was used to wipe down the sampler and mixing bowl/spoon surfaces likely to contact the sample media). Details of the QA/QC procedures followed are provided in Appendix A.

Prior to statistical analysis sediment chemistry data were normalized to percent fines (i.e., silt + clay fractions). The untransformed normalized to percent fines sediment chemistry data were first assessed for normality and then log transformed (log base 10) as required. All data were log transformed, prior to statistical analysis using SYSTAT for Windows Version 5 (SYSTAT, 1992) as a review of the data distribution showed the data violated assumptions of normality. Exposure and reference data were compared using Students t-test. Prior to t-test analysis, Bartlett's test for homogeneity of variances was conducted. Pooled variance t-test results were used when variances were homogeneous. Separate variance t-test results were used when variances were heterogenous. Means were considered to be significantly different when $p< 0.05$.

3.6 BENTHOS SAMPLES

3.6.1 Sample Collection

Samples for benthic invertebrates were collected using a 0.0025 m^2 stainless steel Petite Ponar. Benthic samples were collected synoptically with sediment chemistry samples. One grab sample was collected from each station. Samples were used if there was full penetration of the grab and it remained closed at the surface. Samples were carefully sieved in the field using a 250 μm stainless-steel mesh sieve. All macro invertebrates retained on the sieve were fixed with 10% buffered formalin (shipboard) to attain approximately 7% final concentration. Labeling and field records were prepared as for water and sediment chemistry samples and accompanied the samples to the sorting and taxonomic facilities (Zaranko Environmental Assessment Services, Guelph, ON).

3.6.2 Sorting and Taxonomy

Invertebrates in each sample were counted and identified to genus level. QA/QC for the benthic invertebrate sample analyses included: 1) 10% resort of samples to confirm 95% sorting efficiency, 2) 10% of sample sub-sampled for determination of sub-sampling error, 3) sorted and unsorted fractions retained until taxonomy and sorting efficiency were confirmed, 4) development of a voucher collection, 5) taxonomy verified by an independent expert, 6) all three firms submitted samples to the same taxonomist. Details of the QA/QC procedures followed are provided in Appendix A.

Prior to statistical analysis sediment chemistry data were normalized to percent fines (i.e., silt + clay fractions). The untransformed normalized to percent fines sediment chemistry data were first assessed for normality and then log transformed (log base 10) as required. All data were log transformed, prior to statistical analysis using SYSTAT for Windows Version 5 (SYSTAT, 1992) as a review of the data distribution showed the data violated assumptions of normality. Exposure and reference data were compared using Students t-test. Prior to t-test analysis, Bartlett's test for homogeneity of variances was conducted. Pooled variance t-

test results were used when variances were homogeneous. Separate variance *t*-test results were used when variances were heterogenous. Means were considered to be significantly different when $p < 0.05$.

3.7 FISHERIES

3.7.1 Collection

Fish collection was conducted in the west and south basins of Contwoyto Lake to identify species presence/absence and to calculate catch per unit effort (CPUE) for potential sentinel fish species. The exposure area, as determined from historical data, included Inner and Outer Sun Bay of the west basin of Contwoyto Lake. South Bay, located in the south basin of Contwoyto Lake, was selected as the reference area. Sampling was primarily intended to assess the appropriateness of the south basin as a reference area given the deficiencies identified for reference areas used for previous studies.

Gillnetting was the primary fish capture method employed during the present study, consistent with previous studies undertaken in Contwoyto Lake. Multi-panel floating gillnets, each comprising two 15 m long and 2.5 m deep panels of alternating 5 cm and 10 cm stretched mesh, were deployed within the exposure and reference areas. Gillnet mesh size selection was also guided by historical sampling data which showed that the majority of fish were caught with the two mesh sizes selected for the present study. Sampling locations were selected based on historical sampling locations, water depth, and prevailing current and wind conditions. Attempts were made to select sheltered near-shore locations to facilitate deployment and retrieval of gillnets. In the exposure area, locations were selected in both Inner and Outer Sun Bay to evaluate spatial distribution of fish species. In the reference area, gillnets were closely grouped in a sheltered area of South Bay as a result of strong winds and currents encountered during deployment. Gillnets were set in similar water depth at both the reference and exposure areas (i.e., 2 - 4 m depth). Although the sampling strategy specified that two multi-panel nets would be deployed in each of the exposure and reference areas, a third net was set in the exposure area due to the partial tangling of one gillnet (i.e., 5 cm mesh), which potentially reduced the effectiveness of the net.

Approximately 1 to 1.5 days fishing effort was completed at each of the exposure and reference areas. Fishing effort was extended beyond the projected single day in each area to compensate for the extended travel time by boat to access these areas and to allow for overnight gillnet sets.

Gillnets deployed in the exposure area were checked frequently (i.e., every hour) to assess catch success. To compensate for the low catch rate, a decision was made to leave the gillnets overnight to determine catch success over an extended period. Extended overnight gillnet sets have been necessary for all previous studies undertaken in Contwoyto Lake (i.e., average sets of 27 hours). Following completion of the overnight sets, fish were removed from gillnets, weighed and measured (standard, fork, and total length), and released unharmed or discarded if dead. Fish catches were too low to merit statistical analysis.

3.7.2 Tissue Processing for Metal and MT Analysis

An evaluation was conducted to determine if fish tissue would be collected for metals and metallothionein analyses. The evaluation was based upon the criteria listed in Table 3-2.

No dissections of captured fish were undertaken to obtain tissue for metal and metallothionein analysis. Although potential sentinel species were captured in both exposure and reference areas, numbers captured were generally insufficient to complete these analyses (i.e., numbers captured were below the target 8 fish/2 species/2 areas). In addition, while lake trout are relatively abundant in both areas, the high mobility of this species and the absence of barriers to movement into and out of the exposure area make this species less desirable as a sentinel species. Further, given the difficult logistics at the Lupin mine site due to weather and access considerations, sampling effort was focused on confirming fish presence/absence in the exposure and reference areas rather than on time consuming tissue collection.

Table 3-2. Criteria used for determination of site suitability for collection of fish tissue for metals and metallothionein analyses.

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

When applying the criteria to a site, Criterion #1 was of primary importance, especially regarding sub-criteria "b" (i.e., mobility) and "f" (i.e., fish abundance). If these two sub-criteria were not met, then fish tissue was not collected. Of particular importance in Criterion #2, is sub-criterion "a". Specifically, if a site already had sufficient fish tissue data to provide enough information for planning the sampling element for fish collection for 1997 at this site, then no further destructive sampling occurred.

4.0
RESULTS

4.1 STATUS OF SAMPLE COLLECTION AND ANALYSIS

Field work was conducted September 9 -13. Samples for all parameters as per the sampling plan were submitted except effluent toxicity (Table 4-1).

Table 4-1. Status of sample collection and analysis.

MATRIX	PARAMETERS	NUMBER	DATE COLLECTED	STATUS
Effluent	*Lemna minor* growth inhibition; *Ceriodaphnia dubia* survival & reproduction; Salmonid embryo; *Selenastrum capricornutum* micro plate growth inhibition	0	not collected as mine not discharging	n/a
Receiving Water	total & dissolved metals major ions nutrients hardness/alkalinity DOC/DIC turbidity/TSS	12	September 9-13	revised results received Oct. 18
Sediment	metals TOC loss on Ignition particle size	12	September 9-13	complete results received Oct. 18
Benthos	id + enumeration	12	September 9-13	data received Oct. 23; QA/QC received Dec. 10

na not applicable

4.2 EFFLUENT CHARACTERIZATION AND SUBLETHAL TOXICITY

4.2.1 Chemistry

Effluent chemistry data during discharge (July 15 - August 7) are provided in Table 4-2.

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Table 4-2. Effluent quality permit standards and mean water chemistry of effluent discharge, July 15 - August 7, 1996.

PARAMETER (MG/L)	PERMIT MAXIMUM AVERAGE (MG/L	STANDARDS MAXIMUM FOR ANY GRAB (MG/L)	MEAN	SD	SE	N
Total Hardness	ns	ns	219	6	1.3	23
pH	ns	ns	6.4	0.3	0.1	24
Conductivity (µmhos/cm)	ns	ns	999	26	5	24
Total Cyanide	0.8	1.6	0.02	0.021	0.004	24
Total Arsenic	0.5	1	0.009	0.004	0.008	24
Total Cu	0.15	0.3	0.008	0.008	0.002	24
Total Fe	ns	ns	0.238	0.111	0.023	24
Total Ni	0.1	0.2	0.076	0.008	0.002	24
Total Pb	0.05	0.1	0.0009	0.002	0.0004	24
Total Zn	0.3	0.6	0.238	0.111	0.023	24

ns no permit standard
Source: raw data provided by Robert Martin, Environmental Coordinator, Lupin Mine; Appendix C.3.

4.2.2 Toxicity

During effluent discharge there have been no non-compliance events (AQUAMIN, 1996). In fact, daily discharges are generally one or more orders of magnitude lower than the maximum average concentration (mg/L) permit standards. There are no historic sublethal toxicity data. Acute toxicity data available from the mine indicate no toxicity to rainbow trout, *Daphnia* and Microtox.

4.3 HABITAT CHARACTERIZATION AND CLASSIFICATION

Selected site photographs are provided in Appendix B. Habitat characteristics are shown in Figures 4-1 and 4-2.

Sediment at the exposure area, Inner Sun Bay, was generally silty, although there were areas that contained coarse sediment. The sites with coarse sediment were adjacent to islands. Rocky sites were also noted (e.g., historic site 4 in the channel between Inner and Outer Sun Bay; site C1). Macrophytes were observed throughout Inner Sun Bay, but not in Outer Sun Bay (e.g., near historic sites 5, 6, 7). A red-brown/rust film or layer (possibly due to ferrous bacteria) was observed at most stations in Sun Bay. In general, silty sediment was collected at reference and exposure stations (depths 2.5-5 m in Inner Sun Bay and 4-7 m in Outer Sun Bay).

Habitat characterization at the reference area was restricted to South Bay as Shallow Bay was inaccessible by boat. The area close to the mouth of Shallow Bay was primarily silty with rocky areas near the mouth of the bay and islands. Numerous areas of sandy sediment were noted in the middle of the Bay and to the north-east. Substrate was likely sandy due to input from eroding cliffs on the east side of the Bay. Four of the sites were sampled in the vicinity of historic sites in South Bay. Two stations were positioned between the two main islands in South Bay.

4.4 SAMPLE STATION SELECTION

A summary of habitat characteristics is given in Table 4-3. Sample stations are shown in Figures 4-1 (reference area) and 4-2 (exposure area). GPS coordinates are provided in Table 4-4.

Sample station selection at the exposure area (i.e., Sun Bay) was driven by historical station location (as described in Sutherland, 1988), whether sites contained silty substrate, and our ability to locate new stations that were of similar water depth and substrate type. Stations E-

1, E-2 and E-3 were in Outer Sun Bay and were either at or adjacent to historic Stations 5, 7 and 6. Station E-4 was at or north of historic Station 3. Station E-5 was between historic Stations 3 and 8. Station E-6 was at or adjacent to historic Station 8.

Sample station selection at the reference site (i.e., South Bay) was determined by historic station location (as described in Reid Crowther and R.L. and L., 1984), and whether these stations possessed similar depth and substrate type to exposure stations. In addition, we wanted to locate new stations that were also of similar water depth and substrate type. Stations R-1, R-4, R-5 and R-6 were adjacent to three historic stations (S-4; BI/S-4). Station R-2 and R-3 were north of these same historic stations.

Table 4-3. Habitat characteristics for Sun Bay and South Bay sampling stations.

STATION	DEPTH (M)	SUBSTRATE TYPE	MACROPHYTE DENSITY	COLOUR
E-1	4.5	Silt	none	grey with rust coloured layer at surface
E-2	6.5	Silt	none	grey with rust coloured layer at surface
E-3	7.2	Silt	none	grey with rust coloured layer at surface
E-4	4.2	Silt	moderate	dark grey with rust coloured layer at surface
E-5	4.8	Silt	moderate	dark grey with black streaks and rust coloured layer at surface
E-6	2.7	Silt	high	grey with black streaks; no rust colour
R-1	2.6	Silt	moderate	grey with light brown at surface
R-2	4.2	Silt/Sand	low	grey with light brown at surface
R-3	2.3	Silt/Sand/ some clay	moderate	grey with light brown at surface and rust layer
R-4	1.5	Silt	moderate	grey with rust and light brown layers
R-5	3.3	Silt/Sand	none	grey with light brown layer
R-6	0.9	Silt/Sand	moderate	grey, some grabs with rust layer

Table 4-4. GPS location of reference and exposure stations, Lupin Mine.

AREA	STATION	VTM COORDINATES	
		NORTHING	EASTING
Reference	R1	7281304	496998.4
	R2	7281634	496999.9
	R3	7281872	497146.3
	R4	7281209	497004.2
	R5	7281303	496730.7
	R6	7281040	496777.3
Exposure			
	E1	7293403	478927.5
	E2	7292911	478459.9
	E3	7293062	478861.2
	E4	7292415	479172.7
	E5	7292063	479111.1
	E6	7291195	479313.5

Figure 4-1a. Site study area, including historic and reference sample stations: South Bay

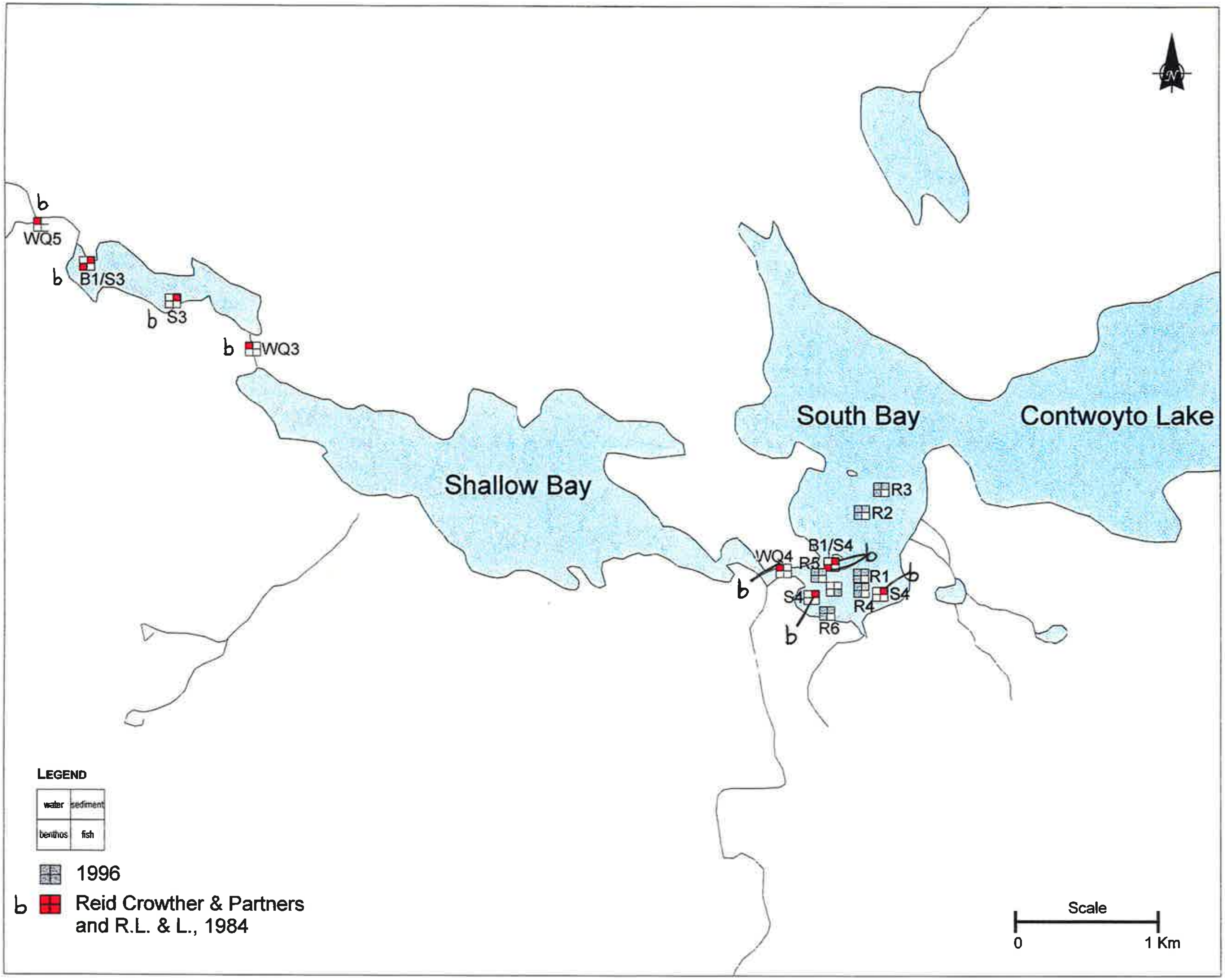


Figure 4-1b. Reference area habitat characterization: South Bay

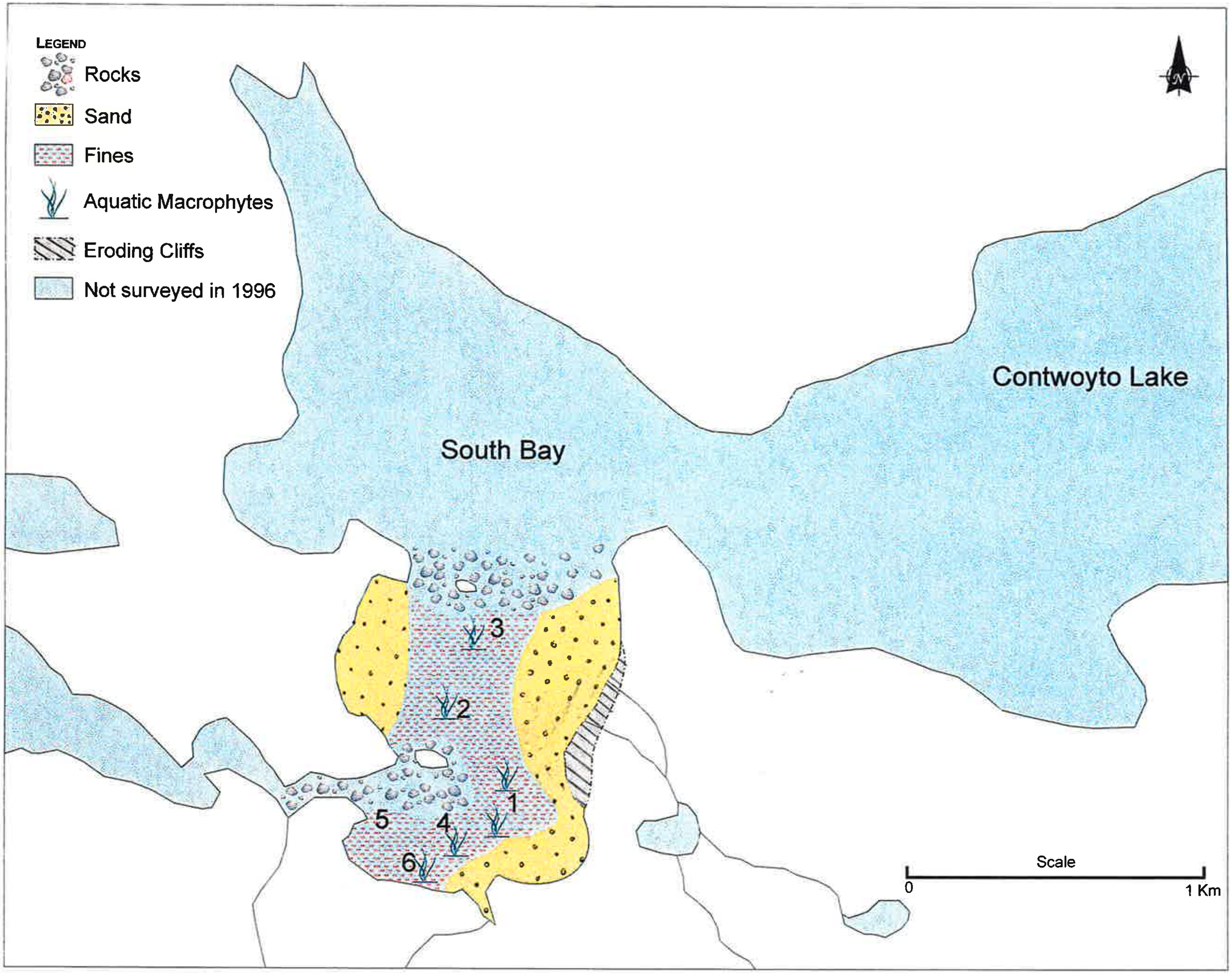


Figure 4-2a. Site study area, including historic and exposure sample stations: Sun Bay

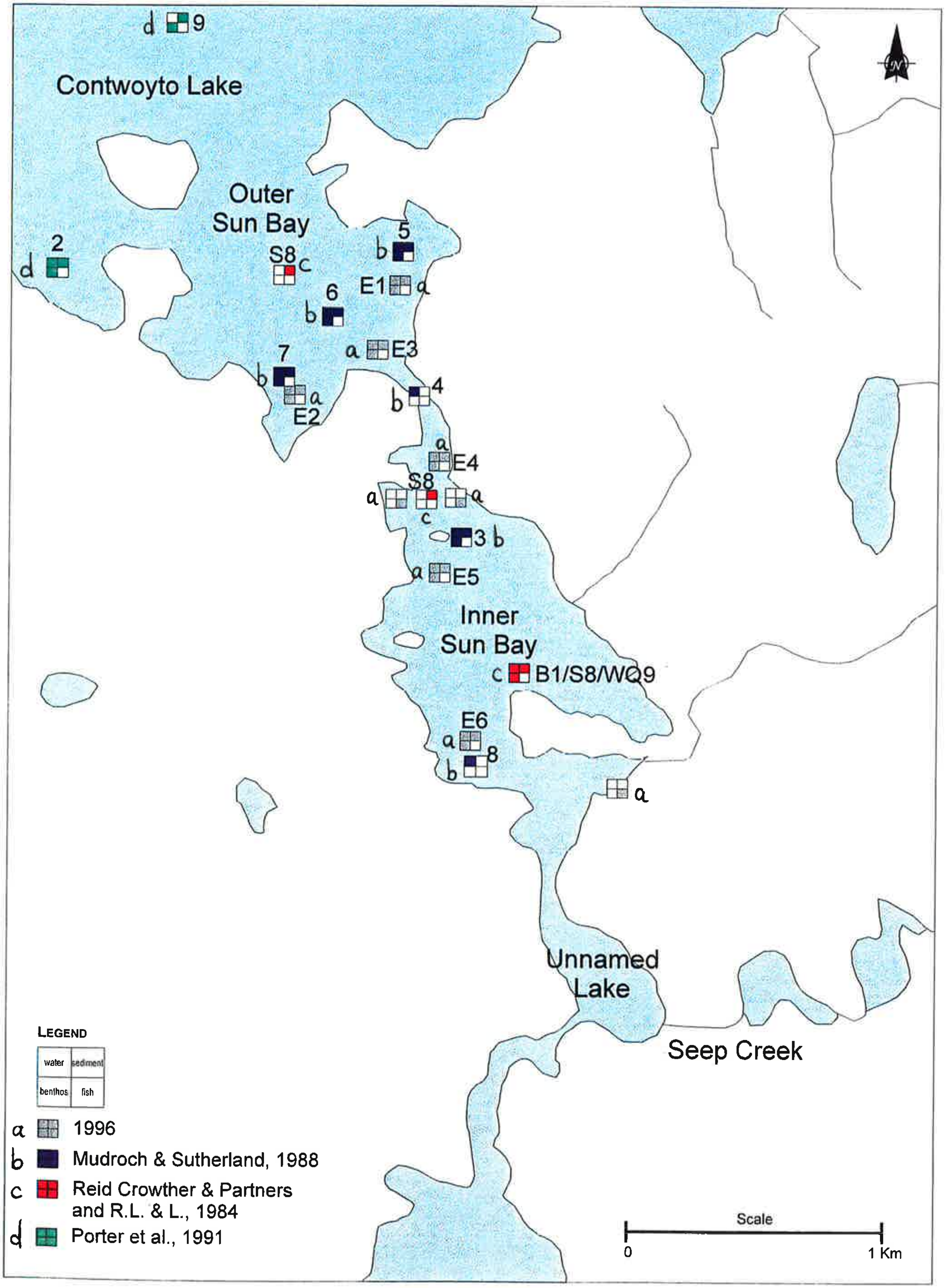
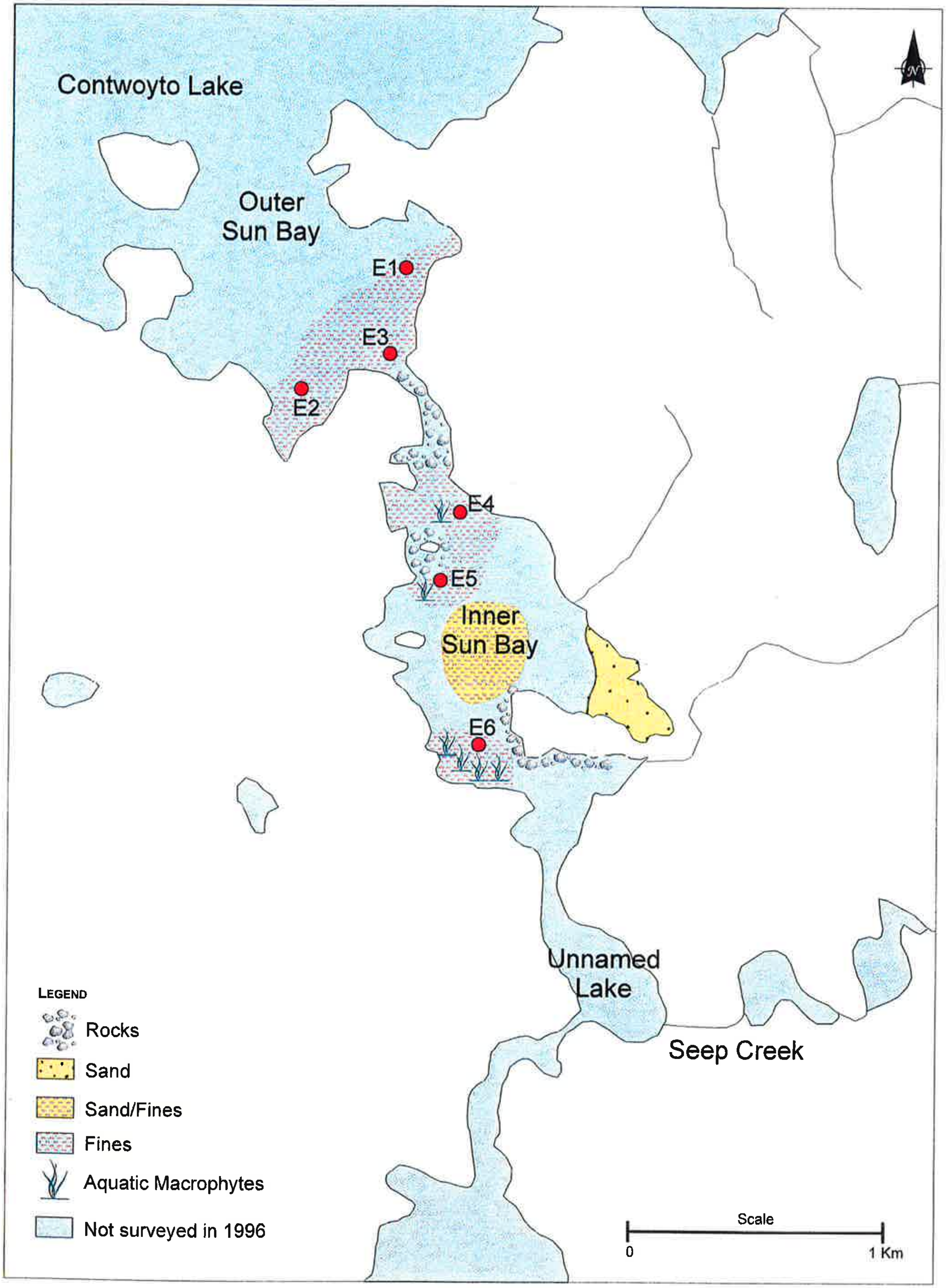


Figure 4-2b. Exposure area, habitat characterization: Sun Bay



4.5 WATER CHEMISTRY

4.5.1 QA/QC

Method Blanks:

Method blanks were used by the analytical laboratory to assess possible laboratory-derived contamination, as well as providing information on the stability of established instrumental baselines. Chromium, lead, selenium and zinc were detected in at least one of three batches of samples analyzed. This indicates that there was laboratory-derived contamination for these parameters but that the instrumental baselines were stable (Appendix C.2). Results for zinc should probably be considered non-detects at 0.005 mg/L (detected in blank) rather than 0.002 mg/L. Chromium, lead and selenium results were background corrected for the process blanks by the analytical lab.

Certified Reference Materials:

The analysis of certified reference materials (CRMs) provided information on the accuracy of the laboratory performing the analysis. The percent recoveries for the certified reference materials (CRMs) are listed in Appendix C.2. All CRM results were between 87 and 111% recovery and within the range considered acceptable by the laboratory.

Matrix Spikes:

Matrix spikes are samples to which a known amount of analyte has been added. The analysis of matrix spikes provided information on the extraction efficiency of the method on the sample matrix. The percent recovery for matrix spikes are presented in Appendix C.2. All matrix spike recovery results were within 20% of the target concentration and within the range considered acceptable by the laboratory. This indicates that the matrix of samples collected from the study site did not affect analyte recovery (accuracy).

Travel Blanks:

The travel blanks for general water chemistry and total metals (Appendix C.2) did not reveal any contaminants with the exception of sodium, ammonia, TKN, DOC, and TIC. The travel blanks for these two tests were provided by MDS.

Laboratory Replicates:

Laboratory replicates were taken by splitting a sample before analysis. The replicates were analyzed as an additional sample to provide information on precision. The results of the replicate samples were compared to determine the relative percent difference (RPD). RPD is calculated as the difference divided by the mean (i.e., $S_1 - S_2) / ((S_1 + S_2) /2)$. The RPDs of the laboratory replicates are listed in Appendix C.2 (Table C2.1). Laboratory replicates had RPDs less than 15% indicating acceptable precision, with the exception of zinc. The RPD for one set of zinc replicates was 29%; however, the RPD for a second replicate was 0%. This apparent discrepancy can be accounted for as these samples were near the detection limit of 0.002 mg/L and less than the method blank of 0.005 mg/L, and in this range better duplication is difficult.

Filter Blanks for Dissolved Metals:

The field filter blank revealed the presence of lead (0.0013 mg/L) and zinc (0.006 mg/L). This analysis was conducted on deionized water shipped from our EVS laboratory to Lupin. Neither lead nor zinc were detected at either reference or exposure stations suggesting no sample contamination occurred.

Field Homogenization Replicates:

Field homogenization replicates are replicate samples that are taken side by side in the water column (as depths were relatively shallow all sampling was directly into bottles below the water surface, approximately 0.5 m). These samples provided information on laboratory precision and sample heterogeneity. The RPD results of the field homogenization replicates are listed in Appendix C.2 (Table C2.1). The majority of parameters for field replicates had RPDs less than 20% indicating acceptable precision and sample collection in the field. The exceptions were dissolved boron, total magnesium, total aluminum and conductivity. Most of these difference were at or near the detection limits; however, for total aluminum there was an order of magnitude difference between the replicates. Whether this is a real difference or a laboratory artifact in unclear.

Field Cross-Contamination Blanks:

As all samples were collected near the surface a sampler was not required and therefore no sampler blank was collected.

Other :

The analytical laboratory did not provide ionic balances for samples for which the ionic strength was low. Ion balance is primarily based on samples having a total dissolved solids content between 25 and 1500 mg/L.

4.5.2 Chemistry

Field water quality data are summarized in Table 4-5 and raw data are provided in Appendix B. There were no significant differences in dissolved oxygen (DO) concentrations between the reference site (11.5 ± 0.1 mg/L; South Bay) and exposure area (11.3 ± 0.4 mg/L; Sun Bay). Conductivity was about 50% higher at the reference area (0.012 ± 0.0004 mS/cm) than the exposure area (0.008 ± 0.0004 mS/cm), while pH tended to be lower (not significantly) at the reference area (5.9 ± 0.05) compared with the exposure area (6.0 ± 0.04). Although turbidity was sometimes erratic it was generally low (i.e., less than 20 NTU), which is consistent with the total suspended solids (TSS) results from the analytical laboratory (e.g., ≤5 mg/L).

Water chemistry data for conventional parameters are summarized in Table 4-5 and raw data are provided in Appendix C. Sulphate, reactive silica, cations, anions, colour, hardness, total dissolved solids (TDS), and dissolved organic carbon (DOC) were all significantly higher in the reference area compared with the exposure area. Cyanide exceeded Canadian freshwater guidelines for the protection of aquatic life at one station at both the reference and exposure areas (0.006 mg/L).

Water chemistry data for total metals are summarized in Table 4-6 and raw data are provided in Appendix C. There were no significant differences between the reference and exposure areas for boron, copper and potassium. Metal levels in water were greater at the reference area compared with the exposure area for aluminum, iron, manganese, nickel and strontium. Aluminum, copper and selenium exceeded Canadian freshwater guidelines for the protection of aquatic life at the reference area, and aluminum and copper exceeded these guidelines at the exposure area.

Water chemistry data for dissolved metals are summarized in Table 4-7 and raw data are provided in Appendix C. There were no significant differences between reference and exposure areas for boron, copper, zinc and potassium. Where differences were detected, there were values at the reference area which exceeded the exposure area. Aluminum, copper and selenium exceeded Canadian freshwater guidelines for the protection of aquatic life at the reference area and aluminum and copper at the exposure area.

Table 4-5. Conventional parameters ($\bar{x}$ ± se mg/L unless otherwise noted) in water samples collected from reference and exposure areas compared with Canadian freshwater guidelines (CCME, 1987) (se = standard error).

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	t^{1}	p^{2}
Field Temperature (°C)	-	6.6 ± 0.34	4.5 ± 0.11	-3.241	0.009*
Field pH	-	5.9 ± 0.05	6.0 ± 0.04	1.997	0.074
Field Conductivity	-	0.012 ± 0.0004	0.008 ± 0.0004	-6.867	<0.001*
Field DO	-	11.5 ± 0.1	11.3 ± 0.4	.4-0.402 ^{4}	0.702
Alkalinity (SiO_2)	-	1.7 ± 0.52	1.8 ± 0.2	0.62	0.549
Sulphate	-	2.8 ± 0.4	1.3 ± 0.3	-2.891	0.016*
Reactive Silica	-	3.1 ± 0.1	1.4 ± 0.1	-9.073	<0.001*
Anion Sum	-	0.101 ± 0.008	0.080 ± 0.003	-2.657	0.024*
Bicarbonate	-	1.5 ± 0.3	1.8 ± 0.3	0.62	0.549
Cation Sum	-	0.168 ± 0.008	0.128 ± 0.005	-4.562	0.001*
Colour (TCU)	-	51.8 ± 1.5	26.8 ± 2.0	-7.962 ^{4}	<0.001*
Conductivity (μS/cm)	-	7.0 ± 0.5	6.0 ± 0.5	-1.368	0.201
Hardness (as $CaCO_3$)	-	5.7 ± 0.4	4.0 ± 0.2	-4.474	0.001*
Ion Balance (%)	-	25.1 ± 3.3	22.9 ± 1.2	-0.377	0.714
Langelier Index (@20°C)	-	-4.90 ± 0.22	-5.13 ± 0.07	-1.006 ^{4,5}	0.352
Langelier Index (@ 4°C)	-	-5.30 ± 0.22	-5.53 ± 0.07	-1.006 ^{4,5}	0.352
pH	6.5-9.0	6.3 ± 0.2	6.1 ± 0.1	-0.807	0.438
Saturation (@20°C)	-	11.2 ± 0.1	11.2 ± 0.0	0.821	0.431
Saturation (@4°C)	-	11.6 ± 0.1	11.6 ± 0.0	0.82	0.431

Table 4-5. Continued.

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	*t*[1]	*p*[2]
TDS	-	**10.8 ± 0.5**	7.0 ± 0.4	-6.038	<0.001*
Turbidity (NTU)	-	**0.4 ± 0.0**	0.3 ± 0.0	-1.906	0.086
Acidity (as Ca CO_3)	-	**3.3 ± 0.4**	3.7 ± 0.6	0.292	0.776
Ammonia (as N)	2.4	**0.06 ± 0.01**	0.03 ± 0.01	-1.897	0.087
TKN (as N)	-	**0.44 ± 0.01**	0.36 ± 0.03	-2.296[4]	0.065
DOC	-	**7.1 ± 0.2**	4.12 ± 0.10	-15.201	<0.001*
TIC (as C)	-	**0.6 ± 0.0**	0.66 ± 0.07	1.15	0.28
Cyanide (Total)	0.005	**0.003 ± 0.001**	0.004 ± 0.001	1.029	0.328

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded.**
Means include half detection values for stations where parameters were non-detects.
-no guideline available
* Statistically significant difference between exposure and reference stations ($p<0.05$)
[1] Students *t*-statistic; all data were logged prior to analyses unless otherwise stated
[2] Probability level
[3] Only 1 value, no standard deviation exists
[4] Variances were not homogeneous as per Bartlett's Test; separate variances T used
[5] Data not logged as values were negative
Parameters analyzed but not detected at 5 or more stations at either the reference or exposure areas include: chloride, fluoride, nitrate, nitrite, ortho-phosphorus, carbonate, total suspended solids

Table 4-6. Total metals ($\bar{x}$ ± se; mg/L) in water samples collected from the reference and exposure areas compared with Canadian freshwater guidelines (CCME, 1987) (se = standard error).

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	*t*[1]	*p*[2]
Aluminum	0.005	**0.118** ± 0.004	**0.040** ± 0.018	-3.066[3]	0.028*
Boron	-	0.007 ± 0.001	0.005 ± 0.001	-0.721	0.487
Copper	0.002	0.002 ± 0.001	0.002 ± 0.000	-0.925	0.377
Iron	0.3	0.162 ± 0.003	0.075 ± 0.011	-6.532[3]	0.001*
Manganese	-	0.010 ± 0.001	0.006 ± 0.001	-2.618	0.026*
Nickel	0.025	0.006 ± 0.000	0.001 ± 0.000	-7.695	<0.001*
Strontium	-	0.008 ± 0.000	0.003 ± 0.001	-6.57[3]	0.001*
Calcium	-	1.067 ± 0.067	0.783 ± 0.031	-3.967	0.003*
Magnesium	-	0.567 ± 0.042	0.400 ± 0.026	-3.32	0.008*
Potassium	-	0.450 ± 0.272	0.492 ± 0.296	0.404	0.695
Sodium	-	0.683 ± 0.017	0.567 ± 0.033	-3.098	0.011*

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded**
Means include half detection values for stations where parameters were non-detects
- no guideline available
* Statistically significant difference between exposure and reference stations ($p<0.05$)
[1] Students *t*-statistic; all data were logged prior to analysis unless otherwise noted
[2] Probability level
[3] Variances were not homogeneous per Bartlett's test; separate variances T used
nd not detected
na not applicable

Parameters analyzed but not detected at 5 or more stations at either the reference or the exposure area include: Antimony, Arsenic, Barium, Beryllium, Bismuth, Cadmium, Chromium, Cobalt, Lead, Mercury, Molybdenum, Selenium, Silver, Thallium, Tin, Uranium, Vanadium, Zinc, Phosphorus

Table 4-7. Dissolved metals ($\bar{x}$ ± se; mg/L) in water samples collected from the reference and exposure areas compared with Canadian freshwater guidelines (CCME, 1987) (se = standard error).

PARAMETER	CRITERIA	REFERENCE	EXPOSURE	*t*[1]	*p*[2]
Aluminum	0.005	**0.11** ± 0.00	**0.03** ± 0.01	-4.222[4]	0.008*
Boron	-	0.003 ± 0.001	0.006 ± 0.002	1.389	0.195
Copper	0.002	**0.003** ± 0.001	0.002 ± 0.001	-1.369	0.201
Iron	0.3	0.10 ± 0.00	0.03 ± 0.00	-12.578	<0.001*
Manganese	-	0.009 ± 0.001	0.005 ± 0.001	-3.277	0.008*
Nickel	0.025	0.006 ± 0.000	0.001 ± 0.000	-7.695	<0.001*
Selenium	0.001	**0.002** ± 0.001	nd	na	na
Strontium	-	0.008 ± 0.000	0.003 ± 0.001	-5.614	0.001*
Zinc	0.03	0.004 ± 0.000	0.003 ± 0.001	-1.503[4]	0.181
Calcium	-	1.18 ± 0.07	0.88 ± 0.03	-4.001	0.003*
Magnesium	-	0.67 ± 0.04	0.42 ± 0.02	-6.060	<0.001
Potassium	-	0.63 ± 0.14	0.65 ± 0.17	0.021	0.984
Sodium	-	0.78 ± 0.02	0.68 ± 0.03	-2.806	0.019*

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded**
Means include half detection values for stations where parameters were non-detects.
\- no guideline available
* Statistically significant difference between exposure and reference stations (*p*<0.05)
[1] Students *t*-statistic; all data logged before analysis unless otherwise noted
[2] Probability level
[3] Only 1 value, no standard deviation exists
[4] Variances were not homogeneous as per Bartlett's test; separate variances T used
nd not detected
na not applicable
Parameters analyzed but not detected at 5 or more stations at either the reference or exposure area: Antimony, Arsenic, Barium, Beryllium, Bismuth, Cadmium, Chromium, Cobalt, Lead, Mercury, Molybdenum, Silver, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc, Phosphorus

4.6 SEDIMENT CHEMISTRY

4.6.1 QA/QC

Method Blanks:

Method blanks were used by the analytical laboratory to assess possible laboratory-derived contamination, as well as providing information on the stability of established instrumental baselines. No contaminants were detected in the method blanks. This indicates that there was no laboratory-derived contamination and that the instrumental baselines were stable (Appendix D.2).

Certified Reference Materials:

The analysis of certified reference materials (CRMs) provided information on the accuracy of the laboratory performing the analysis. The percent recoveries for the certified reference materials (CRMs) are listed in Appendix D.2. All CRM results were between 82 and 111% recovery and within the range considered acceptable by the laboratory (±20%).

Matrix Spikes:

Matrix spikes are samples to which a known amount of analyte has been added. The analysis of matrix spikes provided information on the extraction efficiency of the method on the sample matrix. The percent recovery for matrix spikes is presented in Appendix D.2. All matrix spike recovery results were within 30% of the target concentration and within the range considered acceptable by the laboratory (± 40%). This indicates that the sediment matrix of samples collected from the study site did not affect analyte recovery (accuracy).

Laboratory Replicates:

Laboratory replicates were taken by splitting a sample before analysis. The replicates were analyzed as an additional sample to provide information on precision. The results of the replicate samples were compared to determine the relative percent difference (RPD). The RPDs of the laboratory replicates are listed in Appendix D.2 (Table D2.1). All laboratory replicates had RPDs less than 10% indicating acceptable precision.

Field Homogenization Replicates:

Field homogenization replicates are replicate samples that are split in the field once the sediment has been homogenized. These samples provided information on laboratory precision and sample heterogeneity. The RPD results of the field homogenization replicates are provided in Appendix D2 (Table D2.1). All field replicates had RPDs less than 12% indicating acceptable precision and sample homogenization in the field.

Field Cross-Contamination Blanks:

Field cross-contamination blanks were used to assess the degree to which contaminants may be exchanged from one sample to the next during sample collection and processing. The maximum concentration found in the cross-contamination swipes of the compositing equipment and Ponar grab (minus the swipe blank, i.e., filter) was for iron [(1.8-1.5)+(15-1.5) = 13.8 µg/filter or 0.03 mg/kg for a 500 g sample - worst case scenario based on highest metal concentration and smallest estimated sample size). The additional amount of contamination possible in this worst case scenario was below the detection limit for all analytes except mercury. Mercury was not analyzed for the cross-contamination blanks. Mercury was at or near the detection limit (0.01 mg/kg) for both the reference (0.01 to 0.02 mg/kg) and exposure (0.02 to 0.03 mg/kg) areas, therefore did not indicate an impact, and therefore potential cross-contamination is not of concern. In summary no significant cross contamination occurred in processing the samples in the field.

4.6.2 Chemistry

Physical characteristics are summarized in Table 4-8, metals data are summarized in Table 4-9, and the raw data are provided in Appendix D. Although every effort was made to sample similar habitats at the reference and exposure areas (Table 4-2), significant differences were found for water depth, fines, TOC and loss on ignition (Table 4-8). Sediment data were normalized to fines to reduce the effect of habitat differences on chemistry differences. Metals that were significantly different prior to normalization remained so, indicating that metals were elevated in the exposure area compared with the reference area. Sediment metal levels for barium and mercury were not different between areas. Although metals were elevated at the exposure area, only arsenic and nickel exceeded federal sediment criteria (Environment Canada, 1994). Arsenic exceeded the threshold effects level (5.9 mg/kg) at both the reference (6.1 mg/kg) and exposure (32.3 mg/kg) areas. Nickel exceeded the threshold effects level (18 mg/kg) at the exposure area (27 mg/kg), while arsenic exceeded the probable effects level (17 mg/kg) at the exposure area (32.3 mg/kg).

Table 4-8. Summary of sediment physical characteristics ($\bar{x}$ ± se) collected from Lupin mine site, September 23 - 27, 1996 (se = standard error).

PARAMETER	REFERENCE	EXPOSURE	t^1	p^2
Water depth (m)	2.63 ± 0.50	4.98 ± 0.67	2.564	0.028*
Percent fines ($<63\mu m$)[3]	79.18 ± 4.11	92.94 ± 2.78	2.592	0.027*
Total Organic Carbon (%)	0.86 ± 0.12	1.80 ± 0.19	4.512	0.001*
Loss on Ignition (%)	1.89 ± 0.24	3.79 ± 0.36	4.453	0.001*

Notes:
[1] Students *t*-statistic; all data were logged prior to analysis unless otherwise noted.
[2] Probability level
[3] Percent fines include the silt and clay fractions
* Statistically significant difference between exposure and reference stations ($p<0.05$)

Table 4-9. Total metals ($\bar{x}$ ± se; mg/kg) in sediment samples collected from exposure and reference areas compared with Federal sediment criteria (Environment Canada, 1994) (se = standard error).

PARAMETER	CRITERIA		REFERENCE	EXPOSURE	*t*[1]	*p*[2]
	TEL	PEL				
Arsenic	5.9	17.0	**6.1** ± 0.7	<u>**32.3**</u> ± 7.1	5.958 (5.930)	<0.001* (<0.001*)
Barium	-	-	52.9 ± 3.7	58.7 ± 3.9	1.129 (-0.501)	0.285 (0.627)
Chromium	37.3	90.0	23.4 ± 0.8	34.6 ± 1.5	6.803 (5.061[4])	<0.001* (0.002*)
Cobalt	-	-	5.5 ± 0.3	20.9 ± 6.0	5.100[4] (4.616)	0.003* (0.001*)
Copper	35.7	196.6	8.4 ± 0.4	15.3 ± 1.1	6.911 (5.213)	<0.001* (<0.002*)
Lead	35.0	91.3	1.5 ± 0.2	3.12 ± 0.09	6.658[4] (5.677[4])	<0.001* (<0.002*)
Nickel	18.0	35.9	13.4 ± 0.4	**27.0** ± 2.2	8.322 (6.021)	0.001* (0.005*)
Vanadium	-	-	20.7 ± 0.8	26.5 ± 1.1	4.386 (2.226)	0.001* (0.005*)
Zinc	123.1	314.8	25.6 ± 0.8	50.4 ± 2.8	10.824 (6.816)	<0.001* (<0.001*)
Mercury	0.174	0.486	0.02 ± 0.004	0.02 ± 0.002	1.855 (0.901[4])	0.093 (0.400)
Cyanide	-	-	0.18 ± 0.04	1.07 ± 0.23	6.422 (5.571)	<0.001* (<0.001*)

Means exceeding threshold effects level (TEL) criteria are **bolded**.
Means include half detection values for stations where parameters were no-detects.
Means exceeding probable effects level (PEL) criteria are <u>**bolded and underlined**</u>.

[1] Students *t*-statistic

[2] Probability level

[3] Only 1 value, no standard deviation exists

[4] Variances were not homogenous as per Bartlett's Test; separate variances T used

Values in brackets are for Students t-test on data normalized to % fines

Parameters analysed but not detected at 5 or more stations at either the reference or exposure areas include: Antomony, Beryllium Cadmium, Molybdenum, Selenium, Silver

- no criteria available

* Statistically significant difference between exposure and reference stations, *p*<0.05.

Arsenic and other metals in sediment at South Bay were comparable to levels in 1983 (Reid Crowther and R.L & L., 1984). Therefore, this reference area (i.e., South Bay) was probably not impacted significantly by mine seepage that occurred in 1992. Many sediment metal levels at Sun Bay from this study were similar to levels in 1983 (Reid Crowther and R.L. & L., 1984); however, arsenic was 4 - 5X and lead 2X higher in 1996. The comparison to historic data shows: 1) that the reference area selected was appropriate for sediments and, 2) that arsenic and lead accumulations have increased in the exposure area since pre-discharge conditions. Historically, metals appear to be elevated at Sun Bay compared with South Bay; the arsenic is likely attributable to mine discharge. In addition, arsenic has accumulated to levels of concern (i.e., to greater than probable effects levels), which warrants further investigation to assess potential impacts on biological communities.

4.7 BENTHOS

Results are summarized in Table 4-10; raw data are provided in Appendix E.

4.7.1 QA/QC

Quality control results for benthic invertebrate identification and enumeration were as follows:

- Sieved residues were subsampled in cases where large amounts of organic matter or high organism densities occurred. Subsampling was conducted on 9 of 12 samples. Subsampling error was calculated for two samples: both samples had coefficients of variation <10% (see Table 1 in Appendix E.2).

- All samples were treated with a protein stain to facilitate accurate sorting. Sorting efficiency was determined for two samples by recounting sorted residues; less than 5% of reported total sample abundance was found in each recount (see Table 2 in Appendix E.2).

- A voucher collection was compiled to allow taxonomic verifications by an independent expert if deemed necessary.

- All data transcriptions were checked for accuracy.

These results indicate that all benthic invertebrate community structure data quality objectives were met; data were appropriate to address the objectives of the study.

4.7.2 Community Structure

A total of 60 benthic invertebrate taxa were identified and enumerated at the twelve Contwoyto Lake stations (i.e., 6 exposure and 6 reference). Mean (±1 se) total richness (i.e., number of taxa) and abundance (i.e., number of organisms) and richness and abundance of major taxonomic groups (i.e., annelids, arthropods and molluscs) for exposure and reference areas are presented in Table 4-10.

Overall the benthic community was similar in the reference and exposure areas. Arthropods were the dominant major taxonomic group in terms of both richness (averaging about 70% of total station richness) and abundance (averaging about 60% of total station abundance). The chironomids were the most diverse and abundant group of arthropod taxa, accounting for nearly 45% of total (i.e., all taxa, not just arthropods) station richness and 15% of total station abundance.

While benthic communities in both areas were relatively similar, there were some general differences observed:

- Oligochaetes of family Enchytraeidae were generally more abundant in the exposure area.

- Harpacticoid copepods and ostracods were generally more abundant in the reference area.

- The chironomid *Heterotrissocladius* was more abundant in the exposure area.

Note, however, that there were significant differences in habitat characteristics (see Table 4-8) in addition to the differences in sediment metal concentrations (see Table 4-9). While exposure stations generally contained higher metal concentrations, they were also deeper, contained more fine particles, and contained more organic carbon than reference area stations. The lack of significant differences in benthos variables between areas despite significant differences in sediment metal concentrations suggests that either:

- Habitat differences between areas are confounding potential adverse effects of exposure to higher metal concentrations; or

- Elevated metal concentrations in the exposure area are not resulting in adverse effects to the benthic community.

It is important to note that subtle differences between areas may be due to natural factors (e.g., depth, substrate, recruitment/emergence patterns); the inclusion of a second reference area in future study designs would help to distinguish real effects from natural variability.

Table 4-10. Summary of benthic community variable results ($\bar{x}$ ± se) for exposure and reference areas at Lupin mine site, September 23 - 27, 1996.

PARAMETER[1]	REFERENCE	EXPOSURE	*t*[2]	*p*[3]
Total Richness	22.83 ± 1.14	25.33 ± 1.99	0.976	0.352
Total Abundance	625.67 ± 124.93	413.83 ± 118.53	-1.367	0.202
Annelid Richness	5.17 ± 0.48	5.00 ± 0.45	-0.249	0.808
Annelid Abundance	161.68 ± 59.26	90.83 ± 31.85	-1.068	0.311
Arthropod Richness	16.00 ± 0.93	18.83 ± 1.70	1.195	0.260
Arthropod Abundance	411.08 ± 105.08	209.50 ± 31.10	-1.582	0.145
Mollusc Richness	1.67 ± 0.49	1.67 ± 0.33	0.273	0.790
Mollusc Abundance	52.667 ± 25.207	113.5 ± 76.70	0.907	0.386

Notes: [1] Richness = number of taxa; Abundance = number of organisms; all data logged prior to analysis unless otherwise noted

[2] Students *t*-statistic

[3] Probability level; n.b., all tests were conducted with pooled variances (i.e., Bartlett's test results did not indicate unequal variances for any variables)

* Significant difference between exposure and reference area ($p<0.05$)

4.8 FISHERIES

4.8.1 Relative Abundance

Gillnetting catch data for the exposure and reference areas and CPUE are summarized in Table 4-11. Raw data are provided in Appendix F. In the present study, lake trout, round whitefish, and lake cisco were present in the exposure and reference areas in sufficient numbers to be considered as potential sentinel species. A potentially confounding factor is the apparent uneven distribution of species among exposure and reference areas. Lake trout were captured in both reference and exposure areas. Round whitefish were abundant in the exposure area but only a few fish were captured in the reference area. In contrast, only a few lake cisco were captured in the exposure area, while this species was abundant in the reference area.

4.8.2 Tissue Analysis

As noted in Section 3.7.2, no tissue samples were collected for metals and metallothionein analysis.

Table 4-11. Catch per unit effort (CPUE) for Contwoyto Lake (Lupin Mine).

		# OF FISH CAPTURED					
AREA	**SPECIES**	**ANGLING**	**GILLNETS**	**BEACH SEINE**	**ELECTROSHOCKING**	**MINNOW TRAP**	**CPUE**[1]
Exposure	Burbot		1				0.002
	Lake Cisco		12				0.022
	Lake Trout		16				0.029
	Round Whitefish		2				0.004
Reference	Arctic Grayling		1				0.004
	Burbot		1				0.004
	Lake Cisco		2				0.008
	Lake Trout		14				0.055
	Round Whitefish		9				0.036

[1] Gillnetting CPUE calculation is based on capture rate/15 m panel/hour of gillnet time.

Total Gillnetting Effort was:
Reference: 27 fish captured per 63 hours by 4 panels.
Exposure: 31 fish captured per 108 hours by 5 panels

4.9 LEVEL OF EFFORT

Level of effort is summarized in Table 4-12. Disbursement expenses are summarized in Table 4-13. Note that the levels of effort and disbursements do not include time spent reviewing the suitability of this site for testing hypotheses in 1997, scoring the site criteria or completing the 1997 study design.

Table 4-12. Estimated level of effort for each program element at the Lupin Mine Site.

		LEVEL OF EFFORT (PERSON HOURS)
Project Initiation		9
Literature Review and 1996 Study Design		32
Field Survey		
Planning and Preparation of Field Logistics		35
Site Reconnaissance, Habitat Characterization, and station selection		42
Sublethal toxicity sample collection		n/a
Water Chemistry		5
Sediment Chemistry		10
Benthos		10
Fish	*Population*	42
	Tissue Processing	n/a
Data Analysis and Interpretation		60
Preliminary Surveys and Recommendations Reports		80
Final Draft Survey Reports		64
Progress Reports		10
Conference Calls		10

n/a not applicable

Table 4-13. Expenses and disbursements.

EXPENSE	SUBLETHAL TOXICITY SAMPLE COLLECTION	WATER CHEMISTRY	SEDIMENT CHEMISTRY	BENTHOS	FISH
Travel	<------ $2535.00 ------>				
Accommodations[1]	<------ $200.00 ------>				
Meals[1]	<------ $140.00 ------>				
Miscellaneous Supplies	<------ $2700.00 ------>				
Shipping	<------ $2400.00 ------>				
Analyses	na	$3,370.00	$2,895.00	$2,400.00	na

na not sampled

[1] costs would be higher had mine charged their regular fee of $150 per day per person for accommodations and meals; costs noted were those incurred during travel from Vancouver to Lupin (i.e., Edmonton).

5.0
DISCUSSION

5.1 COMPARISON OF RESULTS WITH HISTORICAL DATA

5.1.1 Reference

Water Chemistry

Although historical reference data are unavailable for South Bay, water chemistry from South Bay in 1996 may be compared to Shallow Bay in 1983 as Shallow Bay is upstream of South Bay. Zinc was higher pre-discharge in 1983 than pre- and post-discharge in 1996; however, this may be due to differing detection limits. Water chemistry data are comparable with historic data.

Table 5-1. Summary of historic total metals in water (mg/L) in Contwoyto Lake (ranges are provided).

BAY	YEAR	MONTH	CONDUCTIVITY	AS	CU	NI	ZN
Shallow/ South Bay[1]	1983	Jun-Sep	8-11	<0.001	0.0015 0.0026	<0.005 0.008	<0.01 0.016
	1996	Sept	5-8	<0.001 0.002	<0.002 0.003	0.004 0.007	<0.002 0.007
Inner Sun Bay	1983	Jun-Sep	10-13	<0.001	0.001 0.0021	<0.005	<0.01 0.017
	1985[2]	Aug	12-15	<0.001	0.0007 0.0008	0.0008 0.0009	0.0005 0.0007
		Sep	335-347	0.184 0.196	0.022 0.027	0.0082 0.0089	0.0386 0.0395
	1996[3]	Jul	9-11	0.0007 0.002	<0.001 0.004	<0.001 0.002	0.001 0.007
		Jul-Aug	149-314	0.0011 0.0014	0.001 0.002	0.012 0.03	0.029- 0.096
		Sept	5-8	<0.002	<0.001 0.004	0.002 0.003	<0.002

[1] data are not available for South Bay; Shallow Bay (which is upstream of South Bay) is used for comparison

[2] pre- (August) and post- (September) discharge data are provided

[3] pre- (July), during (July-August) and post- (September) discharge data are provided; pre- and during discharge data were provided by Robert Martin, Environmental Coordinator, Lupin Mine

Note: 1983 (Reid Crowther and R.L. & L., 1984)
1985 (Murdoch and Sutherland, 1988)

Sediment Chemistry

Reference sediment chemistry from this study (1996) was comparable to historic (1983) sediment chemistry (Table 5-2). This suggests that although methods may have changed over the years [e.g., only measuring metals in fines (<63 µm) fraction (historic) rather than entire sample (1996)] any differences at the exposure area could potentially be attributed to mine activity rather than sampling methodologies.

Table 5-2. Summary of historic and 1996 sediment chemistry (mg/kg) in exposure and reference areas.

BAY	YEAR	MONTH	AS	CU	PB	NI	ZN
Inner Sun Bay (Exposure)	1983	Jun	6.5	28.3	1.8	28.2	55.7
		Aug	6.4	9.4	3.0	24.0	41.4
		Sep	7.3	29.3	3.9	22.6	47.6
	1985	Aug	19.6	15.7	22.4	18.3	52.1
		Sep	16.5	27.2	23.1	24.9	57.7
	1990	Aug	24.2	26.8	4.8	3.5	25.9
	1996	Sep	28.7	14.7	2.9	26.5	51.4
Outer Sun Bay (Exposure)	1983	Jun	7.4	52.6	1.5	26.9	62.9
		Aug	9.7	14.4	2.9	27.1	52.3
		Sep	7.0	45.3	6.9	25.2	50.7
	1985	Aug	43.4	24.8	17.8	22.9	61.1
		Sep	40.3	25.0	20.6	24.6	56.8
	1990	Aug	24.8	20.4	4.9	15.8	36.2
	1996	Sep	35.9	15.9	3.3	28.7	49.3
South Bay (Reference)	1983	Jun	4.0	26.9	2.1	13.2	29.6
		Aug	3.7	20.0	3.5	16.3	34.4
		Sep	3.2	13.2	3.6	14.4	23.7
	1996	Sep	6.0	8.4	2.5	13.4	25.6

Note: 1983 (Reid Crowther and R.L. & L, 1984)
1985 (Mudroch and Sutherland, 1988)
1990 (Porter et al., 1990)

Benthos

Historical benthic community data for South Bay were only available for one study which established baseline conditions prior to the onset of effluent discharge (Reid Crowther and RL & L, 1984). One component of that study was to provide a general characterization of the South Basin (i.e., water basin to south of Lupin Mine), including South Bay and a few smaller lakes.

Overall, the main component of the South Bay (i.e., reference area) benthic community found in 1996 are similar to those found in the baseline assessment; chironomids and oligochaetes were dominant. Because taxonomic identifications were apparently not conducted to the same level as the present study, specific comparisons among studies are inappropriate. In addition, sample collection methods were also different (Eckman vs. Petite Ponar grab).

The historical study did mention a reduction or absence of copepods and ostracods in South Bay in 1983 compared to the previous year's results (Reid Crowther and RL & L, 1984). Both taxa were relatively abundant at South Bay in the present study.

Fisheries

See text under fisheries in Section 5.1.2.

5.1.2 Exposure

Water Chemistry

Water chemistry data are comparable with historic water chemistry data during non-discharge periods. Although metals increase in the receiving environment during discharge, they quickly return to background levels. This is illustrated well by conductivity (Figure 5-1).

As is apparent from Table 5-1, effluent discharge affects the water quality of inner Sun Bay. Specifically, conductivity and both nickel and zinc concentrations were elevated during discharge in 1996 compared to pre- and post-discharge conditions. Mine process changes have improved effluent quality since 1985 (David Honstein, Lupin Mine, pers. comm.).

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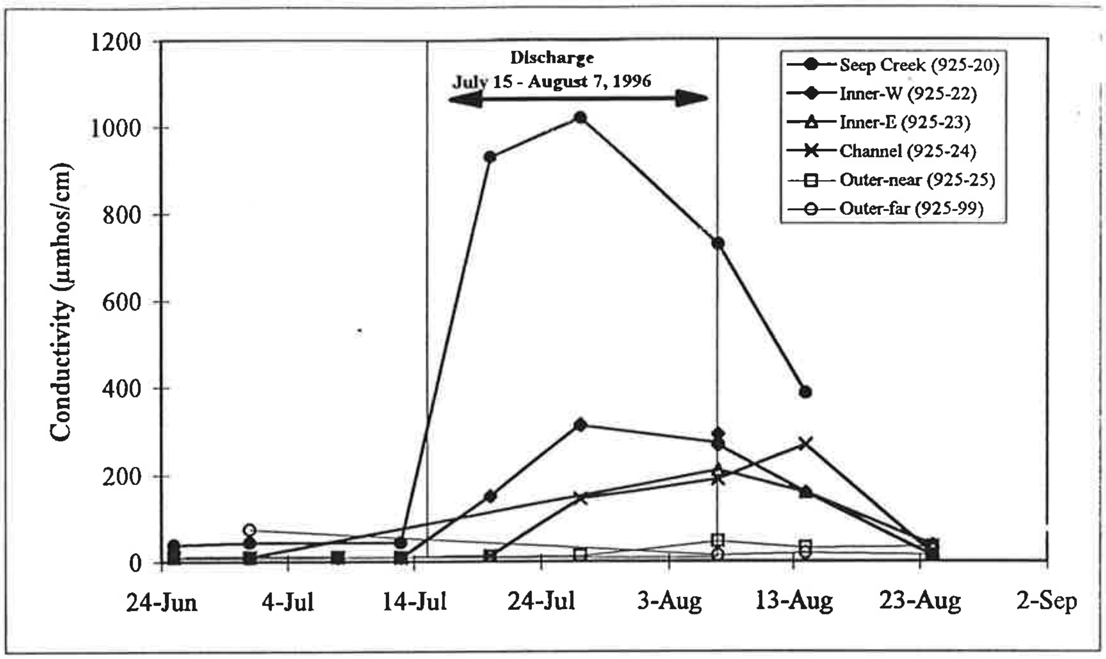
Figure 5-1. Conductivity (μmhos/cm) measured in Seep Creek, and Inner and Outer Sun Bay during effluent discharge in 1996.



Sediment Chemistry

Sediment chemistry metal levels were higher in 1996 than 1990 for As, Ni, and Zn and lower for Cu and Pb (Table 5-2). These trends occurred in both Inner and Outer Sun Bay. However, many of the values remain lower than those in 1985 suggesting that metal accumulations in sediments may not be increasing over time. It is unclear why there was such a large difference in pre-discharge data from 1982-1984 and 1985. One explanation could be that some mine seep occurred prior to the first discharge in September 1985. This would mean that only the 1982-1984 data are representative of pre-discharge/existing conditions.

Benthos

Several studies have addressed benthic community structure in the exposure area. Overall, the 1996 results for the Sun Bay area are consistent with the basic findings of historical studies. Differences in sample collection devices, seasons, and resolution of taxonomic identifications precluded making detailed comparisons.

Moore (1978) sampled stations in the main portion of Contwoyto Lake (one station was located near, but not in, Outer Sun Bay) and found that chironomids dominated the benthic community. The chironomid *Heterotrissocladius* was dominant at Contwoyto Lake stations, but was notably absent in several smaller lakes, presumably due to increased water temperatures in the latter (Moore, 1978).

The first studies to directly address the Sun Bay area were those focused on establishing baseline environmental conditions for the area surrounding the Lupin Mine prior to effluent discharge (e.g., Reid Crowther and R.L. & L., 1984). Chironomids and oligochaetes were present in most samples collected, and chironomids were the dominant species in terms of abundance (Reid Crowther and RL. & L., 1984). The studies showed some high temporal (i.e., seasonal and inter-annual) variability (e.g., ostracod abundance drastically declined between 1982 and 1983).

Mudroch and Sutherland (1988) sampled six stations in Inner and Outer Sun Bay and one reference station just northwest of Outer Sun Bay. Sampling was conducted in August and September of 1985, immediately before and after the onset of effluent discharge from the Lupin Mine. Both pre- and post-discharge benthic communities were generally dominated by chironomids. The mollusc *Pisidium* was also relatively abundant, particularly in Inner Sun Bay.

Porter et al. (1991) conducted a follow up study in 1990 to assess long-term impacts of Lupin Mine effluent on the Sun Bay area. The level of taxanomic resolution of the study was similar to that used in the present study. Again, the benthic community was dominated by chironomids; most differences among stations were attributed to substrate. Sampling stations for the 1996 study avoided the area responsible for most differences among stations.

Fisheries

Fish data from the present study are consistent with historic studies which have shown that fish populations appear to be larger in the south basin and the same species are present in both the west and south basins. A similar distribution was observed for lake cisco in the west (exposure area) and south (reference area) basins, with this species being considerably more abundant in the south basin. In contrast, comparison of round whitefish data shows that higher numbers were captured in the west basin during the present study than during previous studies that found this species to be evenly distributed between west and south basins. Although sex distribution data were not collected in the present study, available data from previous studies for approximately the same sampling period (i.e., August to September) show that males and females of each species are in the exposure and reference areas in similar abundance. The available data suggest that potential sentinel species (i.e., lake trout, round whitefish, and lake cisco) are present in sufficient numbers in the exposure and reference areas to support a larger monitoring program including collection of tissue for metals and metallothionein analysis. Although all species have not been consistently captured in large numbers in both areas, the data suggest that sufficient numbers could be captured given an appropriate level of effort (i.e., with respect to net placement and number, timing, and duration of gillnet sets).

No fish collection was attempted in Seep Creek in the present study due to the late scheduling of this project (i.e., the creek was effectively "dry"). Seep Creek discharge is seasonal with peak discharges occurring during the spring freshet before declining to minimal levels by late summer. Arctic grayling spawning occurs in the creek following freshet. Comparison of pre-decant data from 1983 and data from 1990 indicates that effluent discharges to the creek, which represent a significant component of the total creek discharge (i.e., up to 100% in low discharge years), may be adversely affecting Arctic grayling. However, insufficient data are available to assess whether observed effects (e.g., reduced growth) are a consequence of the effluent discharge (i.e., due to metals in water and sediment and/or temperature fluctuations resulting from discharges), or natural yearly variations in temperature. Additional study of Arctic grayling in Seep Creek and at a reference location would be required to determine whether effluent discharges are adversely affecting this species. Although Concession Creek has previously been used as a reference area, a different reference area should be identified as fish may be exposed to the effluent discharge as they move through Inner Sun Bay and Unnamed Lake to Concession Creek. Previous studies in the south basin indicate that Arctic grayling utilize several creeks (e.g., Decant Creek). Although it was not possible to examine potential creeks in the south basin during the present program, discussions with mine personnel confirmed that Arctic grayling utilize unidentified creeks in this area during the summer spawning period.

5.2 COMPARISON OF REFERENCE VERSUS EXPOSURE AREAS

Water Chemistry

Although there were significant differences between the reference and exposure areas for conductivity, it is unlikely that this difference is due to the mine as effluent was not being discharged. In addition, conductivity was higher at the reference area, as were many metals and major ions in the water column, compared with the exposure area. This suggests that there may be some geological differences between the south (reference) and west (exposure) basins which affect water flowing to the lake. Various metals were not elevated at the exposure area compared with the reference (in fact, the opposite was often observed), suggesting that the water column is not impacted in the long term (e.g., contaminant release from sediments) by mine discharged.

Sediment Chemistry

Various contaminants of concern were elevated in the sediments of the exposure area compared with the reference area. Although only arsenic and nickel exceed federal sediment criteria there is a potential impact zone within Sun Bay. Although metals concentration in sediment at Sun Bay exceed those at South Bay, metals concentrations at Sun Bay may not be significantly greater than previous years indicating that no further accumulations (compared to 1985) have occurred.

Benthos

Notwithstanding the distinct differences observed for sediment metals concentrations, no significant differences were detected between reference and exposure areas for any benthic community variables (i.e., total richness and abundance; richness and abundance of major taxonomic groups). While the benthic communities in both areas were relatively similar, some differences were observed for individual taxa (e.g., enchytraeid oligochaetes, harpacticoid copepods, and the chironomid *Heterotrissocladius*). These differences may be natural (i.e., related to area differences in depth, substrate, recruitment/emergence patterns) or anthropogenic (i.e., related to exposure to metals); the inclusion of a second reference area in future study designs would help to distinguish real (i.e., anthropogenic) effects from natural variability.

Fisheries

Aside from comparative catch data for the exposure and reference areas discussed in Section 5.1, further comparison is not possible given the limited scope of the present study. Specifically, since no effluent discharge occurred during the September monitoring period and no tissue samples were collected for metals and metallothionein, no additional 1996 data are available to assess exposure effects in fish.

However, considerable historic data on fish tissue-metal concentrations are available for the west basin exposure area and for reference areas in Concession Lake and in Contwoyto Lake. These data indicate that, with the exception of arsenic, metal concentrations in lake trout have not changed since the start of effluent discharges. Furthermore, tissue metal concentrations measured in exposure and reference areas are similar. Significant increases in arsenic have been observed in liver tissue taken from fish collected in Inner Sun Bay, with values increasing since the start of effluent discharge in 1985. Although no pre-discharge data are available for Outer Sun Bay, post-discharge values have not increased significantly (Table 2-4). These results are important as they show that fish species such as lake trout, which are expected to have less sediment exposure than benthic-feeding fish species, are accumulating arsenic. No conclusions can be reached on whether arsenic concentrations observed in lake trout are representative of other fish species, especially benthic feeding species, since there are no data for these species.

Summary

Important considerations in selecting the south basin as a reference area include no exposure to mine effluent discharges and comparable background water quality conditions to the west basin. Although the south basin does not receive effluent discharges, the potential for seepage or spills from the tailings management area are a concern. Routine monitoring of surface waters adjacent to the tailings ponds have shown no seepage. However, a spill to the south basin drainage occurred in 1992 following dam failure. Results of the present study did not reveal any elevated sediment-metal concentrations which could be attributed to this event. Water chemistry at the reference area was elevated for some contaminants compared with the exposure area, but water chemistry at the present reference area is variable when compared with historic data. Sediment chemistry at the reference area was not elevated compared with exposure data and historic reference data. This suggests that, although there is potential for mine seepage to reach the south basin, it does not seem to be prolonged as contaminant accumulations in the sediment at this area were not observed. Overall, comparison of historic water and sediment quality data with the results of the present study indicate that background conditions in the west and south basins are similar and that stations sampled in the south basin are not likely influenced significantly by the effluent discharge.

6.0

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE SAMPLING

The mine area was only accessible by mine airplane. Access to Contwoyto Lake was good, although mine personnel had to chauffeur us around the area due to safety concerns and a shortage of vehicles. However, the lake is very large making for a long boat trip from the mine docks (e.g., one hour to either Sun or South Bay and about two hours between them). In addition, inclement weather can make boat access difficult or impossible. Shortly before our arrival the lake was not manageable by small boat due to high winds. During our sampling program winds reached about 20 knots so that one trip to South Bay from the mine took over two hours. Helicopter support should be strongly considered for future studies.

Significant differences in habitat characteristics were found between the exposure and reference areas. The reference area was generally shallower and contained slightly coarser sediments with less organic carbon. Despite these differences, the benthic community did not differ significantly between areas. While differences were not observed in the gross measures analyzed statistically, there were some taxa (e.g., harpacticoid copepods) that did differ between areas. Given the differences in habitat characteristics between areas and the use of only one reference area, it is impossible to attribute such subtle effects to mine-associated metal exposure. Future use of impact assessment (i.e., use of exposure and reference areas) study designs should strongly consider multiple reference areas and/or selecting a new reference area for benthos.

Water flow from Seep Creek through Inner Sun Bay appears to result in transport of sediment-bound metals to depositional areas in Outer Sun Bay. Consequently, an exposure gradient is predicted to occur from relatively high sediment metal concentrations in Outer Sun Bay in a northerly direction. Limited historical data to the northwest of Outer Sun Bay suggest a reduction in sediment metal concentrations; this pattern would be expected to the northeast as well. The likely existence of a sediment contaminant gradient provides a good opportunity to test gradient-type hypotheses (e.g., sediment quality triad).

To measure/detect impacts on the water chemistry of Contwoyto Lake, sampling should be conducted during periods of effluent discharge, otherwise water chemistry is not a suitable parameter to assess impacts of mining activities. We recommend sampling occur one week after initiation of effluent discharge, which would allow some chemical equilibrium to occur. In contrast, sediment chemistry from this study suggests an impact (i.e., accumulation of arsenic) from effluent discharge.

Results of the fish collection component of the present study confirm that the south basin is an appropriate reference area. Presence/absence data showed that the same species are present in both areas and that target catch numbers for the most abundant species (i.e., lake trout, round whitefish, lake cisco) are achievable with reasonable sampling effort. Potential sentinel species present in the west and south basins can be ranked to determine the most appropriate target fish for a pilot monitoring program. Table 6-1 lists characteristics used to evaluate sentinel species. In general, suitable sentinel species will be abundant, benthic, and invest considerable energy in both reproduction and growth. Table 6-2 lists the life history characteristics of potential sentinel species for the Lupin mine area (i.e., lake trout, round whitefish, lake cisco, burbot and Arctic grayling) and ranks these species based on the desired data in Table 6-1. This ranking exercise indicates that burbot are preferred over round whitefish, lake cicso and lake trout. Burbot primarily feed on benthic invertebrates; their close association with sediments, limited mobility and other life history characteristics make them the most suitable sentinel species. Collection methods used in the 1996 studies (i.e., gillnets) were not suitable for capture of demersal fish; angling or trap netting would likely be more efficient. Arctic grayling received a low ranking due to their limited sediment exposure and predominately non-benthic food preference. However, this species has certain desirable characteristics such as spawning congregation in Seep Creek which coincides with the effluent discharge and abundance during this spawning period that merit its consideration as a sentinel species. In particular, Arctic grayling have the unique advantage of being directly exposed to effluent discharges and would provide an indication of the effects of exposure to elevated water-metal concentration. Although lake trout are abundant in Contwoyto Lake, this species has some important undesirable characteristics such as piscivorous rather than benthic food preference and high mobility. Predominantly benthic feeding fish such as burbot or sculpins will respond more rapidly to changes in benthic or pelagic community composition, and tissue from these fish may provide more relevant information about environmental conditions than tissue from lake trout. If these fish are caught in low abundances, then other less suitable species such as lake trout should be considered, as this species is relatively abundant in Contwoyto Lake. The obvious advantage of lake trout as a sentinel species is that adequate sample sizes could be collected with a reasonable effort. The disadvantage of the potentially lower sample sizes for round whitefish and lake cisco (i.e., as a result of limited abundance or uneven distribution between sampling areas) is that power to detect effects would be reduced in comparison to lake trout.

Table 6-1. Life history requirements for a sentinel species to allow the rapid detection of environmental impact (Munkittrick and Dixon, 1989).

Life History Trait	Description	Rating	
Sediment Exposure	Many contaminants accumulate in sediments. Species which are benthic feeders and are intimately exposed to sediment-associated contaminants would show a stronger response.	benthic mid-water surface	+ 0 -
Food	Species which feed on benthic invertebrates will respond faster, and with greater initial magnitude to food chain alterations associated with sediment contamination. Species which feed on organisms external to the aquatic food web (e.g., terrestrial insects) would not reflect changes in the aquatic food web.	benthos mid-water terrestrial	+ 0 -
Food Chain Position	Species which are intermediate in the food chain will reflect changes in both lower (invertebrate) and higher (piscivore) populations.	prey (intermediate) predator (top)	+ -
Spawning Time	Spring spawners face pre-spawning stress and mortality from harsh overwintering conditions, as well as stress from contaminant exposure. Fall spawners spawn immediately after the summer, when food is most abundant, and before any overwintering stress. Therefore, contaminant effects on reproductive parameters would occur more quickly, and be more evident, for spring spawners. Also, spring spawners are more desirable for our study, because we plan to sample in late summer-fall when fall spawners may already be migrating to spawning grounds.	spring spawners fall spawners	+ -
Mobility	Species which spend most of their time in a restricted area, at least for some months prior to sampling, will better reflect exposure conditions and effects in the area of capture.	stationary mobile	+ -
Fecundity	Changes in reproductive effort would be most evident in a species with a high reproductive energy demand.	>20,000 eggs <10,000 eggs	+ -
Growth Rate	Changes in environmental conditions (habitat or food availability) would be reflected quickly in a species with fast growth. A rough estimate of the growth rate can be obtained from change in length from ages 3 to 7. These ages overlap the age of maturity for most species, and food limitations will be reflected in a fish species with rapid growth over this interval.	>50% changes <40% changes	+ -
Longevity	Fish species which have a very short lifespan (e.g., guppies) are difficult to use for monitoring long-term effects. Fish species which have a very long lifespan (e.g., sturgeon) can be slow to respond to environmental changes, or can exhibit resilience which results in a considerable time lag before the detection of adverse effects.	10 to 15 y <5 or >15 y	+ -
Age at Maturity	Species which mature earlier will show effects on reproduction more rapidly.	3 to 6 y >6 y	+ -
Abundance	Obviously, species which are abundant would be easier, and less expensive to monitor. There are also concerns about sampling mortality effects on populations of rare species.	abundant rare/seasonal	+ -

Table 6-2. Suitability of potential Contwoyto Lake (Lupin Mine) sentinel species.

SPECIES	SEDIMENT EXPOSURE	FOOD	FOOD CHAIN	SPAWNING TIME	MOBILITY	FECUNDITY	GROWTH RATE	LONGEVITY	AGE AT MATURITY	ABUNDANCE	RANKING (MAX.= +10)
Lake Trout	-	0	-	-	-	0	+	-	-	+	-4
Arctic Char	-	0	-	-	-	-	+	-	-	-	-7
Round Whitefish	+	+	+	-	nd	-	0	+	+	0	+3
Lake Cisco	+	+	+	-	-	+	-	+	+	0	+3
Burbot	+	+	-	+	+	+	+	+	+	*	+8
Arctic Grayling	-	-	-	+	-	-	-	+	+	0	-3

nd no data available; values were assigned a neutral value in the ranking scheme.
* gill nets not as effective for catching demersal fish as other methods (e.g., angling or trap nets).

An important consideration in future studies will be the viability of fish captured. Protocol requirements for metallothionein specify that tissue collection must be limited to living fish (i.e., fish should be sacrificed immediately prior to dissection). Catch data from the present study indicated that while sufficient numbers of fish can be captured using gillnets, viability of fish was variable among species targeted. Lake trout remained viable following removal from the gillnets and placement in a holding container. In contrast, high mortality occurred among round whitefish and lake cisco. Duration of time between capture and removal from the gillnets appeared to be the main determinant of viability. Possible responses to increase the viability of captured fish include more frequent checking of gillnets and the use of alternate capture methods. Although more intensive attendance during gillnetting is an obvious response it may not be possible given the logistical considerations at the Lupin mine area, most notably access to the exposure and reference areas. Few fish were captured in gillnets during the morning and afternoon while most fish were captured during overnight sets. Although short gillnet sets (i.e., of 1-2 hours duration) in the early morning and evening are possible, alternative means of transportation to the sampling areas (e.g., helicopter) would be necessary due to their distance from the Lupin mine area and the extended travel time by boat. Alternate fishing methods which could be used at the Lupin mine area include angling and beach seining, with angling being the most appropriate to capture adult fish. Angling was attempted during the present study (level of effort was limited to 4 hours and no fish were captured); however, the level of effort required to capture large numbers of fish by this method cannot be estimated.

7.0
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APPENDIX A

Quality Management Plan (QMP)

INTRODUCTION

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

DATA QUALITY OBJECTIVES

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

QUALITY CONTROL OFFICER

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

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

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

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

FIELD PROTOCOLS FOR WATER, SEDIMENT AND BENTHIC SAMPLING

RESPONSIBILITIES AND TRAINING

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

STANDARD OPERATING PROCEDURES

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

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

This information was recorded on field data sheets.

BENTHIC SAMPLING

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

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

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

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

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

- Position the sampler securely to the bottom substrate, parallel to the water flow with the net pointing downstream.

- The sampler is brought down quickly to reduce the escape of rapidly-moving organisms.

- There should be no gaps under the edges of the frame that would allow for washing of water under the net and loss of benthic organisms. Eliminate gaps that may occur along the edge of the Hess/Surber sampler frame by shifting of rocks and gravel along the outside edge of the sampler.

- To avoid excessive drift into the sampler from outside the sample area, the substrate upstream from the sampler should not be disturbed.

- Once the sampler is positioned on the stream bottom, it should be maintained in position during sampling so that the area delineated remains constant.

- Hold the sampler with one hand or brace with the knees from behind.

- Heavy gloves should be required when handling dangerous debris; for example, glass or other sharp objects present in the sediment.

- Turn over and examine carefully all rocks and large stones and rub carefully in front of the net with the hands or a soft brush to dislodge the organisms and pupal cases, etc., clinging to them before discarding.

- Wash larger components of the substrate within the enclosure with stream water; water flowing through the sampler should carry dislodged organisms into the net.

- Stir the remaining gravel and sand vigorously with the hands to a depth of 5-10 cm where applicable, depending upon the substrate, to dislodge bottom-dwelling organisms.

- It may be necessary to hand pick some of the heavier mussels and snails that are not carried into the net by the current.

- Remove the sample by washing out the sample bucket, if applicable, into the sample container (wide-mouthed jar) with 10% buffered formalin fixative.

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

- Rinse the sampler net after each use.

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

Sieving of Benthic Samples

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

Quality Control Protocols for Benthic Identification

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

WATER CHEMISTRY

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

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

Quality Control Protocols for Water Chemistry

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

QC Requirements for Choice of an Analytical Laboratory

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

- Written (or referenced) SOPs for each analytical system
- Instrument calibration and maintenance records
- Clearly enunciated responsibilities of Q/A officer
- Adequate and training of personnel

- Good Laboratory Practices (GLPs)
- Sample preservation and storage protocols
- Sample tracking system (e.g., LIMS system)
- Use of QC samples to ensure control of precision and accuracy (Blanks, replicates, spikes, certified reference materials (minimum effort should be 15-20%)
- Maintenance of control charts and control limits on each QC sample
- Data handling and reporting (blanks, replicates, spike recovery, significant figures)
- Policy for reporting low level data (e.g., ASTM L,W)
- Participation in external audits and round robbins.

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

SEDIMENT SAMPLING

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

Quality Control Protocols for Sediment Sampling

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

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

TOXICITY SAMPLES

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

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

- Control charts
- Adequate data handling and reporting procedures.

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

FISH SAMPLES

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

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

Protocol for Gill Netting

The protocol employed during gill netting was as follows:

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

2) Netting locations were selected that were free of major bottom irregularities or obstructions (steep drop-offs, tree stumps, etc). Upon selection of the preferred site, the net was deployed in a continuous fashion along the selected route. Care was taken to avoid tangles or twists of the net, and to ensure that marker buoys at each end were visible (i.e.,

above water) after setting. Water temperatures were taken on the bottom and at 2 m above the bottom at each end of the net if other than isothermal conditions were present. The location and orientation of the net relative to shoreline features were marked on an appropriate map and/or obtained by electronic positioning equipment (GPS). The above noted information, the water depth at each end of the net, the date, time of day and other relevant information (wind direction and weather conditions, wave height, etc) were recorded in the field book for each netting location.

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

Protocol for Trap Netting

The protocol for trap netting was as follows:

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

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

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

4) When servicing the net, the house float was lifted and the boat was pulled under the anchor line between the house and the house anchor. The boat was then manually pulled sideways to the house of the net, which was then passed over the boat until all fish were concentrated at the near shore end of the house. The house access point was then opened and

the fish were removed, identified and enumerated. The fish required for analysis were retained, while the remainder were released live. The catch and the ancillary environmental data (as above) were recorded in the field book. The house opening was then closed and the boat backed out from beneath the net. Anchors were lifted and reset to re-tension the net as required.

Protocols for Back-Pack Electrofishing

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

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

Analysis of Fish

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

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

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

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

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

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

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

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

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

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

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

REFERENCES

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

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

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

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

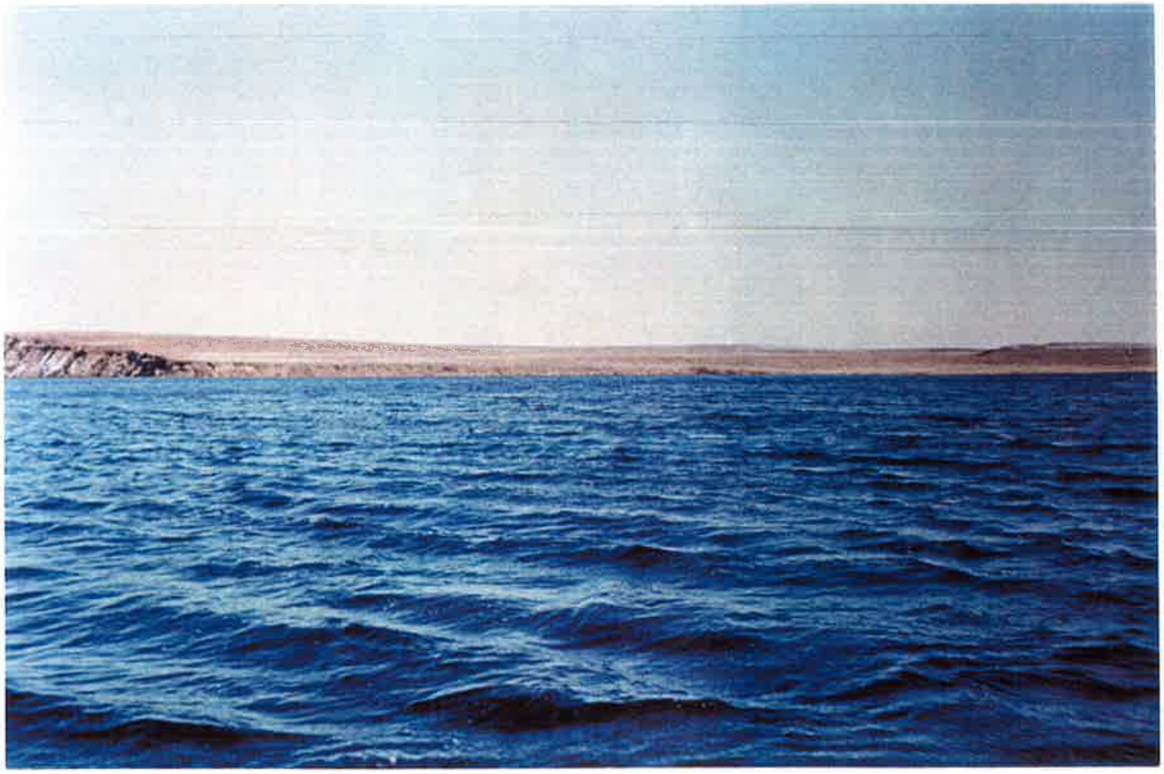
QAMS. 1990. Proposed glossary of quality assurance related terms. Quality Assurance Management Staff. Environmental Protection Agency, Washington, DC.

APPENDIX B

Selected Site Photographs

Photograph B-1. Sun Bay - exposure area, September, 1996.

Photograph B-2. South Bay - reference area, September 1996.



APPENDIX C

Water Quality and Chemistry

ATTACHMENT C.1

Detailed Methods

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted: Date Reported: MDS Ref#: MDS Quotc#:	September 16/96 December 4/96 966263 96-697-GS
Fax:	604-662-8548	Client Ref#: Sampled By:	AETE.3/72901 Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Analysis Performed:

- Alkalinity
- Anions(Cl,NO2,NO3,o-PO4 & SO4)
- Fluoride, Ion Chromatography
- RCAP MS Package, 8 Element ICPAES Scan
- Reactive Silica
- RCAP MS Package, 22 Element ICP-MS Scan
- RCAP Calculations
- Manual Conventionals(pH,Turbidity,Conductivity,Color)
- Acidity
- Mercury, Cold Vapour AA, Digestion Required
- Ammonia
- Total Kjeldahl Nitrogen, Digestion Required
- Dissolved Organic Carbon, as Carbon(Autoanalyzer)
- Total Inorganic Carbon(as C)
- Courier, Original Sample for London
- Courier, Subsample for London
- Total Suspended Solids
- Cyanide, Total(UV-Visible)
- Acid Digestion

Client: EVS Consultants Limited
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V7P 2R4

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MDS Ref#: 966263
MDS Quote#: 96-697-GS

Client Ref#: AETE.3/72901
Sampled By: Gary Mann

Certificate of Analysis

Methodology:

1) Determination of alkalinity in water by automated colorimetry.
   U.S. EPA Method No. 310.2
2) Analysis of anions in water by ion chromatography and/or by colorimetry.
   U.S. EPA Method No. 300.0 or
   U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.
3) Analysis of fluoride in water by Ion Chromatography.
   U.S. EPA Method No. 300.0
   Standard Methods(1985) No. 429.0
4) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
   U.S. EPA Method No. 200.7
5) Analysis of silicon in water by ICPAES and conversion to silica.
   Standard Methods(17th ed.) No. 4500-Si G
6) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
   U.S. EPA Method No. 200.8(Modification)

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Fax:	604-662-8548	Client Ref#:	AETE.3/72901
		Sampled By:	Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Methodology: (Cont'd)

7) Determination of theoretical RCAP parameters by calculation.
   EPL Internal Reference Method
8) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
   U.S. EPA Method No. 150.1, 120.1, 180.1 and 110.3
9) Determination of acidity in water by titration to pH 8.3.
   Standard Methods (17th ed.) No. 2310B
   U.S. EPA Method No. 305.1
10) Cold Vapour Atomic Absorption Analysis of water for mercury.
   U.S. EPA Method No. 245.2
   (Reference - Varian Method No. AA-51)
11) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
   ASTM Method No. D1426-79 C
   Refer - Method No. 1100106 Issue 122289

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North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

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Certificate of Analysis

Methodology: (Cont'd)

12) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289
13) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989
14) The determination of total inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
MOE Method No. ROM-102AC2.1
(Refer Method No. 1102106 Issue 122989)
15) Courier, Original sample for London
16) Courier, Subsample for London
17) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
18) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2

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Attn:	Iain Watson		

Certificate of Analysis

Methodology: (Cont'd)

19) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy. U.S. EPA Method No. 3020

Instrumentation:

1) Cobas Fara Centrifugal Analyzer
2) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
3) Dionex Ion Chromatograph, Series 4500i
4, 5) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
6) PE Sciex ELAN 6000 ICP-MS Spectrometer
7) Calculation from existing results; no instrumentation required.
8) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
9) Titrator
10) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
11,14) Skalar Segmented Flow Analyzer, Model SA 20/40
12,13) Technicon Autoanalyzer
15) COUR-LO-WT add missing information
16) COUR-LS-WT add missing information
17) Precision Mechanical Convention Oven/Sartorius Basic Balance
18) Hach UV - Visible Spectrophotometer, Model DR/3000

MDS
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Certificate of Analysis

19) Thermolyne Hotplate/Hot Block

Sample Description: Water

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

Results: Refer to REPORT of ANALYSIS attached.

fr Certified By
Brad Newman
Service Manager

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

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted:	September 16/96
		Date Reported:	December 4/96
		MDS Ref#:	966267
		MDS Quote#:	96-697-GS
Fax:	604-662-8548	Client Ref#:	AETE-3/72901
		Sampled By:	Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Analysis Performed:

ICP 25 ELEMENT SCAN, FILTERS
Acid Digestion
Courier, Subsample for Halifax
ICP-MS, Decommissioning Package Metals
Loss on Ignition
Mercury, Cold Vapour AA, Digestion Required
Cyanide, Total, Distillation Required
Courier, Subsample for London
Acid Digestion
Moisture Content
Courier, Subsample(Subcontracting)
Total Organic Carbon
Alkalinity
Anions(Cl,NO2,NO3,o-PO4 & SO4)
Fluoride, Ion Chromatography
RCAP MS Package, 8 Element ICPAES Scan
Reactive Silica
RCAP MS Package, 22 Element ICP-MS Scan
RCAP Calculations

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MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901
Sampled By: Gary Mann

Certificate of Analysis

Analysis Performed:

Manual Conventionals(pH,Turbidity,Conductivity,Color)
Acidity
Mercury, Cold Vapour AA, Digestion Required
Ammonia
Total Kjeldahl Nitrogen, Digestion Required
Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Total Inorganic Carbon(as C)
Courier, Original Sample for London
Total Suspended Solids
Cyanide, Total(UV-Visible)
Acid Digestion

Methodology:

1) Analysis of trace metals in filters by Inductively Coupled Plasma.
U.S. EPA Method No. 200.7
(Ministry of Environment ELSCAN)
2) The analysis of alkaline metals in filters by Inductively Coupled Plasma Emission Spectroscopy.
NIOSH Method No. 7300(Modification)
(Ministry of Environment ELSCAN)

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MDS Quote#:	96-697-GS
Client Ref#:	AETE-3/72901
Sampled By:	Gary Mann

Certificate of Analysis

Methodology: (Cont'd)

3) Acid digestion of filters for metals determination by ICP AES.
NIOSH Method No. 7300(Modification)
4) Courier, Subsample for Halifax
5) Analysis of trace metals in soil by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 6020(Modification)
6) The determination of the loss on ignition of organic matter by heating to constant weight @420°C.
McKeague Methods of Soil Analysis # 3.81
7) Analysis of mercury in soil by Cold Vapour Atomic Absorption.
U.S. EPA Method No. 7471
(Reference - Varian Method No. AA-51)
8) Analysis of total cyanide in soil by colourimetry in a continuous liquid flow.
U.S. EPA Method No. 9012
ASTM Method No. D2036-91
(Refer-Method No. 11002202 Issue 122989)

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MDS Quote#:	96-697-GS
Client Ref#:	AETE-3/72901
Sampled By:	Gary Mann

Certificate of Analysis

Methodology: (Cont'd)

9) Courier, Subsample for London
10) Acid digestion of soils for metals determination by inductively coupled plasma atomic emission spectrometry and/or flame or furnace atomic absorption spectroscopy.
U.S. EPA Method No. 3050(Modification)
11) Determination of the moisture content of soil by weight.
ASTM Method No. D2216-80
12) Courier, Subsample for Subcontract Lab.
13) LECO Induction Furnace and coulometric detection.
Based upon ASTM methodology
14) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
15) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1,
365.1 and 375.4.
16) Analysis of fluoride in water by Ion Chromatography.
U.S. EPA Method No. 300.0
Standard Methods(1985) No. 429.0

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Client: EVS Consultants Limited
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MDS Quote#:	96-697-GS
Client Ref#:	AETE-3/72901
Sampled By:	Gary Mann

Certificate of Analysis

Methodology: (Cont'd)

17) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7
18) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G
19) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)
20) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method
21) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1
and 110.3
22) Determination of acidity in water by titration to pH 8.3.
Standard Methods (17th ed.) No. 2310B
U.S. EPA Method No. 305.1

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MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901
Sampled By: Gary Mann

Certificate of Analysis

Methodology: (Cont'd)

23) Cold Vapour Atomic Absorption Analysis of water for mercury.
U.S. EPA Method No. 245.2
(Reference - Varian Method No. AA-51)

24) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
ASTM Method No. D1426-79 C
Refer - Method No. 1100106 Issue 122289

25) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289

26) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989

27) The determination of total inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
MOE Method No. ROM-102AC2.1
(Refer Method No. 1102106 Issue 122989)

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Iain Watson

Date Submitted: September 16/96
Date Reported: December 4/96
MDS Ref#: 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901
Sampled By: Gary Mann

Certificate of Analysis

Methodology: (Cont'd)

28) Courier, Original sample for London
29) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
30) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2
31) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
U.S. EPA Method No. 3020

Instrumentation:

1, 2,17,18) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
3,10,31) Thermolyne Hotplate/Hot Block
4) COUR-HS-SO add missing information
5,19) PE Sciex ELAN 6000 ICP-MS Spectrometer
6) Precision Mechanical Convention Oven/Neytech Furnace
7) Varian SpectrAA 400 Plus AA/Vapour Accessory VGA 76
8,25,26) Technicon Autoanalyzer
9) COUR-LS-SO add missing information

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Iain Watson

Date Submitted: September 16/96
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MDS Ref#: 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901
Sampled By: Gary Mann

Certificate of Analysis

Instrumentation:

11,29) Precision Mechanical Convention Oven/Sartorius Basic Balance
12) CRS-SBC-SO add missing information
13) LECO Induction Furnace, UIC CM5012 CO2 Analyzer
14) Cobas Fara Centrifugal Analyzer
15) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
16) Dionex Ion Chromatograph, Series 4500i
20) Calculation from existing results; no instrumentation required.
21) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
22) Titrator
23) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
24,27) Skalar Segmented Flow Analyzer, Model SA 20/40
28) COUR-LO-WT add missing information
30) Hach UV - Visible Spectrophotometer, Model DR/3000

Sample Description: Filter, Soil, Water

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

Results: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

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

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted: Date Reported: MDS Ref#: MDS Quote#:	October 25/96 December 9/96 967701 96-697-GS
Fax:	604-662-8548	Client Ref#:	AETE-3.72901
Attn:	Iain Watson		

Certificate of Analysis

Analysis Performed:	RCAP MS Package. 8 Element ICPAES Scan Reactive Silica RCAP MS Package, 22 Element ICP-MS Scan
Methodology:	1) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry. U.S. EPA Method No. 200.7 2) Analysis of silicon in water by ICPAES and conversion to silica. Standard Methods(17th ed.) No. 4500-Si G 3) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry. U.S. EPA Method No. 200.8(Modification)
Instrumentation:	1, 2) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer 3) PE Sciex ELAN 6000 ICP-MS Spectrometer

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted: Date Reported: MDS Ref#: MDS Quote#:	October 25/96 December 9/96 967701 96-697-GS
Fax:	604-662-8548	Client Ref#:	AETE-3.72901
Attn:	Iain Watson		

Certificate of Analysis

Instrumentation:

Sample Description: Water

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

Results: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

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

ATTACHMENT C.2

QA/QC

Table C2.1 Relative percent difference (RPD) of water chemistry laboratory replicates.

Parameter	LU-R-1-2 Station	LU-R-1-2 Replicate	RPD	Lu-E-1-1 Station	Lu-E-1-1 Replicate	RPD
METALS						
Aluminum	0.11	0.11	0	nd	nd	np
Antimony	nd	nd	np	nd	nd	np
Arsenic	nd	nd	np	nd	nd	np
Barium	0.005	0.005	0	nd	nd	np
Beryllium	nd	nd	np	nd	nd	np
Bismuth	nd	nd	np	nd	nd	np
Boron	0.006	nd	np	nd	nd	np
Cadmium	nd	nd	np	nd	nd	np
Chromium	nd	nd	np	nd	nd	np
Cobalt	0.001	0.001	0	nd	nd	np
Copper	nd	nd	np	nd	nd	np
Cyanide, Total	nd	nr	na	0.005	nr	na
Iron	0.1	0.11	9.5	0.03	0.02	0.4
Lead	nd	nd	np	nd	nd	np
Manganese	0.000	0.000	0	0.004	0.004	0
Mercury	nd	nr	na	nd	nr	na
Molybdenum	nd	nd	np	nd	nd	np
Nickel	0.006	0.006	0	nd	nd	np
Selenium	nd	nd	np	nd	nd	np
Silver	nd	nd	np	nd	nd	np
Strontium	0.008	0.008	0	0.005	0.005	0
Thallium	nd	nd	np	nd	nd	np
Tin	nd	nd	np	nd	nd	np
Titanium	nd	nd	np	nd	nd	np
Uranium	nd	nd	np	nd	nd	np
Vanadium	nd	nd	np	nd	nd	np
Zinc	0.003	0.003	0	0.004	0.003	28.6
CONVENTIONALS						
Major Ions						
Acidity(as CaCO3)	4	4	0	2	2	0
Alkalinity(as CaCO3)	2	2	0	2	2	0
Anion Sum	0.109	nr	na	0.087	nr	na
Bicarbonate(as CaCO3, calculated)	2	nr	na	2	nr	na
Calcium	1.3	1.3	0	0.9	0.9	0
Carbonate(as CaCO3, calculated)	nd	nr	na	nd	nr	na
Cation Sum	0.184	nr	na	0.135	nr	na
Chloride	nd	nd	np	nd	nd	np
Fluoride	nd	nd	np	nd	nd	np
Hardness(as CaCO3)	6.3	nr	na	4	nr	na
Ion Balance	25.4	nr	na	21.6	nr	na
Magnesium	0.7	0.7	0	0.4	0.4	0
Potassium	0.9	0.7	12.5	0.9	1	10.5
Sodium	0.8	0.9	11.8	0.7	0.8	13.3
Sulphate	3	3	0	nd	nd	np
Nutrients						
Ammonia(as N)	nd	nr	na	nd	nr	na
Dissolved Organic Carbon(DOC)	7.8	nr	na	4	nr	na
Nitrate(as N)	nd	nd	np	nd	nd	np
Nitrite(as N)	nd	nd	np	nd	nd	np
Orthophosphate(as P)	nd	nd	np	nd	nd	np
Phosphorus	nd	nd	np	nd	nd	np
Total Inorganic Carbon(as C)	0.5	nr	na	0.5	nr	na
Total Kjeldahl Nitrogen(as N)	0.45	nr	na	0.44	nr	na
Other						
Colour	56	57	1.8	19	20	5.1
Conductivity - @25°C	8	8	0	6	6	0
Langelier Index at 20°C	-4.17	nr	na	-5.2	nr	na
Langelier Index at 4°C	-4.57	nr	na	-5.6	nr	na
pH	6.8	6.8	0	6	5.9	1.7
Reactive Silica(SiO2)	3.2	3.1	3.2	1.1	1.1	0
Saturation pH at 20°C	11	nr	na	11.1	nr	na
Saturation pH at 4°C	11.4	nr	na	11.5	nr	na
Total Dissolved Solids(Calculated)	11	nr	na	7	nr	na
Turbidity	0.5	0.5	0	0.3	0.3	0
Total Suspended Solids	nd	nr	na	nd	nr	na

nd not detected
nr replicate not analyzed
np not possible to determine
na not applicable because replicate not analyzed

RPD calculated as (s1-s2)/(s1-s2)/2

Table C2.2 Relative percent difference (RPD) of water chemistry field homogenization replicates

Parameter	LU-E-1-6	LU-E-1-6 Field Rep	RPD	LU-E-1-6 Total	LU-E-1-6 Total Field Rep	RPD
METALS						
Aluminum	0.04	0.04	0	0.05	0.44	159.2
Antimony	nd	nd	np	nd	nd	np
Arsenic	nd	nd	np	nd	nd	np
Barium	nd	nd	np	nd	nd	np
Beryllium	nd	nd	np	nd	nd	np
Bismuth	nd	nd	np	nd	nd	np
Boron	0.005	0.015	100	nd	0.008	np
Cadmium	nd	nd	np	nd	nd	np
Chromium	nd	nd	np	nd	nd	np
Cobalt	nd	nd	np	nd	nd	np
Copper	nd	nd	np	0.004	nd	np
Cyanide, Total	0.006	nd	np	-	-	-
Iron	0.03	0.03	0	0.06	0.07	15.4
Lead	nd	nd	np	nd	nd	np
Manganese	0.003	0.003	0	0.004	0.004	0
Mercury	nd	nd	np	nd	nd	np
Molybdenum	nd	nd	np	nd	nd	np
Nickel	nd	nd	np	nd	nd	np
Selenium	nd	nd	np	nd	nd	np
Silver	nd	nd	np	nd	0.0013	np
Strontium	nd	nd	np	nd	nd	np
Thallium	nd	nd	np	nd	nd	np
Tin	nd	nd	np	nd	nd	np
Titanium	nd	nd	np	nd	nd	np
Uranium	nd	nd	np	nd	nd	np
Vanadium	nd	nd	np	nd	nd	np
Zinc	nd	nd	np	nd	nd	np
CONVENTIONALS						
Major Ions						
Acidity(as CaCO3)	4	4	0	-	-	-
Alkalinity(as CaCO3)	2	2	0	-	-	-
Anion Sum	0.072	0.072	0	-	-	-
Bicarbonate(as CaCO3, calculated)	2	2	0	-	-	-
Calcium	0.8	0.8	0	0.7	0.7	0
Carbonate(as CaCO3, calculated)	nd	nd	np	-	-	-
Cation Sum	0.113	0.119	2.6	-	-	-
Chloride	nd	nd	np	-	-	-
Fluoride	nd	nd	np	-	-	-
Hardness(as CaCO3)	3.6	3.6	0	-	-	-
Ion Balance	21.9	24.9	12.8	-	-	-
Magnesium	0.4	0.4	0	0.3	0.4	28.6
Potassium	0.6	0.8	28.6	nd	nd	np
Sodium	0.6	0.6	0	0.5	0.5	0
Sulphate	nd	nd	np	-	-	-
Nutrients						
Ammonia(as N)	nd	nd	np	-	-	-
Dissolved Organic Carbon(DOC)	-	4.2	np	-	-	-
Nitrate(as N)	nd	nd	np	-	-	-
Nitrite(as N)	nd	nd	np	-	-	-
Orthophosphate(as P)	nd	nd	np	-	-	-
Phosphorus	nd	nd	np	nd	nd	np
Total Inorganic Carbon(as C)	-	0.6	np	-	-	-
Total Kjeldahl Nitrogen(as N)	0.34	0.36	5.7	-	-	-
Other						
Colour	27	30	10.5	-	-	-
Conductivity - @25°C	8	5	46.2	-	-	-
Langelier Index at 20°C	-4.94	-5.15	4.2	-	-	-
Langelier Index at 4°C	-5.34	-5.55	3.8	-	-	-
pH	6.3	6.1	3.2	-	-	-
Reactive Silica(SiO2)	1.4	1.4	0	-	-	-
Saturation pH at 20°C	11.2	11.2	0	-	-	-
Saturation pH at 4°C	11.6	11.6	0	-	-	-
Total Dissolved Solids(Calculated)	6	7	15.4	-	-	-
Total Suspended Solids	nd	nr	np	-	-	-
Turbidity	0.3	0.3	0	-	-	-

nd	not detected
np	not possible to determine
nr	replicate not analyzed
na	not applicable because replicate not analyzed
-	analysis not requested

RPD calculated as (s1-s2)/(s1-s2)/2

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 966263
MDS Quote#: 96-697-GS

Client : EVS Consultants Limited
Contact: Iain Watson

Client Ref#: AETE.3/72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	102	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	110	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	LU-R-1-2	0.05	mg/L	nd(b)	0.1	yes	110	88	114	yes	0.31	0.30	0.18	0.42	yes	yes
Nitrite(as N)	LU-R-1-2	0.01	mg/L	nd(b)	0.03	yes	87	80	116	yes	0.17	0.20	0.12	0.28	yes	yes
Orthophosphate(as P)	LU-R-1-2	0.01	mg/L	nd(b)	0.03	yes	98	90	110	yes	0.89	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	102	90	113	yes	na	na	na	na	na	yes
Fluoride	LU-R-1-2	0.02	mg/L	nd	0.04	yes	103	80	120	yes	0.20	0.20	0.12	0.28	yes	yes
Boron	LU-R-1-2	0.005	mg/L	nd(b)	0.02	yes	105	85	115	yes	1.11	1.00	0.60	1.40	yes	yes
Calcium	LU-R-1-2	0.1	mg/L	nd(b)	0.2	yes	98	85	115	yes	1.0	1.0	0.2	1.8	yes	yes
Iron	LU-R-1-2	0.02	mg/L	nd(b)	0.03	yes	97	85	115	yes	1.08	1.00	0.60	1.40	yes	yes
Magnesium	LU-R-1-2	0.1	mg/L	nd(b)	0.2	yes	106	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Phosphorus	LU-R-1-2	0.1	mg/L	nd(b)	0.2	yes	93	85	115	yes	0.8	1.0	0.4	1.6	yes	yes
Potassium	LU-R-1-2	0.5	mg/L	nd(b)	1.0	yes	103	85	115	yes	5.6	5.0	1.0	8.0	yes	yes
Sodium	LU-R-1-2	0.1	mg/L	nd(b)	0.2	yes	105	85	115	yes	1.0	1.0	0.2	1.6	yes	yes
Zinc	LU-R-1-2	0.002	mg/L	0.005(b	0.02	yes	95	85	115	yes	1.08	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	98	80	120	yes	na	na	na	na	na	yes
Aluminum	LU-R-1-2	0.01	mg/L	nd(b)	0.03	yes	96	85	115	yes	0.11	0.100	0.050	0.140	yes	yes
Antimony	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.103	0.100	0.050	0.140	yes	yes
Arsenic	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Barium	LU-R-1-2	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.104	0.100	0.050	0.140	yes	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 966263
MDS Quote#: 96-697-GS

Client : EVS Consultants Limited
Contact: Iain Watson

Client Ref#: AETE.3/72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Beryllium	LU-R-1-2	0.005	mg/L	nd(b)	0.01	yes	103	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Bismuth	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.100	0.100	0.050	0.140	yes	yes
Cadmium	LU-R-1-2	0.0005	mg/L	nd(b)	0.0010	yes	103	85	115	yes	0.1040	0.100	0.050	0.140	yes	yes
Chromium	LU-R-1-2	0.002	mg/L	0.004(b	0.004	yes	109	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Cobalt	LU-R-1-2	0.001	mg/L	nd(b)	0.002	yes	110	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Copper	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Lead	LU-R-1-2	0.0001	mg/L	0.0007(	0.002	yes	102	85	115	yes	0.1040	0.100	0.050	0.140	yes	yes
Manganese	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.113	0.100	0.050	0.140	yes	yes
Molybdenum	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Nickel	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.114	0.100	0.050	0.140	yes	yes
Selenium	LU-R-1-2	0.002	mg/L	0.004(b	0.004	yes	101	85	115	yes	0.115	0.100	0.050	0.140	yes	yes
Silver	LU-R-1-2	0.0003	mg/L	nd(b)	0.0006	yes	101	85	115	yes	0.1020	0.100	0.050	0.140	yes	yes
Strontium	LU-R-1-2	0.005	mg/L	nd(b)	0.01	yes	106	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Thallium	LU-R-1-2	0.0001	mg/L	nd(b)	0.0002	yes	102	85	115	yes	0.1030	0.100	0.050	0.140	yes	yes
Tin	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.103	0.100	0.050	0.140	yes	yes
Titanium	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Uranium	LU-R-1-2	0.0001	mg/L	nd(b)	0.0002	yes	104	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Vanadium	LU-R-1-2	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Colour	na	5	TCU	nd(b)	10	yes	96	85	115	yes	na	na	na	na	na	yes
Conductivity - @25°C	na	1	us/cm	na(b)	na	na	98	91	109	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported: December 4/96
MDS Ref # : 966263
MDS Quote#: 96-697-GS

Client Ref#: AETE.3/72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
pH	na	0.1	Units	na(b)	na	na	101	98	102	yes	na	na	na	na	na	yes
Turbidity	na	0.1	NTU	nd(b)	0.5	yes	97	81	129	yes	na	na	na	na	na	yes
Acidity(as CaCO3)	na	1	mg/L	nd(b)	5	yes	na	na	na	na	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	92	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	92	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	93	77	122	yes	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	99	80	116	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	97	82	118	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.005	mg/L	nd	0.010	yes	96	82	115	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported:	December 4/96
MDS Ref # :	966260
MDS Quote#:	96-697-GS
Client Ref#:	AETE-3.72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	102	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	110	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	Travel Blank	0.05	mg/L	nd(b)	0.1	yes	110	88	114	yes	0.32	0.30	0.18	0.42	yes	yes
Nitrite(as N)	Travel Blank	0.01	mg/L	nd(b)	0.03	yes	87	80	116	yes	0.18	0.20	0.12	0.28	yes	yes
Orthophosphate(as P)	Travel Blank	0.01	mg/L	nd(b)	0.03	yes	98	90	110	yes	0.94	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	102	90	113	yes	na	na	na	na	na	yes
Fluoride	na	0.02	mg/L	nd(b)	0.04	yes	103	80	120	yes	na	na	na	na	na	yes
Boron	Travel Blank	0.005	mg/L	nd(b)	0.02	yes	105	85	115	yes	1.05	1.00	0.60	1.40	yes	yes
Calcium	Travel Blank	0.1	mg/L	nd(b)	0.2	yes	98	85	115	yes	1.0	1.0	0.2	1.8	yes	yes
Iron	Travel Blank	0.02	mg/L	nd(b)	0.03	yes	97	85	115	yes	1.04	1.00	0.60	1.40	yes	yes
Magnesium	Travel Blank	0.1	mg/L	nd(b)	0.2	yes	106	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Phosphorus	Travel Blank	0.1	mg/L	nd(b)	0.2	yes	93	85	115	yes	0.8	1.0	0.4	1.6	yes	yes
Potassium	Travel Blank	0.5	mg/L	nd(b)	1.0	yes	103	85	115	yes	5.6	5.0	1.0	8.0	yes	yes
Sodium	Travel Blank	0.1	mg/L	nd(b)	0.2	yes	105	85	115	yes	1.0	1.0	0.2	1.6	yes	yes
Zinc	Travel Blank	0.002	mg/L	0.005(b	0.02	yes	95	85	115	yes	1.05	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	98	80	120	yes	na	na	na	na	na	yes
Aluminum	Travel Blank	0.01	mg/L	nd(b)	0.03	yes	95	85	115	yes	0.10	0.100	0.050	0.140	yes	yes
Antimony	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Arsenic	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Barium	Travel Blank	0.005	mg/L	nd(b)	0.01	yes	104	85	115	yes	0.104	0.100	0.050	0.140	yes	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported:	December 4/96
MDS Ref # :	966260
MDS Quote#:	96-697-GS
Client Ref#:	AETE-3.72901

Client : EVS Consultants Limited
Contact: Iain Watson

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Beryllium	Travel Blank	0.005	mg/L	nd(b)	0.01	yes	102	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Bismuth	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Cadmium	Travel Blank	0.0005	mg/L	nd(b)	0.0010	yes	105	85	115	yes	0.1060	0.100	0.050	0.140	yes	yes
Chromium	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	111	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cobalt	Travel Blank	0.001	mg/L	nd(b)	0.002	yes	110	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Copper	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	111	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Lead	Travel Blank	0.0001	mg/L	nd(b)	0.002	yes	103	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Manganese	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.113	0.100	0.050	0.140	yes	yes
Molybdenum	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Nickel	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Selenium	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.116	0.100	0.050	0.140	yes	yes
Silver	Travel Blank	0.0003	mg/L	nd(b)	0.0006	yes	103	85	115	yes	0.0992	0.100	0.050	0.140	yes	yes
Strontium	Travel Blank	0.005	mg/L	nd(b)	0.01	yes	105	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Thallium	Travel Blank	0.0001	mg/L	nd(b)	0.0002	yes	104	85	115	yes	0.1040	0.100	0.050	0.140	yes	yes
Tin	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Titanium	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Uranium	Travel Blank	0.0001	mg/L	nd(b)	0.0002	yes	105	85	115	yes	0.1070	0.100	0.050	0.140	yes	yes
Vanadium	Travel Blank	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Colour	na	5	TCU	nd(b)	10	yes	96	85	115	yes	na	na	na	na	na	yes
Conductivity - @25°C	na	1	us/cm	na(b)	na	na	98	91	109	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported: December 4/96
MDS Ref # : 966260
MDS Quote#: 96-697-GS

Client Ref#: AETE-3.72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
pH	na	0.1	Units	na(b)	na	na	101	98	102	yes	na	na	na	na	na	yes
Turbidity	na	0.1	NTU	nd(b)	0.5	yes	97	81	129	yes	na	na	na	na	na	yes
Acidity(as CaCO3)	na	1	mg/L	nd(b)	5	yes	na	na	na	na	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	92	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	93	77	122	yes	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	99	80	116	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	97	82	118	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.005	mg/L	nd	0.010	yes	96	82	115	yes	na	na	na	na	na	yes

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MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901

Client : EVS Consultants Limited
Contact: Iain Watson

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	102	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	110	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	Lu-E-1-1	0.05	mg/L	nd(b)	0.1	yes	110	88	114	yes	0.32	0.30	0.18	0.42	yes	yes
Nitrite(as N)	Lu-E-1-1	0.01	mg/L	nd(b)	0.03	yes	87	80	116	yes	0.18	0.20	0.12	0.28	yes	yes
Orthophosphate(as P)	Lu-E-1-1	0.01	mg/L	nd(b)	0.03	yes	98	90	110	yes	0.89	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	102	90	113	yes	na	na	na	na	na	yes
Fluoride	Lu-E-1-1	0.02	mg/L	nd(b)	0.04	yes	103	80	120	yes	0.17	0.20	0.12	0.28	yes	yes
Boron	Lu-E-1-1	0.005	mg/L	nd(b)	0.02	yes	105	85	115	yes	1.10	1.00	0.60	1.40	yes	yes
Calcium	Lu-E-1-1	0.1	mg/L	nd(b)	0.2	yes	98	85	115	yes	1.1	1.0	0.2	1.8	yes	yes
Iron	Lu-E-1-1	0.02	mg/L	nd(b)	0.03	yes	97	85	115	yes	1.08	1.00	0.60	1.40	yes	yes
Magnesium	Lu-E-1-1	0.1	mg/L	nd(b)	0.2	yes	106	85	115	yes	1.2	1.0	0.2	1.6	yes	yes
Phosphorus	Lu-E-1-1	0.1	mg/L	nd(b)	0.2	yes	93	85	115	yes	0.8	1.0	0.4	1.6	yes	yes
Potassium	Lu-E-1-1	0.5	mg/L	nd(b)	1.0	yes	103	85	115	yes	5.1	5.0	1.0	8.0	yes	yes
Sodium	Lu-E-1-1	0.1	mg/L	nd(b)	0.2	yes	105	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Zinc	Lu-E-1-1	0.002	mg/L	0.005(b	0.02	yes	95	85	115	yes	1.10	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	98	80	120	yes	na	na	na	na	na	yes
Aluminum	Lu-E-1-1	0.01	mg/L	nd(b)	0.03	yes	99	85	115	yes	0.11	0.100	0.050	0.140	yes	yes
Antimony	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Arsenic	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Barium	Lu-E-1-1	0.005	mg/L	nd(b)	0.01	yes	108	85	115	yes	0.106	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
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(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported:	December 4/96
MDS Ref # :	966267
MDS Quote#:	96-697-GS
Client Ref#:	AETE-3/72901

Client : EVS Consultants Limited
Contact: Iain Watson

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Beryllium	Lu-E-1-1	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.102	0.100	0.050	0.140	yes	yes
Bismuth	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Cadmium	Lu-E-1-1	0.0005	mg/L	nd(b)	0.0010	yes	106	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Chromium	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cobalt	Lu-E-1-1	0.001	mg/L	nd(b)	0.002	yes	109	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Copper	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Lead	Lu-E-1-1	0.0001	mg/L	nd(b)	0.002	yes	106	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Manganese	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Molybdenum	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Nickel	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Selenium	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Silver	Lu-E-1-1	0.0003	mg/L	nd(b)	0.0006	yes	106	85	115	yes	0.1040	0.100	0.050	0.140	yes	yes
Strontium	Lu-E-1-1	0.005	mg/L	nd(b)	0.01	yes	108	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Thallium	Lu-E-1-1	0.0001	mg/L	nd(b)	0.0002	yes	105	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Tin	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Titanium	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Uranium	Lu-E-1-1	0.0001	mg/L	nd(b)	0.0002	yes	107	85	115	yes	0.1070	0.100	0.050	0.140	yes	yes
Vanadium	Lu-E-1-1	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Colour	na	5	TCU	nd(b)	10	yes	96	85	115	yes	na	na	na	na	na	yes
Conductivity - @25°C	na	1	us/cm	na(b)	na	na	98	91	109	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported:	December 4/96
MDS Ref # :	966267
MDS Quote#:	96-697-GS
Client Ref#:	AETE-3/72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
pH	na	0.1	Units	na(b)	na	na	101	98	102	yes	na	na	na	na	na	yes
Turbidity	na	0.1	NTU	nd(b)	0.5	yes	97	81	129	yes	na	na	na	na	na	yes
Acidity(as CaCO3)	na	1	mg/L	nd(b)	5	yes	na	na	na	na	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	99	79	120	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	93	77	122	yes	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	99	80	116	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	97	82	118	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.005	mg/L	nd	0.010	yes	96	82	115	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported:	December 9/96
MDS Ref # :	967701
MDS Quote#:	96-697-GS
Client Ref#:	AETE-3.72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
Boron	LU-E-1-FB	0.005	mg/L	nd(b)	0.02	yes	102	85	115	yes	1.01	1.00	0.60	1.40	yes	yes
Calcium	LU-E-1-FB	0.1	mg/L	nd(b)	0.2	yes	98	85	115	yes	1.0	1.0	0.2	1.8	yes	yes
Iron	LU-E-1-FB	0.02	mg/L	nd(b)	0.03	yes	98	85	115	yes	1.02	1.00	0.60	1.40	yes	yes
Magnesium	LU-E-1-FB	0.1	mg/L	nd(b)	0.2	yes	104	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Phosphorus	LU-E-1-FB	0.1	mg/L	nd(b)	0.2	yes	96	85	115	yes	0.9	1.0	0.4	1.6	yes	yes
Potassium	LU-E-1-FB	0.5	mg/L	nd(b)	1.0	yes	97	85	115	yes	4.1	5.0	1.0	8.0	yes	yes
Sodium	LU-E-1-FB	0.1	mg/L	nd(b)	0.2	yes	99	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Zinc	LU-E-1-FB	0.002	mg/L	nd(b)	0.02	yes	100	85	115	yes	1.04	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	LU-E-1-FB	0.5	mg/L	nd(b)	1.0	yes	99	80	120	yes	ns	ns	ns	ns	ns	yes
Aluminum	LU-E-1-FB	0.01	mg/L	nd(b)	0.03	yes	90	85	115	yes	0.14	0.100	0.050	0.140	yes	yes
Antimony	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.102	0.100	0.050	0.140	yes	yes
Arsenic	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	115	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Barium	LU-E-1-FB	0.005	mg/L	nd(b)	0.01	yes	104	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Beryllium	LU-E-1-FB	0.005	mg/L	nd(b)	0.01	yes	110	85	115	yes	0.122	0.100	0.050	0.140	yes	yes
Bismuth	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.100	0.100	0.050	0.140	yes	yes
Cadmium	LU-E-1-FB	0.0005	mg/L	nd(b)	0.0010	yes	105	85	115	yes	0.1070	0.100	0.050	0.140	yes	yes
Chromium	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.113	0.100	0.050	0.140	yes	yes
Cobalt	LU-E-1-FB	0.001	mg/L	nd(b)	0.002	yes	109	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Copper	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.116	0.100	0.050	0.140	yes	yes
Lead	LU-E-1-FB	0.0001	mg/L	nd(b)	0.002	yes	106	85	115	yes	0.1190	0.100	0.050	0.140	yes	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported: December 9/96
MDS Ref # : 967701
MDS Quote#: 96-697-GS

Client Ref#: AETE-3.72901

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Manganese	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.120	0.100	0.050	0.140	yes	yes
Molybdenum	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Nickel	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Selenium	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	114	85	115	yes	0.114	0.100	0.050	0.140	yes	yes
Silver	LU-E-1-FB	0.0003	mg/L	nd(b)	0.0006	yes	108	85	115	yes	0.1150	0.100	0.050	0.140	yes	yes
Strontium	LU-E-1-FB	0.005	mg/L	nd(b)	0.01	yes	113	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Thallium	LU-E-1-FB	0.0001	mg/L	nd(b)	0.0002	yes	105	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Tin	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Titanium	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	96	85	115	yes	0.098	0.100	0.050	0.140	yes	yes
Uranium	LU-E-1-FB	0.0001	mg/L	nd(b)	0.0002	yes	112	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Vanadium	LU-E-1-FB	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.105	0.100	0.050	0.140	yes	yes

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

ATTACHMENT C.3

Receiving Water Results

Table C3-1: Conventional parameters in water samples collected from reference and exposure stations at Lupin Mine on September 10-12, 1996. All measurements are in mg/L, unless otherwise specified.

Parameter	LOQ	Reference Stations									Exposure Stations								
		Lu-R-1-1	Lu-R-1-2	Lu-R-1-3	Lu-R-1-4	Lu-R-1-5	Lu-R-1-6	mean	sd	se	Lu-E-1-1	Lu-E-1-2	Lu-E-1-3	Lu-E-1-4	Lu-E-1-5	Lu-E-1-6	mean	sd	se
Alkalinity(as CaCO3)	1	1	2	2	1	2	2	1.7	0.5	0.2	2	2	2	1	2	2	1.8	0.4	0.2
Chloride	1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Fluoride	0.02	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Nitrate(as N)	0.05	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Nitrite(as N)	0.01	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Orthophosphate(as P)	0.01	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Sulphate	2	3	3	3	3	nd	4	2.8	1.0	0.4	nd	nd	nd	3	nd	nd	1.3	0.8	0.3
Reactive Silica(SiO2)	0.5	3.1	3.2	3.1	3	2.7	3.7	3.1	0.3	0.1	1.1	1.1	1.4	1.9	1.2	1.4	1.4	0.3	0.1
Anion Sum	na	0.088	0.109	0.11	0.079	0.09	0.131	0.101	0.019	0.008	0.087	0.086	0.08	0.084	0.071	0.072	0.080	0.007	0.003
Bicarbonate(as CaCO3, calculated)	1	nd	2	2	nd	2	2	1.5	0.8	0.3	2	2	2	nd	2	2	1.8	0.6	0.3
Carbonate(as CaCO3, calculated)	1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Cation Sum	na	0.18	0.184	0.158	0.166	0.137	0.184	0.168	0.019	0.008	0.135	0.123	0.139	0.139	0.118	0.113	0.128	0.011	0.005
Colour	5	53	56	55	51	50	46	51.8	3.7	1.5	19	33	26	31	25	27	26.8	4.9	2.0
Conductivity - @25°C (µs/cm)	1	5	8	8	7	6	8	7.0	1.3	0.5	6	5	5	7	5	8	6.0	1.3	0.5
Hardness(as CaCO3)	0.1	5.9	6.3	6	5.2	4.2	6.8	5.7	0.9	0.4	4	3.9	4	4.7	3.5	3.6	4.0	0.4	0.2
Ion Balance	0.01	34.3	25.4	17.8	35.4	20.6	16.9	25.1	8.1	3.3	21.6	18.1	26.6	24.6	24.7	21.9	22.9	3.0	1.2
Langelier Index at 20°C	na	-5.66	-4.17	-4.44	-5.12	-4.9	-5.09	-4.90	0.53	0.22	-5.2	-5.19	-5.42	-5.03	-4.98	-4.94	-5.13	0.18	0.07
Langelier Index at 4°C	na	-6.06	-4.57	-4.84	-5.52	-5.3	-5.49	-5.30	0.53	0.22	-5.6	-5.59	-5.82	-5.43	-5.36	-5.34	-5.53	0.18	0.07
pH (units)	0.1	5.7	6.8	6.6	6.3	6.3	5.9	6.3	0.4	0.2	6	6	5.7	6.4	6.2	6.3	6.1	0.3	0.1
Saturation pH at 20°C (units)	na	11.3	11	11	11.4	11.2	11	11.2	0.2	0.1	11.1	11.2	11.2	11.4	11.2	11.2	11.2	0.1	0.0
Saturation pH at 4°C (units)	na	11.7	11.4	11.4	11.8	11.6	11.4	11.6	0.2	0.1	11.5	11.6	11.6	11.8	11.6	11.6	11.6	0.1	0.0
Total Dissolved Solids(Calculated)	1	11	11	11	10	9	13	10.8	1.3	0.5	7	7	8	8	6	6	7.0	0.9	0.4
Turbidity (NTU)	0.1	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.1	0.0	0.3	0.2	0.3	0.5	0.3	0.3	0.3	0.1	0.0
Acidity(as CaCO3)	1	4	4	2	2	4	4	3.3	1.0	0.4	2	6	4	4	2	4	3.7	1.5	0.6
Ammonia(as N)	0.05	0.08	nd	nd	0.07	0.07	0.07	0.06	0.02	0.01	nd	nd	nd	nd	0.07	nd	0.03	0.02	0.01
Total Kjeldahl Nitrogen(as N)	0.05	0.45	0.45	0.45	0.44	0.4	0.42	0.44	0.02	0.01	0.44	0.44	0.38	0.32	0.26	0.34	0.36	0.07	0.03
Dissolved Organic Carbon(DOC)	0.5	7.1	7.8	7.2	7.1	6.7	6.5	7.1	0.5	0.2	4	4	4.4	4.3	3.9	-	4.12	0.22	0.10
Total Inorganic Carbon(as C)	0.5	0.5	0.5	0.5	0.7	0.5	0.7	0.6	0.1	0.0	0.5	0.8	0.8	0.5	0.7	-	0.66	0.15	0.07
Total Suspended Solids	5	nd	nd	nd	nd	nd	nd				nd	nd	nd	5	nd	nd	2.92	1.02	0.42
Cyanide, Total	0.005	0.006	nd	nd	nd	nd	nd	0.003	0.001	0.001	0.005	nd	nd	nd	0.005	0.006	0.004	0.002	0.001

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

Table C3-2: Total metals (mg/L) in water samples collected from reference and exposure stations at Lupin Mine on September 10-12, 1996.

Parameter	LOQ	Reference Stations									Exposure Stations								
		Lu-R-1-1	Lu-R-1-2	Lu-R-1-3	Lu-R-1-4	Lu-R-1-5	Lu-R-1-6	mean	sd	se	Lu-E-1-1	Lu-E-1-2	Lu-E-1-3	Lu-E-1-4	Lu-E-1-5	Lu-E-1-6	mean	sd	se
Aluminum	0.01	0.12	0.13	0.12	0.12	0.12	0.1	0.118	0.010	0.004	nd	nd	0.03	0.1	0.05	0.05	0.040	0.036	0.018
Antimony	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Arsenic	0.002	0.002	nd	nd	nd	nd	nd	0.001	0.000	0.000	nd	nd	nd	nd	nd	nd			
Barium	0.005	nd	0.005	0.005	nd	nd	0.006	0.004	0.002	0.001	nd	nd	nd	nd	nd	nd			
Beryllium	0.005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Bismuth	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Boron	0.005	0.011	0.006	0.006	nd	0.005	0.009	0.007	0.003	0.001	nd	0.005	0.006	0.008	0.008	nd	0.005	0.002	0.001
Cadmium	0.0005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Chromium	0.002	nd	nd	nd	nd	nd	nd				0.004	nd	0.003	nd	nd	nd	0.004	0.001	0.001
Cobalt	0.001	0.001	0.001	0.001	0.001	nd	0.002	0.001	0.000	0.000	nd	nd	nd	nd	nd	nd			
Copper	0.002	0.005	0.002	0.003	nd	nd	nd	0.002	0.002	0.001	nd	nd	nd	nd	nd	0.004	0.002	0.001	0.000
Iron	0.02	0.17	0.16	0.17	0.16	0.16	0.15	0.162	0.008	0.003	0.06	0.06	0.07	0.13	0.07	0.06	0.075	0.027	0.011
Lead	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Manganese	0.002	0.009	0.008	0.009	0.008	0.008	0.015	0.010	0.003	0.001	0.005	0.005	0.007	0.011	0.003	0.004	0.006	0.003	0.001
Mercury	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Molybdenum	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Nickel	0.002	0.006	0.006	0.006	0.005	0.004	0.007	0.006	0.001	0.000	nd	nd	nd	0.003	nd	nd	0.001	0.001	0.000
Selenium	0.002	nd	nd	nd	nd	nd	0.002	0.001	0.000	0.000	nd	nd	nd	nd	nd	nd			
Silver	0.0003	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Strontium	0.005	0.008	0.008	0.008	0.007	0.007	0.009	0.008	0.001	0.000	nd	nd	nd	0.006	nd	nd	0.003	0.001	0.001
Thallium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Tin	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Titanium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	0.003	nd	nd	0.001	0.001	0.000
Uranium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Vanadium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Zinc	0.002	nd	0.004	0.007	0.002	0.003	0.003	0.003	0.002	0.001	nd	nd	nd	nd	nd	nd			
Calcium	0.1	1.1	1.1	1.1	1	0.8	1.3	1.067	0.163	0.067	0.8	0.8	0.8	0.9	0.7	0.7	0.783	0.075	0.031
Magnesium	0.1	0.6	0.6	0.6	0.5	0.4	0.7	0.567	0.103	0.042	0.4	0.4	0.4	0.5	0.4	0.3	0.400	0.063	0.026
Phosphorus	0.1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Potassium	0.5	nd	nd	1.2	nd	nd	0.5	0.450	0.381	0.272	0.8	nd	0.9	0.5	nd	nd	0.492	0.296	0.171
Sodium	0.1	0.7	0.7	0.7	0.7	0.6	0.7	0.683	0.041	0.017	0.6	0.6	0.5	0.7	0.5	0.5	0.567	0.082	0.033

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

Table C3-3: Total dissolved metals (mg/L) in water samples collected from reference and exposure stations at Lupin Mine on September 10-12, 1996.

Parameter	LOQ	Reference Stations									Exposure Stations								
		Lu-R-1-1	Lu-R-1-2	Lu-R-1-3	Lu-R-1-4	Lu-R-1-5	Lu-R-1-6	mean	sd	se	Lu-E-1-1	Lu-E-1-2	Lu-E-1-3	Lu-E-1-4	Lu-E-1-5	Lu-E-1-6	mean	sd	se
Aluminum	0.01	0.11	0.11	0.12	0.11	0.1	0.09	0.11	0.01	0.00	nd	nd	0.01	0.06	0.03	0.04	0.03	0.02	0.01
Antimony	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Arsenic	0.002	0.002	nd	nd	nd	nd	nd	0.001	0.000	0.000	nd	nd	nd	nd	nd	nd			
Barium	0.005	0.005	0.005	0.005	0.005	nd	0.007	0.005	0.001	0.001	nd	nd	nd	nd	nd	nd			
Beryllium	0.005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Bismuth	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Boron	0.005	nd	0.006	nd	nd	nd	nd	0.003	0.001	0.001	nd	nd	nd	0.015	0.009	0.005	0.006	0.005	0.002
Cadmium	0.0005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Chromium	0.002	nd	nd	nd	nd	nd	nd				nd	0.002	0.002	nd	nd	nd	0.001	0.001	0.000
Cobalt	0.001	0.003	0.001	0.001	nd	nd	0.002	0.001	0.001	0.000	nd	nd	nd	nd	nd	nd			
Copper	0.002	0.003	nd	0.002	0.005	nd	0.003	0.003	0.002	0.001	nd	nd	nd	0.003	0.002	nd	0.002	0.001	0.001
Iron	0.02	0.11	0.1	0.11	0.11	0.1	0.09	0.10	0.01	0.00	0.03	0.03	0.03	0.05	0.03	0.03	0.033	0.008	0.003
Lead	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Manganese	0.002	0.008	0.008	0.008	0.008	0.007	0.015	0.009	0.003	0.001	0.004	0.004	0.005	0.009	0.002	0.003	0.005	0.002	0.001
Mercury	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Molybdenum	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Nickel	0.002	0.006	0.006	0.006	0.005	0.004	0.007	0.006	0.001	0.000	nd	nd	nd	0.003	nd	nd	0.001	0.001	0.000
Selenium	0.002	nd	nd	nd	nd	0.003	0.003	0.002	0.001	0.001	nd	nd	nd	nd	nd	nd			
Silver	0.0003	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Strontium	0.005	0.008	0.008	0.008	0.007	0.006	0.009	0.008	0.001	0.000	0.005	nd	nd	0.005	nd	nd	0.003	0.001	0.001
Thallium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Tin	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Titanium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Uranium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Vanadium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Zinc	0.002	0.003	0.003	0.004	0.006	0.003	0.004	0.004	0.001	0.000	0.004	0.002	nd	0.006	0.003	nd	0.003	0.002	0.001
Calcium	0.1	1.2	1.3	1.2	1.1	0.9	1.4	1.18	0.17	0.07	0.9	0.9	0.9	1	0.8	0.8	0.88	0.08	0.03
Magnesium	0.1	0.7	0.7	0.7	0.6	0.5	0.8	0.67	0.10	0.04	0.4	0.4	0.4	0.5	0.4	0.4	0.42	0.04	0.02
Phosphorus	0.1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Potassium	0.5	0.8	0.9	nd	0.9	0.7	nd	0.63	0.31	0.14	0.9	nd	1.1	nd	0.8	0.6	0.65	0.35	0.17
Sodium	0.1	0.8	0.8	0.8	0.8	0.7	0.8	0.78	0.04	0.02	0.7	0.7	0.7	0.8	0.6	0.6	0.68	0.08	0.03

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

ATTACHMENT C.4

Effluent Results

Table C4-1. Effluent chemistry during 1996 discharge, Lupin Mine (Source: Robert Martin, Environmental Coordinator, Lupin Mine)

Date	Stage	Station ID	Rep	Location Description	pH	Total Hardness (mg/L)	Conductivity (µmhos/cm)	NFR (mg/L)	Total Cyanide (mg/L)	Total Arsenic (mg/L)	Total Zn (mg/L)	Total Pb (mg/L)	Total Ni (mg/L)	Total Fe (mg/L)	Total Cu (mg/L)	Total Alkalinity (mg/L)	Temperature (°C)
15-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.83	211	988	0.6	0.012	0.0153	0.193	<0.004	0.071	0.14	0.004		13
15-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.53	209	981	1.6	0.009	0.011	0.203	<0.004	0.074	0.234	0.004		14
16-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.52	210	968	1.9	0.024	0.0138	0.261	<0.004	0.068	0.215	0.015		13
18-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.57	211	1015	3.9	0.012	0.0164	0.275	<0.004	0.068	0.308	0.02		14
19-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.7	211	1009	3.1	0.005	0.0074	0.295	<0.004	0.083	0.395	0.024		15
20-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.67	216	1001	4.6	0.012	0.0071	0.331	<0.004	0.079	0.609	0.034		15
21-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.23	219	988	1	0.014	0.0087	0.258	<0.004	0.073	0.203	0.008		16
22-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.36	219	1024	1.2	0.015	0.0086	0.258	<0.004	0.076	0.175	0.005		16
23-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.44	222	1008	1.2	0.01	0.0087	0.253	<0.004	0.069	0.123	0.005		15
24-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.48	220	1014	0.9	0.011	0.0083	0.265	<0.004	0.069	0.126	0.005		14
25-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.47	223	1002	<0.2	0.022	0.0086	0.263	<0.004	0.069	0.213	0.008		14
26-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.74	213	1036	0.2	0.01	0.0079	0.273	<0.004	0.073	0.275	0.008		14
27-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.06	219	953	1.7	0.016	0.0076	0.273	<0.004	0.075	0.165	0.005		14
28-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.89	220	980	1.8	0.008	0.0079	0.25	<0.004	0.088	0.075	0.003		15
29-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.89	222	979	1.3	0.013	0.0086	0.25	<0.004	0.084	0.189	0.003		15
30-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.33	219	1028	1.6	0.01	0.0099	0.255	<0.004	0.085	0.28	0.003		16
31-Jul-96	During	925-10	1	Effluent discharge to Seep Creek	6.62	222	1023	2.1	0.03	0.0121	0.265	<0.004	0.083	0.241	0.008		16
1-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	6.85	214	1000	41.4	0.017	0.0118	0.25	0	0.084	0.386	0.005		
2-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	6.11	223	1014	19.7	0.1	0.0116	0.273	0.001	0.088	0.301	0.008		
3-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	6.05	220	979	6.6	0.022	0.0164	0.27	0	0.091	0.219	0.005		
4-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	6.16	228	1002	3.5	0.06	0.0117	0.265	0.005	0.083	0.266	0.003		
5-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	5.92	227	1062	4.2	0.0119	0.0021	0.258	0	0.068	0.218	0		
6-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	6.21	235	956	1.9	0.025	0.0001	0.261	0	0.06	0.155	0		
7-Aug-96	During	925-10	1	Effluent discharge to Seep Creek	5.7		966		0.003	0.0005	0.258	0	0.073	0.21	0		
25-Jun-96	Pre	925-20	1	Mouth of Seep Creek	5.02	10.5	38	2	0.018	0.007	0.004	0	0.008	0.26	0.007		
1-Jul-96	Pre	925-20	1	Mouth of Seep Creek	6.27	14	43.9	2.5	0.013		0.006	0	0.009	0.361	0.008		
13-Jul-96	Pre	925-20	1	Mouth of Seep Creek	6.07	17	43	8.7	0.006	0.0074	0.011	<0.002	0.008	0.533	0.01	12	9
20-Jul-96	During	925-20	1	Mouth of Seep Creek	5.63	310	929	0.8	0.008	0.0056	0.258	<0.004	0.095	0.07	0.008	5	19
27-Jul-96	During	925-20	1	Mouth of Seep Creek	5.85		1019		0.01	0.0068	0.265	<0.004	0.103	0.023	0.01		18
7-Aug-96	During	925-20	1	Mouth of Seep Creek	4.6	728	728	1.3	0.0016	0.0062	0.246	0.001	0.087	0.093	0.011		
14-Aug-96	Post	925-20	1	Mouth of Seep Creek	5.11	222	386		0.014		0.1075	0	0.024	0.14375	0		
25-Jun-96	Pre	925-21	1	Mouth of Concession Creek	6.1	3.5	10	0.6	0.03		0.005	0.001	0	0.051	0		
1-Jul-96	Pre	925-21	1	Mouth of Concession Creek	6.04	4	9.3	0.3	0.014		0.005	0	0	0.065	0.001		
13-Jul-96	Pre	925-21	1	Mouth of Concession Creek	6	3	8	6	<0.004	0.0003	0.005	<0.002	0.001	0.076	0.004	8	8
20-Jul-96	During	925-21	1	Mouth of Concession Creek	5.91	3	938	0.3	<0.004	0.0006	0.003	<0.002	0.005	0.059	<0.001	5	19
27-Jul-96	During	925-21	1	Mouth of Concession Creek	6.2	3	9	0.3	0.005	0.0005	0.001	<0.002	0.002	0.05	0.004	7	17
7-Aug-96	During	925-21	1	Mouth of Concession Creek	5.75	9	9	0.6	0.002	0.0005	0.003	0.001	0	0.094	0.001		
14-Aug-96	Post	925-21	1	Mouth of Concession Creek	5.77	4	10		0.002		0.005	0	0.001	0.072	0.002		
25-Jun-96	Pre	925-22	1	Inner Sun Bay - West	6.05	68.5	10	1.8	0.002		0.001	0	0.001	0.047	0		
25-Jun-96	Pre	925-22	2	Inner Sun Bay - West	5.92	3	10	0.4	0.001	0.002	0.001	0.001	0.001	0.05	0		
25-Jun-96	Pre	925-22	3	Inner Sun Bay - West	6.03	3	11	0.3	0.007	0.00156	0.001	0	0.001	0.0555	0		
1-Jul-96	Pre	925-22	1	Inner Sun Bay - West	6.01	6	9.5	0.7	0.01		0.004	0	0.001	0.058	0.002		
1-Jul-96	Pre	925-22	2	Inner Sun Bay - West	6.05	3	9.5	0.6	0.008		0.003	0	0.001	0.07	0.002		
1-Jul-96	Pre	925-22	3	Inner Sun Bay - West	6.03	4	9.3	0.6	0.008		0.003	0	0.001	0.049	0.001		
8-Jul-96	Pre	925-22	1	Inner Sun Bay - West	5.93	50	8.8	1	0.004	0.0007	0.004	<0.002	0.001	0.097	0.001	5	17
8-Jul-96	Pre	925-22	2	Inner Sun Bay - West	6.04	20	8.9	0.2	0.004	0.0008	0.001	<0.002	0.001	0.094	0.001	8	17
8-Jul-96	Pre	925-22	3	Inner Sun Bay - West	6.13	30	8.8	0.2	0.007	0.0009	0.002	<0.002	0.002	0.089	0.001	8	17
13-Jul-96	Pre	925-22	1	Inner Sun Bay - West	6.05	3	9	0.6	<0.004	0.0006	0.006	<0.002	0.001	0.074	0.004	7	11
13-Jul-96	Pre	925-22	2	Inner Sun Bay - West	6.06	1.5	10	0.9	0.004	0.0007	0.007	<0.002	0.001	0.071	0.004	9	11
13-Jul-96	Pre	925-22	3	Inner Sun Bay - West	5.89	3	9	0.4	0.004	0.0007	0.007	<0.002	<0.001	0.076	0.004	7	11
20-Jul-96	During	925-22	1	Inner Sun Bay - West	5.85	30	151	0.3	<0.004	0.0013	0.03	<0.002	0.013	0.078	0.001	5	17
20-Jul-96	During	925-22	2	Inner Sun Bay - West	5.65	30	149	0.6	<0.004	0.0013	0.029	<0.002	0.012	0.08	0.002	3	17

Date	Stage	Station ID	Rep	Location Description	pH	Total Hardness (mg/L)	Conductivity (µmhos/cm)	NFR (mg/L)	Total Cyanide (mg/L)	Total Arsenic (mg/L)	Total Zn (mg/L)	Total Pb (mg/L)	Total Ni (mg/L)	Total Fe (mg/L)	Total Cu (mg/L)	Total Alkalinity (mg/L)	Temperature (°C)
20-Jul-96	During	925-22	3	Inner Sun Bay - West	5.71	30	151	<0.2	0.008	0.0014	0.029	<0.002	0.013	0.087	0.002	5	17
27-Jul-96	During	925-22	1	Inner Sun Bay - West	6.17	62.5	314	0.5	0.005	0.0014	0.068	<0.002	0.026	0.04	0.002	4	16
27-Jul-96	During	925-22	2	Inner Sun Bay - West	6.09	62.5	313	0.3	<0.004	0.0012	0.064	<0.002	0.026	0.032	0.001	4	16
27-Jul-96	During	925-22	3	Inner Sun Bay - West	6.04	63	312	0.5	0.007	0.0014	0.066	<0.002	0.027	0.034	0.001	4	16
7-Aug-96	During	925-22	1	Inner Sun Bay - West	5.8	272	272	0.7	0.003	0.0011	0.089	0.001	0.027	0.078	0.001		
7-Aug-96	During	925-22	2	Inner Sun Bay - West	5.78	292	292	0.4	0.005	0.0011	0.096	0.001	0.03	0.062	0.001		
7-Aug-96	During	925-22	3	Inner Sun Bay - West	5.8	267	267	0.9	0.002	0.013	0.091	0.001	0.027	0.063	0.001		
14-Aug-96	Post	925-22	1	Inner Sun Bay - West	6.06	31	158		0.003		0.04	0	0.01	0.05225	0.002		
14-Aug-96	Post	925-22	2	Inner Sun Bay - West	5.89	29	158		0.003		0.037	0.001	0.011	0.05	0.002		
14-Aug-96	Post	925-22	3	Inner Sun Bay - West	6.02	29	158		0.004		0.038	0.001	0.012	0.05575	0.002		
24-Aug-96	Post	925-22	1	Inner Sun Bay - West	5.55	4	14		0.006	0.001	0.0045	0	0.003	0.277	0.002		
24-Aug-96	Post	925-22	2	Inner Sun Bay - West	5.95	5	14		0.003	0.00052	0.00425	0	0.002	0.187	0.002		
24-Aug-96	Post	925-22	3	Inner Sun Bay - West	5.95	5	13		0.003	0.001	0.006	0	0.003	0.1055	0.016		
25-Jun-96	Pre	925-23	1	Inner Sun Bay - East	5.74	3.2	11	0.3	0.013		0	0.003	0.001	0.0525	0		
1-Jul-96	Pre	925-23	1	Inner Sun Bay - East	5.98	5	11.2	58	0.023		0.012	0	0.004	0.601	0.002		
7-Aug-96	During	925-23	1	Inner Sun Bay - East	5.89	210	210	0.3	0.003	0.0011	0.051	0.001	0.016	0.05	0.004		
14-Aug-96	Post	925-23	1	Inner Sun Bay - East	5.67	7	158	0.2	0.002		0.065	0.001	0.018	0.02875	0.001		
24-Aug-96	Post	925-23	1	Inner Sun Bay - East	5.74	9	38		0.005	0.00057	0.01075	0	0.005	0.14125	0.003		
25-Jun-96	Pre	925-24	1	Channel between Inner and Outer Sun Bay	6.03	1	11	0.9	0.004		0.003	0.002	0.001	0.06	0.002		
1-Jul-96	Pre	925-24	1	Channel between Inner and Outer Sun Bay	5.78	3	10.7	0.4	0.02		0.006	0	0.001	0.043	0.003		
8-Jul-96	Pre	925-24	1	Channel between Inner and Outer Sun Bay	5.61	20	10.6	4.4	<0.004	0.0005	0.002	<0.002	0.001	0.043	0.052	5	9
13-Jul-96	Pre	925-24	1	Channel between Inner and Outer Sun Bay	5.96	3.5	9	0.9	0.005	0.0007	0.01	<0.002	0.001	0.069	0.005	9	9
20-Jul-96	During	925-24	1	Channel between Inner and Outer Sun Bay	5.77	4	13	0.6	<0.004	0.0016	0.001	<0.002	0.001	0.045	0.001	4	11
27-Jul-96	During	925-24	1	Channel between Inner and Outer Sun Bay	6.27	29	144	0.2	0.005	0.0016	0.021	<0.002	0.009	0.036	<0.001	4	15
7-Aug-96	During	925-24	1	Channel between Inner and Outer Sun Bay	5.88	189	189	0.4	0.006	0.0009	0.045	0.001	0.014	0.048	0.052		
14-Aug-96	Post	925-24	1	Channel between Inner and Outer Sun Bay	5.75	4	268	0.3	0.002		0.063	0.001	0.018	0.02525	0.002		
24-Aug-96	Post	925-24	1	Channel between Inner and Outer Sun Bay	5.99	5	20		0.004	0.00047	0.006	0	0.003	0.12025	0.003		
25-Jun-96	Pre	925-25	1	Outer Sun Bay	5.96	3	13	0.1	0.01		0.001	0	0.001	0.03	0		
1-Jul-96	Pre	925-25	1	Outer Sun Bay	6.01	3	11.1	0.3	0.016		0.004	0	0.001	0.039	0.002		
8-Jul-96	Pre	925-25	1	Outer Sun Bay	5.82	40	10	0.2	0.006	0.0005	0.003	<0.002	0.001	0.045	0.057	5	8
13-Jul-96	Pre	925-25	1	Outer Sun Bay	5.73	3	10	0.5	0.006	0.0005	0.009	<0.002	<0.001	0.035	0.005	9	8
20-Jul-96	During	925-25	1	Outer Sun Bay	5.8	2	12	0.6	<0.004	0.0006	0.002	<0.002	0.001	0.038	<0.001	3	9
27-Jul-96	During	925-25	1	Outer Sun Bay	6.02	4	13	0.3	<0.004	0.001	0.002	<0.002	0.002	0.017	<0.001	4	11
7-Aug-96	During	925-25	1	Outer Sun Bay	6.14	46	46	0	0.003	0.0055	0.01	0.001	0.002	0.071	0.057		
14-Aug-96	Post	925-25	1	Outer Sun Bay	5.98	4	32	0.3	0		0.005	0.001	0.002	0.01175	0		
24-Aug-96	Post	925-25	1	Outer Sun Bay	5.73	8	34	2		0.00016	0.009	0	0.003	0.0675	0.001		
1-Jul-96	Pre	925-99	1	Outer Sun Bay		4	73.9	0.4	0.019					0.029	0.002		
7-Aug-96	During	925-99	1	Outer Sun Bay		15	15	0.1	0.002					0.045	0.062		
14-Aug-96	Post	925-99	1	Outer Sun Bay		4	20	0.2	0					0.0085	0		
24-Aug-96	Post	925-99	1	Outer Sun Bay	6.05	4	15.55	0.2					0.005	0.014	0.001		

APPENDIX D

Sediment Chemistry

ATTACHMENT D.1

Detailed Methods

MDS
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Particle Size Distribution of Soils and Sediments

1. Scope and Application

This method is designed for the determination of grain size distribution in soil and sediment samples as referenced in Land Resource Research Institute - Analytical Methods.

2. Summary of Method

A 20 - 30 gram portion of wet sample is spooned into a 250 mL wide-mouth polyproplyene bottle. Excess organic matter and carbonates are destroyed by the addition of hydrogen peroxide and allowing to stand overnight. The sample is dispersed in a distilled water and Calgon solution by mechanical shaking. The sand fraction is separated from the silt and clay by wet sieving through a 63 micron mesh size sieve. The particles remaining on the sieve (i.e. the gravel and sand fractions) are dried and then passed through a nest of sieves in order to separate the fractions using a Rotap. Each fraction is determined gravimetrically.

The silt and clay suspension passing through the 63 micron sieve are transferred to a 1000 mL graduated cylinder for pipette analysis. The sample is diluted to 1000 mL and mixed for 1 minute using a plunger. Twenty mL aliquots are extracted at specific depths and times as defined by a pipetting schedule. These aliquots are transferred to pre-weighed dishes which are placed in a convection oven at 105C and allowed to dry to constant weight. The diameter for each fraction is determined based upon Stoke's Law which relates the settling velocity of spherical particles to their diameter.

3. Quality Assurance

Duplicate analysis of samples is performed at a frequency of 10%. Standard deviation for any given size fraction is +/- 5%.

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted:	September 16/96
		Date Reported:	December 4/96
		MDS Ref#:	966267
		MDS Quote#:	96-697-GS
Fax:	604-662-8548	Client Ref#:	AETE-3/72901
		Sampled By:	Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Analysis Performed:

- ICP 25 ELEMENT SCAN, FILTERS
- Acid Digestion
- Courier, Subsample for Halifax
- ICP-MS, Decommissioning Package Metals
- Loss on Ignition
- Mercury, Cold Vapour AA, Digestion Required
- Cyanide, Total, Distillation Required
- Courier, Subsample for London
- Acid Digestion
- Moisture Content
- Courier, Subsample(Subcontracting)
- Total Organic Carbon
- Alkalinity
- Anions(Cl,NO2,NO3,o-PO4 & SO4)
- Fluoride, Ion Chromatography
- RCAP MS Package, 8 Element ICPAES Scan
- Reactive Silica
- RCAP MS Package, 22 Element ICP-MS Scan
- RCAP Calculations

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Attn:	Iain Watson		

Certificate of Analysis

Analysis Performed:

Manual Conventionals(pH,Turbidity,Conductivity,Color)
Acidity
Mercury, Cold Vapour AA, Digestion Required
Ammonia
Total Kjeldahl Nitrogen, Digestion Required
Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Total Inorganic Carbon(as C)
Courier, Original Sample for London
Total Suspended Solids
Cyanide, Total(UV-Visible)
Acid Digestion

Methodology:

1) Analysis of trace metals in filters by Inductively Coupled Plasma.
   U.S. EPA Method No. 200.7
   (Ministry of Environment ELSCAN)
2) The analysis of alkaline metals in filters by Inductively Coupled Plasma Emission Spectroscopy.
   NIOSH Method No. 7300(Modification)
   (Ministry of Environment ELSCAN)

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Certificate of Analysis

Methodology: (Cont'd)

3) Acid digestion of filters for metals determination by ICP AES.
NIOSH Method No. 7300(Modification)
4) Courier, Subsample for Halifax
5) Analysis of trace metals in soil by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 6020(Modification)
6) The determination of the loss on ignition of organic matter by heating to constant weight @420°C.
McKeague Methods of Soil Analysis # 3.81
7) Analysis of mercury in soil by Cold Vapour Atomic Absorption.
U.S. EPA Method No. 7471
(Reference - Varian Method No. AA-51)
8) Analysis of total cyanide in soil by colourimetry in a continuous liquid flow.
U.S. EPA Method No. 9012
ASTM Method No. D2036-91
(Refer-Method No. 11002202 Issue 122989)

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Certificate of Analysis

Methodology: (Cont'd)

9) Courier, Subsample for London
10) Acid digestion of soils for metals determination by inductively coupled plasma atomic emission spectrometry and/or flame or furnace atomic absorption spectroscopy.
U.S. EPA Method No. 3050(Modification)
11) Determination of the moisture content of soil by weight.
ASTM Method No. D2216-80
12) Courier, Subsample for Subcontract Lab.
13) LECO Induction Furnace and coulometric detection.
Based upon ASTM methodology
14) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
15) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.
16) Analysis of fluoride in water by Ion Chromatography.
U.S. EPA Method No. 300.0
Standard Methods(1985) No. 429.0

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted: Date Reported: MDS Ref#: MDS Quote#:	September 16/96 December 4/96 966267 96-697-GS
Fax:	604-662-8548	Client Ref#: Sampled By:	AETE-3/72901 Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Methodology: (Cont'd)

17) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7
18) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G
19) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)
20) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method
21) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1
and 110.3
22) Determination of acidity in water by titration to pH 8.3.
Standard Methods (17th ed.) No. 2310B
U.S. EPA Method No. 305.1

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Certificate of Analysis

Methodology: (Cont'd)

23) Cold Vapour Atomic Absorption Analysis of water for mercury.
    U.S. EPA Method No. 245.2
    (Reference - Varian Method No. AA-51)
24) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
    ASTM Method No. D1426-79 C
    Refer - Method No. 1100106 Issue 122289
25) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
    ASTM Method No. D3590-84AFD
    Refer - Method No. 1100106 Issue 122289
26) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
    MOE Method No. ROM - 102AC2
    Refer - Method No. 1102106 Issue 122989
27) The determination of total inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
    MOE Method No. ROM-102AC2.1
    (Refer Method No. 1102106 Issue 122989)

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Fax:	604-662-8548	Client Ref#: Sampled By:	AETE-3/72901 Gary Mann
Attn:	Iain Watson		

Certificate of Analysis

Methodology: (Cont'd)

28) Courier, Original sample for London
29) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
30) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2
31) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
U.S. EPA Method No. 3020

Instrumentation:

1, 2,17,18) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
3,10,31) Thermolyne Hotplate/Hot Block
4) COUR-HS-SO add missing information
5,19) PE Sciex ELAN 6000 ICP-MS Spectrometer
6) Precision Mechanical Convention Oven/Neytech Furnace
7) Varian SpectrAA 400 Plus AA/Vapour Accessory VGA 76
8,25,26) Technicon Autoanalyzer
9) COUR-LS-SO add missing information

MDS
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Client Ref#: AETE-3/72901
Sampled By: Gary Mann

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Instrumentation:

11,29) Precision Mechanical Convention Oven/Sartorius Basic Balance
12) CRS-SBC-SO add missing information
13) LECO Induction Furnace, UIC CM5012 CO2 Analyzer
14) Cobas Fara Centrifugal Analyzer
15) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
16) Dionex Ion Chromatograph, Series 4500i
20) Calculation from existing results; no instrumentation required.
21) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
22) Titrator
23) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
24,27) Skalar Segmented Flow Analyzer, Model SA 20/40
28) COUR-LO-WT add missing information
30) Hach UV - Visible Spectrophotometer, Model DR/3000

Sample Description: Filter, Soil, Water

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

Results: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

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

ATTACHMENT D.2

QA/QC

Table D2-1 Relative percent differences (RPD) of (a) laboratory and (b) field replicates of sediment samples

(a) laboratory

Parameter	Lu-R-2-2A	Lu-R-2-2A Replicate	RPD
Antimony	nd	nd	np
Arsenic	4.4	5.6	24
Barium	55.4	59.1	6.5
Beryllium	nd	nd	np
Cadmium	nd	nd	np
Chromium	25.5	27.9	8.9
Cobalt	5	5.4	7.7
Copper	9.4	10	6.2
Lead	nd	nd	np
Molybdenum	nd	nd	np
Nickel	14.6	16	9.2
Selenium	nd	nd	np
Silver	nd	nd	np
Vanadium	22.3	24.4	8.9
Zinc	27.6	30.1	8.7
Loss on Ignition	2.1	2.13	1.4
Mercury	0.02	nr	na
Cyanide, Total	0.3	nr	na

(b) field

Parameter	Lu-E-2-6A	Lu-E-2-6B	RPD
Antimony	nd	nd	np
Arsenic	13.9	13.6	2.2
Barium	47.2	43.5	8.2
Beryllium	nd	nd	np
Cadmium	nd	nd	np
Chromium	28.1	25.9	8.1
Cobalt	9.6	9.1	5.3
Copper	13.6	13	4.5
Lead	2.9	2.8	3.5
Molybdenum	nd	nd	np
Nickel	21.8	20.4	6.6
Selenium	nd	nd	np
Silver	nd	nd	np
Vanadium	22.1	20.1	9.5
Zinc	47.1	43.6	7.7
Loss on Ignition	4.68	4.28	8.9
Mercury	0.02	0.02	0
Cyanide, Total	0.8	1	11

nd	not detected
np	not possible to determine
nr	replicate not analyzed
na	not applicable because replicate not analyzed

Table D2-2 Field cross-contamination swipes.

Parameter (in μg/filter)	Lu-XCON-1 (blank)	Lu-XCON-2 (composite equipment)	Lu-XCON-3 (ponar)	Lu-XCON-1	Lu-XCON-1 Lab Replicate	RPD
Aluminum	nd	nd	2.5	nd	nd	np
Barium	0.2	nd	nd	0.2	0.2	0
Beryllium	nd	nd	nd	nd	nd	np
Bismuth	nd	nd	nd	nd	nd	np
Boron	nd	nd	nd	nd	nd	np
Cadmium	nd	nd	nd	nd	nd	np
Calcium	4.9	2.3	4.2	4.9	4.9	0
Chromium	nd	nd	1	nd	nd	np
Cobalt	nd	nd	nd	nd	nd	np
Copper	0.6	0.3	0.5	0.6	0.6	0
Iron	1.5	1.8	15	1.5	1.5	0
Lead	nd	nd	nd	nd	nd	np
Magnesium	nd	nd	nd	nd	nd	np
Manganese	nd	nd	nd	nd	nd	np
Molybdenum	nd	nd	nd	nd	nd	np
Nickel	1.1	nd	2	1.1	0.9	20
Phosphorus	nd	nd	nd	nd	nd	np
Potassium	nd	nd	nd	nd	nd	np
Silver	nd	nd	nd	nd	nd	np
Sodium	64.8	44.9	60.9	64.8	65	0.3
Strontium	nd	nd	nd	nd	nd	np
Tin	nd	nd	nd	nd	nd	np
Titanium	nd	nd	nd	nd	nd	np
Vanadium	nd	nd	nd	nd	nd	np
Zinc	4.3	1.7	1.7	4.3	4.3	0

nd not detected
np not possible to determine

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Iain Watson

Date Reported: December 4/96
MDS Ref # : 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901

Analysis of Soil, expressed on a dry weight basis

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Antimony	Lu-R-2-2A	2.0	mg/kg	nd(b)	4.0	yes	102	80	120	yes	11.4	12.5	7.5	17.5	yes	yes
Arsenic	Lu-R-2-2A	2.0	mg/kg	nd(b)	4.0	yes	82	80	120	yes	10.7	12.5	7.5	17.5	yes	yes
Barium	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	111	80	120	yes	8.8	12.5	7.5	17.5	yes	yes
Beryllium	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	94	80	120	yes	9.6	12.5	7.5	17.5	yes	yes
Cadmium	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	100	80	120	yes	11.2	12.5	7.5	17.5	yes	yes
Chromium	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	104	80	120	yes	9.6	12.5	7.5	17.5	yes	yes
Cobalt	Lu-R-2-2A	0.8	mg/kg	nd(b)	1.6	yes	102	80	120	yes	10.3	12.5	7.5	17.5	yes	yes
Copper	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	10.2	12.5	7.5	17.5	yes	yes
Lead	Lu-R-2-2A	2.5	mg/kg	nd(b)	5.0	yes	94	80	120	yes	10.9	12.5	7.5	17.5	yes	yes
Molybdenum	Lu-R-2-2A	1.0	mg/kg	nd(b)	2.0	yes	97	80	120	yes	11.3	12.5	7.5	17.5	yes	yes
Nickel	Lu-R-2-2A	1.5	mg/kg	nd(b)	3.0	yes	105	80	120	yes	9.7	12.5	7.5	17.5	yes	yes
Selenium	Lu-R-2-2A	1.0	mg/kg	nd(b)	2.0	yes	90	80	120	yes	9.5	12.5	7.5	17.5	yes	yes
Silver	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	83	80	120	yes	11.1	12.5	7.5	17.5	yes	yes
Vanadium	Lu-R-2-2A	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	10.0	12.5	7.5	17.5	yes	yes
Zinc	Lu-R-2-2A	0.8	mg/kg	nd(b)	1.6	yes	111	80	120	yes	9.9	12.5	7.5	17.5	yes	yes
Mercury	na	0.01	mg/kg	nd	0.02	yes	87	80	123	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.1	mg/kg	nd	0.2	yes	96	62	128	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.1	mg/kg	nd	0.2	yes	96	62	128	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901

Client : EVS Consultants Limited
Contact: Iain Watson

Analysis of Filter

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Aluminum	na	1.5	ug/Filt	nd(b)	3.0	yes	99	80	120	yes	na	na	na	na	na	yes
Barium	na	0.2	ug/Filt	nd(b)	0.4	yes	102	80	120	yes	na	na	na	na	na	yes
Beryllium	na	0.3	ug/Filt	nd(b)	0.6	yes	102	80	120	yes	na	na	na	na	na	yes
Bismuth	na	2.5	ug/Filt	nd(b)	5.0	yes	104	80	120	yes	na	na	na	na	na	yes
Boron	na	0.5	ug/Filt	nd(b)	1.0	yes	102	80	120	yes	na	na	na	na	na	yes
Cadmium	na	0.2	ug/Filt	nd(b)	0.4	yes	105	80	120	yes	na	na	na	na	na	yes
Chromium	na	0.3	ug/Filt	nd(b)	0.6	yes	104	80	120	yes	na	na	na	na	na	yes
Cobalt	na	0.3	ug/Filt	nd(b)	0.6	yes	103	80	120	yes	na	na	na	na	na	yes
Copper	na	0.2	ug/Filt	nd(b)	0.4	yes	102	80	120	yes	na	na	na	na	na	yes
Iron	na	0.3	ug/Filt	nd(b)	0.6	yes	96	80	120	yes	na	na	na	na	na	yes
Lead	na	1.5	ug/Filt	nd(b)	3.0	yes	108	80	120	yes	na	na	na	na	na	yes
Manganese	na	0.3	ug/Filt	nd(b)	0.6	yes	102	80	120	yes	na	na	na	na	na	yes
Molybdenum	na	0.5	ug/Filt	nd(b)	1.0	yes	101	80	120	yes	na	na	na	na	na	yes
Nickel	na	0.5	ug/Filt	nd(b)	1.0	yes	104	80	120	yes	na	na	na	na	na	yes
Phosphorus	na	3.0	ug/Filt	nd(b)	6.0	yes	95	70	130	yes	na	na	na	na	na	yes
Silver	na	0.3	ug/Filt	nd(b)	0.6	yes	101	80	120	yes	na	na	na	na	na	yes
Tin	na	2.5	ug/Filt	nd(b)	5.0	yes	98	80	120	yes	na	na	na	na	na	yes
Titanium	na	2.5	ug/Filt	nd(b)	5.0	yes	98	80	120	yes	na	na	na	na	na	yes
Vanadium	na	0.5	ug/Filt	nd(b)	0.5	yes	102	80	120	yes	na	na	na	na	na	yes
Zinc	na	0.3	ug/Filt	nd(b)	0.6	yes	102	80	120	yes	na	na	na	na	na	yes

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

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 966267
MDS Quote#: 96-697-GS

Client Ref#: AETE-3/72901

Client : EVS Consultants Limited
Contact: Iain Watson

Analysis of Filter

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Calcium	na	0.5	ug/filt	nd(b)	1.0	yes	94	80	120	yes	na	na	na	na	na	yes
Magnesium	na	1.0	ug/filt	nd(b)	2.0	yes	104	80	120	yes	na	na	na	na	na	yes
Potassium	na	20	ug/filt	nd(b)	40	yes	91	80	120	yes	na	na	na	na	na	yes
Sodium	na	2.0	ug/filt	2.5(b)	4.0	yes	97	80	120	yes	na	na	na	na	na	yes
Strontium	na	0.25	ug/filt	nd(b)	0.5	yes	100	80	120	yes	na	na	na	na	na	yes

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

ATTACHMENT D.3

Results

RPC
921 College Hill Road
Fredericton, N.B. E3B 6Z9
Report No: AS/96/4883
Job No: 4000726/7892

MDS Environmental
Services Limited
5595 Fenwick Street
Halifax, N.S. B3H 4M2

October 10, 1996

Grain Size Distribution

	LU-R-2-4A	LU-R-2-5A	LU-R-2-6A	LU-E-2 1A	LU-E-2 2A	LU-E-2-3A	LU-E-2 4A	LU-E-2-5A	LUE-2 6A
Sample ID	29802	29803	29804	29805	29806	29807	29808	29809	29810
RPC #	7892-1	7892-2	7892-3	7892-4	7892-5	7892-6	7892-7	7892-8	7892-9
PHI	% Finer								
-2	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
-1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0	99.91	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97
1	99.75	99.27	99.85	100.00	99.92	99.98	100.00	100.00	99.89
2	99.18	92.40	99.46	99.95	99.32	99.67	99.98	99.97	99.76
3	98.07	75.21	98.87	99.53	97.51	98.29	97.12	99.90	95.10
4	87.37	61.04	86.04	98.47	94.87	94.27	88.90	99.72	81.37
5	53.03	44.09	29.49	91.42	87.06	81.66	78.10	95.33	63.15
6	26.94	22.94	11.25	70.15	68.20	57.11	57.15	74.08	42.05
7	6.53	6.27	3.02	19.29	20.83	17.29	16.91	19.47	13.50
8	4.69	4.52	2.33	12.03	12.56	10.44	10.42	12.23	9.58
9	2.57	2.65	1.39	5.31	4.46	5.13	4.88	6.22	5.48
% Gravel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Sand	12.63	38.96	13.96	1.53	5.13	5.73	11.10	0.28	18.63
% Silt	82.68	56.53	83.71	86.45	82.32	83.84	78.47	87.49	71.80
% Clay	4.69	4.52	2.33	12.03	12.56	10.44	10.42	12.23	9.58

Ross Kean
A. Ross Kean, M.Sc.
Manager, Inorganic Chemistry
Chemical and Biotechnical Services

Dr. Peter Silk, FCIC
Department Head
Chemical and Biotechnical Services

RPC
921 College Hill Road
Fredericton, N.B. E3B 6Z9
Report No: AS/96/4583
Job No: 4000726/7892

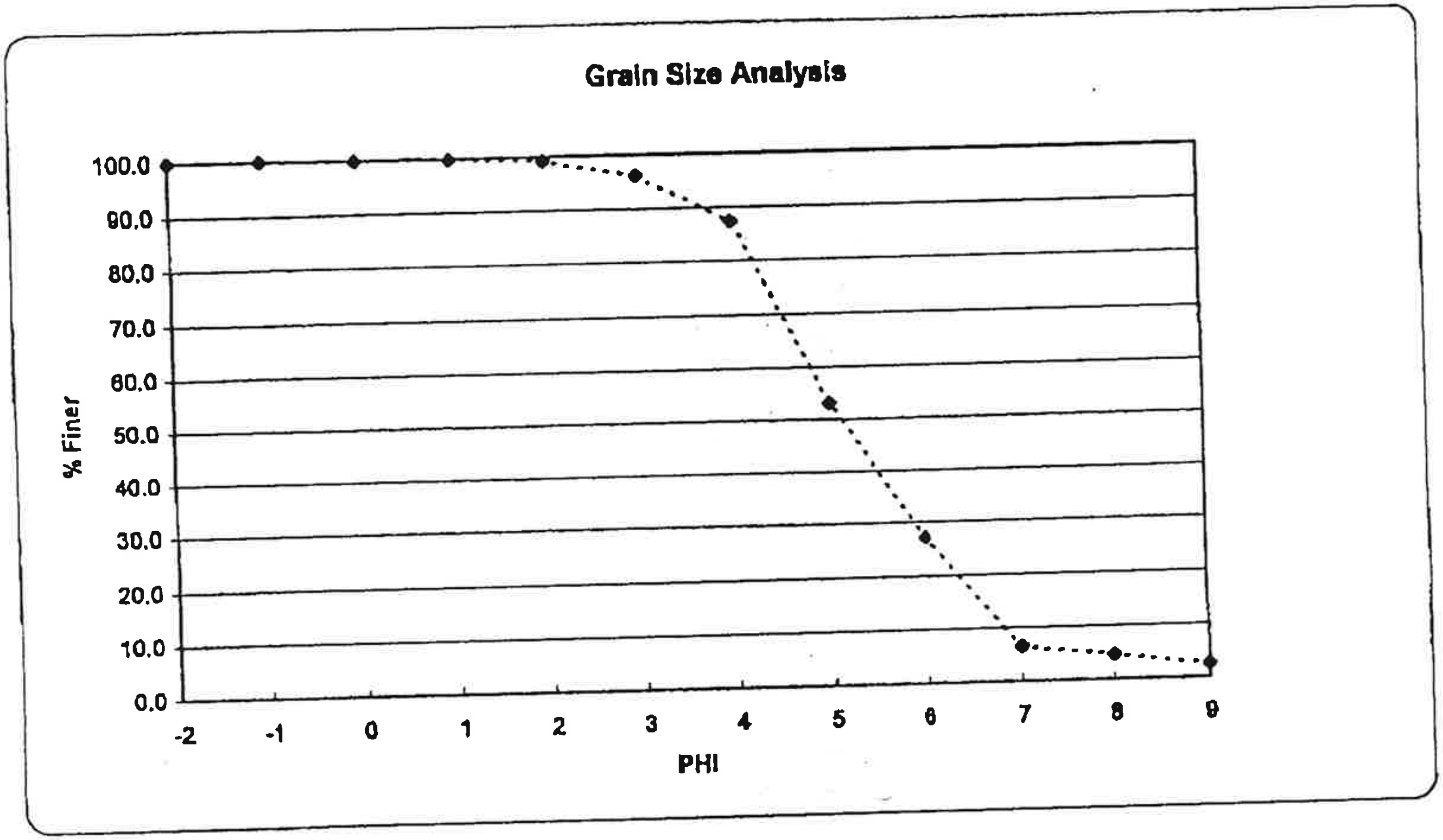
MDS Environmental
Services Limited
5595 Fenwick Street
Halifax, N.S. B3H 4M2

October 10, 1996

Grain Size Distribution

	Lu-E-2-6B	LU-R-2-1B	LU-R-2-2A	LU-R-2-3A
Sample ID	29811	29812	29813	29814
RPC #	7892-10	7892-11	7892-12	7892-13
PHI				
-2	100.00	100.00	100.00	100.00
-1	100.00	100.00	100.00	100.00
0	99.99	100.00	100.00	100.00
1	99.95	99.94	99.97	99.98
2	99.83	99.79	98.57	98.90
3	95.51	98.38	97.54	97.82
4	81.74	76.65	87.31	86.66
5	52.93	28.40	59.59	48.91
6	42.90	13.49	30.77	24.42
7	13.31	3.12	6.84	5.10
8	9.69	2.14	4.64	3.41
9	5.22	1.26	2.38	1.73
% Gravel	0.00	0.00	0.00	0.00
% Sand	18.26	23.35	12.69	13.34
% Silt	72.04	74.52	82.67	83.25
% Clay	9.69	2.14	4.64	3.41

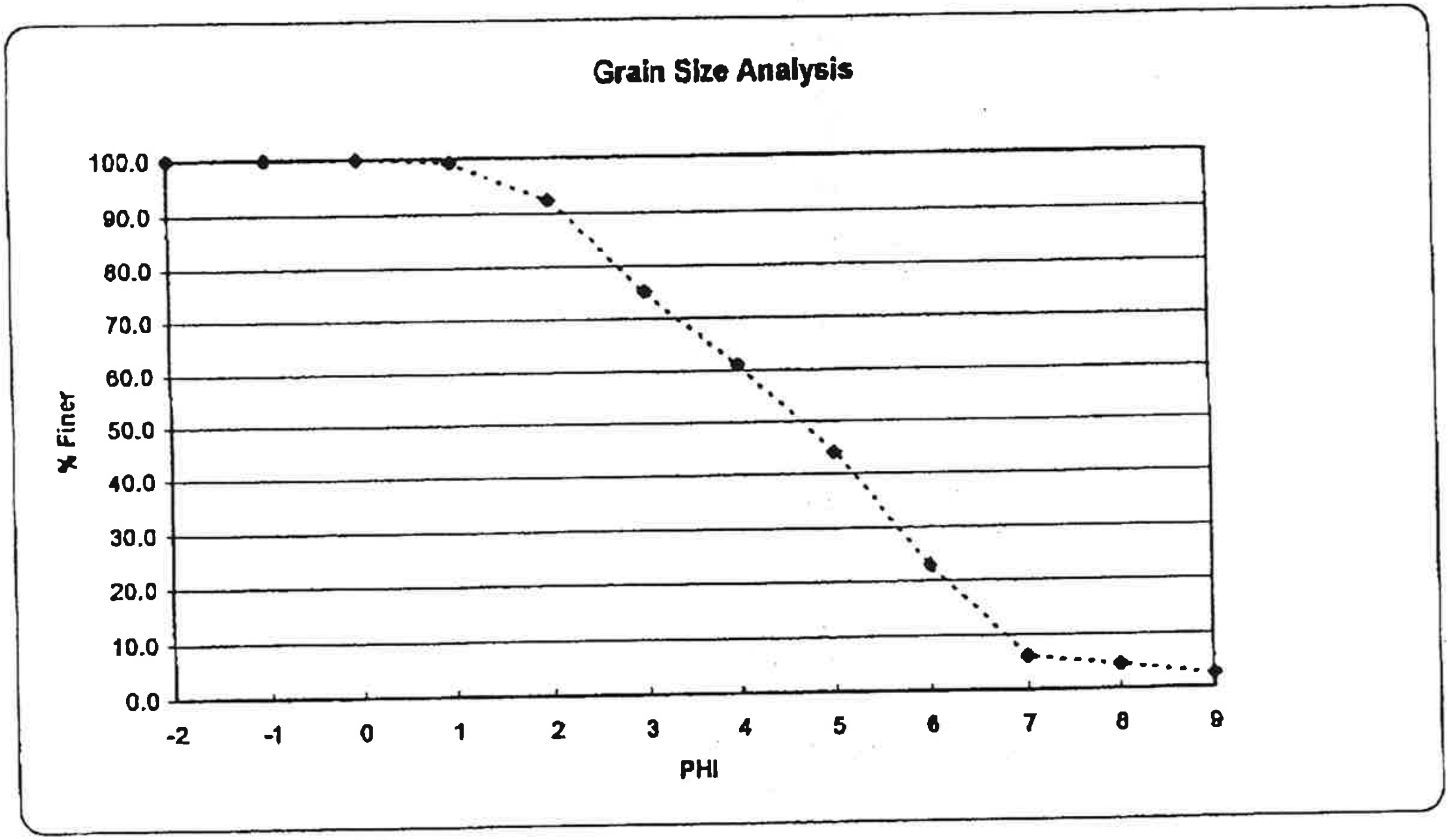
Sample I.D. 29802 Lu-R-2-4A
RPC # 7892-1



% Gravel	0.00
% Sand	12.63
% Silt	82.68
% Clay	4.69

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

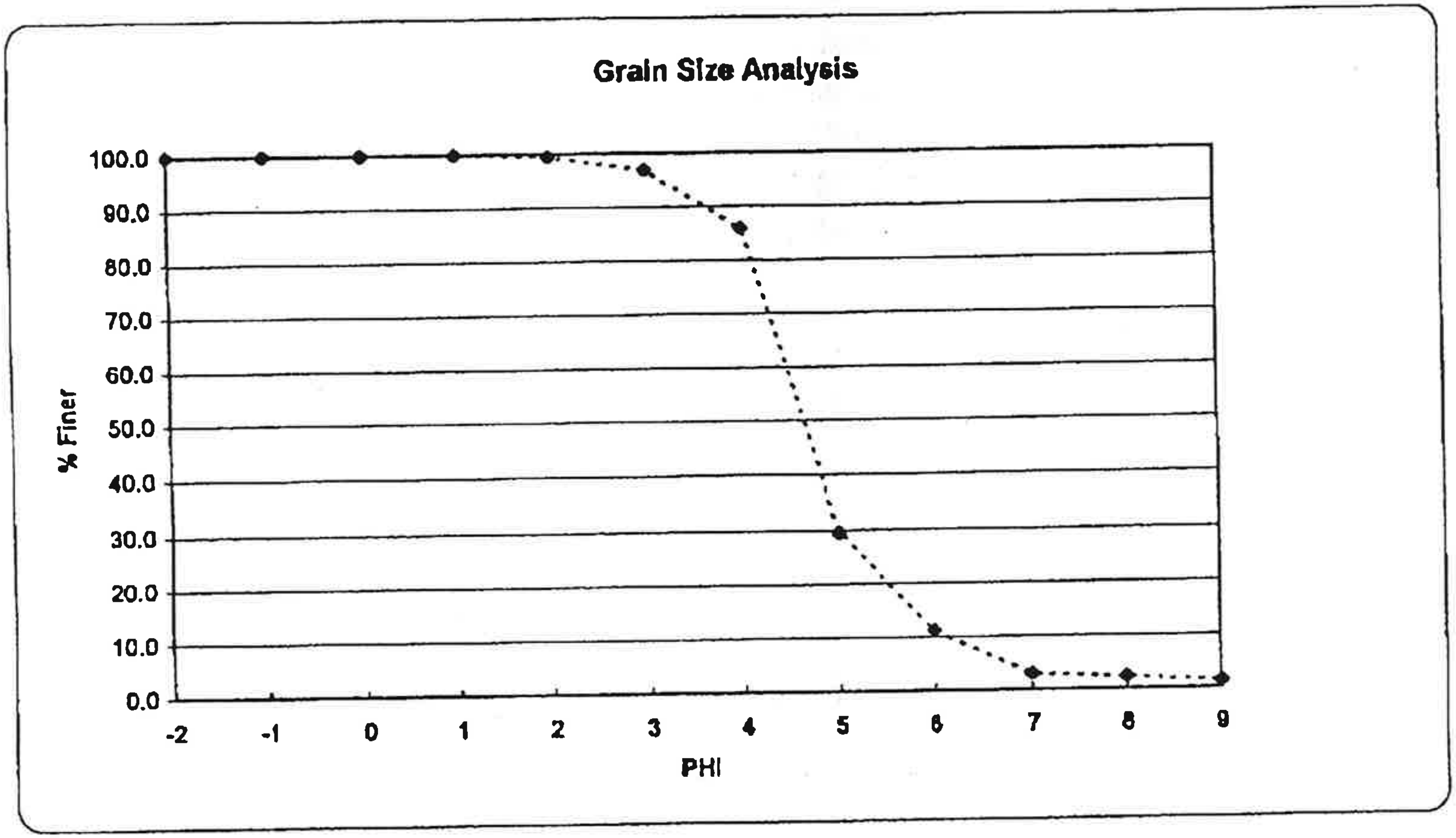
Sample I.D. 29803 LU-R-2-5A
RPC # 7892-2



% Gravel	0.00
% Sand	38.96
% Silt	56.53
% Clay	4.52

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

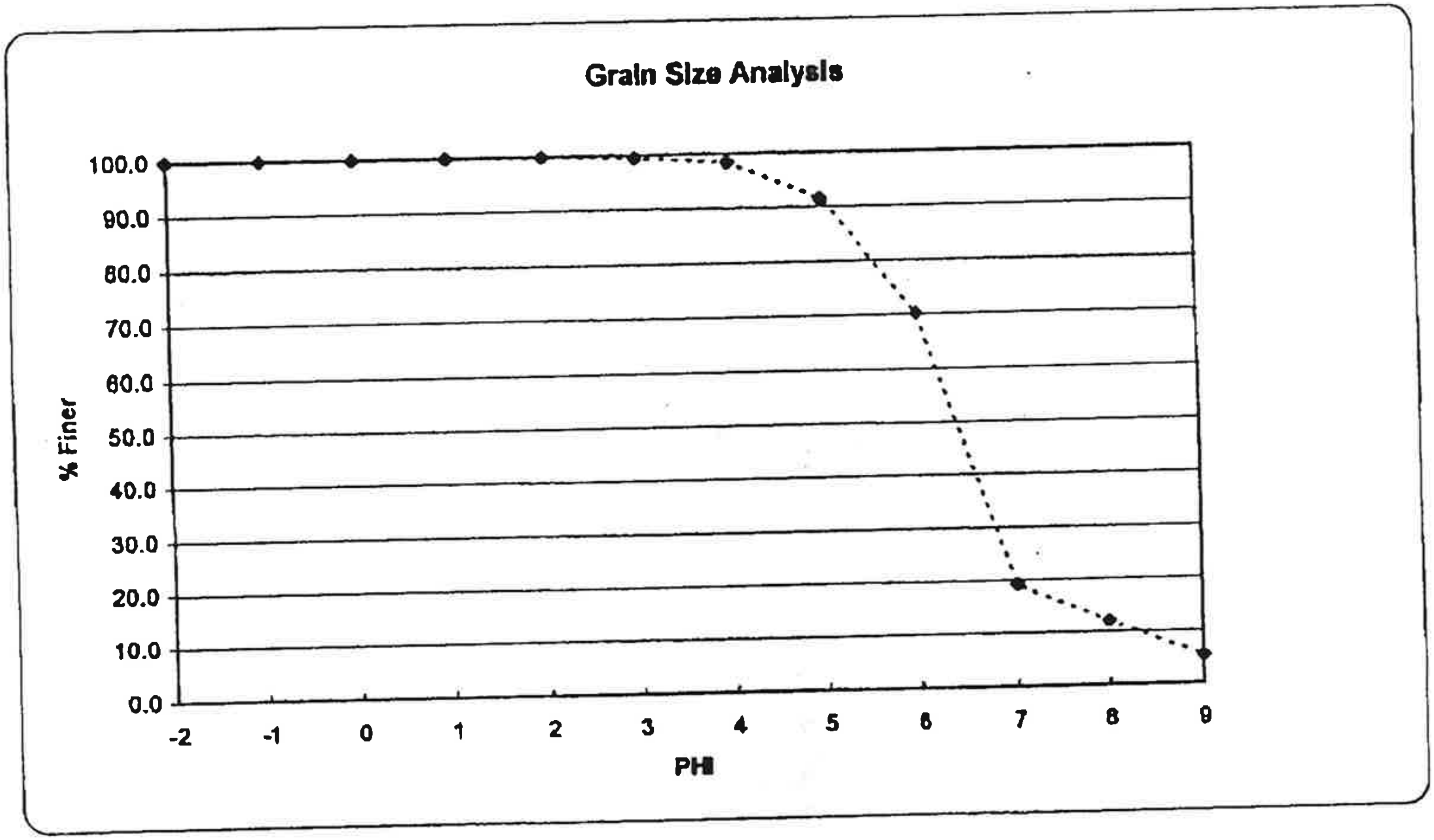
Sample I.D. 29804 Lu-R-2-6A
RPC # 7892-3



% Gravel	0.00
% Sand	13.96
% Silt	83.71
% Clay	2.33

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Sample I.D. 29805 Lu-E-2-1A
RPC # 7892-4

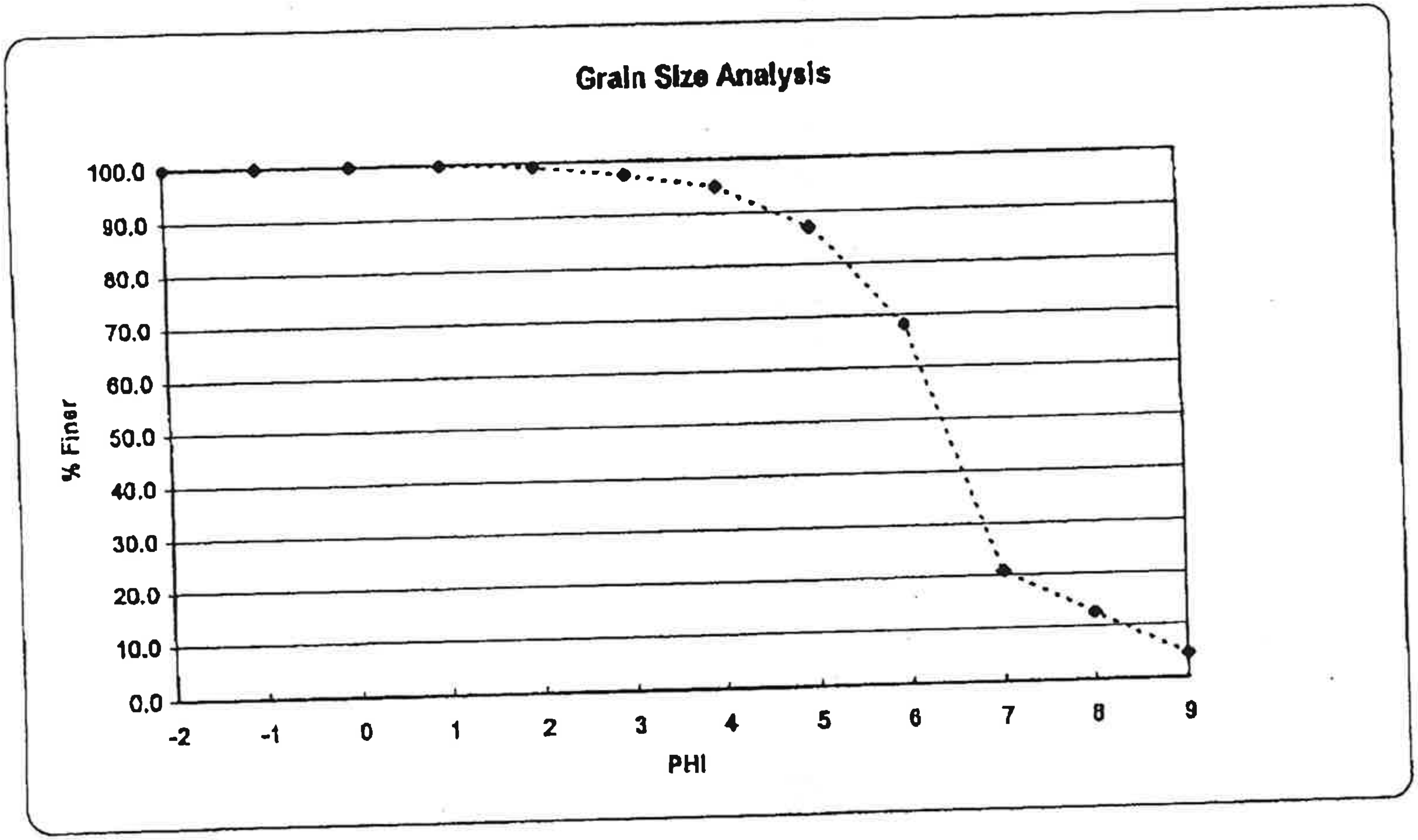


% Gravel	0.00
% Sand	1.53
% Silt	86.45
% Clay	12.03

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Sample I.D. 29806 Lu-E-2-2A

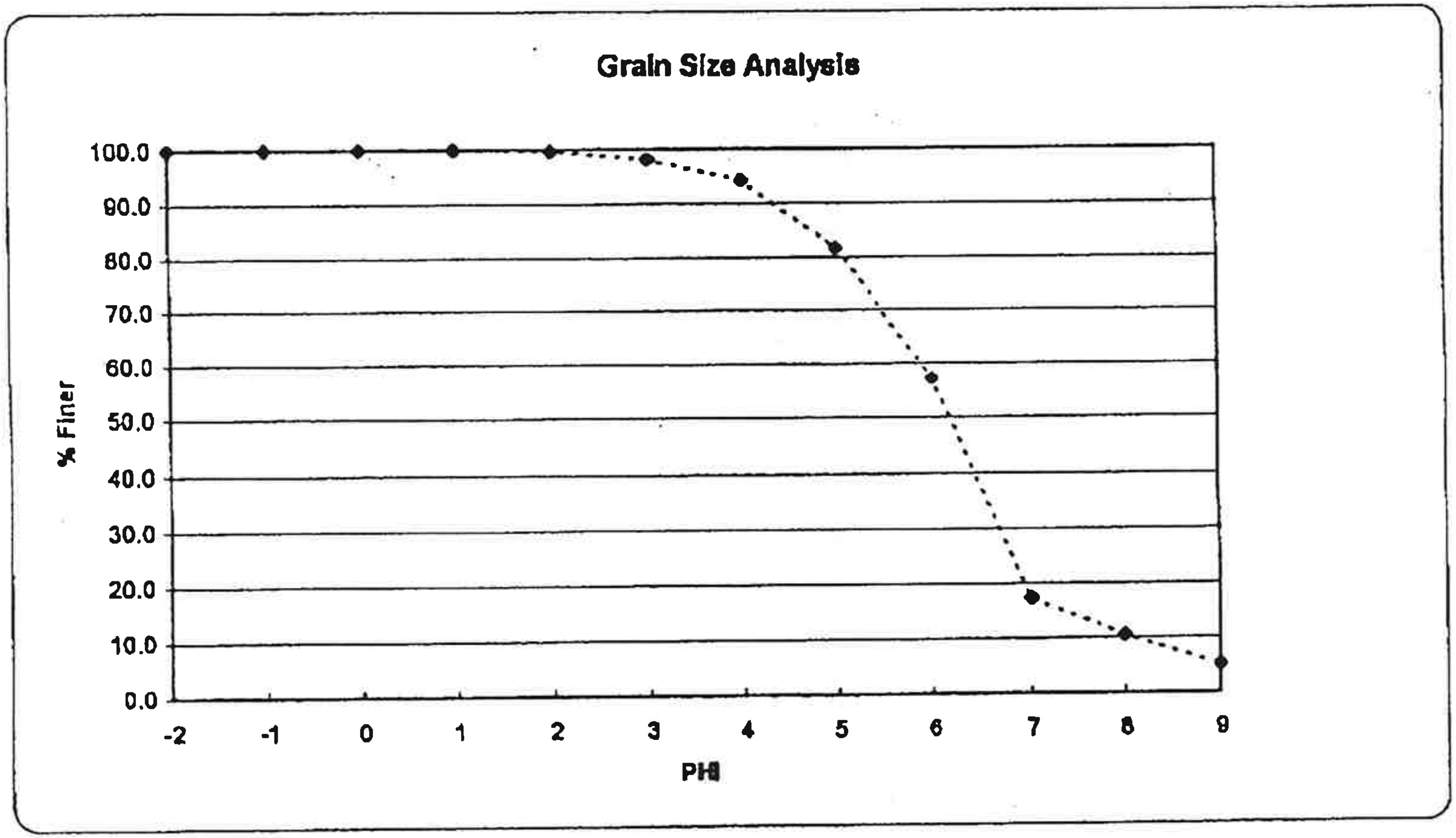
RPC # 7892-5



% Gravel	0.00
% Sand	5.13
% Silt	82.32
% Clay	12.56

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

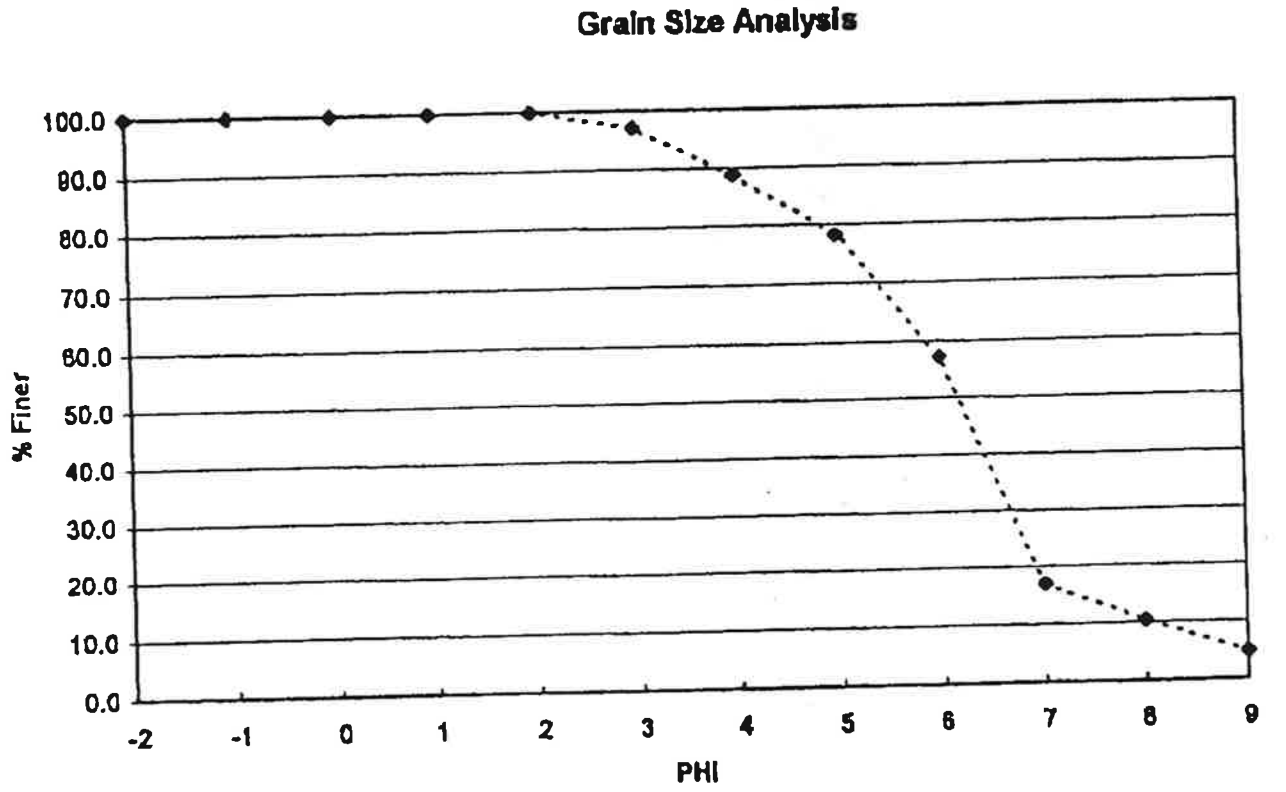
Sample I.D. 29807 LU-E-2-3A
RPC # 7892-6



% Gravel	0.00
% Sand	5.73
% Silt	83.84
% Clay	10.44

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

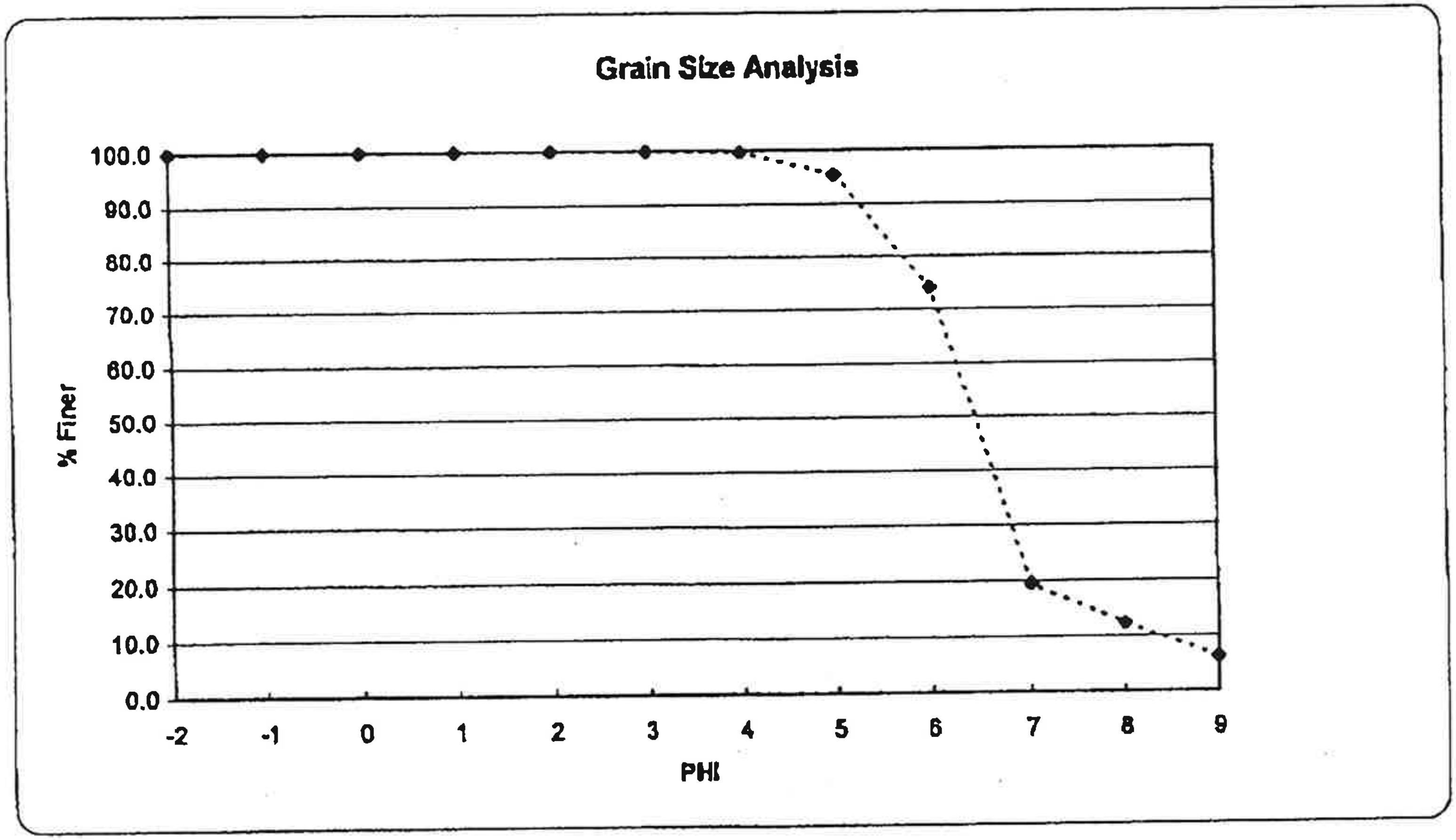
Sample I.D. 29808 Lu-E-2-4A
RPC # 7892-7


Grain Size Analysis

% Gravel	0.00
% Sand	11.10
% Silt	78.47
% Clay	10.42

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

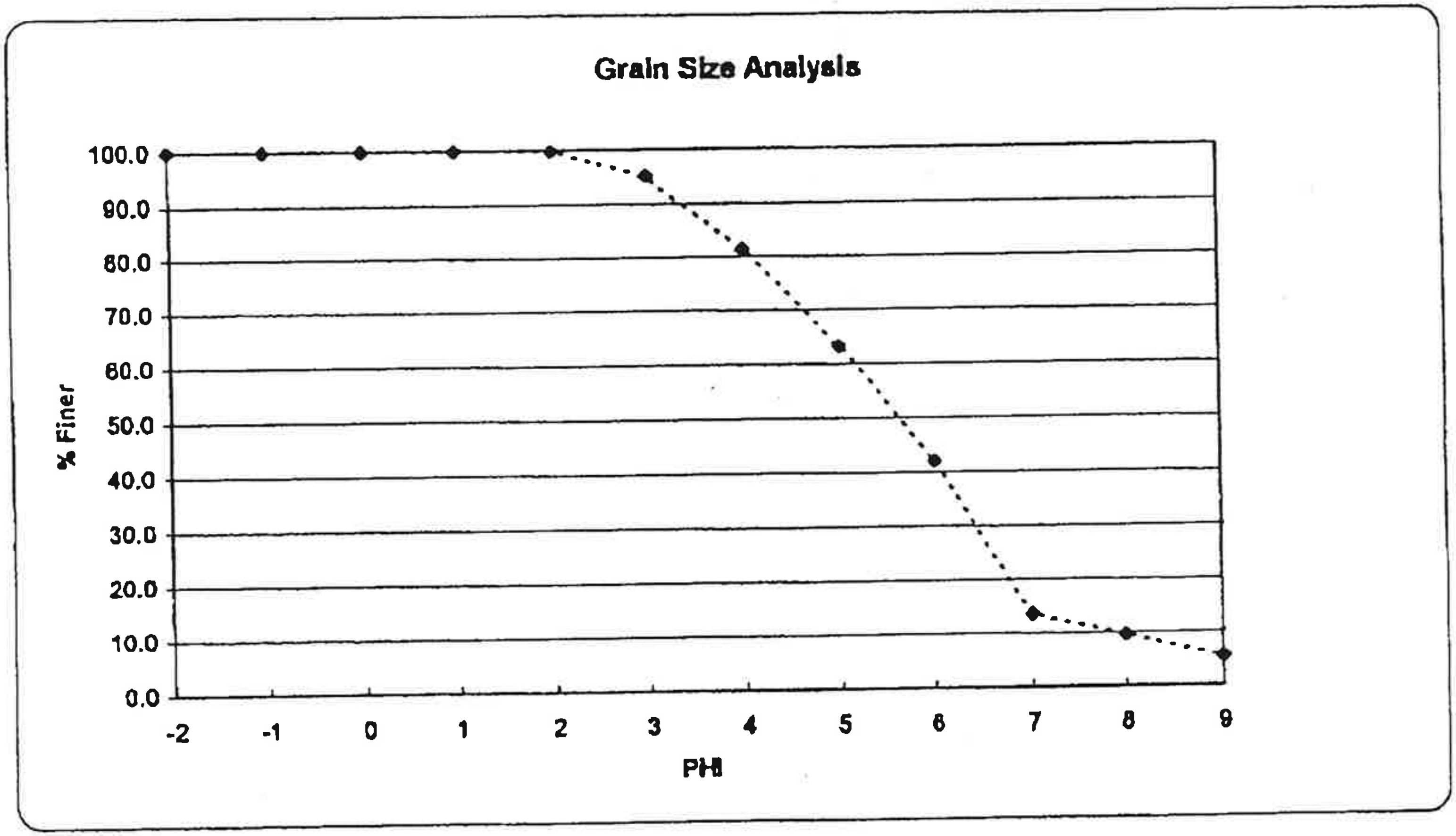
Sample I.D. 29809 Lw-E-2-SA
RPC # 7892-8



% Gravel	0.00
% Sand	0.28
% Silt	87.49
% Clay	12.23

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

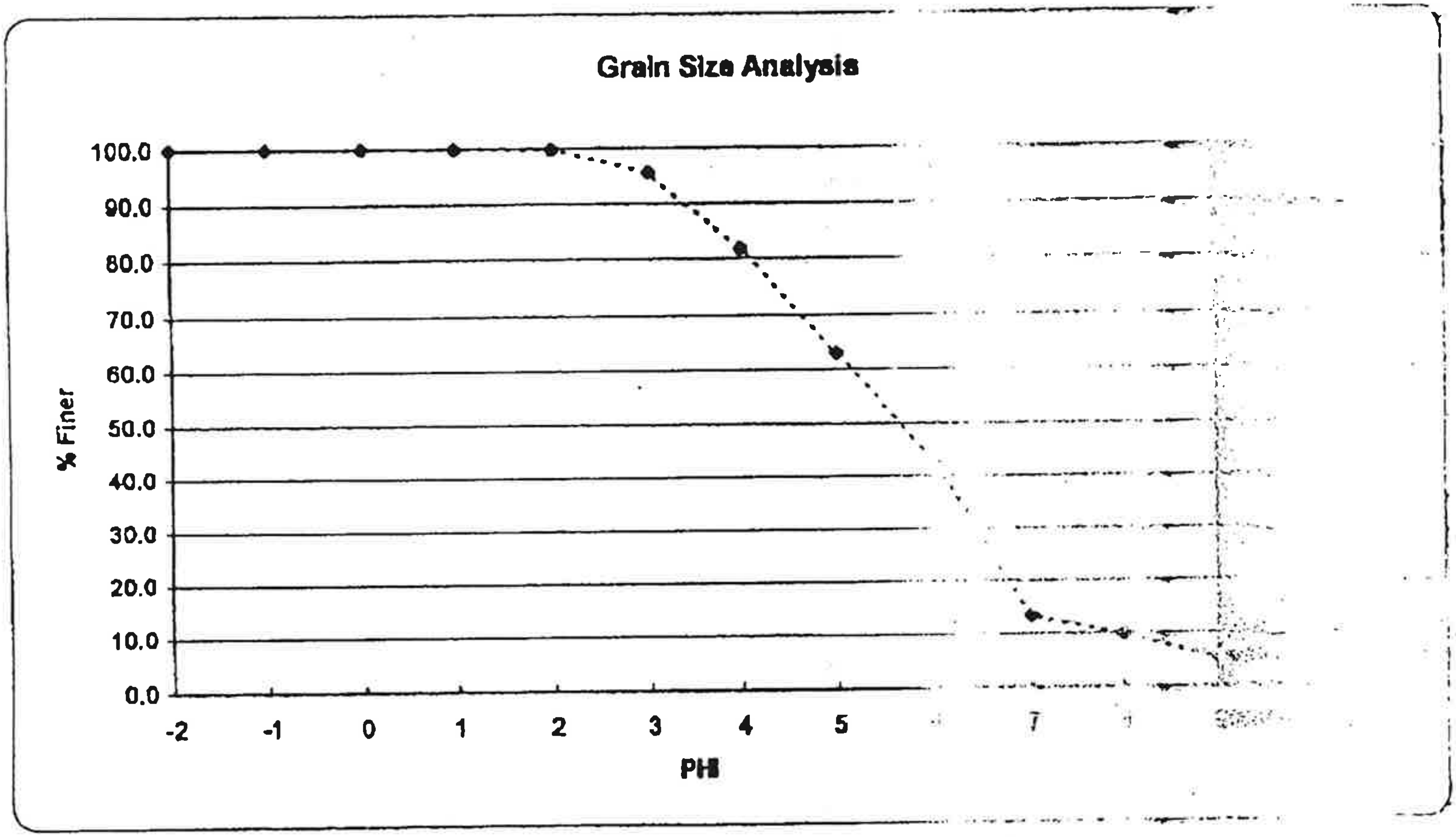
Sample I.D. 29810 Lu-E-2-6A
RPC # 7892-9



% Gravel	0.00
% Sand	18.63
% Silt	71.80
% Clay	9.58

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Sample I.D. 29811 Lu-E-2-6B
RPC # 7892-10

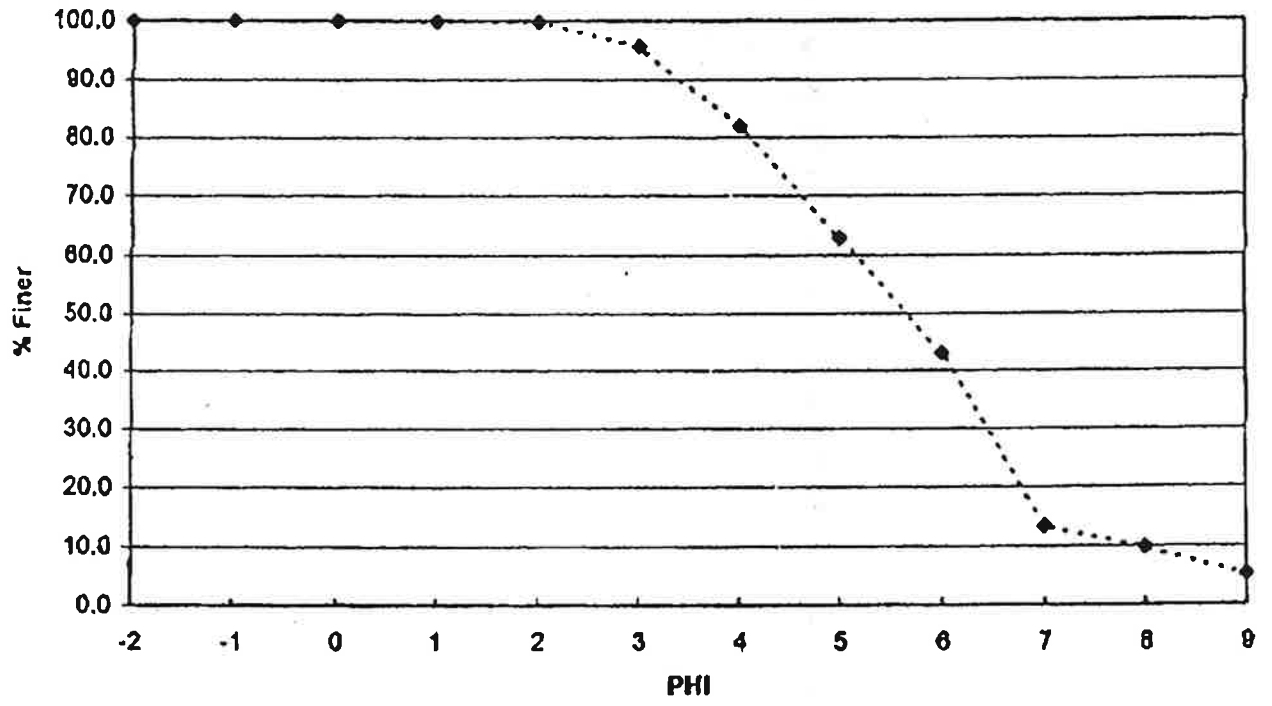


% Gravel	0.00
% Sand	18.28
% Silt	72.04
% Clay	9.69

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Sample I.D. 29811 Lu-E-2-6B
RPC # 7892-10

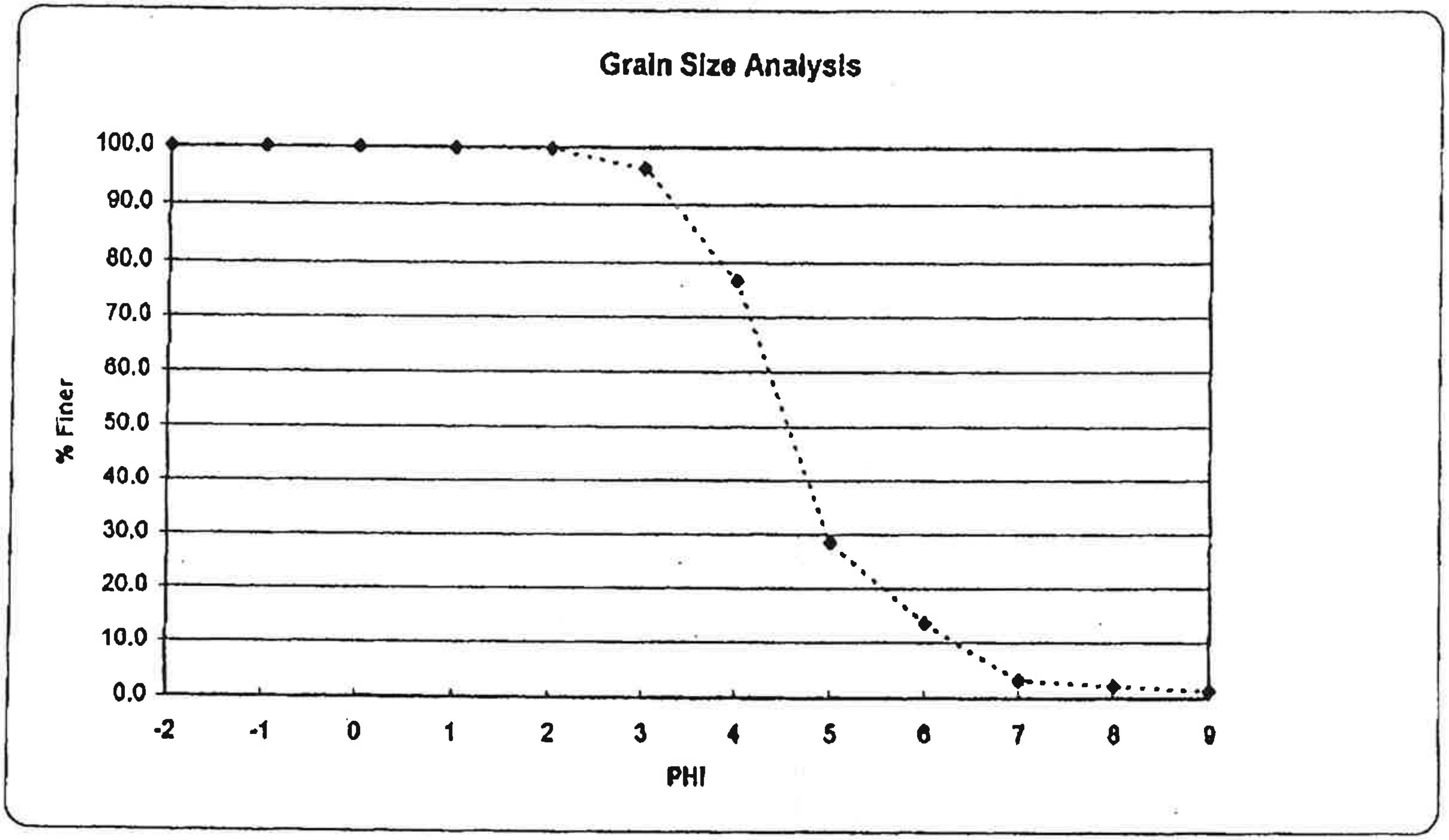
Grain Size Analysis



% Gravel	0.00
% Sand	18.26
% Silt	72.04
% Clay	9.69

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

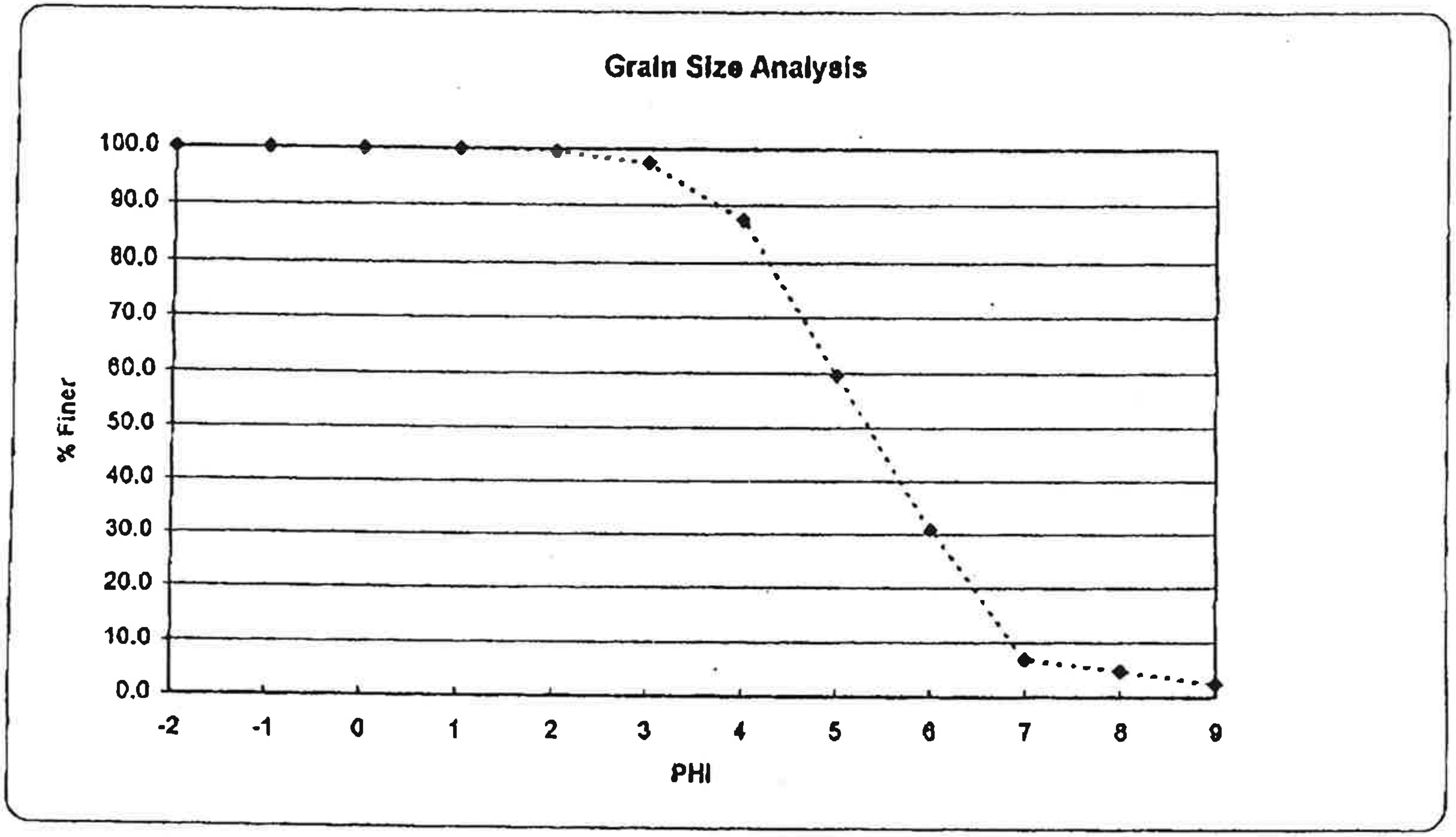
Sample I.D. 29812 LU-R-2-1B
RPC # 7892-11



% Gravel	0.00
% Sand	23.35
% Silt	74.52
% Clay	2.14

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

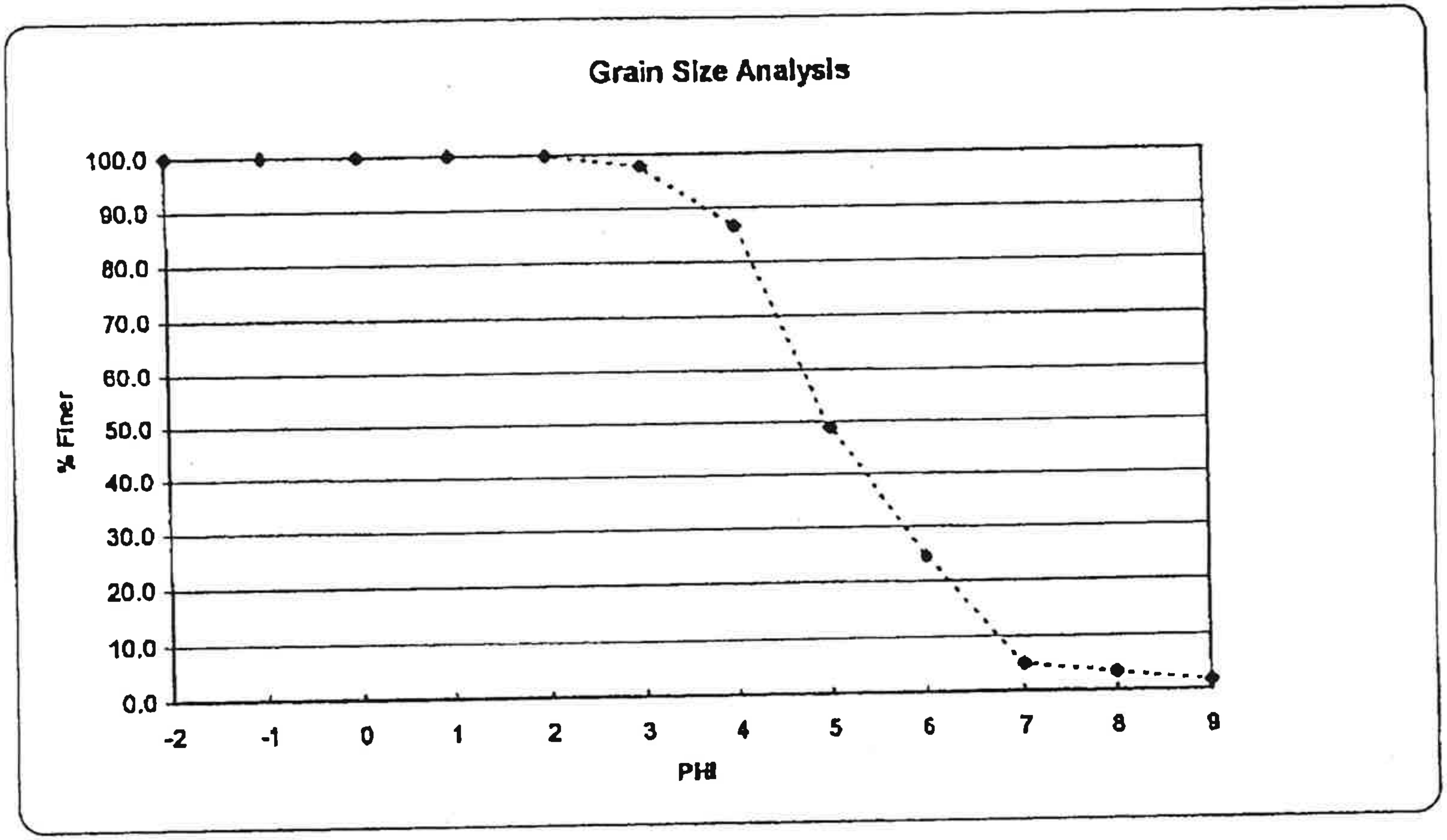
Sample I.D. 29813 Lu-R-2-2A
RPC # 7892-12



% Gravel	0.00
% Sand	12.69
% Silt	82.67
% Clay	4.64

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Sample I.D. 29814 L U - R - Z - 3A
RPC # 7892-13



% Gravel	0.00
% Sand	13.34
% Silt	83.25
% Clay	3.41

RPC
921 College Hill Rd.
Fredericton, N.B.
E3B 6Z9

Table D3-1: Total metals (mg/kg; unless otherwise specified) in sediment samples collected from reference and exposure stations at Lupin Mine on September 10-12, 1996.

Parameter	LOQ	Reference Stations									Exposure Stations								
		Lu-R-2-1B	Lu-R-2-2A	Lu-R-2-3A	Lu-R-2-4A	Lu-R-2-5A	Lu-R-2-6A	mean	sd	se	Lu-E-2-1A	Lu-E-2-2A	Lu-E-2-3A	Lu-E-2-4A	Lu-E-2-5A	Lu-E-2-6A	mean	sd	se
Antimony	2	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Arsenic	2	5.6	4.4	7.5	6.1	4	8.7	6.1	1.8	0.7	15.4	33.3	58.9	27	45.1	13.9	32.3	17.5	7.1
Barium	0.5	51.4	55.4	48.8	50	42.2	69.3	52.9	9.1	3.7	58	72.9	66.7	52.1	55.3	47.2	58.7	9.5	3.9
Beryllium	0.5	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Cadmium	0.5	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Chromium	0.5	21.5	25.5	22.1	23.6	21.4	26.2	23.4	2.1	0.8	37.4	37.1	34.8	33.2	36.9	28.1	34.6	3.6	1.5
Cobalt	0.8	4.2	5	5.7	6	5.8	6.3	5.5	0.8	0.3	18.7	50.4	17.4	14.3	14.9	9.6	20.9	14.8	6.0
Copper	0.5	6.9	9.4	7.5	9.5	8.2	8.8	8.4	1.0	0.4	14.8	19.7	13.3	13	17.5	13.6	15.3	2.7	1.1
Lead	2.5	nd	nd	nd	2.5	nd	nd	1.5	0.5	0.2	3.3	3.4	3.2	2.6	3.1	2.9	3.1	0.2	0.1
Molybdenum	1	nd	nd	nd	nd	nd	nd				nd	1.1	nd	nd	nd	nd	0.6	0.2	0.1
Nickel	1.5	11.8	14.6	12.5	13.7	13.9	13.7	13.4	1.0	0.4	25	36	25.2	23.3	30.6	21.8	27.0	5.3	2.2
Selenium	1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd			
Silver	0.5	nd	nd	nd	1.2	nd	nd	0.4	0.4	0.2	nd	nd	nd	nd	nd	nd			
Vanadium	0.5	19.2	22.3	19.8	21	18.6	23.4	20.7	1.9	0.8	29.2	28.8	26.2	25.1	27.6	22.1	26.5	2.7	1.1
Zinc	0.8	22.3	27.6	24.3	26.4	26.3	26.6	25.6	1.9	0.8	47.6	54.5	45.8	44.5	62.6	47.1	50.4	6.9	2.8
Loss on Ignition (%)	0.01	1.25	2.1	1.38	2.19	2.82	1.6	1.89	0.59	0.24	3.46	4.96	3.23	2.61	3.79	4.68	3.79	0.89	0.36
Mercury	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.002	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.00	0.002
Cyanide, Total	0.1	0.1	0.3	0.1	0.2	0.3	0.1	0.18	0.10	0.04	0.8	0.7	0.9	1	2.2	0.8	1.07	0.56	0.23

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

Table D3-2: Physical characteristics of sediment samples collected from reference and exposure stations at Lupin Mine on September 10 -12, 1996.

Parameter	Reference Stations									Exposure Stations								
	Lu-R-2-1B	Lu-R-2-2A	Lu-R-2-3A	Lu-R-2-4A	Lu-R-2-5A	Lu-R-2-6A	mean	sd	se	Lu-E-2-1A	Lu-E-2-2A	Lu-E-2-3A	Lu-E-2-4A	Lu-E-2-5A	Lu-E-2-6A	mean	sd	se
Water Depth (m)	2.6	4.2	3.3	1.5	3.3	0.9	2.63	1.24	0.50	4.5	6.5	7.2	4.2	4.8	2.7	4.98	1.63	0.67
Substrate fines (%)	76.66	87.31	86.66	77.37	61.05	86.04	79.18	10.07	4.11	98.48	94.88	94.28	88.89	99.72	81.38	92.94	6.82	2.78
Total Organic Carbon (%)	0.6	0.91	0.58	0.97	1.34	0.78	0.86	0.28	0.12	1.99	1.42	1.23	1.88	2.54	1.74	1.80	0.46	0.19
Loss on Ignition (%)	1.25	2.1	1.38	2.19	2.82	1.6	1.89	0.59	0.24	3.46	4.96	3.23	2.61	3.79	4.68	3.79	0.89	0.36

APPENDIX E

Benthic Invertebrate Community Structure

ATTACHMENT E.1

Detailed Methods

SAMPLE PROCESSING

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

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

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

SUBSAMPLING

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

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

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

DETAILED IDENTIFICATION

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

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

VOUCHER COLLECTION

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

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ATTACHMENT E.2

QA/QC

ATTACHMENT E.3

Results

Table 1. Calculation of subsampling error for benthic invertebrate samples from Contwoyto Lake and Echo Bay, September 1996.

Station	Number of Animals in Fraction 1	Number of Animals in Fraction 2	Standard Deviation	Coefficient of Variation
LU-R3-1	287	276	7.78	2.8%
LU-E3-3	143	163	14.14	9.2%

TABLE 2. PERCENTAGE RECOVERY OF BENTHIC INVERTEBRATES FROM SAMPLES FROM CONTWOYTO LAKE AND ECHO BAY, SEPTEMBER 1996.

Station	Number of Animals Recovered	Number of Animals in Re-sort	Percent Recovery
LU-R3-1	287	9	97.0%
LU-E3-3	306	11	96.5%

TABLE 3. FRACTIONS SORTED OF SAMPLES FROM CONTWOYTO LAKE AND ECHO BAY, SEPTEMBER 1996.

Station	Fraction Sorted
LU-R3-1	1/2[a]
LU-R3-2	1/2
LU-R3-3	1/2
LU-R3-4	1/2
LU-R3-5	1/4
LU-R3-6	1/4
LU-E3-1	WHOLE
LU-E3-2	WHOLE
LU-E3-3	WHOLE[b]
LU-E3-4	1/2
LU-E3-5	1/4
LU-E3-6	1/4

[a] two quarters sorted for subsamling error calculations

[b] two halves sorted for subsamling error calculations

QUALITY ASSURANCE AND QUALITY CONTROL MEASURES

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

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

REPORTING BENTHIC MACROINVERTEBRATE DATA

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

Table E3-1 Benthic invertebrates from Lupin mine, 1996.
(densities expressed per sample jar)

TAXA	EXPOSURE - (Sun Bay)						REFERENCE - (South Bay)					
	1	2	3	4	5	6	1	2	3	4	5	6
P. Coelenterata												
Hydra	1	4	5	-	-	-	-	-	-	2	-	-
P. Nematoda	11	12	16	26	1060	44	304	220	238	110	368	500
P. Nemertea												
Prostoma	-	-	-	-	-	-	-	-	2	-	-	-
P. Annelida												
Cl. Oligochaeta												
F. Enchytraeidae	20	10	23	7	9	36	4	-	-	4	-	28
F. Naididae												
Chaetogaster diastrophus	-	-	-	-	-	-	-	-	-	-	12	-
Dero	-	-	1	-	-	-	-	-	-	-	-	-
Nais variabilis	-	-	-	-	53	-	-	-	-	-	-	-
Vejdovskyella comata	-	-	-	-	27	-	-	-	-	2	4	-
F. Tubificidae												
Aulodrilus limnobius	-	-	-	-	-	-	-	-	2	-	-	-
Limnodrilus hoffmeisteri	-	-	-	-	-	-	-	-	-	-	-	8
Rhyacodrilus montana	-	-	-	7	9	16	-	-	-	-	-	-
Tasserkidrilus kessleri	-	-	-	-	-	-	-	-	-	2	-	16
immatures with hair chaetae	-	1	-	59	98	44	-	16	-	14	12	64
immatures without hair chaetae	4	-	-	7	-	-	8	16	2	-	8	-
F. Lumbriculidae	-	-	-	-	-	-	-	-	-	-	4	64
Lumbriculus variegatus	-	2	-	-	2	2	4	6	16	8	-	32
P. Arthropoda												
Cl. Arachnida												
O. Hydracarina	16	7	17	18	16	20	96	14	18	58	24	4
Cl. Maxillopoda												
O. Harpacticoida	6	-	16	6	4	-	172	34	12	24	108	136
Cl. Ostracoda	42	22	5	30	8	-	52	70	16	16	56	104
Cl. Entognatha												
O. Collembola	-	-	-	-	-	-	4	-	-	2	-	-
Cl. Insecta												
O. Trichoptera												
F. Hydroptilidae												
Agraylea	-	-	-	-	4	-	-	2	-	-	-	-
F. Limnephilidae												
Grensia	-	-	-	-	1	-	-	-	-	-	-	-
O. Diptera												
F. Chironomidae												
Chironomid pupae	-	1	-	-	-	-	-	-	-	-	-	-
S.F. Chironominae												
Chironomus	-	-	-	-	-	-	-	-	-	-	12	-
Cladopelma	-	-	-	-	-	-	-	-	-	-	24	-
Cladotanytarsus	-	-	-	-	-	-	-	-	-	-	16	-
Constempellina	2	1	10	52	4	36	116	6	14	44	48	232
Cryptochironomus	-	-	-	-	-	4	-	-	-	-	-	-
Dicrotendipes	-	-	-	-	8	-	8	-	2	-	-	-
Micropsectra	-	12	18	46	8	-	12	10	6	-	44	-
Parachironomus	-	-	-	2	4	-	16	8	8	-	20	-
Paracladopelma	-	-	-	12	-	-	-	-	-	4	-	-
Paratanytarsus	2	4	9	2	40	120	40	-	4	36	-	148
Polypedilum	-	-	-	-	-	-	-	-	2	2	-	-
Sergentia	-	-	-	-	-	-	12	4	4	-	80	-
Stempellinella	2	1	8	20	8	64	-	-	-	-	-	-
Stictochironomus	10	23	19	8	32	-	4	-	-	6	32	72

Table E3-1 Benthic invertebrates from Lupin mine, 1996.
(densities expressed per sample jar)

TAXA	EXPOSURE - (Sun Bay)						REFERENCE - (South Bay)					
	1	2	3	4	5	6	1	2	3	4	5	6
Tanytarsus	5	9	3	4	-	20	32	40	18	22	16	-
Tribe Chironomini	-	-	1	4	4	-	-	-	-	-	-	-
S.F. Diamesinae												
Potthastia	-	-	-	4	-	-	-	-	-	-	-	-
Protanypus	8	1	7	-	8	-	-	-	-	-	-	-
S.F. Orthocladiinae												
Abiskomyia	6	-	4	-	-	-	-	-	-	-	-	-
Corynoneura	-	2	1	-	-	-	-	-	-	-	-	-
Cricotopus	3	-	-	-	8	-	-	-	-	-	-	4
Heterotrissocladius	44	12	34	66	64	20	-	14	-	2	12	-
Hydrobaenus	-	-	-	-	-	-	-	-	-	2	-	-
Mesocricotopus	9	5	-	-	-	-	-	-	-	-	-	-
Paracladius	25	1	17	2	-	-	-	-	-	-	-	-
Parakiefferiella	8	5	33	66	-	80	-	14	-	30	-	24
Psectrocladius	3	1	9	20	12	12	8	4	-	18	28	56
Pseudosmittia	-	-	-	-	-	-	4	-	-	-	-	4
Zalutschia	-	5	13	2	8	12	32	8	16	50	12	8
indet.	-	-	-	-	8	-	-	4	-	6	-	-
S.F. Prodiamesinae												
Monodiamesa	6	-	2	22	4	-	8	-	6	2	-	-
S.F. Tanypodinae												
Ablabesmyia	-	-	1	12	104	4	48	16	8	-	144	-
Procladius	1	5	2	2	20	-	8	8	14	-	68	-
Thienemannimyia complex	1	-	-	-	-	-	-	-	-	-	-	-
F. Empididae												
Chelifera	-	-	-	2	-	-	-	-	-	2	-	16
P. Mollusca												
F. Valvatidae												
Valvata	-	-	-	8	248	60	4	-	12	8	-	-
Cl. Pelecypoda												
F. Sphaeriidae												
Pisidium	14	6	32	92	216	32	148	54	64	-	20	-
Sphaerium nitidum	-	-	-	-	27	-	4	16	4	-	-	-
TOTAL NUMBER OF ORGANISMS	249	152	306	608	2126	626	1148	584	488	476	1172	1520
TOTAL NUMBER OF TAXA	24	23	26	29	32	18	25	22	23	26	24	19

APPENDIX F

Fisheries

ATTACHMENT F.1

Population Survey

Table F1-1: Fish captured in Contwonyto Lake, Lupin Mine: exposure and reference sites

				Lengths		
Date	**Gear**	**Site**	**Species**	**Standard (mm)**	**Forked (mm)**	**Weight (g)**
9/10/06	GN	E	LT	660	nd	2268
9/10/96	GN	E	LT	551	nd	1814
9/11/96	GN	E	LT	725	795	7257
9/11/96	GN	E	LT	nd	nd	nd
9/11/96	GN	E	LT	295	326	680
9/11/96	GN	E	LT	428	462	1134
9/11/96	GN	E	LT	381	540	1588
9/11/96	GN	E	LT	535	582	2041
9/11/96	GN	E	BB	490	nd	nd
9/11/96	GN	E	RW	419	447	1021
9/11/96	GN	E	LT	561	587	2381
9/11/96	GN	E	RW	400	428	907
9/11/96	GN	E	LT	539	574	1588
9/11/96	GN	E	LT	488	526	1474
9/11/96	GN	E	LT	308	324	567
9/11/96	GN	E	RW	389	411	907
9/11/96	GN	E	CL	413	433	907
9/11/96	GN	E	RW	366	391	454
9/11/96	GN	E	RW	384	395	680
9/11/96	GN	E	RW	383	413	1134
9/11/96	GN	E	RW	290	302	170
9/11/96	GN	E	RW	383	395	567
9/11/96	GN	E	AG	296	314	567
9/11/96	GN	E	CL	357	378	680
9/11/96	GN	E	LT	450	469	1474
9/11/96	GN	E	RW	363	371	1361
9/11/96	GN	E	LT	296	307	113
9/12/96	GN	R	LT	513	565	2268
9/12/96	GN	R	LT	nd	nd	nd
9/12/96	GN	R	LT	430	450	907
9/12/96	GN	R	LT	550	597	2381
9/12/96	GN	R	RW	385	400	907
9/12/96	GN	R	RW	410	427	1474
9/12/96	GN	R	LT	878	980	12701
9/12/96	GN	R	LT	454	473	2268
9/12/96	GN	R	LT	475	510	2268
9/12/96	GN	R	CL	394	413	1134
9/12/96	GN	R	BB	489	527	907
9/12/96	GN	R	CL	368	386	907
9/12/96	GN	R	CL	393	411	1134
9/12/96	GN	R	CL	407	446	1814
9/12/96	GN	R	CL	394	416	907
9/12/96	GN	R	CL	333	352	680
9/12/96	GN	R	CL	226	347	454

				Lengths		
Date	**Gear**	**Site**	**Species**	**Standard (mm)**	**Forked (mm)**	**Weight (g)**
9/12/96	GN	R	CL	378	399	1247
9/12/96	GN	R	CL	352	370	1588
9/12/96	GN	R	CL	390	406	1588
9/12/96	GN	R	LT	585	636	4082
9/12/96	GN	R	LT	460	480	1134
9/12/96	GN	R	CL	375	400	680
9/12/96	GN	R	CL	387	415	907
9/12/96	GN	R	LT	622	675	3402
9/12/96	GN	R	LT	547	605	2495

nd = no data available

Site Code: E = Exposure
R = Reference

Gear Type:
GN = Gillnet
BS = Beach Seine
MT = Minnow Trap
EF = Electrofishing
AN = Angling

Fish Species: LT = Lake Trout
CL = Lake Cisco
BB = Burbot
RW = Round Whitefish
AG = Arctic Grayling
RB = Rainbow Trout
TSB = Threespine Stickleback
CAS = Prickly Sculpin
MW = Mountain Whitefish
NSC = Northern Squawfish
CC = Sculpin (General)