Environment

MMG Resources Inc.

Lupin Gold Mine Environmental Effects Monitoring – Cycle 3 Interpretative Report

Prepared by:

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Date:

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May 5th, 2011

Andrew Mitchell
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Dear Mr. Mitchell:

Project No: **60147160**

Regarding: Lupin Gold Mine Environmental Effects Monitoring Cycle 3 Interpretative Report

AECOM is pleased to submit the Lupin Gold Mine Environmental Effects Monitoring Cycle 3 Interpretative Report for MMG Resources Inc. The report provides the required information and biological details as per Environment Canada's accepted Study Design for the mine. If you have any questions or concerns please feel free to contact the undersigned at 250-475-6366.

Sincerely,
AECOM Canada Ltd.

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BM:db
Encl.

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	Tiffany Hnatiuk	March 24, 2011	First Draft
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AECOM Signatures

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EXECUTIVE SUMMARY

1. Overview

Minerals and Metals Group Inc. (MMG) owns the Lupin Gold Mine in western Nunavut, near the shore of Contwoyto Lake. Under the *Metal Mining Effluent Regulations* (MMER), which is enabled under the authority of the Federal *Fisheries Act,* MMG has completed a series of Environmental Effects Monitoring (EEM) studies for the Lupin Mine. An EEM Cycle 1 report was submitted to Environment Canada in 2006, based on 2005 field work, and an EEM Cycle 2 report was submitted to Environment Canada in 2009, based on 2008 field work. This report has been prepared by AECOM on behalf of MMG to satisfy ongoing requirements under the MMER. In particular, AECOM completed a Cycle 3 EEM report, which is the subject of this interpretative report.

The main conclusions of this report are as follows:

- Observations from the Cycle 2 report indicate that fork length and body weight of YOY grayling were statistically different between the Exposure Area and the Reference Area, which triggered the Cycle 3 study to be moved up one year and the move to an Investigation of Cause modality rather than continual monitoring.

- The postulation provided was that there may be some difference in the physical conditions between the two habitats that have caused these differences rather than the effects of the effluent discharge because the effect was seen in non-discharge years.

- The Cycle 3 study was designed to test the temperature theory as well as provide a literature review examining the potential effects of water chemistry, specifically metals. Metal concentrations observed in the Exposure Area water quality data are to low to have been the cause of the differences in fork length and YOY body mass observed.

- The primary theory was a difference in water temperature between the two study areas. This theory was refuted in the 2010 study – the Exposure Area was found to be warmer by 1.0 -1.5 degrees Celsius during the summer months.

- The fact that the regressions fit to the fish condition data did not intercept the origin indicates the differences may be due to the extrapolation of a linear fit when a curvilinear fit was more appropriate for the data set and for extrapolating to hatch size.

- The most likely explanation of the effect is a variance in recruitment date between the Exposure Area and the Reference Area as evidenced by there being no variance in condition and by the fact that the variance in fork length and body mass does not persist in to the 1+ and 2+ age cohorts. Differences in recruitment could have been caused by differences in the timing of spawning grounds accessibility. These differences may have occurred based on localized differences in spring thaw rates (i.e. related to stream morphology, depth, width, etc) and spawning area entrance limitations (i.e. ice jams).

- The variance in fork length and body mass in YOY grayling is not likely attributable to the effect of effluent discharge, therefore the site should resume the normal intervals for EEM monitoring studies.

Per prior communications with Environment Canada and MMER requirements,a subsequent EEM study interpretative report must be provided within 24 months from the submission date of this EEM report.

2. Background

The purpose of an EEM biological study is assess the aquatic ecological effects of effluent release from active metals mines to receiving waters frequented by fish. The overall objective of this Cycle 3 (Investigation of Cause: IOC) study was to further examine possible differences in the growth and/or condition of resident fish populations between the effluent Exposure Area associated with the Lupin Mine periodic discharge from the tailings containment area (TCA) and local reference areas, and to further evaluate alternative hypotheses for the observed differences between the exposure and reference areas, if any. Field data for the Cycle 3 program were collected in the summer of 2010 and are discussed within this Interpretative Report.

The monitoring program is based on a study design wherein selected biological and chemical indicator variables are compared between the direct effluent receiving environment and equivalent samples collected from reference areas. In contrast to the Cycle 1 and 2 EEM studies, comparison is made between the Exposure Area and two rather than one reference areas. The first of these reference areas was the same that had been previously used in the Cycle 1 and Cycle 2 studies. The second reference area was chosen based on the absence of ponds in the area, which was determined to be more similar to the Exposure Area.

The effluent receiving environment, the "Exposure Area", is the Seep Creek system composed of small ponds and tributaries eventually discharging to Outer Sun Bay in the West Arm area of Contwoyto Lake. Reference Area 1 is the Fingers Creek system also composed of small ponds and tributaries. Reference Area 1 is located southeast of the tailings area and drains into the central region of Contwoyto Lake. Reference Area 2 was selected from the surrounding area due to the absence of ponded water, which is similar to the layout of the exposure area. This was hypothesised to be more representative of the exposure area both in Arctic grayling habitat and temperature. Reference Area 2 is an unnamed system located southeast of the tailings area and drains into the northern part of South Bay on Contwoyto Lake.

3. Biological Field Program

Based on the results from the report of the Cycle 2 report, it was determined that there were few if any appreciable effects on the benthic communities between the Exposure Area and reference sites. Therefore, benthos was eliminated from the Cycle 3 study.

Water quality samples were collected in the Exposure and Reference areas. Sampling locations were based on those locations used in the Cycle 1 and 2 studies. For the Cycle 3 study, an additional reference area was added. None of the results from the Reference Area 1 or 2 samples exceeded the CCME guidelines. For the Exposure Area samples (SCP1, SCP1-rep, SNP925-20 and SCD1), all exceeded the guidelines for copper, iron and nickel while only sample SCD1 exceeded the guideline for zinc. All samples had undetectable concentrations of TSS, alkalinity, carbonate, hydroxide, nitrite and cyanide. Many samples had undetectable concentrations of bicarbonate, chloride, fluoride, ammonia, nitrate and total phosphorus. In addition, concentrations of TOC and DOC were very low in all samples.

Sediment samples, along with supporting field chemistry measurements, were collected from each of the study areas. Sediment concentration of arsenic, cobalt, copper, molybdenum, nickel, strontium and zinc were significantly higher in the exposure area in comparison with the reference areas. Many of the other metal parameters did not differ significantly between the areas but concentrations were higher in the Exposure Area as compared to the reference areas. Similarly many of the sediment concentrations did not differ between the two reference areas; however, Reference Area 2 generally had higher concentrations of metals/metalloids.

Based on the lessons learned in Cycle 1 and Cycle 2, electrofishing was used as the only fishing method in the Cycle 3 field program as it was the most effective and efficient from previous years. Electrofishing was conducted around the edges of ponds and in the creeks of the exposure area and each of the reference areas, starting downstream and moving upstream. In total, 308 fish representing three species were captured in the Exposure Area, 161 fish representing six species were captured in Reference Area 1 and 301 fish representing seven species were captured in Reference Area 2.

4. Results

The effluent discharge history of the Lupin Mine from the TCA is an important factor for further evaluation of aquatic ecological effects in the receiving environment. In particular, it is important to note that the Cycle 1 study was completed in 2005 just after the cessation of annual discharge of treated effluent from the Tailings Containment Area (TCA) , while the Cycle 2 study (2008) was completed following three years without any effluent discharge. A discharge did occur in 2009, but not in 2010.

Water quality in the Exposure Area in August, 2010, reflected the historical discharge of treated mine effluent, in that total Al, As, Cd, Cu, Ni, and Zn concentrations exceeded their respective Canadian water quality guideline for freshwater life protection in one or more of the water samples collected. This was dissimilar to the Reference Area samples. Inorganic substances that were significantly elevated in Exposure Area sediments in comparison with Reference Areas 1 and 2 include As, Co, Cu, Mo, Ni, Sr, and Zn.

Of the contaminants of potential concern identified in water or sediment samples from the Lupin Mine Exposure Area, only arsenic was significantly elevated in the whole body tissues of sub-adult Arctic grayling collected from the Exposure Area in comparison with the two reference areas. There was a statistically significant difference between areas in the grayling tissue cobalt concentration; however, the highest average tissue concentration was observed in fish collected from Reference Area 2.

This Cycle 3 EEM study for the Lupin Mine TCA discharge was catalyzed in particular by observations from Cycle 1 and Cycle 2 MMER EEM studies that early life stages of Arctic grayling collected from the effluent Exposure Area exhibited a smaller average body mass and fork length than fish from the Reference Area 1 (Fingers Lake drainage). The 1+ age class of Arctic grayling was the focus of the Cycle 1 (2005) study, while young-of-the-year (0+) grayling were the focus of the Cycle 2 (2008) study.

The average fish size (based on weight or length) in early life stages of Arctic grayling was lower in the fish collected from the Exposure Area in this and previously completed EEM studies; however, it is important to note that no statistically significant differences have been observed in the condition of 0+ and 1+ age class Arctic grayling between the Exposure Area and Reference Area 1, based on an analysis of covariance of body weight on fork length.

A summary of the major findings with regard to Arctic grayling health in the Exposure Area is as follows:

- This Cycle 3 study indicates that YoY Arctic grayling experience significantly higher water temperatures during the summer in the Exposure Area compared to Reference Area 1, by 1.0 to 1.5 ^{o}C on average over the seven week summertime measurement period. This is in contrast to the prior hypothesis that the Fingers Lake Reference Area 1 exhibits greater comparative temperatures and thus more rapid growth of age-0+ and subsequent juvenile grayling life stages. The hypothesis that differences between sites in juvenile grayling length or weight are proportional to differences in average temperature or degree days, therefore, is rejected.

- Furthermore, the Cycle 3 field observations suggest that YoY Arctic grayling experience greater average flow velocity in the the Exposure Area compared to Reference Area 1.

- On average, the YoY (0+) and/or 1+ age class Arctic grayling from the Exposure Area were shorter and lighter than the YoY Arctic grayling from Reference Area 1 (Cycle 1, 2, and 3).

- In August of 2010, there was not a statistically significant difference between the length or weight of the 1+ grayling between the Exposure Area and Reference Area 1, in spite of the noted difference for the 0+ cohort. There appears to be a convergence in the size of grayling from the different areas through their first year after swim-up. This further suggests that the 0+ differences might be attributable to differences in timing of spawning, hatching and swim-up between the two small watershed: A difference of several days to a few weeks in the hatching time on spawning grounds in the two areas would account for the differences in size of 0+ fish based on field observations in August, about one month after hatching from the eggs.

- Statistical analysis (ANCOVA) of the condition for the YoY Arctic grayling from the Exposure Area indicated that the slopes of the regression lines for each population (Exposure Area and Reference Area 1) were not significantly different and the Y-intercepts of the ANCOVA was significantly higher in the Reference Area 1. Therefore, the relationships between length and weight (condition) of the two populations were similar (i.e., they did not differ significantly between the Exposure Area and Reference Area 1.

5. Conclusions

Conclusions from the Cycle 2 report suggested that lower length and weight for YoY or 1+ age class Arctic grayling may be attributable to factors such as water temperature, food availability, competition, and predation. The results of Cycle 3 indicate that the hypothesis regarding lower water temperatures in the Exposure Area having an effect on the growth of YoY Arctic grayling is not supported.

Based on the results of the Cycle 1 and Cycle 2 studies, it is concluded that the benthic invertebrate community in the Exposure Area and Reference Area 1 are substantially similar with regard to numerical abundance as well as species richness and diversity. Some statistically significant differences in various diversity indices were observed in 2005. In 2008, different indicator variables were observed to be statistically significantly different between areas, while other were not. Given the similar average numerical abundance between the two areas, we speculate that the standing stock biomass between the Exposure Area and reference areas would be sufficiently similar to impact the growth of sub-adult Arctic char in the Exposure Area.

Within-season variation in the timing of recruitment between the Exposure Area and Reference Area 1 Arctic grayling populations may be the reason for the statistically significant differences in size (length and weight) of 0+ age class fish observed for both the 2008 and 2010 YoY studies. The spawning window for Arctic grayling occurs immediately post ice out. The area surrounding the Lupin Mine is relatively flat and is dominated by low lying vegetation which should limit potential differences in the spawning window of each study watersheds. Specific influences were not quantified in Cycle 3, however we speculate that a later spawning time and or hatch time in the Exposure Area could have resulted in the differences observed during in season sampling of YoY Arctic grayling. A difference of several days to a few weeks in the hatching time on spawning grounds in the two areas would account for the differences in size of 0+ fish based on field observations in August, about one month after hatching from the eggs.

During the design of the Cycle 3 study for the Lupin Mine, the TAP recommended the conduct a literature review to assess whether or not trace metal concentrations in the water and sediment of the exposure site have been within the range of values that could cause effects in the early life stages of fish. This analysis was strengthened considerably by the availability of recent studies of inorganic element toxicity to early life stages of Arctic grayling (Buhl and Hamilton, 1990; Buhl and Hamilton, 1991), conducted to evaluate possible adverse influences of placer mining activities in Alaskan fluvial systems (especially headwater systems). The results of this analysis indicate that the concentrations of all inorganic elements with the possible exception of copper in water samples collected from the Exposure Area in 2010 are far lower than documented thresholds of effects concentrations for sensitive life stages of salmonid species, including Arctic grayling. Copper was observed in water samples in 2010 at concentrations in the range of 3.5 to 6.0 µg/L. This is in the range that small steelhead fry (*Salmo gairdneri*) have been observed to exhibit mortality (pH 5.7: 96h LC50 of 4.2 µg/L; pH 7.0: 96h LC50 of 2.8 µg/L). In addition, Buhl and Hamilton (1990) observed in Arctic grayling juveniles a copper LC50 in the range of 2.6 to 9.6 µg/L. Alevins were reportedly less sensitive than juveniles, with observed copper LC50s in the range from 24 to 131 µg/L. Spear and Pierce (1979) suggest that adverse effects on growth of freshwater fish would occur at similar or perhaps higher ranges of copper than mortality; i.e. at waterborne concentrations in soft water in the range from 10 to 100 µg/L.

It cannot be precluded that copper exposures in the water are having an effect on juvenile recruitment, through enhanced mortality of early life stages or decreased growth and indirect longer term survival. Nonetheless, the available scientific knowledge suggests that effects if any would be very subtle and hard to detect in field populations, even in the absence of acclimatization or adaptation.

Table of Acronyms and Units

ANCOVA	Analysis of covariance	α	Alpha
ANOVA	Analysis of variance	β	Beta
AO	Authorizing Officer	µg/L	micrograms per litre
BCI	Bray-Curtis Index	µm	micrometres
BIC	Benthic Invertebrate Community	µS/cm	microSeimens per centimetre
CPUE	Catch-per-unit-effort	°C	degrees Celsius
CWQG	Canadian Water Quality Guidelines	Bq/L	Becquerels per litre
DO	Dissolved oxygen	cm	centimetres
EBM	Echo Bay Mines	g	grams
EC	Environment Canada	h	hours
EEM	Environmental Effects Monitoring	ha	hectares
ALS	ALS Laboratory Group	Hz	hertz
FDP	Final Discharge Point	km	kilometres
GPS	Global Positioning System	km^2	square kilometres
ISQG	Interim Sediment Quality Guidelines	L	litre
Kinross	Kinross Gold Corporation	m/s	metres per second
MDL	Method Detection Limit	m^2	square metres
MMER	Metal mining effluent regulations	m^3	cubic metres
QA/QC	Quality assurance / quality control	m^3/d	cubic metres/day
NWB	Nunavut water board	mg/kg	milligrams per kilogram
SD	Standard deviation	mg/L	milligrams per litre
SDI	Simpson's diversity index	mm	millimetres
SE	Standard error	ms	milliseconds
SNP	Surveillance Network Point	NTU	Nephelometric Turbidity Units
TAP	Technical Advisory Panel	s	seconds
TCA	Tailings containment area	V	volts
TGD	Technical guidance document		
TOC	Total organic carbon		
TSS	Total suspended solids		
UTM	Universal Transverse Mercator		

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1. Introduction

The *Metal Mining Effluent Regulation* (MMER) came into effect on June 6, 2002 and is enabled under the Federal *Fisheries Act*. The MMER requires that operating metal mines in Canada carry out Environmental Effects Monitoring (EEM) programs. Under this regulation, metal mines may deposit or discharge effluent containing cyanide, metals, radium-226 and suspended solids to the aquatic environment, but at concentrations that are not acutely lethal to fish. EEM programs are carried out to provide information on the integrity of biological community within the receiving environment. The EEM program was designed as a series of 3-year monitoring and interpretation cycles. The requirements of the current cycle are dependent upon the findings of the previous cycle.

The EEM programs must be implemented in accordance with the MMER, and the generic and specific requirements of the studies are outlined in the documents listed below:

- *Metal Mining Effluent Regulation* (SOR/2002-222) of the *Fisheries Act*
- Metal Mining Guidance Document for Aquatic Environmental Effects (EEM/2002)
- Guidance for Determining Follow-up Actions when Effects Have Been Identified in Environmental Effects Monitoring (EEM) (Environment Canada, 2000)
- Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies (Environment Canada, 2003)

Metal mining EEM programs are the responsibility of both the mine owner and government. The owner is responsible for completing the pre-design study and to propose subsequent cycles of the EEM program. The government is responsible for providing guidance, review and acceptance of study designs, review of reports and review of recommendations for further action.

Environment Canada is responsible for administering certain aspects of the *Fisheries Act* and is responsible for ensuring that EEM programs are undertaken as required. Environment Canada is one member of the Technical Advisory Panel (TAP). The study design and reports are reviewed by the TAP and communication between the mining company and the TAP is managed through Environment Canada. Lupin Gold Mine, which is owned by MMG Resources Inc. (MMG), is subject to MMER. Additional details of mine operating history, aqueous discharges to waters frequented by fish, and the environmental setting are provided in Section 2 of this report.

1.1 Summary of Previous EEM Studies

1.1.1 Cycle 1 Study

A Cycle 1 EEM study was conducted for the Lupin Mine in August 2005 and the report was submitted to Environment Canada (EC) in 2006 (Golder 2006a, b). The exposure and reference areas were determined through a literature and study design submitted to EC for prior approval. The study design was based on a control (reference)/ impact study design. The Cycle 1 study substantially defined the area of aquatic environment that was chemically or physically influenced by treated effluent that is periodically discharged from the tailings containment area (TCA).

A single final effluent discharge point has been previously defined for the Lupin Mine. The expected area of influence of discharge, over Dam 1A and Dam 2 and along “Seep Creek” and its tributary into Inner Sun Bay and then Outer Sun Bay of Contwoyto Lake, was defined through a combination of environmental sampling and plume delineation modeling. The model was used to predict that, under worst-case scenarios, 1% plume concentrations can extend for approximately 1,600 m into Outer Sun Bay. The exposure area, therefore, is formally defined as the Seep Creek drainage system, including various shallow channels and ponds, Inner Sun Bay, and Outer Sun Bay within approximately 1.5 km from the Inner Sun Bay outlet. There is minimal potential for dilution of effluent from the discharge point along Seep Creek prior to discharge into Inner Sun Bay, given the small size of the watershed and limited volume inputs from areas not affected by mining activities.

Various biological and chemical characteristics of the Lupin Mine exposure area were compared to a similar reference area. The Fingers Creek drainage system, to the immediate southeast of the minesite, was investigated as a potentially suitable reference area. As noted in the Cycle 1 and 2 interpretive reports, the channels and small ponds within the Fingers Creek system are slightly deeper on average than the reference area.

In 2005, the exposure area water samples exhibited a slightly depressed pH in the range of 5.8 to 6.1. Metals/metalloids in water samples from the exposure area observed at concentrations greater than their respective Canadian (CCME, 2007) water quality guidelines for freshwater life protection included especially aluminum, arsenic, cadmium, lead, nickel, and zinc. These substances have not been observed to be appreciably elevated in reference area samples.

Under MMER, there is a requirement to conduct sublethal toxicity testing on final effluent, using the juvenile fish (fathead minnow), sensitive pelagic invertebrate (*Ceriodaphnia dubia*), algal species (*Pseudokirchneriella*) and aquatic plants (*Lemna* sp.). The following conclusions were made from the 2005 toxicity testing program (Golder 2006a):

- Undiluted effluent was not acutely toxic to fish. In addition, sublethal effects on growth were not observed;
- Undiluted effluent was not acutely toxic to invertebrates; however, reproductive impairment was observed at 4.1% to 15% effluent concentration range;
- Undiluted effluent affected the growth of algae; 17% to 27% of diluted effluent inhibited algae growth; and
- Undiluted effluent was toxic to plants; growth was inhibited at 10% to 51% effluent and reproductive impairment was observed at <6.1% to 7.8% effluent.

Based on the effluent plume modeling and the toxicity test results, it was predicted that aquatic ecological effects associated with mine effluent discharge might be observed at effluent concentrations as low as 6%. Based on this, the predicted potential zone of effects from effluent extended from the narrows between Inner and Outer Sun Bay, and under worst-case conditions the zone of effects might extend to Outer Sun Bay.

These predictions were further tested through the analysis of field populations of benthic infaunal invertebrates, based on five sample locations for each of the two areas (Exposure, Reference). The Benthic Invertebrate Community (BIC) survey data indicated the following:

- There were no statistically significant differences between the Exposure Area samples and Fingers Creek Reference Area samples for invertebrate density, family richness or the Bray-Curtis Index (BCI); and
- There was a significant difference between the areas in Simpson’s diversity and evenness.

Fish habitat observed in the study area include permanent and intermittent streams which connected larger bodies of water ranging in size from medium-sized lakes over 2 m deep (Fingers Lake), small shallow ponds less than 1 m deep (Seep Creek Ponds) to a very large lake (Contwoyto Lake). The substrate types range from sand to cobble and large boulders, which provided in-stream cover for adults. The Cycle 1 study of resident fish provided information on the relative composition and abundance within the Exposure Area and Fingers Creek Reference Area. In general, the most commonly encountered and most abundant species in both areas were Arctic grayling (*Thymallus arcticus*) and ninespine stickleback (*Pungitius pungitius*). During the Cycle 1 work, 86 Arctic grayling and 99 ninespine stickleback were captured in the exposure area while 52 grayling and one stickleback were captured in the reference area.

The Cycle 1 fish study focused on juvenile (age 1+) Arctic grayling as the target species. Arctic grayling are common to both the exposure and reference areas of the Lupin Mine EEM biological monitoring studies. This species also is commonly fished and consumed by local residents and mine personnel. Age determinations for the captured Arctic grayling indicated that 34 fish were young-of-year (YOY: 0+), 51 were age 1+ and one was age 2+ in the exposure area. In the reference area 8 fish were age 0+, 31 were age 1+ and 6 were age 2+. The general health of Arctic grayling, based on visual analysis, was similar between the reference and the exposure areas.

The major results from the Cycle 1 study on Arctic grayling were as follows:

- Age 1+ Arctic grayling were significantly (31%) heavier and (7%) longer, on average, in the Reference Area than in the Exposure Area.
- Condition was 7.5% greater in the reference fish than in the Exposure Area fish.
- Liver weight to carcass weight was not statistically different between the two areas.
- The supporting variable of liver weight to fork length was 9.5% lower in the Exposure Area than in the Reference Area fish.

This suggests that historical discharges of mine effluent have negatively affected Arctic grayling weight and length of 1+ fish, but not of condition *per se*, since the slope of the weight-length relationship (ANCOVA) was not significantly different between the Reference Area and Exposure Area samples.

1.1.2 Cycle 2 Study

The Cycle 2 EEM study was conducted in August 2008 and the report was submitted to EC in 2009 (AECOM 2009).The study was conducted three years after the last effluent discharge period. Best attempts were made to use the same sampling stations in the exposure area as those that were used in the Cycle 1 study. The Fingers Lake and Fingers Creek areas were designated as the reference area.

Effluent samples were not collected for sublethal toxicity testing for the Cycle 2 study, since no discharge occurred from the TCA since prior to the time the Cycle 1 study was completed.

For all mining-related substances the observed concentrations in water samples collected in 2008 from both the exposure and reference areas were below Canadian (CCME, 2007) guidelines for protection of freshwater life.

The Benthic Invertebrate Community (BIC) assessment conducted during the Cycle 1 study was repeated for the Cycle 2 study, using the previously used sample locations and methods. The Cycle 2 BIC assessment results are as follows:

- There were no statistically significant differences between the Exposure Area samples and Fingers Creek Reference Area samples for invertebrate density, total taxon richness, family richness, Simpson's Diversity, or Simpson's Evenness.
- The Bray-Curtis Index was significantly higher in the Exposure Area in comparison with the Reference Area.

The Cycle 2 fish study focused in juvenile (age 1+) Arctic grayling and adult ninespine stickleback. Fish were collected from the Exposure (Seep Creek system) and Reference (Fingers Creek system) areas at similar locations to those used in the Cycle 1 study (Golder 2006a). Based on Environment Canada (EC) recommendations, both juvenile Arctic grayling and ninespine stickleback were selected as primary sentinel target species for a lethal sampling program. The Cycle 2 study also attempted to further assess spatial differences in and implications of copper accumulation in Arctic grayling livers; however, due to the small fish size an insufficient mass of liver tissue was collected for laboratory analysis. As an alternative, muscle tissue samples taken from Arctic grayling in both areas were submitted for lab analysis of copper concentration

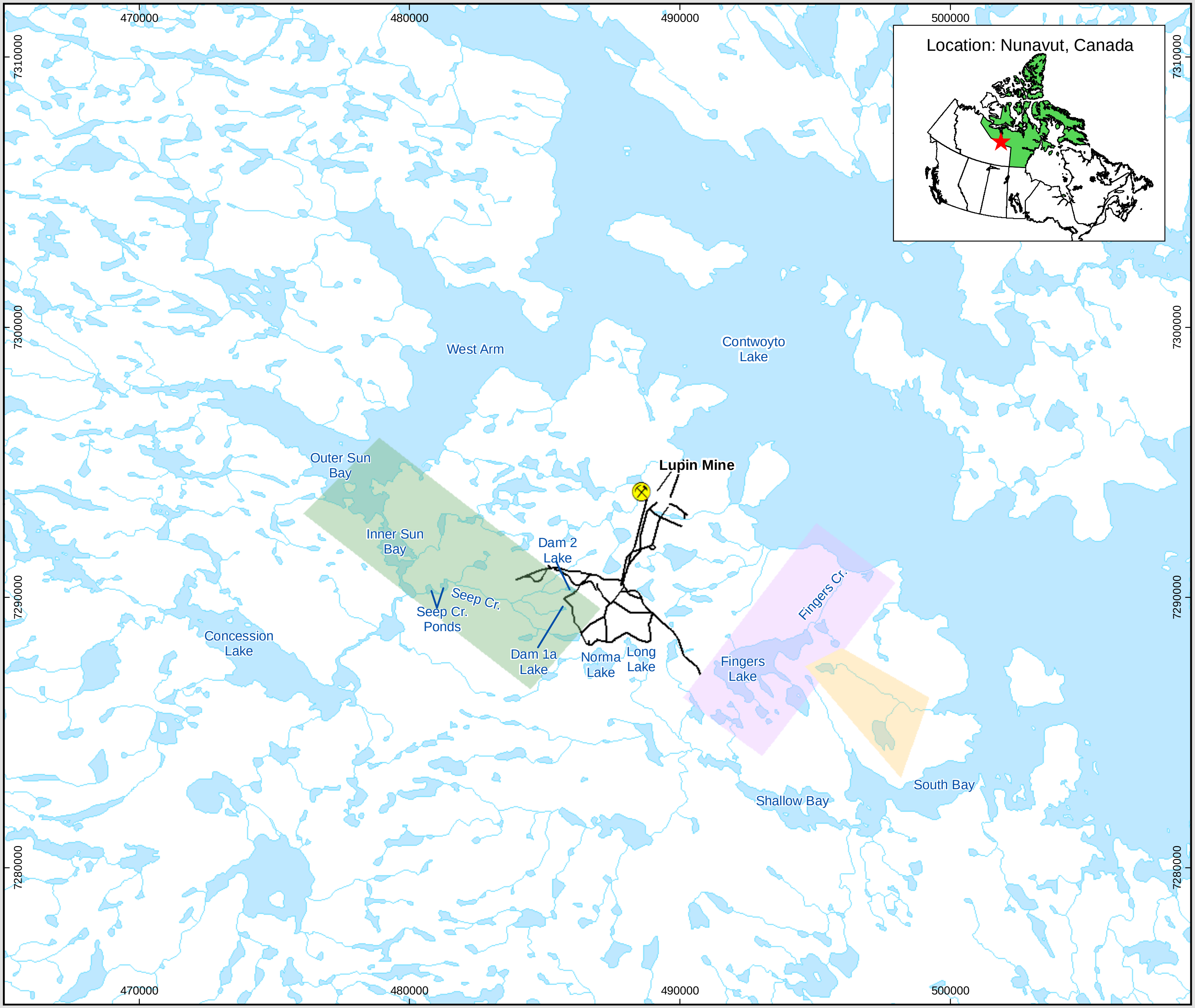
Based primarily on the use of electrofishing, 112 Arctic grayling and 130 ninespine stickleback were captured from the Exposure Area while in the Reference Area the numbers of fish caught were 40 and 96, respectively. All of the fish captured were immature and length-frequency distribution for Arctic grayling indicated that three distinct size classes were captured during the survey. The subsequent age determination indicated that 50% of juvenile Arctic grayling captured in the exposure area were young-of-year (YoY: 0+), only 17% were age 1+ fish, 31% were age 2+ fish and 2% were age 3+ fish. In the reference area, 77% of juveniles were young-of-year, 10% were age 1+, 17 % were age 2+ fish and there were no age 3+ fish captured. Due to the difficulty in catching adequate number of age 1+ Arctic grayling, individuals from all age groups were collected, and the analysis focuses on the 0+ as opposed to 1+ age class. A total of 109 fish from the exposure area and 39 fish from the reference area were used during the lethal sampling program.

External and internal examinations revealed no major abnormalities however two specimens from the exposure and three from the reference areas had slightly pale livers. Analysis of stomach content from larger specimens of Arctic grayling indicated that diet was mainly made up of insects and to a lesser extent juvenile ninespine stickleback.

The major results from the Cycle 2 study on juvenile Arctic grayling and ninespine stickleback were as follows:

- Average fork length and average body weight of 0+ Arctic grayling was significantly higher in the Reference Area than the Exposure Area. The 0+ grayling were on average 44% heavier and 16% longer in the Reference Area in comparison with the Exposure Area.
- An ANCOVA of weight (as the independent variable) versus fork length (as the dependent variable) was completed to assess spatial differences in condition of 0+ grayling. Condition differed between areas but the slope of the relationship was the same in both areas. Condition was 18% higher in the reference over the exposure area.
- There was no significant difference in the relationship of liver weight to carcass weight for young-of-year Arctic grayling by area.
- Body weight and length of ninespine stickleback in the exposure area were significantly heavier and longer, respectively, than reference area individuals. The slope of the length to weight relationship, however, did not differ significantly between areas.
- The ratio of liver weight to total length was statistically significantly different between areas for ninespine stickleback (for a given length, livers were heavier from exposure area versus individuals from the reference area).

File:60147160_C1_Fig1_StudyArea_03Feb10.mxd



Legend

Sampling Areas
- Exposure
- Reference Area 1
- Reference Area 2

Mining Properties
- MMG Minerals Property

All-Season Roads
- Existing Road Alignment

Hydrological Features
- Watercourse
- Waterbody

Map Sources/Notes:
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:250,000 scale.
Exposure and Reference areas delineated by AECOM.

N
W E
S

1 0.5 0 1 2 3 4 Km

1:200,000

UTM Zone 12N, NAD 83

MMG

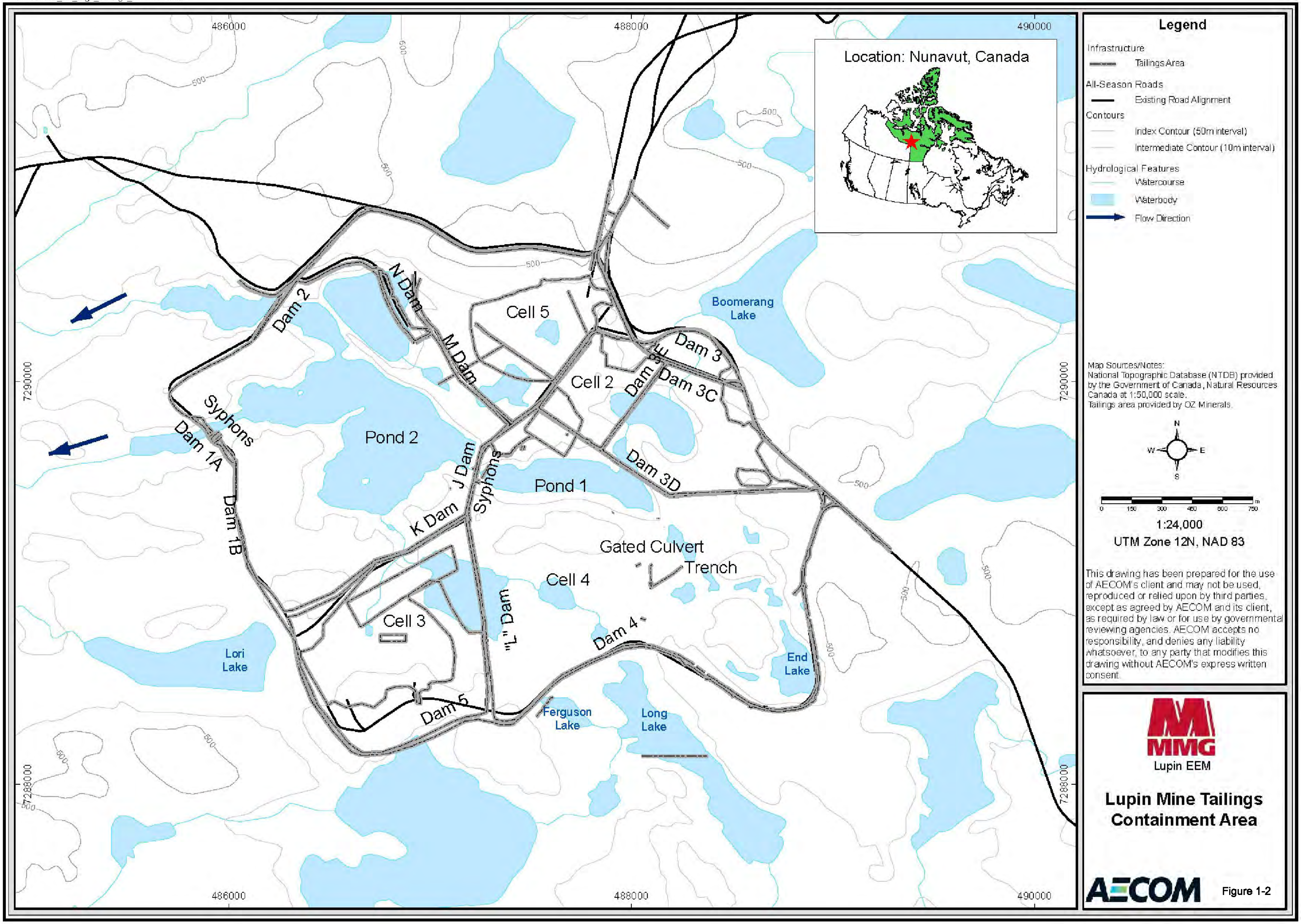
Lupin EEM

Exposure and Reference Study Areas for the Lupin Cycle 3 IOC EEM Program

AECOM

Figure 1-1

File:60147160_C1_Fig2_Tailings_03Feb10.mxd



1.2 Cycle 3 Study Objectives

The major intent of Cycle 3 work program was to further assess whether differences in habitat between the Exposure Area and Reference Area may be the major cause of differences in length and weight of fish in the reference area as compared to the exposure area. The Cycle 3 Investigation of Cause (IOC) EEM study design was submitted to Environment Canada (EC) in February 2010. The study design was reviewed by the TAP and comments were provided back to MMG. MMG contracted AECOM to provide technical guidance, complete the field program and complete the Cycle 3 Interpretative EEM reporting.

Two hypotheses were initially advanced to explain the observed spatial differences in both Cycle 1 and 2 between the size and condition of juvenile Arctic grayling. This is discussed further in Section 1.3, below. The first hypothesis related to differences in temperature regime between the two areas (Figure 1-1). The second hypothesis was that there is a difference in the abundance and/or quality of forage items, especially benthic invertebrates, for the juvenile fish.

The major components evaluated for the Cycle 3 study were as follows:

- Water Quality
- Sediment Quality
- Supporting Environmental Variables
- Fish Condition
- Expectations for effects to juvenile Arctic grayling and other resident fish species based on the current state of scientific/toxicological knowledge

The last of these components is based on comments received from the TAP on the initial Cycle 3 study design, dated April 29, 2010 (see Appendix D of this report). In particular, the TAP wrote –

"4. The facility is recommended to add a study on the potential effect of trace metals in the exposure area on grayling condition. In Phases 1 and 2, trace metal concentrations were shown to be elevated in the exposure area relative to the reference area. In some cases, trace metal concentrations in the exposure area exceeded Canadian Council of Ministers of the Environment (CCME) guidelines for sediment and water quality (CCME 2007). Elsewhere, high trace metal concentrations in the aquatic environment have been associated with decreased condition and other physiological responses in fish (e.g., Woodward et al. 1995; Eastwood and Couture, 2002).

6. The recommended approach for the trace metal study is to conduct a literature review to assess whether or not trace metal concentrations in the water and sediment of the exposure site have been within the range of values that could cause effects in the early life stages of fish. The TAP also recommends a comparison of current trace metal concentrations in fish, water, and sediment samples from exposure and reference sites. Please include a description of field and laboratory methods, and a statistical approach to compare trace metal concentrations between exposure and reference sites."

The proposed assessment of the benthic invertebrate community, and evaluation of effects hypotheses related to juvenile fish food availability, was removed from the initial Cycle 3 study design at the request of the TAP, who wrote:

"2. The facility is recommended to proceed with Hypothesis 1 to assess differences in temperature between exposure and two reference sites, provided they focus on grayling condition as an endpoint, and specify the statistical approach that will be used to test the hypothesis.

3. The facility is recommended to remove Hypothesis 2 from the study design. The hypothesis is based on the assumption that grayling in the exposure and reference systems feed preferentially on specific invertebrate *taxa (Chironomidae and Simulidae), and that their growth rates are correlated with the availability of these prey items. In addition, previous results from Phase 2 contradict the hypothesis, where grayling condition was lower in the exposure area despite high densities of chironomids."*

1.3 Approach and Study Design

There are three phases that comprise the Cycle 3 EEM studies:

Phase 1. Study Design
Phase 2. Study Design Implementation
Phase 3. Interpretation and Report Preparation

This report provides the data and interpretation of the Cycle 3 EEM program to complete the third phase in the above outline. Phase 1 was completed with the approval of the Cycle 3 EEM study design, as per the letter from Ms. Cheryl Baraniecki dated August 3, 2010 and is described in detail below. Documents related to the approval of the study design are provided in Appendices A and B.

1.3.1 EEM Cycle 3 (Investigation of Cause) Study Design

For the Lupin Mine Cycle 3 EEM IOC, a fish survey is required to assess the difference in fish age and length observed in Cycle 2 between Age-0+ Arctic grayling in the Exposure Area and Fingers Creek Reference Area. A review of the primary literature suggests that Arctic grayling are among the most sensitive local species to mining-related ecosystem perturbations that influence juvenile survival. If juvenile survival of Arctic grayling decreases, it can jeopardize the viability of the population (Buzby and Deegan, 2004; Vélez-Espino *et al*. 2006).

Other studies have demonstrated that the growth and survival of 0+ Arctic grayling are strongly dependent on temperature. For example, growth of juvenile Arctic grayling increases with mean water temperature (Deegan *et al*. 1999; Dion and Hughes, 2004; Luecke and MacKinnon, 2006) and a similar pattern of temperature-dependent growth was observed in the closely related European grayling (*Thymallus thymallus*), particularly for the age-0+ cohort in streams (e.g., Mallet *et al.* 1999). It has also been observed that the selection of spawning areas by adult Arctic grayling can lead to the exposure of eggs to cold or warm water, resulting in reduced or enhanced larval Arctic grayling growth rates, respectively (e.g., Luecke and Mackinnon, 2006). Section 3 in this report provides a more detailed discussion of the physiological ecology of Arctic grayling.

Arctic grayling tend to show fidelity to summer feeding grounds (Northcote, 1995). Buzby and Deegan (2004) analyzed 17 years of mark –recapture data to estimate annual survivorship rates of Arctic grayling in the Kuparak River, Alaska. Grayling that spent the summertime in more productive, fertilized zones of experimentally manipulated stream reaches had consistently higher growth rates. In spite of this, none of the observed population parameters, including growth, condition factor, or mean fish size explained appreciable amounts of the observed variance in annual survival rates. An evaluation of interannual or longer term survivorship among Arctic grayling subpopulations in the vicinity of the mine was beyond the scope of the Cycle 3 IOC study, owing to the length of time and resources required to properly conduct such studies. Instead, the focus was on an evaluation of differences in thermal regime through the summertime, open water period between the Lupin Mine TCA Exposure Area and the Fingers Lake Reference area, in comparison with estimates of juvenile growth, including length, weight and condition.

It was hypothesized that the growth rates of age-0+ Arctic grayling will differ between areas with more lentic conditions (i.e. with a major portion of the available habitat occurring in ponds with longer water residence time) as opposed to more lotic conditions (i.e., streams with continuously running water). This, in turn, relates to the thermal regime in these two different types of habitat. A formally stated hypothesis related to potential differences in juvenile growth and conditions is as follows:

- Water temperature for streams with abundant pond habitat will be higher through the growing season, and result in higher growth rates of age-0 Arctic grayling compared with streams with few or no ponds.

1.3.2 Study Design Component

1.3.2.1 Hypothesis: Thermal Influences

1.3.2.1.1 Water Temperature

It is postulated that Fingers Lake, in the Reference Area, provides thermal warming and thus more rapid growth of age-0+ and subsequent juvenile grayling life stages. The Exposure Area lacks significant lake or ponded water areas between the TCA outlet areas and Inner Sun Bay. Water temperatures, therefore, should be colder and thus result in a reduction of grayling age-0+ growth in comparison with the Cycle 1 and 2 Reference Area.

Water temperature typically co-varies with a large number of other variables, including water depth, substrate type, and food availability (as either pelagic/drift invertebrate or benthos). Therefore, a second Reference Area was developed, in a local area that exhibits a relative absence of ponded water (i.e., a hydrological regime intended to be more similar to the Exposure Area). This may also provide insight into a regional variation that may exist in age-0 Arctic grayling growth and survival rates (e.g., Deegan *et al.* 1999). To examine water temperature variations, digital logging thermometers (i.e., Hobo Tidbit loggers) were placed strategically in the field in the Reference, Exposure, and Alternative Reference Areas (see Section 4: Methods for greater detail).

To capture freshet, temperature loggers were placed in early July 2010. It is recognized that this is earlier than the period equal to 6 months after the submission of the Study Design, as required by the MMER. However, this placement is required to fully capture and represent the seasonal variation in water temperature across habitats near Lupin Mine, and to test the thermal hypothesis. No samples other than temperature related to the EEM program were collected.

1.3.2.1.2 Fish Survey

Based on the previous EEM studies, it was proposed to conduct a non-lethal fish survey to determine if the differences observed in the previous two cycles are still evident between the Reference and Exposure Areas. This strategy will allow for analyses to test for correlation between growth and temperature. Data from all three cycles will be used in the analyses. The survey was designed to sample and collect no more than 100 age-0+ Arctic grayling from the Reference and Exposure Areas used in the previous EEM studies.

Since it is hypothesized that the Reference Area from the previous studies may not be the most appropriate system to use (based on the presence of large lake providing increased water temperatures and therefore possible higher temperature-dependent growth rates for age-0 arctic grayling), it was proposed to assess the potential of a more suitable reference stream (i.e. minimal surface area resulting from ponding waters). Reference Area 2 and 3 (identified in Figure 1-1) were surveyed for the presence of Arctic grayling. It was proposed that only one of these would be used for further investigation. A target collection of 100 age-0+ Arctic grayling was desired from each of the Reference (existing), Exposure, and Alternative Reference (new) sampling areas to provide a non-lethal sampling program. Ideally, the sampling will occur in mid to late August. Fish survey endpoint measurements for statistical analysis include:

- Length (total, mm);
- Total body weight;

Any deviations from the submitted Fish Survey as a result of unforeseen timing of sampling or environmental conditions were discussed with MMG Resources and Environment Canada (EC) prior to any modifications, as directed by the MMER. It was proposed, for example, that if for any reason, the fish survey cannot capture 100 fish from an area, the final number of fish captured will be recorded. The focus of this study is age-0+ Arctic grayling. We used the results of the previous EEM cycles to confirm that the ages of the fish used in this study are actually within the age-0+ cohort. Given results of the previous cycles, lethal sampling and collection of fish tissue for copper analysis was not recommended.

A detailed habitat characteristic for Reference, Exposure and Alternative Reference Areas is in Section 2.

1.3.2.2 Water Quality

As outlined in the TGD (EC 2002), water quality sampling is to be completed in areas of biological sampling. Water quality samples were collected at the same location as those for benthos, prior to the collection of the required sediment samples. Parameters measured at each area included the following:

- TSS/TDS
- Conductivity
- Total Hardness
- pH
- Alkalinity
- Bicarbonate
- Carbonate
- Chloride
- Fluoride
- Hydroxide
- Sulphate
- Ammonia
- Nitrate
- Nitrite
- Total phosphorus
- Total cyanide
- DOC/TOC
- Aluminum
- Antimony
- Arsenic
- Barium
- Bismuth
- Boron
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Lithium
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Strontium
- Thallium
- Tin
- Titanium
- Uranium
- Vanadium
- Zinc
- Radium 226

1.3.2.3 Sediment Sampling

Sediments were collected from the Reference, Exposure, and Alternative Reference benthic stations, as recommended in the TGD. Sediment samples will be collected and classified according to the Wentworth Grain-Size Classification. Sediments were analyzed for the following:

- Calcium Carbonate
- Inorganic Carbon
- Total Carbon
- TOC
- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cesium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Mercury
- Molybdenum
- Nickel
- Selenium
- Silver
- Strontium
- Thallium
- Tin
- Uranium
- Vanadium
- Zinc

Phase 2 was completed with the implementation of the fish survey, sediment quality survey and water quality survey.

1.4 Report Structure

Following the introduction, this report is separated into seven main sections (Sections 2 to 8). A description of the sections and report structure is as follows:

Section 2 reviews the study area and setting.

Section 3 discusses the ecological context of the study.

Section 4 presents the study methods.

Section 5 presents the program design and results of the water quality study.

Section 6 presents the program design and results of the sediment survey.

Section 7 presents the program design and results of the fish surveys.

Section 8 discusses Cycle 3 EEM program results, and provides conclusions and recommendations.

2. Study Area and Setting

2.1 Mine History

2.1.1 Mine Setting

The Lupin Mine is located on the west shore of Contwoyto Lake, Nunavut, approximately 300 km south-east of Kugluktuk and 80 km south of the Arctic Circle (65°46' N, 111°15' W) (Figure 1-1).

Mine construction started in August 1980 and was completed in March 1982. The mine was operated continuously from 1982 to 1998 when operations were suspended and the mine went into care and maintenance status. Production resumed in April 2000, but in 2003 the mine went back into care and maintenance following a merger between Echo Bay Mines and Kinross. Operations were started again in 2004 but the mine once again went into care and maintenance in February 2005. In February of 2007, the Lupin Mine was sold to Wolfden Resources Inc. of Thunder Bay, Ontario. A holding company, Lupin Mines Inc., was created as a wholly owned subsidiary of Wolfden Resources Inc. to receive the Lupin assets and it is that company that is the legal owner of the property. In May 2007, Wolfden was acquired by Zinifex Limited of Melbourne Australia and ownership of Lupin Mines Inc. was transferred to Zinifex. In 2008, Zinifex Ltd. and Oxiana Ltd., both of Melbourne Australia merged to form OZ Minerals Ltd. with headquarters in Melbourne. Again, the ownership of Lupin Mines Inc. was transferred to the merged company. In 2009 the Canadian assets of Oz Minerals were sold to China Minmetals Inc. of Bejing, China. Minerals and Metals Group Ltd. was set up in Australia to receive the OZ Minerals assets. Minerals and Metals Group Ltd. is a wholly owned, privately held subsidiary of China Minmetals Inc. In Canada, the operating company for Minerals and Metals Group Ltd. is MMG Resources Canada Inc., which is the sole shareholder of Lupin Mines Inc., which in turn remains the legal owner of the Lupin Mine.

Lupin mine included underground mining and production systems and an ore handling system. Mining and processing equipment was designed to manage up to 2,300 tonnes per day. Materials and supplies were brought into Lupin by air transport and winter road transport while labour was brought in by air transport. Lupin is a self-contained facility with power generation and sewage facilities. The tailings containment area (TCA) is located approximately 7 km south of the mine (Figure 1-2).

2.1.2 Tailings

As reported by Golder (2006a), effluent discharge began in September 1985. Discharge from the TCA was scheduled to occur between July and September. Effluent is discharged from the TCA into Dam Lake and eventually reaches Contwoyto Lake via Seep Creek, Seep Creek Lake, unnamed creek, unnamed lake and Inner Sun Bay of Contwoyto Lake (Figure 1-1, and Figure 1-2).

2.1.3 Activities Since Cycle 2 Interpretive Report

An overview of mine operations, including management of mine water and tailings was provided in the Cycle 1 report (Golder 2006a,b). Some changes to the site have occurred since 2006.

Reclamation activities in the TCA during 2005 saw a major portion of Cell 5 and another portion of Cell 3 covered by a minimum of 1.0 m of esker gravel. The work was carried out between June 23 and September 28, 2005, with a total area covered of approximately 383,001 m^2.

Approximately 250,000 m2 of exposed tailings remain to be covered. This work was scheduled to be completed during the summer of 2006; however, due to the premature shutdown of the 2006 winter road, Lupin did not receive enough fuel to carry out the program as scheduled.

In 2008, as part of the preparation for discharge from the TCA, 76,000 kg of lime was spread on Pond 2. The lime was dispersed over the ice surface and then covered with snow to prevent wind from blowing it around. Effluent was not released in 2008.

In 2009, approximately 3 million cubic litres of effluent was released from tailings pond 2 after effluent was tested for toxicity and passed (A. Mitchell, Lupin Mine, pers. comm.). In spring 2010, ponds 1 and 2 were treated with lime. The mine planned to transfer the treated effluent to pond 2, and subsequently release a small volume after July 15, 2010. Based on volume considerations, there was no necessity to release effluent in 2010, and for this and other reasons, no discharge occurred in 2010.

No further activities have been carried out to date and the mine site remains in care and maintenance.

2.1.4 2009 Effluent Release

2.1.4.1 Overview of Effluent Release

Analytical data from the effluent discharge was taken from July 13 to October 20, 2009. The location of the final discharge point from which samples were collected for effluent characterization is LUP-10. The effluent was released at a rate of approximately 70,000 m^3/d throughout the discharge period.

2.1.4.1 Sampling Methodology

Water quality was monitored at approximately one week intervals between August 16 and October 20, 2009 at several locations in the exposure area downstream of the final discharge point (LUP-10). Table X lists and describes each monitoring station. Monitoring stations are identified on Figure 2-6.

Table 2-1 Water Quality Sampling Stations for 2009 Effluent Discharge– Lupin Mine Site

Sample Station	Location	Coordinates
LUP-10	Pond #2 discharge at Dam 1A. Sample point at siphon discharge	65°43'43.8"N 111°18'23.3"W
LUP-20	West end of Seep Creek before discharge into Unnamed Lake	65°43'57.52"N 111°25'42.87"W
LUP-21	North end of Concession Creek before discharge unto Unnamed Lake	65°43'52.41"N 111°26'42.8"W
LUP-22	Inner Sun Bay near the centre of the bay	65°44'51.71"N 111°27'36.72"W
LUP-24	Inner Sun Bat near the narrows	65°45'33.89"N 111°27'37.75"W
LUP-25	Outer Sun Bay (outside bay at discharge into the main body of Contwoyto Lake)	65°45'41.34"N 111°28'38.72"W

2.1.4.2 Field QA/QC

All samples collected in the field were collected and containerized in new, lab supplied and sealed sample containers, ensuring that potential cross contamination of samples (between sample containers) was eliminated.

Field Blanks and Field Duplicates were collected during the field sampling rounds. Field Blank samples consisted of laboratory supplied de-ionized water being transferred to sample containers in the field to allow for the testing of any potential anomalous contaminants effecting analytical results (in field effect) and field duplicates consisted of a sample composite being split between two sample (container) sets and sent to the laboratory for analysis. This allows for the comparison of separate analytical results of the same sample for the purpose of in lab anomalies.

2.1.4.3 Laboratory QA/QC

All water samples collected as part of the TCA Discharge Procedure and submitted to certified laboratory for analysis (effluent characterization, toxicity and water quality) were collected following the sample collection methodology outlined in the Environment Canada guideline document, Guidance Document for the Sampling and Analysis of Metal Mining Effluent, and the sample collection methodology outlined in Section 6.3 of the Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. Laboratory analytical methodologies, as well as method detection limits for the methodology used are outlined in the laboratory analytical certificates and results, included in Appendix E.

2.1.4.4 Sampling Results and Discussion

Sampling locations area shown in Figure 2-6. Graphical representations of trends in metal concentrations are shown in Figures 2-1 to 2-5. The locations discussed here include the effluent release point (LUP-10), the Exposure Area (LUP-20) and the receiving water body, Contwoyto Lake (LUP- 22, 24, and 25). Table 2-2 shows the monthly average and maximum sampling concentrations in comparison to the maximum concentrations allowed under the MMER. No samples collected during the 2009 effluent release period exceeded either the maximum monthly mean concentrations or the maximum authorised concentrations in a grab sample.

The arsenic concentration of the effluent discharge from Lupin Mine in 2009 increased over the course of the discharge period but was consistently below the MMER guidelines for a single sample set at 1.0 mg/L. The majority of the effluent samples were greater than the CCME standard for aqueous arsenic set at 0.005 mg/L. However, the downgradient samples collected from Seep Creek and Contwoyto Lake were all below the CCME standard over the entire sampling period.

The cadmium concentration of the effluent discharge from Lupin Mine in 2009 was generally constant over the course of the discharge period except for a few spikes that occurred in September. No MMER exists for cadmium. The majority of the effluent samples and downgradient water samples in Seep Creek and Contwoyto Lake were greater than the CCME standard for aqueous cadmium set at 0.000017 mg/L.

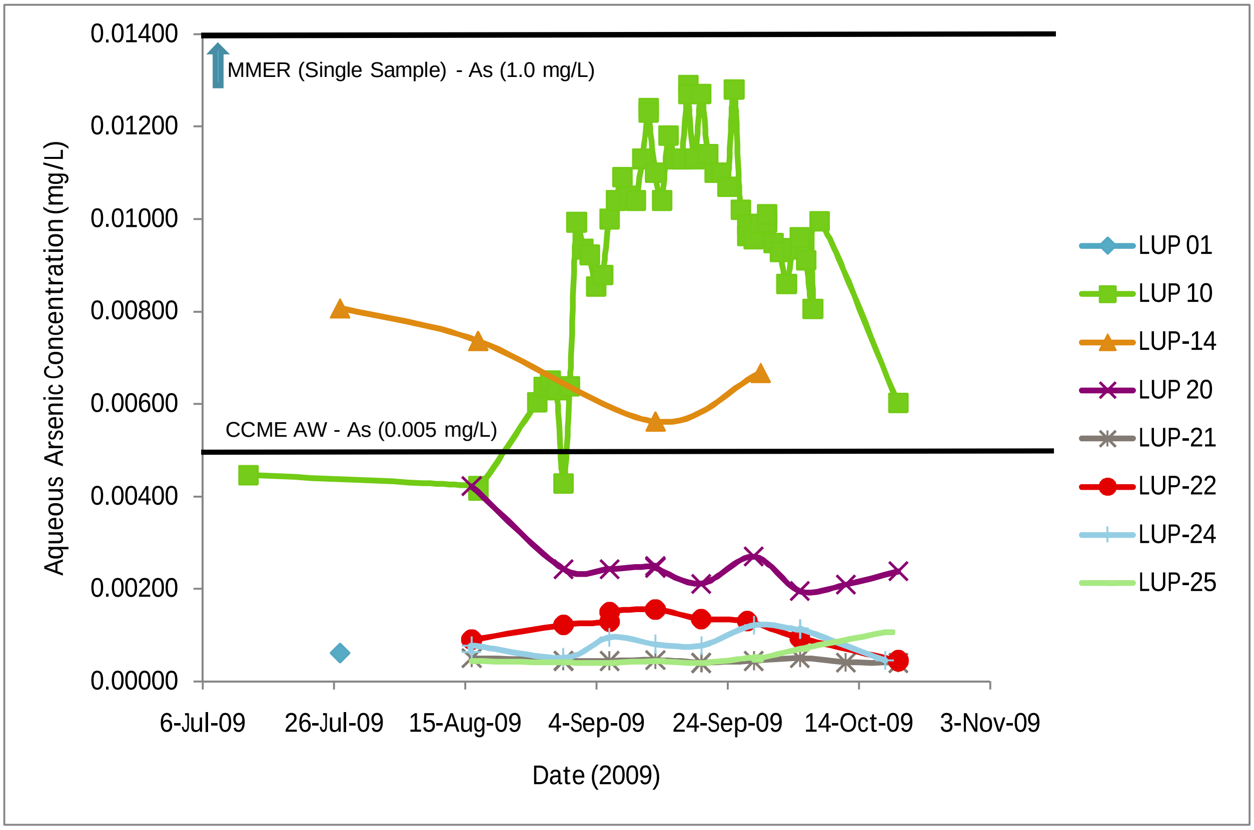


Figure 2-1 Arsenic Concentration in Water Samples (2009 Effluent Release)

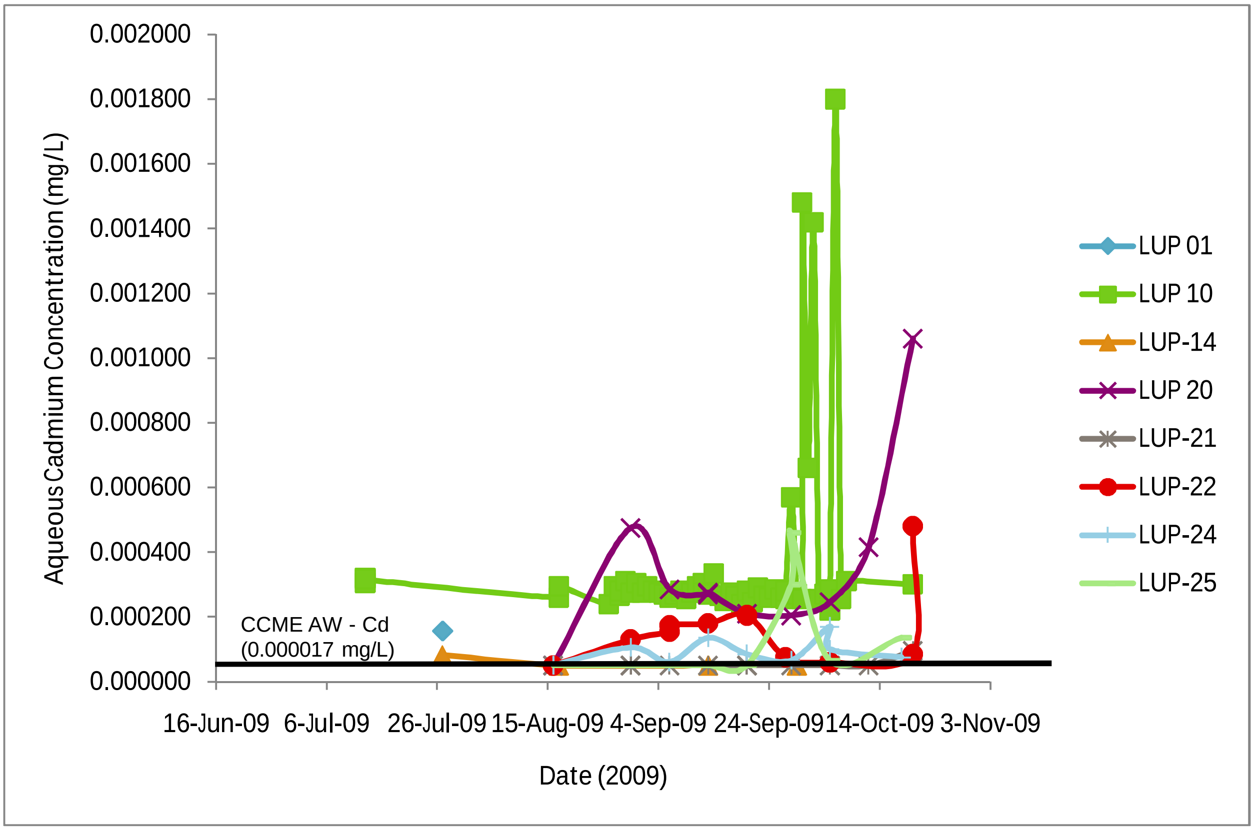


Figure 2-2 Cadmium Concentration in Water Samples (2009 Effluent Release)

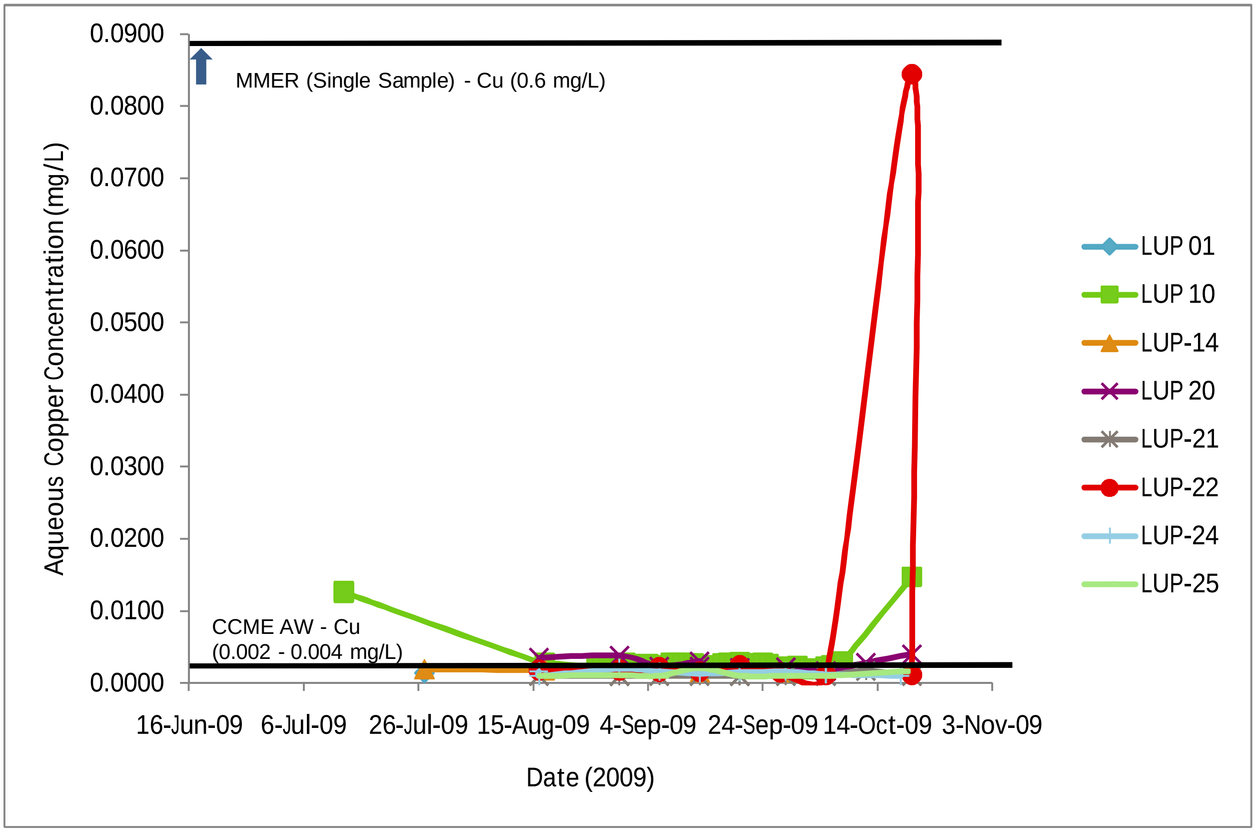


Figure 2-3 Copper Concentration in Water Samples (2009 Effluent Release)

The copper concentration of the effluent discharge from Lupin Mine in 2009 was generally constant over the course of the discharge period except for one spike that occurred in October and was consistently below the MMER guideline for a single sample set at 0.6 mg/L. The majority of the effluent samples and downgradient water samples in Seep Creek were greater than the CCME standard range (hardness dependent) for aqueous cadmium set at 0.002 to 0.004 mg/L. However, the concentrations were generally below the CCME standard for samples collected in Contwoyto Lake.

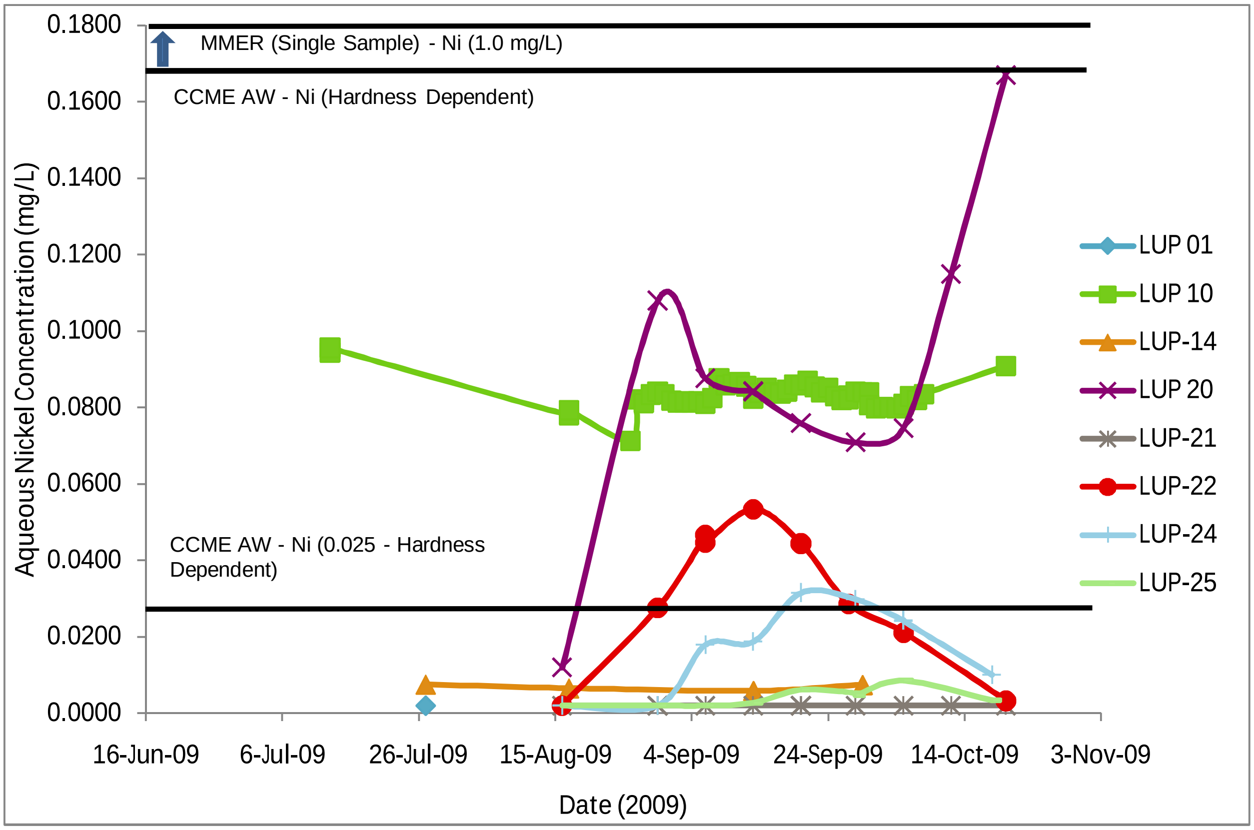


Figure 2-4 Nickel Concentration in Water Samples (2009 Effluent Release)

The nickel concentration of the effluent discharge from Lupin Mine in 2009 was generally constant over the course of the discharge period and was consistently below the MMER guideline for a single sample set at 1.0 mg/L. The majority of the effluent samples and downgradient water samples in Seep Creek were greater than the CCME standard range (hardness dependent) for aqueous nickel set at 0.025 to 0.15 mg/L. In this case the majority of the effluent samples (LUP-10) have a hardness of less than 50 mg/L and therefore are compared to 0.025 mg/L which means they were above the standard. Samples collected from Seep Creek (LUP-20) generally increased over the course of the sampling period including higher concentrations than the actual effluent near the end of the sampling period (October, 2009). The majority of the Seep Creek samples have a hardness of greater than 100 mg/L and therefore are compared to 0.01 mg/L which means they were below the standard, except for the last two samples collected in October had higher concentrations and higher hardness which still placed them below the CCME standard. The majority of the sampling locations in Contwoyto Lake increased until mid September and then declined over rest of the effluent release period. Based on the hardness level of each sample none of the nickel concentrations recorded in Contwoyto Lake in mid September were greater than the CCME standard for nickel. Late season shifts in aqueous metals concentrations contrary to effluent release trends in Contwoyto Lake could be the result of lake mixing caused by fall winds and temperature change.

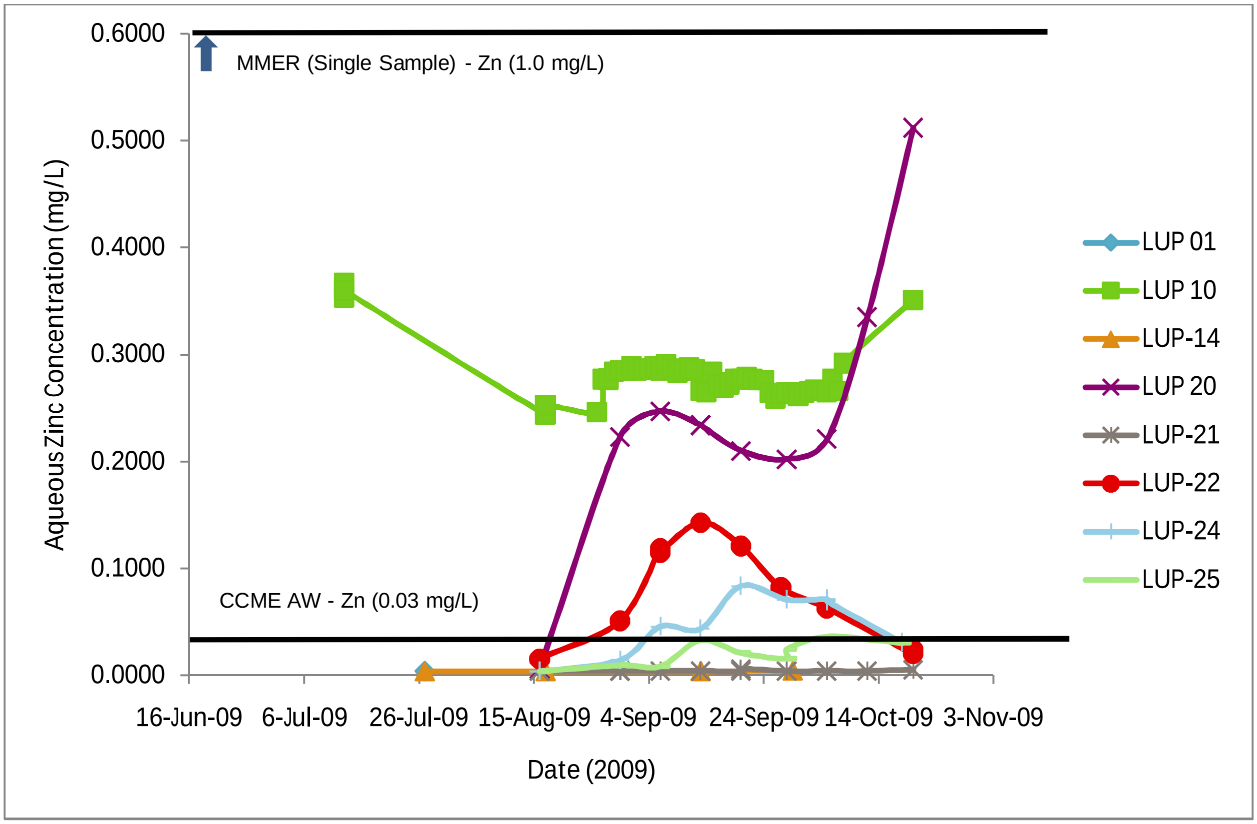


Figure 2-5 Zinc Concentration in Water Samples (2009 Effluent Release)

The zinc concentration of the effluent discharge from Lupin Mine in 2009 was generally constant over the course of the discharge period and were consistently below the MMER guideline for a single sample set at 1.0 mg/L. The majority of the effluent samples and downgradient water samples in Seep Creek were greater than the CCME standard for aqueous zinc set at 0.03 mg/L. Samples collected from Seep Creek generally increased over the course of the sampling period including higher concentrations than the actual effluent near the end of the sampling period (October, 2009). The majority of the sampling locations in Contwoyto Lake increased until mid September and then declined over rest of the effluent release period. A few of the samples highest nickel concentrations recorded in Contwoyto Lake in mid September were greater than the CCME standard for nickel. Late season shifts in aqueous metals concentrations contrary to effluent release trends in Contwoyto Lake could be the result of lake mixing caused by fall winds and temperature change.

Table 2-2 Comparison of Maximum Grab and Maximum Monthly Concentrations Collected During the 2009 Effluent Release Period Compared to MMER Maximum Authorised Concentrations

	Monthly Average (mg/L) – LUP-10				Monthly Average (mg/L) - LUP-20			Monthly Average (mg/L) - LUP-22			Maximum Authorized Monthly Mean Concentration (mg/L) (MMER)	Maximum Concentration (mg/L)	Maximum Authorized Concentration in a Grab Sample (mg/L) (MMER)
	July.	Aug.	Sept.	Oct.	Jul.	Aug.	Sept.	Aug.	Sept.	Oct.			
Arsenic	0.0039	0.0058	0.0107	0.0089	0.0033	0.0024	0.0021	0.0011	0.0014	0.0006	0.5	0.013	1.0
Copper	0.0126	0.0026	0.0025	0.0035	0.0037	0.0024	0.0028	0.0018	0.0019	0.0289	0.3	0.084	0.6
Cyanide	0.0030	0.0020	0.0020	0.0023	0.0020	0.0020	0.0035	0.0020	0.0020	0.0020	1.0	0.005	2.0
Lead	0.0003	0.0002	0.0001	0.0002	0.0003	0.0001	0.0001	0.0004	0.0002	0.0001	0.2	0.004	0.4
Nickel	0.0952	0.0809	0.0838	0.0820	0.0600	0.0806	0.1189	0.0148	0.0435	0.0092	0.5	0.167	1.0
Zinc	0.3600	0.2730	0.2766	0.2780	0.1145	0.2254	0.3560	0.0334	0.1160	0.0357	0.5	0.512	1.0
Total Suspended Solids	3.0	3.1	3.4	3.0	3.0	3.2	3.0	3.0	3.0	3.0	15	8.0	30
Ra-226 (Bq/L)	0.005 Bq/L	N/A	0.02 Bq/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.37 Bq/L	0.02 Bq/L	1.11 Bq/L

	Monthly Average (mg/L) - LUP-24			Monthly Average (mg/L) - LUP-25			Maximum Authorized Monthly Mean Concentration (mg/L) (MMER)	Maximum Concentration (mg/L)	Maximum Authorized Concentration in a Grab Sample (mg/L) (MMER)
	Aug.	**Sept.**	**Oct.**	**Aug.**	**Sept.**	**Oct.**			
Arsenic	0.0006	0.0009	0.0009	0.0004	0.0004	0.0009	0.5	0.013	1.0
Copper	0.0015	0.0015	0.0011	0.0011	0.0012	0.0013	0.3	0.084	0.6
Cyanide	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	1.0	0.005	2.0
Lead	0.0015	0.0002	0.0001	0.0002	0.0003	0.0011	0.2	0.004	0.4
Nickel	0.0020	0.0267	0.0195	0.0020	0.0042	0.0060	0.5	0.167	1.0
Zinc	0.0075	0.0660	0.0572	0.0068	0.0207	0.0335	0.5	0.512	1.0
Total Suspended Solids	3.0	3.3	3.0	5.5	3	4	15	8.0	30
Ra-226 (Bq/L)	N/A	0.005	N/A	N/A	N/A	N/A	0.37 Bq/L	0.02 Bq/L	1.11 Bq/L

ISS/REV: 0A
AECOM FILE NAME: 60147160-00-H-F01-R0X.dwg Saved By: tangw PLOT: 11/05/13 3:07:50 PM A SIZE 8.5" x 11" (215.9mm x 279.4mm)

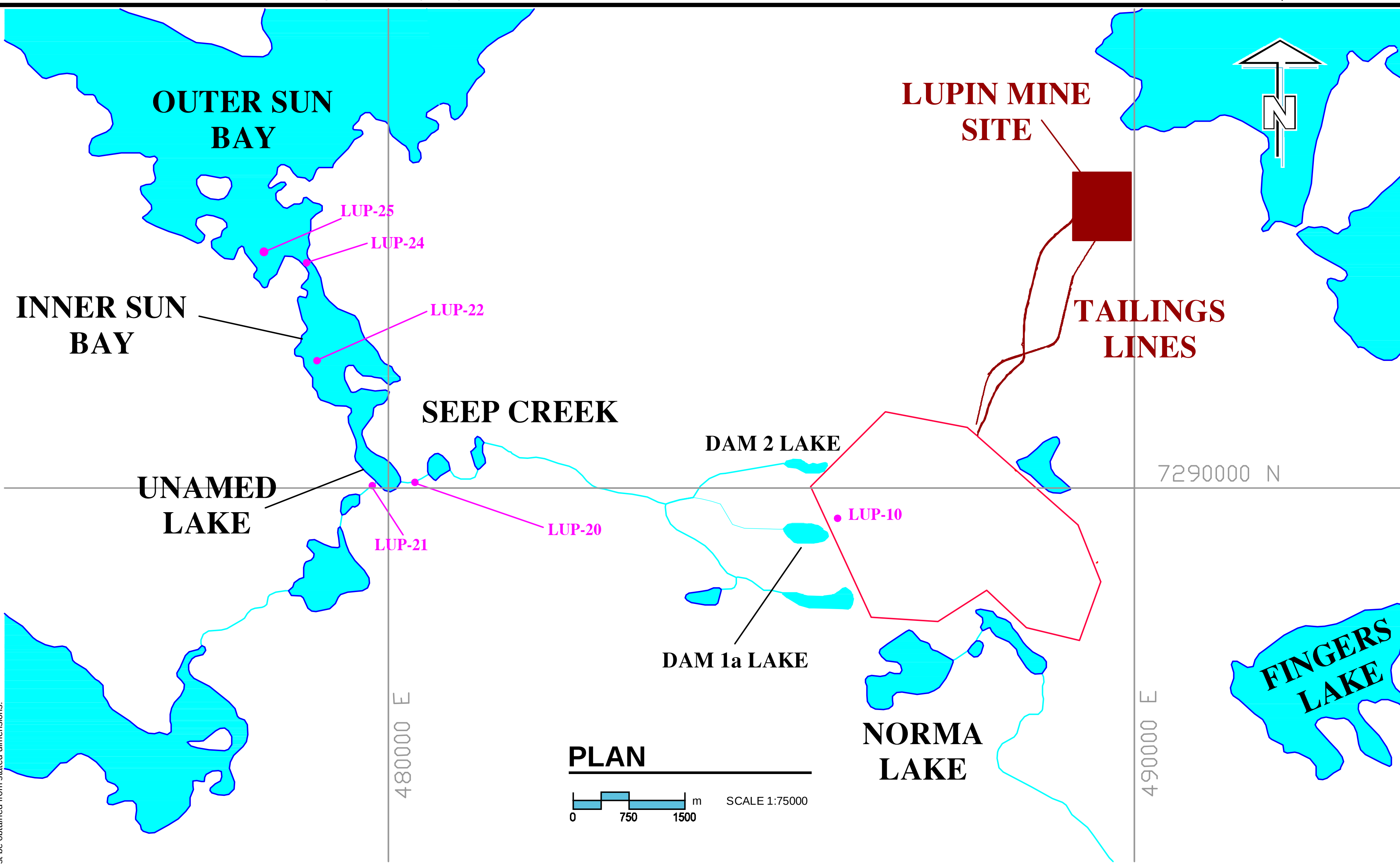


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Figure 2-6

2.2 Environmental Setting

2.2.1 Climate

Climate in this region is semi-arid subarctic with a mean daily temperature of -11.1°C and average annual precipitation of 299 mm (Canadian Climate Normals 1961-2000). Average temperature in May through September is 4.6°C and the heaviest precipitation occurs in June through September (Canadian Climate Normals 1961-2000). Snowfall can occur in any month but the heaviest snowfalls generally occur in October with an average annual snowfall of 138.1 cm (Canadian Climate Normals 1961-2000). The study area is subject to frequent strong winds from the northwest (Beak Consultants Ltd. and Mary Collins Consultants Ltd. 1980; Geocon Ltd. 1980).

2.2.2 Geology and Topography

The bedrock in the vicinity of the Lupin Mine is archean in age including supracrustal rocks of the Yellowknife supergroup of the Slave province of the Canadian shield. Rock types occurring in the vicinity of the mine include ultramafic, mafic, intermediate and felsic volcanic rocks, intrusive rocks and siliciclastic rocks and ironstones. The gold mineralization at the mine is hosted primarily by the ironstones. This region contains intrusive igneous material such as granite (Natural Resources Canada 2003). In the vicinity of the mine, terrain is low and undulating ranging between 450 and 530 m elevation. There are numerous shallow lakes and streams throughout the area (Gartner Lee Limited 2008a, b).

2.2.3 Vegetation

Lupin Mine is located in the subarctic tundra vegetation zone. This is an area characterized by continuous permafrost and “barren ground” vegetation including moss, lichens, heather and dwarf shrub communities in the well-drained areas and grasses and sedges in the wet areas adjacent to waterbodies. Dwarf shrubs, up to 1 m high, occur adjacent to some waterbodies (RCPL and RL&L 1985).

2.2.4 Hydrology

Contwoyto Lake is the major waterbody in the study area with a surface area of approximately 959 km^2 and a drainage area of approximately 8,000 km^2 (Roberge *et al.* 1986). Contwoyto Lake has two outflows. The main outflow to the north, drains to the Burnside River and ultimately to Bathurst Inlet; the smaller outflow to the south, drains to the Contwoyto River and into Back River (Rescan 2002). The main basin of Contwoyto Lake is to the east and south of the mine (Figure 1). To the north of the mine, West Arm extends to the west terminating in a narrow bay (Outer and Inner Sun Bay). This area is west of the mine and ultimately receives mine waste after it has travelled through small lakes and streams.

Seep Creek, a small stream approximately 6.5 km in length, flows westerly from the mine area into Inner Sun Bay (Figure 1-1, 1-2). Seep Creek watershed contains three lakes (Dam 2 Lake, Dam 1A Lake and Unnamed Lake), three headwater streams, two ponds (Seep Creek Ponds 1 and 2) and two embayment areas (Inner and Outer Sun Bay).

- Dam 2 Lake is a small lake, 7 m maximum depth, bordered to the north by a gravel pit and on the east by the TCA

- Dam 1A Lake is a shallow lake (< 1 m) south of Dam 2 Lake; water from the TCA discharges into this lake
- Dam 2 Lake and Dam 1A Lake are drained by tributaries that join to form Seep Creek
- Unnamed Lake is south of Dam 1A Lake
- A tributary from Unnamed Lake joins Seep Creek approximately 400 m downstream of the Dam 2 Lake and Dam 1A Lake tributary confluence

2.3 Historical Water Quality Monitoring and Effluent Plume Study

2.3.1 Historical Water Quality

One final effluent discharge monitoring point occurs at the mine, as identified by Kinross to Environment Canada. This station is identified as Surveillance Network Point (SNP) 925-10. In the Cycle 1 report, water quality results collected from this location were summarized (Golder 2006a). There were no samples collected from this location as part of the EEM program, so the table has not been reproduced. To summarize, several metals and other substances were routinely measured. Routine measurements - including pH, conductivity, total suspended solids (TSS) and metals including arsenic - remained at consistent concentrations and less than the *Authorized Limits of Deleterious Substances,* as defined in Schedule 4 of the MMER.

Conductivity has historically been measured at various sampling points in the exposure area. Field conductivity at the mouth of Seep Creek was recorded at 519 µS/cm (SNP 925-20) while at the mouth of Concession Creek (creek that drains Concession Lake before it enters Seep Creek watershed) it was recorded at 11 µS/cm.

For the 2010 Cycle 3 program, only one water quality sample was collected from SNP 925-20. These results are compared qualitatively to the historical records. The historical records were provided in the Cycle 1 and Cycle 2 report and are reproduced here for comparison to the 2010 results (Table 2-1). Conductivity, hardness and pH were lower in 2008 and 2010 in comparison with 2000 to 2005. TSS, cyanide and total lead were undetectable in the 2010 sample. Ammonia was much lower in the 2010 sample as compared to historic samples. The total copper concentration has not changed appreciably since 2000. While total nickel concentration has decreased, hardness has also decreased and the concentration measured in 2010 was above the CCME guideline for protection of aquatic life. Total zinc has decreased since 2000.

Table 2-3: Summary of Water Quality Monitoring Downstream of Lupin Mine Effluent Discharge Location (SNP 925-20)

			2000[b]	2002 [b]	2005 [b]	2008	2010
Parameter	**Units**	**CCME Aquatic Life[a]**	**Mean**	**Mean**	**Mean**	**Sept '08**	**Aug '10**
pH	pH unit	6.5-9.0	***6.03***	6.48	***5.7***	***5.6***	6.86
Conductivity	uS/cm		887	748	519	65.8	67.3
Hardness	mg/L		231	199	135	24	22.9
TSS	mg/L		0.53	0.93	<2	<3	<3.0
Alkalinity	mg/L		<5	7.4	<5	<5	6.2
Cyanide	mg/L	0.005	***0.007*** [c]	***0.015***	***0.016***	<0.002	<0.0020
Ammonia	mg/L	0.019	***2.72***	***0.72***	***0.64***	<0.005	0.0086
Arsenic	mg/L	0.005	0.0024	0.0036	0.0032	0.00186	0.00672
Cadmium	mg/L	0.000017	<0.0006	0.00017	0.00017	0.00006	0.000014
Copper	mg/L	0.002-0.004	***0.005***	***0.004***	***0.005***	***0.0052***	***0.00427***
Lead	mg/L	0.001-0.007	<0.002	0.0002	0.0001	<0.00005	<0.000050
Nickel	mg/L	0.025-0.15	0.115	0.0755	0.0762	0.0426	***0.0175***
Zinc	mg/L	0.03	***0.228***	***0.146***	***0.159***	***0.0392***	0.00823

Notes: a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007;

b) Golder, 2006a;

c) Values higher than CCME WQG_{AL} are shown in italics and bold (as well as values with a pH < 6.5)

2.3.2 Historical Effluent Plume Study

The MMER requires an estimate of effluent concentration at 250 m downstream from the final discharge point (FDP) and a description of effluent mixing within the environment to a concentration of 1%. When effluent is being released, it is common to use field conductivity measurements as a way to measure effluent concentration.

At Lupin Mine, 250 m downstream of the FDP is within Dam 1A Lake. In 2005, field conductivity measured from the effluent was 847 µS/cm and the lab measured conductivity from the sample in Dam 1A Lake was 738 µS/cm. Base flows in Seep Creek are very low and it has been estimated that up to 90% of the flow is due to effluent discharge (RL&L and DFO 1991). Based on the conductivity of the sample from 250 m downstream of the FDP, the water in the receiving system was comprised of 87% effluent.

A mixing and dispersion model was developed by Golder (2004) to describe the movement and concentration of effluent from the FDP to Outer Sun Bay. The model predicted that the 1% effluent limit would extend 850 to 1200 m from the mouth of the narrows in Outer Sun Bay.

The dispersion model was initially developed using data from 2000 and 2002 but results were updated with data from 2005 (Golder 2006b). Runoff conditions were lower in 2005 than originally modelled. When these conditions were included and the model was re-analyzed, the 1% dispersion limit extended to 1630 m beyond station SNP 925-25. The 2005 results from the sample at SNP 925-25 were considered consistent with the model.

2.4 Exposure and Reference Areas

2.4.1 Exposure Area

Seep Creek, Seep Creek Ponds and Sun Bay were designated as the Exposure Area (Golder 2006a). Best attempts were made to use the same sampling stations in the exposure area in the Cycle 3 study as were used in the Cycle 1 and Cycle 2 study based on data provided in the Cycle 2 report. The aquatic habitat in the Exposure Area, downstream of the TCA, is referenced as the Seep Creek watershed. Lakes Dam 2, Dam 1A and unnamed are west of the TCA. Dam 1A Lake receives effluent from the FDP. Dam 1A Lake is drained by Seep Creek. The creek that drains Dam 1A Lake joins with the creek that drains Dam 2 Lake (Seep Creek). Seep Creek flows for approximately 2.5 km before it enters two ponds (Seep Creek Pond 2 and Seep Creek Pond 1). Seep Creek is a well defined channel, 1 to 4 m wide with substrate dominated by boulders (RCPL and RL&L 1985). Seep Creek Ponds 1 and 2 are shallow (less than 1.5 m).

Historically, Lake trout, Arctic grayling, Arctic cisco (*Coregonus autumnalis*), round whitefish (*Prosopium cylindraceum*), ninespine stickleback and slimy sculpin (*Cottus cognatus*) have been documented in Seep Creek (RCPL and RL&L 1985). Fish use this stream for spawning, feeding and juvenile rearing in the early part of the open water season (RL&L and DFO 1991).

2.4.2 Reference Area 1

Fingers Lake and Fingers Creek was designated as Reference Area 1. The Fingers Lake watershed is located east of the mine. Like the Seep Creek watershed, the Fingers Lake watershed also has a connection to Contwoyto Lake. Fingers Creek flows for approximately 3 km between Fingers Lake and Contwoyto Lake. Fingers Creek is between 1 to 3 m wide with substrate dominated by silt, boulders and cobble in the upper reaches, cobble gravel and silt in the middle reaches and cobble and boulders in the lower reaches. Habitat varied between shallow flat in the upper reaches and shallow run in the lower reaches.

Fingers Lake has a maximum depth of 6 m and a surface area of 3.7 km^2. Lake trout (*Salvelinus namaycush*) and Arctic char (*Salvelinus alpinus*) have been captured in Fingers Lake (Moore 1978) and prior to the Cycle 1 EEM study, fish capture data for Fingers Creek had not been previously collected.

2.4.3 Reference Area 2

A second reference area was included in the Cycle 3 study to better understand availability of fish habitat in the vicinity of the exposure area. Reference Area 2 is southeast of reference area 1 but the two areas are not hydrologically connected. Reference area 2, like area 1, drains to Contwoyto Lake but unlike area 1, it has two small ponds in the drainage area as opposed to one large pond. The creek flows for about 3 km between the upper pond and Contwoyto Lake. The creek is about 1 to 2 m wide with a substrate dominated by boulders and fines.

3. Ecological Context

The appropriate design of an EEM program and interpretation of results requires a good understanding of the physiological ecology and life history of the resident aquatic species of interest (Barrett and Munkittrick, 2010; Gray *et al.,* 2002). Arctic grayling were chosen as the species of the fish survey on recommendation from Environment Canada (EC). A brief synopsis of the ecology of this species is provided below, based in part on summaries provided by Scott and Crossman (1979) and Northcote (1995; 2000). Additional ecological studies that are directly relevant to the interpretation of this Cycle 3 study are also discussed in Section 8 (Conclusions and Recommendations).

The Arctic grayling (*T. arcticus*) is a freshwater fish in the family Salmonidae and subfamily Thymallinae. The Arctic grayling is a strikingly coloured fish; the back is purple to blue-black or blue-grey with sides of a pinkish iridescence having a number of V-shaped or diamond shaped spots. The head is olive-green with a mauve iridescence. The Arctic grayling is distinguished from the similar grayling (e.g. the European grayling *Thymallus thymallus*) by the absence of dorsal and anal spines and by the presence of a larger number of soft rays in the fins. There is a dark midlateral band between the pectoral and pelvic fins. The adult Arctic grayling can grow to a maximum recorded length of 76 cm and a maximum recorded weight of 3.8 kg; while the average length is 30-38 cm and the average weight is 0.5-1.5 kg. (Scott and Crossman, 1979).

The Arctic grayling has a holarctic distribution occurring in northern freshwater drainages from Hudson Bay west to the Pacific Ocean, north to the Bering Sea to the Kara and Orb rivers of North Eurasia and south into Asia to northern Mongolia. Grayling prefer cold waters of mid-sized to large rivers and lakes. They are omnivorous fish, with the most important food items comprising of crustaceans, insects and insect larvae. Adult grayling can become piscivorous, feeding on smaller fish, the young of year grayling feed on zooplankton and insect larvae. (Scott and Crossman, 1979)

Grayling are spring spawners and move into spawning areas during ice break-up, which can vary over their subarctic habitat, from April to June. As the ice breaks up in the small streams, the adults migrate from larger rivers and lakes to small gravel or rock bottomed tributaries. Graylings have been found to spawn in habitats ranging from small shallow stream, to large rivers and lakes with substrates ranging from fines and gravels to cobbles and boulders. (Scott & Crossman 1979).

Hatching time is temperature driven and therefore is very site-specific. Hatching in northwestern Canada has been found to occur from 16 to 18 days after fertilization at 9 °C. The relationship between temperature and hatching is suspected to be curvilinear; however, there have been no carefully controlled studies to confirm this. The newly emergent grayling fry can range from 8 to 15 mm in length at hatch and spend 8 days absorbing their yolk, but begin to take food at 3 days after hatching. The fry feed predominantly on benthic invertebrates, with terrestrial insect becoming a larger part of their diet as they become older. The fry remain in the stream near the spawning area for several weeks, and then move out into deeper and faster moving water. Growth is fast in the first year, with the young of the year in Nueltin Lake, NWT measuring 64mm in length by late August (Harper, 1964). Growth in subsequent years varies by latitude and temperature, with slower growth occurring at more northern latitudes. (Northcote, 1995)

Both male and female grayling can reach sexual maturity at 4 years, but the majority of spawners are 6-9 years of age. Once spawners have reached sexual maturity they can spawn every year. (Scott & Crossman 1979). The maximum reported longevity varies between populations, but ages up to 13+ years have been documented for some higher latitude populations (DeCicco, 2002).

4. Methods

4.1 Water Quality

Water quality samples were collected in the exposure and reference areas as part of the Cycle 1 (2005) and Cycle 2 (2008) programs and again in the Cycle 3 field program (Figures 4-1, 4-2 and 4-3). Sample collection and results from the Cycle 3 program are presented below. The Cycle 3 field program was completed between August 18 and 29, 2010. Water temperature loggers were installed on July 7, 2010, but no field data other than field measurements at the logger sites were collected at that time.

4.1.1 Study Design

Sampling locations were based on those locations used in the Cycle 1 and 2 studies. For the Cycle 3 study, an additional reference area was added. Water quality samples were collected from each area to characterize water quality for the entire area. Grab water samples were collected but analyzed separately. Field data was also collected to characterize physical conditions during sample collection. The general sampling effort for the entire August field program is summarized in Table 4-1.

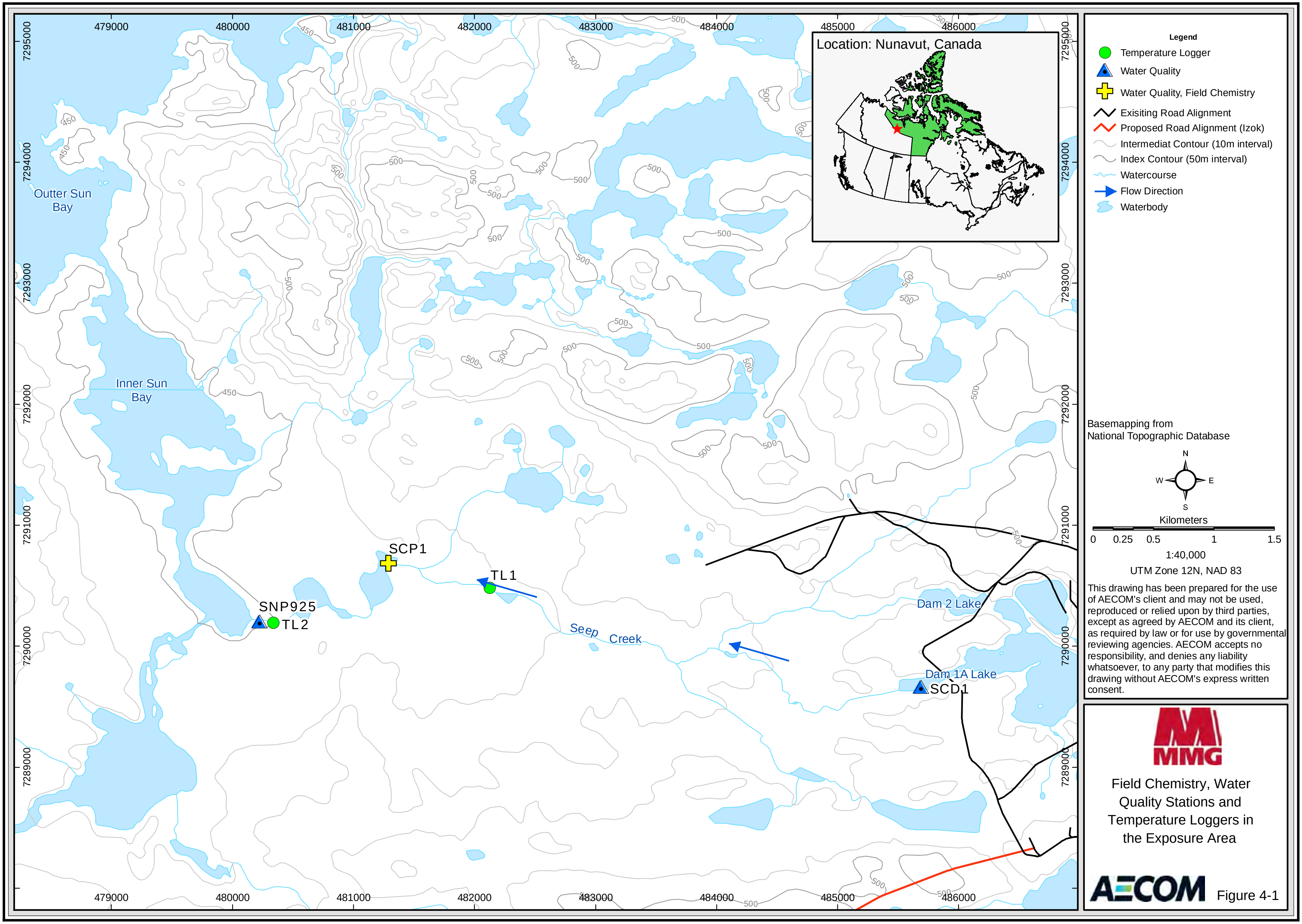
Table 4-1: Summary of Sampling Effort

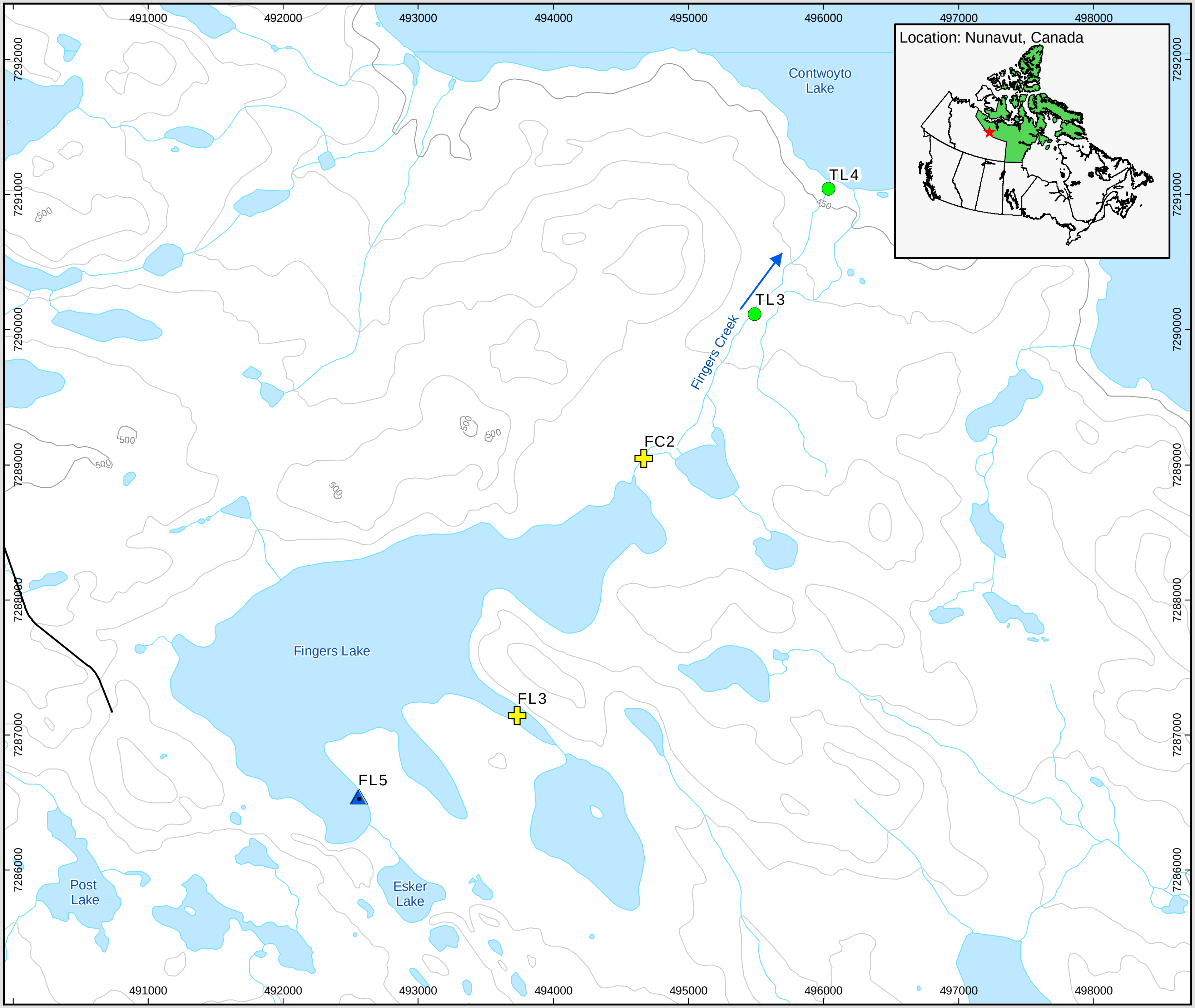
Area	Site	Zone	Easting	Northing	Field Chemistry	WQ	SQ	Fish
Exposure	SCD1	12W	485695	7289659		yes		
	SCP1	12W	481289	7290694	yes	yes+rep	yes	yes
	SCP2	12W	481065	7290479			yes	yes
	SCP3	12W	480953	7290309			yes	yes
	SCP4	12W	480747	7290395			yes	yes
	SCP5	12W	480594	7290521	yes		yes	yes
	SNP925	12W	480216	7290212		yes		yes
Reference 1	FC2	12W	494671	7289051	yes	yes		yes
	FL1	12W	492274	7286480		yes	yes	
	FL2	12W	493858	7287207			yes	
	FL3	12W	493717	7287001	yes	yes	yes	
	FL4	12W	492970	7286781			yes	
	FL5	12W	492552	7286547			yes	
Reference 2	R2-Creek	12W	497213	7286679				yes
	R2-1	12W	497453	7284512	yes	yes	yes	
	R2-2	12W	497305	7285367		yes	yes	
	R2-3	12W	495529	7287452	yes	yes	yes	
	R2-4	12W	497648	7284697			yes	
	R2-5	12W	494949	7287511			yes	

4.1.2 Methods

At each station *in situ* measurements were collected for pH, temperature (°C), conductivity (µS/cm), turbidity (NTU) and dissolved oxygen (mg/L) The meters were calibrated each day. Sampling coordinates were recorded with a hand-held GPS unit. Site conditions were noted and all information was recorded in a field log book.

Map Document: 60147160_C1_Fig3-1_FieldCWaterQ_Exposure_15April2011.mxd





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Lupin EEM

Field Chemistry, Water Quality Stations and Temperature Loggers in Reference Area 1

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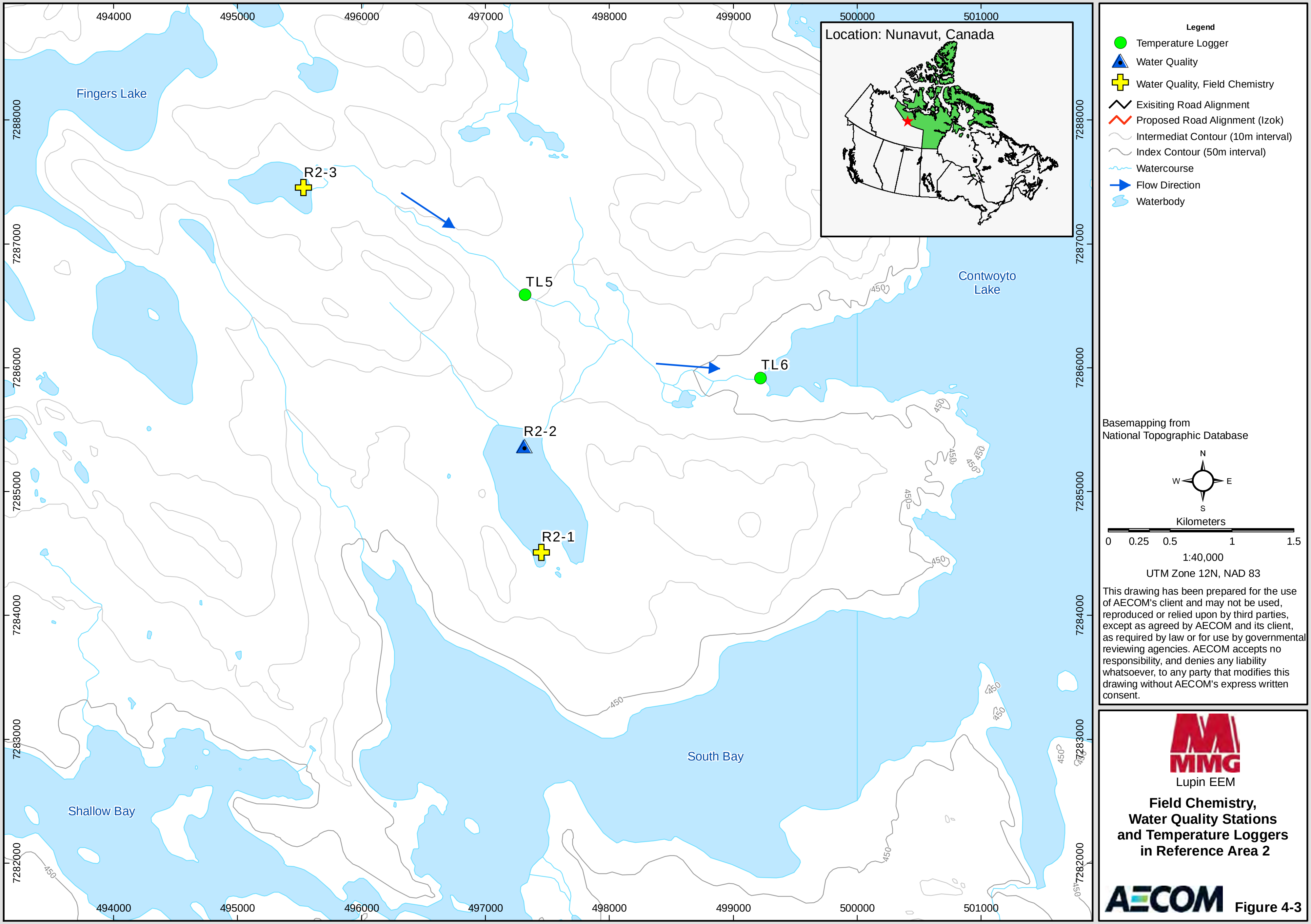
Figure 4-2

Map Document: 60147160_C1_Fig3-2_FieldCWaterQ_Reference1_15April2011.mxd



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Field Chemistry, Water Quality Stations and Temperature Loggers in Reference Area 2

AECOM

Figure 4-3

Map Document: 60147160_C1_Fig3-2_FieldCWaterQ_Reference2_15April2011.mxd

Water samples for lab analysis were collected directly into the lab supplied bottles. Sampling followed recognized sampling protocol, including methods outlined in MMER technical guidance document (TGD) (Environment Canada 2002) and appropriate measures were taken to avoid sample contamination. Bottles were placed approximately 0.2 – 0.5 m below the water surface at each sampling location and allowing the bottle to fill. Pre-measured preservatives provided by the laboratory were used for the appropriate samples. Samples collected for total organic carbon were preserved with hydrochloric acid, and samples collected for metals (total and dissolved) were preserved with nitric acid, and samples collected for nutrients (ammonia, nitrite, etc.) were preserved with sulphuric acid.

After sampling was completed, a chain of custody form was filled out. The samples were packed into coolers and shipped to the ALS Laboratory in Yellowknife, on the next available plane leaving camp. Samples were analyzed for:

- general chemistry including total suspended solids, alkalinity and major ions,
- cyanide,
- radium-226,
- total and dissolved organic carbon,
- nutrients including ammonia, nitrate, nitrite and total phosphorus, and
- total and dissolved metals.

4.1.2.1 QA/QC

Quality assurance/quality control protocols are a necessary component to any environmental sampling program. For this study, field blanks, trip blanks and field replicates were used. The blanks are used to detect potential sample contamination during collection, shipping and analysis. Trip and field blanks are sample bottles filled with distilled water and analyzed for the same suite of parameters as the test samples. These are used to test for possible contamination of water samples. The trip blank bottles are filled at the lab with distilled water, and travel with all the sample bottles to the field and back again. The trip blank is used to test if any contamination is introduced into the samples through handling and transportation. Field blank bottles are filled with distilled water at one of the sampling stations following the same protocols as sample collection. The field blank is used to assess contamination introduced to the sample as a result of handling and processing samples in the field. When a parameter in either the field or trip blank is detectable, further consideration is given, whereby the concentration is compared to the analytical detection limit of the particular parameter. When the value is less than the practical quantification limit (PQL), it is not considered further. The PQL is five times the Method Detection Limit (MDL) and is defined as the minimum concentration that can be measured within specified limits of precision and accuracy. Constituents with results below the PQL mean that the constituent being analyzed is not present in a sufficient amount to be reliably quantified.

4.1.2.2 Statistical Analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL) was used to conduct statistical analysis at a confidence level of 95% ($\alpha = 0.05$). Data were tested for homogeneity of variance using Levene's test and normality using the Shapiro-Wilk test. Significant differences in water chemistry and physical parameters were determined using a one-way ANOVA and Tukey's test (when appropriate). Non normal data sets were analysed using the non parametric Kruskal-Wallis and Tukey's test (where appropriate). Water temperature records were collected for approximately 7 weeks from July 7th to August 27th 2010 using in situ data loggers. Differences in the water temperature records collected from the Exposure Area, Reference Area 1 and Reference Area 2 were analysed using the Friedman repeated measures ANOVA based on ranks and Tukey's test.

4.2 Sediment Quality

4.2.1 Study Design

Sediment samples, along with supporting field chemistry measurements, were collected from each of the study area. There were five sampling stations in the Exposure Area (Figure 4-4), five sampling stations in Reference Area 1 (Figure 4-5) and five sampling stations in Reference Area 2 (Figure 4-6). Sediment samples were collected and analyzed for total organic carbon and total metals content in order to correlate with similar measurements in the tissues of fish as well as water quality samples. The field program was completed between August 18 and August 29.

4.2.2 Field Methods

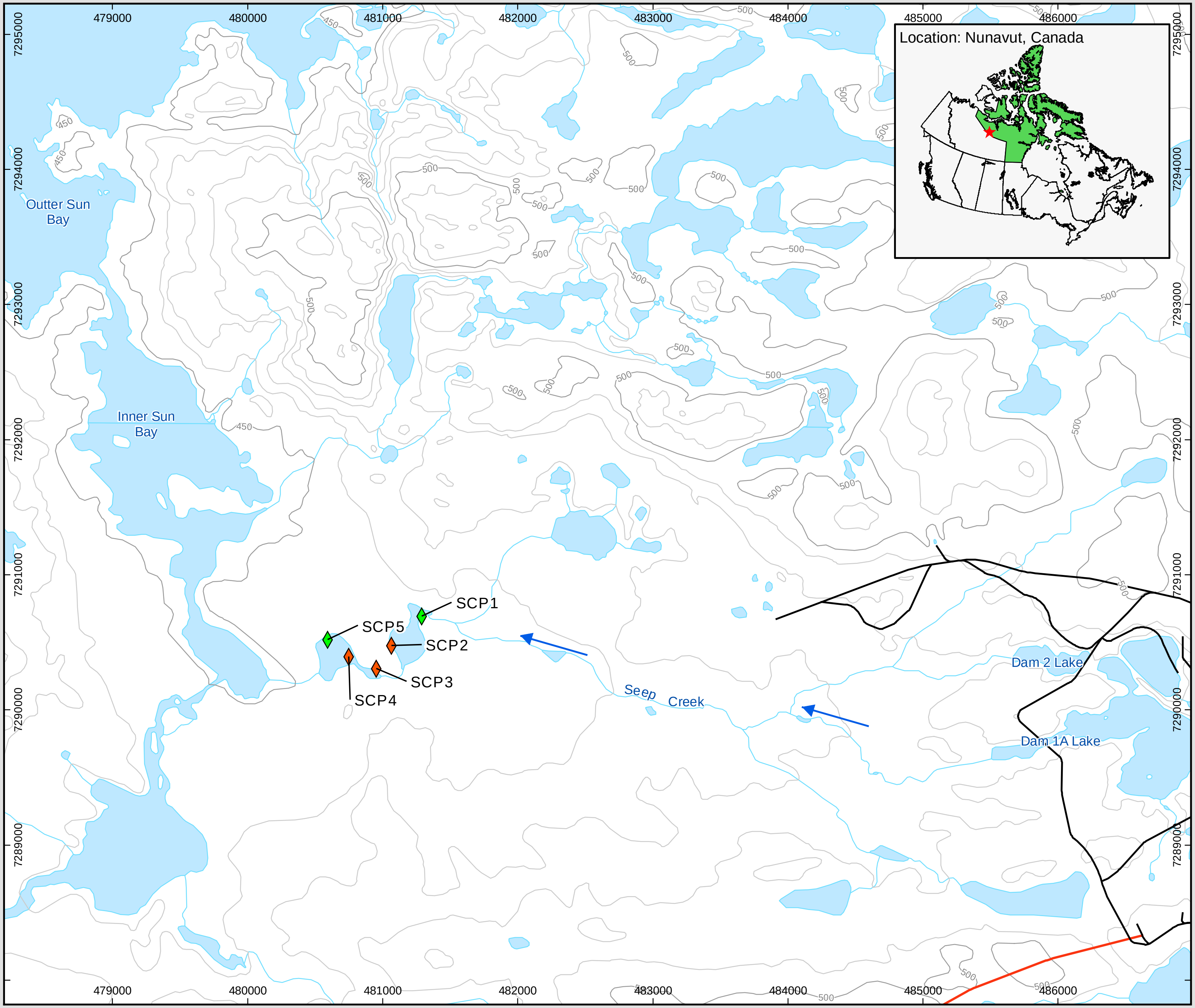
At each station, at least five replicate samples were collected and combined into a composite sample for the site. Dependant on the conditions and bottom composition (particularly cobble and rocky bottoms), some sites used more than five grabs to make up the composite sample. If a sub-sample was obtained that was intact and showed layering of sediments, a plastic spoon was used to remove the top 3 cm of the sub-sample to be used in the composite sample. All samples were collected using an Eckman grab. Supporting environmental data was taken at a few of the sites that were determined to be representative of the sample area.

Composite samples were drained of as much water as was possible, and stored in lab-provided plastic, sealable bags. After sampling was completed, a chain of custody form was filled out. In total, five composite samples were taken from the exposure area, five from reference area 1 and five from reference area 2, and were submitted for laboratory analysis. The samples were packed into coolers and shipped to ALS Laboratory in Yellowknife, NWT. Samples were analyzed for:

- Particle size
    - Course sand and gravel (> 2mm)
    - Sand (0.2 mm to 2.0 mm)
    - Silt (0.2 mm to 0.063 mm)
    - Clay (<0.004 mm)
- Total Organic Carbon
- Total metals

4.2.2.1 Statistical Analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL) was used to conduct statistical analysis at a confidence level of 95% ($\alpha = 0.05$). Data were tested for homogeneity of variance using Levene's test and normality using the Shapiro-Wilk test. Differences in sediment chemistry, total carbon, total organic carbon, inorganic carbon, and calcium carbonate were determined using a one-way ANOVA and Tukey's test (when appropriate). Non normal data sets were analysed using the non parametric Kruskal-Wallis and Tukey's test (where appropriate).



Legend

- Sediments
- Sediments, Field Chemistry
- Exisiting Road Alignment
- Proposed Road Alignment (Izok)
- Intermediat Contour (10m interval)
- Index Contour (50m interval)
- Watercourse
- Flow Direction
- Waterbody

Basemapping from National Topographic Database

N W E S

Kilometers

0 0.25 0.5 1 1.5

1:40,000

UTM Zone 12N, NAD 83

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Sediment Sampling Stations in Exposure Area

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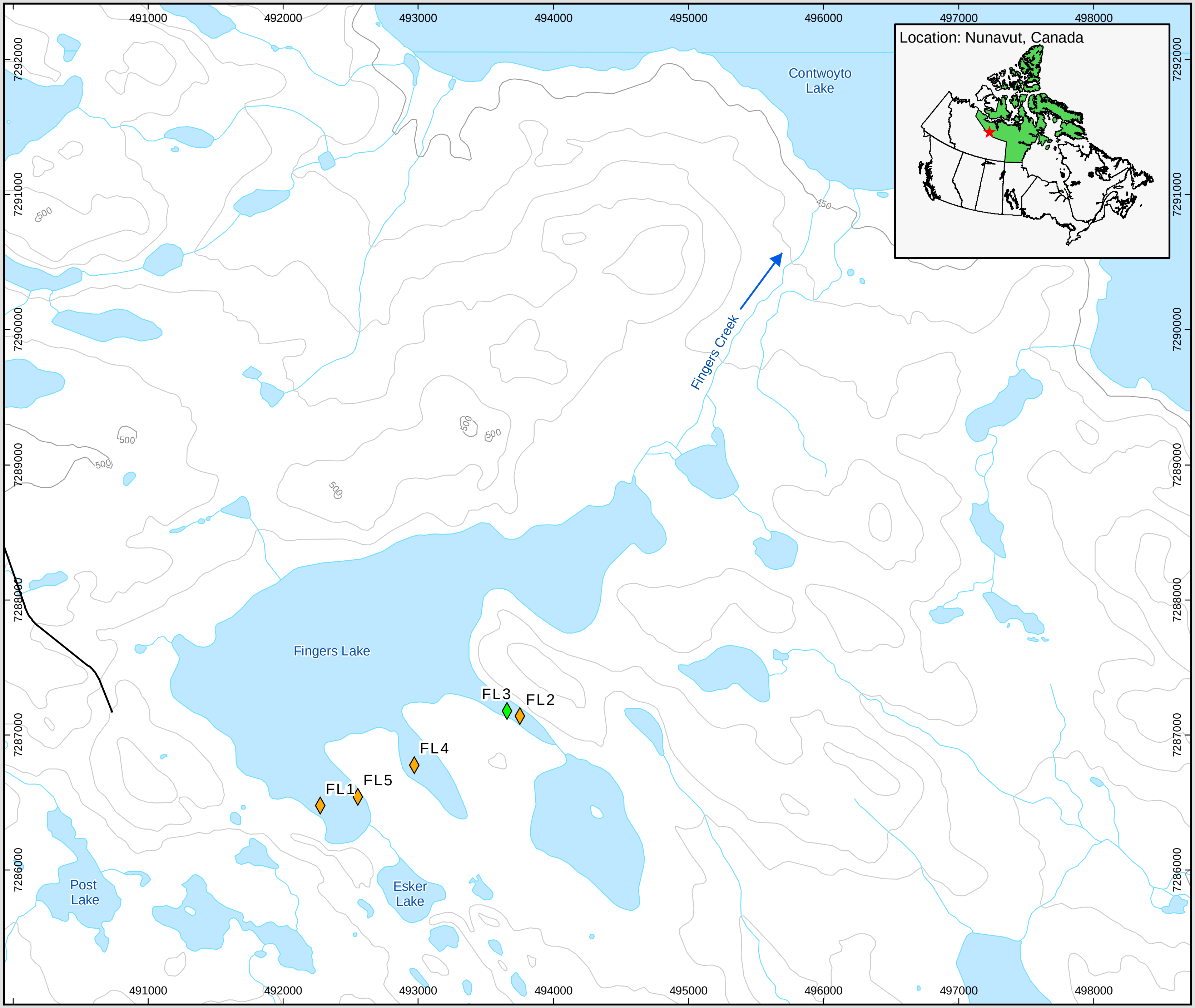
Figure 4-4

Map Document: 60147160_C1_Fig4-1_SedimentSampling_Exposure_15April2011.mxd



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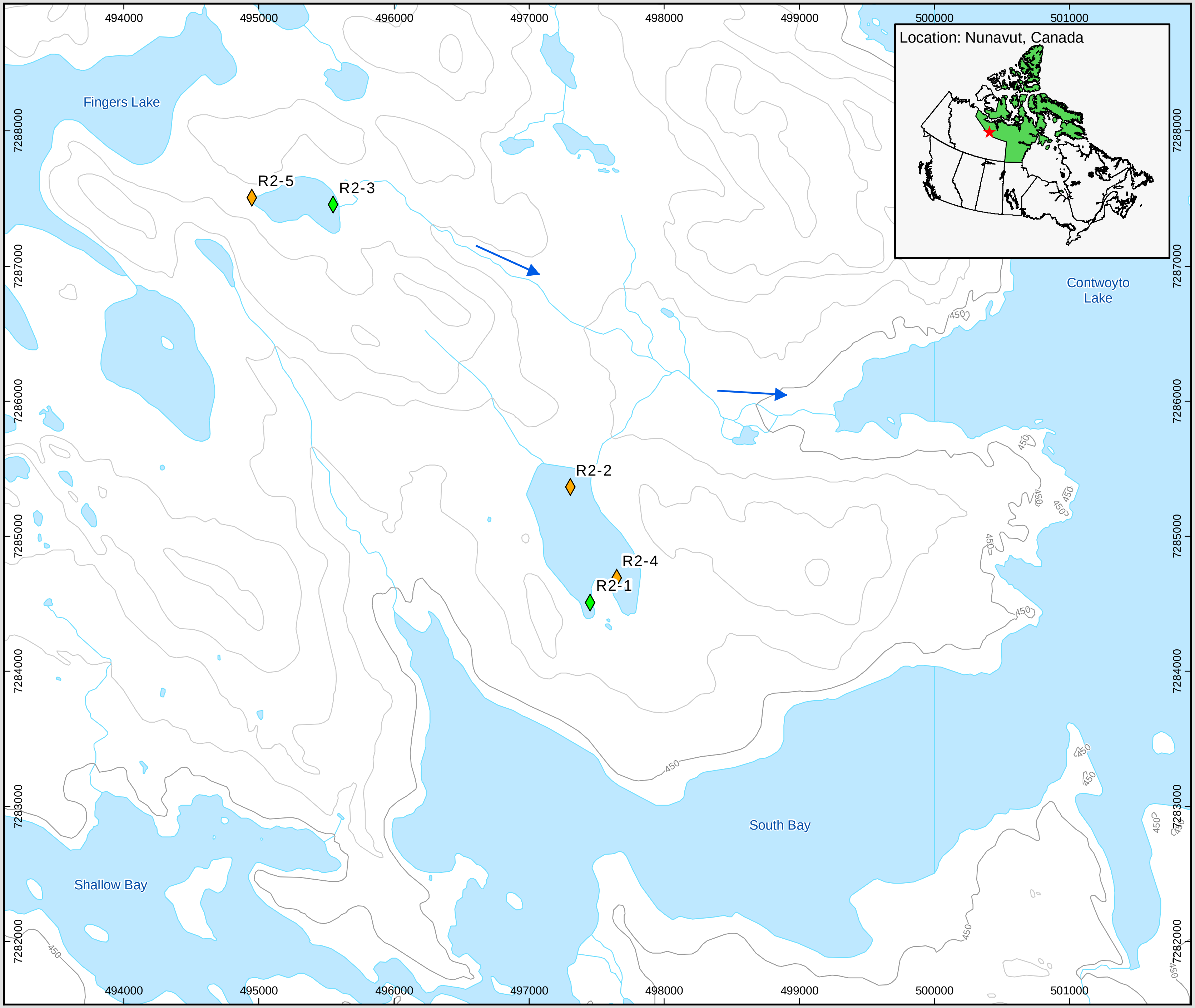
Sediment Sampling Stations in Reference Area 1

AECOM

Figure 4-5

Map Document: 60147160_C1_Fig4-2_FSedimentSampling_Reference1_15April2011.mxd



Legend

- Sediments
- Sediments, Field Chemistry
- Exisiting Road Alignment
- Proposed Road Alignment (Izok)
- Intermediat Contour (10m interval)
- Index Contour (50m interval)
- Watercourse
- Flow Direction
- Waterbody

Basemapping from National Topographic Database

N W E S

Kilometers

0 0.25 0.5 1 1.5

1:40,000

UTM Zone 12N, NAD 83

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Sediment Sampling Stations in Reference Area 2

AECOM

Figure 4-6

Map Document: 60147160_C1_Fig4-2_SedimentSampling_Reference2_15April2011.mxd

4.3 Fish Survey

4.3.1 Study Design

The purpose of the survey was to determine if differences in habitat may be causing differences in length and weight of fish in the reference areas as compared to the exposure area. A second reference area was added from the Cycle 2 sampling program based on the layout being similar to the exposure area. This similarity would allow for a more accurate compassion of the two areas, and to more accurately analyse the effects of the effluent on fish populations. The field program was completed between August 18th and 29th, 2011. Fish were collected from the Exposure Area (Seep Creek system), Reference Area 1 (Fingers Creek system) and Reference Area 2 (unnamed system to the southeast of the Fingers Creek system) in areas that were similar to the Cycle 1 and Cycle 2 studies. Based on the results of the Cycle 2 study and the recommendations of Environment Canada (EC), juvenile Arctic grayling were selected as the primary sentinel target species for a non-lethal sampling program.

The preliminary study design was to attempt to capture 100 Age-0+ Arctic grayling fish from each area. During the sampling program, fewer than 100 Arctic grayling per area were captured along with several hundred of other species. All fish that were captured were measured and weighted. Ten of the age-0+ Arctic grayling, and an additional 10 from other age classes from each area were sacrificed for aging structures. The carcasses of these fish were also submitted for metal analysis. The metals that were tested for include aluminum, arsenic, cobalt, copper, nickel and zinc. Fish survey sampling locations for the exposure and reference areas are listed in Appendix C, Table C-1, and are mapped in Figures 4-7, 4-8, and 4-9.

4.3.2 Field Methods

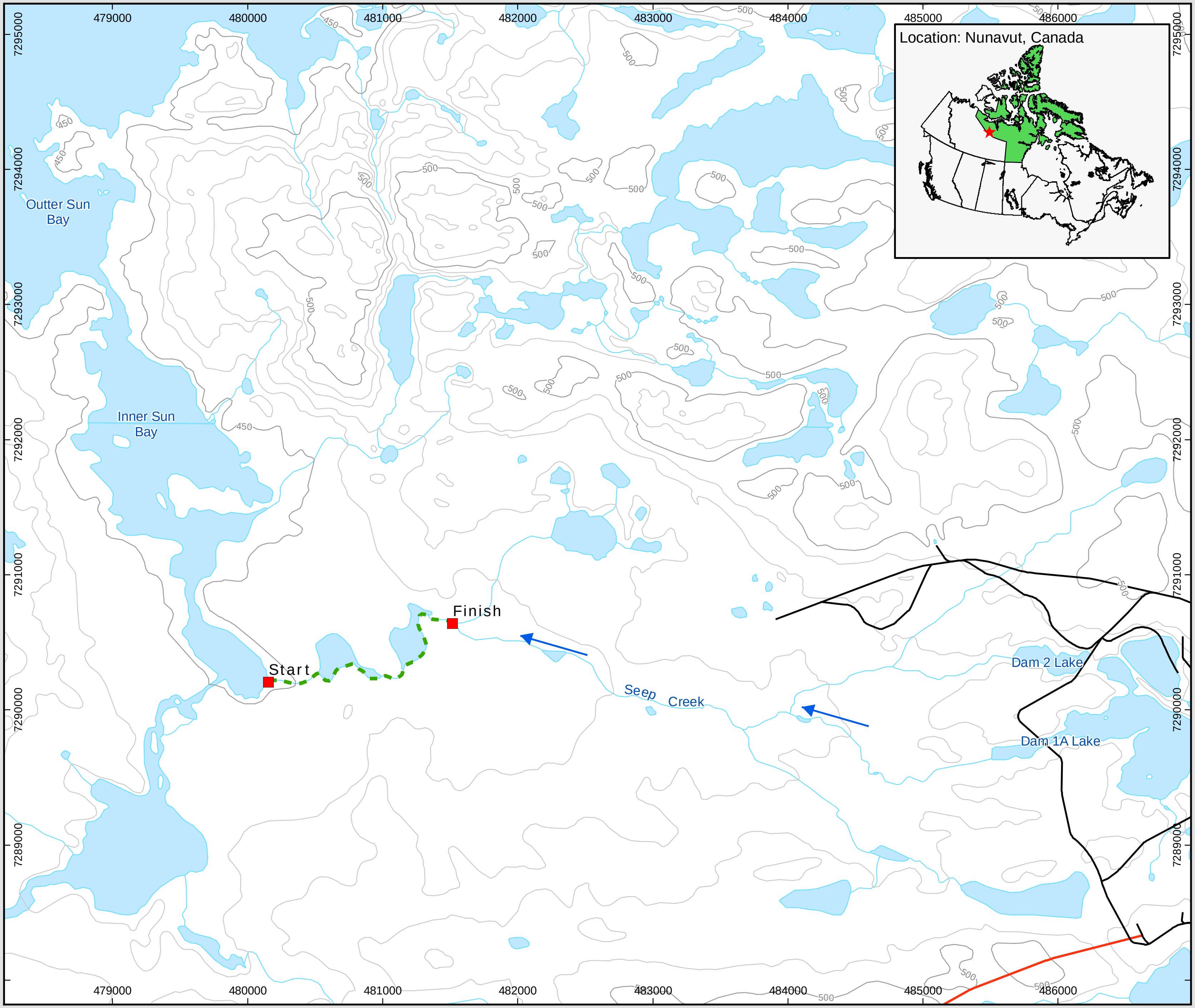
4.3.2.1 Fish Capture

Based on the lessons learned in Cycle 1 and Cycle 2, electrofishing with a Smith-Root LR-24 Backpack Electrofisher, was used as the only fishing method in the Cycle 3 field program as it was the most effective and efficient from previous years. Electrofishing was conducted around the edges of ponds and in the creeks of the exposure area and each of the reference areas, starting downstream and moving upstream. Start and end coordinates were recorded for each survey section along with the total effort in seconds, voltage, frequency and duty cycle settings.

All fish that were captured were weighed and measured, and released into similar waters that they were captured from. A habitat assessment with supporting environmental data was taken form each of the study areas. Data recorded included water depth, water velocity, water temperature and field water chemistry (pH, conductivity, dissolved oxygen and turbidity). All measurements were recorded on waterproof paper forms.

4.3.2.2 Field Laboratory Analyses

All fish that were captured were weighted and measured shortly after they were captured (Appendix C, Tables C-2, C-3 and C-4). Fish troughs were used for length measurements to within 1 mm. Fish weights were measured using an Ohaus Adventurer Pro AV-53 balance (accuracy 0.001 g). This scale only read up to 50 g, and so heavier body weights were measured with an Acculab VI-200 balance (accuracy 0.01 g). All measurements were recorded on waterproof, standardize data forms.



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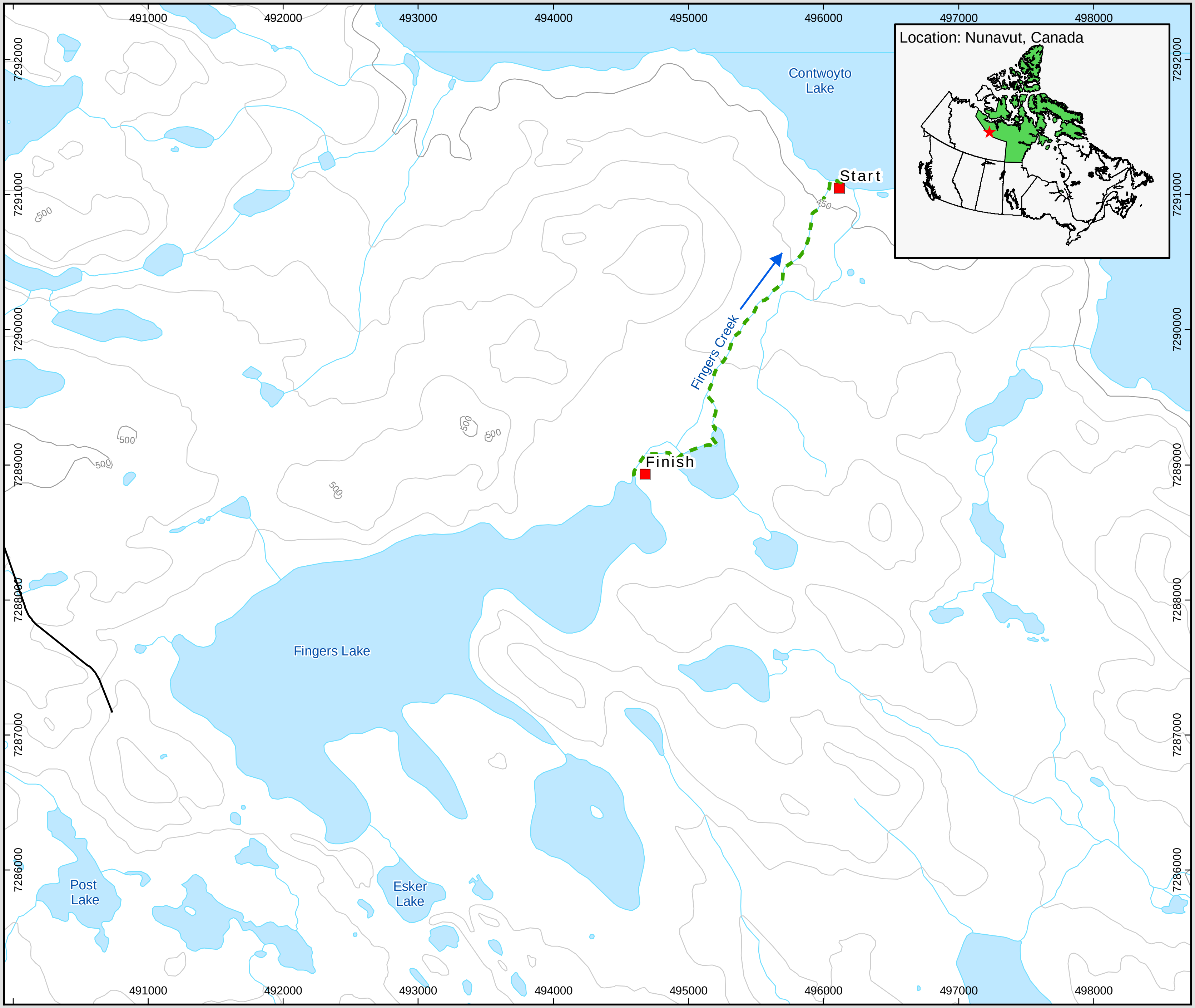
MMG
Lupin EEM

Fish Sampling Stations in Exposure Area

AECOM

Figure 4-7

Map Document: 60147160_C1_Fig5-1_FishSampling_Exposure_15April2011.mxd



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MMG

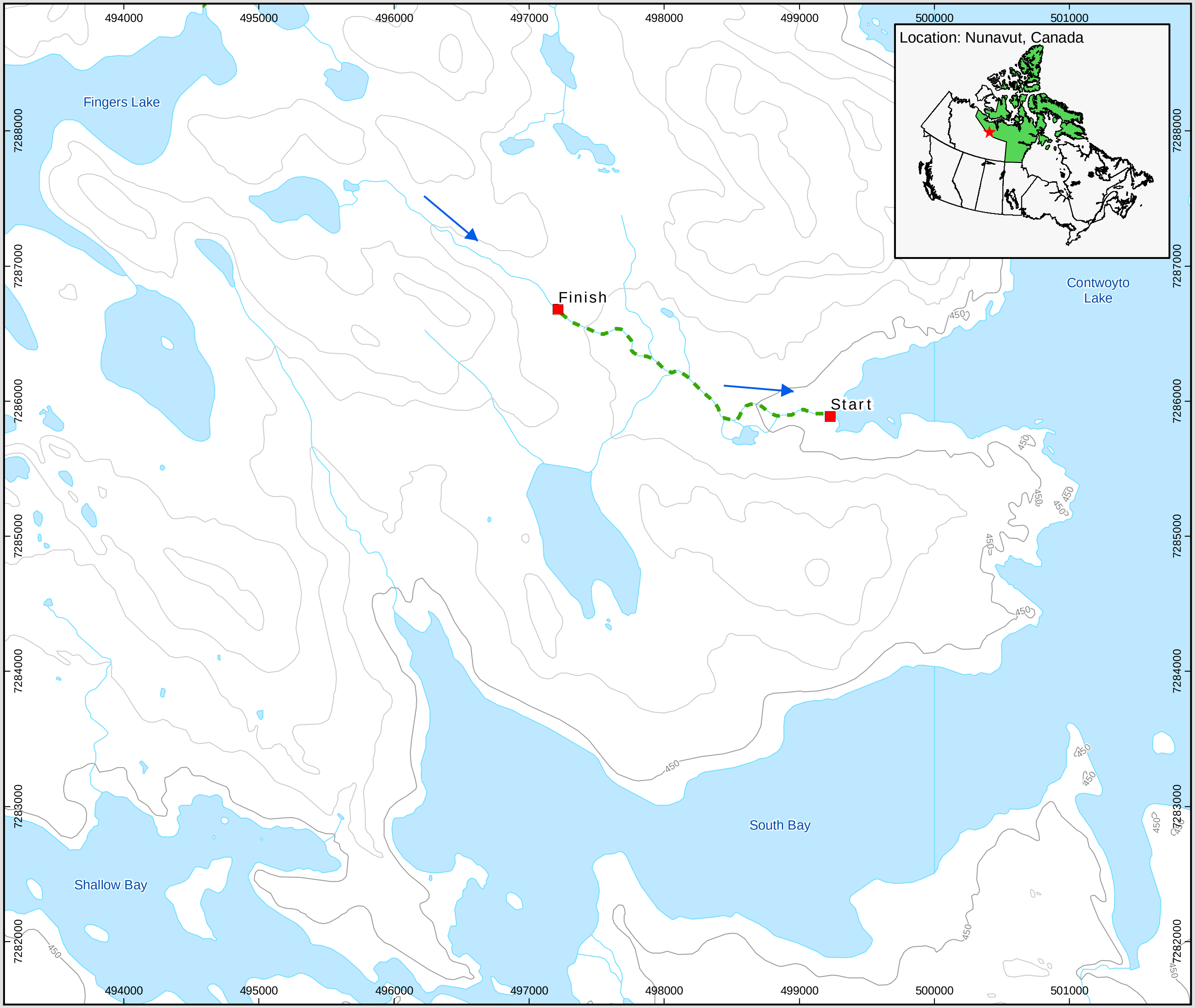
Lupin EEM

Fish Sampling Stations in Reference Area 1

AECOM

Figure 4-8

Map Document: 60147160_C1_Fig5-2_FishSampling_Reference1_15April2011.mxd



Legend
- Electrofishing Start/Finish
- Electrofishing
- Exisiting Road Alignment
- Proposed Road Alignment (Izok)
- Intermediat Contour (10m interval)
- Index Contour (50m interval)
- Watercourse
- Flow Direction
- Waterbody

Basemapping from
National Topographic Database

N
W E
S

Kilometers
0 0.25 0.5 1 1.5

1:40,000

UTM Zone 12N, NAD 83

MMG
Lupin EEM

Fish Sampling Stations in Reference Area 2

AECOM

Figure 4-9

Map Document: 60147160_C1_Fig5-3_FishSampling_Reference2_15April2011.mxd

The Arctic Grayling that were selected for the removal of aging structures were processed in the field after the rest of the fish had been released back into the watercourse. Attempts were made to place these fish far enough away that they were not likely to be recaptured. Aging structures (otoliths) were collected from the selected Arctic grayling and were placed into individually labelled and sealed envelopes. At the completion of the field program, they were sent to North Shore Environmental Ltd. in Thunder Bay, Ontario, for age determination (Appendix C Table C-5).

Those Arctic grayling that were selected for aging structures were also submitted for metals analysis. The heads were removed and the carcass kept frozen until the field program was completed. These carcasses were then organized into approximately 10 gram composite samples. A minimum of 10 grams of fish tissue was required by the lab for analysis of metal concentration in the tissue. Eleven composite samples were submitted for the exposure area, nine composite samples for Reference Area 1 and nine composite samples for Reference Area 2. A chain of custody form was filled out, and all fish tissue samples were submitted to ALS Laboratory Group in Edmonton, Alberta for metals analysis. The metals that were tested included aluminum, arsenic, cobalt, copper, nickel and zinc. These samples were prepared using EPA 200.3 method and the analysis was performed using EPA 6020 standards.

4.3.2.3 Statistical Analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL) was used to conduct statistical analysis at a confidence level of 95% ($\alpha = 0.05$). Data were tested for homogeneity of variance using Levene's test and normality using the Shapiro-Wilkes test. Differences in fish body weights were compared between reference and exposure areas using analysis of covariance (ANCOVA) using length as a covariate. Potential differences between metals accumulation by the different age groups in the Exposure Area and the Reference Areas were evaluated using a t-test. Significant differences in metals concentration in all age classes of arctic grayling tissue were determined using an analysis of variance (ANOVA) and Tukey's test (where appropriate). Non normal data sets were analysed using the non-parametric Kruskal-Wallis and Dunns test (where appropriate).

5. Effluent and Water Quality Results

The following section provides a brief description of the effluent and water quality monitoring programs initiated as a result of the MMER.

5.1 Effluent Characterization

Samples for effluent characterization have been collected in the TCA at station SNP 925-10. Effluent was released from the TCA at various periods from 1994 to 2010 (Table 5-1). Effluent was not released during the 2010 field program.

Table 5-1: Total Annual Discharge Volumes from Lupin Mine TCA (SNP 925-10) 1994 to 2010

Year	Annual Total (m^3)	Discharge Period
1994	863,868	July 15 - 29
1995	938,715	July 15 – August 2
1996	1,139,233	July 15 – August 7
1997	2,892,289	July 15 – September 1
1998	0	n/a
1999	0	n/a
2000	2,701,360	July 15 – September 2
2001	0	n/a
2002	3,102,895	July 15 – September 7
2003	0	n/a
2004	0	n/a
2005	1,682,135	July 15 – August 11
2006	0	n/a
2007	0	n/a
2008	0	n/a
2009	2,897,461	July 25th – Oct 7th
2010	0	n/a

Samples for effluent characterization were collected in 2000, 2002 and 2005 and constituents listed in Schedule 4 of MMER were analyzed. Up to 2005, none of the constituents exceeded the authorized limits. Samples for effluent characterization were not collected in 2010, as there was no effluent discharge (Table 3-1).

5.2 Water Quality

Water quality samples were collected in the exposure and reference areas as part of the Cycle 1 (2005) and Cycle 2 (2008) programs and again in the Cycle 3 field program (Figures 4-1, 4-2 and 4-3). Results from the Cycle 3 program are presented below. The Cycle 3 field program was completed between August 18 and 29, 2010. Water temperature loggers were installed on July 7, 2010, but no field data other than field measurements at the logger sites were collected at that time.

Sampling locations, sampling dates and field chemistry are in provided in Appendix A, Tables A-1 and A-2. Water temperature, pH, conductivity and DO were measured at every station when water quality samples were collected (Appendix A, Table A-2). Grab water samples for laboratory analyses were collected from three locations in the Exposure Area (SCD1, SCP1, SNP925) (Table 4-2; Figure 4-1), from three locations in Reference Area 1 (FC2, FL3, FL5) (Figure 4-2) and from these locations in Reference Area 2 (R2-1, R2-2, R2-3) (Figure 4-3). The intent of collecting these samples was to characterize water quality in each of the three areas. It was decided to have samples analyzed separately rather than as a composite sample to represent the study areas. Complete lab water quality data and detection limits are in provided Appendix A, Tables A-3 and A-4.

Results were compared to the Canadian water quality guidelines for protection of freshwater life (CCME 2007). None of the results from the reference area samples exceeded the CCME guidelines. For the exposure area samples (SCP1, SCP1-rep, SNP925-20 and SCD1), all exceeded the guidelines for copper, iron and nickel while only sample SCD1 exceeded the guideline for zinc. All samples had undetectable concentrations of TSS, alkalinity, carbonate, hydroxide, nitrite and cyanide. Many samples had undetectable concentrations of bicarbonate, chloride, fluoride, ammonia, nitrate and total phosphorus. In addition, concentrations of TOC and DOC were very low in all samples.

Total and dissolved metals were analyzed to low-level detection limits in samples SCP1 and SCP1-rep and were analyzed to ultra-low level detection limits in all other samples.

5.2.1 Discussion and Comparison to Cycles 1 and 2

The Seep Creek drainage system is the direct receiving environment of Lupin mine effluent. The ponds and channels that make up the exposure area are shallow. The Fingers Creek drainage system was selected as an appropriate reference monitoring area for Cycles 1, 2 and 3 and was designated as Reference Area 1 in Cycle 3. The ponds and creeks that make up this system are slightly deeper than the exposure area. This was observed in Cycle 1 and Cycle 2. Based on the data collected in Cycle 3, average depth in the creeks of the exposure area are very similar to depth in the creek of reference area 1. For Cycle 3, a second reference area was added and was designated as Reference Area 2.

Conductivity was variable but high in the exposure area but very low in both reference areas (Table 5-2 and 5-3). Conductivity was highest in Dam 1A Lake (SCD1) and decreased through Seep Creek and into Seep Creek Ponds. In 2010, conductivity was higher in SCD1 as compared to previous years but was generally lower in Seep Creek Pond in 2010 as compared to previous years. Water hardness followed a similar pattern. Nitrogen was lower in SCD1 in 2010 but higher in Pond 1 as compared to previous years. TP and TOC concentrations have been similar in all 3 monitoring cycles.

In the exposure area samples, the only metals that exceeded the guidelines were cadmium, copper, iron, nickel and zinc (Table 5-2). All other metals were less than the guidelines. Cadmium, copper and nickel have exceeded the guidelines in all samples from all three cycles. Zinc concentration in SCD1 from Cycle 3 was still above the guideline. In SCD1, aluminum, cadmium, copper, lead, nickel and zinc have decreased from Cycle 1 through Cycle 3, while arsenic remained about the same, even increased slightly. In SCP1, aluminum, cadmium, nickel and zinc decreased from Cycle 1 through Cycle 3, while arsenic, copper and lead remained about the same.

Conductivity, hardness, pH, ammonia and phosphorus concentrations were similar across all reference area samples. Conductivity and hardness were lower in the reference areas as compared to the exposure area. Nutrients were generally lower in the reference area samples than in the exposure area samples. Finally, none of the metals from the reference area samples exceeded the guidelines.

Notable increases between 2008 and 2010 at SCD1 and SCP1 occurred for pH (SCD1 and SCP1), TOC (SCD1 and SCP1), conductivity (SCD1 only), nitrate (SPC1 only), and total arsenic (SCD1 and SCP1). Conversely, notable decreases were observed for conductivity and hardness (SCP1 only); ammonia, nitrate and total lead (SCD1 only), and total aluminum, total cadmium, total copper, total nickel, and total zinc (SCD1 and SCP1).

Table 5-2: Summary of Water Quality Results from Cycle 3 Compared to Cycle 1 and 2 for the Exposure Area

			Lupin Mine Tailings Containment Area (Dam 1A Lake Area)				Seep Creek				
Parameter	**Units**	**CCME Aquatic Life**	**Dam 1A (2005)**	**SCD1 (2008)**	**SCD1 (2010)**	**% Change (SCD1)**	**SCP1 (2008)**	**SCP1 (2010)**	**% Change (SPC1)**	**Seep Creek Ponds 1&2(2005)**	**SCP5 (2008)**
Physical Tests											
pH	pH unit	6.5-9.0	*5.8*	*4.9*	6.89	+16.9%	*5.5*	6.7	+9.8%	*6.1*	*5.6*
Conductivity	µS/cm		738	175	217	+10.7%	76.8	71.6	-3.5%	141	65.4
Hardness	mg/L		186	63	68.3	+4.0%	29	24.2	-9.0%	37	24
Alkalinity	mg/L		<5	<5	<5	--	<5	<5	--	<5	<5
Nutrients											
Ammonia	mg/L	0.019	0.51	0.014	0.0086	-23.9%	<0.005	0.0101	--	<0.05	<0.005
Nitrate	mg/L	13	5.7	0.15	0.0125	-84.6%	0.016	0.0647	+60.3%	0.4	<0.006
TP	mg/L		<0.02	0.005	0.0036	-16.3%	0.004	0.0036	-5.3%	<0.02	0.004
TOC	mg/L		2	4	5.2	+13.0%	4	6.6	+24.5%	6	6
Total Metals											
Aluminum	mg/L	0.1	**0.11**	**0.461**	**0.031**	-87.4%	**0.151**	0.074	-34.2%	0.0724	**0.151**
Arsenic	mg/L	0.005	**0.0068**	0.00377	**0.00816**	+36.8%	0.00165	0.00406	+42.2%	0.00293	0.00194
Cadmium	mg/L	0.000017	**0.000411**	**0.000336**	**0.000065**	-67.6%	0.000082	0.000023	-56.2%	0.0000913	0.000066
Copper	mg/L	0.002-0.004	**0.0131**	**0.0197**	**0.00597**	-53.5%	0.0037	0.0035	-2.8%	**0.00653**	0.0038
Lead	mg/L	0.001	**0.00115**	0.00013	0.000062	-35.4%	<0.00005	<0.0001	--	**0.00139**	<0.00005
Nickel	mg/L	0.025	**0.133**	**0.17**	**0.0354**	-65.5%	**0.0537**	0.0255	-35.6%	**0.0284**	**0.0433**
Zinc	mg/L	0.03	**0.314**	**0.19**	**0.0507**	-57.9%	**0.0455**	0.013	-55.6%	**0.0404**	**0.0405**

Note: Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. Concentrations that exceed the guidelines are in bold.

Overall, all of the water quality parameters from 2008, and 2010 from both Reference Area 1 (Fingers Creek and Fingers Lake) and Reference Area 2 were below the CCME water quality guidelines for the protection of aquatic life (Table 5-3). Likewise, all of the water quality parameters collected in 2005, except for pH from Fingers Creek, were below the CCME guidelines. The percentage changes between samples collected in 2008 and 2010 at FL5 and FC2 indicate considerable natural variability in physical parameters, nutrients and total metals concentrations. Most notably, a small increase in arsenic concentration identified at both FL5 and FC2.

Table 5-3: Summary of Water Quality Results from Cycle 3 Compared to Cycle 1 and 2 for the Reference Areas

			Fingers Lake – Reference Area 1					**Fingers Creek – Reference Area 1**				**Reference Area 2**
Parameter	**Units**	**CCME Aquatic Life**	**Fingers Lake (2005)**	**FL1 (2008)**	**FL5 (2008)**	**FL5 (2010)**	**% Change (FL5)**	**Fingers Creek (2005)**	**FC2 (2008)**	**FC2 (2010)**	**% Change (FC2)**	**Reference Area 2 -Av (2010)**
Physical Tests												
pH	pH unit	6.5-9.0	6.5	6.6	6.6	6.75	+1.1%	**6.3**	6.6	6.92	+2.4%	6.62
Conductivity	uS/cm		14.8	12.2	13.1	11.7	-5.6%	15.3	13.2	3.2	-61.0%	12.2
Hardness	mg/L		5	4	5	4	-11.1%	7	7	5.8	-9.4%	4.27
Alkalinity	mg/L		<5	<5	<5	<5	--	<5	<5	<5	--	<5
Nutrients												
Ammonia	mg/L	0.019	<0.05	<0.005	<0.005	<0.005	--	<0.05	<0.005	<0.005	--	0.006
Nitrate	mg/L	13	0.1	<0.006	0.007	<0.006	--	0.1	<0.006	<0.006	--	<0.006
TP	mg/L		0.02	0.008	0.008	0.0185	+39.6%	<0.02	0.005	0.0016	-51.5%	0.0177
TOC	mg/L		3	3	3	3.2	+3.2%	3	3	3.4	+6.3%	4.2
Total Metals												
Aluminum	mg/L	0.1	0.0164	0.0162	0.0158	0.0374	+40.6%	0.0103	0.0192	0.0171	-5.8%	0.0198
Arsenic	mg/L	0.005	0.00207	0.00133	0.00143	0.00167	+7.7%	0.00121	0.00121	0.00175	+18.2%	0.000700
Cadmium	mg/L	0.000017	0.0000089	<0.000017	<0.000017	<0.00005	--	<0.000002	<0.000017	<0.00005	--	<0.00005
Copper	mg/L	0.002-	0.000562	<0.0006	<0.0006	<0.0006	--	0.00039	<0.0006	<0.0006	--	0.0016
Lead	mg/L	0.001	0.000279	<0.00005	<0.00005	<0.00005	--	0.000013	<0.00005	<0.00005	--	0.000063
Nickel	mg/L	0.025	0.000394	0.00044	0.00059	0.000526	-5.7%	0.000339	0.00065	0.00065	+0.0%	0.00364
Zinc	mg/L	0.03	0.00216	<0.0008	<0.0008	<0.0008	--	0.00167	<0.0008	<0.0008	--	0.0095

Note: Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. Concentrations that exceed the guidelines are in bold.

Water Quality Highlights:

- Metals concentrations in water samples collected from both of the reference areas in 2008, and 2010 were below the CCME water quality guidelines for the protection of aquatic life.
- The percentage changes between samples collected in 2008 and 2010 at FL5 and FC2 indicate considerable natural variability in physical parameters, nutrients and total metals concentrations. Most notably, a small increase in arsenic concentration identified at both FL5 and FC2.
- Notable increases in water quality parameters and metals concentrations in the Exposure Area between 2008 and 2010 occurred for pH (SCD1 and SCP1), TOC (SCD1 and SCP1), conductivity (SCD1 only), nitrate (SPC1 only), and total arsenic (SCD1 and SCP1). Conversely, notable decreases were observed for conductivity and hardness (SCP1 only); ammonia, nitrate and total lead (SCD1 only), and total aluminum, total cadmium, total copper, total nickel, and total zinc (SCD1 and SCP1).

6. Sediment Results

Samples for sediment quality along with physical measurements of the habitat were collected from the five locations chosen during Cycle 2. Analytical results are in Appendix B, Table B-1.

6.1 Statistical Analysis

Summary statistics were run for all of the parameters that were tested for in the sediment samples. The results of the statistical analysis are shown in Table 6-2.

6.2 Sediment Quality

Sediment sample texture was predominantly sandy in both of the reference areas and more silty sand in the Exposure Area. There was a significantly greater proportion of clay in the exposure area samples than in the reference area samples, although the relative percent composition of clay particles in each area was less than 5% of the entire sample. No other statistical differences were identified (Table 6-1).

Table 6-1: Summary of Sediment Textural Characteristics

Parameter	Units	Exposure Area Mean	Reference Area 1 Mean	Reference Area 2 Mean	p-value
Sand	%	53.8	80.0	79.4	*n.s.*
Silt	%	42.0	17.6	18.6	*n.s.*
Clay	%	4.2*	2.4	2.5	**0.04**
Fragments > 2mm	%	2.30	1.33	1.73	*n.s.*

Statistically significant comparisons ($p<0.05$) are in bold font.

Sediment concentration of arsenic, cobalt, copper, molybdenum, nickel, strontium and zinc were significantly higher in the exposure area in comparison with the reference areas. Many of the other metal parameters did not differ significantly between the areas but concentrations were higher in the exposure area as compared to the reference areas. Similarly many of the sediment concentrations did not differ between the two reference areas; however, Reference Area 2 generally had higher concentrations of metals/metalloids.

Table 6-2: Summary of Statistical Analysis on Sediment Quality Results from Cycle 3

		Exposure		Reference Area 1		Reference Area 2		ANOVA Results			
Parameters	Units (dw)	# Samples	Mean	# Samples	Mean	# Samples	Mean	Significant Difference Detected	Normality	Test Conducted	(p-value)
$CaCO_3$ Equivalent	%	5	0.80	5	0.80	5	0.94	No	Failed	Kruskal-Wallis	0.37
Inorganic Carbon	%	5	0.10	5	0.10	5	0.11	No	Failed	Kruskal-Wallis	0.37
Total Carbon by Combustion	%	5	2.32	5	1.34	5	1.76	No	Failed	Kruskal-Wallis	0.16
Total Organic Carbon	%	5	2.30	5	1.33	5	1.73	No	Failed	Kruskal-Wallis	0.18
Aluminum (Al)	mg/kg	5	8930	5	4820	5	6010	No	Failed	Kruskal-Wallis	0.09
Antimony (Sb)	mg/kg	5	0.20	5	0.20	5	0.20	No	Failed	Kruskal-Wallis	1.00
Arsenic (As)	**mg/kg**	**5**	**92.7**	**5**	**12.0**	**5**	**7.60**	**Yes**	**Passed**	**ANOVA and Tukeys Test**	**0.01**
Barium (Ba)	mg/kg	5	51.4	5	34.9	5	40.1	No	Passed	P - ANOVA	0.18
Beryllium (Be)	mg/kg	5	1.00	5	1.00	5	1.00	No	Failed	Kruskal-Wallis	1.00
Cadmium (Cd)	mg/kg	5	0.50	5	0.50	5	0.50	No	Failed	Kruskal-Wallis	1.00
Chromium (Cr)	mg/kg	5	43.8	5	19.2	5	29.5	No	Passed	P- ANOVA	0.11
Cobalt (Co)	**mg/kg**	**5**	**49.8**	**5**	**5.88**	**5**	**6.92**	**Yes**	**Failed**	**Kruskal-Wallis and Tukeys Test**	**0.01**
Copper (Cu)	**mg/kg**	**5**	**33.3**	**5**	**11.4**	**5**	**16.5**	**Yes**	**Failed**	**Kruskal-Wallis and Tukeys Test**	**0.04**
Iron (Fe)	mg/kg	5	18100	5	8370	5	11200	No	Failed	Kruskal-Wallis	0.06
Lead (Pb)	mg/kg	5	5.00	5	5.00	5	5.00	No	Failed	Kruskal-Wallis	1.00
Mercury (Hg)	mg/kg	5	0.05	5	0.05	5	0.05	No	Failed	Kruskal-Wallis	1.00
Molybdenum (Mo)	**mg/kg**	**5**	**1.74**	**5**	**1.00**	**5**	**1.14**	**Yes**	**Failed**	**Kruskal-Wallis and Tukeys Test**	**0.03**
Nickel (Ni)	**mg/kg**	**5**	**67.7**	**5**	**14.96**	**5**	**29.3**	**Yes**	**Passed**	**ANOVA and Tukeys Test**	**0.01**
Selenium (Se)	mg/kg	5	0.50	5	0.50	5	0.50	No	Failed	Kruskal-Wallis	1.00
Silver (Ag)	mg/kg	5	1.00	5	1.00	5	1.00	No	Failed	Kruskal-Wallis	1.00
Strontium (Sr)	**mg/kg**	**5**	**10.2**	**5**	**4.92**	**5**	**5.72**	**Yes**	**Passed**	**ANOVA and Tukeys Test**	**0.03**
Thallium (Tl)	mg/kg	5	0.50	5	0.50	5	0.50	No	Failed	Kruskal-Wallis	1.00
Tin (Sn)	mg/kg	5	5.00	5	5.00	5	5.00	No	Failed	Kruskal-Wallis	1.00
Uranium (U)	mg/kg	5	2.00	5	2.00	5	2.00	No	Failed	Kruskal-Wallis	1.00
Vanadium (V)	mg/kg	5	27.0	5	16.6	5	18.80	No	Failed	Kruskal-Wallis	0.08
Zinc (Zn)	**mg/kg**	**5**	**85.4**	**5**	**24.8**	**5**	**37.2**	**Yes**	**Passed**	**ANOVA and Tukeys Test**	**<0.001**

Statistically significant comparisons (p<0.05) in bold font.

Sediment Quality Highlights:

- Reference Area 1 and 2 sediment predominantly sandy and was more silty with significantly more clay in the Exposure Area.
- Sediment concentration of arsenic, cobalt, copper, molybdenum, nickel, strontium and zinc were significantly higher in the exposure area in comparison with the reference areas.
- Many of the other metal parameters did not differ significantly between the areas but concentrations were higher in the exposure area as compared to the reference areas.
- The majority of the sediment concentrations did not differ between the two reference areas; however, Reference Area 2 generally had higher concentrations of metals/metalloids.

7. Fish Survey

7.1 Fish Habitat Characteristics

The fish habitats found in the study area include permanent and intermittent streams which connected larger bodies of water ranging in size from medium-sized lakes over 2 m deep (Fingers Lake), small shallow ponds less than 1 m deep (Seep Creek Ponds) to a very large lake (Contwoyto Lake). The Exposure Area consisted of Seep Creek and its tributaries, which originated in Dam 1A Lake immediately below the tailings pond discharge area and terminated at Inner Sun Bay. The drainage consisted of a number of shallow lakes and ponds that drain into Seep Creek.

A habitat assessment was completed on August 27, 2010 along a 1 km section of Seep Creek in an area that was determined by the field crew to be representative of the watercourse as a whole. Depth, width and velocity measurements were taken every 200 m, and water chemistry measurements were taken at the end of the 1 km section. Seep Creek flows in an irregular pattern, is routinely confined, and contains infrequent side bars and islands. The average channel width was observed to be 5.0 m (range of 2.49 m to 10.4 m) and the average wetted width was 4.7 m (range of 2.49 m to 8.86 m). The average water depth was 0.4 m (range 0.26 to 0.58 m) and the average velocity was 2.9 m/s (range 1.45 m/s to 6.07 m/s). The calculated average flow velocity for the Exposure Area was approximately 3 m^3/s, assuming a rectangular channel cross-section. There was a single velocity measurement of 0.05 m/s taken at a depth of 0.08 m. This measurement was left out of the average velocity calculation. One residual pool was measured as having a depth of 0.42 m. The dominant substrate material present was boulders and the subdominant substrate was cobbles. The banks were composed of fine sediments and gravels and were vertical and sloped in shape. Instream cover was provided by abundant boulders, trace undercut banks, trace deep pools and moderate amounts of instream, submerged vascular vegetation. Habitat consisted of riffles, class 3 runs (<0.5 m in depth) and class 3 flats (<0.5 m in depth). Several water chemistry measurements were taken, including; dissolved oxygen (11.4 mg/L), conductivity (59 µs/cm), pH (8.95), temperature (7.5^o C) and turbidity (2.13 NTU).

Reference Area 1 consists of Fingers Lake which drains by the way of Fingers Creek into Contwoyto Lake. Two shallow ponds also empty into Fingers Creek via three intermittent creeks, along with significant amounts of overland flow. A habitat assessment was completed on August 20, 2010 along a 1.4 km section of Fingers Creek in an area that was determined by the field crew to be representative of the watercourse as a whole. Depth, width and velocity measurements were taken every 200 m, and water chemistry measurements were taken at the end of the 1.4 km section. Fingers Creek was observed to flow in an irregular pattern, was occasionally confined, and contained occasional islands. The average channel and wetted widths were both 1.6 m (range 0.50 m to 2.44 m). The average water depth was 0.3 m (range 0.23 to 0.42 m) and the average velocity was 1.5 m/s (range 0.50 m/s to 3.60 m/s). The average flow velocity was estimated to be approximately 0.7 m^3/s, which is more than three-fold less than estimated for the Exposure Area. There was a single velocity measurement of 0.00 m/s taken at a depth of 0.23 m. This measurement was left out of the average velocity calculation as the meter was malfunctioning when it was taken. Several residual pool depths were taken, with an average depth of 0.5 m (range 0.44 m to 0.59 m). The dominant substrate material present was boulders and the subdominant substrates were cobbles and fine sediments. The banks were composed of fine sediments and organics and were vertical and sloped in shape. Instream cover was provided by abundant boulders, trace undercut banks, trace deep pools and moderate amounts of instream, submerged vascular vegetation, algae and mosses. Habitat consisted of riffles, class 3 runs (<0.5 m in depth) and class 3 flats (<0.5 m in depth). Several water chemistry measurements were taken, including; conductivity (6 µs/cm), pH (7.5) and temperature (5.8^{o}C).

Reference Area 2 consists of an unnamed creek that originates in a small pond in to the south of Fingers Lake, and flows into Contwoyto Lake. The drainage was selected based on the lack of ponds found along the length of the creek. A habitat assessment was done on August 22, 2010 along a 1 km section of the unnamed creek in an area that was determined by the field crew to be representative of the watercourse as a whole. Depth, width and velocity measurements were taken every 200 m, and water chemistry measurements were taken at the end of the 1 km section. The unnamed creek was observed to flow in an irregular pattern, was occasionally confined, and contained occasional islands. There were also several flooded sections. The average channel and wetted widths were both 1.7 m (range 1.30 m to 1.93 m). The average water depth was 0.3 m (range 0.21 to 0.45 m) and the average velocity was 2.9 m/s (range 1.00 m/s to 6.32 m/s). Several residual pool depths were taken, with an average depth of 0.8 m (range 0.55 m to 1.15 m). The dominant substrate material present was fine sediments and the subdominant substrate was boulders. The banks were composed of fine sediments and were vertical in shape. Instream cover was provided by abundant instream, submerged vascular vegetation, trace deep pools and moderate amounts of boulders. Habitat consisted of riffles, class 3 runs (<0.5 m in depth), class 3 pools (<0.5 m in depth) and class 2 pools (0.5 m to 1.0 m in depth). Several water chemistry measurements were taken, including; dissolved oxygen (10.2 mg/L), conductivity (10 µs/cm), pH (7.2), temperature (8.3̊C) and turbidity (1.03 NTU).

Based on the habitat assessments, all three of the areas would have good quality rearing habitat, due to sufficient cover, water depth and water flow. The Exposure Area and Reference Area 1 would have good spawning habitat, due to the presence of appropriate substrates of boulders, cobbles and gravel. Reference Area 2 would have poor to moderate spawning habitat, due to the dominant substrate being fine sediments. Reference Area 1 and two would be moderate to good overwintering habitat, due to the presence of deep pools. Although the exposure area had occasional deep pools, it would only be classified as poor to moderate overwintering habitat. A summary of these findings can be found in Appendix C, Table C-6.

7.2 Fish Capture Data

Sampling of the creeks and ponds was conducted by backpack electrofishing. In total, 308 fish representing three species were captured in the Exposure Area (Appendix C Table C-2), 161 fish representing six species were captured in Reference Area 1 (Appendix C Table C-3) and 301 fish representing seven species were captured in Reference Area 2 (Appendix C Table C-4). Table 7-1 shows that the same amount of effort was needed to catch fish in the Exposure Area and Reference Area 2. It also indicates that it was much more difficult to catch fish in Reference Area 1.

Capture results for the sentinel target species indicate that 30 Arctic grayling were captured in the Exposure Area, 25 were caught in Reference Area 1 and 33 were captured in Reference Area 2. Approximately the same amount of effort was used in the Exposure Area and Reference Area 2 (10,328 seconds and 10,373 seconds, respectively) and approximately 50% more effort was needed in Reference Area 1 (15,968 seconds). The raw data are includes in Appendix C, Table C-1. Age distribution based on otolith aging and size class distribution data is discussed in Section 7.1.4.1.

Table 7-1: 2010 Lupin EEM Fish Catch Summary and CPUE

Fish Species	Exposure Area	Reference Area 1	Reference Area 2
Ninespine Stickleback (NSSB)	193	16	158
Arctic Grayling (ARGR)	28	25	33
Burbot (BURB)	2	30	4
Slimy Sculpin (SLSC)	0	73	66
Round Whitefish (RNWH)	0	2	7
Lake Trout (LKTR)	0	15	22
Arctic Char (ARCH)	0	0	11
Total	223	161	301
Effort (hours)	2:52:20	4:25:45	2:52:45
CPUE (fish/hour)	**78**	**36**	**104**

7.3 Supporting Environmental Variables

The supporting environmental variables collected from the Exposure Area and the two reference areas included seven weeks of stream temperature data (July-August, 2010), morphometric indicators of fish condition, and metals concentrations in Arctic grayling tissue. Based on capture results, fish tissue samples were analysed for ages 0+, 1+, and 2+ in the Exposure Area (n=3, 6, and 1, respectively), ages 0+ and 1+ in Reference Area 1 (n=2 and 5 respectively), and just the 2+ age class in Reference Area 2 (n=9). Analytical results for metals concentration in fish tissue samples taken from Arctic grayling are provided in Appendix C, Tables C-7.

We evaluated evidence of potential differences between metals accumulation by the different age groups in the Exposure Area and the reference areas using a t-test. No statistically significant differences were detected between age cohorts within an area (i.e. $p>0.05$ for all comparisons); therefore, all age groups were pooled to compare between areas, using an analysis of variance (ANOVA). Table 7-2 provides a summary of the statistical analysis conducted on metals concentrations in fish tissue between sampling areas. Significantly greater fish tissue concentrations were observed in juvenile Arctic grayling for arsenic ($p<0.006$) and cobalt ($p<0.001$) between the Exposure Area and Reference Area 1. Despite elevated concentrations of aluminum, copper, nickel, and zinc in water and or sediment, no statistically significant differences were observed between the Exposure Area and reference areas for these metals. Potential implications of the metals concentrations in fish tissue and potential effects thresholds for Arctic grayling are discussed in Section 8 of this report.

Table 7-2: Summary of Statistical Analyses of Metals Concentration in Arctic Grayling Tissue from Cycle 3

Parameters	Units (dw)	Exposure		Reference Area 1		Reference Area 2		ANOVA Results		
		# Samples	Mean	# of Samples	Mean	# of Samples	Mean	Significant Difference	Test Conducted	(p-value)
% Moisture	%	11	76.6	9	75.64	9	77.32	No	ANOVA and Tukeys Test	0.120
Aluminum (Al)	mg/kg	11	3.50	9	2.10	9	3.80	No	Kruskal-Wallis	0.110
Arsenic (As)	mg/kg	11	0.31	9	0.09	9	0.10	Yes	Kruskal-Wallis and Dunns	**0.006**
Cobalt (Co)	mg/kg	11	0.16	9	0.08	9	0.22	Yes	Kruskal-Wallis and Dunns	**0.001**
Copper (Cu)	mg/kg	11	0.72	9	0.75	9	0.65	No	ANOVA	0.105
Nickel (Ni)	mg/kg	11	0.28	9	0.24	9	0.29	No	Kruskal-Wallis	0.141
Zinc (Zn)	mg/kg	11	19.3	9	17.31	9	16.70	No	Kruskal-Wallis	0.168

Statistically significant comparisons ($p<0.05$) are in bold font.

7.3.1 Stream Temperature Data

To investigate the impacts of potential differences between stream temperature on Arctic grayling growth and surviva, six (6) temperature data loggers were installed in early July 2011. Each logger was set to record water temperature every 30 minutes, and collected approximately 7 weeks of *in situ* temperature data. The average weekly temperatures at each logging station are presented in Table 7-3 and are graphically presented in Figure 7.1.

Table 7-3: Stream Data Logger Results for the Exposure and References Areas

	Reference Area 1 (downstream)	Reference Area 1 (upstream)	Reference Area 2 (downstream)	Reference Area 2 (upstream)	Exposure Area (downstream)	Exposure Area (upstream)
Mean	12.8	13.1	13.1	13.3	14.3	13.6
Median:	12.8	12.9	13.1	13.4	14.4	13.8
Mode:	12.9	12.5	12.9	13.9	14.2	15.2
Maximum:	23.1	24.2	21.5	21.8	22.4	20.8
Minimum:	4.9	5.0	5.8	5.7	6.2	6.5
Std Dev:	3.9	4.1	3.5	3.7	3.5	3.1

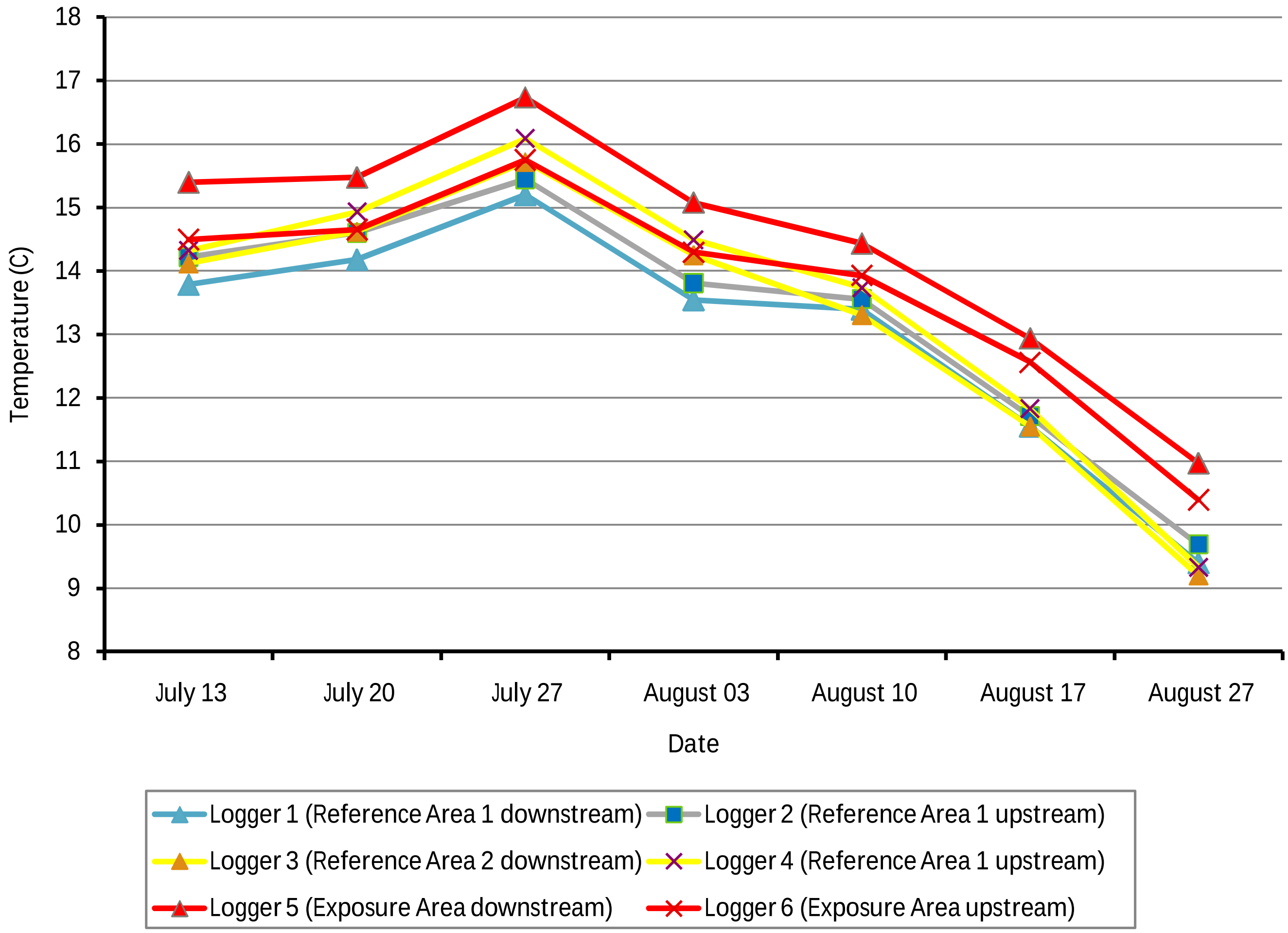


Figure 7-1: Stream Data Logger Results for the Exposure and References Areas

Differences in stream temperatures were determined by comparing the temperature profiles recorded by each data logger (n=2441) using an ANOVA with repeated measures. Stream temperatures were significantly greater in the Exposure Area compared to both Reference Area 1 ($p<0.05$) and Reference Area 2 ($p<0.05$). Within the Exposure Area the downstream location was significantly warmer than the upstream location ($p<0.05$). Between the reference areas, the upstream location in Reference Area 2 had significantly greater temperatures than both of the locations within Reference Area 1. No other statistically significant comparisons were identified.

The observed pattern of temperature differences between the Exposure Area and Reference Area 1 were in contrast to the hypothesis that the Reference Area 1 habitat was generally warmer than the Exposure Area.

Supporting Variable Highlights:

- Despite elevated concentrations of several metals in juvenile Arctic grayling tissue only arsenic and cobalt were significantly greater between the Exposure Area and Reference Area 1.
- Stream temperatures were significantly greater in the Exposure Area compared to both Reference Area 1 and Reference Area 2 which was in contrast to the hypothesis set forth in Cycle 3.

7.4 Fish Health

7.4.1 General Health

A total of 29 fish from the Exposure Area, 25 fish from Reference Area 1, and 33 fish from Reference Area 2 were collected for lethal sampling and associated experimental observations. External examinations revealed no major abnormalities (Appendix C; Table C-2 to C-4).

7.4.2 Summary Statistics (All Ages)

All of the fish captured were immature and length-frequency distribution for Arctic grayling indicated that three distinct size classes were captured during the survey of the three areas (Figure7-4). The subsequent age determination was targeted at young-of-year (YoY) (0+) Arctic grayling and indicated that 67% of juveniles were YoY, 29% were age 1+, and 5 % were age 2+ fish (Figure 7.4). In Reference Area 1, 50% of juveniles were YoY, 50% were age 1+, 9 % were age 2+ fish (Figure 7.4). In Reference Area 2, 100% of juveniles were age 2+ fish (Figure 19). No age 3^+ fish captured from any of the three survey areas. Summary statistics for all age classes were calculated for fork length, and weight for both the Exposure Area and reference areas (Table 7-4; Figures 7-2, 7-3, and 7-4). The detailed results of the age determinations for Arctic grayling are listed in Appendix C Table C-Y.

Table 7-4: Summary Statistics for Arctic Grayling (all ages)

Location	Variable	n	Median	Mean	SD	SE	Minimum	Maximum
Exposure	Fork Length(mm)	29	7.9	6.4	3.2	0.6	5.3	19
	Total weight (g)		7.7	2.4	15	2.7	1.3	78
Reference Area 1	Fork Length(mm)	25	9.4	7.2	3.0	0.6	5.8	15
	Total weight (g)		12	3.7	10	2.0	2.1	31
Reference Area 2	Fork Length(mm)	33	18	17	3.1	0.5	13	25
	Total weight (g)		70	56	49	8.5	22	218

Note:SD-Standard Deviation, SE-Standard Error

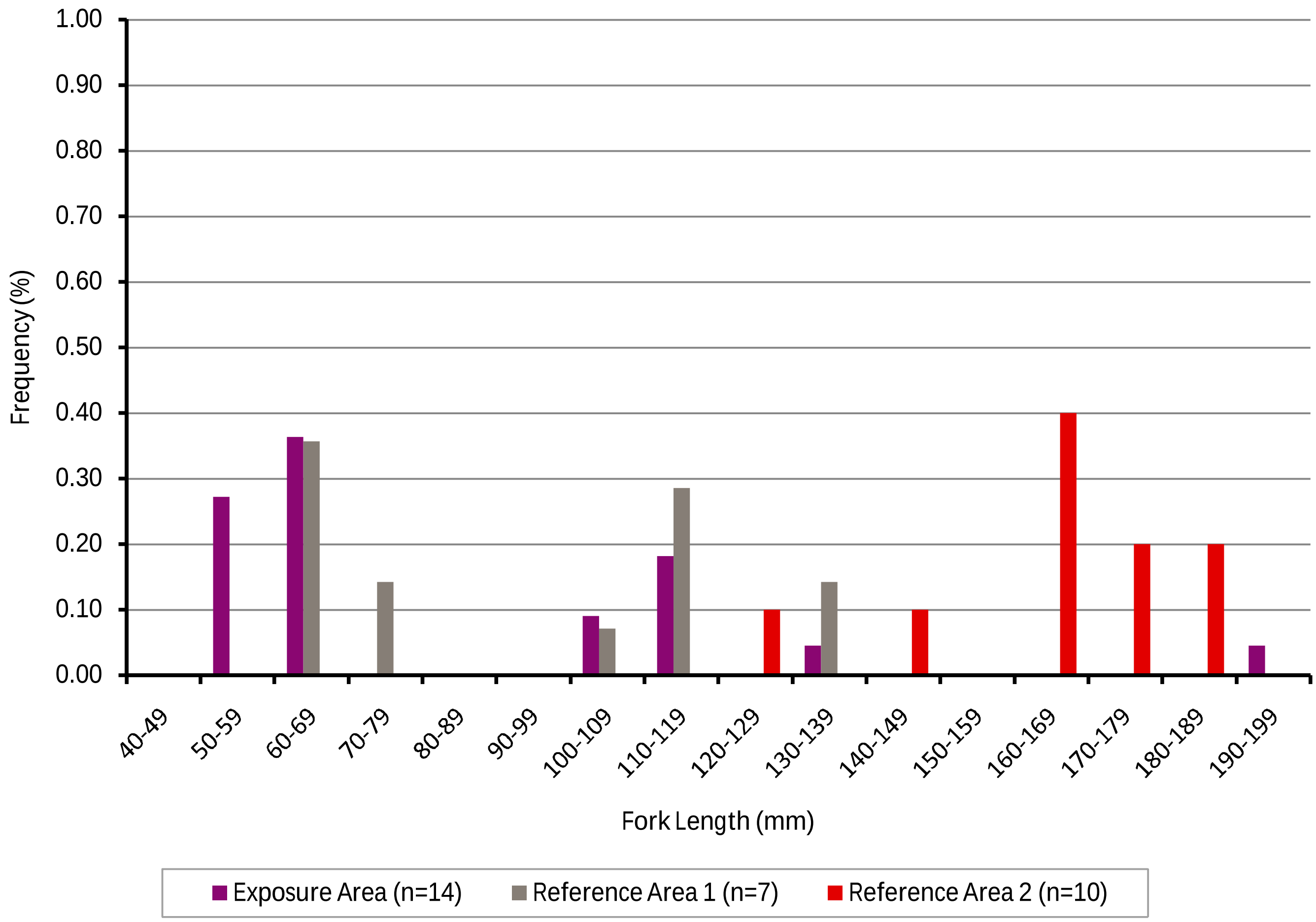


Figure 7-2: Fork Length Frequency Distribution for Arctic Grayling (all ages) from Each Survey Area (2010)

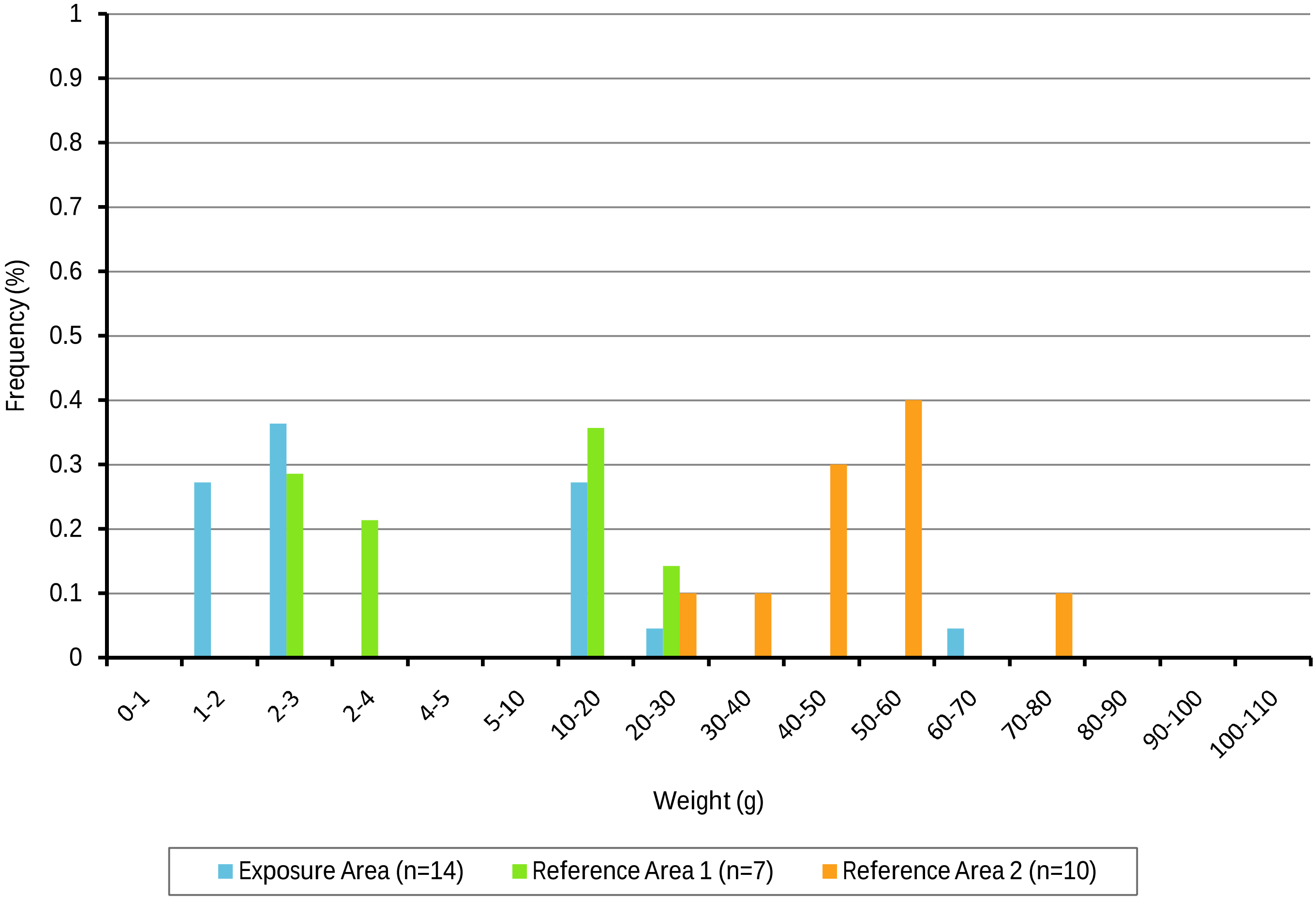


Figure 7-3: Weight Frequency Distribution for Arctic Grayling (all ages) from Each Survey Area (2010)

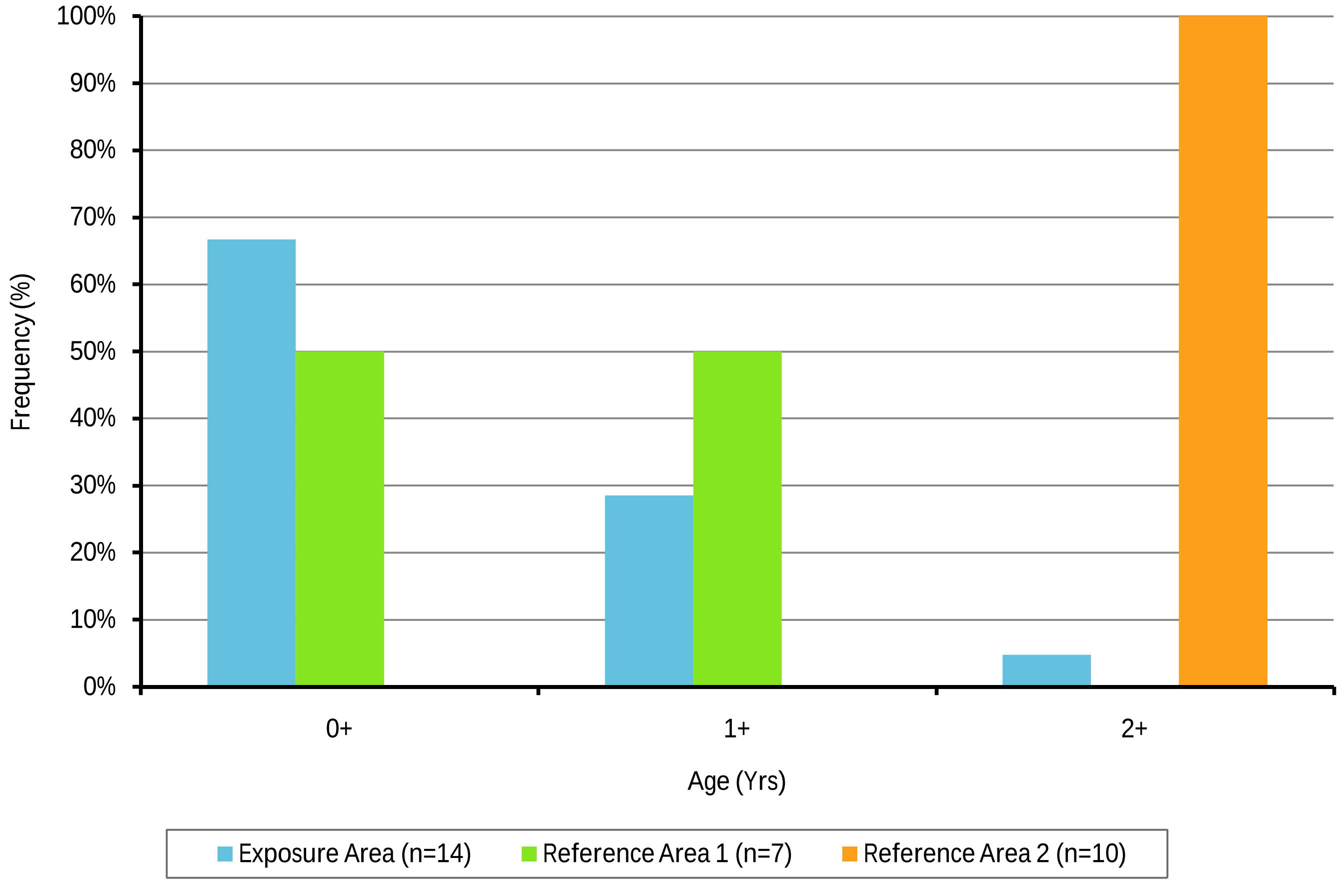


Figure 7-4: Frequency Distribution of Arctic Grayling Age Categories (2010)

7.4.3 Summary Statistics for Young-of-Year (0+) Grayling

Summary statistics for young-of-year (YoY) Arctic grayling which were used in the subsequent analyses are listed in Table 7-5. The results of the statistical analysis of the effect and supporting variables for YoY Arctic grayling are outlined in the subsequent section along with the results of the tissue analysis for metals concentration for Arctic grayling.

Table 7-5: Summary Statistics for Arctic Grayling (YoY)

Location	Variable	n	Median	Mean	SD	SE	Minimum	Maximum
Exposure Area	Fork Length(mm)	14	2.2	2.1	0.50	0.13	1.3	2.9
	Total weight (g)	14	6.2	6.3	0.40	0.10	5.5	6.7
Reference Area 1	Fork Length(mm)	7	3.0	2.9	0.35	0.13	2.5	3.6
	Total weight (g)	7	6.8	6.8	0.30	0.12	6.2	7.1
Reference Area 2	Fork Length(mm)	0	-	-	-	-	-	-
	Total weight (g)	0	-	-	-	-	-	-

Note:SD-Standard Deviation, SE-Standard Error

7.4.4 YOY Fork Length and Body Mass

The fork length-frequency and total weight-frequency distributions for YoY (0+) fish are presented in Figures 7-5 and 7-6, respectively. The supporting variables of total body weight and length of young-of-year Arctic grayling were statistically different between Exposure and Reference Areas (t-test, p=0.002 for both weight and length). The 0+ fish in the reference area weighed 30% more and were 9% longer than individuals in the Exposure Area.

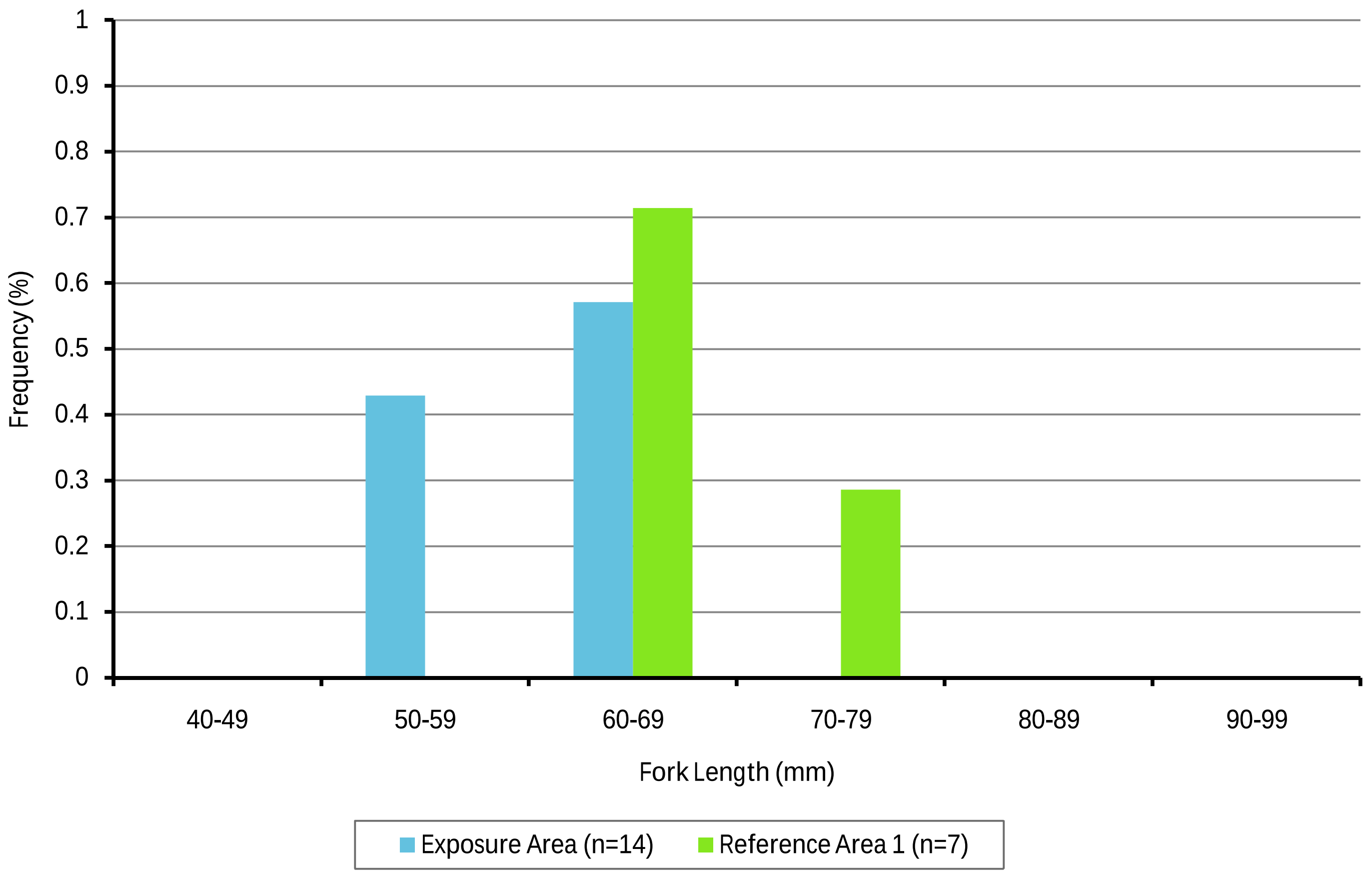


Figure 7-5: Fork Length Frequency Distribution for YoY (0+) Arctic Grayling from the Exposure Area and Reference Area 1 (2010)

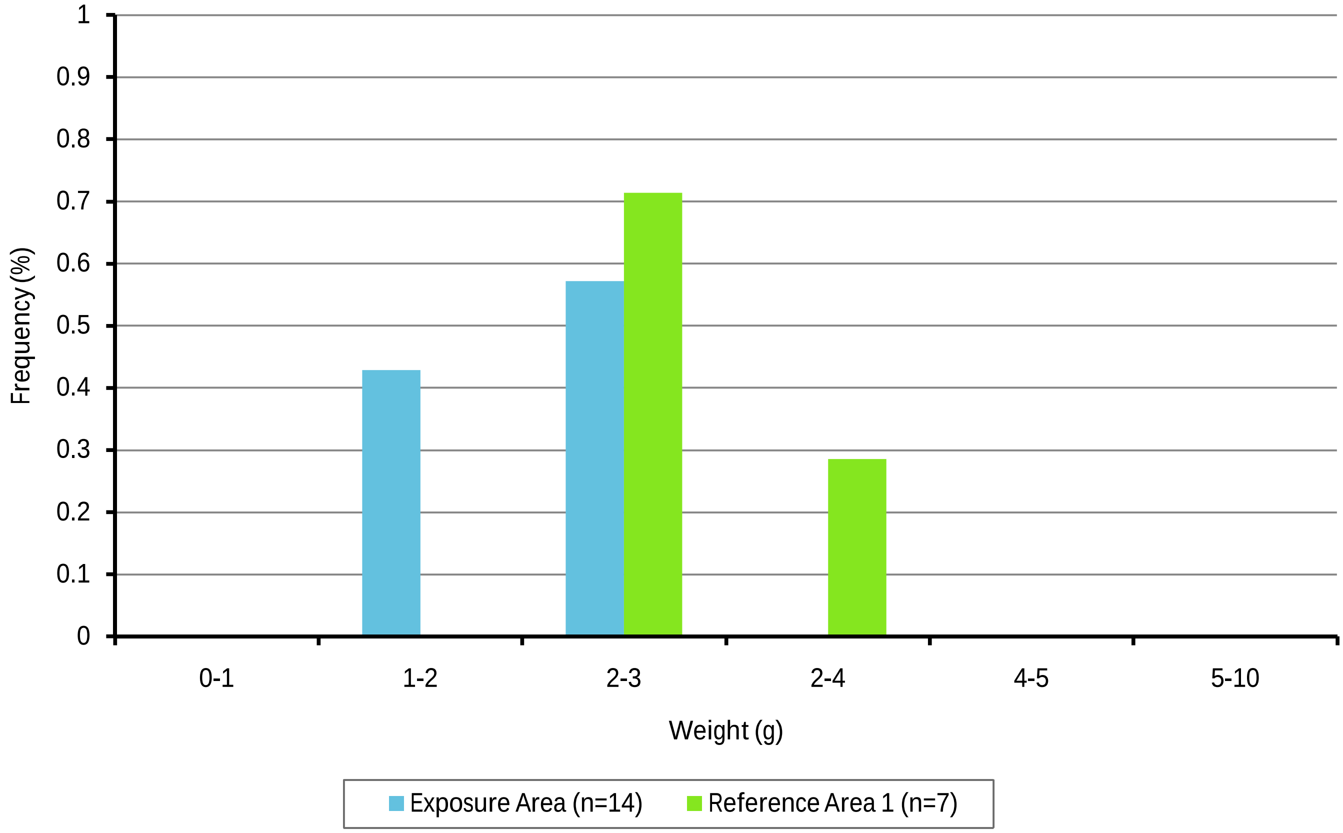


Figure 7-6: Weight Frequency Distribution for YoY (0+) Arctic Grayling from the Exposure Area and Reference Area 1 (2010)

7.4.6 Fish Condition

The effect endpoint of condition for young-of-year Arctic grayling as determined by comparing the fork length-total weight relationship statistically compared between the exposure and reference areas (Figure 7-7). No YoY Arctic grayling were collected from Reference Area 2 and therefore the YoY analysis only included Exposure Area and Reference Area 1 fish. Based on the results of the analysis of covariance analysis (ANCOVA: Table 7-6), no statistically significant difference in the particulars of the weight-length relationship was observed between sites. The interaction term was not significant indicating that the slopes were similar between the two areas, however the intercept was significantly higher in the reference area. This indicates that the condition of 0+ grayling (as opposed to length or weight) could not be statistically distinguished between the two major areas.

Table 7-6: Results of the Statistical Analysis (ANCOVA) for Arctic Grayling Condition (Covariation of Body Weight on Fork Length) Between the Exposure Area and Reference Area 1.

Data Set	Age Class	Interaction (p-value)	Significant Difference Between Areas	Intercept (p-value)	Intercepts significantly different	Direction of Difference
2010	YoY (0+)	0.359	No	< 0.001	Yes	Reference > Exposure
2008 & 2010	YoY (0+)	0.168	No	< 0.001	Yes	Reference > Exposure
2010	1+	0.112	No	< 0.001	Yes	Reference > Exposure

The linear length-weight relationships for the 2010 0+ grayling were described by the following equations:

Reference Area 1: Total weight (g) = 0.0945 x Fork length (mm) – 3.44; r^2=0.92

Exposure Area: Total weight (g) = 0.116 x Fork length (mm) – 4.99; r^2=0.87

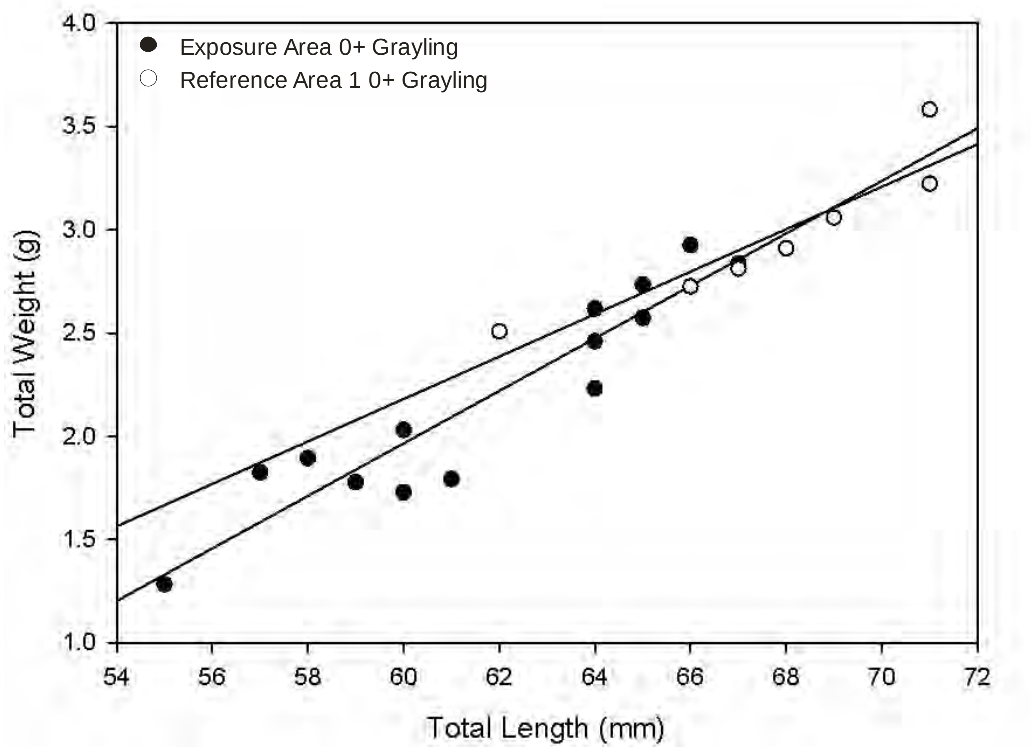


Figure 7-7: Relationship of 2010 Young of the Year (0+) Arctic Grayling Total Weight to Fork Length (Condition)

In addition to YoY (0+) Arctic grayling, weight to fork length relationships were compared for age 1+ and 2+ Arctic grayling collected in 2010. Linear least-square estimates of the weight-length relationships are shown below.

2010 age 1+ Arctic grayling

Reference Area 1: Total weight (g) = 0.4403 x Fork length (mm) – 36.0430; r^2=0.96

Exposure Area: Total weight (g) = 0.5163 x Fork length (mm) – 41.8910; r^2=0.97

2010 age 2+ Arctic grayling

Reference Area 1 only : Total weight (g) = 0.7583 x Fork length (mm) – 75.876; r^2=0.91

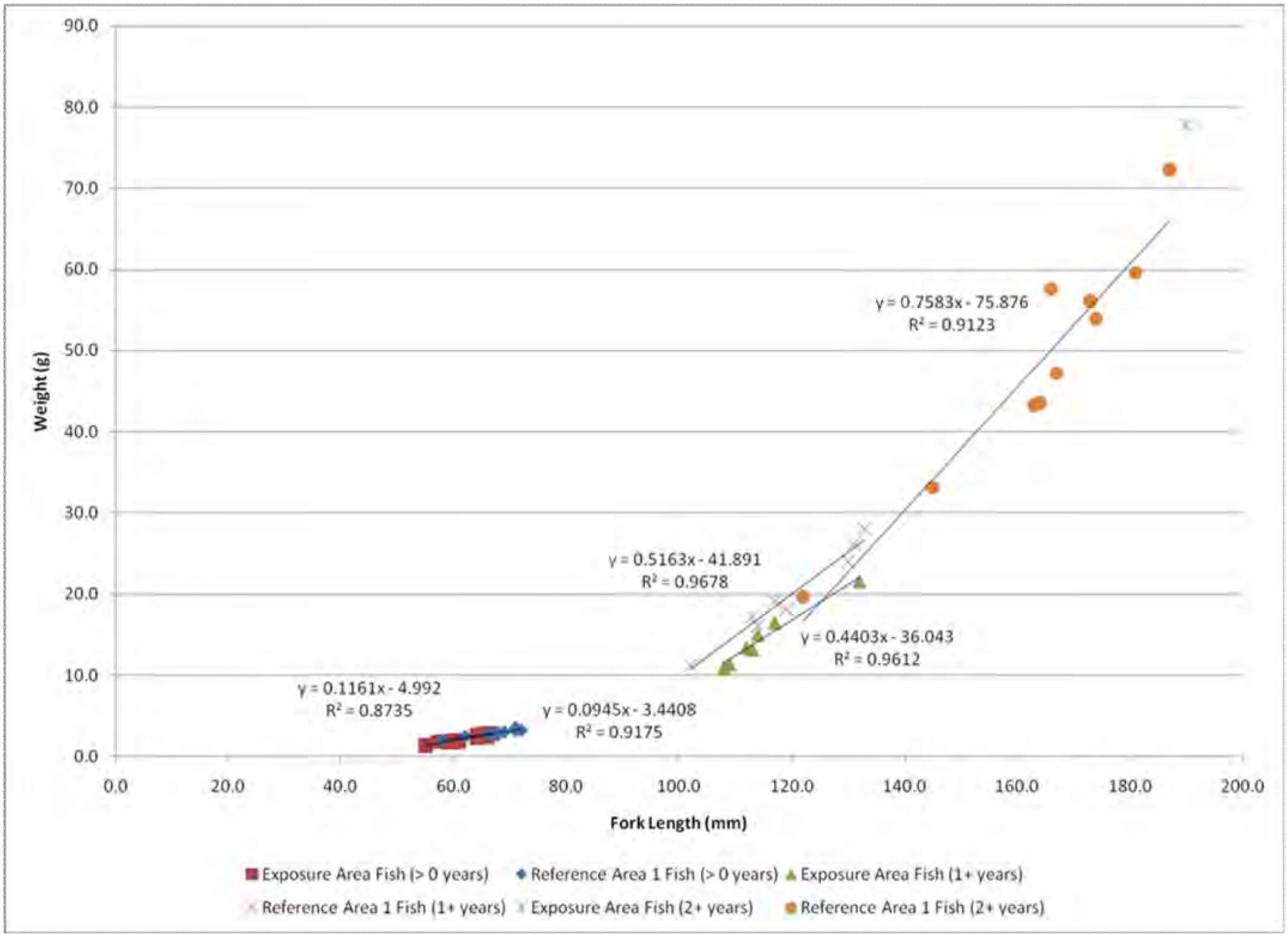


Figure 7-8: Relationship of Total Weight to Fork Length (Condition) for all 2010 Arctic Grayling Age Classes

The slope of the weight-length relationship clearly increases with age through the first (0+), second (1+), and third (2+) year of development.

Statistical analysis of differences in the 1+ age between the Exposure Area and Reference Area 1 were analysed using an ANCOVA. For the 1+ aged Arctic grayling the interaction term was not significant, indicating that the slopes (particulars of dependence of weight on fork length) were similar between the two areas; however, the intercept was significantly higher in the reference area.

An important observation is that both the lengths and weights of age 1+ Arctic grayling strongly overlap for the Exposure Area and Reference Area collections. There were no statistically significant differences between the two major collection areas in either weight or length as supporting effects endpoints. This is in contrast to observations for the 0+ fish.

The body condition effect endpoint for YoY (0+) Arctic grayling as determined by comparing the fork length-total weight relationship was further compared between the 2008 and 2010 collections for both the Exposure Areas and Reference Area 1 (Figure 7-9). Each age class from each season are shown independently with their respective linear length-weight relationship. In each comparison (using an ANCOVA), the interaction terms were not significant ($p>0.05$) indicating that the slopes were similar, however the intercepts were significantly different between each group ($p<0.001$).

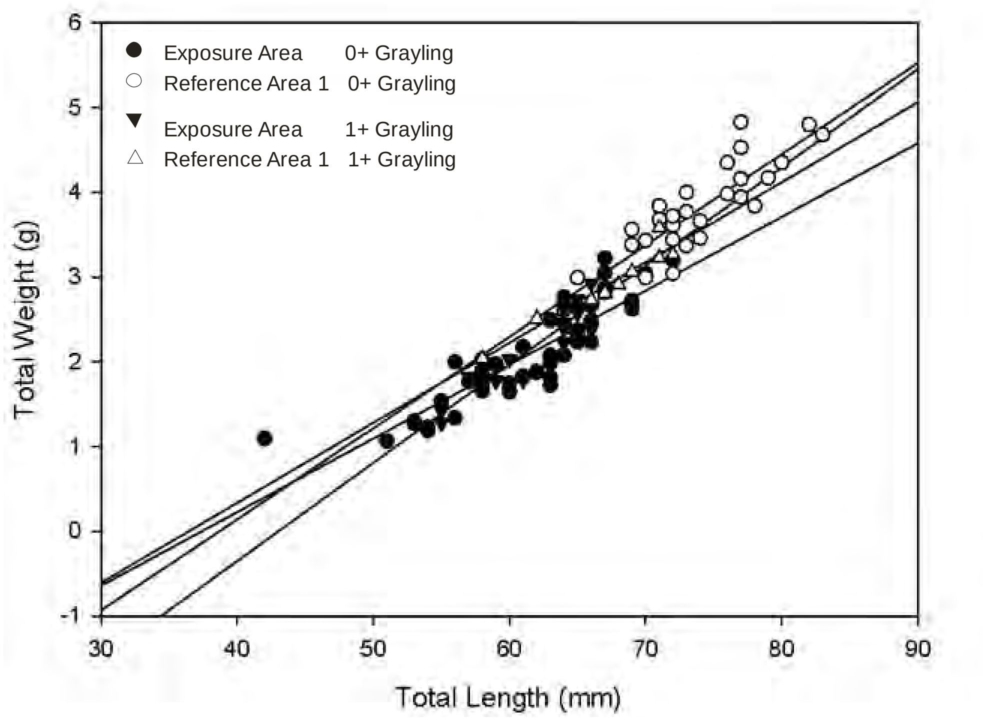


Figure 7-9: Comparison of the Total Weight to Fork Length (Condition) Relationship for both the 2008 and 2010 YoY Arctic Grayling Sampling Seasons.

The linear length-weight relationships were described by the following equations:

<u>2008 YoY (0+) Arctic grayling:</u>

Reference Area 1: Total weight (g) = 0.1077 x Fork length (mm) – 4.1607; $r^2=0.75$

Exposure Area: Total weight (g) = 0.0871 x Fork length (mm) – 3.2529; $r^2=0.79$

<u>2010 YoY Arctic grayling:</u>

Reference Area 1: Total weight (g) = 0.0945 x Fork length (mm) – 3.4408; $r^2=0.92$

Exposure Area: Total weight (g) = 0.1161 x Fork length (mm) – 4.992; $r^2=0.87$

Comparisons of a linear (Figure 7-10) and a curvilinear regression fit (Figure 7-11) applied to the Arctic grayling captured in the Exposure Area and Reference Area in 2008 and 2010 data indicate that, for both the 2008 and 2010 collections - the curvilinear relationship has a slightly higher co-efficient of determination (r^2) (i.e., 0.85 and 0.83 for 2008 and 2010, respectively) than the linear r^2 value (0.83 and 0.80, respectively). Similarly, when comparing all of the Reference and Exposure Area fish together as one data set, the curvilinear relationship (r^2) between fork length and weight was slightly (1%) higher than the linear relationship shown in Figures 7-12 (0.902 and 0.895, respectively).

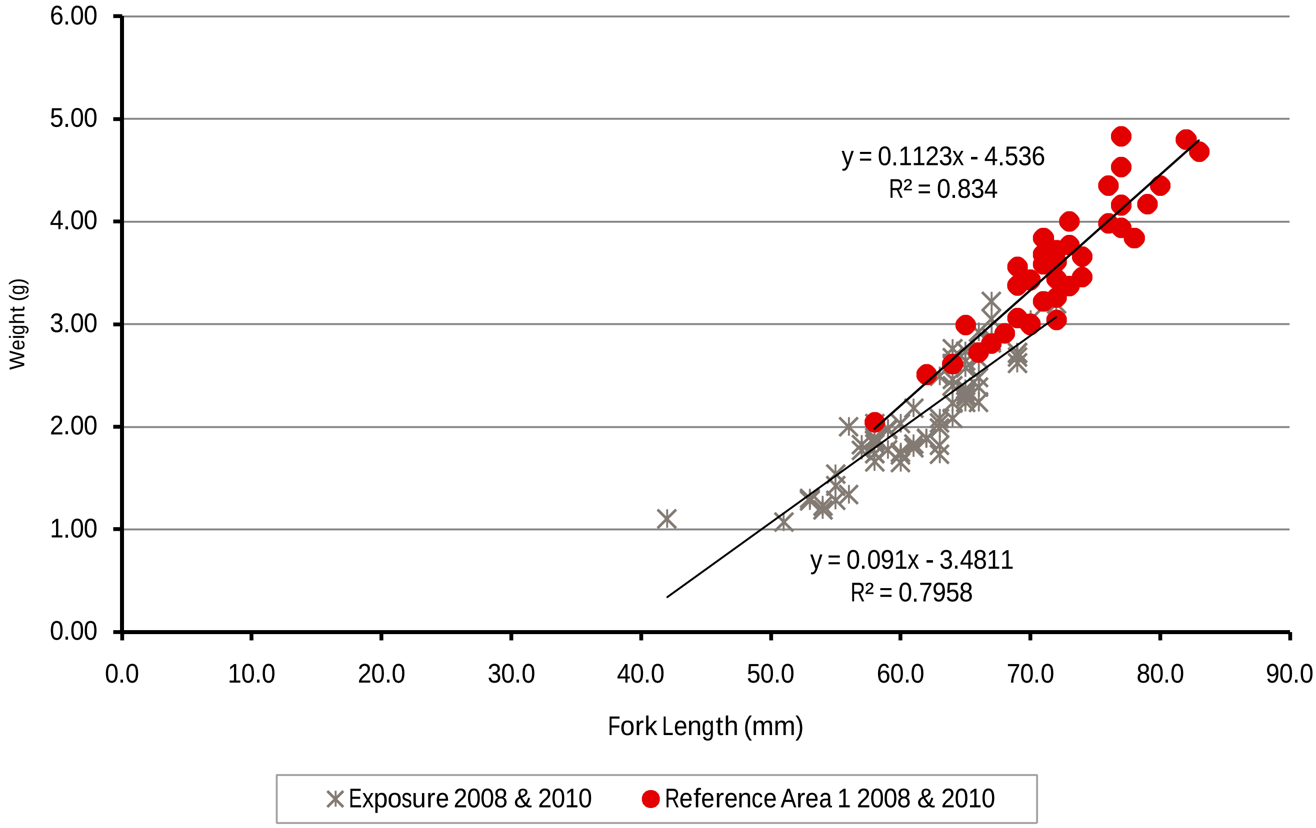


Figure 7-10: Linear Comparison of the Total Weight to Fork Length (Condition) Relationship of the 2008 and 2010 YoY (0+) Arctic Grayling.

Linear Regression: Total weight (g) = 0.117 x Fork length (mm) – 5.0202, r^2=0.895

Curvilinear Regression: Total weight (g) = 0.122 $e^{0.0461x}$ Fork length (mm) – 4.9920, r^2=0.902

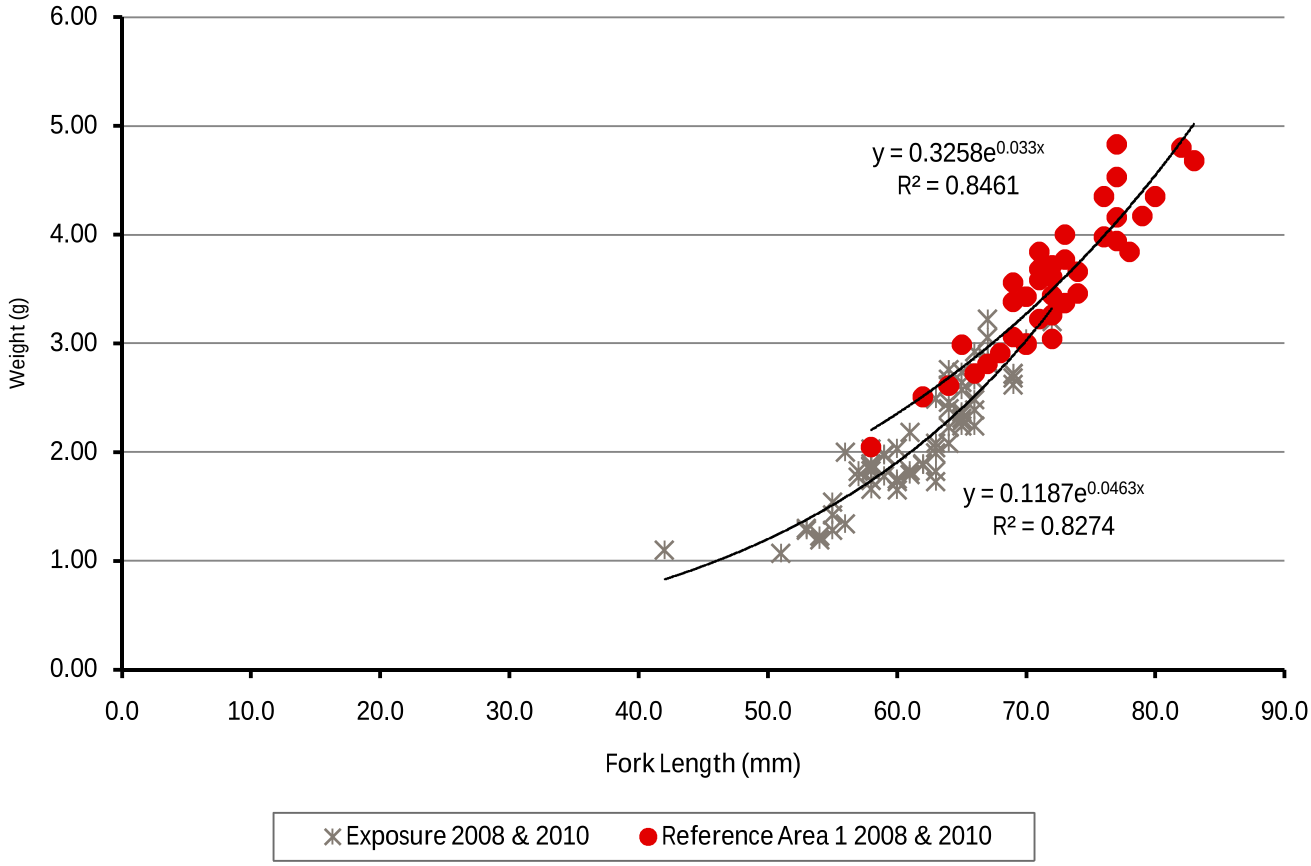


Figure 7-11: Curvilinear Comparison of the Total Weight to Fork Length (Condition) Relationship of the 2008 and 2010 YoY (0+) Arctic Grayling.

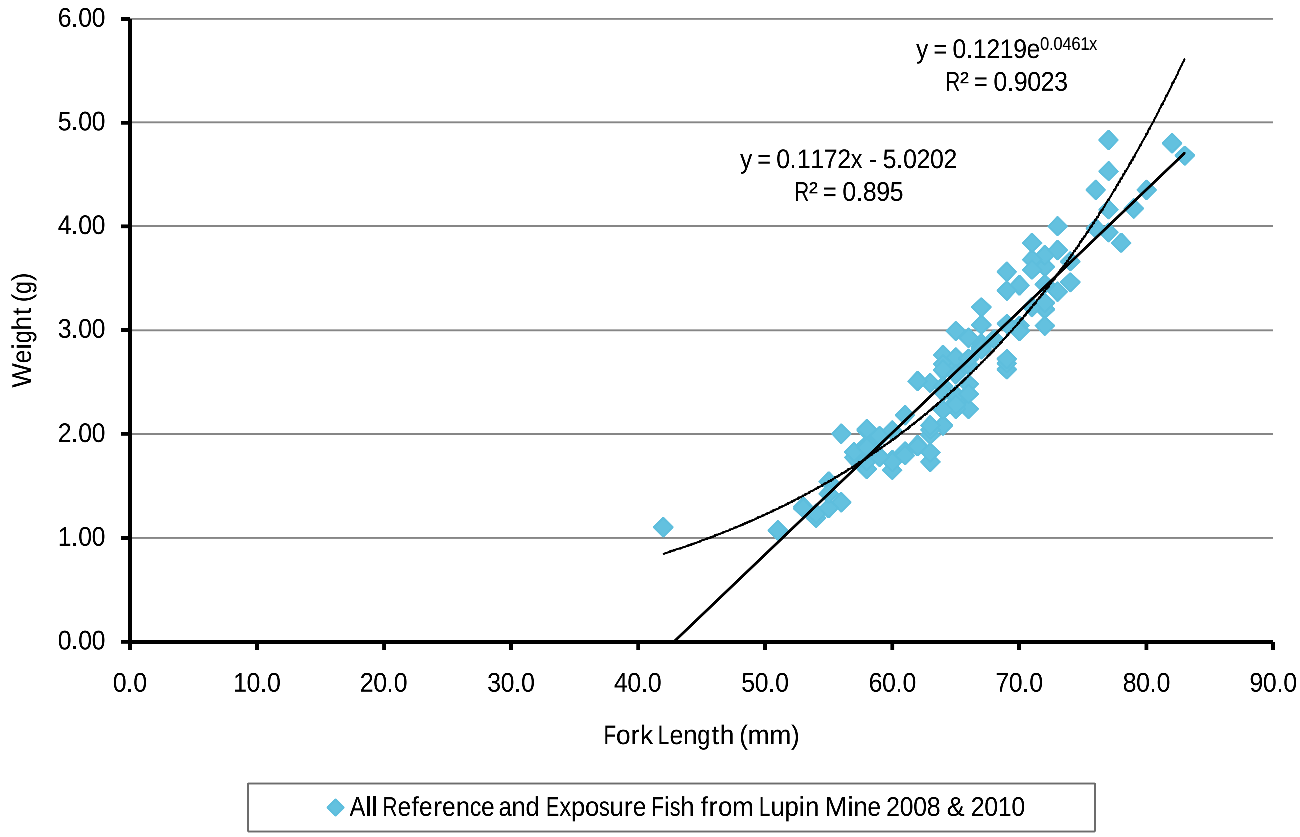


Figure 7-12: Linear and Curvilinear Regressions of all Reference and Exposure Area Fish Collected and Aged in 2008 and 2010.

Overall, the data analysis for fish collections indicates the following:

- There has been a consistently observed, statistically significant difference over the Cycle 2 (2008) and Cycle 3 (2010) EEM studies in the average fork length and wet weight of YOY (0+) Arctic grayling between the Lupin Mine Exposure Area and Reference Area 1. Exposure Area 0+ grayling have tended to be smaller in both length and weight during the August collection period than 0+ fish collected from Reference Area 1.

- For the 2010 fish samples, no statistically significant difference was observed in the average fork length or wet weight of 1+ as opposed to the 0+ age class fish. Between-site differences in age-specific average weight or length do not persist over the first year of development (between 0+ and 1+ cohorts).

- Based on the outcomes of the analysis of covariance (ANCOVA) of 0+ grayling wet body weight on fork length, there was no statistically significant difference in the condition (i.e., weight-length ratio) of 0+ grayling between the Exposure Area and Reference Area 1 for either 2008 or 2010.

- Analysis of covariance results for 0+ grayling, as above, have consistently shown a statistically significant difference in the y-intercepts between the two areas, in both 2008 and 2010. The y-intercept value effectively represents the weight-length ratio at age 0, prior to emergence from the egg. The condition at or prior to emergence would not be influenced by local environmental conditions, since mature adults (4+ age group and older) are expected to move into the Exposure Area only immediately prior to spawning, and their bioenergetics and reproductive development/health (and that of fertilized eggs) are more likely to be influenced by conditions in deeper waters, beyond the influence of mine effluent. There is no plausible ecophysiological explanation for an observed statistically significant difference in embryo condition prior to emergence or swim-up. Rather, the significant differences in the y-intercepts between sites in the ANCOVA models are best explained as numerical model artefacts. In particular, the fact that the average length of 0+ grayling differs between sites, coupled with the fact that weight-length relationships would not be expected to scale linearly over the first few weeks to months of growth, would tend to result in differences in the predicted y-intercept for a least-squares linear fit based simply on site differences in leverage.

- Taking into account body weight-fork length relationships for juvenile Arctic grayling across both collection years (2008, 2010), age classes present (0+, 1+, 2+) and areas (Exposure Area, Reference Area 1), the data are consistent with a global curvilinear fit as illustrated in Figure 7-13, and as further described by the following relationship:

$$\textbf{Whole body wet wet (g)} = 0.122 \times e^{[0.0461 \times \text{fork length}]}; \quad r^2 = 90.2\%$$

8. Discussion

The effluent discharge history of the Lupin Mine from the TCA is an important factor for further evaluation of aquatic ecological effects in the receiving environment. In particular, it is important to note that the Cycle 1 study was completed in 2005 just after the cessation of annual discharge of treated effluent from the TCA (Table 5-1), while the Cycle 2 study (2008) was completed following three years without any effluent discharge. A discharge did occur in 2009, but not in 2010. Overall, the volume of treated effluent discharged to the Seep Creek ecosystem since 1998 has averaged approximately 0.80 million m^3/annum, with active discharges having occurred in 2000, 2002, 2005 and 2009. In comparison the average annual discharge in the four years prior to 1998 was approximately 1.5 million m^3/annum.

Water quality in the Exposure Area in August, 2010, reflected the historical discharge of treated mine effluent, in that total Al, As, Cd, Cu, Ni, and Zn concentrations (Table 5-2) exceeded their respective Canadian water quality guideline for freshwater life protection in one or more of the water samples collected. This was dissimilar to the Reference Area samples (Table 5-3). Inorganic substances that were significantly elevated in Exposure Area sediments in comparison with Reference Areas 1 and 2 include As, Co, Cu, Mo, Ni, Sr, and Zn (Table 6-2).

Of the contaminants of potential concern identified in water or sediment samples from the Lupin Mine Exposure Area, only arsenic was significantly elevated in the whole body tissues of sub-adult Arctic grayling collected from the Exposure Area in comparison with the two reference areas. There was a statistically significant difference between areas in the grayling tissue cobalt concentration; however, the highest average tissue concentration was observed in fish collected from Reference Area 2.

8.1 Growth of Juvenile Grayling in the Lupin Mine Exposure Area

This Cycle 3 EEM study for the Lupin Mine TCA discharge was catalyzed by an observation from Cycle 1 and Cycle 2 MMER EEM studies that early life stages of Arctic grayling collected from the effluent Exposure Area exhibited a smaller average body mass and fork length than fish from the Reference Area 1 (Fingers Lake drainage). The 1+ age class of Arctic grayling was the focus of the Cycle 1 (2005) study, while young-of-the-year (0+) grayling were the focus of the Cycle 2 (2008) study.

The average fish size (based on weight or length) in early life stages of Arctic grayling was lower in the fish collected from the Exposure Area in this and previously completed EEM studies; however, it is important to note that no statistically significant differences have been observed in the condition of 0+ and 1+ age class Arctic grayling between the Exposure Area and Reference Area 1, based on an analysis of covariance of body weight on fork length.

A summary of the major findings with regard to Arctic grayling health in the Exposure Area is as follows:

- This Cycle 3 study indicates that YoY Arctic grayling experience significantly higher water temperatures during the summer in the Exposure Area compared to Reference Area 1, by 1.0 to 1.5 ^{o}C on average over the seven week summertime measurement period. This is in contrast to the prior hypothesis that the Fingers Lake Reference Area 1 exhibits greater comparative temperatures and thus more rapid growth of age-0+ and subsequent juvenile grayling life stages. The hypothesis that differences between sites in juvenile grayling length or weight are proportional to differences in average temperature or degree days, therefore, is rejected.

- Furthermore, the Cycle 3 field observations suggest that YoY Arctic grayling experience greater average flow velocity in the Exposure Area compared to Reference Area 1.

- On average, the YoY (0+) and/or 1+ age class Arctic grayling from the Exposure Area were shorter and lighter than the YoY Arctic grayling from Reference Area 1 (Cycle 1, 2, and 3).

- In August of 2010, there was not a statistically significant difference between the length or weight of the 1+ grayling between the Exposure Area and Reference Area 1, in spite of the noted difference for the 0+ cohort. There appears to be a convergence in the size of grayling from the different areas through their first year after swim-up. This further suggests that the 0+ differences might be attributable to differences in timing of spawning, hatching and swim-up between the two small watershed: A difference of several days to a few weeks in the hatching time on spawning grounds in the two areas would account for the differences in size of 0+ fish based on field observations in August, about one month after hatching from the eggs.

- Statistical analysis (ANCOVA) of the condition for the YoY Arctic grayling from the Exposure Area indicated that the slopes of the regression lines for each population (Exposure Area and Reference Area 1) were not significantly different and the Y-intercepts of the ANCOVA was significantly higher in the Reference Area 1. Therefore, the relationships between length and weight (condition) of the two populations were similar (i.e., they did not differ significantly between the Exposure Area and Reference Area 1.

Conclusions from the Cycle 2 report suggested that lower length and weight for YoY or 1+ age class Arctic grayling may be attributable to factors such as water temperature, food availability, competition, and predation. The results of Cycle 3 indicate that the hypothesis regarding lower water temperatures in the Exposure Area having an effect on the growth of YoY Arctic grayling is not supported (Figure 7-1).

Impacts on the YoY Arctic grayling population caused by competition and predation in the Exposure Area and Reference Area 1 are stream dependent and site specific information was not collected as part of Cycle 3. Food availability analysis conducted during Cycle 2 indicated that the benthic invertebrate community in the Exposure Area exhibited significantly lower Simpson indices of diversity and evenness. However, these differences were not significant and the proposed correlation between growth and the availability of specific taxa (Chironomidiae) was not supported by the Cycle 2 results (high densities of chironomids found in the Exposure Area). The statistically significant benthic community metrics were not consistent between the Cycle 1 and Cycle 2 studies, and overall it was concluded that the benthic invertebrate community in the Exposure Area and Reference Area 1 are substantially similar with regard to numerical abundance as well as species richness and diversity. Given the similar average numerical abundance between the two areas, it is unlikely that the standing stock biomass would be different enough to impact the growth of sub-adult Arctic char in the Exposure Area.

Juvenile Arctic grayling have been observed to occupy different positions within a stream based on size and distance from the river mouth (Baccante, 2010). Hughes and Reynolds (1994) indicated that Arctic grayling in upstream stream reaches are, on average, larger than those downstream. This work supported work conducted by Tack (1980) that indicated that downstream areas are generally colonised by young grayling that gradually move upstream as they get larger and older. Tack (1980) speculated that this behaviour would provide larger fish with a feeding advantage primarily because fish with the upstream position would have first access to drifting prey items such as floating insects. This and allied studies support the importance of drift prey items for Arctic grayling foraging, as opposed to benthic invertebrates. Fish position within the streams surveyed may have influenced the results of the morphometrics analysed in this study. It should be noted that the fish sampling was conducted over comparable distances (approximately 1.5 km) within their respective watersheds. However, Reference Area 1 was sampled along the entire section of Fingers Creek from Contwoyto Lake to Fingers Lake (headwaters of the Fingers Watershed), whereas the Exposure Area was surveyed along the lowest portion of Seep Creek beginning at the mouth of Seep Creek (discharge point into Inner Sun Bay).

The studies by Hughes (1992), Hughes and Reynolds (1994), Hughes (1999) and Baccante (2010) show increases in mean fork length with distance from the mouth of rivers for primarily riverine populations of Arctic grayling, which include all age/size classes, as well as fish that spend their entire life in the riverine environment. The Contyowto Lake and Seep Creek Arctic grayling populations, however, are predominantly lacustrine (lake-dwelling populations), the life history of which departs from most of the populations that have been the subject of published scientific studies (e.g. Clark, 1992; Deleray and Kaya, 1992; Deegan *et al.* 1999; Buzby and Deegan, 2000, 2004; DeCicco, 2002; Jones and Tonn, 2004; Deegan *et al* 2005; Clarke *et al* 2007). Jones *et al* (2003) completed a study of the feeding preferences of young-of-the-year Arctic grayling in lake outlet streams from the Barrenlands of the Northwest Territories.

In the Lupin Mine Exposure Area, it is assumed that gravid adults (spawners) move into Outer Sun Bay and then into Inner Sun Bay in the spring near the time of break-up, and that the adults move up Seep Creek to optimal (and sub-optimal) spawning areas at the earliest opportunity, depending on annual variations in ice melt and associated limitations imposed by channel morphology and depth for the movement from deeper water to more shallow areas in the system. After spawning, hatching, and swim-up, the 0+ age class will forage in shallow lower velocity areas of the creeks, ponds and side-channels (in part to limit predation). Prior to freeze-up, the 0+ fish must migrate to deeper waters to survive the winter. The over-wintering habitat of sub-adult Arctic char (or other fish species found in the Exposure Area) has not been identified to date, but survivorship in this habitat may be at least as critical to overall continued population recruitment as growth and survivorship while occupying summer-time foraging areas. We speculate that 0+ Arctic grayling would move into Inner Sun Bay for over-wintering. Juvenile and adult arctic grayling show considerable fidelity and tend to return to the same summer-time foraging areas as occupied previously (Buzby and Deegan, 2004). For the Lupin Mine EEM study area, therefore, it is speculated that 1+ and 2+ age classes re-enter the Exposure Area and equivalent habitats in the reference areas in the summer-time open water period. After reaching 2+ years of age, fish probably remain in deeper waters to forage, having grown large enough to limit risks of predation by other fish species present under summer-time conditions.

Differences in recruitment could have been caused by differences in the timing of spawning grounds accessibility. These differences may have occurred based on localized differences in spring thaw rates (i.e. related to stream morphology, depth, width, etc) and spawning area entrance limitations (i.e. ice jams).

Based on the ANCOVA analyses presented in Section 7, the linear models adequately describe growth over the growing season. However, graphical comparisons of the weight-length relationship in YoY Arctic grayling indicated that a curvilinear relationship provided a better approximation of the growth of Exposure and Reference Area 1 grayling collected in 2008 and 2010 (Figures 7-10 and 11) as well as for all YoY grayling collected in 2008 and 2010 (Figures 7-12 and 13). The results shown in Figure 7-8 show that despite the size differences in YoY Arctic grayling the slopes of the 1+ Arctic grayling also did not differ significantly. Therefore the differences detected in average length and weight between the Exposure Area and Reference Area 1 populations do not appear to be diverging in subsequent age classes.

The curvilinear relationships shown in Figures 7-11 and 7-12 indicate that a curvilinear growth trajectory does a better job of representing both populations over the growing season. This would be consistent with observations by various researchers that condition increases through the growing season. The length-weight ratio would not be expected to be consistent through the season and across different age classes. A survival advantage is conferred on fish that have higher energetic reserves immediately prior to freeze-up.

Within-season variation in the timing of recruitment between the Exposure Area and Reference Area 1 Arctic grayling populations may be the reason for the statistically significant differences in size (length and weight) of 0+ age class fish observed for both the 2008 and 2010 YoY studies. The spawning window for Arctic grayling occurs immediately post ice out. The area surrounding the Lupin Mine is relatively flat and is dominated by low lying vegetation which should equalise the influence of external factors on the timing of ice out and thus potential differences in the spawning window of each study watersheds. However, watershed specific factors such as stream depth and morphology may have a more significant influence on the timing of ice out and therefore the timing of the return of gravid adults. Specific potential influences were not quantified in Cycle 3; however, we speculate that a later spawning time and or hatch time in the Exposure Area would have resulted in the differences observed during in season sampling of YoY Arctic grayling. Extrapolation of the summer water temperatures recorded during 2010 would not accurately represent the late winter and early spring conditions of these survey areas. Coad *et al*. (2005) recommended sampling for Arctic grayling - used as a sentinel fish species in pulp and paper and metal mining environmental effects monitoring fish population surveys - should be conducted in late fall (as late as possible before ice cover).

Therefore a more accurate comparison of Arctic grayling size between the Exposure Area and Reference Area 1 would require later sampling times than were conducted in Cycles 2 and 3. A preferred approach for assessing growth variability in sub-adult populations would be to conduct sampling on at least two dates through the summer-time open period, for the purpose of directly estimating average increase in biomass per day in the nursery areas.

8.2 Comparison of Water Chemistry with Literature-derived Threshold Values for Freshwater Fish

The 2010 water chemistry data were screened against the Canadian water quality guidelines for freshwater life protection, taking into account the influence of hardness or pH on toxicological thresholds where relevant. The pH of water samples collected in 2010 from the Lupin Exposure Area ranged from 6.69 to 6.89, which was similar to the reference areas. The Exposure Area hardness differed from that of the reference areas, however, with a range of 22.9 to 68.3 mg/L as $CaCO_3$ equivalents in the Exposure Area samples at a range of 3.2 to 5.8 mg/L in the reference areas.

Assuming a hardness of 23 mg/L (the lowest end of the documented range), site-specific water quality guidelines can be calculated based on methods prescribed by CCME, as follows:

Table 8-1: Comparison of maximum observed concentration in water sample from Exposure Area to hardness-specific water quality guidelines, per CCME guidance

Substance	Equation for calculating CCME WQQ based on water hardness	Result (µg/L)		Highest Observed Value – Exposure Area (2010)
		(hardness = 23 mg/L)	Hardness = 3.2 mg/L)	
aluminum	= 5 µg/L if pH < 6.5; = 100 µg/L if pH ≥ 6.5	100	100	112
cadmium	$= 10^{\{0.86[\log(\text{hardness})] - 3.2\}}$ µg/L	0.0094	0.0017	0.065
copper	$= e^{0.8545\{\ln(\text{hardness})] - 1.465\}}$ x 0.2 µg/L	2	2	6.0
lead	$= e^{1.273\{\ln(\text{hardness})] - 4.7055\}}$ µg/L	1	1	0.10
nickel	$= e^{0.76\{\ln(\text{hardness})] + 1.06\}}$ µg/L	31	25	35.4

At a pH of 7.0 and temperature of 10^oC, the Canadian water quality guideline for total ammonia is 10.3 mg/L NH_3. In comparison, the observed range in water samples collected in 2010 from the Exposure Area was 0.009 to 0.014

mg/L – approximately three orders of magnitude lower than the guideline. No aquatic toxicity would be expected from the observed ammonia levels, therefore.

Substances measured in surface water from the exposure area in 2010 that exceeded the generic or hardness-specific water quality guidelines for freshwater life protection included the following:

- aluminum
- arsenic
- **cadmium**
- **copper**
- **iron**
- mercury (one replicate of one sample only)
- nickel
- zinc (one sample only)

The substances that exceeded their respective WQG by more than two-fold in more than two samples are shown in bold. These are the primary candidates for any possible sub-acute toxicity (based on effects other than mortality). This in turn is based on the fact that the CCME water quality guidelines for freshwater life protection tend to be based on preventing effects to all species including aquatic animals that are often more sensitive to metals/metalloids in water when available in a freely available, ionized form.

Cadmium:

The $CWQG_{FL}$ for cadmium was re-visited in 1999. While the interim water quality guideline (freshwater life protection) for cadmium was set at 0.017 µg/L, this is based on (i) a 16 day LOEL for the waterflea *Daphnia magna* of **0.17 µg/L**, coupled with (ii) a 10-fold safety factor. In comparison, finfish appear to be less sensitive to cadmium. According to CCME (1999a) –

> "Data on the acute toxicity of cadmium to freshwater fish were available for 23 species (Environment Canada 1994). Salmonids appear to be the most sensitive family of fish. Cusimano et al. (1986) reported 96- and 168-h LC50s of <0.5 µg L^{-1} for rainbow trout *(Oncorhynchus mykiss)* fry exposed to cadmium. A number of other studies on rainbow trout, chinook salmon *(O. tshawytscha)*, and coho salmon *(O. kisutch)* also reported acute lethal toxicity (10–50%) after exposures to cadmium levels that ranged from 0.8 to 1.4 µg×L^{-1} (Chapman 1978; Finlayson and Verrue 1982; Spehar and Carlson 1984; Buhl and Hamilton 1991). Chronically exposed fish demonstrated toxic effects at concentrations similar to those used in acute tests. In a 46-d study, significant reductions in body weight (11%) and fork length (6%) in Atlantic salmon *(Salmo salar)* alevins were evident at cadmium concentrations of 0.47 µg×L^{-1} (Rombough and Garside 1982). A 12.5% reduction in survival was reported for the striped bass *(Morone saxatilis)* following a 12-d exposure to cadmium levels of 0.5 µg·L-1 (Wright et al. 1985). Steelhead *(O. mykiss)* parr were also relatively sensitive, exhibiting 200-h LC50 and LC10 values of 0.9 and 0.7 µg×L-1, respectively (Chapman 1978). Spehar et al. (1978) exposed American flagfish *(Jordanella floridae)* for 30 d to cadmium levels of 8.5 µg ×L^{-1} and found a 19% reduction in survival. Japanese medaka *(Oryzias latipes)* suffered 25% mortality following an 18-d exposure to cadmium levels of 7 µg×L^{-1} (Canton and Slooff 1982)."

Perhaps the most relevant set of test results to the Lupin Phase III EEM is the 46-d exposure of Atlantic salmon alevins, with an effects size of 11% for body weight and 6% for fork length when exposure to **0.47 µg/L** Cd. This is approximately one order of magnitude greater than the maximum observed water column concentration in the Exposure Area in 2010.

Copper:

The Canadian Council of Ministers of the Environment does not have a WQG development fact sheet available online (http://ceqg-rcqe.ccme.ca/) for copper. Nonetheless, the province of British Columbia has developed Approved Water Quality Criteria for Copper (1987) (http://www.env.gov.bc.ca/wat/wq/BCguidelines/copper/copper.html accessed online 02 May, 2011) based on substantially the same information used in the development of the copper Canadian water quality guideline for freshwater life protection. The BC water quality criterion is set at 2 µg/L for water bodies with low hardness (<50 mg/L as $CaCO_3$) and 4 µg/L when water hardness is greater than 50 mg/L. This is intended as a 30-day average. Aquatic toxicity data used in the derivation of the BC water quality criteria and Canadian water quality quality guideline for freshwater life protection are provided in the Technical Appendix available at http://www.env.gov.bc.ca/wat/wq/BCguidelines/copper/coppertech.pdf (accessed online 02 May, 2011). Effects on freshwater fish are reviewed in Section 5.5.1 of the Technical Appendix. The document states:

> "A search of the literature indicated that small steelhead (Salmo gairdneri) fry (1 to 6 g) were the most sensitive fish species tested to date[68]. LC50 values were calculated for 96 and 168 h exposure periods to copper in soft water (10 mg/L $CaCO_3$) at pH 4.7, 5.7, and 7.0. Fish were acclimated to test pH for eight days prior to testing. The 96 h LC50's for copper at the three pH levels were 66.0, 4.2 and 2.8 µg/L, respectively. The 168 h LC50's were similar to the 96 h values. Interestingly, the fish were most tolerant at the lowest pH. Chinook salmon (Oncorhynchus tshawytsca) fry were also found to have a low tolerance to copper, with a 96 h LC50 of 10 µg/L when tested in soft water (13 mg/L $CaCO_3$) at pH 7.2[182].
> Based on the acute toxicity/hardness relationship, Spear and Pierce (1979) have developed formulae for predicting the toxicity (LC50's) for copper to certain taxonomic groups of fishes. For example, the LC50s' for coho and chinook salmon range from 10 µg/L in soft water to 125 µg/L in hard water according to the equation:
>
> LC50 (mg/L Cu) = $0.0014\ H^{0.79}$ (mg/L $CaCO_3$), were H represents water hardness.
>
> The development of this formula incorporated exposure periods ranging from 24 hours to 21 days. Similar equations have been developed for the order Perciformes (perch-like fish), the order Cypriniformes (minnow-like fishes), and other salmonid species."

The range of copper concentrations at which different non-lethal responses in freshwater fish have been observed was reviewed by Spear and Pierce (1979). The following figure is reproduced in Figure 8-1.

The available studies suggest that the lower threshold for effects on growth would be similar or perhaps slightly higher than the lower threshold for sub-chronic to chronic mortality in juvenile forms of freshwater salmonids.

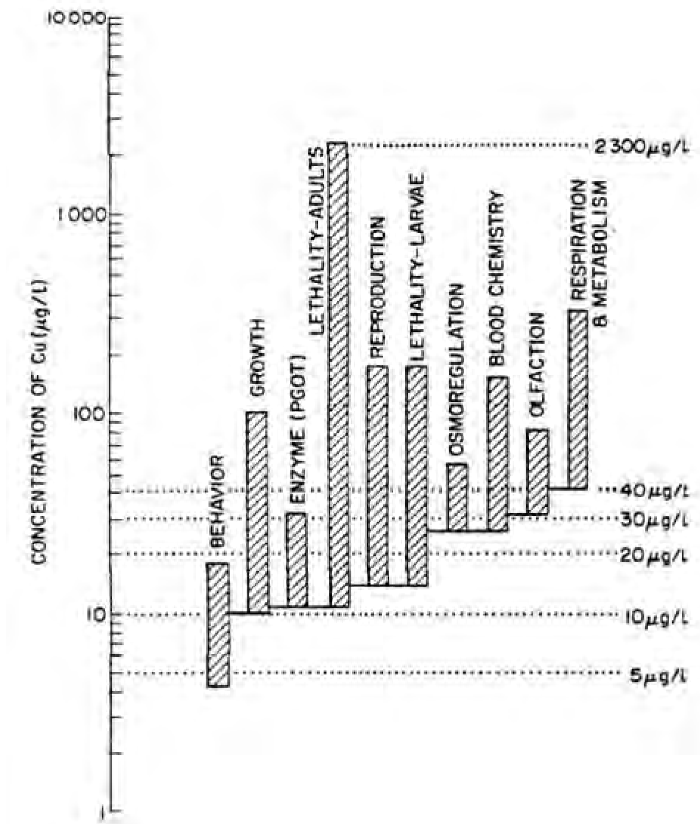


Figure 8-1: Thresholds and ranges of Cu (µg/L) associated with various sublethal effects in freshwater fish (from Spear and Pierce, 1979). The data are for low hardness waters that are relatively free of complexing agents.

<u>Iron:</u>

The Canadian Council of Ministers of the Environment does not have a WQG development fact sheet available online (http://ceqg-rcqe.ccme.ca/) for iron. Nonetheless, the province of British Columbia has developed Approved Water Quality Criteria for Iron (2008) (http://www.env.gov.bc.ca/wat/wq/BCguidelines/iron/iron_overview.pdf; accessed online 02 May, 2011) based on substantially the same information used in the development of the copper Canadian water quality guideline for freshwater life protection. According to this document, "To protect freshwater aquatic life guideline for iron is 1 mg/L for total iron and 0.35 mg/L for dissolved iron."

In 2010, the concentrations of total (not dissolved iron) measured in the Lupin mine exposure area were as follows:

- SCP-1: 0.382 mg/L
- SCF-1 0.463 mg/L
- SNP 925-20: 0.760 mg/L
- SCD-1: 0.157 mg/L

All results were lower than 1 mg/L total iron, as referenced above.

According to the BC Water Quality Criterion for Iron – Technical Appendix:

> "The life stage of fish exposed to iron is very important in terms of long-term impact. In a number of studies, different life stages of three species of fish (fathead minnow, coho salmon and brook trout) were examined for sensitivity to lime-neutralized iron hydroxide. The safe upper limit of lime-neutralized iron in suspension for survival, growth, and reproduction of the fathead minnow was between 0.29 and 1.87 mg/L iron and the initial deleterious effect occurred during the egg incubation stage (Smith *et al.* 1973). For coho, the safe upper limit lay between 0.97 and 1.27 mg/L (lime-neutralized suspended) iron, with initial deleterious effect occurring during the early alevin development stage (Smith and Sykora 1976). Finally, the safe upper limit for brook trout was between 7.5 and 12.5 11 mg/L (lime-neutralized suspended) iron, with deleterious effects occurring during the juvenile development stage (Sykora *et al.* 1972a, 1972b, 1975 cited in Smith and Sykora 1976). Highly sensitive fish appear to be affected by lime-neutralized iron hydroxide suspensions earlier in their life history than species of lower sensitivity (Smith and Sykora 1976)."

and

> "Smith and Sykora (1976) exposed brook trout and coho salmon at various concentrations (12, 6, 3, 1.5 and 0.75 mg/L) of lime-neutralized suspended iron. They found that none of the concentrations had an effect on the hatching success of brook trout or coho salmon. Also, brook trout alevin survival and size at 30, 60 and 90 days post-hatch did not change in response to an increase in lime-neutralized suspended iron concentration (Sykora et al. 1975). However, Sykora et al. (1972a) found that brook trout had retarded growth at 12 mg/L suspended iron and higher, and fish exposed to levels exceeding 6 mg/L were more susceptible to injury and disease. At 50 mg/L suspended iron, viability of brook trout eggs was greatly reduced (Sykora et al. 1972a). Coho salmon alevin survival at 30, 60, and 90 days post-hatch was similar in the 3, 1.5 and 0.75 mg/L suspended iron and control solutions, but declined sharply in 6 and 12 mg/L suspended iron water. They suggest that the safe upper limit for prolonged exposure of coho salmon egg and alevin stages may lie between 0.75 and 1.5 mg/L suspended iron."

In light of this information, it is unlikely that the observed total iron concentrations observed in surface water in July 2010 would result in altered growth or development after the swim-up stage.

8.2.1 Comparison of Water Chemistry with Literature-derived Threshold Values for Arctic Grayling

A few key research studies (Buhl and Hamilton, 1990; Buhl and Hamilton, 1991) have directly evaluated the sensitivity of early life stages of Arctic grayling to metals/metalloids and other aspects of water quality. These studies were motivated by concerns about the effects of placer mining in Alaska and the Yukon. Waste materials from placer mining, and especially the washing process, is typically discharged to settling ponds above the wetted stream channel. The decanted effluent is then discharged; however, the discharge typically contains elevated levels of fine suspended particulates (e.g. measurable as increased turbidity) and trace inorganics in dissolved and fine particulate form. Placer mines are often located in headstream valleys which are important spawning and nursery grounds for grayling.

Table 8-2, below, is reproduced from Buhl and Hamilton (1990). The data are based on laboratory-based toxicity tests using hatchery stock. Eggs were hatched in a vertical flow incubator, and fry were subsequently exposed in fiberglass troughs. Juveniles were exposed in circular tanks. Mean and range (in parentheses) for hardness were 41.3 (40.0-43.0) mg/L and for alkalinity 30.9 (30.0-32.0) mg/L (both as CaC03). The pH ranged from 7.1 to 8.0 and the mean conductivity was 158 (range, 143-179) µmhos/cm at 25°C.

As will be noted from Table 8-3, threshold of effect concentrations for arsenic, lead and zinc were much high than observed in surface water samples from the Lupin mine Exposure Area. Conversely, the lowest 96h LC50 for copper was 2.58 µg/L (for 0.34 g fry from an Alaskan hatchery).

Juvenile Arctic grayling were much more sensitive to copper than juvenile coho (*Oncorhynchus kisutch:* minimum LC50 of 15.1 µg/L) or rainbow trout (*Onchorynchus mykiss*: minimum LC50 of 13.8 µg/L). For graying, there was a difference in sensitivity in different years (eggs hatched and tested in 1985 vs 1986 vs 1987). The observed LC50 by year for grayling juveniles was as follows:

- 1985: 2.6 µg/L
- 1986: 30.0 µg/L
- 1987: 49.3 µg/L

Arctic grayling juveniles were observed to be more sensitive than the other two species tested for arsenic and zinc as well.

Table 8-2: Toxicological thresholds for chronic effects on Young-of-Year (YOY) Arctic Grayling (*Thymallus arcticus*)

Substance of Concern	Species	Lifestage	Benchmark	Value (µg/L) Mean (95% UCLM)	Reference
Arsenic (as arsenate)	Arctic Grayling	fry [AK][a]	96 h LC_{50}	5020 (3510-7170)	[1]
		0.20 g ww [AK]		4760 (3830-5920)	[1]
		0.34 g ww [AK]		5500 (4050-7470)	[1]
		alevin [MT] [b]		102000 (75000-141000)	[1]
		0.85 g ww [MT]		47700 (35000-65000)	[1]
		alevin [MT]		197000 (145000-267000)	[1]
		0.97 g ww [MT]		32500 (25300-41600)	[1]
		1.85 g ww [MT]		30900 (21900-43600)	[1]
Copper	Arctic Grayling	fry [AK]	96 h LC_{50}	9.6 (6.9 – 13.3)	[1]
		0.20 g ww [AK]		2.70 (1.87 – 3.90)	[1]
		0.34 g ww [AK]		2.58 (1.73 – 3.84)	[1]
		alevin [MT][b]		67.5 (48.6 – 93.7)	[1]
		alevin [MT]		23.9 (20.1 – 28.4)	[1]
		0.85 g ww [MT]		30.0 (20.2 – 44.6)	[1]
		alevin [MT]		131 (110-155)	[1]
		0.85 g ww [MT]		49.3 (40.3-60.3)	[1]
Lead		fry [AK]	96 h LC_{50}	12000 (9200-15600)	[1]
		0.34 g ww [AK]		<320	[1]
		alevin [MT]		>36000	[1]
		0.85 g ww [MT]		<1700	[1]
		alevin [MT]		>36000	[1]
		0.97 g ww [MT]		<1000	[1]
Zinc		fry [AK]	96 h LC_{50}	315 (234-424)	[1]
		0.20 g ww [AK]		142 (114-178)	[1]
		0.34 g ww [AK]		112 (83-150)	[1]
		alevin [MT]		1580 (900-2770)[c]	[1]
		0.85 g ww [MT]		166 (127-217)	[1]
		alevin [MT]		2920 (2510-3400)	[1]
		0.97 g ww [MT]		168 (143-197)	[1]
		1.85 g ww [MT]		168 (96-295)	

References: [1] Buhl, K.J. and S. J. Hamilton, 1990. *Comparative toxicity of inorganic contaminants released by placer mining to early life stages of salmonids.* Ecotox. Environ. Safety 20: 325-342.

Notes: [a]: stock sourced from Alaska hatchery
[b] : stock sourced from Montana hatchery
[c]: only 50% mortality observed in highest test conc.

Buhl and Hamilton (1990) further demonstrated that testing with mixtures of arsenate, copper, lead and zinc did not appreciably alter copper toxicity thresholds.

When these four metals/metalloids were added to test water at concentrations approximating ratios in effluent from placer operations, it was concluded that copper accounted for greater than 97% of the summed toxicity units.

Buhl and Hamilton (1991) reported on the toxicity to juvenile life stages of Arctic grayling of nine metals/metalloids in addition to the four reported in their 1990 paper, including arsenite, cadmium, hexavalent chromium, gold, mercury, nickel, selenate, selenite, and silver. Of these, arsenic, cadmium, mercury and nickel are relevant to the interpretation of the Lupin Cycle 3 data, since these were observed in surface water samples at concentrations exceeding Canadian water quality guidelines for freshwater life protection. A summary of the Buhl and Hamilton (1991) toxicity data for grayling are provided below.

Table 8-3: Toxicological Thresholds of Sub-adult Arctic Grayling for Arsenite, Cadmium, Mercury and Nickel (adapted from Buhl and Hamilton, 1991)

Substance	Alevin		Juvenile		Lupin Exposure Area 2010 Range
	96 h LC50	95% Confidence Range	96 h LC50	95% Confidence Range	
Arsenite	27700	23500-32700	13700	11600-16100	4.1-8.2
Cadmium	6.1	4.7-7.8	4.0	1.5-9.7	0.014-0.060
Mercury	124	106-146	218	186-256	<0.020-0.073
Nickel	8200	5600-12000	8700	6700-11400	18-35

8.2.2 Overall Interpretations

It is concluded from the ecotoxicological thresholds presented above that the majority of the inorganics measured in surface water samples from the Lupin Mine Exposure Area were far below threshold concentrations beyond which adverse effects to juvenile Arctic grayling might be expected. The exception to this was total copper, which occurred in water samples in 2010 at concentrations in the range of 3.5 to 6.0 µg/L.

This is in the range that small steelhead fry (*Salmo gairdneri*) have been observed to exhibit mortality (pH 5.7: 96h LC50 of 4.2 µg/L; pH 7.0: 96h LC50 of 2.8 µg/L). In addition, Buhl and Hamilton (1990) observed in Arctic grayling juveniles a copper LC50 in the range of 2.6 to 9.6 µg/L. Alevins were reportedly less sensitive than juveniles, with observed copper LC50s in the range from 24 to 131 µg/L.
Spear and Pierce (1979) suggest that adverse effects on growth of freshwater fish would occur at similar or perhaps higher ranges of copper than mortality; i.e. at waterborne concentrations in soft water in the range from 10 to 100 µg/L.

The actual 2010 water sample data for the Lupin Mine Exposure Area is shown below:

- SCP-1: 3.5 µg/L
- SCF-1: 5.3 µg/L
- SNP 925-20: 4.3 µg/L
- SCD-1: 6.0 µg/L

It cannot be precluded that copper exposures in the water are having an effect on juvenile recruitment, through enhanced mortality of early life stages or decreased growth and indirect longer term survival. Nonetheless, the available scientific knowledge suggests that effects if any would be very subtle and hard to detect in field populations, even in the absence of acclimatization or adaptation.

Toxicological thresholds are compared above to observed concentrations of copper and other inorganic substances in water column samples collected in July 2010. Prior to swim-up, developing eggs would be exposed to interstitial water contained within sediments in spawning areas. It is possible that sediment interstitial water in the Exposure Area would exhibit higher concentrations of mining-related inorganic substances than the overlying surface waters. For preferred spawning habitat, however, the degree of porosity of pea-sized gravels and high rates of diffusive and advective exchange with overlying water would suggest a substantial similarity between interstitial water and overlying water concentrations. Interstitial waters in the creek bed have the potential to exhibit higher concentrations of inorganic elements than overlying waters in areas affected by sorption to sediments from historical effluent discharge and in increasingly finer sediments. Such sediments, however, would comprise less favourable spawning habitat from a number of perspectives, including especially oxygen availability and degree of exposure to metabolites associated with early diagenesis of streambed sediments, including ammonia and sulfide. Furthermore, high concentrations of copper or other inorganic substances in sediment interstitial water would likely have the primary effect of decreasing hatching success and the viability of swim-up fry.

The fact that 0+ Arctic grayling are relatively abundant in the Exposure Area suggests that interstitial water quality is having a very minor if any on effect recruitment to the swim-up stage.

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Appendix A

Water Quality – Field and Lab Data

Table A-1. Field Data collected during installation of temperature loggers

07-Jul-10 Zone 12W

Logger #	Name	Waterbody	Time	E	N	Location Description	Temp (°C)	pH	DO (mg/L)	Conductivity (micro-S/ cm)	Width (m)	Depth (m)	Velocity (m/s)	Photos
9765603	TL6	Ref Crk#2	8:30 AM	0499300 E	7285661 N	~30m u/s of mouth; on CUB	8	7	11.1	2.5	0.8	0.44	0.3	303-311
9765607	TL5	Ref Crk#2	9:10 AM	0497305 E	7286445 N	b/w two low spots	10.5	7.5	8.9	8	1.3	0.24	0.2	312-313
9765608	TL4	Ref Crk#1 (Fingers Creek)	9:40 AM	0496103 E	7290874 N	~20-25 m u/s of mouth	10.5	7.3	10.6	4	1.4	1.45	0.33	314-328
9765610	TL3	Ref Crk#1	10:15 AM	0495665 E	7290042 N	~400 m u/s of mouth	10	7	10.2	5	1.95	0.65	0.33	329-330
9765611	TL2	Seep Creek	10:50 AM	0480323 E	7289985 N	d/s	13.1	6.7	10.1	48	3	0.27	0.33	333-336
9765612	TL1	Seep Creek	11:15 AM	0482157 E	7290265 N	u/s above second pond	13.2	6.62	10.2	61	2.5	0.4	0.2	338-339
9722569		Ref Crk#5	11:50 AM	0480307 E	7291329 N	creek north of Seep Creek	12.1	6.9	10.4	3	1.2	0.45	0.33	340-341

Table A-2. Field Data Collected During Sampling Program

Site	Date	Zone	Easting	Northing	Depth (m)	Air Temp (Celcius)	Temp (Celcius)	D.O (mg/L)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Methed in Use	Comments
SCD1	40417	12W	485695	7289659		2	-	-	-	-	-	Water	
SCP1	40413	12W	481289	7290694		13	12	10.5	8.24	61	6.37	Water, Sediments	Exposure Area - Pond 1, Replicate SCF1
SCP2	40413	12W	481065	7290479		13	-	-	-	-	-	Sediments	
SCP3	40413	12W	480953	7290309		13	-	-	-	-	-	Sediments	
SCP4	40413	12W	480747	7290395		13	-	-	-	-	-	Sediments	
SCP5	40413	12W	480594	7290521		13	13.8	9.1	8.4	60	7.33	Sediments	Exposure Area - Pond 2
SNP925	40417	12W	480216	7290212		2	-	-	-	-	-	Water	
FC	40408	12W	496044	7290859		10	5.8		7.5	6		Habitat Assessment	The assessment and the sample were taken from the same creek on different days
FC2	40417	12W	494671	7289051		2	-	-	-	-	-	Water	
FL1	40411	12W	492274	7286480		11	-	-	-	-	-	Water, Sediments	
FL2	40411	12W	493858	7287207		11	-	-	-	-	-	Sediments	
FL3	40411	12W	493717	7287001		11	10.8	10.3	8.13	5	1.78	Water, Sediments	
FL4	40411	12W	492970	7286781		11	-	-	-	-	-	Sediments	
FL5	40411	12W	492552	7286547		11	-	-	-	-	-	Sediments	
R2-1	40416	12W	497453	7284512		10	12.8	9.7	8.11	11	1.07	Water, Sediments	Reference Area 2 - Pond 2
R2-2	40416	12W	497305	7285367		10	-	-	-	-	-	Water, Sediments	
R2-3	40416	12W	495558	7287668		10	10.5	10.2	8.69	5	1.55	Water, Sediments	Reference Area 2 - Pond 1
R2-4	40416	12W	497648	7284697		10	-	-	-	-	-	Sediments	
R2-5	40416	12W	494949	7287511		10	-	-	-	-	-	Sediments	

Table A-3. Water Quality Lab Results

Sample ID	Units	CCME Aquatic Life					Reference Area 1 FL3	FL5	FC2	Reference Area 2 R2-1	R2-2	R2-3
Date Sampled			23-AUG-10	23-AUG-10	27-AUG-10	27-AUG-10	21-AUG-10	21-AUG-10	27-AUG-10	26-AUG-10	26-AUG-10	26-AUG-10
Time Sampled			09:30	10:00	10:30	11:00	11:30	10:30	09:00	09:30	10:30	12:30
ALS Sample ID			L923781-1	L923781-2	L925725-2	L925725-3	L923262-1	L923262-2	L925725-1	L925358-1	L925358-2	L925358-3
Matrix			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests												
Total Suspended Solids	mg/L		<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Conductivity (EC)	uS/cm		71.6	71.5	67.3	217	11.5	11.7	13.2	10.6	10.2	15.9
Hardness (as CaCO3)	mg/L		24.2	25.0	22.9	68.3	4.0	4.0	5.8	4.2	3.2	5.4
pH	pH	6.5-9.0	6.69	6.76	6.86	6.89	6.78	6.75	6.92	6.46	6.74	6.67
TDS (Calculated)	mg/L		36.0	36.6	37.1	132	4.2	4.1	5.1	3.7	3.3	6.8
Major Ions												
Alkalinity, Total (as CaCO3)	mg/L		<5.0	<5.0	6.2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bicarbonate (HCO3)	mg/L		5.2	5.5	7.6	<5.0	5.1	<5.0	<5.0	<5.0	<5.0	<5.0
Carbonate (CO3)	mg/L		<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	mg/L		1.12	1.15	1.50	11.0	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fluoride (F)	mg/L		0.054	0.057	0.066	0.129	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Hydroxide (OH)	mg/L		<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion Balance	%		Low EC	Low EC	Low EC	105	Low EC	Low EC	Low EC	Low EC	Low EC	Low EC
Sulfate (SO4)	mg/L		23.7	24.3	20.8	79.5	2.49	2.49	2.49	1.90	1.94	4.58
Nutrients												
Ammonia-N	mg/L	0.019	0.0101	0.0141	0.0086	0.0086	<0.0050	<0.0050	<0.0050	<0.0050	0.0079	<0.0050
Nitrate+Nitrite-N	mg/L		0.0647	0.0357	<0.0060	0.0125	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060
Nitrate-N	mg/L	13	0.0647	0.0357	<0.0060	0.0125	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060
Nitrite-N	mg/L	0.06	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Phosphorus, Total	mg/L		0.0036	0.0033	0.0027	0.0036	<0.0010	0.0185	0.0016	0.0046	0.0038	0.0448
Cyanides												
Cyanide, Total	mg/L	0.005	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Organic / Inorganic Carbon												
Dissolved Organic Carbon	mg/L		6.4	6.3	10.4	5.1	3.1	3.7	3.1	4.1	4.3	4.4
Total Organic Carbon	mg/L		6.6	6.5	10.7	5.2	3.3	3.2	3.4	4.2	4.1	4.4
Total Metals (Undigested)												
Aluminum (Al)-Total	mg/L	0.005-0.1[b]	0.074	0.112	0.0864	0.0310	0.0133	0.0374	0.0171	0.0162	0.0165	0.0268
Antimony (Sb)-Total	mg/L		<0.00040	<0.00040	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Arsenic (As)-Total	mg/L	0.005	0.00406	0.00544	0.00672	0.00816	0.00171	0.00167	0.00175	0.000704	0.000683	0.000698
Barium (Ba)-Total	mg/L		0.00845	0.00884	0.00631	0.00880	0.00153	0.00168	0.00190	0.00162	0.00149	0.00237
Beryllium (Be)-Total	mg/L		<0.0010	<0.0010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Bismuth (Bi)-Total	mg/L		<0.00020	<0.00020	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Boron (B)-Total	mg/L		<0.020	<0.020	0.0053	0.0198	0.0025	0.0028	0.0022	0.0031	0.0029	0.0023
Cadmium (Cd)-Total	mg/L	0.000017[c]	***0.000023***	<0.00020	<0.000050	***0.000065***	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Cadmium (Cd)-Total	mg/L				0.000014	0.000060	<0.000010	<0.000010	<0.000010			
Calcium (Ca)-Total	mg/L		5.34	4.89	5.37	17.1	0.856	0.781	0.955	0.777	0.757	1.24
Chromium (Cr)-Total	mg/L	0.001	<0.00080	<0.00080	0.000388	0.000063	0.000069	0.000130	0.000079	0.000065	<0.000060	0.000063
Cobalt (Co)-Total	mg/L		0.00261	0.00301	0.00120	0.00352	<0.00010	<0.00010	0.00016	0.00011	0.00010	0.00020
Copper (Cu)-Total	mg/L	0.002-0.004[d]	***0.0035***	***0.0053***	***0.00427***	***0.00597***	<0.00060	<0.00060	<0.00060	0.00088	0.00093	0.00300
Iron (Fe)-Total	mg/L	0.3	***0.382***	***0.463***	***0.760***	***0.157***	0.0384	0.0449	0.0942	0.0709	0.0689	0.0989
Lead (Pb)-Total	mg/L	0.001-0.007[e]	<0.00010	0.00010	<0.000050	0.000062	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000090
Lithium (Li)-Total	mg/L				0.00526	0.00931	0.00100	0.00115	0.00120	0.00125	0.00122	0.00160
Magnesium (Mg)-Total	mg/L		2.59	2.34	2.39	4.80	0.547	0.539	0.600	0.449	0.446	0.705
Manganese (Mn)-Total	mg/L		0.0360	0.0356	0.0226	0.0800	0.00436	0.00352	0.0116	0.00417	0.00329	0.00311
Mercury (Hg)-Total	mg/L	0.000026	<0.000020	0.000073	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Total	mg/L	0.073	0.00010	0.00014	0.000162	0.000115	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Nickel (Ni)-Total	mg/L	0.025-0.15[f]	***0.0255***	***0.0258***	***0.0175***	***0.0354***	0.000504	0.000526	0.000650	0.00177	0.00193	0.00723
Potassium (K)-Total	mg/L		0.13	0.37	0.550	1.93	0.386	0.410	0.435	0.408	0.403	0.425
Selenium (Se)-Total	mg/L	0.001	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Silver (Ag)-Total	mg/L	0.0001	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Total	mg/L		2.3	2.2	2.72	13.6	0.474	0.443	0.474	0.480	0.480	0.643
Strontium (Sr)-Total	mg/L		0.0266	0.0265	0.0283	0.0797	0.00472	0.00476	0.00563	0.00456	0.00440	0.00724
Thallium (Tl)-Total	mg/L		<0.00010	<0.00010	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Tin (Sn)-Total	mg/L		<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L		<0.0050	<0.0050	0.00070	0.00013	0.00034	0.00090	0.00025	0.00016	0.00017	<0.00010
Uranium (U)-Total	mg/L		<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Vanadium (V)-Total	mg/L		<0.00050	<0.00050	0.000303	<0.000050	<0.000050	0.000106	<0.000050	<0.000050	<0.000050	<0.000050
Zinc (Zn)-Total	mg/L	0.03	0.0130	0.0136	0.00823	***0.0507***	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	0.00124

Sample ID	Units	CCME Aquatic Life					Reference Area 1			Reference Area 2		
							FL3	FL5	FC2	R2-1	R2-2	R2-3
Dissolved Metals												
Aluminum (Al)-Dissolved	mg/L		0.054	0.054	0.0696	0.0146	0.00610	0.00907	0.00754	0.0196	0.00871	0.0177
Antimony (Sb)-Dissolved	mg/L		<0.00040	<0.00040	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Arsenic (As)-Dissolved	mg/L		0.00363	0.00364	0.00547	0.00495	0.00150	0.00159	0.00152	0.000723	0.000659	0.000685
Barium (Ba)-Dissolved	mg/L		0.00844	0.00831	0.00602	0.00879	0.00165	0.00152	0.00178	0.00164	0.00147	0.00231
Beryllium (Be)-Dissolved	mg/L		<0.00050	<0.00050	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Bismuth (Bi)-Dissolved	mg/L		<0.000050	<0.000050	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Boron (B)-Dissolved	mg/L		0.0060	0.0056	0.0056	0.0195	0.0030	0.0033	0.0026	0.0035	0.0035	0.0026
Cadmium (Cd)-Dissolved	mg/L		<0.00010	0.000025	0.000080	0.000070	<0.00001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Calcium (Ca)-Dissolved	mg/L		5.44	5.59	5.35	18.9	0.83	0.836	1.09	0.85	0.746	1.29
Chromium (Cr)-Dissolved	mg/L		<0.00040	<0.00040	0.000309	<0.000060	<0.000060	0.00197	<0.000060	0.000086	<0.000060	0.000068
Cobalt (Co)-Dissolved	mg/L		0.00246	0.00245	0.00111	0.00344	<0.00010	<0.00010	0.00013	0.00011	<0.00010	0.00015
Copper (Cu)-Dissolved	mg/L		0.00321	0.00323	0.00407	0.00527	<0.00060	<0.00060	<0.00060	0.00095	0.00101	0.00282
Iron (Fe)-Dissolved	mg/L		-	-	0.407	0.0614	0.0220	0.0410	0.0390	0.0660	0.0052	0.0285
Lead (Pb)-Dissolved	mg/L		<0.00010	<0.00010	0.000057	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L		-	-	0.00538	0.00909	0.00097	0.00103	0.00121	0.00120	0.00121	0.00164
Magnesium (Mg)-Dissolved	mg/L		2.57	2.67	2.38	5.12	0.46	0.48	0.595	0.458	0.439	0.702
Manganese (Mn)-Dissolved	mg/L		-	-	0.0218	0.0774	0.00259	0.00135	0.00998	0.00383	0.00139	0.00215
Mercury (Hg)-Dissolved	mg/L		<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Dissolved	mg/L		<0.00010	<0.00010	0.000156	0.000110	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Nickel (Ni)-Dissolved	mg/L		0.0251	0.0247	0.0172	0.0346	0.000476	0.000474	0.000699	0.00189	0.00191	0.00716
Potassium (K)-Dissolved	mg/L		0.49	0.42	0.76	1.96	0.388	0.32	0.68	0.403	0.35	0.429
Selenium (Se)-Dissolved	mg/L		<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Silver (Ag)-Dissolved	mg/L		<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L		2.3	2.3	2.6	13.1	0.441	<1.0	0.474	0.495	0.515	0.646
Strontium (Sr)-Dissolved	mg/L		0.0264	0.0265	0.0280	0.0803	0.00494	0.00464	0.00559	0.00464	0.00442	0.00718
Thallium (Tl)-Dissolved	mg/L		<0.000050	<0.000050	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Tin (Sn)-Dissolved	mg/L		<0.00020	0.00047	0.00045	<0.00010	0.00012	0.00028	<0.00010	0.00032	0.00508	0.00014
Titanium (Ti)-Dissolved	mg/L		0.00057	0.00061	0.00058	<0.00010	<0.00010	0.00034	0.00012	0.00046	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L		<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Vanadium (V)-Dissolved	mg/L		<0.00010	<0.00010	0.000237	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Zinc (Zn)-Dissolved	mg/L		0.0164	0.0169	0.00827	0.0490	0.00110	<0.00080	<0.00080	0.00187	0.00241	0.00142
85												
220&(blank)&Radium-226	Bq/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007

Al *b) 0.005mg/L at pH < 6.5, [Ca2+] < 4 mg/L, DOC < 2 mg/L: 0.1 mg/L at pH ≥ 6.5, [Ca2+] ≥ 4 mg/L, DOC ≥ 2 mg/L*

Cd *c) Hardness based guideline = $10^{\{0.86[\log(hardness)]-3.2\}}$*

Cu *d) 0.002 mg/L at [CaCO3] = 0 - 120 mg/L; 0.003 mg/L at [CaCO3] =120 - 180 mg/L; 0.004 mg/L at [CaCO3] >180mg/L*

Pb *e) 0.001 mg/L at [CaCO3] = 0 - 60 mg/L; 0.002 mg/L at [CaCO3] =60 - 120 mg/L; 0.004 mg/L at [CaCO3] =120 -180mg/L; 0.007 mg/L at [CaCO3] > 180mg/L*

Ni *f) 0.025 mg/L at [CaCO3] = 0 - 60 mg/L; 0.065 mg/L at [CaCO3] =60 - 120 mg/L; 0.110 mg/L at [CaCO3] =120 -180mg/L; 0.150 mg/L at [CaCO3] > 180mg/L*

italics *results exceed CCME Aquatic Life Guidelines*

Table A-4. Water Quality Detection Limits

	Units		Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits	Detection Limits
Sample ID		CCME Aquatic Life	SCP-1	SCP-1-rep	SNP 925	SCD-1	FL3	FL5	FC2	R2-1	R2-2	R2-3	FB	TB
Date Sampled														
Time Sampled														
ALS Sample ID														
Matrix														
Physical Tests														
Total Suspended Solids	mg/L	6.5-9.0	3.0											
Conductivity (EC)	uS/cm		0.20											
Hardness (as CaCO3)	mg/L		-											
pH	pH		0.10											
TDS (Calculated)	mg/L		-											
Major Ions														
Alkalinity, Total (as CaCO3)	mg/L		5.0											
Bicarbonate (HCO3)	mg/L		5.0											
Carbonate (CO3)	mg/L		5.0											
Chloride (Cl)	mg/L		0.50											
Fluoride (F)	mg/L		0.050											
Hydroxide (OH)	mg/L		5.0											
Ion Balance	%		-											
Sulfate (SO4)	mg/L		0.050											
Nutrients														
Ammonia-N	mg/L	0.019	0.0050											
Nitrate+Nitrite-N	mg/L		0.0060											
Nitrate-N	mg/L	13	0.0060											
Nitrite-N	mg/L	0.06	0.0020											
Phosphorus, Total	mg/L		0.0010											
Cyanides														
Cyanide, Total	mg/L	0.005	0.0020											
Organic / Inorganic Carbon														
Dissolved Organic Carbon	mg/L		1.0											
Total Organic Carbon	mg/L		1.0											
Total Metals (Undigested)			**Low-Level**		**Ultra-low level**									
Aluminum (Al)-Total	mg/L	0.005-0.1[b]	0.020		0.00030									
Antimony (Sb)-Total	mg/L		0.00040		0.000030									
Arsenic (As)-Total	mg/L	0.005	0.00040		0.000030									
Barium (Ba)-Total	mg/L		0.00020		0.000050									
Beryllium (Be)-Total	mg/L		0.0010		0.00020									
Bismuth (Bi)-Total	mg/L		0.00020		0.000030									
Boron (B)-Total	mg/L		0.020		0.0010									
Cadmium (Cd)-Total	mg/L	0.000017[c]	0.00020		0.000050									
Cadmium (Cd)-Total	mg/L		-		0.000010									
Calcium (Ca)-Total	mg/L		0.50		0.020									
Chromium (Cr)-Total	mg/L	0.001	0.00080		0.000060									
Cobalt (Co)-Total	mg/L		0.00020		0.00010									
Copper (Cu)-Total	mg/L	0.002-0.004[d]	0.0010		0.00060									
Iron (Fe)-Total	mg/L	0.3	0.010		0.0050									
Lead (Pb)-Total	mg/L	0.001-0.007[e]	0.00010		0.000050									
Lithium (Li)-Total	mg/L		0.10		0.00010									
Magnesium (Mg)-Total	mg/L		0.0020		0.0040									
Manganese (Mn)-Total	mg/L		0.000020		0.00010									
Mercury (Hg)-Total	mg/L	0.000026	-		0.000020									
Molybdenum (Mo)-Total	mg/L	0.073	0.00010		0.000060									
Nickel (Ni)-Total	mg/L	0.025-0.15[f]	0.00020		0.000060									
Potassium (K)-Total	mg/L		0.10		0.020									
Selenium (Se)-Total	mg/L	0.001	0.00040		0.00010									
Silver (Ag)-Total	mg/L	0.0001	0.00040		0.00010									
Sodium (Na)-Total	mg/L		1.0		0.0050									
Strontium (Sr)-Total	mg/L		0.00020		0.00010									
Thallium (Tl)-Total	mg/L		0.00010		0.000030									
Tin (Sn)-Total	mg/L		0.00040		0.00010									
Titanium (Ti)-Total	mg/L		0.0050		0.00010									
Uranium (U)-Total	mg/L		0.00010		0.000050									
Vanadium (V)-Total	mg/L		0.00050		0.000050									
Zinc (Zn)-Total	mg/L	0.03	0.0040		0.00080									
Dissolved Metals			**Low-Level**		**Ultra-low level**									
Aluminum (Al)-Dissolved	mg/L		0.010		0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030
Antimony (Sb)-Dissolved	mg/L		0.00040		0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030
Arsenic (As)-Dissolved	mg/L		0.00040		0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030
Barium (Ba)-Dissolved	mg/L		0.00010		0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Beryllium (Be)-Dissolved	mg/L		0.00050		0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
Bismuth (Bi)-Dissolved	mg/L		0.000050		0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030
Boron (B)-Dissolved	mg/L		0.0020		0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Cadmium (Cd)-Dissolved	mg/L		0.000010		0.000050	0.000050	0.000050	0.000010	0.000010	0.000050	0.000050	0.000050	0.000050	0.000050
Calcium (Ca)-Dissolved	mg/L		0.50		0.50	0.020	0.020	0.50	0.50	0.020	0.50	0.50	0.020	0.020
Chromium (Cr)-Dissolved	mg/L		0.00040		0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060
Cobalt (Co)-Dissolved	mg/L		0.00010		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Copper (Cu)-Dissolved	mg/L		0.00060		0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
Iron (Fe)-Dissolved	mg/L		-		0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Lead (Pb)-Dissolved	mg/L		0.00010		0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Lithium (Li)-Dissolved	mg/L		-		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Magnesium (Mg)-Dissolved	mg/L		0.10		0.10	0.0040	0.0040	0.0040	0.10	0.10	0.10	0.10	0.0040	0.10
Manganese (Mn)-Dissolved	mg/L		-		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Mercury (Hg)-Dissolved	mg/L		0.000020		0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020
Molybdenum (Mo)-Dissolved	mg/L		0.00010		0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060
Nickel (Ni)-Dissolved	mg/L		0.00010		0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060	0.000060
Potassium (K)-Dissolved	mg/L		0.10		0.020	0.020	0.10	0.020	0.020	0.10	0.020	0.10	0.10	0.020
Selenium (Se)-Dissolved	mg/L		0.00040		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Silver (Ag)-Dissolved	mg/L		0.00020		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Sodium (Na)-Dissolved	mg/L		1.0		0.0050	1.0	1.0	0.0050	1.0	1.0	1.0	1.0	0.0050	0.0050
Strontium (Sr)-Dissolved	mg/L		0.00010		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Thallium (Tl)-Dissolved	mg/L		0.000050		0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030	0.000030
Tin (Sn)-Dissolved	mg/L		0.00020		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Titanium (Ti)-Dissolved	mg/L		0.00030		0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Uranium (U)-Dissolved	mg/L		0.00010		0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Vanadium (V)-Dissolved	mg/L		0.000225		0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Zinc (Zn)-Dissolved	mg/L		0.00025		0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080
85														
220&(blank)&Radium-226	Bq/L		0.01											

Table A-5. Water Quality Lab Results - QA/QC

				Expsosure Area					
Sample ID	**Units**	**CCME Aquatic Life**	**DL**	**SCP1**	**SCP1-rep**	**RPD (%)**	**DL**	**FB- FIELD BLANK**	**TB- TRIP BLANK**
Date Sampled				23-AUG-10	23-AUG-10			23-AUG-10	23-AUG-10
Time Sampled				09:30	10:00			11:00	11:00
ALS Sample ID				L923781-1	L923781-2			L923781-3	L923781-4
Matrix				Water	Water			Water	Water
Physical Tests									
Total Suspended Solids	mg/L		3.0	<3.0	<3.0			<3.0	<3.0
Conductivity (EC)	uS/cm		0.20	71.6	71.5	0.14%		0.92	0.81
Hardness (as CaCO3)	mg/L		-	24.2	25.0	3.25%		<1.0	<1.0
pH	pH	6.5-9.0	0.10	6.69	6.76	1.04%		6.20	5.82
TDS (Calculated)	mg/L		-	36.0	36.6	1.65%		<1.0	<1.0
Major Ions									
Alkalinity, Total (as CaCO3)	mg/L		5.0	<5.0	<5.0			<5.0	<5.0
Bicarbonate (HCO3)	mg/L		5.0	5.2	5.5	5.61%		<5.0	<5.0
Carbonate (CO3)	mg/L		5.0	<5.0	<5.0			<5.0	<5.0
Chloride (Cl)	mg/L		0.50	1.12	1.15	2.64%		<0.50	<0.50
Fluoride (F)	mg/L		0.050	0.054	0.057	5.41%		<0.050	<0.050
Hydroxide (OH)	mg/L		5.0	<5.0	<5.0			<5.0	<5.0
Ion Balance	%		-	Low EC	Low EC			Low TDS	Low TDS
Sulfate (SO4)	mg/L		0.050	23.7	24.3	2.50%		<0.050	<0.050
Nutrients									
Ammonia-N	mg/L	0.019	0.0050	0.0101	0.0141	33.06%		<0.0050	<0.0050
Nitrate+Nitrite-N	mg/L		0.0060	0.0647	0.0357	57.77%		<0.0060	<0.0060
Nitrate-N	mg/L	13	0.0060	0.0647	0.0357	57.77%		<0.0060	<0.0060
Nitrite-N	mg/L	0.06	0.0020	<0.0020	<0.0020			<0.0020	<0.0020
Phosphorus, Total	mg/L		0.0010	0.0036	0.0033	8.70%		<0.0010	<0.0010
Cyanides									
Cyanide, Total	mg/L	0.005	0.0020	<0.0020	<0.0020			<0.0020	<0.0020
Organic / Inorganic Carbon									
Dissolved Organic Carbon	mg/L		1.0	6.4	6.3	1.57%		<1.0	<1.0
Total Organic Carbon	mg/L		1.0	6.6	6.5	1.53%		<1.0	<1.0
Total Metals (Undigested)			**Low-Level**						
Aluminum (Al)-Total	mg/L	0.005-0.1[b]	0.020	0.074	0.112	40.86%	0.00030	0.00032	<0.00030
Antimony (Sb)-Total	mg/L		0.00040	<0.00040	<0.00040		0.000030	<0.000030	<0.000030
Arsenic (As)-Total	mg/L	0.005	0.00040	0.00406	0.00544	29.05%	0.000030	<0.000030	<0.000030
Barium (Ba)-Total	mg/L		0.00020	0.00845	0.00884	4.51%	0.000050	0.000071	<0.000050
Beryllium (Be)-Total	mg/L		0.0010	<0.0010	<0.0010		0.00020	<0.00020	<0.00020
Bismuth (Bi)-Total	mg/L		0.00020	<0.00020	<0.00020		0.000030	<0.000030	<0.000030
Boron (B)-Total	mg/L		0.020	<0.020	<0.020		0.0010	0.0025	0.0021
Cadmium (Cd)-Total	mg/L	0.000017[c]	0.00020	0.000023	<0.00020		0.000050	<0.000050	<0.000050
Cadmium (Cd)-Total	mg/L		-				0.000010	<0.000010	<0.000010
Calcium (Ca)-Total	mg/L		0.50	5.34	4.89	8.80%	0.020	0.022	<0.020
Chromium (Cr)-Total	mg/L	0.001	0.00080	<0.00080	<0.00080		0.000060	<0.000060	<0.000060
Cobalt (Co)-Total	mg/L		0.00020	0.00261	0.00301	14.23%	0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	0.002-0.004[d]	0.0010	***0.0035***	***0.0053***	40.91%	0.00060	<0.00060	<0.00060
Iron (Fe)-Total	mg/L	0.3	0.010	***0.382***	***0.463***	19.17%	0.0050	<0.0050	<0.0050
Lead (Pb)-Total	mg/L	0.001-0.007[e]	0.00010	<0.00010	0.00010		0.000050	<0.000050	<0.000050
Lithium (Li)-Total	mg/L		0.10				0.00010	0.00049	0.00045
Magnesium (Mg)-Total	mg/L		0.0020	2.59	2.34	10.14%	0.0040	<0.0040	<0.0040
Manganese (Mn)-Total	mg/L		0.000020	0.0360	0.0356	1.12%	0.00010	<0.00010	<0.00010
Mercury (Hg)-Total	mg/L	0.000026	-	<0.000020	0.000073		0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Total	mg/L	0.073	0.00010	0.00010	0.00014	33.33%	0.000060	<0.000060	<0.000060
Nickel (Ni)-Total	mg/L	0.025-0.15[f]	0.00020	***0.0255***	***0.0258***	1.17%	0.000060	<0.000060	<0.000060
Potassium (K)-Total	mg/L		0.10	0.13	0.37	96.00%	0.020	<0.020	<0.020
Selenium (Se)-Total	mg/L	0.001	0.00040	<0.00040	<0.00040		0.00010	<0.00010	<0.00010
Silver (Ag)-Total	mg/L	0.0001	0.00040	<0.00040	<0.00040		0.00010	<0.00010	<0.00010
Sodium (Na)-Total	mg/L		1.0	2.3	2.2	4.44%	0.0050	0.0742	<0.0050
Strontium (Sr)-Total	mg/L		0.00020	0.0266	0.0265	0.38%	0.00010	<0.00010	<0.00010
Thallium (Tl)-Total	mg/L		0.00010	<0.00010	<0.00010		0.000030	<0.000030	<0.000030
Tin (Sn)-Total	mg/L		0.00040	<0.00040	<0.00040		0.00010	0.00850	<0.00010
Titanium (Ti)-Total	mg/L		0.0050	<0.0050	<0.0050		0.00010	<0.00010	<0.00010
Uranium (U)-Total	mg/L		0.00010	<0.00010	<0.00010		0.000050	<0.000050	<0.000050
Vanadium (V)-Total	mg/L		0.00050	<0.00050	<0.00050		0.000050	<0.000050	<0.000050
Zinc (Zn)-Total	mg/L	0.03	0.0040	0.0130	0.0136	4.51%	0.00080	<0.00080	<0.00080
Dissolved Metals			**Low-Level**						
Aluminum (Al)-Dissolved	mg/L		0.010	0.054	0.054	0.00%	0.00030	0.00212	<0.00030
Antimony (Sb)-Dissolved	mg/L		0.00040	<0.00040	<0.00040		0.000030	<0.000030	<0.000030
Arsenic (As)-Dissolved	mg/L		0.00040	0.00363	0.00364	0.28%	0.000030	0.000055	<0.000030
Barium (Ba)-Dissolved	mg/L		0.00010	0.00844	0.00831	1.55%	0.000050	0.000159	<0.000050
Beryllium (Be)-Dissolved	mg/L		0.00050	<0.00050	<0.00050		0.00020	<0.00020	<0.00020
Bismuth (Bi)-Dissolved	mg/L		0.000050	<0.000050	<0.000050		0.000030	<0.000030	<0.000030
Boron (B)-Dissolved	mg/L		0.0020	0.0060	0.0056	6.90%	0.0010	0.0023	0.0022
Cadmium (Cd)-Dissolved	mg/L		0.000010	<0.000010	0.000025		0.000050	<0.000010	<0.000010
Calcium (Ca)-Dissolved	mg/L		0.50	5.44	5.59	2.72%	0.020	<0.50	<0.50
Chromium (Cr)-Dissolved	mg/L		0.00040	<0.00040	<0.00040		0.000060	<0.000060	<0.000060
Cobalt (Co)-Dissolved	mg/L		0.00010	0.00246	0.00245	0.41%	0.00010	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L		0.00060	0.00321	0.00323	0.62%	0.00060	<0.00060	<0.00060
Iron (Fe)-Dissolved	mg/L		-	-	-		0.0050	<0.0050	<0.0050
Lead (Pb)-Dissolved	mg/L		0.00010	<0.00010	<0.00010		0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L		-	-	-		0.00010	0.00044	0.00048
Magnesium (Mg)-Dissolved	mg/L		0.10	2.57	2.67	3.82%	0.0040	<0.10	<0.0040
Manganese (Mn)-Dissolved	mg/L		-	-	-		0.00010	0.00036	<0.00010
Mercury (Hg)-Dissolved	mg/L		0.000020	<0.000020	<0.000020		0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Dissolved	mg/L		0.00010	<0.00010	<0.00010		0.000060	<0.000060	<0.000060
Nickel (Ni)-Dissolved	mg/L		0.00010	0.0251	0.0247	1.61%	0.000060	0.000248	<0.000060
Potassium (K)-Dissolved	mg/L		0.10	0.49	0.42	15.38%	0.10	<0.020	<0.10
Selenium (Se)-Dissolved	mg/L		0.00040	<0.00040	<0.00040		0.00010	<0.00010	<0.00010
Silver (Ag)-Dissolved	mg/L		0.00020	<0.00020	<0.00020		0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L		1.0	2.3	2.3	0.00%	0.0050	<1.0	<1.0
Strontium (Sr)-Dissolved	mg/L		0.00010	0.0264	0.0265	0.38%	0.00010	0.00024	<0.00010
Thallium (Tl)-Dissolved	mg/L		0.000050	<0.000050	<0.000050		0.000030	<0.000030	<0.000030
Tin (Sn)-Dissolved	mg/L		0.00020	<0.00020	0.00047		0.00010	0.00843	<0.00010
Titanium (Ti)-Dissolved	mg/L		0.00030	0.00057	0.00061	6.78%	0.00010	0.00013	<0.00010
Uranium (U)-Dissolved	mg/L		0.00010	<0.00010	<0.00010		0.000050	<0.000050	<0.000050
Vanadium (V)-Dissolved	mg/L		0.000225	<0.00010	<0.00010		0.000050	<0.000050	<0.000050
Zinc (Zn)-Dissolved	mg/L		0.00025	0.0164	0.0169	3.00%	0.00080	<0.00080	<0.00080
85									
220&(blank)&Radium-226	Bq/L		0.01	<0.01	<0.01		0.01	<0.01	<0.01

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007

Al *b) 0.005mg/L at pH < 6.5, [Ca2+] < 4 mg/L, DOC < 2 mg/L: 0.1 mg/L at pH $\geq$ 6.5, [Ca2+] $\geq$ 4 mg/L, DOC $\geq$ 2 mg/L*

Cd *c) Hardness based guideline = $10^{\{0.86[\log(hardness)]-3.2\}}$*

Cu *d) 0.002 mg/L at [CaCO3] = 0 - 120 mg/L; 0.003 mg/L at [CaCO3] =120 - 180 mg/L; 0.004 mg/L at [CaCO3] >180mg/L*

Pb *e) 0.001 mg/L at [CaCO3] = 0 - 60 mg/L; 0.002 mg/L at [CaCO3] =60 - 120 mg/L; 0.004 mg/L at [CaCO3] =120 -180mg/L; 0.007 mg/L at [CaCO3] > 180mg/L*

Ni *f) 0.025 mg/L at [CaCO3] = 0 - 60 mg/L; 0.065 mg/L at [CaCO3] =60 - 120 mg/L; 0.110 mg/L at [CaCO3] =120 -180mg/L; 0.150 mg/L at [CaCO3] > 180mg/L*

italics *results exceed CCME Aquatic Life Guidelines*

Appendix B

Sediment Quality – Lab Data

Table B-1. Sediment Quality Lab Results

										Reference Area 1					Reference Area 2				
Sample ID	**Units**	**ISQG[a]**	**PEL[b]**	**Detection Limits**						**FL1**	**FL2**	**FL3**	**FL4**	**FL5**	**R2-1**	**R2-2**	**R2-3**	**R2-4**	**R2-5**
Date Sampled					23-AUG-10	23-AUG-10	23-AUG-10	23-AUG-10	23-AUG-10	21-AUG-10	21-AUG-10	21-AUG-10	21-AUG-10	21-AUG-10	26-AUG-10	26-AUG-10	26-AUG-10	26-AUG-10	26-AUG-10
Time Sampled					10:30	11:30	12:30	13:30	15:00	16:00	12:30	12:00	14:30	15:30	10:00	11:00	11:30	14:00	15:00
ALS Sample ID					L923781-5	L923781-6	L923781-7	L923781-8	L923781-9	L923262-3	L923262-4	L923262-5	L923262-6	L923262-7	L925358-4	L925358-5	L925358-6	L925358-7	L925358-8
Matrix					Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Particle Size																			
% Sand	%			1.0	71.6	78.0	84.0	25.8	9.4	85.8	83.4	57.2	85.6	88.0	95.8	62.4	84.4	61.8	92.6
% Silt	%			1.0	23.2	16.4	12.6	72.4	85.4	12.2	15.0	38.6	11.8	10.2	3.0	33.2	13.4	36.2	7.0
% Clay	%			1.0	5.2	5.6	3.4	1.8	5.2	2.0	1.6	4.2	2.6	1.8	1.2	4.4	2.2	2.0	<1.0
Fragments > 2mm	%			1.0	<1.0	17.0	<1.0	<1.0	2.1	<1.0	<1.0	<1.0	6.7	<1.0	1.5	18.6	12.1	<1.0	<1.0
Organic / Inorganic Carbon																			
CaCO3 Equivalent	%			0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	1.51	<0.80	<0.80	<0.80
Inorganic Carbon	%			0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13	<0.10	<0.10	<0.10
Total Carbon by Combustion	%			0.1	3.7	2.5	0.6	1.5	3.3	0.4	0.5	5.0	0.4	0.4	0.5	6.2	0.5	1.2	0.4
Total Organic Carbon	%			0.10	3.68	2.45	0.62	1.49	3.28	0.38	0.54	4.96	0.35	0.44	0.51	6.04	0.52	1.21	0.39
Metals																			
Aluminum (Al)	mg/kg			50	6490	7220	5150	11000	14800	4170	4350	7890	3800	3890	4630	11800	3670	5480	4470
Antimony (Sb)	mg/kg			0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)	mg/kg	5.9	17.0	0.20	***146***	***196***	***35.1***	***36.0***	***50.6***	***11.2***	***11.1***	***24.7***	7.06	5.89	***6.96***	***17.8***	4.42	2.66	***6.15***
Barium (Ba)	mg/kg			5.0	42.2	65.3	31.9	52.0	65.8	32.1	35.8	47.8	30.8	27.9	36.8	64.9	20.5	43.4	34.8
Beryllium (Be)	mg/kg			1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium (Cd)	mg/kg	0.6	3.5	0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Chromium (Cr)	mg/kg	37.3	90.0	0.50	26.6	36.9	23.7	***57.1***	***74.6***	17.7	17.9	29.1	15.5	15.9	20.3	***59.4***	13.7	35.1	19.1
Cobalt (Co)	mg/kg			1.0	44.7	143	19.4	16.9	25.2	5.5	4.9	9.2	5.1	4.7	4.5	13.3	4.7	5.3	6.8
Copper (Cu)	mg/kg	35.7	197.0	2.0	***46.8***	***46.8***	19.2	22.3	31.2	8.3	6.8	27.1	7.7	6.9	3.7	***45.3***	9.6	13.8	10.2
Iron (Fe)	mg/kg			200	16200	23700	9360	17500	23600	7550	7280	13300	6380	7340	8040	27100	5590	7280	7750
Lead (Pb)	mg/kg	35.0	91.3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Mercury (Hg)	mg/kg	0.17	0.486	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Molybdenum (Mo)	mg/kg			1.0	1.8	3.4	<1.0	1.1	1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.7	<1.0	<1.0	<1.0
Nickel (Ni)	mg/kg			2.0	87.8	109	32.5	47.4	62.0	12.0	11.4	27.9	12.8	10.7	14.8	65.1	16.7	26.9	23.2
Selenium (Se)	mg/kg			0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Silver (Ag)	mg/kg			1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Strontium (Sr)	mg/kg			1.0	9.7	14.6	6.0	9.2	11.5	3.5	4.6	9.6	3.7	3.2	2.5	10.7	4.2	6.5	4.7
Thallium (Tl)	mg/kg			0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Tin (Sn)	mg/kg			5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Uranium (U)	mg/kg			2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Vanadium (V)	mg/kg			1.0	20.6	21.4	17.8	33.2	42.2	14.6	15.2	26.8	13.2	13.1	16.5	36.5	9.8	17.4	13.8
Zinc (Zn)	mg/kg	123	315	10	121	113	47	65	81	18	20	50	18	18	45	68	16	30	27

a) Interim Sediment Quality Guidelines, Canadian sediment quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2002
a) Probable Effects Levels, Canadian sediment quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2002

italics *results exceed ISQG*
italics *results exceed PEL*

Appendix C

Fish Survey Data – Field and Lab Data

Table C-1: Lupin 2010 Catch and Effort Summary Data for Electrofishing by Area

Area	Waypoint	NAD 83	Easting	Northing	Section Survey	Date	Length (m)	# Seconds	NSSB	BURB	ARGR	SLSC	RNWH	LKTR	ARCH
	44	12W	480153	7290206											
	45	12W	480265	7290206	44-45	27-Aug-10	100	926	22	1	2				
	46	12W	480353	7290187	45-46	27-Aug-10	100	886	21						
	47	12W	480411	7290180	46-47	27-Aug-10	60	612	5		3				
	48	12W	480500	7290231	47-48	28-Aug-10	100	1138	41		1				
	49	12W	480592	7290200	48-49	28-Aug-10	100	585	2		4				
Exposure	50	12W	480787	7290351	49-50	28-Aug-10		1046	5						
	51	12W	480787	7290346	50-51	28-Aug-10	255	1250	20		8				
	52	12W	480998	7290224	51-52	29-Aug-10	120	1240	11		4				
	53	12W	481181	7290326	52-53	29-Aug-10	110	839	17		2				
	54	12W	481220	7290333	53-54	29-Aug-10	50	521	6		1				
	55	12W	481344	7290684	54-55										
	56	12W	481425	7290662	55-56	29-Aug-10	100	731	43	1	3				
	57	12W	481515	7290642	56-57	29-Aug-10		554	83		2				
TOTAL								**10328**	**193**	**2**	**28**	**0**	**0**	**0**	**0**
	1	12W	496119	7291050											
	2	12W	496044	7290953	1-2	18-Aug-10	126	1012			1	13	1	4	
	3	12W	495985	7290851	2-3	18-Aug-10	120	889				1		1	
	4	12W	495957	7290730	3-4	18-Aug-10	125	525							
	5	12W	495926	7290569	4-5	18-Aug-10	165	1109			2		1		
	6	12W	495804	7290465	5-6	18-Aug-10	165	968				1		1	
	7	12W	495748	7290313	6-7	18-Aug-10	200	796			2			1	
	8	12W	495643	7290199	7-8	18-Aug-10	160	984		2		2			
	9	12W	495554	7290116	8-9	18-Aug-10	125	854				4		2	
Reference Area 1	10	12W	495473	7290026	9-10	19-Aug-10	120	576			2	2		2	
	11	12W	495407	7289929	10-11	19-Aug-10	120	635	2		2	3		3	
	12	12W	495376	7289828	11-12	19-Aug-10	120	567		2		2			
	13	12W	495272	7289689	12-13	19-Aug-10	175	877		1	1	6			
	14	12W	495236	7289562	13-14	19-Aug-10	150	789		4	1	3			
	15	12W	495766	7289447	14-15	19-Aug-10	150	839		4	2			1	
	16	12W	495143	7289319	15-16	19-Aug-10	150	790		2	2	3			
	17														
	18	12W	495036	7289172	16-18	19-Aug-10	200	1053	1	5	3	17			
	19	12W	494939	7289125	18-19	20-Aug-10	140	720	5		1	3			
	20	12W	494785	7289112	19-20	20-Aug-10	200	876	1	5	3	5			
	21	12W	494680	7288932	20-21	20-Aug-10	275	1109	7	5	3	8			
TOTAL								**15968**	**16**	**30**	**25**	**73**	**2**	**15**	**0**
	26	12W	499230	7285887											
	27	12W	499092	7285908	26-27	22-Aug-10	155	966	4			8			
	28	12W	498967	7285912	27-28	22-Aug-10	150	779	7	1	2	12	1	2	
	29	12W	498813	7285879	28-29	22-Aug-10	150	797	17	2	3	5		2	
	30	12W	498721	7285941	29-30	22-Aug-10	130	664	5		7	2	1	3	
	31	12W	498613	7285964	30-31	22-Aug-10	140	500	3		5	1			
	32	12W	498485	7285886	31-32	22-Aug-10	150	651	6		3	8	1	1	
	33	12W	498487	7285891	32-33	24-Aug-10	150	630	3		3	5			1
Reference Area 2	34	12W	498289	7286105	33-34	24-Aug-10	175	856	30		2	7	1		
	35	12W	498295	7286095	34-35	24-Aug-10	150	956	26		3	7		3	1
	36	12W	498080	7286116	35-36	24-Aug-10	100	476	5			8			
	37	12W	498030	7286190	36-37	24-Aug-10	100	872	4		1	1			6
	38	12W	497958	7286260	37-38	25-Aug-10	100	286	4		1		1	1	
	39	12W	497840	7286314	38-39	25-Aug-10	130	576	11		1	1		2	1
	40	12W	497722	7286340	39-40	25-Aug-10	135	446	6				2	2	
	41														
	42	12W	497260	7286620	41-42	25-Aug-10	140	572	20		1	1		3	1
	43	12W	497213	7286679	42-43	25-Aug-10	90	346	7	1	1			3	1
TOTAL								**10373**	**158**	**4**	**33**	**66**	**7**	**22**	**11**

Table C-2: Fish Morphometric Data from the Lupin 2010 EEM Exposure Area

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
27-Aug-10	-	E001	NSSB	2.667	7.7	44-45	-	ok
27-Aug-10	-	E002	BURB	0.959	5.1	44-45	-	ok
27-Aug-10	-	E003	NSSB	0.212	3.4	44-45	-	ok
27-Aug-10	-	E004	NSSB	0.255	3.6	44-45	-	ok
27-Aug-10	-	E005	NSSB	0.162	3.0	44-45	-	ok
27-Aug-10	-	E006	NSSB	0.577	4.6	44-45	-	ok
27-Aug-10	-	E007	NSSB	0.362	4.1	44-45	-	ok
27-Aug-10	-	E008	NSSB	0.408	4.1	44-45	-	ok
27-Aug-10	-	E009	NSSB	0.200	3.5	44-45	-	ok
27-Aug-10	-	E010	NSSB	0.197	3.5	44-45	-	ok
27-Aug-10	-	E011	NSSB	0.260	3.6	44-45	-	ok
27-Aug-10	-	E012	NSSB	0.278	3.8	44-45	-	ok
27-Aug-10	-	E013	NSSB	0.187	3.2	44-45	-	ok
27-Aug-10	-	E014	NSSB	0.245	3.5	44-45	-	ok
27-Aug-10	-	E015	NSSB	0.285	3.8	44-45	-	ok
27-Aug-10	-	E016	NSSB	0.148	3.1	44-45	-	ok
27-Aug-10	-	E017	NSSB	0.169	2.9	44-45	-	ok
27-Aug-10	-	E018	NSSB	0.233	3.4	44-45	-	ok
27-Aug-10	-	E019	NSSB	0.154	2.9	44-45	-	ok
27-Aug-10	-	E020	NSSB	0.090	2.5	44-45	-	ok
27-Aug-10	-	E021	NSSB	0.377	4.0	44-45	-	ok
27-Aug-10	-	E022	NSSB	0.117	3.6	44-45	-	ok
27-Aug-10	-	E023	NSSB	0.163	3.2	44-45	-	ok
27-Aug-10	SW	E024	ARGR	21.554	13.2	44-45	ot	ok
27-Aug-10	SW	E025	ARGR	10.958	10.8	44-45	ot	ok
27-Aug-10	-	E026	NSSB	0.311	4.2	45-46	-	ok
27-Aug-10	-	E027	NSSB	0.228	3.8	45-46	-	ok
27-Aug-10	-	E028	NSSB	0.208	3.4	45-46	-	ok
27-Aug-10	-	E029	NSSB	0.120	2.8	45-46	-	ok
27-Aug-10	-	E030	NSSB	0.208	3.4	45-46	-	ok
27-Aug-10	-	E031	NSSB	0.468	4.3	45-46	-	ok
27-Aug-10	-	E032	NSSB	0.399	3.8	45-46	-	ok
27-Aug-10	-	E033	NSSB	0.292	3.4	45-46	-	ok
27-Aug-10	-	E034	NSSB	0.282	3.7	45-46	-	ok
27-Aug-10	-	E035	NSSB	0.198	3.2	45-46	-	ok
27-Aug-10	-	E036	NSSB	0.333	3.6	45-46	-	ok
27-Aug-10	-	E037	NSSB	0.407	3.9	45-46	-	ok
27-Aug-10	-	E038	NSSB	0.363	4.0	45-46	-	ok
27-Aug-10	-	E039	NSSB	0.430	4.1	45-46	-	ok
27-Aug-10	-	E040	NSSB	0.213	3.5	45-46	-	ok
27-Aug-10	-	E041	NSSB	0.621	4.6	45-46	-	ok
27-Aug-10	-	E042	NSSB	0.320	3.9	45-46	-	ok
27-Aug-10	-	E043	NSSB	0.275	3.9	45-46	-	ok
27-Aug-10	-	E044	NSSB	0.378	4.3	45-46	-	ok
27-Aug-10	-	E045	NSSB	0.369	3.9	45-46	-	ok
27-Aug-10	-	E046	NSSB	0.251	3.1	45-46	-	ok
27-Aug-10	-	E047	NSSB	0.313	3.9	46-47	-	ok
27-Aug-10	-	E048	NSSB	0.286	3.9	46-47	-	ok
27-Aug-10	-	E049	NSSB	0.239	3.5	46-47	-	ok
27-Aug-10	-	E050	NSSB	0.287	3.9	46-47	-	ok
27-Aug-10	-	E051	NSSB	0.189	3.4	46-47	-	ok
27-Aug-10	SW	E052	ARGR	15.056	11.4	46-47	ot	missing scales from caudal area, possible b
27-Aug-10	SW	E053	ARGR	13.238	11.3	46-47	ot	ok
27-Aug-10	SW	E054	ARGR	2.734	6.5	46-47	ot	ok
28-Aug-10	-	E055	NSSB	0.198	2.9	47-48	-	ok
28-Aug-10	-	E056	NSSB	0.237	3.5	47-48	-	ok
28-Aug-10	-	E057	NSSB	0.248	3.6	47-48	-	ok
28-Aug-10	-	E058	NSSB	0.303	3.7	47-48	-	ok
28-Aug-10	-	E059	NSSB	0.235	3.6	47-48	-	ok
28-Aug-10	-	E060	NSSB	0.106	2.7	47-48	-	ok

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
28-Aug-10	-	E061	NSSB	0.278	3.9	47-48	-	ok
28-Aug-10	-	E062	NSSB	0.230	3.7	47-48	-	ok
28-Aug-10	-	E063	NSSB	0.192	3.1	47-48	-	ok
28-Aug-10	-	E064	NSSB	0.113	2.4	47-48	-	ok
28-Aug-10	-	E065	NSSB	0.169	3.1	47-48	-	ok
28-Aug-10	-	E066	NSSB	0.141	2.7	47-48	-	ok
28-Aug-10	-	E067	NSSB	0.309	3.8	47-48	-	ok
28-Aug-10	-	E068	NSSB	0.337	3.8	47-48	-	ok
28-Aug-10	-	E069	NSSB	0.306	3.9	47-48	-	ok
28-Aug-10	-	E070	NSSB	0.282	3.7	48-49	-	ok
28-Aug-10	-	E071	NSSB	0.148	2.8	48-49	-	ok
28-Aug-10	SW	E072	ARGR	2.618	6.4	48-49	ot	ok
28-Aug-10	SW	E073	ARGR	2.925	6.6	48-49	ot	ok
28-Aug-10	SW	E074	ARGR	2.836	6.7	48-49	ot	ok
28-Aug-10	SW	E075	ARGR	1.283	5.5	48-49	ot	ok
28-Aug-10	-	E076	NSSB	0.275	3.7	49-50	-	ok
28-Aug-10	-	E077	NSSB	0.249	3.4	49-50	-	ok
28-Aug-10	-	E078	NSSB	0.160	2.3	49-50	-	ok
28-Aug-10	-	E079	NSSB	0.262	3.1	49-50	-	ok
28-Aug-10	-	E080	NSSB	0.101	2.5	49-50	-	ok
28-Aug-10	-	E081	NSSB	0.150	3.0	50-51	-	ok
28-Aug-10	-	E082	NSSB	0.267	3.5	50-51	-	ok
28-Aug-10	-	E083	NSSB	0.333	4.0	50-51	-	ok
28-Aug-10	-	E084	NSSB	0.131	2.6	50-51	-	ok
28-Aug-10	-	E085	NSSB	0.228	3.5	50-51	-	ok
28-Aug-10	-	E086	NSSB	0.272	3.5	50-51	-	ok
28-Aug-10	-	E087	NSSB	0.184	2.6	50-51	-	ok
28-Aug-10	-	E088	NSSB	0.576	5.1	50-51	-	ok
28-Aug-10	-	E089	NSSB	0.179	3.1	50-51	-	ok
28-Aug-10	-	E090	NSSB	0.243	2.9	50-51	-	ok
28-Aug-10	SW	E091	ARGR	2.573	6.5	50-51	ot	ok
28-Aug-10	SW	E092	ARGR	2.230	6.4	50-51	ot	ok
28-Aug-10	SW	E093	ARGR	1.894	5.8	50-51	ot	ok
28-Aug-10	SW	E094	ARGR	2.421	6.7	50-51	-	ok, could not retrieve otolith
28-Aug-10	SW	E095	ARGR	2.459	6.4	50-51	ot	ok
28-Aug-10	SW	E096	ARGR	1.825	5.7	50-51	ot	ok
28-Aug-10	SW	E097	ARGR	1.368	5.3	50-51	-	ok, could not retrieve otolith
28-Aug-10	SW	E098	ARGR	2.031	6.0	50-51	ot	ok
29-Aug-10	-	E099	NSSB	0.414	4.1	51-52	-	ok
29-Aug-10	TH	E100	ARGR	77.800	19.0	51-52	ot	ok
29-Aug-10	TH	E101	ARGR	13.429	11.2	51-52	ot	ok
29-Aug-10	SW	E102	ARGR	16.524	11.7	51-52	ot	ok
29-Aug-10	-	E103	NSSB	0.326	3.9	51-52	-	ok
29-Aug-10	-	E104	NSSB	0.252	3.7	51-52	-	ok
29-Aug-10	-	E105	NSSB	0.252	3.8	51-52	-	ok
29-Aug-10	-	E106	NSSB	0.106	2.7	51-52	-	ok
29-Aug-10	-	E107	NSSB	0.188	3.1	51-52	-	ok
29-Aug-10	-	E108	NSSB	0.184	3.2	51-52	-	ok
29-Aug-10	-	E109	NSSB	0.265	3.7	51-52	-	ok

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
29-Aug-10	-	E110	NSSB	0.220	3.4	51-52	-	ok
29-Aug-10	-	E111	NSSB	0.307	3.8	51-52	-	ok
29-Aug-10	-	E112	NSSB	0.637	4.8	51-52	-	ok
29-Aug-10	SW	E113	ARGR	1.729	6.0	51-52	-	ok
29-Aug-10	SW	E114	ARGR	1.778	5.9	52-53	-	ok
29-Aug-10	SW	E115	ARGR	1.669	6.0	52-53	-	ok, could not retrieve otolith
29-Aug-10	-	E116	NSSB	0.221	3.5	52-53	-	ok
29-Aug-10	-	E117	NSSB	0.221	3.5	52-53	-	ok
29-Aug-10	-	E118	NSSB	0.553	4.8	52-53	-	ok
29-Aug-10	-	E119	NSSB	0.306	3.9	52-53	-	ok
29-Aug-10	-	E120	NSSB	0.178	3.1	52-53	-	ok
29-Aug-10	-	E121	NSSB	0.200	3.4	52-53	-	ok
29-Aug-10	-	E122	NSSB	0.183	3.3	52-53	-	ok
29-Aug-10	-	E123	NSSB	0.459	4.5	52-53	-	ok
29-Aug-10	-	E124	NSSB	0.173	3.2	52-53	-	ok
29-Aug-10	-	E125	NSSB	0.155	3.0	52-53	-	ok
29-Aug-10	-	E126	NSSB	0.267	3.8	52-53	-	ok
29-Aug-10	-	E127	NSSB	0.287	4.0	52-53	-	ok
29-Aug-10	-	E128	NSSB	0.163	3.1	52-53	-	ok
29-Aug-10	-	E129	NSSB	0.166	3.3	52-53	-	ok
29-Aug-10	-	E130	NSSB	0.291	3.8	52-53	-	ok
29-Aug-10	-	E131	NSSB	0.275	3.6	52-53	-	ok
29-Aug-10	-	E132	NSSB	0.196	3.5	52-53	-	ok
29-Aug-10	-	E133	NSSB	0.277	3.7	52-53	-	ok
29-Aug-10	SW	E134	ARGR	1.793	6.1	53-54	ot	ok
29-Aug-10	-	E135	NSSB	0.368	4.1	53-54	-	ok
29-Aug-10	-	E136	NSSB	0.383	4.2	53-54	-	ok
29-Aug-10	-	E137	NSSB	0.097	2.6	53-54	-	ok
29-Aug-10	-	E138	NSSB	0.318	3.9	53-54	-	ok
29-Aug-10	-	E139	NSSB	0.472	4.4	53-54	-	ok
29-Aug-10	-	E140	NSSB	0.272	3.9	53-54	-	ok
29-Aug-10	-	E141	BURB	10.243	11.1	55-56	-	ok
29-Aug-10	-	E142	NSSB	0.246	3.6	55-56	-	ok
29-Aug-10	-	E143	NSSB	0.205	2.9	55-56	-	ok
29-Aug-10	-	E144	NSSB	0.331	3.5	55-56	-	ok
29-Aug-10	-	E145	NSSB	0.258	3.9	55-56	-	ok
29-Aug-10	-	E146	NSSB	0.380	4.2	55-56	-	ok
29-Aug-10	-	E147	NSSB	0.382	3.8	55-56	-	ok
29-Aug-10	-	E148	NSSB	0.294	3.5	55-56	-	ok
29-Aug-10	-	E149	NSSB	0.414	3.6	55-56	-	ok
29-Aug-10	-	E150	NSSB	0.478	3.9	55-56	-	ok
29-Aug-10	-	E151	NSSB	0.347	3.9	55-56	-	ok
29-Aug-10	SW	E152	ARGR	2.385	6.6	55-56	ot	ok
29-Aug-10	SW	E153	ARGR	1.866	5.8	55-56	ot	ok
29-Aug-10	SW	E154	ARGR	1.423	5.5	55-56	ot	ok
29-Aug-10	SW	E155	ARGR	2.400	6.4	56-57	ot	ok
29-Aug-10	SW	E156	ARGR	11.390	10.9	56-57	ot	ok
29-Aug-10	-	E157	NSSB	2.404	6.1	56-57	-	ok
29-Aug-10	-	E158	NSSB	0.479	4.1	56-57	-	ok
29-Aug-10	-	E159	NSSB	0.522	4.4	56-57	-	ok
29-Aug-10	-	E160	NSSB	0.423	3.6	56-57	-	ok
29-Aug-10	-	E161	NSSB	0.600	4.2	56-57	-	ok
29-Aug-10	-	E162	NSSB	0.569	4.6	56-57	-	ok
29-Aug-10	-	E163	NSSB	0.601	4.3	56-57	-	ok
29-Aug-10	-	E164	NSSB	0.248	2.9	56-57	-	ok
29-Aug-10	-	E165	NSSB	0.621	3.9	56-57	-	ok
29-Aug-10	-	E166	NSSB	0.652	4.2	56-57	-	ok
29-Aug-10	-	E167	NSSB	1.038	4.7	56-57	-	ok

Note:

a) ot = otollith

Table C-3: Fish Morphometric Data from the Lupin 2010 EEM Reference Area One

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
18-Aug-10	-	R1-001	SLSC	2.210	6.5	1-2	-	ok
18-Aug-10	-	R1-002	SLSC	1.425	5.5	1-2	-	ok
18-Aug-10	-	R1-003	SLSC	2.625	7.1	1-2	-	ok
18-Aug-10	-	R1-004	SLSC	1.529	5.8	1-2	-	ok
18-Aug-10	-	R1-005	SLSC	1.599	6.0	1-2	-	ok
18-Aug-10	-	R1-006	SLSC	3.010	7.4	1-2	-	ok
18-Aug-10	-	R1-007	SLSC	3.272	7.1	1-2	-	ok
18-Aug-10	-	R1-008	SLSC	2.613	7.1	1-2	-	ok
18-Aug-10	-	R1-009	SLSC	0.939	5.1	1-2	-	ok
18-Aug-10	-	R1-010	SLSC	5.201	8.5	1-2	-	ok
18-Aug-10	-	R1-011	SLSC	3.245	7.4	1-2	-	ok
18-Aug-10	-	R1-012	SLSC	1.214	5.4	1-2	-	ok
18-Aug-10	-	R1-013	SLSC	1.589	5.8	1-2	-	ok
18-Aug-10	-	R1-014	RNWH	3.242	7.7	1-2	-	ok
18-Aug-10	-	R1-015	LKTR	5.514	8.1	1-2	-	ok
18-Aug-10	SW	R1-016	ARGR	2.910	6.8	1-2	ot	ok
18-Aug-10	-	R1-017	LKTR	2.770	6.6	1-2	-	ok
18-Aug-10	-	R1-018	LKTR	2.138	6.6	1-2	-	ok
18-Aug-10	-	R1-019	LKTR	2.902	6.6	1-2	-	ok
18-Aug-10	-	R1-020	SLSC	4.058	7.7	2-3	-	ok
18-Aug-10	-	R1-021	LKTR	12.688	10.2	2-3	-	ok
18-Aug-10						3-4		
18-Aug-10	-	R1-022	RNWH	8.630	10.0	4-5	-	ok
18-Aug-10	SW	R1-023	ARGR	11.205	10.2	4-5	ot	ok
18-Aug-10	SW	R1-024	ARGR	17.239	11.3	4-5	ot	ok
18-Aug-10	-	R1-025	SLSC	2.537	6.6	5-6	-	ok
18-Aug-10	-	R1-026-01	LKTR	19.125	11.7	5-6	-	ok
18-Aug-10	-	R1-026-02	LKTR	12.444	10.3	6-7	-	ok
18-Aug-10	TH	R1-027	ARGR	3.222	7.1	6-7	-	ok
18-Aug-10	SW	R1-028	ARGR	26.182	13.1	6-7	ot	ok
18-Aug-10	-	R1-029	BURB	0.908	5.2	7-8	-	ok
18-Aug-10	-	R1-030	BURB	0.765	5.0	7-8	-	ok
18-Aug-10	-	R1-031	LKTR	-	18.3	8-9	-	ok, wieght not recorded
18-Aug-10	-	R1-032	LKTR	12.690	10.4	8-9	-	ok
18-Aug-10	-	R1-033	SLSC	4.323	7.7	8-9	-	ok
18-Aug-10	-	R1-034	SLSC	1.842	6.1	8-9	-	ok
18-Aug-10	-	R1-035	SLSC	2.274	6.3	8-9	-	ok
18-Aug-10	-	R1-036	SLSC	1.820	5.9	8-9	-	ok
18-Aug-10	-	R1-037	LKTR	16.334	11.1	9-10	-	ok
18-Aug-10	-	R1-038	LKTR	20.334	12.0	9-10	-	ok
18-Aug-10	-	R1-039	SLSC	3.228	7.2	9-10	-	ok
18-Aug-10	-	R1-040	SLSC	3.362	7.4	9-10	-	ok
18-Aug-10	TH	R1-041	ARGR	28.001	13.3	9-10	ot	ok
18-Aug-10	SW	R1-042	ARGR	18.123	11.9	9-10	ot	ok
19-Aug-10	-	R1-043	LKTR	26.694	13.3	10-11	-	ok
19-Aug-10	-	R1-044	LKTR	26.615	13.2	10-11	-	ok
19-Aug-10	-	R1-045	SLSC	1.770	6.0	10-11	-	ok
19-Aug-10	-	R1-046	SLSC	2.039	6.0	10-11	-	ok
19-Aug-10	-	R1-047	SLSC	3.022	6.6	10-11	-	ok
19-Aug-10	-	R1-048	LKTR	0.835	4.4	10-11	-	ok
19-Aug-10	-	R1-049	NSSB	0.253	3.7	10-11	-	ok
19-Aug-10	-	R1-050	NSSB	0.292	3.5	10-11	-	ok
19-Aug-10	TH	R1-051	ARGR	24.004	13.0	10-11	ot	ok
19-Aug-10	SW	R1-052	ARGR	19.130	11.7	10-11	ot	ok

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
19-Aug-10	-	R1-053	SLSC	2.668	6.7	11-12	-	ok
19-Aug-10	-	R1-054	SLSC	3.164	7.0	11-12	-	ok
19-Aug-10	-	R1-055	BURB	1.223	5.9	11-12	-	ok
19-Aug-10	-	R1-056	BURB	1.134	5.6	11-12	-	ok
19-Aug-10	-	R1-057	BURB	1.859	6.4	12-13	-	ok
19-Aug-10	-	R1-058	SLSC	1.750	5.8	12-13	-	ok
19-Aug-10	-	R1-059	SLSC	3.162	6.9	12-13	-	ok
19-Aug-10	-	R1-060	SLSC	1.667	5.7	12-13	-	ok
19-Aug-10	-	R1-061	SLSC	1.897	6.1	12-13	-	ok
19-Aug-10	-	R1-062	SLSC	2.504	6.5	12-13	-	ok
19-Aug-10	-	R1-063	SLSC	0.561	4.2	12-13	-	ok
19-Aug-10	SW	R1-064	ARGR	2.811	6.7	12-13	ot	ok
19-Aug-10	-	R1-065	SLSC	3.586	7.5	13-14	-	ok
19-Aug-10	-	R1-066	SLSC	3.212	7.1	13-14	-	ok
19-Aug-10	-	R1-067	SLSC	1.479	5.8	13-14	-	ok
19-Aug-10	-	R1-068	BURB	1.387	6.0	13-14	-	ok
19-Aug-10	-	R1-069	BURB	0.672	4.8	13-14	-	ok
19-Aug-10	-	R1-070	BURB	1.333	6.1	13-14	-	ok
19-Aug-10	-	R1-071	BURB	1.088	5.5	13-14	-	ok
19-Aug-10	SW	R1-072	ARGR	2.725	6.6	13-14	ot	ok
19-Aug-10	-	R1-073	LKTR	34.243	15.9	14-15	-	ok
19-Aug-10	-	R1-074	BURB	1.251	5.8	14-15	-	ok
19-Aug-10	-	R1-075	BURB	1.323	5.8	14-15	-	ok
19-Aug-10	-	R1-076	BURB	1.476	6.1	14-15	-	ok
19-Aug-10	-	R1-077	BURB	1.203	5.6	14-15	-	ok
19-Aug-10	SW	R1-078	ARGR	3.059	6.9	14-15	ot	ok
19-Aug-10	TH	R1-079	ARGR	16.096	11.4	14-15	ot	ok
19-Aug-10	-	R1-080	SLSC	1.821	6.0	15-16	-	ok
19-Aug-10	-	R1-081	SLSC	7.043	8.7	15-16	-	ok
19-Aug-10	-	R1-082	SLSC	1.944	6.2	15-16	-	ok
19-Aug-10	-	R1-083	BURB	1.619	6.1	15-16	-	ok
19-Aug-10	-	R1-084	BURB	1.458	6.2	15-16	-	ok
19-Aug-10	SW	R1-085	ARGR	3.581	7.1	15-16	ot	ok
19-Aug-10	SW	R1-086	ARGR	3.261	7.2	15-16	ot	ok
19-Aug-10	-	R1-087	SLSC	1.759	6.2	16-18	-	ok
19-Aug-10	-	R1-088	SLSC	2.288	6.4	16-18	-	ok
19-Aug-10	-	R1-089	SLSC	0.404	3.8	16-18	-	ok
19-Aug-10	-	R1-090	SLSC	2.581	6.5	16-18	-	ok
19-Aug-10	-	R1-091	SLSC	0.540	4.3	16-18	-	ok
19-Aug-10	-	R1-092	SLSC	7.910	8.7	16-18	-	ok
19-Aug-10	-	R1-093	SLSC	1.104	4.9	16-18	-	ok
19-Aug-10	-	R1-094	SLSC	1.793	5.9	16-18	-	ok
19-Aug-10	-	R1-095	SLSC	4.622	7.7	16-18	-	ok
19-Aug-10	-	R1-096	SLSC	1.778	6.1	16-18	-	ok
19-Aug-10	-	R1-097	SLSC	2.855	7.0	16-18	-	ok
19-Aug-10	-	R1-098	SLSC	1.010	5.2	16-18	-	ok
19-Aug-10	-	R1-099	SLSC	0.574	4.5	16-18	-	ok
19-Aug-10	-	R1-100	SLSC	0.498	4.1	16-18	-	ok
19-Aug-10	-	R1-101	SLSC	0.416	3.6	16-18	-	ok
19-Aug-10	-	R1-102	SLSC	0.581	4.2	16-18	-	ok
19-Aug-10	-	R1-103	SLSC	0.464	3.8	16-18	-	ok
19-Aug-10	-	R1-104	NSSB	0.465	4.4	16-18	-	ok
19-Aug-10	-	R1-105	BURB	1.964	6.6	16-18	-	ok
19-Aug-10	-	R1-106	BURB	0.938	4.9	16-18	-	ok
19-Aug-10	-	R1-107	BURB	0.863	5.0	16-18	-	ok
19-Aug-10	-	R1-108	BURB	0.623	4.5	16-18	-	ok
19-Aug-10	-	R1-109	BURB	0.445	3.7	16-18	-	ok

Day Collected	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
19-Aug-10	SW	R1-110	ARGR	2.046	5.8	16-18	ot	ok
19-Aug-10	SW	R1-111	ARGR	2.508	6.2	16-18	ot	ok
19-Aug-10	SW	R1-112	ARGR	19.702	12.2	16-18	ot	ok
20-Aug-10	-	R1-113	ARGR	30.762	14.6	18-19	-	ok - no otolith taken
20-Aug-10	-	R1-114	NSSB	0.189	3.3	18-19	-	ok
20-Aug-10	-	R1-115	NSSB	0.282	3.6	18-19	-	ok
20-Aug-10	-	R1-116	NSSB	0.188	3.6	18-19	-	ok
20-Aug-10	-	R1-117	SLSC	0.559	4.1	18-19	-	ok
20-Aug-10	-	R1-118	SLSC	0.808	4.8	18-19	-	ok
20-Aug-10	-	R1-119	SLSC	1.691	6.1	18-19	-	ok
20-Aug-10	-	R1-120	NSSB	0.219	3.1	18-19	-	ok
20-Aug-10	-	R1-121	NSSB	0.148	2.7	18-19	-	ok
20-Aug-10	-	R1-122	BURB	1.452	6.4	19-20	-	ok
20-Aug-10	-	R1-123	ARGR	2.369	6.1	19-20	-	ok
20-Aug-10	-	R1-124	ARGR	3.676	7.1	19-20	-	ok
20-Aug-10	-	R1-125	SLSC	0.514	4.1	19-20	-	ok
20-Aug-10	-	R1-126	SLSC	1.296	5.3	19-20	-	ok
20-Aug-10	-	R1-127	ARGR	2.601	6.4	19-20	-	ok
20-Aug-10	-	R1-128	BURB	1.306	6.1	19-20	-	ok
20-Aug-10	-	R1-129	SLSC	0.861	4.5	19-20	-	ok
20-Aug-10	-	R1-130	BURB	1.003	5.4	19-20	-	ok
20-Aug-10	-	R1-131	BURB	1.105	5.5	19-20	-	ok
20-Aug-10	-	R1-132	BURB	0.716	5.0	19-20	-	ok
20-Aug-10	-	R1-133	NSSB	0.109	2.6	19-20	-	ok
20-Aug-10	-	R1-134	SLSC	0.403	3.9	19-20	-	ok
20-Aug-10	-	R1-135	SLSC	0.061	1.8	19-20	-	ok
20-Aug-10	-	R1-136	ARGR	23.272	12.5	20-21	-	ok
20-Aug-10	-	R1-137	ARGR	22.271	12.0	20-21	-	ok
20-Aug-10	-	R1-138	ARGR	3.564	7.2	20-21	-	ok
20-Aug-10	-	R1-139	BURB	1.225	5.9	20-21	-	one eye bloody and swollen
20-Aug-10	-	R1-140	SLSC	2.734	6.6	20-21	-	ok
20-Aug-10	-	R1-141	SLSC	5.940	8.0	20-21	-	ok
20-Aug-10	-	R1-142	SLSC	0.648	4.4	20-21	-	ok
20-Aug-10	-	R1-143	BURB	1.486	6.2	20-21	-	ok
20-Aug-10	-	R1-144	SLSC	5.756	8.6	20-21	-	ok
20-Aug-10	-	R1-145	SLSC	2.311	6.6	20-21	-	ok
20-Aug-10	-	R1-146	BURB	1.339	6.0	20-21	-	ok
20-Aug-10	-	R1-147	NSSB	0.273	3.6	20-21	-	ok
20-Aug-10	-	R1-148	NSSB	0.204	3.5	20-21	-	ok
20-Aug-10	-	R1-149	NSSB	0.124	2.7	20-21	-	ok
20-Aug-10	-	R1-150	BURB	1.481	5.1	20-21	-	ok
20-Aug-10	-	R1-151	SLSC	2.997	6.5	20-21	-	ok
20-Aug-10	-	R1-152	SLSC	4.503	7.7	20-21	-	ok
20-Aug-10	-	R1-153	NSSB	0.165	3.2	20-21	-	ok
20-Aug-10	-	R1-154	SLSC	0.897	4.8	20-21	-	ok
20-Aug-10	-	R1-155	NSSB	0.180	3.2	20-21	-	ok
20-Aug-10	-	R1-156	BURB	1.293	5.8	20-21	-	ok
20-Aug-10	-	R1-157	NSSB	0.166	3.3	20-21	-	ok
20-Aug-10	-	R1-158	NSSB	0.214	3.5	20-21	-	ok

Note:

a) ot = otollith

Table C-4: Fish Morphometric Data from the Lupin 2010 EEM Reference Area Two

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
22-Aug-10	-	R2-001	NSSB	1.320	5.8	26-27	-	ok
22-Aug-10	-	R2-002	NSSB	0.222	3.4	26-27	-	ok
22-Aug-10	-	R2-003	NSSB	0.239	3.4	26-27	-	ok
22-Aug-10	-	R2-004	SLSC	4.444	8.0	26-27	-	ok
22-Aug-10	-	R2-005	SLSC	3.341	7.3	26-27	-	ok
22-Aug-10	-	R2-006	SLSC	3.885	7.2	26-27	-	ok
22-Aug-10	-	R2-007	SLSC	5.743	8.6	26-27	-	ok
22-Aug-10	-	R2-008	SLSC	1.622	6.1	26-27	-	ok
22-Aug-10	-	R2-009	SLSC	1.205	5.4	26-27	-	ok
22-Aug-10	-	R2-010	SLSC	3.210	7.3	26-27	-	ok
22-Aug-10	-	R2-011	SLSC	1.795	6.0	26-27	-	ok
22-Aug-10	-	R2-012	NSSB	0.121	2.9	26-27	-	ok
22-Aug-10	-	R2-013	RNWH	3.145	7.6	27-28	-	ok
22-Aug-10	-	R2-014	SLSC	2.233	7.1	27-28	-	ok, very skinny tail
22-Aug-10	-	R2-015	LKTR	6.818	8.7	27-28	-	ok
22-Aug-10	-	R2-016	SLSC	3.906	7.1	27-28	-	ok
22-Aug-10	-	R2-017	NSSB	1.306	5.7	27-28	-	ok
22-Aug-10	-	R2-018	SLSC	1.543	5.9	27-28	-	ok
22-Aug-10	-	R2-019	SLSC	2.597	7.0	27-28	-	ok
22-Aug-10	-	R2-020	SLSC	3.802	7.5	27-28	-	ok
22-Aug-10	-	R2-021	NSSB	0.225	3.4	27-28	-	ok
22-Aug-10	-	R2-022	SLSC	3.273	7.3	27-28	-	ok
22-Aug-10	-	R2-023	SLSC	2.954	6.9	27-28	-	ok
22-Aug-10	-	R2-024	SLSC	1.439	5.5	27-28	-	ok
22-Aug-10	-	R2-025	NSSB	1.591	6.7	27-28	-	ok
22-Aug-10	-	R2-026	SLSC	1.971	6.3	27-28	-	ok
22-Aug-10	-	R2-027	NSSB	1.564	6.2	27-28	-	ok
22-Aug-10	-	R2-028	SLSC	1.644	5.7	27-28	-	ok
22-Aug-10	-	R2-029	NSSB	0.381	3.7	27-28	-	ok
22-Aug-10	-	R2-030	SLSC	1.827	6.2	27-28	-	ok
22-Aug-10	-	R2-031	NSSB	0.253	4.1	27-28	-	ok
22-Aug-10	-	R2-032	SLSC	3.507	7.4	27-28	-	ok
22-Aug-10	-	R2-033	NSSB	0.630	4.8	27-28	-	ok
22-Aug-10	-	R2-034	BURB	24.887	16.7	27-28	-	ok
22-Aug-10	-	R2-035	LKTR	58.500	17.4	27-28	-	ok
22-Aug-10	SW	R2-035	ARGR	43.281	16.3	27-28	-	ok
22-Aug-10	SW	R2-036	ARGR	72.300	18.7	27-28	-	ok
22-Aug-10	-	R2-037	LKTR	145.300	22.0	28-29	-	ok
22-Aug-10	-	R2-038	LKTR	~350	30.3	28-29	-	ok, fish was too heavy for scales and too light for spring scale
22-Aug-10	-	R2-039	BURB	203.500	34.7	28-29	-	ok
22-Aug-10	-	R2-040	BURB	272.400	34.1	28-29	-	ok
22-Aug-10	-	R2-041	NSSB	0.207	3.4	28-29	-	ok
22-Aug-10	-	R2-042	NSSB	0.151	2.8	28-29	-	ok
22-Aug-10	-	R2-042	NSSB	0.272	3.6	28-29	-	ok
22-Aug-10	-	R2-043	NSSB	0.238	3.5	28-29	-	ok
22-Aug-10	-	R2-044	NSSB	0.229	3.3	28-29	-	ok
22-Aug-10	-	R2-045	NSSB	0.575	4.5	28-29	-	ok
22-Aug-10	-	R2-046	NSSB	0.219	3.2	28-29	-	ok
22-Aug-10	-	R2-047	NSSB	0.217	3.0	28-29	-	ok
22-Aug-10	-	R2-048	NSSB	0.343	3.9	28-29	-	ok
22-Aug-10	-	R2-049	NSSB	0.662	4.9	28-29	-	ok
22-Aug-10	-	R2-050	NSSB	0.786	5.0	28-29	-	ok

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
22-Aug-10	-	R2-051	NSSB	0.697	4.8	28-29	-	ok
22-Aug-10	-	R2-052	NSSB	1.533	6.0	28-29	-	ok
22-Aug-10	-	R2-053	NSSB	0.379	4.0	28-29	-	ok
22-Aug-10	-	R2-054	NSSB	0.244	3.3	28-29	-	ok
22-Aug-10	-	R2-055	NSSB	0.436	4.0	28-29	-	ok
22-Aug-10	-	R2-056	NSSB	0.444	4.3	28-29	-	ok
22-Aug-10	-	R2-057	SLSC	4.650	7.9	28-29	-	ok
22-Aug-10	-	R2-058	SLSC	1.959	6.3	28-29	-	ok
22-Aug-10	-	R2-059	SLSC	1.670	6.0	28-29	-	ok
22-Aug-10	-	R2-060	SLSC	4.383	7.8	28-29	-	ok
22-Aug-10	-	R2-061	SLSC	2.957	7.2	28-29	-	ok
22-Aug-10	SW	R2-062	ARGR	56.100	17.3	28-29	ot	ok
22-Aug-10	SW	R2-063	ARGR	33.128	14.5	28-29	ot	ok
22-Aug-10	SW	R2-064	ARGR	57.600	16.6	28-29	ot	ok
22-Aug-10	-	R2-065	ARGR	187.400	24.6	29-30	-	ok, large body fish, did not use for tissue sample
22-Aug-10	-	R2-066	LKTR	18.273	12.0	29-30	-	ok
22-Aug-10	-	R2-067	LKTR	18.804	11.7	29-30	-	ok
22-Aug-10	-	R2-068	NSSB	2.105	7.0	29-30	-	ok
22-Aug-10	-	R2-069	ARGR	65.000	18.2	29-30	-	ok
22-Aug-10	-	R2-070	LKTR	17.233	11.6	29-30	-	ok
22-Aug-10	-	R2-071	NSSB	1.700	6.8	29-30	-	ok
22-Aug-10	-	R2-072	SLSC	4.009	7.7	29-30	-	ok
22-Aug-10	-	R2-073	NSSB	1.409	5.8	29-30	-	ok
22-Aug-10	-	R2-074	SLSC	2.148	6.5	29-30	-	ok
22-Aug-10	-	R2-075	ARGR	23.107	13.5	29-30	-	ok, not taken for tissue sample
22-Aug-10	-	R2-076	NSSB	1.170	5.5	29-30	-	ok
22-Aug-10	-	R2-077	NSSB	0.229	3.4	29-30	-	ok
22-Aug-10	SW	R2-078	ARGR	59.600	18.1	29-30	ot	ok
22-Aug-10	SW	R2-079	ARGR	53.900	17.4	29-30	ot	ok
22-Aug-10	-	R2-080	RNWH	65.200	20.0	29-30	-	ok
22-Aug-10	SW	R2-081	ARGR	47.200	16.7	29-30	ot	ok
22-Aug-10	SW	R2-082	ARGR	43.600	16.4	29-30	ot	ok
22-Aug-10	-	R2-083	ARGR	218.500	25.2	30-31	-	ok, not taken for tissue sample
22-Aug-10	-	R2-084	ARGR	178.100	24.4	30-31	-	ok, not taken for tissue sample
22-Aug-10	-	R2-085	ARGR	110.600	21.0	30-31	-	ok, not taken for tissue sample
22-Aug-10	-	R2-086	ARGR	65.500	18.4	30-31	-	ok, not taken for tissue sample
22-Aug-10	-	R2-087	ARGR	46.300	15.5	30-31	-	ok, not taken for tissue sample
22-Aug-10	-	R2-088	NSSB	0.400	4.0	30-31	-	ok
22-Aug-10	-	R2-089	NSSB	0.200	3.7	30-31	-	ok
22-Aug-10	-	R2-090	SLSC	4.400	7.9	30-31	-	ok
22-Aug-10	-	R2-091	NSSB	0.300	3.8	30-31	-	ok
22-Aug-10	-	R2-092	ARGR	50.100	16.3	31-32	-	ok
22-Aug-10	-	R2-093	ARGR	38.642	15.5	31-32	-	ok
22-Aug-10	-	R2-094	ARGR	58.400	17.9	31-32	-	ok
22-Aug-10	-	R2-095	LKTR	40.564	15.8	31-32	-	ok
22-Aug-10	-	R2-096	NSSB	2.159	7.2	31-32	-	ok
22-Aug-10	-	R2-097	NSSB	0.168	3.0	31-32	-	ok
22-Aug-10	-	R2-098	SLSC	3.216	7.1	31-32	-	ok
22-Aug-10	-	R2-099	SLSC	6.020	8.4	31-32	-	ok
22-Aug-10	-	R2-100	SLSC	3.928	7.8	31-32	-	ok
22-Aug-10	-	R2-101	SLSC	5.562	8.2	31-32	-	ok
22-Aug-10	-	R2-102	SLSC	2.454	6.5	31-32	-	ok
22-Aug-10	-	R2-103	NSSB	0.247	3.5	31-32	-	ok
22-Aug-10	-	R2-104	SLSC	3.170	7.1	31-32	-	ok
22-Aug-10	-	R2-105	SLSC	6.281	8.7	31-32	-	ok
22-Aug-10	-	R2-106	RNWH	4.662	7.9	31-32	-	ok

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
22-Aug-10	-	R2-107	SLSC	3.744	7.2	31-32	-	ok
22-Aug-10	-	R2-108	NSSB	0.248	3.7	31-32	-	ok
22-Aug-10	-	R2-109	NSSB	0.216	3.6	31-32	-	ok
22-Aug-10	-	R2-110	NSSB	0.188	3.2	31-32	-	ok
24-Aug-10	-	R2-111	ARGR	56.900	16.7	32-33	-	ok, not taken for tissue sample
24-Aug-10	-	R2-112	ARGR	103.600	20.5	32-33	-	ok, not taken for tissue sample
24-Aug-10	-	R2-113	ARGR	42.271	16.3	32-33	-	ok, not taken for tissue sample
24-Aug-10	-	R2-114	ARCH	9.684	9.6	32-33	-	ok, not taken for tissue sample
24-Aug-10	-	R2-115	SLSC	4.812	7.9	32-33	-	ok
24-Aug-10	-	R2-116	SLSC	2.992	6.9	32-33	-	ok
24-Aug-10	-	R2-117	SLSC	4.440	8.0	32-33	-	ok
24-Aug-10	-	R2-118	SLSC	4.347	7.4	32-33	-	ok
24-Aug-10	-	R2-119	SLSC	2.669	6.6	32-33	-	ok
24-Aug-10	-	R2-120	NSSB	0.223	3.5	32-33	-	ok
24-Aug-10	-	R2-121	NSSB	0.229	3.3	32-33	-	ok
24-Aug-10	-	R2-122	NSSB	0.240	3.3	32-33	-	ok
24-Aug-10	-	R2-123	ARGR	163.500	24.0	33-34	-	ok, not taken for tissue sample
24-Aug-10	-	R2-124	SLSC	8.838	10.1	33-34	-	ok
24-Aug-10	-	R2-125	SLSC	4.980	7.9	33-34	-	ok
24-Aug-10	-	R2-126	NSSB	0.272	3.6	33-34	-	ok
24-Aug-10	-	R2-127	NSSB	0.292	4.5	33-34	-	ok
24-Aug-10	-	R2-128	NSSB	0.201	3.5	33-34	-	ok
24-Aug-10	-	R2-129	NSSB	0.165	3.2	33-34	-	ok
24-Aug-10	-	R2-130	RNWH	3.239	7.9	33-34	-	ok
24-Aug-10	-	R2-131	NSSB	0.292	3.4	33-34	-	ok
24-Aug-10	-	R2-132	NSSB	1.582	6.0	33-34	-	ok
24-Aug-10	-	R2-133	NSSB	0.300	3.4	33-34	-	ok
24-Aug-10	-	R2-134	SLSC	0.653	8.6	33-34	-	ok
24-Aug-10	-	R2-135	SLSC	1.711	6.7	33-34	-	ok
24-Aug-10	-	R2-136	NSSB	0.237	3.6	33-34	-	ok
24-Aug-10	-	R2-137	SLSC	4.128	7.8	33-34	-	ok
24-Aug-10	-	R2-138	ARGR	30.591	15.1	33-34	-	ok, not taken for tissue sample
24-Aug-10	-	R2-139	NSSB	2.506	7.2	33-34	-	ok
24-Aug-10	-	R2-140	NSSB	0.993	5.5	33-34	-	ok
24-Aug-10	-	R2-141	NSSB	0.197	3.4	33-34	-	ok
24-Aug-10	-	R2-142	NSSB	0.200	3.0	33-34	-	ok
24-Aug-10	-	R2-143	NSSB	0.272	3.9	33-34	-	ok
24-Aug-10	-	R2-144	NSSB	0.167	3.4	33-34	-	ok
24-Aug-10	-	R2-145	SLSC	4.378	7.6	33-34	-	ok
24-Aug-10	-	R2-146	NSSB	0.174	3.4	33-34	-	ok
24-Aug-10	-	R2-147	NSSB	0.207	3.4	33-34	-	ok
24-Aug-10	-	R2-148	NSSB	0.175	3.2	33-34	-	ok
24-Aug-10	-	R2-149	NSSB	0.281	3.7	33-34	-	ok
24-Aug-10	-	R2-150	NSSB	0.235	3.6	33-34	-	ok
24-Aug-10	-	R2-151	NSSB	0.086	2.5	33-34	-	ok
24-Aug-10	-	R2-152	SLSC	1.623	6.3	33-34	-	ok
24-Aug-10	-	R2-153	NSSB	0.234	3.3	33-34	-	ok
24-Aug-10	-	R2-154	NSSB	0.198	3.2	33-34	-	ok
24-Aug-10	-	R2-155	NSSB	0.302	4.1	33-34	-	ok
24-Aug-10	-	R2-156	NSSB	0.202	3.2	33-34	-	ok
24-Aug-10	-	R2-157	NSSB	0.207	3.6	33-34	-	ok
24-Aug-10	-	R2-158	NSSB	0.107	3.0	33-34	-	ok
24-Aug-10	-	R2-159	NSSB	0.182	3.4	33-34	-	ok
24-Aug-10	-	R2-160	NSSB	0.194	3.2	33-34	-	ok
24-Aug-10	-	R2-161	NSSB	0.110	2.6	33-34	-	ok
24-Aug-10	-	R2-162	NSSB	0.195	3.6	33-34	-	ok
24-Aug-10	-	R2-163	ARGR	56.100	16.6	34-35	-	ok, not taken for tissue sample

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
24-Aug-10	-	R2-164	ARGR	82.000	18.9	34-35	-	ok, not taken for tissue sample
24-Aug-10	-	R2-165	ARGR	58.000	17.0	34-35	-	ok, not taken for tissue sample
24-Aug-10	-	R2-166	LKTR	115.400	21.4	34-35	-	ok
24-Aug-10	-	R2-167	LKTR	42.013	15.3	34-35	-	ok
24-Aug-10	-	R2-168	ARCH	104.300	21.0	34-35	-	ok
24-Aug-10	-	R2-169	NSSB	0.220	3.4	34-35	-	ok
24-Aug-10	-	R2-170	NSSB	0.210	3.5	34-35	-	ok
24-Aug-10	-	R2-171	NSSB	0.213	3.6	34-35	-	ok
24-Aug-10	-	R2-172	NSSB	0.224	3.8	34-35	-	ok
24-Aug-10	-	R2-173	NSSB	0.212	3.5	34-35	-	ok
24-Aug-10	-	R2-174	NSSB	0.240	3.3	34-35	-	ok
24-Aug-10	-	R2-175	NSSB	1.637	6.5	34-35	-	ok
24-Aug-10	-	R2-176	NSSB	0.322	3.8	34-35	-	ok
24-Aug-10	-	R2-177	NSSB	1.463	6.0	34-35	-	ok
24-Aug-10	-	R2-178	NSSB	0.211	3.4	34-35	-	ok
24-Aug-10	-	R2-179	NSSB	2.013	6.9	34-35	-	ok
24-Aug-10	-	R2-180	NSSB	0.301	3.7	34-35	-	ok
24-Aug-10	-	R2-181	NSSB	0.294	3.6	34-35	-	ok
24-Aug-10	-	R2-182	NSSB	0.333	3.8	34-35	-	ok
24-Aug-10	-	R2-183	NSSB	0.205	3.2	34-35	-	ok
24-Aug-10	-	R2-184	NSSB	0.289	3.7	34-35	-	ok
24-Aug-10	-	R2-185	NSSB	0.193	3.2	34-35	-	ok
24-Aug-10	-	R2-186	NSSB	0.462	4.1	34-35	-	ok
24-Aug-10	-	R2-187	NSSB	0.241	3.6	34-35	-	ok
24-Aug-10	-	R2-188	NSSB	0.264	3.5	34-35	-	ok
24-Aug-10	-	R2-189	NSSB	0.379	4.2	34-35	-	ok
24-Aug-10	-	R2-190	LKTR	8.057	9.3	34-35	-	ok
24-Aug-10	-	R2-191	NSSB	0.222	3.4	34-35	-	ok
24-Aug-10	-	R2-192	NSSB	0.229	3.5	34-35	-	ok
24-Aug-10	-	R2-193	SLSC	3.860	7.3	34-35	-	ok
24-Aug-10	-	R2-194	SLSC	3.698	7.5	34-35	-	ok
24-Aug-10	-	R2-195	SLSC	4.269	7.6	34-35	-	ok
24-Aug-10	-	R2-196	SLSC	2.230	6.3	34-35	-	ok
24-Aug-10	-	R2-197	SLSC	4.400	8.1	34-35	-	ok
24-Aug-10	-	R2-198	NSSB	0.282	3.6	34-35	-	ok
24-Aug-10	-	R2-199	SLSC	6.601	8.7	34-35	-	ok
24-Aug-10	-	R2-200	SLSC	6.506	8.7	34-35	-	ok
24-Aug-10	-	R2-201	NSSB	0.284	3.6	34-35	-	ok
24-Aug-10	-	R2-202	NSSB	0.327	3.7	34-35	-	ok
24-Aug-10	-	R2-203	NSSB	1.757	6.6	35-36	-	ok
24-Aug-10	-	R2-204	SLSC	4.207	7.9	35-36	-	ok
24-Aug-10	-	R2-205	SLSC	3.315	7.2	35-36	-	ok
24-Aug-10	-	R2-206	SLSC	6.043	8.5	35-36	-	ok
24-Aug-10	-	R2-207	SLSC	3.046	6.9	35-36	-	ok
24-Aug-10	-	R2-208	NSSB	0.209	3.4	35-36	-	ok
24-Aug-10	-	R2-209	NSSB	0.232	4.6	35-36	-	ok
24-Aug-10	-	R2-210	SLSC	4.901	7.9	35-36	-	ok
24-Aug-10	-	R2-211	NSSB	1.808	6.8	35-36	-	ok
24-Aug-10	-	R2-212	SLSC	3.997	7.4	35-36	-	ok
24-Aug-10	-	R2-213	SLSC	2.875	6.6	35-36	-	ok
24-Aug-10	-	R2-214	NSSB	0.201	3.5	35-36	-	ok
24-Aug-10	-	R2-215	SLSC	0.134	3.1	35-36	-	ok
24-Aug-10	-	R2-216	ARGR	59.200	18.1	36-37	-	ok
24-Aug-10	-	R2-217	ARCH	18.525	11.9	36-37	-	ok
24-Aug-10	-	R2-218	ARCH	20.941	12.4	36-37	-	ok
24-Aug-10	-	R2-219	ARCH	20.948	12.6	36-37	-	ok
24-Aug-10	-	R2-220	ARCH	17.387	11.8	36-37	-	ok

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
24-Aug-10	-	R2-221	ARCH	12.690	10.7	36-37	-	ok
24-Aug-10	-	R2-222	ARCH	7.571	8.8	36-37	-	ok
24-Aug-10	-	R2-223	NSSB	1.758	6.3	36-37	-	ok
24-Aug-10	-	R2-224	SLSC	4.322	7.8	36-37	-	ok
24-Aug-10	-	R2-225	NSSB	0.262	3.7	36-37	-	ok
24-Aug-10	-	R2-226	NSSB	0.366	4.0	36-37	-	ok
24-Aug-10	-	R2-227	NSSB	0.287	3.7	36-37	-	ok
25-Aug-10	-	R2-228	ARGR	42.378	15.7	37-38	-	ok
25-Aug-10	-	R2-229	LKTR	8.430	9.9	37-38	-	ok
25-Aug-10	-	R2-230	RNWH	4.615	8.2	37-38	-	ok
25-Aug-10	-	R2-231	NSSB	1.478	5.9	37-38	-	ok
25-Aug-10	-	R2-232	NSSB	0.225	3.5	37-38	-	ok
25-Aug-10	-	R2-233	NSSB	0.220	3.3	37-38	-	ok
25-Aug-10	-	R2-234	NSSB	0.159	3.0	37-38	-	ok
25-Aug-10	-	R2-235	LKTR	79.000	18.3	38-39	-	ok
25-Aug-10	-	R2-236	ARGR	27.854	14.0	38-39	-	ok
25-Aug-10	-	R2-237	LKTR	44.374	15.4	38-39	-	ok
25-Aug-10	-	R2-238	SLSC	6.118	8.6	38-39	-	ok
25-Aug-10	-	R2-239	ARCH	7.092	8.5	38-39	-	ok
25-Aug-10	-	R2-240	NSSB	0.204	3.4	38-39	-	ok
25-Aug-10	-	R2-241	NSSB	0.177	3.3	38-39	-	ok
25-Aug-10	-	R2-242	NSSB	0.272	3.5	38-39	-	ok
25-Aug-10	-	R2-243	NSSB	0.211	3.3	38-39	-	ok
25-Aug-10	-	R2-244	NSSB	0.242	3.5	38-39	-	ok
25-Aug-10	-	R2-245	NSSB	0.248	3.4	38-39	-	ok
25-Aug-10	-	R2-246	NSSB	0.216	3.1	38-39	-	ok
25-Aug-10	-	R2-247	NSSB	0.273	3.2	38-39	-	ok
25-Aug-10	-	R2-248	NSSB	0.248	3.4	38-39	-	ok
25-Aug-10	-	R2-249	NSSB	0.242	3.4	38-39	-	ok
25-Aug-10	-	R2-250	NSSB	0.225	3.3	38-39	-	ok
25-Aug-10	-	R2-251	RNWH	8.873	10.3	39-40	-	ok
25-Aug-10	-	R2-252	LKTR	14.232	11.2	39-40	-	ok
25-Aug-10	-	R2-253	RNWH	7.544	9.2	39-40	-	ok
25-Aug-10	-	R2-254	LKTR	5.647	7.6	39-40	-	ok
25-Aug-10	-	R2-255	NSSB	0.178	3.4	39-40	-	ok
25-Aug-10	-	R2-256	NSSB	0.201	3.3	39-40	-	ok
25-Aug-10	-	R2-257	NSSB	0.177	3.2	39-40	-	ok
25-Aug-10	-	R2-258	NSSB	0.225	3.5	39-40	-	ok
25-Aug-10	-	R2-259	NSSB	0.186	3.5	39-40	-	ok
25-Aug-10	-	R2-260	NSSB	0.212	3.4	39-40	-	ok
25-Aug-10	-	R2-261	LKTR	63.000	17.8	41-42	-	ok
25-Aug-10	-	R2-262	SLSC	10.401	9.2	41-42	-	ok
25-Aug-10	-	R2-263	ARGR	50.700	16.5	41-42	-	ok
25-Aug-10	-	R2-264	LKTR	24.448	12.8	41-42	-	ok
25-Aug-10	-	R2-265	ARCH	16.364	11.2	41-42	-	ok
25-Aug-10	-	R2-266	LKTR	39.236	15.4	41-42	-	ok
25-Aug-10	-	R2-267	NSSB	0.146	2.9	41-42	-	ok
25-Aug-10	-	R2-268	NSSB	0.184	3.3	41-42	-	ok
25-Aug-10	-	R2-269	NSSB	0.160	3.0	41-42	-	ok
25-Aug-10	-	R2-270	NSSB	0.203	3.4	41-42	-	ok
25-Aug-10	-	R2-271	NSSB	0.265	3.4	41-42	-	ok
25-Aug-10	-	R2-272	NSSB	0.197	3.4	41-42	-	ok
25-Aug-10	-	R2-273	NSSB	0.155	2.8	41-42	-	ok
25-Aug-10	-	R2-274	NSSB	0.113	2.5	41-42	-	ok
25-Aug-10	-	R2-275	NSSB	0.234	3.3	41-42	-	ok
25-Aug-10	-	R2-276	NSSB	0.222	3.2	41-42	-	ok
25-Aug-10	-	R2-277	NSSB	0.265	3.6	41-42	-	ok

Date Sampled	Dissected by:	Fish ID	Species	Total Weight (g)	Fork Length (cm)	Area Taken (WP)	Age Strucure[a]	Condition/Comments
25-Aug-10	-	R2-278	NSSB	0.191	2.8	41-42	-	ok
25-Aug-10	-	R2-279	NSSB	0.166	2.8	41-42	-	ok
25-Aug-10	-	R2-280	NSSB	0.164	3.3	41-42	-	ok
25-Aug-10	-	R2-281	NSSB	0.133	2.9	41-42	-	ok
25-Aug-10	-	R2-282	NSSB	0.188	3.5	41-42	-	ok
25-Aug-10	-	R2-283	NSSB	0.273	3.5	41-42	-	ok
25-Aug-10	-	R2-284	NSSB	0.210	3.2	41-42	-	ok
25-Aug-10	-	R2-285	NSSB	0.259	3.5	41-42	-	ok
25-Aug-10	-	R2-286	NSSB	0.147	2.9	41-42	-	ok
25-Aug-10	-	R2-287	BURB	217.000	32.2	42-43	-	ok
25-Aug-10	-	R2-288	LKTR	109.300	20.6	42-43	-	ok
25-Aug-10	-	R2-289	ARGR	22.208	12.8	42-43	-	ok
25-Aug-10	-	R2-290	ARCH	10.077	9.8	42-43	-	ok
25-Aug-10	-	R2-291	LKTR	19.789	11.9	42-43	-	ok
25-Aug-10	-	R2-292	NSSB	1.605	5.9	42-43	-	ok
25-Aug-10	-	R2-293	LKTR	23.042	12.7	42-43	-	ok
25-Aug-10	-	R2-294	NSSB	0.242	3.5	42-43	-	ok
25-Aug-10	-	R2-295	NSSB	0.193	3.1	42-43	-	ok
25-Aug-10	-	R2-296	NSSB	0.168	3.1	42-43	-	ok
25-Aug-10	-	R2-297	NSSB	0.180	2.8	42-43	-	ok
25-Aug-10	-	R2-298	NSSB	0.204	3.3	42-43	-	ok
25-Aug-10	-	R2-299	NSSB	0.126	2.7	42-43	-	ok

Note:

a) ot = otollith

Table C-5: Arctic Grayling Age Determination (Performed By Northshore Environmental)

Fish ID	Species	Total Weight (g)	Fork Length (cm)	Age Strucure	Age	Confidence
E024	ARGR	21.554	13.2	ot	1	6 to 7
E025	ARGR	10.958	10.8	ot	1	7
E052	ARGR	15.056	11.4	ot	1	7
E053	ARGR	13.238	11.3	ot	1	6 to 7
E054	ARGR	2.734	6.5	ot	0	6
E072	ARGR	2.618	6.4	ot	0	7
E073	ARGR	2.925	6.6	ot	0	7
E074	ARGR	2.836	6.7	ot	0	7
E075	ARGR	1.283	5.5	ot	0	7
E091	ARGR	2.573	6.5	ot	0	7
E092	ARGR	2.230	6.4	ot	0	7
E093	ARGR	1.894	5.8	ot	0	7
E095	ARGR	2.459	6.4	ot	0	6 to 7
E096	ARGR	1.825	5.7	ot	0	7
E098	ARGR	2.031	6.0	ot	0	7
E100	ARGR	77.800	19.0	ot	2	7
E101	ARGR	13.429	11.2	ot	1	7
E102	ARGR	16.524	11.7	ot	1	7
E113	ARGR	1.729	6.0	ot	0	7
E114	ARGR	1.778	5.9	ot	0	7
E134	ARGR	1.793	6.1	ot	0	7
E152	ARGR	2.385	6.6	ot	missing	
E153	ARGR	1.866	5.8	ot	missing	
E154	ARGR	1.423	5.5	ot	missing	
E155	ARGR	2.400	6.4	ot	missing	
E156	ARGR	11.390	10.9	ot	missing	
R1-016	ARGR	2.910	6.8	ot	0	7
R1-023	ARGR	11.205	10.2	ot	1	6 to 7
R1-024	ARGR	17.239	11.3	ot	1	7
R1-027	ARGR	3.222	7.1	ot	0	7
R1-028	ARGR	26.182	13.1	ot	1	7
R1-041	ARGR	28.001	13.3	ot	1	6 to 7
R1-042	ARGR	18.123	11.9	ot	1	6 to 7
R1-051	ARGR	24.004	13.0	ot	missing	
R1-052	ARGR	19.130	11.7	ot	1	7
R1-064	ARGR	2.811	6.7	ot	0	6
R1-072	ARGR	2.725	6.6	ot	0	7
R1-078	ARGR	3.059	6.9	ot	0	7
R1-079	ARGR	16.096	11.4	ot	1	7
R1-085	ARGR	3.581	7.1	ot	0	7
R1-086	ARGR	3.261	7.2	ot	missing	
R1-110	ARGR	2.046	5.8	ot	missing	
R1-111	ARGR	2.508	6.2	ot	0	7
R1-112	ARGR	19.702	12.2	ot	2	6 to 7
R2-035	ARGR	43.281	16.3	ot	2	7
R2-036	ARGR	72.300	18.7	ot	2	6 to 7
R2-062	ARGR	56.100	17.3	ot	2	7
R2-063	ARGR	33.128	14.5	ot	2	7
R2-064	ARGR	57.600	16.6	ot	2	7
R2-078	ARGR	59.600	18.1	ot	2	7
R2-079	ARGR	53.900	17.4	ot	2	7
R2-081	ARGR	47.200	16.7	ot	2	7
R2-082	ARGR	43.600	16.4	ot	2	7

Table C-6: Lupin 2010 Fish Habitat Data

Area	Date Sampled	Cross-section (m)	Channel Width (m)	Wetted Width (m)	Depth (m)	Average Velocity (m/s)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Tempurture (C)	Turbidity (NTU)
Exposure	27-Aug-10	200	3.47	3.47	0.26	2.16	11.4	59	8.95	7.5	2.13
		400	5.03	5.03	0.58	2.89					
		600	10.4	8.86	0.48	4.56					
		800	3.8	3.8	0.26	2.95					
		1000	2.49	2.49	0.52	1.47					
Reference Area 1	20-Aug-10	200	1.16	1.16	0.26	3.6	-	6	7.5	-	1.03
		400	2.44	2.44	0.3	0.5					
		600	1.5	1.5	0.42	0.7					
		800	1.13	1.13	0.38	1.6					
		1000	1.24	1.39	0.36	1.2					
		1200	0.5	0.75	0.23	1.2					
		1400	3.16	3.16	0.23	0					
Reference Area 2	22-Aug-10	200	1.3	1.3	0.23	3.65	10.2	10	7.2	8.3	1.03
		400	1.74	1.74	0.3	6.32					
		600	1.93	1.93	0.29	2.8					
		800	1.92	1.92	0.45	3.2					
		1000	1.55	1.55	0.21	1.7					

Table C-7: Results of Metals Analysis from Fish Tissue Samples Lupin EEM 2010

Sample ID	Units	Detection Limits											
Date Sampled		25-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10	29-AUG-10
Time Sampled		00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00
ALS Sample ID		L926613-1	L926613-29	L926613-28	L926613-27	L926613-26	L926613-23	L926613-20	L926613-25	L926613-22	L926613-21	L926613-24	L926613-19
Matrix		Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Physical Tests													
% Moisture	%	0.10	75.9	76.1	77.5	75.8	77.8	80.0	74.0	80.9	74.2	76.6	73.9
Metals													
Aluminum (Al)-Total	mg/kg	2.0	<2.0	3.6	<2.0	<2.0	2.3	2.1	<2.0	<2.0	4.8	<2.0	4.7
Arsenic (As)-Total	mg/kg	0.010	0.164	0.151	0.070	0.195	0.385	0.544	0.068	0.263	0.973	0.154	0.468
Cobalt (Co)-Total	mg/kg	0.020	0.206	0.183	0.130	0.131	0.073	0.142	0.107	0.215	0.199	0.167	0.257
Copper (Cu)-Total	mg/kg	0.040	0.777	0.722	0.626	0.670	0.828	0.807	0.539	0.574	0.894	0.698	0.779
Nickel (Ni)-Total	mg/kg	0.010	0.295	0.276	0.343	0.237	0.230	0.286	0.242	0.256	0.357	0.264	0.321
Zinc (Zn)-Total	mg/kg	0.20	18.2	16.0	17.6	16.6	25.0	23.4	14.1	18.8	26.7	16.9	18.7

Table C-7: Results

	Reference Area 1								
Sample ID	R1-C1 (INCL.RI-024)	R1-C2 (INCL.R1-041)	R1-C3 (INCL.R1-042)	R1-C4 (INCL.R1-028)	R1-C5 (INCL.R1-023,R1-016)	R1-C6 (INCL.R1-052)	R1-C7 (INCL.R1-051)	R1-C8 (INCL.R1-085,R1-072,R1-079,R1-064,R1-111)	R1-C9 (INCL.R1-112,R1-110,R1-078,R1-086)
Date Sampled	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10	20-AUG-10
Time Sampled	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00
ALS Sample ID	L926613-18	L926613-17	L926613-13	L926613-12	L926613-16	L926613-11	L926613-15	L926613-14	L926613-10
Matrix	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Physical Tests									
% Moisture	76.3	75.4	74.7	73.7	77.7	75.3	76.3	75.7	75.7
Metals									
Aluminum (Al)-Total	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.1	<2.0
Arsenic (As)-Total	0.089	0.077	0.071	0.093	0.084	0.060	0.102	0.109	0.095
Cobalt (Co)-Total	0.101	0.070	0.048	0.088	0.118	0.051	0.079	0.067	0.063
Copper (Cu)-Total	0.727	0.706	0.944	0.696	0.913	0.676	0.673	0.717	0.674
Nickel (Ni)-Total	0.237	0.204	0.204	0.225	0.310	0.238	0.312	0.231	0.222
Zinc (Zn)-Total	16.2	14.9	16.8	14.8	25.7	16.0	17.0	17.8	16.6

Table C-7: Results

	Reference Area 2								
Sample ID	R2-C1 (INCL.R2-035)	R2-C2 (INCL.R2-036)	R2-C3 (INCL.R2-062)	R2-C4 (INCL.R12-063)	R2-C5 (INCL.R2-064)	R2-C6 (INCL.R2-078)	R2-C7 (INCL.R2-079)	R2-C8 (INCL.R2-082)	R2-C9 (INCL.R2-081)
Date Sampled	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10	25-AUG-10
Time Sampled	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00
ALS Sample ID	L926613-5	L926613-8	L926613-9	L926613-6	L926613-4	L926613-7	L926613-3	L926613-2	L926613-1
Matrix	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Physical Tests									
% Moisture	77.2	77.3	78.0	79.4	77.5	76.7	76.2	75.9	77.7
Metals									
Aluminum (Al)-Total	<2.0	<2.0	<2.0	2.6	<2.0	2.4	2.1	2.1	9.8
Arsenic (As)-Total	0.051	0.068	0.074	0.127	0.052	0.105	0.059	0.067	0.284
Cobalt (Co)-Total	0.083	0.097	0.152	0.333	0.118	0.271	0.099	0.135	0.708
Copper (Cu)-Total	0.566	0.629	0.592	0.579	0.611	0.698	0.654	0.691	0.806
Nickel (Ni)-Total	0.194	0.258	0.299	0.293	0.205	0.306	0.295	0.264	0.538
Zinc (Zn)-Total	14.4	17.4	17.2	17.5	15.9	16.8	16.1	16.4	18.6

Appendix D

Lupin Cycle 3 EEM Program Field Work Plan and Correspondence with the Technical Advisory Panel

Appendix D – Cycle 3 Study Design Correspondence

1. **Lupin Gold Mine Site Characterization and Cycle 3 Environmental Effects Monitoring Investigation of Cause Study Design Report**

2. **Technical Advisory Panel Review Comments on “Lupin Gold Mine Site Characterization and Cycle 3 Environmental Effects Monitoring Investigation of Cause Study Design Report”**

3. **Letter Correspondence: Study Design Addendum for Lupin Cycle 3 Environmental Effects Monitoring Study**

4. **Letter Correspondence: Study Design Addendum for Lupin Cycle 3 Environmental Effects Monitoring Study**

5. **Technical Advisory Panel comments on the Study Design Addendum for the Lupin Phase 3 EEM study**