AQUATIC RESOURCE ASSESSMENT
KENO VALLEY AREA
2010

prepared for

First Nation of the Na-Cho Nyäk Dun

and

Assessment and Abandoned Mines Branch
Energy, Mines and Resources
Government of Yukon

March 2011

Aquatic Resource Assessment
Keno Valley Area
2010

Nicholas de Graff, Can-nic-a-nick Environmental Sciences
P.O. Box 10106, Whitehorse, YT Y1A 7A1

Bonnie Burns, LaBerge Environmental Services
Suite 1, 405 Ogilvie St, Whitehorse, YT Y1A2S5

Recommended citation: de Graff, N. and B. Burns. 2011. Aquatic Resource Assessment of the Keno Valley Area - 2010. Prepared for the First Nation of the Na-Cho Nyäk Dun and Assessment and Abandoned Mines Branch, Department of Energy Mines and Resources, Government of Yukon. 37 p + appendices.

Cover Photo: Christal Creek (site C@PM) near the Paddy Mine site.
Photo Credits: N. de Graff

ABSTRACT

Water quality within the Christal Creek and Duncan Creek watersheds of the Keno Valley area in the central Yukon has been a concern since the 1950's. The long history of mining in the area has resulted in a number of seepages that contribute metals, such as cadmium, lead and zinc that pose a threat to aquatic life. This project was conducted in July of 2010 with the purpose to investigate the ecological health of potentially impacted streams associated with mining activity in the Keno Valley through evaluating water quality, stream sediment chemistry, benthic communities, and contaminants in fish and vegetation. The project also included a training component to build capacity within the First Nation of Nacho Nyäk Dun government.

The water quality and sediment data indicates that the Christal Creek drainage is more contaminated than the Lightning Creek/Duncan Creek watershed. The tissue analyses for vegetation show that riparian plants uptake cadmium and zinc, however levels were generally comparable with plants from other areas of the Yukon. Results from the CABIN analysis conclude that benthic communities in Christal Creek are potentially stressed and not in reference condition. Benthic communities in Lightning, Williams and Duncan creeks are in reference condition. Slimy sculpin and Arctic grayling were captured in both the Christal Creek and Lightning Creek/Duncan Creek drainages. Lead concentrations in tissue of slimy sculpin in Christal Creek were above the INAC database average for this species and an order of magnitude higher than other freshwater fish sampled in the Yukon River Basin. Arctic grayling generally had low levels of metal contaminates at all sites.

TABLE OF CONTENTS

List of Figures

List of Tables

LIST OF APPENDICES

1.0 INTRODUCTION

Mining activities have occurred in the Elsa and Keno districts of the central Yukon off and on since the early 1900s. These activities have, and continue to have, influences on the watersheds in this area. To meet water licence requirements and for closure planning purposes, the current mine operator (Alexco Resources Corporation) conducts a variety of monitoring programs at the site, measuring water quality and the condition of other aquatic ecosystem components. Federal and territorial government agencies also carry out some monitoring and investigations of aquatic conditions.

Despite reporting of aquatic conditions by Alexco and government agencies, First Nation of the Na-Cho Nyäk Dun (NND) citizens remain concerned about environmental conditions and whether mine related contaminants are causing adverse effects on the environment and potentially humans, through traditional/subsistence use of local flora and fauna. To address the outstanding concerns of its citizens, the NND has recognized the need to conduct its own monitoring program to confirm the status of important environmental components and respond to citizens' concerns.

Due to the increased activity and current mining at Bellekeno, a focus of this study was on lower Lightning Creek below Keno City to the confluence of Duncan Creek. In addition, reporting by Alexco indicates that metal concentrations have increased significantly between KV6 and KV7 on Christal Creek. The current study also focused on Christal Creek, a tributary of the McQuesten River, to investigate possible inputs and any effects on the ecology of this area.

Both Alexco and the federal government have acknowledged the desire of the NND to play a more active role in monitoring and understanding environmental conditions. Through a cooperation agreement, Alexco provides financial support for the NND to participate in planning for mine exploration and development. The federal government provides financial resources to the NND to support their participation in closure planning for the Keno Hill Mine properties. Components of the budgets for each of these financial support programs are dedicated for monitoring programs.

The fieldwork coincided with the seven-week environmental monitoring program (BEAHR) offered to NND members. Students from this program were trained in all aspects of the environmental monitoring procedures encompassed within the current study from July 13 to 15, 2010.

2.0 OBJECTIVES

The project was intended to supplement historic information that has been collected and is currently being collected by Alexco Resource Corporation. The project represents a aquatic resource assessment with the following study objectives:

1. Build capacity in FNNND community members, and particularly youth, through informal training on the job, and experiential opportunities;

2. Investigate the ecological health of potentially impacted streams associated with mining activity in the Keno Valley through evaluating water quality, stream sediment chemistry, benthic communities, and contaminants in fish and vegetation.

3.0 STUDY AREA

The watersheds in the study area originate in the Gustavus Range of the Yukon Plateau in the north-central Yukon near the town of Keno, about 350 km north of Whitehorse. The study area is situated within the traditional territory of the First Nation of the Na-Cho Nyäk Dun. The two principle drainages are Christal Creek, which flows northeast into the McQuesten River and Lighting and Duncan creeks that flow south into the Mayo River. Both rivers are tributaries of the Stewart River, a large tributary of the Yukon River drainage basin. The study area and drainages are located in the Boreal Cordillera ecozone that is characterized by mountain ranges that contain numerous high peaks and extensive plateaus, and are separated by wide valleys and lowlands. Landscape features are primarily the result of past glacial activity, erosion and widespread deposits of glacial origin. Black spruce, trembling aspen, balsam poplar, and white birch are the most common forest types. At higher elevations, scrub birch and willow occur in subalpine sections with extensive landscapes of rolling alpine tundra characterized by sedge-dominated meadows, and lichen-colonized rock fields. The climate in this region is an interior subalpine type with long cold winters and summers that are brief and cool.

4.0 METHODS

4.1 Descriptions of Study Sites

A total of 10 sites were assessed during the study. Table 1 shows a summary of collected samples taken at each site in the Keno Valley study area during July 2010. Maps showing the locations of each sampling site are presented in Figures 1 and 2. All of the sites were sampled for water quality. Seven of the sites received more detailed assessments based on the quality of the habitat and likelihood of catching fish. Sampling sites were distributed between Christal Creek and Duncan Creek (including Lighting and Williams creeks).

The furthest upstream site on Christal Creek was KV6 located at the culverts on the Silver Trail Highway crossing just downstream of Christal Lake. Christal Lake was formally the receiving waters of tailings from past milling activities. Exposed tailings originating from historic mine workings in the area are currently being eroded into Christal Lake and Christal Creek. The recently constructed Alexco Mill is also at the headwaters but was not operating during the assessment and no surface discharges have occurred in the watershed from the facility. Sites DCR Seep and KV6 TRIB were in close proximity and represented small surface flows reporting to the headwaters of Christal Creek. These sites were only characterized for water quality. Site C@PM was located further downstream on a steeper gradient section of the mainstem of Christal Creek near the site of the Paddy Mine. An abandoned road, with dense regenerated alder, was used to access the site. A small tributary stream that was found along the abandoned road was also characterized for water quality and denoted as site PMRD TRIB. The road formally connected the old Paddy Mine site to the Hanson Lake road and ultimately the Silver Trail Highway. KV7 was the furthest downstream site on the mainstem of Christal Creek. The site was easily assessable from a bridge crossing on the Hanson Lake road.

In the Duncan Creek drainage the most upstream sample site was KV41 in the mainstem of Lightning Creek. Lightning Creek is a major tributary to Duncan Creek. The location of site KV41 was within the community of Keno City at a road crossing that provides access to the Alexco adit that is currently being actively mined. The site is also immediately below a placer mine that is active during the summer months. Site LTG1 was further downstream in Lightning Creek just upstream of its confluence with Duncan Creek. This site was also road assessable utilizing a seasonal trail off the Duncan Creek Road. Further along the Duncan Creek road a smaller tributary stream crossing known as Williams Creek was also characterized as site WILC. This site represented an undisturbed tributary of Duncan Creek however the section downstream of the Duncan Creek road was heavily influenced by placer mining. A local placer miner expressed interest in placer mining this small tributary in the near future. This site is therefore not a good candidate for future use as an undisturbed reference site. The mainstem of Duncan Creek has been heavily modified from historic placer mining activities. Site DC@B was the furthest downstream site and was located on the mainstem of Duncan Creek at the Mayo Lake road bridge crossing.

4.2 Water Chemistry and Discharge

Surface water quality samples were collected at each site in a fast flowing section of the stream prior to any other sampling activity. Maxxam Analytical of Burnaby, B.C, provided all sampling supplies. At each site, samples were collected in one-litre plastic bottles for general chemistry and in 250 mL plastic bottles for the analysis of nutrients. Samples to be analyzed for total metals were collected in 100 mL plastic bottles. The dissolved metals samples were filtered in the field using disposable sterile syringes and in-line filters (filter pore size 0.45 microns). Dissolved and total metals samples were preserved with nitric acid. All samples were kept cool prior to air shipment to the Maxxam laboratory. In-situ measurements of temperature, pH, conductivity and total dissolved solids were collected at each site using a hand-held Hanna Multi-probe.

Discharge was measured at selected sites. An area with a uniform cross section was chosen and the velocity and depth were measured using a AA Price velocity meter. Ten or more readings were taken across the profile of the stream. Total discharge was calculated as the sum of these individual discharges (area x velocity).

4.3 Stream Sediments

Composite stream sediment samples were collected with a stainless steel trowel from seven sites in the study area (KV6, C@PM, KV7, KV41, LTG1, WILC and DC@B). Fine-grained materials from recently deposited areas at each site were chosen and placed into ziplock bags and kept cool. Samples were shipped to Maxxam Analytical, along with the water quality samples. At the lab the samples were acidified and analyzed for the elements by ICPMS.

4.4 Riparian Vegetation

Vegetation for tissue analysis was collected at selected sites. As blueberries (*Vaccinium uliginosum*) are a frequent food source for NND citizens, blueberries were collected along Christal Creek at KV6 and KV7 and analyzed for metal content. Several species of riparian willow leaves and the most recent year of twig growth were collected at Williams Creek, a proposed reference site, and at KV7. Disposable latex gloves were worn when collecting the various tissues and placed into zip-lock freezer bags. Samples were kept cool and shipped to the Maxxam Analytical. At the lab the plant tissues were analyzed by CRC-ICPMS.

4.5 Benthic Community

A 400 µm mesh kick-net was used to sample benthic organisms at each site. The CABIN (Canadian Aquatic Biomonitoring Network) protocol for collection of benthic macroinvertebrates was followed. This required the placement of the kick net downstream of the collector, flat side of the net resting on the substrate of the stream. The collector walked backward, away from the net, kicking the substrate to disturb it to a depth of about 5 cm. For large boulders, the net is held downstream while brushing each boulder by foot. At each site the collector zigzagged over the stream bottom from bank to bank in an upstream direction for 3 minutes. Generally, sections of stream chosen for sampling were those that were near riffle-pool transitions. When sampling was completed, the net was washed with distilled water into a 250 µm sieve and the residue was place into a 1-litre container and preserved using 10% formalin. Samples were shipped to a CABIN certified invertebrate taxonomist for identification and enumeration.

The CABIN (Canadian Aquatic Biomonitoring Network) protocol was also used sorting, identification and enumeration of benthic macroinvertebrates. Each sample was first rinsed and elutriated to remove sand and gravel. The elutriate was checked for mollusks and caddisfly cases. The remaining organic component was examined to estimate densities. If the total number of invertebrates in the sample was estimated to be over 600 then the sample was subsampled using a Marchant Box subsampler. The sample was distributed in the Marchant box and cells were extracted one by one in a random way (using a random number table) until 325 invertebrates were counted. Ostracods, flatworms, pelagic crustaceans, terrestrial drop-ins were extracted and counted but did not count towards the total numbers. If 50 cells (of 100) were extracted and the total count was less than 300 then the whole sample would be sorted and identified. The invertebrates were identified to lowest level possible except for the phyla Nemata and the Oligochaete families. For quality assurance and control, three samples were resorted by a different sorter to test sorting efficiency. All three samples achieved a sorting efficiency of greater than 90%. Resulting benthic data was entered into the Environment Canada CABIN online database. Various metrics were calculated for each sample that included taxonomic richness, Shannon-Weiner diversity index, number of Ephemeroptera-Plecoptera-Tricoptera (EPT) taxa and species dominance expressed as a percentage.

For the CABIN database entry and subsequent analysis, the Yukon Reference Model (CABIN 2010) was used to compare test sites with reference sites. For this analysis several GIS metrics were calculated from the Canadian Land Cover Atlas (NRC 1995). Calculated variables that were needed to run the modal included climate (maximum January temperature, snow and rain accumulations in June and January), basin area, basin perimeter, elevation, stream order, stream length, stream density and several landscape variables (Bailey pers. com. 2010). Landscape variables required the grouping of different cover types in the watershed. Groupings included low shrubs, high shrubs, bryoids and herbs to represent alpine landcover. Forest landcover was represented by dense, open and sparse coniferous and broadleaf vegetation. Mixed wood open was also included in this designation. Unregenerated forest represented exposed land, rock and rubble from the land cover atlas. These variables and those recorded on the CABIN field sheets were input into the CABIN database and used in the analysis. Using the analytical tools in CABIN, an assessment report was completed for each of the study sites. The final output of the assessment report was the determination of the overall condition of the site. Sites were classified as unstressed (reference condition), potentially stressed, stressed or severely stressed.

4.6 Fish Community

A 50 to 100 meter section of the stream was identified at each sampling site. CABIN (2010) field assessment sheets were used to record reach data. This included the geo-referencing of each site with a hand held Garmin GPS (datum WGS 87). Determined attributes from field measurements included those related to site (date, time, elevation and location), channel characteristics (bank full and wetted widths, flow stage and slope), fish cover (habitat types, canopy coverage, riparian vegetative and periphyton coverage on substrate), substrate data (100 pebble count, embeddedness of armour layer and interstitial material) and discharge. Digital photographs included upstream and downstream perspectives of each sampled site.

Fish sampling was conducted under a permit obtained from Fisheries and Oceans Canada. At each site electrofishing and minnow trapping were the primary techniques used to establish fish presence and to collect specimens for the tissue metal analysis. For electrofishing, the conductivity of the water was first noted to assist in the initial setup. A minimum crew size of two people was used during each sampling episode. Captured fish were placed in a water filled bucket. A tally of fish that were observed or “flipped” but avoided capture with the dipnet was also recorded. Voltage was adjusted to enable fish in the bucket to recover within 5 to 20 seconds. A standard waveform of between 275 to 500 volts and a 15% duty cycle was effectively used throughout the project. Galvanized ¼ inch “Gee” type minnow traps, which were baited with suspended sacs of Yukon River salmon roe, were also utilized at each sampling site using methods described by the Yukon River Panel (2007). Minnow traps were set in various habitat types such as scour pools, side-channels, undercut banks or in woody debris that offered cover for fish. A total of 5 minnow traps were set for an overnight period at each sample site. Soak times were recorded for each trap. All captured fish during the project were measured for either a fork or total length (± 1 mm) and weight (± 0.1 gm). Weight was determined using a digital scale by first blotting excess water from the fish and then placing each fish into a container on the scale. A total length was recorded for slimy sculpin and a fork length for Arctic grayling. Fish were given time to recover in a bucket before being live-released away from the current near their site of capture.

Several Arctic grayling and slimy sculpin were retained for ICPMS metal analysis. Tissue was collected from Arctic grayling and whole body samples were taken for slimy sculpin. Generally, the largest specimens from each capture site were euthanized and placed in individual Whirlpac® plastic bags. Collections were immediately placed on ice and subsequently frozen within 48 hours. For shipment, samples were packed with ice packs and couriered to Maxxam Analytical. Analytical results were expressed in wet weights to compare results with other sites in the Yukon and Alaska where fish have been tested.

5.0 RESULTS AND DISCUSSION

5.1 Water Quality and Discharge

Water samples were collected from all ten of the sampling locations from July 13 through to 16, 2010. Several of the sample sites are not included in any regular sampling program by ERDC or NND, but were chosen for this study to further characterize the applicable watersheds. Specifically they are; a seep along the Duncan Creek road (DCR Seep), a small tributary at site KV6 on Christal Creek (KV6 TRIB), Christal Creek at Paddy Mine (C@PM), a small tributary on Paddy Mine access road (PMRD TRIB), Lightning Creek (LTG1), Williams Creek (WILC) and Duncan Creek at the bridge (DC@B).

Table 2 summarizes selected parameters however the complete analytical report can be examined in Appendix I. Various ions, physical attributes and only those metals where the CCME guidelines for the protection of freshwater aquatic life (CCME 1999) have been exceeded are included in Table 2.

The water temperature reflected seasonally and diurnal sampling conditions except for DCR Seep, which appears to be draining a permafrost area. Natural concentrations of sulphate in surface waters range from 10 to 80 mg/L (CCREM 1987). The sites affected by mining had levels higher than this and were located within the Christal Creek drainage. The two sampled tributaries of Christal Creek (KV6 TRIB and PMRD TRIB) had concentrations within the normal range for sulphate.

Very low levels of nutrients were documented in the study area. All sites had fairly high conductivity and corresponding total dissolved solids. Most of the sites had clear water although DCR Seep, LTG1 and KV6 TRIB were slightly turbid. All sampled waters were slightly alkaline and pH ranged from 7.79 at KV41 to 8.27 at WILC.

Discharge was measured and calculated at several of the sites. Flow at KV6 upstream of the culvert at the water sample site was 0.122 m^3/s. Flow was also measured downstream of the culvert and downstream of the tributary, and had a discharge of 0.115 m^3/s. The difference, about 0.007 m^3/s or 7 L/s, is believed to be contributions of the tributary flowing alongside the Keno Highway to Christal Creek. This small flow represented about 6 percent of the flow in the creek during the time of sampling. Discharge was not measured at Paddy Mine, however the flow had doubled at KV7.

The waters of the Christal Creek drainage were hard to very hard and may be related to treatment discharges and associated use of lime. The Lightning Creek sites had soft water and Williams Creek and Duncan Creek waters were hard. The toxicity of several metals changes depending on the hardness of the water. Generally, the toxicity of most metals increases as the hardness of the water decreases. Consequently several metals have different guidelines depending on the hardness of the sampled water.

The guideline for cadmium (0.017 ug/L) is very conservative but varies with the hardness of the water in question. Since there was both soft and hard water in the study area, the calculation using the formula 10{0.86[log(hardness)]-3.2}, was used to determine the site specific guideline for each site. These calculated values are listed in the row underneath the cadmium results. The applicable CCME guidelines were exceeded at most of the sites in both drainages, with the highest concentrations occurring at the DCR Seep and KV6. Sites PMRD TRIB and WILC both met the cadmium guideline.

The guideline for copper also changes with hardness. For soft waters (0 to 120 mg/L as CaCO3) the guideline is 2 ug/L, for hard waters (120 to 180) the guideline is 3 ug/L and for very hard waters (>180) the guideline is 4 ug/L. The CCME guideline for copper was slightly exceeded at KV6 TRIB and at DC@B, in the total metals samples only. It is believed that only a small fraction of the total copper originated from bound particles suspended in the sample from site DC@B (TSS = 5 mg/L). A much higher fraction of copper may have been bound to suspended particles at site KV6 TRIB (TSS = 61 mg/L).

The guideline for lead varies with hardness as well. For soft waters the guideline is 2 ug/L, for hard waters the guideline is 4 ug/L and for very hard waters the guideline is 7 ug/L. The guideline for lead was exceeded at KV6 and KV6 TRIB in the total metals samples only. The relatively low TSS values for both samples (TSS = 2 mg/L and 5 mg/L) suggest lead was predominantly in the dissolved form.

The guideline for arsenic was exceeded at DCR Seep and KV6, and for cobalt at DCR Seep only. Iron concentrations exceeded the guideline in the Christal Creek drainage only, at sites DCR Seep and KV6 TRIB.

The guideline for zinc was exceeded in both drainages, however it was met at KV6 TRIB, PMRD TRIB, LTG1 and WILC. The highest concentration of 157 ug/L was documented at DCR Seep.

The remaining metals have a single guideline. The guideline for aluminum was exceeded at most of the sites in the Duncan Creek drainage and only at KV6 in the Christal Creek drainage. The aluminum exceedance values at sites in the Duncan Creek drainage may be related to the slightly elevated TSS in the samples. All of the dissolved metals samples met the guideline.

This study examined two of the drainages that are affected by past and present mining activities on Galena Hill, Sourdough Hill and the south side of Keno Hill. Past mining activities on the northern side of Keno Hill however, also affect drainages but sampling in this area was beyond the scope of the budget for this study. Sampling was conducted on several creeks draining the north slope of Keno Hill during 2010 for a study examining the baseline conditions of a proposed road to the Rau property (LES 2011). These creeks are within the Keno Ladue River watershed, a tributary to the Stewart River. Some of these waterbodies were sampled in 2009 by Environment Canada (unpublished data, Environmental Protection). Table 3 summarizes the sites sampled and Table 4 summarizes relevant data.

Discharge from Sadie Ladue adit becomes Creek I, confirmed by over flights and ground truthing by Environment Canada in 2009. Concentrations in Creek I are fairly consistent in each dataset with relatively high levels of cadmium and zinc entering the small shallow lake (named Tailings Lake by EC). This lake drains into Gambler Lake via a short stream. Concentrations of cadmium in Gambler Gulch exceeded the CCME guidelines although the zinc levels were below but close to the zinc guideline. Gambler Gulch debouches into Gambler Lake which then drains to Ladue Lake via Ladue Creek. Ladue Lake is the headwater for Keno Ladue River of which Faro Gulch and Silver Basin Gulch are tributaries. Faro Gulch which drains the north face of Keno Hill has relatively high levels of cadmium, lead and zinc, although most concentrations were lower than those recorded at Creek I. Silver Basin Gulch which also drains the north face of Keno Hill had uncontaminated water for the metals examined. It appears that the Keno Ladue River may be influenced by cadmium levels from Faro Gulch.

To put all of the sites examined into perspective, zinc and cadmium concentrations were sorted from lowest to highest and graphed separately in Figure 4.

Although the order of the sites isn't exactly the same, the overall trend is similar; the sites with higher zinc values have higher cadmium values. Cadmium and zinc are chemically similar and this trend is not unexpected. Ten of the 21 samples had zinc concentrations below the CCME guideline. Since the guideline for cadmium changes with hardness, the guideline could not be plotted on Figure 4 but the first four samples met their respective guideline. These four samples were also included in the ten samples that met the guideline for zinc. Most of the sites that met the guidelines were several of the streams north of Keno Hill, and some of the tributaries to Duncan Creek and Christal Creek. DCR seep, KV6 and the Sadie Ladue adit had the greatest concentrations of both metals. The highest concentrations were documented in the Sadie Ladue drainage but do not seem to have had much affect on Keno Ladue River.

5.2 Stream Sediments

The analytical results for the stream sediment analysis are presented in Appendix II. Of the 30 metals analyzed, only sodium was not detected at any of the sites. Six of the metals are examined in detail as they may be found in the ore bodies or waste rock in the study area, can be toxic to aquatic organisms and have sediment quality guidelines available for comparison (Table 5). The concentrations of these metals are compared to the CCME (1999) interim freshwater sediment quality guidelines (ISQG) and to the probable effects level (PEL). Generally, concentrations greater than the PEL have a 50% incidence of creating adverse biological effects.

The concentrations of the metals in the stream sediments collected at KV6 had significantly greater levels of all of the metals examined than at the other sites. The concentrations of all the metals exceeded the ISGQ here, and concentrations of arsenic, cadmium, lead and zinc greatly exceeded the PEL. This site is located on Christal Creek downstream of Christal Lake and thus receives fine sediment that leaves the lake. The fine sediment in the lake likely originates from past deposits of tailings in the lake and continual erosion of tailings in the area. Christal Lake is also the receiving water for the treated discharges from Galkeno 300 and 900. The Belle Keno mill located in Keno near Christal Lake was not operational during the sampling program, but its effluent will also discharge to Christal Lake once milling begins. The high contaminant concentrations in sediments could be cause for concern for the health and well being of aquatic biota in this reach. Based on catches, fairly high densities of slimy sculpin inhabit Christal Creek both below and above the highway culverts at site KV6.

Downstream on Christal Creek near the Paddy Mine, concentrations had significantly decreased, however levels had increased somewhat further downstream at KV7. The concentrations of arsenic, cadmium, lead and zinc were greater than the PEL at both of these sites.

Concentrations were significantly lower on the Duncan Creek drainage with the highest concentrations found at KV41, Lightning Creek upstream of the Keno City bridge but downstream of the Bellekeno adit discharge site. Overall, the same trend was followed on the Duncan Creek drainage as the Christal Creek drainage with metal concentrations decreasing the further one progressed downstream, with the exception of zinc. Total zinc levels decreased from KV41 to LTG1 but then increased to KV41 levels at site DC@B in lower Duncan Creek. This may be an artifact of slightly greater suspended sediment (TSS) in the samples from sites KV41 and DC@B. Concentrations were low however when compared to the Christal Creek values, although the ISQG was slightly exceeded on the Duncan drainage. Concentrations in the stream sediments collected from Williams Creek were the lowest in the study area for cadmium, copper, lead and zinc. Williams Creek was the only other site besides KV6 that had detectable concentrations of mercury in the sediment, however the CCME guidelines were met at WILC. The PEL for arsenic was exceeded at all of the sites. The ISQG was exceeded for cadmium and zinc on the Duncan Creek drainage sites (excluding WILC) and at KV41 only for lead.

Several of the sites in the current study were sampled for the first time in 2010, whereas KV6, KV7 and KV41 have recent data collected sporadically. On previous monitoring programs conducted by LES, stream sediments were collected from these sites in 2004, 2005 and 2007 (LES 2008). In 2009, ERDC/Minnow Environmental collected sediment samples as a requirement of License #QZ06-074 (Minnow 2010 and ERDC files).

Methods and analyses were similar between studies and the data have been summarized in Table 6 and graphed in Figure 3.

Concentrations of the metals have consistently been greater at KV6 than at the other two sites with the exception of samples collected in 2009. Photographs of site KV6 in Minnow's report could indicate that the stream sediment samples were collected downstream of the road crossing (Minnow 2010). During the other surveys, sediment samples were collected from the depositional areas upstream of the culvert near the established water quality and hydrology site. Concentrations of the various metals downstream on Christal Creek at KV7 are considerably lower, on average up to 7 times lower for arsenic and lead, and around 2 or 3 times lower for cadmium and zinc.

The metal concentrations in the stream sediments collected at KV41 over time have been very low and with the exception of arsenic, have not exceeded the PEL.

5.3 Riparian Vegetation

Two types of vegetation were examined in 2010, blueberries (*Vaccinium uliginosum*) and willow (*Salix sp*). Willow leaves and the current year's growth of twigs were analyzed separately. Several species of riparian willow were collected however they were analyzed as one composite sample per site. To put the vegetation data collected during this survey into context, it was compared to previous available data that could be acquired. The analytical results for the vegetation analysis are presented in Appendix III.

5.3.1 Blueberries

Blueberry bushes are fairly prevalent throughout several areas of the Keno/Elsa district. Blueberries are a tasty snack and are a frequent food source for NND members. Bushes were observed at the sites KV6 and KV7 only and several grams of berries were collected for metal analysis. As blueberries were not observed in any control areas, research for metal data from other sources was pursued. Blueberries had been analyzed in 1993 and 1995 from sites in Haines Junction, Ross River, Watson Lake and Whitehorse (Gamberg 2010). In 2001 Heather Nicholson examined arsenic levels in blueberries around the Mount Nansen area, Yukon. The data from all sources have been summarized in Table 7 for the parameters that exceeded guidelines in the stream sediment samples. Soil samples were not collected of the terrestrial sediment at the vegetation sites.

Arsenic was detected in the blueberries collected from Christal Creek and Mt. Nansen with concentrations ranging from 0.04 ppm to 0.08 ppm. Cadmium was detected at half of the sites and ranged from 0.02 ppm in blueberries collected at Haines Junction to 0.52 ppm in blueberries at KV7. Lead was frequently recorded in blueberries with those from Christal Creek having the lower concentrations. The highest level of 0.67 ppm was recorded in blueberries collected in Whitehorse. Concentrations of zinc were recorded in all blueberries and ranged from 8.8 ppm to 44.3 ppm, both sites in Watson Lake.

There are no Canadian guidelines for metal content in fruit although the Canadian Food Inspection Agency has conducted sampling in concentrated fruit juices (Canadian Food Inspection Agency web site). Only one sample had been analyzed of blueberry concentrate so for the purposes of this study, comparisons have been made with the complete set of 23 different types of concentrated fruit juices that were tested. The number of samples (N), range of values and average metal concentrations have been summarized in Table 8.

The arsenic values documented in Christal Creek are below but close to the mean in the fruit juice concentrates. Cadmium concentrations recorded in blueberries from Christal Creek were significantly higher than the maximum concentration in the tested fruit juice concentrates. The sample size (2) from Christal Creek is much too small and further testing should be undertaken to confirm these high levels. Lead levels in the Christal Creek blueberries were similar to the mean of the juice concentrates. Zinc concentrations were about three times higher in the Christal Creek blueberries than the maximum recorded in the fruit juice concentrate, however higher concentrations were found in blueberries from other areas of the Yukon.

5.3.2 Willow (*Salix sp*)

Willow leaves and first year twig growth were collected at KV7 and at the reference site WILC to examine metal uptake in vegetation in attempts to determine if there may be any contamination to browsing moose using willows as a primary food source on the Elsa/Keno site. The two types of vegetation have been examined separately.

5.3.2.1 Leaves

There are no guidelines on metal content in vegetation regarding consumption by wildlife. In attempts to put the current data into perspective, comparisons have been made with a similar survey that was conducted in 2003 where willow leaves and twigs were collected at various locations following the contaminant pathways at Silver King and at No Cash Creek in the Elsa study area (LES, 2004). Control sites well away from the contaminant pathways were also established. In Table 9 the control sites and the exposed sites are grouped together. The same metals were considered as for blueberries.

Arsenic concentrations were the same in the control and exposed sites in 2010. Arsenic was not detected in the other samples however the method detection limit was greater than the levels recorded in 2010 so it is unknown how the current values compare to the other sites.

Cadmium concentrations were an order of magnitude greater at KV7 than at the reference site, WILC. When compared to the 2003 study, the concentration at KV7 was significantly lower than the majority of the sites along the Silver King and No Cash Creek pathways. The exceptions were the last sites along each pathway where concentrations were reduced.

Higher levels of lead were found in the willow leaves from KV7 than at the reference site WILC. However both of these concentrations were less than the method detection limit used during the 2003 study.

Zinc was detected at all sites and ranged from 160 ppm at WILC to 2150 ppm at the uppermost Silver King site within the contaminant pathway. The zinc concentration at KV7 was higher than the other control sites but lower than most of the exposed sites. Again the exceptions were the last sites along each pathway where concentrations were reduced.

5.3.2.2 Twigs

More data on metal content in willow twigs was available and the current set of samples was compared to the 2003 study, as well as to results from a database (Gamberg 2010). The same metals were reviewed and are presented in Table 10.

Arsenic concentrations in 2010 were similar in WILC leaves and twigs, whereas the concentration in KV7 leaves was somewhat higher than in the twigs. Arsenic was detected at some of the Watson Lake sites where a lower detection limit was used. The highest concentration of 1.02 ppm was documented in willow twigs from Watson Lake.
The concentration of cadmium in the willow twigs at KV7 was approximately an order of magnitude greater than at WILC and the levels were very similar to the levels documented in the willow leaves. Cadmium was detected at most sites and ranged from 0.1 ppm in Watson Lake to 30.1 ppm at one of the Silver King sites. Several sites had higher cadmium concentrations in the willow twigs than recorded at KV7.

Levels of lead were higher in the twigs at KV7 than at WILC and were very similar to the concentrations in the willow leaves at these sites. The willow twigs located in the No Cash Creek contaminant pathway had higher concentrations than at KV7, with the greatest concentrations documented at the control site here.

Zinc concentrations in the twigs at KV7 were over twice that at WILC, but both concentrations were lower than those recorded at these sites in the willow leaves. Zinc was detected in all of the samples and ranged from 30.4 ppm at a site in Watson Lake to 892 ppm in willow twigs at Teslin. Zinc levels were higher at all of the No Cash Creek sites and most of the Silver King sites than at KV7.

Ohlson and Staaland (2001) conducted a study to determine the mineral nutrition ecology of moose (*Alces alces*) by analyzing 18 elements in 14 species of plants, including willow (twigs), during each of the four seasons of the year. Of the 14 species tested, willows contained the highest concentration of cadmium, with a peak of 9 ppm documented at one of their four sites. This value is higher than that recorded at KV7, however is lower than that documented at Silver King. It should be noted, however, that No Cash Creek and the Silver King area are subject to concentrated flows with high contaminant levels, so higher contaminant concentrations in vegetation might be expected.

There is no evidence that cadmium is biologically essential or beneficial, but it is known that in sufficient concentrations it is toxic to all forms of life. Animals eating or drinking cadmium can develop liver disease, high blood pressure and nerve or brain damage (Lenntech 2010). It can accumulate in the kidneys creating kidney damage.

Through hunting donations, Yukon moose kidneys have been analyzed for cadmium concentrations for several years. This data is in a database and encompasses each of the hunting zones (Gamberg 2011). Of 502 kidneys analyzed throughout the Yukon, cadmium concentrations ranged from 4.3 ppm to 134.1 ppm wet weight with a mean of 27.8 ppm. The Elsa/Keno area lies within Zone 4, specifically subzones 4 and 5. Only four moose kidneys were analyzed per zone and the average in Zone 4, was 33.3 ppm and 20.8 ppm wet weight in Zone 5.

Frøslie *et al* (1986) investigated cadmium concentrations in kidneys in moose throughout Norway. Of 796 analyses the mean concentration was 2.9 ppm wet weight, with values ranging from 0.1 ppm to 19 ppm. Cadmium is persistent in the body and they found that concentrations increased as the age of the moose increased. The primary source of cadmium in Norway is through long-range atmospheric transport from central and western Europe.

Concentrations in Yukon moose kidneys were around an order of magnitude greater than that in Norwegian moose kidneys. Yukon hunters have normally reported healthy moose and no gross abnormalities were evident on the kidneys when analyzed (Gamberg pers. com. 2011). There are naturally occurring high levels of cadmium in the geology of several areas of the Yukon and in turn, high levels in willows, which are hyper-accumulators of cadmium. It is suspected that Yukon moose have evolved to be tolerant of the high concentrations of cadmium consumed through their diet.

5.4 Benthic Community

The lowest taxonomic richness or number of identified taxa in the benthic collections was 11 species for sites KV41 and WILC in the Duncan Creek drainage (Table 11). At all other sites the taxonomic richness was higher than the reference sites mean of 11.4 species. The highest taxonomic richness was 21 species recorded at the most downstream site DC@B on the mainstem of Duncan Creek. Species diversity ranged from a low of 0.87 at site KV41 to 2.52 at site DC@B. The mean diversity for the Yukon CABIN reference sites was 1.44. The highest recorded number of EPT (Ephemeroptera-Plecoptera-Tricoptera) was 9 species that was associated with 4 sites that included C@PM, KV7, LTG1 and DC@B. The lowest number of EPT taxa was 5 species at site KV6 on Christal Creek. The Yukon reference site average for the number of EPT taxa was 5.4 species per site. Percentages of the most dominant taxa ranged from a low of 16.4 percent at site DC@B to a high of 80.2 percent at site KV41. The two most dominant combined taxa ranged from 30.8 percent at site DC@B to 86.9 percent at site KV41. The Yukon reference site average for the most dominant and 2 most dominant groups were 52.1 percent and 70.9 percent, respectfully.

A summary of identified benthic species and relative abundances of each from collected kick net samples during August for each sample site are presented in Appendix IV. Results from the CABIN/BEAST analysis are presented in individual site assessment reports in Appendix V. Potentially stressed sites were KV6, C@PM and KV7, which represent all of the sites assessed in Christal Creek. Sites in the Duncan Creek drainage were all in reference condition and considered to be unstressed. Individual sites were compared to the Yukon CABIN database that includes nearly 300 reference sites throughout the Yukon River Basin. Comparisons to previous benthic results by other researchers were not considered due to differences in collection techniques, sorting and identification protocols.

5.5 Fish Community

5.5.1 Fish Habitat

Average channel widths in Christal Creek ranged from 2.2 to 4.9 m (Table 12). Wetted widths at the time of survey ranged from 1.7 to 3.6 m, with flows considered at a moderate stage at all sites. The greatest maximum channel depth was measured at KV6 of 0.36 meters. Stream slope ranged from 1.0 percent at KV7 to a maximum of 2.3 percent at C@PM. Canopy coverage was the greatest at KV6 and estimated to be between 76 and 100 percent. Overall, thick riparian grown provided a good canopy coverage and plenty of overhanging vegetation along the stream margins at all sites on Christal Creek. Riffles were the most common stream feature in Christal Creek. Pool habitat was much less common and only observed at KV7 the most downstream site. The dominant vegetative type along the banks was shrub with no noticeable instream vegetation at any of the Christal Creek sites. Periphyton coverage on the stream substrate, while noticeable, made the rocks only slightly slippery at sites. The dominant substrate at KV6 and C@PM were medium sized gravels (3.2 to 6.4 cm). Small gravels (1.6 to 3.2 cm) dominated the substrate at KV7. Substrates at all sites were generally loose and minimally embedded.

Average channel widths at sites in the Duncan Creek watershed ranged considerably. Being located on a small tributary, site WILC on Williams Creek was the least in width at only 1.9 meters. The greatest channel width was recorded at site DC@B on the mainstem of Duncan Creek just upstream of the Mayo River confluence. The greatest maximum channel depth was also measured at this site of 0.38 meters. Stream gradient ranged from 1.3 percent at sites LTG1 and DC@B to 2.3 percent at WILC on Williams Creek. With the exception of the Williams Creek site, with canopy coverage of between 51 to 75 percent, canopy coverage was generally low at sites in Duncan and Lightning creeks due to the large channel widths. For all sites the dominant vegetative type along the banks was shrub and no noticeable instream vegetation was observed. Riffles and straight runs were commonly observed at all sites however pools were only obvious at LTG1. Rapids were present at sites KV41 and DC@B. The dominant substrate material was cobble that was 6.4 to 12.8 cm in size for sites KV41, WILC and DC@B. Large gravels, 3.2 to 6.4 cm in size, dominated the substrate at site LTG1. Substrates at all sites were generally loose and minimally embedded.

5.5.2 Fish Species

Only two species of freshwater fish were captured during this survey that included slimy sculpin (*Cottus cognatus*) and Arctic grayling (*Thymallus arcticus*). A summary of catches at each site and associated method of capture are presented in Tables 13 and 14. The highest densities of sculpin were found at site KV6 in Christal Creek and site DC@B in the lowest reach of Duncan Creek. Captured slimy sculpin ranged in size from 29 to

105 mm in total length and represented juvenile and adult life history stages at each of these sites. Slimy sculpin fry were only observed at site DC@B in Duncan Creek. Slimy sculpin were not captured at site KV7 in Christal Creek or sites KV41 and WILC in the Duncan Creek drainage. Low densities of Arctic grayling were recorded at site KV7 in Christal Creek and sites KV41, LTG1 and DC@B in Duncan Creek drainage. Captured Arctic grayling ranged in size from 91 mm to 240 mm and represented juvenile and adult life history stages. Arctic grayling fry were not observed or captured at any of the assessed sites. Measurements of fish and their locations of capture are presented in Appendix VI.

5.5.3 Fish Contaminants

The laboratory results of chemical analysis of 15 whole body slimy sculpin collected from two sites in Christal Creek and three sites in the Duncan Creek watershed are presented in Appendix VII. For simplicity, seven of the most toxic contaminants in the aquatic environment (As, Cd, Cu, Hg, Pb, Se and Zn) were chosen for further analysis and comparison to other data. Table 15 summarizes the concentrations of these contaminants that were found in Arctic grayling tissue and whole body slimy sculpin collected at each site. Included are comparisons in concentrations of each contaminant found in collected fish tissue samples and compared to four different benchmarks that include 1) INAC (2009) database for slimy sculpin residues in various locations and drainages in the Yukon Territory; 2) USGS (2011) database for freshwater fish in various locations in Alaska; 3) CCME (1999) guidelines for the protection of wildlife consumers of aquatic biota; and 4) Canadian Food Agency (2009) fish tissue guidelines for the consumption of fish and fish products.

The current CCME (1999) guidelines for the protection of wildlife consumers of aquatic biota address those substances for which aquatic food sources are the main route of exposure. These guidelines apply to any aquatic species consumed by wildlife, including fish, shellfish, invertebrates, or aquatic plants. To date, only a few substances have had a guideline developed and include DDT, dioxins and furans, PCBs, toxaphene and methylmercury. These substances are known to bioaccumulate and can be persistent in aquatic food chains. The recommended tissue residue guideline (TRGs) for these substances represent the concentration of the contaminant in an aquatic organism that is not expected to result in adverse effects in predaceous wildlife. Conversely, the Canadian Food Inspection Agency (2009) has also developed TRGs for chemical contaminants and toxins in Canadian fish and fish products. These guidelines were prepared to promote product and process standards that contribute to the achievement of acceptable quality and safety of fish and seafood products in the consumer marketplace.

Arsenic concentrations for sampled slimy sculpin were generally low in comparison to the mean and maximum concentrations from the INAC and USGS databases. Values ranged from a low of 0.06 ug/g for Arctic grayling at KV41 to a high of 0.95 ug/g in slimy sculpin at site KV6. The Canadian guideline for the consumption of fish and fish products is currently set at 3.50 ug/g and well above the concentrations found in this study.

Cadmium concentrations in the tissues of Arctic grayling were low and near the level of detection at all sampled sites. Slimy sculpin had generally higher concentrations with the highest at sites KV6 and DC@B of 0.44 ug/g and 0.48 ug/g, respectfully. These values were above the mean averages but below the maximums found in fish from the INAC and USGS databases. Currently there are no guidelines for cadmium concentrations in fish tissues.

Arctic grayling copper concentrations were consistent and did not exceed the detection level of 0.05 ug/g. Average concentrations ranged from 0.80 ug/g to 1.30 ug/g in slimy sculpin. These values were below the INAC database average of 1.6 ug/g but above the USGS database average of 0.70 ug/g. The maximum reported concentration in slimy sculpin from the INAC database was 27.60 ug/g for a composite sample of four collected from Wolf Creek in 1998.

Lead concentrations in Arctic grayling tissue were low and did not exceed 0.09 ug/g. This concentration was below the mean and maximum concentrations reported in fish in the INAC and USGS databases. Concentration of lead in slimy sculpin ranged from 0.13 ug/g at site DC@B to a high of 5.66 ug/g at site KV6. The high concentration at KV6 exceeded the INAC and USGS database averages. The maximum reported concentration in slimy sculpin from the INAC database was 29.40 ug/g from Flat Creek in 1994. Previous whole body slimy sculpin results reported from Christal Creek in 1994 ranged from 0.18 ug/g to 14.91 ug/g. The Canadian guideline of lead for the consumption of fish and fish products is 0.5 ug/g. There is currently no guideline for the protection of wildlife consumers of aquatic biota.

Mercury concentrations in sculpin were consistently low at all but one site and near the detection level of 0.01 ug/g. Site DC@B had a concentration of 0.040 ug/g in slimy sculpin, which was above the CCME (1999) tissue residue guideline of 0.033 ug/g for wildlife consumers. All concentrations for Arctic grayling were well below the Canadian guideline of 0.5 ug/g for the consumption of fish and fish products. The mean and maximum concentrations in whole body sculpin from the INAC database were 0.02 ug/g and 0.17 ug/g, respectfully. Since virtually all (>95%) of the mercury present in an organism is methylmercury (Bloom 1992), the values determined for total mercury in this study were thought to be comparable to the CCME guideline.

Average selenium concentrations were consistent between sites for both fish species and did not exceed 1.71 ug/g. Slimy sculpin concentrations in the INAC database averaged 1.70 ug/g. This value is well above the average and maximum concentrations reported for freshwater fish in the USGS database of 0.51 ug/g and 0.85 ug/g, respectfully. The highest reported concentration for a slimy sculpin in the INAC database was 9.00 ug/g reported from Christal Creek in 1994. Currently there are no guidelines for selenium concentrations in fish tissues.

Zinc concentrations in fish from each site ranged from 13.9 ug/g in Arctic grayling at KV7 to 43.9 ug/g in slimy sculpin at DC@B. These values are below or near the average concentration of 42.2 ug/g reported in slimy sculpin from the INAC database. The maximum concentration in the INAC database was 187.1 ug/g reported from VanGorda Creek. The USGS database for other freshwater fish averaged 34.8 ug/g with a maximum of 56.4 ug/g reported for a single fish. Currently there are no guidelines for zinc concentrations in fish tissues.

6.0 CONCLUSIONS

1. The water quality data indicates that the Christal Creek drainage is more contaminated than the Lightning Creek/Duncan Creek watershed. Specifically, sites DCR Seep and KV6 had the highest concentrations of metals of concern.

2. The stream sediment results show very poor quality for the support of freshwater aquatic life at KV6. Concentrations of arsenic in the stream sediments were high throughout both watersheds and exceeded the PEL for all sites.

3. The tissue analyses for vegetation show that the plants blueberries and willows uptake cadmium and zinc, however levels were generally comparable with plants from other areas of the Yukon although sample sizes were low and some of the comparisons were from other sites in the Keno Valley. Additional sampling of vegetation should be conducted to confirm levels especially in the Christal Creek drainage.

4. The site assessment results of the CABIN analysis suggest that the benthic communities in Christal Creek are potentially stressed and not in reference condition.

5. The site assessment results of the CABIN analysis suggest that the benthic communities in Lightning, Williams and Duncan creeks are unstressed and in reference condition.

6. Slimy sculpin and Arctic grayling were captured in both the Christal Creek and Lightning Creek/Duncan Creek drainages.

7. The highest densities of slimy sculpin were found at site KV6 in Christal Creek and site DC@B in the lowest reach of Duncan Creek.

8. Arctic grayling were captured only in low densities in the Christal Creek and Lightning Creek/Duncan Creek drainages and were primarily of juvenile and sub-adult life history stages.

9. Lead concentrations of slimy sculpin at site KV6 on Christal Creek were above the INAC database average for this species and an order of magnitude higher than other freshwater fish sampled in the Yukon River Basin.

10. Mercury concentrations of slimy sculpin at site DC@B on Duncan Creek were slightly elevated and above the CCME guideline for the protection of wildlife consumers.

11. Arctic grayling generally had low levels of metal contaminates at all sites where they were sampled in Christal Creek and Lightning Creek/Duncan Creek drainages.

7.0 RECOMMENDATIONS

1. The source and destination of DCR seep should be determined. There is some question whether it flows to Christal Lake or flows under the road and empties into Lightning Creek. It supposedly does not originate from an old adit, but this should be confirmed.

2. Three of the sites within this study are monitored regularly by ERCD however NND desires data on some sites that are not included in any of their monitoring programs. With this in mind, it would be beneficial if NND assumed responsibility for part of the regular monthly monitoring program that exists under the current water license, as well as the addition of several sites of their choosing. This would provide a level of transparency to the sampling programs as well as confirm data analysis and trends.

3. Sources of metal contaminants entering Christal Creek should be aggressively managed to prevent any further degradation to the aquatic ecology currently in Christal Creek. The ecological services provided by the biota in Christal Creek in attenuating metal contaminants is likely precluding further downstream effects over a larger area. If at all possible, efforts to improve water quality in Christal Creek over the longer term should be an important goal in any future reclamation plan.

4. Concern has arisen recently regarding the contamination loading of Cache Creek, which flows into the South McQuesten River considerably upstream of Christal Creek. A study examining similar parameters as this study should be conducted here to build and expand upon the survey conducted by EDI in 2004 and 2005.

8.0 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the efforts of Dennis Buyck, Lands Manager for the First Nation of Na-Cho Nyäk Dun for overseeing the project, providing guidance and delivering both administrative and financial support. A word of thanks is also extended to Bill Slater for his contributions to the design of the project, knowledge of the area and development of the study objectives. Frank Patch provided administrative and financial support on behalf of the Assessment and Abandoned Mines Branch of the Yukon Department of Energy, Mines and Resources. Logistical support and the coordination of the BEAHR training component of the program was admirably coordinated by Josee Tremblay, the Mining Reclamation Coordinator for the First Nation of Na-Cho Nyäk Dun. The venerable efforts of Sarah Johnson, a summer student with the First Nation of the Na-Cho Nyäk Dun, are acknowledged for her excellent field assistance. Thanks to invertebrate biologist Sue Salter, who despite her busy schedule provided timely processing of collected benthic samples. Appreciation is also extended to Environment Canada for use of the CABIN for data input and subsequent analysis using the reference condition approach to individual sites. Dr. Adam Yates provided GIS support for variables that were needed in the CABIN analysis. Thanks to all.

9.0 REFERENCES

Bloom, N. 1992. On the Chemical Form of Mercury in Edible Fish and Marine Invertebrate Tissue. Canadian Journal of Fisheries and Aquatic Sciences, 1992, 49:1010-1017, 10.1139/f92-113

CABIN. 2010. Canadian Aquatic Biomonitoring Network. Environment Canada. Web Site: http://ec.gc.ca/rcba-cabin [accessed March 2011]

Canadian Council of Minister of the Environment (CCME). 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg, Canada.

Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Guidelines. Task Force of Water Quality Guidelines. Ottawa, Canada.

Canadian Food Inspection Agency. 2009. Canadian guidelines for chemical contaminants and toxins in fish and fish products. Web site: http://www.inspection.gc.ca/english/fssa/fispoi/man/samnem/app3e.shtml [accessed March 2011]

Canadian Food Inspection Agency. Food Safety Action Plan 2008-2009.. http://www.inspection.gc.ca/english/fssa/microchem/resid/2008-2009/fruite.shtml - t3_3 [accessed on April 2010]

Environmental Dynamics Inc. (EDI). 2005. South McQuesten Water Quality Sampling Program – Year 2. Yukon River Panel Project CRE-23-04.

Frøslie A., A. Haugen, G. Holt and G. Norheim. 1986. Levels of cadmium in liver and kidneys from Norwegian cervides. Bulletin of Environmental Contamination and Toxicology. Volume 37, Number 1, 453-460.

Gamberg, Mary. 2010. Database on metals in vegetation tissues.

Gamberg, Mary. 2011. Database on cadmium in moose kidneys.

INAC. 2009. Northern Contaminants Program (NCP) – Yukon Database. Whitehorse, Yukon.

Laberge Environmental Services. 2004. Receiving water and contaminant pathway monitoring in the Keno Valley, 2003, Special Projects #2. Prepared for Nacho Nyak Dun Development Corporation.

Laberge Environmental Services. 2011. Biophysical Investigations for the Proposed Rau Road Route. ATAC Resources Ltd.

Laberge Environmental Services. 2008. Keno Valley Stream Sediment and Benthic Invertebrate Monitoring Programs, 2007. Prepared for Access Consulting Group, Whitehorse, Yukon.

Lenntech. 2010. Water Treatment Solutions. [accessed April 2010] http://www.lenntech.com/periodic/elements/cd.htm - ixzz1JvWXHL7i

Minnow Environmental Inc. 2010. Analyses of Invertebrate and Sediment Data for the Keno Hill Mine Water License (QZ06-074). Prepared for Elsa Reclamation and Development Company Ltd, Vancouver, BC.

Nicholson, Heather, C. 2002. Arsenic in Plants Important to Two Yukon First Nations: Impacts of Gold Mining and Reclamation Practices. MPERG Report 2002-4.
NRC. 2004. The Atlas of Canada. Land Cover. Web Site: http://atlas.nrcan.gc.ca/site/english/maps/environment/forest/forestcanada/landcover [accessed March 2011]

Ohlson, M. and H. Staaland. 2001. Mineral diversity in wild plants: benefits and bane for moose. OIKOS 94: 442-454.

USGS. 2011. Biomonitoring Environmental Status and Trends (BEST) Large Rivers Monitoring Network. Web site: http://www.cerc.usgs.gov/data/best/search/ [accessed March 2011]

Yukon River Panel. 2007. Protocol for collection and reporting of data from juvenile salmon sampled in Canadian R&E Projects. Prep. for the Yukon River Panel by Fisheries and Oceans Canada. 1 p.

10.0 AUTHORITIES CONSULTED

Bailey, J. 2010. John Bailey Consulting, 177 Arctic Drive, P.O. Box 10205, Whitehorse, YT. Y1A 7A1 E-mail: jbailey@northwestel.net

Gamberg, M. 2011. Gamberg Consulting, Box 10460, Whitehorse, YT. Y1A 7A1.
E-mail: mary.gamberg@northwestel.net

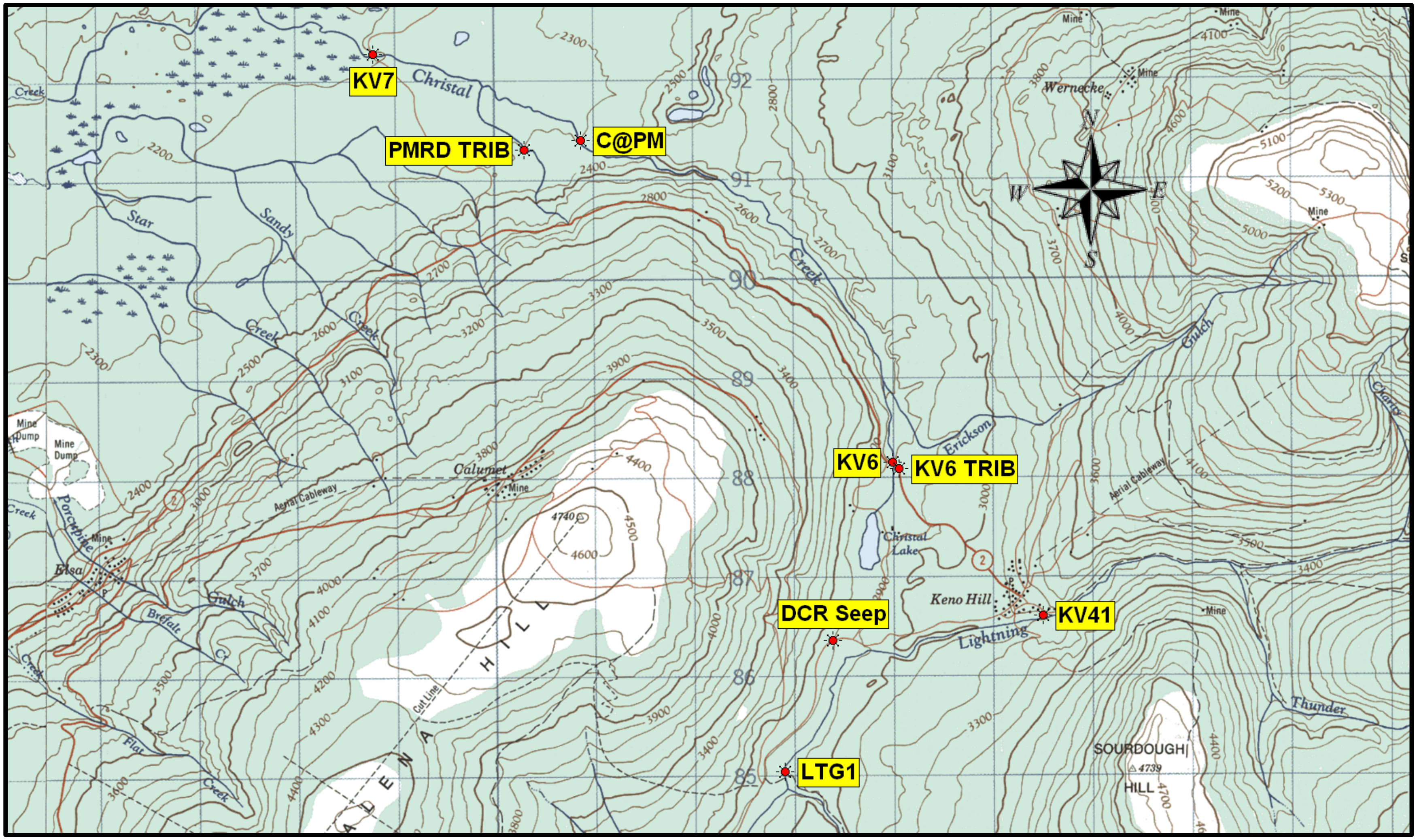

Figure 1 Sampling sites on Christal and Lightning creeks, July 2010.

1.5 0 1 2 3 km

SCALE 1 : 50,000

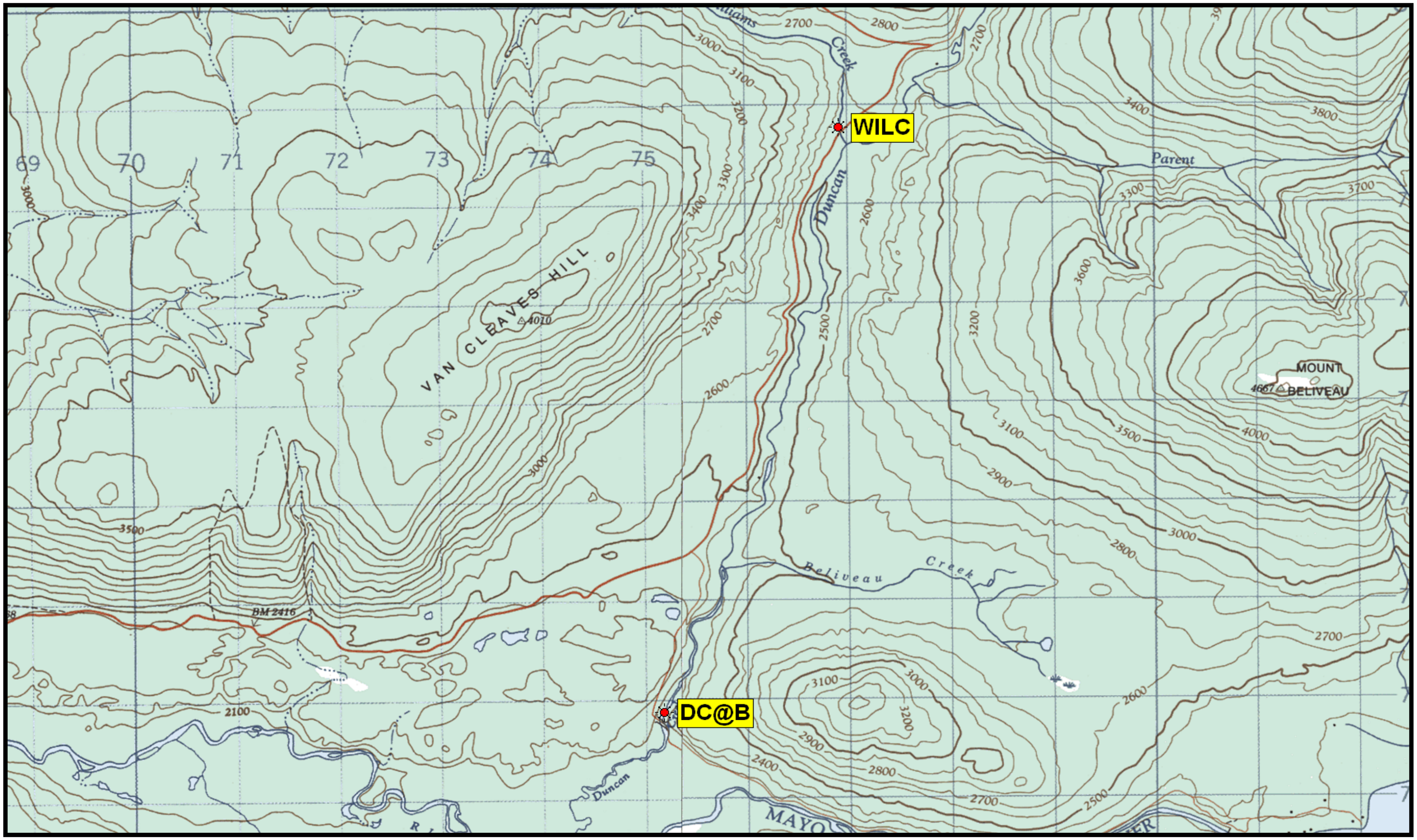

Figure 2 Sampling sites located on Williams and Duncan creeks, July 2010.

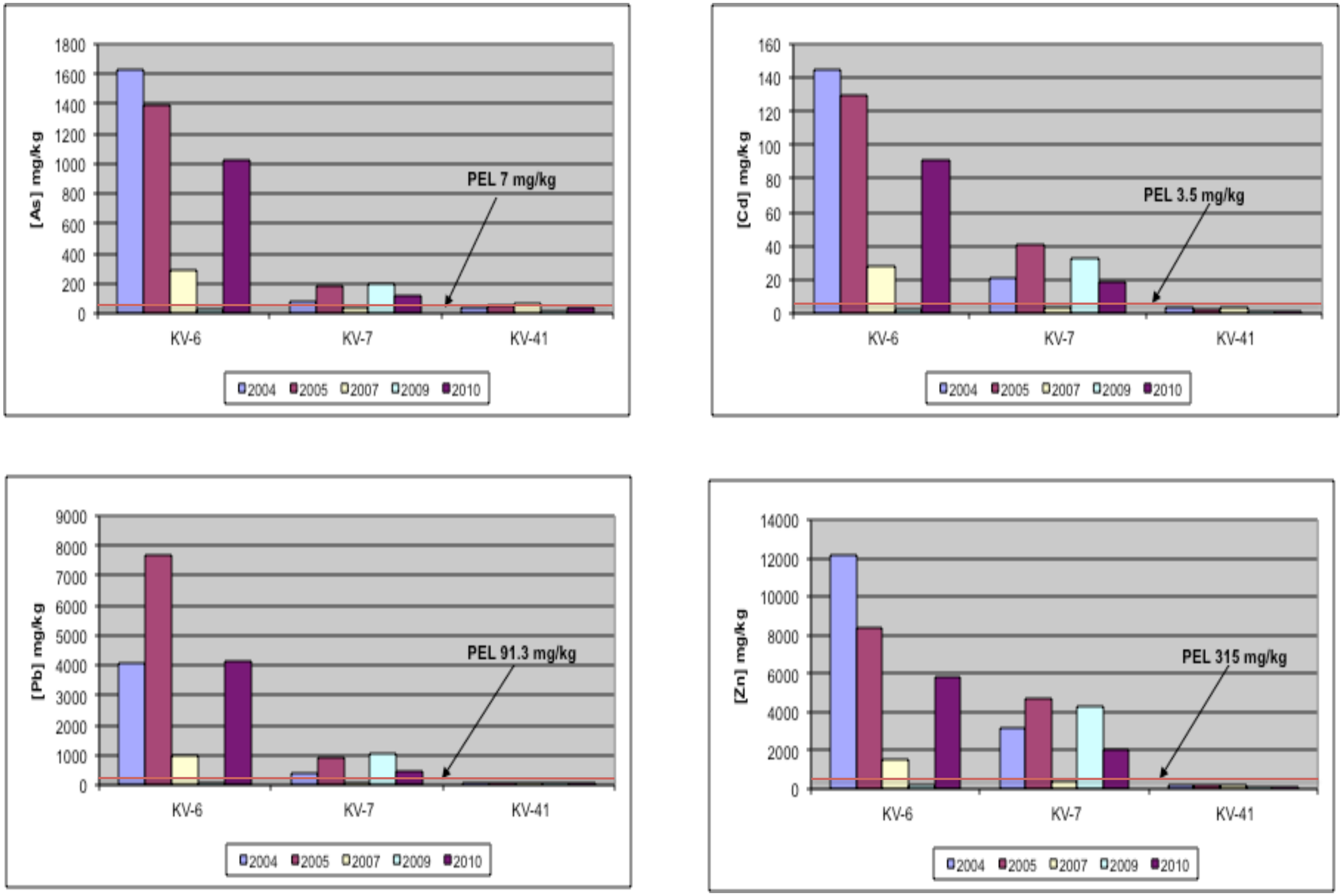

Figure 3 Comparisons of sediment concentrations over time at three study sites from 2004 to 2010.

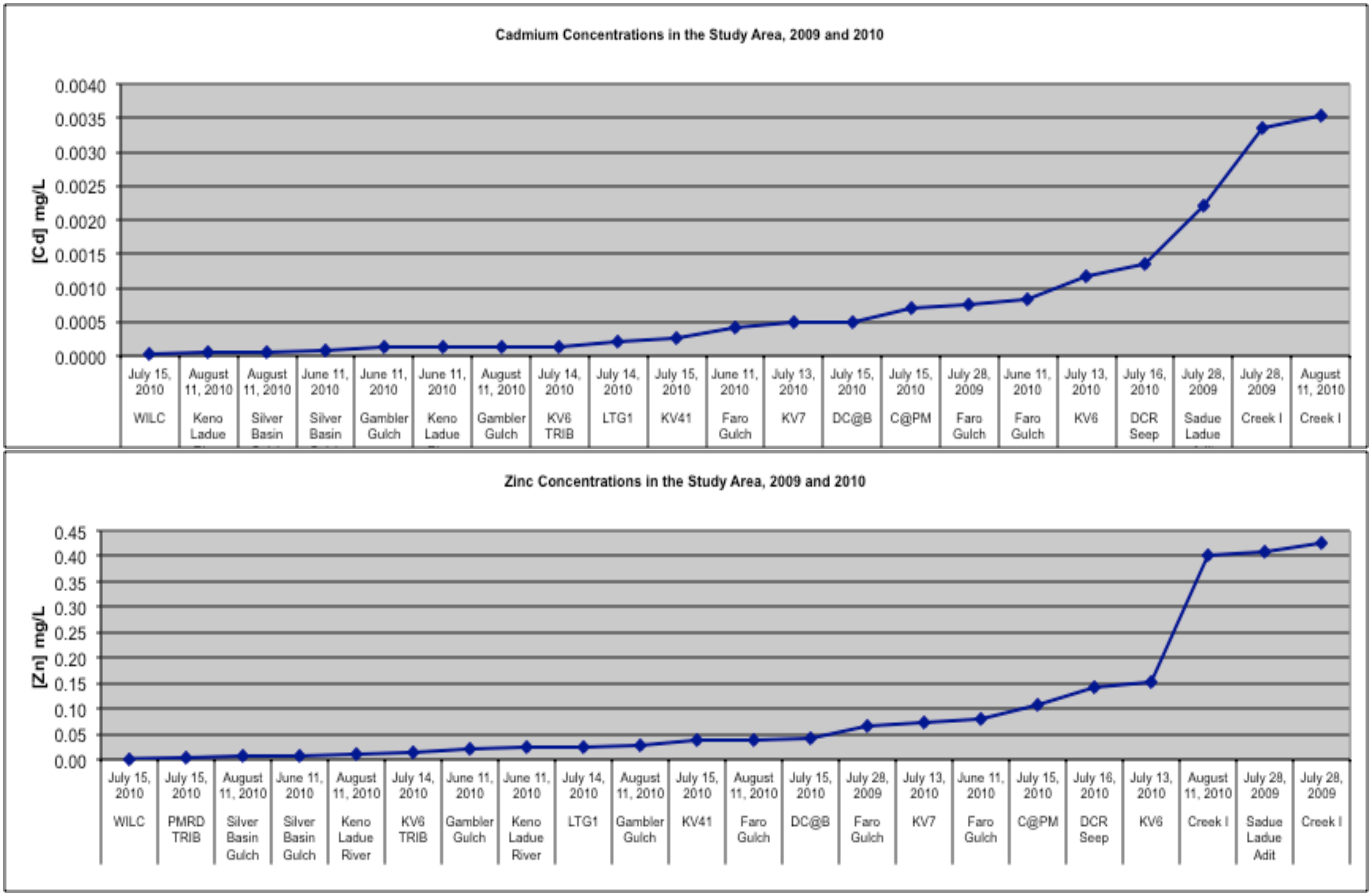

Figure 4 Cadmium (top) and zinc (bottom) concentrations (mg/L) at all sites on all occasions in 2009 and 2010.

Table 1 Summary of samples collected at sites in the Keno Valley area during July of 2010.

SAMPLE SITE		SITE CODE	WATER SAMPLES	SEDIMENT SAMPLES	VEGETATION SAMPLES	BENTHIC SAMPLES	FISH TISSUE	
							AG	SS
Christal Creek	Christal Creek at HWY	KV6	X	X	X	X		X
	Christal Creek at Paddy Mine	C@PM	X	X		X		
	Christal Creek at Hanson Road	KV7	X	X	X	X	X	
	Tributary on Paddy Mine Road	PMRDTRIB	X					
	Tributary to KV6 at HWY	KV6TRIB	X					
	Duncan Road Seep	DCR Seep	X					
Duncan Creek	Lightning Creek at Keno City	KV41	X	X	X	X	X	
	Lightning Cr u/s Duncan Creek	LTG1	X	X	X	X	X	X
	Williams Creek at HWY	WILC	X	X	X	X		
	Duncan Creek at Bridge	DC@B	X	X	X	X		X

Table 2 Results of chemical analysis from sites in the Keno Valley area during July of 2010.

PARAMETER	CCME Guideline	CHRISTAL CREEK DRAINAGE					DUNCAN CREEK DRAINAGE				
		DCR Seep	KV6	KV6 TRIB	C@PM	PMRD TRIB	KV7	KV41	LTG1	WILC	DC@B
Sampling Date		10-07-16	10-07-13	10-07-14	10-07-15	10-07-15	10-07-13	10-07-15	10-07-14	10-07-15	10-07-15
Water Temperature ^{o}C	none	0.6	12.2	7.5	5.5	4.8	6.1	6.3	7.2	7.3	11.8
Discharge m^3/second	none	-	0.108	0.007	-	-	0.237	0.697	0.772	0.098	4.72
Alkalinity (Total as CaCO3) mg/L	none	99	98	130	130	140	130	44	50	150	85
Dissolved Sulphate (SO4) mg/L	none	140	290	57	160	28	160	43	45	27	52
Nutrients											
Nitrate plus Nitrite (N) mg/L	none	<0.02(1)	0.09 (2)	<0.02(2)	0.06 (2)	<0.02 (2)	0.06 (2)	0.13 (2)	0.10 (2)	<0.02 (2)	0.07 (2)
Phosphorus (P) mg/L	none	0.009	0.006	0.009	<0.005	<0.005	0.009	0.009	0.008	0.009	<0.005
Physical Properties											
Conductivity uS/cm (lab)	none	485	764	351	548	317	572	188	204	309	273
Conductivity uS/cm (field)	none	476	748	338	542	307	551	177	192	292	261
pH	none	7.82	8.11	8.17	8.24	8.19	8.08	7.79	7.84	8.27	8.08
Total Suspended Solids mg/L	none	26	2	61	5	<1	2	10	7	<1	5
Total Dissolved Solids mg/L	none	330	600	230	410	210	400	110	130	210	170
Calculated Parameters											
Total Hardness (CaCO3) mg/L	none	247	443	180	304	168	298	85.2	84.3	169	134

PARAMETER	CCME Guideline	CHRISTAL CREEK DRAINAGE					DUNCAN CREEK DRAINAGE				
		DCR Seep	KV6	KV6 TRIB	C@PM	PMRD TRIB	KV7	KV41	LTG1	WILC	DC@B
Metals by ICPMS ug/L											
Total Aluminum (Al)	100	79.6	8.7	**378**	32.5	5.6	16.1	**123**	**132**	19.3	**377**
Dissolved Aluminum (Al)	none	1.9	9.7	14.1	5.5	5.5	4.2	3.2	5.2	14.0	99.8
Total Arsenic (As)	5	**35.4**	**5.05**	3.05	2.84	1.12	2.21	1.87	1.95	4.24	1.08
Dissolved Arsenic (As)	none	**30.4**	3.48	1.16	2.09	1.10	1.96	1.35	1.21	3.94	0.74
Total Cadmium (Cd)	Varies	**1.34**	**1.18**	**0.141**	**0.699**	<0.005	**0.491**	**0.256**	**0.213**	0.023	**0.501**
Dissolved Cadmium (Cd)	none	**1.12**	**0.930**	0.016	**0.563**	0.006	**0.412**	**0.191**	**0.133**	0.010	**0.335**
Calculated Cadmium guideline:	varies	*0.072*	*0.119*	*0.055*	*0.086*	*0.052*	*0.085*	*0.029*	*0.029*	*0.052*	*0.043*
Total Cobalt (Co)	4	**4.29**	0.127	1.11	0.185	0.029	0.093	0.189	0.215	0.043	2.10
Dissolved Cobalt (Co)	none	3.91	0.108	0.234	0.100	0.025	0.061	0.018	0.064	0.039	1.86
Total Copper (Cu)	varies	1.10	0.47	**3.69**	1.01	1.04	0.67	1.20	1.33	1.13	**3.55**
Dissolved Copper (Cu)	none	0.07	0.38	1.01	0.64	1.09	0.63	0.47	1.01	1.05	1.86
Total Iron (Fe)	300	**2960**	180	**1250**	181	23	110	127	168	181	296
Dissolved Iron (Fe)	none	**2320**	42	137	55	19	39	4	19	134	47
Total Lead (Pb)	varies	0.831	**9.62**	**4.74**	1.95	0.028	1.05	1.72	1.45	0.078	0.368
Dissolved Lead (Pb)	none	0.031	0.802	0.128	0.379	0.032	0.241	0.016	0.175	0.041	0.035
Total Zinc (Zn)	30	**142**	**151**	15.2	**107**	1.8	**71.9**	**36.7**	25.5	1.6	**41.0**
Dissolved Zinc (Zn)	none	**157**	**138**	3.4	**94.1**	2.5	**69.8**	27.4	19.6	1.6	17.3

NOTE: Values where the CCME guideline for the protection of freshwater aquatic life have been exceeded are displayed in bold and are highlighted.

Table 3 Site descriptions of creeks draining the north face of Keno Hill.

SITE	SITE DESCRIPTION
Creek I	Creek draining the Sadie Ladue adit and mining area and empties into an unnamed lake (Tailings Lake)
Gambler Gulch	Creek draining the north face of Keno Hill and empties into Gambler Lake
Faro Gulch	Creek draining the north face of Keno Hill, trib to Keno Ladue R
Silver Basin Gulch	Creek draining the north face of Keno Hill, trib to Keno Ladue R
Keno Ladue River	Downstream of the above inputs

Table 4 Selected water quality data from sites north of Keno Hill, 2009 and 2010.

SITE	DATE	COND uS/cm	HARDNESS mg/L (CaCO3)	CADMIUM mg/L	LEAD mg/L	ZINC mg/L
Sadie Ladue Adit	July 28/09	529	459	**0.00222**	0.0013	**0.41**
Creek I	July 28/09	712	393	**0.00335**	0.00037	**0.427**
	Aug 11/10	620	346	**0.00354**	**0.0053**	**0.400**
Gambler Gulch	June 11/10	308	165	**0.00012**	<0.0001	0.02
	Aug 11/10	400	201	**0.00014**	0.0005	0.026
Faro Gulch	July 28/09	319	195	**0.00076**	0.003	**0.065**
	June 11/10	335	174	**0.00084**	**0.0158**	**0.081**
	Aug 11/10	418	205	**0.00042**	0.0029	**0.038**
Silver Basin Gulch	June 11/10	522	282	0.00007	0.0002	0.008
	Aug 11/10	627	326	0.00006	<0.0001	0.006
Keno Ladue River	June 11/10	284	146	**0.00014**	0.0007	0.024
	Aug 11/10	302	148	0.00004	0.0006	0.009

NOTE: Values in bold and highlighted have exceeded the CCME guideline for the protection of freshwater aquatic life.

Table 5 Stream sediment metal concentrations (mg/kg) from sites in the Keno Valley area during July of 2010.

SAMPLE SITE		pH	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Christal Creek	KV6	7.51	**1,030.0**	**91.4**	**67.6**	**4,130**	**0.18**	**5,820**
	C@PM	8.05	**72.9**	**6.4**	25.1	**198**	<0.05	**698**
	KV7	7.97	**121.0**	**18.8**	32.2	**453**	<0.05	**2,010**
Duncan Creek	KV41	7.71	**34.8**	**1.4**	21.9	**42**	<0.05	**146**
	LTG1	7.62	**25.2**	**1.0**	20.2	32	<0.05	**124**
	WILC	8.02	**28.1**	0.3	9.2	12	0.13	51
	DC@B	8.01	**20.1**	**1.2**	19.6	20	<0.05	**145**
Guidelines	ISQG		5.9	0.6	35.7	35	0.17	123
	PEL		17.0	3.5	197.0	91	0.49	315

Note: ISQG = Interim Freshwater Sediment Quality Guidelines, in **red** where exceeded.
PEL = Probable Effects Level (>50% of adverse effects occur above this level), shaded where exceeded.

Table 6 Stream sediment metal concentrations (ppm) from various sites in the Keno Valley area.

SITE	YEAR	Arsenic	Cadmium	Lead	Zinc
KV6	2004	1,623	145	4,067	12,140
	2005	1,387	130	7,700	8,337
	2007	284	28	954	1,483
	2009	32	3	73	237
	2010	1,030	91	4,130	5,820
KV7	2004	83	21	413	3,130
	2005	185	41	902	4,710
	2007	35	4	56	404
	2009	194	32	1,040	4,330
	2010	121	19	453	2,010
KV41	2004	35	4	77	226
	2005	51	3	72	228
	2007	62	3	82	247
	2009	18	1	19	74
	2010	35	1	42	146

Table 7 Metal concentrations in blueberries from various Yukon sites, 1993 to 2010.

SITE	YEAR	Arsenic	Cadmium	Lead	Zinc
KV6	2010	0.08	0.38	0.04	32.3
KV7	2010	0.07	0.52	0.03	30.8
Mt. Nansen	1984	N.D.	---	---	---
Mt. Nansen	2001	0.04	---	---	---
Mt. Nansen	2001	0.09	---	---	---
Mt. Nansen	2001	N.D.	---	---	---
Haines Junction	1995	N.D.	0.02	0.14	14
Ross River	1993	N.D.	N.D.	N.D.	36.2
Ross River	1993	N.D.	0.355	N.D.	14.2
Watson Lake	1993	N.D.	N.D.	N.D.	15.7
Watson Lake	1995	N.D.	N.D.	0.08	8.8
Watson Lake	1993	N.D.	N.D.	N.D.	44.3
Watson Lake	1993	N.D.	N.D.	N.D.	21.5
Whitehorse	1995	N.D.	N.D.	0.67	10.5
Whitehorse	1995	N.D.	0.04	0.04	11.5
Whitehorse	1995	N.D.	0.08	<0.01	12.8

Table 8 Metal concentrations (ppm) in various fruit juice concentrates.

METAL	N	RANGE	MEAN
Arsenic	134	0.005 to 0.65	0.08
Cadmium	75	0.002 to 0.09	0.01
Lead	117	0.002 to 0.23	0.04
Zinc	184	0.11 to 12.16	3.28

Table 9 Metal concentrations (ppm) in willow leaves (*Salix sp*) in the Keno Valley area.

	SITE	YEAR	ARSENIC	CADMIUM	LEAD	ZINC
REFERENCE SITES	**Williams Creek**	2010	0.15	0.98	0.08	160
	No Cash Creek	2003	<2	<0.05	<0.5	203
	Silver King	2003	<2	<0.05	<0.5	207
EXPOSED SITES	**KV-7**	2010	0.15	9.58	0.33	681
	No Cash Creek Sites	2003	<2	35.4	<0.5	2150
		2003	<2	33.3	<0.5	1730
		2003	<2	28.2	<0.5	1580
		2003	<2	6.49	<0.5	992
	Silver King Sites	2003	<2	33.6	<0.5	1220
		2003	<2	40.4	<0.5	1260
		2003	2	0.709	<0.5	442

Table 10 Metal concentrations (ppm) in willow (*Salix sp*) twigs at various sites in the Keno Valley area.

SITE	YEAR	ARSENIC	CADMIUM	LEAD	ZINC
WILC	2010	0.16	0.91	0.06	130
KV-7	2010	0.08	8.24	0.38	330
NCC1	2003	<2	15.1	2	558
NCC2	2003	<2	12	0.59	364
NCC3	2003	<2	10	1.2	418
NCC4	2003	<2	2.74	<0.5	270
NCC Control	2003	<2	<0.05	3.3	191
SKT1	2003	<2	30.1	0.61	628
SKT2	2003	<2	14.9	<0.5	467
SKT3	2003	<2	0.941	<0.5	314
SKT Control	2003	<2	3.21	<0.5	209
Teslin	1995	<0.01	3.98	0.21	892
Watson Lake	1995	0.0637	5.78	0.294	191
Watson Lake	1994	<1	<0.1	<0.5	30.4
Watson Lake	1995	0.0183	10.2	0.038	193
Watson Lake	1995	1.02	3.52	0.025	200
Watson Lake	1994	<1	0.6	<0.5	86.3
Watson Lake	1994	<1	0.4	<0.5	91.2
Watson Lake	1994	<1	0.1	<0.5	93.1
Watson Lake	1994	<1	0.9	<0.5	55.4
Watson Lake	1995	0.0227	2.52	<0.01	137
Watson Lake	1995	0.0335	0.366	<0.01	141
Watson Lake	1995	0.0616	4.17	0.078	155
Watson Lake	1995	0.0431	5.49	0.057	201
Watson Lake	1995	<0.01	21.6	0.013	207
Watson Lake	1995	0.0159	2.4	0.031	105

Table 11 Metrics derived from analysis of collected benthic samples collected at sites in the Keno Valley area during July of 2010. All sites were treated as test sites for comparison to reference sites in the Yukon CABIN database.

PARAMETER	REFERENCE SITES MEAN	SAMPLE SITE						
		Christal Creek Drainage			Duncan Creek Drainage			
		KV6	C@PM	KV7	KV41	LTG1	WILC	DC@B
Total Number of Taxa Present	11.4	12.0	12.0	14.0	11.0	15.0	11.0	21.0
Shannon Weiner Diversity	1.44	1.59	1.66	1.67	0.87	1.56	1.70	2.52
EPT Taxa (number)	5.4	5.0	9.0	9.0	7.0	9.0	6.0	9.0
% of Dominant Taxa	52.1	45.8	32.9	37.2	80.2	55.8	36.7	16.4
% of 2nd Dominant Taxa	70.9	68.0	62.1	56.5	86.9	72.0	58.3	30.8

Table 12 Aquatic habitat characteristics determined at sites in the Keno Valley area during July of 2010.

PARAMETER		SAMPLE SITE						
		Christal Creek Drainage			Duncan Creek Drainage			
		KV6	C@PM	KV7	KV41	LTG1	WILC	DC@B
SITE	Survey Date	July 13, 2010	July 15, 2010	July 13, 2010	July 14, 2010	July 14, 2010	July 15, 2010	July 16, 2010
	Site Elevation (m)	859	724	685	943	856	775	673
	Latitude & Longitude	63.92231 -135.3254	63.95081 -135.3905	63.95808 -135.4348	63.90794 -135.2956	63.89381 -135.3484	63.83720 -135.4691	63.78419 -135.5035
CHANNEL	Ave. Channel Width (m)	2.2	4.9	3.1	8.0	4.6	1.9	20.1
	Ave. Wetted Width (m)	1.7	3.6	2.8	6.1	4.4	1.7	11.8
	Max. Channel Depth (m)	0.36	0.29	0.22	0.28	0.29	0.16	0.38
	Stage	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
	Gradient (%)	1.7	2.3	1.0	1.9	1.3	2.3	1.3
COVER	Canopy Coverage (%)	76-100	26-50	51-75	1-25	1-25	51-75	1-25
	Dominant Bank Vegetation	Shrubs	Shrubs	Shrubs	Shrubs	Shrubs	Shrubs	Shrubs
	Riffle in Reach	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Rapid in Reach	No	Yes	Yes	Yes	No	No	Yes
	Straight Run in Reach	No	Yes	No	Yes	Yes	Yes	Yes
	Pool in Reach	No	No	Yes	No	Yes	No	No
	Instream Vegetation	None	None	None	None	None	None	None
MORPHOLOGY	Dominant Bed Material (cm)	3.2-6.4	3.2-6.4	1.6-3.2	6.4-12.8	3.2-6.4	6.4-12.8	6.4-12.8
	Subdominant Bed Material (cm)	1.6-3.2	6.4-12.8	3.2-6.4	1.6-3.2	6.4-12.8	3.2-6.4	3.2-6.4
	Surrounding Material (cm)	<0.1	0.2-1.6	<0.1	0.1-0.2	<0.1	<0.1	<0.1
	Embeddedness	0.25	0.50	0.25	0.25	0.25	0.25	0.25
	Periphyton (mm)	0.5-1	0.5-1	0.5-1	0.5-1	0.5-1	0.5-1	5-20

Table 13 Summary of sampling effort and total catch using two fish capture methods at sites in the Christal Creek and Duncan Creek drainage basins during August of 2010.

SAMPLE SITE		CAPTURE METHOD	SAMPLE EFFORT	CATCH		OBSERVATIONS
				AG	SS	
Christal Creek	KV6	MNT	25.0 hrs	0	13	
	KV6	Electro	179 sec	0	26	5 sculpin
	KV7	MNT	22.5 hrs	0	0	
	KV7	Electro	729 sec	1	0	
Duncan Creek	KV41	MNT	31.0 hrs	0	0	
	KV41	Electro	547 sec	2	0	
	LTG1	MNT	26.7 hrs	0	7	
	LTG1	Electro	615 sec	1	1	
	WILC	Electro	482 sec	0	0	
	DC#B	MNT	19.7 hrs	0	9	
	DC#B	Electro	653 sec	1	23	24 sculpin and fry

Legend: MNT = Minnow trap (5 traps)
Electro = Electrofisher

Table 14 Comparison of total fish catches at fish sampling sites in the Christal Creek and Duncan Creek drainage basins during August of 2010.

SPECIES	SAMPLE SITE					
	Christal Creek Drainage		Duncan Creek Drainage			
	KV6	KV7	KV41	LTG1	WILC	DC@B
Arctic grayling	0	1	2	1	0	1
Slimy sculpin	39	0	0	8	0	32

Table 15 Summary of fish total metal concentrations (ug/g wet weight) in fish from sites in the Keno Valley area during July of 2010.

SAMPLE SITE		Species (N)	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Zinc
Christal Creek	KV7	Arctic grayling (1)	0.12	0.04	<0.50	0.07	<0.020	1.00	13.90
	KV6	Slimy sculpin (3)	0.95	0.44	0.80	**5.66**	<0.010	0.80	42.60
Duncan Creek	KV41	Arctic grayling (2)	0.06	<0.01	<0.50	0.06	0.020	1.27	14.90
	LTG1	Arctic grayling (1)	0.07	0.02	0.50	0.09	0.020	1.71	18.50
	LTG1	Slimy sculpin (2)	0.37	0.14	0.80	0.21	0.015	1.56	30.55
	DC@B	Slimy sculpin (2)	0.36	0.48	1.30	0.13	0.040	0.99	43.90
NCP Database Slimy Sculpin	Maximum		**10.20**	1.03	27.60	**29.40**	0.170	9.00	187.10
	Average (N)		1.90 (72)	0.16 (72)	1.60 (72)	**2.40** (72)	0.020 (62)	1.70 (57)	42.20 (72)
USGS Database Freshwater Fish	Maximum		1.95	1.49	1.49	-	**0.650**	0.85	56.40
	Average (N)		2.10 (31)	0.07 (9)	0.70 (31)	<0.27	0.240 (31)	0.51 (31)	34.80 (31)
CCME guideline			-	-	-	-	0.033[a]	-	-
CFIA guideline			3.50[b]	-	-	0.50[b]	0.500[b]	-	-

NCP = DIAND, Northern Contaminants Program Yukon Database for slimy sculpin;
USGS = US Geological Survey – Biomonitoring of Environmental Status and Trends (BEST) Large Rivers Monitoring Network – Database for freshwater fish;
CCME = Canadian Council of Ministers of the Environment, Canadian Guidelines for the Protection of Wildlife Consumers of Aquatic Biota – [a] MeHg Tissue Residue Guideline, in shaded where exceeded;
CFIA = Canadian Food Inspection Agency, Canadian Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products – [b] for all freshwater fish products, in red where exceeded.

APPENDIX I

WATER QUALITY ANALYSIS

LOW LEVEL DISSOLVED METALS IN WATER (WATER) – COC Number 8319251 – Maxxam Job #:B059186 – Report Date 2010/08/10

Maxxam ID		**V53753**	**V53754**	**V53755**	**V53756**	**V53757**	**V53758**	**V53759**	**V53760**	**V53761**	**V53762**	
Sampling Date		**10-07-16 17:30**	**10-07-13 16:15**	**10-07-14 17:15**	**10-07-15 10:30**	**10-07-15 12:30**	**10-07-13 11:15**	**10-07-15 9:45**	**10-07-14 14:10**	**10-07-15 14:30**	**10-07-15 17:00**	
	Units	**DCR Seep**	**KV6**	**KV6TRIB**	**C@PM**	**PMRDTRIB**	**KV-7**	**KV41**	**LTG1**	**WILC**	**DC@B**	**RDL**
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	N/A
Misc. Inorganics												
Dissolved Hardness (CaCO3)	mg/L	249	422	178	301	163	301	85.5	92.6	166	138	0.5
Dissolved Metals by ICPMS												
Dissolved Aluminum (Al)	ug/L	1.9	9.7	14.1	5.5	5.5	4.2	3.2	5.2	14.0	99.8	0.2
Dissolved Antimony (Sb)	ug/L	0.94	0.34	0.16	0.27	0.12	0.25	0.27	0.26	0.97	0.44	0.02
Dissolved Arsenic (As)	ug/L	30.4	3.48	1.16	2.09	1.10	1.96	1.35	1.21	3.94	0.74	0.02
Dissolved Barium (Ba)	ug/L	25.4	49.3	40.0	49.6	36.7	48.8	45.2	44.8	42.9	45.7	0.02
Dissolved Beryllium (Be)	ug/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Dissolved Bismuth (Bi)	ug/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.084	<0.005	<0.005	0.005
Dissolved Boron (B)	ug/L	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	50
Dissolved Cadmium (Cd)	ug/L	1.12	0.930	0.016	0.563	0.006	0.412	0.191	0.133	0.010	0.335	0.005
Dissolved Chromium (Cr)	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Dissolved Cobalt (Co)	ug/L	3.91	0.108	0.234	0.100	0.025	0.061	0.018	0.064	0.039	1.86	0.005
Dissolved Copper (Cu)	ug/L	0.07	0.38	1.01	0.64	1.09	0.63	0.47	1.01	1.05	1.86	0.05
Dissolved Iron (Fe)	ug/L	2320	42	137	55	19	39	4	19	134	47	1
Dissolved Lead (Pb)	ug/L	0.031	0.802	0.128	0.379	0.032	0.241	0.016	0.175	0.041	0.035	0.005
Dissolved Lithium (Li)	ug/L	12.3	12.1	7.2	5.6	0.6	5.9	1.5	1.6	1.3	5.1	0.5
Dissolved Manganese (Mn)	ug/L	720	186	204	112	2.66	63.1	10.6	36.3	9.29	31.6	0.05
Dissolved Molybdenum (Mo)	ug/L	0.33	0.27	0.50	0.42	0.32	0.40	0.20	0.20	0.23	0.23	0.05

Maxxam ID		V53753	V53754	V53755	V53756	V53757	V53758	V53759	V53760	V53761	V53762	
Sampling Date		10-07-16 17:30	10-07-13 16:15	10-07-14 17:15	10-07-15 10:30	10-07-15 12:30	10-07-13 11:15	10-07-15 9:45	10-07-14 14:10	10-07-15 14:30	10-07-15 17:00	
	Units	DCR Seep	KV6	KV6TRIB	C@PM	PMRDTRIB	KV-7	KV41	LTG1	WILC	DC@B	RDL
Dissolved Nickel (Ni)	ug/L	7.71	1.97	1.42	1.18	0.69	1.02	0.42	0.56	0.90	12.2	0.02
Dissolved Selenium (Se)	ug/L	<0.04	0.79	0.11	0.73	0.06	0.73	0.68	0.57	0.12	0.89	0.04
Dissolved Silicon (Si)	ug/L	5530	2360	2960	2790	1730	2710	2640	2490	3260	2550	100
Dissolved Silver (Ag)	ug/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Dissolved Strontium (Sr)	ug/L	168	227	91.6	201	96.8	205	73.8	85.1	226	171	0.05
Dissolved Thallium (Tl)	ug/L	0.049	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Dissolved Tin (Sn)	ug/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Dissolved Titanium (Ti)	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Dissolved Uranium (U)	ug/L	0.120	3.46	0.885	1.86	0.638	1.76	0.172	0.294	1.43	0.795	0.002
Dissolved Vanadium (V)	ug/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
Dissolved Zinc (Zn)	ug/L	157	138	3.4	94.1	2.5	69.8	27.4	19.6	1.6	17.3	0.1
Dissolved Zirconium (Zr)	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1
Dissolved Calcium (Ca)	mg/L	77.5	129	61.4	90.2	43.3	89.8	26.2	27.9	47.6	40.1	0.05
Dissolved Magnesium (Mg)	mg/L	13.6	24.4	5.87	18.5	13.3	18.6	4.86	5.53	11.4	9.30	0.05
Dissolved Potassium (K)	mg/L	0.33	0.18	0.08	0.26	<0.05	0.27	0.15	0.16	0.26	0.26	0.05
Dissolved Sodium (Na)	mg/L	1.38	1.45	0.90	1.28	0.58	1.28	0.70	0.72	1.23	0.88	0.05
Dissolved Sulphur (S)	mg/L	59	124	24	64	11	65	16	16	<10	21	10

RDL = Reportable Detection Limit;   EDL = Estimated Detection Limit

LOW LEVEL TOTAL METALS IN WATER (WATER) – COC Number 8319251 – Maxxam Job #: B059186 – Report Date: 2010/08/10

Maxxam ID		**V53753**	**V53754**	**V53755**	**V53756**	**V53757**	**V53758**	**V53759**	**V53760**	**V53761**	**V53762**	
Sampling Date		**10-07-16 17:30**	**10-07-13 16:15**	**10-07-14 17:15**	**10-07-15 10:30**	**10-07-15 12:30**	**10-07-13 11:15**	**10-07-15 9:45**	**10-07-14 14:10**	**10-07-15 14:30**	**10-07-15 17:00**	
Calculated Parameters	**Units**	**DCR Seep**	**KV6**	**KV6TRIB**	**C@PM**	**PMRDTRIB**	**KV7**	**KV41**	**LTG1**	**WILC**	**DC@B**	**RDL**
Total Hardness (CaCO3)	mg/L	247	443	180	304	168	298	85.2	84.3	169	134	0.5
Total Metals by ICPMS												
Total Aluminum (Al)	ug/L	79.6	8.7	378	32.5	5.6	16.1	123	132	19.3	377	0.2
Total Antimony (Sb)	ug/L	1.03	0.38	0.17	0.25	0.12	0.24	0.27	0.28	0.93	0.47	0.02
Total Arsenic (As)	ug/L	35.4	5.05	3.05	2.84	1.12	2.21	1.87	1.95	4.24	1.08	0.02
Total Barium (Ba)	ug/L	29.5	47.3	62.8	49.0	35.5	47.5	50.9	49.2	41.9	46.5	0.02
Total Beryllium (Be)	ug/L	0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Total Bismuth (Bi)	ug/L	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Total Boron (B)	ug/L	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	50
Total Cadmium (Cd)	ug/L	1.34	1.18	0.141	0.699	<0.005	0.491	0.256	0.213	0.023	0.501	0.005
Total Chromium (Cr)	ug/L	0.1	<0.1	0.4	<0.1	<0.1	<0.1	0.2	0.3	<0.1	<0.1	0.1
Total Cobalt (Co)	ug/L	4.29	0.127	1.11	0.185	0.029	0.093	0.189	0.215	0.043	2.10	0.005
Total Copper (Cu)	ug/L	1.10	0.47	3.69	1.01	1.04	0.67	1.20	1.33	1.13	3.55	0.05
Total Iron (Fe)	ug/L	2960	180	1250	181	23	110	127	168	181	296	1
Total Lead (Pb)	ug/L	0.831	9.62	4.74	1.95	0.028	1.05	1.72	1.45	0.078	0.368	0.005
Total Lithium (Li)	ug/L	12.2	12.0	7.5	5.3	0.6	5.7	1.5	1.8	1.2	4.9	0.5
Total Manganese (Mn)	ug/L	747	215	277	141	3.08	75.5	23.6	47.0	13.0	37.5	0.05
Total Molybdenum (Mo)	ug/L	0.30	0.21	0.35	0.37	0.27	0.38	0.13	0.21	0.23	0.18	0.05

Maxxam ID		**V53753**	**V53754**	**V53755**	**V53756**	**V53757**	**V53758**	**V53759**	**V53760**	**V53761**	**V53762**	
Sampling Date		**10-07-16 17:30**	**10-07-13 16:15**	**10-07-14 17:15**	**10-07-15 10:30**	**10-07-15 12:30**	**10-07-13 11:15**	**10-07-15 9:45**	**10-07-14 14:10**	**10-07-15 14:30**	**10-07-15 17:00**	
Calculated Parameters	**Units**	**DCR Seep**	**KV6**	**KV6TRIB**	**C@PM**	**PMRDTRIB**	**KV7**	**KV41**	**LTG1**	**WILC**	**DC@B**	**RDL**
Total Nickel (Ni)	ug/L	8.70	1.98	3.79	1.43	0.62	1.07	0.82	0.89	0.93	13.3	0.02
Total Selenium (Se)	ug/L	<0.04	0.90	0.13	0.71	0.06	0.69	0.66	0.50	0.11	0.86	0.04
Total Silicon (Si)	ug/L	5820	2670	3290	2820	1790	2810	2770	2330	3530	2680	100
Total Silver (Ag)	ug/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.016	<0.005	<0.005	0.005
Total Strontium (Sr)	ug/L	166	223	90.7	197	95.0	198	73.1	84.9	225	169	0.05
Total Thallium (Tl)	ug/L	0.054	0.006	0.006	0.002	<0.002	0.002	<0.002	0.004	<0.002	<0.002	0.002
Total Tin (Sn)	ug/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total Titanium (Ti)	ug/L	4.0	<0.5	9.8	1.2	<0.5	<0.5	2.4	4.6	0.5	1.0	0.5
Total Uranium (U)	ug/L	0.146	3.34	1.12	1.81	0.610	1.78	0.211	0.324	1.49	0.881	0.002
Total Vanadium (V)	ug/L	0.2	<0.2	1.7	<0.2	<0.2	<0.2	0.2	0.3	<0.2	<0.2	0.2
Total Zinc (Zn)	ug/L	142	151	15.2	107	1.8	71.9	36.7	25.5	1.6	41.0	0.1
Total Zirconium (Zr)	ug/L	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1
Total Calcium (Ca)	mg/L	76.0	138	62.3	90.0	45.1	88.8	25.6	24.2	48.7	38.3	0.05
Total Magnesium (Mg)	mg/L	14.0	24.0	5.98	19.2	13.6	18.4	5.19	5.79	11.6	9.36	0.05
Total Potassium (K)	mg/L	0.33	0.16	0.07	0.27	<0.05	0.26	0.17	0.18	0.26	0.25	0.05
Total Sodium (Na)	mg/L	1.43	1.43	0.76	1.33	0.57	1.26	0.75	0.74	1.23	0.80	0.05
Total Sulphur (S)	mg/L	58	125	23	64	12	65	16	17	<10	21	10

RDL = Reportable Detection Limit; EDL = Estimated Detection Limit

RESULTS OF CHEMICAL ANALYSES OF WATER – COC Number 8319251 – Maxxam job #: B059186 – Report Date: 2010/08/10

Maxxam ID		V53753		V53754		V53755	V53756	V53757	V53758	V53759	V53760	V53761	V53762	
Sampling Date		**10-07-16 17:30**		**10-07-13 16:15**		**10-07-14 17:15**	**10-07-15 10:30**	**10-07-15 12:30**	**10-07-13 11:15**	**10-07-15 9:45**	**10-07-14 14:10**	**10-07-15 14:30**	**10-07-15 17:00**	
ANIONS	**Units**	**DCR Seep**	**RDL**	**KV6**	**RDL**	**KV6 TRIB**	**C@PM**	**PMRD TRIB**	**KV7**	**KV41**	**LTG1**	**WILC**	**DC@B**	**RDL**
Nitrite (N)	mg/L	<0.005 (1)	0.005	<0.005 (2)	0.005	<0.005 (2)	<0.005 (2)	<0.005 (2)	<0.005 (2)	<0.005 (2)	<0.005 (2)	<0.005 (2)	<0.005 (2)	0.005
Calculated Parameters														
Nitrate (N)	mg/L	<0.02	0.02	0.09	0.02	<0.02	0.06	<0.02	0.06	0.13	0.10	<0.02	0.07	0.02
Misc. Inorganics														
Alkalinity (Total as CaCO3)	mg/L	99	0.5	98	0.5	130	130	140	130	44	50	150	85	0.5
Alkalinity (PP as CaCO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Bicarbonate (HCO3)	mg/L	120	0.5	120	0.5	150	160	180	160	54	61	180	100	0.5
Carbonate (CO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Hydroxide (OH)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Anions														
Dissolved Sulphate (SO4)	mg/L	140	0.5	290	5	57	160	28	160	43	45	27	52	0.5
Nutrients														
Nitrate plus Nitrite (N)	mg/L	<0.02 (1)	0.02	0.09 (2)	0.02	<0.02 (2)	0.06 (2)	<0.02 (2)	0.06 (2)	0.13 (2)	0.10 (2)	<0.02 (2)	0.07 (2)	0.02
Total Phosphorus (P)	mg/L	0.009	0.005	0.006	0.005	0.009	<0.005	<0.005	0.009	0.009	0.008	0.009	<0.005	0.005
Physical Properties														
Conductivity	uS/cm	485	1	764	1	351	548	317	572	188	204	309	273	1
pH	pH Units	7.82		8.11		8.17	8.24	8.19	8.08	7.79	7.84	8.27	8.08	
Physical Properties														
Total Suspended Solids	mg/L	26	1	2	1	61	5	<1	2	10	7	<1	5	1
Total Dissolved Solids	mg/L	330	10	600	10	230	410	210	400	110	130	210	170	10

RDL = Reportable Detection Limit; EDL = Estimated Detection Limit
(1) Sample analysed past recommended hold time; (2) Samples arrived to laboratory past recommended hold time.

APPENDIX II

STREAM SEDIMENT ANALYSIS

CSR/CCME METALS IN SOIL (SOIL) – COC Number 8319252 – Maxxam Job #: B059186 – Report Date: 2010/08/10

Maxxam ID		**V53763**	**V53764**	**V53765**	**V53766**	**V53767**	**V53768**	**V53769**	
Sampling Date		**10-07-13 17:30**	**10-07-15 0:00**	**10-07-13 13:07**	**10-07-14 18:20**	**10-07-14 18:40**	**10-07-15 18:55**	**10-07-15 12:05**	
Misc. Inorganics	**Units**	**KV6**	**C@PM**	**KV7**	**KV41**	**LTG1**	**WILC**	**DC@B**	**RDL**
Soluble (2:1) pH	pH Units	7.51	8.05	7.97	7.71	7.62	8.02	8.01	0.01
Total Metals by ICPMS									
Total Aluminum (Al)	mg/kg	5880	6130	6000	5280	5350	5850	5980	100
Total Antimony (Sb)	mg/kg	96.2	4.9	9.5	1.9	1.8	2.1	1.7	0.1
Total Arsenic (As)	mg/kg	1030	72.9	121	34.8	25.2	28.1	20.1	0.2
Total Barium (Ba)	mg/kg	185	188	244	96.1	98.0	131	90.7	0.1
Total Beryllium (Be)	mg/kg	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Total Bismuth (Bi)	mg/kg	0.3	0.1	0.2	<0.1	<0.1	<0.1	0.1	0.1
Total Cadmium (Cd)	mg/kg	91.4	6.37	18.8	1.37	1.01	0.28	1.20	0.05
Total Calcium (Ca)	mg/kg	5850	11300	11200	2440	2610	3180	2930	100
Total Chromium (Cr)	mg/kg	12	12	11	12	11	9	9	1
Total Cobalt (Co)	mg/kg	12.9	8.7	13.0	6.3	5.9	5.2	10.3	0.3
Total Copper (Cu)	mg/kg	67.6	25.1	32.2	21.9	20.2	9.2	19.6	0.5
Total Iron (Fe)	mg/kg	43800	19100	24200	15900	14200	12800	15200	100
Total Lead (Pb)	mg/kg	4130	198	453	41.5	31.9	12.2	19.9	0.1
Total Magnesium (Mg)	mg/kg	3300	5600	5500	2530	2590	2490	2790	100
Total Manganese (Mn)	mg/kg	16000	2000	7560	373	328	518	391	0.2
Total Mercury (Hg)	mg/kg	0.18	<0.05	<0.05	<0.05	<0.05	0.13	<0.05	0.05
Total Molybdenum (Mo)	mg/kg	1.8	1.1	1.9	0.8	0.8	0.3	0.7	0.1
Total Nickel (Ni)	mg/kg	32.8	23.0	38.4	17.4	16.1	11.4	29.3	0.8
Total Phosphorus (P)	mg/kg	772	885	908	682	659	554	593	10
Total Potassium (K)	mg/kg	249	272	245	186	215	219	197	100
Total Selenium (Se)	mg/kg	1.5	0.9	1.2	<0.5	<0.5	<0.5	<0.5	0.5
Total Silver (Ag)	mg/kg	66.5	2.21	5.51	0.60	0.56	0.14	0.19	0.05
Total Sodium (Na)	mg/kg	<100	<100	<100	<100	<100	<100	<100	100
Total Strontium (Sr)	mg/kg	19.8	33.4	34.6	12.3	13.5	22.0	15.5	0.1
Total Thallium (Tl)	mg/kg	0.08	0.06	0.07	<0.05	<0.05	<0.05	<0.05	0.05
Total Tin (Sn)	mg/kg	2.2	0.3	0.9	0.4	0.2	0.2	1.9	0.1
Total Titanium (Ti)	mg/kg	88	121	88	145	147	78	87	1
Total Vanadium (V)	mg/kg	16	18	17	19	18	14	13	2
Total Zinc (Zn)	mg/kg	5820	698	2010	146	124	51	145	1
Total Zirconium (Zr)	mg/kg	0.6	0.7	0.7	0.8	0.8	<0.5	0.6	0.5

RDL = Reportable Detection Limit; EDL = Estimated Detection Limit

Appendix II Stream Sediment Analysis

APPENDIX III

VEGETATION ANALYSIS

ELEMENTS BY ATOMIC SPECTROSCOPY (TISSUE (PLANT)) – COC Number 8319253 – Maxxam Job #: B059186 – Report Date: 2010/08/10

Maxxam ID		V53777	V53778	V53779	V53780	V53781	V53782	
Sampling Date		10-07-13 17:30	10-07-13 13:00	10-07-13 13:00	10-07-13 13:00	10-07-15 15:30	10-07-15 15:30	
Total Metals by ICPMS	**Units**	**KV6 BLUEBERRIES**	**KV7 BLUEBERRIES**	**KV7 WILLOW LEAVES**	**KV7 WILLOW TWIGS**	**WILC WILLOW LEAVES**	**WILC WILLOW TWIGS**	**RDL**
Total Aluminum (Al)	mg/kg	47	46	10	5	16	14	1
Total Antimony (Sb)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Arsenic (As)	mg/kg	0.08	0.07	0.15	0.08	0.15	0.16	0.01
Total Barium (Ba)	mg/kg	4.6	9.5	5.6	6.3	10.1	12.7	0.1
Total Beryllium (Be)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Bismuth (Bi)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Boron (B)	mg/kg	15	21	23	20	16	17	5
Total Cadmium (Cd)	mg/kg	0.38	0.52	9.58	8.24	0.98	0.91	0.01
Total Calcium (Ca)	mg/kg	1710	1390	11400	5740	10700	5070	10
Total Chromium (Cr)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Total Cobalt (Co)	mg/kg	<0.1	<0.1	0.2	<0.1	1.0	0.3	0.1
Total Copper (Cu)	mg/kg	4.8	4.5	5.6	5.2	4.9	6.5	0.5
Total Iron (Fe)	mg/kg	14	10	51	25	113	53	10
Total Lead (Pb)	mg/kg	0.04	0.03	0.33	0.38	0.08	0.06	0.01
Total Magnesium (Mg)	mg/kg	580	611	2800	1280	2920	1080	10
Total Manganese (Mn)	mg/kg	21.5	39.9	75.1	41.0	511	154	0.1
Total Mercury (Hg)	mg/kg	<0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01
Total Molybdenum (Mo)	mg/kg	<0.1	<0.1	0.3	0.1	0.2	<0.1	0.1
Total Nickel (Ni)	mg/kg	1.4	0.7	3.0	1.2	1.3	1.0	0.1
Total Phosphorus (P)	mg/kg	1140	1410	1510	1220	2290	2110	10
Total Potassium (K)	mg/kg	4900	6390	14600	8360	8210	7680	10
Total Selenium (Se)	mg/kg	0.04	<0.01	0.23	0.13	0.08	0.06	0.01
Total Silver (Ag)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Sodium (Na)	mg/kg	<10	<10	<10	<10	<10	<10	10
Total Strontium (Sr)	mg/kg	3.0	2.5	19.4	13.4	40.4	26.7	0.1
Total Thallium (Tl)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Tin (Sn)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Titanium (Ti)	mg/kg	<1	<1	<1	<1	<1	<1	1
Total Uranium (U)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Vanadium (V)	mg/kg	<2	<2	<2	<2	<2	<2	2
Total Zinc (Zn)	mg/kg	32.3	30.8	681	330	160	130	0.1

RDL = Reportable Detection Limit; EDL = Estimated Detection Limit

APPENDIX IV

BENTHIC SORTING RESULTS

Classification	Site:	KV6	KV7	KV41	C@PM	LTG1	DC@B	WILC
	Subsample:	**4/100**	**6/100**	**9/100**	**10/100**	**9/100**	**13/100**	**8/100**
Order: Ephemeroptera								
Family: Ameletidae								
Ameletus sp.	nymph		1		3	1	3	1
Family: Baetidae								
Acentrella sp.	nymph						2	
Baetis sp.	nymph	1	3	1			2	23
Baetis bicaudatus	nymph			12		5		108
Family: Ephemerellidae	nymph (juv./dam.)						1	
Drunella coloradensis	nymph					1		
Drunella doddsi	nymph					6	9	
Family: Heptageniidae	nymph (juv./dam.)		3	8		1	21	4
Cinygmula sp.	nymph				1	5	3	4
Epeorus sp.	nymph		1	14		3	2	6
Order: Plecoptera	nymph (juv./dam.)		1			1		
Family: Capniidae	nymph (juv./dam.)	1	1		1	1	26	18
Family: Chloroperlidae								
Suwallia sp.	nymph			2	1	5	33	
Family: Nemouridae								
Podmosta sp.	nymph							76
Zapada sp.	nymph	37	53	2	89	22	44	1
Zapada oregonensis group	nymph			3	3			
Family: Perlodidae	nymph (juv./dam.)	5	2	2	6		22	
Isoperla sp.	nymph	3					2	
Megarcys sp.	nymph			1	1			
Family: Taeniopterygidae	nymph (juv./dam.)			1	1			
Order: Trichoptera	larvae (juv./dam.)			1				
Family: Glossosomatidae								
Glossosoma sp.	larvae		1		2	1		

Appendix IV Benthic Sorting Results

Classification	Site:	KV6	KV7	KV41	C@PM	LTG1	DC@B	WILC
	Subsample:	**4/100**	**6/100**	**9/100**	**10/100**	**9/100**	**13/100**	**8/100**
Family: Limnephilidae	larvae (juv./dam.)		1					
Family: Rhyacophilidae								
Rhyacophila sp.	larvae	5	13	8	21	19	3	1
Order: Diptera								
Family: Ceratopogonidae								
Ceratopogon sp.	larvae						1	
Mallochohelea sp.	larvae						1	
Probezzia sp.	larvae						1	
Family: Chironomidae	pupae	5	19	38	9	15	3	1
Family: Chironomidae	larvae							12
Subfamily : Orthocladiinae								
Cricotopus/Orthocladius		5	13	2	10	36	13	3
Eukiefferiella sp.		59	32			18	6	6
Heleniella sp.		2						
Rheocricotopus sp.					3			
Tvetenia sp.								1
Subfamily : Diamesinae								
Diamesa sp.				224	30	120	25	
Pagastia sp.							3	
Family: Deuterophlebiidae								
Deuterophlebia sp.	larvae			3				
Family: Dixidae								
Dixella sp.	larvae	1						
Family: Empididae								
Chelifera/Metachela sp.	larvae	11	2		16	8	3	
Clinocera sp.	larvae			6	1	9	2	1
Oreogeton sp.	larvae			1		1		1
Family: Psychodidae UID	larvae						1	
Family: Simuliidae	pupae	5	7		4			

Classification	Site:	KV6	KV7	KV41	C@PM	LTG1	DC@B	WILC
	Subsample:	**4/100**	**6/100**	**9/100**	**10/100**	**9/100**	**13/100**	**8/100**
Family: Simuliidae	larvae (juv./dam.)	2			7			
Prosimulium sp.	larvae	12	115	1	71	1		65
Simulium sp.	larvae	13	1				20	8
Family: Tipulidae	larvae (juv./dam.)	2						
Dicranota sp.	larvae		1					
Limnophila sp.	larvae	1						
Rhabdomastix sp.	larvae						1	
Order: Collembola								
Family: Poduridae	larvae						1	1
Super-Order: Acariformes	deutonymph	1			1	2	8	
Family: Aturidae								
Aturus sp.	adult						4	
Family: Feltriidae								
Feltria sp.	adult						3	
Family: Hydrozetidae	adult	3				1	1	1
Family: Hygrobatidae								
Hygrobates sp.	adult						4	
Family: Oxidae								
Oxus sp.	adult							
Family: Sperchontidae								
Sperchon sp.	adult					5	5	
Phylum: Annelida								
Class: Oligochaeta								
Family: Lumbriculidae		146	62			55	26	15
Rhynchelmis sp.							9	1
Sub-Family: Tubificinae				11	64			

APPENDIX V

CABIN ASSESSMENT REPORTS

Site Assessment Report

Site Metadata

Site	C@PM
Sample Date	Jul 15 2010
Latitude	N 63° 57' 2.9"
Longitude	W 135° 23' 25.7"
Altitude	2420
Feature Name	Christal Creek
Stream Order	2

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.95
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Potentially Stressed
Vector 2 Vs Vector 3	Unstressed
Overall	Potentially Stressed

Site Assessment Report

Site Metadata

Site	KV7
Sample Date	Jul 13 2010
Latitude	N 63° 57' 29.1"
Longitude	W 135° 26' 5.3"
Altitude	2248
Feature Name	Christal Creek
Stream Order	2

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.67
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Potentially Stressed
Vector 2 Vs Vector 3	Unstressed
Overall	Potentially Stressed

Site Assessment Report

Site Metadata

Site	KV6
Sample Date	Jul 13 2010
Latitude	N 63° 55' 20.3"
Longitude	W 135° 19' 31.6"
Altitude	2818
Feature Name	Christal Creek
Stream Order	1

Site Photograph

Down Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.87
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Potentially Stressed
Vector 1 Vs Vector 3	Potentially Stressed
Vector 2 Vs Vector 3	Unstressed
Overall	Potentially Stressed

Site Assessment Report

Site Metadata

Site	KV41
Sample Date	Jul 14 2010
Latitude	N 63° 54' 28.6"
Longitude	W 135° 17' 44.3"
Altitude	3094
Feature Name	Lightning Creek
Stream Order	4

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.93
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Unstressed
Vector 2 Vs Vector 3	Unstressed
Overall	Unstressed

Site Assessment Report

Site Metadata

Site	LTG1
Sample Date	Jul 14 2010
Latitude	N 63° 53' 37.7"
Longitude	W 135° 20' 54.4"
Altitude	2807
Feature Name	Lightning Creek
Stream Order	4

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.97
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Unstressed
Vector 2 Vs Vector 3	Unstressed
Overall	Unstressed

Site Assessment Report

Site Metadata

Site	WILC
Sample Date	Jul 15 2010
Latitude	N 63° 50' 13.9"
Longitude	W 135° 28' 8.6"
Altitude	2542
Feature Name	Williams Creek
Stream Order	3

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.97
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Unstressed
Vector 2 Vs Vector 3	Unstressed
Overall	Unstressed

Site Assessment Report

Site Metadata

Site	DC@B
Sample Date	Jul 16 2010
Latitude	N 63° 47' 3.1"
Longitude	W 135° 30' 12.6"
Altitude	2207
Feature Name	Duncan Creek
Stream Order	5

Site Photograph

Up Stream

Bray-Curtis Analysis

Description	Value
Bray-Curtis Distance	0.98
Bray Curtis Reference Median	2664.38

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Unstressed
Vector 1 Vs Vector 3	Unstressed
Vector 2 Vs Vector 3	Unstressed
Overall	Unstressed

Appendix VI

FISH CAPTURE DATA

Species	Sample Site	Length (mm)*	Weight (gms)	Notes
Arctic grayling	DC@B	91	8.5	
Arctic grayling	KV41	180	78.1	Metal Analysis
Arctic grayling	KV41	223	148.0	Metal Analysis
Arctic grayling	KV7	240	182.0	Metal Analysis
Arctic grayling	LTG1	142	39.8	Metal Analysis
Slimy sculpin	DC@B	29	0.5	
Slimy sculpin	DC@B	31	0.3	
Slimy sculpin	DC@B	32	0.4	
Slimy sculpin	DC@B	39	0.8	
Slimy sculpin	DC@B	41	0.9	
Slimy sculpin	DC@B	50	1.3	
Slimy sculpin	DC@B	50	1.2	
Slimy sculpin	DC@B	51	1.8	
Slimy sculpin	DC@B	51	1.3	
Slimy sculpin	DC@B	56	1.6	
Slimy sculpin	DC@B	57	1.8	
Slimy sculpin	DC@B	60	2.1	
Slimy sculpin	DC@B	63	2.1	
Slimy sculpin	DC@B	63	3.1	
Slimy sculpin	DC@B	66	2.6	
Slimy sculpin	DC@B	67	3.3	

Species	Sample Site	Length (mm)*	Weight (gms)	Notes
Slimy sculpin	DC@B	67	3.2	
Slimy sculpin	DC@B	67	3.4	
Slimy sculpin	DC@B	68	3.2	
Slimy sculpin	DC@B	69	3.8	
Slimy sculpin	DC@B	70	3.7	
Slimy sculpin	DC@B	71	4.2	
Slimy sculpin	DC@B	72	3.6	
Slimy sculpin	DC@B	74	3.9	
Slimy sculpin	DC@B	76	4.5	
Slimy sculpin	DC@B	77	5.5	
Slimy sculpin	DC@B	80	5.8	
Slimy sculpin	DC@B	80	5.5	Metal Analysis
Slimy sculpin	DC@B	80	5.3	
Slimy sculpin	DC@B	84	5.3	
Slimy sculpin	DC@B	85	5.1	
Slimy sculpin	DC@B	89	5.3	Metal Analysis
Slimy sculpin	KV6	36	0.6	
Slimy sculpin	KV6	36	0.7	
Slimy sculpin	KV6	37	0.7	
Slimy sculpin	KV6	37	0.5	
Slimy sculpin	KV6	38	0.7	

Species	Sample Site	Length (mm)*	Weight (gms)	Notes
Slimy sculpin	KV6	40	0.7	
Slimy sculpin	KV6	40	0.8	
Slimy sculpin	KV6	40	0.9	
Slimy sculpin	KV6	40	0.7	
Slimy sculpin	KV6	42	0.9	
Slimy sculpin	KV6	42	0.8	
Slimy sculpin	KV6	42	0.9	
Slimy sculpin	KV6	42	0.9	
Slimy sculpin	KV6	43	0.8	
Slimy sculpin	KV6	45	1.0	
Slimy sculpin	KV6	45	0.9	
Slimy sculpin	KV6	45	1.1	
Slimy sculpin	KV6	47	1.6	
Slimy sculpin	KV6	53	1.5	
Slimy sculpin	KV6	56	2.0	
Slimy sculpin	KV6	58	2.1	
Slimy sculpin	KV6	59	1.4	
Slimy sculpin	KV6	60	2.0	
Slimy sculpin	KV6	61	2.0	
Slimy sculpin	KV6	63	2.6	
Slimy sculpin	KV6	64	3.0	

Species	Sample Site	Length (mm)*	Weight (gms)	Notes
Slimy sculpin	KV6	68	3.0	
Slimy sculpin	KV6	69	2.3	
Slimy sculpin	KV6	71	4.2	
Slimy sculpin	KV6	82	6.3	
Slimy sculpin	KV6	85	8.2	
Slimy sculpin	KV6	88	8.1	
Slimy sculpin	KV6	91	8.0	
Slimy sculpin	KV6	96	9.2	
Slimy sculpin	KV6	100	11.8	
Slimy sculpin	KV6	105	12.8	Metal Analysis
Slimy sculpin	KV6	105	14.5	Metal Analysis
Slimy sculpin	KV6	105	14.7	Metal Analysis
Slimy sculpin	KV6	105	14.6	
Slimy sculpin	LTG1	72	4.1	Metal Analysis
Slimy sculpin	LTG1	80	6.4	
Slimy sculpin	LTG1	86	8.9	
Slimy sculpin	LTG1	93	9.7	
Slimy sculpin	LTG1	94	8.0	
Slimy sculpin	LTG1	94	8.9	
Slimy sculpin	LTG1	98	7.9	
Slimy sculpin	LTG1	100	11.5	Metal Analysis

APPENDIX VII

FISH TISSUE ANALYSIS

ELEMENTS BY ATOMIC SPECTROSCOPY (TISSUE ANIMAL) – COC Number 8319254 - Maxxam Job #: B059186 - Report Date: 2010/08/10

Maxxam ID		**V53792**	**V53793**	**V53794**	**V53795**	**V53796**	**V53797**	**V53798**	**V53799**	**V53800**	**V53801**	**V53802**	
Sampling Date		**10-07-14 18:00**	**10-07-14 18:00**	**10-07-14 18:00**	**10-07-13 14:30**	**10-07-14 11:45**	**10-07-14 11:45**	**10-07-14 16:30**	**10-07-14 16:30**	**10-07-15 18:40**	**10-07-15 17:30**	**10-07-15 17:30**	
Total Metals by ICPMS	**Units**	**KV6-S1**	**KV6-SS2**	**KV6-SS3**	**KV7-AG1**	**KV41-AG1**	**KV41-AG2**	**LTG1-AG1**	**LTG1-SS1**	**LTG1-SS2**	**DC@B-SS1**	**DC@B-SS2**	**RDL**
Total Aluminum (Al)	mg/kg	6	10	16	2	<1	1	3	43	20	16	22	1
Total Antimony (Sb)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Arsenic (As)	mg/kg	0.87	1.06	0.91	0.12	0.06	0.05	0.07	0.38	0.35	0.52	0.20	0.01
Total Barium (Ba)	mg/kg	1.6	1.1	1.2	0.4	0.9	0.9	1.1	2.1	1.0	3.6	2.7	0.1
Total Beryllium (Be)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Bismuth (Bi)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Boron (B)	mg/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5
Total Cadmium (Cd)	mg/kg	0.54	0.32	0.46	0.04	<0.01	0.01	0.02	0.16	0.11	0.51	0.45	0.01
Total Calcium (Ca)	mg/kg	13300	4560	8340	7230	4470	4770	4190	7900	4110	16800	13700	10
Total Chromium (Cr)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Total Cobalt (Co)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.4	0.1
Total Copper (Cu)	mg/kg	0.7	0.8	0.9	<0.5	<0.5	<0.5	0.5	0.8	0.8	1.3	1.2	0.5
Total Iron (Fe)	mg/kg	55	57	68	10	<10	<10	10	89	48	45	47	10
Total Lead (Pb)	mg/kg	8.01	4.81	4.16	0.07	0.08	0.03	0.09	0.29	0.12	0.14	0.11	0.01
Total Magnesium (Mg)	mg/kg	371	299	353	387	313	338	318	285	301	396	378	10
Total Manganese (Mn)	mg/kg	37.8	34.0	17.4	6.7	1.8	2.3	2.0	14.3	4.8	22.2	11.7	0.1
Total Mercury (Hg)	mg/kg	<0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.05	0.02	0.01
Total Molybdenum (Mo)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Nickel (Ni)	mg/kg	0.2	0.1	0.2	0.2	<0.1	<0.1	<0.1	0.3	0.2	0.4	0.8	0.1
Total Phosphorus (P)	mg/kg	8920	4470	6570	6600	4880	5270	4860	5920	4630	10400	9740	10
Total Potassium (K)	mg/kg	2720	2860	2850	4370	3690	3960	3720	2280	2980	2430	2960	10
Total Selenium (Se)	mg/kg	0.64	0.99	0.78	1.00	1.38	1.15	1.71	1.53	1.59	0.97	1.00	0.01
Total Silver (Ag)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Sodium (Na)	mg/kg	1320	870	975	827	602	592	653	897	901	1440	1330	10
Total Strontium (Sr)	mg/kg	5.5	1.9	3.5	5.5	4.9	4.3	3.7	7.7	3.5	17.5	14.2	0.1
Total Thallium (Tl)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Tin (Sn)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Titanium (Ti)	mg/kg	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	1
Total Uranium (U)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Total Vanadium (V)	mg/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2
Total Zinc (Zn)	mg/kg	53.1	37.6	37.1	13.9	14.0	15.7	18.5	31.3	29.8	43.2	44.5	0.1

RDL = Reportable Detection Limit; EDL = Estimated Detection Limit

Appendix VII Fish Tissue Analysis