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GIANT MINE REMEDIATION PROJECT (GMRP)

2011 Baker Creek Assessment Giant Mine, Yellowknife, NWT

Submitted to:
Public Works and Government Services Canada
(PWGSC)
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REPORT

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Executive Summary

Giant Mine (the Site) consists of an inactive gold mine located approximately 5 km north of the centre of Yellowknife, Northwest Territories. The Giant Mine Remediation Project (the Project) involves the implementation of the Giant Mine Remediation Plan to stabilize the Site, isolate contaminants from the environment, and to establish safe site conditions that allow for the restoration of ecological processes. The primary contaminant associated with the Site is arsenic.

Baker Creek is a small creek that passes through the Site before discharging into Yellowknife Bay, and is known to be contaminated by arsenic (and other contaminants) in water and sediment. The focus of the present study, which incorporates historic and new data, is to provide information to assist in management determinations of how best "...to restore Baker Creek to a condition that is as productive as possible, given the constraints of hydrology and climate."

Ongoing arsenic inputs from several sources could affect the long-term success of any remediation activities directed to contaminated sediments and tailings. These sources include historical atmospheric deposition from upstream reaches of Baker Creek above the mine site and discharge of treated effluent into Baker Creek. Effluent discharges are anticipated to continue for several years pending construction of a new treatment plant that would discharge treated effluent directly to Yellowknife Bay. In addition, realignments of a number of sections of Baker Creek are proposed to restore the creek to a more natural state and to prevent potential flooding of nearby open pits and the underground workings. The actions contemplated under the Project are intended to improve water and sediment quality within Baker Creek to benefit the aquatic ecosystem and to allow the creek to be used as a public recreational area.

Although numerous environmental studies pertaining to the mine site and/or Yellowknife Bay had been conducted since the 1970s, the information available regarding sediment quality and biota specific to Baker Creek was limited and in some cases too dated to be considered representative of current conditions. Available field data, although limited, indicated that aquatic biota had recolonized Baker Creek in recent years. Thus, to some extent, natural processes appeared to be reducing the effects of elevated concentrations of metals, metalloids (such as arsenic), and non-metals (such as selenium), which are collectively termed metals in this report. However, the extent of this apparent reduction, and thus of current environmental conditions, remained to be determined. Similarly, current and possible future human health risks associated with recreational and worker exposure to water and sediments and fish consumption needed to be determined based on the most up-to-date information and risk assessment procedures.

Ecological Assessment

Existing data for water, sediment and tissue chemistry (benthic invertebrates and fish), aquatic toxicity (water column and sediment), benthic invertebrate and fish communities were compiled and reviewed in detail to confirm that they were suitable for ecological assessment and that the data quality was acceptable. Relevant chemistry data were screened against applicable guidelines for protection of aquatic life to identify contaminants of potential concern (COPCs). Aquatic receptors were selected to provide representation for each ecosystem component in Baker Creek including lower food chain organisms such as algae and invertebrates, and fish (small-bodied fish such as Slimy Sculpin and Ninespine Stickleback, and large-bodied fish such as Northern Pike and Arctic Grayling).

Exposure pathways for aquatic receptors are routes by which receptors could potentially be exposed to COPCs in various environmental media. These were determined. A COPC was considered to represent a potential risk to aquatic life only if it could reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a COPC to reach a receptor, then there cannot be a risk, regardless of the COPC concentration. Exposure pathways that could be applied to aquatic receptors living in Baker Creek are: direct contact with COPCs in surface water; direct contact with COPCs in sediment; and, ingestion of dietary items with elevated COPC concentrations.

A 2011 field sampling program was undertaken to support the assessment of Baker Creek sediments and supplement historic data. This sampling program was limited to collection of samples associated with the aquatic environment within Baker Creek, and did not include sampling of soil, wildlife, or terrestrial biota.

Water quality data from 2011 indicate that lower Baker Creek continues to receive inputs of water-borne arsenic independent of the seasonal discharge of treated effluent. Surface water in Upper Baker Creek (above Baker Creek Pond) and Trapper Creek are a continuing source of arsenic to Baker Creek but at lower concentrations than in the treated effluent. Baker Creek surface water is not acutely toxic to juvenile Rainbow Trout or the water flea *Daphnia magna*, but when treated effluent is being discharged, surface water causes sublethal effects on water flea reproduction and algal growth in the laboratory.

Sediment arsenic concentrations were elevated and, in both Baker and Trapper Creeks, were generally above sediment quality guidelines, as well as the current Government of the Northwest Territories (GNWT 2003) remediation objective of 150 mg/kg dry weight (dw) set for the boat launch near Giant Mine. The highest arsenic concentration was more than 30 times higher than the GNWT remediation objective. The maximum arsenic concentration measured in surface sediments in this Baker Creek assessment was similar to the maximum arsenic concentration measured in 2005 (4,790 compared to 4,170 mg/kg dw).

Results from the subsurface sediment samples were generally consistent with those reported for surface sediments, with elevated concentrations of COPCs present at depth. The highest subsurface arsenic concentration measured in this Baker Creek assessment was 21,300 mg/kg dw (at 15 to 20 cm depth), which was almost three times higher than the maximum subsurface arsenic concentration (7,660 mg/kg dw at 30 to 35 cm depth) measured in 2005.

Benthic invertebrates were observed at all stations within Baker Creek, even those where sediment contaminant concentrations were elevated and laboratory sediment toxicity test results indicated lethality. This indicates that recolonization of Baker Creek has progressed since mining operations ceased, despite the continued presence of elevated concentrations of COPCs in sediments.

Metals concentrations in periphyton and benthic invertebrate tissues were elevated in Baker Creek compared to the Yellowknife River reference area, particularly antimony and arsenic, but also copper, lead, mercury, nickel, and/or zinc (depending on the tissue type). This indicates that these metals are biologically available in Baker Creek. However, variations in a number of tissue metal concentrations in these organisms confounded comparisons between Baker Creek (including Trapper Creek) and the Yellowknife River.

There were no obvious major differences among (bottom-dwelling) invertebrate communities in Baker Creek, Trapper Creek and the Yellowknife River. There was, however, only sporadic occurrence of mayflies in Baker Creek compared to their consistent presence at Yellowknife River reference stations. Overall, the magnitude of the effect of elevated sediment COPC concentrations in Baker Creek sediments on depositional benthic invertebrate communities can be qualitatively described as low but with uncertainty due to variability in the reference area data.

In contrast, benthic invertebrate communities in erosional (e.g., cobble) habitats of Baker Creek exhibited differences from the communities in similar habitat in the Yellowknife River. The erosional benthic invertebrate community within Baker Creek appears to reflect exposure to COPCs from treated effluent rather than historical sediment contamination.

In general, fish in Baker Creek have higher tissue metals concentrations than in reference areas. Small-bodied fish such as Slimy Sculpin that are year-round residents of Baker Creek contain substantially higher concentrations of metals than Yellowknife River fish. More bioaccessible arsenic was present in Slimy Sculpin collected from Baker Creek than from the Yellowknife River. Summer residents of Baker Creek such as Ninespine Stickleback have only slightly elevated concentrations of metals compared to the reference areas. Evaluation of potential effects of the elevated metals concentrations on fish health and the health of wildlife eating those fish was outside the scope of this assessment.

Adult spring migrant fish that use Baker Creek for a limited period each year, such as Arctic Grayling, have tissue metal concentrations that are higher than in other areas of the Northwest Territories. For most metals, mean concentrations in young-of-the-year Arctic Grayling fish tissue from Baker Creek were greater than in Arctic Grayling adult fish tissue. However, these conclusions are based on relatively small sample sizes and their ecological significance is unknown. Large-bodied fish such as Northern Pike and Lake Whitefish also contained elevated concentrations of some metals in comparison to Yellowknife River fish. Fish from Reach 6 appeared to have the most elevated concentrations, particularly of arsenic. A weight of evidence (WOE) approach was used to integrate the available data into a single “balance of probabilities” conclusion regarding the potential for unacceptable adverse ecological impacts in Baker Creek related to historic sediment contamination. This WOE approach incorporated sediment chemistry, benthic community structure, and the results of laboratory sediment toxicity tests. Six of the 26 depositional exposure stations, located near the mouth of Baker Creek, within and downstream of Baker Pond, and in Upper Baker Creek and Trapper Creek were classified as having negligible adverse effects despite elevated sediment metals concentrations. Twelve of the 26 depositional exposure stations, located throughout Baker Creek and in Trapper Creek, were classified as having potential adverse effects related to elevated sediment metals concentrations (particularly arsenic) and low or moderate sediment toxicity. The remaining 8 of 26 depositional exposure stations, again distributed through Baker Creek, were classified as having significant adverse effects based on elevated sediment metals concentrations and high sediment toxicity (in some cases 100% mortality in the laboratory tests).

However, benthic invertebrates were observed at all stations within Baker Creek, even those where sediment contaminant concentrations were highly elevated and laboratory sediment toxicity tests results indicated lethality. Clearly recolonization of Baker Creek sediments by fish food organisms has occurred since mining operations ceased despite sediment contamination that can adversely affect sensitive laboratory test organisms. Further, there was no spatial gradient of potential adverse effects from upstream to downstream; sediment contaminant and laboratory toxicity “hot spots” were located throughout Baker Creek. Two adjacent stations in mid Baker Creek were categorized as having negligible adverse effects in one case and significant adverse effects in the other.

Human Health Assessment

The selection of human receptors for the Baker Creek Site considered future uses and remediation plans for Baker Creek. On this basis, adult and toddler recreational users and adult construction workers were chosen as appropriate human receptors. Potential risks were assessed for people living in communities near the Giant Mine who may in future be potentially exposed to COPCs resulting from recreational use of Baker Creek (e.g., fishing, trapping, wading) or for people involved in implementation of remediation projects at Baker Creek. For COPCs that can cause cancer, only adults were assessed. For non-carcinogenic COPCs, both adults and toddlers were evaluated. Toddlers (i.e., children from 7 months to 4 years of age) are considered to be more sensitive to the effects of chemicals than adults, as they typically take in higher amounts of chemicals relative to their body weight. Also, toddlers take in higher amounts of chemicals when they play outside (e.g., in the creek) and put soil or sediment in their mouths. In addition, some chemicals such as lead have been shown to be more toxic to toddlers than adults. Health Canada recommends evaluating the toddler life-stage of childhood because this is typically the most sensitive child life-stage.

It was assumed that an adult or toddler living in one of the nearby communities may visit Baker Creek for recreational purposes every weekend for three months per year. This is a very conservative assumption as the public are actively discouraged from using a contaminated site and, currently, the upstream reaches of Baker Creek are off limits to the public. In addition, recreational activities are typically spread among locations, not restricted to a single location on a consistent, repetitive basis. It was assumed that a recreational user would fish in Baker Creek. It was considered unlikely that a recreational user would swim in Baker Creek, but this potential exposure was evaluated in order to understand the potential risks should this occur. Relevant exposure pathways for the recreational user are incidental sediment ingestion, fish ingestion, incidental surface water ingestion, dermal contact with sediment, and dermal contact with surface water. For the calculation of dermal contact exposure, it was assumed that the hands, feet, lower legs and forearms of the recreational user may come into contact with sediment and that their whole body may come into contact with surface water.

It was assumed that remediation plans for Baker Creek would require a construction worker to spend 13 weeks of the year working at the Site for 5 days per week. The construction worker may wade into the water wearing waterproof pants and footgear during construction activities. It was assumed that the construction worker would not be fishing in Baker Creek; they would be present at the Site to work only. Relevant exposure pathways for the construction worker are incidental sediment ingestion, incidental surface water ingestion, dermal contact with sediment, and dermal contact with water. For the calculation of dermal contact exposure, it was assumed that the hands and forearms of the construction worker may come into contact with sediment and surface water.

The human health risk assessment identified potential unacceptable risk for adults, toddlers and construction workers exposed to sediment, surface water and fish from Baker Creek. The two primary COPCs at the site related to human health risks are arsenic and antimony. Based on the above assumptions, arsenic exhibited potential for human health risk via ingestion of fish tissue as well as dermal contact with sediment, whereas antimony was primarily a concern in sediments via the dermal contact exposure pathway.

Based on the results of this assessment, swimming and barefoot wading by an adult or toddler recreational user should be limited in Baker Creek, in particular in upstream areas presently off-limits for recreational use. If construction or remediation activities take place at the Site, a Health and Safety plan should be in place to limit exposure to COPCs in sediment and water. In particular, appropriate personal protective equipment should be used to prevent dermal contact with sediment (e.g., gloves, long sleeves).

This study predicted higher potential human health risks than were predicted previously for four reasons. First, fish tissue concentrations have increased in Baker Creek, possibly due to the fact that benthic invertebrate communities have re-established within the creek, providing increased exposure to fish from benthic prey. Second, the current assessment was based on short exposures that, counter-intuitively but per Health Canada protocols, result in higher risk estimates than longer exposures for sub-chronic effects. Third, the methodology by which sediment dermal contact is assessed has changed; in particular, dermal loading rates (amount of sediment that sticks to the body) have increased. Fourth, the current human health assessment was limited to exposure to sediment, water, and fish from Baker Creek while the previous (2006) multi-media health assessment evaluated exposure from total chronic exposure (country foods from multiple locations, dietary contribution from store bought foods, air and water quality, etc.) in the Yellowknife area.

Periodic monitoring of sport fish should continue, to determine whether COPC concentrations are changing over time. Recommendations are provided for additional investigations that are outside the scope of the present study but will reduce present uncertainties in the human health assessment, including:

- Further information on the intended use of Baker Creek for fishing (e.g., frequency, preferred species, preferred tissue type) and other recreational purposes (frequency and location of swimming/wading);
- Confirmation from Health Canada on the need to use recently updated sediment (Intrinsik 2011) and sub-chronic protocols that are significantly more conservative than historic approaches; and,
- Updating the human health assessment with revised information and placing the findings into context with exposure from other metal (e.g., arsenic) sources in Yellowknife (fish from other locations, other dietary pathways) relative to exposure from Baker Creek.

Study Limitations

This report has been prepared for the use of Public Works and Government Services Canada (PWGSC) based on PWGSC's Terms of Reference for this work. Any use of this report by a third party or any reliance on or decisions made based on it, are the responsibility of the third parties. Should additional parties require reliance on this report, written authorization from Golder Associates Ltd. will be required. No assurance is made regarding the accuracy and completeness of these data. Golder Associates Ltd. disclaims responsibility for consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

The services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The content of this report is based on information compiled from a number of sources, included data collected by Golder Associates Ltd., other consultants, government and university researchers, our present understanding of the Site conditions, and our professional judgment in light of such information at the time of this report. With respect to data collected from site investigations conducted by others, we have relied on the accuracy of those data in good faith. This report provides a professional opinion and, therefore, no warranty is either expressed, implied, or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change.

The findings and conclusions of this report are valid only as of the date of the report, and are specific to Baker Creek PWGSC Terms of Reference for this wor.

If new information is discovered in future work, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as and if required.

Abbreviations and Acronyms

AANDC	Aboriginal Affairs and Northern Development Canada (formerly INAC)
AB	Arsenobetaine
AC	Arsenocholine
ALS	ALS Environmental Laboratory
As	Arsenic
AVS	Acid Volatile Sulphide
BA	Bioaccessible Arsenic
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
COPC	Contaminant of Potential Concern
CRM	Certified Reference Material
CSM	Conceptual Site Model
CVAFS	Cold Vapour Atomic Fluorescence Spectrophotometry
d	day
DAR	Developer’s Assessment Report
DCNJV	Deton’Cho/Nuna Joint Venture
DFO	Fisheries and Oceans Canada
DL	Detection Limit
DMA	Dimethylarsenic Acid
DO	Dissolved Oxygen
DQO	Data Quality Objective
dw	Dry Weight
ED	Exposure Duration
EDI	Estimated Daily Intake
EEM	Environmental Effects Monitoring
EPT	Ephemeroptera, Plecoptera and Trichoptera (invertebrate taxa)
ESG	Environmental Sciences Group (RMC)
ETP	Effluent Treatment Plant
FCSAP	Federal Contaminated Sites Action Plan
h	Hour
HPLC	High Performance Liquid Chromatography
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectrometry
ILCR	Incremental Lifetime Cancer Risk
INAC	Indian and Northern Affairs Canada (now AANDC)
ISQG	Interim Sediment Quality Guideline
GNWT	Government of Northwest Territories
LAET	Lowest Apparent Effect Threshold
LEL	Lowest Effect Level
LOE	Line of Evidence
MMA	Monomethylarsonic Acid

MMER	Metal Mining Effluent Regulation
µmol/g	micromoles per gram
NG	No Guideline
NM	Not Measured
NMDS	Non-Metric Multidimensional Scaling
PC	Principal Component
PCA	Principal Component Analysis
PEL	Probable Effect Level
PWGSC	Public Works and Government Services Canada
QA/QC	Quality Assurance / Quality Control
RAF	Relative Absorption Factor
RAIS	Risk Assessment Information System
RfD	Reference Dose
RMC	Royal Military College of Canada (Kingston, ON)
ROPC	Receptor of Potential Concern
RPD	Relative Percent Difference
RSL	Reference Screening Limit
SD	Standard Deviation
SE	Standard Error
SEI	Simpson’s Evenness Index
SEL	Severe Effect Level
SF	Slope Factor
SL	Screening Level
SEM	Simultaneously Extractable Metals
SNP	Surveillance Network Program
SRM	Standard Reference Material
SQG	Sediment Quality Guideline
t	tonnes
TC	Trapper Creek
TCA	Tailings Containment Area
TDS	Total Dissolved Solids
TETRA	Tetramethylarsonium Ion
TMAO	Trimethylarsine Oxide
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
TSS	Total Suspended Solids
UCLM	Upper Confidence Level of the Mean
U/S	Upstream
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WOE	Weight of Evidence
WQG	Water Quality Guideline
ww	Wet Weight
YKR	Yellowknife River
YOY	Young-of-Year

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1.0 INTRODUCTION

1.1 Background

Giant Mine (the Site) consists of an inactive gold mine located approximately 5 km north of the centre of Yellowknife (Figure 1), Northwest Territories. Historically, the mine produced gold from 1948 until 1999, after which time ownership was transferred to the Department of Indian and Northern Affairs Canada (INAC – presently Aboriginal Affairs and Northern Development Canada [AANDC]). INAC immediately transferred ownership to Miramar Giant Mine Ltd. (MGML), who ceased all ore processing activities at the Site but continued to mine and transport ore to the neighbouring Con Mine for processing until 2004. All mining activities ceased in July 2004, after which INAC resumed management and the Deton'Cho/Nuna Joint Venture (DCNJV) was retained to operate and maintain the Site in compliance with current regulations.

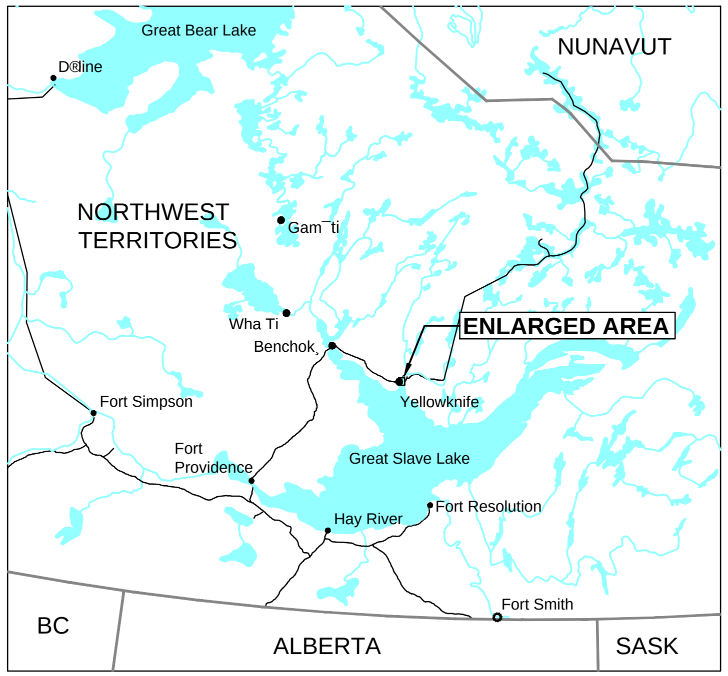
The Site is subject to the jurisdictional authority of both the territorial and federal governments. The federal and territorial governments entered into a Cooperation Agreement for the Giant Mine Remediation Project on March 15, 2005. This agreement established that both parties would implement a care and maintenance plan for the Site that protects human health, public safety, and the environment.

The Site is considered to include the lands within the boundaries of former Lease L3668T (currently designated reserve R662T). Two affected areas located outside this lease are also included as part of the Site: the Giant Mine town site; and, an area of historic tailings deposition along the north shore of Yellowknife Bay.

A remediation plan for the Site was prepared for INAC by its Technical Advisor, and reviewed by an Independent Review Panel (the 2007 Remediation Plan; SRK and SENES 2007). The Government of the Northwest Territories (GNWT) also contributed to the development and finalization of the plan. The 2007 Remediation Plan provides a detailed description of the current Site conditions, details of the proposed remediation activities, an assessment of post-remediation conditions, and a monitoring plan and schedule. A Developer's Assessment Report (DAR; INAC and GNWT 2010) for the overall mine site was submitted in October 2010. Those two documents outline proposed remediation activities for the mine site.

The Giant Mine Remediation Project (the Project) involves the implementation of the Giant Mine Remediation Plan to stabilize the site, isolate contaminants from the environment, and establish safe site conditions that allow for the restoration of ecological processes. The primary contaminant associated with the Site is arsenic, although other contaminants are also present and warrant consideration.

In 2009, Public Works and Government Services Canada (PWGSC) and INAC retained AECOM Canada Ltd. (AECOM) and, as a subconsultant, Golder Associates Ltd. (Golder) to develop a Giant Mine remediation preliminary design and Class B cost estimate, based upon the 2007 Remediation Plan. To facilitate the development of the preliminary design and cost estimate, multiple tasks were created to provide a breakdown of individual aspects of the 2007 Remediation Plan. The Terms of Reference for the work reported herein were developed to maximize the information that could be generated based on available funding levels.



KEY PLAN

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NOTES

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REFERENCE

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Revision/Révision	Description/Description	Date/Date
0	ISSUED WITH RPT-0005-REV2	2013-03-08
B	ISSUED WITH RPT-0005-REV1	2012-09-28
A	ISSUED WITH RPT-0005-REV0	2012-07-24

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Project title/Titre du projet
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REMEDIATION PROJECT
YELLOWKNIFE, N.W.T.

BAKER CREEK

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Drawn by/Dessiné par: RH
PWGSC Project Manager/Administrateur de Projets TPSGC: PWGSC
PWGSC, Architectural and Engineering Resources Manager/Ressources Architectural et de Directeur d'ingénierie, TPSGC
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KEY PLAN

Project No./No. du projet	Sheet/Feuille	Revision no./La Révision no.
R.014204	FIGURE 1	0

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Baker Creek is a small creek that passes through the Site before discharging into Yellowknife Bay (Figure 2), and is known to be contaminated by arsenic (and other contaminants) in water and sediment. One of the remediation objectives identified by SRK and SENES (2007) was "...to restore Baker Creek to a condition that is as productive as possible, given the constraints of hydrology and climate." In the context of the Project, this restoration objective can be interpreted as re-establishment of a biological community with quality and function equal to that of a similar but non-contaminated water body in the region.

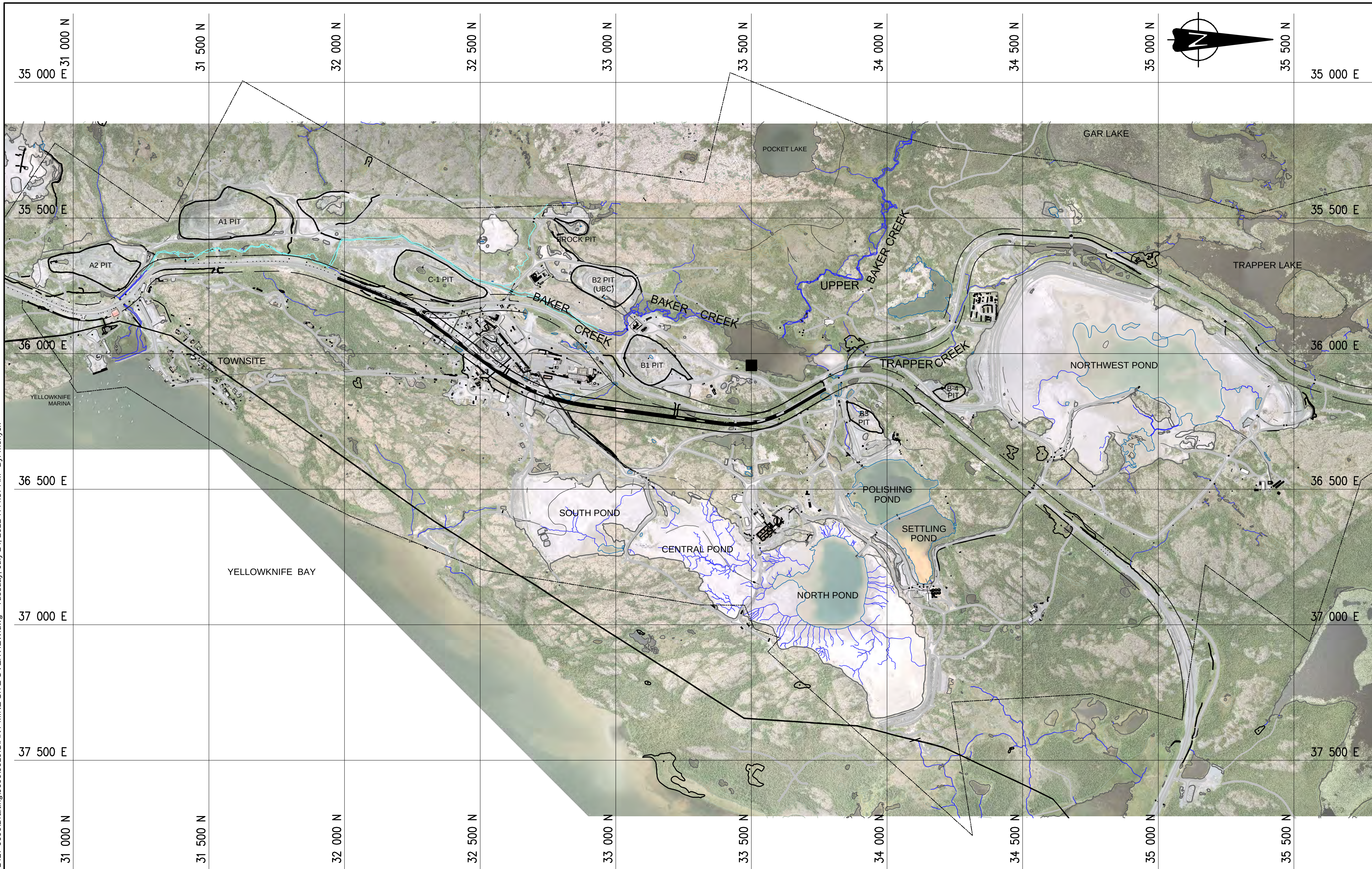
Options for remediation of Baker Creek include removal of contaminated sediments and tailings; however, ongoing inputs of arsenic resulting from several sources could affect the long-term success of such removal. These sources include historical atmospheric deposition from upstream reaches of Baker Creek above the mine site and discharge of treated effluent into Baker Creek. The actions contemplated under the Project are intended to improve water and sediment quality within Baker Creek to benefit the aquatic ecosystem and to allow the creek to be considered as a public recreational area, pending the City of Yellowknife and Government of the Northwest Territories final plans for the land.

Aquatic communities in Baker Creek are potentially affected by the following:

- Historical deposition of tailings in the creek;
- Accumulation of metals[1] and metalloids (particularly arsenic) in sediments from atmospheric deposition (associated with historical milling processes) and run-off;
- Extensive physical alteration of the creek (i.e., channelization, channel diversion, sedimentation, culvert construction);
- Periodic treated effluent discharge; and,
- Run-off from the Site.

Although numerous environmental studies pertaining to the mine site and/or Yellowknife Bay have been conducted since the 1970s, the information available regarding sediment quality and biota specific to Baker Creek is limited and in some cases too dated to be considered representative of current conditions. Fisheries and Oceans Canada (DFO) and other participants at the Baker Creek Restoration and Remediation Options workshops held in September and December 2009 indicated that there was insufficient information on the aquatic community of Baker Creek, particularly in the vicinity of Baker Creek Pond, to evaluate restoration options or to make an informed decision on preferred restoration options for Baker Creek.

[1] Note that throughout this document, the term "metals" includes metalloids such as arsenic and non-metals such as selenium.



LEGEND

■ LOCATION OF TREATED EFFLUENT ENTRY TO BAKER CREEK (RELOCATED IN 2011)

0 150 300 450 600 750

SCALE IN METRES

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GIANT MINE SITE OVERVIEW

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GIANT MINE SITE OVERVIEW

Information needs for Baker Creek identified by DFO in December 2009 and April 2010 were:

- Fish species abundance, community composition and habitat use;
- Benthic invertebrate abundance and community composition;
- Magnitude, spatial extent, and toxic effects of sediment contamination;
- Contaminant concentrations in fish tissues; and,
- Traditional knowledge.

1.2 Study Objectives

In June 2011, Golder prepared a data gap analysis and sampling plan specific to Baker Creek (Golder 2011a). The objective was to determine the magnitude and extent of sediment contamination and toxicity in Baker Creek, to assess benthic invertebrate abundance and community composition, and to measure contaminant concentrations in fish and benthic invertebrate tissues. Traditional knowledge was not included as it was understood that component was to be initiated by INAC. Golder's approach to undertaking the data gap analysis and sampling plan for Baker Creek was to apply the *Framework for Addressing and Managing Aquatic Contaminated Sites under the Federal Contaminated Sites Action Plan (FCSAP)* (Chapman 2011; Chapman and Smith 2012). The FCSAP aquatic sites framework outlines a tiered framework for the adaptive management of contaminated sites under federal custody, based on current risk assessment techniques and scientific knowledge, and is intended to address both ecological and human health risks associated with suspected contaminated aquatic sites. This framework consists of four tiers (information gathering, screening level assessment, detailed level assessment, and risk management) that encompass a series of 10 steps progressing from the initial identification of a suspect aquatic site through assessment, management actions, and long-term monitoring to confirm that remediation goals have been met. The data gap analysis and sampling plan undertaken for Baker Creek corresponded to the first tier of the FCSAP aquatic sites framework. Information gathering (also known as problem formulation) provides the foundation for assessment by summarizing available information and supporting the development of site-specific conceptual models. Moreover, it provides a focus for data collection, analysis and reporting, and can be used to determine the scope and approach of the subsequent assessment by delineating and identifying potential contaminant sources, pathways, and receptors.

The Golder (2011a) data gap analysis and sampling plan for Baker Creek was presented and discussed at a multi-agency[2] meeting in Yellowknife, NWT on June 14, 2011, which was convened and chaired by PWGSC. During that meeting, a number of modifications to the draft sampling plan were discussed, and Golder prepared a brief addendum letter (Golder 2011b) to document those modifications and their associated timelines. PWGSC subsequently requested that Golder proceed with the proposed assessment of Baker Creek sediments and aquatic biota.

The overall objective of the 2011 Baker Creek assessment was to generate information required to support decision-making with regard to remediation of Baker Creek sediments. This assessment was designed to address contaminant bioavailability in Baker Creek because, although contaminant concentrations in Baker Creek sediments significantly exceed sediment quality guidelines (SQGs), available field data, although limited, indicated that aquatic biota have recolonized several reaches of Baker Creek in recent years.

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[2] The meeting was attended by representatives from Golder, PWGSC, DFO, Environment Canada, INAC, and GNWT.

Specific objectives of the 2011 Baker Creek assessment were to:

- Conduct a comprehensive field sampling program to collect samples of water, sediment, benthic invertebrates, periphyton, and fish from Baker Creek and nearby reference areas;
- Assess the spatial extent and magnitude (horizontal and vertical) of sediment contamination in Baker Creek;
- Conduct laboratory sediment toxicity tests to assess potential effects of sediment exposure to aquatic organisms;
- Characterize the benthic invertebrate community within Baker Creek and nearby reference areas;
- Determine tissue metals concentrations in multiple trophic levels (periphyton, benthic invertebrates, and fish); and,
- Perform integrated assessments to assess the potential impacts to ecological and human health associated with direct and indirect exposure to Baker Creek sediments.

1.3 Report Organization

This report documents the findings of the 2011 Baker Creek assessment, which was designed to assess both ecological and human health aspects of Baker Creek sediment contamination. Information from the data gap analysis (Golder 2011a) has also been included for continuity. The report is organized as follows:

- Section 2.0 (Site Description) and Section 3.0 (Review of Previous Investigations) – These sections present information on the site description and review of previous investigations, which are part of information gathering but have common application to both the ecological and human health assessments.
- Section 4.0 (Ecological Assessment) – This section presents information on the ecological component of the Baker Creek assessment. There is an information gathering subsection that contains information specific to the ecological component, regarding data compilation and screening to identify contaminants of potential concern (COPCs), identification of receptors of potential concern (ROPCs), exposure pathways, and a conceptual site model (CSM). Methods, results and discussion pertaining to each line of evidence (LOE) are presented, along with an integrated weight of evidence (WOE) assessment, and discussion of the relationships between LOEs.
- Section 5.0 (Human Health Assessment) – This section presents information on the human health component of the Baker Creek assessment. There is an information gathering subsection that contains information specific to the human health component, regarding data compilation and screening to identify contaminants of potential concern (COPCs), sensitive sub-populations, exposure pathways, and a conceptual site model (CSM). Findings from the exposure and effects assessments, along with assessment characterization, are presented.
- Section 6.0 (Conclusions) and Section 7.0 (Recommendations) – Overall conclusions from the ecological and human health assessments, and recommendations for future actions, are provided.

2.0 SITE DESCRIPTION

2.1 Giant Mine Site Description

Site information summarized here is from Golder (2003, 2005, 2008a, 2011c), unless otherwise cited.

2.1.1 Physical Description

Giant Mine is a gold mine located approximately 5 km north of the City of Yellowknife, NWT, at latitude 62°31'N and longitude 114°21'W. The area of land within the mine surface lease boundary is 949 hectares and consists of forty individual leases. The Giant Mine is one of two gold mines located in close proximity to Yellowknife, the other being the Con Mine. The original mine claims were staked in July 1935 and the Giant ore deposit was discovered in 1943. The Giant Mine began production in 1948 and underwent numerous ownership changes during its 56-year history (Golder 2001).

The Giant Mine gold deposits occur within the Archeon-aged Yellowknife Greenstone Belt, located in the southeast corner of the Slave Province and extending north from Great Slave Lake for a distance of over 50 km. The Yellowknife Greenstone Belt is bounded to the west by younger granitic rocks of the Western Plutonic Complex and to the east by silica-bearing sedimentary rocks of the Burwash Formation.

The Site consists of a central valley containing Baker Creek, and its tributary Trapper Creek. The ridges on either side of the creek are 10 to 20 m high, and the slopes are rock controlled. There is limited thickness of soil on the ridge slopes. Mining activity in the Baker Creek Valley has significantly altered the local topography, and portions of the creek channel have been relocated three times.

Features of the Site are illustrated in Figure 2. The mine infrastructure has the following components:

- Eight abandoned open pits;
- An underground mine with numerous underground workings, including an area for arsenic trioxide storage;
- Several mine waste rock stockpiles;
- Four original tailings containment areas (TCAs);
- A tailings re-treatment plant (out of service since 1990);
- An effluent treatment plant (ETP);
- A mill site complex with a roaster and several warehouses; and,
- A town site.

In general, surface runoff across the Site is controlled by outcropping bedrock on the southwest and southeast sides of the lease boundary. Trapper Creek and Baker Creek collect runoff and direct water flow eastward and southward through the property. Creation of the Northwest, South, Central, and North TCAs and the settling and polishing ponds have altered the direction of natural flow. The Northwest TCA has required the relocation of Trapper Creek. Dam 11 at the South TCA has redirected the natural flow from the pond area that was towards

Yellowknife Bay to the north through the Central Pond into the North Pond and from there into the effluent treatment plant. The open pits have small individual catchment areas that direct surface water underground; this water is pumped back to the surface and treated at the ETP before being discharged into Baker Creek during open water conditions.

Environment Canada maintains records of climate normals that characterize average climate conditions for various Canadian locations, and that are updated at the end of each decade. The following mean climate data were available for Yellowknife, NWT for the period 1971 to 2000[3] (Environment Canada 2012a):

- Mean annual air temperature is -4.6°C;
- Mean annual snowfall is 151.8 mm;
- Mean annual rainfall is 164.5 mm;
- Mean annual wind speed is 14 km/h; and,
- Most frequent wind direction is from the east.

2.1.2 Historical Operations

The Giant Mine ore body has a strike length of over 4,500 m. In the past, both underground and open pit mining methods were used at Giant Mine. However, open pit operations ceased in 1990, when the near-surface mineable reserves were exhausted. The mine continued to operate as an underground mine, at an approximate production rate of 1,000 tonnes/day (t/d) until 1999, and then at a reduced production rate of 300 t/d from 1999 to 2004.

Between 1942 and 1999, ore processing at both Giant Mine and Con Mine released arsenic to the atmosphere. Historical atmospheric emissions of arsenic at Giant Mine, and the subsequent settling of particles, contaminated soil on the mine property and contaminated surface water and sediments within and beyond the mine site boundaries. Con Mine also had atmospheric emissions until an autoclave was installed.

Waste rock generated during open pit operations and development of underground access drifts or raises was used at the mine for construction of tailing retention structures, access roads and ramps, lay-down areas, berms, and as mine backfill. There are three main areas, located south of the Upper Baker Creek pit, where waste rock is currently stockpiled on the Site. Testing indicated that waste rock had low potential for generation of acid rock drainage, as the rock was generally acid consuming, and leach testing demonstrated that the waste rock had limited ability to act as a source of arsenic to receiving waters (Golder 2003).

Ore was milled on site from 1948 until 1999. Understanding the historical milling process is relevant to the current Site water quality and resulting environmental effects because the by-products of milling were a significant source of contamination to air, water, and sediment in the local environment. There were three main ways by which contaminants from the mill entered the environment:

- Airborne emissions from the roaster stack;
- Direct disposal of tailings into Yellowknife Bay; and,
- Milled tailings and minewater in the TCAs, which were treated and released to Baker Creek.

[3] The decade ending in 2000 is the most recent decade for which data are available.

Mine tailings were continuously deposited at the Site from the time production began in 1948. Historical aerial photographs indicate that tailings were initially deposited east of the mill in a small drainage channel that leads to Back Bay of Great Slave Lake. Between 1948 and 1951, tailings were deposited directly into Back Bay. Between 1951 and 1968, tailings from the mill were redirected through a new pipeline and deposited into a small lake (Bow Lake) northeast of the mine. The liquid portion of the tailings drained into Baker Creek, which discharged into Yellowknife Bay, and also northeast towards the mouth of the Yellowknife River. From 1968 to 1987, the bulk of the mill tailings were deposited northeast of the mill, in an area known as the original tailings area. This area included the South, Central, and North TCAs (also known as South Pond, Central Pond and North Pond). The natural topography directed surface runoff and mine tailings towards Baker Creek. The bulk of tailings were deposited in the Northwest TCA (or Northwest Pond) after 1987, and no tailings have been produced since operations ceased in 1999.

2.1.3 Effluent Treatment and Characteristics

In 1981, an ETP was installed using alkaline chlorination to reduce cyanide concentrations in effluent from the TCAs. This treatment process was replaced in 1988 by hydrogen peroxide oxidation. Both processes oxidize arsenite species (As^{3+}) to arsenates (As^{5+}). Ferric sulphate is added after the pH is adjusted with lime to approximately 8.5 and an iron to arsenic molar ratio of 10:1 is established. After treatment, effluent is released to a settling pond, then flows to a polishing pond, and finally is discharged to Baker Creek through a pipeline.

As part of the agreement with INAC, the Government of the Northwest Territories (GNWT), PWGSC and DCNJV operate the ETP on a seasonal basis to remove groundwater that infiltrates the mine. This is done to prevent the arsenic trioxide storage chambers from flooding and potentially releasing arsenic into the environment. This practice will continue until a long-term management method for the stored arsenic trioxide is implemented. As part of the Project (SRK and SENES 2007), construction of a new ETP is proposed that will discharge treated effluent year-round directly to Yellowknife Bay instead of seasonally to Baker Creek.

As part of the water license (N1L2-0043) that was active until July 2005, the effluent discharged from the mine is monitored under the Surveillance Network Program (SNP). Although the water license is no longer active because the mine is no longer owned and operated by MGML, INAC contracted DCNJV to provide care and maintenance of the mine site and to operate the ETP to meet the water license effluent discharge criteria. In addition to the water license requirements, the effluent must also be monitored for deleterious substances and meet the discharge limits required in the Metal Mining Effluent Regulations (MMER).

The volume and scheduling of effluent discharge varies from year to year depending on operational requirements and weather conditions. The mine typically discharges effluent during the open water season between July and September. In some years, additional effluent may have been discharged in early spring (e.g., May 1998) or late fall (e.g., November 1997, November 1998).

Modelling of the current plume in Yellowknife Bay was performed under the MMER program; it assumed different effluent dilution scenarios at the outlet of the marsh near the breakwater where the effluent meets open water. This modeling was based on the current practice of discharging treated effluent directly to Baker Creek. Under the best-case dilution scenario, the effluent concentration is estimated to reach 1% within 122 m of the mouth of Baker Creek. Under the worst-case dilution scenario, the effluent concentration is estimated to reach 1% at 785 m into the open water area of Yellowknife Bay. The average dilution scenario estimates the effluent concentration to reach 1% at 187 m into the open water in Yellowknife Bay.

Treated effluent is the main point source of contaminants to the Baker Creek receiving environment. In addition to the effluent discharged from the mine, Baker Creek is subject to several non-point source anthropogenic inputs unrelated to the mine. These include inputs from the territorial highway (i.e., Ingraham Trail) that runs parallel to the creek and from the privately-owned marina at the mouth of Baker Creek.

2.2 Baker Creek Biophysical Description

References to locations within Baker Creek are made in terms of the numbered reaches used to delineate sections of the creek, from downstream Reach 0 (where Baker Creek empties into Yellowknife Bay) to upstream Reach 6 (Baker Creek Pond, where mine effluent was previously discharged during mine operations and where treated effluent continues to be discharged during summer months). For the purpose of this report, "Upper Baker Creek" refers to the section of the creek from Martin Lake to the upstream margin of "Baker Creek Pond" (Reach 6) within the mine lease area. Trapper Creek is the major tributary to Baker Creek, and enters on the north side of Baker Creek Pond.

Baker Creek originates at Duckfish Lake, located approximately 25 km northwest of the mine. Baker Creek flows south and southeast from Duckfish Lake, through a series of wetland ponds and bedrock outcrops and into a marsh that is separated by a breakwater from Yellowknife Bay. The drainage area of Baker Creek is estimated to be 121 km^2 (Environment Canada 2011b). After draining from Duckfish Lake, Baker Creek forms the outlet of Martin Lake, which is a popular local fishery. Past studies have documented a variety of fish species present in Baker Creek and in Yellowknife Bay; however, it is unknown whether Baker Creek provides overwintering habitat because no formal winter studies have been conducted in this area.

Peak discharge occurs during spring freshet, which is typically in May. Between 1983 and 2010, the latest data available, peak daily discharge volumes ranged from 0.27 to 8.35 m^3/s (Environment Canada 2012b). Baker Creek flow volumes are variable, and the upper reach of the stream can be ephemeral. In contrast, lower Baker Creek (downstream of the mine discharge) flows continually due to the inputs of treated effluent.

Baker Creek primarily consists of lotic (flowing water) habitat with variable water depths and substrates along its reaches. Water depths within the creek vary from a few centimetres (cm) to 2.3 metres (m) deep. At the mouth of Baker Creek, where it flows into Yellowknife Bay, a large marsh area is located on the west bank of the bay, which supports predominantly *Equisetum* sp. (horsetail) and a smaller patch of *Potamogeton* sp. (pondweed). East of the marsh area, the water from Baker Creek flows along the breakwater and into the main body of Yellowknife Bay. Substrates in this area are dominated by fine material (i.e., silt and sand), and are representative of a depositional area.

Nearby communities include the Giant Mine Townsite, Latham Island, the City of Yellowknife and the Dettah Community (SENES 2006). There is access to Baker Creek from the Ingraham Trail, Highway 4 and from the Giant Mine property. Upper Baker Creek is accessible from the Vee Lake Road. Most reaches of the creek are accessible by vehicle or by foot. Baker Creek is not navigable with the exception of a few small ponded areas (Golder 2008a).

For the purpose of this report, the study area was limited to Baker Creek (exclusive of the riparian zone) and only addressed the environmental media contained within the creek (water, sediment, benthic invertebrates, and fish tissues). The boundaries of the study area therefore follow the boundaries of Baker Creek. Brief descriptions of the discrete reaches within Baker Creek are outlined below; these are based on information from the DAR (INAC and GNWT 2010) and observations made in 2010 in conjunction with a reconnaissance survey (Golder 2010a) and habitat mapping of the creek reaches (Golder 2011b):

- Reach 0 (Great Slave Lake Inflow): At the mouth of Baker Creek, where it flows into Yellowknife Bay behind a constructed breakwater, a large marsh area is located on the west bank of the bay, which supports predominantly *Equisetum* sp. (horsetail) and a smaller patch of *Potamogeton* sp. (pondweed). East of the marsh area, water from Baker Creek flows along the breakwater and into the main body of Yellowknife Bay. The substrates in this area are dominated by fine material (i.e., silt and sand), and are representative of a depositional area. There is a small marina located adjacent to the mouth of Baker Creek.

- Reach 1 (Highway and Trail crossing): This reach is 395 m total length. Here the creek flows through a culvert under Highway 4 (Ingraham Trail); this culvert is monitored to prevent obstructions and can act as a barrier to fish migration during high and low flows. The channel appears to have been diverted as it is confined with boulder/cobble substrate to a narrow area between the A2 Pit and Highway 4. This reach consists of a mixture of erosional and depositional habitats, with little fine-grained material.

- Reach 2 (Natural Reach): This reach is 600 m total length. Much of this reach is in natural condition and has not been disturbed by historical mine operations, although there are two decommissioned road crossing embankments. This reach consists primarily of depositional habitat, consisting of fine-grained material.

- Reach 3 (Diverted Reach): This reach is 750 m total length. This portion of the creek is channelized with no floodplain. The creek substrate is composed primarily of large materials (>70 mm) with some finer sediments in the lower sub-reaches.

- Reach 4 (Restored Reach): This reach is 350 m total length. This portion of Baker Creek was realigned to the west side of the Ingraham Trail (Highway 4) in summer 2006 to isolate the contaminated Mill Pond from Baker Creek and to prevent seepage of Baker Creek into the underground mine. The realigned portion of Baker Creek was designed to maintain and improve fish habitat in the creek (Golder 2008b). Secondary objectives of the realignment were to provide a stable flood conveyance channel, maintain or improve fish passage, and provide spawning and rearing habitat for native fish species.

- Reach 5 (Natural Reach): This reach is 425 m total length. It is another natural reach of Baker Creek that provides fish habitat, although it has been disturbed by past mining activity.

- Reach 6 (Baker Creek Pond): Baker Pond currently receives treated effluent from the mine on a seasonal basis. The bottom of Baker Pond and the shoreline contain mine tailings, which were disturbed in May 2011 as a result of the change in flow of Upper Baker Creek as a result of ice accumulation (see below).

- Upper Reaches: This portion of Baker Creek is in its natural state and has not been disturbed by mining activities. However, it does contain elevated arsenic concentrations in water and sediment as a result of atmospheric deposition associated with historical ore milling operations.

An unexpected water diversion event occurred in Baker Creek in spring 2011. The normal flow path of Upper Baker Creek from Martin Lake to Baker Creek Pond (Reach 6) is through a series of wetlands and a waterfall entering the pond. However, during winter 2010/2011, ice built up above Reach 6 for a distance of approximately 1 km. In May 2011, early spring flows from Martin Lake flowed north around the ice instead of through the ice, creating a new channel that eroded an old mine road. The new channel entered Reach 6 at a location where mine tailings were historically deposited on lake sediments during early mining operations. This flow eroded sediment from the tailings area, resulting in short-term high turbidity throughout the downstream portion of Baker Creek and causing a sediment plume that reached the mouth of Baker Creek where it enters Yellowknife Bay. Environmental monitoring and remediation activities were undertaken to correct this flow diversion and to assess immediate potential impacts to Baker Creek. The conclusion of the monitoring studies was that re-suspended sediments and tailings from above Baker Creek Pond had likely been deposited throughout Baker Creek, including areas not previously considered to be depositional (e.g., Reach 4). This event also affected comparisons of 2011 conditions to those reported in previous studies of Baker Creek. This newly deposited material may remain in place or may be flushed further downstream as flows increase in Baker Creek during seasonal discharge of treated effluent. The field sampling program for the 2011 Baker Creek assessment was not modified as a result of this diversion event.

2.3 Yellowknife River Reference Area

The mouth of the Yellowknife River resembles the habitat in the Baker Creek exposure area because it has sections with flowing water followed by flat water, marsh habitat, varying water depths, and open areas exposed to wave action. It has therefore been used as a reference area for Giant Mine Environmental Effects Monitoring (EEM) activities since 2005 (Golder 2005, 2008a, 2011c). For consistency, and because an alternative reference area has not been identified to date, the mouth of the Yellowknife River was used as the reference area for the Baker Creek assessment.

The mouth of the Yellowknife River is located approximately 1 km upstream from the mine property. The Yellowknife River is accessible at the bridge crossing on the Ingraham Trail where there is a day-use Territorial Park with a boat launch.

An inlet area located at the northern part of the Yellowknife River, approximately 0.5 km from the outflow of Prosperous Lake, has been used as an additional reference location for EEM fish surveys. The inlet has access to the main river system through a small channel, with water depths ranging from approximately 0.5 to 2.5 m. Submergent and emergent vegetation are also present, similar to vegetation found in both Baker Creek and Yellowknife Bay. The substrate consists of silt, fine sand and organic debris.

The Yellowknife River drains a large watershed (16,300 km^2) that extends to the north of Great Slave Lake. Between 1988 and 2010, mean annual discharge of the Yellowknife River (at the outlet of Prosperous Lake) was 42.0 m^3/s (Environment Canada 2012b). The Yellowknife River is dominated by riverine habitat, although lacustrine habitat occurs downstream where the river enters Yellowknife Bay. There are extensive reed beds in an isolated bay located along the north shore immediately downstream of the outlet of Prosperous Lake and Tartan Rapids. Reed beds are also located along the south shore near Yellowknife Bay.

Water and sediment chemistry data suggest that the Yellowknife River has not been contaminated by the mine with the exception of one focal area (R09). Recreational use of the Yellowknife River (e.g., boating, fishing) is high during the summer. The mouth of the Yellowknife River, where it enters into Great Slave Lake, is a traditional site for subsistence fishing by the Yellowknives Dene and is also a popular site for recreational fishing. These activities may have an impact on the fish populations, particularly Cisco, which are heavily harvested recreationally and commercially in the fall.

3.0 REVIEW OF PREVIOUS INVESTIGATIONS

The Giant Mine is a contaminated site with years of in-stream data collection for Baker Creek by numerous agencies and universities. However, because contaminant bioavailability has not been well established, Baker Creek cannot presently be classified under the FCSAP aquatic sites framework without additional investigation directed by the findings of previous studies. An additional issue is that historical investigations of exposure and effect were conducted at different times (and with different objectives), making linkages between contamination and environmental response difficult to discern. Accurate classification is required to determine what management activities are required, confirming that any such activities (e.g., dredging) are in fact required and do not, per the FCSAP aquatic sites framework, cause more harm than they remedy.

Several previous investigations were identified as being potentially relevant to Baker Creek, and were therefore reviewed as part of the data gap analysis. SENES (2002, 2003, 2006) previously conducted three risk assessments pertaining to the Giant Mine site; these were used to provide information regarding human receptors at the Giant Mine and potential exposure pathways.

SENES (2002) conducted a Tier 2 ecological and human health risk assessment for the management of arsenic trioxide dust at the Giant Mine that included an ecological risk assessment of the potential impact of treated effluent discharge (short–term) and groundwater seepage (long-term) on aquatic biota in Baker Creek. The main goal of that risk assessment was to identify a minimum acceptable target for arsenic releases to the aquatic environment. The assessment did not consider sediment contamination due to historic discharges, but indicated that arsenic concentrations reported in Baker Creek sediments continued to pose a potential risk to aquatic biota. SENES (2002) recommended that future monitoring of benthic invertebrates and fish be undertaken in Baker Creek and Back Bay (part of Yellowknife Bay) to evaluate potential impacts from arsenic sediment concentrations under current conditions.

SENES (2003) completed a screening-level human health risk assessment for the Giant Mine site, and identified a potential health risk to residents of Latham Island communities near the Giant Mine due to exposure to antimony, lead, nickel and arsenic (SENES 2003). Later review of the results by SENES, applying the use of site-specific transfer factors, resulted in hazard quotients (HQs) below the targeted 0.5 for lead and nickel. Incidental consumption of soil was the primary driver of the elevated antimony HQ, and SENES (2006) concluded that after remediation of the arsenic-contaminated soils at the Site antimony concentrations would be below the Canadian Council of Ministers of the Environment (CCME) guideline of 20 mg/kg. Based on the results of the SENES (2003) screening-level risk assessment, a Tier 2 Human Health and Ecological Risk Assessment of the Giant Mine site was undertaken (SENES 2006). Due to the elimination of antimony, lead, and nickel as COPCs, SENES (2006) only evaluated the risk posed by arsenic to people living near the Giant Mine from a variety of exposure pathways. The result of that risk assessment indicated the greatest source of arsenic exposure was market foods; predicted arsenic exposure levels for residents in the area were within the typical range for people living in Canada.

Data on treated effluent quality, surface water, pore water and sediment quality, benthic invertebrate community structure, and tissue chemistry data for benthic invertebrates and fish were reviewed from the following sources: Andrade (2006); Dillon (2002a,b, 2004); Falk et al. (1973a,b); Golder (2005, 2008a,b, 2009, 2010b, 2011c); Jacques Whitford (2006); and, Mace (1998).

Additionally, the most recent four years (2007 to 2010) of treated effluent and surface water data from the Surveillance Network Program carried out at Giant Mine as required under Part B, Item 5 of the former Water License, N1L2-043, were included in the information gathering.

Several studies to date have suggested that it is the historical sediment contamination in Baker Creek and Yellowknife Bay that poses the greatest risk to aquatic life, rather than the seasonal discharge of mine effluent to these receiving environments (Dillon 2002a,b; SENES 2002; Golder 2006, 2008a). Measurements of total arsenic concentrations in Baker Creek sediments collected in 2005 at various depths ranged from 82.8 to 7,660 mg/kg dw (Jacques Whitford 2006). With implementation of effluent treatment and the shutdown of processing operations at Giant Mine, the chemistry of Giant Mine effluent and surface waters in Baker Creek has changed substantially over the last three decades. Although waterborne total arsenic concentrations in Baker Creek (0.12 to 0.21 mg/L in 2006; Golder 2008a) exceeded the CCME total arsenic guideline for the protection of aquatic life (0.005 mg/L; CCME 1999), concentrations were considerably lower than those recorded during the 1970s prior to the initiation of effluent treatment in the 1980s (e.g., 9.1 mg/L reported by Moore et al. 1978).

3.1.1 Chemistry Data

3.1.1.1 Treated Effluent

Treated effluent is currently discharged to Baker Creek during the open water season, from approximately July to September. The treated effluent is discharged via a pipeline at the upper end of Baker Creek Pond (Reach 6). Under the SNP, effluent quality is monitored on a regular basis throughout the discharge period at SNP Station 43-1. Analyses are conducted on grab samples collected directly from a tap on the discharge pipe 175 m upstream of the actual point of discharge (Golder 2011c).

The DCNJV is responsible for operation of the effluent treatment plant, as part of the care and maintenance of the mine site, and conducts regular monitoring of the treated effluent discharge at SNP Station 43-1 during the open water season as part of a larger SNP monitoring program for the mine site. The effluent characterization requirements call for daily sampling (24-h composite samples) for pH and MMER deleterious substances, and weekly sampling for aluminum, cadmium, iron, mercury, molybdenum, ammonia, nitrate, hardness, and alkalinity.

As part of the requirements of the EEM program specified in the Metal Mining Effluent Regulations (MMER), Golder has conducted monthly sampling of treated effluent at SNP Station 43-1 during the open water season from 2003 to 2010. Temperature, pH, dissolved oxygen, and conductivity are measured in the field, and grab samples are collected for laboratory analyses of major ions, nutrients, total cyanide, total and dissolved metals, Radium-226, oil and grease, and sulphide.

Data for treated effluent sampled between 2007 and 2010 for SNP monitoring, and from 2003 to 2010 for EEM/MMER monitoring, were used for COPC screening and are provided in Appendix A.

3.1.1.2 Surface Water

Monitoring of surface water quality in Baker Creek and its tributaries has been undertaken as part of previous independent investigations of Baker Creek, and is ongoing through the SNP and EEM/MMER monitoring programs.

Dillon (2002a,b) conducted sampling of water, sediment, and biota at four stations in Baker Creek (two in Reach 0 and two upstream of Reach 6) in October 2001 and June 2002. Jacques Whitford (2006) collected surface water samples in August/September 2005 for analysis of general water quality, dissolved metals, major ions and arsenic speciation.

As part of ongoing SNP or EEM/MMER monitoring activities, surface water quality is monitored during the open water season at three locations upstream of Baker Creek Pond (SNP Station 43-11 in Upper Baker Creek, and SNP Stations 43-15 and 43-16 in Trapper Creek), at the outlet to Baker Creek Pond (defined as the Baker Creek Exposure Point for EEM sampling; Golder 2011c), and at two locations near the mouth of Baker Creek (SNP Stations 43-5 and 43-12).

3.1.1.3 Porewater

Jacques Whitford (2006) collected porewater samples in August/September 2005 and analysed these for general water quality, dissolved metals, major ions and arsenic speciation. Data were not compared to CCME guidelines for protection of aquatic life.

A study in Yellowknife Bay (Andrade 2006) showed the arsenic concentrations in porewater above the beached tailings were elevated relative to the surface water (1,010 µg/L at 1.8 cm depth below the sediment water interface [arsenate or pentavalent arsenic]) but were lower at the immediate sediment water interface (15 µg/L). The arsenic could have been remobilizing from the sediment into the water.

The porewater concentrations of arsenic in Baker Creek were elevated at the sediment water interface (117 to 181 µg/L [arsenate, forming the bulk of the total arsenic]). Arsenic trioxide (As^{3+}), which is a more toxic form of arsenic than arsenate (As^{5+}), was lower in concentration at the sediment water interface, but rose steeply to 5,815 µg/L by 18 cm depth. The highest porewater arsenic concentrations were found in the Baker Creek marsh area (Andrade 2006). The effect, if any, of these porewater concentrations on surface water concentrations and aquatic organisms is not known.

3.1.1.4 Sediment

Dillon (2002a,b) conducted sampling of water, sediment and biota at four stations in Baker Creek (two in Reach 0 and two upstream of Reach 6) in October 2001 and June 2002. Triplicate samples of surficial sediment were collected using a trowel. In October 2001, the samples were analysed for total organic carbon (TOC), grain size and total metals, whereas in June 2002 they were only analysed for grain size and five metals (antimony, arsenic, copper, nickel and zinc). Concentrations of arsenic, cadmium, chromium, copper, lead and zinc exceeded CCME sediment quality guidelines for protection of aquatic life.

SENES (2002) made reference to sediment data for Baker Creek from the 1990s, and to the sediment data collected by Dillon (2002a,b), in their Tier 2 risk assessment of arsenic trioxide.

Jacques Whitford (2006) conducted an investigation of Baker Creek sediments in August/September 2005. Sediment cores (maximum 35 cm depth) were collected at 18 stations encompassing Reaches 1 to 6; three depth intervals per core were analysed for TOC and total metals including arsenic. A subset of sediment samples was also analysed for grain size, acid volatile sulphide (AVS) and other geochemical properties, including extraction tests to assess arsenic bioaccessibility. Total arsenic concentrations ranged from 82.8 to 7,660 mg/kg dry weight (dw); concentrations were highest at stations in Reaches 3 and 6, and generally increased with depth. Sediment chemistry data were not compared to CCME guidelines for protection of aquatic life.

Golder (2005) conducted sediment sampling in conjunction with benthic invertebrate sampling in 2004 as part of the EEM Phase 1 program for the Giant Mine. Surficial (top 5 cm) sediments were collected from 10 stations, all located in Reach 0 at the mouth of Baker Creek, and analysed for TOC, grain size, and total metals. Golder (2008a) conducted similar surficial sediment sampling (sediment depth not specified) at five stations in Reach 0 for the EEM Phase 2 program in September 2006; samples were analysed for TOC, grain size and total arsenic.

Golder (2010b) collected one sediment sample (sediment depth not specified) from a pool near Riffle 2 in Reach 4 in July 2009, as part of the 2009 grayling study. This sediment grab sample had a total arsenic concentration of approximately 30 mg/kg dw.

3.1.1.5 Tissue

Benthic Invertebrates

Dillon (2002a,b) conducted sampling of water, sediment and biota at four stations in Baker Creek (two in Reach 0 and two upstream of Reach 6) in October 2001 and June 2002.

An artificial substrate study by Dillon (2002b) provided qualitative community data that suggested benthic invertebrates may have recolonized Baker Creek close to the mouth, but that downstream invertebrate composition may differ from that recorded upstream. Furthermore, mean arsenic tissue concentrations in invertebrates that colonized the downstream substrates were approximately three times higher than corresponding upstream tissue concentrations (136 versus 43 µg/g dw)[4]. The authors recommended an increase in sample sizes for all parameters in future studies and also recommended that a reference stream be sampled in addition to upper Baker Creek.

In summary, there are only limited benthic invertebrate tissue data available for Baker Creek, and these data are confined to Reach 0 and upper Baker Creek (one sampling event).

[4] Based on 5 upstream tissue samples and 10 downstream tissue samples.

Fish

In 2002, metal concentrations in muscle tissue from fish captured from Baker Creek upstream of the mine site (approximately Reach 6) had higher concentrations of arsenic, nickel and zinc relative to fish caught downstream (approximately Reach 0; Dillon 2002b); mean arsenic concentrations in these fish tissues were 24 µg/g dw in upstream samples as compared to 3 µg/g dw downstream.

De Rosemond et al. (2008) sampled fish from Back Bay (in Yellowknife Bay, beyond Reach 0) and determined that White Sucker had higher concentrations of arsenic than Lake Whitefish, Northern Pike, and Walleye. Tissue arsenic concentrations observed in this survey were ≤1.15 µg/g dw in muscle, ≤2.52 µg/g dw in liver, and ≤8.92 µg/g dw in the gastrointestinal tract, and were consistently higher in the gastrointestinal tract than in muscle tissue.

The most recent fish tissue data available for Baker Creek were for Arctic Grayling that were sampled in Reach 4 in 2009 as part of an ongoing study to assess their usage of Reach 4 (Golder 2010c). These data are provided in Appendix A.

3.1.2 Aquatic Toxicity

Jacques Whitford (2006) conducted an investigation of Baker Creek sediments in August/September 2005. Whole-sediment toxicity tests were conducted on surface (top 10 cm) grab samples collected from five stations in Reaches 1, 2, 3, 5 and 6, using the freshwater invertebrates *Hyalella azteca* (amphipod) and *Chironomus tentans* (midge). Sediments were moderately or highly toxic to both test species, except that the Reach 1 sample was non-toxic to *C. tentans*. Jacques Whitford (2006) attributed the observed sediment toxicity to copper rather than to arsenic, but did not provide a rationale for this conclusion. It appears that these are the only sediment toxicity data available for Baker Creek; no tests have been conducted in the years since this study. The observation of recolonization, although uncertain, suggests that sediment toxicity and/or physical effects to biota have decreased. Additional study is required to assess this possibility, as discussed later in this report.

3.1.3 Benthic Invertebrate Communities

Historical studies in the 1970s prior to the onset of effluent treatment at the Giant Mine documented that benthic invertebrates were virtually absent in lower Baker Creek, compared with an abundance of invertebrates in upper Baker Creek, upstream of the Giant Mine (Falk et al. 1973a,b; Moore et al. 1978). The virtual absence of benthic invertebrate communities was attributed to elevated sediment contaminant concentrations in Baker Creek, primarily arsenic concentrations. Falk et al. (1973a,b) documented the absence of invertebrates at four sampling stations within Baker Creek. Moore et al. (1978) documented that Baker Creek was largely devoid of fauna downstream of the mine, although oligochaetes (aquatic worms) were present in very low numbers (<100 individuals per square metre [ind/m^2]).

An artificial substrate study by Dillon (2002b) provided qualitative community data that suggested benthic invertebrates may have recolonized Baker Creek close to the mouth, but that downstream invertebrate composition might differ from that recorded upstream. In July 2002, dipteran (true fly) larvae (e.g., Simuliidae and Chironomidae), Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) nymphs and larvae were observed in Baker Creek at locations upstream of the mine; dipteran larvae were the most abundant taxa. Ephemeroptera, Plecoptera, and Trichoptera (i.e., EPT taxa) were absent from locations downstream of the mine (i.e., areas exposed to effluent) but oligochaetes, ostracods, and dipteran larvae were present. The absence of the EPT taxa is sometimes used as an indicator of potential environmental alteration in freshwater systems. The authors recommended increasing sample sizes for all parameters in future studies and sampling a reference stream in addition to upper Baker Creek.

Preliminary data collected in 2004 by Golder (2010a) also suggested that benthic invertebrates have recolonized Baker Creek in Reach 4. Both richness and abundance were lower in the depositional sample from a pool habitat compared to the erosional sample from a riffle/glide habitat, but oligochaetes and dipteran larvae were represented in both habitats, with mayflies and blackfly larvae also represented in the erosional habitat.

Recent quantitative benthic invertebrate studies conducted in Baker Creek as part of the Phase 1 and 2 EEM programs evaluated the potential effects of the periodic effluent discharge into Baker Creek, but did not evaluate the potential effects of historical sediment contamination on benthic invertebrate communities (Golder 2006, 2008a). Artificial substrate samplers (Hester-Dendy multiplates) were deployed close to the mouth of Baker Creek (exposure area), in Yellowknife Bay (exposure area), and in the Yellowknife River (reference area) for a colonization period of between 66 and 70 days. These artificial substrates were located on the stream bed where colonizing invertebrates were primarily exposed to potential waterborne contaminants. Both studies concluded that effects of the present day effluent discharge on the benthic invertebrate community could conservatively be characterized as low. The studies also concluded that historical sediment contamination likely poses a greater risk to aquatic life in Yellowknife Bay compared to periodic discharge of mine effluent.

The above review of existing information suggests that benthic invertebrates have recolonized Baker Creek, although the degree of the recovery in the various reaches has not been sufficiently evaluated.

In 2004, artificial substrates were used to assess the effects of present-day effluent discharge on the invertebrate community (Golder 2005). In general, the invertebrate community colonizing artificial substrates was characterized by low density and richness, but moderate to high diversity and evenness. A relatively high proportion of the total invertebrates were accounted for by taxa considered to be sensitive to contaminants such as metals (i.e., mayflies). Results from this study indicated that the effect of the discharged effluent could be conservatively characterized as low. The use of artificial substrates (which target effects via the water column pathway) and biological findings again highlighted the low level of effects predicted from the water column relative to the greater magnitude of response observed in studies of the bottom sediments. These results suggest that the historical sediment contamination likely poses a greater risk to aquatic life in Yellowknife Bay than the periodic discharge of mine effluent. They also suggest that the benthic community, at least at the mouth of the creek, may be recovering.

Information on the benthic invertebrate community within the Yellowknife River is limited (Golder 2008a). Falk et al. (1973a,b) sampled in 1972 and found 25 genera. The benthic invertebrate community was dominated by chironomids, oligochaetes and nematodes. However, biting midges (Ceratopogonidae), clams, and snails were also relatively abundant in the Yellowknife River. Artificial substrates were used for the 2004 Phase 1 EEM invertebrate community structure assessment (Golder 2005). A total of 32 families were identified, which were dominated by mayflies (Ephemeroptera), dipterans (primarily of the midge family Chironomidae), amphipods (Amphipoda), and occasionally by polycentropodid caddisflies (Trichoptera) (Golder 2005).

3.1.4 Fish Communities

In 2002, metal concentrations in fish captured from Baker Creek upstream of the mine site (approximately Reach 6) had higher concentrations of arsenic, nickel and zinc relative to fish caught downstream (approximately Reach 0; Dillon 2002a). De Rosemond et al. (2008) sampled fish from Back Bay (in Yellowknife Bay, beyond Reach 0) and determined that White Sucker had higher concentrations of arsenic than Lake Whitefish, Northern Pike, and Walleye.

Since these early studies, the majority of fishery efforts at Baker Creek have been fish surveys, with sampling efforts focusing on Reach 4 (Figure 2). This portion of the creek was realigned in summer 2006 and, therefore, reflects conditions in the absence of historical sediment contamination. Since the realignment, spawning by Arctic Grayling, Northern Pike, and Sucker species has been demonstrated in Reach 4. Young-of-the-year (YOY) habitat use has also been described for this realigned portion of Baker Creek (Golder 2008b). In 2008, further surveys in Reach 4 confirmed spawning of Arctic Grayling, with further efforts undertaken to determine food availability and sediment deposition in the areas where spawning activities were documented. A number of recent fish surveys have documented fish species, including Arctic Grayling, Walleye and Northern Pike, residing and spawning in the lower reaches of Baker Creek during the spring spawning period. Northern Pike are believed to reside in Reach 5 and may overwinter in this area. Arctic Grayling YOY have been observed in Reach 6 (below the waterfall), and it is believed they hatched in this location rather than migrating to it (Paul Vecsei, Golder, personal communication). It is unlikely that small-bodied sentinel species such as Ninespine Stickleback or Slimy Sculpin are present in the higher reaches of Baker Creek, as they have only been observed in the lower creek (Reach 0).

Phase 1 of the EEM program for the Giant Mine used mesocosm studies to investigate the effects of mine effluent on fish, studies which unfortunately were inconclusive with respect to effects on fish health (Golder 2006). In Phase 2, effects on Ninespine Stickleback and Slimy Sculpin from Reach 0 of Baker Creek were identified; fish had significantly reduced condition relative to the reference area in Yellowknife River (Golder 2008a). Further EEM studies in September 2010 continued to investigate these sentinel fish species in Reach 0. Fish health parameters, the age and gonad histology of Slimy Sculpin, as well as the population structure of Ninespine Stickleback in the creek, were investigated.

A fish salvage in the mill pond along Baker Creek was conducted in winter 2006 when Baker Creek was being rerouted away from the mill area (Golder 2008a). A total of 93 fish were removed from the pond. Six different species of fish of various ages and sizes were captured (unpublished data collected for INAC by Golder): Northern Pike, Burbot, Lake Whitefish, Longnose Sucker, Ninespine Stickleback, and Lake Cisco. Lake Cisco have not previously been captured in Baker Creek. It is not known whether the fish captured were migrants that could not outmigrate or if they were residents of the ponds along the creek.

4.0 ECOLOGICAL ASSESSMENT

4.1 Information Gathering

4.1.1 Historical Data Compilation and Screening

Existing data for water, sediment and tissue chemistry (benthic invertebrates and fish), aquatic toxicity (water column and sediment), benthic invertebrate and fish communities were compiled and reviewed in detail to confirm that they were suitable and that the data quality was acceptable. Relevant chemistry data were screened against applicable guidelines for protection of aquatic life to identify COPCs.

Historical data pertaining to treated effluent, surface water, sediment and tissue were collected from previous investigations identified in Section 3.0. For those studies that were considered relevant to the current Baker Creek assessment, data were compiled and screened against aquatic life guidelines (Appendix A).

Treated Effluent and Surface Water

Treated effluent has been discharged into Baker Creek at the upper end of Baker Creek Pond (Reach 6) since 1981. Although the Remediation Plan (SRK and SENES 2007) proposed that a new treatment plant be constructed and that treated effluent be discharged directly to Yellowknife Bay instead of Baker Creek, approval and construction are pending, and it is therefore assumed that effluent discharge to Baker Creek will continue for several more years. Treated effluent is currently only discharged to Baker Creek during summer months, but at times it can account for the majority of flow through Baker Creek. Therefore, it was considered appropriate to screen data for treated effluent, as well as Baker Creek surface water, for identification of COPCs.

For aquatic receptors, the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* for freshwater (CCME 1999) were used for data screening.

Although the guidelines for metals for both aquatic life and human health were intended to be applied to total metals concentrations, they were used for screening against both total and dissolved metals data because there were some samples for which only dissolved metals data were available.

Table 1 provides a list of the constituents analysed and the COPCs identified in treated effluent and surface water, for aquatic receptors. Maximum concentrations measured in both the treated effluent and surface water were compared to WQGs in order to identify COPCs. For the surface water data, the Baker Creek reach where the maximum concentration occurred was also identified. In cases where the maximum concentration occurred in either Upper Baker Creek (upstream of Baker Creek Pond) or Trapper Creek (a tributary to Baker Creek that enters the north side of Baker Creek Pond), two maxima were reported: the maximum concentration reported to occur between Reach 0 and Baker Creek Pond, and the maximum concentration reported in either Upper Baker Creek (UBC) or Trapper Creek (TC). Although these latter two waterbodies were upstream of Baker Creek Pond, they have been affected by historical mining operations and therefore do not represent background conditions.

Table 1: Summary of Contaminants of Potential Concern (COPCs) for Aquatic Life in Baker Creek Water

Substance	Maximum Concentration (mg/L)			Aquatic Life Guidelines[1]	Retained as COPC for Aquatic Life?
	In Treated Effluent	In Surface Water	Reach With Maximum Concentration		
Ammonia (total)	0.059	1.02	0	2.68	NO
Aluminum	0.305	0.634 / 0.952	0 / TC	0.1	**YES**
Antimony	1.1	0.454	6	NG	NO
Arsenic	0.609	0.969	6	0.005	**YES**
Barium	0.025	0.062	0	NG	NO
Beryllium	<0.005	0.0001	multiple	NG	NO
Bismuth	<0.2	<0.0001 to <0.2	multiple	NG	NO
Boron	0.40	0.35	6	1.5	NO
Cadmium	0.0011	0.0001	2 and 3	0.000117 / 0.000033	**YES**
Calcium	488	444	6	NG	NO
Cesium	0.0003	0.0001	2 and 3	NG	NO
Chloride	626	479	6	120	**YES**
Chromium	0.0011	0.0053	0	NG	NO
Cobalt	0.0802	0.021 / 0.0411	6 / UBC	NG	NO
Copper	0.042	0.0202	6	0.012 / 0.000236	**YES**
Cyanide	0.0162	0.0198	0	0.005	**YES**
Fluoride	0.145	0.122	6	0.12	NO
Iron	0.222	1.03 / 1.29	0 / TC	0.3	**YES**
Lead	0.007	0.00483	0	0.038 / 0.00318	**YES**
Lithium	0.08	0.045	6	NG	NO
Magnesium	101	95	6	NG	NO
Manganese	0.50	0.135 / 0.177	0 / TC	NG	NO
Mercury	0.000011	0.000056	6	0.000026	**YES**
Molybdenum	0.0305	0.0251	6	0.073	NO
Nickel	0.10	0.0616	6	0.419 / 0.0096	**YES**
Nitrate	15	11.4	6	2.935	**YES**
Nitrite	0.309	0.043	6	0.06	NO
Phosphorus	<0.3	<0.3	multiple	NG	NO
Potassium	14	12.7	6	NG	NO
Rubidium	0.011	0.0049	3	NG	NO
Selenium	12.9	0.0046	6	0.001	**YES**
Silicon	2.55	2.06 / 4.69	6 / TC	NG	NO
Silver	<0.01	0.0001 to <0.01	multiple	0.0001	**YES**
Sodium	224	204	6	NG	NO
Strontium	4.59	4.34	6	NG	NO
Sulphate	1,260	1,210	6	NG	NO
Thallium	0.0001	0.0003 to <0.2	multiple	0.0008	**YES**
Tin	<0.03	<0.03	multiple	NG	NO
Titanium	0.016	0.02 / 0.034	0 / TC	NG	NO
Uranium	0.013	0.00306	6	0.015	NO
Vanadium	0.048	0.03	6	NG	NO
Zinc	0.0713	0.041 / 0.052	0 / UBC	0.030	**YES**
Radium-226	0.02	0.03 (Bq/L)	6	NG	NO

COPC = Contaminant of Potential Concern; NG = No guideline; NM = Not measured; TC = Trapper Creek; UBC = Upper Baker Creek

1. CCME (1999) Water Quality Guidelines for Protection of Aquatic Life (freshwater). Guidelines for cadmium, copper, lead and nickel are hardness-dependent. A default hardness of 700 mg/L as $CaCO_3$ was used for screening treated effluent, and hardness of 100 mg/L as $CaCO_3$ was used to screen surface water data.

Sediment

For aquatic receptors, sediment chemistry data were initially only screened against freshwater *Canadian Sediment Quality Guidelines for Protection of Aquatic Life* (CCME 1999) in the data gap analysis (Golder 2011a). For the ecological assessment reported here, the sediment chemistry data were screened against two additional sets of SQGs: Ontario Ministry of Environment and Energy (OMOEE 1993) SQGs; and, freshwater sediment quality values developed for Washington State (Avocet Consulting 2003). The OMOEE and Washington State SQGs were included because they encompass more inorganic parameters than the CCME SQGs. The Washington State values represent lowest Apparent Effect Thresholds (LAETs) derived from amphipod, chironomid or Microtox® sediment toxicity data; for this application, only the LAETs derived from amphipod or chironomid test data were used. The CCME Interim Sediment Quality Guideline (ISQG) and OMOEE Lowest Effect Level (LEL) represent lower-bound SQGs, concentrations at which adverse biological effects are rare or not expected to occur in the majority of sediment-dwelling organisms. Conversely, the CCME Probable Effect Level (PEL) and OMOEE Severe Effect Level (SEL) represent concentrations at or above which adverse biological effects often occurred in the toxicity database. The Washington State LAETs represent the highest concentration at which the biological response in the sediment toxicity test was not statistically different from the negative control. The approach of using SQGs from multiple jurisdictions was intended to provide an indication of the uncertainty associated with these guidelines, and also to evaluate where Baker Creek sediments fall along the continuum of available guidelines. As these SQGs were developed for the purpose of screening, and not for quantitative evaluation of ecological risk, exceedances of one or more guidelines should not be interpreted as a direct indication of probability or magnitude of harm.

Arsenic concentrations are naturally elevated in the area around Yellowknife, NWT, and a site-specific Remediation Objective of 150 mg/kg for arsenic in sediment has been developed for this region (GNWT 2003). This remediation objective is based on average natural background concentrations in and around Yellowknife, and was developed for publicly accessible areas (e.g., public boat launch) where people were likely to come into contact with sediments (GNWT 2003). Arsenic concentrations were elevated in sediments from multiple locations in Baker Creek, with the maximum concentration being more than 50 times the GNWT (2003) Remediation Objective. GNWT (2003) did not develop site-specific Remediation Objectives for metals other than arsenic.

Table 2 presents the constituents analysed and COPCs identified in sediment, for aquatic receptors.

4.1.2 Selection of Contaminants of Potential Concern (COPCs)

Contaminants of potential concern (COPCs) were identified by comparing historical measured concentrations in the various environmental media to relevant guidelines outlined below. If one or more measured concentrations of a substance in an applicable medium exceeded the screening guideline, then the substance was identified as a COPC and retained for future consideration in the assessment. Substances that were detected but did not have an applicable screening guideline were noted but not retained as COPCs for either water or sediment measurements, since the absence of a screening guideline indicates a low level of environmental concern.

Table 2: Summary of Contaminants of Potential Concern (COPCs) for Aquatic Life in Baker Creek Sediments

Substance	Maximum Concentration (mg/kg dw)	Reach	CCME (1999) Interim Sediment Quality Guideline (ISQG)	OMOEE (1993) Lowest Effect Level (LEL)	Washington State LAET (Avocet 2003)	Retained as COPC for Aquatic Life?
Aluminum	45,900	0	NG	NG	NG	NO
Antimony	984	0	NG	NG	0.6	**YES**
Arsenic	7,660	5	5.9	6	31.4	**YES**
Barium	250	1	NG	NG	NG	NO
Beryllium	1.6	0	NG	NG	0.46	**YES**
Bismuth	4.5	5	NG	NG	NG	NO
Boron	7.67	0	NG	NG	NG	NO
Cadmium	20.7	5	0.6	0.6	2.39	**YES**
Calcium	56,400	6	NG	NG	NG	NO
Cesium	1.5	3	NG	NG	NG	NO
Chromium	117	4	37.3	26	133	**YES**
Cobalt	208	5	NG	NG	NG	NO
Copper	5,470	6	35.7	16	619	**YES**
Gallium	5.8	0	NG	NG	NG	NO
Gold	8.43	0	NG	NG	NG	NO
Iron	216,000	5	NG	20,000	NG	**YES**
Lanthanum	27.8	0	NG	NG	NG	NO
Lead	3,480	5	35	31	335	**YES**
Lithium	65.5	0	NG	NG	NG	NO
Magnesium	35,200	4	NG	NG	NG	NO
Manganese	2,230	6	NG	460	NG	**YES**
Mercury	0.54	0	0.17	0.2	0.8	**YES**
Molybdenum	<8	6	NG	NG	NG	NO
Nickel	438	5	NG	16	113	**YES**
Phosphorus	1,130	0	NG	600	NG	**YES**
Potassium	9,750	0	NG	NG	NG	NO
Rubidium	24.4	3	NG	NG	NG	NO
Scandium	6.0	0	NG	NG	NG	NO
Selenium	4.6	0	NG	NG	NG	NO
Silicon	685	6	NG	NG	NG	NO
Silver	22.2	5	NG	NG	3.5	**YES**
Sodium	740	0	NG	NG	NG	NO
Strontium	129	0	NG	NG	NG	NO
Sulphur	5,788	0	NG	NG	NG	NO
Thallium	0.69	5	NG	NG	NG	NO
Thorium	11.4	0	NG	NG	NG	NO

Substance	Maximum Concentration (mg/kg dw)	Reach	CCME (1999) Interim Sediment Quality Guideline (ISQG)	OMOEE (1993) Lowest Effect Level (LEL)	Washington State LAET (Avocet 2003)	Retained as COPC for Aquatic Life?
Tin	<20	2	NG	NG	NG	NO
Titanium	1,490	0	NG	NG	NG	NO
Tungsten	17.5	0	NG	NG	NG	NO
Uranium	6	U/S	NG	NG	NG	NO
Vanadium	138	4	NG	NG	NG	NO
Zinc	4,180	5	123	120	683	**YES**

COPC = Contaminant of Potential Concern; dw = dry weight; ISQG = Interim Sediment Quality Guideline; LAET = Lowest Apparent Effect Threshold; LEL = Lowest Effect Level; NG = No guideline; U/S = Upstream of mine activities

The data screening process for identification of COPCs based on the comparison of maximum measured concentrations to guidelines for protection of aquatic life was considered to be conservative (i.e., protective). COPCs identified at this point may not pose a risk to aquatic life; however, this cannot be determined until an ecological assessment is conducted. A quantitative estimate of the risks posed by identified COPCs to aquatic life is expected to be part of future assessment activities.

COPCs for aquatic receptors were selected based on comparison of measured concentrations in effluent, water and sediment to applicable federal or other guidelines. A summary of COPC screening for aquatic receptors is provided in Table 3.

4.1.3 Selection of Receptors of Potential Concern (ROPCs)

Aquatic receptors were selected to provide representation for each ecosystem component in Baker Creek:

- Phytoplankton community;
- Zooplankton;
- Benthic Invertebrates; and,
- Fish (small-bodied fish such as Slimy Sculpin and Ninespine Stickleback, and large-bodied fish such as Northern Pike and Arctic Grayling).

Table 3: Candidate Contaminants of Potential Concern (COPCs) for Aquatic Life

Substance	Surface Water[1]	Sediment[2]	Retained as COPC?
Aluminum	✓	NG	**YES**
Antimony	NG	✓	**YES**
Arsenic	✓	✓	**YES**
Beryllium	NG	✓	**YES**
Cadmium	✓	✓	**YES**
Chloride	✓	NM	**YES**
Chromium	NG	✓	**YES**
Copper	✓	✓	**YES**
Cyanide	✓	NM	**YES**
Fluoride	✓	NM	**YES**
Iron	✓	✓	**YES**
Lead	✓	✓	**YES**
Manganese	NG	✓	**YES**
Mercury	✓	✓	**YES**
Nickel	✓	✓	**YES**
Nitrate	✓	NM	**YES**
Selenium	✓	NG	**YES**
Silver	✓	✓	**YES**
Thallium	✓	NG	**YES**
Zinc	✓	✓	**YES**

COPC = Contaminant of Potential Concern; NG = No guideline; NM = Not measured; ✓= Chemical exceeds guideline, therefore was retained for further assessment; - = Chemical did not exceed guideline, or the chemical was not detected.

1. Canadian Water Quality Guidelines for Protection of Aquatic Life (CCME 1999)
2. Canadian Sediment Quality Guidelines for Protection of Aquatic Life (CCME (1999)

4.1.4 Aquatic Life Exposure Pathways

Exposure pathways for aquatic receptors are routes by which receptors could potentially be exposed to COPCs in various environmental media. A COPC was considered to represent a potential risk to aquatic life only if it could reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a COPC to reach a receptor, then there cannot be a risk, regardless of the COPC concentration.

Exposure pathways that could be applied to aquatic receptors in Baker Creek are:

- Direct contact with COPCs in surface water by freshwater biota;
- Direct contact with COPCs in sediment by freshwater biota; and,
- Ingestion of dietary items with elevated COPC concentrations.

4.1.5 Assessment and Measurement Endpoints

The concepts of assessment and measurement endpoints serve to translate overall site management goals into a specific focus for the assessment. In simple terms, the assessment endpoints describe what is being protected, and the measurement endpoints describe the tools used to evaluate whether the ecological values are being protected. These concepts are formally defined as follows in the FCSAP aquatic sites framework document (Chapman 2011):

- **Assessment Endpoint**: "*The explicit expression of the environmental value that is to be protected; the undesired effect whose probability of occurrence is estimated in a risk assessment. Examples include extinction of an endangered species, eutrophication of a lake, or loss of a fishery*."
- **Measurement Endpoint**: "*An expression of an observed or measured response to a hazard; a measurable environmental characteristic that is related to the valued characteristic chosen as the assessment endpoint*."

The overall assessment endpoint for the ecological assessment is the maintenance of productive and diverse populations and communities of aquatic biota (both invertebrates and fish) in Baker Creek that are not adversely affected by COPCs in water, sediments or their tissues. Specific assessment endpoints, risk hypotheses, and measurement endpoints applicable to the Baker Creek ecological assessment are presented in Table 4.

4.1.6 Conceptual Site Model (CSM)

Based on the data gap analysis documented in the previous sections, a preliminary conceptual site model (CSM) was developed for aquatic receptors (Figure 3). This preliminary CSM identifies candidate receptors and exposure pathways.

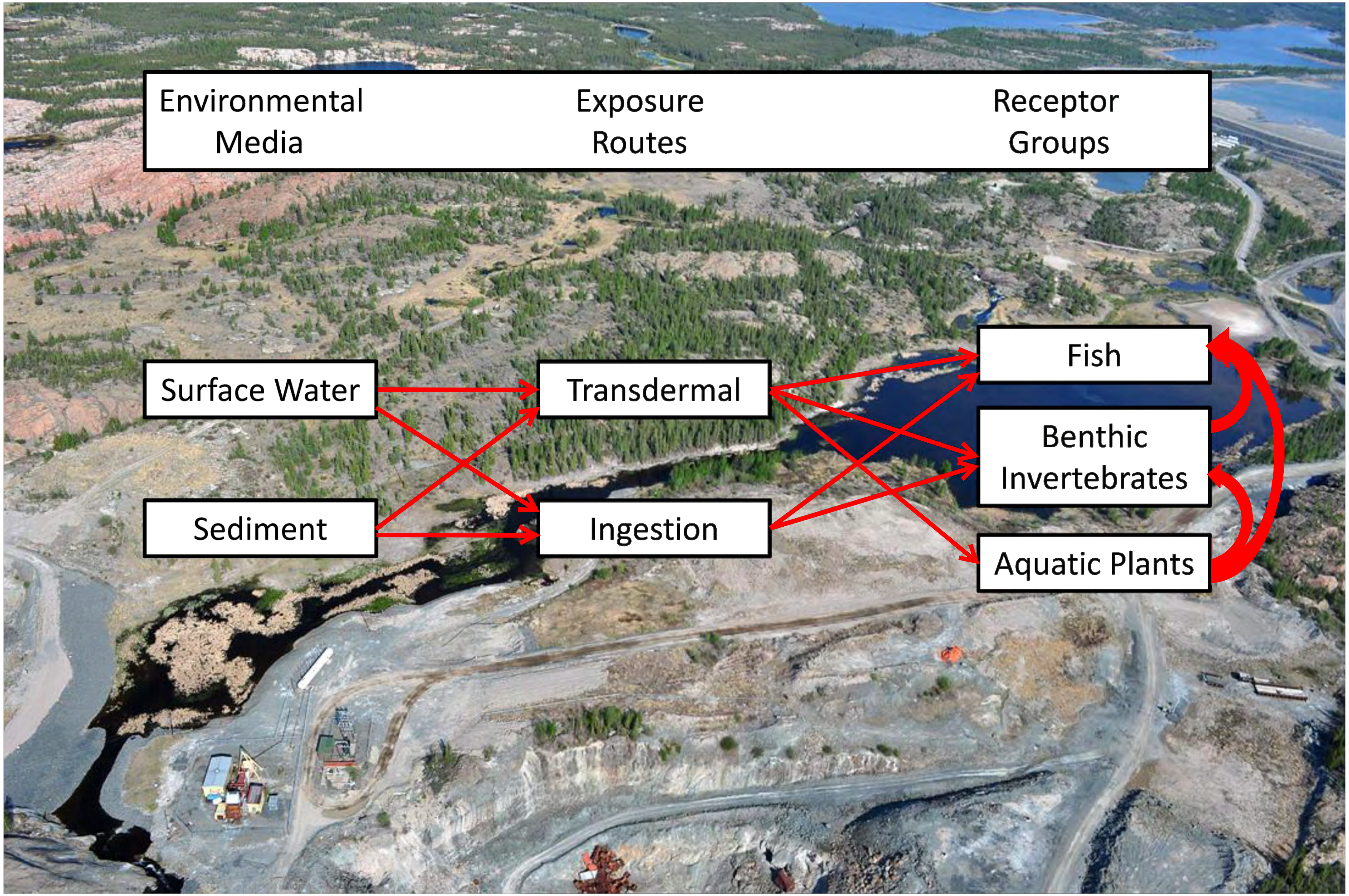
The FCSAP aquatic sites framework document (Chapman 2011) defines CSMs as "*A diagrammatic representation of a site and its environment that represents what is known or suspected about contaminant sources as well as the physical, chemical and biological processes that affect contaminant transport to potential environmental receptors*."

CSMs are particularly useful for contaminated aquatic site assessments, such as the one proposed for Baker Creek, which rely on weight-of-evidence (WOE) approaches and multi-media sampling programs (Chapman 2011; Chapman and Smith 2012).

Table 4: Assessment Endpoints, Risk Hypotheses and Measurement Endpoints for Receptors of Potential Concern in Baker Creek

Assessment Endpoints	Risk Hypotheses (Null Hypotheses)	Measurement Endpoints
Benthic Invertebrate Community Maintenance of the health and ecological integrity of the infaunal benthic invertebrate community.	Substances in Baker Creek sediments that are related to historical mining operations or continued inputs of treated effluent will not result in an adverse impact on the benthic invertebrate community.	Determine the magnitude and bioavailability of sediment contaminant concentrations through the measurement of sediment chemistry including AVS-SEM concentrations. Compare sediment chemistry results to CCME guidelines. Measure the potential lethal and sublethal effects of sediments to representative benthic invertebrate species (14-d *Hyalella azteca* and 10-d *Chironomus* sp. whole sediment toxicity tests). Measure the potential lethal and sublethal effects of Baker Creek surface water to representative phytoplankton and zooplankton species (72 h *Pseudokirchneriella subcapitata*, 3-brood *Ceriodaphnia dubia*) in laboratory toxicity tests. Measure and evaluate in situ changes to the benthic invertebrate community in Baker Creek relative to appropriate Yellowknife River reference stations.
Water Column Organisms Maintenance of the health and ecological integrity of water column organisms that form part of the fish food chain.	Substances leaching from Baker Creek sediments to the water column that are related to historical mining operations or continued inputs of treated effluent will not result in an adverse impact on water column organisms in Baker Creek.	Determine the magnitude of surface water contaminant concentrations in Baker Creek. Compare water chemistry results to CCME water quality guidelines and other relevant benchmarks. Measure the potential lethal and sublethal effects of Baker Creek surface water to representative phytoplankton and zooplankton species (72-h *Pseudokirchneriella subcapitata*, 3-brood *Ceriodaphnia dubia*) in laboratory toxicity tests. Compare toxicity test results to results from tests performed on treated effluent samples.
Fish Community Maintenance of the health and ecological integrity of fish populations.	Substances leaching from Baker Creek sediments to the water column that are related to historical mining operations or continued inputs of treated effluent will not result in a direct adverse impact on fish.	Determine the magnitude of surface water contaminant concentrations in Baker Creek. Compare results to CCME water quality guidelines and other relevant benchmarks. Determine the magnitude of tissue contaminant concentrations in benthic invertebrate and fish tissues in Baker Creek. Compare results to tissue guidelines and other relevant benchmarks.
Maintenance of the functional integrity of populations of fish food organisms.	The food supply for fish populations will not be impaired.	Not assessed directly – relies on endpoint results for benthic invertebrate community and water column organisms.

Note: Consideration of inputs from the Upper Baker Creek watershed were outside the Terms of Reference for this work.



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0	ISSUED WITH RPT-0005-REV2	2013-03-08
B	ISSUED WITH RPT-0005-REV1	2012-09-28
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Client/client
PUBLIC WORKS GOVERNMENT SERVICES CANADA

Project title/Titre du projet
GIANT MINE REMEDIATION PROJECT YELLOWKNIFE, N.W.T.

BAKER CREEK

Approved by/Approuve par: CM
Designed by/Concept par: CAM
Drawn by/Dessine par: RH
PWGSC Project Manager/Administrateur de Projets TPSGC: PWGSC
PWGSC, Architectural and Engineering Resources Manager/Ressources Architectural et de Directeur d'ingénierie, TPSGC
Client/client: PWGSC

Drawing title/Titre du dessin
ECOLOGICAL CONCEPTUAL MODEL

Project No./No. du projet	Sheet/Feuille	Revision no./La Révision no.
R.014204	FIGURE 3	0

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ECOLOGICAL CONCEPTUAL MODEL

4.2 Sample Collection Program

The 2011 field sampling program undertaken to support the assessment of Baker Creek sediments is described below. This sampling program was limited to the collection of samples associated with the aquatic environment within Baker Creek, and did not include sampling of soil, wildlife, or terrestrial biota. At the request of PWGSC, the sampling program was designed to include elements that would normally be part of a screening-level assessment as well as elements that would most likely be needed for a detailed-level assessment.

Briefly, the study design incorporated the following:

- Surface water sampling in Baker Creek (upstream and downstream of Baker Creek Pond) and the Yellowknife River reference area during open water conditions for water chemistry analyses and water-column toxicity testing, and collection of water samples from other locations for water chemistry analyses concurrent with sampling of other environmental media. Additional water quality sampling in Baker Creek was not proposed as Surveillance Network Program (SNP) monitoring data were expected to be available.
- Sediment quality sampling to allow for updated characterization of surface and subsurface sediment chemistry to complement and verify data from previous studies (e.g., Jacques Whitford 2006), and to account for such physical changes to Baker Creek as the re-alignment of Reach 4 in summer 2006. It was essential that sediment chemistry data be collected synoptically with the sediment toxicity and benthic community data.
- Benthic invertebrate sampling (with enumeration, taxonomy, and chemical analysis) to provide information regarding community composition and tissue metals concentrations in both erosional and depositional habitats in the exposure area, as well as upstream of Reach 6 (Baker Creek Pond) in Upper Baker Creek, and the Yellowknife River reference watercourse.
- Fish tissue sampling to include collection of several fish species in 2011, as well as analyses of fish tissue samples collected in 2010 and archived for potential use in this program.
- Fish community surveys of Trapper Lake and Lower Martin Lake, to assess presence or absence of fish in those waterbodies.

Sampling locations used for collection of water, sediment, benthic invertebrate, and fish samples are shown in Figure 4, Figure 5, Figure 6, and Figure 7. Field program records are provided in Appendix B.

The original study design called for sampling of a total of 30 stations from depositional habitat: 24 stations in lower Baker Creek (Baker Creek Pond to the mouth of Baker Creek); 3 stations in upper Baker Creek (upstream of Baker Creek Pond); and, 3 stations in the Yellowknife River reference area. This assumed an average of three stations per reach for Reaches 0 to 5, and six stations within Baker Creek Pond, with the actual distribution of sediment sampling locations dependent on the amount of depositional substrate available within each reach. Following the June 2011 multi-agency meeting to discuss the data gap analysis and sampling plan (Golder 2011a,b), the study design was modified to reduce the number of depositional sampling stations in Reaches 1 and 3 from three to two, and to re-allocate those two stations to Trapper Creek. The actual number of depositional stations sampled was 29, as only 5 stations could be sampled within Baker Creek Pond. Depositional stations were sampled for sediment chemistry and toxicity, benthic invertebrate community structure, and benthic invertebrate tissue chemistry.

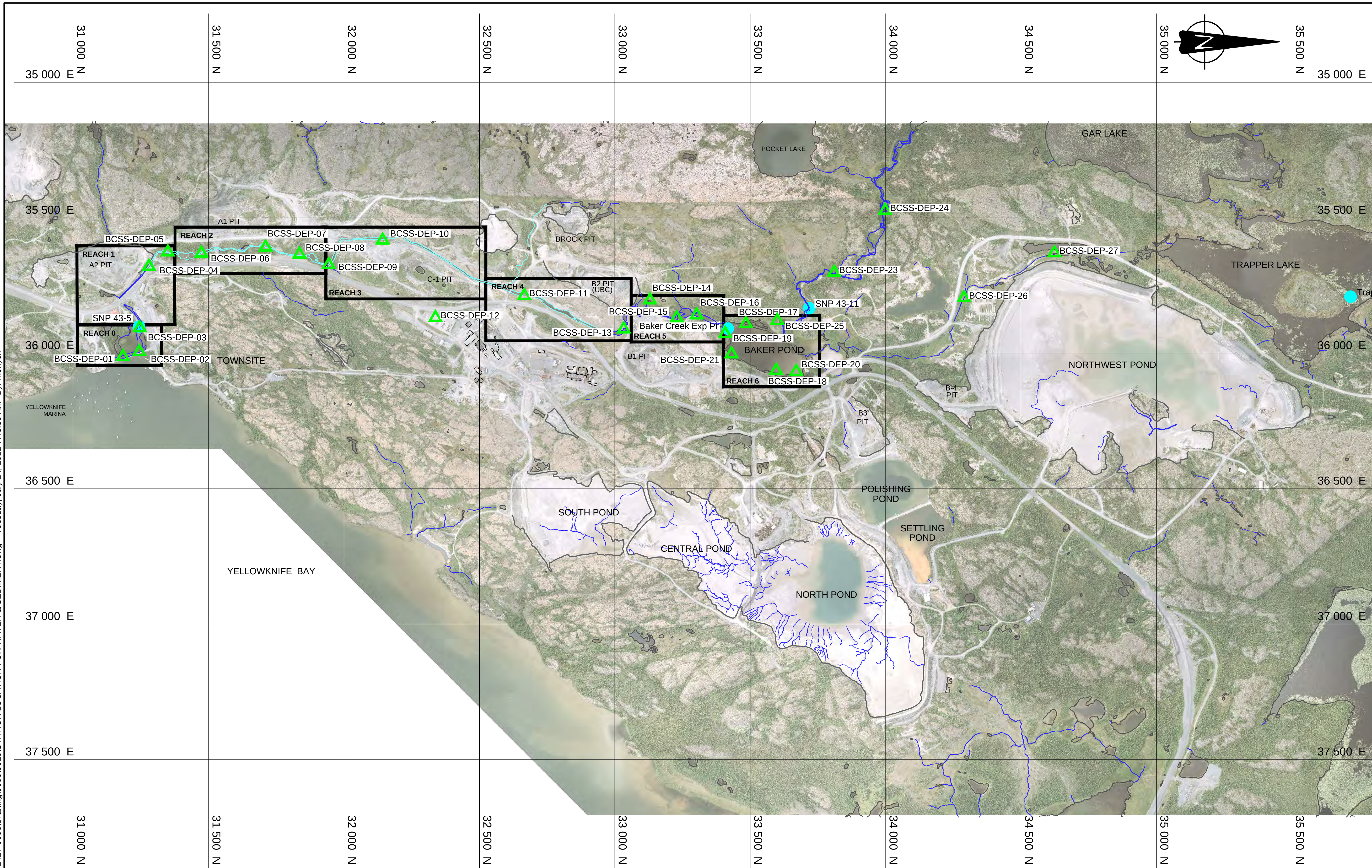
The original study design called for sampling of a total of 17 stations from erosional habitat: 12 stations in lower Baker Creek (Reach 0 to 5); 2 stations in upper Baker Creek (upstream of Baker Creek Pond); and, 3 stations in the Yellowknife River reference area. This assumed an average of two stations per reach in Baker Creek and no erosional habitat stations in Baker Creek Pond, with the actual distribution of sampling locations dependent on the amount of erosional habitat available within each reach. The actual number of erosional stations sampled was 15: one station in Reach 0; three stations in Reach 1; two stations in Reaches 2 and 3; three stations in Reach 4; one station in Reach 5; and, three stations in the Yellowknife River reference area. Erosional habitat was not identified in Upper Baker Creek because of low stream flow in September; therefore, no erosional sampling was completed in that area. Erosional stations were sampled for benthic invertebrate community structure, benthic invertebrate tissue chemistry, and periphyton tissue chemistry.

4.2.1 Water Quality (Chemistry and Toxicity)

For the 2011 Baker Creek field sampling program, single grab samples of surface water were collected from each of nine locations in Baker Creek (upstream and downstream of Baker Creek Pond) and Yellowknife River reference areas, as well as from two lakes that supply Baker Creek (Trapper Lake and Martin Lake):

- Upper Baker Creek (SNP Station 43-11), sampled September 19, 2011 (Figure 4);
- Baker Creek Pond outlet (Baker Creek Exposure Point, used for EEM sampling), sampled September 19, 2011 (Figure 4);
- Lower Baker Creek near mouth (SNP Station 43-5), sampled September 20, 2011 (Figure 4);
- Yellowknife River reference areas: one station near the reference area sediment sampling stations, sampled October 11, 2011; and, three stations further upstream in the Prosperous Lake reference area for fish tissue collection (two samples collected in McMeekan Bay and one at Tartan Rapids), sampled July 13, 2011 (Figure 6);
- Trapper Lake (upstream of Trapper Creek, a tributary to Baker Creek Pond), sampled September 14, 2011 (Figure 4); and,
- Martin Lake (upstream of Upper Baker Creek), sampled September 16, 2011 (Figure 7).

Water samples from Prosperous Lake, Martin Lake, Trapper Lake, and the Yellowknife River were collected by Golder personnel specifically for this Baker Creek assessment. Water samples from Stations SNP43-11 and the Baker Creek Exposure Point were collected by Golder personnel on behalf of DCNJV. The water sample from Station SNP43-5 was collected by DCNJV personnel. Data from these three locations were used for SNP and/or EEM/MMER monitoring in addition to this Baker Creek assessment.



LEGEND

- WATER SAMPLING STATION
- DEPOSITIONAL SEDIMENT SAMPLING STATION
- REACH BOUNDARY

0 300 600 900m

SCALE IN METERS

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0	ISSUED WITH RPT-0005-REV2	2013-03-08
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A	ISSUED WITH RPT-0005-REV0	2012-07-24

Client/client

PUBLIC WORKS GOVERNMENT SERVICES CANADA

Project title/Titre du projet

GIANT MINE REMEDIATION PROJECT
YELLOWKNIFE, N.W.T.

BAKER CREEK

Approved by/Approuvé par: CM

Designed by/Concept par: CAM

Drawn by/Dessiné par: RH

PWGSC Project Manager/Administrateur de Projets TPSGC: PWGSC

PWGSC, Architectural and Engineering Resources Manager/Ressources Architectural et de Directeur d'ingénierie, TPSGC

Client/client: PWGSC

Drawing title/Titre du dessin

STATION LOCATIONS FOR WATER AND SEDIMENT (DEPOSITIONAL HABITAT) SAMPLING IN BAKER CREEK, TRAPPER CREEK, AND TRAPPER LAKE

Project No./No. du projet	Sheet/Feuille	Revision no./La Révision no.
R.014204	FIGURE 4	0

Drawing File: N:\Bur-Graphics\Projects\2009\1427\09-1427-0006\Drafting\9000\9610\STATION LOCATION FOR WATER & SEDIMENT.dwg Tuesday, July 24, 2012 7:45:30 AM By: rhorlyck

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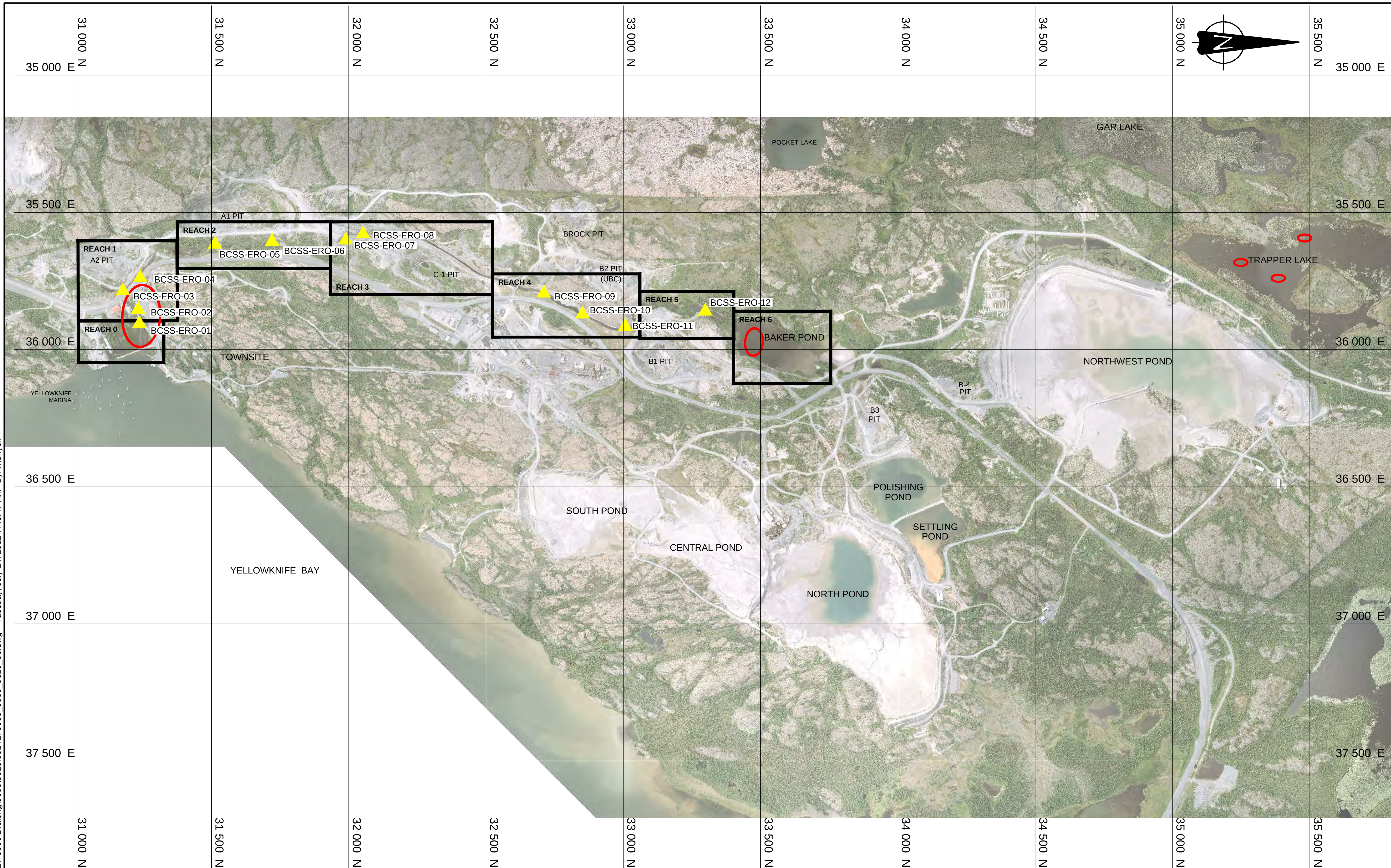
STATION LOCATION FOR WATER & SEDIMENT



LEGEND

- ▲ EROSIONAL SEDIMENT SAMPLING STATION
- ○ FISH SAMPLING AREA
- ▭ REACH BOUNDARY

0 300 600 900m

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GIANT MINE REMEDIATION PROJECT
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RH

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PWGSC

PWGSC, Architectural and Engineering Resources Manager/ Ressources Architectural et de Directeur d'ingénierie, TPSGC

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STATION LOCATIONS FOR SEDIMENT (EROSIONAL HABITAT) AND FISH SAMPLING AT BAKER CREEK, TRAPPER CREEK, AND TRAPPER LAKE

Project No./No. du projet	Sheet/Feuille	Revision no./La Révision no.
R.014204	FIGURE 5	0

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LEGEND

- WATER SAMPLING STATIONS
- DEPOSITIONAL SEDIMENT SAMPLING LOCATIONS
- EROSIONAL SEDIMENT SAMPLING STATIONS
- FISH SAMPLING AREA

REFERENCES

1. IMAGE FROM GOOGLE EARTH, DATE RETRIEVED: APRIL 17, 2012

0 600 1,200 1,800m
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Client/client

**PUBLIC WORKS
GOVERNMENT SERVICES
CANADA**

Project title/Titre du projet

**GIANT MINE
REMEDIATION PROJECT
YELLOWKNIFE, N.W.T.**

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Drawn by/Dessine par
RH

PWGSC Project Manager/Administrateur de Projets TPSGC
PWGSC

PWGSC, Architectural and Engineering Resources Manager/ Ressources Architectural et de Directeur d'ingénierie, TPSGC

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STATION LOCATIONS FOR WATER, SEDIMENT (DEPOSITIONAL AND EROSIONAL HABITAT) AND FISH SAMPLING AT YELLOWKNIFE RIVER AND PROSPEROUS LAKE REFERENCE AREAS

Project No./No. du projet	Sheet/Feuille	Revision no./ La Révision no.
R.014204	FIGURE 6	0

Drawing File: N:\Bur-Graphics\Projects\2009\1427\09-1427-0006\Drafting\9000\9610\STATION LOCATIONS FOR WATER, SEDIMENT....dwg Layout:STATION LOCATIONS FOR WATER SEDIMENT... Tuesday, July 24, 2012 7:48:01 AM By: rhorbyck

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LEGEND

- WATER SAMPLING LOCATIONS
- FISH SAMPLING AREA (2011)

REFERENCES

1. IMAGE FROM GOOGLE EARTH, DATE RETRIEVED: APRIL 17, 2012

0 250 500 750m

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YELLOWKNIFE, N.W.T.

BAKER CREEK

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Drawn by/Dessiné par
RH

PWGSC Project Manager/Administrateur de Projets TPSGC
PWGSC

PWGSC, Architectural and Engineering Resources Manager/ Ressources Architectural et de Directeur d'ingénierie, TPSGC

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PWGSC

Drawing title/Titre du dessin

STATION LOCATIONS FOR
WATER AND FISH SAMPLING
AT LOWER MARTIN LAKE

Project No./No. du projet	Sheet/Feuille	Révision no./La Révision no.
R.014204	FIGURE 7	0

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All nine locations were sampled for water chemistry analyses. In addition, the three Baker Creek locations and one Yellowknife River reference location were also sampled for aquatic toxicity testing. Prior to collecting the surface water samples, field measurements were made of water temperature, pH, dissolved oxygen, specific conductivity, and turbidity at each sampling location. Field turbidity was measured using a calibrated LaMotte turbidity meter, and the other field measurements were taken using a calibrated YSI 650 MDS water quality meter connected to an YSI 600 QS multi-parameter water quality probe. No water depth measurements were taken.

Plastic sample bottles used for water sample collection were triple-rinsed with surface water prior to sample collection; pre-cleaned glass bottles required for sample collection were used as provided without rinsing. Surface water sample bottles were filled by submerging each sample bottle approximately 30 centimetres (cm) below the water surface; creek samples were collected with the bottle opening facing upstream. Samples for aquatic toxicity testing were collected by filling three 20-L plastic pails at each location, except that only one 20-L pail was collected at the Yellowknife River reference station.

Travel blanks and field blanks were collected in conjunction with the Prosperous Lake and Station SNP43-5 samples, and separate field duplicate samples were collected at Trapper Lake and Martin Lake.

Samples for water chemistry analyses were preserved, as applicable, and shipped to ALS Environmental (ALS; Burnaby, BC) for analysis, except that the Prosperous Lake samples were shipped to ALS (Edmonton, AB) for analysis. Samples for aquatic toxicity tests were kept cool and shipped to HydroQual Laboratories Ltd. (HydroQual; Calgary, AB) for acute and chronic toxicity testing.

4.2.2 Sediment Quality (Chemistry and Toxicity)

Collection of sediment samples to assess sediment quality in Baker Creek must be conducted in conjunction with the benthic invertebrate sampling program described below in order for these lines of evidence (LOE) to be comparable to each other. Although the sediment coring program conducted in 2005 by Jacques Whitford (2006) characterized vertical contamination in Baker Creek sediments, both surface and core sediment samples were collected in 2011 for chemistry analyses to characterize the current horizontal and vertical extent of contamination.

The benthic invertebrate sampling program described in the next subsection involved sampling of both erosional and depositional habitats; however, sediment quality was only assessed at the stations chosen to represent depositional habitats, where contaminant accumulation was expected to be greatest.

Sampling of surface sediments was conducted by Ekman grab (0.0232 m^2 area), the same equipment used for benthic invertebrate sampling at depositional stations. At each station, a minimum of three grabs were collected. The top 5-cm sediment layer from each grab was subsampled and homogenized to generate one composite sample that was then split into aliquots for chemistry analyses and sediment toxicity testing.

Field duplicate samples were collected at three stations as part of the field quality assurance/quality control (QA/QC) program. These field duplicates were processed in the same manner as the regular samples (using separately collected grab or core samples), and were assigned unique identifiers so that the analytical laboratory would not know that they were field duplicates. These field duplicates, which were collected for both surface and subsurface sediments, were identified as: Station BCSS-DEP-100 (duplicate of BCSS-DEP-8); Station BCSS-DEP-101 (duplicate of BCSS-DEP-16); and, Station BCSS-DEP-102 (duplicate of BCSS-DEP-28).

In addition to the surface sediment sampling described above, sediment cores were collected at each of the 29 stations using a 10-cm diameter Tech-Ops corer. Subsamples from approximately the top, middle and bottom 5-cm sections of each core were collected for chemistry analyses to determine the vertical extent of sediment contamination. Sediment toxicity tests were not performed on these core samples but were restricted to surficial sediments as noted above because this is the primary habitat for resident benthic biota.

Sediment chemistry samples were packed in coolers with ice packs and shipped to ALS (Burnaby, BC) for analyses. Sediment toxicity samples were initially stored under refrigeration at the Golder Yellowknife office until the sediment chemistry results were available and the subset of samples for toxicity testing could be selected and shipped to HydroQual (Calgary, AB).

4.2.3 Benthic Invertebrate Community Composition

Given the diverse habitat within Baker Creek, benthic invertebrate communities associated with both depositional and erosional habitats were evaluated. Synoptic sampling of depositional habitats with sediment chemistry and toxicity provided information on the potential effects of sediment-associated COPCs on benthic community structure in Baker Creek, and indirectly on the bioavailability of COPCs to benthic invertebrates. Data from depositional habitat provided an indication of worst-case effects on sediment-dwelling organisms subject to the highest exposure to COPCs, whereas data from erosional habitat provided a better measure of biodiversity and productivity in Baker Creek, given that erosional stream habitats are generally characterized by higher invertebrate abundance and diversity. A gradient design was used for both erosional and depositional habitats, where the unit of replication was the station.

Depositional Stations

A total of 29 depositional benthic invertebrate samples were collected using a standard 15-cm Ekman grab (0.0232 m^2 sampling area). Sampling at depositional stations was done concurrently with sampling for sediment chemistry and toxicity testing.

Each composite sample consisted of three subsamples, which were collected according to Golder Technical Procedure 8.6-1: *Benthic Invertebrate Sampling* (unpublished file information). The contents of each Ekman grab were examined to verify that, at a minimum, the top 5 cm of sediment was collected. Physical habitat (i.e., water depth, substrate characteristics) was standardized among depositional stations to the maximum extent possible. Due to the presence of vegetation at several depositional stations, the field crew had to push the Ekman grab into the substrate to break through the vegetation and obtain a sample of bottom sediments.

Subsamples were field-sieved using a 250-µm mesh sieve bag and the retained material was transferred to a pre-labelled sample bottle. Due to the high organic content in many of the subsamples, multiple sample bottles were required for each depositional station. Benthic invertebrate samples were preserved with 10% buffered formalin, and a second internal waterproof label was inserted into each sample bottle. The lids of sample bottles were sealed with Parafilm prior to shipping to the taxonomist (Dr. Jack Zloty Ltd., Summerland, BC) for enumeration and taxonomic identification.

Erosional Stations

Erosional benthic invertebrate community samples were collected using a standard 30 cm Surber sampler with a 0.0929 m^2 sampling area and 250-µm mesh net. Sampling was performed according to Golder Technical Procedure 8.6-1: *Benthic Invertebrate Sampling* (unpublished file information). Three discrete replicate samples were collected at 15 erosional stations, for a total of 45 erosional benthic invertebrate samples. Physical habitat (i.e., water depth, substrate characteristics) was standardized among erosional stations to the maximum extent possible.

Material retained in the 250-µm mesh net was transferred to a pre-labelled sample bottle. Benthic invertebrate samples were preserved with 10% buffered formalin, and a second internal waterproof label was inserted into each sample bottle. The lids of sample bottles were sealed with Parafilm prior to shipping to the same taxonomist (Dr. Jack Zloty) for enumeration and taxonomic identification.

4.2.4 Benthic Invertebrate and Periphyton Tissue

In conjunction with sampling for benthic invertebrate community composition, benthic invertebrate tissues were sampled concurrently from depositional and erosional habitat stations. Periphyton are a complex mixture of algae, bacteria, microbes, and detritus attached to submerged surfaces, representing an exposure pathway for benthic invertebrates in erosional habitats. Periphyton tissues were sampled concurrently at the erosional habitat stations. These benthic tissue data provided a measure of the bioavailability of arsenic and other contaminants to the invertebrate community in Baker Creek and the potential for transfer to higher trophic levels such as fish.

Benthic Invertebrate Tissue - Depositional Stations

Benthic invertebrate tissue samples were collected from 29 depositional stations located in Baker Creek, Trapper Creek, and the Yellowknife River (Figure 4 and Figure 6).

One composite sediment sample was collected for benthic invertebrate tissues at each of the 29 depositional stations using a standard 15-cm Ekman grab with a sampling area of 0.0232 m^2. Each composite sample consisted of three subsamples, which were collected according to Golder's Technical Procedure 8.6-1: *Benthic Invertebrate Sampling* (unpublished file information). The contents of each Ekman grab were examined to verify that, at a minimum, the top 5 cm of sediment was collected. Physical habitat (i.e., water depth, substrate characteristics) was standardized among depositional stations to the extent possible under field conditions. Due to the presence of vegetation at several depositional stations, the Ekman grab had to be physically pushed into the substrate to break through the vegetation and obtain a sediment sample. All subsamples were field-sieved using a 250-µm mesh sieve bag, and the retained material was transferred to a Ziploc bag. An adequate volume of water was added to each sample bag to submerge the organic material. These samples were kept cool and in the dark until they were sorted at the Golder office in Yellowknife.

Depositional benthic invertebrate tissue samples were sorted by placing a portion of the organic material and debris in a small clean basin and adding sufficient deionized water to suspend the sample. Forceps were used to tease apart the organic debris and remove the benthic invertebrates, which were temporarily stored in a clean Petri dish containing deionized water. This process was repeated until all the organic material and debris had been sorted. Once all invertebrates were removed from a given sample, a photograph of the invertebrate tissue sample was taken as a permanent record of the taxa submitted for analysis. Sample wet weights and descriptions of the benthic invertebrates in each tissue sample were recorded. A clean glass scintillation vial with a small volume of deionized water was pre-weighed and the invertebrates were transferred from the petri dish into the vial. The deionized water was required to facilitate the removal of the small-sized invertebrates from the forceps. Once all the sorted benthic invertebrates were transferred, the vial was re-weighed and a final sample wet weight was recorded on a sample tracking sheet. Field duplicate benthic invertebrate tissue samples were collected, but were not sorted due to time limitations. Instead, field split samples were generated from samples collected at Stations BCSS-DEP-21, BCSS-DEP-26, and BCSS-DEP-28. The samples were then double-labelled and frozen prior to submission to ALS (Burnaby, BC) for chemistry analyses.

Benthic Invertebrate Tissues - Erosional Stations

Benthic invertebrate tissue samples were sampled from 15 erosional stations in Baker Creek (Reaches 0 to 5) and the Yellowknife River (Figure 5 and Figure 6). No erosional tissue samples were collected from Reach 6 in Baker Creek (Baker Pond) or Trapper Creek, due to a lack of erosional habitat in these areas.

One composite benthic sample was collected for benthic invertebrate tissues at each erosional station using a standard 30-cm Surber sampler with a sampling area of 0.0929 m² and a 250-µm mesh net. Each composite sample consisted of three subsamples, collected according to Golder's Technical Procedure 8.6-1: *Benthic Invertebrate Sampling* (unpublished file information). Physical habitat (i.e., water depth, substrate characteristics) was standardized among erosional stations to the extent possible under field conditions. Material retained in the 250-µm mesh net was transferred to a Ziploc bag. An adequate volume of water was added to each sample bag to submerge the organic material. These samples were kept cool and in the dark until they were sorted at the Golder office in Yellowknife.

Erosional benthic invertebrate tissue samples were sorted by transferring the contents in the sample bottle to a small clean basin. These samples contained enough residual water such that no deionized water was required. Benthic invertebrates were retrieved from the basin and temporarily stored in a clean Petri dish containing deionized water. Once all invertebrates were removed from a given sample, a photograph of the invertebrate tissue sample was taken as a permanent record of the taxa submitted for analyses. Sample wet weights and descriptions of the benthic invertebrates in each tissue sample were recorded. A clean glass scintillation vial with a small volume of deionized water was pre-weighed, and the invertebrates were transferred from the petri dish into the vial. The deionized water was required to facilitate the removal of the small-sized invertebrates from the forceps. Once all the sorted benthic invertebrates were transferred, the vial was re-weighed and a final sample wet weight was recorded on a sample tracking sheet. Field duplicate benthic invertebrate tissue samples were collected, but were not sorted due to time limitations. Instead, one field split sample was generated from the sample collected at Station BCSS-ERO-08. The samples were then double-labelled and frozen prior to submission to ALS (Burnaby, BC) for chemistry analyses.

Periphyton Tissues – Erosional Stations

One periphyton composite sample was collected at each of the 15 erosional stations that were sampled for benthic invertebrate tissues, according to Golder Technical Procedure 8.9-1: *Benthic Algae Sampling Methods* (unpublished file information). Rocks were gathered from the sampling area and placed in a large plastic tub that had been thoroughly rinsed with ambient water. Plastic utensils were used to scrape the periphyton from the rocks. The periphyton was transferred to labelled Whirlpak bags until a minimum of two grams (g) of wet weight tissue was obtained. Separate field duplicate periphyton tissue samples were collected at Stations BCSS-ERO-08 and BCSS-ERO-10. The periphyton tissue samples were kept cool and in the dark until they were transported to the Golder office in Yellowknife, where they were frozen prior to submission to ALS (Burnaby, BC) for chemistry analyses.

4.2.5 Fish for Tissue Contaminant Concentrations

Five fish species were sampled in 2010 and 2011 to provide tissue samples for chemistry analyses. Fish were sampled from select reaches in Baker Creek and where possible in the Yellowknife River reference area. Target species represented three small-bodied fish (Arctic Grayling, Slimy Sculpin, and Ninespine Stickleback) and two large-bodied fish (Northern Pike and Lake Whitefish).

Arctic Grayling (*Thymallus arcticus*) are a migrant fish species that enters Baker Creek in spring to spawn; adults outmigrate in spring and young outmigrate in early summer. Fish tissue samples from adults and young provide information to assess potential ecological and human health risks for fish that spend time in contact with the Baker Creek spring water conditions and elevated sediment concentrations but are not usually exposed to treated mine effluent. Slimy Sculpin (*Cottus cognatus*) are a resident, benthic fish species that live in direct contact with the sediment. Their small home range means that tissue contaminant concentrations are truly reflective of conditions in Baker Creek. Ninespine Stickleback (*Pungitius pungitius*) have been used as a sentinel species in a variety of northern EEM programs, including at Giant Mine. Ninespine Stickleback are omnivorous feeders, targeting plankton and benthic invertebrates as food sources and, later in their lives, including fish eggs in their diet. Ninespine Stickleback are thought to reside in Baker Creek between spring and fall. Slimy Sculpin and Ninespine Stickleback are themselves a food source for larger piscivorous fish species in the system at Baker Creek (e.g., Northern Pike), making their tissue contaminant burden relevant for both ecological and human health risk assessment. Northern Pike (*Esox lucius*) are carnivores, actively pursuing fish and small mammals as food, and thus represent a top predator in the aquatic ecosystem. Northern Pike are thought to reside year-round in Baker Creek. The tissue contaminant burden of Northern Pike is therefore also highly relevant to both an ecological and human health risk assessment of Baker Creek. Lake Whitefish (*Coregonus clupeaformis*) are likely year-round residents of deeper water habitat in Baker Creek, but they may also migrate in and out of the creek into Yellowknife Bay and Great Slave Lake. They appear to be omnivorous, eating benthic invertebrates, fish eggs, YOY fish, and Ninespine Stickleback. Lake Whitefish do not appear to be targeted for capture and consumption by local anglers in spring in Baker Creek; however, Lake Whitefish are one of the most commonly eaten fish from Yellowknife Bay and Great Slave Lake. Tissue concentrations of Lake Whitefish are relevant to both an ecological and human health assessment of Baker Creek.

4.2.5.1 Small-bodied Fish Collection and Tissue Processing

Arctic Grayling

Arctic Grayling YOY were captured on June 28 and 30, 2011, during routine freshet monitoring in Baker Creek. The fish were captured by block seine using a 10 m x 1.5 m beach seine net with a 2-mm Delta Knotless mesh. The seine was used for 2-minute sets facing upstream at the bottom of the culvert in Reach 1 of Baker Creek to capture any YOY fish exiting the creek. Accidental mortalities from this freshet monitoring program were frozen archived as whole-bodied fish and used as tissue chemistry samples for the Baker Creek assessment program.

A total of 24 frozen archived YOY Arctic Grayling from Baker Creek were composited to create 4 whole-body tissue samples (each composite consisted of 5 to 7 fish). The samples were sent to ALS (Burnaby, BC) for analysis of total metals, lipid content, and moisture content only.

Slimy Sculpin

Slimy Sculpin were captured on September 15, 2010, during the Giant EEM Phase 3 program (Golder 2011c). Fish were captured from Reach 0 in Baker Creek and from a Yellowknife River reference area (Figures 6 and 7). Slimy Sculpin were captured using a backpack electrofisher and dip net. The fish underwent a detailed fish health examination, and their gonads and otoliths were removed for analyses. The fish carcasses were then frozen archived and used as tissue chemistry samples for the Baker Creek assessment program.

Sixty frozen archived Slimy Sculpin (30 from Baker Creek and 30 from Yellowknife River) were used to create 20 composite samples (10 composites of 3 fish each, from each of 2 locations) for tissue chemistry analyses in 2011. Each frozen archived Slimy Sculpin consisted of a carcass that included all internal structures except for otoliths and gonads, which were removed during the previous program (i.e., liver and viscera were included). Three adult Slimy Sculpin of similar length, weight, age, sex, and maturity, from the same area, were grouped together and placed in a single Ziploc bag to create one composite sample. This composite sample was given a new identification number, and the old numbers were recorded on a datasheet.

Each composite Slimy Sculpin sample was analysed for total metals, lipid content (%), moisture content (%), and arsenic speciation/organic arsenic. The samples were sent to ALS (Burnaby, BC) for further processing and analysis. Because of the need to use different digestion techniques for the metals and arsenic speciation analyses, ALS cut each fish in each composite sample in half laterally and analysed one half of the composite sample for total metals, lipids, and moisture, and then froze the other half. The frozen archived samples were sent to the specialized ALS analytical laboratories in Sweden to be analysed for arsenic speciation and organic arsenic analysis.

Ninespine Stickleback

Ninespine Stickleback that were used as tissue chemistry samples in this study were captured during the Giant EEM Phase 3 program in July 2010 and then frozen archived. Fish were captured from Reach 1 and 0 in Baker Creek and from a reference area in the Yellowknife River (Figures 6 and 7).

Ninespine Stickleback were captured using a 10 m x 1.5 m beach seine net, with a 2-mm Delta Knotless mesh. Accidental mortalities during the Giant Mine Phase 3 EEM program were frozen archived as whole-bodied fish and were used for the fish tissue chemistry samples for the Baker Creek assessment. The fish underwent a detailed fish health examination in 2010, and their gonads and otoliths were removed for analyses. The fish carcasses were then frozen as archive samples which were used as tissue chemistry samples for this program in 2011. Additional information on field collection methods and fish health assessment results for Ninespine Stickleback used in this study is available in Golder (2011c).

All small-bodied fish tissue samples were composited (i.e., more than one whole-bodied fish in each sample) to achieve the minimum required weight of 0.8 g wet weight (ww) for the laboratory analysis of tissue chemistry.

Frozen archived whole-bodied Ninespine Stickleback from Baker Creek and the Yellowknife River were composited to create four samples from each location. A total of 39 fish from Baker Creek and 43 fish from the Yellowknife River were used to create the composite tissue samples.

The samples were sent to ALS (Burnaby, BC) for analysis of total metals, lipid content, and moisture content.

4.2.5.2 Large-bodied Fish Collection and Tissue Processing

Adult Northern Pike and Lake Whitefish were captured from Baker Creek and a reference area (Yellowknife River) in summer 2011 to collect fillet and liver tissue samples for tissue chemistry analyses.

A total of 10 adult Northern Pike and 10 adult Lake Whitefish were captured from both Baker Creek and the Yellowknife River in 2011. Northern Pike from Baker Creek were captured using a combination of field methods including gill netting and angling. All Lake Whitefish from Baker Creek were captured using gill nets. One 75-m multimesh gill net, with a mesh size of 24 mm to 117 mm, was deployed for two overnight (19 hour) sets in Reach 6 (pond area) in Baker Creek (Figure 5).

All of the Northern Pike from the Yellowknife River were captured from the Tartan Rapids area on July 13, 2011, by four people angling for one and a half hours. Lake Whitefish from the Yellowknife River were captured from the Prosperous Lake area using two multimesh gill nets (one measuring 75 m in length and with a mesh size of 24 mm to 117 mm, and the other measuring 50 m in length with a mesh size of 22 mm to 120 mm) that were each set overnight (19 hours) (Figure 6).

The 10 Northern Pike from Baker Creek were processed for fish health and tissue sample collection immediately after capture in the summer of 2011. These tissue samples were then frozen archived for future laboratory analyses. All other fish captured in 2011 were frozen archived as whole bodies and then processed for fish health and tissue sample collection in November 2011.

Water quality measurements of pH, temperature, dissolved oxygen, and specific conductivity were collected from each sampling area using a YSI 650 MDS water quality meter connected to an YSI 600 QS multi-parameter water quality probe.

The Northern Pike and Lake Whitefish were processed for fish health and tissue chemistry samples according to Golder Technical Procedures TP-8.16-0: *Fish Health Assessment – Metals* (unpublished file information). Care was taken to not contaminate samples by using clean nitrile gloves, new plastic wrapped cutting boards, and new scalpel blades for each fish. Each fish was assigned an appropriate biomarker number and examined for external and internal physical abnormalities, sex, maturity, length (mm), and weight (g). After examinations were complete, tissue samples were collected.

Age structures were collected from each fish including otoliths, scales, finrays, and cleithra (Northern Pike only). The age structures were cleaned, dried, and placed in labelled paper envelopes. The age structures were sent to North/South Consultants Inc. (Winnipeg, MB) for age analysis.

Two skinless fillet samples were collected from the dorsal side of each fish. Each fillet was wrapped in plastic wrap and individually placed in a labelled Ziploc bag and then frozen archived until ready to be shipped. The liver from each fish was also collected and split in half laterally (as opposed to anterior and posterior sections). Each half was wrapped in plastic wrap, individually placed in a labelled Ziploc bag and then frozen archived until ready to be shipped. One fillet sample and one liver sample from each fish were sent to ALS (Burnaby, BC) for analysis of total metals, lipid content (%) and moisture content (%). The other fillet and liver sample was sent to the Environmental Sciences Group (ESG) at the Royal Military College of Canada (RMC; Kingston, ON) for arsenic speciation/organic arsenic analysis.

The remaining viscera (i.e., intestines, stomach) and carcasses were placed in a large labelled Ziploc bags and frozen archived.

4.2.6 Fish Community Surveys

A Golder-DFO field crew visited Lower Martin Lake and Trapper Lake in September 2011 to document whether fish were present or absent in each waterbody (Figure 5 and Figure 7). Both Lower Martin Lake and Trapper Lake flow into Baker Creek, and there is a possibility that fish can migrate between the lakes and Baker Creek.

Field crews recorded fish and habitat observations and collected supporting environmental variables in both Lower Martin Lake and Trapper Lake. Water quality measurements of pH, temperature, dissolved oxygen, and specific conductivity were collected using a YSI 650 MDS water quality meter connected to an YSI 600 QS multi-parameter water quality probe. Water quality samples were collected as grab samples from the side of the boat. Bathymetry was also recorded from 15 different locations throughout Lower Martin Lake, and from 40 different locations in Trapper Lake, using a weighted sounding line off the side of the boat. All inlets, outflows, and culverts were documented and observed for fish presence or absence. Additional information such as GPS coordinates, photographs, and habitat observations was also recorded.

Lower Martin Lake

Lower Martin Lake was surveyed for fish presence or absence on September 15 and 16, 2011. Seine netting was conducted using a 10 m long, 1.5 m wide, 2-mm Delta Knotless mesh beach seine net. One single-mesh gill net (measuring 100 m in length with a 95 mm mesh size) and two multi-mesh gill nets (one measuring 75 m in length with a mesh size of 24 mm to 117 mm, and the other measuring 50 m in length with a mesh size of 22 mm to 120 mm) were also set throughout Lower Martin Lake. The gill nets were set for three to four hours, checked for fish, and then reset and left overnight (19 hours).

Captured fish were counted and identified to species; length (mm), weight (g), and maturity were determined on subsets of the catch. A total of 465 fish representing six species (Cisco, Lake Whitefish, Northern Pike, Walleye, Ninespine Stickleback, and a Lake Whitefish-Cisco hydrid). Fifteen adult Lake Whitefish, 10 adult Northern Pike, and 1 adult Walleye were retained for future tissue analyses by DFO. Additional fisheries information is available upon request.

Trapper Lake

Trapper Lake was surveyed for fish presence/absence on September 14, 2011. Electrofishing was conducted in three main areas of Trapper Lake using a SmithRoot LR24 Backpack Electrofishing unit. Two multi-mesh gill nets (one measuring 75 m in length and with a mesh size of 24 mm to 117 mm, and the other measuring 50 m in length with a mesh size of 22 mm to 120 mm) were also set for four hours each in different areas of Trapper Creek. No fish were observed or captured in Trapper Creek.

4.2.7 Quality Assurance/Quality Control (QA/QC) - Field Program

The generation of quality data begins with sample collection. Therefore, the integrity of the sample collection process is of utmost importance to the success of the investigation. To confirm sample integrity, the following were undertaken:

- Samples were collected and processed by qualified, experienced personnel according to detailed specific work instructions that were provided to field personnel for each field task prior to the field program;
- Samples were collected in such a way that no foreign material was introduced to the sample and no material of interest escaped from the sample prior to analysis;
- Sample handling or contact with contaminating materials/surfaces was minimized;
- Decontamination of sampling equipment was conducted to minimize cross-contamination between sampling stations, including rinsing of samplers with site water before each deployment, cleaning and sealing core tubes, and cleaning of equipment used to composite sediment samples;
- Samples were placed in appropriate clean containers and preserved (where appropriate) so that no material of interest was lost due to adsorption, degradation, or volatilization;
- Sufficient sample volumes were collected so that required detection limits could be met and quality control samples analysed (including field duplicate samples for chemistry analyses);
- Field notes were recorded in waterproof field notebooks and on preprinted waterproof field data sheets, and field data were checked at the end of each day for completeness and accuracy;
- Samples were packaged and shipped to the laboratory by appropriate means, so that holding times and storage conditions for the analyses were met; and,
- Chain-of-custody forms were used to track all sample shipments from the field to the applicable analytical laboratories.

4.3 Water Quality (Chemistry and Toxicity) Line of Evidence

4.3.1 Methods

4.3.1.1 Chemistry Analyses

Surface water samples collected from six locations in Baker Creek, Yellowknife River, Trapper Lake, and Lower Martin Lake in September and October 2011 were submitted to ALS (Burnaby, BC) for chemistry analyses. The surface water samples collected from three locations in Prosperous Lake in July 2011 were submitted to ALS (Edmonton, AB) for chemistry analyses.

Water samples collected by Golder personnel were analysed for the suite of parameters normally used for EEM monitoring: physical tests, anions and nutrients, total cyanide, total and dissolved organic carbon, total and dissolved metals, and oil and grease. The sample collected by DCNJV from Station SNP 43-5 at the mouth of Baker Creek was only analysed for physical tests, ammonia, total cyanide, and total and dissolved metals.

4.3.1.2 Toxicity Tests

Acute and chronic toxicity tests were performed on water samples collected from three Baker Creek locations: Station SNP 43-11 in Upper Baker Creek, Baker Creek Exposure Point at the outlet of Baker Creek Pond, and Station SNP 43-5 at the mouth of Baker Creek. It was assumed that Yellowknife River water would not be acutely toxic, and therefore only chronic toxicity tests were performed on the sample collected from that reference area.

The following acute and chronic toxicity tests were performed by HydroQual (Calgary, AB):

- Acute toxicity tests with juvenile Rainbow Trout (*Oncorhynchus mykiss*) according to Method EPS 1/RM/13 (Environment 2000a). The test duration was 96 h and survival was the endpoint measured. A dilution series was tested to determine the 96-h LC50 (the concentration of sample estimated to be lethal to 50% of the test organisms).
- Acute toxicity tests with a water flea (*Daphnia magna*) according to Method EPS 1/RM/14 (Environment Canada 2000b). The test duration was 48 h and survival was the endpoint measured. A dilution series was tested to determine the 48-h LC50.
- Chronic toxicity tests with a different genus and species of water flea (*Ceriodaphnia dubia*) than for acute toxicity testing, according to Method EPS 1/RM/21 (Environment Canada 2007a). The test duration was approximately 7 d (defined as the point when at least 60% of controls have produced three broods of offspring), and survival and reproduction were the endpoints measured. A dilution series was tested to determine the LC25 and LC50 (sample concentrations estimated to be lethal to 25 and 50% of test organisms, respectively) for survival, and the IC25 and IC50 (sample concentrations estimated to cause a 25 and 50% inhibitory effect in a sublethal endpoint, respectively) for reproduction.
- Chronic toxicity tests with an alga (*Pseudokirchneriella subcapitata*) according to Method EPS 1/RM/25 (Environment Canada 2007b). The test duration was 72 h and growth inhibition was the endpoint measured. A dilution series was tested to determine the 72-h IC25 and IC50.

4.3.2 Quality Assurance/Quality Control (QA/QC)

Quality Assurance/Quality Control (QA/QC) is an integral component of laboratory operations as a means of confirming that the data being generated are of acceptable quality and are scientifically defensible. It includes the routine analysis of quality control (QC) samples to assess performance of the method for the type of samples under investigation.

4.3.2.1 Chemistry Analyses

For the water chemistry analyses, QC samples submitted for analyses consisted of travel and field blanks, method blanks, field and laboratory duplicates, reference materials, and/or method analyte spikes. Descriptions for each of these types of QC samples, as well as the results obtained, are summarized below. Additional details are provided in the ALS laboratory reports in Appendix C.

- Travel Blank and Field Blank: The travel blank and field blank are aliquots of analyte-free water that are provided by the analytical laboratory and taken into the field during sampling. The travel blank is returned to the laboratory with the samples, with its seal unbroken. The travel blank's purpose is to identify contamination associated with sample handling, transport or storage. The field blank is opened in the field, handled in the same manner as the samples, and returned to the laboratory. Its purpose is to identify contamination associated with sample collection and processing in the field. The data quality objective (DQO) for travel and field blanks is that target analytes are not detected. Ammonia was detected in the field blank that was submitted with the Prosperous Lake samples; the concentration was approximately two times the DL (0.0108 versus 0.0050 mg/L N), but was also similar to the sample concentrations (0.012 to 0.0191 mg/L N). ALS repeated the analysis and the original result was confirmed. Therefore, because of contamination of the field blank, the ammonia results for the Prosperous Lake samples should be used with caution.
- Method Blank: The method blank is a clean sample matrix that undergoes laboratory processing identical to that carried out for samples, to determine whether any laboratory contamination might have entered the analytical procedure. The DQO for method blanks is that target analytes are not detected. None of the target analytes were detected in the method blanks.
- Laboratory Duplicate: Laboratory duplicates or replicates consist of two or more independently subsampled portions of the same sample, prepared separately and analysed by the same methods. Their purpose is to evaluate analytical precision using samples of unknown characteristics. The DQO for laboratory duplicates is expressed as the relative percent difference (RPD) between the original sample and the laboratory duplicate. RPDs were calculated as[5]:

$$RPD = 100\left|\frac{sample - duplicate}{(sample + duplicate)/2}\right|$$

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[5] Concentrations less than five times the DL were not included in RPD calculations because analytical variability near the DL is high and does not provide a good measure of variability.

The RPD for laboratory duplicates should typically be ≤20% for metals analyses, when results for both the sample and the duplicate are at least five times the DL. The RPDs for laboratory duplicates ranged from <1 to 12%.

- Field Duplicate: Field duplicates or replicates consist of two or more separately collected field samples that are submitted to the laboratory as independent samples and used to evaluate sample variability. The DQO for field duplicates was that the RPD be ≤25%, as recommended by MOE (1997). The RPDs for the field duplicates ranged from <1 to 37%; the RPDs for copper, lead, and silicon were >25% for the Trapper Creek field duplicate.
- Laboratory Control Sample or Matrix Spike: A sample, clean matrix, or reagent fortified with a known quantity of the analyte(s) of interest prior to undergoing sample processing identical to that carried out for the samples. The results of this sample provide information on matrix effects and/or any losses incurred during sample preparation. The DQOs varied from ±10% to ±50% of the target value, depending on the analyte. Results for these QC samples ranged from 70 to 110% recovery.
- Reference Material: This can be a certified reference material (CRM) or a standard reference material (SRM) that has been certified to contain specific concentrations of one or more parameters. A reference material can also be other than a CRM or an SRM, not certified but considered by analysts to be useable as a reference material if no suitable CRM or SRM is available. It may come from an external supplier or be prepared in-house. The DQOs for CRMs were to have recoveries 80 to 120% of target values. Recoveries for the CRMs ranged from 84 to 108%.

4.3.2.2 Toxicity Tests

The following QA/QC procedures were applied to the water-column toxicity tests:

- Negative controls using clean laboratory dilution water were used to confirm that appropriate test acceptability criteria were met;
- Reference toxicant tests were used to assess the relative health and sensitivity of the test organisms to confirm that they were appropriate for use in testing; and,
- Water quality parameters (temperature, dissolved oxygen, pH, and conductivity) were monitored during testing to confirm that the test organisms were not subjected to stress unrelated to the test material. Any adjustments made during testing (e.g., temperature, aeration) were documented, with explanations given for the corrective action.

The water-column toxicity test results were evaluated based on the performance of negative controls, reference toxicant tests, and compliance with the specified testing conditions (e.g., maintenance of water quality, no unusual observations during testing). Water quality measurements during testing (e.g., temperature, pH, dissolved oxygen, conductivity) were within acceptable ranges. Tests with all four species met the applicable test acceptability criteria for negative control performance and were considered valid. Reference toxicant test results for each method were consistent with HydroQual's historical test performance and were considered acceptable.

4.3.3 Results and Discussion

4.3.3.1 Chemistry Analyses

Results of chemistry analyses performed on the nine surface water samples are summarized in Table 5. Copies of the ALS laboratory reports are provided in Appendix C.

Of the target analytes, nitrite, total and dissolved forms of eight metals (bismuth, boron, chromium, cobalt, mercury, phosphorus, tin, and vanadium), and dissolved lead, were undetected in all nine water samples. Of these undetected analytes, only mercury was identified as a COPC based on screening of historical data.

Three COPCs (cadmium, silver, and thallium) were undetected in all nine surface water samples, but the DLs used were above their respective CCME WQGs. Cadmium DLs ranged from 0.000050 to 0.00020 mg/L; it is not uncommon for cadmium DLs to be above the WQG, which varies as it is hardness-dependent. Silver DLs historically ranged from 0.0001 to 0.01 mg/L, as compared to the WQG of 0.0001 mg/L. Similarly, thallium DLs have historically ranged from 0.0001 to 0.2 mg/L. When the lower DL was used in the past, thallium concentrations ranged from 0.0001 to 0.0003 mg/L (Appendix A), which was below the WQG of 0.0008 mg/L.

There were no exceedances of WQGs in the three water samples collected from Prosperous Lake, the reference area for fish tissue collection located upstream on the Yellowknife River. However, these three samples did not necessarily have the lowest concentrations of all target analytes.

Chloride concentrations ranged from 1.86 mg/L in the Prosperous WQ3 sample to 227 mg/L at the Baker Creek Exposure Point. Only the latter station had a chloride concentration that was above the CCME WQG (120 mg/L).

Although not identified as a COPC during data screening, total dissolved solids (TDS) concentrations were elevated at the Baker Creek Exposure Point (1,380 mg/L) and at Station SNP 43-5 near the creek mouth (1,490 mg/L), as compared to the other water samples (31 to 214 mg/L). The TDS ionic composition in the Baker Creek Exposure Point sample was approximately 47% sulphate, whereas the sulphate contribution was lower at the other stations.

Fluoride concentrations ranged from 0.068 to 0.134 mg/L, except that fluoride was reported as undetected (<0.40 mg/L) based on an elevated DL for the Baker Creek Exposure Point sample. Apart from that sample, fluoride was only above the WQG in the Trapper Lake sample (0.134 versus 0.12 mg/L).

Total cyanide was undetected (<0.005 mg/L) in the three Prosperous Lake samples, and ranged from 0.0053 to 0.0082 mg/L in the other samples. Concentrations were highest in the Baker Creek Exposure Point sample. Direct comparisons to the cyanide WQG were not applicable because the CCME WQG for cyanide (0.005 mg/L) is expressed in terms of free cyanide rather than total cyanide.

Table 5: Summary of Water Chemistry Data for 2011 Baker Creek Assessment

Sample ID Date Sampled ALS Sample ID	Units	CCME Water Quality Guidelines	SNP 43-11 19-SEP-11 L1060802-3	Baker Creek Exposure Pt 19-SEP-11 L1060802-4	SNP 43-5 20-Sep-11 L1060894-1	Yellowknife River 11-OCT-11 L1070459-1	Prosperous Lake WQ1 13-JUL-11 L1031383-1	Prosperous Lake WQ2 13-JUL-11 L1031383-2	Prosperous Lake WQ3 13-JUL-11 L1031383-3	Trapper Lake 14-SEP-11 L1058576-1	Martin Lake 16-SEP-11 L1059686-1
Physical Tests											
Conductivity	uS/cm		146	1830	2010	NM	57.9	57.9	55.9	NM	NM
Hardness (as CaCO3)	mg/L		71.6	890	899	28.3	21.5	21.6	21.3	132	47.1
pH	pH	6.5 - 9.0	7.97	7.83	7.9	7.60	7.71	7.74	7.74	7.90	7.88
Total Suspended Solids	mg/L		<1.0	21.6	2.2	33.4	<3.0	<3.0	<3.0	4.8	2.7
Total Dissolved Solids	mg/L		109	1380	1490	45.8	36	34	31	214	87.8
TDS (Calculated)	mg/L		NM	NM	NM	NM	29.3	28.8	30.8	NM	NM
Turbidity	NTU		1.49	7.03	1.81	12.7	2.35	2.16	1.27	2.87	1.99
Anions and Nutrients											
Acidity (as CaCO3)	mg/L		1.7	6.6	NM	2.3	NM	NM	NM	5.0	2.7
Alkalinity, Bicarbonate (HCO3)	mg/L		66.5	74.9	NM	25.6	27.5	26.0	28.4	84.8	109
Alkalinity, Carbonate (CO3)	mg/L		<1.0	<1.0	NM	<1.0	<5.0	<5.0	<5.0	<1.0	<1.0
Alkalinity, Hydroxide (OH)	mg/L		<1.0	<1.0	NM	<1.0	<5.0	<5.0	<5.0	<1.0	<1.0
Alkalinity, Total (as CaCO3)	mg/L		66.5	74.9	NM	25.6	22.5	21.3	23.3	84.8	109
Ammonia (as N)	mg/L		0.0093	0.0179	0.0116	0.0594	0.0122	0.0144	0.0191	0.0120	<0.0050
Bromide (Br)	mg/L		<0.050	2.9	NM	<0.050	NM	NM	NM	0.069	<0.050
Chloride (Cl)	mg/L	120	3.43	227	NM	2.58	2.22	2.22	1.86	19.2	2.93
Fluoride (F)	mg/L	0.12	0.109	<0.40	NM	0.071	0.068	0.069	0.071	0.134	0.111
Nitrate and Nitrite (as N)	mg/L		0.0132	1.78	NM	<0.0051	<0.0060	<0.0060	<0.0060	<0.0051	<0.0051
Nitrate (as N)	mg/L	2.935	0.0132	1.78	NM	<0.0050	<0.0060	<0.0060	<0.0060	<0.0050	<0.0050
Nitrite (as N)	mg/L	0.06	<0.0010	<0.020	NM	<0.0010	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L		0.830	0.744	NM	0.311	0.238	0.215	0.214	1.62	0.904
Phosphorus (P)-Total Dissolved	mg/L		0.0100	0.0091	NM	0.0026	0.0047	0.0023	0.0017	0.0167	0.0050
Phosphorus (P)-Total	mg/L		0.0177	0.0483	NM	0.0241	0.0112	0.0084	0.0060	0.0451	0.0146
Sulphate (SO4)	mg/L		5.10	654	NM	3.79	3.17	3.18	3.06	26.8	2.88
Sulphide as S	mg/L		<0.020	0.021	NM	<0.020	<0.0020	<0.0020	<0.0020	<0.020	<0.020
Organic / Inorganic Carbon											
Dissolved Organic Carbon	mg/L		15.0	10.9	NM	5.05	5.2	5.0	5.2	22.1	14.6
Total Organic Carbon	mg/L		16.6	11.1	NM	5.87	6.1	5.9	5.6	22.1	15.8
Total Metals											
Aluminum (Al)-Total	mg/L	0.1	0.0253	0.0903	0.0508	0.565	0.064	0.064	0.046	0.0515	0.0336
Antimony (Sb)-Total	mg/L		0.00124	0.231	0.22	<0.00010	<0.00040	<0.00040	<0.00040	0.00599	0.00118
Arsenic (As)-Total	mg/L	0.005	0.0294	0.229	0.208	0.00121	0.00046	0.00045	<0.00040	0.160	0.0392
Barium (Ba)-Total	mg/L		0.012	0.021	0.033	0.011	0.0106	0.00491	0.00438	0.025	0.012
Beryllium (Be)-Total	mg/L		<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	<0.0010	<0.0050	<0.0050
Bismuth (Bi)-Total	mg/L		<0.20	<0.20	<0.20	<0.20	<0.00020	<0.00020	<0.00020	<0.20	<0.20
Boron (B)-Total	mg/L	1.5	<0.10	0.20	0.21	<0.10	<0.020	<0.020	<0.020	<0.10	<0.10
Cadmium (Cd)-Total	mg/L	0.000009 - 0.0002	<0.000050	<0.00010	<0.00010	<0.000050	<0.00020	<0.00020	<0.00020	<0.000050	<0.000050
Calcium (Ca)-Total	mg/L		19.0	223	260	7.16	5.10	5.33	5.19	30.7	12.6
Chromium (Cr)-Total	mg/L	0.001 (CrVI); 0.0089 (CrIII)	<0.010	<0.010	<0.010	<0.010	<0.00080	<0.00080	<0.00080	<0.010	<0.010
Cobalt (Co)-Total	mg/L		<0.010	<0.010	<0.010	<0.010	<0.00020	<0.00020	<0.00020	<0.010	<0.010
Copper (Cu)-Total	mg/L		<0.00050	0.0117	0.01	0.00129	<0.0010	<0.0010	0.0011	0.00108	<0.00050
Iron (Fe)-Total	mg/L	0.30	0.228	0.166	0.092	0.518	0.053	0.044	0.031	0.094	0.048
Lead (Pb)-Total	mg/L	0.001 - 0.007	<0.000050	0.00086	0.0004	0.000237	<0.00010	<0.00010	<0.00010	0.000314	0.000073
Lithium (Li)-Total	mg/L		<0.010	0.021	0.024	<0.010	NM	NM	NM	<0.010	<0.010
Magnesium (Mg)-Total	mg/L		6.65	53.7	58.7	2.61	2.02	2.09	2.03	12.3	3.91
Manganese (Mn)-Total	mg/L		0.0358	0.0241	0.0191	0.0093	0.0043	0.0035	<0.0020	0.0109	0.0551
Mercury (Hg)-Total	mg/L	0.000026	<0.000010	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010
Molybdenum (Mo)-Total	mg/L	0.073	0.000242	0.0126	0.0121	0.000123	<0.00010	<0.00010	0.00010	0.00108	0.000431
Nickel (Ni)-Total	mg/L	0.029 - 0.507	<0.00050	0.0214	0.0165	0.00104	0.00042	0.00038	0.00040	0.00058	<0.00050
Phosphorus (P)-Total	mg/L		<0.30	<0.30	<0.30	<0.30	NM	NM	NM	<0.30	<0.30
Potassium (K)-Total	mg/L		2.1	7.6	8.3	<2.0	0.98	1.05	1.02	<2.0	<2.0
Selenium (Se)-Total	mg/L	0.001	<0.00010	0.00049	0.00044	<0.00010	<0.00040	<0.00040	<0.00040	<0.00010	<0.00010
Silicon (Si)-Total	mg/L		0.756	0.897	0.594	1.81	NM	NM	NM	0.918	0.342
Silver (Ag)-Total	mg/L	0.0001	<0.010	<0.010	<0.010	<0.010	<0.00040	<0.00040	<0.00040	<0.010	<0.010
Sodium (Na)-Total	mg/L		4.5	93.8	108	2.7	2.2	2.2	2.1	9.4	3.0
Strontium (Sr)-Total	mg/L		0.0729	1.88	2.09	0.0306	0.0246	0.0253	0.0242	0.129	0.0491
Thallium (Tl)-Total	mg/L	0.0008	<0.20	<0.20	<0.20	<0.20	<0.00010	<0.00010	<0.00010	<0.20	<0.20
Tin (Sn)-Total	mg/L		<0.030	<0.030	<0.030	<0.030	<0.00040	<0.00040	<0.00040	<0.030	<0.030
Titanium (Ti)-Total	mg/L		<0.010	0.027	0.019	0.027	0.0051	<0.0050	<0.0050	<0.010	<0.010
Uranium (U)-Total	mg/L	0.015	0.000443	0.00200	0.00204	0.000325	0.00020	0.00020	0.00022	0.000355	0.000359
Vanadium (V)-Total	mg/L		<0.030	<0.030	<0.030	<0.030	<0.00050	<0.00050	<0.00050	<0.030	<0.030
Zinc (Zn)-Total	mg/L	0.030	<0.0040	0.0056	0.0087	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Dissolved Metals											
Aluminum (Al)-Dissolved	mg/L		0.0067	<0.0060	<0.0060	0.0167	0.012	0.012	<0.010	0.0078	0.0190
Antimony (Sb)-Dissolved	mg/L		0.00117	0.268	0.219	<0.00010	<0.00040	<0.00040	<0.00040	0.00581	0.00120
Arsenic (As)-Dissolved	mg/L		0.0209	0.250	0.193	0.00115	0.00047	0.00049	<0.00040	0.172	0.0404
Barium (Ba)-Dissolved	mg/L		0.011	0.020	0.033	<0.010	0.00447	0.00441	0.00393	0.025	0.011
Beryllium (Be)-Dissolved	mg/L		<0.0050	<0.0050	<0.0050	<0.0050	<0.00050	<0.00050	<0.00050	<0.0050	<0.0050
Bismuth (Bi)-Dissolved	mg/L		<0.20	<0.20	<0.20	<0.20	<0.000050	<0.000050	<0.000050	<0.20	<0.20
Boron (B)-Dissolved	mg/L		<0.10	0.22	0.21	<0.10	0.0046	0.0049	0.0044	<0.10	<0.10
Cadmium (Cd)-Dissolved	mg/L		<0.000050	<0.00010	<0.00010	<0.000050	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050
Calcium (Ca)-Dissolved	mg/L		18.2	256	264	7.21	5.34	5.28	5.30	32.1	12.4
Chromium (Cr)-Dissolved	mg/L		<0.010	<0.010	<0.010	<0.010	<0.00040	<0.00040	<0.00040	<0.010	<0.010
Cobalt (Co)-Dissolved	mg/L		<0.010	<0.010	<0.010	<0.010	<0.00010	<0.00010	<0.00010	<0.010	<0.010
Copper (Cu)-Dissolved	mg/L		<0.00050	0.0082	0.0073	0.00082	0.00067	0.00090	0.00066	0.00075	<0.00050
Iron (Fe)-Dissolved	mg/L		0.100	<0.010	0.011	0.012	<0.010	<0.010	0.013	0.013	<0.010
Lead (Pb)-Dissolved	mg/L		<0.000050	<0.00010	<0.00010	<0.000050	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L		<0.010	0.024	0.023	<0.010	NM	NM	NM	<0.010	<0.010
Magnesium (Mg)-Dissolved	mg/L		6.32	60.7	58.6	2.49	1.99	2.04	1.96	12.6	3.89
Manganese (Mn)-Dissolved	mg/L		0.0061	<0.0050	0.0181	<0.0050	<0.0020	<0.0020	<0.0020	<0.0050	<0.0050
Mercury (Hg)-Dissolved	mg/L		<0.000010	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L		0.000229	0.0145	0.0116	0.000119	<0.00010	<0.00010	<0.00010	0.000996	0.000411
Nickel (Ni)-Dissolved	mg/L		<0.00050	0.0230	0.0157	<0.00050	0.00037	0.00045	0.00039	<0.00050	<0.00050
Phosphorus (P)-Dissolved	mg/L		<0.30	<0.30	<0.30	<0.30	NM	NM	NM	<0.30	<0.30
Potassium (K)-Dissolved	mg/L		2.0	8.3	8.3	<2.0	0.96	1.04	1.53	<2.0	<2.0
Selenium (Se)-Dissolved	mg/L		<0.00010	0.00050	0.00046	<0.00010	<0.00040	<0.00040	<0.00040	<0.00010	<0.00010
Silicon (Si)-Dissolved	mg/L		0.657	0.707	0.486	0.457	NM	NM	NM	0.728	0.308
Silver (Ag)-Dissolved	mg/L		<0.010	<0.010	<0.010	<0.010	<0.00020	<0.00020	<0.00020	<0.010	<0.010
Sodium (Na)-Dissolved	mg/L		4.3	107	109	2.7	2.1	2.2	3.0	9.5	2.9
Strontium (Sr)-Dissolved	mg/L		0.0686	2.14	2.07	0.0288	0.0247	0.0245	0.0234	0.129	0.0476
Thallium (Tl)-Dissolved	mg/L		<0.20	<0.20	<0.20	<0.20	<0.000050	<0.000050	<0.000050	<0.20	<0.20
Tin (Sn)-Dissolved	mg/L		<0.030	<0.030	<0.030	<0.030	<0.00020	<0.00020	<0.00020	<0.030	<0.030
Titanium (Ti)-Dissolved	mg/L		<0.010	0.025	0.018	<0.010	<0.00030	<0.00030	<0.00030	<0.010	<0.010
Uranium (U)-Dissolved	mg/L		0.000414	0.00221	0.00197	0.000209	0.00016	0.00016	0.00017	0.000338	0.000335
Vanadium (V)-Dissolved	mg/L		<0.030	<0.030	<0.030	<0.030	<0.00010	<0.00010	<0.00010	<0.030	<0.030
Zinc (Zn)-Dissolved	mg/L		<0.0040	<0.0040	0.0079	<0.0040	<0.0010	<0.0010	<0.0010	<0.0040	<0.0040
Cyanides											
Cyanide, Total	mg/L	0.005	0.0053	0.0082	0.0069	0.0055	<0.0050	<0.0050	<0.0050	0.0071	0.0068
Aggregate Organics											
Oil and Grease	mg/L		<1.0	<1.0	-	<1.0	<1.0	<1.0	<1.0	1.1	<1.0

Notes:
NM = not measured
Concentration exceeds CCME WQG
DL exceeds CCME WQG
Cyanide WQG is for free CN, whereas total cyanide was measured

Total aluminum and total iron concentrations only exceeded their respective WQGs in the Yellowknife River reference area sample. Concentrations of these two metals were at least nine and three times higher, respectively, in the Yellowknife River than in any of the other samples.

Total arsenic concentrations were lowest in the Yellowknife River and Prosperous Lake reference areas, ranging from <0.0004 to 0.00121 mg/L. Total arsenic concentrations were above the WQG (0.005 mg/L) in all the other samples, including stations upstream of Baker Creek Pond: Station SNP 43-11 (0.0294 mg/L); Trapper Lake (0.160 mg/L); and, Martin Lake (0.0392 mg/L). These results indicate continuing arsenic inputs to Baker Creek, unrelated to treated effluent discharge. Total arsenic concentrations were 0.229 and 0.208 mg/L, respectively, at the Baker Creek Exposure Point and at Station SNP43-5.

4.3.3.2 Toxicity Tests

Results of the acute and chronic toxicity tests performed on the four water samples from Baker Creek and the Yellowknife River reference area are summarized in Table 6. Copies of the HydroQual laboratory reports are provided in Appendix D.

None of the Baker Creek water samples were acutely toxic (the Yellowknife River reference sample was not tested for acute toxicity) to juvenile Rainbow Trout or to *Daphnia magna*.

Neither the upstream Baker Creek water sample (Station SNP 43-11) nor the Yellowknife River reference sample demonstrated chronic toxicity to *Ceriodaphnia dubia* or *Pseudokirchneriella subcapitata*. However, the Baker Creek Exposure Point sample demonstrated adverse effects in the chronic toxicity tests, with reduced *Ceriodaphnia* reproduction and inhibition of algal growth, and the Station SNP 43-5 sample also demonstrated inhibition of algal growth.

Table 6: Summary of Water Column Toxicity Test Results for 2011 Baker Creek Assessment

Test Type	Biological Endpoint	Test Statistic[1]	Station			
			SNP43-11	Baker Creek Exposure Point	SNP43-5	YK River (reference)
96-h Rainbow Trout	Survival	LC25	>100	>100	>100	Not tested
		LC50	>100	>100	>100	Not tested
48-h *Daphnia magna*	Survival	LC25	>100	>100	>100	Not tested
		LC50	>100	>100	>100	Not tested
3-brood *Ceriodaphnia dubia*	Survival	LC25	>100	>100	>100	>100
		LC50	>100	>100	>100	>100
	Reproduction	IC25	>100	61	>100	>100
		IC50	>100	90	>100	>100
72-d Algae	Growth Inhibition	IC25	>91	53	38	>91
		IC50	>91	>91	>91	>91

1. All test statistics are reported as percent volume of sample.

4.3.3.3 Summary

Water quality was assessed in Baker Creek (upstream and downstream of Baker Pond), the Yellowknife River reference area, and several other water bodies. Samples from Baker Creek were collected in September 2011, while treated effluent was being discharged, and therefore represented worst-case water quality conditions. Parameter concentrations were generally highest in lower Baker Creek (at the outlet to Baker Creek Pond and at the creek mouth), reflecting the amount of treated effluent present, except that total aluminum and iron concentrations were higher in the Yellowknife River. Water hardness and TDS concentrations were elevated in lower Baker Creek. Arsenic concentrations were elevated in lower Baker Creek and Trapper Lake, but were also above the WQG at Station SNP43-11 on Upper Baker Creek and further upstream in Martin Lake. This result indicates that lower Baker Creek continues to receive inputs of water-borne arsenic independent of the seasonal discharge of treated effluent. DLs used for three COPCs (cadmium, silver, and thallium) were above their respective WQGs, and therefore these analytes could not be fully assessed. It is possible that use of appropriately low DLs would result in silver or thallium being eliminated as COPCs. Water from upper and lower Baker Creek was not acutely toxic to Rainbow Trout or *Daphnia magna*, but there were sublethal effects on invertebrate reproduction and algal growth in the samples from lower Baker Creek.

4.4 Sediment Chemistry Line of Evidence

4.4.1 Methods

The following chemical analyses were performed on all sediment samples (surface grabs and subsurface core samples): grain size; TOC; and, total metals including arsenic and mercury.

Acid volatile sulphides/simultaneously extractable metals (AVS-SEM) were analysed in surface sediment samples, but not in sediment core samples. AVS-SEM is an accepted chemical surrogate of bioavailability for divalent metals because sediments with an excess of AVS (relative to SEM) have relatively low divalent metal bioavailability since divalent metal cations (i.e., cadmium, copper, lead, nickel and zinc) are sequestered as insoluble metal-sulphide complexes (and thus have low bioavailability). Although AVS-SEM can predict a lack of toxicity, it cannot predict toxicity. Although arsenic is not routinely included in the SEM measurement (due to an incomplete understanding of how different extraction techniques influence SEM arsenic concentrations), it was included in these analyses due to the importance of arsenic as a COPC in Baker Creek.

4.4.2 Quality Assurance/Quality Control (QA/QC)

For the surface and subsurface sediment chemistry analyses, QA/QC procedures were: field and laboratory duplicates; method blanks; reference materials; and/or, method analyte spikes. Results of analyses of these QC samples are summarized below, and additional details are provided in Appendix E (brief definitions of each type of QC sample are provided in Section 4.3.2.1). Sediment chemistry data are reported on a dry weight (dw) basis.

- Method Blank: Target analytes were not detected in the method blanks, with three exceptions. Arsenic was detected in two method blanks (0.097 and 0.291 mg/kg, compared to the DL of 0.05 mg/kg), but at concentrations that were orders of magnitude lower than those reported for the sediment samples. SEM zinc was detected in one method blank (0.0388 micromoles per gram [µmol/g], compared to the DL of 0.005 µmol/g); this concentration was at least three times lower than the concentrations reported for the sediment samples.

- Laboratory Duplicates: The RPDs for the laboratory duplicates ranged from <1 to 17%, which met the DQO.
- Field Duplicates: The RPDS for the field duplicates were ≤25% for the majority of metals detected in the three sets of field duplicates; the highest RPD was 54% for molybdenum in the BCSS-DEP-101 field duplicate.
- Reference Material: Percent recoveries for analyses of CRMs ranged from 71 to 113%, which met the DQO.

4.4.3 Results and Discussion

4.4.3.1 Surface Sediments

Results of chemistry analyses performed on the surface sediment samples collected from the top 5-cm layer from each of the 29 depositional stations are summarized in Table 7. Copies of the ALS laboratory reports are provided in Appendix E. Sediment chemistry results are reported on a dry weight (dw) basis.

Sediments from the 29 depositional stations consisted primarily of fine-grained materials (silt plus clay). Percent fines content ranged from 76.6 to 99.7%, except for Station BCSS-DEP-01 in Reach 0 (50.4% fines) and the three Upper Baker Creek stations (BCSS-DEP-23, BCSS-DEP-24, and BCSS-DEP-25) that were 50.3 to 61.0% fines. Sediments from the three Yellowknife River reference stations (BCSS-DEP-28, BCSS-DEP-29, and BCSS-DEP-30) had fines contents ranging from 77.2 to 94.2%, which was consistent with the majority of the Baker Creek stations.

Sediment TOC concentrations were variable among depositional stations in Baker Creek, Trapper Creek, and the Yellowknife River reference area. Baker Creek TOC concentrations ranged from 0.29% at Station BCSS-DEP-11 to 8.19% at Station BCSS-DEP-13 (both stations located in Reach 4), whereas TOC concentrations in the Yellowknife River reference area ranged from 0.94 to 1.60%.

Spatial distributions of concentrations of the 14 sediment COPCs identified during data screening are illustrated in Figure 8 to Figure 11 and summarized below. These figures show the magnitude of the concentration ranges measured in surface sediments, and the spatial variability for each COPC along the length of Baker Creek, including Upper Baker Creek (UBC), Trapper Creek (TC), and the Yellowknife River (YKR) reference area.

Table 7: Results of Chemistry Analyses Performed on Surface Sediment Samples From Baker Creek and Yellowknife River, 2011

Reach / Waterbody	Units	Sediment Quality Guidelines or Objectives						Reach 0			Reach 1		Reach 2			Reach 3		Reach 4			Reach 5		
Golder Sample ID		CCME ISQG	CCME PEL	OMOEE LEL	OMOEE SEL	WDOE LAET	GNWT Remediation Objective	BCSS-DEP01	BCSS-DEP02	BCSS-DEP03	BCSS-DEP04	BCSS-DEP05	BCSS-DEP06	BCSS-DEP07	BCSS-DEP08	BCSS-DEP09	BCSS-DEP10	BCSS-DEP11	BCSS-DEP12	BCSS-DEP13	BCSS-DEP14	BCSS-DEP15	BCSS-DEP16
Date Sampled								05-OCT-11	05-OCT-11	05-OCT-11	23-SEP-11	23-SEP-11	23-SEP-11	26-SEP-11	26-SEP-11	27-SEP-11	26-SEP-11	27-SEP-11	27-SEP-11	27-SEP-11	28-SEP-11	28-SEP-11	27-SEP-11
ALS Sample ID								L1070145-7	L1070145-6	L1070145-5	L1066704-1	L1066704-2	L1066704-3	L1066704-4	L1066704-5	L1066704-6	L1066704-7	L1066704-8	L1066704-9	L1066704-10	L1066704-11	L1066704-12	L1066704-13
Physical Tests																							
Moisture	%							38.2	58.2	59.5	61.4	62.9	52.5	27.8	43.1	43.7	52.9	30.0	36.4	65.2	75.0	50.8	81.7
pH (1:2 soil:water)	pH units							7.32	7.26	7.35	7.72	7.36	7.18	7.69	7.82	7.74	7.30	7.84	7.91	7.10	6.75	7.22	6.81
Particle Size																							
% Gravel (>2mm)	% dw							6.21	0.50	1.10	0.14	<0.10	<0.10	1.45	<0.10	<0.10	2.30	1.40	2.40	1.35	2.03	<0.10	3.14
% Sand (2.0mm - 0.063mm)	% dw							43.4	11.0	14.3	8.68	7.34	18.0	6.35	9.26	15.5	7.97	9.17	9.37	22.0	16.6	10.8	18.0
% Silt (0.063mm - 4um)	% dw							33.6	77.6	72.7	69.9	67.7	58.2	51.3	74.0	64.1	47.8	40.8	61.0	66.9	35.0	68.5	51.3
% Clay (<4um)	% dw							16.8	10.8	11.9	21.2	25.0	23.9	40.9	16.7	20.4	41.9	48.7	27.3	9.73	46.4	20.7	27.5
% Fines (silt + clay)	% dw							50.4	88.4	84.6	91.1	92.7	82.1	92.2	90.7	84.5	89.7	89.5	88.3	76.6	81.4	89.2	78.8
Organic / Inorganic Carbon																							
Total Organic Carbon	% dw			1	10	9.82		1.37	3.44	4.28	2.28	3.02	2.96	0.38	1.43	1.72	2.18	0.29	0.38	8.19	7.24	2.60	7.33
Total Metals																							
Aluminum (Al)	mg/kg dw							13500	11800	16100	14500	15200	14300	14100	15300	14000	17700	15300	13200	11600	13500	11000	10400
Antimony (Sb)	mg/kg dw					0.6		**77.8**	**192**	**296**	**150**	**206**	**215**	**7.54**	**882**	**182**	**27.7**	**1.04**	**7.64**	**140**	**74.6**	**745**	**193**
Arsenic (As)	mg/kg dw	5.9	17	6	33	31.4	150	541	1520	1870	1190	1640	1620	93.3	4790	2510	321	11.8	43.4	2270	507	4170	1000
Barium (Ba)	mg/kg dw							90.2	46.8	74.3	85.5	81.8	69.4	129	39.9	67.1	159	161	116	53.5	89.1	56.4	48.6
Beryllium (Be)	mg/kg dw					0.46		**0.51**	0.30	0.40	0.40	0.44	0.42	0.45	0.23	0.35	**0.61**	**0.60**	0.42	0.37	**0.47**	0.35	0.36
Bismuth (Bi)	mg/kg dw							0.21	0.20	0.43	0.25	0.31	0.29	0.27	0.42	0.24	0.27	0.27	0.24	0.20	<0.20	1.39	<0.20
Cadmium (Cd)	mg/kg dw	0.6	3.5	0.6	10	2.39		0.392	0.705	1.42	0.789	1.12	1.06	0.104	**2.81**	0.718	0.258	0.083	0.087	0.833	0.216	**8.45**	0.464
Calcium (Ca)	mg/kg dw							6010	10300	15800	11300	10600	8250	4040	24900	8740	5780	4540	4210	8830	6390	6020	6580
Chromium (Cr)	mg/kg dw	37.3	90	26	110	133		37.9	35.1	48.0	41.3	44.6	39.5	42.8	47.5	39.8	43.5	41.3	41.8	29.1	32.5	40.5	26.8
Cobalt (Co)	mg/kg dw							14.7	33.5	59.4	34.2	30.7	35.9	10.4	35.5	37.8	21.4	10.1	10.2	19.4	12.6	113	20.2
Copper (Cu)	mg/kg dw	35.7	197	16	110	619		109	264	508	174	277	272	33.7	276	145	59.2	23.4	29.4	242	386	**926**	**1950**
Iron (Fe)	mg/kg dw			20000	40000			24900	24700	35400	30400	34200	31000	22000	50000	30600	28000	22700	20500	20900	17800	126000	16200
Lead (Pb)	mg/kg dw	35	91.3	31	250	335		40.0	85.8	140	107	161	144	9.83	467	100	19.2	7.12	7.09	63.4	14.7	**1420**	54.8
Lithium (Li)	mg/kg dw							23.9	20.1	27.0	24.5	26.0	24.3	29.0	22.6	22.7	28.7	31.2	27.7	18.9	22.4	17.9	18.2
Magnesium (Mg)	mg/kg dw							8450	8950	12000	9960	11000	10400	8290	16500	10700	9750	9100	8180	6600	6350	7060	5400
Manganese (Mn)	mg/kg dw			460	1100			309	274	405	590	472	432	331	692	447	355	314	321	389	195	490	206
Mercury (Hg)	mg/kg dw	0.17	0.49	0.2	2	0.8		0.0499	0.118	0.166	0.133	0.182	0.179	0.0095	0.428	0.135	0.0352	0.0075	0.0065	**0.836**	0.0980	0.343	0.0969
Molybdenum (Mo)	mg/kg dw							0.86	2.45	3.23	1.58	1.71	1.53	0.68	1.47	0.73	1.36	0.52	0.95	1.25	3.38	2.37	2.30
Nickel (Ni)	mg/kg dw			16	75	113		38.9	70.4	122	67.8	67.8	73.3	28.6	81.3	69.5	43.9	26.9	29.4	58.3	45.0	231	92.0
Phosphorus (P)	mg/kg dw			600	2000			437	429	559	504	566	472	516	394	410	491	431	504	445	423	424	417
Potassium (K)	mg/kg dw							2340	1470	2080	2120	2170	1910	3430	1100	1700	3210	3950	3190	950	2300	1660	1510
Selenium (Se)	mg/kg dw							0.43	1.46	2.70	0.78	0.88	0.90	<0.20	0.72	0.82	0.84	<0.20	<0.20	0.92	0.88	0.93	2.00
Silver (Ag)	mg/kg dw					3.5		0.87	3.01	**4.49**	2.37	**3.57**	2.98	0.15	**6.32**	1.89	0.36	<0.10	0.11	1.49	1.59	**11.4**	**8.41**
Sodium (Na)	mg/kg dw							280	250	340	390	370	280	480	190	240	390	520	420	300	430	330	390
Strontium (Sr)	mg/kg dw							33.6	35.4	55.5	46.9	40.5	31.9	27.2	35.1	25.8	44.0	32.9	23.7	71.3	57.7	32.8	52.8
Thallium (Tl)	mg/kg dw							0.172	0.171	0.245	0.189	0.217	0.196	0.188	0.304	0.166	0.231	0.207	0.169	0.116	0.191	0.623	0.142
Tin (Sn)	mg/kg dw							<2.0	<2.0	2.2	<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
Titanium (Ti)	mg/kg dw							500	342	512	464	468	407	661	190	374	595	693	654	291	446	453	306
Uranium (U)	mg/kg dw							1.87	1.39	1.90	2.06	1.75	1.75	1.51	0.638	1.15	2.10	1.82	2.08	2.78	2.74	1.84	3.09
Vanadium (V)	mg/kg dw							46.5	41.8	59.3	45.2	47.3	44.7	40.9	53.4	46.3	50.9	41.8	38.4	38.0	33.9	34.7	27.0
Zinc (Zn)	mg/kg dw	123	315	120	820	683		117	197	375	228	310	308	57.9	604	205	88.8	52.1	51.6	154	95.2	**1510**	350
Inorganic Parameters																							
Acid Volatile Sulphides (AVS)	µmol/g dw							3.48	91.3	91.5	36.3	36.0	23.8	<0.20	<0.25	1.82	25.7	<0.20	4.64	<0.30	28.1	<0.29	<0.63
Simultaneously Extractable Metals (SEM)																							
Arsenic (As)-Extractable	µmol/g dw							0.584	0.478	0.682	1.90	1.68	1.17	1.01	15.6	6.66	0.199	0.068	0.161	6.53	0.748	49.8	6.78
Cadmium (Cd)-Extractable	µmol/g dw							<0.0050	<0.0050	<0.0050	<0.0050	<0.010	<0.0050	<0.0050	0.0080	<0.0050	<0.0050	<0.0050	<0.0050	0.0051	<0.0050	0.0288	<0.010
Copper (Cu)-Extractable	µmol/g dw							0.545	0.454	0.553	0.969	1.94	1.17	0.463	2.66	1.78	0.302	0.297	0.243	3.74	1.13	11.1	17.6
Lead (Pb)-Extractable	µmol/g dw							0.093	0.193	0.259	0.274	0.524	0.398	0.039	1.66	0.442	0.052	0.025	<0.020	0.356	0.057	6.33	0.352
Mercury (Hg)-Extractable	µmol/g dw							<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Nickel (Ni)-Extractable	µmol/g dw							0.232	0.737	0.943	0.689	0.72	0.828	0.151	0.529	0.853	0.369	0.130	0.206	0.755	0.485	0.961	2.31
Zinc (Zn)-Extractable	µmol/g dw							0.838	2.15	3.33	2.34	3.66	3.58	0.337	4.43	2.18	0.641	0.234	0.309	1.89	1.49	9.62	8.78
Sum of SEM (ΣSEM), excluding SEM-As	µmol/g dw							1.71	3.53	5.09	4.27	6.84	5.98	0.99	9.29	5.26	1.36	0.69	0.76	6.75	3.16	28.04	29.04
AVS - ΣSEM	µmol/g dw							1.77	87.77	86.42	32.03	29.16	17.82	-0.89	-9.16	-3.44	24.34	-0.59	3.88	-6.60	24.94	-27.89	-28.73

Concentration exceeds CCME ISQG
Concentration exceeds CCME PEL
Concentration exceeds OMOEE LEL
Concentration exceeds OMOEE SEL
Concentration exceeds WDOE LAET
Concentration exceeds GNWT remed. Obj.

Table 7: Results of Chemistry Analyses Performed on Surface Sediment Samples From Baker Creek and Yellowknife Fver, 2011

Reach / Waterbody	Units	Sediment Quality Guidelines or Objectives						Reach 6					Upper Baker Creek			Trapper Creek		Yellowknife River Reference			Field Duplicates		
Golder Sample ID		CCME ISQG	CCME PEL	OMOEE LEL	OMOEE SEL	WDOE LAET	GNWT Remediation Objective	BCSS-DEP17	BCSS-DEP18	BCSS-DEP19	BCSS-DEP20	BCSS-DEP21	BCSS-DEP23	BCSS-DEP24	BCSS-DEP25	BCSS-DEP26	BCSS-DEP27	BCSS-DEP28	BCSS-DEP29	BCSS-DEP30	BCSS-DEP100 (field dup of BCSS-DEP-8)	BCSS-DEP101 (field dup of BCSS-DEP-16)	BCSS-DEP102 (field dup of BCSS-DEP-28)
Date Sampled								21-SEP-11	21-SEP-11	22-SEP-11	22-SEP-11	22-SEP-11	30-SEP-11	28-SEP-11	30-SEP-11	29-SEP-11	29-SEP-11	04-OCT-11	04-OCT-11	04-OCT-11	26-SEP-11	27-SEP-11	04-OCT-11
ALS Sample ID								L1066704-14	L1066704-15	L1066704-16	L1066704-17	L1066704-18	L1066704-22	L1066704-19	L1066704-23	L1069356-1	L1069356-2	L1070145-1	L1070145-4	L1070145-2	L1066704-20	L1066704-21	L1070145-3
Physical Tests																							
Moisture	%							82.2	56.7	52.9	31.7	69.2	65.9	80.9	68.7	55.1	49.0	35.6	48.4	37.7	51.2	72.7	39.1
pH (1:2 soil:water)	pH units							7.59	7.75	7.23	7.89	7.61	6.70	6.90	6.60	7.07	7.13	6.74	6.31	6.55	7.69	6.93	6.58
Particle Size																							
% Gravel (>2mm)	% dw							<0.10	<0.10	<0.10	<0.10	<0.10	0.45	1.62	0.64	1.11	1.91	0.10	<0.10	0.66	<0.10	0.49	<0.10
% Sand (2.0mm - 0.063mm)	% dw							0.99	0.50	1.66	0.38	0.35	49.3	37.4	48.1	13.9	14.3	22.8	5.82	14.2	14.7	16.7	18.1
% Silt (0.063mm - 4um)	% dw							40.6	71.3	63.8	74.1	49.2	46.2	44.9	44.4	66.8	45.2	69.3	77.1	60.6	67.5	52.5	75.2
% Clay (<4um)	% dw							58.4	28.2	34.5	25.6	50.5	4.05	16.1	6.90	18.2	38.7	7.86	17.1	24.5	17.8	30.3	6.62
% Fines (silt + clay)	% dw							99.0	99.5	98.3	99.7	99.7	50.3	61.0	51.3	85.0	83.9	77.2	94.2	85.1	85.3	82.8	81.8
Organic / Inorganic Carbon																							
Total Organic Carbon	% dw			1	10	9.82		5.98	1.24	2.76	0.72	2.34	7.86	6.96	4.32	4.21	3.87	0.94	1.60	1.23	1.55	6.13	1.18
Total Metals																							
Aluminum (Al)	mg/kg dw							20300	16700	14500	17300	20700	9180	10100	11400	11400	14200	5710	6200	12300	16100	13500	7530
Antimony (Sb)	mg/kg dw					0.6		**162**	**338**	**87.9**	**411**	**258**	**4.73**	**4.37**	**55.6**	**7.73**	**3.38**	0.11	0.12	0.23	**921**	**163**	0.14
Arsenic (As)	mg/kg dw	5.9	17	6	33	31.4	150	**1080**	**1430**	**267**	**1870**	**827**	**178**	**165**	**410**	**212**	**63.1**	5.39	2.52	5.43	**5420**	**854**	6.44
Barium (Ba)	mg/kg dw							125	58.0	110	37.4	99.3	112	91.9	103	104	138	39.7	50.1	108	43.7	66.5	51.7
Beryllium (Be)	mg/kg dw					0.46		**0.69**	0.33	**0.52**	0.28	**0.58**	0.35	0.38	**0.47**	0.41	**0.62**	0.24	0.27	**0.53**	0.25	0.46	0.31
Bismuth (Bi)	mg/kg dw							0.26	0.31	0.26	0.26	0.39	<0.20	<0.20	<0.20	<0.20	0.21	<0.20	<0.20	<0.20	0.43	0.24	<0.20
Cadmium (Cd)	mg/kg dw	0.6	3.5	0.6	10	2.39		0.536	1.44	0.454	2.16	1.09	0.094	0.102	0.105	0.094	0.089	<0.050	0.076	0.096	**2.99**	0.528	<0.050
Calcium (Ca)	mg/kg dw							12100	19300	5090	34700	13000	4640	5350	4440	4770	7330	1810	1680	2870	23200	7560	2470
Chromium (Cr)	mg/kg dw	37.3	90	26	110	133		45.9	47.3	38.8	43.8	57.1	23.9	25.3	27.9	28.9	29.6	15.8	16.1	30.7	47.9	35.4	20.0
Cobalt (Co)	mg/kg dw							62.7	40.7	10.6	24.5	60.1	5.90	5.72	9.70	9.64	8.90	4.23	3.92	7.63	38.3	21.9	5.25
Copper (Cu)	mg/kg dw	35.7	197	16	110	619		**793**	**1170**	60.4	**1090**	457	13.2	12.3	417	15.8	17.9	7.67	9.27	18.4	260	**1810**	9.84
Iron (Fe)	mg/kg dw			20000	40000			28200	37500	21200	39200	40300	13800	12500	15500	18300	18400	8910	9170	17900	50900	21100	11000
Lead (Pb)	mg/kg dw	35	91.3	31	250	335		39.3	233	68.2	264	202	5.67	5.74	10.2	9.12	8.50	4.00	3.79	9.35	**468**	69.5	4.86
Lithium (Li)	mg/kg dw							36.8	26.3	29.4	28.4	36.5	19.4	21.8	21.8	20.2	23.1	11.1	11.5	23.2	24.8	25.0	14.9
Magnesium (Mg)	mg/kg dw							9190	14500	7580	18200	13900	4210	4440	5230	5720	6260	2830	3100	5840	16300	7230	3560
Manganese (Mn)	mg/kg dw			460	1100			448	697	258	794	639	1440	1560	745	296	284	121	108	204	738	345	158
Mercury (Hg)	mg/kg dw	0.17	0.49	0.2	2	0.8		0.0590	0.183	0.0370	0.262	0.116	0.0327	0.0294	0.0365	0.0238	0.0173	0.0055	0.0073	0.0116	0.444	0.0930	0.0068
Molybdenum (Mo)	mg/kg dw							7.86	0.77	1.47	0.73	1.68	0.66	1.06	1.26	0.73	<0.50	<0.50	<0.50	0.53	1.60	1.32	<0.50
Nickel (Ni)	mg/kg dw			16	75	113		**134**	**122**	32.6	87.9	**152**	13.3	14.1	31.1	18.6	20.2	10.0	10.9	21.2	83.3	91.3	12.8
Phosphorus (P)	mg/kg dw			600	2000			708	486	513	390	536	562	590	479	499	401	337	245	448	429	534	426
Potassium (K)	mg/kg dw							3690	2020	2320	1490	3620	880	1330	1630	2150	2740	900	1190	2380	1120	1900	1160
Selenium (Se)	mg/kg dw							2.44	1.09	0.27	0.77	1.50	0.23	0.23	0.65	<0.20	<0.20	<0.20	<0.20	<0.20	0.72	1.80	<0.20
Silver (Ag)	mg/kg dw					3.5		**4.40**	**5.65**	0.55	**3.76**	**3.68**	<0.10	<0.10	1.88	<0.10	<0.10	<0.10	<0.10	<0.10	**6.47**	**6.89**	<0.10
Sodium (Na)	mg/kg dw							980	300	370	200	570	140	170	220	270	340	120	120	240	200	440	160
Strontium (Sr)	mg/kg dw							93.4	36.5	38.9	35.2	60.7	22.0	26.4	29.5	25.9	43.9	11.0	13.7	27.0	35.2	58.0	15.6
Thallium (Tl)	mg/kg dw							0.262	0.230	0.196	0.219	0.295	0.090	0.095	0.129	0.133	0.169	0.072	0.086	0.170	0.306	0.187	0.089
Tin (Sn)	mg/kg dw							<2.0	<2.0	2.5	<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
Titanium (Ti)	mg/kg dw							552	304	587	258	638	303	347	466	441	552	345	328	669	209	453	453
Uranium (U)	mg/kg dw							4.53	0.725	2.38	0.442	1.42	7.63	9.47	4.72	2.33	2.36	2.01	1.75	3.13	0.697	3.23	2.56
Vanadium (V)	mg/kg dw							49.9	51.9	37.4	52.3	60.3	20.7	20.7	27.9	30.2	34.3	17.2	18.2	34.5	54.1	34.5	22.1
Zinc (Zn)	mg/kg dw	123	315	120	820	683		151	422	127	554	331	42.7	41.6	74.0	59.2	42.8	19.4	23.8	42.6	652	351	24.4
Inorganic Parameters																							
Acid Volatile Sulphides (AVS)	µmol/g dw							107	<0.32	25.0	<0.20	8.64	2.37	2.64	<0.39	41.7	14.4	<0.20	<0.25	<0.21	3.48	<0.30	<0.20
Simultaneously Extractable Metals (SEM)																							
Arsenic (As)-Extractable	µmol/g dw							0.737	14.6	0.479	18.7	4.67	0.819	0.501	1.19	0.983	0.087	0.053	<0.030	0.038	11.3	3.77	0.061
Cadmium (Cd)-Extractable	µmol/g dw							<0.010	0.0081	<0.0050	0.0114	<0.010	<0.0050	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0065	<0.0050	<0.0050
Copper (Cu)-Extractable	µmol/g dw							0.246	14.4	0.310	19.0	4.40	0.100	0.114	5.88	0.160	0.132	0.113	0.209	0.192	2.01	16.8	0.122
Lead (Pb)-Extractable	µmol/g dw							0.073	1.15	0.146	1.12	0.852	<0.020	<0.040	0.032	0.039	0.026	<0.020	0.031	0.039	1.29	0.283	<0.020
Mercury (Hg)-Extractable	µmol/g dw							<0.000050	<0.000050	<0.000050	0.000070	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Nickel (Ni)-Extractable	µmol/g dw							1.22	1.73	0.240	0.872	2.31	<0.050	<0.10	0.300	0.092	0.104	<0.050	0.097	0.085	0.599	1.46	0.057
Zinc (Zn)-Extractable	µmol/g dw							1.59	4.97	1.19	5.45	3.90	0.304	0.363	0.784	0.575	0.268	0.0910	0.211	0.167	4.34	5.22	0.0929
Sum of SEM (ΣSEM), excluding SEM-As	µmol/g dw							3.13	22.26	1.89	26.45	11.46	0.40	0.48	7.00	0.87	0.53	0.20	0.55	0.48	8.25	23.76	0.27
AVS - ΣSEM	µmol/g dw							103.87	-22.10	23.11	-26.35	-2.82	1.97	2.16	-6.80	40.83	13.87	-0.10	-0.42	-0.38	-4.77	-23.61	-0.17

Concentration exceeds CCME ISQG
Concentration exceeds CCME PEL
Concentration exceeds OMOEE LEL
Concentration exceeds OMOEE SEL
Concentration exceeds WDOE LAET
Concentration exceeds GNWT remed. Obj.

Antimony had the largest concentration range of the 14 sediment COPCs, varying by more than 8,000 times from the lowest to the highest concentration (Figure 8; top left panel). Sediment concentrations were low at the three Yellowknife River reference stations (0.11 to 0.23 mg/kg), whereas concentrations ranged from 1.04 to 882 mg/kg at stations in Baker Creek. Concentrations were highest at Station BCSS-DEP-08, followed by Station BCSS-DEP-15, and were generally low in Upper Baker Creek and Trapper Creek. Antimony concentrations were above the WDOE LAET of 0.6 mg/kg (Avocet Consulting 2003) at all stations except the Yellowknife River reference area.

Arsenic concentrations ranged from 2.52 mg/kg at Station BCSS-DEP-29 (Yellowknife River reference) to 4,790 mg/kg at Station BCSS-DEP-08 (Figure 8; top right panel). Only the three Yellowknife River reference stations had arsenic concentrations that were below the CCME ISQG, and therefore not expected to be associated with adverse biological effects. Of the Baker Creek and Trapper Creek stations, arsenic concentrations were above the CCME PEL at 25 of 26 stations, and were above the GNWT (2003) remediation objective of 150 mg/kg dw at 22 of 26 stations. The highest arsenic concentration was more than 30 times higher than the GNWT (2003) remediation objective. Arsenic concentrations were highest at Station BCSS-DEP-08, followed by Station BCSS-DEP-15. Reach 4 was expected to have relatively low arsenic concentrations because this reach was realigned to a new location on the west side of the Ingraham Trail (Highway 4) in 2006. Two of the Reach 4 stations had relatively low arsenic concentrations (11.8 and 43.4 mg/kg), but the third station had one of the highest arsenic concentrations (2,370 mg/kg). The maximum arsenic concentration measured in surface sediments in this Baker Creek assessment was similar to the maximum arsenic concentration measured in 2005 (4,790 compared to 4,170 mg/kg measured by Jacques Whitford [2006]).

Beryllium concentrations ranged from 0.23 mg/kg at Station BCSS-DEP-08 to 0.69 mg/kg at Station BCSS-DEP-17, varying by less than a factor of three (Figure 8; bottom left panel). Beryllium concentrations were variable, with no distinctions between stations in Baker Creek, Trapper Creek, or the Yellowknife River reference area. Ten stations had beryllium concentrations that were above the WDOE LAET of 0.46 mg/kg.

Cadmium concentrations ranged from <0.05 mg/kg at Station BCSS-DEP-28 in the Yellowknife River reference area to 8.45 mg/kg at Station BCSS-DEP-15 (Figure 8; bottom right panel). Concentrations were low at stations located in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. There were 11 stations with cadmium concentrations above the CCME ISQG, but Station BCSS-DEP-15 was the only one above the CCME PEL.

Chromium concentrations ranged from 15.8 mg/kg at Station BCSS-DEP-28 to 57.1 mg/kg at Station BCSS-DEP-21 in Baker Creek Pond (Figure 9; top left panel). Concentrations were generally lower in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. Seventeen stations had chromium concentrations above the CCME ISQG (25 stations were above the OMOEE LEL), but none were above the CCME PEL.

Copper concentrations ranged from 7.67 mg/kg at Station BCSS-DEP-28 to 1,975 mg/kg at Station BCSS-DEP-16 (Figure 9; top right panel). Concentrations were generally low at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. Copper concentrations were above the CCME ISQG at 5 stations, and above the CCME PEL at 14 stations.

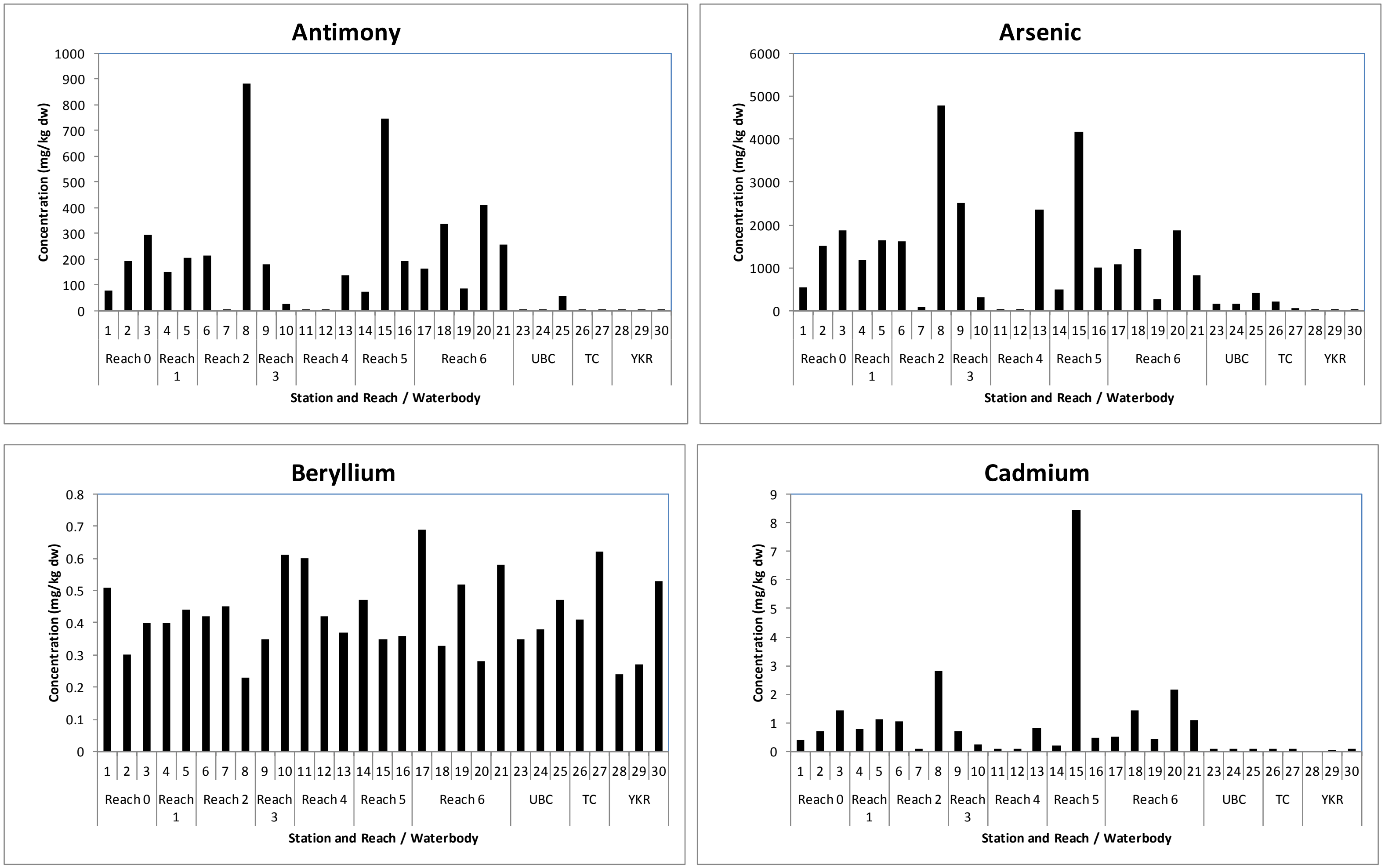


Figure 8: Spatial Distributions of Antimony, Arsenic, Beryllium, and Cadmium Concentrations in Surface Sediments at Depositional Stations, 2011

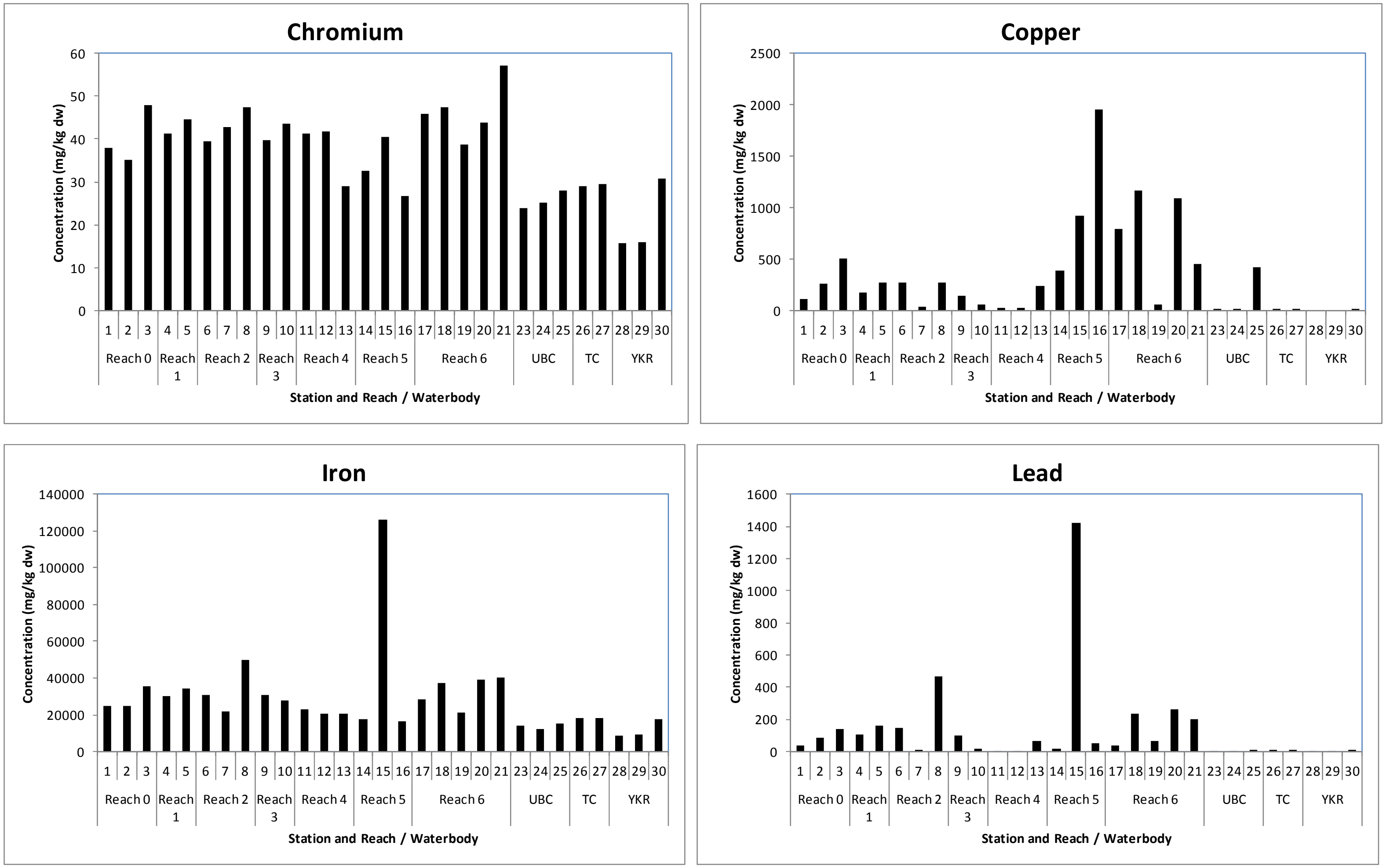


Figure 9: Spatial Distributions of Chromium, Copper, Iron, and Lead Concentrations in Surface Sediments at Depositional Stations, 2011

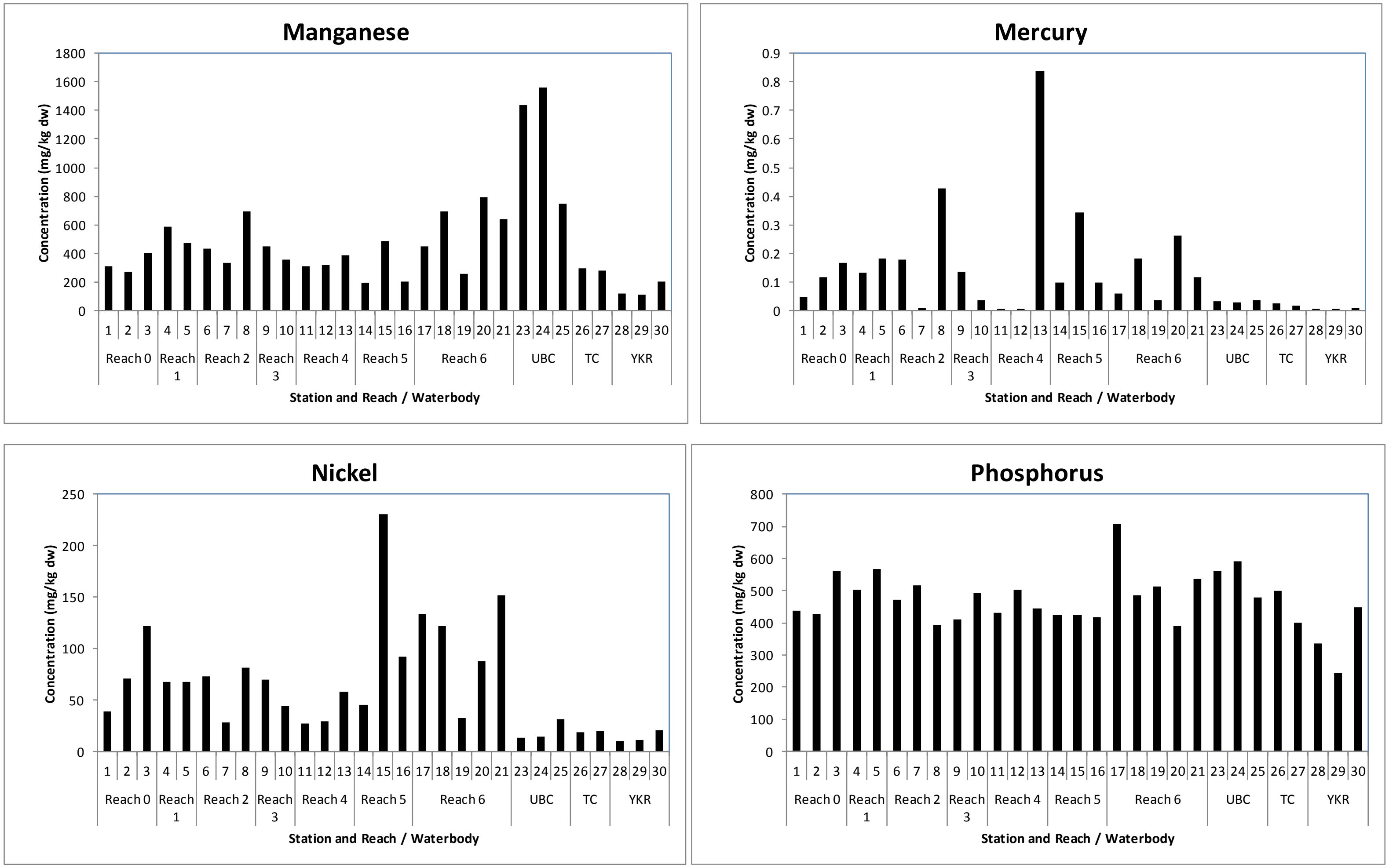
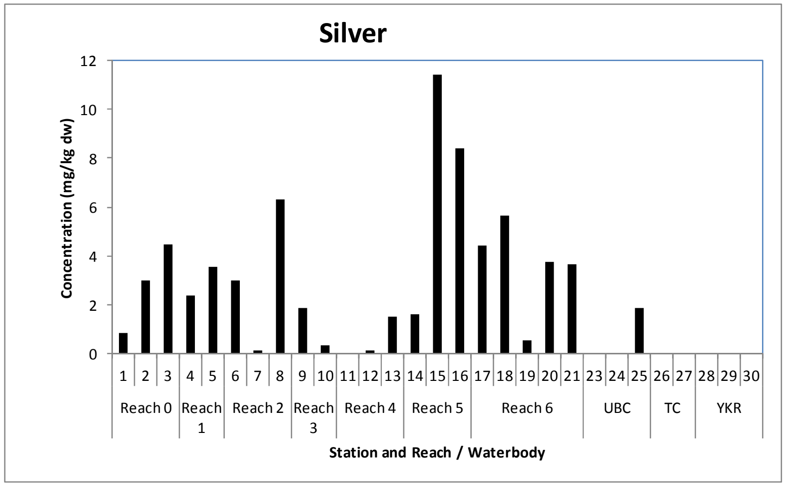


Figure 10: Spatial Distributions of Manganese, Mercury, Nickel, and Phosphorus Concentrations in Surface Sediments at Depositional Stations, 2011



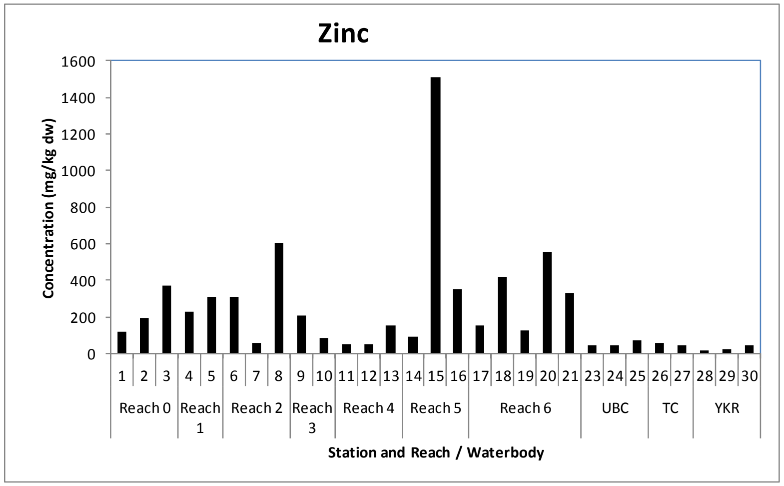


Figure 11: Spatial Distributions of Silver and Zinc Concentrations in Surface Sediments at Depositional Stations, 2011

Iron concentrations ranged from 8,901 mg/kg at Station BCSS-DEP-28 in the Yellowknife River reference area to 126,000 mg/kg at Station BCSS-DEP-15 (Figure 9; bottom left panel). Concentrations were also elevated at Station BCSS-DEP-08. Sixteen stations had iron concentrations above the OMOEE LEL, and three had concentrations above the OMOEE SEL.

Lead concentrations ranged from 3.79 mg/kg at Stations BCSS-DEP-29 in the Yellowknife River Reference area to 1,420 mg/kg at Station BCSS-DEP-15 (Figure 9; bottom left corner). Concentrations were also elevated at Station BCSS-DEP-08, and lower at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. Lead concentrations were above the CCME PEL at 10 stations in Baker Creek, and above the OMOEE SEL at three stations in Baker Creek.

Manganese concentrations ranged from 108 mg/kg at Station BCSS-DEP-29 to 1,560 mg/kg at Station BCSS-DEP-24 in Upper Baker Creek (Figure 10; top left panel). The highest manganese concentrations occurred at two stations in Upper Baker Creek. Concentrations at 10 stations were above the OMOEE LEL, and 2 were above the OMOEE SEL for manganese.

Mercury concentrations ranged from 0.0055 mg/kg at Station BCSS-DEP-28 to 0.836 mg/kg at Station BCSS-DEP-13, located in Reach 4 (Figure 10; top right panel). The sample from Station BCSS-DEP-13 required dilution and adjustment of its DL prior to analysis for mercury due to its high concentration. Mercury concentrations were also elevated at Station BCSS-DEP-08, and lower at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area.

Nickel concentrations ranged from 10 mg/kg at Station BCSS-DEP-28 to 231 mg/kg at Station BCSS-DEP-15 (Figure 10; bottom left panel). Concentrations were highest at Station BCSS-DEP-15 and also elevated at Station BCSS-DEP-21 in Baker Creek Pond. Nickel concentrations were generally low at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. There were 25 stations with nickel concentrations above the OMOEE LEL, of which 8 stations had concentrations above the OMOEE SEL.

Phosphorus concentrations were approximately 245 mg/kg at Station BCSS-BCSS-DEP-17 (Figure 10; bottom right panel). Concentrations were variable among all sampling stations, with no one area having higher or lower concentrations.

Silver concentrations were <0.10 mg/kg in sediments from all but one of the stations from Upper Baker Creek, Trapper Creek, the Yellowknife River reference area, and one station from Reach 4 (Station BCSS-DEP-11). The highest silver concentration was 11.4 mg/kg at Station BCSS-DEP-15 (Figure 11; top left panel). Elevated silver concentrations also occurred at Stations BCSS-DEP-16 and BCSS-DEP-8. There were nine stations with silver concentrations above the WDOE LAET (Avocet 2003) of 3.5 mg/kg.

Zinc concentrations ranged from 19.4 mg/kg at Station BCSS-DEP-28 to 1,510 mg/kg at Station BCSS-DEP-15, and were also elevated at Station BCSS-DEP-08 (Figure 11; top right panel). Zinc concentrations were generally low at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area. Eight stations had zinc concentrations above the CCME ISQG, and seven stations had zinc concentrations above the CCME PEL.

Review of the surface sediment chemistry data identified four distinct spatial distributions for COPCs:

- Concentrations of antimony, arsenic, cadmium, iron, lead, nickel, silver, and zinc were highest at either Station BCSS-DEP-08 or BCSS-DEP-15. Concentrations were generally low at stations in Upper Baker Creek, Trapper Creek, and the Yellowknife River reference area.
- Concentrations of beryllium, chromium, and phosphorus did not have large concentration ranges, and there was little difference between the Baker Creek and Yellowknife River reference area stations.
- Mercury was the only COPC to have its highest concentration occur at Station BCSS-DEP-13.
- Manganese was the only COPC to have its highest concentrations occur in Upper Baker Creek, indicating that this may be a continuing source of manganese to the downstream reaches of Baker Creek.

4.4.3.2 Subsurface Sediments

Results of chemistry analyses performed on the subsurface sediment samples are summarized in Table 8. Copies of the ALS laboratory reports are provided in Appendix E. The study design called for collection of 5-cm core sections from the top, middle, and bottom of each core sample. However, if the core penetration depth was <30 cm, then only the top and bottom sections were sampled, and if there were distinct visible depth horizons in the sediment, then more than three core sections may have been sampled at the discretion of the field crew. In general, the results from the subsurface sediment samples were consistent with those reported for surface sediments, with elevated concentrations of COPCs present at depth. The highest arsenic concentration measured in this Baker Creek assessment was 21,300 mg/kg at Station BCSS-DEP-09 (15 to 20 cm), which was almost three times higher than the maximum subsurface arsenic concentration (7,660 mg/kg at 30 to 35 cm in Reach 5) measured in 2005 in Baker Creek sediments (Jacques Whitford 2006).

4.4.3.3 Metals Bioavailability (AVS and SEM Data)

Acid volatile sulphides (AVS) were analysed in surface sediment samples as a surrogate for metal bioavailability (DiToro et al. 1990; Ankley et al. 1991; Chapman 1996; Casas and Crecelius 1994). AVS concentrations were undetected (<0.20 to <0.63 µmol/g at nine stations in Baker and Trapper Creeks, and at all three stations in the Yellowknife River reference area (Table 7). The highest AVS concentration was 107 µmol/g, at Station BCSS-DEP-17 in Baker Creek Pond.

Concentrations of six individual SEMs (cadmium, copper, lead, mercury, nickel and zinc) are reported in Table 7. Arsenic is not routinely included in the SEM measurement (due to an incomplete understanding of how different extraction techniques influence SEM arsenic concentrations) and the AVS-SEM model has not been verified for arsenic to the same extent as for the divalent metals typically included in the SEM measurement. However, arsenic can form metal or metalloid sulphides less soluble than iron and manganese monosulfides, and it is probable that sulphide plays an important role in modifying the bioavailability of arsenic in anoxic sulfidic sediments (Wang and Chapman 1999; Wilkin and Ford 2002).

Detected concentrations of individual SEMs were summed to provide a “sum of SEM (ΣSEM)” concentration for each surface sediment station. These ΣSEM concentrations ranged from 0.20 µmol/g to 29.0 µmol/g.

Table 8: Summary of Subsurface Sediment Chemistry Data for 2011 Baker Creek Assessment

Reach / Water Body	Units	Sediment Quality Guidelines (SQGs)					GNWT (2003) Remediation Objective	Reach 0					Reach 1				Reach 2					
Station								BCSS-DEP01		BCSS-DEP02		BCSS-DEP03	BCSS-DEP04		BCSS-DEP05		BCSS-DEP06		BCSS-DEP07	BCSS-DEP08		
Core Interval Sampled								5 to 10 cm	10 to 15 cm	10 to 15 cm	25 to 26 cm	10 to 15 cm	5 to 10 cm	15 to 20 cm	10 to 15 cm	20 to 25 cm	10 to 15 cm	20 to 25 cm	5 to 10 cm	5 to 10 cm	10 to 15 cm	15 to 20 cm
Date Sampled		CCME	CCME	OMOEE	OMOEE	WDOE		05-OCT-11	05-OCT-11	05-OCT-11	05-OCT-11	05-OCT-11	23-SEP-11	23-SEP-11	23-SEP-11	23-SEP-11	23-SEP-11	23-SEP-11	26-SEP-11	26-SEP-11	26-SEP-11	26-SEP-11
ALS Sample ID		ISQG	PEL	LEL	SEL	LAET		L1073578-1	L1073578-2	L1073578-3	L1073578-4	L1073578-5	L1073578-6	L1073578-7	L1073578-8	L1073578-9	L1073578-10	L1073578-11	L1073578-12	L1073578-13	L1073578-14	L1073578-15
Physical																						
Moisture	%							22.8	23.8	29.4	40.7	42.1	47.9	29.8	48.3	47.1	50.0	32.6	25.0	36.6	31.4	26.7
pH (1:2 soil:water)	pH							7.23	7.18	7.76	7.95	7.41	7.30	7.20	7.24	7.44	7.07	7.45	7.56	7.66	7.88	7.88
Gravel (>2mm)	% dw							4.98	3.42	<0.10	<0.10	<0.10	1.05	14.4	0.44	0.91	0.54	0.65	0.88	<0.10	<0.10	<0.10
Sand (2.0mm - 0.063mm)	% dw							45.9	39.8	11.6	3.19	12.4	6.55	19.4	14.2	15.5	8.55	8.94	3.22	0.72	1.60	1.44
Silt (0.063mm - 4um)	% dw							21.9	21.7	66.3	87.0	70.9	72.6	36.8	67.3	63.0	66.2	68.5	36.1	86.1	84.4	76.5
Clay (<4um)	% dw							27.2	35.1	22.1	9.82	16.7	19.8	29.5	18.1	20.5	24.7	21.9	59.8	13.2	14.0	22.0
Fines (silt + clay)	% dw							49.1	56.8	88.4	96.8	87.6	92.4	66.3	85.4	83.5	90.9	90.4	95.9	99.3	98.4	98.5
Total Organic Carbon	% dw			1	10	9.82		0.46	0.55	1.31	0.86	3.44	1.63	1.25	3.03	2.45	3.78	2.27	0.10	0.42	0.33	0.67
Total Metals																						
Aluminum (Al)	mg/kg dw							15200	16600	17600	18000	16300	16600	20700	16800	18900	15000	16300	23100	13100	13400	14600
Antimony (Sb)	mg/kg dw					0.6		**12.6**	**12.4**	**222**	**2470**	**249**	**196**	**178**	**198**	**351**	**300**	**469**	**8.69**	**2670**	**2050**	**1320**
Arsenic (As)	mg/kg dw	5.9	17	6	33	31.4	150	**111**	**134**	**2360**	**14300**	**1760**	**1590**	**657**	**1710**	**3750**	**1220**	**2840**	**86.8**	**13700**	**8970**	**6860**
Barium (Ba)	mg/kg dw							107	134	83.2	69.5	73.4	93.4	123	91.5	59.4	82.6	68.5	241	33.1	32.1	70.2
Beryllium (Be)	mg/kg dw					0.46		**0.62**	**0.68**	0.45	0.25	**0.47**	**0.49**	**0.67**	**0.53**	0.39	**0.53**	0.41	**0.92**	<0.20	<0.20	0.30
Bismuth (Bi)	mg/kg dw							0.21	0.23	0.30	0.69	0.43	0.30	0.29	0.55	0.33	0.27	0.30	0.38	0.61	0.89	1.18
Cadmium (Cd)	mg/kg dw	0.6	3.5	0.6	10	2.39		0.187	0.247	0.958	**8.57**	1.35	1.01	0.498	1.11	1.65	1.04	1.71	0.099	**10.3**	**8.14**	**7.58**
Calcium (Ca)	mg/kg dw							3450	3990	10200	23900	14200	7070	7560	9020	15800	7030	19100	5610	24400	28400	22000
Chromium (Cr)	mg/kg dw	37.3	90	26	110	133		35.1	39.0	49.2	56.3	46.1	45.8	51.7	45.6	52.7	39.7	43.5	57.6	44.1	46.4	50.7
Cobalt (Co)	mg/kg dw							10.6	11.4	33.1	28.0	45.1	38.4	42.0	41.9	64.4	45.5	27.1	13.9	25.2	36.8	38.9
Copper (Cu)	mg/kg dw	35.7	197	16	110	619		62.3	68.3	382	449	456	182	162	381	**1770**	297	**1030**	35.8	203	261	279
Iron (Fe)	mg/kg dw			20000	40000			25000	26800	32700	70000	31500	33700	31700	33800	44400	25200	35100	30800	63900	62100	59600
Lead (Pb)	mg/kg dw	35	91.3	31	250	335		12.5	13.6	117	**546**	126	141	60.4	147	260	84.0	234	10.4	**692**	**903**	**956**
Lithium (Li)	mg/kg dw							27.3	28.7	29.7	24.4	26.7	28.8	36.1	28.5	29.6	27.7	27.1	44.6	20.3	21.1	23.7
Magnesium (Mg)	mg/kg dw							7920	8440	12500	17000	11000	10700	12400	11200	16600	8800	13400	11700	15300	16600	15500
Manganese (Mn)	mg/kg dw			460	1100			277	341	379	674	365	690	597	513	647	409	517	385	666	709	629
Mercury (Hg)	mg/kg dw	0.17	0.49	0.2	2	0.8		0.0169	0.0182	0.147	0.599	0.170	0.165	0.0755	0.173	0.251	0.107	0.251	0.0117	0.774	**0.957**	**1.06**
Molybdenum (Mo)	mg/kg dw							0.75	0.86	1.48	2.42	2.67	1.03	1.40	1.22	1.34	3.63	2.03	0.63	2.79	2.24	2.33
Nickel (Ni)	mg/kg dw			16	75	113		29.0	31.8	80.1	76.4	100	66.1	99.4	82.0	**140**	88.9	94.1	38.2	54.5	87.9	93.0
Phosphorus (P)	mg/kg dw			600	2000			428	466	495	504	549	543	499	573	477	497	466	552	437	392	507
Potassium (K)	mg/kg dw							2590	3100	2390	1660	2250	2560	3360	2640	1850	2260	1730	5800	1390	1270	1930
Selenium (Se)	mg/kg dw							0.34	0.42	1.36	1.11	2.32	0.64	1.94	1.03	2.44	1.61	1.53	<0.20	0.89	0.76	0.74
Silver (Ag)	mg/kg dw					3.5		0.23	0.25	**5.12**	**7.13**	**4.60**	2.91	1.69	**4.00**	**10.5**	2.19	**5.63**	0.18	**8.53**	**9.22**	**10.3**
Sodium (Na)	mg/kg dw							260	300	270	210	310	370	400	330	220	300	220	700	200	200	270
Strontium (Sr)	mg/kg dw							32.7	37.5	29.1	68.4	48.8	30.9	44.3	38.5	31.5	36.5	33.9	48.0	30.9	23.0	24.2
Thallium (Tl)	mg/kg dw							0.173	0.206	0.174	0.288	0.198	0.184	0.230	0.190	0.159	0.186	0.175	0.297	0.430	0.481	0.540
Tin (Sn)	mg/kg dw							<2.0	<2.0	<2.0	<2.0	2.8	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	mg/kg dw							527	592	520	320	526	572	785	585	397	502	404	1070	95.3	162	335
Uranium (U)	mg/kg dw							2.07	2.33	1.45	0.528	1.85	1.85	2.11	2.06	1.10	3.31	2.02	1.70	0.369	0.300	0.934
Vanadium (V)	mg/kg dw							45.5	48.2	57.5	65.7	55.0	51.1	62.9	52.4	62.7	42.2	50.1	59.7	46.1	49.3	52.4
Zinc (Zn)	mg/kg dw	123	315	120	820	683		66.2	71.3	280	**2570**	363	286	160	313	606	250	518	72.3	**2890**	**1460**	**1320**

CCME = Canadian Council of Ministers of the Environment (1999); OMOEE = Ontario Ministry of Environment and Energy (1993); WDOE = Washington State Department of Ecology (Avocet Consulting 2003); ISQG = Interim Sediment Quality Guideline; LAET = Lowest Apparent Effect Threshold; LEL = Lowest Effect Level; PEL = Probable Effect Level; SEL = Severe Effect Level

Concentration exceeds CCME ISQG
Concentration exceeds CCME PEL
Concentration exceeds OMOEE LEL
Concentration exceeds OMOEE SEL
Concentration exceeds WDOE LAET
Concentration exceeds GNWT (2003) Remediation Objective

Reach 3					Reach 4						Reach 5						
BCSS-DEP09			BCSS-DEP10		BCSS-DEP11		BCSS-DEP12	BCSS-DEP13			BCSS-DEP14		BCSS-DEP15			BCSS-DEP16	
5 to 10 cm	10 to 15 cm	15 to 20 cm	5 to 10 cm	15 to 20 cm	5 to 10 cm	15 to 20 cm	10 to 15 cm	10 to 15 cm	15 to 20 cm	25 to 30 cm	5 to 10 cm	10 to 15 cm	5 to 10 cm	10 to 15 cm	40 to 45 cm	10 to 15 cm	20 to 25 cm
27-SEP-11	27-SEP-11	27-SEP-11	26-SEP-11	26-SEP-11	27-SEP-11	27-SEP-11	27-SEP-11	27-SEP-11	27-SEP-11	27-SEP-11	28-SEP-11	28-SEP-11	28-SEP-11	28-SEP-11	28-SEP-11	27-SEP-11	27-SEP-11
L1073578-16	L1073578-17	L1073578-18	L1073578-19	L1073578-20	L1073578-21	L1073578-22	L1073578-23	L1073578-24	L1073578-25	L1073578-26	L1073578-27	L1073578-28	L1073578-29	L1073578-30	L1073578-31	L1073578-32	L1073578-33
35.9	31.6	38.4	35.6	26.3	29.1	25.1	21.1	63.3	57.4	58.3	80.3	62.2	25.3	30.9	29.5	40.8	25.9
7.96	7.99	7.76	7.00	6.96	7.78	7.99	8.00	6.23	5.48	5.57	6.18	6.15	8.11	8.13	8.29	7.33	7.34
<0.10	<0.10	<0.10	15.0	6.13	1.49	5.38	0.81	3.55	5.60	3.76	<0.10	<0.10	<0.10	<0.10	<0.10	0.42	0.17
1.29	4.43	7.50	12.9	10.9	9.08	10.7	7.54	10.6	12.8	8.16	6.23	2.27	4.85	5.32	8.94	12.3	5.39
84.9	86.9	83.6	42.0	42.1	40.7	33.2	41.4	71.5	74.3	81.4	72.4	67.9	90.0	90.2	88.4	53.9	44.7
13.8	8.71	8.89	30.1	40.9	48.7	50.7	50.2	14.4	7.32	6.64	21.4	29.9	5.17	4.47	2.65	33.4	49.8
98.7	95.6	92.5	72.1	83.0	89.4	83.9	91.6	85.9	81.6	88.0	93.8	97.8	95.2	94.7	91.1	87.3	94.5
0.40	0.32	0.65	1.40	1.03	<0.10	<0.10	<0.10	11.8	10.2	13.1	15.7	13.9	<0.10	0.21	<0.10	3.80	0.52
15400	10900	14300	21100	19700	20600	21700	20100	12000	11800	11600	11300	18300	7700	7470	6940	16100	17900
1840	2120	3140	26.5	19.8	2.87	0.96	0.76	280	201	149	214	93.3	1990	1980	2030	89.0	12.1
7700	8920	21300	406	234	23.6	11.2	18.4	1900	1360	604	1370	1010	6970	6530	6860	610	105
32.3	28.8	54.2	161	198	209	216	200	89.8	96.7	91.7	94.7	216	26.9	23.2	18.2	123	178
<0.20	<0.20	0.21	0.67	0.69	0.76	0.83	0.77	0.40	0.51	0.45	0.43	0.81	<0.20	<0.20	<0.20	0.63	0.73
1.04	0.66	0.78	0.28	0.28	0.33	0.38	0.35	<0.20	<0.20	<0.20	0.22	0.27	2.89	2.85	3.58	0.25	0.25
6.95	5.62	10.4	0.261	0.181	0.123	0.146	0.107	0.323	0.315	0.515	0.422	0.489	23.3	22.2	24.0	0.351	0.113
38500	37800	32200	8180	6250	5940	8430	6040	12000	9260	8940	12100	14000	13700	13200	12300	5830	4210
59.4	36.9	49.8	49.8	47.9	53.2	59.6	54.7	28.9	27.5	28.7	31.6	41.2	54.3	51.7	59.2	38.4	41.7
55.4	34.0	29.0	22.7	22.3	12.8	13.9	12.8	21.2	19.2	15.8	21.1	15.2	250	244	281	19.4	10.8
234	182	152	94.1	49.0	29.5	31.9	29.4	856	408	225	3490	635	613	607	659	882	96.5
76500	56900	70700	32200	29500	28400	30400	28600	22600	17400	15300	17100	22500	296000	285000	332000	22800	22600
880	594	639	20.6	15.2	9.73	9.42	8.83	32.2	9.98	6.23	37.1	19.5	3440	3350	4050	42.1	11.3
23.4	18.6	23.8	33.2	30.7	38.7	43.9	39.6	19.2	19.5	19.4	17.7	26.8	8.6	7.8	5.2	28.6	32.9
19300	16200	16700	13000	10500	11300	12800	11200	5180	4630	4630	6250	7580	8930	8400	7720	7330	7470
890	795	777	450	345	396	447	410	330	188	112	181	214	508	461	465	443	310
0.645	0.729	0.782	0.0393	0.0251	0.0094	0.0104	0.0092	0.0838	0.0351	0.0221	0.530	0.259	0.832	0.906	0.865	0.0630	0.0134
2.89	1.54	2.78	1.17	1.55	0.76	0.69	0.71	3.27	3.48	2.38	6.12	2.80	4.44	4.38	5.02	1.00	0.66
125	77.9	66.6	48.3	42.8	34.1	36.7	34.5	43.5	30.0	40.4	131	63.1	504	482	589	65.3	30.5
368	367	500	513	492	554	562	559	675	676	677	490	613	250	219	191	529	482
1170	980	1620	3470	3610	5070	5540	4860	1550	1380	1360	1940	3120	1820	1810	1600	2990	3030
1.02	0.62	0.94	0.76	1.00	<0.20	<0.20	<0.20	1.80	1.17	0.94	3.54	1.73	1.01	1.08	1.08	1.04	0.34
8.94	7.09	10.5	0.45	0.27	0.12	0.11	0.12	1.72	1.03	1.03	9.41	1.74	22.1	21.1	27.9	3.94	0.34
170	140	180	400	400	670	700	620	370	280	300	700	630	290	280	250	420	410
33.4	29.4	72.5	38.8	37.1	46.8	40.9	37.5	73.3	60.0	53.4	81.0	89.2	18.7	15.9	10.4	49.1	41.5
0.323	0.214	0.327	0.223	0.242	0.260	0.272	0.251	0.119	0.120	0.116	0.168	0.215	0.565	0.570	0.614	0.198	0.226
<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	<2.0	<2.0
151	132	146	760	787	884	985	909	362	337	344	379	542	705	683	671	600	691
0.323	0.361	0.506	2.20	2.61	2.67	2.31	2.34	4.93	5.98	5.75	2.83	4.21	0.376	0.271	0.085	2.82	1.80
59.5	40.9	52.3	64.2	58.9	56.6	63.3	57.1	30.0	26.8	26.2	32.8	45.4	40.1	37.5	38.3	40.7	44.4
1350	1270	2710	94.8	75.2	66.7	69.2	63.5	86.7	59.5	78.5	173	111	3830	3550	3640	260	78.1

Reach 6									Upper Baker Creek			Trapper Creek					YK River Reference				
BCSS-DEP17		BCSS-DEP18		BCSS-DEP19			BCSS-DEP21		BCSS-DEP24			BCSS-DEP26		BCSS-DEP27			BCSS-DEP28	BCSS-DEP29		BCSS-DEP30	
5 to 10 cm	10 to 15 cm	5 to 10 cm	10 to 15 cm	10 to 15 cm	15 to 20 cm	25 to 30 cm	5 to 10 cm	15 to 20 cm	5 to 10 cm	10 to 15 cm	44 to 49 cm	5 to 10 cm	10 to 15 cm	5 to 10 cm	10 to 15 cm	20 to 25 cm	5 to 10 cm	5 to 10 cm	10 to 15 cm	5 to 10 cm	10 to 15 cm
21-SEP-11	21-SEP-11	21-SEP-11	21-SEP-11	22-SEP-11	22-SEP-11	22-SEP-11	22-SEP-11	22-SEP-11	28-SEP-11	28-SEP-11	28-SEP-11	29-SEP-11	29-SEP-11	29-SEP-11	29-SEP-11	29-SEP-11	04-OCT-11	04-OCT-11	04-OCT-11	04-OCT-11	04-OCT-11
L1073578-34	L1073578-35	L1073578-36	L1073578-37	L1073578-38	L1073578-39	L1073578-40	L1073578-41	L1073578-42	L1073578-43	L1073578-44	L1073578-45	L1073578-46	L1073578-47	L1073578-48	L1073578-49	L1073578-50	L1073578-51	L1073578-52	L1073578-53	L1073578-54	L1073578-55
66.0	60.2	38.4	28.4	55.4	47.8	43.5	47.8	36.3	56.0	58.1	43.5	25.1	25.5	37.0	27.2	25.4	25.6	32.3	29.5	22.3	19.5
6.44	6.96	7.99	8.31	7.41	7.02	7.53	7.77	7.99	6.77	6.70	6.20	7.19	7.65	7.07	7.33	7.59	5.60	5.34	5.10	5.70	5.57
<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.69	<0.10	<0.10	2.02	0.22	2.39	0.22	0.32	<0.10	<0.10	0.14	<0.10	<0.10
2.33	1.81	0.89	0.49	2.97	2.19	1.26	0.94	2.98	45.2	40.4	36.7	8.76	7.58	12.7	7.22	5.60	28.2	2.60	2.36	6.70	14.4
75.8	71.8	59.6	79.7	74.5	72.1	62.8	42.8	88.9	51.6	56.7	59.6	35.6	31.6	38.5	34.1	30.7	61.3	59.6	51.3	53.0	58.6
21.9	26.4	39.5	19.8	22.5	25.7	35.9	56.3	8.16	2.52	2.87	3.73	53.6	60.7	46.4	58.4	63.4	10.5	37.8	46.2	40.3	27.0
97.7	98.2	99.1	99.5	97.0	97.8	98.7	99.1	97.1	54.1	59.6	63.3	89.2	92.3	84.9	92.5	94.1	71.8	97.4	97.5	93.3	85.6
11.1	**10.1**	0.76	0.23	3.74	2.51	1.97	0.77	0.48	4.50	5.28	5.21	0.65	0.39	0.37	2.74	0.18	0.63	0.99	0.77	0.17	0.13
14500	14600	19200	17700	15200	16400	17600	22000	7640	8540	8920	10100	18700	21500	19600	21700	23700	6830	16600	19100	16500	13400
281	**172**	**304**	**547**	**118**	**119**	**142**	**207**	**1540**	**3.65**	**4.51**	**1.73**	**3.22**	**0.79**	**3.45**	**1.78**	**0.65**	**0.99**	**0.81**	**1.02**	0.39	0.45
2090	**1840**	**1670**	**2190**	**953**	**854**	**808**	**559**	**5070**	**105**	**121**	**66.1**	**77.6**	29.0	**65.3**	**38.7**	15.7	10.1	8.28	9.84	6.58	6.69
81.8	101	76.0	16.0	94.8	99.7	108	152	24.0	59.2	62.1	63.5	209	241	204	223	248	51.6	160	196	165	124
0.48	**0.53**	**0.49**	<0.20	**0.57**	**0.58**	**0.59**	**0.78**	<0.20	0.29	0.31	0.36	**0.78**	**0.95**	**0.82**	**0.92**	**1.03**	0.32	**0.69**	**0.85**	**0.86**	**0.61**
0.23	0.22	0.33	0.29	0.28	0.29	0.29	0.36	3.62	<0.20	<0.20	<0.20	0.28	0.31	0.29	0.29	0.32	<0.20	0.28	0.30	0.31	0.23
0.543	0.556	1.39	3.12	0.643	0.677	0.440	0.463	**22.7**	0.073	0.079	0.065	0.113	0.135	0.110	0.109	0.125	0.056	0.194	0.205	0.199	0.156
9640	9070	21400	43700	6270	5600	6270	10900	16500	3880	4170	4030	4870	5410	7140	5650	5860	1920	3390	3570	3480	3080
38.6	38.9	52.9	49.6	42.0	44.1	48.4	57.6	55.8	22.8	23.2	27.3	43.4	45.5	44.4	45.6	47.4	19.9	41.2	44.9	40.5	32.4
70.2	25.3	36.9	23.1	43.7	40.0	29.7	34.0	232	4.89	4.83	4.83	12.5	12.7	12.0	12.0	12.6	5.50	9.66	11.2	10.3	8.29
3290	**2270**	**2360**	355	**1120**	**817**	**811**	405	**1120**	9.63	10.2	11.0	24.4	25.4	24.9	24.7	25.3	10.2	22.4	25.2	21.9	17.2
21400	18700	38100	47700	24200	25300	26900	33200	262000	10300	10400	11300	26400	28600	25800	27400	30800	10300	21900	24400	22600	17400
40.9	18.4	201	**416**	65.3	76.2	54.6	65.6	**2980**	4.44	4.57	4.46	10.8	11.0	11.2	11.0	11.4	5.06	8.96	9.69	10.9	7.91
25.0	25.5	32.5	25.0	29.0	31.1	34.5	41.7	9.1	18.1	19.1	20.1	31.9	36.2	33.7	36.4	39.4	13.4	29.6	34.5	28.4	23.2
7010	6600	15000	21200	7420	8350	9340	12000	9870	3850	3930	4340	9180	9860	9510	9850	10600	3360	7630	8670	7460	5810
289	249	668	975	364	341	343	467	552	486	465	274	310	394	290	307	380	137	249	295	247	205
0.214	0.101	0.134	0.347	0.0802	0.0680	0.0623	0.0555	0.539	0.0229	0.0236	0.0118	0.0170	0.0149	0.0201	0.0174	0.0159	0.0071	0.0140	0.0138	0.0136	0.0122
6.81	3.83	0.75	0.89	2.33	2.19	1.40	0.86	6.31	0.81	0.84	0.55	0.72	0.57	0.53	<0.50	<0.50	<0.50	0.70	0.83	0.97	0.59
252	**143**	**159**	67.4	**130**	**120**	**134**	**130**	**523**	12.5	12.7	14.0	29.1	31.1	30.2	30.4	31.7	12.2	27.3	31.3	27.9	21.6
533	651	489	384	590	592	593	565	270	480	507	524	599	603	527	553	603	411	495	519	572	499
2070	1790	2890	1030	2530	2830	3420	5180	1710	890	880	1010	4290	4860	4240	4890	5390	1060	3090	3820	3390	2670
5.17	3.11	1.79	1.16	2.27	2.45	1.93	1.91	2.17	<0.20	0.20	0.24	<0.20	<0.20	0.22	<0.20	<0.20	<0.20	0.36	0.45	0.25	0.23
21.8	**13.5**	**9.10**	**4.01**	**7.49**	**5.41**	**5.98**	**6.65**	**23.8**	<0.10	<0.10	<0.10	0.12	0.13	0.12	0.12	0.13	<0.10	<0.10	0.12	0.14	0.11
480	460	350	150	420	420	460	660	310	130	130	150	530	600	480	550	650	150	340	400	310	270
78.3	67.1	41.1	33.1	45.1	39.2	36.7	56.2	18.9	18.0	18.8	20.1	46.9	58.9	53.3	56.0	69.2	11.6	33.0	38.4	42.4	32.8
0.194	0.166	0.221	0.190	0.206	0.226	0.238	0.296	0.558	0.076	0.082	0.089	0.247	0.278	0.242	0.263	0.285	0.088	0.249	0.288	0.242	0.185
<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	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
437	500	459	105	566	599	683	895	383	285	260	338	862	959	856	977	1020	362	759	849	845	695
5.02	5.95	0.927	0.126	2.87	2.19	1.98	1.72	0.246	7.33	8.46	9.27	2.42	2.25	2.94	2.32	2.16	2.46	3.00	2.51	4.35	3.50
37.8	36.0	57.9	62.6	41.2	42.6	46.6	59.5	36.8	18.3	18.9	22.1	49.8	55.0	49.0	53.4	56.2	21.0	45.2	50.5	45.1	36.7
201	125	543	645	215	240	180	169	**3920**	33.7	34.7	34.0	69.5	69.5	63.0	65.5	71.3	24.0	59.0	65.1	56.4	44.2

AVS and ΣSEM data can be expressed as either ratios (AVS:ΣSEM) or molar differences (AVS–ΣSEM). In this report, the results are provided in molar differences because these provide a better indication of the magnitude of excess AVS (and thus its limitations on metal bioavailability) than the ratio approach. Stations BCSS-DEP-07, BCSS-DEP-08, BCSS-DEP-09, BCSS-DEP-11, BCSS-DEP-13, BCSS-DEP-15, BCSS-DEP-16, BCSS-DEP-17, BCSS-DEP-18, BCSS-DEP-20, BCSS-DEP-21, BCSS-DEP-25, BCSS-DEP-29, and BCSS-DEP-30 had negative AVS–ΣSEM values, ranging from -0.30 to -28.4 µmol/g, which were likely related to undetected or low AVS concentrations at these stations. Among the other 15 stations, AVS–ΣSEM ranged from 0 to 88 µmol/g. The excess of AVS at these 15 stations indicated that metals were not likely to be bioavailable. At the stations with negative AVS–ΣSEM values, metals may or may not be bioavailable.

4.5 Benthic Invertebrate and Periphyton Tissue Chemistry Line of Evidence

4.5.1 Methods

4.5.1.1 Chemistry Analyses

Total metals concentrations in benthic invertebrate and periphyton tissue samples were analysed by high resolution inductively coupled plasma mass spectrometry (ICP-MS), except that mercury concentrations were analysed by cold vapour atomic fluorescence spectrophotometry (CVAFS). Lipid content was only analysed in samples of sufficient volume. Further details regarding the analytical methods are provided in the ALS laboratory report in Appendix F. Records of sample wet weights (ww) and descriptions of the benthic invertebrates included in each tissue sample are documented in Appendix F, Table F-1.

The benthic invertebrate and periphyton tissue samples underwent the standard acid digestion procedure for metals, and analysis of the digested extracts included silver as well as the other metals. Silver concentrations were detected in the tissue samples within the range where silver may become unstable and precipitate during the analysis, using the standard digestion procedure for metals. Therefore, ALS deemed the silver data to be potentially unreliable, and silver concentrations were not reported. Tissue samples have been placed on extended hold at ALS. Provided there is sufficient tissue available, which remains to be determined, these samples could potentially be re-analysed using an acid digestion procedure specific to silver analysis in tissues (Can Dang, ALS Environmental, pers. comm.). However, presently such potential re-analyses do not appear to be necessary as detailed later in this report.

Three depositional invertebrate tissue samples (BCSS-DEP-10-BI, BCSS-DEP-15-BI, and BCSS-DEP-20-BI) and one erosional invertebrate tissue sample (BCSS-ERO-01-BI) were removed from the invertebrate tissue data sets because the sample volumes submitted to ALS in these samples were <0.01 g wet weight (ww). In discussion with ALS, it was determined that the analysis of tissue samples with such low sample weights (substantially below the minimum sample weight recommended by ALS) did not produce reliable data (Can Dang, ALS Environmental, pers. comm.).

4.5.1.2 Data Analyses

Benthic invertebrate and periphyton tissue chemistry data, reported on a dry weight (dw) basis, were reviewed and tabulated. Due to the necessary addition of a minimal quantity of deionized water to some invertebrate samples during the sorting of invertebrates for tissue analysis, the moisture data were artificially elevated for a number of samples. Therefore, moisture data were removed from the tissue datasets. This did not affect the analysis of total metal concentrations because the samples were dried and then analysed for metals (i.e., concentrations were reported as dw).

The overall study design was a gradient design; however, Lower Baker Creek was also divided into seven reaches (Reaches 0 to 6). Metals concentrations in benthic invertebrate and periphyton tissues within Baker Creek, and between Baker Creek and the Yellowknife River reference area, were compared. The potential for relationships between metals concentrations measured in co-located sediments and depositional invertebrate tissues was investigated in Section 4.9.2, as was the potential for relationships between metals concentrations measured in co-located periphyton and erosional invertebrate tissues.

To provide a spatial summary of metal concentrations, summary statistics (mean, median, minimum, maximum, standard deviation [SD], and standard error [SE]) were calculated on a reach-by-reach basis. Some reaches had fewer than three replicate samples, so data from the following reaches in Lower Baker Creek were pooled to allow "within pooled reach variability" to be calculated (Reaches 0 and 1; Reaches 2 and 3; and, Reaches 4 and 5). Reach 6 (Baker Pond) and data from Upper Baker Creek, the Yellowknife River, and Trapper Creek were not pooled as sufficient replicates were available for the above data analyses.

At stations where field duplicate/split samples were generated, an average of metal concentrations reported for original and field duplicate samples was calculated and used in the summary statistic calculations, as well as for graphical presentation purposes. Where metals concentrations were reported below the detection limit (DL), a value of one-half the DL was used for summary statistics and graphical presentation purposes.

Ten primary aquatic COPCs were identified according to the following rationale:

- Eight of the aquatic COPCs identified in Section 4.1.2 were present in Baker Creek sediments at concentrations exceeding PEL or SEL sediment quality guidelines (Section 4.4) (i.e., arsenic, cadmium, copper, lead, manganese, mercury, nickel and zinc).
- Selenium was identified as a primary COPC due to concerns regarding potential effects related to the bioaccumulation of selenium in the tissues of egg-laying vertebrates, as a result of dietary exposure to selenium. Elevated organo-selenides accumulated by adult female vertebrates can be transferred to the eggs, with possible subsequent toxicity in embryos and juveniles (Chapman et al. 2010). Benthic invertebrates represent an important component in the diets of fish and other egg-laying vertebrates, and thus may represent a source of selenium.
- Antimony was identified as a primary COPC because there were notable differences in sediment antimony concentrations among stations in Baker Creek, and between the Yellowknife River stations and Baker Creek stations (Section 4.4).

These 10 primary COPCs were graphed to evaluate spatial trends within Baker Creek and to compare Baker Creek data to reference conditions in the Yellowknife River. For each station and tissue type, primary COPC concentrations >2 and >10 times the Yellowknife River reference mean value were identified.

4.5.2 Quality Assurance/Quality Control (QA/QC)

Method blanks, laboratory duplicates, field duplicate/split samples, and certified reference material (CRM) were analysed by ALS to assess precision, accuracy, and possible contamination during laboratory analyses. Laboratory QC data were reviewed upon receipt to confirm that the DQOs had been met and the appropriate QA/QC information had been reported. DQOs specified by ALS for the analysis of metals in periphyton and benthic invertebrate tissues were met for the majority of analyses. Additional information is provided in the ALS laboratory report (Appendix F).

- Method Blanks: There were some cases where trace positive results were detected in laboratory method blanks. These were evaluated further by ALS to determine whether the concentrations detected would significantly affect the concentrations measured in the samples. Where the sample concentration was less than five times the method blank concentration, the DL was raised to deal with this contamination detected in the method blank.

- Laboratory Duplicates: There were some cases where the RPDs for laboratory duplicates were greater than the DQOs specified by ALS. Upon further investigation by ALS, this difference was attributed to sample heterogeneity. The highest frequency of deviations from DQOs was for the periphyton samples, which could be heterogeneous in terms of biotic composition and residual abiotic particulate matter attached to the periphyton matrix. Furthermore, homogenization of the sample prior to subsampling and digestion may not have been complete. However, given that all laboratory duplicate measurements were within a factor of two of the original results, the data were considered to be reliable.

- Field Split Samples: RPDs calculated between split depositional invertebrate samples were >25% for a number of metals, including a number of aquatic COPCs, in at least one of the three split samples collected (Appendix F, Table F-2). The RPDs for the three split depositional invertebrate samples ranged from 1 to 147%. The RPDs calculated for the single erosional invertebrate split sample were >25% for a number of metals, but only for two of the aquatic COPCs (RPDs of 29% for arsenic and 37% for iron) (Appendix F, Table F-3); the RPDs ranged from 3 to 55%. A certain degree of variability is potentially expected with this type of biological tissue sampling for the following reasons:

  - The split composite samples may consist of different relative abundances of various invertebrate taxa and/or sizes of individuals present, and different taxa may have different tissue burdens of a given metal and varying amounts of sediment associated with their gut contents;

  - Despite best efforts, some residual particulate matter may remain attached to individual invertebrates following the rinsing of tissue samples; and,

  - During laboratory analyses, homogenization of the sample prior to digestion may not have been complete, such that subsampling before analysis may result in additional variability in the results.

- Field Duplicates: The RPDs calculated for the one set of periphyton field duplicate samples were >25% for a number of metals, but only for one of the aquatic COPCs (RPD of 59% for mercury) (Appendix F, Table F-4). The RPDs ranged from 0 to 59%. Similar to the collection of benthic invertebrate tissues, a certain level of variability is potentially expected with the collection of periphyton tissues for the following reasons:
  - The two field duplicate composite samples may consist of different relative abundances of various periphyton taxa and/or sizes of individuals present, and different taxa may have different tissue burdens of a given metal;
  - The periphyton tissue sample may contain some residual particulate matter attached to the periphyton matrix; and,
  - During laboratory analyses, homogenization of the sample prior to digestion may not have been complete, such that subsampling for analysis will result in variability in the results.

4.5.3 Results and Discussion

Results of the benthic invertebrate and periphyton tissue chemistry analyses are summarized in Table 9, Table 10, and Table 11. Results are reported on a dry weight (dw) basis. Summary statistics for each tissue type are presented in Appendix F, Tables F-5 to F-7.

4.5.3.1 Primary Aquatic COPCs

The 10 primary COPCs were graphed to evaluate spatial trends within Baker Creek and to compare Baker Creek data to reference conditions in the Yellowknife River (Figure 12 to Figure 17). For each station and tissue type, primary COPC concentrations >2 and >10 times the Yellowknife River reference mean value were identified (Table 12 to Table 14).

Depositional Benthic Invertebrates

Concentrations of the majority of primary COPCs measured in depositional invertebrate tissues were variable within and among designated reaches in Lower Baker Creek, Upper Baker Creek and Trapper Creek (Figure 12 to Figure 14). Arsenic concentrations were particularly variable within Reach 0 and Reach 2, where peak concentrations were more than an order of magnitude higher than those measured at other stations within these reaches. The greatest disparity was observed between Stations BCSS-DEP-07 and BCSS-DEP-08 in Reach 2, where arsenic concentrations were 38 times higher at Station BCSS-DEP-08 compared to Station BCSS-DEP-07 (Table 9). Variability in tissue concentrations was also evident in the Yellowknife River reference area for a number of primary COPCs, notably cadmium, copper, manganese and mercury.

Table 9: Trace Metal Concentrations in Depositional Benthic Invertebrate Tissues Collected From Baker Creek, Trapper Creek and the Yellowknife River

Waterbody/Reach	Units	Standard RDL[1]	Baker Creek - Reach 0			Baker Creek - Reach 1		Baker Creek - Reach 2			Baker Creek - Reach 3
Sample ID			BCSS-DEP-01-BI	BCSS-DEP-02-BI	BCSS-DEP-03-BI	BCSS-DEP-04-BI	BCSS-DEP-05-BI	BCSS-DEP-06-BI	BCSS-DEP-07-BI	BCSS-DEP-08-BI	BCSS-DEP-09-BI
Date Sampled			05-OCT-11	05-OCT-11	05-OCT-11	23-SEP-11	23-SEP-11	23-SEP-11	26-SEP-11	26-SEP-11	27-SEP-11
ALS Sample ID			L1110217-1	L1110217-2	L1110217-3	L1110217-4	L1110217-5	L1110217-6	L1110217-7	L1110217-8	L1110217-9
Matrix			Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
QA/QC											
Metals											
Aluminum (Al)-Total	mg/kg dwt	2	4170	659	164	2340	2330	662	961	2750	334
Antimony (Sb)-Total	mg/kg dwt	0.01	63.3	11.0	5.67	10.0	31.1	4.75	2.25	141	7.86
Arsenic (As)-Total	mg/kg dwt	0.02	427	155	59.6	129	275	47.5	19.0	729	157
Barium (Ba)-Total	mg/kg dwt	0.05	37.6	15.7	18.2	32.4	56.6	7.57	7.31	24.4	10.3
Beryllium (Be)-Total	mg/kg dwt	0.01	0.103	0.024	<0.020	0.081	0.081	<0.030	0.036	0.057	<0.080
Bismuth (Bi)-Total	mg/kg dwt	0.01	0.068	0.046	<0.020	0.039	<0.060	<0.030	0.018	0.032	<0.080
Boron (B)-Total	mg/kg dwt	1	49.9	16.1	19.4	46.7	138	26.6	102	32.8	184
Cadmium (Cd)-Total	mg/kg dwt	0.01	1.53	0.268	0.119	0.762	0.540	0.298	0.380	0.336	0.205
Calcium (Ca)-Total	mg/kg dwt	60	147000	232000	332000	283000	166000	57800	2030	215000	102000
Cesium (Cs)-Total	mg/kg dwt	0.005	0.312	0.060	0.019	0.250	0.226	0.064	0.124	0.146	0.041
Chromium (Cr)-Total	mg/kg dwt	0.05	12.4	2.84	1.24	7.77	8.21	2.92	15.1	8.23	2.09
Cobalt (Co)-Total	mg/kg dwt	0.02	6.78	4.56	2.19	5.83	4.06	1.38	1.91	12.5	1.67
Copper (Cu)-Total	mg/kg dwt	0.05	83.2	113	38.9	157	86.9	70.5	36.8	90.7	44.9
Gallium (Ga)-Total	mg/kg dwt	0.02	1.20	0.204	0.065	0.769	0.75	0.201	0.354	0.764	<0.16
Iron (Fe)-Total	mg/kg dwt	1	7960	1950	598	3550	4230	1030	1150	5390	960
Lead (Pb)-Total	mg/kg dwt	0.02	70.2	4.97	1.50	17.4	21.9	3.45	1.53	24.3	2.96
Lithium (Li)-Total	mg/kg dwt	0.1	4.78	0.79	<0.20	3.10	2.77	0.76	1.45	4.05	<0.80
Magnesium (Mg)-Total	mg/kg dwt	100	3460	2270	2730	2900	2320	2130	1240	2260	1460
Manganese (Mn)-Total	mg/kg dwt	0.02	232	156	195	301	165	58.3	72.9	105	96.4
Mercury (Hg)-Total	mg/kg dwt	0.02	<0.040	0.032	<0.010	<0.020	<0.060	0.027	0.075	0.026	<0.035
Molybdenum (Mo)-Total	mg/kg dwt	0.02	0.346	0.589	0.361	0.915	2.05	0.616	0.397	0.822	3.77
Nickel (Ni)-Total	mg/kg dwt	0.05	14.5	6.56	3.58	12.6	10.4	4.18	7.99	22.8	7.99
Phosphorus (P)-Total	mg/kg dwt	400	7730	4020	4180	4220	13300	7020	7350	1530	4200
Potassium (K)-Total	mg/kg dwt	2000	<4000	1700	<2000	1100	<6000	6300	9100	<2000	<7000
Rhenium (Re)-Total	mg/kg dwt	0.01	<0.020	<0.020	<0.020	<0.020	<0.060	<0.030	<0.010	<0.020	<0.080
Rubidium (Rb)-Total	mg/kg dwt	0.05	5.01	1.92	0.91	4.26	5.01	2.61	13.2	2.97	0.95
Selenium (Se)-Total	mg/kg dwt	0.1	1.75	0.99	0.49	0.73	1.98	0.61	1.06	0.57	<0.80
Sodium (Na)-Total	mg/kg dwt	2000	<4000	2200	<2000	1700	<6000	2500	8500	2100	<7000
Strontium (Sr)-Total	mg/kg dwt	0.05	331	367	592	497	546	105	6.62	307	137
Tellurium (Te)-Total	mg/kg dwt	0.02	<0.040	<0.040	<0.040	<0.040	<0.12	<0.060	<0.020	<0.040	<0.16
Thallium (Tl)-Total	mg/kg dwt	0.002	0.0520	0.0205	0.0127	0.0524	0.048	0.0195	0.0252	0.0283	<0.016
Thorium (Th)-Total	mg/kg dwt	0.01	0.666	0.168	0.063	0.670	0.874	0.186	0.419	0.525	0.237
Tin (Sn)-Total	mg/kg dwt	0.02	0.079	<0.040	<0.040	<0.040	<0.12	<0.060	0.051	0.045	<0.16
Titanium (Ti)-Total	mg/kg dwt	0.05	76.9	17.6	4.20	59.5	81.4	17.9	45.1	45.3	14.2
Uranium (U)-Total	mg/kg dwt	0.002	0.219	0.257	0.0964	0.451	0.391	0.0706	0.0999	0.257	0.113
Vanadium (V)-Total	mg/kg dwt	0.02	12.9	2.67	0.736	7.11	6.40	1.80	2.39	9.06	1.01
Yttrium (Y)-Total	mg/kg dwt	0.01	1.15	0.422	0.072	1.33	0.911	0.232	0.411	0.852	0.117
Zinc (Zn)-Total	mg/kg dwt	0.5	324	50.4	28.5	81.3	183	123	117	152	132
Zirconium (Zr)-Total	mg/kg dwt	0.2	2.74	<0.40	<0.40	0.52	2.2	<0.60	1.42	1.85	<1.6
Aggregate Organics											
Lipid Content	-	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.3	-	<0.5	-

Waterbody/Reach	Baker Creek - Reach 4		Baker Creek - Reach 5		Baker Creek - Reach 6 (Baker Pond)					Upper Baker Creek		
Sample ID	BCSS-DEP-12-BI	BCSS-DEP-13-BI	BCSS-DEP-14-BI	BCSS-DEP-16-BI	BCSS-DEP-17-BI	BCSS-DEP-18-BI	BCSS-DEP-19-BI	BCSS-DEP-21-BI	BCSS-DEP-200-BI	BCSS-DEP-23-BI	BCSS-DEP-24-BI	BCSS-DEP-25-BI
Date Sampled	27-SEP-11	27-SEP-11	28-SEP-11	27-SEP-11	21-SEP-11	21-SEP-11	22-SEP-11	22-SEP-11	22-SEP-11	30-SEP-11	28-SEP-11	30-SEP-11
ALS Sample ID	L1110217-12	L1110217-13	L1110217-14	L1110217-16	L1110217-17	L1110217-18	L1110217-19	L1110217-21	L1110217-31	L1110217-23	L1110217-24	L1110217-25
Matrix	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
QA/QC								FDA	FD			
Metals												
Aluminum (Al)-Total	2020	960	2600	435	583	1060	94.2	376	440	35.3	2430	35.9
Antimony (Sb)-Total	6.31	13.8	25.5	7.20	74.8	24.7	5.23	9.51	12.0	0.171	0.647	1.84
Arsenic (As)-Total	36.2	125	196	44.5	94.4	111	42.0	62.3	127	141	86.9	125
Barium (Ba)-Total	39.9	32.3	31.0	8.98	5.57	8.79	14.9	13.9	26.4	1.00	19.5	6.72
Beryllium (Be)-Total	0.067	0.031	0.106	<0.020	<0.040	<0.040	<0.010	0.014	0.015	<0.030	0.085	<0.030
Bismuth (Bi)-Total	0.043	<0.030	0.120	0.054	<0.040	<0.040	<0.010	<0.010	<0.010	<0.030	0.086	<0.030
Boron (B)-Total	149	110	46.4	101	43.4	82.4	1.5	15.7	2.4	69.0	54.7	129
Cadmium (Cd)-Total	0.759	0.432	0.142	0.067	0.125	0.617	0.191	0.273	0.227	0.034	0.061	0.053
Calcium (Ca)-Total	47400	101000	212000	11700	84800	167000	262000	305000	313000	1500	5430	15800
Cesium (Cs)-Total	0.250	0.113	0.330	0.059	0.071	0.096	0.0162	0.0510	0.0543	<0.015	0.324	<0.015
Chromium (Cr)-Total	6.50	4.23	8.18	3.91	4.32	3.13	1.35	1.16	2.02	4.37	11.0	3.32
Cobalt (Co)-Total	3.32	2.18	3.82	5.19	4.26	3.29	0.330	3.58	3.33	0.348	1.20	0.526
Copper (Cu)-Total	41.6	83.2	158	61.6	75.2	316	12.3	82.1	34.8	33.0	17.8	52.6
Gallium (Ga)-Total	0.761	0.342	0.919	0.160	0.216	0.308	0.037	0.138	0.156	<0.060	0.790	<0.060
Iron (Fe)-Total	2340	1340	4120	681	1080	1900	515	908	1500	240	2920	610
Lead (Pb)-Total	1.63	4.30	3.63	5.68	1.94	19.5	1.91	5.01	7.08	0.089	1.28	0.241
Lithium (Li)-Total	2.98	1.29	3.64	0.66	0.76	1.31	0.14	0.56	0.59	<0.30	3.65	<0.30
Magnesium (Mg)-Total	2680	2280	2050	810	1240	1730	3030	2170	3650	830	1540	770
Manganese (Mn)-Total	466	160	163	212	67.1	104	119	187	296	81.4	324	33.6
Mercury (Hg)-Total	0.054	0.049	<0.010	<0.040	0.069	<0.040	0.0117	0.0154	0.0144	0.035	<0.030	<0.13
Molybdenum (Mo)-Total	3.81	1.38	2.34	0.271	1.35	0.710	0.312	0.433	0.349	0.212	0.869	0.273
Nickel (Ni)-Total	12.8	11.0	14.1	5.15	10.6	9.53	1.85	7.44	8.13	1.97	5.16	2.14
Phosphorus (P)-Total	12900	14100	5190	4830	4960	2990	3240	1470	2100	6610	5530	7400
Potassium (K)-Total	6800	7400	2900	<4000	4600	<4000	1400	<1000	<2000	7400	3600	<10000
Rhenium (Re)-Total	<0.040	<0.030	<0.020	<0.020	<0.040	<0.040	<0.010	<0.010	<0.010	<0.030	<0.030	<0.030
Rubidium (Rb)-Total	6.82	8.08	7.03	2.93	4.80	2.09	1.12	1.64	1.63	3.31	8.90	1.20
Selenium (Se)-Total	5.41	2.38	1.14	1.13	3.11	1.22	0.42	0.48	0.52	1.40	1.22	2.72
Sodium (Na)-Total	<4000	3000	2800	<4000	<4000	<4000	2500	2200	2200	5300	3400	<10000
Strontium (Sr)-Total	235	573	364	63.7	120	230	384	549	516	3.50	15.0	25.8
Tellurium (Te)-Total	<0.080	<0.060	<0.040	<0.040	<0.080	<0.080	<0.020	<0.020	<0.020	<0.060	<0.060	<0.060
Thallium (Tl)-Total	0.0369	0.0418	0.0506	0.0098	0.0132	0.112	0.0210	0.0259	0.0274	0.0138	0.0263	0.0134
Thorium (Th)-Total	0.739	0.298	0.705	0.161	0.172	0.256	0.043	0.123	0.113	0.063	0.989	0.126
Tin (Sn)-Total	<0.080	<0.060	0.075	0.051	0.094	0.111	<0.020	<0.020	<0.020	<0.060	0.073	<0.060
Titanium (Ti)-Total	92.0	33.8	136	18.6	23.1	32.9	3.96	10.4	9.12	1.57	112	1.84
Uranium (U)-Total	1.82	0.879	1.06	0.0746	0.242	0.105	0.0956	0.0956	0.0881	0.0532	2.06	0.0455
Vanadium (V)-Total	5.09	2.55	6.46	1.40	1.74	3.31	0.602	1.30	1.93	0.067	4.73	0.156
Yttrium (Y)-Total	0.804	0.282	1.14	0.194	0.257	0.420	0.097	0.151	0.166	<0.030	1.12	<0.030
Zinc (Zn)-Total	191	144	89.6	158	100	163	30.7	40.3	33.1	498	212	404
Zirconium (Zr)-Total	2.29	1.12	3.79	0.60	0.94	1.38	<0.20	<0.20	<0.20	<0.60	2.06	<0.60
Aggregate Organics												
Lipid Content	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	<0.5	-

Waterbody/Reach	Trapper Creek			YellowKnife River (Reference)			
Sample ID	BCSS-DEP-26-BI	BCSS-DEP-201-BI	BCSS-DEP-27-BI	BCSS-DEP-28-BI	BCSS-DEP-102-BI	BCSS-DEP-29-BI	BCSS-DEP-30-BI
Date Sampled	29-SEP-11	29-SEP-11	29-SEP-11	04-OCT-11	04-OCT-11	04-OCT-11	04-OCT-11
ALS Sample ID	L1110217-26	L1110217-32	L1110217-27	L1110217-28	L1110217-33	L1110217-29	L1110217-30
Matrix	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
QA/QC	FDA	FD		FDA	FD		
Metals							
Aluminum (Al)-Total	7860	6690	197	484	673	1390	354
Antimony (Sb)-Total	1.68	0.453	0.429	0.060	0.070	0.417	0.040
Arsenic (As)-Total	257	130	144	1.33	1.57	9.52	0.970
Barium (Ba)-Total	70.6	58.3	6.10	18.8	34.0	174	45.8
Beryllium (Be)-Total	0.282	0.223	<0.030	<0.020	0.030	0.050	<0.030
Bismuth (Bi)-Total	0.149	0.110	<0.030	<0.020	0.063	0.021	<0.030
Boron (B)-Total	134	72.4	58.1	31.5	32.4	32.6	54.2
Cadmium (Cd)-Total	0.358	0.195	<0.030	0.215	0.286	0.833	0.368
Calcium (Ca)-Total	3370	2580	7740	34400	33200	88100	32300
Cesium (Cs)-Total	0.884	0.777	0.024	0.054	0.072	0.154	0.040
Chromium (Cr)-Total	17.5	16.5	0.86	1.90	2.39	3.32	1.19
Cobalt (Co)-Total	5.62	3.67	1.36	0.506	0.807	2.12	0.789
Copper (Cu)-Total	39.6	24.7	29.3	42.1	45.0	94.4	32.4
Gallium (Ga)-Total	2.79	2.32	0.066	0.169	0.230	0.491	0.125
Iron (Fe)-Total	12200	9000	1030	602	792	1440	459
Lead (Pb)-Total	5.52	4.03	0.324	0.280	0.368	1.00	0.221
Lithium (Li)-Total	9.91	9.08	<0.30	0.53	0.88	1.64	0.36
Magnesium (Mg)-Total	3530	3590	1170	1120	1380	1920	1170
Manganese (Mn)-Total	304	177	40.1	30.7	41.3	122	31.8
Mercury (Hg)-Total	0.060	0.044	0.096	0.043	0.100	<0.020	<0.050
Molybdenum (Mo)-Total	1.23	0.755	0.226	0.552	0.783	0.631	0.533
Nickel (Ni)-Total	10.1	8.96	0.58	1.14	1.26	3.31	1.77
Phosphorus (P)-Total	7110	5430	8270	5140	7860	9930	8560
Potassium (K)-Total	6900	4300	9700	3800	5300	5100	3900
Rhenium (Re)-Total	<0.040	<0.020	<0.030	<0.020	<0.020	<0.020	<0.030
Rubidium (Rb)-Total	18.2	14.6	2.90	2.62	4.31	6.85	3.81
Selenium (Se)-Total	1.38	1.05	1.14	0.79	0.83	0.59	0.46
Sodium (Na)-Total	5100	2300	7900	<2000	2500	2200	<2000
Strontium (Sr)-Total	20.4	15.8	16.3	43.8	63.3	145	95.3
Tellurium (Te)-Total	<0.080	<0.040	<0.060	<0.040	<0.040	<0.040	<0.060
Thallium (Tl)-Total	0.0876	0.0763	<0.0060	0.0139	0.0251	0.0580	0.0232
Thorium (Th)-Total	3.36	2.97	0.211	0.287	0.541	0.460	0.179
Tin (Sn)-Total	0.143	0.116	<0.060	<0.040	<0.040	<0.040	<0.060
Titanium (Ti)-Total	322	246	8.08	29.2	35.3	47.8	17.7
Uranium (U)-Total	1.67	0.868	0.0318	0.250	0.376	0.717	0.226
Vanadium (V)-Total	19.0	13.7	0.446	1.19	1.67	3.55	0.948
Yttrium (Y)-Total	3.77	2.70	0.045	0.342	0.470	0.735	0.246
Zinc (Zn)-Total	207	137	218	84.9	93.6	126	157
Zirconium (Zr)-Total	9.97	8.17	<0.60	0.69	0.76	0.69	0.74
Aggregate Organics							
Lipid Content	<0.5	-	0.5	1.5	2.2	0.9	1

Notes:

mg/kg = milligrams per kilogram

dwt = dry weight tissue

FD = field duplicate (split sample)

FDA = field duplicate (split sample) analyzed

RDL = reported detection limit

[1] Standard RDL. Higher RDLs may be reported where the analytical laboratory raised the MDL.

Table 10: Trace Metal Concentrations in Periphyton Tissues Collected From Lower Baker Creek and the Yellowknife River

Waterbody/Reach	Units	Standard RDL[1]	Baker Creek - Reach 0		Baker Creek - Reach 1		Baker Creek - Reach 2		Baker Creek - Reach 3			Baker Creek - Reach 4		Baker Creek - Reach 5		Yellowknife River (Reference)		
Sample ID			**BCSS-ERO-01-PERI**	**BCSS-ERO-02-PERI**	**BCSS-ERO-03-PERI**	**BCSS-ERO-04-PERI**	**BCSS-ERO-05-PERI**	**BCSS-ERO-06-PERI**	**BCSS-ERO-07-PERI**	**BCSS-ERO-08-PERI**	**BCSS-ERO-21-PERI**	**BCSS-ERO-09-PERI**	**BCSS-ERO-10-PERI**	**BCSS-ERO-11-PERI**	**BCSS-ERO-12-PERI**	**BCSS-ERO-15-PERI**	**BCSS-ERO-16-PERI**	**BCSS-ERO-17-PERI**
Date Sampled			20-SEP-11	20-SEP-11	20-SEP-11	30-SEP-11	30-SEP-11	30-SEP-11	03-OCT-11	03-OCT-10	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	04-OCT-11	04-OCT-11	04-OCT-11
ALS Sample ID			L1110265-1	L1110265-2	L1110265-3	L1110265-4	L1110265-5	L1110265-6	L1110265-7	L1110265-7	L1110265-16	L1110265-9	L1110265-10	L1110265-11	L1110265-12	L1110265-13	L1110265-14	L1110265-15
Matrix			Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
QA/QC										FDA	FD							
Metals																		
Aluminum (Al)-Total	mg/kg dwt	4	21100	19700	18000	21200	19100	19200	23700	20100	15700	13800	15800	9820	16700	11500	15200	11000
Antimony (Sb)-Total	mg/kg dwt	0.02	4.47	7.82	1.73	3.73	3.88	4.39	1.69	2.05	1.92	1.11	2.00	9.32	5.32	0.011	0.013	0.032
Arsenic (As)-Total	mg/kg dwt	0.04	1510	1500	1120	1220	1780	1480	1010	849	806	411	886	1090	1030	4.79	7.26	6.76
Barium (Ba)-Total	mg/kg dwt	0.1	153	76.1	127	140	148	136	120	129	108	73.4	105	87.9	105	87.7	142	107
Beryllium (Be)-Total	mg/kg dwt	0.02	0.874	0.453	0.816	0.973	0.839	0.772	0.672	0.753	0.533	0.525	0.525	0.322	0.645	0.569	0.730	0.428
Bismuth (Bi)-Total	mg/kg dwt	0.02	0.381	0.267	0.357	0.436	0.385	0.345	0.280	0.278	0.217	0.231	0.233	0.189	0.269	0.209	0.314	0.182
Boron (B)-Total	mg/kg dwt	2	38.0	16.6	19.0	31.6	34.7	32.9	39.9	43.6	75.5	15.3	87.2	51.9	25.1	42.9	59.3	73.5
Cadmium (Cd)-Total	mg/kg dwt	0.02	1.04	1.20	0.812	0.973	1.03	1.01	0.676	0.604	0.572	0.285	0.576	1.33	0.959	0.073	0.158	0.103
Calcium (Ca)-Total	mg/kg dwt	30	28300	42400	13900	10600	16600	16700	44000	22200	28700	11900	27900	98700	45700	8660	7950	7970
Cesium (Cs)-Total	mg/kg dwt	0.01	3.25	1.75	3.09	3.72	3.23	2.85	2.51	2.76	2.00	1.83	2.01	1.18	2.68	1.86	2.20	1.37
Chromium (Cr)-Total	mg/kg dwt	0.1	49.3	50.5	44.2	51.3	47.4	47.9	70.4	49.6	44.3	41.6	46.3	26.0	39.6	26.8	35.5	23.4
Cobalt (Co)-Total	mg/kg dwt	0.04	33.8	44.4	28.0	26.6	31.8	37.6	32.4	28.4	26.4	16.8	27.7	34.9	45.1	6.39	8.18	5.40
Copper (Cu)-Total	mg/kg dwt	0.1	207	86.3	215	283	214	207	205	152	152	61.5	165	200	831	9.86	15.4	11.2
Gallium (Ga)-Total	mg/kg dwt	0.04	6.91	5.42	6.08	7.11	6.75	6.28	7.23	7.17	5.68	4.56	5.60	3.48	5.51	4.11	5.41	3.94
Iron (Fe)-Total	mg/kg dwt	2	30600	35100	26100	28600	28900	28700	33900	26900	21700	20200	22900	16000	22000	14900	17700	12400
Lead (Pb)-Total	mg/kg dwt	0.04	120	119	125	165	114	110	53.5	42.7	33.2	25.0	40.6	50.6	88.8	5.12	7.65	4.40
Lithium (Li)-Total	mg/kg dwt	0.2	42.2	46.7	42.7	48.2	40.5	38.2	41.0	35.0	27.5	32.5	28.1	14.1	32.0	23.0	30.0	18.8
Magnesium (Mg)-Total	mg/kg dwt	50	14400	23900	14800	15400	12700	13700	17200	11600	9500	11800	10000	6720	10100	6560	8200	5210
Manganese (Mn)-Total	mg/kg dwt	0.04	1770	900	1010	637	1630	1900	1850	1670	1740	633	1730	3050	1920	326	531	445
Mercury (Hg)-Total	mg/kg dwt	0.01	0.117	0.174	0.110	0.140	0.136	0.124	0.073	0.070	0.038	0.0447	0.047	0.049	0.103	0.0075	0.0119	<0.010
Molybdenum (Mo)-Total	mg/kg dwt	0.04	1.46	1.06	1.01	1.03	1.34	1.57	1.17	1.15	1.37	0.952	1.30	1.54	1.14	0.332	0.482	0.378
Nickel (Ni)-Total	mg/kg dwt	0.1	94.8	69.3	73.3	74.8	96.9	104	104	87.5	88.1	46.9	89.4	149	159	18.1	26.3	20.6
Phosphorus (P)-Total	mg/kg dwt	200	780	570	700	690	820	810	1300	870	740	550	770	610	660	630	1080	1100
Potassium (K)-Total	mg/kg dwt	1000	6600	2800	5800	7100	6100	5600	5100	5700	4400	3000	4600	4000	4400	3800	5000	3900
Rhenium (Re)-Total	mg/kg dwt	0.02	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	<0.020	<0.020	<0.010	<0.020	<0.020	<0.010	<0.010	<0.010	<0.020
Rubidium (Rb)-Total	mg/kg dwt	0.1	46.1	19.6	41.0	52.0	43.6	38.3	34.0	38.8	26.9	21.8	27.3	18.3	35.4	26.3	35.7	23.9
Selenium (Se)-Total	mg/kg dwt	0.2	0.82	0.40	0.70	0.76	0.79	0.71	0.91	0.73	0.59	0.27	0.65	1.11	0.92	<0.10	0.19	<0.20
Sodium (Na)-Total	mg/kg dwt	1000	1100	<1000	<1000	<1000	<1000	<1000	1200	1100	1200	<1000	1200	1500	<1000	<1000	<1000	<1000
Strontium (Sr)-Total	mg/kg dwt	0.1	147	91.6	101	81.0	108	95.1	156	119	123	49.8	115	336	168	31.6	47.8	46.3
Tellurium (Te)-Total	mg/kg dwt	0.04	0.039	0.038	0.031	0.042	0.042	0.036	<0.040	<0.040	<0.040	0.024	<0.040	<0.040	0.037	<0.020	<0.020	<0.040
Thallium (Tl)-Total	mg/kg dwt	0.004	0.359	0.175	0.307	0.397	0.339	0.295	0.241	0.261	0.183	0.157	0.188	0.132	0.276	0.152	0.210	0.131
Thorium (Th)-Total	mg/kg dwt	0.02	9.30	4.99	9.74	11.7	10.8	10.2	8.45	9.93	8.32	8.38	8.53	3.51	7.43	8.09	10.6	5.93
Tin (Sn)-Total	mg/kg dwt	0.04	0.564	0.297	0.338	0.481	0.385	0.393	0.238	0.382	0.298	0.281	0.203	0.169	0.284	0.225	0.223	0.160
Titanium (Ti)-Total	mg/kg dwt	0.1	597	348	456	580	560	572	595	655	646	543	670	340	468	458	566	454
Uranium (U)-Total	mg/kg dwt	0.004	1.45	0.894	1.41	1.53	1.52	1.74	1.35	1.51	1.39	1.48	1.36	0.851	1.39	6.19	7.61	7.89
Vanadium (V)-Total	mg/kg dwt	0.04	55.8	65.2	44.5	52.3	50.8	51.6	64.3	52.6	45.3	41.8	47.3	29.5	39.4	28.7	34.8	24.1
Yttrium (Y)-Total	mg/kg dwt	0.02	9.29	8.05	9.01	10.1	9.79	9.96	8.25	9.21	7.95	8.78	8.09	3.66	7.02	9.45	10.9	7.30
Zinc (Zn)-Total	mg/kg dwt	1	338	200	267	304	326	301	257	237	198	89.6	210	327	369	35.4	46.5	35.8
Zirconium (Zr)-Total	mg/kg dwt	0.4	24.4	14.8	24.7	28.2	26.2	24.9	23.3	26.0	20.8	16.9	17.9	11.5	20.0	23.1	28.5	17.2
Aggregate Organics																		
Lipid Content	%	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Notes:

mg/kg = milligrams per kilogram
dwt = dry weight tissue
FD = field duplicate
FDA = field duplicate analyzed
RDL = reported detection limit

Table 11: Trace Metal Concentrations in Erosional Benthic Invertebrate Tissues Collected From Lower Baker Creek and the Yellowknife River

Waterbody/Reach	Units	Standard RDL[1]	Baker Creek - Reach 0	Baker Creek - Reach 1		Baker Creek - Reach 2		Baker Creek - Reach 3			Baker Creek - Reach 4		Baker Creek - Reach 5		YellowKnife River (Reference)		
Sample ID			BCSS-ERO-02-BI	BCSS-ERO-03-BI	BCSS-ERO-04-BI	BCSS-ERO-05-BI	BCSS-ERO-06-BI	BCSS-ERO-07-BI	BCSS-ERO-08-BI	BCSS-ERO-202-BI	BCSS-ERO-09-BI	BCSS-ERO-10-BI	BCSS-ERO-11-BI	BCSS-ERO-12-BI	BCSS-ERO-15-BI	BCSS-ERO-16-BI	BCSS-ERO-17-BI
Date Sampled			20-SEP-11	20-SEP-11	30-SEP-11	30-SEP-11	30-SEP-11	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	03-OCT-11	04-OCT-11	04-OCT-11	04-OCT-11
ALS Sample ID			L1110235-2	L1110235-3	L1110235-4	L1110235-5	L1110235-6	L1110235-7	L1110235-8	L1110235-16	L1110235-9	L1110235-10	L1110235-11	L1110235-12	L1110235-13	L1110235-14	L1110235-15
Matrix			Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
QA/QC									FDA	FD							
Metals																	
Aluminum (Al)-Total	mg/kg dwt	2	1020	1080	566	519	691	516	323	230	435	315	849	278	3870	1070	2640
Antimony (Sb)-Total	mg/kg dwt	0.01	7.85	8.39	6.95	5.32	4.92	3.75	2.71	3.25	4.08	2.64	5.96	5.67	0.058	<0.020	0.023
Arsenic (As)-Total	mg/kg dwt	0.02	105	74.3	70.6	67.5	54.9	33.3	17.6	13.1	26.1	24.2	71.8	36.6	2.59	1.64	3.37
Barium (Ba)-Total	mg/kg dwt	0.05	43.6	49.4	8.67	35.6	16.8	25.1	27.9	40.8	30.0	5.46	26.8	5.05	32.2	13.6	37.6
Beryllium (Be)-Total	mg/kg dwt	0.01	<0.060	<0.050	<0.020	<0.020	<0.030	<0.030	<0.030	<0.030	<0.030	<0.020	<0.030	<0.020	0.127	0.038	0.049
Bismuth (Bi)-Total	mg/kg dwt	0.01	<0.060	<0.050	0.028	<0.020	<0.030	0.032	0.101	0.079	0.079	<0.020	<0.030	0.023	0.062	0.022	0.049
Boron (B)-Total	mg/kg dwt	1	124	252	44.4	76.7	84.4	42.9	66.4	61.3	53.2	71.0	48.3	40.0	56.9	36.6	30.8
Cadmium (Cd)-Total	mg/kg dwt	0.01	0.430	0.666	0.470	0.625	0.538	0.533	0.470	0.602	0.574	0.723	0.462	0.088	0.248	1.90	0.304
Calcium (Ca)-Total	mg/kg dwt	60	148000	108000	9930	120000	40600	91000	79700	131000	87800	38500	86100	9390	3390	84000	167000
Cesium (Cs)-Total	mg/kg dwt	0.005	0.126	0.147	0.076	0.077	0.085	0.069	0.060	0.053	0.065	0.044	0.113	0.048	0.506	0.129	0.173
Chromium (Cr)-Total	mg/kg dwt	0.05	2.92	2.65	3.48	1.33	3.57	3.23	1.75	2.19	1.62	4.14	4.73	2.77	12.2	3.37	11.3
Cobalt (Co)-Total	mg/kg dwt	0.02	2.61	5.32	3.05	1.74	2.07	2.51	1.27	0.893	1.62	0.969	3.43	7.14	3.74	4.62	2.43
Copper (Cu)-Total	mg/kg dwt	0.05	101	52.7	42.5	83.0	62.3	69.7	72.4	92.8	68.9	61.1	80.4	50.6	63.9	19.4	20.6
Gallium (Ga)-Total	mg/kg dwt	0.02	0.36	0.34	0.208	0.198	0.210	0.167	0.112	0.115	0.155	0.112	0.272	0.101	1.47	0.367	0.987
Iron (Fe)-Total	mg/kg dwt	1	1750	1400	995	815	1000	687	413	283	582	511	1100	458	4750	1470	4080
Lead (Pb)-Total	mg/kg dwt	0.02	4.36	5.32	10.5	2.02	3.65	1.21	0.715	0.407	0.710	0.996	3.43	2.61	1.66	0.543	1.25
Lithium (Li)-Total	mg/kg dwt	0.1	1.17	1.43	0.73	0.78	0.83	0.62	0.46	0.47	0.51	0.39	0.96	0.29	5.48	1.28	4.34
Magnesium (Mg)-Total	mg/kg dwt	100	2610	1790	920	2250	1740	1580	1620	2060	1900	1300	1910	1620	2220	940	2260
Manganese (Mn)-Total	mg/kg dwt	0.02	333	602	240	177	144	237	113	103	112	67.1	263	254	189	56.0	158
Mercury (Hg)-Total	mg/kg dwt	0.02	0.194	0.093	0.017	0.068	0.087	0.032	0.073	0.076	0.034	0.060	0.079	0.132	0.042	0.052	0.015
Molybdenum (Mo)-Total	mg/kg dwt	0.02	2.05	0.78	0.267	0.664	0.465	0.609	0.590	0.881	0.730	0.846	1.01	0.371	0.879	0.294	0.598
Nickel (Ni)-Total	mg/kg dwt	0.05	7.96	5.69	4.60	5.30	4.59	5.55	4.54	5.07	4.94	3.70	7.29	6.65	10.3	4.09	4.98
Phosphorus (P)-Total	mg/kg dwt	400	15900	15200	6030	13200	10800	11500	12500	14200	13400	7150	14000	7090	4270	5750	3080
Potassium (K)-Total	mg/kg dwt	2000	<6000	<10000	5500	6900	7100	5500	6900	6500	6000	3700	6600	7000	4400	3300	3000
Rhenium (Re)-Total	mg/kg dwt	0.01	<0.060	<0.050	<0.020	<0.020	<0.030	<0.030	<0.030	<0.030	<0.030	<0.020	<0.030	<0.020	<0.030	<0.020	<0.020
Rubidium (Rb)-Total	mg/kg dwt	0.05	4.62	5.94	8.60	8.06	9.56	7.92	7.68	7.25	6.93	2.19	8.22	8.86	10.5	5.80	4.82
Selenium (Se)-Total	mg/kg dwt	0.1	1.14	1.70	1.28	1.74	1.63	1.39	1.61	1.55	1.52	1.56	1.92	1.23	0.43	1.22	0.39
Sodium (Na)-Total	mg/kg dwt	2000	<6000	<10000	5400	5800	6200	4700	4200	3300	3300	2600	3700	7100	<3000	<2000	<2000
Strontium (Sr)-Total	mg/kg dwt	0.05	651	551	55.1	710	233	448	464	737	498	86.1	504	55.6	12.9	90.9	167
Tellurium (Te)-Total	mg/kg dwt	0.02	<0.12	<0.10	<0.040	<0.040	<0.060	<0.060	<0.060	<0.060	<0.060	<0.040	<0.060	<0.040	<0.060	<0.040	<0.040
Thallium (Tl)-Total	mg/kg dwt	0.002	0.053	0.052	0.0174	0.0613	0.0387	0.0375	0.0419	0.0603	0.0362	0.0218	0.0389	0.0109	0.0540	0.0248	0.0287
Thorium (Th)-Total	mg/kg dwt	0.01	0.233	0.385	0.206	0.134	0.155	0.143	0.098	0.155	0.108	0.099	0.187	0.088	1.74	0.538	0.889
Tin (Sn)-Total	mg/kg dwt	0.02	<0.12	<0.10	<0.040	<0.040	<0.060	<0.060	<0.060	<0.060	<0.060	0.060	0.078	<0.040	0.114	<0.040	<0.040
Titanium (Ti)-Total	mg/kg dwt	0.05	38.8	44.5	23.2	17.4	24.2	19.7	12.9	8.28	18.0	15.4	30.5	10.7	196	49.3	94.5
Uranium (U)-Total	mg/kg dwt	0.002	0.205	0.265	0.0492	0.0763	0.0972	0.0913	0.0518	0.0673	0.104	0.0631	0.127	0.0278	8.42	1.25	1.24
Vanadium (V)-Total	mg/kg dwt	0.02	2.75	2.70	1.57	1.51	1.79	1.42	0.844	0.574	1.23	0.940	2.18	0.974	9.52	2.58	6.73
Yttrium (Y)-Total	mg/kg dwt	0.01	0.329	0.563	0.222	0.163	0.237	0.191	0.124	0.085	0.151	0.132	0.217	0.091	2.16	0.635	0.939
Zinc (Zn)-Total	mg/kg dwt	0.5	125	150	141	106	141	108	99.1	79.8	114	159	126	133	251	268	71.3
Zirconium (Zr)-Total	mg/kg dwt	0.2	<1.2	1.5	0.61	0.69	0.64	<0.60	<0.60	<0.60	<0.60	<0.40	0.80	<0.40	5.39	1.51	2.33
Aggregate Organics																	
Lipid Content	%	0.5	<0.5	<0.5	-	<0.5	<0.5	0.6	0.7	0.6	1.2	-	0.6	<0.5	<0.5	<0.5	1.4

Notes:

mg/kg = milligrams per kilogram

dwt = dry weight tissue

FD = field duplicate (split sample)

FDA = field duplicate (split samples) analyzed

RDL = reported detection limit

[1] Standard RDL. Higher RDLs may be reported where the analytical laboratory raised the MDL.

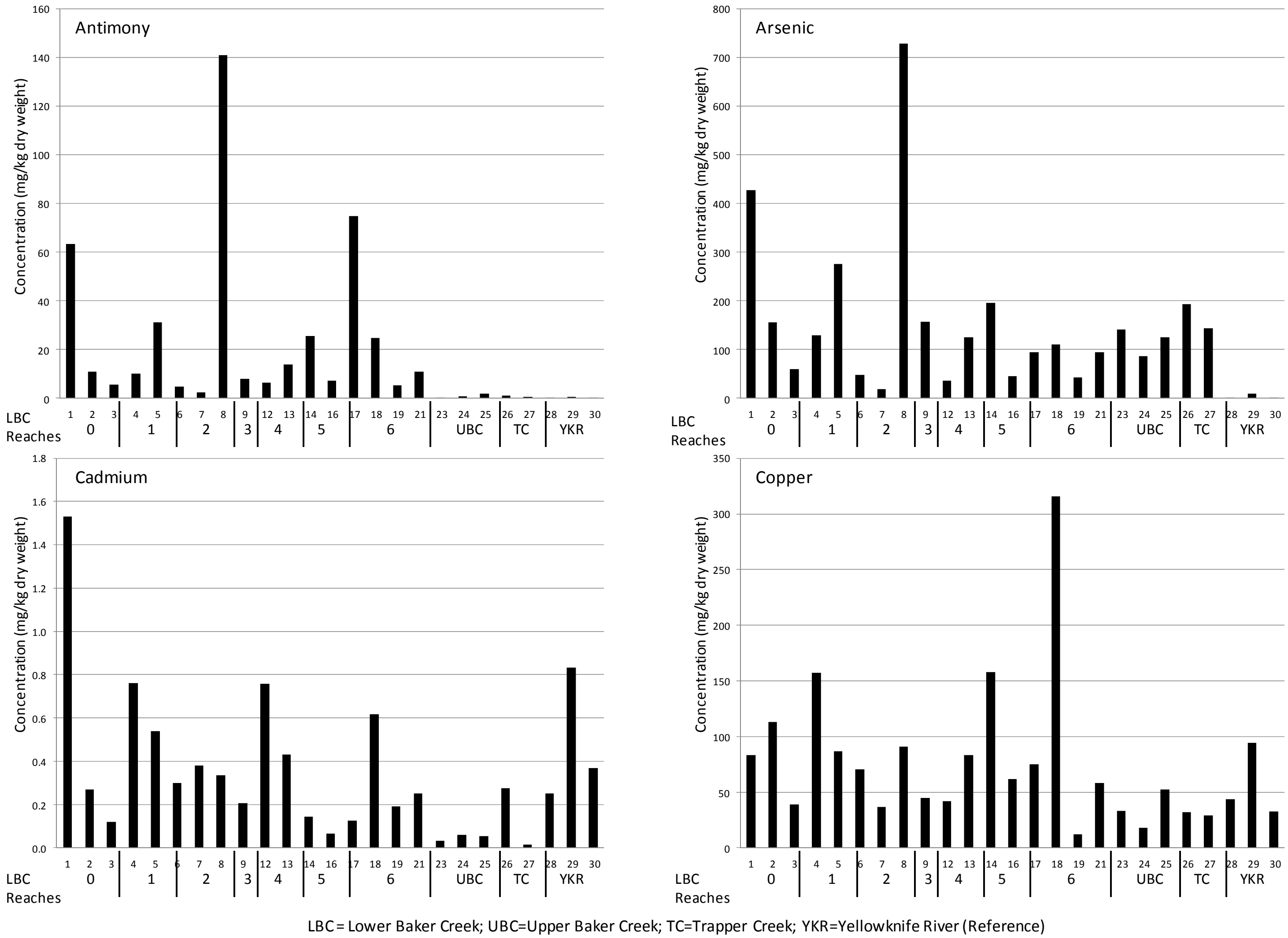


Figure 12: Concentrations of Antimony, Arsenic, Cadmium, and Copper in Depositional Benthic Invertebrate Tissues

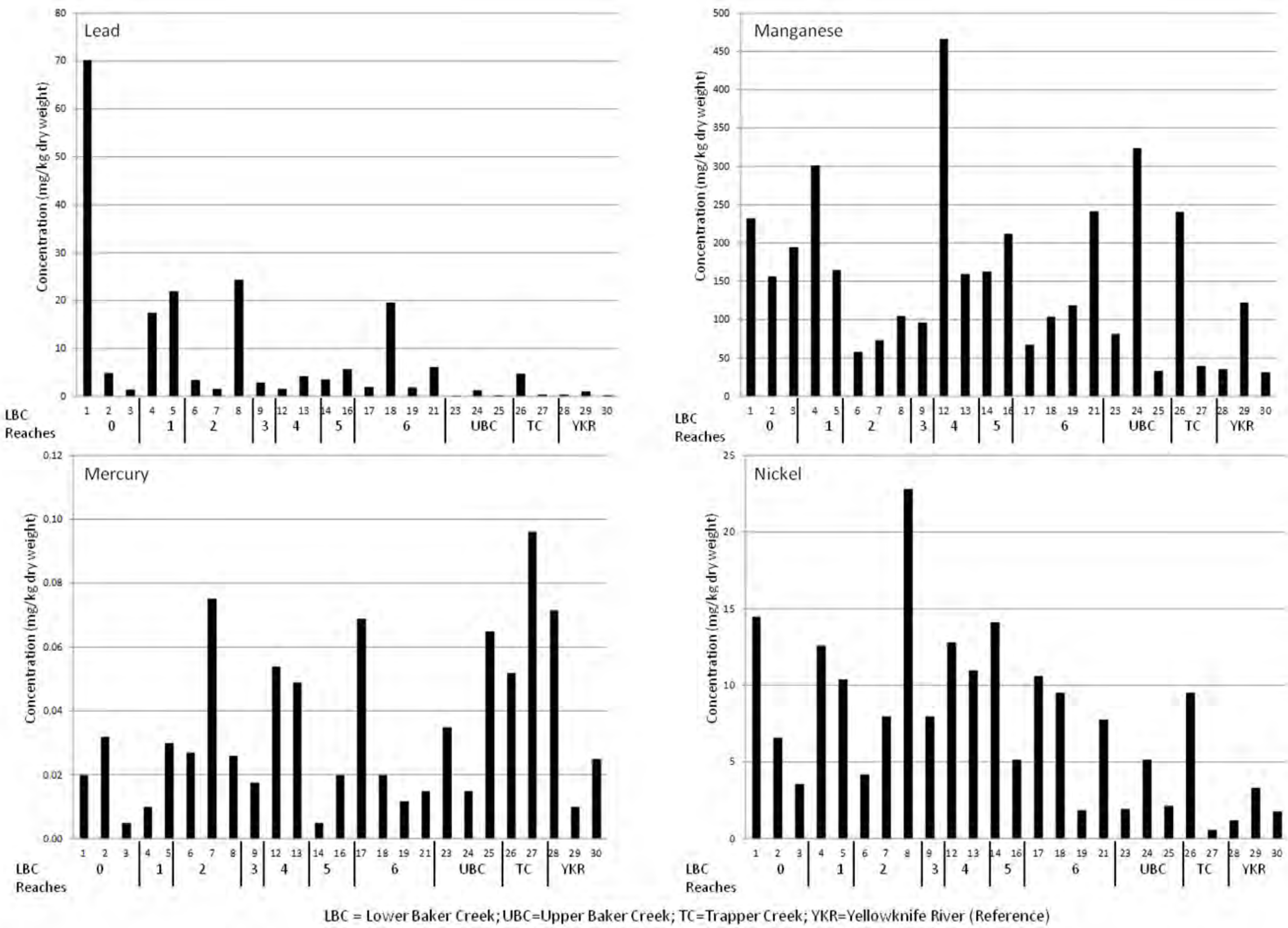


Figure 13: Concentrations of Lead, Manganese, Mercury and Nickel in Depositional Benthic Invertebrate Tissues

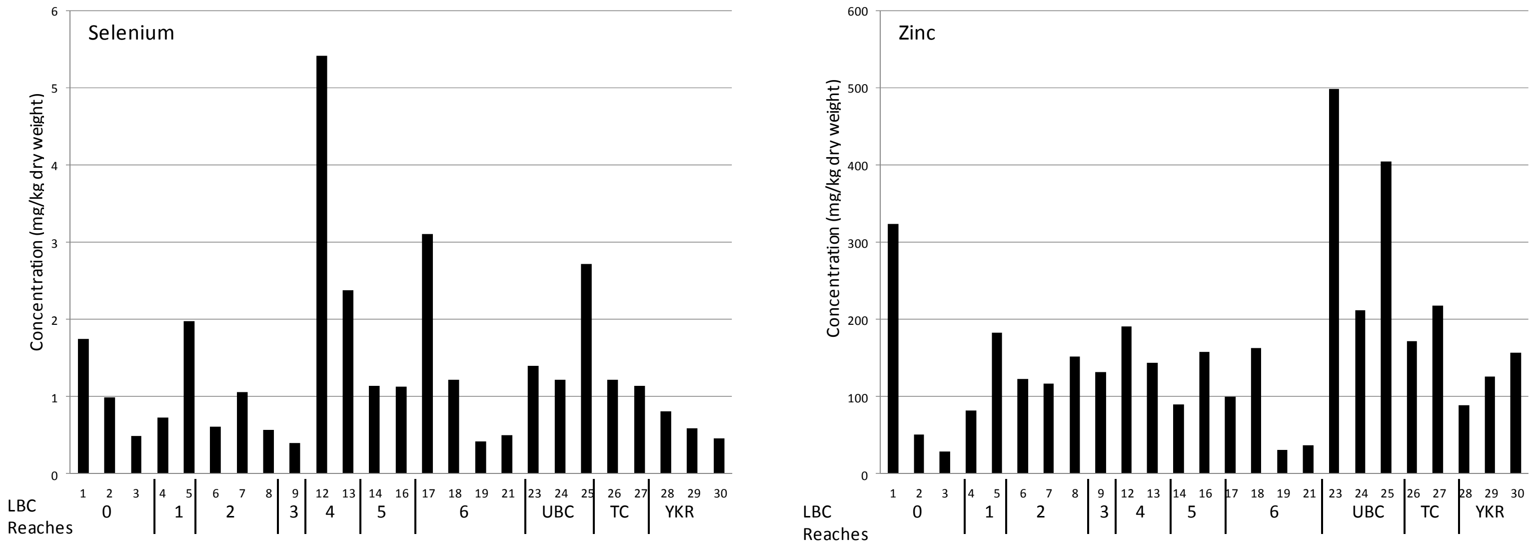


Figure 14: Concentrations of Selenium and Zinc in Depositional Benthic Invertebrate Tissues

Table 12: Summary of Primary COPCs in Depositional Benthic Invertebrate Tissues at Concentrations Above the Yellowknife River Reference Mean Value

Waterbody or Reach	Station	Primary COPCs That Exceed the Yellowknife River Reference Mean Value
LBC-Reach 0	1	**Antimony**, **Arsenic**, Cadmium, **Lead**, Manganese, Nickel, Selenium, **Zinc**
	2	**Antimony**, **Arsenic**, Lead, Manganese, Nickel
	3	**Antimony**, **Arsenic**, Lead, Manganese
LBC-Reach 1	4	**Antimony**, **Arsenic**, Copper, **Lead**, Manganese, Nickel
	5	**Antimony**, **Arsenic**, **Lead**, *Mercury*, Manganese, Nickel, Selenium
LBC-Reach 2	6	**Antimony**, **Arsenic**, Lead
	7	**Antimony**, Arsenic, Lead, Mercury, Nickel
	8	**Antimony**, **Arsenic**, **Lead**, **Nickel**
LBC-Reach 3	9	**Antimony**, **Arsenic**, Lead, Nickel
LBC-Reach 4	12	**Antimony**, Arsenic, Lead, Manganese, Mercury, Nickel, Selenium
	13	**Antimony**, **Arsenic**, Lead, Manganese, Nickel, Selenium
LBC-Reach 5	14	**Antimony**, **Arsenic**, Copper, Lead, Manganese, Nickel
	16	**Antimony**, **Arsenic**, **Lead**, Manganese, Nickel
LBC-Reach 6	17	**Antimony**, **Arsenic**, Lead, *Mercury*, Nickel, Selenium
	18	**Antimony**, **Arsenic**, Copper, **Lead**, Nickel
	19	**Antimony**, **Arsenic**, Lead
	21	**Antimony**, **Arsenic**, Lead, Manganese, Nickel
	21 (Split)	**Antimony**, **Arsenic**, **Lead**, Manganese, Nickel
Upper Baker Creek	23	**Arsenic**, Selenium, **Zinc**
	24	Antimony, **Arsenic**, Lead, Manganese, Nickel
	25	**Antimony**, **Arsenic**, *Mercury*, Selenium, **Zinc**
Trapper Creek	26	Antimony, **Arsenic**, **Lead**, Manganese, *Mercury*, Nickel, Selenium
	26 (Split)	Antimony, **Arsenic**, Lead, Manganese, Nickel
	27	Antimony, **Arsenic**, *Mercury*

Notes:

COPC is defined as: Contaminant of Potential Concern whose concentration is greater than two times the Yellowknife River reference mean value.

Italicised COPCs were compared to a YKR reference mean value that was below a reported detection limit (half the detection limit was used in the comparison).

COPC – [bolded] Concentration greater than ten times the Yellowknife River reference mean value.

LBC – Lower Baker Creek.

YKR – Yellowknife River.

Split – Field Split Sample.

The following relationships were noted when concentrations of primary COPCs in depositional invertebrate tissues were compared among stations in Baker Creek, Trapper Creek and the Yellowknife River:

Several primary COPCs were present in the mine-influenced watercourses at concentrations above the Yellowknife River reference mean, as summarized in Table 12.

- Arsenic in Baker and Trapper Creeks and antimony in Lower Baker Creek were most frequently present at concentrations more than 10 times the Yellowknife River reference mean.
- Lead concentrations were more than 10 times the Yellowknife River reference mean at six stations located throughout Lower Baker Creek, and at one station in Trapper Creek. Zinc was also present at concentrations more than 10 times the Yellowknife River reference mean at two stations in Upper Baker Creek and in Lower Baker Creek (Reach 0).
- Arsenic and antimony concentrations at the sampled stations in Baker and Trapper Creeks were greater than two times the Yellowknife River reference mean[6]. Lead, manganese and nickel concentrations were frequently greater than two times the Yellowknife River reference mean in these mine-influenced creeks, and selenium was periodically present at concentrations greater than two times the Yellowknife River reference mean.
- Concentrations of cadmium, copper and mercury were generally within the reference concentration range reported for the Yellowknife River, although the Yellowknife River concentration range was more variable for these metals compared to the other primary COPCs.

Periphyton

Concentrations of the 10 primary COPCs (i.e., antimony, arsenic, cadmium, copper, lead, manganese, mercury, nickel, selenium and zinc) were higher in periphyton collected from Lower Baker Creek compared to the Yellowknife River (Figure 15 to Figure 17). Concentrations of COPCs in periphyton appeared to be less variable among the Yellowknife River stations compared to the benthic invertebrate tissue samples. However, the majority of primary COPCs measured in periphyton in Lower Baker Creek were variable within and among designated reaches.

Periphyton concentrations of the majority of primary COPCs were at least two times the Yellowknife River reference mean concentration at stations in Lower Baker Creek (Table 13). Antimony and arsenic were present at concentrations more than 10 times the Yellowknife River reference mean at stations in Lower Baker Creek (Table 13). Periphyton copper and mercury concentrations were more than 10 times greater than the Yellowknife River reference mean at the majority of Lower Baker Creek stations.

Lead concentrations were greater than the Yellowknife River reference mean, mainly in the lower reaches of Baker Creek (i.e., Reaches 0, 1 and 2). For the most part, cadmium concentrations were greater than two times the Yellowknife River reference mean, but concentrations at Stations BCSS-ERO-02 and BCSS-ERO-11 were greater than 10 times the Yellowknife River reference mean.

[6] Except for the invertebrate sample collected from Station 23 in Upper Baker Creek

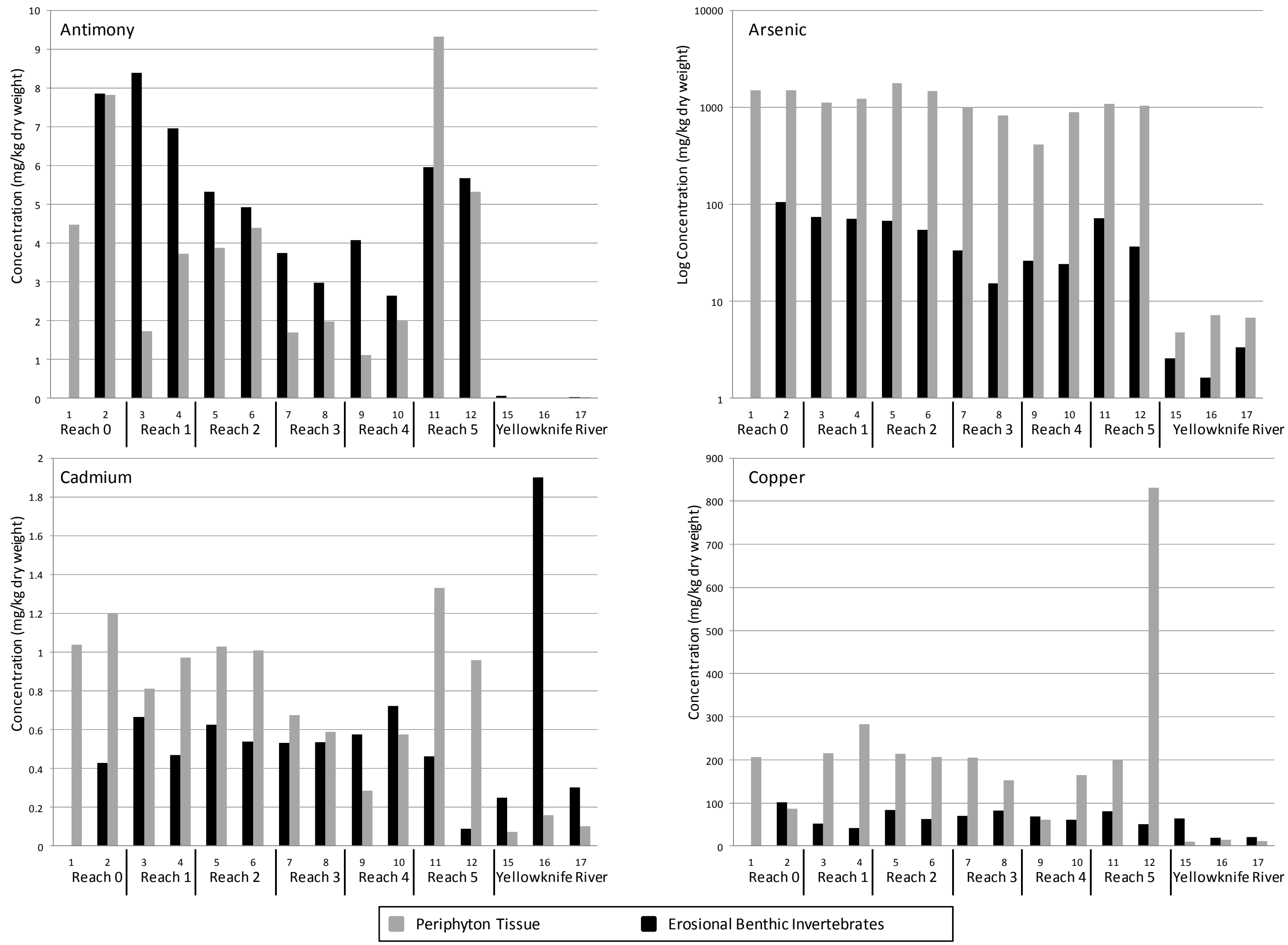


Figure 15: Concentrations of Antimony, Arsenic, Cadmium, and Copper in Periphyton and Erosional Benthic Invertebrate Tissues

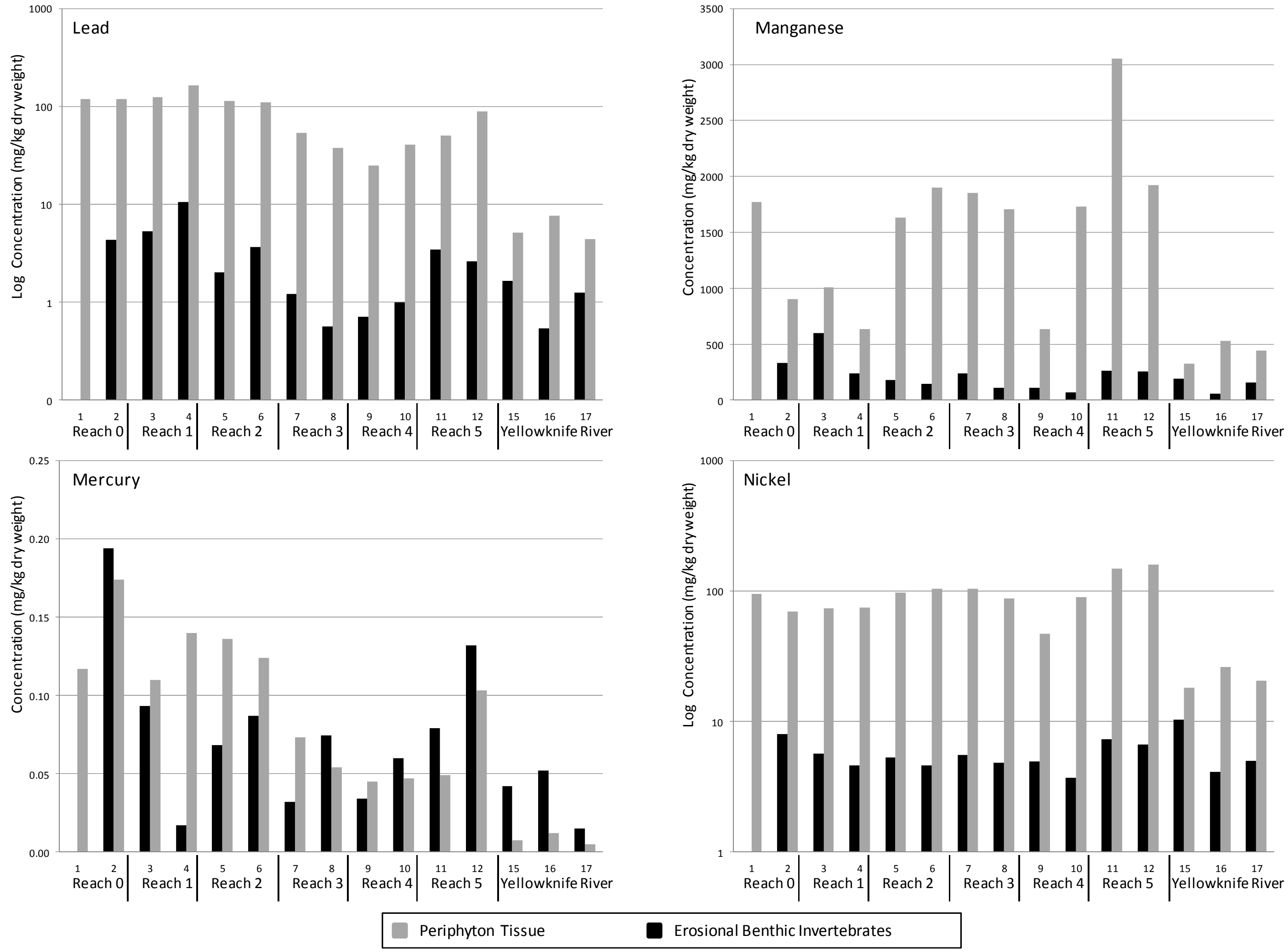
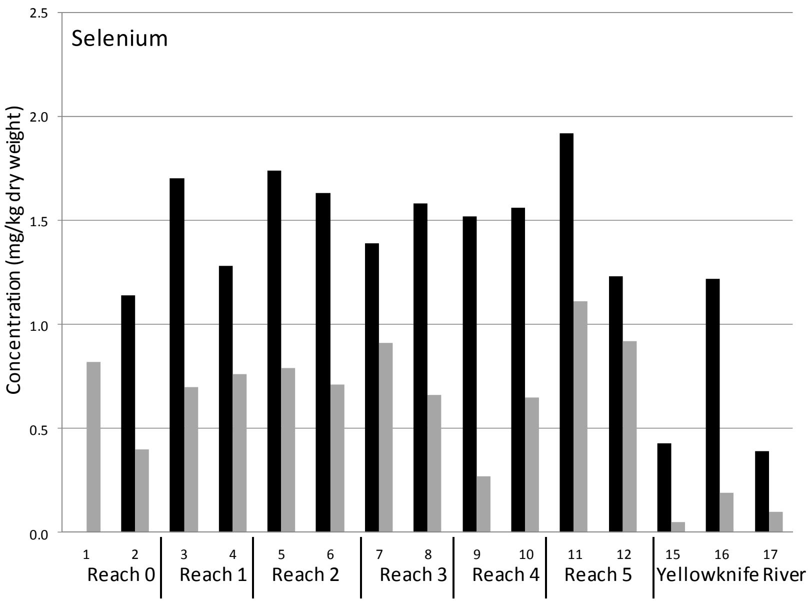


Figure 16: Concentrations of Lead, Manganese, Mercury and Nickel in Periphyton and Erosional Benthic Invertebrate Tissues



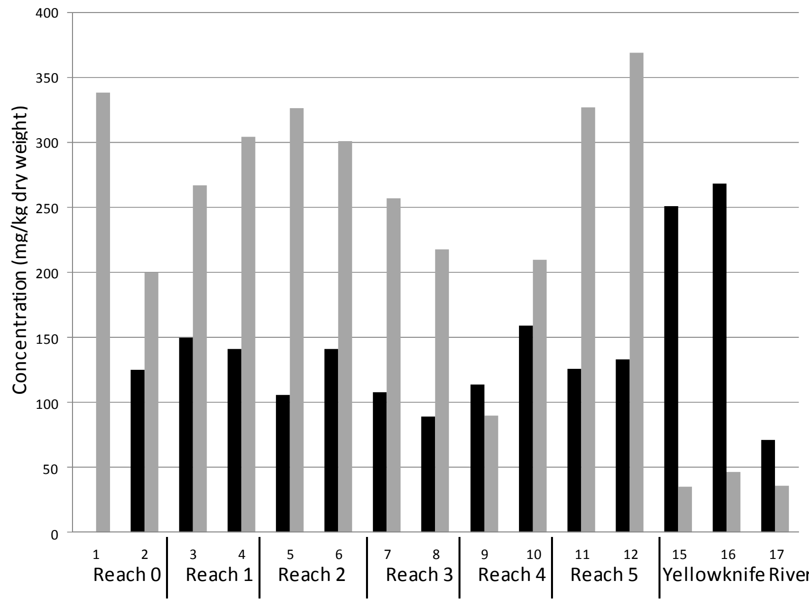


Figure 17: Concentrations of Selenium and Zinc in Periphyton and Erosional Benthic Invertebrate Tissues

Table 13: Summary of Primary COPCs in Periphyton Tissues Collected from Lower Baker Creek at Concentrations Above the Yellowknife River Reference Mean Value

LBC Reach	Station	Primary COPCs That Exceed the Yellowknife River Reference Mean Value
0	1	**Antimony, Arsenic**, Cadmium, **Copper, Lead,** Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
	2	**Antimony, Arsenic**, **Cadmium,** Copper, **Lead,** Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
1	3	**Antimony, Arsenic**, Cadmium, **Copper, Lead,** Manganese, ***Mercury***, Nickel, *Selenium*, Zinc
	4	**Antimony, Arsenic**, Cadmium, **Copper, Lead, *Mercury*,** Nickel, *Selenium*, Zinc
2	5	**Antimony, Arsenic**, Cadmium, **Copper, Lead,** Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
	6	**Antimony, Arsenic**, Cadmium, **Copper, Lead,** Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
3	7	**Antimony, Arsenic**, Cadmium, **Copper,** Lead, Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
	8	**Antimony, Arsenic,** Cadmium, **Copper,** Lead, Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc
	8 (Duplicate)	**Antimony, Arsenic,** Cadmium, **Copper,** Lead, Manganese, *Mercury*, Nickel, *Selenium*, Zinc
4	9	**Antimony, Arsenic,** Cadmium, Copper, Lead, *Mercury*, Nickel, *Selenium*, Zinc
	10	**Antimony, Arsenic,** Cadmium, **Copper,** Lead, Manganese, *Mercury*, Nickel, *Selenium*, Zinc
5	11	**Antimony, Arsenic**, **Cadmium, Copper,** Lead, Manganese, *Mercury*, Nickel, ***Selenium*****,** Zinc
	12	**Antimony, Arsenic**, Cadmium, **Copper, Lead,** Manganese, ***Mercury*****,** Nickel, *Selenium*, Zinc

Notes:

COPC – Contaminant of Potential Concern; Concentration greater than two times the Yellowknife River reference mean value.

COPC – [bolded] Concentration greater than ten times the Yellowknife River reference mean value.

Italicised COPCs were compared to a YKR reference mean value that was below a reported detection limit (half the detection limit was used in the comparison).

LBC – Lower Baker Creek.

YKR – Yellowknife River.

Duplicate – Field Duplicate Sample.

Erosional Invertebrates

Concentrations of primary COPCs measured in erosional invertebrates in Lower Baker Creek were typically lower than those measured in depositional invertebrate tissues (Appendix F, Tables F-5 and F-7). However, in the Yellowknife River this was not always the case, and invertebrate tissue concentrations tended to be similar between erosional and depositional habitats for most primary COPCs. Similar to the depositional invertebrate tissue dataset, concentrations of the majority of the primary COPCs measured in erosional invertebrate tissues were variable within and among reaches in Lower Baker Creek (Figure 15 to Figure 17). Variability in tissue concentrations was also evident in the Yellowknife River for a number of primary COPCs, notably cadmium, selenium and zinc.

Antimony was measured in invertebrate tissues at concentrations more than 10 times the Yellowknife River reference mean at the Lower Baker Creek erosional stations (Table 14). Arsenic concentrations were greater than 10 times the Yellowknife River reference mean at 8 stations, and between 2 and 10 times greater than the Yellowknife River reference mean at 3 stations.

Selenium concentrations at 8 stations and mercury concentrations at 7 stations were between 2 and 10 times greater than the Yellowknife River reference mean. Concentrations of copper and lead were greater than two times the Yellowknife River reference mean at six stations (Table 14).

Table 14: Summary of Primary COPCs in Erosional Benthic Invertebrate Tissues at Concentrations Above the Yellowknife River Reference Mean Value

LBC Reach	Station	Primary COPCs That Exceed the Yellowknife River Reference Mean Value
0	2	**Antimony, Arsenic**, Copper, Lead, Manganese, Mercury
1	3	**Antimony, Arsenic**, Lead, Manganese, Mercury, Selenium
	4	**Antimony, Arsenic**, Lead
2	5	**Antimony, Arsenic**, Copper, Selenium
	6	**Antimony, Arsenic**, Lead, Mercury, Selenium
3	7	**Antimony, Arsenic**, Copper, Selenium
	8	**Antimony,** Arsenic, Copper, Mercury, Selenium
	8 (Split)	**Antimony,** Arsenic, Copper, Mercury, Selenium
4	9	**Antimony, Arsenic**, Selenium
	10	**Antimony,** Arsenic, Selenium
5	11	**Antimony, Arsenic**, Copper, Lead, Mercury, Selenium
	12	**Antimony, Arsenic**, Lead, Mercury

Notes:

COPC is defined as: Contaminant of Potential Concern whose concentration is greater than two times the Yellowknife River reference mean value.

COPC – [bolded] Concentration greater than ten times the Yellowknife River mean value.

LBC – Lower Baker Creek.

YKR – Yellowknife River.

Split – Field Split Sample.

Potential for Biomagnification

Concentrations of the primary COPCs were higher in periphyton tissues than in erosional invertebrate tissues, with the exception of antimony, mercury and selenium, which tended to be present at higher concentrations in invertebrate tissues. Mercury is known to biomagnify within aquatic food chains as methyl mercury (MeHg), whereas antimony is not known to biomagnify (e.g., Campbell et al. 2005). Selenium is similar to mercury, in that dietary uptake and bioaccumulation of organic forms of these metals/metalloids can result in adverse effects at higher trophic levels. However, as discussed by Hodson et al. (2010), the propensity of mercury to biomagnify as methyl mercury is far greater than for organo-selenium compounds. Biomagnification is defined in Chapman (2011) as: "*Uptake of one or more of certain organic contaminants (e.g., methyl mercury, PCBs – not all organic contaminants biomagnify) via dietary uptake through a food chain resulting in increasing concentrations through three or more trophic levels. Inorganic substances such as metals (e.g., inorganic mercury) and metalloids do not biomagnify.*"

The relative difference in mercury concentrations between invertebrates and periphyton was most pronounced at Lower Baker Creek Stations BCSS-ERO-04, BCSS-ERO-05, BCSS-ERO-06, and BCSS-ERO-07 (periphyton concentration > invertebrate concentration), and the Yellowknife River (invertebrate concentration > periphyton concentration) (Figure 16). For other stations in Lower Baker Creek, mercury concentrations in periphyton and invertebrates were similar. In contrast, selenium concentrations were consistently higher in erosional invertebrate tissues compared to periphyton collected from stations located in Baker Creek and the Yellowknife River (Figure 17).

4.5.3.2 Secondary Aquatic COPCs

Aquatic COPCs identified in Section 4.1.2 that were considered to be secondary with respect to the assessment of metals in benthic invertebrate and periphyton tissues in Baker Creek were beryllium, chromium, iron, and silver[7].

The following observations were made for concentrations of secondary COPCs in depositional benthic invertebrate tissues sampled in Baker and Trapper Creeks, and in the Yellowknife River:

- Beryllium concentrations at the Baker Creek stations ranged between <0.010 and 0.106 mg/kg, with the higher concentrations reported for pooled Reaches 0/1 and 4/5 (Appendix F, Table F-5). Reference concentrations in the Yellowknife River spanned a narrower range, with a lower maximum value (i.e., <0.020 to 0.050 mg/kg). A higher concentration of 0.253 mg/kg[8] was reported for Station BCSS-DEP-26 in Trapper Creek (Table 9).
- Chromium and iron concentrations were elevated in Baker and Trapper Creeks compared to the Yellowknife River (Appendix F, Table F-5). Mean chromium concentrations in pooled Reaches 0/1, 2/3, 4/5, and Upper Baker Creek were approximately two to three times the Yellowknife River reference mean. Mean iron concentrations in pooled Reaches 0/1, 2/3, 4/5 were approximately two to four times the Yellowknife River reference mean. Maximum chromium and iron concentrations were <10 times the Yellowknife River reference mean.

[7] Silver tissue data were not available (see Section 4.5.2.2).

[8] Average of two split samples collected from Station BCSS-DEP-26 in Trapper Creek.

- In Reach 6, chromium and iron concentrations were mostly within the reference concentration range, whereas the highest concentrations of both metals were reported for Station BCSS-DEP-26 in Trapper Creek (Table 9).

The following observations were made regarding concentrations of secondary COPCs in periphyton tissues at stations sampled in Baker and Trapper Creeks, and the Yellowknife River:

- Beryllium concentrations in periphyton at Lower Baker Creek stations spanned a similar concentration range to that reported for reference stations in the Yellowknife River (Appendix F, Table F-6).
- Mean chromium and iron values for the pooled reaches in Lower Baker Creek were up to two times higher than the corresponding Yellowknife River reference mean concentration (Appendix F, Table F-6). The maximum chromium concentration reported in Lower Baker Creek was 2.5 times the Yellowknife River reference mean concentration, whereas the maximum iron concentration reported in Lower Baker Creek was 2.3 times the Yellowknife River reference mean.

The following observations were made regarding concentrations of secondary COPCs in erosional invertebrate tissues at Lower Baker Creek stations:

- Concentrations of beryllium and chromium spanned a higher concentration range at the Yellowknife River reference stations, compared to Lower Baker Creek where concentrations were below DLs (Appendix F, Table F-7). Within the Yellowknife River reference area, beryllium concentrations at Station BCSS-ERO-15 were three times higher than at the other two reference stations.
- The Yellowknife River reference mean for chromium was three to four times higher than the mean values calculated for the pooled reaches in Lower Baker Creek. The Yellowknife River reference mean for iron was 2.5 to 5 times higher than the mean values calculated for the pooled reaches in Lower Baker Creek. Within the Yellowknife River reference area, chromium and iron concentrations at Stations BCSS-ERO-15 and BCSS-ERO-17 were approximately three times higher than at Station BCSS-ERO-16.

4.5.3.3 Summary

Concentrations of the majority of primary COPCs measured in periphyton and benthic invertebrate tissues were variable within and among designated reaches in Lower Baker Creek, Upper Baker Creek, and Trapper Creek. Variability in benthic invertebrate tissue concentrations was also evident in the Yellowknife River for a number of primary COPCs, notably cadmium, copper, manganese and mercury. By comparison, concentrations of primary COPCs in periphyton appeared to be less variable among the Yellowknife River stations.

For a number of primary COPCs there was large spatial variability in tissue metals concentrations within Baker Creek and/or within the Yellowknife River reference area, which confounded the comparison between exposure and reference stations. For some primary COPCs, such as antimony and arsenic, the relative difference between concentrations at mine-influenced stations and reference stations was large enough to detect by visual examination, and spatial variability posed less of an issue.

It is likely that the variation in tissue metals concentrations in benthic invertebrates and periphyton reflects a number of factors, including concentrations in water and bottom sediments, and the taxonomic composition of tissue samples. The influence of sediment COPC concentrations on invertebrate tissue concentrations is evaluated further in Section 4.9.2. The influence of taxonomic composition could not be evaluated based on the available data.

Concentrations of antimony and arsenic in benthic invertebrate tissues were most frequently present in Lower Baker Creek at concentrations more than 10 times the Yellowknife River reference mean. Arsenic was most frequently present in Upper Baker Creek and in Trapper Creek tissue samples at concentrations more than 10 times the Yellowknife River reference mean. In periphyton, concentrations of antimony, arsenic and copper in Lower Baker Creek were most frequently more than 10 times the Yellowknife River reference mean. Concentrations of lead and mercury in periphyton were also frequently more than 10 times the Yellowknife River reference mean.

4.6 Fish Tissue Chemistry Line of Evidence

4.6.1 Methods

4.6.1.1 Chemistry Analyses

Large-bodied fish tissues (i.e., muscle filet and liver) from individual fish were submitted for chemical analyses, whereas individual small-bodied fish were combined to form composite samples to yield sufficient sample size (i.e., sample mass) for the chemical analyses (Appendix G, Table G-1). Whenever possible, composite samples were composed of similar sized fish. Large-bodied fish tissue samples (i.e., muscle filet and liver from Northern Pike and Lake Whitefish) were also submitted for arsenic bioaccessibility and arsenic speciation analyses.

Total Metals

Fish tissue metals analyses were performed by ALS (Burnaby, BC). Tissue mercury analyses were carried out using methods adapted from USEPA Method 200.3 *Sample Procedures for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues*. Tissue samples were homogenized and subsampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was performed by atomic fluorescence spectrophotometry, adapted from USEPA Method 245.7. Lipid analysis was carried out using procedures adapted from the *Official Methods of Analysis of AOAC International, Method 983.23, 16th Edition, 3rd Revision, 1997*. The procedure involved a solvent extraction of a subsample of the tissue using a combination of chloroform and methanol in the presence of an enzyme. The extract was then evaporated to dryness and the residue weighed to determine lipid content. Metals in tissue were analysed by high resolution ICP-MS modified from USEPA Method 200.8, (Revision 5.5). The sample preparation procedure was modified from USEPA Method 200.3. Analytical results were reported on a wet weight basis. The method for total metals in tissue was adapted from USEPA Method 200.3 *Sample Procedures for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues*. Tissue samples were homogenized and subsampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was by Inductively Coupled Plasma - Optical Emission Spectrophotometry (ICP-OES), adapted from USEPA Method 6010B, and results were reported on a wet weight basis. Tissue moisture analyses were carried out gravimetrically by drying the sample at 105°C for a minimum of six hours.

Arsenic Speciation and Bioaccessibility (Large-bodied Fish Tissue)

Arsenic speciation analyses of large-bodied fish for total arsenic, inorganic arsenic (combined As^{III} and As^{V}) and organic arsenic (monomethylarsonic acid [MMA], dimethylarsenic acid [DMA], arsenobetaine [AB], trimethylarsine oxide [TMAO], arsenocholine [AC], tetramethylarsonium ion [TETRA], and arsenosugars) were performed by the Environmental Sciences Group (ESG) at the Royal Military College of Canada (RMC; Kingston, ON). Arsenic speciation analyses were performed subsequent to the bioaccessibility extractions and, therefore, these analyses represent the speciation of bioaccessible arsenic only and not the total arsenic present in the sample. The chemical extraction process used in ESG-RMC's arsenic bioaccessibility and speciation analyses mimics the human digestive chemical milieu and measures the chemical form in which arsenic exists in tissue samples, thus providing information for the human health assessment.

Detailed methods for the large-bodied fish arsenic speciation analyses are provided in Appendix G. Briefly, samples were freeze-dried and ground prior to analyses to obtain homogenous samples. To obtain the bioaccessible arsenic for the human receptor of food, the ESG Glycine method was employed (Appendix G). All extracts were analysed for total arsenic by ICP-MS. Total arsenic in fish samples was obtained by nitric acid digestion and analysis using ICP-AES. Speciation analysis was carried out on the extracts by high performance liquid chromatography (HPLC) and ICP-MS. The HPLC method was anion exchange chromatography, and cation exchange chromatography was carried out to confirm the identification of AB in the samples. The following species (as standards) could be separated by the methods used: inorganic As^{III} and As^{V}, AB, DMA, MMA, arsenosugars, TMAO, AC, and TETRA. Inorganic arsenic refers to the sum of As^{III} and As^{V}; they are reported in this way since no attempt was made to prevent their inter-conversion during the analyses, and because in solution they behave in a toxicologically similar fashion.

Arsenic Speciation (Small-bodied Fish Tissue)

Small-bodied fish arsenic speciation analyses measured inorganic arsenic (sum of As^{III} and As^{V}) and organic arsenic (MMA and DMA). These analyses were performed by ALS Environmental's specialist laboratory in Sweden. Small-bodied fish arsenic speciation was conducted on extracts by anion chromatography and hydride generation by ICP-MS. Briefly, extracts were analysed by ion chromatography (IC; Hamilton PRP-X100 column in a Bischoff gradient system) with post column hydride generation and detection by ICPMS (Thermo Fisher Element 2). The use of hydride generation provided improved sensitivity and thus better limits of reporting, but meant that only As^{III}, As^{V}, DMA, and MMA were measured in small-bodied fish (i.e., Slimy Sculpin) tissue.

4.6.1.2 Data Interpretation

Fish tissue metal concentrations were interpreted by comparison with both newly collected samples from reference areas (e.g., Yellowknife River) and with available data from the literature from other areas in the region. Data from early years (1972) were excluded from interpretation as they were deemed too old to be representative of current conditions at the Site. This is consistent with the approach taken in the Human Health Assessment described in Section 5.0. To perform summary statistics on the tissue chemistry data, a value of one-half the DL was substituted for non-detected values. Similarly, a value of one-half the DL was substituted for non-detected arsenic speciation data, and where trace concentrations were reported (i.e., trace amounts observed, but values less than the reporting limit); samples were removed entirely from the analysis for that parameter in the calculation of summary stats (Appendix G, Table G3). Where tissue chemistry data were presented in the literature as dry weight, a wet weight conversion factor of 0.2 was applied, based on an approximate 80% moisture content of fish tissue (i.e., muscle). This conversion factor was applied to data from Dillon (2002b) and de Rosemond et al. (2004). The datasets used for calculation of summary statistics were the same as those used for the human health COPC screening (Section 5.1.1.3), but data interpretation was limited to those metals identified in the COPC screening for aquatic life (Table 3).

The Canadian Food Inspection Agency (CFIA 2011) has established guidelines for fish and fish products intended for consumption for arsenic, lead, and mercury. However, only the mercury guideline applies to edible fish tissues (i.e., these regulations only apply to fish intended for commercial sale and not personal consumption). Consideration of fish tissue concentrations as they relate to human consumption is presented in the Human Health Assessment (Section 5.0); therefore, all discussion of fish tissue metal concentrations here is presented relevant to appropriate reference areas rather than to guidelines.

4.6.2 Quality Assurance/Quality Control (QA/QC)

Upon receipt from the laboratory, analytical data were reviewed and any unexpected results (e.g., high arsenic concentrations in Arctic Grayling tissue) were revisited and follow-up was requested. The laboratory confirmed the accuracy of these results. For the fish tissue analyses, DLs were raised for a number of samples due to target analytes being measured at comparable concentrations in the method blank. These parameters included lithium, strontium, yttrium, and zinc. A total of 31 samples were affected for the lithium and zinc analyses. It was also noted the Slimy Sculpin fish tissue samples collected in 2010 exceeded the recommended hold time for mercury and lipid analyses. As per the benthic invertebrate and periphyton tissue chemistry QA/QC (see Section 4.5.2), the fish tissue samples underwent the standard acid digestion procedure for metals, and the digested extract was analysed for silver. The silver concentrations detected in the tissue samples were within the range where silver may become unstable and precipitate during the analysis, using the standard digestion procedure for metals. Therefore, ALS deemed the silver analytical data to be potentially unreliable, and silver concentrations were not reported for fish tissue. The tissue samples have been placed on extended hold at ALS and, provided there is sufficient tissue available, which still needs to be determined, these samples could be re-analysed using an acid digestion procedure specific to silver analysis in tissues (Can Dan, ALS Environmental, pers. comm.). However, at present such re-analyses do not appear to be necessary.

All data were reviewed and screened for data entry errors, and any data that appeared questionable related to known biological processes of metals accumulation and excretion.

4.6.3 Results and Discussion

There was large variability in metal concentrations between fish species, tissues, and locations (Appendix G, Table G-2). Concentrations of many aquatic life COPCs (e.g., aluminum, chromium, lithium, nickel, thallium and zinc) were present at equal or higher concentrations in fish collected from the Yellowknife River compared to Baker Creek, indicating exposure to these metals is not likely related to Giant Mine historical contamination in Baker Creek.

Within Baker Creek, there were large variations in concentrations of metals among the different reaches. Reaches 1 and 6 consistently had the highest fish tissue metals concentrations. Further, there were differences among reaches based on fish species and tissue types (Appendix G). Figures G-1 to G-26, referenced throughout Section 4.6.3, are provided in Appendix G. Notable patterns for fish tissue metals concentrations among fish species (and tissue types) are summarized below.

4.6.3.1 Arctic Grayling

For most metals, mean concentrations in whole-body YOY Arctic Grayling were greater than in adult fish tissues (Appendix G, Table G2). The YOY Arctic Grayling spend up to one month in Baker Creek and are actively feeding. Adult Arctic Grayling migrate seasonally to and from the immediate study area and stay in the creek a maximum of two to three weeks, and seem to have reduced foraging during spawning.

- Arctic Grayling adults have lower concentrations of tissue metals than YOY, with the exceptions of lithium (i.e., below detection in both adults and YOY) and mercury (i.e., higher in adult muscle than YOY whole body). Thallium was not measured in adult fish and cannot be compared. This pattern of lower concentration is consistent with a previous study of Arctic Grayling YOY from Baker Creek in 2009 (Golder 2010b). Sample sizes of adult tissues are low and limit conclusions.
- Aluminum concentrations in Arctic Grayling YOY collected from Reach 1 were 16 times higher than aluminum concentrations from fish collected from Reach 0 in 2009, and were 2 times higher those collected from Reach 4 in 2009.
- It is possible that the higher YOY Arctic Grayling metal concentrations are due to elevated viscera concentrations and, therefore, may not represent assimilation of metals into the muscle or liver tissues (i.e., the young hatch in Baker Creek, eat plankton and invertebrates with elevated metal concentrations, and these food items are in the stomach or digestive tract at the time of sampling). The determination of which tissues in YOY Arctic Grayling have elevated concentrations of metals, and of arsenic in particular, is beyond the scope of the present project.
- The level of arsenic in adult Arctic Grayling ovaries in 2009 was elevated in comparison to Grayling flesh and liver, which may or may not indicate the potential for maternal effects. Arctic Grayling YOYcollected in Reach 1 in 2011 had higher concentrations of aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, thallium, and zinc compared to Arctic Grayling collected from Reach 0 and Reach 4 in 2009.
- The difference in arsenic concentrations between whole-body YOY collected in 2011 and 2009 was large; fish collected from Reach 1 in 2011 had arsenic concentrations 14 times higher than Reach 0 and four times higher than Reach 4 in 2009 (Appendix G, Table G2). This could indicate that the overflow event in May 2011 mobilized arsenic into the creek, and this arsenic was bioavailable to resident fish species.
- There are no Arctic Grayling tissues from a reference area for the present study. However, many of the metals have higher concentrations in Baker Creek adult and YOY Arctic Grayling compared to 1996 Arctic Grayling reference results from other areas in the Northwest Territories including Nahanni River, Lac de Gras and Lac du Sauvage (Golder 2010b). The relevance of these areas for comparison is not fully known given that their geology is not similar to Baker Creek.

4.6.3.2 Northern Pike

Northern Pike metal concentrations were higher in liver than in muscle tissue, with the exception of aluminum, arsenic, lithium, and mercury (Appendix G, Table G2). Lithium concentrations were below detection level in both liver and muscle tissues. The high liver metal concentrations may be indicative of elevated metal exposures while the fish were resident in Baker Creek. It is not fully known if the tissue metal burdens of adult Northern Pike directly represent conditions in Baker Creek as Northern Pike are thought to seasonally migrate in and out of the creek. However, given that Reach 6 has sufficient depth to allow overwintering, it may be that some Northern Pike are resident in the creek.

- Northern Pike muscle collected from Reach 1 had aluminum concentrations 14 times higher than those collected from Reach 6 and 43 times higher than those collected from the Yellowknife River (Appendix G, Table G2). Tissue concentrations were higher in 2011 in both liver and muscle tissues compared to 2002 in Baker Creek, and from tissues collected from the reference areas. The elevated aluminum concentrations in Baker Creek Reach 1 are consistent in both Arctic Grayling and Northern Pike.
- Arsenic concentrations in Northern Pike were highest in muscle filets collected from Reach 6 and Reach 1. Mean liver arsenic concentrations in Reach 6 were 2 times higher than Reach 1, 7 times higher than Reach 0, and 15 times higher than samples collected from the Yellowknife River (Appendix G, Table G2). Mean liver arsenic concentrations were 2.5 times higher in Northern Pike collected from Reach 6 than in Reach 1, and 88 times higher than liver arsenic concentrations from Northern Pike collected from Yellowknife River (Appendix G, Table G2). These results indicate arsenic is bioavailable to large-bodied fish that reside seasonally in Baker Creek.
- Mercury was present at comparable concentrations in Northern Pike muscle filets collected from Reach 1 and Reach 6, and these concentrations were approximately 2.5 times higher than those measured in the Yellowknife River (Appendix G, Table G2).

4.6.3.3 Lake Whitefish

Lake Whitefish liver and muscle samples were collected in 2011 from both Baker Creek and the Yellowknife River (Appendix G, Table G1). Tissue metal concentrations were generally higher in liver compared to muscle, and lithium concentrations were below detection in both tissue types.

- The trend of elevated aluminum concentrations in Baker Creek that was seen in YOY Arctic Grayling and adult Northern Pike was absent in Lake Whitefish. Liver aluminum concentrations were two times higher in Yellowknife River compared to fish collected from Baker Creek (Appendix G, Table G2).
- Lake Whitefish liver and muscle arsenic concentrations were higher in Baker Creek Reach 6 compared to Lake Whitefish collected from Yellowknife River (Appendix G, Table G2). Mean liver arsenic concentrations were 5 times higher in Baker Creek Reach 6 than in the Yellowknife River. Muscle arsenic concentrations were three times higher in Baker Creek Reach 6 than in the Yellowknife River.

- Arsenic concentrations in Lake Whitefish muscle and liver tissue collected from Back Bay in 2003 were comparable to 2011 reference area concentrations (Appendix G, Table G2). Consistent with Northern Pike tissue data, these results for Lake Whitefish indicate arsenic is bioavailable to large-bodied fish that seasonally inhabit or reside in Baker Creek.
- Mean mercury concentrations in Lake Whitefish muscle was comparable between Baker Creek Reach 6 and Yellowknife River (Appendix G, Table G2). Liver mercury concentrations were higher in the reference area compared to Baker Creek Lake Whitefish. Comparisons between the size and age of fish and mercury body burdens were not made.

4.6.3.4 Ninespine Stickleback

Ninespine Stickleback whole body samples were collected from Baker Creek Reach 0 and Yellowknife River in 2011. Viscera and liver tissue arsenic data were available from Horseshoe Island Bay (i.e., another regional reference area) and Jackfish Bay (i.e., another regional historically mine-impacted area) (Appendix G, Table G1) from 2007 and 2009, respectively (Appendix G, Table G1). Most metals were higher in whole body Ninespine Stickleback collected from Baker Creek than Yellowknife Bay, with the exception of mercury.

- Whole-body mean aluminum concentrations in Ninespine Stickleback were three times higher in Baker Creek Reach 0 than in Yellowknife River (Appendix G, Table G2), making the trend from YOY Arctic Grayling and adult Northern Pike consistent with the findings in Ninespine Stickleback, a small-bodied fish that spends a portion of its life in Baker Creek.
- Mean whole-body Ninespine Stickleback arsenic concentrations from Baker Creek Reach 0 were two times higher than those measured in the Yellowknife River in 2011 (Appendix G, Table G2). These concentrations of arsenic are comparable to those measured in viscera collected from Ninespine Stickleback from Jackfish Bay in 2009 (Appendix G, Table G2) (Golder 2010d). These results suggest, at least in small-bodied fish species, that a large proportion of whole body arsenic is located in the viscera.
- Liver arsenic concentrations were low for fish from both Jackfish Bay (downstream of another contaminated site) and Horseshoe Island Bay (a local reference area) (Appendix G, Table G2) (Golder 2012d), further indicating whole-body arsenic body burden could be associated with viscera rather than liver-specific contamination in these small-bodied fish.
- Mean mercury concentration in whole body Ninespine Stickleback collected from Baker Creek Reach 0 was less than the whole body mercury concentration in Ninespine Stickleback collected from Yellowknife River (Appendix G, Table G2).

4.6.3.5 Slimy Sculpin

Adult Slimy Sculpin whole body samples (excluding gonads and otoliths) were collected in 2010 from Reach 0 of Baker Creek and the Yellowknife River. The adult Slimy Sculpin collected in Baker Creek will have spent their entire lives in close proximity to the location in which they were collected, and have been in close association with the sediment throughout their lives.

- Mean aluminum concentrations in whole body Slimy Sculpin were 1.5 times higher in Baker Creek relative to the Yellowknife River (Appendix G, Table G2), consistent with the trend of elevated aluminum concentrations in YOY Arctic Grayling, adult Northern Pike, and Ninespine Stickleback.
- Slimy Sculpin collected from Reach 0 had 41 times higher concentrations of arsenic than Slimy Sculpin collected in the Yellowknife River (Appendix G, Table G2). As with YOY Arctic Grayling, it is possible the high arsenic concentrations in whole body Slimy Sculpin are due to elevated viscera concentrations rather than incorporation into liver or other body tissues, but this would need to be confirmed. The present results indicate that arsenic in Baker Creek is bioavailable to resident fish species. The implications of such high arsenic concentrations on fish health, and on wildlife consumers of fish, is unknown and beyond the scope of the present study.
- Mean whole body mercury concentration in Slimy Sculpin from Baker Creek was comparable to that in fish collected from Yellowknife River (Appendix G, Table G2).

4.6.3.6 Burbot

Although only one Burbot was collected upstream of Reach 6 in 2002 (Dillon 2002) and no additional fish samples were available during the 2011 fish collections, this single Burbot from 2002 had the second highest measured arsenic from all areas (Appendix G, Table G2). The cause of this elevated arsenic concentration is unknown, and Burbot concentrations warrants further investigation. There were no Burbot available from the reference area for comparison; there are generally very few Burbot in Baker Creek. Burbot in Yellowknife Bay or Back Bay would be the relevant sampling area.

4.6.3.7 Other Fish Species

Longnose Sucker, White Sucker, Shiner species, Northern Pike, Lake Whitefish and Walleye were collected from other areas in the region in 2002, 2003 and 2007, and are discussed for perspective on interspecies variability in arsenic concentrations in liver and muscle tissues, and for insight towards concentrations of arsenic in species collected outside, but close to, Baker Creek.

- Longnose Sucker and White Sucker collected from Back Bay in 2003 had the highest concentrations of arsenic in liver tissue relative to all other species collected in Back Bay (Appendix G, Table G2). Muscle tissue arsenic concentrations were also higher in Longnose Sucker collected from Back Bay in 2003. Northern Pike from this study had the highest liver concentrations, particularly the fish from Reach 6.

- Walleye collected in Back Bay had liver and muscle arsenic concentrations comparable to Lake Whitefish collected from the same area (Appendix G, Table G2). Liver arsenic concentrations in Walleye were higher than liver concentrations in Northern Pike, while Walleye muscle arsenic concentrations were lower than Northern Pike. As with the present study, these results indicate there are interspecies differences in the tissue type where the highest arsenic concentrations are observed.
- Additional small-bodied fish data was available for Shiner species collected in 2007 from another regional exposure area of a contaminated area, Jackfish Bay, and the regional reference area, Horseshoe Island Bay (Appendix G, Table G1). Whole body Shiner species had elevated arsenic concentrations in Jackfish Bay relative to Horseshoe Island Bay. These results indicate another regional historically contaminated mine site has biologically available arsenic that is taken up by resident small-bodied species.

4.6.3.8 Arsenic Speciation

Different arsenic species exhibit different levels of toxicity. It is most accurate to consider three levels of toxicity, where inorganic arsenic is considered toxic, organoarsenicals (e.g., DMA, MMA, etc.) are potentially toxic, and AB is the only definitively non-toxic arsenical (Appendix G, Statement on Toxicity of Arsenic Species).

There are higher concentrations of bioaccessible arsenic in muscle and liver tissue from Northern Pike and Lake Whitefish collected from Baker Creek compared to the same species collected from the Yellowknife River (Appendix G, Table G3); Northern Pike liver tissue from Baker Creek have approximately 10 times higher concentrations of bioaccessible arsenic than liver from Northern Pike in the Yellowknife River. Of the total arsenic present in tissue samples, the percentage of arsenic that is bioaccessible (i.e., the percentage of total arsenic in these fish tissues that would be absorbed by a human consuming the tissues, which may include liver) is comparable between Baker Creek and Yellowknife River. Therefore, the relationship between total arsenic and percent arsenic bioaccessibility can be summarized as follows:

- There is more arsenic present in fish tissues collected from Baker Creek (i.e., total arsenic concentrations are higher in Baker Creek),
- There is more bioaccessible arsenic present in fish tissues at Baker Creek (i.e., bioaccessible arsenic concentrations are higher in Baker Creek), and,
- Percent bioaccessible arsenic in fish tissues at Baker Creek (i.e., the proportion of arsenic in the tissue that is bioaccessible) is similar between Baker Creek and Yellowknife River.

Therefore, because there are higher concentrations of total arsenic present in fish tissue in Baker Creek, and because percent bioaccessibility is the same between Baker Creek and Yellowknife River, a greater amount of arsenic could be absorbed by consumers of fish from Baker Creek than Yellowknife River simply because there are higher concentrations of arsenic present in the fish tissues from Baker Creek. Percent bioaccessible arsenic is highest in Northern Pike liver tissue (approximately 70 to 90%) and Lake Whitefish muscle tissue (approximately 85 to 90%). It is unknown if these bioaccessibility measurements translate directly to comparable assimilation efficiencies in wildlife consumers of fish tissues, as the analytical procedure and extraction technique used to determine arsenic bioaccessibility in large-bodied fish tissues mimicked the human digestive system.

Upon further analysis of the bioaccessible arsenic fraction from large-bodied fish tissues (i.e., proportion of the bioaccessible arsenic present in the various forms), Northern Pike collected from Reach 6 had the highest concentrations of inorganic arsenic and DMA compared to fish collected from either Reach 1 or the Yellowknife River (Appendix G, Table G3). Concentrations of inorganic arsenic in Lake Whitefish liver bioaccessible extractions were below detection at Baker Creek Reach 6 and the Yellowknife River. Lake Whitefish collected from Baker Creek had higher concentrations of DMA, MMA, AB, TMAO, and TETRA than Lake Whitefish collected from the Yellowknife River. Concentrations of arsenosugars were below detection in fish tissues collected from all sites, with the exception of Northern Pike muscle from Reach 6. These results indicate the most toxic form of arsenic (i.e., inorganic arsenic), and the potentially toxic forms (e.g., DMA, MMA) are bioaccessible and present in large-bodied fish and, therefore, are available to humans, and likely to wildlife consumers, at higher concentrations in Baker Creek than the Yellowknife River.

The small-bodied resident fish Slimy Sculpin provide the best indication of arsenic speciation concentrations in Baker Creek, where they spend their entire life in close proximity to the sediment. The arsenic speciation analysis for Slimy Sculpin were performed differently than for the large-bodied fish; extraction procedures did not isolate only bioaccessible arsenic (i.e., arsenic made available by human digestion). Total arsenic speciation concentrations were measured directly in the small-bodied fish tissues and, therefore, represent actual speciation in the fish tissues without any assumption of fish consumer (i.e., humans or wildlife) processing. Slimy Sculpin inorganic arsenic, DMA and MMA concentrations were 12 to 14 times higher in Reach 0 of Baker Creek relative to the Yellowknife River, indicative of elevated concentrations of these forms of arsenic in the sediment of Baker Creek (Appendix G, Table G3).

In summary, more total arsenic and bioaccessible arsenic is present in large-bodied fish tissues collected at Baker Creek than in the Yellowknife River. Concentrations of total arsenic, inorganic arsenic, DMA and MMA are higher in Slimy Sculpin from Baker Creek than Yellowknife River, indicating elevated concentrations of arsenic in the sediment of Baker Creek are bioavailable to both small- and large-bodied fish species.

4.6.3.9 Fish Community

On the basis of limited fishing in September 2011, no fish were captured in Trapper Lake. No fish tissue was collected. Further surveys during spring flows could be done to confirm the absence of fish. However, because the maximum depth of Trapper Lake is 1.3 m and overwintering habitat is limited, fish presence in this lake is thought to be unlikely.

Fishing was done over two days in September 2011 in lower Martin Lake. Six species of fish were captured: Lake Whitefish, Cisco, Lake Whitefish-Cisco hybrid, Ninespine Stickleback, Northern Pike, and Walleye. Fish were archived for tissue analysis. Data on total numbers of fish and sizes of fish captured can be provided upon request.

4.7 Sediment Toxicity Line of Evidence

4.7.1 Methods

A tiered approach was applied to the sediment toxicity testing program, to determine which sediments from the 29 depositional stations merited such testing. Samples were stored until the results of the depositional sediment chemistry analyses were available, and those data were used to select a subset of 21 stations (18 stations from Baker Creek or Trapper Creek plus 3 Yellowknife River reference stations) for toxicity testing. Stations for toxicity testing were selected to bracket the range of COPC concentrations reported for the sediment samples, and to include at least one station from each reach or waterbody associated with Baker Creek.

Standard Environment Canada test methods for 14-d *Hyalella azteca* and 10-d *Chironomus tentans* survival and growth tests, consistent with those used by Jacques Whitford (2006), were performed. The results for each sediment from the exposure stations were compared to the average response for the Yellowknife River reference stations to determine whether <20% or >50% adverse effects were observed per the FCSAP aquatic sites framework (Chapman 2011). These thresholds were used to classify observed adverse effects as negligible, moderate, or severe relative to reference station responses.

4.7.1.1 Hyalella azteca

Hyalella azteca is a freshwater crustacean commonly found in lakes and streams throughout temperate North America. This amphipod typically burrows into the surface of the sediment layer to feed. It was selected by Environment Canada as a standard toxicity test organism because it has a short generation time, a widespread and abundant distribution, is ecologically important, and has a wide tolerance to different grain sizes. The test endpoints measured were survival and growth.

The 14-d *H. azteca* survival and growth test was conducted according to procedures described in Environment Canada (1997a). Sediment samples were tested in three batches (due to limits on the number of samples HydroQual could test at one time), with one of the three reference sediments included in each batch. Test organisms were two to nine days old at test initiation. For each sediment sample, six replicate test containers were prepared (five for the toxicity test, plus one replicate for measuring porewater ammonia on Day 0). The negative control sediment was clean sand. The control/dilution water was the standard laboratory water used by HydroQual for freshwater sediment toxicity tests. The test was conducted in 375-mL glass jars, each containing 100 mL of sediment and 175 mL of overlying dilution/control water. Each replicate contained 10 amphipods. The exposure period was 14 days at 23 ± 1°C under a 16:8 h light: dark photoperiod. Overlying water was not renewed during the test; gentle aeration was provided and test organisms were fed 3.5 mL per replicate three times per week of a mixture of fermented trout chow, yeast, and alfalfa powder. Temperature, pH, conductivity and dissolved oxygen (DO) were monitored daily; hardness, alkalinity, and total ammonia were measured in composite samples of overlying water on Days 0 and 14. Final counts of amphipod survival were made on Day 14, and average individual dry weight was determined for surviving amphipods from each replicate. The test was considered valid if mean control survival was ≥80% and mean control individual dry weight was ≥0.1 mg/amphipod. A 96-h water-only reference toxicant test was tested concurrently.

4.7.1.2 *Chironomus tentans*

Chironomus tentans is a freshwater midge whose larvae are common in depositional lentic environments such as ponds, lakes, and sloughs. The larvae are benthic filter-feeders that mainly consume organic matter and detritus, and are in turn important food sources for higher trophic levels such as fish and waterfowl. Chironomid larvae inhabit the first few centimetres of sediment, and then pupate and emerge as non-feeding adults (Environment Canada 1997b). This species was selected by Environment Canada as a standard toxicity test organism because it has a short generation time, is widespread and abundant in distribution, is ecologically important, and has a wide tolerance of different sediment grain sizes. The test endpoints were larval survival and growth.

The 10-d *C. tentans* survival and growth test was conducted according to procedures described in Environment Canada (1997b). Sediment samples were tested in three batches (due to limits on the number of samples HydroQual could test at one time), with one of the three reference sediments included in each batch. Test organisms were third instar at test initiation. For each test sediment sample, six replicate test containers were prepared (five for the toxicity test plus one for measuring interstitial ammonia on Day 0). The negative control sediment was clean sand. The control/dilution water was the standard laboratory water used by HydroQual for freshwater sediment toxicity tests. The test was conducted in 375-mL glass jars, each containing 100 mL of sediment (or sludge) and 175 mL of overlying dilution/control water. Each replicate contained 10 chironomids. The exposure period was 10 days at 23 ± 1°C under a 16:8 h light:dark photoperiod. Overlying water was not renewed during the test; gentle aeration was provided and test organisms were fed 1.5 mL per replicate of a TetraMin suspension daily. Temperature, pH, conductivity, and DO were monitored daily; hardness, alkalinity, and total ammonia were measured in composite samples of overlying water on Days 0 and 10. Final counts of chironomid survival were made on Day 10, and average individual dry weight was determined for surviving chironomids from each replicate. The test was considered valid if mean control survival was ≥70% and mean control individual dry weight was ≥0.6 mg/chironomid. A 96-h water-only reference toxicant test was tested concurrently.

4.7.2 Quality Assurance/Quality Control (QA/QC)

The following QA/QC procedures were applied to the sediment toxicity tests:

- Negative controls using clean laboratory sediment (sand) and dilution water were used to confirm that appropriate test acceptability criteria were met;
- Reference toxicant tests were used to assess the relative health and sensitivity of the test organisms to confirm that they were appropriate for use in testing; and,
- Water quality parameters (temperature, DO, pH and conductivity) were monitored during testing to confirm that the test organisms were not subjected to stress unrelated to the test material. Any adjustments made during testing (e.g., temperature, aeration) were documented, with explanations made for any corrective actions.

The sediment toxicity test results were evaluated based on the performance of negative controls, reference toxicant tests, and compliance with the specified testing conditions (e.g., maintenance of water quality, no unusual observations during testing). Water quality measurements during testing (e.g., temperature, pH, dissolved oxygen, conductivity) were within acceptable ranges. Tests with both species met the test acceptability criteria for negative control performance with respect to survival and growth, and were considered valid. Reference toxicant test results were consistent with historical test performance by HydroQual and were considered acceptable.

4.7.3 Results and Discussion

Results of the 14-d *H. azteca* sediment toxicity tests are summarized in Table 15, and results of the 10-d *C. tentans* sediment toxicity tests are summarized in Table 16. Copies of the HydroQual laboratory reports are provided in Appendix H.

Results for the sediment toxicity tests are presented with the samples grouped into the three batches in which they were tested. A Yellowknife River reference sediment was included in each batch of samples. Data from the three reference stations were combined to calculate a pooled reference mean for each test endpoint. The numerical values corresponding to 20 and 50% reductions in the pooled reference mean for each endpoint were also provided.

4.7.3.1 Hyalella azteca Toxicity Tests

Survival

For the *H. azteca* toxicity tests, mean survival in the negative controls for each batch of samples ranged from 80 to 92%, which met the test acceptability criterion of ≥80%. Mean survival in the three reference sediments ranged from 64 to 94%, and pooled mean reference survival was 83%.

Mean survival among the test sediments ranged from 0% for six stations (BCSS-DEP-04, BCSS-DEP-08, BCSS-DEP-15, BCSS-DEP-18, BCSS-DEP-20, and BCSS-DEP-21) to 98% for Station BCSS-DEP-07. Of note was the fact that the highest and lowest mean survivals occurred at adjacent stations in Baker Creek: Stations BCSS-DEP-07 and BCSS-DEP-08 in Reach 2.

Nine of the 18 "exposure" samples from Baker Creek or Trapper Creek stations had a <20% reduction in mean survival compared to the pooled reference, and adverse effects were therefore considered negligible. Three "exposure" stations (BCSS-DEP-06, BCSS-DEP-19, and BCSS-DEP-13) had mean survival that was reduced by 20 to 50% relative to the pooled reference and the difference was statistically significant ($p < 0.05$); adverse effects were therefore considered moderate. Six "exposure" stations had mean survival that was reduced by >50% relative to the pooled reference (as noted above these samples had 0% mean survival), and adverse effects were therefore considered severe.

Dry Weight

Mean dry weight in the negative controls for each batch of samples ranged from 0.14 to 0.28 mg/amphipod, which met the test acceptability criterion of ≥0.1 mg/amphipod. Mean dry weight in the three reference sediments ranged from 0.25 to 0.34 mg/amphipod, and pooled mean reference dry weight was 0.31 mg/amphipod,

Mean dry weight among the test sediments with mean survivals greater than zero ranged from 0.17 mg/amphipod for Station BCSS-DEP-13 to 0.39 mg/amphipod for Station BCSS-DEP-14.

Seven of the 18 "exposure" samples from Baker Creek or Trapper Creek stations had a <20% reduction in mean dry weight compared to the pooled reference, and adverse effects were therefore considered negligible. Five "exposure" stations (BCSS-DEP-01, BCSS-DEP-03, BCSS-DEP-07, BCSS-DEP-13, and BCSS-DEP-24) had mean dry weight that was reduced by 20 to 50% relative to the pooled reference and thedifference was statistically significant (p <0.05); adverse effects were therefore considered moderate. For the six "exposure" stations with 0% mean survival, adverse effects on dry weight were presumed to be severe.

4.7.3.2 Chironomus Tentans Toxicity Tests

Survival

For the *C. tentans* tests, mean survival in the negative controls for each batch of samples ranged from 72 to 90%, which met the test acceptability criterion of ≥70%. Mean survival in the three reference sediments ranged from 46 to 82%, and pooled mean reference survival was 67%. The Station BCSS-DEP-30 reference sediment had high replicate variability; two replicates had low survival, two had high survival, and one had intermediate survival. HydroQual did not observe anything unusual about this sample, such as the presence of native organisms, that might explain this variability, and therefore the sample was accepted as is.

Mean survival among the test sediments ranged from 0% for two stations (BCSS-DEP-15 and BCSS-DEP-20) to 88% for Station BCSS-DEP-12.

Ten of the 18 "exposure" samples from Baker Creek or Trapper Creek stations had a <20% reduction in mean survival compared to the pooled reference, and adverse effects were therefore considered negligible. Two "exposure" stations (BCSS-DEP-26 and BCSS-DEP-19) had mean survival that was reduced by 20 to 50% relative to the pooled reference, but the difference was not statistically significant (p <0.05) and adverse effects were therefore considered low. Six "exposure" stations (BCSS-DEP-04, BCSS-DEP-08, BCSS-DEP-15, BCSS-DEP-18, BCSS-DEP-20, and BCSS-DEP-21) had mean survival that was reduced by >50% relative to the pooled reference, and adverse effects were therefore considered severe.

Dry Weight

Mean dry weight in the negative controls for each batch of samples ranged from 1.5 to 3.11 mg/chironomid, which met the test acceptability criterion of ≥0.6 mg/chironomid. Mean dry weight in the three reference sediments ranged from 1.72 to 3.06 mg/chironomid, and pooled mean reference dry weight was 2.43 mg/chironomid.

Mean dry weight among the test sediments with mean survivals greater than zero ranged from 0.25 mg/chironomid for Station BCSS-DEP-08 to 3.03 mg/chironomid for Station BCSS-DEP-10.

Six of the 18 "exposure" samples from Baker Creek or Trapper Creek stations had a <20% reduction in mean dry weight compared to the pooled reference, and adverse effects were therefore considered negligible. Three "exposure" stations (BCSS-DEP-07, BCSS-DEP-19, and BCSS-DEP-26) had mean dry weight that was reduced by 20 to 50% relative to the pooled reference, but the difference was not statistically significant (p <0.05) and adverse effects were therefore considered low. Two "exposure" stations (BCSS-DEP-01 and BCSS-DEP-11) had mean dry weight that was reduced by 20 to 50% relative to the pooled reference and the difference was statistically significant (p <0.05); adverse effects were therefore considered moderate. Seven "exposure" stations (the six stations previously identified as having severe effects on the survival endpoint, plus BCSS-DEP-13) had mean dry weight that was reduced by >50% relative to the pooled reference, and adverse effects were therefore considered severe.

4.7.3.3 Potential Confounding Factors

There are several confounding factors that have the potential to influence the results of sediment toxicity tests. These are briefly considered here.

- Ammonia concentrations in interstitial and overlying water in the test containers represent a potential confounding factor in sediment toxicity tests because elevated concentrations can result in lethal or sublethal effects on test organisms (Environment Canada 1997a,b). However, it is unlikely that ammonia concentrations in the test containers contributed to reduced survival or growth of either *H. azteca* or *C. tentans* during testing, based on the following:
  - The highest interstitial ammonia concentration reported for either test species was 4.78 mg/L N. The highest ammonia concentrations in the overlying water were 3.34 mg/L N for the 14-d *H. azteca* tests and 3.14 mg/L N for the 10-d *C. tentans* tests.
  - Ankley et al. (1995) reported 96-h LC50s for total ammonia of 64 to 105 mg/L N for *H. azteca*, and Schubauer-Berigan et al. (1995) reported a 10-d LC50 for total ammonia of 186 mg/L N for *C. tentans*.
- Particle Size: Both test species are generally tolerant of a wide-range of particle sizes (i.e., >90% silts and clays to 100% sand). Samples for the 2011 Baker Creek assessment varied in their particle size distributions (50.3 to 99.7% fines), but were within the normal range of particle sizes tolerated by both test species.
- Total Organic Carbon (TOC): TOC content ranged from 0.29% at Station BCSS-DEP-11 to 8.19% at Station BCSS-DEP-13. Suedel and Rogers (1994) reported that *H. azteca* was tolerant of a wide range of TOC concentrations but that *C. tentans* had low survival in samples with organic content of 0.91% or less because the organisms were unable to find sufficient material to construct their larval cases. Four Baker Creek sediment samples had low TOC content, ranging from 0.29 to 0.72%. Three of those samples had mean chironomid survivals ranging from 62 to 88%, but mean survival was zero in Sample BCSS-DEP-20 that had 0.72% TOC.

Table 15: Results of 14-d Sediment Toxicity Tests with *Hyalella azteca*

Sample ID	Testing Batch	Survival (out of 10) Mean ± SD	Reduction Relative to Reference (%)	Growth (Dry Weight) (mg/org) Mean ± SD	Reduction Relative to Reference (%)
BCSS-DEP-04	1	0	>50	0	>50
BCSS-DEP-08	1	0	>50	0	>50
BCSS-DEP-11	1	8.0 ± 1.6	<20	0.27 ± 0.08	<20
BCSS-DEP-14	1	8.4 ± 0.9	<20	0.39 ± 0.06	<20*
BCSS-DEP-20	1	0	>50	0	>50
BCSS-DEP-26	1	9.4 ± 0.9	<20	0.29 ± 0.02	<20
BCSS-DEP-28 - Ref	1	9.4 ± 0.9	<20	0.34 ± 0.06	<20
Control Sediment	1	9.2 ± 0.8	NA	0.28 ± 0.02	NA
BCSS-DEP-06	2	5.8 ± 2.2	20 – 50*	0.28 ± 0.04	<20
BCSS-DEP-10	2	6.8 ± 2.3	<20	0.32 ± 0.03	<20
BCSS-DEP-15	2	0	>50	0	>50
BCSS-DEP-18	2	0	>50	0	>50
BCSS-DEP-19	2	6.2 ± 1.5	20 – 50*	0.31 ± 0.04	<20
BCSS-DEP-21	2	0	>50	0	>50
BCSS-DEP-29 - Ref	2	6.4 ± 1.9	20 – 50*	0.33 ± 0.09	<20
Control Sediment	2	8.0 ± 1.4	NA	0.14 ± 0.08	NA
BCSS-DEP-01	3	9.0 ± 1.0	<20	0.22 ± 0.02	20 – 50*
BCSS-DEP-03	3	9.0 ± 1.2	<20	0.18 ± 0.02	20 – 50*
BCSS-DEP-07	3	9.8 ± 0.4	<20	0.22 ± 0.03	20 – 50*
BCSS-DEP-12	3	9.4 ± 0.9	<20	0.36 ± 0.03	<20
BCSS-DEP-13	3	6.4 ± 1.8	20 – 50*	0.17 ± 0.03	20 – 50*
BCSS-DEP-24	3	7.6 ± 2.3	<20	0.20 ± 0.01	20 – 50*
BCSS-DEP-30 - Ref	3	9.2 ± 1.1	<20	0.25 ± 0.04	20 - 50
Control Sediment	3	9.0 ± 1.7	NA	0.15 ± 0.04	NA
Pooled Reference		8.3		0.31	
20% reduction		6.7		0.25	
50% reduction		4.2		0.15	

NA = not applicable; Asterisks (*) identify treatments that were significantly lower ($p < 0.05$) than the pooled reference.

Table 16: Results of 10-d Sediment Toxicity Tests with *Chironomus Tentans*

Sample ID	Testing Batch	Survival (out of 10) Mean ± SD	Reduction Relative to Reference (%)	Growth (Dry Weight) (mg/org) Mean ± SD	Reduction Relative to Reference (%)
BCSS-DEP-04	1	2.0 ± 2.9	>50*	0.42 ± 0.48	>50*
BCSS-DEP-08	1	1.0 ± 1.0	>50*	0.25 ± 0.27	>50*
BCSS-DEP-11	1	8.2 ± 1.1	<20	1.69 ± 0.16	20 – 50*
BCSS-DEP-14	1	6.6 ± 1.3	<20	2.03 ± 0.28	<20
BCSS-DEP-20	1	0	>50	0	>50
BCSS-DEP-26	1	5.0 ± 2.6	20 - 50	1.40 ± 0.57	20 - 50
BCSS-DEP-28 - Ref	1	7.4 ± 1.5	<20	3.06 ± 0.45	<20
Control Sediment	1	9.0 ± 1.0	NA	3.11 ± 0.15	NA
BCSS-DEP-06	2	8.6 ± 0.9	<20	1.96 ± 0.38	<20
BCSS-DEP-10	2	8.2 ± 1.3	<20	3.03 ± 0.47	<20
BCSS-DEP-15	2	0	>50	0	>50
BCSS-DEP-18	2	2.4 ± 1.7	>50	0.39 ± 0.12	>50
BCSS-DEP-19	2	5.4 ± 3.6	20 - 50	1.63 ± 1.03	20 - 50
BCSS-DEP-21	2	3.0 ± 1.7	>50	0.67 ± 0.48	>50
BCSS-DEP-29 - Ref	2	8.2 ± 1.6	<20	2.52 ± 0.50	<20
Control Sediment	2	7.2 ± 2.4	NA	1.5 ± 0.43	NA
BCSS-DEP-01	3	8.4 ± 1.9	<20	1.66 ± 0.22	20 – 50*
BCSS-DEP-03	3	8.6 ± 1.3	<20	2.22 ± 0.54	<20
BCSS-DEP-07	3	6.2 ± 1.9	<20	1.86 ± 0.39	20 – 50
BCSS-DEP-12	3	8.8 ± 0.8	<20	2.22 ± 0.78	<20
BCSS-DEP-13	3	5.8 ± 0.4	<20	0.83 ± 0.18	>50*
BCSS-DEP-24	3	7.2 ± 0.4	<20	2.24 ± 0.70	<20
BCSS-DEP-30 - Ref	3	4.6 ± 3.8	20 - 50	1.72 ± 1.14	20 - 50
Control Sediment	3	8.6 ± 0.9	NA	2.58 ± 0.93	NA
Pooled Reference		6.7		2.43	
20% reduction		5.4		1.95	
50% reduction		3.4		1.22	

NA = not applicable; Asterisks (*) identify treatments that were significantly lower ($p < 0.05$) than the pooled reference.

4.8 Benthic Invertebrate Community Line of Evidence

4.8.1 Methods

4.8.1.1 Laboratory Processing and Taxonomy

Benthic invertebrate samples were submitted to Dr. Jack Zloty for taxonomic identification and enumeration. Benthic invertebrate samples were stained with rose Bengal prior to sorting in the laboratory.

Depositional benthic invertebrate samples were separated into a coarse fraction (>1 mm) and a fine fraction (0.5 to 1 mm) using nested sieves. The entire coarse fractions were sorted. This consisted of completely and systematically sorting organisms from the coarse fraction on a gridded Petri dish under a dissecting microscope at 7 to 10 times magnification. Fine fractions were sorted using following established protocols (Wrona et al. 1982; Glozier et al. 2002). The subsampling device consisted of the Imhoff cone subsampler described by Wrona et al. (1982). The fine material was placed into an Imhoff cone, and water was added to provide a total volume of 1 L. This mixture was agitated with air released from an air stone at the bottom of the cone for five minutes to ensure thorough mixing. Subsamples of 25 mL volume were removed from the Imhoff cone and systematically sorted for organisms on a gridded Petri dish under a dissecting microscope. The number of subsamples depended on the number of organisms present in the subsample, as outlined in established protocols (e.g., Wrona et al. 1982; Glozier et al. 2002). The abundances of each taxon occurring in the total fine fraction were obtained by multiplying the counts of each taxon in the subsamples by the subsampling factor. These abundances were then added to the abundances obtained from the coarse fraction for each taxon.

Organisms were identified and counted using dissecting or compound microscopes, as required. Invertebrates were identified to the lowest practical taxonomic level (i.e., genus and species, where possible) using current literature and nomenclature. Target taxonomic levels are listed below. Note that Nematoda were only identified to the phylum level, whereas Hydracarina and Ostracoda were identified to order, and so on.

- Phylum – Nematoda;
- Order – Hydracarina, Ostracoda;
- Family – Oligochaeta, Unionidae;
- Genus – Cnidaria, Ceratopogonidae, Chironomidae, Coleoptera, Empididae, Ephemeroptera, Gastropoda, Odonata, Plecoptera, Pisidiidae, Simuliidae, Tabanidae, Tipulidae and Trichoptera (aside from those taxa identified to the species level); and,
- Species – Amphipoda and Hirudinea.

Organisms that could not be identified to the desired taxonomic level (e.g., immature or damaged specimens) were reported as a separate category at the lowest level of taxonomic resolution possible. This was typically the family level, which is the level recommended for Metal Mining EEM (Environment Canada 2011). The most common taxa were distinguishable based on gross morphology and required only a few slide mounts (5 to 10) for verification. Organisms that required detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate mounting medium. All rare or less commonly occurring taxa were also mounted on slides for identification.

4.8.1.2 Data Analysis

Approach

The benthic invertebrate community study was designed as a gradient study, with the objective of sampling at locations representing a wide range of COPC concentrations in bottom sediments. The Yellowknife River was chosen as the reference area, where concentrations of sediment COPCs were expected to be lower than in Baker Creek.

The primary objective of this study component was to determine whether benthic invertebrate communities in mine-affected areas of Baker Creek differed from those in the reference area. To address this objective, differences in benthic invertebrate communities between Baker Creek and the Yellowknife River were evaluated visually based on plots of benthic community variables by reach and stream, and non-metric multidimensional scaling (NMDS) ordination plots.

The second objective of the benthic invertebrate community analysis was to evaluate whether the benthic community was significantly related to sediment COPC concentrations, and whether the direction of significant relationships was consistent with potential adverse effects due to sediment contamination.

The range of variation was high in the sediment metals dataset. For a number of sediment COPCs (i.e., cadmium, chromium, lead, manganese, mercury), the maximum concentration measured in the Yellowknife River (reference area) was within the range of concentrations measured in mine-affected reaches of Baker Creek. This suggested that a simple comparison of Yellowknife River vs. Baker Creek benthic invertebrate communities may not be a sensitive method to evaluate potential differences in the benthic community between mine-affected areas and reference areas. Therefore, detecting a relationship between sediment COPC concentrations and benthic community variables was considered to be an indication of effects (i.e., an alteration or a change), even in the absence of obvious differences in benthic community characteristics between Baker Creek and the Yellowknife River.

Invertebrate Community Variables

Raw invertebrate abundance data were received from the taxonomist in electronic format. During the preparation of the data for analysis, the following non-benthic organisms were removed:

- Crustacea (Copepoda, Cladocera) – removed because they are planktonic organisms;
- Heteroptera (Corixidae) – removed because they are not strictly benthic organisms;
- Diptera pupae – removed because they are not strictly benthic organisms; and,
- Terrestrial invertebrates – removed because they are not aquatic benthic invertebrates.

Raw abundance values were converted to individuals per square metre (ind/m^2) based on the total bottom area of the Ekman grab (0.0232 m^2) for depositional samples and the Surber sampler (0.0929 m^2) for erosional samples. The following community variables were calculated for each station:

- Total invertebrate abundance expressed as density (total density);
- Richness (at the lowest taxonomic level);
- Relative abundance, as percentages in major invertebrate groups;
- Presence or absence of each invertebrate taxon at each station;
- Simpson's evenness index (SEI; based on data at the lowest taxonomic level); and,
- Dominant invertebrates (taxa accounting for at least 5% of the community in a minimum of 20% of total samples and present in all sampled waterbodies).

Evaluation of total density provided an indication of potential adverse effects on invertebrate abundance; total density was expected to decline with increasing COPC concentrations. Richness provides an indication of the diversity of invertebrates in an area, with a higher richness value typically indicating a more healthy and balanced community.

Relative abundance quantifies the relative proportion of each family composing the invertebrate community. Presence or absence was quantified through a presence/absence matrix at the lowest taxonomic level for each station. These two biotic measures were used as additional descriptors and were not used in the statistical analyses.

Simpson's evenness index (SEI) is a measure of the relative abundances of the different taxa contributing to the community in an area. The SEI compares the observed community to a hypothetical community that consists of the same number of taxa in equal abundance. A community dominated by one or two taxa is considered to be less even than one in which several different taxa have similar abundances. The SEI values range between 0 and 1, whereby higher values indicate a balanced community consisting of more taxa that are evenly distributed among taxonomic groups. Lower values indicate a community dominated by few taxa. These communities are often referred to as "stressed" and may reflect the influence of natural and/or anthropogenic disturbances.

In addition to the standard community variables listed above, spatial trends in abundances of invertebrates in the Ephemeroptera, Plecoptera and Trichoptera (EPT) orders were also evaluated in erosional habitat, where they usually represent the most sensitive component of the benthic community.

Statistical Analyses

Benthic invertebrate community variables and environmental variables were tested for normality and screened for outliers using probability plots prior to running linear regression analysis, and based on diagnostic tests during regression analysis. All data were normally distributed with the exception of total density and the densities of individual taxa, which were $\log_{10}$ (x+1) transformed before analysis.

Pearson correlation coefficients (r) were calculated to determine whether habitat variables (i.e., water depth, water velocity, percent fine sediments, sediment TOC, and aquatic plant cover) were correlated with benthic invertebrate community variables. Habitat variables were included in the correlation analysis if they varied over a sufficient range to potentially affect the benthic invertebrate community or represented a potential confounding factor.

Linear regression analyses of the benthic invertebrate community variables were completed using an independent variable that reflects exposure to mine-related COPCs. The exposure variable used in gradient analysis of depositional data was principal component 1 (PC-1) derived from principal component analysis (PCA) of the sediment metals data. Direct measures of exposure (i.e., sediment or water chemistry data) were not available for erosional habitats. Specific conductivity (hereafter referred to as conductivity) was assessed to determine its usefulness as an exposure variable. Water quality data collected between 2009 and 2011 for the Surveillance Network Program and Metal Mining Effluent Regulations effluent and surface water quality monitoring programs were used to evaluate relationships between field measured conductivity and stream water concentrations of five COPCs (i.e., antimony, arsenic, copper, manganese and nickel) that were measured above the analytical detection limit at most stations.

Statistical tests were performed using the SYSTAT 11 software package (SYSTAT 2004). Potential outliers were identified during statistical testing as those having studentized residuals >|3|. If outliers were identified and removed from the dataset, the linear regressions were re-run. Correlations and linear regressions were considered significant at $P \leq 0.05$.

NMDS, a multivariate ordination technique, was used to assess potential differences in invertebrate community structure between Baker Creek and the Yellowknife River, separately for each habitat type. This analysis was run on a station-by-station distance matrix generated from the invertebrate abundance data at the lowest taxonomic level[9] Based on the distance matrix, NMDS was used to derive a new two-dimensional configuration that preserved the pair-wise ecological distances among stations. NMDS was thus used to represent a multidimensional taxonomic data set in two dimensions that captured the major patterns of spatial variation in invertebrate abundances and community composition.

Abundance values were $\log_{10}(x+1)$ transformed prior to multivariate analysis to reduce the influence of numerically dominant taxa and to allow the NMDS to capture a more balanced representation of the community as a whole. A station-by-station Bray-Curtis distance matrix was generated from the invertebrate abundance data and used as the input for the NMDS procedure. Two dimensions were selected for the NMDS after confirming that the final stress value of the configuration was sufficiently low (<0.2) (Clarke 1993). The resulting NMDS dimensions (i.e., Dimension 1 and Dimension 2) were interpreted by conducting Spearman rank correlations between dimension scores and invertebrate abundances. Spearman rank correlations between the original species abundance and NMDS Dimension variables DIM-1 and DIM-2 indicate which invertebrate taxa were most closely associated with each dimension.

[9] Species, genus or the lowest practical level benthic taxa that could be identified to by the taxonomist.

4.8.2 Quality Assurance/Quality Control (QA/QC)

Invertebrate sample sorting efficiency was verified by performing spot checks of leftover debris in randomly selected samples accounting for 10% of total samples. The data quality objective was a minimum recovery of 90% of the total organisms. If more than 10% of the total number of organisms removed from the sample were found in the debris, then all samples were re-sorted by a different individual than the original sorter. In addition, if an entire taxonomic group was omitted by the sorter, then all samples were re-sorted, again by a different individual. Sorting efficiency was calculated as a percentage based on the number of organisms initially recovered from the sample and the re-sort count. Results for re-sorted benthic invertebrate samples are provided in Appendix I (Tables I-1 and I-2) and indicate that the quality of the benthic invertebrate data was acceptable.

A reference collection was prepared that consisted of several representative specimens from each taxon preserved in 70% isopropyl alcohol. The reference collection has been archived by Dr. Jack Zloty for possible comparative purposes with benthic invertebrate data from future studies and quality control (QC) of future taxonomic identifications.

4.8.3 Results and Discussion

4.8.3.1 Depositional Habitat

4.8.3.1.1 Effect of Habitat Variation

Detailed habitat data are provided in Appendix I, Table I-3. The following physical factors varied sufficiently among depositional stations to potentially contribute to inter-station variation in benthic invertebrate community structure:

- Water depth (0.1 to 2.1 m);
- Aquatic vegetation cover (0 to 100%);
- Proportion of fine sediments (silt + clay; 50.3 to 99.7%); and,
- Sediment total organic carbon (TOC; 0.3 to 8.2%).

These variables were included in a correlation analysis to investigate their influence on benthic community variables. SEI and densities of Ostracoda, *Cricotopus/Orthocladius, Cladotanytarsus* and *Paratanytarsus* were significantly correlated with one or more habitat variable (Table 17). Scatter-plots of significant relationships indicated that these relationships were generally weak and highly influenced by zero density values, with the exception of those with SEI (Appendix I, Figure I-1). Therefore, water depth and TOC were used as additional independent variables in the regression analysis to evaluate the potential effect of sediment contamination on SEI. Habitat variables were not included in regressions for density variables.

Table 17: Correlations between Benthic Invertebrate Community Variables and Selected Habitat Variables in Depositional Habitat in Baker Creek, Trapper Creek and the Yellowknife River, 2011

Variable	Pearson Correlation Coefficient (*r*)			
	Water Depth	% Fines	TOC	Plant Cover
Total Density	0.220	-0.080	0.134	0.260
Richness	0.124	-0.067	-0.088	0.259
SEI	**-0.512**	-0.304	**0.566**	0.012
Nematoda Density	0.154	-0.144	0.042	0.142
Tubificinae Density	0.056	-0.209	0.086	-0.212
Hydracarina Density	0.340	-0.096	0.200	0.069
Ostracoda Density	0.248	**0.410**	**-0.569**	0.294
Cricotopus/Orthocladius Density	-0.104	0.176	-0.265	**0.545**
Cladotanytarsus Density	0.237	0.143	**-0.401**	0.348
Micropsectra Density	0.310	0.210	-0.082	0.267
Paratanytarsus Density	0.216	0.316	-0.127	**0.479**

Notes: **Bolding** indicates significant correlation; SEI = Simpson's Evenness Index

Critical value (alpha = 0.05, n = 29, 2-tailed test) = 0.367.

4.8.3.1.2 Benthic Invertebrate Community Analysis

Benthic Invertebrate Community Characteristics

Total density was highly variable in Baker Creek (1,335 to 110,509 ind/m^2), Trapper Creek (73,639 to 119,566 ind/m^2), and the Yellowknife River (7,650 to 40,573 ind/m^2) (Table 18). Richness varied less among stations, with an overall range of 14 to 38 taxa. Total density and richness were positively correlated with one another, which is common in benthic invertebrate data. SEI values were generally low, ranging from 0.10 to 0.47. None of these variables showed spatial trends along Baker Creek, and there were no obvious differences between Baker Creek, the Yellowknife River and Trapper Creek (Figure 18 to Figure 20).

Relative densities of major taxonomic groups exhibited high variability among stations in Baker Creek, and only minor differences were apparent between communities of Baker Creek, Trapper Creek, and the Yellowknife River (Figure 21). Benthic invertebrate communities in Baker Creek were typically dominated by Diptera (24 to 93%) consisting of various midge genera. Diptera accounted for 33 to 56% and 42 to 68% of the benthic invertebrate communities in Trapper Creek and the Yellowknife River, respectively. Ostracods and aquatic worms (Oligochaeta) were occasionally dominant in Baker Creek, but accounted for 20% or less of total invertebrates in Trapper Creek and the Yellowknife River. The percentage of nematodes was higher at two of the three stations in the Yellowknife River than at stations in Baker and Trapper creeks.

Table 18: Summary of Benthic Invertebrate Community Variables for Depositional Habitat in Baker Creek, Trapper Creek and Yellowknife River, 2011

Waterbody	Reach	Station	Total Density	Richness	SEI
Baker Creek	Reach 0	BCSS-DEP-01	28,230	28	0.13
		BCSS-DEP-02	39,123	27	0.29
		BCSS-DEP-03	19,361	17	0.42
	Reach 1	BCSS-DEP-04	71,989	26	0.19
		BCSS-DEP-05	30,225	22	0.31
	Reach 2	BCSS-DEP-06	16,576	20	0.34
		BCSS-DEP-07	15,242	15	0.15
		BCSS-DEP-08	14,926	18	0.22
	Reach 3	BCSS-DEP-09	110,509	29	0.23
		BCSS-DEP-10	21,872	21	0.25
	Reach 4	BCSS-DEP-11	41,276	34	0.22
		BCSS-DEP-12	15,873	22	0.27
		BCSS-DEP-13	52,241	23	0.25
	Reach 5	BCSS-DEP-14	35,019	21	0.37
		BCSS-DEP-15	6,631	18	0.34
		BCSS-DEP-16	3,229	14	0.47
	Reach 6	BCSS-DEP-17	44,462	26	0.26
		BCSS-DEP-18	17,423	22	0.22
		BCSS-DEP-19	33,870	20	0.13
		BCSS-DEP-20	1,335	14	0.17
		BCSS-DEP-21	52,844	29	0.10
Upper Baker Creek	n/a	BCSS-DEP-23	20,796	22	0.45
	n/a	BCSS-DEP-24	44,677	23	0.32
	n/a	BCSS-DEP-25	23,006	23	0.33
Trapper Creek	n/a	BCSS-DEP-26	73,639	27	0.43
	n/a	BCSS-DEP-27	119,566	38	0.23
Yellowknife River	n/a	BCSS-DEP-28	38,908	30	0.15
	n/a	BCSS-DEP-29	40,573	31	0.36
	n/a	BCSS-DEP-30	7,650	14	0.36

Notes: n/a = not applicable; SEI = Simpson's Evenness Index.

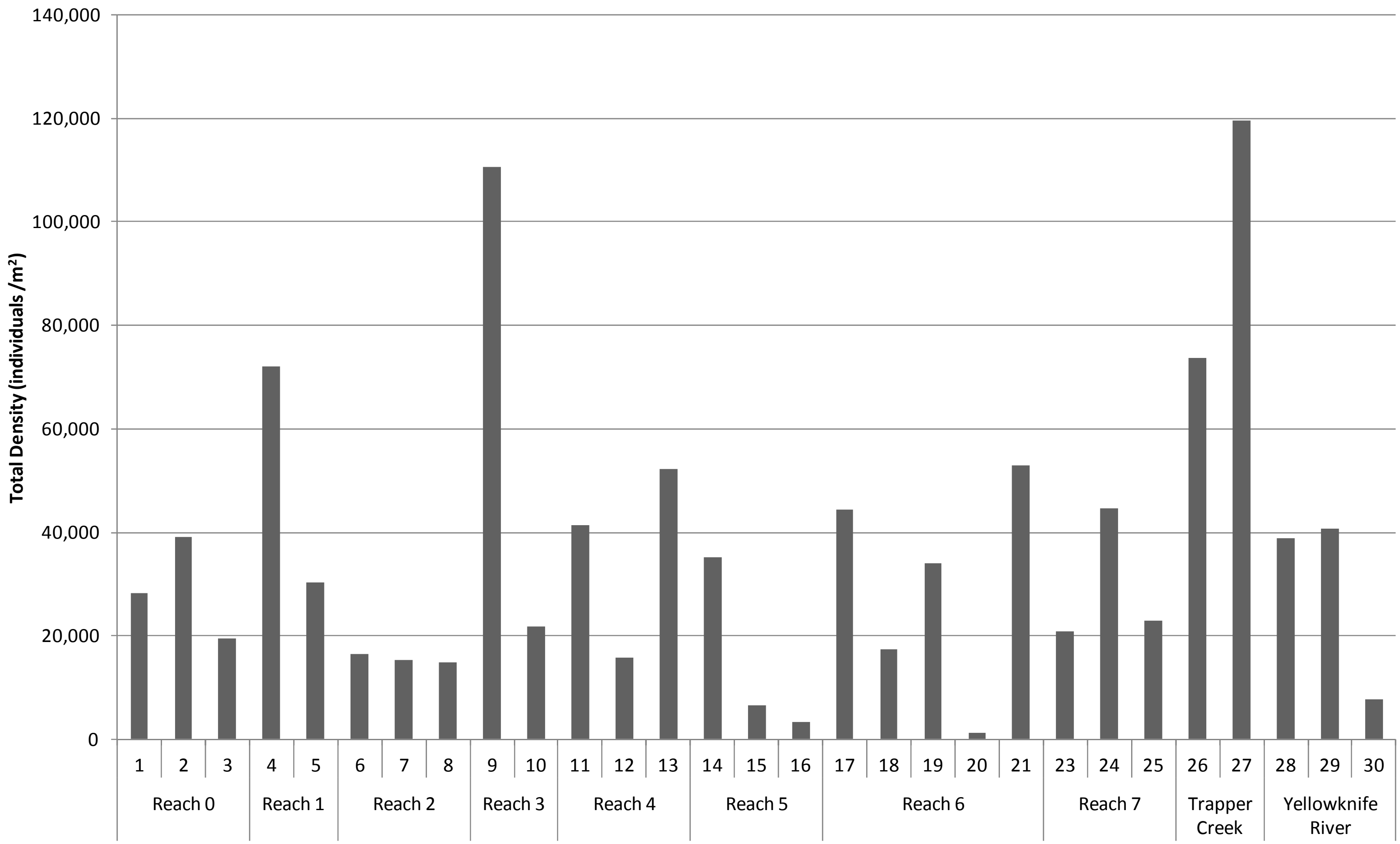


Figure 18: Variation in Total Benthic Invertebrate Density in Depositional Habitat in Baker Creek, Trapper Creek and Yellowknife River, 2011

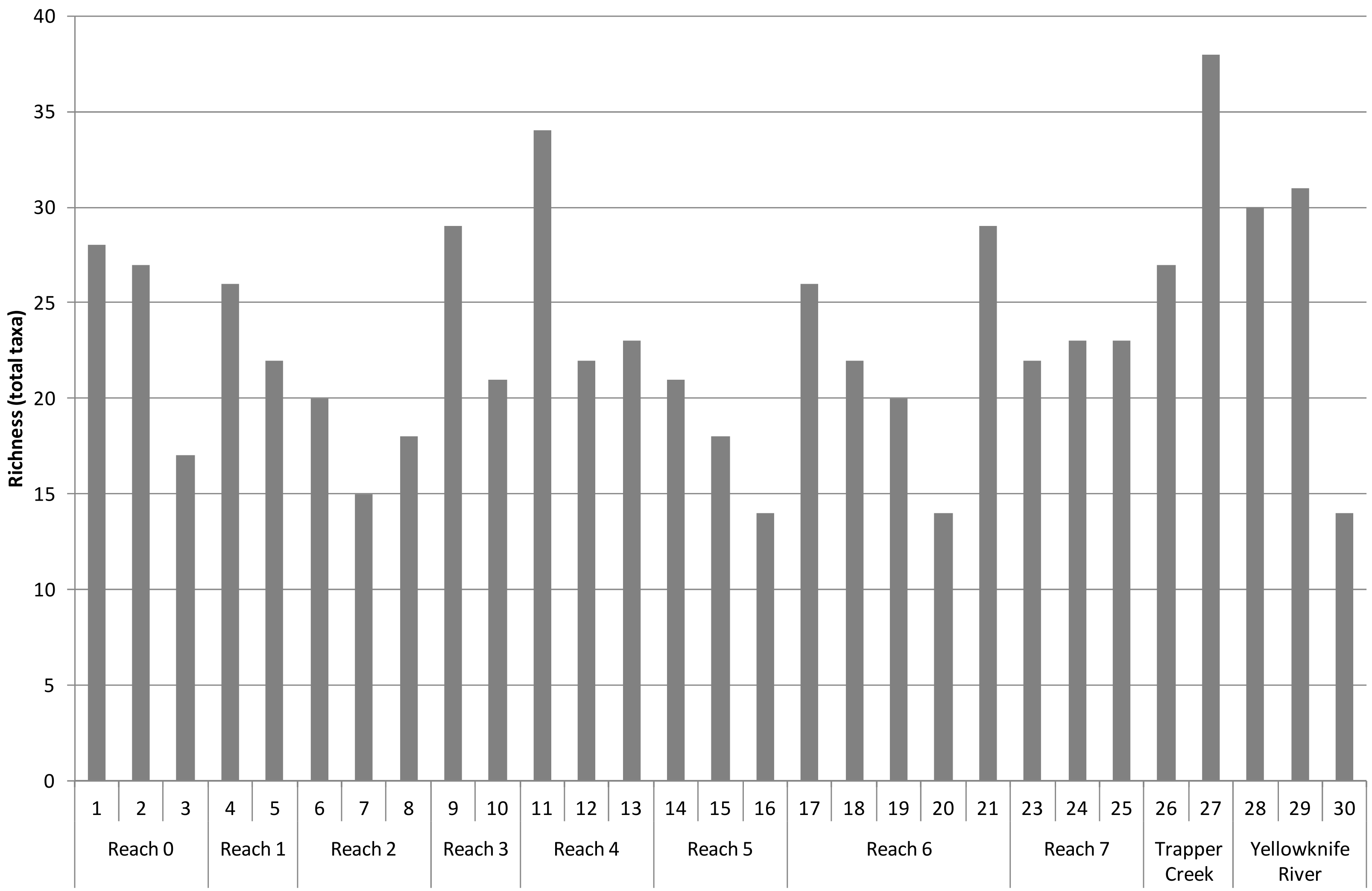


Figure 19: Variation in Benthic Invertebrate Richness in Depositional Habitat in Baker Creek, Trapper Creek and Yellowknife River, 2011

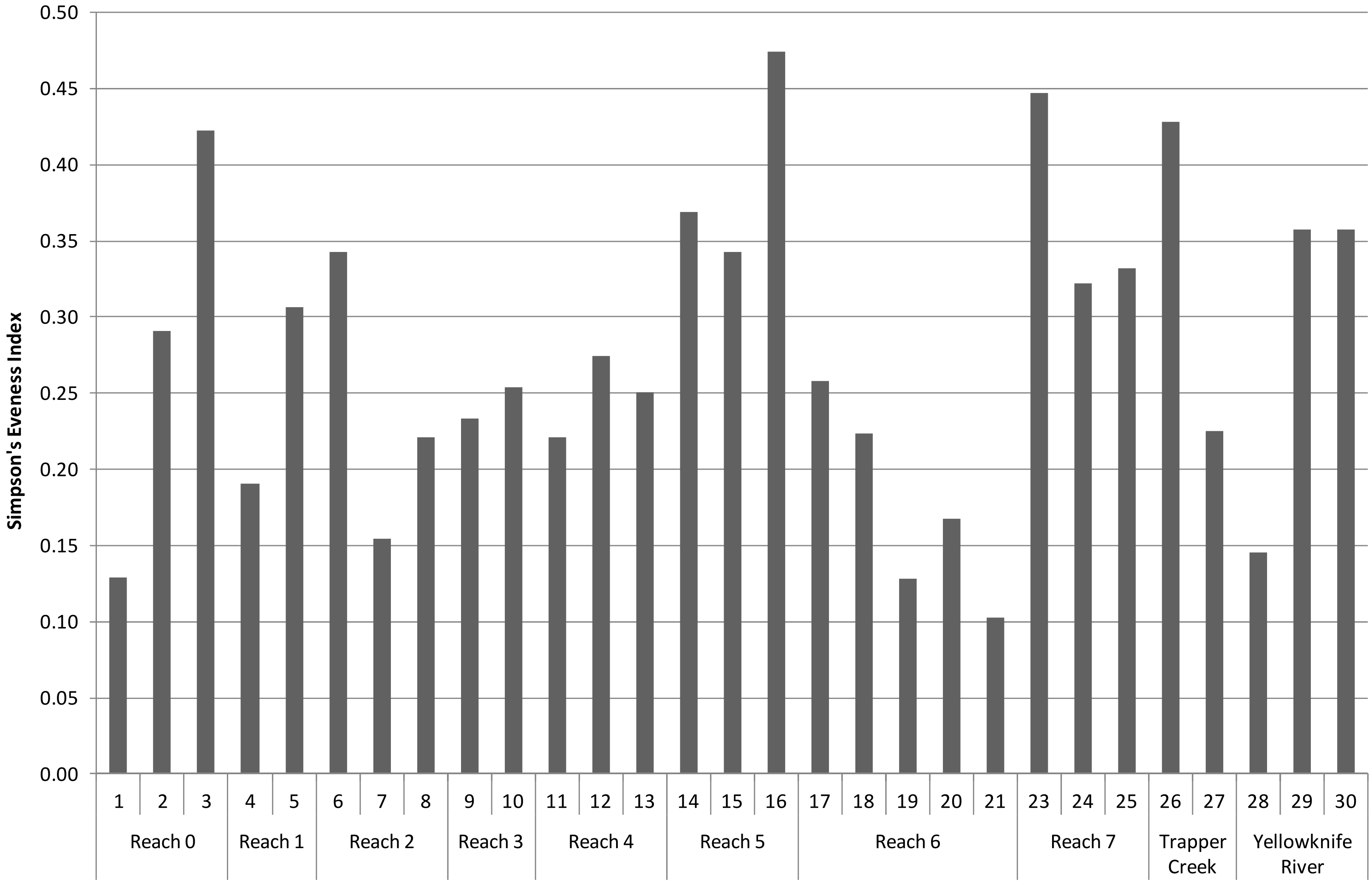


Figure 20: Variation in Simpson's Evenness Index in Depositional Habitat in Baker Creek, Trapper Creek and Yellowknife River, 2011

Evaluation of presence or absence of invertebrate taxa identified few differences between Baker Creek, Trapper Creek and the Yellowknife River in terms of community composition. Nine taxa were unique to the Yellowknife River stations, including two mayflies (*Hexagenia* and *Ephemera*), two caddisflies (*Oecetis* and *Molanna*), and four midge genera (Table 20). In comparison, five taxa were unique to Trapper Creek and 24 taxa were unique to Baker Creek, which reflected the variation in sampling effort in these streams relative to Baker Creek. All six mayfly taxa identified from depositional stations were present in the Yellowknife River, but were only sporadically present in Baker Creek despite the larger sampling effort, which suggests a potential negative effect on mayflies in Baker Creek, consistent with the known sensitivity of mayflies to metals.

4.8.3.1.3 Regression Analysis of Depositional Benthic Community Data

Results of linear regression analyses of benthic community variables as a function of sediment COPC concentration[10] are summarized in Table 19. There were marginally significant negative relationships between sediment COPC concentration, and richness and Nematoda density, consistent with the expected effect of increasing COPC concentrations on these variables. SEI was significantly related to water depth and TOC, but was not related to sediment COPC concentration. The coefficient of determination values for the two significant relationships with sediment COPC concentration were low (<0.2) and scatter-plots revealed weak relationships (Figure 22).

Table 19: Results of Linear Regression Analyses of Sediment COPC Concentration vs. Benthic Community Variables – Depositional Habitat

Variable	Y-Intercept	Slope	Coefficient of Determination (r^2)	*P*-value[1]
Total Density	ns			0.408
Richness[2]	23.24	-2.047	0.114	0.073
SEI[3]	-	-	-	**<0.001**
Depth	0.256	-0.105	0.508	**0.004**
TOC		0.021		**0.001**
Nematoda Density (one outlier removed)	3.215	-0.383	0.170	**0.029**
Tubificinae Density	ns			0.114
Hydracarina Density	ns			0.697
Ostracoda Density	ns			0.771
Cricotopus/Orthocladius Density	ns			0.853
Cladotanytarsus Density	ns			0.395
Micropsectra Density	ns			0.319
Paratanytarsus Density	ns			0.169

ns = results were not significant; < = less than; - = not applicable.

1. **Bolded** values indicate significant regression at $P < 0.05$.
2. Regression statistics are provided because result is approaching significance.
3. SEI = Simpson's Evenness Index. Results of forward stepwise multiple regression are shown; sediment COPC concentration was not part of the final regression model.

[10] The exposure variable used in gradient analysis of depositional data was principal component 1 (PC-1) derived from principal component analysis (PCA) of the sediment metals data (see Appendix I, Table I-4 for PCA results).

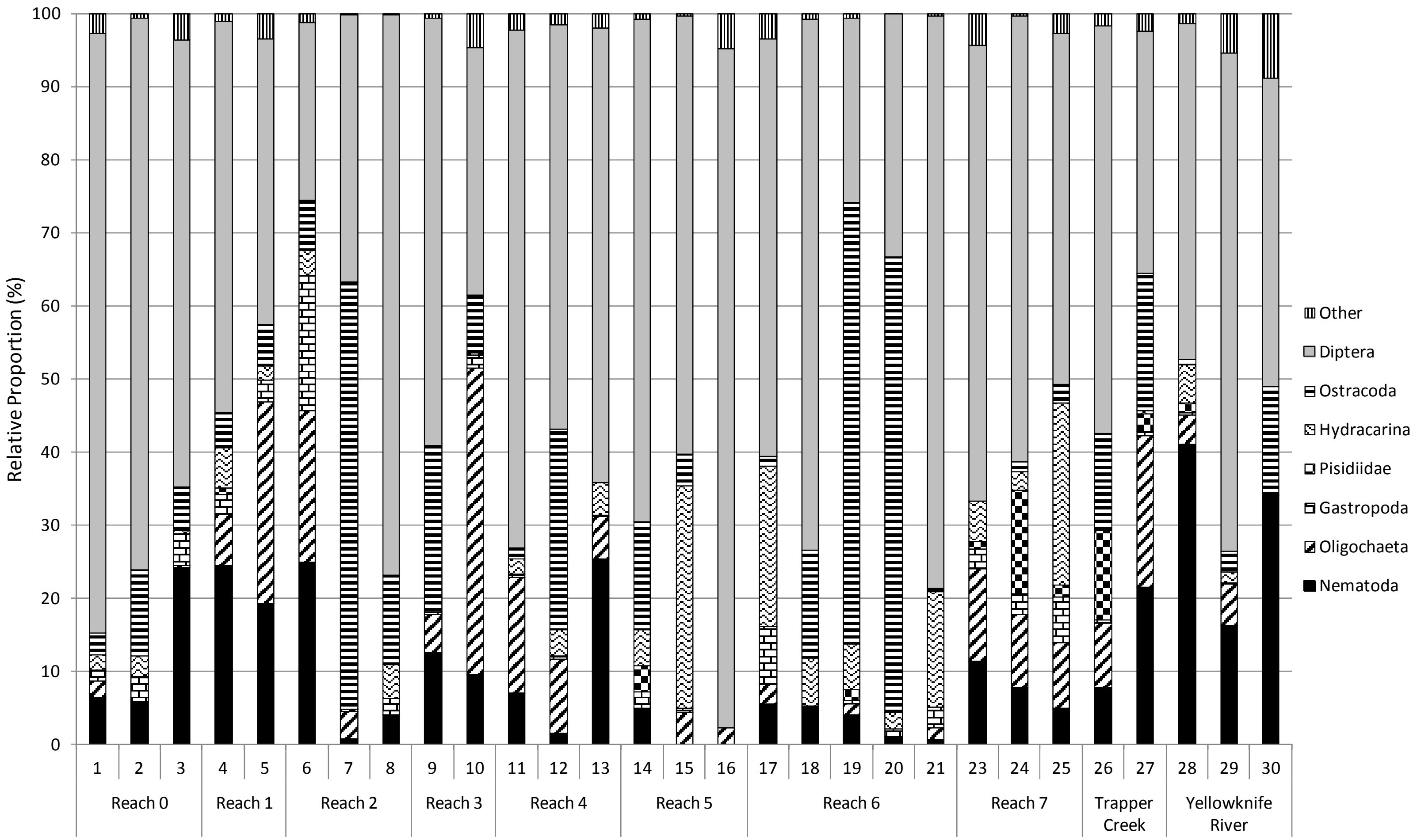


Figure 21: Benthic Invertebrate Community Composition by Major Taxonomic Groups in Depositional Habitat in Baker Creek, Trapper Creek and Yellowknife River, 2011

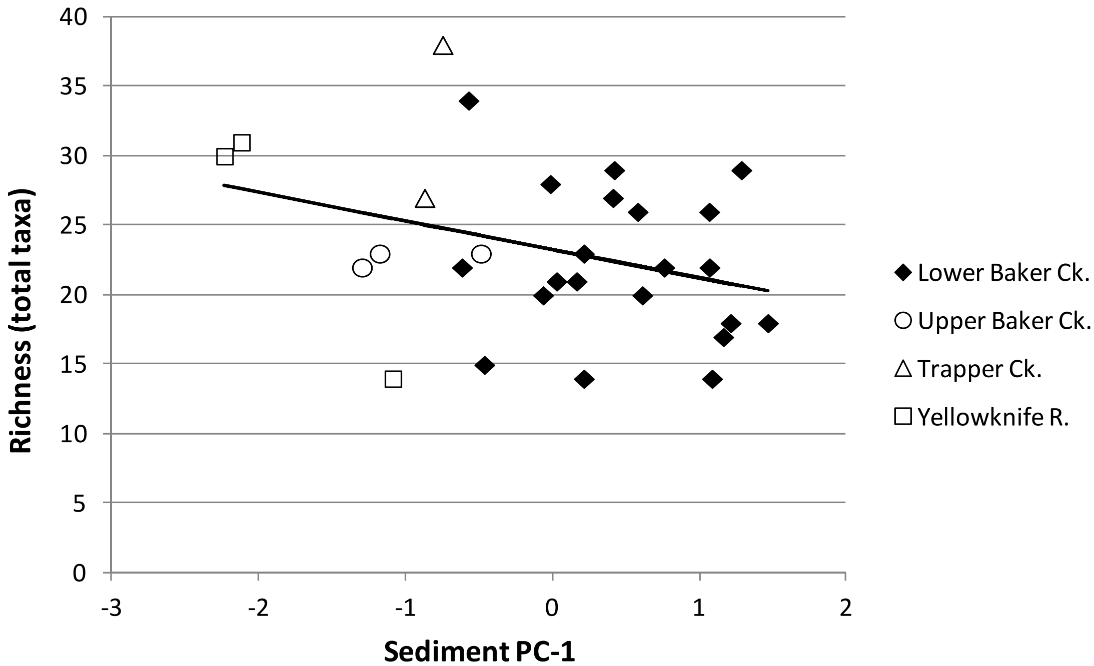
Table 20: Presence/Absence of Benthic Invertebrate Taxa in Baker Creek, Trapper Creek and Yellowknife River, 2011

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek								Trapper Creek	Yellowknife River
					Reach 0	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7		
Nematoda	-	-	-	-	X	X	X	X	X	X	X	X	X	X
Hirudinea	Erpobdellidae	-	-	*Erpobdella punctata*	-	X	X	-	-	-	-	X	X	X
		-	-	*Nephelopsis obscura*	-	-	-	-	-	-	-	X	-	-
	Glossiphoniidae	-	-	*Glossiphonia complanata*	-	X	-	-	-	-	-	-	X	-
		-	-	*Helobdella fusca*	X	-	-	-	-	-	-	-	-	-
		-	-	*Helobdella stagnalis*	-	-	-	-	X	-	-	-	-	-
Oligochaeta	Enchytraeidae	-	-	-	-	X	X	X	X	-	-	X	X	-
	Naididae	Naidinae	-	-	-	X	X	X	X	-	-	-	-	-
		Tubificinae	-	-	X	X	X	X	X	X	X	X	X	X
Gastropoda	Physidae	-	-	*Physa*	X	-	X	X	X	X	X	X	X	-
	Planorbidae	-	-	*Armiger crista*	X	-	-	-	-	-	-	-	-	-
		-	-	*Gyraulus*	X	X	X	X	X	X	X	X	X	-
		-	-	*Helisoma*	X	-	-	-	-	-	X	-	-	X
	Lymnaeidae	-	-	*Lymnaea*	X	X	X	X	X	X	X	-	X	X
	Valvatidae	-	-	*Valvata sincera*	-	-	-	-	-	-	X	X	-	X
		-	-	*Valvata tricarinata*	X	-	-	-	-	-	-	-	-	-
Bivalvia	Pisidiidae	-	-	-	X	X	X	X	-	X	X	X	X	X
Hydracarina	-	-	-	-	X	X	X	-	X	X	X	X	X	X
Ostracoda	-	-	-	-	X	X	X	X	X	X	X	X	X	X
Amphipoda	Gammaridae	-	-	*Gammarus lacustris*	-	-	X	X	X	X	X	-	-	X
	Hyalellidae	-	-	*Hyalella azteca*	X	X	X	X	X	X	X	X	X	X
Ephemeroptera	Baetidae	-	-	*Callibaetis*	-	-	-	-	-	-	X	-	-	X
	Caenidae	-	-	*Caenis*	-	X	-	-	X	-	X	-	X	X
	Ephemeridae	-	-	*Ephemera*	-	-	-	-	-	-	-	-	-	X
		-	-	*Hexagenia limbata*	-	-	-	-	-	-	-	-	-	X
	Ephemerellidae	-	-	-	X	-	-	-	-	-	-	-	-	X
	Leptophlebiidae	-	-	*Leptophlebia*	X	-	-	-	X	-	-	X	-	X
Trichoptera	Hydroptilidae	-	-	*Oxyethira*	-	-	-	X	-	-	-	-	-	-
	Leptoceridae	-	-	*Mystacides*	-	-	-	-	-	-	X	-	-	-
		-	-	*Oecetis*	-	-	-	-	-	-	-	-	-	X
	Limnephilidae	-	-	*Limnephilus*	-	-	-	-	-	-	-	-	X	-
	Molannidae	-	-	*Molanna*	-	-	-	-	-	-	-	-	-	X
	Phryganeidae	-	-	*Agrypnia*	X	X	X	-	X	X	X	-	-	X
		-	-	*Phryganea*	-	-	-	-	X	-	-	-	-	-
	Polycentropodidae	-	-	*Neureclipsis*	-	-	-	-	-	X	-	-	-	-
		-	-	*Polycentropus*	X	X	X	X	X	X	-	X	X	-
Odonata - Anisoptera	Aeshnidae	-	-	*Aeshna*	X	X	X	-	-	-	X	-	-	-
	Corduliidae	-	-	-	-	-	-	-	-	-	X	X	-	-
	Libellulidae	-	-	-	-	-	-	X	X	X	X	X	X	-
Odonata - Zygoptera	Coenagrionidae	-	-	*Enallagma*	X	X	-	X	X	-	X	X	-	-

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek								Trapper Creek	Yellowknife River
					Reach 0	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7		
Coleoptera	Chrysomelidae	-	-	*Donacia*	-	-	-	X	X	X	-	-	X	-
	Dytiscidae	-	-	*Agabus*	-	-	-	-	-	-	-	-	X	-
		-	-	*Neoporus*	-	-	-	-	-	X	-	-	-	-
	Haliplidae	-	-	*Haliplus*	X	X	X	-	X	-	-	-	X	-
Diptera	Chironomidae	Tanypodinae	Coelotanypodini	*Clinotanypus*	X	-	-	-	-	-	X	X	-	-
			Macropelopiini	*Derotanypus*	-	-	-	-	-	-	-	-	X	-
			Pentaneurini	-	X	X	X	X	X	X	X	X	X	X
			Procladiini	*Procladius*	X	X	X	X	X	X	X	X	X	X
		Diamesinae	Protanypini	*Potthastia longimana* group	-	-	-	-	-	-	-	-	-	X
		Orthocladiinae	Orthocladiini	*Acricotopus*	-	-	-	-	X	X	-	-	X	-
				Corynoneura	X	X	-	-	X	-	X	X	X	X
				Cricotopus / Orthocladius	X	X	X	X	X	X	X	-	X	X
				Heterotrissocladius	-	-	-	-	-	-	-	-	-	X
				Nanocladius	-	-	-	-	-	-	-	X	-	-
				Parakiefferiella	-	-	X	X	X	-	X	X	X	X
				Psectrocladius	X	X	X	X	X	X	X	X	X	X
				Chironomus	X	-	-	-	X	-	X	-	X	-
				Cladopelma	-	-	-	-	-	X	-	X	-	-
				Cryptochironomus	X	-	-	X	X	X	X	X	X	X
				Cryptotendipes	-	-	-	-	-	-	-	-	X	-
				Demicryptochironomus	-	-	-	X	X	-	-	-	-	X
				Dicrotendipes	X	-	-	X	X	-	X	-	X	X
				Endochironomus	-	-	-	-	-	-	-	X	X	X
				Epoicocladius	-	-	-	-	-	-	-	-	-	X
				Glyptotendipes	-	-	-	-	-	-	X	-	X	-
				Microtendipes	-	-	-	-	-	-	-	X	X	-
				Pagastiella	-	-	X	X	-	-	X	-	-	X
				Parachironomus	X	X	X	X	X	X	X	X	-	-
				Paracladopelma	-	-	-	X	-	-	-	X	-	X
				Paralauterborniella	-	-	-	-	-	-	-	-	-	X
				Paratendipes	X	-	X	X	-	-	-	-	-	-
				Phaenopsectra	-	-	-	-	-	-	-	X	-	-
				Polypedilum	X	-	X	-	X	X	-	X	X	X
				Stictochironomus	X	-	-	-	-	-	-	X	X	X
				Tribelos	-	-	-	-	-	-	-	X	-	-
			Pseudochironomini	*Pseudochironomus*	-	-	-	-	-	-	-	-	X	-
				Cladotanytarsus	X	X	X	X	X	X	X	X	X	X
				Micropsectra	X	X	X	X	X	X	X	X	X	X
				Micropsectra / Tanytarsus	X	-	-	X	-	-	X	-	-	-
				Paratanytarsus	X	X	X	X	X	X	X	X	X	X
				Stempellina	-	-	-	-	-	-	-	-	X	X
				Stempellinella	-	-	-	-	-	-	-	X	-	X
				Tanytarsus	-	-	-	-	-	-	-	-	-	X

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek								Trapper Creek	Yellowknife River
					Reach 0	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7		
	Ceratopogonidae	Ceratopogoninae	-	*Bezzia*	X	X	X	X	X	X	X	X	X	X
			-	*Ceratopogon*	-	-	-	-	-	X	-	-	X	-
			-	*Culicoides*	-	X	-	X	X	X	-	-	-	-
			-	*Probezzia*	X	X	X	X	X	X	X	X	X	X
		Dasyheleinae	-	*Dasyhelea*	-	-	X	-	X	-	X	-	-	X
	Simuliidae	-	-	*Simulium*	-	-	-	-	X	-	-	-	-	-
	Tabanidae	-	-	*Chrysops*	-	-	-	-	-	X	X	-	X	X
	Tipulidae	-	-	*Pilaria*	-	X	-	-	-	-	-	-	-	-
Total Taxa					***39***	***31***	***32***	***35***	***42***	***33***	***41***	***40***	***45***	***48***

Notes: X = indicates taxon present; - = indicates taxon absent.



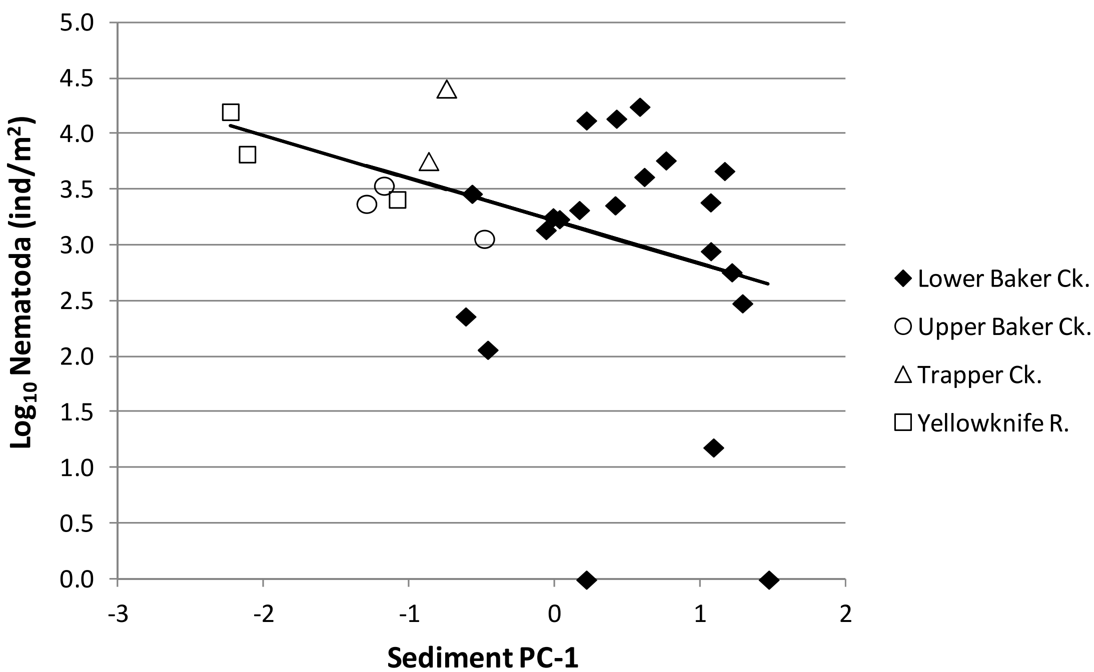


Figure 22: Scatterplots of Significant Linear Regressions for Depositional Stations in Baker Creek, Trapper Creek and the Yellowknife River, 2011

4.8.3.1.4 Multivariate Analysis of Depositional Benthic Community Data

The two-dimensional configuration generated by NMDS from the depositional benthic invertebrate data set had a stress value of 0.182, which represents a "fair" fit of the ordination results to the input data, in qualitative terms (Clarke 1993).

The NMDS ordination and Spearman rank correlation analyses (Appendix I, Table I-5) identified the following with regard to Dimension 1:

- NMDS Dimension 1 had a significant positive relationship with abundances of several midge genera (*Ablabesmyia, Microtendipes, Corynoneura*, *Polypedilum, Procladius,* and *Chironomus), Gyraulus (*gastropod), Tubificinae (aquatic worm), nematodes, and Pisidiidae (bivalves). NMDS Dimension 1 was also positively related to total invertebrate density. Thus, as Dimension 1 scores increased, the abundances of the aforementioned taxa and total abundance increased.

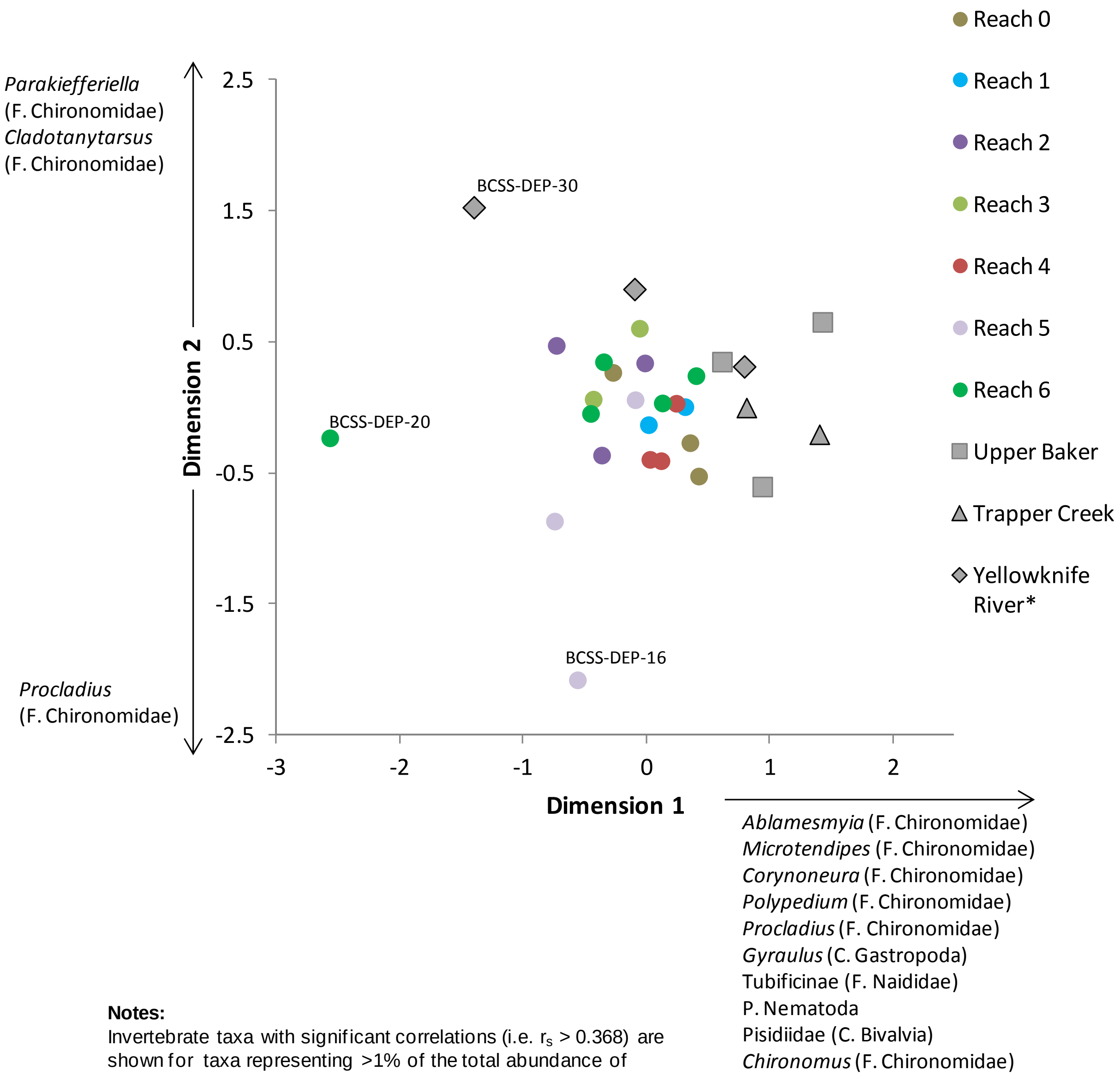
The NMDS ordination and correlation analyses identified the following with regard to Dimension 2:

- NMDS Dimension 2 had a significant positive relationship with abundances of two midge genera (*Parakiefferiella* and *Cladotanytarsus*). Thus, as Dimension 2 scores increased, abundances of these genera of midges increased.
- NMDS dimension 2 had a significant negative relationship with the midge genus *Procladius*. Thus, as Dimension 2 scores decreased, there was an increase in *Procladius* abundance.

Overall, benthic community composition in depositional habitat was highly variable among stations. Multivariate analysis did not identify a clear separation in community structure between reference locations on the Yellowknife River and stations on Baker and Trapper Creeks.

The majority of stations tended to cluster near the centre of the ordination plot, and there was no separation between sample locations in different streams along either NMDS dimension (Figure 23). Upper Baker Creek, Trapper Creek and Yellowknife River stations (grey symbols in Figure 23), corresponding to lower concentrations of COPCs in sediments, had slightly higher scores along one or both NMDS dimensions compared to the remainder of the Baker Creek stations. Stations with higher scores on Dimension 1 had generally higher abundances of a number of benthic organisms, as described above. Conversely, lower Baker Creek stations, which tended to be located toward the lower left of the ordination plot, had generally lower abundances of these taxa related to higher levels of sediment contamination.

Stations that appeared to have substantially different community composition from most other stations were identified in the Yellowknife River (BCSS-DEP-30), Reach 5 of Baker Creek (BCSS-DEP-16), and Reach 6 of Baker Creek (BCSS-DEP-20). These stations were situated at the extremes of the ordination plot and tended to have low abundance and richness compared to other stations.



Notes:
Invertebrate taxa with significant correlations (i.e. $r_s > 0.368$) are shown for taxa representing >1% of the total abundance of invertebrates sampled.
F= Family; O = Order; C = Class; P = Phylum
*indicates reference location

Figure 23: NMDS Ordination Plot for Benthic Invertebrate Abundance at Depositional Stations in Baker Creek, Trapper Creek and Yellowknife River, 2011

4.8.3.2 *Erosional Habitat*

4.8.3.2.1 Effect of Habitat Variation

Detailed habitat data are provided for each station in Appendix I, Table I-3. The substrate was similar among sampling stations. The following physical factors varied sufficiently among erosional stations to potentially contribute to inter-station variation in benthic invertebrate community structure:

- Water velocity varied from 0 to 0.54 m/s; and,
- Water depth varied moderately, from 0.13 to 0.47 m.

These variables were included in a correlation analysis to investigate their influence on benthic community variables. Total density and SEI were significantly correlated with water velocity, and density of *Micropsectra*/*Tanytarsus* was significantly correlated with water depth (Table 21). Scatter-plots of significant relationships indicated that relationships with water velocity were highly influenced by one station, but were otherwise weak (Appendix I, Figure I-2). The correlation with water depth was also weak and reflected the influence of two data points (Appendix I, Figure I-2). Based on this information, habitat variation, as reflected by the water velocity and water depth data, was considered unlikely to interfere with the gradient analysis.

Table 21: Correlations between Benthic Invertebrate Community Variables and Selected Habitat Variables in Erosional Habitat in Baker Creek and the Yellowknife River, 2011

Variable	Pearson Correlation Coefficient (*r*)	
	Water Velocity	Water Depth
Total Density	**0.564**	0.276
Richness	0.307	0.309
SEI	**-0.539**	0.447
Pisidiidae Density	0.289	0.418
Hydracarina Density	0.316	0.172
Larsia Density	-0.167	0.473
Thienemannimyia Density	0.467	0.226
Cricotopus / Orthocladius Density	-0.103	-0.110
Psectrocladius Density	-0.082	0.380
Micropsectra Density	-0.212	-0.235
Micropsectra / Tanytarsus Density	-0.206	**0.641**
Simulium Density	0.286	-0.503

Notes: **Bolding** indicates significant correlation; SEI = Simpson's Evenness Index.

Critical value (alpha = 0.05, n = 15, 2-tailed test) = 0.514.

4.8.3.2.2 Exposure Variable Evaluation

Detailed results of the linear regression analyses for conductivity and selected COPCs are provided in Appendix I, Figure I-3. There was a strong linear relationship between conductivity and antimony (r^2 = 0.986), copper (r^2 = 0.874), and nickel (r^2 = 0.971). The linear relationship between conductivity and arsenic with the full data set was strong (adjusted r^2 = 0.746). However, one outlier was identified, specifically the arsenic concentration measured at the Baker Creek Exposure Point on July 14, 2009 (0.530 mg/L). The 2009 to 2011 water quality data were previously validated and no issues were identified; therefore, a detailed QC review of these data was not completed as part of this study. This single arsenic concentration was well beyond the range of the remaining data for this location (0.094 to 0.234 mg/L). Removal of this outlier further strengthened the linear relationship between conductivity and arsenic (r^2 = 0.888). Manganese was the only COPC included in this assessment where a linear relationship with conductivity could not be established (r^2 = 0.034).

Based on the results of this assessment and on the strong linear relationships between conductivity and antimony, arsenic, copper and nickel, conductivity was determined to be a useful exposure variable for the erosional stations. Therefore, conductivity was used in the linear regressions with the benthic community variables to determine whether exposure to mine-related COPCs resulted in changes in the benthic community.

There is uncertainty regarding the source of the COPCs in erosional habitat. Benthic invertebrates in this type of environment have a greater exposure to waterborne contaminants than to those in sediment. Therefore, the source of COPCs within the erosional habitats is likely related to residual treated effluent. Results of the gradient analyses conducted on depositional data were expected to provide a more accurate indication of effects due to sediment-associated COPCs in Baker Creek.

4.8.3.2.3 Benthic Invertebrate Community Analysis

Data Screening

A detailed list of invertebrate taxa collected during the sediment study and raw abundance data are provided in Appendix I, Table I-6, and QC data are provided in Appendix I, Tables I-1 and I-7. The following outliers were identified for the erosional stations:

- Station BCSS-ERO-08 – lowest level SEI; and,
- Station BCSS-ERO-15 - *Cricotopus* / *Orthocladius* density.

While the validity of these data was confirmed, the potential influence of the outliers on the study results necessitated the analysis of the erosional dataset with and without these data.

Benthic Invertebrate Community Characteristics

With the exception of two stations, total density was lower at the majority of stations within Baker Creek (2,691 to 12,914 ind/m^2) compared to stations within the Yellowknife River (13,685 to 28,529 ind/m^2) (Table 22; Figure 24). Total density at Station BCSS-ERO-08 (14,245 ind/m^2) was comparable to Yellowknife River stations, while the density at Station BCSS-ERO-11 (34,255 ind/m^2) was higher compared the Yellowknife River stations. The higher density at these two stations was related to large numbers of blackfly (*Simulium*) larvae. This was likely related to higher water velocity at Station BCSS-ERO-08; however, the reason for the high blackfly abundance, particularly in one sample, at Station BCSS-ERO-11, is unknown.

Richness was lower at stations in Baker Creek, ranging between 18 and 24 taxa, compared to stations in the Yellowknife River, where it ranged from 31 to 34 taxa (Table 22; Figure 25).

Table 22: Summary of Benthic Invertebrate Community Variables for Erosional Habitat in Baker Creek and Yellowknife River, 2011

Waterbody	Reach	Station	Total Density	Richness	SEI
Baker Creek	Reach 0	BCSS-ERO-01	2,691	22	0.28
	Reach 1	BCSS-ERO-02	9,914	21	0.31
		BCSS-ERO-03	3,760	20	0.27
		BCSS-ERO-04	12,914	18	0.35
	Reach 2	BCSS-ERO-05	3,100	19	0.38
		BCSS-ERO-06	6,204	23	0.39
	Reach 3	BCSS-ERO-07	5,902	21	0.34
		BCSS-ERO-08	14,245	20	0.11
	Reach 4	BCSS-ERO-09	6,408	21	0.29
		BCSS-ERO-10	11,780	24	0.26
		BCSS-ERO-11	34,255	22	0.30
	Reach 5	BCSS-ERO-12	10,309	20	0.32
Yellowknife River	n/a	BCSS-ERO-15	13,685	31	0.36
	n/a	BCSS-ERO-16	28,529	31	0.33
	n/a	BCSS-ERO-17	15,479	34	0.30

Notes: n/a = not applicable; SEI = Simpson's Evenness Index.

Values of SEI were more variable in Baker Creek, ranging between 0.11 and 0.39 compared to stations in the Yellowknife River, where values ranged from 0.30 to 0.36 (Table 22; Figure 26). In general, these SEI values indicate generally low diversity overall in the benthic invertebrate communities in both streams. The particularly low SEI value at Station BCSS-ERO-11 is reflective of a very high proportion of blackfly larvae. There was no obvious difference in evenness between Baker Creek and the Yellowknife River.

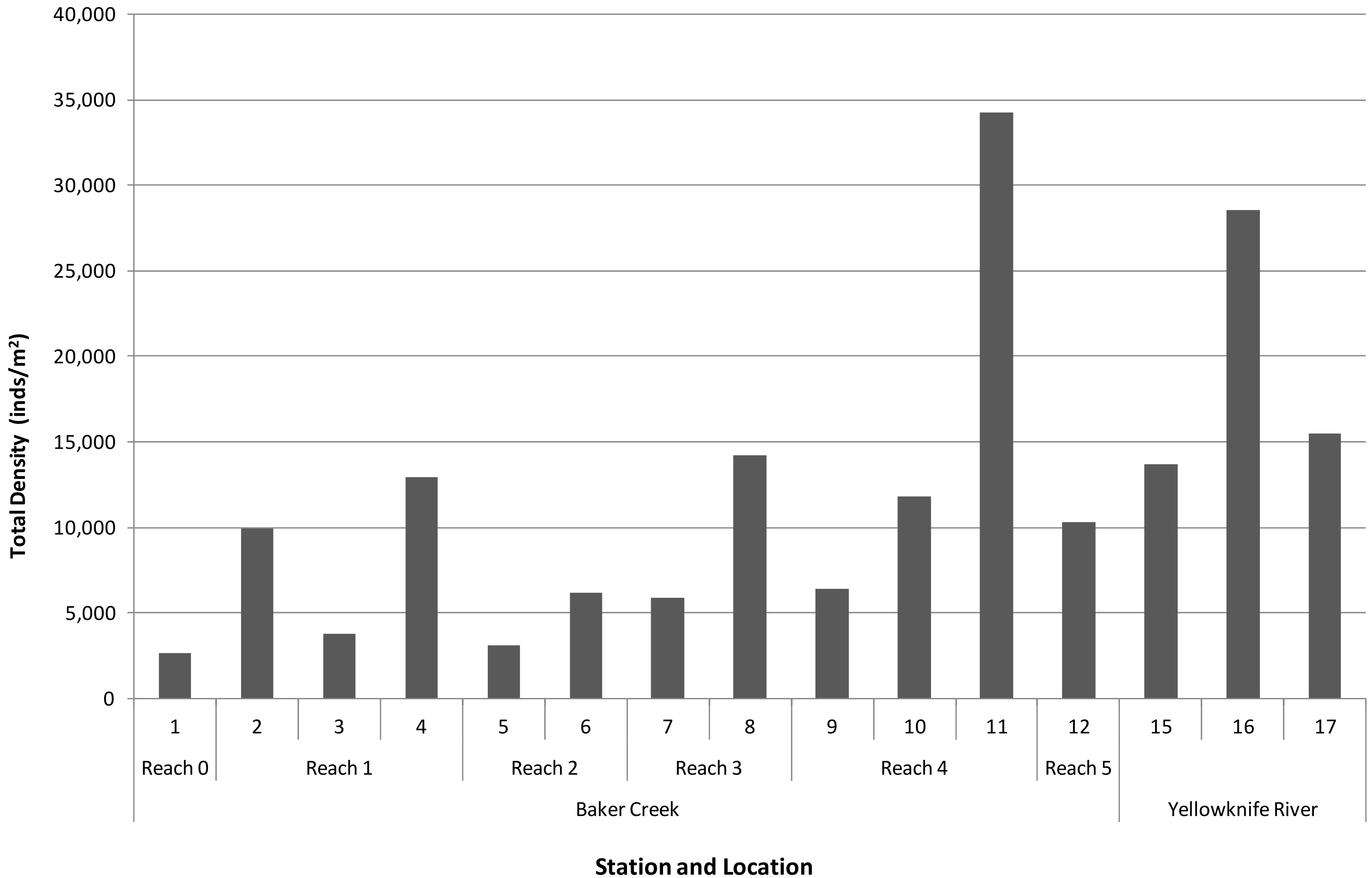


Figure 24: Variation in Total Benthic Invertebrate Density in Erosional Habitat in Baker Creek and Yellowknife River, 2011

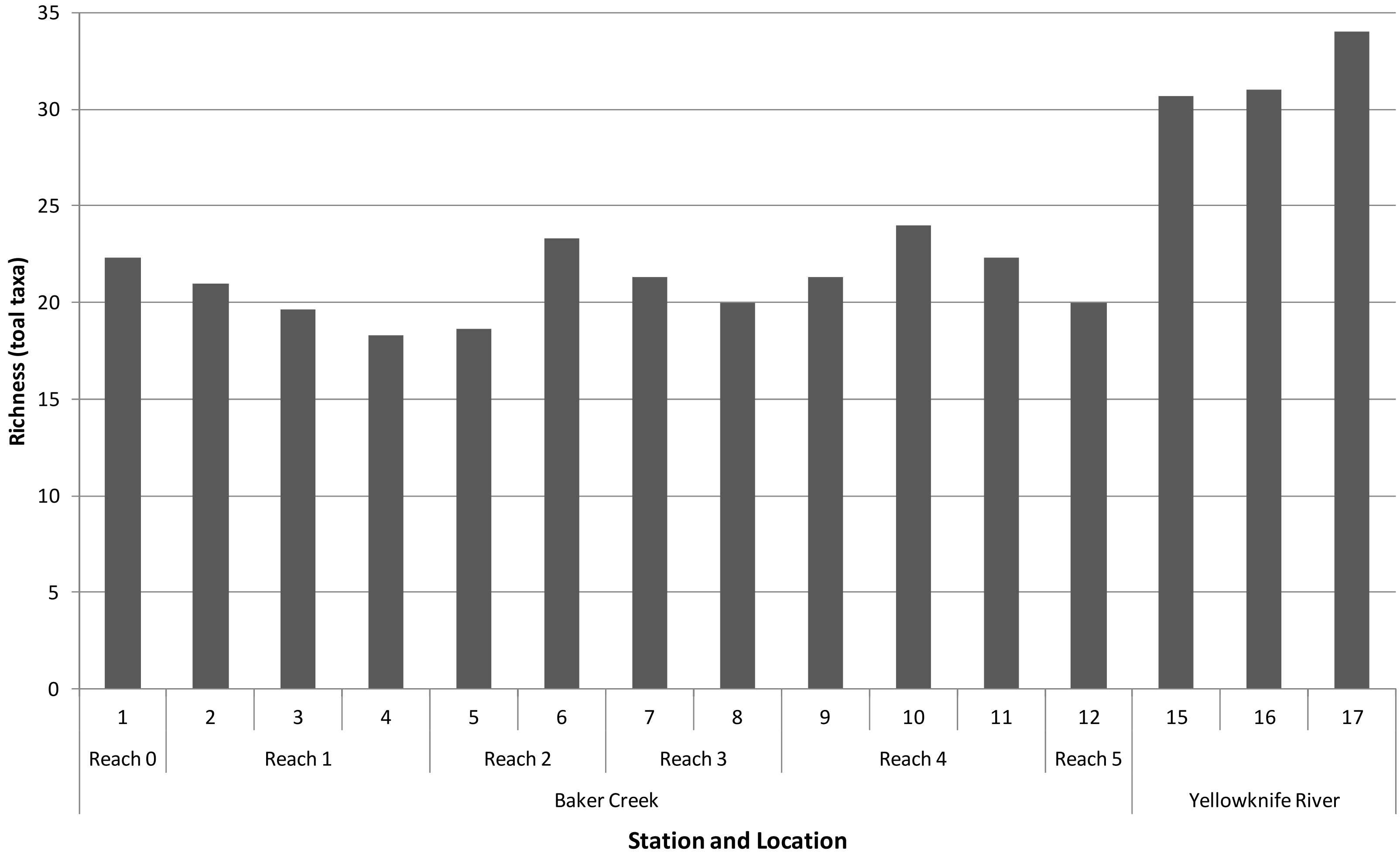


Figure 25: Variation in Benthic Invertebrate Richness in Erosional Habitat in Baker Creek and Yellowknife River, 2011

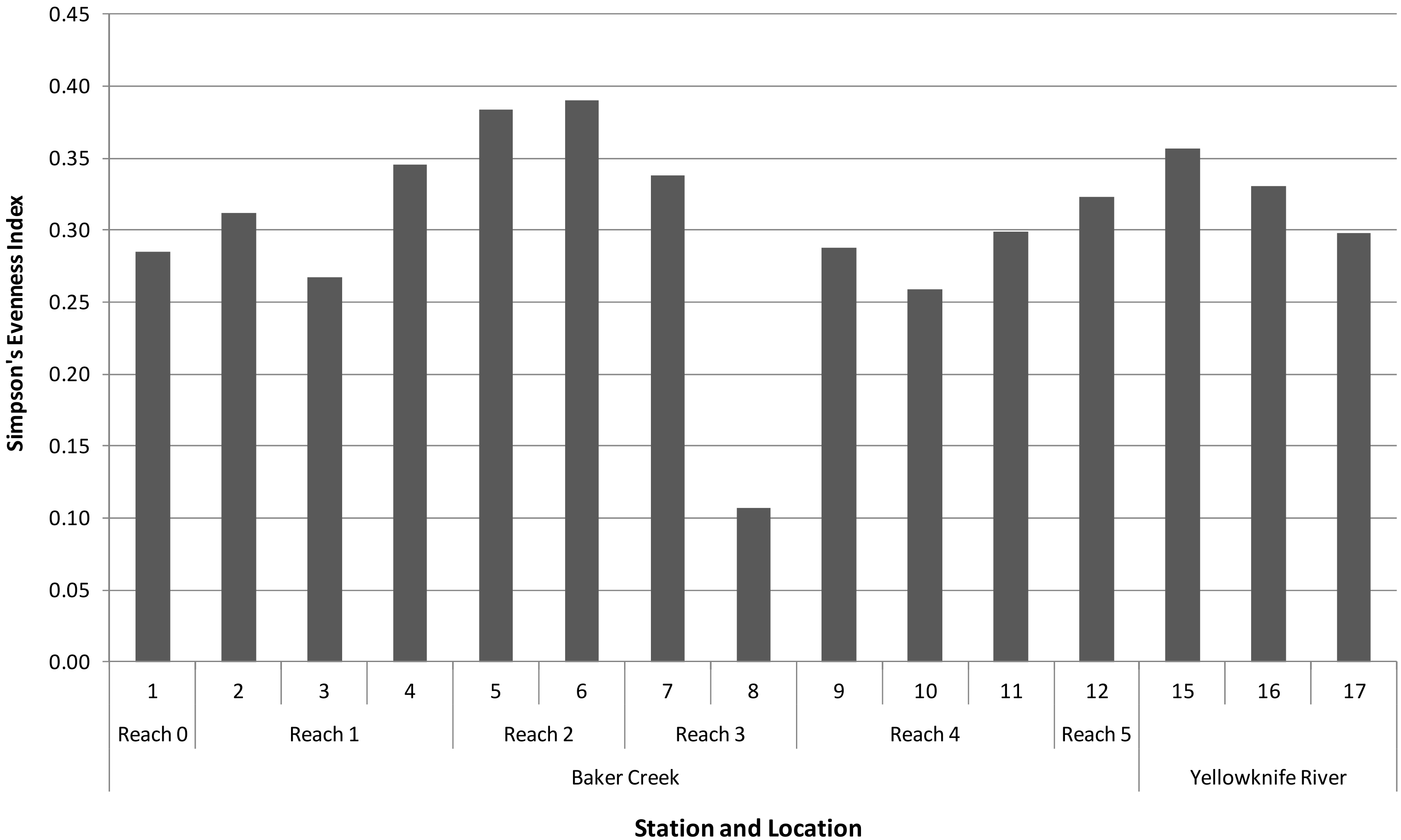


Figure 26: Variation in Simpson's Evenness Index in Erosional Habitat in Baker Creek and Yellowknife River, 2011

The relative densities of major taxonomic groups exhibited variability among stations within Baker Creek, and Baker Creek communities differed from Yellowknife River communities (Figure 27). Overall, the benthic invertebrate communities within Baker Creek were dominated by Diptera (76 to 98%), predominantly various midge taxa and blackflies. In contrast, Diptera accounted for 37 to 46% of the benthic invertebrate community in the Yellowknife River. Ostracods accounted for approximately 10% of the benthic invertebrate communities at Stations BCSS-ERO-09 and BCSS-ERO-10, but comprised a small proportion of the community (0 to 3%) at the remaining Baker Creek and Yellowknife River stations. Bivalves occurred at higher relative densities (9 to 22%) at the Yellowknife River stations, whereas this group accounted for less than 1% of the community in Baker Creek.

Ephemeroptera, Plecoptera and Trichoptera (EPT) are generally considered to be sensitive to environmental disturbances and typically exhibit reduced densities in contaminated areas where metals are biologically available to toxic levels (Barbour et al. 1999; Resh and Jackson 1993). EPT were present in low proportions (1 to 6%) at all stations in Baker Creek, with the exception of Station BCSS-ERO-12 (Reach 5), where EPT accounted for 13% of total density (Figure 27). This proportion of EPT was comparable to two stations in the Yellowknife River (BCSS-ERO-15 and BCSS-ERO-17), but lower than at the third Yellowknife River station (BCSS-ERO-16). Similarly, stations in the Yellowknife River had higher total mean densities of Ephemeroptera (815 to 1,033 ind/m^2), Plecoptera (90 to 151 ind/m^2), and Trichoptera (614 to 8,436 ind/m^2) compared to stations in Baker Creek (Ephemeroptera [7 to 273 ind/m^2], Plecoptera [0 to 4 ind/m^2] and Trichoptera [0 to 1,317 ind/m^2]) (Figure 28).

Overall, there was an obvious difference in benthic community composition between Baker Creek and the Yellowknife River. The type of difference can be described as greater dominance by midges and lower richness and diversity in Baker Creek, along with reduced numbers of sensitive invertebrates. The observed difference is consistent with the expected negative effect of elevated concentrations of mine-related COPCs in stream water and sediments in Baker Creek.

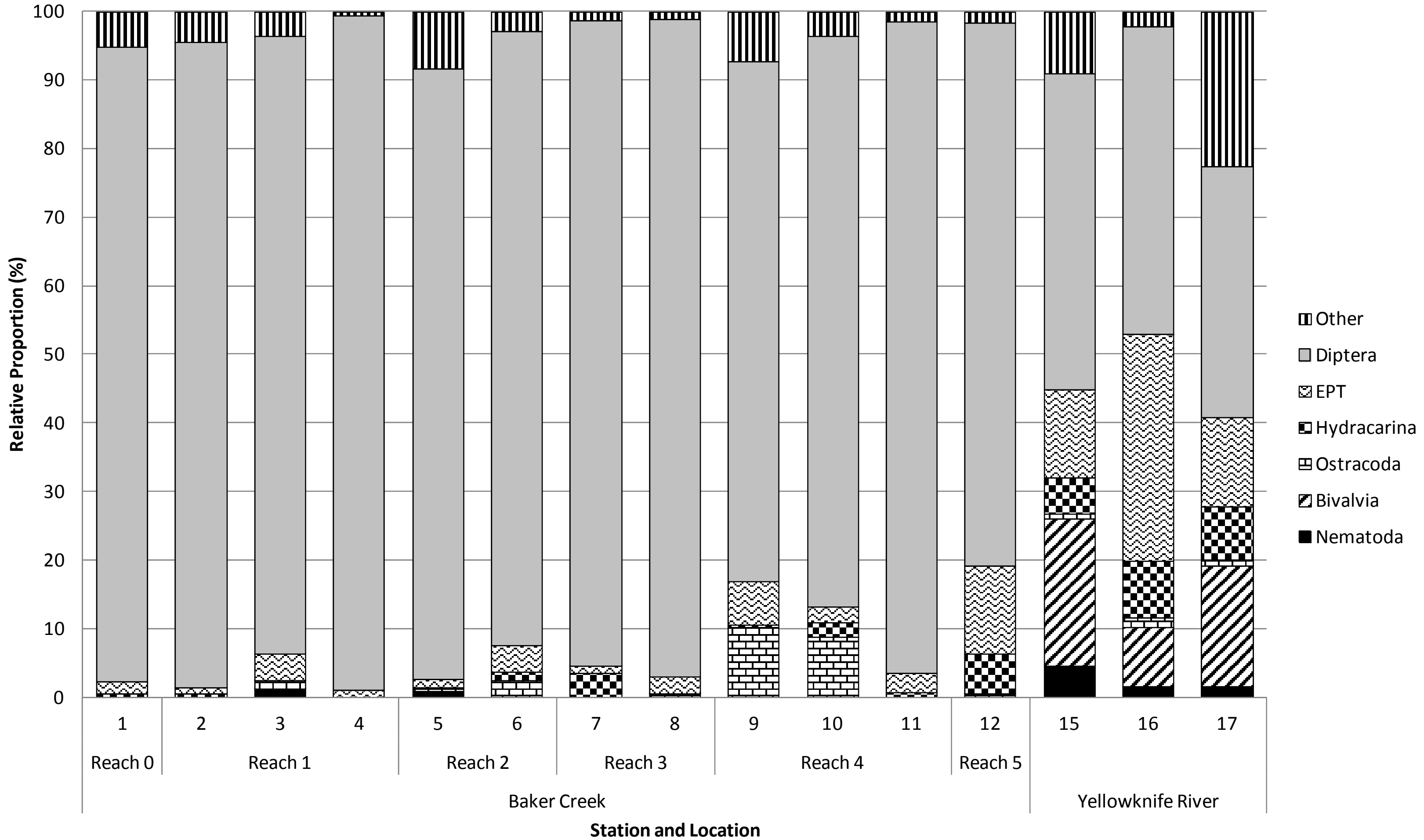


Figure 27: Benthic Invertebrate Community Composition by Major Taxonomic Groups in Erosional Habitat, 2011

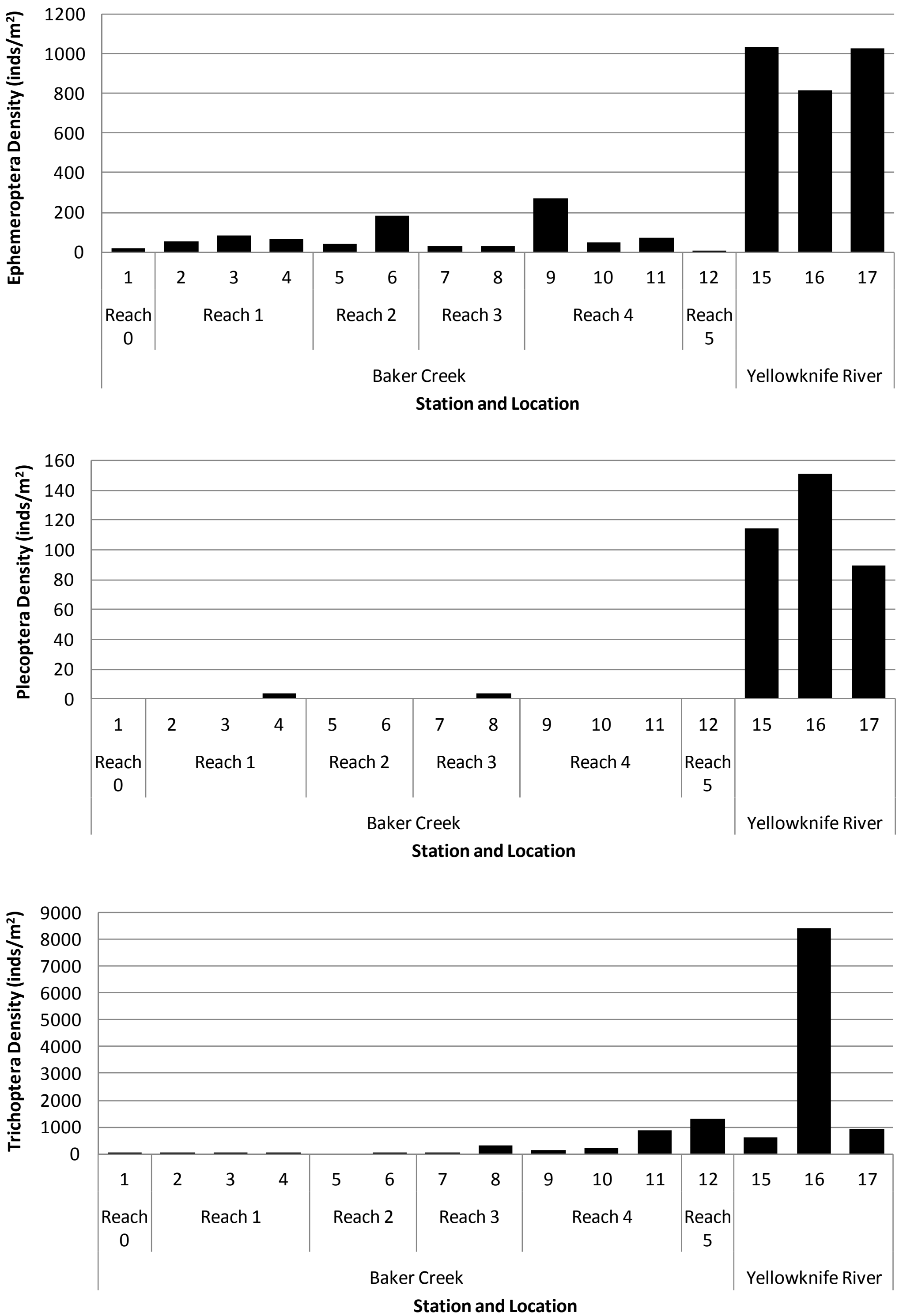


Figure 28: Ephemeroptera, Plecoptera and Trichoptera Density in Baker Creek and the Yellowknife River, 2011

Evaluation of the presence or absence of invertebrate taxa identified differences between Baker Creek and the Yellowknife River in terms of community composition. Twenty-one taxa were unique to the Yellowknife River stations (Table 23). Although lowest level richness exhibited little variation between stations within Baker Creek, there were differences among stations in the number and types of families present. The following eight taxa were present at only one station within Baker Creek and were also present at the Yellowknife River stations:

- Hydridae – Station BCSS-ERO-07;
- *Helobdella stagnalis* (leech) – Station BCSS-ERO-06;
- *Valvata sincera* (bivalve) – Station BCSS-ERO-02;
- *Agrypnia* sp. (caddisfly) – Station BCSS-ERO-11;
- *Synorthocladius* sp. (midge) – Station BCSS-ERO-09;
- *Cryptochironomus* sp. (midge) – Station BCSS-ERO-10;
- *Corynocera* sp. (midge) – Station BCSS-ERO-01; and,
- *Tanytarsus* sp. (midge) – Station BCSS-ERO-04.

The following seven taxa were present at only one station within Baker Creek and were absent from the Yellowknife River:

- *Callibaetis* (mayfly) – Station BCSS-ERO-05;
- *Ophiogomphus* (dragonfly) – Station BCSS-ERO-07;
- *Oreodytes* (dytiscid beetle) – Station BCSS-ERO-07;
- *Acricotopus* sp. (midge) – Station BCSS-ERO-10;
- *Paracladopelma* (midge) – Station BCSS-ERO-07;
- *Paralauterborniella* (midge) – Station BCSS-ERO-03; and,
- *Dasyhelea* (biting midge) – Station BCSS-ERO-05.

Table 23: Presence/Absence of Benthic Invertebrate Taxa in Erosional Habitat in Baker Creek and Yellowknife River, 2011

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek												Yellowknife River		
					Reach 0	Reach 1			Reach 2		Reach 3		Reach 4			Reach 5			
					BCSS-ERO-01	BCSS-ERO-02	BCSS-ERO-03	BCSS-ERO-04	BCSS-ERO-05	BCSS-ERO-06	BCSS-ERO-07	BCSS-ERO-08	BCSS-ERO-09	BCSS-ERO-10	BCSS-ERO-11	BCSS-ERO-12	BCSS-ERO-15	BCSS-ERO-16	BCSS-ERO-17
Cnidaria	Hydridae	-	-	*Hydra*	-	-	-	-	-	-	X	-	-	-	-	-	X	X	X
Nematoda	-	-	-	-	X	-	X	-	X	-	-	X	X	X	X	-	X	X	X
Hirudinea	Erpobdellidae	-	-	*Erpobdella punctata*	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-
		-	-	*Nephelopsis obscura*	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
	Glossiphoniidae	-	-	*Glossiphonia complanata*	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
		-	-	*Helobdella fusca*	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-
		-	-	*Helobdella stagnalis*	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
Oligochaeta	Enchytraeidae	-	-	-	X	-	X	-	-	X	X	X	-	X	-	X	X	-	X
	Lumbriculidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
	Naididae	-	-	-	X	X	X	X	X	X	-	X	X	X	-	X	X	X	X
		Naidinae	-	-	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X
		Tubificinae	-	-	-	-	X	-	-	X	-	X	X	X	-	-	-	-	X
Gastropoda	Physidae	-	-	*Physa*	X	X	X	-	-	-	-	X	X	X	X	X	X	-	-
		-	-	*Gyraulus*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Lymnaeidae	-	-	-	X	X	-	-	X	X	X	X	X	X	-	X	X	X	X
	Valvatidae	-	-	*Valvata sincera*	-	X	-	-	-	-	-	-	-	-	-	-	X	X	X
Bivalvia	Pisidiidae	-	-	-	X	X	X	-	-	-	X	-	-	-	-	X	X	X	X
	Unionidae	-	-		-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
Hydracarina	-	-	-	-	X	X	X	-	-	X	X	X	X	X	X	X	X	X	X
Ostracoda	-	-	-	-	-	X	X	X	X	X	-	X	X	X	-	X	X	X	X
Amphipoda	Gammaridae	-	-	*Gammarus lacustris*	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-
	Hyalellidae	-	-	*Hyalella azteca*	X	X	X	X	X	X	-	X	X	X	X	X	-	X	X
Ephemeroptera	Baetidae	-	-	*Acerpenna*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
		-	-	*Callibaetis*	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
		-	-	*Baetis*	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
	Caenidae	-	-	*Caenis*	X	-	-	-	-	X	-	-	X	-	-	-	X	X	-
	Ephemeridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X
	Heptageniidae	-	-	*Maccaffertium terminatum*	X	-	-	-	-	-	-	-	-	X	X	-	X	-	X
	Leptophlebiidae	-	-	*Leptophlebia*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plecoptera	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X	X	X
Trichoptera	Apataniidae	-	-	*Apatania*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
	Glossosomatidae	-	-	*Glossosoma*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
	Hydropsychidae	-	-	*Cheumatopsyche*	X	-	-	-	-	-	-	X	-	-	X	X	-	X	X
		-	-	*Hydropsyche*	-	-	-	-	-	-	-	X	-	X	X	X	-	-	-
	Hydroptilidae	-	-	*Hydroptila*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
		-	-	*Oxyethira*	X	-	-	-	-	X	X	X	X	X	X	X	X	X	-
	Lepidostomatidae	-	-	*Lepidostoma*	X	-	-	-	-	-	-	-	X	-	-	-	X	X	X
	Leptoceridae	-	-	*Ceraclea*	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X
		-	-	*Oecetis*	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-
	Phryganeidae	-	-	*Agrypnia*	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-
	Polycentropodidae	-	-	*Neureclipsis*	X	-	X	X	-	-	-	X	-	X	X	X	X	X	X
		-	-	*Polycentropus*	X	X	X	X	-	X	X	X	X	X	X	X	-	-	-

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek												Yellowknife River		
					Reach 0	Reach 1			Reach 2		Reach 3		Reach 4			Reach 5			
					BCSS-ERO-01	BCSS-ERO-02	BCSS-ERO-03	BCSS-ERO-04	BCSS-ERO-05	BCSS-ERO-06	BCSS-ERO-07	BCSS-ERO-08	BCSS-ERO-09	BCSS-ERO-10	BCSS-ERO-11	BCSS-ERO-12	BCSS-ERO-15	BCSS-ERO-16	BCSS-ERO-17
Odonata - Anisoptera	Aeshnidae	-	-	*Aeshna*	-	X	-	-	X	X	-	X	-	-	-	X	-	-	-
	Gomphidae	-	-	*Ophiogomphus*	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Odonata - Zygoptera	Coenagrionidae	-	-	*Enallagma*	-	-	-	X	-	X	-	-	-	X	X	-	-	-	-
Coleoptera	Dytiscidae	-	-	*Oreodytes*	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
		-	-	*Stictotarsus*	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-
	Haliplidae	-	-	*Haliplus*	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-
Diptera	Chironomidae	Tanypodinae	Pentaneurini	*Ablabesmyia*	X	X	X	X	-	X	X	X	-	X	-	X	X	X	-
				Labrundinia	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X
				Larsia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
				Nilotanypus	-	-	-	-	-	-	X	X	-	-	-	-	X	-	-
				Thienemannimyia group	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			Procladiini	*Procladius*	-	X	-	-	-	-	X	-	-	X	-	X	-	-	-
		Diamesinae	Protanypini	*Pagastia*	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
		Prodiamesinae	-	*Monodiamesa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Orthocladiinae	Orthocladiini	*Acricotopus*	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
				Brillia	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
				Corynoneura	X	X	-	X	X	X	X	X	X	X	X	X	-	X	X
				Cricotopus / Orthocladius	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X
				Epoicocladius	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
				Eukiefferiella	-	-	-	-	-	-	X	-	-	X	X	-	X	-	-
				Heterotrissocladius	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
				Nanocladius	-	-	X	-	-	-	-	X	-	-	X	X	X	-	-
				Parakiefferiella	-	-	-	-	X	X	X	-	X	X	X	-	X	X	X
				Psectrocladius	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
				Synorthocladius	-	-	-	-	-	-	-	-	X	-	-	-	X	X	X
				Tvetenia	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-
				Cryptochironomus	-	-	-	-	-	-	-	-	-	X	-	-	X	X	X
				Demicryptochironomus	X	-	-	X	X	X	-	X	-	X	-	-	-	-	-
				Dicrotendipes	-	-	-	X	-	X	-	-	-	-	-	X	X	-	-
				Microtendipes	-	-	-	-	X	X	-	-	-	-	-	-	X	X	X
				Nilothauma	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X
				Pagastiella	-	-	X	-	X	X	-	-	X	-	-	-	-	-	-
				Parachironomus	X	-	X	-	-	-	-	-	X	X	X	X	-	X	-
				Paracladopelma	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
				Paralauterborniella	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
				Paratendipes	X	-	-	-	-	-	-	-	-	X	-	-	X	-	-
				Phaenopsectra	-	-	-	-	-	-	X	-	-	X	-	-	X	X	-
				Polypedilum	-	X	-	X	-	-	-	-	-	-	-	-	X	X	X
				Saetheria	X	X	-	-	-	-	X	-	-	-	-	-	X	-	-
				Stictochironomus	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-
				Xenochironomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
			Tanytarsini	*Cladotanytarsus*	X	X	X	-	X	X	X	-	X	X	-	-	-	-	-
				Corynocera	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-

Major Taxon	Family	Subfamily	Tribe	Genus/Species	Baker Creek												Yellowknife River		
					Reach 0	Reach 1			Reach 2		Reach 3		Reach 4			Reach 5			
					BCSS-ERO-01	BCSS-ERO-02	BCSS-ERO-03	BCSS-ERO-04	BCSS-ERO-05	BCSS-ERO-06	BCSS-ERO-07	BCSS-ERO-08	BCSS-ERO-09	BCSS-ERO-10	BCSS-ERO-11	BCSS-ERO-12	BCSS-ERO-15	BCSS-ERO-16	BCSS-ERO-17
				Micropsectra	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
				Micropsectra / Tanytarsus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
				Paratanytarsus	X	X	X	X	X	X	X	X	X	X	X	-	X	-	-
				Stempellina	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-
				Stempellinella	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X
				Tanytarsus	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-
	Ceratopogonidae	Ceratopogoninae	-	*Bezzia*	-	X	-	X	X	X	X	-	X	-	X	X	-	-	-
			-	*Probezzia*	-	-	X	X	X	X	-	-	X	X	-	X	-	X	-
		Dasyheleinae	-	*Dasyhelea*	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
	Empididae	-	-	*Chelifera*	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		-	-	*Hemerodromia*	-	X	X	-	-	X	-	-	X	-	-	-	-	-	-
	Simuliidae	-	-	*Simulium*	-	-	X	-	X	X	X	X	X	X	X	X	X	-	-
Total Taxa					***36***	***31***	***33***	***28***	***31***	***37***	***33***	***33***	***35***	***43***	***31***	***33***	***57***	***46***	***44***

Notes: X = indicates taxon present; - = indicates taxon absent.

4.8.3.2.4 Regression Analysis of Erosional Benthic Community Data

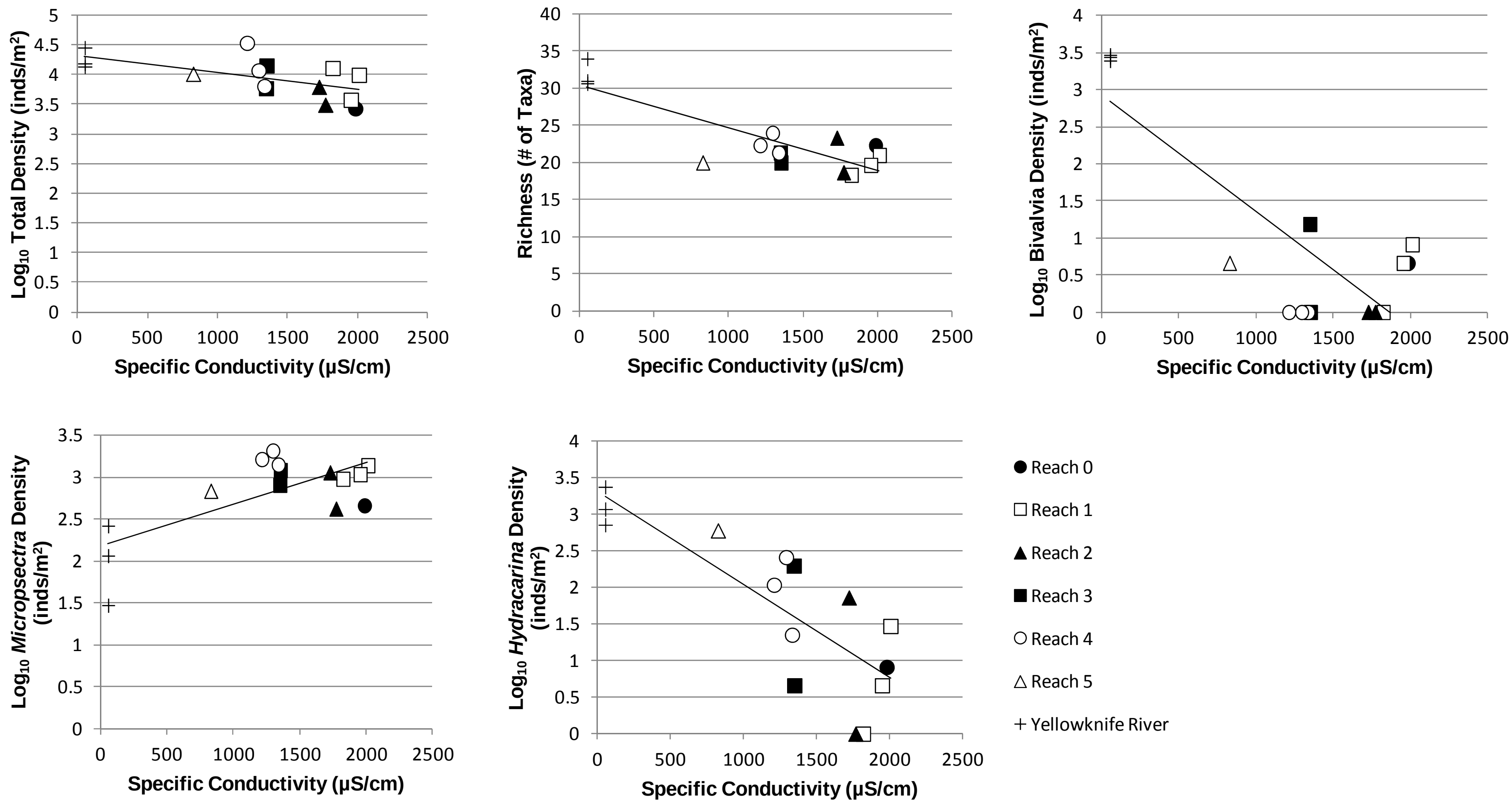
Results of the linear regression analyses of benthic community variables as a function of conductivity are summarized in Table 24. There were significant relationships between conductivity and five community variables: total density; richness; Bivalvia density; Hydracarina density; and, *Micropsectra* density (Figure 29). Conductivity explained a large proportion (39 to 73%) of the total variation in these variables, suggesting that exposure to COPCs has affected the benthic invertebrate communities within Baker Creek. However, it is not possible to determine whether this exposure is related to effluent, historical contamination of sediment within Baker Creek, or a combination of these two potential sources of COPCs. In addition, because the reference area is outside of Baker Creek, part of the variation in benthic community structure is likely related to natural, habitat-related differences between Baker Creek and the Yellowknife River.

Table 24: Results of Linear Regression Analyses of Specific Conductivity vs. Benthic Community Variables – Erosional Habitat

Variable	Y-Intercept	Slope	Coefficient of Determination (r^2)	*p*-value
Total Density	4.329	-0.0003	0.392	**0.013**
Richness	30.52	-0.006	0.728	**<0.001**
SEI (one outlier removed)	Ns			0.797
Bivalvia Density	2.921	-0.002	0.679	**<0.001**
Hydracarina Density	3.305	-0.001	0.660	**<0.001**
Larsia Density	ns			0.849
Thienemannimyia Density	ns			0.110
Cricotopus/*Orthocladius* Density (one outlier removed)	ns			0.702
Psectrocladius Density	ns			0.341
Micropsectra Density	2.177	0.0005	0.499	**0.003**
Micropsectra / Tanytarsus Density	ns			0.611
Simulium Density	ns			0.511

Notes: **Bolded** values indicate significant regression at $P < 0.05$; ns = results were not significant; < = less than. SEI = Simpson's Evenness Index.

Total density, richness, and densities of Bivalvia and Hydracarina exhibited decreasing trends with increasing conductivity (Figure 29). Densities of the midge *Micropsectra* increased with higher conductivity. This increase in density may be a reflection of habitat differences or could indicate a tolerance to mine-related COPCs.



Notes: ind/m^2 = individuals per square metre; µS/cm = microSiemens per centimetre.

Figure 29: Scatterplots of Significant Linear Regressions for Erosional Habitat in Baker Creek and the Yellowknife River, 2011

4.8.3.2.5 Multivariate Analysis of Erosional Benthic Community Data

Using ecological distances generated from the benthic invertebrate community data as the input, NMDS arranged sampling stations in two dimensions. The stress value of the final configuration was 0.056, which represented a good fit of the ordination results to the input data, in qualitative terms (Clarke 1993).

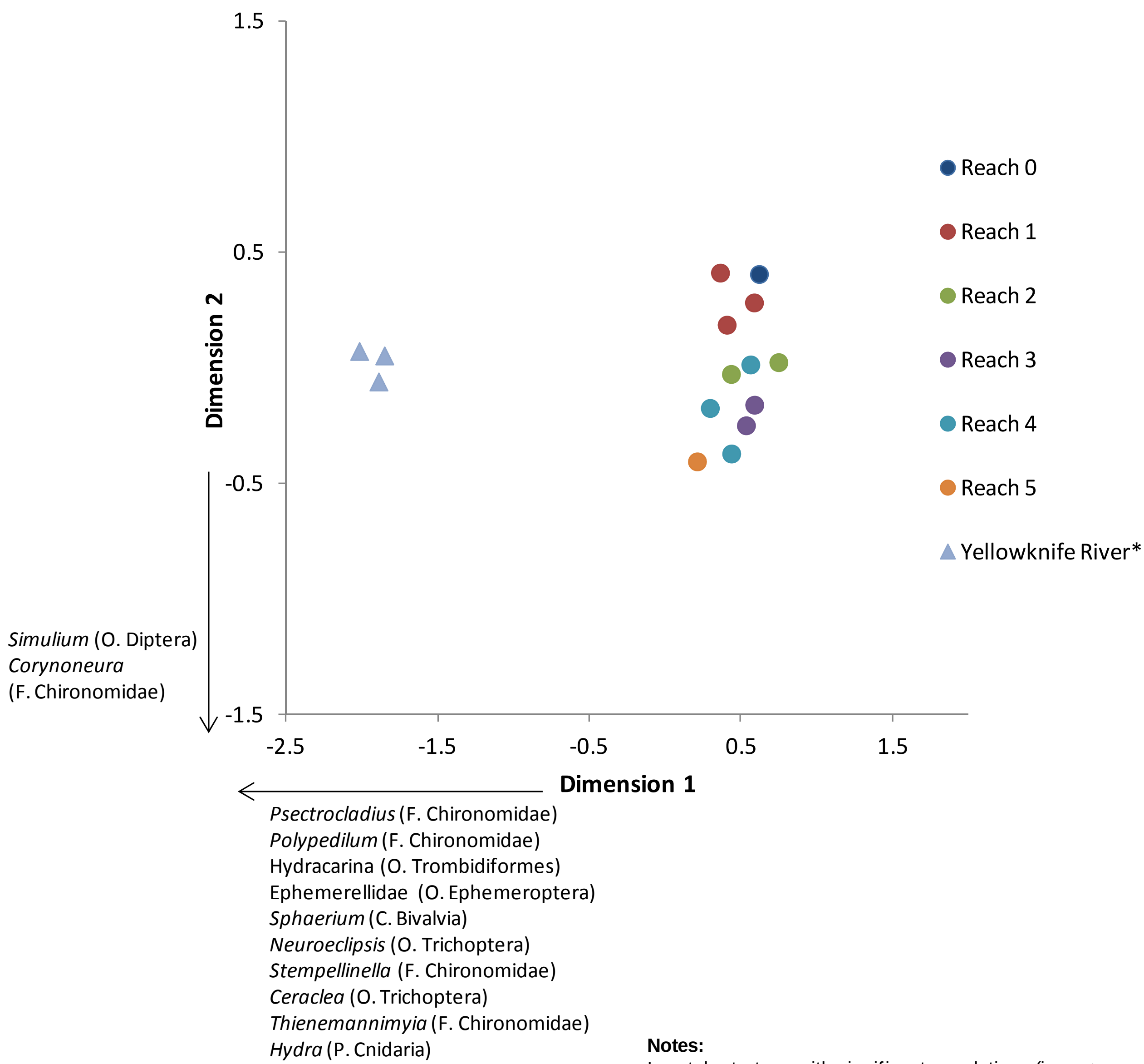
The NMDS ordination plot shown in Figure 30 illustrates ecological distances among erosional stations in Baker Creek and reference locations in the Yellowknife River. Stations that are close together on this plot have similar benthic invertebrate communities, whereas stations that are farther apart have dissimilar communities. Spearman rank correlations between the original taxa abundances and NMDS dimension variables were used to identify invertebrate taxa that were most closely associated with each dimension, and to allow an evaluation of the relative similarities or dissimilarities between the communities present at the stations sampled. Taxa associated with each dimension are shown along each axis in Figure 30, and results of the Spearman correlation analysis are provided in Appendix I, Table I-8.

Reference stations in the Yellowknife River were tightly clustered on the left side of the ordination plot, and were separated from stations located in Baker Creek (Figure 30). The reaches sampled along Baker Creek were similar in community composition and generally clustered at the centre of the ordination plot.

Separation between the Yellowknife River reference area and the sampled reaches in Baker Creek was apparent along NMDS Dimension 1 (Figure 30). The NMDS ordination and Spearman rank correlation analyses identified that Dimension 1 had a significant negative relationship with the abundances of several midge genera (i.e., *Psectrocladius*, *Polypedilum*, *Stempellinella*, and *Thienemannimyia*), Hydracarina (water mites), Ephemerellidae (mayfly), *Sphaerium* (bivalve), two caddisfly genera (*Neureclipsis* and *Ceraclea)*, and *Hydra* (P. Cnidaria). Thus, as Dimension 1 scores decreased to the left of Figure 30, the abundance of these taxa increased.

There was no apparent separation of Baker Creek and Yellowknife River communities along NMDS Dimension 2 (Figure 30); however, Dimension 2 values appear to decrease with increasing distance downstream in Baker Creek (Reach 0 to Reach 5), suggesting a gradual change in community composition along the length of Baker Creek. The NMDS ordination and Spearman rank correlations identified that Dimension 2 had a significant negative relationship with abundances of the midge genus *Corynoneura* and the blackfly *Simulium*. Thus, as Dimension 2 scores decreased, the abundance of these taxa increased.

In general, the multivariate analysis indicated there were differences between the benthic erosional communities of Baker Creek and reference locations. The taxa which yielded significant correlations along Dimension 1 were typically present only at the reference stations. For instance, bivalves (*Sphaerium*), mayflies (Ephemerellidae), midges (*Polypedilum* and *Stempellinella*), and caddisflies (*Ceraclea*) were present at reference stations, but were rare or entirely absent in the sampled reaches on Baker Creek. Community composition within individual reaches of Baker Creek was generally similar (clustering closely together on Figure 30). Some differences were apparent between the upstream and downstream reaches of Baker Creek, as indicated by moderate separation along Dimension 2. Reaches 3, 4, and 5 tended to have lower Dimension 2 scores and, therefore, higher numbers of the blackfly *Simulium* and the midge *Corynoneura* compared to the lower reaches of Baker Creek (i.e., Reaches 0, 1, and 2). Habitat differences, particularly water velocity, may account for the increased *Simulium* densities in specific reaches.



Notes:
Invertebrate taxa with significant correlations (i.e. r_s > 0.521) are shown for taxa representing >0.5% of the total abundance of invertebrates sampled.
F= Family; O = Order; C = Class; P = Phylum
* indicates reference location.

Figure 30: NMDS Ordination Plot for Benthic Invertebrate Abundance at Erosional Stations in Baker Creek and the Yellowknife River, 2011

4.8.3.3 Summary

Analysis of depositional benthic invertebrate data identified no obvious differences among benthic invertebrate communities in Baker Creek, Trapper Creek and the Yellowknife River. Neither total density nor richness showed spatial trends along Baker Creek, and there were no apparent differences between Baker Creek, the Yellowknife River, and Trapper Creek. The ranges of variation in total density and richness were greater in Baker Creek than in the Yellowknife River; however, this would be expected even in the absence of an effect in Baker Creek, as considerably more stations were sampled in Baker Creek (24 stations) than in the Yellowknife River (3 stations).

Relative densities of major taxonomic groups were highly variable among stations in Baker Creek, and only minor differences were apparent between the communities of Baker Creek, Trapper Creek, and the Yellowknife River. Presence or absence of benthic invertebrate taxa in terms of unique taxa in each stream appeared to reflect the different sampling effort among streams. The only potential effect of higher sediment COPC concentrations in lower Baker Creek was the sporadic occurrence of mayflies in this stream, compared to their consistent presence at reference stations in the Yellowknife River.

The SEI values were relatively low in all three streams, indicating all stations had benthic communities dominated by a few taxa. Regression analysis revealed that evenness reflected variation in habitat features among stations rather than sediment COPC concentrations. Richness and Nematoda density were significantly negatively related to sediment COPC concentration. Although these relationships were weak, they were consistent with a low level effect on the benthic community at stations with elevated COPC concentrations. Multivariate analysis did not identify a clear separation in community structure between reference stations in the Yellowknife River and stations in Baker and Trapper Creeks. Rather, it revealed a subtle gradient in community composition, in which stations with lower sediment COPC concentrations had slightly higher total abundances and abundances of taxa associated with NMDS Dimension 1. Overall, the magnitude of the effect of elevated sediment COPC concentrations in Baker Creek sediments on depositional benthic invertebrate communities can be qualitatively described as low.

Benthic invertebrate communities in erosional habitats of Baker Creek exhibit differences from the communities in similar habitat in the Yellowknife River. Richness was consistently lower at all stations in Baker Creek compared to stations in the Yellowknife River. Evenness values were relatively low in both Baker Creek and the Yellowknife River, indicating all areas had benthic communities dominated by a few taxa. High densities of the blackfly larva (*Simulium*) were present at some stations, but this was likely a reflection of higher water velocities at those stations rather than exposure to mine-related COPCs. Multivariate analysis, which compares the entire communities rather than individual variables, identified clear differences in community structure between Baker Creek and the Yellowknife River. Nevertheless, habitat variation among stations and between Baker Creek and the Yellowknife River remain a potential confounding factor that may account for some of the observed differences in benthic community structure. It may be that the erosional benthic invertebrate community within Baker Creek is reflective of exposure to COPCs from treated effluent rather than historical sediment contamination, but this would require further field investigation.

4.9 Assessment Characterization

4.9.1 Weight of Evidence (WOE) Assessment

A WOE approach was used to integrate the available data into a single “balance of probabilities” conclusion regarding the potential for unacceptable adverse ecological impacts in the study area. As defined by Chapman et al. (2002), WOE is a determination related to possible ecological impacts based on multiple lines of evidence (LOE). This determination incorporates judgments concerning the quality, extent, and congruence of the data contained in the different LOE.

This section is organized as follows:

- The WOE decision framework used to evaluate each individual LOE is presented in Section 4.9.1.1;
- The decision framework used to guide the integration of multiple LOE into a single rating regarding the potential for adverse ecological impacts is presented in Section 4.9.1.2; and,
- Station-by-station WOE results are presented in Section 4.9.1.3.

4.9.1.1 WOE Framework

The WOE decision framework is normally established *a priori* and then each LOE is assessed against that framework. For example, the sediment chemistry LOE is assessed by comparing sediment COPC concentrations to SQGs, and the sediment toxicity LOE is assessed using the magnitude (i.e., whether the change is <20% or >50%) and statistical significance of reductions in toxicity endpoints relative to average reference performance.

The present study was designed with the intent that the Yellowknife reference stations would be representative of background conditions and that the benthic invertebrate community LOE would be assessed using the magnitude and statistical significance of differences in benthic invertebrate community metrics relative to those reference stations (similar to the approach used for the sediment toxicity LOE).

Sediment Chemistry LOE

Sediment chemistry was evaluated by comparing bulk sediment concentrations to the applicable numerical SQGs. Because arsenic concentrations were above upper-bound sediment SQGs and the GNWT (2003) remediation objective in sediments from 26 of the exposure stations, two metrics were used for the sediment chemistry LOE. The first metric was based on the sediment arsenic concentration only, and the second metric was based on the other metals measured in the sample.

- Concentrations that were less than the ISQG were considered indicative of a negligible potential for adverse effects (and were assigned a rating of “○”);
- Concentrations greater than the ISQG but less than the PEL were considered indicative of a moderate potential for adverse effects (and were assigned a rating of “⦿”); and,
- Concentrations greater than the PEL were considered indicative of a severe potential for adverse effects (and were assigned a rating of “●”).

Analytes without numerical SQGs were not included in this LOE, but were included in the correlation analyses (Section 4.9.2).

Sediment Toxicity LOE

Sediment toxicity data were evaluated using the following decision criteria:

- A reduction in endpoint performance of <20% (relative to the average reference performance) was considered indicative of a negligible potential for adverse effects (and was assigned a rating of "○");
- A reduction in endpoint performance of ≥20% that was not statistically significant (relative to the average reference performance) was considered indicative of a low potential for adverse effects (and was assigned a rating of "○*");
- A reduction in endpoint performance of ≥20% and statistically significant (relative to the average reference performance) was considered indicative of a moderate potential for adverse effects (and was assigned a rating of "⦿"); and,
- A reduction in endpoint performance of >50% (relative to the average reference performance) was considered indicative of a severe potential for adverse effects (and was assigned a rating of "●").

Following classification of each individual toxicity test endpoint as described above, the toxicity data were then integrated into a single measure of sediment toxicity prior to integration with other LOE. Decision criteria for determining the integrated sediment toxicity rating are provided in Table 25, and the ratings themselves are summarized in Table 26 on a sample-by-sample basis. The integrated sediment toxicity rating was intended to reflect the following principles:

- More weight was assigned to acute toxicity data (e.g., amphipod or chironomid survival) versus chronic toxicity data (e.g., growth, expressed in terms of dry weight). This does not mean that reductions in growth are not considered indicative of an adverse effect but, rather, those substantial decreases in organism survival will likely result in greater effects on population stability than decreases in growth.
- Toxicity data that demonstrated a statistically significant difference (p <0.05) relative to the average reference performance were weighted higher than toxicity data that did not demonstrate a statistically significant difference.

Table 25: *A Priori* "rules" used for Integrating Individual Toxicity LOE into a Sediment Toxicity Rating

Observed Pattern in Toxicity Data	Symbol	Narrative Statement
Greater than a 50% reduction in at least one acute endpoint (i.e., survival).	●	Adverse effects related to sediment toxicity are probable
Greater than or equal to a 20% reduction in two acute endpoints (i.e., survival) and the differences are statistically significant.	●	Adverse effects related to sediment toxicity are probable
Greater than a 50% reduction in two non-acute endpoints (i.e., growth), and the differences are statistically significant.	●	Adverse effects related to sediment toxicity are probable
Greater than a 50% reduction in one non-acute endpoint (i.e., growth), and the difference is statistically significant.	⦿	Adverse effects related to sediment toxicity are possible
Greater than or equal to a 20% reduction in at least one acute endpoint (i.e., survival) and the differences are statistically significant.	⦿	Adverse effects related to sediment toxicity are possible
Greater than a 50% reduction in one non-acute endpoint (i.e., growth), but the difference is not statistically significant.	○#	Adverse effects related to sediment toxicity are possible, but likely limited in magnitude
Greater than or equal to a 20% reduction in two acute endpoints (i.e., survival) but the differences are not statistically significant.	○#	Adverse effects related to sediment toxicity are possible but likely limited in magnitude
Greater than or equal to a 20% reduction in one non-acute endpoint (i.e., growth), and the difference is statistically significant.	○#	Adverse effects related to sediment toxicity are possible but likely limited in magnitude
Greater than or equal to a 20% reduction in one non-acute endpoint (i.e., growth), but the difference is not statistically significant.	○	No adverse effects related to sediment toxicity anticipated
Less than a 20% reduction in all endpoint performance.	○	No adverse effects related to sediment toxicity anticipated

Table 26: Integration of Individual Toxicity LOE into the WOE Sediment Toxicity Rating

Reach on Waterbody	Station ID	14-d *Hyalella* (Survival – Growth)	10-d *Chironomus* (Survival – Growth)	Integrated Sediment Toxicity Rating
Reach 0	BCSS-DEP-01	○ - ⦿	○ - ⦿	○#
	BCSS-DEP-03	○ - ⦿	○ - ○	○#
Reach 1	BCSS-DEP-04	● - ●	● - ●	●
Reach 2	BCSS-DEP-06	⦿ - ○	○ - ○	⦿
	BCSS-DEP-07	○ - ⦿	○ - ○*	○#
	BCSS-DEP-08	● - ●	● - ●	●
Reach 3	BCSS-DEP-10	○ - ○	○ - ○	○
Reach 4	BCSS-DEP-11	○ - ○	○ - ⦿	○#
	BCSS-DEP-12	○ - ○	○ - ○	○
	BCSS-DEP-13	⦿ - ⦿	○ - ●	⦿
Reach 5	BCSS-DEP-14	○ - ○	○ - ○	○
	BCSS-DEP-15	● - ●	● - ●	●
Baker Pond (Reach 6)	BCSS-DEP-18	● - ●	● - ●	●
	BCSS-DEP-19	⦿ - ○	○* - ○*	⦿
	BCSS-DEP-20	● - ●	● - ●	●
	BCSS-DEP-21	● - ●	● - ●	●
Upper Baker Creek	BCSS-DEP-24	○ - ⦿	○ - ○	○#
Trapper Creek	BCSS-DEP-26	○ - ○	○* - ○*	○
Yellowknife River	BCSS-DEP-28 - Ref	○ - ○	○ - ○	○
	BCSS-DEP-29 - Ref	⦿ - ○	○ - ○	⦿
	BCSS-DEP-30 - Ref	○ - ○*	○* - ○*	○

See Table 25 for guidelines used to integrate individual toxicity LOE into a combined toxicity assessment.

Benthic Invertebrate Community LOE

Benthic taxonomy data provide information about adverse potential effects under realistic exposure conditions (i.e., the in situ data reflect the bioavailability of COPCs under field conditions). The main advantage of benthic community data is that they directly assess the biological endpoint of interest. The main disadvantage of benthic community data is that they are subject to natural variability and micro-scale influences that are difficult to control for and that may obscure underlying trends. The benthic community endpoints evaluated within the WOE framework for Baker Creek were:

- Abundance: the total number of organisms per square metre;
- Taxonomic richness: the number of different taxa in an area. Higher richness values usually indicate a more healthy and balanced community; and,
- Evenness: a measure of how evenly distributed the taxonomic groups (i.e., families) are within each replicate area. A lower evenness value indicates that the community is dominated by a few taxonomic groups.

Separate ratings were assigned to the abundance, richness and evenness metrics based on >20% or >50% reductions (and statistically significant differences) relative to the reference stations. Interpretation of the benthic community data within the WOE framework was based on a comparison of the results from individual exposed stations to the mean endpoint performance observed at the three reference locations. The evaluation of benthic community metrics applied the following decision criteria:

- A reduction of <20% (relative to the average reference performance) was considered to represent a negligible effect (and was scored as "○");
- A reduction of ≥20% (relative to the average reference performance) was considered to represent a moderate effect (and was scored as "⦿"); and,
- A reduction of >50% (relative to the average reference performance) was considered to represent a high effect (and was scored as "●").

4.9.1.2 Relative Weight of Each LOE

A key aspect of the WOE approach is the application of professional judgment in terms of the weight assigned to each individual LOE. This application of professional judgment included consideration of, among other factors, the following ecological implications: known sensitivity to COPCs; influence of confounding factors such as sediment grain size; and, inherent biological variation in test organism performance. The relative weight of each LOE was evaluated based on the following principles:

- Sediment Chemistry versus Toxicity/Benthic Alteration LOE: Sediment chemistry LOE were assigned minimal weight in the WOE since the presence of a contaminant in the environment does not necessarily imply an adverse ecological effect. The lack of a consistent biological response despite elevated COPC concentrations illustrates the limited utility of numerical SQGs in a WOE assessment (Chapman and Mann 1999; Chapman et al. 2002).

- Toxicity versus Benthic Community LOE: The benthic community LOE was assigned more weight than the integrated sediment toxicity rating (Chapman and Anderson 2005). The benthic survey provided good spatial coverage of Baker Creek (as did the other LOEs), as well as information about actual conditions in the creek with respect to benthic community structure. Although the toxicity test LOE used standardized tests with two species and multiple endpoints (and met all test acceptability criteria), there are wide margins of uncertainty associated with extrapolating from laboratory-generated data to field conditions. There has also been debate in the literature (e.g., Wang et al. 2004, 2005; Borgmann et al. 2005) regarding the suitability of *H. azteca* for assessing the toxicity of sediment-associated contaminants, which may result in this species over-estimating sediment-associated toxicity. Briefly, *H. azteca* is primarily epibenthic (i.e., inhabiting the sediment surface rather than burrowing into it as do other invertebrates such as chironomid larvae and oligochaetes) and obtains little of its food from sediments, but the nature of the laboratory test conditions increases direct sediment contact as the amphipod burrows into the sediment to find food and protective cover (making these organisms more vulnerable to sediment contaminants than would be the case under field conditions).

4.9.1.3 WOE Results and Discussion

The results of the WOE assessment on a station-by-station basis are summarized in Table 27. Each LOE used in the WOE assessment was evaluated independently. Note that sediment chemistry was summarized separately for arsenic (As) and for other metals.

Six of the 26 depositional exposure stations were classified as having "negligible adverse effects" based on the integrated WOE assessment. These stations were located in Reaches 0 and 1 (near the mouth of Baker Creek), Reaches 5 and 6 (within and downstream of Baker Creek Pond), and in Upper Baker Creek and Trapper Creek. Although all six stations were characterized as having high sediment chemistry concentrations (for both arsenic and other metals), there were no adverse effects on the benthic invertebrate community, and little or no adverse effects in sediment toxicity tests.

Twelve of the 26 depositional exposure stations were classified as having "potential adverse effects" based on the integrated WOE assessment. These stations were located in Reaches 0, 2, 3, and 4, and also in Upper Baker Creek and Trapper Creek. These stations were characterized as have high arsenic concentrations and high or moderately high concentrations of other metals, and low or moderate effects on either sediment toxicity or benthic invertebrate community metrics.

The remaining 8 of 26 depositional exposure stations were classified as having "significant adverse effects" based on the integrated WOE assessment. These stations (BCSS-DEP-04, BCSS-DEP-08, BCSS-DEP-15, BCSS-DEP-16, BCSS-DEP-18, BCSS-DEP-19, BCSS-DEP-20, and BCSS-DEP-21) were located in Reaches 1, 2, 5 and 6. These stations, particularly Stations BCSS-DEP-08 and BCSS-DEP-15, had high concentrations of multiple COPCs. Six stations had 100% mortality in the *H. azteca* sediment toxicity tests and 70 to 100% mortality in the *C. tentans* sediment toxicity tests; one station had moderate effects to multiple endpoints and one station was not selected for toxicity testing. These stations all had some degree of effect on the benthic invertebrate community as well.

Table 27: WOE Assessment for Baker Creek Sediments

Reach on Waterbody	Station ID	Sediment Chemistry (As-Other)[1]	Sediment Toxicity	Benthic Invertebrates[2]	Overall Assessment For Adverse Effects
Reach 0	BCSS-DEP-01	● - ◉	○[#]	○ - ○ - ●	Potential
	BCSS-DEP-02	● - ●	Not tested	○ - ○ - ○	Negligible
	BCSS-DEP-03	● - ●	○[#]	◉ - ◉ - ○	Potential
Reach 1	BCSS-DEP-04	● - ●	●	○ - ○ - ◉	Significant
	BCSS-DEP-05	● - ●	Not tested	○ - ○ - ○	Negligible
Reach 2	BCSS-DEP-06	● - ●	◉	◉ - ◉ - ○	Potential
	BCSS-DEP-07	● - ◉	○[#]	◉ - ◉ - ◉	Potential
	BCSS-DEP-08	● - ●	●	◉ - ◉ - ◉	Significant
Reach 3	BCSS-DEP-09	● -●	Not tested	○ - ○ - ◉	Potential
	BCSS-DEP-10	● - ◉	○	◉ - ○ - ○	Potential
Reach 4	BCSS-DEP-11	◉ - ◉	○[#]	○ - ○ - ◉	Potential
	BCSS-DEP-12	● - ◉	○	◉ - ○ - ○	Potential
	BCSS-DEP-13	● - ●	◉	○ - ○ - ○	Potential
Reach 5	BCSS-DEP-14	● - ●	○	○ - ○ - ○	Negligible
	BCSS-DEP-15	● - ●	●	● - ◉ - ○	Significant
	BCSS-DEP-16	● - ●	Not tested	● - ◉ - ○	Significant
Baker Pond (Reach 6)	BCSS-DEP-17	● - ●	Not tested	○ - ○ - ○	Negligible
	BCSS-DEP-18	● - ●	●	◉ - ○ - ◉	Significant
	BCSS-DEP-19	● - ◉	◉	○ - ◉ - ●	Significant
	BCSS-DEP-20	● - ●	●	● - ◉ - ◉	Significant
	BCSS-DEP-21	● - ●	●	○ - ○ - ●	Significant
Upper Baker Creek	BCSS-DEP-23	● - ●	Not tested	◉ - ○ - ○	Potential
	BCSS-DEP-24	● - ●	○[#]	○ - ○ - ○	Negligible
	BCSS-DEP-25	● - ●	Not tested	◉ - ○ - ○	Potential
Trapper Creek	BCSS-DEP-26	● - ◉	○	○ - ○ - ○	Negligible
	BCSS-DEP-27	● - ◉	Not tested	○ - ○ - ◉	Potential
Yellowknife River	BCSS-DEP-28 - Ref	○ - ○	○	○ - ○ - ◉	Potential
	BCSS-DEP-29 - Ref	○ - ○	◉	○ - ○ - ○	Negligible
	BCSS-DEP-30 - Ref	○ - ◉	○	● - ◉ - ○	Potential

1. Benthic invertebrate metrics presented for total abundance, taxa richness, and SEI.

LEGEND

Chemistry	○	All analyte concentrations are less than the CCME ISQG or OMOEE LEL.
	◉	One or more analyte concentrations are greater than the CCME ISQG or OMOEE LEL.
	●	One or more analyte concentrations are greater than the CCME PEL or OMOEE SEL.
Toxicity		See Table 26 for integrated sediment toxicity rating
Benthic Community	○	Less than 20% reduction relative to reference.
	◉	Greater than or equal to 20% reduction relative to reference.
	●	Greater than 50% reduction relative to reference.

4.9.2 Relationships Among Lines of Evidence (LOE)

Potential relationships between measures of exposure (i.e., chemistry data) and measures of effect (i.e., toxicity and benthic community data) were explored using multivariate statistical analyses.

Multivariate analyses are well suited to situations where the interrelationships between many variables (e.g., multiple COPCs, habitat characteristics, toxicity data, and benthic community structure) need to be examined in an objective manner. A multivariate approach enables consideration of the fact that in order for a toxic substance to be responsible for an adverse biological effect, it is first necessary that a relationship between the dose or concentration of the toxic substance and the level of biological response exist. Situations where a relationship between sediment chemistry and the measure of effect is lacking suggest that the observed adverse biological effects are being influenced by factors other than site-specific COPCs and, therefore, remediation of site-specific contaminants may not result in an improvement in biological function.

The multivariate statistical analyses were intended to explore the following questions:

- Are there quantitative relationships between the distribution of individual COPCs and the measures of biological effect (i.e., toxicity and benthic community measures)?
- Are these COPCs related to historical Giant Mine operations or are they naturally elevated?
- Are there relationships between the measures of biological effect (i.e., toxicity and benthic community) and physical characteristics of the sediment such as TOC or grain size?

A correlation does not provide definitive evidence that a cause-and-effect relationship between the measure of effect and the specific COPC exists; it merely indicates that a statistical relationship between two variables is present. However, this relationship can be instructive in determining both the strength of association and what additional investigations are needed to provide additional certainty.

4.9.2.1 Methods

Spearman rank correlation analyses were used to examine the potential relationships among physicochemical, toxicity and benthic community measurements. The following data were used in the correlation analyses:

- Chemical parameters potentially associated with the former Giant Mine (i.e., metals), and physical variables such as grain size (percent clay, silt, sand), and TOC;
- Sediment toxicity data from each endpoint (survival and dry weight) and species, evaluated individually; and,
- Benthic community data, reduced to two surrogate variables (called DIM-1 and DIM-2) using NMDS. Summary metrics for the benthic community (e.g., richness, abundance and evenness) were also evaluated individually.

One-tailed significance tests were used for testing the relationships between: (a) chemical parameters versus toxicity test metrics; and, (b) chemical parameters versus diversity, abundance and evenness metrics. The hypothesis is that *increasing* concentrations of chemical parameters will correspond with *decreasing* performance of toxicity test endpoints. A statistically significant relationship between increasing concentrations and increasing performance is not relevant for site management purposes.

Two-tailed tests were used for testing the relationships between: (a) physical parameters (e.g., grain size, TOC) and toxicity test performance; (b) chemical parameters and benthic community structure (DIM1 and DIM2); and, (c) habitat characteristics and benthic community diversity, abundance, and richness. There is no *a priori* expectation that performance in the toxicity test or benthic community measures would increase or decrease in response to these parameters.

4.9.2.2 Results and Discussion

Relationships Among Sediment Chemistry Parameters

Results of the Spearman rank correlations performed on the sediment chemistry data collected from the depositional sampling stations are presented in Table 28. Data for all metals, including non-COPCs, were included in these analyses along with particle size and TOC. Only noteworthy statistically significant ($p \leq 0.05$) correlations are summarized below.

- There was a weak negative correlation between TOC and percent fines (r_s = -0.448). This was somewhat unexpected as fine-grained sediments tend to be associated with elevated TOC content. However, although sediments at depositional stations were primarily fine-grained material, a wide range of TOC concentrations were measured (0.29 to 8.19%) and in some cases the sediment was 90% fines but had <0.5% TOC.
- There were very strong positive correlations (r_s >0.9) among antimony, arsenic, cadmium, lead, mercury, nickel, silver, and zinc. These metals had similar spatial distributions, with maximum concentrations occurring at either Station BCSS-DEP-08 or BCSS-DEP-15.

Relationships Between Sediment Chemistry and Sediment Toxicity

Results of the Spearman rank correlations between sediment chemistry parameters and the survival and dry weight endpoints from the two sediment toxicity tests are presented in Table 29. For these comparisons, significant negative correlations were an indication that the toxicity test endpoint decreased as the sediment chemistry concentration increased.

- Chironomid survival was a less sensitive endpoint than *H. azteca* survival, or the dry weight endpoints for either test species, based on the strength of the correlations.
- *Hyalella* survival and dry weight, and chironomid dry weight, all had strong negative correlations (r_s < -0.7) with antimony, cadmium, lead, mercury, and zinc. These three test endpoints also correlated negatively with arsenic concentrations, although the correlation was not as strong. There was not a clear concentration-response between survival and COPC concentrations. Although both test species had 90 or 100% mortality when tested with the two sediments that had the highest arsenic concentrations (BCSS-DEP-08 and BCSS-DEP-15), as well as high concentrations of other metals, similar high mortality also occurred at other stations where metals concentrations were not as high. At other stations with similar metals concentrations, both species had higher survival.

Table 28: Spearman Rank Correlations for Depositional Sediment Chemistry Data

Variable	Sed_Fines	Sed_TOC	Sed_Al	Sed_Sb	Sed_As	Sed_Ba	Sed_Be	Sed_Bi	Sed_Cd	Sed_Ca	Sed_Cr	Sed_Co	Sed_Cu	Sed_Fe	Sed_Pb	Sed_Li	Sed_Mg	Sed_Mn	Sed_Hg	Sed_Mo	Sed_Ni	Sed_P	Sed_K	Sed_Se	Sed_Ag	Sed_Na	Sed_Sr	Sed_Tl	Sed_Ti	Sed_U	Sed_V
Sed_TOC	-.448(*)																														
Sed_Al	.658(**)	-0.26																													
Sed_Sb	0.355	0.116	.494(**)																												
Sed_As	0.14	0.241	0.362	.916(**)																											
Sed_Ba	0.005	-0.023	0.23	-.496(**)	-.531(**)																										
Sed_Be	0.063	0.063	.415(*)	-0.266	-0.318	.835(**)																									
Sed_Bi	.588(**)	-0.317	.741(**)	.666(**)	.544(**)	0.001	0.095																								
Sed_Cd	0.362	0.107	.509(**)	.962(**)	.931(**)	-.486(**)	-0.242	.686(**)																							
Sed_Ca	0.36	0.193	.647(**)	.846(**)	.822(**)	-.385(*)	-0.147	.562(**)	.847(**)																						
Sed_Cr	.682(**)	-0.345	.893(**)	.644(**)	.498(**)	0.086	0.201	.882(**)	.645(**)	.648(**)																					
Sed_Co	.430(*)	0.044	.630(**)	.890(**)	.834(**)	-0.261	-0.019	.756(**)	.874(**)	.798(**)	.761(**)																				
Sed_Cu	0.306	0.192	.472(**)	.866(**)	.751(**)	-0.362	-0.05	.496(**)	.816(**)	.725(**)	.561(**)	.806(**)																			
Sed_Fe	.565(**)	-0.256	.740(**)	.836(**)	.757(**)	-0.197	-0.024	.901(**)	.854(**)	.761(**)	.871(**)	.884(**)	.643(**)																		
Sed_Pb	.431(*)	-0.018	.561(**)	.955(**)	.889(**)	-.454(*)	-0.182	.723(**)	.973(**)	.817(**)	.678(**)	.877(**)	.804(**)	.893(**)																	
Sed_Li	.599(**)	-.368(*)	.868(**)	0.184	0.016	.538(**)	.615(**)	.589(**)	0.19	0.289	.766(**)	.368(*)	0.228	.493(**)	0.251																
Sed_Mg	.593(**)	-0.323	.869(**)	.741(**)	.656(**)	-0.138	0.027	.817(**)	.747(**)	.786(**)	.914(**)	.790(**)	.582(**)	.913(**)	.790(**)	.654(**)															
Sed_Mn	0.111	0.123	0.307	.478(**)	.483(**)	-0.032	-0.151	.392(*)	.525(**)	.489(**)	.397(*)	.392(*)	0.358	.467(*)	.432(*)	0.212	.429(*)														
Sed_Hg	0.183	0.261	.376(*)	.905(**)	.963(**)	-.554(**)	-0.312	.526(**)	.950(**)	.840(**)	.470(*)	.784(**)	.761(**)	.733(**)	.905(**)	0.011	.638(**)	.490(**)													
Sed_Mo	0.135	.485(**)	0.308	.665(**)	.616(**)	-0.17	0.111	0.359	.623(**)	.552(**)	.411(*)	.701(**)	.707(**)	.433(*)	.581(**)	0.152	0.361	0.177	.585(**)												
Sed_Ni	.409(*)	0.108	.571(**)	.926(**)	.825(**)	-0.355	-0.062	.667(**)	.891(**)	.810(**)	.694(**)	.957(**)	.921(**)	.814(**)	.886(**)	0.301	.721(**)	.369(*)	.804(**)	.734(**)											
Sed_P	0.115	0.285	0.271	0.03	-0.032	.545(**)	.437(*)	0.214	0.07	0.067	0.309	0.151	0.028	0.09	-0.009	.489(**)	0.125	.416(*)	-0.036	0.332	0.069										
Sed_K	.391(*)	-0.302	.590(**)	-0.118	-0.259	.747(**)	.859(**)	0.342	-0.133	-0.048	.497(**)	0.169	0.04	0.229	-0.029	.785(**)	0.295	-0.184	-0.285	0.091	0.097	.370(*)									
Sed_Se	0.167	.446(*)	.388(*)	.790(**)	.759(**)	-0.363	-0.061	.428(*)	.771(**)	.743(**)	.450(*)	.836(**)	.836(**)	.558(**)	.708(**)	0.111	.498(**)	0.291	.755(**)	.825(**)	.883(**)	0.182	-0.058								
Sed_Ag	0.34	0.14	.435(*)	.943(**)	.845(**)	-.498(**)	-0.232	.594(**)	.894(**)	.776(**)	.598(**)	.882(**)	.939(**)	.735(**)	.879(**)	0.14	.636(**)	.383(*)	.821(**)	.732(**)	.953(**)	-0.005	-0.088	.849(**)							
Sed_Na	.373(*)	-0.008	.555(**)	0.152	0.028	.511(**)	.667(**)	.422(*)	0.112	0.185	.532(**)	.405(*)	0.347	0.3	0.17	.655(**)	0.332	-0.111	0.012	.448(*)	.383(*)	.393(*)	.803(**)	0.315	0.239						
Sed_Sr	0.277	.393(*)	.604(**)	.498(**)	.463(*)	0.022	.382(*)	.367(*)	.525(**)	.675(**)	.476(**)	.581(**)	.639(**)	.420(*)	.507(**)	.387(*)	.449(*)	0.067	.526(**)	.669(**)	.639(**)	0.202	0.323	.711(**)	.554(**)	.635(**)					
Sed_Tl	.632(**)	-0.213	.816(**)	.692(**)	.529(**)	0.046	0.245	.875(**)	.695(**)	.619(**)	.887(**)	.786(**)	.638(**)	.869(**)	.739(**)	.631(**)	.794(**)	0.31	.535(**)	.544(**)	.755(**)	0.185	.458(*)	.528(**)	.666(**)	.515(**)	.553(**)				
Sed_Ti	0.202	-0.301	0.341	-0.324	-.424(*)	.782(**)	.837(**)	0.229	-0.303	-0.329	0.298	-0.036	-0.173	0.034	-0.21	.633(**)	0.053	-0.247	-.469(*)	0.003	-0.118	.408(*)	.889(**)	-0.223	-0.274	.644(**)	0.107	0.269			
Sed_U	-.552(**)	.608(**)	-.416(*)	-.499(**)	-.406(*)	.446(*)	.393(*)	-.600(**)	-.471(**)	-.421(*)	-.555(**)	-.465(*)	-0.269	-.670(**)	-.562(**)	-0.218	-.694(**)	-0.11	-.382(*)	0.049	-.402(*)	0.35	0.009	-0.145	-.398(*)	0.04	0.051	-.446(*)	0.169		
Sed_V	.562(**)	-0.29	.894(**)	.687(**)	.603(**)	-0.041	0.144	.802(**)	.703(**)	.754(**)	.931(**)	.781(**)	.557(**)	.887(**)	.730(**)	.696(**)	.965(**)	.401(*)	.576(**)	.380(*)	.709(**)	0.208	.376(*)	.519(**)	.602(**)	.378(*)	.513(**)	.806(**)	0.153	-.598(**)	
Sed_Zn	.377(*)	0.07	.512(**)	.982(**)	.903(**)	-.484(**)	-0.237	.682(**)	.953(**)	.832(**)	.648(**)	.887(**)	.876(**)	.844(**)	.963(**)	0.194	.745(**)	.416(*)	.899(**)	.633(**)	.927(**)	-0.029	-0.071	.773(**)	.942(**)	0.218	.543(**)	.708(**)	-0.283	-.511(**)	.685(**)

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 29: Spearman Rank Correlations Between Sediment Chemistry and Sediment Toxicity Variables

Variable	*Hyalella azteca* Survival	*Hyalella azteca* Dry Weight	*Chironomus tentans* Survival	*Chironomus tentans* Dry Weight
Aluminum	-0.444*	-0.399*	-0.165	-0.341
Antimony	-0.729**	-0.716**	-0.495*	-0.735**
Arsenic	-0.653**	-0.698**	-0.424*	-0.664**
Barium	0.453*	0.351	0.333	0.277
Beryllium	0.277	0.301	0.313	0.198
Bismuth	-0.508**	-0.568**	-0.193	-0.438*
Cadmium	-0.738**	-0.773**	-0.528**	-0.710**
Calcium	-0.699**	-0.715**	-0.426*	-0.628**
Chromium	-0.399*	-0.526**	-0.206	-0.403*
Cobalt	-0.656**	-0.663**	-0.338	-0.583**
Copper	-0.644**	-0.628**	-0.418*	-0.646**
Iron	-0.677**	-0.750**	-0.428*	-0.691**
Lead	-0.744**	-0.740**	-0.564**	-0.763**
Lithium	-0.106	-0.139	0.059	-0.136
Magnesium	-0.559**	-0.602**	-0.23	-0.517**
Manganese	-0.634**	-0.807**	-0.422*	-0.520**
Mercury	-0.727**	-0.722**	-0.509**	-0.700**
Molybdenum	-0.424*	-0.266	-0.114	-0.234
Nickel	-0.691**	-0.681**	-0.404*	-0.638**
Phosphorus	0.147	-0.143	0.149	0.1
Potassium	0.292	0.187	0.209	0.07
Selenium	-0.616**	-0.536**	-0.217	-0.371*
Silver	-0.696**	-0.667**	-0.436*	-0.638**
Sodium	0.026	0.01	0.094	-0.092
Strontium	-0.482*	-0.419*	-0.254	-0.392*
Thallium	-0.586**	-0.525**	-0.358	-0.513**
Titanium	0.438*	0.265	0.319	0.25
Uranium	0.443*	0.452*	0.236	0.409*
Vanadium	-0.457*	-0.594**	-0.138	-0.433*
Zinc	-0.726**	-0.728**	-0.520**	-0.765**

** Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed).

Relationships Between Benthic Invertebrate Tissue and Sediment/Periphyton Metal Concentrations

Depositional Benthic Invertebrate and Sediment Concentrations

Of the aquatic COPCs[11], antimony, arsenic, copper and lead tissue concentrations in invertebrates were significantly positively correlated with corresponding sediment concentrations at depositional stations in Baker Creek, Trapper Creek and the Yellowknife River (Table 30). Concentrations of beryllium, cadmium, chromium, iron, manganese, mercury, selenium[12], and zinc in invertebrate tissues were not significantly correlated with respective sediment concentrations measured at co-located stations ($\alpha = 0.05$). Stronger positive relationships were identified for antimony, arsenic and lead ($r > 0.5$; $p < 0.01$) compared to copper and nickel ($r < 0.5$; $0.01 < p < 0.05$). The relationships between sediment and invertebrate tissue concentrations for these five COPCs, measured at depositional stations located in Baker Creek, Trapper Creek and the Yellowknife River, are shown graphically in Figure 31 and Figure 32.

The invertebrate-sediment relationships for antimony and arsenic in Lower Baker Creek were influenced by the point representing Station BCSS-DEP-08 (Reach 2), where sediment and tissue concentrations were substantially higher than those measured at other depositional stations (Figure 31). For most stations in Lower Baker Creek the general trend for arsenic and antimony was an increase in invertebrate tissue concentrations with increasing sediment concentrations. However, there was variability in the invertebrate-sediment data and the observed relationship was not always proportional. The same was true for copper, lead and nickel, for which the following was noted:

- The invertebrate-sediment relationship observed for copper was influenced by Station BCSS-DEP-20 (Reach 6) where copper was elevated in both sediment and invertebrate tissues, and Station BCSS-DEP-16 (Reach 5) where copper was elevated in sediment but not to the same degree in invertebrate tissues.
- The invertebrate-sediment relationship observed for lead was influenced by Station BCSS-DEP-08 (Reach 2) where lead was elevated in sediment but not invertebrate tissues, and for Station BCSS-DEP-01 (Reach 0) where the opposite was true.

Sediment concentrations were generally higher in Lower Baker Creek compared to Upper Baker Creek, Trapper Creek and the Yellowknife River. However, this did not always translate into higher invertebrate tissue concentrations in Lower Baker Creek compared to Upper Baker Creek, Trapper Creek and the Yellowknife River. This observation is not unexpected given that the presence of a contaminant in the sediment does not necessarily imply that the contaminant is bioavailable for uptake into aquatic biota.

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[11] Silver and phosphorus were not included because silver concentrations were not measured in invertebrate tissues, and phosphorus is not a trace metal or metalloid.

[12] Selenium was not identified as an aquatic COPC, but was included in the statistical correlation analysis due to concerns regarding potential effects related to the bioaccumulation of selenium in the tissues of egg-laying vertebrates (as a result of dietary exposure to selenium). Elevated organo-selenides accumulated by adult female vertebrates can be transferred to the eggs, with possible subsequent toxicity in embryos and juveniles (Chapman et al. 2010). Benthic invertebrates represent an important component in the diets of fish and other egg-laying vertebrates, and thus may represent a source of selenium.

Table 30: Spearman Rank Correlations Between Depositional Benthic Invertebrate Tissue and Sediment Metals Concentrations

Trace Metal Sediment Parameters	Trace Metal Parameters Measured in Depositional Benthic Invertebrate Tissues												
	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Zinc
Antimony	**0.730(**)**	0.358	-0.097	0.079	-0.059	0.485(*)	0.157	**0.700(**)**	0.212	-0.266	0.425(*)	-0.162	-0.318
Arsenic	**0.732(**)**	**0.536(**)**	0.054	0.042	0.03	0.474(*)	0.206	**0.638(**)**	0.149	-0.194	0.473(*)	-0.095	-0.238
Beryllium	0.037	-0.049	-0.078	-0.139	-0.118	-0.304	-0.117	-0.108	-0.075	0.18	-0.036	0.155	0.018
Cadmium	**0.717(**)**	0.356	-0.06	0.133	-0.057	0.485(*)	0.148	**0.655(**)**	0.137	-0.311	0.414(*)	-0.205	-0.34
Chromium	**0.633(**)**	0.165	0.02	0.267	-0.036	0.266	0.178	0.485(*)	0.141	-0.126	0.475(*)	-0.17	-0.39
Copper	**0.688(**)**	0.209	-0.198	-0.098	-0.102	0.489(*)	0.009	**0.506(**)**	0.075	-0.161	0.341	0.064	-0.252
Iron	**0.676(**)**	0.339	0.021	0.299	-0.07	0.369	0.225	**0.635(**)**	0.117	-0.148	0.460(*)	-0.236	-0.336
Lead	**0.700(**)**	0.354	-0.082	0.191	-0.123	0.481(*)	0.155	**0.703(**)**	0.118	-0.302	0.391	-0.292	-0.369
Manganese	0.245	0.34	0.103	-0.148	0.229	0.04	0.075	0.136	0.078	0.067	0.229	0.249	0.298
Mercury	**0.717(**)**	0.504(*)	0.043	0.096	-0.01	**0.554(**)**	0.211	**0.652(**)**	0.142	-0.29	0.443(*)	-0.097	-0.222
Nickel	**0.738(**)**	0.211	-0.183	0.02	-0.179	0.474(*)	0.047	**0.601(**)**	0.138	-0.232	0.397(*)	-0.143	-0.413(*)
Selenium	**0.654(**)**	0.217	-0.229	-0.159	-0.186	0.478(*)	-0.042	0.474(*)	0.162	-0.295	0.274	-0.026	-0.403(*)
Zinc	**0.718(**)**	0.352	-0.111	0.102	-0.065	0.490(*)	0.147	**0.724(**)**	0.219	-0.279	0.417(*)	-0.189	-0.309

Notes

** Statistical correlation is significant at the α=0.01 level (2-tailed); displayed in grey highlight and bolded

* Correlation is significant at the α=0.05 level (2-tailed); displayed in grey highlight

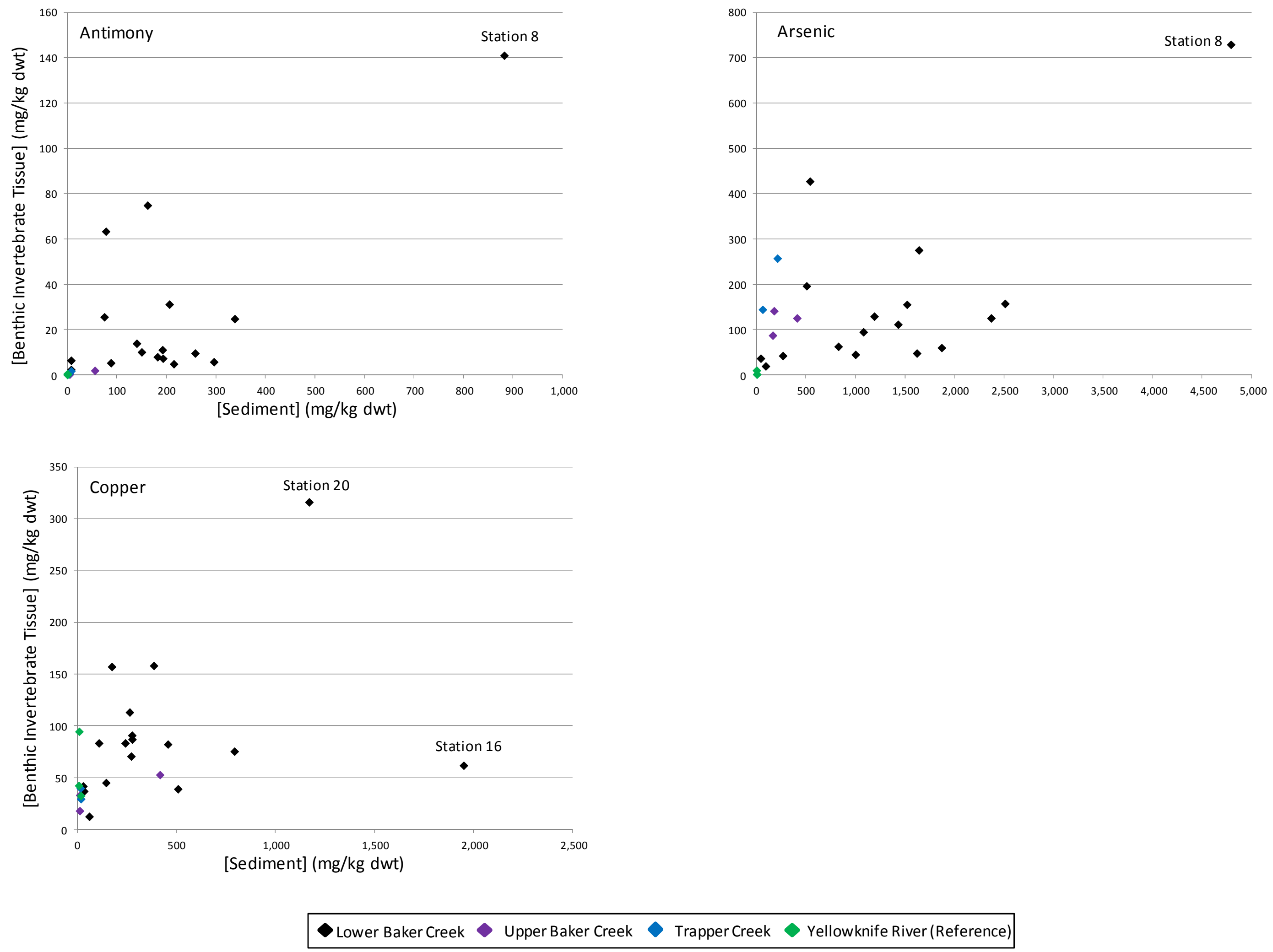

Figure 31: Comparison of Antimony, Arsenic, and Copper Concentrations in Benthic Invertebrate Tissues and Sediments at Depositional Stations

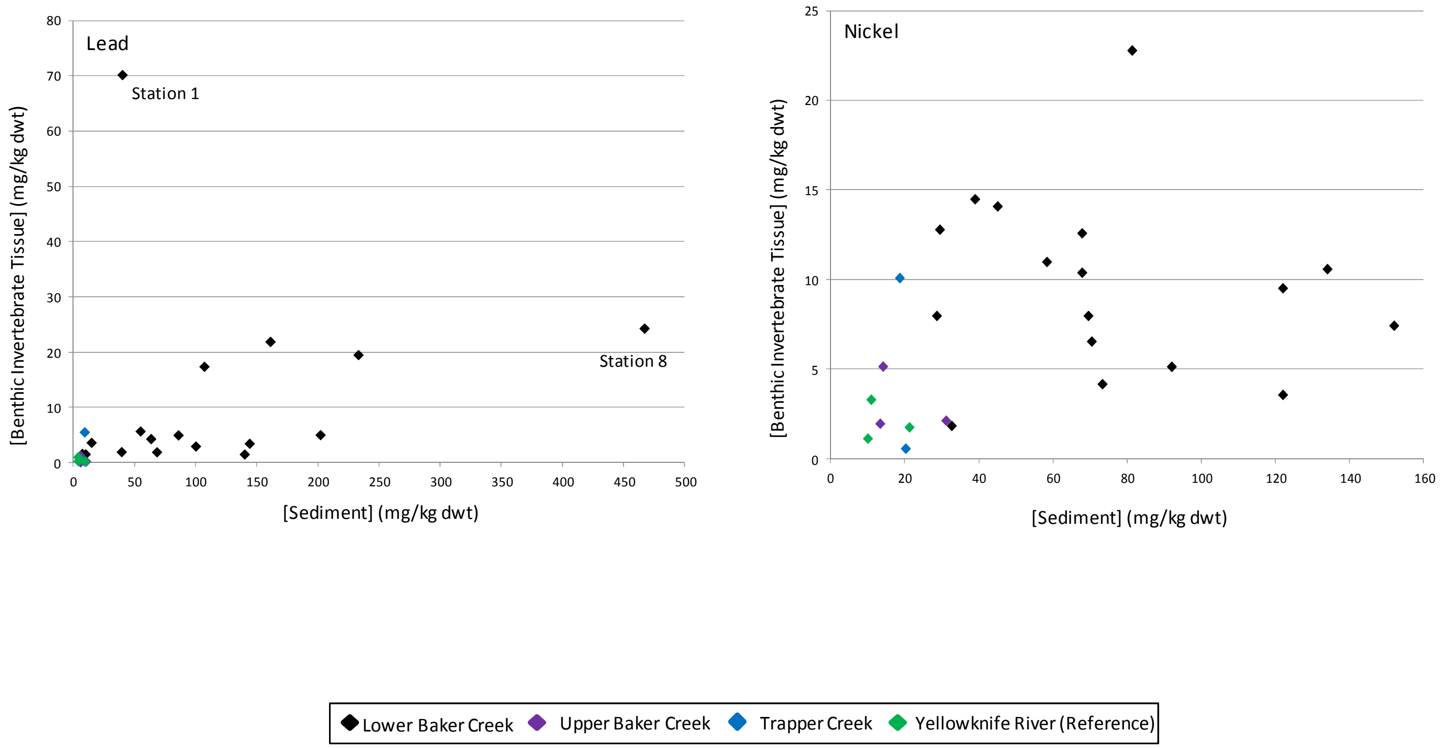

Figure 32: Comparison of Lead and Nickel Concentrations in Benthic Invertebrate Tissues and Sediments at Depositional Stations

Erosional Benthic Invertebrate and Periphyton Concentrations

Of the aquatic COPCs[13], antimony, arsenic and lead tissue concentrations in erosional invertebrates were significantly positively correlated with concentrations of these trace metals in periphyton collected from co-located stations in Lower Baker Creek and the Yellowknife River reference area (Table 31; Figure 33). The same was also true for selenium[14]. Concentrations of beryllium, cadmium, chromium, copper, iron, manganese, mercury, and zinc in invertebrate tissues were not significantly correlated with the respective sediment concentrations (α = 0.05 level).

The relationships between periphyton and invertebrate tissue concentrations for antimony, arsenic, lead and selenium, determined at co-located erosional stations in Lower Baker Creek and the Yellowknife River are shown graphically in Figure 33. In general, as concentrations in periphyton increased, so did concentrations in invertebrate tissues, and a dose-response relationship was observed despite some variability in the data. Concentrations of antimony and arsenic were substantially higher in both periphyton and benthic invertebrates collected from Lower Baker Creek, compared to the Yellowknife River. There was more variability observed for selenium within the Yellowknife River reference area, compared to antimony, arsenic and lead.

Relationships Between Benthic Invertebrate Community Metrics and Sediment Chemistry

There were a number of statistically significant (p <0.05) correlations between benthic invertebrate community metrics and sediment COPC concentrations, although these correlations were not strong:

- Benthic abundance was negatively correlated (i.e., abundance decreased with increasing COPC concentration) with sediment antimony, copper, silver, and zinc concentrations (r_s <-0.4), but not with sediment arsenic
- Taxonomic richness, based on identifications to the lowest taxonomic level, was negatively correlated with sediment antimony, arsenic, copper, lead, nickel, silver, and zinc (r_s <-0.5) concentrations; when taxonomic richness was evaluated at the family level, the only significant correlation was positive with sediment beryllium (r_s = 0.332).
- The only significant correlation between evenness (SEI), as determined at either the lowest taxonomic level or at the family level, and sediment COPC concentrations was a negative correlation with sediment chromium (r_s = -0.387).
- The DIM1 scores, derived from NMDS multivariate statistical analyses, were negatively correlated with sediment antimony, cadmium, chromium, copper, iron, lead, nickel, silver, and zinc concentrations (r_s <-0.5); there were no significant correlations between DIM2 scores and sediment COPCs.

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[13] Silver and phosphorus were not included because silver concentrations were not measured in invertebrate tissues, and phosphorus was not relevant to the assessment because it is not a trace metal or metalloid.

[14] Selenium was not an identified as an aquatic COPC, but was included in the statistical correlation analysis due to concerns regarding potential effects related to the bioaccumulation of selenium in the tissues of egg-laying vertebrates (as a result of dietary exposure to selenium). Elevated organo-selenides accumulated by adult female vertebrates can be transferred to the eggs, with possible subsequent toxicity in embryos and juveniles (Chapman et al. 2010). Benthic invertebrates represent an important component in the diets of fish and other egg-laying vertebrates, and thus may represent a source of selenium.

4.9.3 Uncertainty

All screening level and detailed level assessments are subject to uncertainty. The following sources of uncertainty in the individual LOE and the overall approach are discussed below:

- Measurement uncertainty: refers to missing or ambiguous data resulting from inadequate sampling, analytical errors, or lack of site-specific data. Note that parameter uncertainty is not the same as parameter variability.
- Structural uncertainty: refers to limitations in how the available data or models represent reality. This uncertainty can be reduced by incorporating more precise and site-specific physical, chemical, and ecological information into the WOE.

Table 31: Spearman Rank Correlations Between Erosional Benthic Invertebrate Tissue and Periphyton Tissue Metals Concentrations

Trace Metal Parameters	Trace Metal Parameters Measured in Periphyton Tissues												
Measured in Erosional	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Zinc
Antimony	**0.714(**)**	**0.807(**)**	0.229	**0.807(**)**	0.367	**0.697(**)**	0.499	**0.886(**)**	0.393	**0.811(**)**	0.411	0.534(*)	**0.666(**)**
Arsenic	**0.763(**)**	**0.877(**)**	0.15	**0.881(**)**	0.393	0.644(*)	0.565(*)	**0.873(**)**	0.442	**0.824(**)**	0.447	0.538(*)	0.648(*)
Beryllium	-0.539(*)	-0.509	-0.359	-0.475	-0.428	**-0.750(**)**	-0.409	-0.482	-0.616(*)	-0.487	**-0.731(**)**	**-0.716(**)**	**-0.750(**)**
Cadmium	-0.229	0.121	0.396	-0.064	0.2	0.079	0.211	0.086	-0.007	0.029	-0.029	-0.088	-0.042
Chromium	-0.191	-0.38	-0.436	-0.257	-0.415	-0.376	-0.508	-0.42	-0.138	-0.451	-0.194	-0.292	-0.305
Copper	0.468	0.42	-0.172	0.521	0.345	-0.02	0.481	0.235	0.327	0.363	0.282	0.319	0.187
Iron	-0.288	-0.134	-0.238	-0.143	-0.407	-0.481	-0.31	-0.165	-0.578(*)	-0.196	-0.616(*)	-0.569(*)	-0.481
Lead	0.587(*)	**0.714(**)**	0.257	**0.675(**)**	0.24	0.596(*)	0.349	**0.789(**)**	0.222	**0.714(**)**	0.257	0.341	0.53
Manganese	0.49	0.508	-0.009	0.578(*)	0.116	0.468	0.244	0.631(*)	0.244	0.534(*)	0.253	0.415	0.459
Mercury	**0.675(**)**	0.543(*)	0.009	0.596(*)	0.081	0.367	0.323	0.473	0.53	0.508	0.429	0.314	0.442
Nickle	0.218	0.152	-0.317	0.275	-0.2	0.02	-0.042	0.174	0.011	0.147	0.013	0.121	0.112
Selenium	0.473	0.521	0.312	0.560(*)	0.182	0.521	0.284	0.415	0.644(*)	0.345	0.614(*)	0.613(*)	0.648(*)
Zinc	-0.2	-0.11	0.161	-0.172	-0.172	0.013	-0.216	0.011	-0.123	-0.09	-0.157	-0.262	-0.11

Notes

** Statistical correlation is significant at the α=0.01 level (2-tailed); displayed in grey highlight and bolded

* Correlation is significant at the α=0.05 level (2-tailed); displayed in grey highlight

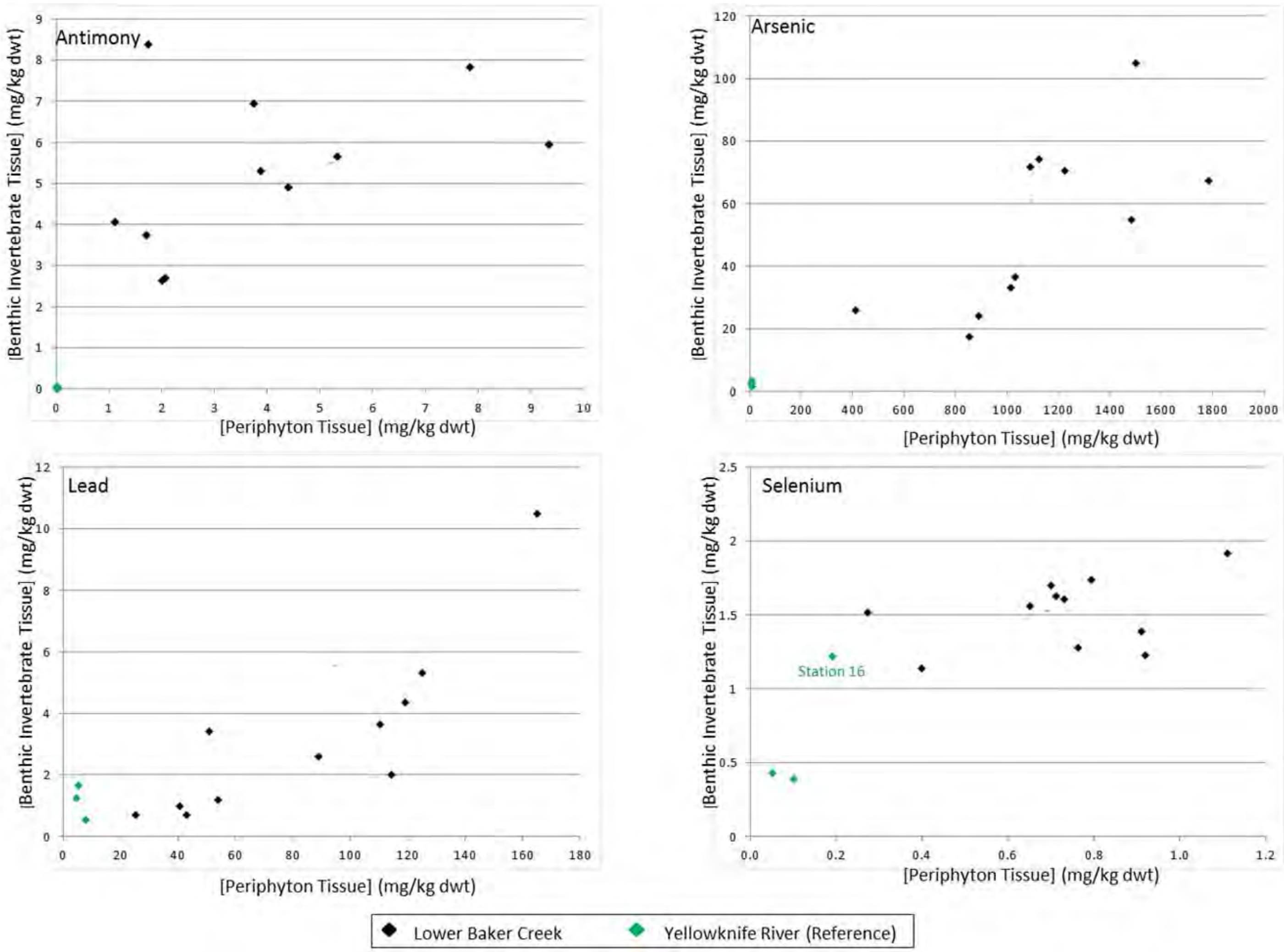

Figure 33: Comparison of Benthic Invertebrate and Periphyton Tissue Metals Concentrations at Erosional Stations

4.9.3.1 Parameter Uncertainty

- Chemistry: The chemistry line of evidence has low measurement uncertainty because samples were collected and analysed using established procedures which included consideration of QA/QC. No significant QA/QC items were identified that suggested the sediment chemistry data were not sufficiently reliable for management purposes.
- Toxicity: The toxicity line of evidence has low measurement uncertainty. It was based on two different toxicity tests with sublethal endpoints, and involved a comparison to field-collected reference stations that provides a more realistic approach than making comparisons to laboratory negative controls. Confounding factors (e.g., ammonia, grain size) that influence toxicity test results were also considered. No significant QA/QC items were identified that suggested that the toxicity data were unreliable.
- Benthic Community: The benthic community abundance, richness and evenness LOE has low to moderate measurement uncertainty. There were a relatively large number of stations, but no individual replicates. Data were evaluated relative to field-collected reference stations. Taxonomic identification involves professional judgment which may contribute measurement uncertainty, especially when making comparisons between studies. Voucher collections and the use of standardized taxonomic keys were included to reduce the influence of this factor.

Overall, parameter uncertainty is unlikely to impact the overall conclusions of this Baker Creek assessment.

4.9.3.2 Structural Uncertainty

WOE assessments are designed to reduce structural uncertainty by including different types of data so that the limitations of one LOE are balanced against the strengths of another LOE. The use of conservative decision criteria in the WOE also reduces the potential influence of structural uncertainty. There were several sources of structural uncertainty in the current assessment that should be considered:

- Representativeness of Chemistry Data: The study design was intended to be gradient-based such that benthic and toxicity test samples were collected across the entire range of COPC concentrations documented in Baker Creek. Although the sample stations were distributed along the length of Baker Creek, even with additional testing the possibility cannot be ruled out that areas with elevated contamination have not been sampled. However, given the relatively large number of samples that were collected, the likelihood that large areas of elevated contamination have not been detected is small.
- Synopticity: There is low uncertainty with respect to the assumption of synopticity between the chemistry samples and the biology samples (except for fish tissues) because these samples were collected concurrently; the correlation approach applied assumes representativeness between an individual grab sample and its immediate surroundings.

Overall, the structural uncertainty described above is unlikely to substantially change the overall conclusions of this Baker Creek assessment.

5.0 HUMAN HEALTH ASSESSMENT

5.1 Information Gathering

The following section summarizes the information gathering steps specific to the human health screening assessment, which was highly conservative. Golder (2011a) initially conducted an information gathering exercise for Baker Creek as part of the 2011 *Data Gap Analysis and Sampling Plan for Baker Creek,* which identified contaminants of potential concern (COPC), receptors and exposure pathways for humans. Following the data gap analysis, additional sampling was conducted in 2011 to address the identified data gaps. Historic site data are summarized in Section 3.0 and results from the recent sampling program are summarized in Section 4.2.

The information gathering steps outlined below provide an update to the Golder (2011a) report:

- Inclusion of new (2011) data;
- Updating of screening criteria (in particular inclusion of USEPA regional screening levels from April 2012); and,
- Omission of some historical data that were not deemed appropriate for the assessment (e.g., fish tissue data from 1972 and 2002 that were collected while the mine was operational).

5.1.1 COPC Screening

Contaminants of potential concern (COPCs) were identified by comparing the historical and recent (2011) measured concentrations in the various environmental media to relevant guidelines for the protection of human health (Appendix A). If one or more measured concentrations of a substance in an applicable medium exceeded the applicable screening guideline, then the substance was identified as a COPC and retained for consideration in the assessment. Substances that were detected but did not have an applicable screening guideline were noted but not identified as COPCs, as were substances that could not be assessed quantitatively due to lack of toxicity reference values (TRVs).

COPCs for human health were selected based on comparison of measured concentrations in effluent, water, sediment, and fish tissue samples from Baker Creek to applicable federal and GNWT guidelines. Data from Reaches 0 through 6, as well as from Upper Baker Creek and Trapper Creek were considered in the COPC screening. Data from the former Reach 4 (now diverted) and from reference stations (i.e., Yellowknife River) were not included in the COPC screening, although they are included in the data compilation in Appendix A for information. The review of human health screening guidelines involved the following sources: Health Canada (2010), CCME (1999), GNWT (2003) and USEPA (2012a,b).

The following sections describe the results of COPC identification in each individual matrix.

5.1.1.1 Treated Effluent and Surface Water

Treated effluent has been discharged into Baker Creek at the upper end of Baker Creek Pond (Reach 6) since 1981. Although the Remediation Plan (SRK and SENES 2007) proposed that a new treatment plant be constructed and that treated effluent be discharged directly to Yellowknife Bay instead of Baker Creek, approval and construction are pending and it is therefore assumed that effluent discharge to Baker Creek will continue for several more years. Treated effluent is currently only discharged to Baker Creek during summer months, but at times it can account for the majority of flow through Baker Creek. Therefore, it was considered appropriate to screen data for treated effluent as well as Baker Creek surface water, for identification of COPCs.

For human health, data were screened against the *Guidelines for Canadian Drinking Water Quality* (Health Canada 2010). Where Canadian drinking water guidelines were not available, United States Environmental Protection Agency Regional Screening Levels (RSL) for tap water (USEPA 2012a) were used. The USEPA tap water RSLs were derived based on an acceptable hazard quotient (HQ) of 1 for non-carcinogens, and an acceptable incremental lifetime cancer risk (ILCR) of 10^{-6} for carcinogens. Health Canada has adopted an acceptable HQ of 0.2 and ILCR of 10^{-5}, respectively, and therefore the RSLs were adjusted (i.e., RSL×0.2 for non-carcinogens and RSL×10 for carcinogens) to reflect the acceptable limits in Canada.

Although the guidelines for metals were intended to be applied to total metals concentrations, they were used for screening against both total and dissolved metals data because there were some samples for which only dissolved metals data were available.

A parameter was retained as a COPC if the maximum concentrations for either treated effluent or surface water exceeded the selected screening criterion.

Table 32 summarizes the screening of COPCs for treated effluent and surface water for the human health assessment. Note that surface water, during summer months, included treated effluent inputs.

5.1.1.2 Sediment

For human health, no applicable sediment quality guidelines are available; therefore, sediment chemistry data were screened using *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* (CCME 1999), under residential land use. Where CCME soil quality guidelines were not available, USEPA (2012a) RSLs for residential soil were applied. As was the case for drinking water (Section 5.1.1.1), the USEPA soil RSLs were derived based on an HQ of 1 for non-carcinogens and an ILCR of 10^{-6} for carcinogens, whereas Health Canada's acceptable target risk levels are an HQ of 0.2 and an ILCR of 10^{-5}. Therefore, the soil RSLs were adjusted (i.e., RSL×0.2 for non-carcinogens and RSL×10 for carcinogens) to reflect the target limits in Canada.

Table 32: Summary of Contaminants of Potential Concern (COPCs) for Human Health in Baker Creek and Associated Tributaries Water

Substance	Maximum Concentration (mg/L)[1]				Human Health Drinking Water Guidelines[2]	Retained as a COPC for Human Health?
	Treated Effluent	Surface Water	Location of Maximum Surface Water Concentration[9]	Sample ID and Date		
Ammonia (total)	0.059	1.02	Reach 0	SNP 43-12; 31-Aug-09	NG	NO[5]
Aluminum	0.305	0.952	Trapper Creek	SNP 43-16; 14-June-10	0.1	**YES**
Antimony	1.1	0.5	Upper Baker Creek	SNP 43-11; 12-Aug-03	0.006	**YES**
Arsenic	<3 (0.609)	0.969	Reach 6	BC Exp. Pt.; 17-Jul-08	0.010	**YES**
Barium	0.025	0.062	Reach 0	E3; 29-Jul-10	1.0	NO
Beryllium	<0.005 (0.0001)	<0.005 (0.0001)	Multiple	NA	0.0032 [3]	**YES**[7]
Bismuth	<0.2	<0.2	Multiple	NA	NG	NO
Boron	0.40	0.35	Reach 6	BC Exp. Pt.; 13-Sep-10	5	NO
Cadmium	<0.01 (0.0011)	<0.01 (0.0011)	Trapper Creek	SNP 43-11; 17-Aug-05	0.005	**YES**[7]
Calcium	488	444	Reach 6	BC Exp. Pt.; 13-Sep-10	NG	NO
Cesium	0.0003	0.0001	Multiple	Dillon 2004	NG	NO
Chloride	626	479	Reach 6	BC Exp. Pt.;20-Aug-04	250	**YES**
Chromium	<0.01 (0.0011)	<0.01 (0.0053)	Multiple	NA	0.05	NO
Cobalt	0.0802	0.0411	Reach 6	BC-4; 19-Oct-01	0.00094 [3]	**YES**
Copper	0.042	0.0202	Reach 6	BC Exp. Pt.; 30-Jul-07	1.0	NO
Cyanide	<0.05 (0.0162)	0.0198	Reach 0	SNP 43-5; 16-May-07	0.2	NO
Fluoride	<0.5 (0.145)	<0.4 (0.134)	Multiple	NA	1.5	NO
Iron	0.222	1.29	Trapper Creek	SNP 43-16; 20-Sep-10	0.3	**YES**
Lead	<0.05 (0.007)	<0.05 (0.00483)	Reach 0	SNP 43-5; 7-Jul-08	0.010	NO
Lithium	0.08	0.045	Reach 6	BC Exp. Pt.; 7-Aug-08	0.0062 [3]	**YES**
Magnesium	101	95	Reach 6	BC Exp. Pt.; 13-Sep 10	NG	NO
Manganese	0.50	0.177	Trapper Creek	SNP 43-15; 3-Sep-07	0.32	NO
Mercury	<0.0002 (0.000011)	<0.0002 (0.000056)	Multiple	NA	0.001	NO
Molybdenum	0.0305	0.0251	Reach 6	BC Exp. Pt.; 27-Aug-08	0.0156 [3]	**YES**
Nickel	0.10	0.0616	Reach 6	BC Exp. Pt.; 14-Sep-05	0.06 [3]	**YES**
Nitrate-N	15	12.2	Upper Baker Creek	SNP 43-11; 12-Aug-03	10	**YES**
Nitrite-N	0.309	0.043	Reach 6	BC Exp. Pt.; 13-Sep-10	1.0	NO
Phosphorus	<0.3	<0.3	Multiple Reaches	NA	NG	NO
Potassium	14	12.7	Reach 6	BC Exp. Pt; 13-Sep-10	NG	NO
Rubidium	0.011	0.0049	Reach 3	Site 5; 21-Aug-03	NG	NO
Selenium	12.9[4]	<0.2 (0.0046)	Multiple	NA	0.01	**YES**[7]
Silicon	2.55	4.69	Trapper Creek	SNP 43-15; 2-Sep-08	NG	NO

Substance	Maximum Concentration (mg/L)[1]				Human Health Drinking Water Guidelines[2]	Retained as a COPC for Human Health?
	Treated Effluent	Surface Water	Location of Maximum Surface Water Concentration[9]	Sample ID and Date		
Silver	<0.01 (0.0002)	<0.02 (0.0001)	Multiple Reaches	NA	0.0142 [3]	NO
Sodium	224	204	Reach 6	BC Exp. Pt.; 14-Sep-05	200[7]	NO
Strontium	4.59	4.34	Reach 6	BC Exp. Pt.; 14-Sep-05	1.86 [3]	**YES**
Sulphate	1260	1210	Reach 6	BC Exp. Pt.; 13-Sep-10	500	NO[5,6]
Thallium	<0.2 (0.0001)	<0.2 (0.0003)	Upper Baker Creek	BC-4; 19-Oct-01	0.00032	**YES**[7]
Tin	<0.03	<0.03 (0.0006)	Upper Baker Creek	NA	1.86 [3]	NO
Titanium	0.016	0.034	Trapper Creek	SNP 43-16; 20-Sep-10	NG	NO
Uranium	<0.5 (0.013)	<0.5 (0.00306)	Reach 6	BC Exp. Pt.; 5-Jul-06	0.02	**YES**[7]
Vanadium	0.048	<0.04 (0.030)	Reach 6	BC Exp. Pt.; 14-Sep-05	0.0156 [3]	**YES**[7]
Zinc	0.0713	0.052	Upper Baker Creek	BC-4; 19-Oct-01	5	NO
Radium-226	<0.05 (0.02)	0.03	Reach 6	BC Exp. Pt.; 26-Sep-07	0.5 (Bq/L)	NO

COPC = Contaminant of Potential Concern; NG = No guideline; NM = Not measured

1. Maximum detected concentration shown in brackets when maximum concentration was based on a non-detect value.
2. Health Canada Guidelines for Canadian Drinking Water Quality unless otherwise noted (Health Canada 2010).
3. United States Environmental Protection Agency (USEPA) Regional Screening Levels (RSL) for tap water (USEPA 2012a). RSLs were adjusted (non-carcinogens: multiplied by 0.2; carcinogens: multiplied by 10).
4. Selenium as dissolved fraction, sample was not analysed for total selenium. Other samples analysed for total selenium had values ≤0.017 mg/L.
6. Substance lacks a toxicity reference value (TRV) and cannot be assessed quantitatively.
7. Guideline is based on aesthetic concern; no health-based guideline is available.
8. Substance screened in based on elevated detection limit, maximum detected concentration was below screening criterion.
9. Treated effluent is currently only discharged to Baker Creek during summer months, but at times it can account for the majority of flow through Baker Creek so maximum surface water concentration may include treated effluent inputs.

Arsenic concentrations are naturally elevated in the area around Yellowknife, NWT and a site-specific Remediation Objective of 150 mg/kg for arsenic in sediment has been developed for this region (GNWT 2003; it is assumed this value is in dry weight although such is not specified). This remediation objective is based on average natural background concentrations in and around Yellowknife, and was developed for publicly accessible areas (e.g., public boat launch) where people are likely to come into contact with sediments (GNWT 2003).

Table 33 presents the constituents analysed and COPCs identified in sediment for the human health risk assessment.

5.1.1.3 Fish Tissue

Relevant guidelines for fish tissue consumption by humans were those provided by USEPA (2012b); fish tissue concentrations were screened against the USEPA RSLs. As was the case for drinking water and soil, the USEPA RSLs for fish tissue were derived based on an HQ of 1 for non-carcinogens and an ILCR of 10^{-6} for carcinogens, whereas Health Canada's acceptable risk levels are an HQ of 0.2 and an ILCR of 10^{-5}, respectively. Therefore, the RSLs for fish tissues were adjusted (i.e., RSL×0.2 for non-carcinogens and RSL×10 for carcinogens) to reflect the acceptable limits in Canada.

The Canadian Food Inspection Agency (CFIA) has established guidelines for arsenic, lead, and mercury in fish and fish products intended for human consumption; however, only the mercury guideline applies to edible fish tissues. Additionally, these regulations only apply to fish intended for commercial sale and not personal consumption.

Data from early years (1972) were excluded from the screening as they were deemed too old to be representative of current conditions at the Site. In addition, data collected by Dillon (2002b) were excluded based on the following rationale:

1) Data quality uncertainties. There remains uncertainty as to whether the Dillon (2002b) fish tissue concentrations were reported in wet weight or dry weight concentrations. The reported arsenic concentrations were high in Dillon (2002b) relative to those measured in 1972 and in recent years. These data were also excluded from the SENES (2006) risk assessment. The units presented could not be confirmed at the time of this report; and,

2) Availability of more recent data. Tissue samples collected in 2009 and 2011 were considered more appropriate for characterizing current conditions at the Site. Sufficient recent data were available for the calculation of summary statistics.

The dataset used for screening was composed of the fish collected in 2009 and 2011 by Golder. All large-bodied fish species were included, with a total of 28 muscle samples, 27 liver samples, and 3 ovary samples collected between 2009 and 2011.

Table 33: Summary of Contaminants of Potential Concern (COPCs) for Human Health in Baker Creek Sediments

Substance	Maximum Concentration (mg/kg dw)[1]	Reach	CCME Soil Quality Guideline Residential[2]	GNWT Sediment Remediation Objective[3]	Retained as COPC for Human Health?
Aluminum	45900	0	15400 [4]	-	**YES**
Antimony	3140	0	20 [5]	-	**YES**
Arsenic	21300	5	12	150	**YES**
Barium	250	1	500	-	NO
Beryllium	1.6	0	4 [5]	-	NO
Bismuth	<40 (4.5)	5	NG	-	NO[6]
Boron	7.67	0	3200 [4]	-	NO
Cadmium	24.0	5	10	-	**YES**
Calcium	56400	6	NG	-	NO[6]
Cesium	1.5	3	NG	-	NO[6]
Chromium	117	4	64	-	**YES**
Cobalt	281	5	50 [5]	-	**YES**
Copper	5470	6	63	-	**YES**
Gallium	5.80	0	NG	-	NO[7]
Gold	8.43	0	NG	-	NO[6]
Iron	332000	5	11000 [4]	-	**YES**
Lanthanum	28	0	NG	-	NO[6]
Lead	4050	5	140	-	**YES**
Lithium	66.5	0	32 [4]	-	**YES**
Magnesium	35200	4	NG	-	NO[6]
Manganese	2230	6	360 [4]	-	**YES**
Mercury	1.06	0	6.6	-	NO
Molybdenum	<80 (7.86)	6	10	-	**YES**[7]
Nickel	589	5	50	-	**YES**
Phosphorus	1130	0	NG	-	NO[6]
Potassium	21600	0	NG	-	NO[6]
Rubidium	24.4	3	NG	-	NO[6]
Scandium	5.98	0	NG	-	NO[6]
Selenium	<100 (5.17)	0	1	-	**YES**
Silicon	685	6	NG	-	NO[6]
Silver	27.9	5	20 [5]	-	**YES**
Sodium	17820	0	NG	-	NO[6]
Strontium	129	0	9400 [4]	-	NO
Sulphur	5788	0	NG	-	NO[6]
Thallium	<100 (0.69)	5	1	-	**YES**[7]
Thorium	11.38	0	NG	-	NO[6]
Tin	<20 (2.8)	2	50 [5]	-	NO

Substance	Maximum Concentration (mg/kg dw)[1]	Reach	CCME Soil Quality Guideline Residential[2]	GNWT Sediment Remediation Objective[3]	Retained as COPC for Human Health?
Titanium	1490	0	NG	-	NO
Tungsten	17.52	0	NG	-	NO[6]
Uranium	9.47	U/S	23	-	NO
Vanadium	138	4	130	-	**YES**
Zinc	4180	5	200	-	**YES**

COPC = Contaminant of Potential Concern; dw = dry weight; NG = No guideline; NM = Not measured; U/S = Upstream of mine activities

1. Maximum detected concentration shown in brackets when maximum concentration was based on a non-detect value.
2. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 1999), Residential Land Use, unless noted.
3. GNWT (2003) Remediation Objective for arsenic is based on average natural background concentrations in and around Yellowknife, and was developed for non-residential, publically-accessible areas (i.e., public boat launch).
4. United States Environmental Protection Agency (USEPA 2012a) Regional Screening Levels (RSL) for residential soil. RSLs were adjusted (non-carcinogens: multiplied by 0.2; carcinogens: multiplied by 10).
5. Interim guideline.
6. No screening criterion available. Substance lacks toxicity reference values (TRV) and cannot be assessed quantitatively.
7. Substance screened in based on elevated detection limit, maximum detected concentration was below screening criterion.

It was assumed that humans would primarily consume muscle tissue from fish caught in Baker Creek, but that it was possible some individuals may consume other fish tissues, including liver and ovaries. Maximum contaminant concentrations were therefore summarized separately for fish muscle, liver and ovaries. This provided a comparison of potential exposure to COPCs between individuals who may consume the bulk of their fish as muscle tissue to individuals who may consume a greater quantity of liver or ovary tissues.

Table 34 summarizes the screening of COPCs for fish tissue for the human health risk assessment.

5.1.1.4 Summary of Human Health Contaminants of Potential Concern

The results of screening of historical Baker Creek data indicated that 24 contaminants exceeded relevant guidelines for the protection of human health. Arsenic, antimony, cobalt, iron, and selenium were the only COPCs to exceed the screening guidelines in all the media analysed. A summary of human health COPC screening is provided in Table 35.

Table 34: Summary of Contaminants of Potential Concern (COPCs) for Human Health in Fish Tissues from Creek

Substance	Maximum Concentration in Liver (mg/kg)	Maximum Concentration in Muscle (mg/kg)	Maximum Concentration in Ovary (mg/kg)	Reach[1]	USEPA Region 3 Risk Screening Level[2] (mg/kg)	Retained as COPC
Aluminum	5.6	17.7	17.2	1	280	No
Antimony	**0.259**	0.0377	0.057	1	0.108	**YES**
Arsenic	**22.8**	**4.48**	**1.11**	1	0.021	**YES**
Barium	0.915	0.248	0.24	0	54	No
Beryllium	0.05	0.05	0.05	0	0.54	No
Bismuth	0.0297	0.0254	0.015	0	NG	No[8]
Cadmium	**0.288**	0.0029	0.0194	1	0.28	**YES**
Calcium	675	2940	1930	0	NG	No
Chromium	0.652	**2.26**	0.05	6	Cr (III) 400,	**YES** [7]
					Cr (VI) 0.82 [3]	
Cobalt	**0.544**	0.0531	**0.123**	1	0.082	**YES**
Copper	**51.9**	0.449	1.02	6	10.8	**YES**
Iron	**276**	31.3	60.7	6	190	**YES**
Lead	**0.116**	**0.0473**	**0.051**	1	0.000028 [4]	**YES**
Lithium	0.05	0.05	0.05	4	0.54	No
Magnesium	313	402	228	0	NG	No[8]
Manganese	3.73	2.43	2.43	1	38	No
Mercury	**0.226**	**0.397**	0.0226	6	0.028 [6]	**YES**
Molybdenum	0.279	0.055	0.016	6	1.36	No
Nickel	0.359	0.28	0.05	1	5.4	No
Phosphorous	4560	3860	3670	0	NG	No[8]
Potassium	4240	5190	3760	0	NG	No[8]
Selenium	**3.31**	0.88	1.3	0	1.36	**YES**
Sodium	1560	680	1520	0	NG	No[8]
Strontium	1.29	2.59	1.86	0	162	No
Thallium	**0.022**	**0.00802**	0	6	0.0028 [5]	**YES**
Tin	0.0398	0.0322	0.025	1	162	No
Titanium	0.25	0.574	0.61	1	NG	No[8]
Uranium	0.0176	0.00119	0.0047	0	0.82 [5]	No
Vanadium	0.622	0.05	0.05	6	1.36	No
Zinc	**141**	7.0	36.2	1	82	**YES**

COPC = Contaminant of Potential Concern; NG = No guideline; Concentrations are based on wet weight.

1. Reach in which the maximum concentration overall was observed.
2. USEPA Region 3 Screening Levels, Fish (USEPA 2012b). Screening levels (SL) were adjusted (non-carcinogens: SL multiplied by 0.2; carcinogens: SL multiplied by 10).
3. Chromium (III) – Insoluble Salts; Chromium (VI) – Particulates.
4. Guideline for tetraethyl lead.
5. Soluble salts.
6. Guideline for methylmercury.
7. Retained based on exceedence of Chromium VI screening level.
8. No screening criterion available. Substance lacks toxicity reference values (TRV) and cannot be assessed quantitatively.

Table 35: Contaminants of Potential Concern (COPCs) for the Human Health Screening Assessment

Substance	Surface Water(1)	Sediment(2)	Fish(3)	Retained as COPC
Aluminum	✓	✓ 5	-	**YES**
Antimony	✓	✓	✓	**YES**
Arsenic	✓	✓	✓	**YES**
Beryllium	✓6	-	-	**YES**
Cadmium	✓	✓	✓	**YES**
Chloride	✓	NM	NM	**YES**
Chromium	-	✓	✓	**YES**
Cobalt	✓ 4	✓	✓	**YES**
Copper	-	✓	✓	**YES**
Iron	✓	✓ 5	✓	**YES**
Lead	-	✓	✓	**YES**
Lithium	✓ 4	✓ 5	-	**YES**
Manganese	-	✓ 5	-	**YES**
Mercury	-	-	✓	**YES**
Molybdenum	✓ 4	✓6	-	**YES**
Nickel	✓ 4	✓	-	**YES**
Nitrate-N	✓	NM	NM	**YES**
Selenium	✓	✓	✓	**YES**
Silver	-	✓	NM	**YES**
Strontium	✓	-	-	**YES**
Thallium	✓6	✓6	✓	**YES**
Uranium	✓6	-	-	**YES**
Vanadium	✓4	✓	-	**YES**
Zinc	-	✓	✓	**YES**

COPC = Contaminant of Potential Concern; NG = No guideline but chemical was detected and therefore retained for further assessment; NM = Not measured; ✓= Chemical exceeds guideline, therefore was retained for further assessment; - = Chemical did not exceed guideline, or the chemical was not detected.

1. Canadian Drinking Water Guideline (Maximum Acceptable Concentration) (Health Canada 2010).
2. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 1999) - Residential Land Use.
3. USEPA (2012b) Region 3 Screening Levels for Fish).
4. USEPA Regional Screening Levels (RSL) for tap water (USEPA 2012a). RSLs were adjusted (non-carcinogens: multiplied by 0.2; carcinogens: multiplied by 10).
5. USEPA RSLs, Residential Soil Guidelines (USEPA 2012a). Screening levels (SL) were adjusted (non-carcinogens: SL multiplied 0.2; carcinogens: SL multiplied by 10).

5.1.2 Receptors of Potential Concern

The selection of human receptors for the Baker Creek Site was based on information provided by the SENES (2006) Tier 2 Risk Assessment and the goals outlined in the Giant Mine Remediation Plan (SRK and SENES 2007) regarding future uses and remediation plans for Baker Creek. Based on this information, the human receptors identified were adult and toddler recreational users and adult construction workers. It was assumed that these receptors would live in the communities near the Giant Mine:

- Giant Mine Townsite;
- Latham Island;
- City of Yellowknife; and,
- Dettah Community.

Potential risks were assessed for people living in the communities identified above who may in future be potentially exposed to COPCs resulting from recreational use of Baker Creek (e.g., fishing, trapping, wading) or for people involved in implementation of remediation projects at Baker Creek.

For COPCs that can cause cancer, only adults were assessed; for non-carcinogenic COPCs, both adults and toddlers were evaluated. Adults are assessed for carcinogenic COPCs because the duration of their lifestage is consistent with a lifetime exposure and an assessment of cancer risk is conducted on the basis of a lifetime average daily dose, while the toddler lifestage duration is considered too short to represent a lifetime exposure. The use of amortization for less than lifetime durations for exposures for carcinogenic risk assessment is currently under review by Health Canada (2009). Toddlers (i.e., from 7 months to 4 years of age) are considered to be more sensitive to the effects of chemicals than adults, as they typically take in higher amounts of chemicals relative to their body weight. Also, toddlers take in higher amounts of chemicals when they play outside (in the creek) and put soil (sediment) in their mouths. In addition, some chemicals such as lead have been shown to be more toxic to toddlers than adults. Health Canada (2009) recommends evaluating the toddler life-stage of childhood because this is typically the most sensitive child life-stage.

5.1.3 Exposure Pathways of Potential Concern

The objective of the human health exposure pathway screening process was to identify potential routes by which people could be exposed to COPCs under current and future conditions, and the relative significance of these pathways to the total exposure. Note that this process evaluated conservative present and future possibilities (e.g., toddlers swimming in Baker Creek), not probabilities. A COPC was considered to represent a potential health risk only if it could reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a COPC to reach a receptor, then there cannot be a risk, regardless of the COPC concentration.

The exposure pathways that apply to human receptors are the following:

- Ingestion of fish with elevated COPC concentrations for recreational users. It is assumed construction workers will be on site only for work purposes and will not consume fish;
- Direct skin contact with COPCs in surface water for recreational users and for construction workers;

- Incidental ingestion of COPCs in surface water for recreational users and construction workers; and,
- Direct contact with COPCs in sediment, including incidental ingestion and dermal contact for recreational users and construction workers.

The exposure pathways considered but determined to be not applicable to recreational users or construction workers are:

- Ingestion of COPCs in plants or berries, as no known edible plants or berries have been identified within Baker Creek, and the riparian area of the creek was not included in this scope of work;
- Incidental ingestion or inhalation of COPCs in soil, inhalation of COPCs from the air, and ingestion and dermal contact with COPCs in groundwater are not considered applicable pathways because the human health risk assessment scope only includes the aquatic media within Baker Creek;
- Inhalation of volatiles from indoor or outdoor air are not considered applicable pathways because no volatile COPCs have been measured within Baker Creek; and
- Inhalation of sediment particulates, because there is no evidence of significant release of bed sediment particles to air based on the hydrology of Baker Creek.

5.1.4 Conceptual Site Model

Conceptual Site Models (CSMs) identify receptors and exposure pathways. The FCSAP aquatic sites framework document (Chapman 2011) defines CSMs as "*A diagrammatic representation of a site and its environment that represents what is known or suspected about contaminant sources as well as the physical, chemical and biological processes that affect contaminant transport to potential environmental receptors*." The CSM for human health is provided as Figure 34.

POTENTIAL RECEPTORS

BASELINE/PROJECT

CONTAMINATED MEDIA	CONTAMINATED RELEASE/TRANSPORT MECHANISMS		EXPOSURE ROUTES	Construction Worker[1], Adult	Recreational User[2], Adult	Recreational User, Toddler
Surface Soil	Plant Uptake	Plant/Berries	Ingestion	NA[3]	NA[3]	NA[3]
Surface Soil	Erosion	Soil Dust	Inhalation	NA[3]	NA[3]	NA[3]
Surface Soil	Soil	Soil	Ingestion	NA[3]	NA[3]	NA[3]
Surface Soil	Soil	Soil	Dermal Contact	NA[3]	NA[3]	NA[3]
Surface Soil	Volatilization	Indoor Air	Inhalation	NA[3]	NA[3]	NA[3]
Surface Soil	Volatilization	Outdoor Air	Inhalation	NA[3]	NA[3]	NA[3]
Groundwater	Volatilization/ Vapour Migration	Indoor Air	Inhalation (Vapour)	NA[3]	NA[3]	NA[3]
Groundwater	Volatilization/ Vapour Migration	Outdoor Air	Inhalation (Vapour)	NA[3]	NA[3]	NA[3]
Groundwater	Groundwater	Groundwater	Ingestion	NA[3]	NA[3]	NA[3]
Groundwater	Groundwater	Groundwater	Dermal Contact	NA[3]	NA[3]	NA[3]
Surface Water	Surface Water	Surface Water	Incidental Ingestion	C	C	C
Surface Water	Surface Water	Surface Water	Dermal Contact	C	C	C
Surface Water	Bioaccumulation in Fish Tissue	Fish Tissue	Ingestion		C	C
Sediment	Sediment	Sediment	Incidental Ingestion	C	C	C
Sediment	Sediment	Sediment	Dermal Contact	C	C	C
Sediment	Erosion	Sediment Particulate	Inhalation (Particulates)	NA	NA	NA
Sediment	Bioaccumulation in Fish Tissue	Fish Tissue	Ingestion		C	C
Air	Deposition of Soil	Plants/Small or Large Mammals	Ingestion	NA[3]	NA[3]	NA[3]
Air	Air	Outdoor Air	Inhalation	NA[3]	NA[3]	NA[3]

LEGEND

C Complete Exposure Pathway

NA Not Applicable Pathway

☐ Incomplete Exposure Pathway

1 Construction Worker is assumed to not be consuming traditional foods.

2 Recreational Users and Hunters / Trappers were not assessed as part of the multi-media assessment because the First Nations Community Receptor is a composite of these exposures and considered protective of these receptor exposures.

3 Pathway is not considered applicable because only COPCs in media within Baker Creek are being assessed.

Public Works and Government Services Canada / Travaux publics et Services gouvernementaux Canada

REAL PROPERTY SERVICES
Western Region
SERVICES IMMOBILIERS
Région de l'ouest

PRELIMINARY
NOT FOR CONSTRUCTION

Golder Associates

DO NOT SCALE DRAWINGS

Revision/Révision	Description/Description	Date/Date
0	ISSUED WITH RPT-0005-REV2	2013-03-08
B	ISSUED WITH RPT-0005-REV1	2012-09-28
A	ISSUED WITH RPT-0005-REV0	2012-07-24

Client/client

PUBLIC WORKS GOVERNMENT SERVICES CANADA

Project title/Titre du projet

GIANT MINE REMEDIATION PROJECT YELLOWKNIFE, N.W.T.

BAKER CREEK

Approved by/Approuvé par: CM

Designed by/Concept par: CAM

Drawn by/Dessiné par: RH

PWGSC Project Manager/Administrateur de Projets TPSGC: PWGSC

PWGSC, Architectural and Engineering Resources Manager/ Ressources Architectural et de Directeur d'ingénierie, TPSGC

Client/client: PWGSC

Drawing title/Titre du dessin

HUMAN HEALTH CONCEPTUAL MODEL

Project No./No. du projet	Sheet/Feuille	Revision no./La Révision no.
R.014204	FIGURE 34	0

5.2 Exposure Assessment

5.2.1 Characterization of Potential Receptors

Human receptors may travel to Baker Creek from the nearby locations of the Giant Mine Townsite, Latham Island, the City of Yellowknife and the Dettah community for recreational purposes or for hypothetical future remedial/construction activities.

Recreational Users

It was assumed that an adult or toddler living in one of the nearby communities may visit Baker Creek for recreational purposes every weekend for three months per year. This is a very conservative assumption as the public are actively discouraged from using a contaminated site and, currently, Reach 2 and upwards (up to and including Reach 6) are off limits to the public, plus recreational activities are typically spread among locations, not restricted to a single location on a consistent, repetitive basis. It is assumed that a recreational user may fish in Baker Creek. It is considered unlikely that a recreational user would swim in Baker Creek, but this potential exposure has been evaluated in order to understand the potential risks should this occur. Relevant exposure pathways for the recreational user are incidental sediment ingestion, fish ingestion, incidental surface water ingestion, dermal contact with sediment and dermal contact with surface water. For the calculation of dermal contact exposure, it was assumed that the hands, feet, lower legs and forearms of the recreational user may come into contact with sediment and that their whole body may come into contact with surface water.

Construction Worker

Remediation plans for Baker Creek may require a construction worker to spend time at the Site. It was assumed that a construction worker may spend 13 weeks of the year working at the Site for 5 days per week. The construction worker may wade into the water wearing waterproof pants and footgear during construction activities. It was assumed that the construction worker would not be fishing in Baker Creek; they would be present at the Site to work only. Relevant exposure pathways for the construction worker are incidental sediment ingestion, incidental surface water ingestion, dermal contact with sediment, and dermal contact with water. For the calculation of dermal contact exposure, it was assumed that the hands and forearms of the construction worker may come into contact with sediment and surface water.

5.2.2 Exposure Frequency and Duration

The exposure parameters for the recreational user and construction worker are presented in Table 36. The sediment ingestion rates are based on recommendations from a review report (Meridian 2011) submitted to Health Canada. SENES (2003) completed a screening level risk assessment for the Giant Mine Site and reviewed dietary survey information collected in the nearby communities of Yellowknife Dene living in Dettah and Ndilo and the Dene / Metis from the larger regional area. Based on these studies, SENES (2003) used a fish ingestion rate of 124 g/d ww for children and 167 g/d ww for adults. These fish ingestion rates have been adopted herein for the toddler and adult recreational users. A toddler will eat less fish than a child; therefore, adopting the child fish ingestion rate for toddlers represents an overestimate but was conservatively used because other data were not available.

Incidental surface water ingestion rates while swimming have been provided in the United States Environmental Protection Agency's Exposure Factors Handbook (USEPA 2011). Mean and 97th percentile ingestion rates are presented in USEPA (2011) based on studies completed in swimming pools. As Baker Creek is not considered a desirable location for swimming, the mean incidental water ingestion rate was adopted for the assessment. The incidental water ingestion rate presented for a child was conservatively adopted for the toddler. The construction worker may be wading in the water, and an incidental water ingestion rate equivalent to that of a swimmer was conservatively adopted. It was also conservatively assumed that recreational users spend 1 hour per day swimming and that construction workers may spend 5 hours per day wading. Health Canada (2009) was used as the source for the whole body surface area for recreational swimmers.

Intrinsik Environmental Sciences Inc. has provided interim guidance to Health Canada on the evaluation of direct exposure to contaminated sediments (Intrinsik 2011). Intrinsik's report provides sediment-specific dermal loading factors determined through beach-related activities. These dermal loading factors for each relevant body part were used in the assessment, along with the surface area for each body part. It was assumed that there was 1 dermal event per day for sediment dermal contact.

Body weights and exposure durations were adopted from Health Canada (2009). Exposure frequency for a construction worker was adopted from Health Canada (2009). For the remote wildlands land use (camping, hunting, fishing), Health Canada (2009) recommends 13 weeks per year on site and 7 days per week on site. While it is considered possible that a recreational user could visit Baker Creek for 13 weeks per year, it is not expected that recreational users would camp next to Baker Creek, and certainly not for long periods of time. Recreational users could visit Baker Creek from nearby communities for up to 2 days per week, likely on the weekends, in order to fish or swim. An exposure frequency of 2 days per week for 13 weeks per year was conservatively used for the recreational user. The selected exposure period for recreational users and construction workers at the Site is most representative of a sub-chronic exposure (i.e., exposures occurring periodically for less than 90 days, see Section 5.3.2). As such, sub-chronic toxicity reference values (TRVs) were employed for non-carcinogens where possible and exposure concentration was not amortized over the year (i.e., the weeks per year term was not included in the exposure calculations).

The averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was 80 years based on Health Canada (2009).

5.2.3 Exposure Equations

Exposure estimate equations used for the human health exposure assessment were adopted from Health Canada (Health Canada 2009) and are presented in Table 37.

Table 36: Exposure Parameters for Human Health

Parameter	Toddler Rec. User	Adult Rec. User	Reference	Construction Worker	Reference
Sediment ingestion rate (kg/d)	0.0001	0.000028	Meridian (2011)	0.000028	Meridian (2011)
Fish ingestion rate (kg/d)	0.124	0.167	SENES (2003)	N/A	N/A
Incidental surface water ingestion rate (L/hr)	0.049	0.021	USEPA (2011)	0.021	Assumed 10% of rate for swimming
Dermal loading of sediment to hands (kg/m^2-event)	0.0049	0.0049	Intrinsik (2011)	0.0049	Intrinsik (2011)
Dermal loading of sediment to feet (kg/m^2-event)	0.21	0.21	Intrinsik (2011)	N/A	Intrinsik (2011)
Dermal loading of sediment to legs (kg/m^2-event)	0.007	0.007	Intrinsik (2011)	N/A	Intrinsik (2011)
Dermal loading of sediment to forearms (kg/m^2-event)	0.0017	0.0017	Intrinsik (2011)	0.0017	Intrinsik (2011)
Dermal events per day	1	1	Assumed	1	Assumed
Surface area of hands (m^2)	0.043	0.089	Intrinsik (2011)	0.089	Intrinsik (2011)
Surface area of feet (m^2)	0.043	0.119	Intrinsik (2011)	N/A	Intrinsik (2011)
Surface area of legs (m^2)	0.0845	0.286	Intrinsik (2011)	N/A	Intrinsik (2011)
Surface area of forearms (m^2)	0.0445	0.125	Intrinsik (2011)	0.125	Intrinsik (2011)
Surface area for swimming / wading – water contact (cm^2)	6,130	17,640	Health Canada (2009)	2,140	Intrinsik (2011)
Hours per day swimming / wading	1	1	Assumed	5	Assumed
Body weight (kg)	16.5	70.7	Health Canada (2009)	70.7	Health Canada (2009)
Exposure duration (ED; yr)	4.5	80	Health Canada (2009)	35	Health Canada (2009)
Weekly Exposure frequency (d/wk)	2	2	Assumed	5	Health Canada (2009)
Yearly Exposure frequency (wk/yr)	N/A for non-carcinogens; 13 for carcinogens (for adults only)		Assumed	N/A for non-carcinogens; 13 for carcinogens	Health Canada (2009)
Averaging time	ED for non-carcinogens; 80 for carcinogens (for adults only)		Health Canada (2009)	ED for non-carcinogens; 60 for carcinogens	Health Canada (2009)

N/A = Not applicable; ED = exposure duration

Table 37: Exposure Equations for Human Health

Pathway	Equation and Equation Parameters
Incidental Water Ingestion	$EDI_{water} = \frac{C_w \times IR_{swim} \times RAF_{oral} \times EF \times ED \times ET}{BW \times AT \times CF_1}$
	EDI_{water} = exposure due to incidental ingestion of water (mg chemical/kg bw – day) C_W = chemical concentration in water (mg/L) IR_{swim} = incidental water ingestion rate (L/h) RAF_{oral} = relative absorption factor for oral ingestion (unitless) EF = exposure frequency (d/wk) ED = exposure duration (yr) ET = exposure time (hr) BW = receptor body weight (kg) AT = averaging time (yrs) CF_1 = conversion factor (7 d/wk)
Dermal Absorption from Surface Water	$EDI_{SKIN\text{-}WATER} = \frac{C_w \times SA_{SKIN} \times Kp \times EF \times ET \times ED}{BW \times CF_1 \times CF_2 \times AT}$
	$EDI_{SKIN\text{-}WATER}$= exposure due to dermal absorption of COPCs in water (mg chemical/kg body weight-. day) C_W = chemical concentration in water (mg/L) SA_{SKIN} = surface area of exposed skin (cm^2) Kp = dermal permeability coefficient (cm/hr) EF = exposure frequency (d/wk) ET = exposure time (hr) ED = exposure duration (yr) BW = receptor body weight (kg) CF_1 = conversion factor (7 d/wk) CF_2 = conversion factor (1000 cm^3/L) AT = averaging time (yr)
Dermal Absorption from Sediment	$EDI_{SKIN\text{-}SOIL} = \frac{C_S \times SD_{SKIN} \times SA_{SKIN} \times RAF_{dermal} \times EV \times EF \times ED}{BW \times AT \times CF_1}$
	$EDI_{SKIN\text{-}SOIL}$ = exposure due to dermal absorption of COPCs from sediment (mg chemical/kg body weight-day) C_s = chemical concentration in soil (mg/kg) SD_{SKIN} = sediment loading (kg/m^2 –event) SA_{SKIN} = surface area of exposed skin (m^2) RAF_{dermal} = absorption factor for the skin (unitless) EV = number of dermal events per day EF = exposure frequency (d/wk) ED = exposure duration (yr) BW = receptor body weight (kg) CF_1 = conversion factor (7 d/wk) AT = averaging time (yr)
Sediment Ingestion	$EDI_{sed} = \frac{C_{sd} \times IR_s \times RAF_{oral} \times EF \times ED}{BW \times AT \times CF_1}$
	EDI_{sed} = exposure due to ingestion of sediment (mg chemical/kg body weight - day) Csd = chemical concentration in sediment (mg/kg) IR_s = receptor sediment ingestion rate (kg/day) RAF_{oral} = relative absorption factor for oral ingestion (unitless) EF = exposure frequency (d/wk) ED = exposure duration (yr) BW = receptor body weight (kg) CF_1 = conversion factor (7 d/wk) AT = averaging time (yr)

Pathway	Equation and Equation Parameters
Fish Ingestion	$EDI_{fish} = \frac{C_{fish} \times IR_{fish} \times RAF_{oral} \times EF \times ED}{BW \times AT \times CF_1}$
	EDI_{fish} = exposure due to ingestion of prey (mg chemical/kg body weight - day) C_{fish} = concentration of chemical in food i (mg/kg) IR_{fish} = receptor ingestion rate for food i (kg/day) RAF_{oral} = relative absorption factor for oral ingestion (unitless) EF = exposure frequency (d/wk) ED = exposure duration (yr) BW = receptor body weight (kg) CF_1 = conversion factor (7 d/wk) AT = averaging time (yr)

mg = milligram; kg = kilogram; L = Litre; m^3 = cubic metre; d = days; yr = years; hr = hours; cm^2 = square centimetres; cm^3 = cubic centimetres; wk = week

5.2.4 Exposure Concentrations

COPCs were identified by comparing the maximum detected concentrations for each parameter with the appropriate screening criteria in each matrix (Section 5.1.1). However, the use of maximum concentrations for estimating exposure concentrations is not necessarily appropriate, as this approach ignores the spatial distribution of COPCs across the Site. It also does not reflect that receptors are likely to be exposed to a range of concentrations, as populations of each receptor will not spend all of their time in the area with the maximum concentration.

Consequently, upper limit exposure concentrations were derived for use in the exposure equations. Upper limit exposure concentrations include the 95% upper confidence level of the mean (95% UCLM) or the 90th percentile. Summary statistics, including average, maximum, 90th percentile and 95% UCLM, were calculated for the COPCs in each matrix and are presented in Appendix J. One half of the detection limit was substituted for non-detected values for the purpose of computing summary statistics. The datasets used for calculation of summary statistics were the same as those used for the COPC screening (Section 5.1.1). For fish tissue, only those species consumed by the public (i.e., Arctic Grayling, Lake Whitefish, and Northern Pike) were used to estimate exposure concentrations. Also, summary statistics were computed separately for each tissue type (muscle, liver and ovary).

The 95% UCLM (calculated using the ProUCL software [version 4.1]) was selected preferentially over the other summary statistics calculated as the exposure concentration used for modelling when appropriate (i.e., sample size >10, detection frequency >50%). When detection frequency was low (<50%), the 90th percentile concentration was selected as the exposure concentration. In cases where sample size was less than 10, the maximum concentration was retained for the exposure calculations. Exposure concentrations are summarized in Table 38; for fish tissue, the maximum exposure concentration among the three tissue types presented in the table was selected as the exposure concentration for modelling.

Table 38: Exposure Concentrations Used in the Screening Assessment Calculations

COPC	Exposure Concentrations				
	Water (mg/L)	Sediment (mg/kg dw)	Fish Liver (mg/kg ww)	Fish Muscle (mg/kg ww)	Fish Ovary (mg/kg ww)
Nutrients					
Chloride	81.7	NM	NM	NM	NM
Nitrate-N	5.32	NM	NM	NM	NM
Metals					
Aluminum	0.117	18300	2.76	2.80	17.2
Antimony	0.0544	464	0.0957	0.015	0.057
Arsenic	0.126	2080	3.22	1.61	1.11
Beryllium	0.0025	0.549	0.05	0.05	0.05
Cadmium	0.0005	3.118	0.131	0.0025	0.0194
Chromium	0.005	47.6	0.162	0.139	0.05
Cobalt	0.005	36.8	0.248	0.0195	0.123
Copper	0.00349	765	15.0	0.305	1.02
Iron	0.292	56600	138	9.55	60.7
Lead	0.000406	508	0.0541	0.0109	0.051
Lithium	0.013	28.3	0.05	0.05	0.05
Manganese	0.0378	598	2.25	0.941	2.43
Mercury	0.0001	0.306	0.143	0.192	0.0226
Molybdenum	0.00317	1.75	0.174	0.005	0.016
Nickel	0.00589	93.3	0.141	0.05	0.05
Selenium	0.002	1.24	2.22	0.518	1.3
Silver	0.005	5.27	NM	NM	NM
Strontium	0.489	44.5	0.627	1.14	1.86
Thallium	0.1	0.245	0.0142	0.00512	NM
Uranium	0.000558	3.35	0.00783	0.001	0.0047
Vanadium	0.015	53.1	0.14	0.05	0.05
Zinc	0.00874	633	62.5	5.21	36.2

mg/kg dw - miligrams of COPC per kilogram of sediment in dry weight; mg/kg ww - milligrams of COPC per kilogram of tissue in wet weight; NM - Not Measured

5.2.5 Arsenic Speciation Analysis of Fish Tissue

Arsenic bioaccessibility and speciation testing was conducted by the Environmental Sciences Group (ESG) of the Royal Military College of Canada (RMC; Kingston, ON) on fish tissue samples collected in Reach 1 and 6 by Golder in 2011. Methods and results of the fish tissue analyses are summarized in Section 4.6 and Appendix G. The percent bioaccessible arsenic (% BA) averaged 78% in fish liver tissue (range 37% to 147%) and 72% in fish muscle tissue (range 41% to 110%). The percent of inorganic arsenic as a fraction all total arsenic averaged 9% in fish liver tissue (range 2% to 25%) and averaged 11% in fish muscle tissue (range 8% to 13%). The percent of non-arsenobetaine (non-AB) averaged 90% in fish liver tissue (range 66% to 98%) and averaged 65% in fish muscle tissue (range 23% to 94%).

To calculate arsenic exposure concentrations for carcinogenic effects, the percent of inorganic arsenic in fish liver (9%) was applied; for non-carcinogenic effects, the percent of non-AB in fish muscle tissue (90%) was applied. Further discussion on the relative toxicity of arsenic species is provided in Section 5.3.3.

5.2.6 Bioavailability and Relative Absorption Factors

The detection of COPCs in various environmental media does not necessarily reflect the actual concentrations available to biological systems and therefore may not reflect the "toxicologically-relevant" exposure point concentration. When a person ingests a chemical in sediment / fish / water, some portion (from 0 to 100%) of the total concentration of the chemical will be absorbed by the body. For oral exposure, this portion of the chemical absorbed from the matrix (e.g., sediment) is deemed to be "bioavailable" (i.e., that fraction of the administered dose that reaches the systemic circulation in vivo; Oomen et al. 2002). The bioavailability adjustment is incorporated into the human health assessment through the use of relative absorption factors (RAFs), which are described further below.

Relative absorption factors allow for corrections to be made for the matrix to which a receptor is exposed. For example, toxicity reference values (TRVs) are often based on studies in which exposure occurs via contaminated water or food. The bioavailability of chemicals in sediment may be different due to the potential binding of chemicals to the inorganic and/or organic matrix of the sediment. Consequently, when comparing exposure rates from sediment ingestion to the TRVs generated from exposure to chemicals in water or food, some correction for relative bioavailability is generally accepted as being reasonable.

Health Canada (2009) recommends that a RAF of 1.0 should conservatively be applied for all oral ingestion unless site-specific data have been collected. For Baker Creek, site-specific data for bioavailability have only been collected for arsenic for fish and sediment. As discussed in Section 5.1.5, for arsenic in fish a bioaccessibility factor of 9% was applied in the evaluation of carcinogenic effects and a bioaccessibility factor of 90% was applied in the evaluation of non-carcinogenic effects based on the types of arsenic compounds that are considered to be carcinogenic and non-carcinogenic. SENES (2006) conducted bioaccessiblity analyses on sediments collected in Baker Creek. Sediment samples were collected at seven locations across the Site, from Baker Creek Pond to Reach 0. The overall mean value of the acid extracts was 26.8%; this value was used for the bioaccessibility of sediment for the sediment ingestion pathway in the health assessment.

Dermal RAFs for soil are available from Health Canada (2009), and these dermal RAFs for soil have been adopted for sediment because sediment RAFs are unavailable. If no information was available on the RAF for a specific chemical or exposure route, the RAF was conservatively assumed to be equal to 1.0 or 100% for oral ingestion and 0.01 or 1% for dermal exposure (Ontario Ministry of the Environment 2011). The RAFs used in the human health assessment are provided in Table 39.

Table 39: Relative Absorption Factors (RAFs) for Sediment and Water

COPC	Sediment[1]		Water	Reference[2]
	Oral RAF	Dermal RAF	Oral RAF	
Aluminum	1	0.01	1	Assumed
Antimony	1	0.1	1	Health Canada (2009)
Arsenic	1	0.03	1	Health Canada (2009)
Beryllium	1	0.1	1	Health Canada (2009)
Cadmium	1	0.01	1	Health Canada (2009)
Chloride	1	0.01	1	Assumed
Chromium	1	0.1	1	Health Canada (2009)
Cobalt	1	0.01	1	Health Canada (2009)
Copper	1	0.06	1	Health Canada (2009)
Iron	1	0.01	1	Assumed
Lead	1	0.006	1	Health Canada (2009)
Lithium	1	0.01	1	Assumed
Manganese	1	0.01	1	Assumed
Mercury	1	0.466	1	Health Canada (2009)
Molybdenum	1	0.01	1	Health Canada (2009)
Nickel	1	0.01	1	Health Canada (2009)
Nitrate	1	0.01	1	Assumed
Selenium	1	0.01	1	Health Canada (2009)
Silver	1	0.25	1	Health Canada (2009)
Strontium	1	0.01	1	Assumed
Thallium	1	0.01	1	Health Canada (2009)
Uranium	1	0.1	1	Health Canada (2009)
Vanadium	1	0.1	1	Health Canada (2009)
Zinc	1	0.1	1	Health Canada (2009)

1. Soil RAFs were adopted for sediment contact.
2. Where RAFs were not provided, the RAF was assumed to be 1 for oral ingestion and 0.01 for dermal exposure.

5.2.6.1 Dermal Permeability Coefficients

Recreational users and construction workers were considered to be directly exposed to COPCs in surface water via dermal contact while swimming or wading. The Risk Assessment Information System (RAIS 2012) provides chemical-specific dermal permeability coefficients for water. The coefficients used in the human health risk assessment are provided in Table 40.

Table 40: Dermal Permeability Coefficients (source RAIS 2012)

COPC	Dermal Permeability Coefficient (cm/hr)	COPC	Dermal Permeability Coefficient (cm/hr)
Aluminum	0.001	Manganese	0.001
Antimony	0.001	Mercury	0.001
Arsenic	0.001	Molybdenum	0.001
Beryllium	0.001	Nickel	0.0002
Cadmium	0.001	Nitrate	0.001
Chloride	0.001	Selenium	0.001
Chromium	0.001	Silver	0.0006
Cobalt	0.0004	Strontium	0.001
Copper	0.001	Thallium	0.001
Iron	0.001	Uranium	0.001
Lead	0.0001	Vanadium	0.001
Lithium	0.001	Zinc	0.0006

5.3 Toxicity Assessment

Toxicity assessment involves the classification of the potential toxic effects of COPCs and the estimation of the concentrations of chemicals to which people could be exposed without experiencing adverse effects to their health. Toxicity assessment is conducted for all COPCs and considers possible modes of toxicity associated with different routes and durations of exposure. The toxicity assessment provides an estimate of how much chemical exposure may occur without unacceptable human health effects occurring from lifetime exposure (or a significant portion of lifetime), and provides a basis to interpret predicted exposure rates.

5.3.1 Contaminant Classification

Regulatory agencies classify chemicals based on their mode of action (i.e., threshold versus non-threshold substances). For substances exhibiting a threshold for toxicity (non-carcinogens), agencies evaluate the available toxicological data and estimate an acceptable level of exposure at or below which no adverse effects are anticipated. For non-threshold substances (carcinogens), any level of exposure is assumed to theoretically pose a potential risk, and a slope factor is used to predict risks from estimated exposures.

Several organizations have developed classification systems based on the carcinogenic potential of chemicals. The classification systems for Health Canada (2009), the USEPA (2012a) and the International Agency for Research on Cancer (IARC 2012) are presented in Table 41.

Table 41: Carcinogen Classification from Health Canada, IARC and USEPA

Health Canada[1]	IARC[2]	USEPA[3]	Description
Group I	Group 1	Group A	Human carcinogen
Group II	Group 2A	Group B	Probable human carcinogen
		B1	Limited human evidence available
		B2	Inadequate human evidence, sufficient animal evidence
Group III	Group 2B	Group C	Possible human carcinogen
Group IV			Unlikely to be carcinogenic to humans
Group V	Group 4	Group E	Probably not carcinogenic to humans
Group VI	Group 3	Group D	Unclassifiable as to human carcinogenicity

1. Health Canada (2009)
2. IARC (2012)
3. USEPA (2012a)

The classifications for the COPCs at Baker Creek are provided in Table 42. Some of the COPCs have been identified as potential carcinogens, but the data are based on inhalation exposure or insufficient data exist to develop an oral slope factor. Due to the lack of an available oral slope factor, these COPCs have not been evaluated as carcinogens. The only COPC assessed as a carcinogen was arsenic.

Table 42: Carcinogen Classification for the Contaminants of Potential Concern (COPCs) at Baker Creek

COPC	Health Canada	USEPA	IARC	Assessed as a Carcinogen?[1]
Aluminum	NC	NC	NC	No
Antimony	NC	NC	2B	No
Arsenic	Group I	Group A	1	**Yes**
Beryllium	NC	Group B1[2]	1	No
Cadmium	Group II	Group B1	1	No
Chloride	-	NC	-	No
Chromium	Group I	NC	3	No
Cobalt	NC	NC	2B	No
Copper	NC	D	NC	No
Iron	NC	NC	NC	No
Lead	Group IIIB	B2	2B	No
Lithium	NC	NC	NC	No
Manganese	NC	D	-	No
Mercury	NC	D	3	No
Molybdenum	NC	NC	NC	No
Nickel	Group I	NC	2B	No
Nitrate	NC	NC	2A	No
Selenium	NC	D	3	No
Silver	NC	D	NC	No
Strontium	NC	NC	NC	No
Thallium	NC	NC	NC	No
Uranium	Group V	NC	NC	No
Vanadium	NC	NC	2B	No
Zinc	NC	D	NC	No

- = Not provided by the regulatory agency.
1. Only assessed as a carcinogen if an oral slope value wa available; several chemicals have been classified as a carcinogen based on inhalation exposure and not by the oral pathway, therefore oral slope factors have not been developed.
2. Carcinogenic potential cannot be determined via the oral route, but is a known / likely human carcinogen via the inhalation route.

5.3.2 Toxicity Reference Values

Toxicity Reference Values (TRVs) are established by regulatory agencies and are chemical doses that represent the amount of a chemical that an individual, including sensitive subpopulations such as children and the elderly, could be exposed to without experiencing adverse health effects.

Chemical compounds may exhibit different toxicological mechanisms of action depending on the route of exposure (i.e., ingestion, inhalation, dermal). In this assessment, preference was given to pathway-specific TRVs; however, dermal TRVs were not available for any of the COPCs; therefore, the typically more conservative oral TRVs were adopted for the dermal pathway.

The exposure frequency used for the recreational user was 26 days per year and for the construction worker it was 65 days per year. Exposure is generally classified in the following categories:

- Acute: Single event occurring within a day;
- Sub-acute: Multiple events occurring for up to 14 days;
- Sub-chronic: Multiple events occurring for up to 90 days; and,
- Chronic: Multiple events occurring for more than 90 days.

Exposure at the Site would be considered sub-chronic, therefore sub-chronic TRVs were applied where possible. Sub-chronic TRVs are available from the ATSDR (2012), which has intermediate minimal risk levels for exposures between 15 and 364 days and USEPA (2012c), which has provisional peer reviewed toxicity values for sub-chronic exposure. Where a sub-chronic TRV was not available, the chronic TRV was conservatively applied. Chronic TRVs from the following agencies were compiled and reviewed in order to identify the most scientifically defensible and appropriate TRVs for use in the human health assessment:

- Health Canada (Health Canada 2009);
- USEPA Integrated Risk Information System (IRIS) (USEPA 2012d);
- USEPA Regional Screening Levels (RSLs) (USEPA 2012a,b); and,
- World Health Organization (WHO 2011).

The TRVs used in the human health assessment are presented as oral reference doses (RfDs) for non-carcinogenic chemicals, and as slope factors for carcinogenic chemicals (i.e., arsenic). The RfD is defined as the amount of chemical that humans, including sensitive individuals such as children and the elderly, could be exposed to continuously on a daily basis without experiencing any adverse health outcome. The slope factor is derived from dose-response relationships from epidemiological or animal toxicity studies that measure the relationship between exposure to cancer-causing chemicals and incidence of cancer. The RfDs and slope factors selected for the human health assessment along with a brief summary of the toxicological endpoints upon which the TRVs were based are provided in Table 43. A more detailed description of acute, sub-chronic and chronic toxicity for each of the COPCs is provided in Appendix K.

Table 43: Toxicity Reference Values used in the Human Health Assessment

COPC	Sub-chronic Oral Reference Dose (mg/kg/day)	Chronic Oral Reference Dose (mg/kg/day)	Slope Factor $(mg/kg/day)^{-1}$	Target Organ / Effect	Source
Aluminum	1	-	-	Decreased forelimb grip strength in mice / rats	ATSDR (2012)
Antimony	0.0004	-	-	Reduced lifespan, serum chemistry changes in rats	USEPA (2012c)
Arsenic	-	0.0003	1.8	Non-carcinogenic: hyperpigmentation, skin lesions and possible vascular complications; Carcinogenic: kidney, bladder, lung, liver	RfD: USEPA (2012d); SF: Health Canada (2009)
Beryllium	-	0.002	-	Non-carcinogenic Small intestinal lesions	USEPA (2012d)
Cadmium	0.0005	-	-	Decrease in bone mineral density	ATSDR (2012)
Chloride	-	0.1	-	No observed adverse effects	USEPA (2012d)
Chromium	0.005	-	-	Mycrocytic, hypochromic anemia	ATSDR (2012)
Cobalt	0.01	-	-	Increased levels of erythrocytes	ATSDR (2012)
Copper	0.01	-	-	Gastrointestinal effects	ATSDR (2012)
Iron	0.7	-	-	Gastrointestinal effects	USEPA (2012c)
Lead	-	0.0006 (child); 0.0013 (adult)	-	Brain, central nervous system, cardiovascular system, kidneys, blood	WHO (2011)
Lithium	0.002	-	-	Adverse effects on several organs and systems	USEPA (2012c)
Manganese	-	0.1 (0 – 19 years); 0.2 (20+ years)	-	Parkinsonian-like neurotoxicity	Health Canada (2009)
Mercury	-	0.0003	-	Nephrotoxicity	Health Canada (2009)
Molybdenum	-	0.027 (12 – 19 years); 0.028 (20+ years)	-	Reproductive effects	Health Canada (2009)
Nickel	-	0.011	-	Post-implantation perinatal lethality	Health Canada (2009)
Nitrate	-	1.6	-	Methemoglobinemia	USEPA (2012d)
Selenium	-	0.0062 (0.6 – 4 years); 0.0057 (20+ years)	-	Selenosis	Health Canada (2009)
Silver	-	0.005	-	Argyria	USEPA (2012d)
Strontium	2	-	-	Skeletal toxicity	ATSDR (2012)
Thallium	-	0.00001	-	Alopecia, changes in blood pressure, liver & kidney damage, reproduction	RfD: USEPA (2012b); Target Organ: USEPA (2012d)
Uranium	0.0002	-	-	Renal toxicity	ATSDR (2012)
Vanadium	0.01	-	-	Hematological alterations and blood pressure	ATSDR (2012)
Zinc	0.3	-	-	Significant decrease in erythrocyte superoxide dismutase activity	ATSDR (2012)

Note: Oral reference doses were adopted for the dermal pathway.
RfD – Reference dose; SF – slope factor, "-" – not available

5.3.3 Toxicity of Arsenic Species in Fish Tissue

Several forms of arsenic species (inorganic and organic) have been detected in fish tissue. Arsenic toxicity is more complex compared to that of other metals due to the various oxidation states (0 as arsenic, +V as arsenate, +III as arsenite, and –III as arsine; Sharma and Sohn 2009) and its presence in numerous organic compounds (WHO 2010). Health Canada (2009) classified arsenic as carcinogenic to humans (Group I) but did not include organoarsenic compounds in the assessment. Inorganic arsenic has been placed in Group 1 (classified as a carcinogen to humans) by WHO (World Health Organization); arsenobetaine (AB) and other organic arsenic compounds that are not metabolized in humans are placed in Group 3 (not classifiable as to carcinogenicity in humans), and monomethylarsonic acids (MMA) and dimethylarsenic acids (DMA) are placed in Group 2B (possibly carcinogenic to humans) (WHO 2010). Of the various oxidation states arsenic can be found in, As^{III} is more toxic compared to As^{V} in animal studies (Lin et al. 2008).

Several forms of organic arsenic were detected in the fish tissue samples analysed by ESG: arsenosugars, AB, arsenocholine, trimethylarsine oxide, tetramethylarsonium ion, MMA and DMA. Of these seven compounds, AB is known to be non-toxic to humans because it is not metabolized and is rapidly excreted through the kidneys (Ritchie et al. 2004). The ingestion of other organoarsenic compounds (except MMA and DMA) is also unlikely to cause arsenic poisoning (Roy and Saha 2002). MMA and DMA are possible human carcinogens due to metabolic activation from ingestion (Van de Wiele et al. 2010).

After inorganic arsenic is ingested, it undergoes a series of methylation and oxidation reactions in the liver cells to form methylated arsenic compounds that are more easily excreted in the urine compared to inorganic arsenic itself (Cohen et al. 2006). The general pathway of arsenic methylation following ingestion is shown in Figure 35. After inorganic arsenic is ingested (iAs^{III} is preferentially taken up by cells compared to iAs^{V}), it enters cells where it is methylated and oxidized to MMA^{V} and then reduced to MMA^{III} (an unstable intermediate) and methylated to DMA^{V}. DMA^{V} is a major excretory metabolite in humans, where approximately 70% of excreted arsenic is in this form (Cohen et al. 2006). Although methylation has long been thought of as a detoxification process (Eisler 1988), it is likely that the reactive intermediate (MMA^{III}) contributes to the toxicity of arsenic (Petrick et al. 2000; Singh et al. 2007; Styblo et al. 2000).

Figure 35: Newly proposed metabolism of inorganic arsenic (as cited in Cohen et al. 2006)

The carcinogenic potential of DMA^{III} and DMA^{V} is not as clearly demonstrated as MMA^{III} in various animal studies. DMA^{V} was found to be carcinogenic to the rat bladder, but it was not found to be carcinogenic in mice. The metabolic pathway of arsenic ingestion in rats is different from that in humans in that the clearance of inorganic arsenic is slower. MMA^{III} and DMA^{III} are retained in the red blood cells in rats and MMA^{III} in biliary excretions for a longer period of time compared to humans and are further metabolized to trimethylarsine before excretion (Cohen et al. 2006).

Although DMA^{V} was found to be carcinogenic to the rat bladder, it was not found to be carcinogenic in mice. Direct extrapolation of arsenic toxicity in animal studies to humans may not be straightforward compared to other metals. The metabolic capabilities and pathways of arsenic vary between species and even among individuals in the same species. For example, following exposure to inorganic arsenic, 40% to 70% of the dose was absorbed, processed, and excreted within 48 hours in humans (Cohen et al. 2006). A greater fraction (75% to 95%) of the ingested dose was excreted within 48 hours in mice and rabbits, whereas in rats 5% to 20% of the ingested dose was excreted (Cohen et al. 2006). In addition, while DMA^{V} is the major excretory metabolite in humans, DMA^{V} is metabolized further to DMA^{III} and trimethylarsine before excretion (Cohen et al. 2006). Therefore, because of the differences in metabolic pathways between rats and humans, it is unlikely that DMA^{V} is carcinogenic to humans based on rat studies (Cohen et al. 2006).

Another aspect that adds to the complexity of arsenic toxicity is whether the ingested dose is inorganic or organic arsenic. Studies have shown (as cited in Cohen et al. 2006) that MMA^{V} directly administered to humans is readily absorbed and rapidly excreted with limited further metabolism. A study comparing the direct uptake of DMA^{III} and DMA^{V} among rats, hamsters, mice and humans found that DMA^{III} was taken up more efficiently compared to DMA^{V} in all animal cells but that DMA^{III} was most efficiently taken up by rat cells and least efficiently by human cells (Cohen et al. 2006). DMA^{III} was also shown to be retained the longest in rat cells compared to human cells, and oxidation efficiency from DMA^{III} to DMA^{V} was also higher in human cells compared to rat cells (Cohen et al. 2006). These differences mean that the concentration of DMA^{III} in rat cells is higher than in human cells due to higher uptake, higher retention, and lower oxidation efficiency.

The differences in metabolic capabilities between animal species and the form of arsenic that is ingested (inorganic or organic) must be considered when interpreting animal toxicity and carcinogenic studies. Generally, ingestion of inorganic arsenic is carcinogenic because of methylation to the reactive intermediate MMA^{III}. As a result, the percent of inorganic arsenic in fish muscle tissue (17%) was used to calculate the carcinogenic effects of ingesting fish. MMA was not detected in most speciation samples, and comprised only a small fraction (approximately 1%) of total arsenic. DMA was also not considered as a carcinogen for reasons described above. The site-specific bioaccessibility information indicates that the percent of inorganic arsenic in fish muscle tissue was higher than that in fish liver tissue.

The percent of non-AB (including inorganic arsenic) in fish muscle tissue was used to calculate the non-carcinogenic effects of fish ingestion given that AB is considered to be non-toxic to humans. This correction assumes that the toxicity of other organic arsenic species is similar to inorganic arsenic, which is conservative given that the available toxicity studies on animals suggest that organic forms of arsenic are less toxic than inorganic arsenic (refer to ESG's expert statement on toxicity of arsenic species in Appendix G).

5.4 Assessment Characterization

The final step in a risk assessment, referred to as the characterization step, involves comparing the estimated exposure to the TRV. The hazard quotient (HQ) values for each COPC are calculated as the ratio of the estimated exposure (based on the exposure assessment) to the TRV (based on the toxicity assessment), according to the following equation:

$$HQ = \frac{EDI}{TRV}$$

Where:
HQ = hazard quotient;
EDI = estimated daily intake; and,
TRV = toxicity reference value based on dose or daily intake.

The HQ indicates whether the amount of a COPC taken in by people is greater than the amount of the COPC below which there would be essentially no risk of adverse health effects (i.e., if the HQ is less than 0.2 it is extremely unlikely that adverse health effects would occur). If the HQ is greater than 0.2, the possibility of adverse effects cannot be ruled out and, given the relatively high level of conservatism in this assessment, further consideration of site-specific factors is required to determine whether a risk truly exists. To evaluate the acceptability of environmental exposures to non-carcinogenic substances, Health Canada (2009) has established that the health risks associated with an HQ of less than 0.2 are essentially negligible.

Carcinogenic or non-threshold substances are evaluated using the Incremental Lifetime Cancer Risk (ILCR). The ILCR is the increased risk attributed to exposure, above and beyond background cancer risks caused by genetics, lifestyle, and other non-chemical factors. The ILCR was calculated using the following equation:

$$ILCR = EDI \times SF$$

Where:
ILCR = Incremental Lifetime Cancer Risk;
EDI = Estimated Daily Intake (mg/kg-d); and,
SF = Slope Factor $(mg/kg\text{-}d)^{-1}$.

To evaluate the acceptability of environmental exposures to carcinogenic substances, regulatory agencies have established that an incremental increase in cancer incidence of 1 in 100,000 (i.e., ILCR of 1E-5) is essentially negligible (Health Canada 2009). The HQ and ILCR results for the recreational user and construction worker are presented in Sections 5.4.1.1 and 5.4.1.2.

5.4.1.1 Results for the Recreational User

Hazard quotients for the adult and toddler recreational user for each COPC are provided in Table 44.

Table 44: Hazard Quotient for Recreational User

COPC	Hazard Quotient for Toddler Recreational User	Hazard Quotient Adult Recreational User
Aluminum	0.1	0.03
Antimony	**22.6**	**13.3**
Arsenic	**60.1**	**30.0**
Beryllium	0.1	0.02
Cadmium	**0.6**	0.2
Chloride	**0.8**	0.1
Chromium	**0.3**	0.1
Cobalt	0.07	0.02
Copper	**4.1**	**1.5**
Iron	**0.7**	**0.2**
Lead	**2.5**	**0.3**
Lithium	0.1	0.04
Manganese	0.07	0.01
Mercury	**1.5**	**0.5**
Molybdenum	0.01	0.004
Nickel	0.06	0.02
Nitrate	0.003	0.0005
Selenium	**0.8**	**0.3**
Silver	0.05	0.03
Strontium	0.002	0.001
Thallium	**12.7**	**2.6**
Uranium	**0.4**	**0.2**
Vanadium	0.1	0.07
Zinc	**0.5**	0.2

Notes: Hazard quotients greater than 0.2 are shown in **bold**

In the human health assessment an acceptable risk threshold is an HQ of 0.2. Hazard quotients for the toddler were above 0.2 for antimony, arsenic, cadmium, chloride, chromium, copper, iron, lead, mercury, selenium, thallium, uranium and zinc. Hazard quotients for the adult were above 0.2 for antimony, arsenic, copper, iron, lead, mercury, selenium, thallium, and uranium.

Figure 36 and Figure 37 show the contribution of each exposure pathway to the overall HQ for COPCs with an HQ above 0.2.

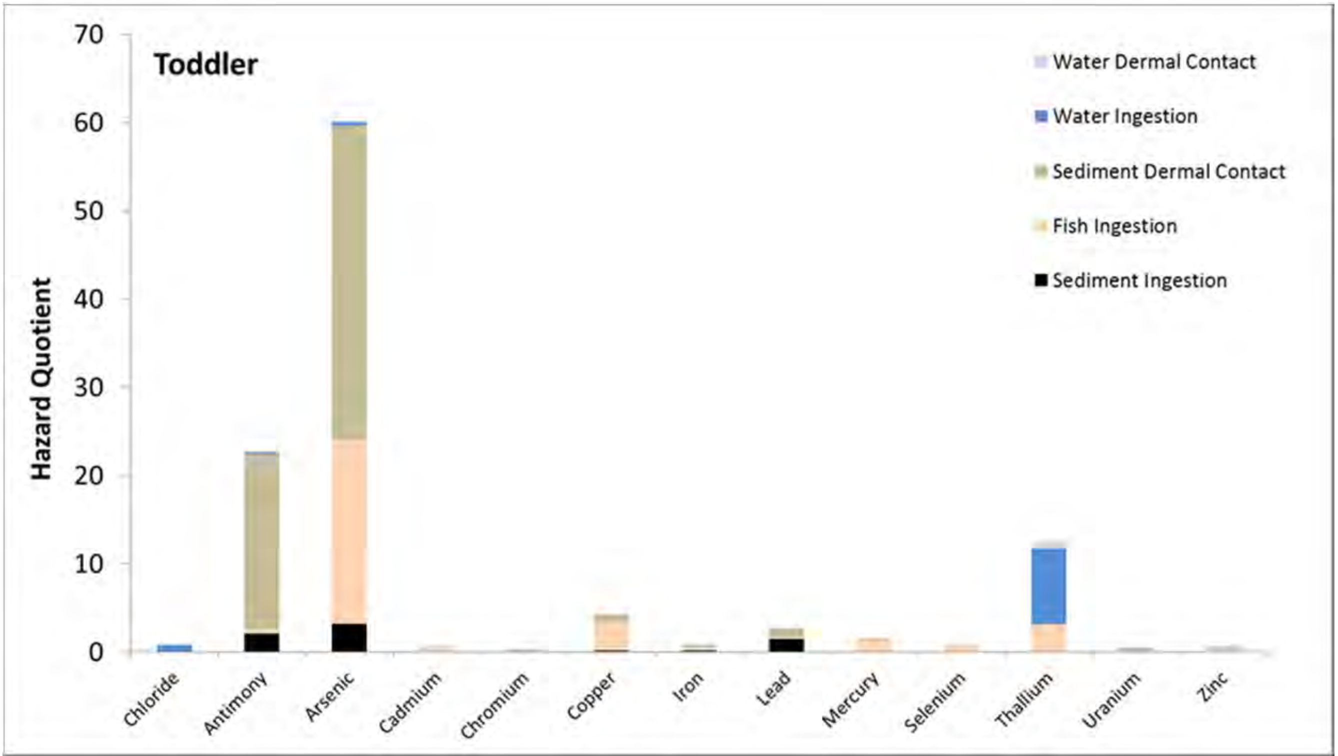

Figure 36: Contribution of Exposure Pathways to the HQs for the Toddler Recreational User

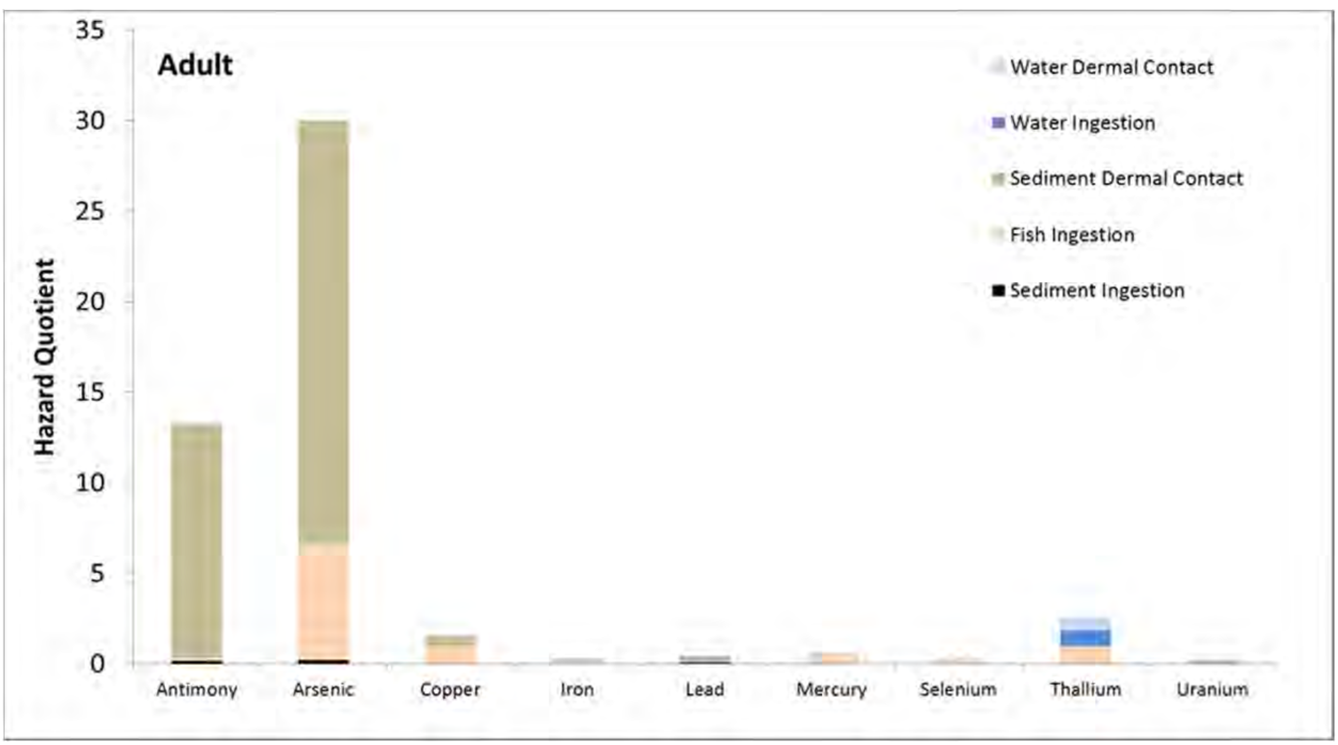

Figure 37: Contribution of Exposure Pathways to the HQs for the Adult Recreational User

The primary exposure pathways for each COC with an HQ above 0.2 are provided below:

Toddler

- Antimony: sediment dermal contact
- Arsenic: fish ingestion, sediment dermal contact
- Cadmium: fish ingestion
- Chloride: water ingestion
- Chromium: sediment dermal contact
- Copper: fish ingestion
- Iron: fish ingestion
- Lead: sediment ingestion
- Mercury: fish ingestion
- Selenium: fish ingestion
- Thallium: water ingestion
- Uranium: sediment dermal contact
- Zinc: fish ingestion

Adult

- Antimony: sediment dermal contact
- Arsenic: fish ingestion, sediment dermal contact
- Copper: fish ingestion
- Iron: fish ingestion
- Lead: sediment dermal contact
- Mercury: fish ingestion
- Selenium: fish ingestion
- Thallium: fish ingestion, water ingestion
- Uranium: sediment dermal contact

The primary exposure pathways for most of the COPCs for the toddler and adult recreational users were sediment dermal contact and fish ingestion. The sediment dermal contact pathway relied on the following assumptions:

- 95% UCLM sediment concentrations;
- Recently derived sediment loading factors (Intrinsik 2011);
- The assumption that hands, feet, lower legs and forearms may come into contact with sediment; and,
- A conservative and presently unrealistic exposure frequency of 26 days spent wading per year with 1 dermal event per day.

New sediment dermal loading factors (Intrinsik 2011) were used in this risk assessment, and these are 5 times higher than the Health Canada (2009) soil dermal loading factor for hands and 17, 70 and 2,100 times higher than the Health Canada (2009) soil dermal loading factors for arms, legs and feet, respectively that were typically used in the past. The new sediment dermal loading rates cause an increase in the risk estimates associated with sediment exposure and also increase the relative contribution of dermal sediment contact to the overall risk estimate. To evaluate the influence of these conservative dermal loading factors, exposure estimates were re-calculated using sediment loading factors published by Kissel et al. (1996) for reed gatherers in tidal flats[15]. The sediment loading factor for feet in Kissel et al. (1996) is approximately 30 times lower than that recommended in Intrinsik (2011). Results indicate a reduction in the HQ for antimony from 22.6 to 3.8 (toddler) and from 13.3 to 0.98 (adult), and a reduction in the HQ for arsenic from 60.1 to 26.5 (todder) and from 30.0 to 8.0 (adult). Therefore, the resulting risk estimates are highly sensitive to the dermal loading factors used in the risk calculations.

For the fish ingestion pathway, it was assumed that fish caught from Baker Creek were consumed for 26 days per year at a daily intake rate based on dietary surveys of the local community (from SENES 2003). The fish ingestion rate for children from the dietary survey was adopted for the toddler, which represents an overestimate. The fish ingestion rate used for the toddler was 0.124 kg/day, while Health Canada (2009) recommends 0.095 kg/day for toddlers. If the Health Canada fish ingestion rate for toddlers was used, the HQ for arsenic would decrease from 60.1 to 55.2. In general, adoption of the Health Canada (2009) fish ingestion rate for toddlers results in only a minor reduction in HQ values, and does not reduce any of the elevated HQs to below the target risk threshold of 0.2.

The maximum fish concentrations among the 95% UCLM for liver, muscle and ovary were used as exposure concentrations. The fish consumption rates used in the risk assessment are most representative of fish muscle (i.e., filet), and would likely over-estimate the consumption of fish liver and/or ovary. For most COPCs, including arsenic, the 95% UCLM concentration in liver was the greatest among tissues and was used as the exposure concentration. Mercury, one of the COPCs with elevated HQs for which fish ingestion was a large contributor to total exposure, exhibited the highest concentrations in fish muscle. Therefore, consumption rates are likely not overly conservative for the assessment of mercury. For arsenic, a factor was applied to account for the fraction

[15] Kissel et al. (1996) reported geometric mean sediment loading values of 0.66 mg/cm^2 for hands, 0.63 mg/cm^2 for feet, 0.036 mg/cm^2 for arms, and 0.16 mg/cm^2 for legs.

of non-AB arsenic (non-carcinogenic assessment) and the fraction of inorganic arsenic (carcinogenic assessment) based on site-specific data. Fish ingestion was a primary exposure pathway contributing to the HQs for arsenic, cadmium, copper, iron, selenium, thallium and zinc. A sensitivity analysis was conducted where the 95% UCLM for muscle were used as an exposure concentration for fish ingestion for these COPCs instead of the 95% UCLM for liver. The results of the sensitivity analysis indicate that the HQs for cadmium, selenium and zinc for the toddler and iron and selenium for the adult were below the target risk threshold of 0.2. For arsenic, use of the muscle data, and the non-AB arsenic factor of 65%, resulted in a reduction of the fish consumption HQ of approximately 50%. However, the overall arsenic HQ for all exposure pathways was only reduced from 60.1 to 49.7. The sensitivity analysis provides a range of risk estimates for those people who eat primarily fish organs relative to those who eat only fish muscle tissue.

The primary exposure pathway for thallium and chloride was incidental water ingestion while swimming. It was assumed that the toddler spends two days per week swimming for an hour per day in Baker Creek. Of the 231 water samples collected, thallium was detected only 11 times, and many of the detection limits for thallium were elevated (<0.2 mg/L). The exposure concentration used in the human health assessment was half of the detection limit, which was 0.1 mg/L. The maximum detected concentration of thallium was 0.0003 mg/L. If the maximum detected thallium concentration in water was used instead of half of the detection limit, the total HQ decreased from 12.7 to 4.2 for the toddler.

Arsenic was the only COPC evaluated as a carcinogen. Carcinogenic effects were evaluated for the adult recreational worker, not the toddler, since carcinogenic effects result from long-term exposure. The ILCR for arsenic for the adult recreational user was 3.3E-3, which is above the target ILCR of 1E-5. The contribution of different exposure pathways to the adult recreational user ILCR is shown in Figure 38.

Similar to non-carcinogenic effects, the primary exposure pathways for the adult recreational user for arsenic as a carcinogen were sediment dermal contact and fish ingestion. The key assumptions for these pathways have been discussed above.

5.4.1.2 Results for the Construction Worker

Hazard quotients for the construction worker for each COPC are provided in Table 45.

Hazard quotients for the construction were above the target risk threshold of 0.2 for antimony, arsenic and thallium. Figure 39 shows the contribution of different exposure pathways to the total HQ for antimony, arsenic and thallium.

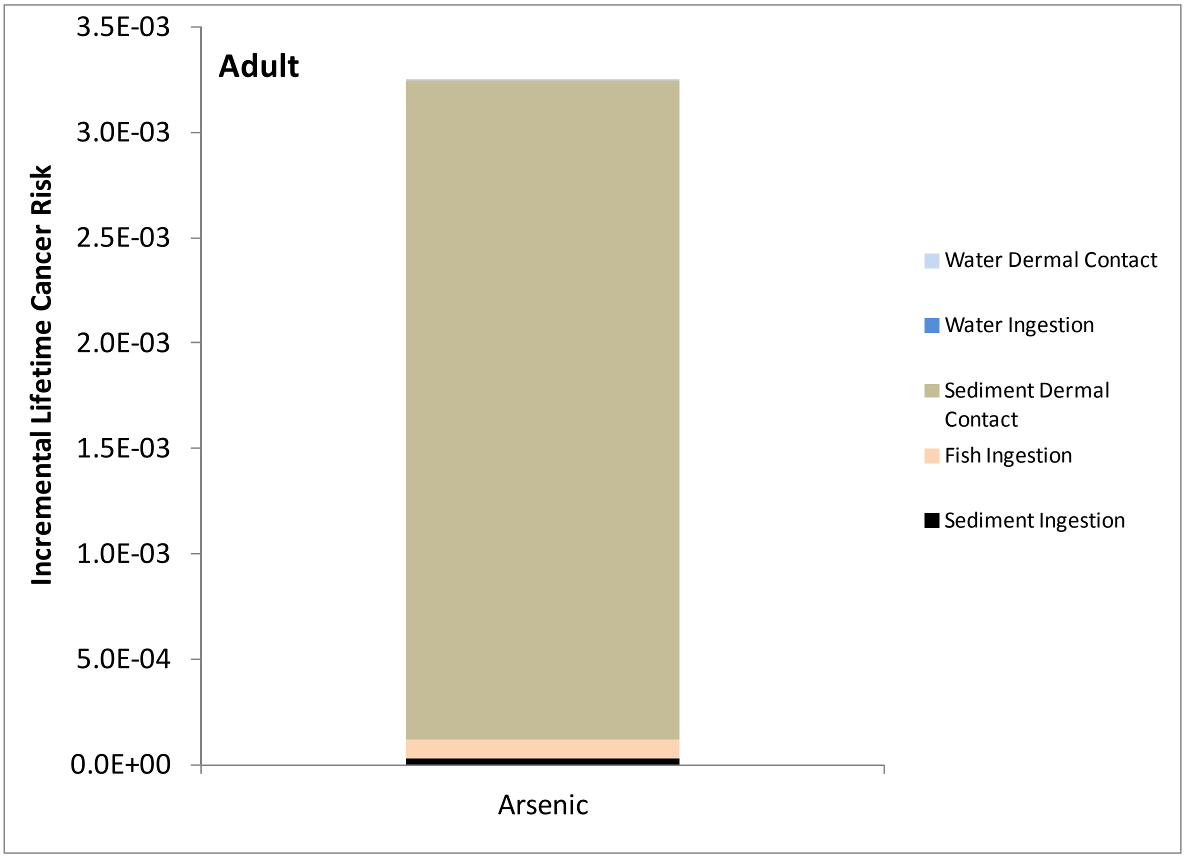

Figure 38: Contribution of Exposure Pathways to the ILCR for the Adult Recreational User

Table 45: Hazard quotients for Construction Worker

COPC	Hazard Quotient for the Construction Worker	COPC	Hazard Quotient for the Construction Worker
Aluminum	0.006	Manganese	0.001
Antimony	**1.1**	Mercury	0.003
Arsenic	**2.0**	Molybdenum	0.00005
Beryllium	0.0005	Nickel	0.003
Cadmium	0.002	Nitrate	0.0008
Chloride	0.2	Selenium	0.0002
Chromium	0.01	Silver	0.002
Cobalt	0.001	Strontium	0.00006
Copper	0.05	Thallium	**2.4**
Iron	0.03	Uranium	0.02
Lead	0.1	Vanadium	0.005
Lithium	0.006	Zinc	0.002

Notes: Hazard quotients above 0.2 are shown in **bold**

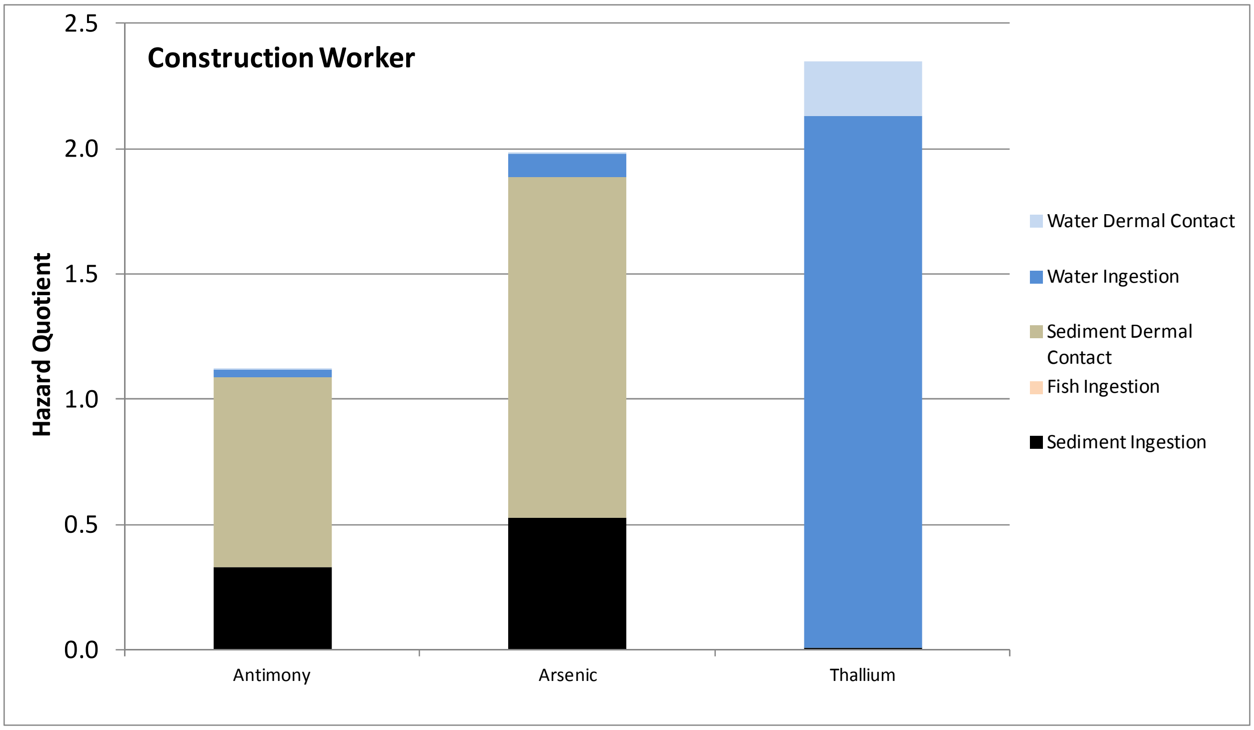

Figure 39: Contribution of Exposure Pathways to Hazard Quotients for the Construction Worker

The primary exposure pathways for the construction worker were sediment dermal contact and sediment ingestion for antimony and arsenic and water ingestion for thallium. Exposure concentrations for thallium have been discussed for the recreational user. For sediment contact, it was assumed that the construction worker spent 65 days at the Site for 35 years in contact with the 95% UCLM concentrations in sediment. It is considered highly unlikely that a construction worker would spend 35 years working at Baker Creek; actual exposure durations are more likely to be under 10 years, which would be within the timeframe of a typical remediation project. Recently derived sediment ingestion rates (Meridian 2011) and sediment dermal loading factors (Intrinsik 2011) were assumed. It was assumed that the hands and forearms of the construction worker may come into direct contact with sediment. Use of alternate sediment loading factors (i.e., Kissel et al. 1996) did not yield a large reduction in risk estimates because the feet (body part with the largest discrepancy between the two sources) were not assumed to be exposed to sediment for the construction worker. A site-specific bioaccessibility factor was applied for sediment ingestion.

The ILCR for arsenic for the construction worker was 1.5E-4, which is above the target ILCR of 1E-5. The contribution of different exposure pathways to the construction worker ILCR is shown in Figure 40.

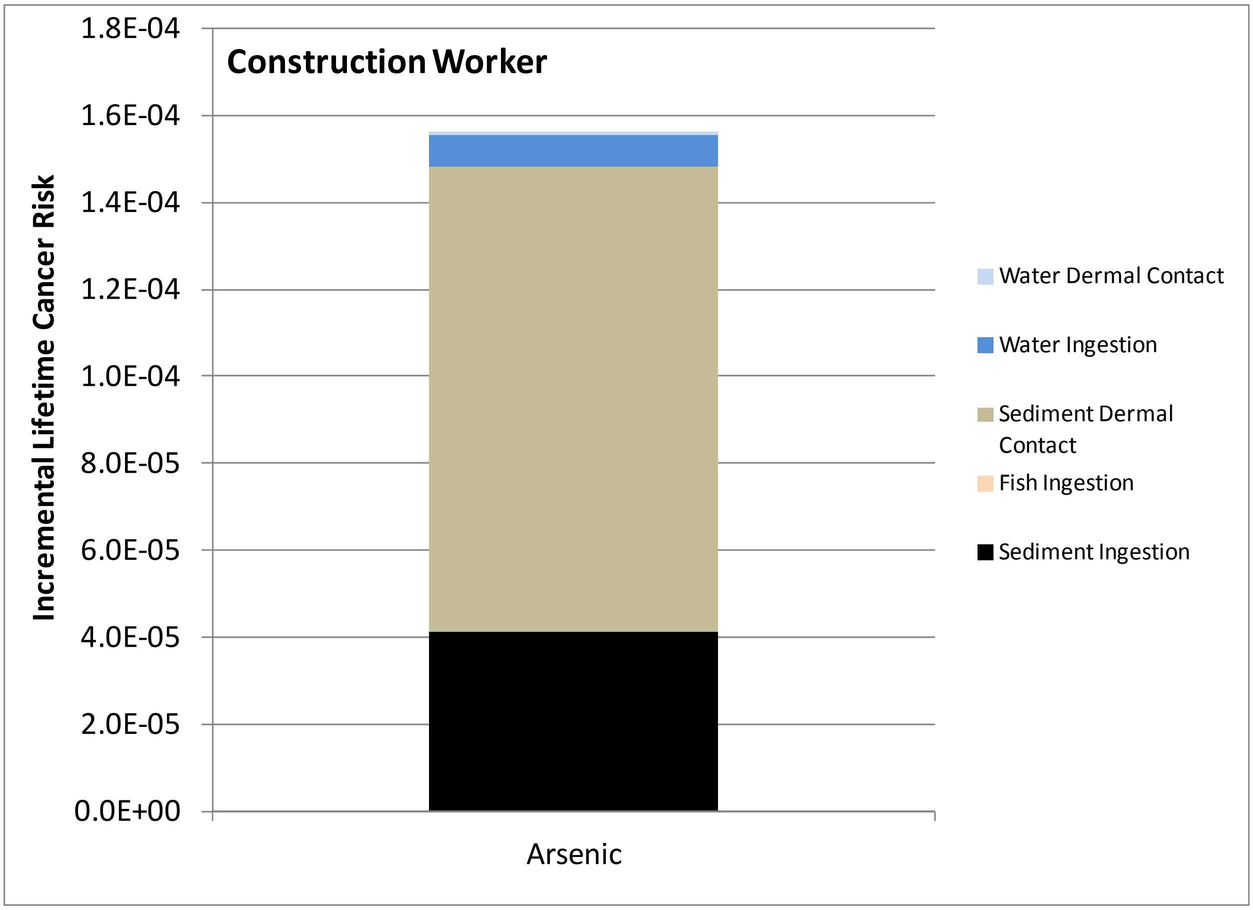

Figure 40: Contribution of Exposure Pathways to the ILCR for the Construction Worker

Similar to non-carcinogenic exposure, the primary exposure pathways for the construction worker for carcinogenic arsenic were sediment dermal contact and sediment ingestion.

5.4.2 Summary and Evaluation

For those parameters where the calculated exposure, based on conservative assumptions, is above acceptable risk targets for human health receptors, the key exposure pathways are as follows:

- Toddler Recreational User
  - Sediment dermal contact – antimony, arsenic, chromium and uranium
  - Sediment ingestion – lead
  - Fish ingestion – arsenic, cadmium, copper, mercury, iron, selenium and zinc
  - Water ingestion – thallium, chloride

- Adult Recreational User
  - Sediment dermal contact – antimony, arsenic, lead, and uranium
  - Fish ingestion – arsenic, copper, mercury, iron, selenium, and thallium
- Construction Worker
  - Sediment dermal contact – arsenic, antimony
  - Sediment ingestion – arsenic
  - Water ingestion – thallium

5.4.2.1 Effect of Variation in Exposure Concentrations

The 95% UCLM concentrations in sediment, fish tissue and surface water were used as exposure concentrations. As noted above, the key exposure pathways that contributed to the majority of the unacceptable risks were sediment dermal contact and ingestion of fish. Water pathways only contributed to significant risks for thallium, which may not be a real risk given the large number of non-detects and the assumptions based on those non-detect concentrations. The spatial variability of the sediment and fish concentrations was evaluated to determine whether there are areas within Baker Creek that would be better than others for use for recreational purposes.

Figure 41 shows the average concentrations in sediment across the Site for the COPCs with the highest risk estimates (antimony, arsenic, copper, iron, and lead). The selected exposure concentration (indicated by the dashed line) was higher than the average concentration in Reaches 0, 1, and 4 for all parameters, indicating that the risk estimates are generally conservative for these reaches. Reaches 2, 3, 5 and 6 exhibited the highest concentrations, with averages that were often above the selected exposure concentration. Concentrations in Upper Baker Creek (UBC) and Yellowknife River (YK) were lower than the other reaches for all parameters (Figure 41). At this time, Reaches 0 and 1 are the only reaches on the Site that are accessible to the public; therefore, sediment exposure estimates are considered conservative for current use of the Site. Future use may include all reaches; however, this possibility cannot be assessed at this time.

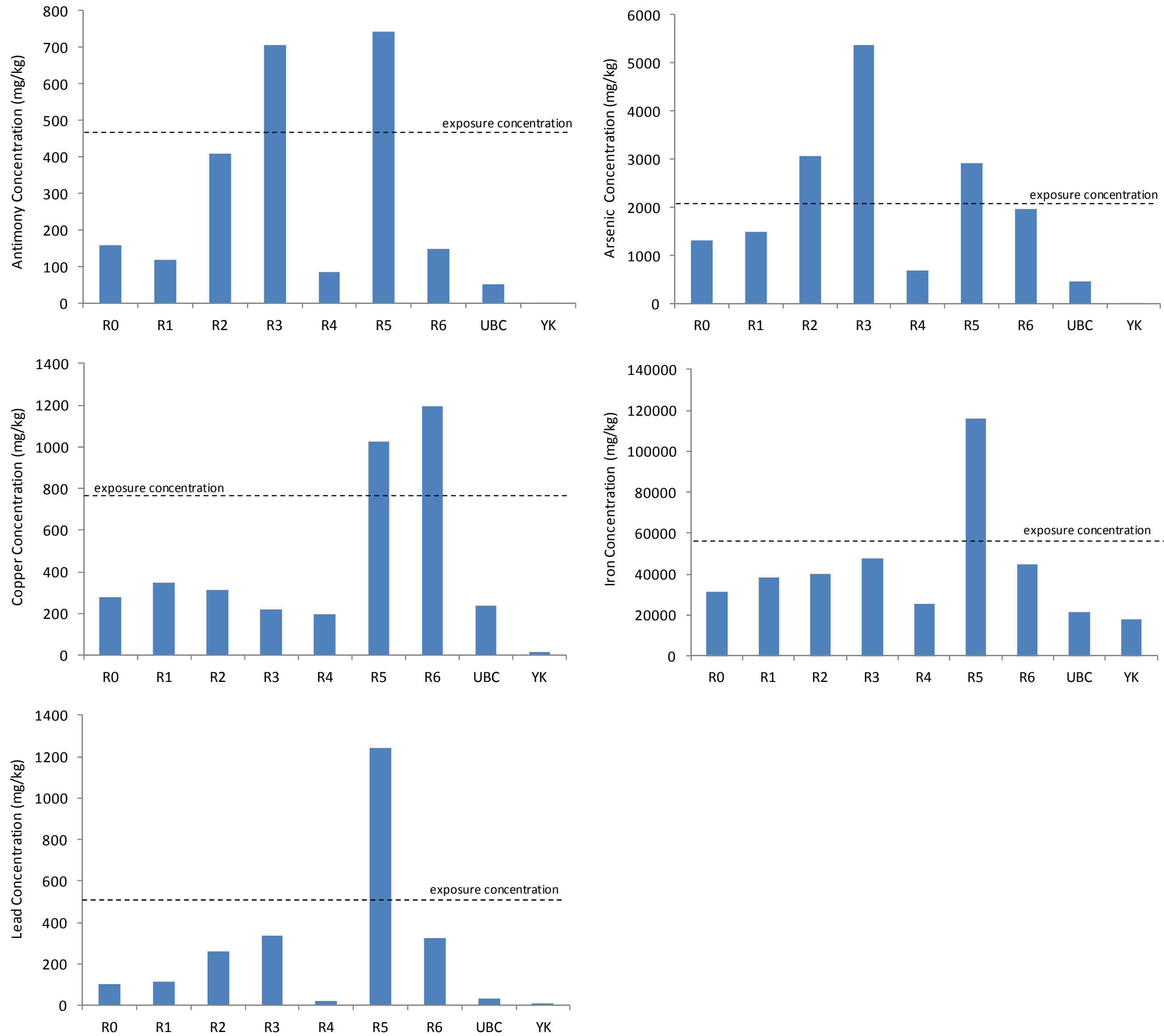

Figure 41: Average Concentration in Sediment for Reaches 0-6 (R0-R6), Upper Baker Creek (UBC) and Yellowknife River (YK)

Figure 42 shows the average concentration in various fish species and tissue type by reach for the COPCs with the highest risk estimates related to fish ingestion (arsenic, copper, and mercury). Contaminant concentrations were measured in fish liver, muscle and ovaries in Arctic Grayling (ARGR), Northern Pike (NRPK) and Lake Whitefish (LKWH) in Reaches 0, 1, 4, 6 and the Yellowknife River (Figure 42).

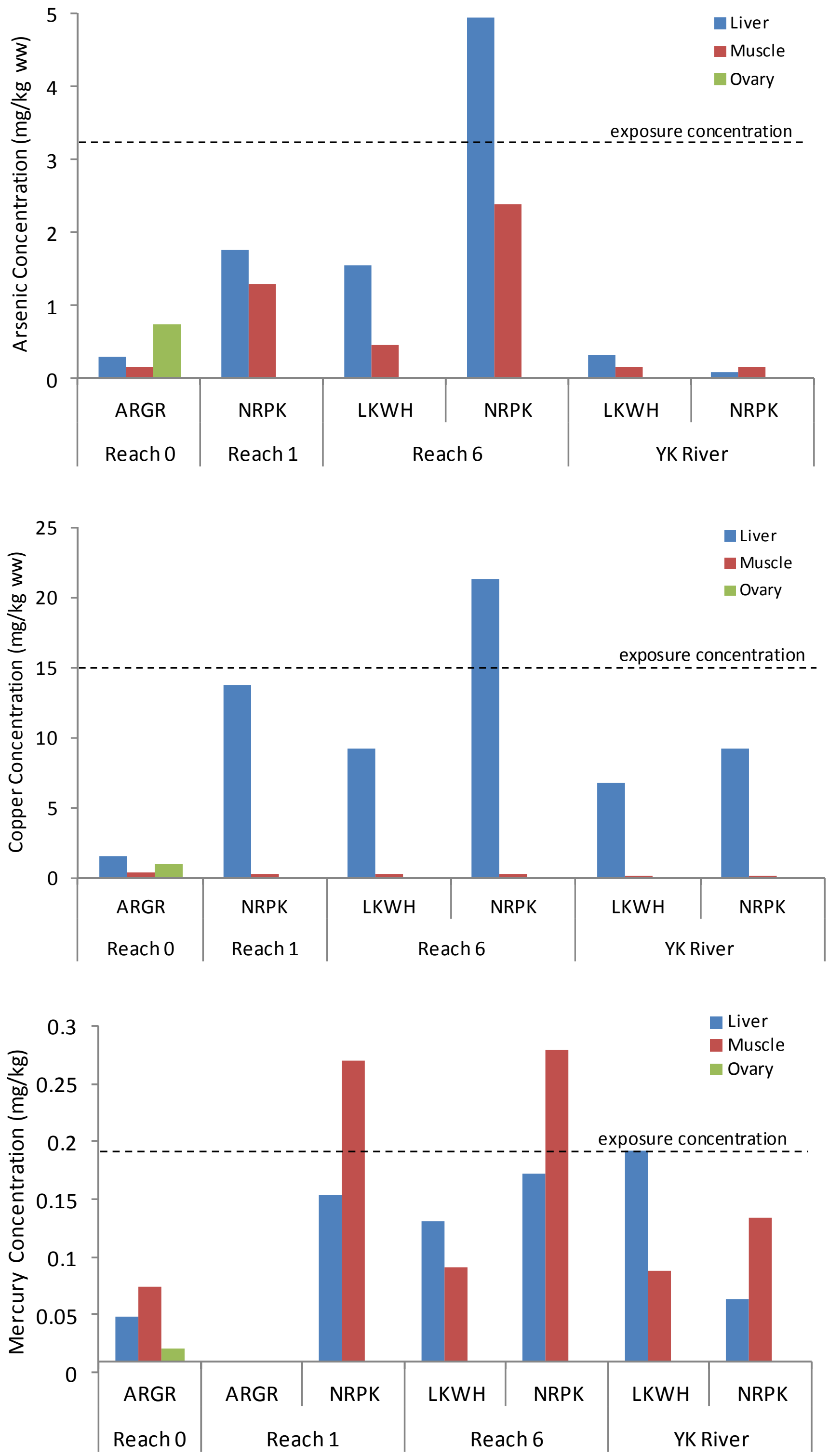

Figure 42: Average Concentration in Fish by Tissue Type, Fish Species, and Reach

For arsenic and copper, the highest concentrations were found in the liver of Northern Pike and Lake Whitefish from Reaches 1 and 6. Concentrations measured in muscle are lower than those measured in liver for both arsenic and copper, with the biggest differences between these tissues observed for copper. For mercury, the highest concentrations analysed were found in the muscle of Northern Pike from Reaches 1 and 6.

5.4.2.2 Background Exposure to Arsenic

Daily exposure to arsenic occurs because arsenic is ubiquitous in nature and is present in air, water and food. The Government of Canada (1993) included an assessment of exposure of Canadians to background levels of arsenic in air, water, soil and food. The report indicated that ingestion of water and food were the primary sources of arsenic exposure. The report provides estimates of total daily exposure to inorganic arsenic from environmental and dietary sources ranging from 0.1 to 2.6 µg/kg-body weight (bw)/day. In areas near point sources (i.e., mines or smelters), exposure may be up to 35 µg/kg-bw/day. The estimated daily intakes for Baker Creek of 18 µg/kg-bw/day for the toddler recreational user and 9.0 µg/kg-bw/day for the adult recreational user, based on a sub-chronic recreational exposure, are above typical the Canadian background exposure but below exposure doses expected near point sources (i.e., mines). The predicted daily intake for the construction worker is 0.60 µg/kg-bw/day, which corresponds to background conditions in other areas of Canada.

5.4.3 Uncertainty

The key sources of uncertainty in the human health assessment are:

- Exposure Concentrations – Sample sizes and detection frequencies were sufficient to calculate 95% UCLMs for most COPCs using data from all reaches. These concentrations represent a conservative measure of average exposure to each matrix assuming that people are exposed equally to all reaches. However, plots of concentration by reach (Figure 41 and Figure 42) suggest that average concentrations vary by reach and by fish species. Therefore, if people are spending all their time in the reach with the highest concentration or consuming the fish with the maximum concentration, the exposure concentrations may not be conservative. This scenario is unlikely but possible. Similarly, if humans are spending all their time in the reach with the lowest concentration or consuming the fish with the lowest concentration, the exposure concentrations will be overly conservative.
- Exposure Frequencies – It was assumed that a recreational user would spend 26 days per year at the Site. This is considered a maximum because the temperature in the area would preclude recreational use for much of the year and also because it is known to be a contaminated site and would not be considered a preferable spot for recreational use, particularly for adults bringing toddlers. Currently, Reach 2 and upwards are off limits to the public. Thus, exposure frequencies may be overly conservative.
- Swimming Assumptions – It is considered that a toddler and adult may swim in Baker Creek for 1 hour each time they visit, and that their whole bodies may come into contact with surface water and that their hands, feet, forearms and lower legs may come into contact with sediment. This is considered more of a future scenario, as most of Baker Creek is currently off limits and it is known to be a contaminated site. This is also considered a possible but unlikely scenario.

- Toxicity Assessment – Extrapolation from animal studies in the laboratory to the possible effects that may result from exposure to metals from the Site is uncertain. To conservatively compensate for uncertainty in extrapolating from animal studies to humans, it is standard practice in human health risk assessment to assume that people are more sensitive to the toxic effects of a substance than are laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower); however, the uncertainty factor varies by chemical and should therefore be evaluated on a chemical-specific basis. This margin of safety is used so that doses less than the toxicity benchmark are safe and that minor exceedances of these benchmarks are unlikely to cause adverse health effects. The toxicity assessment has a relatively high level of inherent conservatism.

6.0 OVERALL SUMMARY AND CONCLUSIONS

An assessment of the ecological and human health risk associated with Baker Creek sediment was completed. This was based on the current conditions of the creek without remediation, and conservatively assumed that the possible end-use of the creek might include fishing, swimming/wading, and that construction activity in the creek would occur during remediation.

6.1 Ecological Assessment

An ecological assessment was undertaken to gather data and assess the ecological health of Baker Creek with the objective of determining whether adverse biological effects were associated with elevated sediment contaminant concentrations present in the creek. This assessment gathered new data on sediment quality (chemistry and toxicity), benthic invertebrate community structure, and benthic invertebrate and periphyton tissue contaminant concentrations. Additional data on water quality (chemistry and toxicity) and fish tissue concentrations were also collected. Sediment chemistry data were used to characterize the spatial extent and magnitude of contaminant concentrations in Baker Creek sediments, and the toxicity tests and benthic invertebrate community sampling were used to determine the status and contaminant stress on aquatic communities present in Baker Creek.

On the basis of the findings of the ecological assessment, the following conclusions were reached:

Water Quality

- When treated effluent is discharging to Baker Creek in summer, the treated effluent accounts for a substantial portion of the volume of water in lower Baker Creek (i.e., below Baker Creek Pond), and there is little or no gradient in water quality with distance downstream toward the creek mouth.
- The contaminant of potential concern (COPCs) to aquatic life in Baker Creek surface water is arsenic. Cadmium, silver, and thallium were undetected; however, detection limits were higher than their respective water quality guidelines and therefore these parameters could not be fully assessed as COPCs. Better analytical detection limits should be possible in any future assessments. COPCs during treated effluent discharge are arsenic and chloride.
- During effluent discharge, surface water in lower Baker Creek has higher arsenic concentrations than upstream in upper Baker Creek (above Baker Creek Pond), as well as higher conductivity, hardness, total dissolved solids (TDS; including constituent ions such as calcium, chloride, magnesium, potassium, sodium, sulphate), nitrate, ammonia, aluminum, antimony, molybdenum, nickel, selenium, strontium, and uranium.
- Surface water in upper Baker Creek and the Yellowknife River is not acutely toxic to juvenile Rainbow Trout or the water flea *Daphnia magna*, nor does it cause sublethal effects on water flea reproduction and algal growth in the laboratory. When treated effluent is being discharged, surface water in lower Baker Creek is also not acutely toxic to Rainbow Trout or *Daphnia magna* but causes sublethal effects to water flea reproduction and algal growth in the laboratory.

- Water quality data from 2011 indicate that Baker Creek continues to receive inputs of water-borne arsenic independent of the seasonal discharge of treated effluent. Surface water in Upper Baker Creek (above Baker Creek Pond) and Trapper Creek (tributary feeding into Baker Creek Pond) is a continuing source of arsenic to Baker Creek although at lower concentrations than in the treated effluent.

Sediment Quality

- Sediment contaminant concentrations measured in September 2011 may have been influenced by the May 2011 overflow event that resulted in sediments being released from the Baker Creek Pond area into lower Baker Creek.
- Fourteen COPCs were identified for sediment for aquatic life in Baker Creek Pond and/or lower Baker Creek: antimony, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, phosphorus, silver, and zinc. Arsenic, cadmium copper, iron, lead, manganese, mercury, nickel, and zinc were present at one or more stations at elevated concentrations above upper-bound sediment quality guidelines (SQGs; i.e., at concentrations where toxicity was likely but not certain).
- Sediment chemistry concentrations were generally lower in upper Baker Creek and Trapper Creek (except for elevated manganese concentrations in upper Baker Creek) than in the rest of Baker Creek. Five sediment COPCs were identified in upper Baker Creek and/or Trapper Creek: arsenic, chromium, copper, manganese, and nickel.
- There was no spatial gradient of sediment COPC concentrations in Baker Creek in 2011. Sediment chemistry concentrations varied over the length of the creek, in an inconsistent pattern. For example, two adjacent stations in Reach 2 represented the best and worst conditions in terms of sediment quality. This lack of a spatial gradient was also observed in 2005.
- It had been expected that sediment arsenic concentrations would be relatively low in Reach 4 because it had been realigned in 2006. This was the case for two stations in this reach; however, the third station had one of the highest arsenic concentrations in the surface sediments in Baker Creek (possibly related to deposition following the May 2011 overflow event).
- Sediment arsenic concentrations were elevated in both Baker and Trapper Creeks. Concentrations are above sediment quality guidelines for protection of aquatic life. The highest arsenic concentration was more than 30 times higher than the GNWT remediation objective for the boat launch at Giant Mine, which was set to be protective of human health.
- The range of sediment arsenic concentrations measured in September 2011 was comparable to the range previously reported from a survey conducted in 2005. The maximum arsenic concentration measured in surface sediments in the present Baker Creek assessment was similar to the maximum arsenic concentration measured in 2005 (4,790 compared to 4,170 mg/kg dw).

- Subsurface sediments were sampled to depths ranging from 10 to 49 cm. Results from the subsurface sediment samples were generally consistent with those reported for surface sediments, with elevated concentrations of COPCs present at depth. The highest subsurface arsenic concentration measured in this Baker Creek assessment (21,300 mg/kg dw measured in the 15-20 cm depth interval at a station in Reach 3) was almost three times higher than the maximum subsurface arsenic concentration measured in 2005 (7,660 mg/kg dw measured in the 30-35 cm depth interval at a station in Reach 5). Although benthic invertebrates are more likely to inhabit the top 5 to 10 cm of sediments, it is possible that some species occur at greater sediment depths and therefore are potentially exposed to elevated arsenic concentrations. Sediments may also be disturbed as a result of ice scour or high water flows during spring freshet.

- Laboratory sediment toxicity tests were performed on a subset of 18 stations from Baker and Trapper Creeks selected to represent all reaches within Baker Creek and the range of sediment arsenic concentrations across all stations. Sediments from six stations were acutely toxic to both test species, with 0 to 30% mean survival (in Reaches 1, 2, 5 and 6); three stations had moderate toxicity, with 20 to 50% effects on survival and/or growth (in Reaches 2, 4, and 6); and, nine stations had little or no toxicity, with <20% effects on survival and/or growth (in Reaches 0, 2, 3, 4, 5, Upper Baker Creek, and Trapper Creek). In general, the toxicity of the sediment samples was variable among stations between reaches; Reach 6 had the most consistent toxicity pattern, with four of five stations showing toxicity.

- Although three of the four toxicity test endpoints (survival and growth for two species) had strong negative correlations with antimony, cadmium, lead, mercury, and zinc (and arsenic to a lesser extent), there were no clear concentration-response relationships between laboratory survival and concentrations of those COPCs. Although there was ≥90% mean mortality for the two sediments with the highest arsenic concentrations, there were also instances of inconsistent responses to sediments with lower arsenic concentrations (e.g., for two sediments with similar concentrations, one would have high mortality and the other would not).

Benthic Invertebrates and Periphyton

- Benthic invertebrates were observed at all stations within Baker Creek, even those where sediment contaminant concentrations were elevated and laboratory sediment toxicity tests results indicated lethality. This indicates that recolonization of Baker Creek has progressed since mining operations ceased, despite the continued presence of elevated concentrations of COPCs in sediments.

- Metals concentrations in periphyton and benthic invertebrate tissues were elevated in Baker Creek compared to the Yellowknife River reference area, particularly antimony and arsenic, but also copper, lead, mercury, nickel, and/or zinc (depending on the tissue type). This indicates that these metals are biologically available in Baker Creek. However, variations in a number of tissue metal concentrations in these organisms confounded comparisons between Baker Creek (including Trapper Creek) and the Yellowknife River.

- Whereas in past years, these items may not have been present in the creek for fish to feed on, they now represent a food source for fish, albeit one that is also a source of dietary metals to the fish.

- There were no obvious major differences among (bottom-dwelling) invertebrate communities in Baker Creek, Trapper Creek and the Yellowknife River. There was, however, only sporadic occurrence of mayflies in Baker Creek, compared to their consistent presence at Yellowknife River reference stations.
- Overall, the magnitude of the effect of elevated sediment COPC concentrations in Baker Creek sediments on depositional benthic invertebrate communities can be qualitatively described as low but with uncertainty due to variability in the reference area data.
- In contrast, benthic invertebrate communities in erosional (cobble) habitats of Baker Creek exhibited differences from the communities in similar habitats in the Yellowknife River. The erosional benthic invertebrate community within Baker Creek appears to reflect exposure to COPCs from treated effluent rather than historical sediment contamination.

Fish

- A fish community is present in the portion of Baker Creek that runs through Giant Mine, which was not the case in the 1970s during active mine operations. Two tributary lakes connected to Baker Creek were briefly examined for presence or absence of fish in 2011: Trapper Lake and Martin Lake. Trapper Lake likely does not contain fish because it is shallow in depth. Martin Lake contains a number of fish species that may be able to migrate downstream to access the reaches of Baker Creek at Giant Mine; upstream movement of fish from Baker Creek into Martin Lake is unlikely because of the intermittent connection to lower Baker Creek. Fish tissue samples collected from Martin Lake in 2011 were archived.
- In general, fish in Baker Creek have higher tissue metals concentrations than those in reference areas.
- Comparisons of concentration of metals in fish tissues between reaches within Baker Creek were difficult; variability between fish concentrations was high. Further studies should focus on a control-impact design examining exposure versus reference differences.
- Small-bodied fish such as Slimy Sculpin that are year-round residents of Baker Creek contain substantially higher concentrations of metals than Yellowknife River fish. More bioaccessible arsenic was present in Slimy Sculpin collected from Baker Creek than from the Yellowknife River. Summer residents of Baker Creek such as Ninespine Stickleback have only slightly elevated concentrations of metals compared to the reference areas. Evaluation of potential effects of the elevated metals concentrations on fish health and the health of wildlife eating those fish was outside the scope of this assessment.
- Adult spring migrant fish that use Baker Creek for a limited period each year, such as Arctic Grayling, have tissue metal concentrations that are higher than in other areas of the Northwest Territories. The applicability of these comparisons with other areas is not known; in general, the geology is not similar to Baker Creek and thus tissue comparisons should be interpreted with caution. A local, more relevant, reference area should be determined.
- For most metals, mean concentrations in YOY Arctic Grayling fish tissue from Baker Creek were greater than in Arctic Grayling adult fish tissue. However, these conclusions are based on relatively small sample sizes, and their ecological significance is unknown.

- Large-bodied fish such as Northern Pike and Lake Whitefish also contained elevated concentrations of some metals in comparison to Yellowknife River fish.
- The most notable contaminant in fish tissues was arsenic, although other metals were also present in liver and muscle. Some contaminants such as iron or lithium were found at similar concentrations in fish from Baker Creek and the Yellowknife River reference area, indicating that their presence in fish tissues was not due to historical contamination in Baker Creek.
- Mercury concentrations were variable between Baker Creek and Yellowknife River fish. Examination of the patterns of mercury concentration by size and species was outside the scope of this study.

Ecological Assessment Conclusion

A weight of evidence (WOE) approach was used to integrate the available data regarding the potential for unacceptable adverse ecological impacts in Baker Creek related to historic sediment contamination. This WOE approach incorporated lines of evidence (LOEs) for sediment chemistry, benthic community structure, and the results of laboratory sediment toxicity tests. The fish community and fish tissue concentrations were considered separately because data were not available for all reaches and fish were likely be move throughout the creek.

Results of the WOE assessment for the 26 depositional stations in Baker Creek and Trapper Creek are summarized in Table 46.

Table 46: Overall Sediment Ecological Effects Assessment by Reach

Reach or Waterbody	Overall Assessment of Effects
Reach 0	■ Negligible adverse effects (Station 2) ■ Potential adverse effects (Station 1, 3) ■ Significant adverse effects (no stations)
Reach 1	■ Negligible adverse effects (Station 5) ■ Potential adverse effects (no stations) ■ Significant adverse effects (Station 4)
Reach 2	■ Negligible adverse effects (no stations) ■ Potential adverse effects (Station 6, 7) ■ Significant adverse effects (Station 8)
Reach 3	■ Negligible adverse effects (no stations) ■ Potential adverse effects (Station 9, 10) ■ Significant adverse effects (no stations)
Reach 4	■ Negligible adverse effects (no stations) ■ Potential adverse effects (Station 11, 12, 13) ■ Significant adverse effects (no stations)
Reach 5	■ Negligible adverse effects (Station 14) ■ Potential adverse effects (no stations) ■ Significant adverse effects (Station 15, 16)

Reach or Waterbody	Overall Assessment of Effects
Reach 6	■ Negligible adverse effects (Station 17) ■ Potential adverse effects (no stations) ■ Significant adverse effects (Station 18, 19, 20, 21)
Upper Baker Creek	■ Negligible adverse effects (Station 24) ■ Potential adverse effects (Station 23, 25) ■ Significant adverse effects (no stations)
Trapper Creek	■ Negligible adverse effects (Station 26) ■ Potential adverse effects (Station 27) ■ Significant adverse effects (no stations 8)

- Eight stations were classified as having significant adverse effects based on elevated sediment metals concentrations and high sediment toxicity (in some cases 100% mortality in the laboratory tests).
- Twelve stations were classified as having potential adverse effects related to elevated sediment metals concentrations (particularly arsenic) and low or moderate sediment toxicity.
- Six stations were classified as having negligible adverse effects despite elevated sediment metals concentrations.
- There was no gradient of potential adverse effects from upstream to downstream; sediment contaminant and toxicity "hot spots" (on the basis of laboratory tests) were located throughout Baker Creek. For instance, two adjacent stations in mid Baker Creek were categorized as, in one case, having negligible adverse effects and, in the other case, having significant adverse effects. Similarly, there was no spatial gradient of COPC concentrations, with high concentrations at one end of Baker Creek decreasing to lower concentrations at the other end. Significant adverse effects were only identified within Lower Baker Creek (including Baker Creek Pond), whereas potential adverse effects were also identified in Upper Baker Creek and Trapper Creek.
- Relationships between sediment metals concentrations and tissue concentrations in benthic invertebrates were examined. Arsenic and antimony concentrations were highest in tissues at Station 8 (Reach 2), which also had the highest sediment concentrations of these two metals.
- Benthic invertebrates were observed at all stations within Baker Creek, even those where sediment contaminant concentrations were highly elevated and laboratory sediment toxicity tests results indicated lethality. Clearly, recolonization of Baker Creek sediments by fish food organisms has occurred since mining operations ceased, despite sediment contamination that adversely affected sensitive laboratory test organisms.
- Fish use of Baker Creek and fish tissue concentrations in Baker Creek were not incorporated directly into the station-by-station WOE analysis that integrated results from the sediment chemistry, sediment toxicity, and benthic invertebrate LOEs. Data on fish use and tissue concentrations were not available for all reaches of Baker Creek, and it is also likely that fish move between reaches of the creek. It can be concluded that sediment metals are biologically available to fish, benthic invertebrates, and periphyton. Whether the effluent is also contributing bioavailable metals is unknown.

6.2 Human Health Assessment

A human health assessment was conducted that examined exposure to metals in Baker Creek, with consideration of incidental ingestion of surface water and sediment, dermal contact with surface water, and sediment and fish ingestion. Representative human receptors selected were a toddler and adult recreational user and a construction worker. Exposure concentrations were based on the compilation of historical data throughout Baker Creek. Chemicals of potential concern were identified by screening against relevant human health screening guidelines. Exposure parameters were selected from Health Canada (2009) and other sources (Intrinsik 2011; USEPA 2012a,b). Conservative fish ingestion rates, sediment bioaccessibility, and fish bioaccessibility factors were applied for arsenic.

The human health risk assessment identified potential unacceptable risk for adults, toddlers and construction workers exposed to sediment, surface water and fish from Baker Creek. This is based on the current conditions of the creek with no remediation. It is important to note that these potential risk estimates are based on conservative exposure scenarios and that some additional uncertainties need to be addressed prior to finalizing the human health risk conclusions; however, addressing these additional uncertainties was outside the scope of this study.

The risk estimates for contaminants of potential concern (COPCs) that exceed target risk levels provided by Health Canada are described in greater detail below. For COPCs that do not cause cancer, risk estimates are compared to a hazard quotient (HQ) of 0.2, and for COPCs that do cause cancer, predicted risk estimates are compared to an incremental lifetime cancer risk (ILCR) of 1 in 100,000 or 1.0E-5.

For non-carcinogens, HQs above the target risk threshold of 0.2 were observed for approximately half of the COPCs (13 out of 24). However, the majority of the predicted HQs were low (<1.0), indicating that the potential for risk is unlikely for these substances. Parameters that exhibited HQs greater than 1.0 and ILCRs greater than 1.0E-5 (i.e., 1 in 100,000) are summarized below (Table 47) by dominant exposure pathway.

Table 47: Summary of Elevated Risk Estimates for Contaminants of Potential Concern

Dominant Exposure Pathway	Parameter	Receptor	Risk Estimate (HQ or ILCR)	Comment
Fish Ingestion	Arsenic	Toddler and Adult Recreational User	All pathways (total): HQ = 60.1 (toddler) HQ = 30.0 (adult) ILCR = 3.3E-4 (adult) Fish Ingestion only: HQ = 20.7 (toddler) HQ = 6.5 (adult) ILCR = 8.8E-5 (adult)	Exposure concentration was based on liver tissue. Concentration in muscle is approximately half that in liver, but would still result in HQs above the threshold using the same (conservative) exposure parameters. Highest concentration observed in Reach 6 followed by Reach 1.
	Copper	Toddler and Adult Recreational User	All pathways (total): HQ = 4.1 (toddler) HQ = 1.5 (adult) Fish Ingestion only: HQ = 3.2 (toddler) HQ = 1.0 (adult)	Exposure concentration was based on liver tissue. Concentrations in muscle are lower and would result in HQs ≤1 for the fish ingestion pathway (low potential for risk).

Dominant Exposure Pathway	Parameter	Receptor	Risk Estimate (HQ or ILCR)	Comment
	Thallium	Toddler Recreational User	All pathways: HQ = 12.7 Fish Ingestion: HQ = 3.0	
	Antimony	Toddler Recreational User	All pathways: HQ = 22.6 Fish Ingestion: HQ = 2.1	
	Mercury	Toddler Recreational User	All pathways: HQ = 1.5 Fish Ingestion: HQ = 1.4	Exposure concentration based on muscle tissue. Conservative consumption rates assumed. Highest mercury concentrations observed in reaches 1 and 6.
Sediment Dermal Contact	Arsenic	Toddler and Adult Recreational User; Construction worker	All pathways: 60.1 (toddler) HQ = 30.0 (adult) HQ = 2.0 (const.) ILCR = 3.3E-4 (adult) ILCR= 1.6E-3 (const.) Sediment dermal: HQ = 35.7 (toddler) HQ = 23.2 (adult) HQ = 1.4 (construction) ILCR (adult) = 3.1E-3 ILCR (const.) = 1.1E-4	Conservative sediment loading factors were used, and it was assumed that receptors would come into contact with sediment (lower arms/legs, hands and feet) while wading or swimming 2 days per week. Use of alternate loading factors (Kissel et al. 1996), particularly the lower loading factor for feet, resulted in a large reduction in exposure for this pathway (approximately 15-20 times lower), but HQs remained above 1 for these two parameters. Highest concentrations were observed in Reaches 2, 3 and 5. Average concentrations in the reaches currently accessible to the public (Reach 0 and 1) were approximately 50-80% lower.
	Antimony	Toddler and Adult Recreational User	All pathways: 22.6 (toddler) 13.3 (adult) Sediment dermal: 19.9 (toddler) 13 (adult)	
Water Ingestion and Water Dermal Contact	Thallium	Toddler and Adult Recreational User; Construction Worker	All pathways: HQ = 12.7 (toddler) HQ = 2.6 (adult) HQ = 2.4 (const.) Water ingestion and dermal contact: HQ = 9.6 (toddler) HQ = 1.6 (adult) HQ = 2.3 (const.)	Exposure concentration was based on an elevated detection limit. Thallium was not detected in the majority of water samples collected from Baker Creek. The maximum detected concentration (0.0003 mg/L) results in acceptable risk via the water contact pathways. The potential for risk is considered low to negligible for exposure from water ingestion and dermal contact.

The above summary suggests that the two primary contaminants of concern for human health at the Site are arsenic and antimony. Arsenic exhibited potential for risk via ingestion of fish tissue as well as dermal contact with sediment, whereas antimony was primarily a concern in sediments via the dermal contact exposure pathway.

For arsenic, it is important to place the predicted ILCR values in context with background intake for the typical Canadian because background intake for arsenic may be elevated above target risk levels in many areas of Canada (Government of Canada 1993; OMOEE 1999). The estimated daily intakes for Baker Creek of 18 µg/kg-bw/day for the toddler recreational user and 9.0 µg/kg-bw/day for the adult recreational user (based on a sub-chronic recreational exposure) are above the typical Canadian background exposure but below exposure doses expected near point sources (i.e., mines). The predicted daily intake for the construction worker is 0.60 µg/kg-bw/day, which corresponds to background conditions in other areas of Canada.

This study predicted higher potential human health risks than were predicted previously for four reasons. First, fish tissue concentrations appear to have increased in Baker Creek, possibly due to the fact that benthic invertebrate communities have re-established within the creek, providing increased exposure to fish from benthic prey. Second, the current assessment was based on short exposures that, counter-intuitively but per Health Canada protocols, result in higher risk estimates than longer exposures for sub-chronic effects. Third, the methodology by which sediment dermal contact is assessed has changed; in particular, dermal loading rates (amount of sediment that sticks to the body) have increased. Fourth, the current human health assessment was limited to exposure to sediment, water and fish from Baker Creek, whereas the previous (SENES 2006) multi-media health assessment evaluated exposure from total chronic exposure (country foods from multiple locations, dietary contribution from store bought foods, air and water quality, etc.) in the Yellowknife area.

7.0 OVERALL COMMENTS

The following comments are provided as a result of the ecological and human health assessments on the basis of key exposure pathways, variation in exposure concentrations, and uncertainties discussed previously. These comments include more detailed and site-specific assessments that were outside the Terms of Reference of the present study.

Recommendations

- The end-use of Baker Creek during and after remediation must be established by the Project Team. The human health assessment of the creek depends on the proposed future use of the creek.
- Swimming and barefoot wading by an adult or toddler recreational user should be limited in Baker Creek. In particular upstream areas, presently off-limits for recreational use, must remain closed to restrict dermal contact of exposed skin to sediment. Access to Reach 0 and Reach 1 should be re-examined if future use of the creek is intended to include swimming or wading.
- As construction or remediation activities take place at the Site, a Health and Safety plan should be in place to limit exposure of staff to COPCs in sediment and water. In particular, appropriate personal protective equipment should be used to prevent dermal contact with sediment (e.g., gloves, long sleeves).
- Although fish consumption from Baker Creek contributed to potential health risks predicted for arsenic, the background concentrations of arsenic can also often be elevated above target ILCR values in areas of Canada. For arsenic, it is important to place these findings into a multi-media context with chronic exposure from sources in Yellowknife (fish from other locations, dietary contribution from store-bought foods, air and water quality, etc.) relative to exposure from Baker Creek. The development of a fish consumption advisory, or restriction of fish access into Baker Creek, or a multimedia assessment of areas outside of Baker Creek were not included within the scope of this study. The Developer’s Assessment Report (DAR) for the Giant Mine suggested that advisories against eating fish taken from the creek may be necessary pending the results of monitoring studies. Final decisions on the acceptability of eating fish from Baker Creek under current conditions depend on review of the assumptions, methods and result of this assessment, and review by Health Canada.
- Periodic monitoring of tissue metals concentrations in sport fish in Baker Creek should continue, to determine whether concentrations are changing (i.e., are they decreasing or increasing over time?).

The present human health assessment needs to be refined based on the following, which are beyond the scope of this study:

- Confirmation from Health Canada on the need to use the recently updated sediment (Intrinsik 2011) and sub-chronic amortization protocols as they are significantly more conservative than historic approaches;
- Confirmation of elevated fish tissue concentrations with additional sampling of sport fish and burbot from Reach 1 and Reach 0 to determine whether concentrations in fish tissue changed after the May 2011 overflow event;

- Further information on the intended use of Baker Creek for fishing (e.g., frequency, preferred species, preferred tissue type) and other recreational purposes (frequency and location of swimming/wading);
- Updating the human health assessment with revised information, and placing the findings into context with exposure from other metal (e.g., arsenic) sources in Yellowknife (fish from other locations, other dietary pathways) relative to exposure from Baker Creek; and,
- Collection of additional Arctic Grayling samples from Baker Creek as well as a reference area to confirm that adult concentrations are lower than young and whether the elevated concentration of arsenic observed in whole-body samples of young grayling is the result of sediment/food uptake that may be eventually excreted from the fish, or whether the arsenic concentration is found in the young fish's muscle or organ tissue and whether this is in part due to the May 2011 overflow event.

Suggestions to Fill Minor Data Gaps or Review Existing Data

- A low level effect was detected in the depositional benthic invertebrate community of Baker Creek; however, reference data were more variable than desirable. Additional stations within the reference area would be needed if further detailed comparisons to Baker Creek are needed for management decision-making.
- Data on thallium and silver in water should be reviewed with the analytical laboratory. This review should include determining whether data with a lower DL are available for the 2011 samples; re-examination of the existing dataset with the analytical laboratory could be done to confirm whether thallium or silver should continue to be retained as COPCs. This applies to both thallium and silver in the ecological context, and to thallium in the human health context.
- Baker Creek samples exceed the free cyanide guideline but were measured as total cyanide; on the basis of the review of the water quality data, when effluent is in the creek Baker Creek water samples consistently exceed the free cyanide guideline. However, the exceedences are within a factor of two. Future samples should include both total cyanide, as per the Metal Mining Regulation and free cyanide to compare to the WQG.
- Additional Burbot samples should be collected from Baker Creek to provide a better understanding of arsenic tissue concentrations in this species. The arsenic concentration measured in the one Burbot sample collected to date (Dillon 2002b) appeared elevated (units [dry or wet weight] to be confirmed) compared to other fish species in Baker Creek. This fish was excluded from the human health assessment. Baker Creek is not known to be a preferred location for collection of Burbot, and this fish is more typically harvested from Back Bay or Yellowknife Bay; therefore, the concentrations should be confirmed from Yellowknife and Back Bay.
- Reach 4 sediment concentrations appeared to be elevated in 2011 compared to 2009 (Golder 2010b). This could suggest the sediment release from the Jo-Jo tailings area in May 2011 impacted the newly constructed Reach 4. However, this should be interpreted with caution as only one sample from each year is available. Further samples should be collected from various areas of Reach 4 to confirm this finding.

8.0 CLOSURE

We trust this report provides you with the information you require at this time. Should you have any questions regarding the contents of this report, or require any further information, please do not hesitate to contact the undersigned.

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