# SURVEY OF SELENIUM IN WATER, ZOOPLANKTON AND FISH IN LAKE KOOCANUSA, BRITISH COLUMBIA, 2008

**Report prepared for**
**Environmental Protection, Kootenay Region, British Columbia Ministry of Environment on behalf of the Elk Valley Selenium Task Force**

**By**

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## Disclaimer

Interpretations and opinions expressed in this report are solely those of author.

## Executive Summary

In August of 2008, a survey of selenium (Se) in water, zooplankton and fish (with a focus on kokanee) in Lake Koocanusa, upstream and downstream of the Elk River confluence, was conducted by Kootenay Region, Environmental Protection staff. Selenium is elevated in the Elk River as a result of coal mining within the basin, averaging 4.26 µg/L in 2008, compared to 0.09 µg/L in the Kootenay River. The goal of this study was to determine metals concentration, specifically Se, above and below inputs from the Elk River, to answer the following questions: 1) Are there risks to the aquatic environment, based on a comparison with current aquatic life water quality guidelines and tissue-based thresholds; 2) Do these data corroborate historical data for Lake Koocanusa, where available; and 3) Are there significant differences in concentrations among the sites?

Historic flow gauging and water quality monitoring indicate that while the Elk River supplies approximately 26% of the water flowing into Lake Koocanusa, in 2008 it was responsible for 95% of the total Se loading. The Se loading from the Elk River in 2008 was estimated to be 10 t/yr, a 5-fold increase from 1.9 t/yr in 1986.

In this survey the influence of Se loadings from the Elk River on water column concentrations in Lake Koocanusa was apparent, with an average of 0.11 µg/L upstream, 1.33 µg/L in the Elk River forebay, and 0.84 µg/L at a location 17 km below the confluence, all differences being statistically significant. At all three locations, surface water Se concentrations were higher near the bottom of the reservoir compared to the surface, probably as a result of uptake by bacteria and phytoplankton in surface waters and subsequent downward transport due to settling.

The 8 to 12 fold increases in water-column Se at the downstream sites were not reflected in zooplankton uptake from the same locations, where respective averages were 2.89, 3.25, and 3.11 µg Se/g dw, and these differences were not statistically significant.

Research has found that the major pathway of Se bioaccumulation in fish is food-chain transfer rather than direct uptake from water, thus Se concentrations in kokanee should more resemble those of the zooplankton than the water-column. This was indeed found to be the case in this survey, with mean kokanee whole body Se of 2.11, 2.49, and 2.61 µg/g dw from the same water and zooplankton sampling locations, respectively. Only the difference between the Kikomun (2.11) and Rexford (2.61) site means were found to be statistically significant. As was the case for zooplankton, kokanee whole-body Se did not exhibit the 8 to 12 fold increases at the downstream sites observed in the water-column.

Based on recent research in the scientific literature, the reason for the lack of Se bioaccumulation in zooplankton, despite large increases in water concentrations, is hypothesized to be due to

limited uptake by the phytoplankton on which they feed, caused by local water chemistry. The dominant form of Se entering the reservoir from the Elk River is believed to be selenate, the least bioavailable form, and its uptake by phytoplankton, is further inhibited by elevated sulphate concentrations, which enter the reservoir from both the Elk and Kootenay Rivers. Selenate uptake by phytoplankton, transfer to upper tropic levels has been reported in the literature to take over a week in laboratory studies and thus may not occur in Lake Koocanusa until nearer the Libby Dam, 70 km downstream. These hypotheses need to be confirmed through additional sampling.

A similar, though less extensive survey was carried out in 2002, in which sampling was only conducted at the upstream site. Zooplankton Se concentrations in 2002 at this site were similar to 2008 (i.e., 2 to 3 µg Se/g dw), while concentrations in kokanee were higher in 2002. Kokanee muscle tissue averaged 2.4 µg Se/g dw in 2002 versus 1.82 µg Se/g dw in 2008, while ovary tissue averaged 6.6 µg Se/g dw in 2002 versus 3.43 µg Se/g dw in 2008. Whether these differences are a reflection of annual variation (i.e., fish movement and feeding patterns), differences in sampling and analytical methods, or a real decrease in tissue Se is unknown. Over this 6-year period, the average annual total Se concentration in the Elk River just upstream of the reservoir has risen from 2.4 to 4.26 µg/L.

Peamouth chub were also sampled in 2008, but only at a downstream site near Rexford, Montana. This species was found to contain significantly more Se than kokanee from the same location. Both species were sampled in pre-spawning condition to allow analysis of egg Se, but because peamouth spawn in the spring, kokanee in the fall, samples were taken in May and September respectively. Whether the higher Se in peamouth was due to the time of year, species differences in Se bioaccumulation or differences in diet is not known. The benthic invertebrates which, in addition to zooplankton, form a part of the peamouth's diet, were not sampled in this survey and, based on research conducted in other ecosystems, may bioaccumulate greater quantities of Se than zooplankton from the same waters.

None of the data generated from this survey were found to exceed British Columbia Se guidelines for the protection of aquatic life for water (i.e., 2.0 µg/L as a mean of at least 5 samples over a 30 day period) or fish tissue (i.e., (interim) whole body concentration of 1.0 µg Se/g ww as a mean of 5 independent samples). Though the guideline for water could not be properly evaluated because sampling was only carried out over a two day period in August, only 2 of 29 sample results exceeded 2.0 µg/L by a small amount (i.e., the highest result was 2.73 µg/L.

Data were also evaluated using the recently-developed Elk Valley Selenium Monitoring and Management Framework and it's step-wise water/biota monitoring triggers, which, if exceeded, prompt certain additional monitoring and management efforts. None of these triggers were exceeded in Lake Koocanusa in 2008 suggesting that no additional ramp-up efforts in terms of monitoring or management need be taken at this time. The Framework does recommend the maintenance of a basic monitoring program even when triggers are not exceeded.

Recommendations were made to repeat this survey in approximately three years, with a number of changes. Some of the more important of these recommended changes include:

- Analysis of water samples for Se speciation (i.e., selenate, selenite, organoselenide);
- Sampling benthic invertebrates, fed on by certain species of fish, that may bioaccumulate Se at greater rates than zooplankton from the same site;
- Sampling additional fish species, prioritized on the basis of the potential exposure to Se through food-chain relationships. Future surveys should eventually sample the Se content of all species present in the reservoir;
- The inclusion of additional sample sites farther down the reservoir, including at least one at Forebay, just upstream of the Libby Dam; and
- The inclusion of stable isotope ratio techniques, that have been employed successfully in the upper Elk River watershed, to identify Se uptake by various primary producers (phytoplankton, detrital microbial flora living on the bottom sediments) and confirm trophic transfer relationships.

## Acknowledgements

This study was co-funded provided by Teck Coal and the B.C. Ministry of Environment. Coordination and management of this project was handled by Jolene Raggett, Environmental Protection, Kootenay Region, B.C. Ministry of Environment (MoE). The field and fish processing team consisted of Jolene Raggett, Jody Frenette, Paul Saso, Chris Marsh, Alison Neufeld, Carrie Morita, and John Bell (B.C. MoE). Fish samples were kindly supplied by Mike Hensler and his staff from Montana Fish, Wildlife and Parks.

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# 1.0 Introduction

The potentially toxic nature of elevated water-borne selenium (Se) has been well established for over the past three decades (Eisler, 1985). When bioaccumulated by the female via food chain and transferred to the yolk of developing eggs, Se has been found to cause reproductive failure and teratogenic deformities in developing embryos of fish (Lemly, 1993) and aquatic birds (Ohlendorf *et al*., 1986). This mode of toxic response is a controversial issue, with no consistent response threshold and considerable variability in species sensitivity arising from contemporary research (Holm *et al*., 2005; Kennedy *et al*., 2000; Lemly, 1993; Rudolph, 2008).

The release of significant quantities of soluble Se from surface coal mining operations into the Elk River system was first discovered in 1995, followed in 1996 by an initial survey of Se in water, sediment and biota conducted in 1996 (McDonald and Strosher, 1998). In the years since this discovery, there have been numerous studies conducted in the vicinity of the coal mines to determine the magnitude of Se bioaccumulation in the aquatic ecosystem and any potential toxic effects in various receptor species of fish, birds and amphibians (see Appendix 2 in Canton *et al*., 2008).

The Elk River is one of three major rivers feeding Lake Koocanusa and has been reported to supply 26% of the mean annual flow into the reservoir. The other two major inflowing rivers are the Kootenay River, supplying 62% of the mean annual flow, and the Bull River, providing 11% (Hamilton *et al.*, 1990).

Selenium, in addition to numerous other water quality variables, has been monitored bi-weekly on the Elk River, at the Highway 93 Bridge just above its entry into Lake Koocanusa, since 1986. This monitoring has been conducted under the B.C. – Canada Water Quality Monitoring Agreement, a joint effort of the two levels of government to gather long-term water chemistry data on important waterways throughout the province (Env. Can., 2008). Data from this site have been summarized by Wipperman and Weber (1997), B.C. Min. Environ. (2000) and most recently by Swain (2007), and have been reproduced graphically in McDonald and Strosher (1998) and Golder Associates (2007). Unfortunately, the latest synopsis (Swain, 2007) only included data from 1997 to 2005. Figure 1 includes all data for total Se at this site from 1986 to 2008, and clearly indicates that there is an increasing trend over this 22-year period from around 1 µg/L in 1986 to 5 µg/L in 2008 (Env. Can., 2008). Total Se at this site on the Elk River now routinely exceeds British Columbia's 2 µg/L Se guideline for the protection of aquatic life (Nagpal, 2001).

A site on the Kootenay River (Fenwick Station), located just upstream of Lake Koocanusa at full pool, has been similarly sampled bi-weekly since 1986 (Env. Can., 2008). Selenium

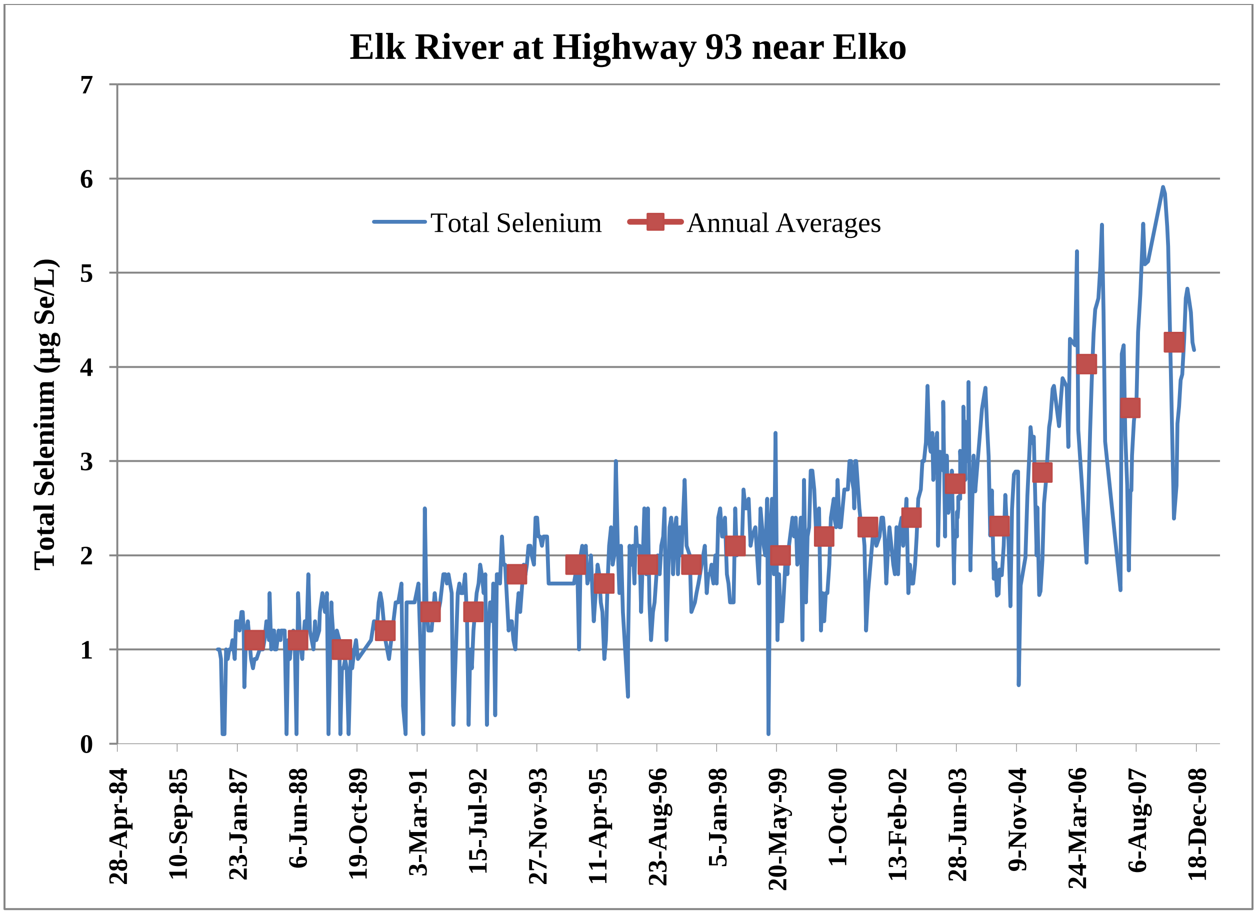



**Figure 1. Total Selenium in the Elk River at Highway 93**

(data from Env. Can. web site http://www.waterquality.ec.gc.ca/EN/navigation/search.htm accessed May 2009)

concentrations in the Kootenay River are much lower than in the Elk River and show no distinct trends over time (Figure 2). In March 2003 the total Se analytical method detection limit (MDL) for this program was decreased from 0.1 to 0.05 µg Se/L. Prior to March 2003, 25% of the results on the Kootenay River were flagged as less the than the MDL, compared to 8% after, suggesting that the recent data more accurately represent the actual concentrations of total Se at this site. Note that the value axis (y-axis) scale of Figure 2 is approximately one tenth that of Figure 1.

Calculations for estimating the loading of Se from each of these three rivers into Lake Koocanusa are detailed in Appendix I. Total Se loading estimates for the Elk River indicate a 5-fold increase over the 22 year sampling record, 1986 to 2008, from 1912 kg/yr to 10,183 kg/yr. This represents an average increase of 376 kg Se/yr or 19.7% per year, based on the 1986 loading. Total Se loadings for the Kootenay River at Fenwick, upstream of the reservoir

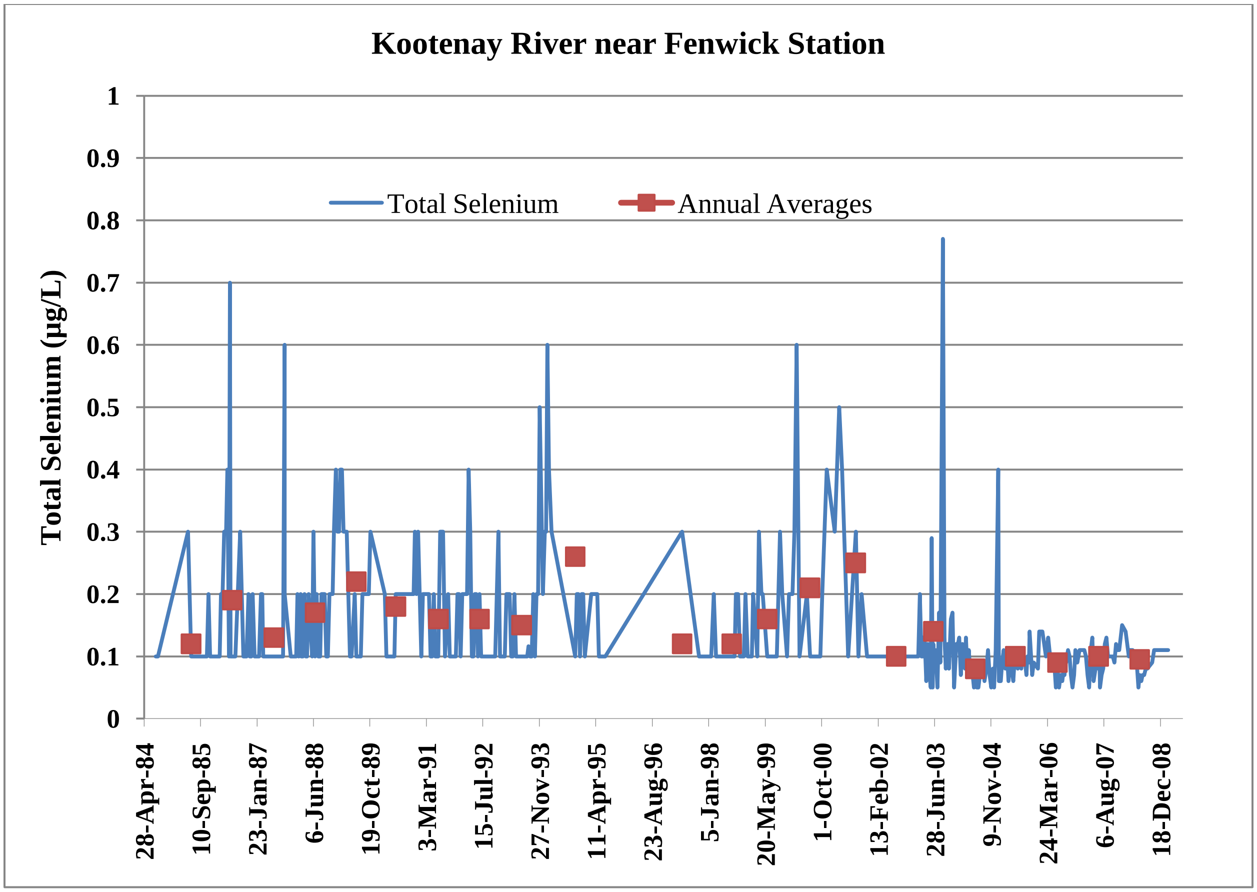



**Figure 2. Total Selenium in the Kootenay River at Fenwick Station**

(data from Env. Can. web site http://www.waterquality.ec.gc.ca/EN/navigation/search.htm accessed May 2009)

at full pool, were estimated to average 489 kg Se/yr in 2008. While comparable water quality monitoring has not been implemented on the Bull River, the 2008 loading, proportional to that of the Kootenay River, was estimated to be 87 kg Se/yr. The total Se loading to Lake Koocanusa from these three major inflowing rivers for 2008 can thus be estimated as:

10,183 kg (Elk River) + 489 kg (Kootenay River) + 87 kg (Bull River) = 10,759 kg/yr.

Based on these rough estimates, the Elk River, which provides approximately 26% of the water to Lake Koocanusa, appeared, in 2008, to provide 95% of the total Se loading. The trend in Figure 1 suggests that, in the absence of effective mitigation measures, the Se loading from the Elk River to Lake Koocanusa will continue to rise into the future.

An initial survey of Se bioaccumulation in net zooplankton (that portion of the zooplankton community captured by a plankton net with a particular mesh size, this typically includes larger crustacea, allowing smaller rotifers, etc., to pass through) and kokanee (*Oncorhynchus nerka*) in

Lake Koocanusa was conducted in 2002, using Kinbasket Reservoir on the Columbia River, 350 km to the north, as a reference site (McDonald 2005). This study reported that there was no significant difference in the Se concentrations in axial muscle, liver and egg tissue from eight female kokanee from Lake Koocanusa compared with that from six kokanee from Kinbasket Reservoir. Duplicate zooplankton hauls done on each reservoir also differed very little, both hauls from Kinbasket containing 0.1 µg Se/g wet wt., compared to 0.2 µg Se/g wet wt. from Koocanusa. In 2002, fish and zooplankton samples from Lake Koocanusa were taken only from the vicinity of Kikomun Creek, approximately 10 km upstream from where the Elk River enters the reservoir, and consequently may have not been representative of tissue Se concentrations in biota located downstream.

The goal of this study, as outlined in the Ministry of Environment's *Study Plan: 2008 Selenium Survey of Koocanusa Reservoir* attached to the contract with Spirogyra Scientific Consulting, "is to determine concentrations of metals, specifically selenium, in three specific ecosystem compartments: water, zooplankton and fish tissue, within Lake Koocanusa above and below inputs from the Elk River."

"The resulting data will be used to evaluate the following:

1. Are there risks to the aquatic environment, based on a comparison with current aquatic life water quality guidelines and tissue-based thresholds?
2. Do these data corroborate historical data for Lake Koocanusa (Hamilton, *et al*., 1990; McDonald, 2005), where available?
3. Are significant differences in concentrations among the sites?"

To address these goals, five sub-samples of water and zooplankton were sampled at each of three locations along the reservoir, near Kikomun (upstream of the Elk River), off the Elk River, and just upstream of the U.S. border in August 2008. Two species of fish, kokanee (*Oncorhynchus nerka*), and peamouth chub (*Mylocheilus caurinus*), were also sampled at similar locations. In order to compare data with the 2002 survey, egg and muscle tissue were analyzed, as well as whole body. To ensure adequate egg tissue could be collected, each species was sampled in pre-spawning condition. Thus, kokanee, a fall-spawner, were captured at Kikomun, just upstream of the Elk River, and the Rexford area in early September. Peamouth, a spring-spawner, were sampled in May in the Rexford area, just south of the U.S. border, but could not be sampled at the upstream sites because the reservoir was too low at this time of year.

The design of this study was developed by the Elk Valley Selenium Task Force. Field sampling for water and zooplankton was carried out by staff from B.C. MoE. Fish samples were provided by the Montana Department of Fish, Wildlife and Parks, who have conducted gill net surveys of the reservoir since its impoundment in the mid-1970's (Hoffman *et al.*, 2002).

## 2.0 Methods

Water and zooplankton sampling was conducted by staff from B.C. Environmental Protection, Kootenay Region between August 5 and 7, 2008 at three locations along the reservoir (Figure 3):

- Koocanusa at Kikomun Creek Bailey Bridge (EMS # E272043);
- Koocanusa at Elk River (EMS # E272044); and,
- Koocanusa Gold Creek to U.S. Border (EMS # E272045)

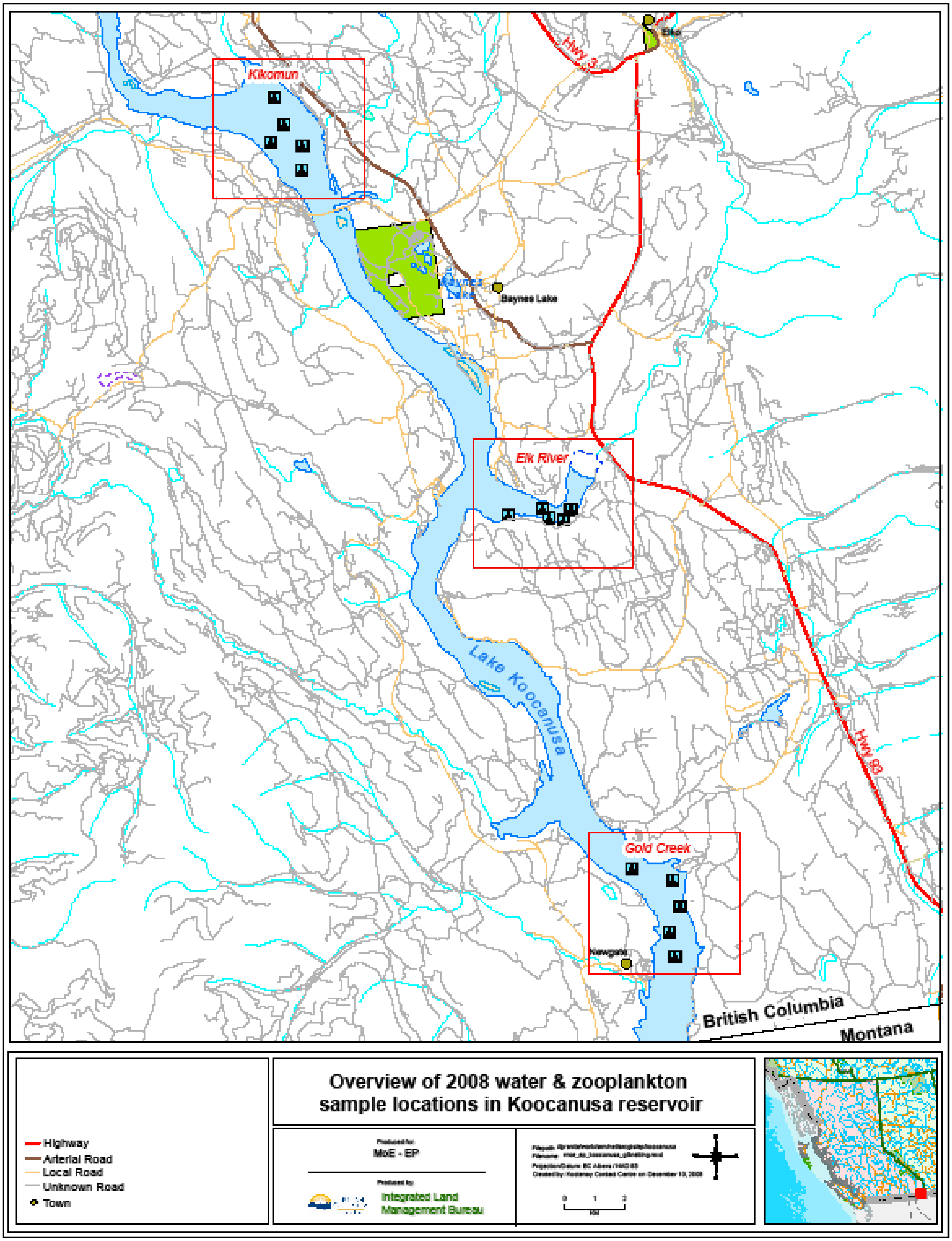
At each site, five sub-samples of water and zooplankton were taken a few hundred meters apart to provide spatial replication (Figures 4, 5, and 6). At each replicate location, the following data were collected:

- GPS UTM coordinates were recorded using a Garmin eTrex Venture® receiver.
- Depth, temperature, dissolved oxygen, conductivity, pH and chlorophyll *a* were recorded using a Hydrolab Surveyor 4A data logger and a model MS5 Sonde.
- At 1 m below the surface, and 1 m off the bottom, discrete water samples were taken using a 5 L Van Dorn bottle. These were dispensed into clean polyethylene bottles provided by the laboratory, with no preservatives added, placed in coolers on ice and shipped via ground courier to Maxxam Analytics in Burnaby, BC at the end of each day, arriving the following day.
- A 10-minute horizontal zooplankton tow was conducted using a 50 cm diameter net with a 150 µm mesh at a depth of 1 to 5 m. Samples were rinsed through a 150 µm mesh to remove the water and placed in 125 ml glass jars. These samples were held on ice and frozen at the end of each day. All samples were held in a -20°C freezer until they were shipped frozen to Maxxam Analytics on August 11, 2008. At the laboratory, the samples were stored at -20°C until they were analyzed.

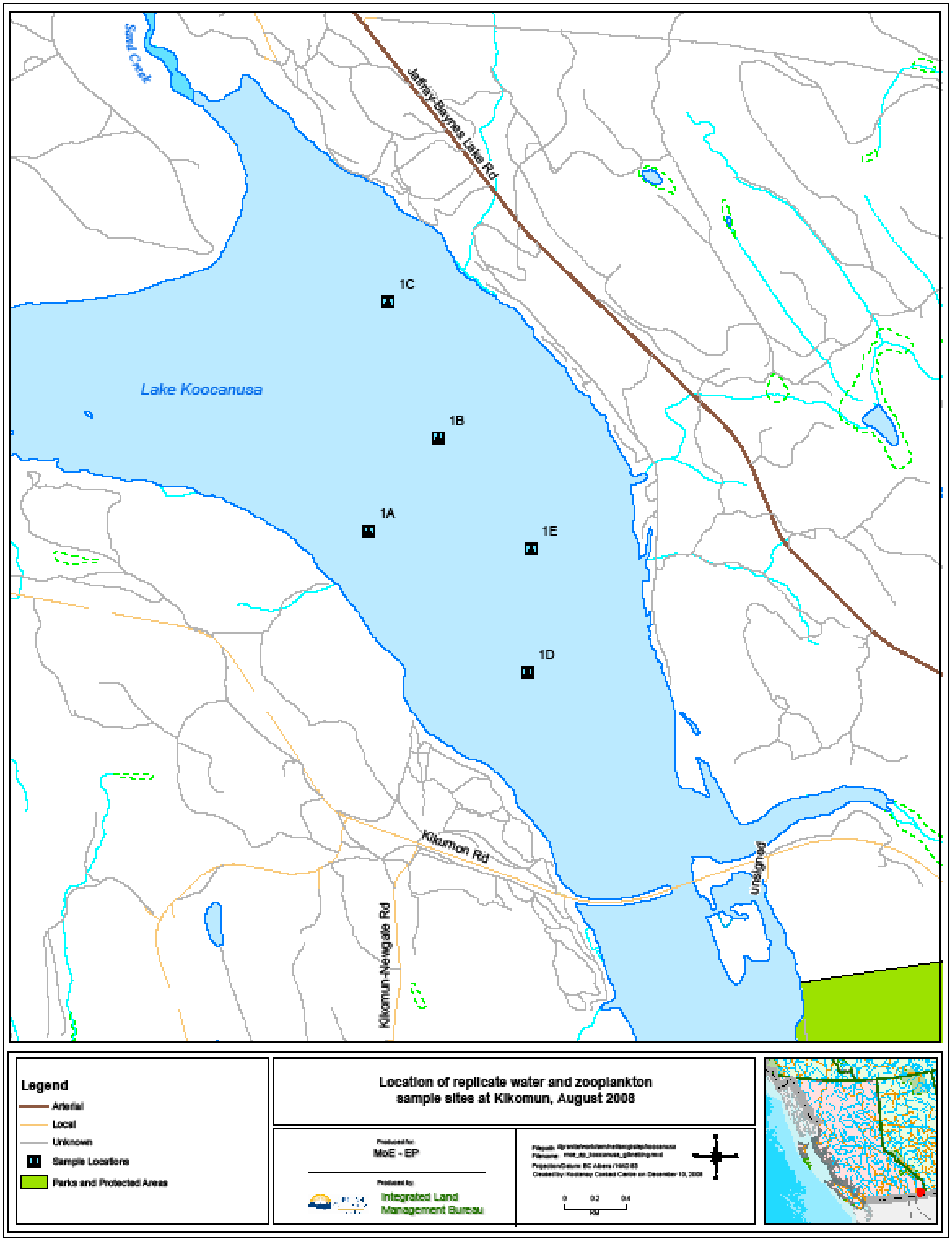
Site information (site and replicate numbers, sample dates and times, UTM coordinates, and field notes) can be found in Appendix II. Parameters analyzed, analytical methods, and reportable detection limits (RDLs) for water and biological tissue (i.e., zooplankton and fish) samples are listed in Appendix III.

Fish were captured by Montana Fish, Wildlife and Parks as part of their annual fish indexing surveys, conducted since impoundment. Spawning female peamouth chub were captured by overnight gill-net sets on May 13/14, 2008 at 12 sites in the Rexford, MT area, from just south of the Canada-US border to just south of the Tobacco River confluence (Figure 8). Spawning female kokanee were captured similarly on September 15/16, 2008 at 8 of the 12 peamouth sites in the Rexford area (Figure 8) and at 8 locations in Canada (Figure 7), extending from just north of Kikomun Creek to the Elk River confluence.

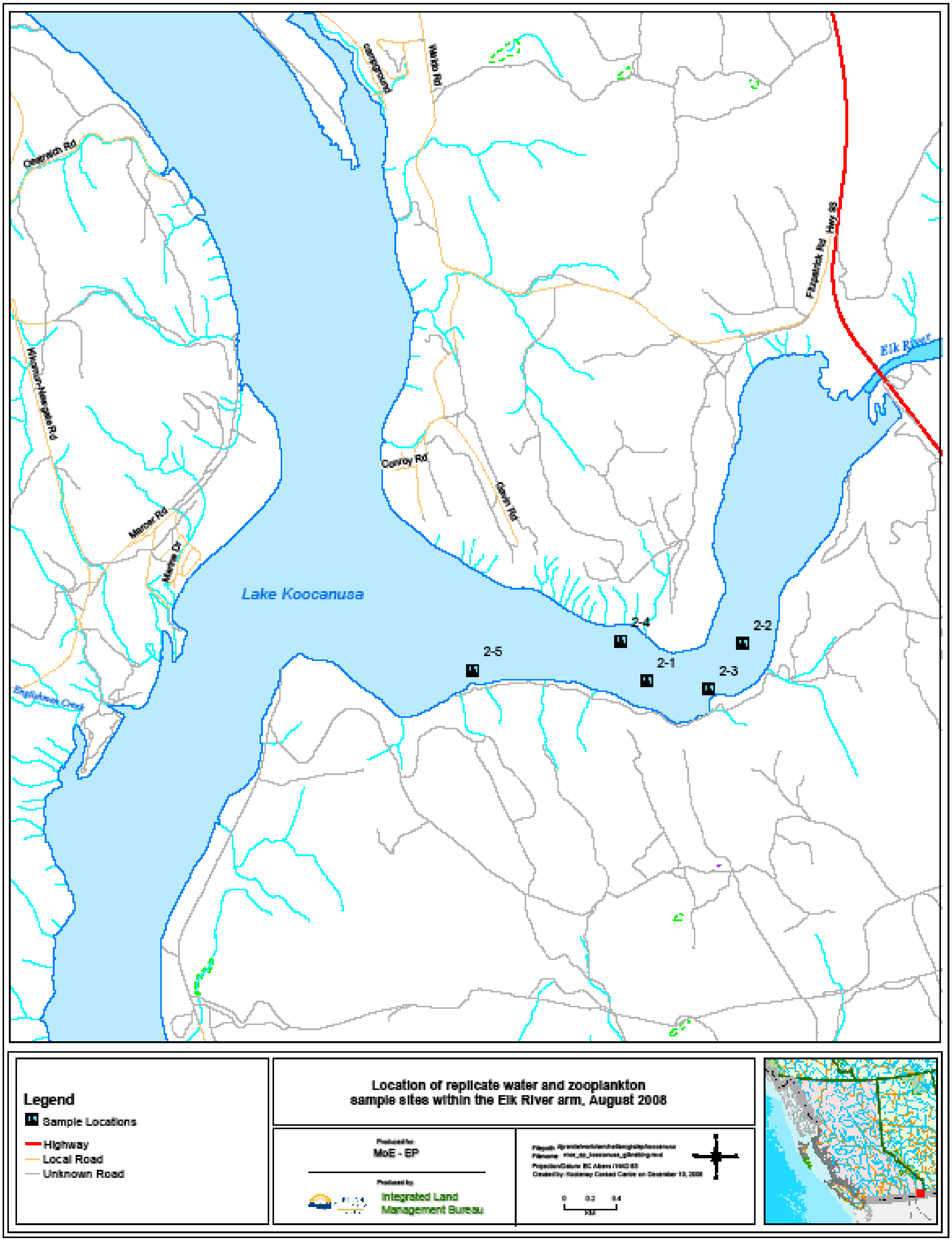
**Figure 3 Lake Koocanusa Water and Zooplankton Sample Sites**



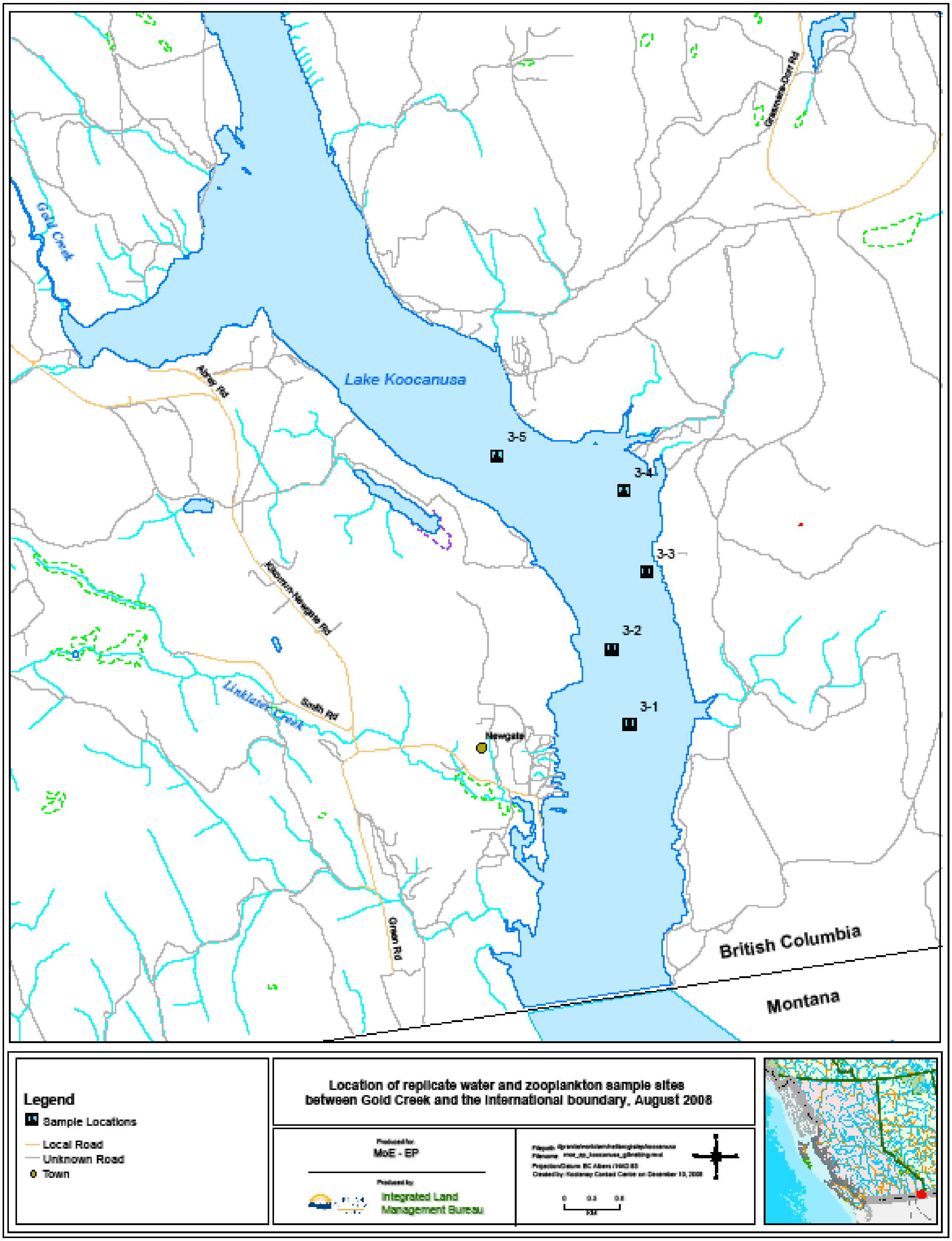
## Figure 4 Kikomun Site Water and Zooplankton Replicates



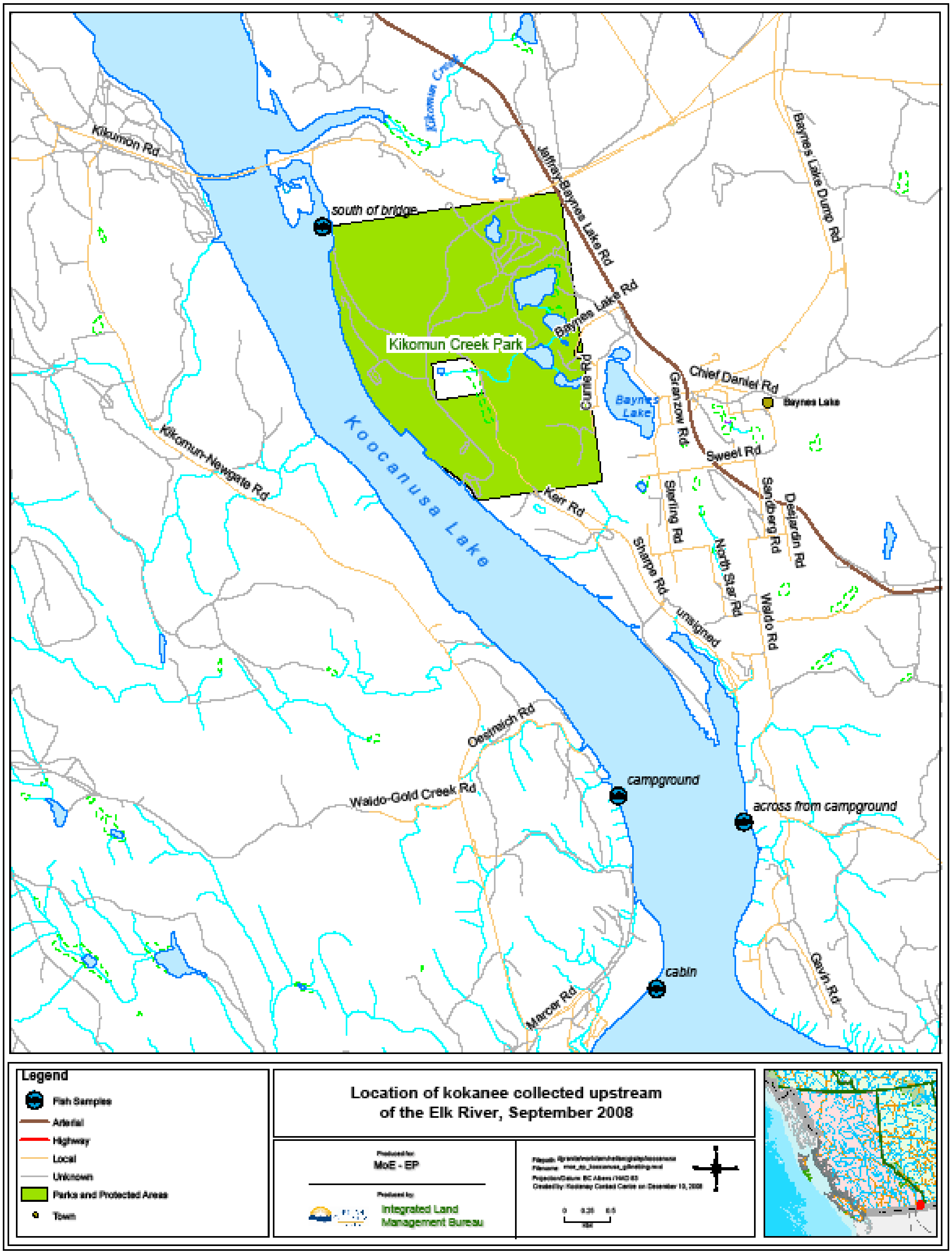
# Figure 5 Elk River Site Water and Zooplankton Replicates



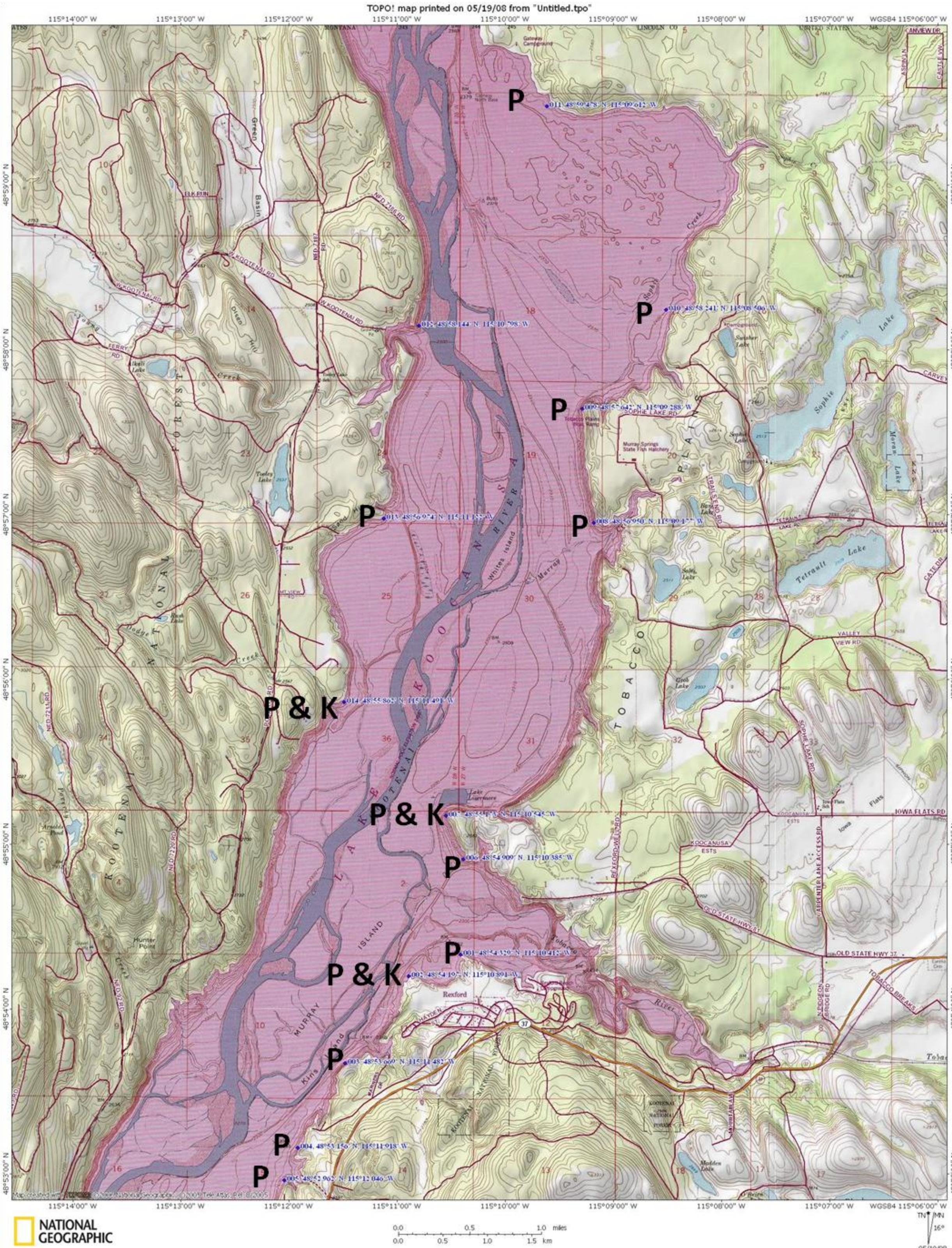
# Figure 6 Gold Creek Site Water and Zooplankton Replicates



## Figure 7 Fish Capture Sites – Canadian Reach



## Figure 8 Fish Capture Sites – United States Reach




**P = Peamouth Chub (May 13/14, 2008)** **K = Kokanee (September 16/17, 2008)**

Fish were frozen whole in individually labelled Ziploc bags immediately after capture and held at -20°C. To obtain samples of axial muscle and ovary, a subset of fish were partially thawed and processed on October 20 and 21, 2008 using current standard methods (USEPA 2000). These tissues were placed in individual labelled whirl-pack bags and re-frozen after processing. All samples were shipped to Maxxam Analytics, where they were held frozen until analysis.

For all zooplankton and fish tissue samples, the water content (% moisture) was determined analytically, and used to convert wet weight analyses to dry weights, thereby normalizing for water content, (Appendices VIII and X). This conversion was done using the following formula:

$$\text{Dry weight (mg/kg)} = \frac{\text{Wet weight (mg/kg)}}{(100 - \%\ \text{moisture}) \times 0.01}$$

The statistical significance of the different Se concentrations in water, zooplankton and fish collected from various sites and depths were compared using Analysis of Variance (ANOVA) ($p \leq 0.05$). These calculations, and the accompanying comparison graphs, were conducted using the Analyse-it® version 2.12 add-in software for Microsoft Excel. All other tables and graphs were produced using Microsoft Excel 2007.

## 2.1 Quality Assurance/Quality Control

All analytical results in this study were transcribed by the author from laboratory certificates of analysis into the tables found in Appendices VI, V, VIII, and X. Transcription accuracy was verified by the author by double checking all table data entries against the certificates of analysis at a later date from that of the original entry. All results are stored on the B.C. MoE's EMS database under the respective site numbers. Original Certificates of Analysis are available from the B.C. MoE Environmental Protection office in Nelson, B.C.

Quality Assurance (QA)/Quality Control (QC) of the analytical results in this study fall into two categories, laboratory QA/QC and field QA/QC. The former involves the efforts of the laboratory to ensure that the precision, accuracy and level of contamination of its operations meet best laboratory practices, and begins with the accreditation of the analytical laboratory, Maxxam Analytics, with the Canadian Association for Laboratory Accreditation Inc. (CALA). The latter includes efforts by the study team to ensure that field methods did not introduce unacceptable sources of contamination or error. Full details of both laboratory and field QA/QC are provided in Appendix IV. For the purposes of this report only QA/QC for total Se are summarized below.

Laboratory QA/QC consisted of blanks, duplicates, reference standards and sample spikes with known quantities of the analyte of interest in each batch of regular samples. All laboratory QA/QC data for Se were critically evaluated to determine adherence with CALA's QC criteria. Based on this evaluation, all data met these criteria.

Field QA/QC for water sampling included a duplicate sample at the Elk River site plus a field blank, and an equipment blank on the Van Dorn sampler. Based on the same duplicate and blank QC criteria as those employed by Maxxam Analytics (± 25% RPD and < RDL), all field QA/QC total Se samples were within acceptable limits.

Field QA/QC for biological tissues consisted of duplicate samples for fish axial muscle and ovary. Duplicate axial muscle samples consisted of one sample from either side of the same fish. Duplicate ovary samples consisted of splitting the egg mass in half. No zooplankton duplicates were done in this survey. All fish tissue Se duplicate samples were within control limits.

## 3.0 Results

A complete list of results for all the parameters analyzed is provided in Appendix V (water), VIII (zooplankton), and X (fish). For the purposes of this report, a detailed synopsis and assessment has only been completed for Se.

## 3.1 Water

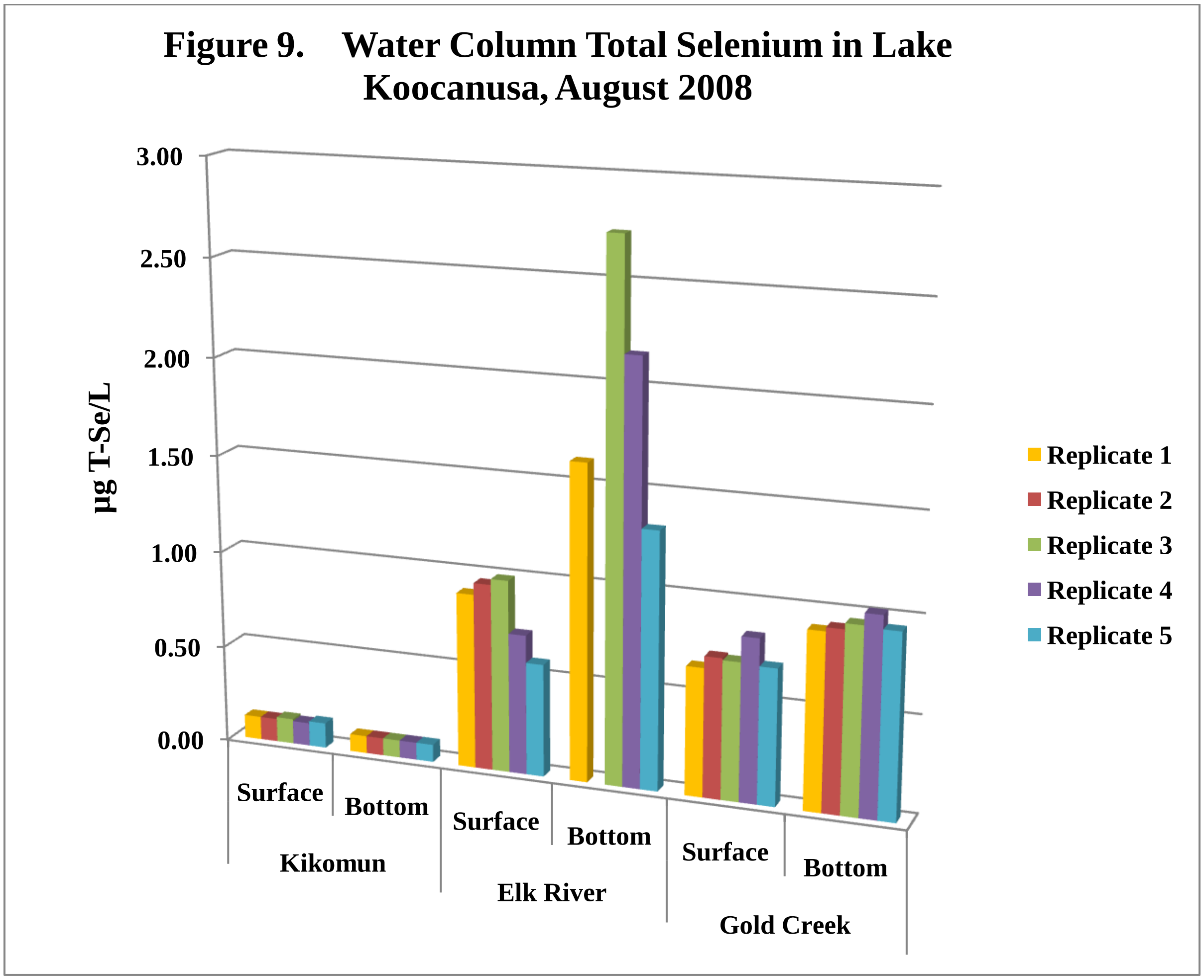
Results of total Se analyses of water samples collected at the three sites along the reservoir are summarized in Table 1, and presented graphically in Figure 9. As previously mentioned, each "site" was comprised of 5 spatial replicate samples taken roughly 100 m apart. At each of these replicate locations, a sample was taken at 1 m below the surface and 1 m off the bottom. Reservoir depth at each site differed substantially from 2 to 7 m at the Elk River to 23 to 30 m at Gold Creek (Appendix II).

**Table 1 Water Column Total Selenium in Lake Koocanusa, August 2008.**

| Site | Depth | Replicate | | | | | Mean | Site Mean | Site SD |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | |
| **Kikomun** | Surface | 0.12 | 0.12 | 0.13 | 0.12 | 0.13 | 0.12 | 0.11 | 0.018 |
| | Bottom | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | | |
| **Elk River** | Surface | 0.90 | 0.96 | 0.99 | 0.72 | 0.58 | 0.83 | 1.33 | 0.72 |
| | Bottom | 1.62 | | 2.73 | 2.16 | 1.32 | 1.96 | | |
| **Gold Creek** | Surface | 0.66 | 0.72 | 0.71 | 0.84 | 0.70 | 0.73 | 0.84 | 0.13 |
| | Bottom | 0.91 | 0.93 | 0.96 | 1.02 | 0.95 | 0.95 | | |

**Notes:**
1. All results in µg/L.
2. Samples taken August 5 - 7, 2008.
3. All surface samples were taken at 1 m depth, bottom sample depths vary: 6 - 8 m at Kikomun; 3 - 7 m at the Elk River; 23 to 30 m at Gold Creek.
4. No bottom sample taken at Elk River, Replicate 2 as total depth was 1.98 m.

When Se concentrations in the replicate water samples are averaged by site and depth, none of the means exceeded the BC Aquatic Life Guideline (ALG) of 2 µg/L, although this cannot be considered a true evaluation of the guideline, which is intended to be a temporal mean of at least 5 samples taken over a 30-day period. Two of the individual grab samples did, however, exceed this ALG value. Additionally, five of the 29 individual Se results exceeded the current CCME national guideline for the protection of aquatic life of 1 µg/L by small margins; the maximum concentration observed being 2.73 µg/L.




When the water column total Se data were analyzed using a two-way analysis of variance (ANOVA), site location and depth being the two influencing factors (Appendix VI-A), differences in both cases were found to be statistically significant ($p < 0.0001$). There was also a significant and strong interaction between depth and site location on the overall variance ($p < 0.0001$) making it difficult to determine whether site location or depth was the main factor affecting water column Se concentration.

It must be noted that two conditions required for ANOVA tests, normal distribution of results and equal sample population size, were not precisely met by these data. It is reasonable to expect that the concentration of Se, or any other variable, at various points throughout reservoir large, well mixed body of water like Lake Koocanusa, would be normally distributed. The skewed nature of the results at the Elk River site is probably a function of turbulent mixing of higher-Se water from the river and lower-Se water of the reservoir. In terms of equal sample populations, there was no bottom sample taken at replicate 2 at the Elk River site because it was too shallow (i.e., 1.98 m depth). Analyse-it® statistical add-in for Excel would not perform the ANOVA without a matching value for all depths at all sites so a value of 2.50 µg/L, based on the surface to bottom relationships at the other four replicates (see Figure 7), was inserted (Appendix VI-A).

While active mixing is a reasonable explanation for the large replicate sample variance in the Elk River forebay, it would seem an unlikely cause of surface-bottom differences at the Gold Creek site, 17 km farther downstream where the reservoir was 28 to 30 m deep. The probable reason for higher concentrations in bottom samples at this site is uptake by bacteria and phytoplankton near the surface followed by settling and accumulation in the deeper strata (Simmons and Wallschläger, 2005). The lack of complete mixing of the water column at this site at the time of sampling was evidenced by the 10 °C gradient from surface to bottom (Appendix VII).

When surface and bottom samples from each site are pooled and analyzed by a one-way ANOVA, followed by Tukey's multiple comparison procedure, the differences between the mean water column Se at all sites were found to be significant ($p<0.0001$) (Appendix VI-B).

In summary, the Se loading from the Elk River caused the water column total Se concentration in Canadian portion of Lake Koocanusa in August 2008 to increase approximately 8-fold, from 0.11 µg/L at the upstream Kikomun site to 0.84 µg/L at the Gold Creek site, approximately 30 km downstream. Off the mouth of the Elk River, 13 km below Kikomun, the mean total Se concentration (1.33 µg/L) was 12-fold higher than upstream and the results more variable.

## 3.2 Zooplankton

Data for all parameters analyzed for net zooplankton samples are provided in Appendix VIII. The sub-appendix for each site includes a table of the original laboratory analyses in wet weights plus the percent moisture of each replicate sample. Beside each of these tables is a table of dry weight conversions for parameters that were found above the minimum RDL.

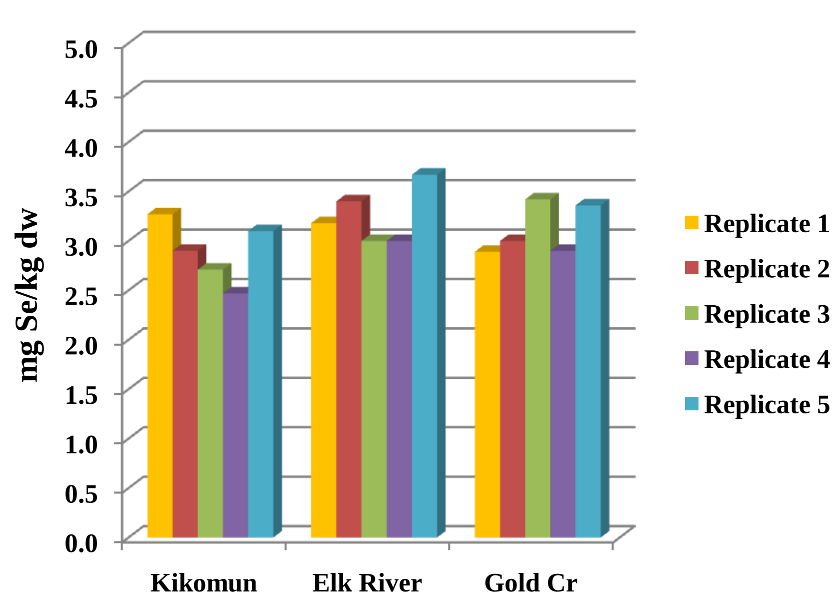
Zooplankton dry weight Se calculations from Appendix VIII are summarized in Table 2 and presented graphically in Figure 10. Unlike the water samples, Se in net zooplankton did not differ significantly from site to site and exhibited considerably lower intra-site sample variance (one-way ANOVA ($p > 0.05$), Appendix IX).

**Table 2 Selenium in Net Zooplankton in Lake Koocanusa, August 2008.**

| Site | Replicate | | | | | Site Mean | Site SD |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| Kikomun | 3.27 | 2.90 | 2.71 | 2.47 | 3.10 | 2.89 | 0.32 |
| Elk River | 3.18 | 3.40 | 3.00 | 3.00 | 3.67 | 3.25 | 0.29 |
| Gold Creek | 2.89 | 3.00 | 3.42 | 2.90 | 3.36 | 3.11 | 0.26 |

**Notes:**
1. All results in mg Se/kg Dry wt.
2. Samples taken August 5 - 7, 2008.

**Figure 10. Selenium Net Zooplankton in Lake Koocanusa, August 2008**



## 3.3 Fish

Analytical data for all fish tissue are presented Appendix X, including wet weights and dry weights conversions as for zooplankton.

The gill net sites, established by Montana Fish, Wildlife, did not match precisely the water and zooplankton sampling sites established by B.C. MoE (Figures 7 and 8) so fish from various locations were pooled to provide the best match (Tables 4 and 5). Kokanee were captured in September near Kikomun, upstream of the Elk River, and above the Tobacco River confluence in Montana (Figures 7 and 8). Peamouth chub were captured in May but only in the reach from the U.S. border south to the Tobacco River confluence (Figure 8). The timing of sample collection was necessary to target ovary tissue from these two species, which spawn at different times of the year. It should be noted that this difference may confound comparisons of tissue Se concentrations.

The B.C. interim guideline for Se in fish tissue is 1.0 µg Se/g of body weight (i.e., whole body) on a wet weight basis as a mean of at least 5 independent samples (Nagpal, 2001). To facilitate evaluation of fish Se concentration data gathered in this survey against this guideline whole body wet weight results from Appendix X have been averaged and summarized in Table 3. This guideline was not exceeded at any of the sites for either species.

**Table 3 Mean Whole Body Selenium Wet Weights in Fish from Lake Koocanusa (2008)**

| Species | Location | Mean (µg Se/g ww) | SD (µg Se/g ww) | n |
|---|---|---|---|---|
| Kokanee | Kikomun | 0.51 | 0.01 | 3 |
| | Elk River | 0.56 | 0.06 | 7 |
| | Border to Rexford | 0.57 | 0.08 | 10 |
| Peamouth | Border to Rexford | 0.85 | 0.15 | 10 |

### 3.3.1 Kokanee

Selenium concentrations (expressed in µg/g dry weight) in kokanee whole body, axial muscle and ovary tissue pooled into the three sites described above are listed in Table 4 and compared graphically in Figure 11. It is apparent from this Figure 11 that ovary tissue in kokanee had higher concentrations of Se (site means ranging from 3.43 to 3.93 µg Se/g dw) than axial muscle (site means ranging from 1.77 to 1.89 µg Se/g dw), with whole body levels being intermediate to both (site means ranging from 2.10 to 2.61 µg Se/g dw). The site means for each tissue were analyzed using one-way ANOVA's, and in cases where the F-statistic confirmed that the site means were significantly different ($p \leq 0.05$), Tukey's multiple comparison procedure was used to find out which site means for each tissue were significantly different (Appendix XII).

# Table 4 Selenium in Kokanee from Lake Koocanusa, 2008

### Canadian Reach (Kikomun Bridge to Elk River)

| Tissue | Fish Number (Appendix X-A, B, C) Results in µg Se/g DW | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Whole Body | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 |
| | 1.85 | 2.44 | 2.30 | 2.17 | 2.70 | 2.28 | 2.35 | 2.48 | 2.58 | 2.46 |
| | | | | | | | | | | |
| Axial Muscle | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| | 1.79 | 1.86 | 2.05 | 1.56 | 1.91 | 1.60 | 1.95 | 1.86 | 1.48 | 1.81 |
| | | | | | | | | | | |
| Ovary | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| | 3.24 | 3.24 | 3.66 | male fish | 3.86 | 3.75 | 3.53 | 4.61 | 2.78 | 3.72 |

South of bridge | Across from campground | North of cabin

### United States Reach (U.S. - Canada border to Rexford)

| Tissue | Fish Number (Appendix X-D, E, F) Results in µg Se/g DW | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Whole Body | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 |
| | 2.43 | 2.33 | 3.19 | 2.81 | 2.46 | 2.87 | 2.54 | 2.56 | 2.42 | 2.52 |
| | | | | | | | | | | |
| Axial Muscle | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| | 1.95 | 1.90 | 1.55 | 1.96 | 2.28 | 1.85 | 1.70 | 1.50 | 1.83 | 2.38 |
| | | | | | | | | | | |
| Ovary | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| | 3.51 | 4.80 | 4.10 | 4.72 | 3.31 | 3.51 | 3.43 | male fish | 4.48 | 3.54 |

### Site Groupings for Statistical Comparisons

| Kokanee: Whole Body Se | | |
|---|---|---|
| Kikomun | Elk River | Rexford |
| 1.85 | 2.44 | 2.43 |
| 2.30 | 2.70 | 2.33 |
| 2.17 | 2.28 | 3.19 |
| | 2.35 | 2.81 |
| | 2.48 | 2.46 |
| | 2.58 | 2.87 |
| | 2.46 | 2.54 |
| | | 2.56 |
| | | 2.42 |
| | | 2.52 |

| Kokanee: Axial Muscle | | |
|---|---|---|
| Kikomun | Elk River | Rexford |
| 1.86 | 1.79 | 1.95 |
| 2.05 | 1.91 | 1.90 |
| 1.56 | 1.60 | 1.55 |
| | 1.95 | 1.96 |
| | 1.86 | 2.28 |
| | 1.48 | 1.85 |
| | 1.81 | 1.70 |
| | | 1.50 |
| | | 1.83 |
| | | 2.38 |

| Kokanee: Ovary | | |
|---|---|---|
| Kikomun | Elk River | Rexford |
| 3.24 | 3.24 | 3.51 |
| 3.66 | 3.86 | 4.80 |
| 3.41 | 3.75 | 4.10 |
| | 3.53 | 4.72 |
| | 4.61 | 3.31 |
| | 2.78 | 3.51 |
| | 3.72 | 3.43 |
| | | 4.48 |
| | | 3.54 |

**Site Groupings:** Kikomun = South of bridge; Elk River = Across from campground + North of cabin; Rexford = U.S. Reach.

Fictitious result added (median of other 2) because software requires at least 3 values for graphing (Figure 8). Value not included in statistical analyses.

These analyses indicated that the only statistically-significant difference was between the Kikomun and Rexford sites for whole body Se (Appendix XII-A). For the sample sizes available (only n = 3 at Kikomun), there was no evidence that the differences between any of the other site means were statistically significant (i.e., all samples came from the same population).

### 3.3.2 Peamouth Chub

Peamouth chub were only collected at one site reach from the International Border south to Rexford, so an evaluation of spatial trends in Se content in this species along the reservoir, in relation to the Elk River source, cannot be conducted. The Se content, on a dry weight basis, in peamouth captured in this reach is summarized in Table 5.

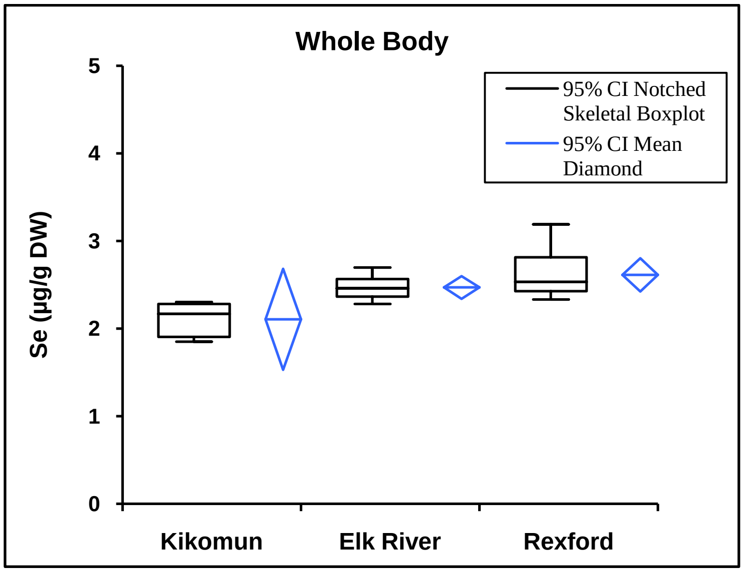
**Table 5 Selenium in Peamouth Chub from U.S. Border to Rexford, May 2008**

| Tissue | Fish No. (Appendix X-G, H, I) Results in µg Se/g dry weight | | | | | | | | | | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | | |
| Body | 3.68 | 3.14 | 3.13 | 2.36 | 4.15 | 3.46 | 2.74 | 3.70 | 3.63 | 3.77 | 3.38 | 0.54 |
| | | | | | | | | | | | | |
| Axial | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | | |
| Muscle | 2.33 | 1.75 | 5.35 | 2.60 | 2.79 | 2.32 | 4.37 | 6.42 | 2.33 | 2.78 | 3.30 | 1.54 |
| | | | | | | | | | | | | |
| Ovary | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | | |
| | 5.00 | 5.64 | 11.34 | 9.25 | 10.24 | 5.64 | 8.50 | 9.69 | 6.43 | 6.49 | 7.82 | 2.25 |

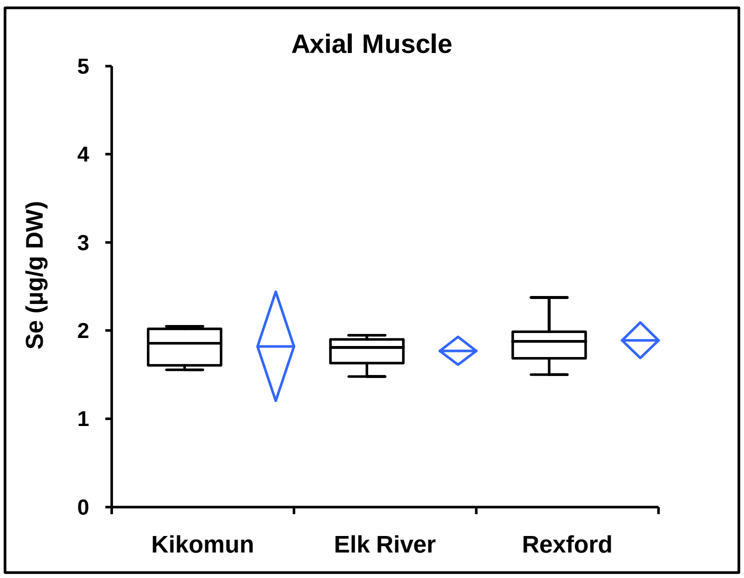
These data can, however, be compared with the Se content in kokanee captured from the same reach, keeping in mind that the spawning fish were captured at different times of year (i.e., peamouth were captured in May, the kokanee in September). Peamouth from this part of the reservoir were found to contain greater quantities of Se, particularly in ovary tissue which was approximately twice the Se concentration as kokanee ovary (Figure 12). In both Figures 11 and 12 the scale of the x-axis of the three graphs for whole body, muscle and ovary is identical in order to ensure accurate visual comparison, but was increased from a maximum of 5 to 12 µg Se/g dw in Figure 12 to accommodate higher Se concentrations in peamouth.

The different Se content of these two species was compared using one-way ANOVA and Tukey's multiple comparison procedures (Appendix XIII). These tests confirmed that mean Se concentrations in whole body, muscle and ovary of kokanee and peamouth chub captured in the reach from the international border to Rexford in 2008 were significantly different ($p < 0.05$). What cannot be determined from these data is whether these differences are due to sampling at different times (i.e., peamouth in May, kokanee in September) or the result of real differences in the relative bioaccumulation of Se by each species.

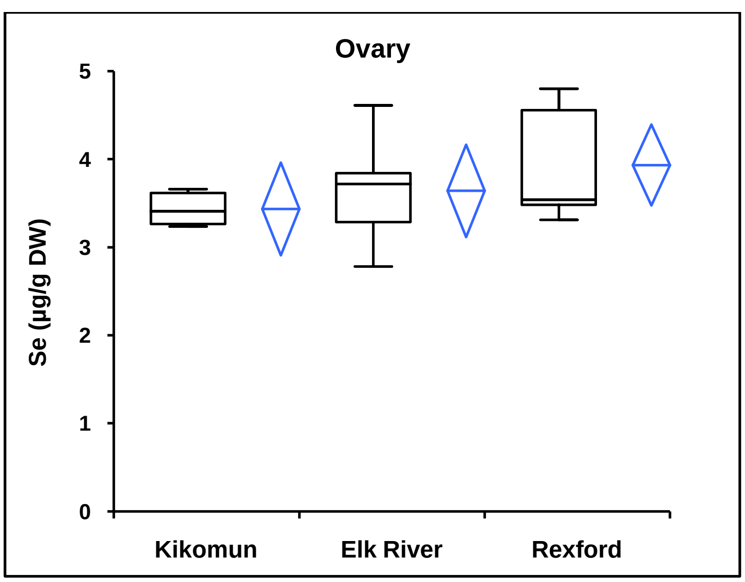
## Figure 11 Selenium in Lake Koocanusa Kokanee: Site Comparisons




| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kikomun | 3 | 2.108 | 1.531 to 2.684 | 0.1339 | 0.2320 |
| Elk River | 7 | 2.469 | 2.341 to 2.598 | 0.0525 | 0.1388 |
| Rexford | 10 | 2.614 | 2.425 to 2.802 | 0.0834 | 0.2638 |

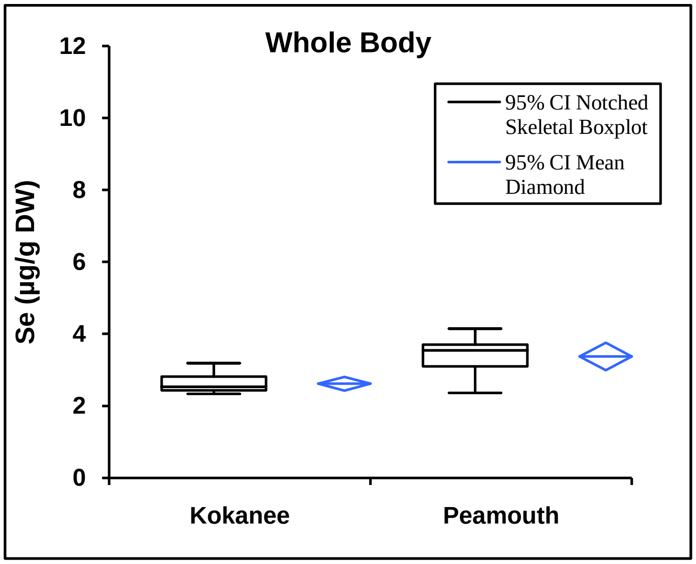



| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kikomun | 3 | 1.821 | 1.202 to 2.440 | 0.1439 | 0.2492 |
| Elk River | 7 | 1.771 | 1.613 to 1.929 | 0.0646 | 0.1710 |
| Rexford | 10 | 1.890 | 1.689 to 2.091 | 0.0887 | 0.2805 |

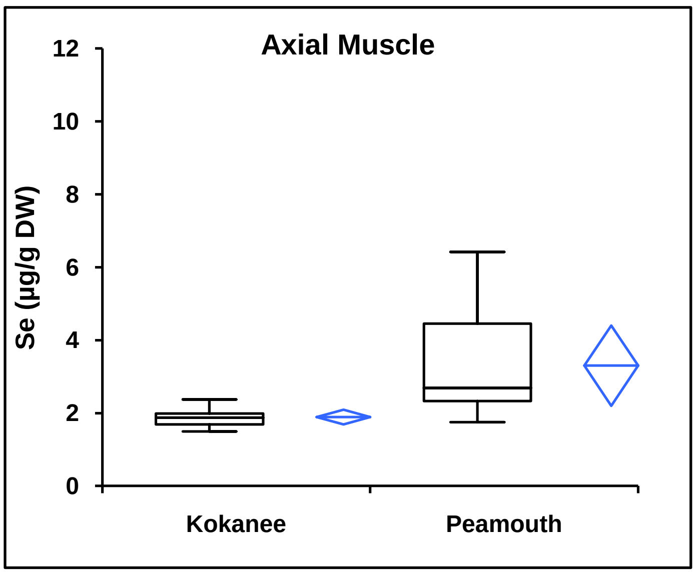



| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kikomun | 3 | 3.434 | 2.907 to 3.962 | 0.1226 | 0.2124 |
| Elk River | 7 | 3.640 | 3.116 to 4.163 | 0.2140 | 0.5663 |
| Rexford | 9 | 3.933 | 3.474 to 4.391 | 0.1989 | 0.5966 |

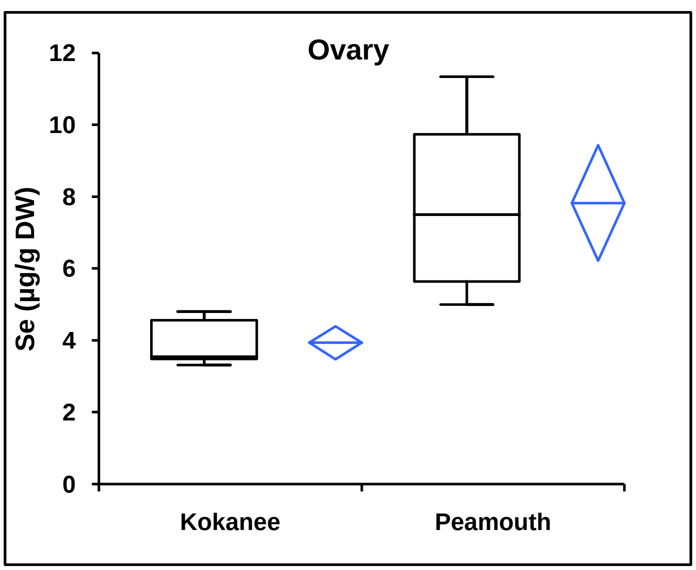
**Figure 12 Comparison of Selenium in Kokanee and Peamouth Chub from Lake Koocanusa, U.S. Border to Rexford Reach in 2008.**




| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kokanee | 10 | 2.614 | 2.425 to 2.802 | 0.0834 | 0.2638 |
| Peamouth | 10 | 3.376 | 2.993 to 3.759 | 0.1692 | 0.5350 |




| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kokanee | 10 | 1.890 | 1.689 to 2.091 | 0.0887 | 0.2805 |
| Peamouth | 10 | 3.304 | 2.202 to 4.406 | 0.4870 | 1.5401 |




| | n | Mean | 95% CI | SE | SD |
|---|---|---|---|---|---|
| Kokanee | 9 | 3.933 | 3.474 to 4.391 | 0.1989 | 0.5966 |
| Peamouth | 10 | 7.822 | 6.215 to 9.429 | 0.7103 | 2.2462 |

## 4.0 Discussion

One of the goals of this study was to determine if there were risks to the aquatic environment, as determined by comparing results against water quality guidelines and tissue-based thresholds. Comparisons of data with B.C. guidelines for the protection of aquatic life have been done in the results section above and are not repeated here. However, in 2008, a panel of Se experts proposed a framework for the monitoring and management of Se in the Elk Valley, including Se concentration triggers (Canton *et al.*, 2008). Data from this survey have been evaluated against these triggers.

The monitoring and management framework, intended to be a step-wise process, established Se concentration triggers for water, invertebrate (receptor diet) tissue and receptor species tissues. The triggers serve as a guide for additional monitoring activities and mitigation efforts, depending on whether they are exceeded or not. While the expert report does not specifically mention applying the framework as far downstream as Lake Koocanusa, evaluating the results of this survey against these recently established Se concentration triggers for river system immediately upstream is considered prudent.

The water trigger is the BC ALG and thus cannot be properly evaluated in Lake Koocanusa until there is the appropriate temporal mean available (at least 5 samples in 30 days).

The invertebrate trigger is 5 µg Se/g dw as a mean of triplicate samples from a site. Zooplankton was the only invertebrate sampled in this study, and none of the net zooplankton Se site means from Lake Koocanusa exceeded this trigger. The trigger was also not exceeded by taking the 3 highest values from each site nor even taking the 3 highest values from all 15 hauls (mean = 3.50 µg Se/g dw). Canton *et al.* (2008) suggest that exceeding the invertebrate trigger should lead to further Se monitoring in the appropriate fish, amphibian or bird receptors plus consideration of Se management options.

The fish tissue trigger is a whole body concentration of 6 µg Se/g dw and is intended to apply to a sampling location mean. None of the fish site means from Lake Koocanusa exceeded this value in 2008, the highest being peamouth chub from the Rexford area, which had a whole body mean of 3.38 µg Se/g dw. Exceeding the fish tissue whole body Se trigger by less than 20% prompts additional confirmatory sampling and if the trigger is exceeded by greater than 20% a Se management plan should developed and implemented with the intent of reducing Se inputs to the system (Canton *et al.*,2008).

When the Elk Valley Selenium Monitoring and Management Framework, developed for the upper basin in 2008, is used evaluate the results of this survey in Lake Koocanusa, none of the triggers were exceeded, meaning there is no need to move to the next steps for monitoring and management. In the upper basin, the framework recommends maintaining a basic water and invertebrate tissue monitoring program even when the triggers are not exceeded. An equivalent program for Lake Koocanusa, plus suggestions for further investigation into Se uptake and trophic transfer, is recommended below.

Another goal of this survey was to compare the current findings with those of a similar, though less extensive survey conducted in 2002 (McDonald, 2005), and any other available historic data. The 2002 survey sampled zooplankton and kokanee from the Kikomun area only, upstream of the Elk River, but water samples were not taken. The B.C. Ministry of Environment conducted routine sampling of water and plankton from the Canadian portion of Lake Koocanusa from 1972 to 1991, but Se was never included in the analyses (Hamilton, *et al.*, 1990).

In 2002 duplicate zooplankton hauls from Kikomun each contained 1 µg Se/g dw, with dry weights calculated using an assumed 80% moisture (McDonald, 2005). When the average percent moisture measured in 2008 of 90% (n = 15) is used, the 2002 dry weights become 2 µg Se/g dw. Higher analytical detection limits in 2002 notwithstanding, these results are similar to the 2008 Kikomun mean of 2.89 µg Se/g dw. The 2008 means from the Elk River (3.25 µg Se/g dw) and Gold Creek (3.11 µg Se/g dw), downstream of the Se source, were not statistically different from that of the Kikomun site. Given the higher detection limit and small sample size in 2002, it is not possible to determine if zooplankton Se has risen significantly over the past 6 years.

McDonald (2005) also sampled net zooplankton Se content in Kinbasket Reservoir, a reference site located 350 km north on the Columbia River, and found duplicate hauls contained 1 µg Se/g dw (similarly adjusted using the 2008 percent moisture data). This was similar to a net zooplankton sample from Connor Lake, a remote lake located on the western, non-coal bearing side of the Elk River valley, which contained 1.03 µg Se/g dw (McDonald and Strosher, 2000), and might be considered background for non-seleniferous lakes in south-eastern British Columbia, though additional confirmatory data are needed.

Whole body fish tissue analysis was not done in 2002, but the mean concentration in axial muscle from kokanee captured at Kikomun was 2.4 ± 0.2 µg Se/g dw (n = 8) and 6.6 ± 1.4 µg Se/g dw (n = 8) in ovary tissue (McDonald, 2005). These ovary Se dry weight results from 2002 have been re-calculated as above using the average percent moisture analyses from 2008 (62%) instead of the assumed value used by McDonald (2005) (70%). Muscle dry weights reported by McDonald (2005) needed no adjustment because the assumed moisture content (78%) matched that measured in 2008. The corrected kokanee tissue Se found in 2002 at Kikomun were higher than those found in 2008 when mean axial muscle and ovary concentrations were 1.82 ± 0.25 µg Se/g dw (n = 3) and 3.43 ± 0.21µg Se/g dw (n = 3) respectively, the latter being half that found in 2002.

Higher kokanee muscle and ovary Se in 2002 compared to 2008 is puzzling considering that the Se loading from the Elk River nearly doubled over this period, insofar as it is reflected in an increase in the mean annual concentration at the Highway 93 site, from 2.4 µg/L in 2002 to 4.26 µg/L in 2008 (Figure 1). This may be due to the lower analytical detection limits employed in 2008, 0.01 µg Se/g ww down from 0.1 µg Se/g ww in 2002, or simply annual variation.

The final objective of this study was to examine the distribution of Se content in the water column, zooplankton, and kokanee in relation to the Elk River Se source.

Based on sampling at three sites, water column concentrations showed the combined influence of the influx of Se from the Elk River and the downstream flow vector operating in the reservoir. The lowest concentrations were found upstream of the Elk River at Kikomun (mean = 0.11 ± 0.02 µg/L), which were similar to those farther above in the Kootenay River (0.07 µg/L the month before), and the highest concentrations were found in the Elk River forebay (mean = 1.33 ± 0.72 µg/L), reflective of the elevated levels in the Elk River upstream (3.58 µg/L the month before). The deeper, more completely mixed Gold Creek reach downstream had Se concentrations intermediate to these other two sites (mean = 0.84 ± 0.13 µg/L). Site differences in water column Se were statistically significant in all cases ($p<0.0001$).

Despite a 12-fold increase in water-borne Se concentrations at the Elk River forebay and 8-fold increase at Gold Creek, over the Kikomun site upstream, mean net zooplankton Se from the same sites did not differ significantly. Food-chain transfer has long been recognized as the major pathway for Se bioaccumulation in aquatic consumer organisms (Sandholm *et al.*, 1973; Simmons and Wallschläger, 2005). Given the lack of significant Se bioaccumulation in zooplankton, a primary consumer, it is not surprising that kokanee, a secondary consumer feeding mainly on the former, did not show significantly elevated tissue levels.

The mobility of fish to feed, prior to capture, throughout the 40 km long reach, from Kikomun to Rexford, Mo, where fish were sampled, was recognized as a potentially confounding factor for interpreting Se bioaccumulation in fish captured along this reach. Zooplankton, though mobile over short distances and subject to displacement by water currents, are unlikely to move between sites several kilometres apart. The failure of zooplankton in this vicinity of Lake Koocanusa to bioaccumulate Se in response to large increases in total Se concentrations in the water they inhabit warrants further discussion.

Though invertebrates and fish can bioaccumulate Se directly from water, organoselenides being the most bioavailable form, followed by selenite, then selenate, the major pathway is through the diet of these consumer organisms (Orr *et al*., 2006). The major entry point of water-borne Se into aquatic biota, however, is via the uptake of inorganic oxyanions (selenate and selenite) by algae, bacteria and macrophytes and biotransformation into selenoamino acids, which are further transformed into selenoproteins by consumers (invertebrates and fish) (Maier and Knight 1994; Orr *et al*., 2006). The uptake of Se from water by primary producers has recently been described as the "enrichment function, and considered to be "the single largest step in the bioaccumulation of Se" (Chapman, *et al.*, 2009).

Macrophyte community development in littoral areas is severely limited in Lake Koocanusa due to the large annual draw-down, which leaves algae and bacteria, both pelagic and benthic, to play the major role in Se uptake and biotransformation.

In a recent review of Se biogeochemistry and ecotoxicology, Simmons and Wallschläger (2005) suggest that selenite, found in mildly reducing environments, is more bioavailable to algae and cyanobacteria than selenate, which dominates in alkaline, oxidizing conditions. Selenium is released from the coal mines into the Elk River predominantly as selenate, selenite being largely undetectable mine drainage (Day, 2004). Since reducing conditions, where conversion to selenite would occur, are unlikely to be encountered in the river or Canadian portion of the reservoir, it is reasonable to assume that most of the total Se in the water column of Lake Koocanusa, immediately downstream of the Elk River, is selenate. This can easily be confirmed by further sampling and analysis for Se speciation at the Elk River site (Figure 1) and in the reservoir.

In laboratory experiments Riedel, *et al.* (1996) observed the uptake of selenate by phytoplankton, followed by a transformation to, and release of, selenite, but the process took 10 days. The rate of water movement through Lake Koocanusa is not known but the uptake of Se by phytoplankton, and subsequent trophic transfer to zooplankton, may not be significant until farther down the reservoir.

Another factor that may explain the lack of significant Se bioaccumulation by zooplankton in this study is the presence of elevated concentrations of sulphate, which has been found to inhibit the uptake of selenate by algae and invertebrates (Simmons and Wallschläger, 2005). The concentration of sulphate in the reservoir, across all sites sampled in 2008, averaged about 22 mg/L (Appendix V), and both the Elk and Kootenay Rivers, just upstream of Lake Koocanusa, annually range from 15 to 50 mg/L (Env. Can., 2009). Large quantities of sulphate are released by coal mining into the Elk River, with concentrations as high as 700 mg/L in mine drainage (Day, 2004), 20 to 100 mg/L immediately downstream, and 6 mg/L or less above mine activity (MEMPR-ERIP, 2009). The source of sulphate in the Kootenay River is probably gypsum mine activity upstream of Canal Flats (MEMPR, 2008), where the annual range is 10 to 60 mg/L, versus 5 to 10 mg/L farther upstream in Kootenay National Park at Kootenay Crossing (Env. Can., 2009).

In summary, the limited bioaccumulation of Se by zooplankton in response to elevated water concentrations, observed in this study, may be due to limited uptake the phytoplankton and bacteria on which they feed. Uptake by these primary producers is limited because the Se in the water column is predominantly selenate, the least bioavailable form, and is further inhibited by elevated sulphate. Confirmation of this hypothesis will require analysis of water samples for Se species and an examination of Se uptake by the primary producers in the reservoir, possibly using the stable isotope techniques employed by Orr *et al.* (2006) in the upper watershed, to confirm food-chain relationships and biotransformation factors.

Orr *et al.* (2006), summarizing the literature, describe the bottom sediments in aquatic ecosystems as the ultimate sink for Se, due to the uptake of Se by algae and bacteria and subsequent deposition through settling. Selenium content in water samples in this study from the deeper, downstream Gold Creek site were consistent with this observation. Total Se in surface samples at this site averaged 0.73 ± 0.07 µg/L while samples from around 28 m, 1 m off the bottom, averaged 0.95 ± 0.04 µg/L (n=5 in each case), this difference being significant as determined by one-way ANOVA (p=0.0002). The water column at this site at the time of sampling was not subject to complete vertical mixing as evidenced by the 10°C gradient from surface to bottom. The accumulation of Se in bottom sediments is followed by uptake by the microbial flora colonizing the deposited detritus, biotransformation to organoselenides and consumption by benthic consumer organisms (Orr *et al.*, 2006).

Orr *et al.* (2006) concluded that the greater Se uptake in exposed lentic areas, compared to lotic, in the Elk Valley near the coal mines, was the result of uptake and biotransformation of Se oxyanions to organoselenium by macrophytes and bacteria colonizing the sediment and detritus, which accumulates at a much greater rate due to greater hydraulic retention times. Though the wetlands and off-channel ponds studied by these authors differ greatly from a large reservoir like Lake Koocanusa, the potential importance uptake and cycling of Se by benthic detrital food-chains in the reservoir should not be overlooked.

Evidence has been found to suggest that Se uptake and cycling by the sediment-linked processes in lakes and reservoirs may exceed that of pelagic processes. In a study of Se uptake by caged golden shiner (*Notemigonus crysoleucas*) in Se-contaminated Hyco Reservoir, fish exposed to the sediments accumulated more Se than those suspended in the water column (Woock, 1984). McDonald and Strosher (2000) reported a concentration of 2.66 µg Se/g DW in epibenthic amphipods from Connor Lake, a remote alpine reference lake, in which the net zooplankton yielded a concentration of 1.03 µg Se/g dw.

In this survey, the significantly greater bioaccumulation of Se by peamouth chub, compared to kokanee, from the same site (though sampled 4 months apart) may have been due to a greater propensity on the part of that species to bioaccumulate Se, or to higher levels of Se in its diet. Peamouth, like kokanee, feed on zooplankton, but are more opportunistic feeders with a broader range of diet including benthic insect larvae (e.g., chironomids, mayflies, caddisflies), molluscs and small fishes (Scott and Crossman, 1979). Selenium bioaccumulation in benthic invertebrates was not evaluated in this survey. Future surveys should consider adding this component to determine the relative exposure risk to benthic feeding fishes, perhaps in conjunction with the use of stable isotope ratios, mentioned above, to confirm food-chain relationships and biotransformation factors.

The findings of this survey and the above discussion of related information from the literature raises several important questions:

1. Though zooplankton 17 km downstream of the Elk River source did not bioaccumulate significant Se despite an 8-fold increase in water concentration, do zooplankton 70 km farther downstream near the Libby Dam bioaccumulate significantly more Se due to uptake and biotransformation processes along the reservoir?
2. Depending on the answer to #1, do kokanee, and other species of fish, nearer the dam bioaccumulate relatively more Se than those nearer the U.S. border?
3. Do benthic invertebrates bioaccumulate more Se than zooplankton because the net accumulation of Se in bottom sediments is readily taken up by detrital bacteria and algae, biotransformed to organoselenides and bioaccumulated by consumer organisms.
4. Depending on the answer to #3, do benthic feeding fishes bioaccumulate relatively more Se than pelagic feeding fishes from the same part of the reservoir?

Other questions concerning Se uptake and cycling in the reservoir, critical to answering the above, include:

5. What is the proportion of each form of Se (selenate, selenite, organoselenide) in the Elk River as it enters Lake Koocanusa?
6. If the assumption that most of the Se enters as selenate, the least bioavailable form, is correct (to be confirmed by #5), is there a shift to more bioavailable forms farther down the reservoir due to uptake and transformation processes?

The additional monitoring and research required to answer these questions are included in the following recommendations.

## 5.0 Recommendations

The following recommendations for future monitoring and research are based on the findings of the 2008 survey and related information from the scientific literature. They pertain to Lake Koocanusa in its entirety, which lies across the border between Canada and the United States.

- It is recommended that a survey similar to this one be conducted again in approximately 3 years (2011) to evaluate trends in this downstream lentic environment, but with consideration for the following additions and modifications.

- Water sample analysis should include Se speciation, selenate and selenite at a minimum to confirm the dominant form of Se and determine if biotransformation of selenate to selenite and organic forms occurs further downstream within the reservoir. Such analysis should also be carried out on several samples from the long-term site on Elk River at Highway 93.

- In future surveys, water and zooplankton sampling should be carried out as in 2008. However, the Elk River site, where river and reservoir water is actively mixing, need not be sampled (sample Kikomun and Gold Creek). The number of samples collected at each site should be reviewed using power analysis to ensure adequate replication to evaluate statistical significance.

- Water and zooplankton sampling should also be conducted at a site just upstream of the Libby Dam, in the area referred to as Forebay to evaluate whether the pelagic food chain within the reservoir takes longer to transform and accumulate Se.

- In addition to net zooplankton, logistical problems notwithstanding (e.g., separating phyto- from zooplankton), an effort should be made to sample net phytoplankton for Se content at the same locations. Information on Se uptake at the base of the food-web, recently termed the 'enrichment function', may help explain why large increases in water-borne Se are not reflected by similar increases in primary consumer (zooplankton) bioaccumulation.

- Benthic invertebrates, as a potential source of food-chain Se exposure, should be sampled at Kikomun, Gold Creek and at other sites downstream as determined by the fish sampled (i.e., when benthivores are being sampled). Benthic consumer Se bioaccumulation can be compared to zooplankton values from the same location to evaluate the respective roles of each of these communities in reservoir Se uptake and cycling.

- In the U.S. portion of the reservoir, fish should be sampled at Rexford and at Forebay, just upstream of the Libby Dam in the vicinity of the water/plankton/invertebrate sampling.

- Consideration should be given to utilizing the stable isotope ratio techniques employed by Orr, *et al.* (2006) in studying Se uptake and cycling in lotic and lentic areas in the upper Elk River. Such techniques could be applied to Se uptake and transformation by primary producers and consumers in the benthic and pelagic communities to confirm food-chain associations and the relative importance of each to Se cycling in the reservoir.

- In addition to kokanee and peamouth chub, other species of fish inhabiting the reservoir should also be sampled as various species accumulate Se at different rates based on life history characteristics. Hoffman *et al.* (2002) reports the presence of the following additional species in the reservoir: rainbow trout, Kamloops rainbow trout, westslope cutthroat trout, bull trout (char), mountain whitefish, burbot, northern pike minnow, redside shiner, largescale sucker, longnose sucker, and yellow perch. Successive surveys of Lake Koocanusa should eventually sample the Se content of all these species, prioritized on the basis of potential food-chain exposure to Se.

- Future fish tissue Se analysis need only include whole body and ovary. Including axial muscle in the 2008 survey was important for comparison to historical data, which did not include whole body analysis, now the "tissue" of choice for Se assessments.

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# LIST OF APPENDICES

# Appendix I Calculations for Selenium Loading to Lake Koocanusa

Flows in the Elk River are typical of streams in mountainous terrain in Western North America, with minima occurring in late winter followed by 10-fold greater maxima in the early summer due to melting snowpack. For the period of record, 1924 to 1996, the lowest mean monthly discharge at the Phillips Bridge site (08NK005) was observed in February (i.e., 20.4 $m^3$/s) and highest in June (i.e., 258 $m^3$/s) (Water Survey of Can., 2008).

The mass loading of Se delivered by the Elk River into Lake Koocanusa can be calculated using the average mean monthly discharge (i.e., 75.8 $m^3$/s) over the 72-year gauging record and the total Se concentrations sampled at the same site since 1986. In 1986, the average total Se concentration at this site was 0.8 µg/L (n = 14), yielding an average loading of 5.24 kg/d or 1912 kg/yr. In 2008, the average Se concentration at this site on the Elk River was 4.26 µg/L (n = 18), resulting in an average loading of 27.9 kg/d or 10,183 kg/yr, a 5-fold increase over this 22-year period. This represents an increase in Se loading of 376 kg/yr or 19.7% per year, based on the 1986 loading. It must be stressed that these loadings are approximate, being based on a mean of 10 to 20 total Se grab samples per year and one period-of-record average monthly flow.

The actual mean monthly discharge in 1986 (i.e., 78.6 $m^3$/s) was similar to the period-of-record average, but annual averages (since 1934, the first year with data for every month) have ranged from 39.6 $m^3$/s in 1944 to 112 $m^3$/s in 1974. Unfortunately, this gauging station was shut down in 1996, so there are no flow data available after this period.

The Kootenay River at Fort Steele (08NG065), the closest flow gauging station to the Fenwick Station water quality monitoring site, has been gauged since 1963, and continues to be in operation. For the period of record: 1963 to 2007, the lowest mean monthly discharge was recorded in February (i.e., 37.1 $m^3$/s) and highest in June (i.e., 638 $m^3$/s) (Water Survey of Canada, 2008).

Using the same method of calculation as that applied for the Elk River (above), the mass loading of Se delivered by the Kootenay River to Lake Koocanusa can be calculated using the average mean monthly discharge (i.e., 173 $m^3$/s) over the 42-year gauging record at the Fort Steele site, and the total Se concentrations analyzed at the Fenwick Station site. For comparison purposes, only the 2008 loading has been calculated because earlier MDLs were inadequate to calculate a meaningful loading. In 2008, the average total Se concentration in the Kootenay River at this site was 0.09 µg/L (n = 15) resulting in an average loading of 1.34 kg/d or 489 kg/yr.

Comparable calculations for the Bull River are not possible because, although this stream has flow gauging (Bull River near Wardner 08NG002), comparable water quality monitoring has never been implemented. The geology of the Bull River basin is dominated by Palaeozoic sediments, similar to the large portions of the Kootenay River basin, but unlike the Mesozoic-dominated Elk River valley (Min.

Energy, Mines and Petrol. Res., 2009).  This, plus the relative small amount of industrial development or settlement in the basin, makes it reasonable to assume that total Se concentrations in the Bull River would be similar to those in the Kootenay River.  Using the percentages of average annual flow contribution to Lake Koocanusa mentioned above of 62% for the Kootenay River and 11% for the Bull River, the proportional average annual loading for 2008 would be approximately (11/62 x 489 =) 87 kg/yr.

The total Se loading to Lake Koocanusa for 2008 can now be estimated as:

10,183 kg (Elk River) + 489 kg (Kootenay River) + 87 kg (Bull River) = 10,759 kg/yr.

Based on these rough estimates, the Elk River, which provides approximately 26% of the water to Lake Koocanusa, in 2008, appeared to provide some 95% of the total Se loading.  The trend in Figure 1 suggests that, in the absence of effective mitigation measures, the Se loading from the Elk River to Lake Koocanusa will continue to rise into the future.

# Appendix II Site Information and Field Notes

| Site # | Date | Time | UTM | UTM | Secchi (m) | Total Depth (m) | Notes |
|---|---|---|---|---|---|---|---|
| **Kikomun** | | | | | | | |
| 1B | 05-Aug-08 | 10:10 | 624501 | 5460326 | 4.9 | 9.8 | Water samples @ 1 m and 8 m. Zooplankton green/brown in colour with some red copepods. |
| 1A | 05-Aug-08 | 11:45 | 624330 | 5460334 | 4.7 | 9.7 | Water samples @ 1 m and 8 m. Zooplankton green/brown in colour with some red copepods. |
| 1C | 05-Aug-08 | 12:45 | 624220 | 5461959 | 4.7 | 8.1 | Water samples @ 1 m and 6 m. Zooplankton similar to previous sites. |
| 1D | 05-Aug-08 | 14:30 | 624810 | 5459445 | 5.0 | 9.6 | Water samples @ 1 m and 7 m. Zooplankton similar to previous sites. Additional individual zooplankton moisture sample collected here. |
| 1E | 05-Aug-08 | 13:45 | 624937 | 5460242 | 4.7 | 9.7 | Water samples @ 1 m and 7 m. Zooplankton similar to previous sites, althoguh less abundant. May have towed at slightly shallower depth (i.e., 1 - 2 m). |
| **Gold Cr.** | | | | | | | |
| 3-1 | 06-Aug-08 | 9:30 | 633719 | 5431938 | 7.1 | 28.2 | Water samples @ 1 m and 23 m. Zooplankton similar to previous sites. More periphyton (slimy brown) observed at site 3. |
| 3-2 | 06-Aug-08 | 10:45 | 633632 | 5432775 | 6.8 | 17.4 | Water samples @ 1 m and 14 m. |
| 3-3 | 06-Aug-08 | 11:30 | 634106 | 5433558 | 6.8 | 35.0 | Water samples @ 1 m and 30 m. |
| 3-4 | 06-Aug-08 | 12:15 | 633981 | 5434466 | 6.8 | 29.0 | Water samples at 1 m and 25 m. |
| 3-5 | 06-Aug-08 | 13:30 | 632668 | 5435019 | 7.3 | 30.6 | Water samples at 1 m and 25 m. Additional individual zooplankton moisture sample at this site. |
| **Elk R.** | | | | | | | |
| 2-1 | 06-Aug-08 | 14:45 | 631447 | 5446936 | to bottom | 3.5 | Water samples at 1 m and 3 m. QC samples collected here - site replicate, field blank, equipment blank. Zooplankton extremely abundant relative to other sites. |
| 2-2 | 07-Aug-08 | 9:15 | 632216 | 5447126 | to bottom | 2.0 | Water samples ONLY at 1 m due to shallow depth. Lots of fish visible, John Bell thought they were suckers. |
| 2-3 | 07-Aug-08 | 10:15 | 631910 | 5446812 | to bottom | 3.6 | Water samples at 1 m and 3 m. |
| 2-4 | 07-Aug-08 | 11:00 | 631289 | 5447269 | to bottom | 5.0 | Water samples @ 1 m and 3.5 m. |
| 2-5 | 07-Aug-08 | 11:45 | 630131 | 5447191 | 7.3 | 8.9 | Water samples @ 1 m and 7 m. |

# Appendix III-A Analytical Methods and Detection Limits: Water Samples

| Variable | Units | Analytical Method (Maxxam Analytics Inc., Burnaby, B.C.) | RDL * |
|---|---|---|---|
| pH | | BRN SOP-00264 R2.0, Based on SM-4500H+B | 0.1 |
| Total Hardness | mg/L | Calculated as $CaCO_3$ | 0.5 |
| Total Suspended Solids (non-filterable residue) | mg/L | BRN SOP-00277 R2.0, Based on SM-2540 D | 4 |
| Total Dissolved Solids (filterable residue) | mg/L | ING443 Rev 5.1, APHA 2540C | 10 |
| Total Alkalinity | mg/L | BRN SOP-00264 R2.0, Based on SM 2320B | 0.5 |
| Sulphate : Diss | mg/L | Automated Colourimetry, BRN SOP-00243 R1.0, Based on EPA 375.4 | 0.5 |
| Chloride: Diss | mg/L | Automated Colourimetry, BRN SOP-00234 R1.0, Based on EPA 325.2 | 0.5 |
| Ammonia (N) | mg/L | BRN SOP-00221 R3.0, Based on SM-4500MH3G | 0.005 |
| Nitrite (N) | mg/L | BRN SOP-00233 R1.0, EPA 353.2 | 0.002 |
| Nitrate (N) | mg/L | Calculated from (NO2 + NO3) - NO2 | 0.002 |
| Nitrate + Nitrite (N) | mg/L | BRN SOP-00233 R1.0, Based on EPA 353.2 | 0.002 |
| Total Organic Nitrogen (N) | mg/L | Calculated from TKN + $NH_4$ | 0.02 |
| Total Kjeldahl Nitrogen (N) | mg/L | Calculated from TN - (NO2 + NO3) | 0.02 |
| Total Nitrogen (N) | mg/L | BRN SOP-00242 R2.0, Based on SM-4500N C | 0.02 |
| Orthophosphate (P) | mg/L | BRN WOP-00235 R3.0, SM 4500 PF (Konelab) | 0.001 |
| Total Phosphorus (P) | mg/L | BRN WOP-00236 R4.0, SM 4500 | 0.002 |
| Calcium | mg/L | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Magnesium | mg/L | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Potassium | mg/L | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Sodium | mg/L | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Sulphur | mg/L | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Aluminium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.2 |
| Antimony | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.02 |
| Arsenic | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.02 |
| Barium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.02 |
| Beryllium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Bismuth | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.005 |
| Boron | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 50 |
| Cadmium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.005 |
| Chromium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Cobalt | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.005 |
| Copper | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Iron | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 1 |
| Lead | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.005 |
| Lithium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.5 |
| Manganese | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Molybdenum | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Nickel | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.02 |
| Selenium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.04 |
| Silicon | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 100 |
| Silver | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.005 |
| Stontium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Thallium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.002 |
| Tin | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Titanium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.5 |
| Uranium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.002 |
| Vanadium | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.2 |
| Zinc | µg/L | ICPMS Low Level (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |

* RDL = Reportable Detection Limit, calculated using raw data.

## Appendix III-B Analytical Methods and Detection Limits: Biological Tissue Samples

| Variable | Units | Analytical Method (Maxxam Analytics Inc., Burnaby, B.C.) | RDL * |
|---|---|---|---|
| Moisture | % | BRN SOP-00321 R3.0, Ont MOE -E 3139 | 0.3 |
| Aluminium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 1 |
| Antimony | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Arsenic | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Barium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Beryllium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Bismuth | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Boron | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 5 |
| Cadmium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Calcium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Chromium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.5 |
| Cobalt | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Copper | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.5 |
| Iron | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Lead | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Magnesium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Manganese | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Mercury | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Molybdenum | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Nickel | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Phosphorus | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Potassium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Selenium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.01 |
| Silver | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Sodium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 10 |
| Strontium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Thallium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Tin | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |
| Titanium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 1 |
| Uranium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.05 |
| Vanadium | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 2 |
| Zinc | mg/kg | CRC ICPMS (total), BRN SOP-00206, Based on EPA 200.8 | 0.1 |

* RDL = Reportable Detection Limit, calculated using raw data.

*Note: the units "µg/g" and "mg/kg", whether wet weight or dry weight, are identical and can be used interchangeably.*

# Appendix IV Quality Assurance/Quality Control

Maxxam Analytics' QC criteria for water samples are as follows:

| | |
|---|---|
| Matrix spikes and spikes | 75 to 125% recovery |
| Blanks | < Reportable Detection Limit (RDL) (0.04 µg/L for total Se) |
| Duplicates | < 25% Relative Percent Difference (RPD) |

Maxxam includes the batch QC results with each certificate of analysis. These documents are not included in this report but can be obtained from the BC Environmental Protection office in Nelson, BC.

In the eight QA batches for the seven certificates of analysis for water sample analyses, the total Se QC criteria (listed above) were met in all the spikes, matrix spikes, and blanks. In four of the batches, the RPD for the duplicates was reported as "non-calculable", meaning that analyte concentrations in both the sample and duplicate were less than 5 times the RDL. In the other four batches, the duplicate QC criteria were met.

Maxxam Analytics' QC criteria for the biological tissue samples are as follows:

| | |
|---|---|
| Matrix spikes, spikes and QC standards | 75 to 125% recovery |
| Blanks | < RDL (0.01 µg/g wet wt. for Se) |
| Duplicates | < 35% RPD |

Batch QA for Se in the three zooplankton tissue certificates of analysis were all within QC limits. The Se batch QA for the seventeen fish tissue certificates of analysis were all within QC limits, except for four blanks, which all reported concentrations of 0.02 µg Se/g ww.

Field QA/QC for water sampling included taking one duplicate sample at the Elk River site plus a field blank, and an equipment blank on the Van Dorn sampler. The field blank involved filling the standard sample bottles with de-ionized water prior to field deployment, transporting them into the field along with the regular samples, opening the lid for 10 seconds at the site, and shipping along with the regular samples. The purpose of the field blank was to confirm that there was no contamination introduced from the sample bottles, transport, or sampling handling procedures. The Van Dorn sampler blank involved adding de-ionized water to the Van Dorn bottle, after rinsing with same, then drawing samples in the same fashion as regular sampling, with the intention of detecting any contamination introduced from the Van Dorn sampler itself. Duplicate samples were taken from the Van Dorn sampler sequentially.

Results of the water sampling field QA/QC are listed in Table IV-1. Based on the same duplicate and blank QC criteria as those employed by Maxxam Analytics (± 25% RPD and < RDL), all field QA/QC total Se samples were within control limits.

## Table IV-1. Field QA for Water Samples

| Variable | Units | E272044 1m (Repl #1) | Duplicate | RPD (%) | Field Blank | Van Dorn Blank |
|---|---|---|---|---|---|---|
| pH | | 8.3 | 8.4 | 1.2 | 5.7 | 6.4 |
| Total Hardness | mg/L | 98.9 | 109 | 9.3 | <0.5 | <0.5 |
| Total Suspended Solids | mg/L | <4 | <4 | n/a | <4 | <4 |
| Total Dissolved Solids | mg/L | 130 | 130 | 0.0 | <10 | <10 |
| Total Alkalinity | mg/L | 98 | 98 | 0.0 | <0.5 | 0.9 |
| Sulphate : Diss | mg/L | 18 | 19 | 5.3 | <0.5 | <0.5 |
| Chloride: Diss | mg/L | 1.9 | 1.9 | 0.0 | <0.5 | <0.5 |
| Ammonia (N) | mg/L | <0.005 | <0.005 | n/a | <0.005 | <0.005 |
| Nitrite (N) | mg/L | 0.009 | <0.002 | n/a | <0.002 | <0.002 |
| Nitrate (N) | mg/L | 0.069 | 0.077 | 10.4 | <0.002 | 0.003 |
| Total Organic Nitrogen (N) | mg/L | 0.06 | 0.06 | 0.0 | 0.06 | <0.02 |
| Total Nitrogen (N) | mg/L | 0.14 | 0.14 | 0.0 | 0.06 | <0.02 |
| Orthophosphate (P) | mg/L | 0.002 | 0.002 | 0.0 | 0.001 | <0.001 |
| Total Phosphorus (P) | mg/L | 0.005 | 0.005 | 0.0 | 0.002 | <0.002 |
| **Total Metals by ICPMS** | | | | | | |
| Calcium | mg/L | 27.2 | 30.0 | 9.3 | <0.05 | 0.05 |
| Magnesium | mg/L | 7.50 | 8.29 | 9.5 | <0.05 | <0.05 |
| Potassium | mg/L | 0.37 | 0.41 | 9.8 | <0.05 | <0.05 |
| Sodium | mg/L | 1.96 | 2.10 | 6.7 | <0.05 | <0.05 |
| Sulphur | mg/L | 8 | 8 | 0.0 | <3 | <3 |
| Aluminium | µg/L | 5.9 | 6.5 | 9.2 | <0.2 | 1.3 |
| Antimony | µg/L | 0.05 | 0.05 | 0.0 | <0.02 | <0.02 |
| Arsenic | µg/L | 0.30 | 0.29 | 3.4 | <0.02 | <0.02 |
| Barium | µg/L | 34.3 | 37.5 | 8.5 | <0.02 | 0.07 |
| Beryllium | µg/L | <0.01 | <0.01 | n/a | <0.01 | <0.01 |
| Bismuth | µg/L | <0.005 | <0.005 | n/a | <0.005 | <0.005 |
| Boron | µg/L | <50 | <50 | n/a | <50 | <50 |
| Cadmium | µg/L | 0.013 | 0.019 | 30.0 | <0.005 | <0.005 |
| Chromium | µg/L | <0.1 | <0.1 | n/a | <0.1 | <0.1 |
| Cobalt | µg/L | 0.018 | 0.024 | 25.0 | <0.005 | <0.005 |
| Copper | µg/L | 0.32 | 0.44 | 27.3 | <0.05 | 0.16 |
| Iron | µg/L | 3 | 4 | 25.0 | <1 | <1 |
| Lead | µg/L | 0.089 | 0.146 | 39.0 | <0.005 | 0.042 |
| Lithium | µg/L | 1.6 | 1.6 | 0.0 | <0.5 | <0.5 |
| Manganese | µg/L | 0.75 | 0.87 | 13.8 | <0.05 | <0.05 |
| Molybdenum | µg/L | 0.61 | 0.63 | 3.2 | <0.05 | <0.05 |
| Nickel | µg/L | 1.24 | 2.50 | 50.4 | <0.02 | 0.44 |
| Selenium | µg/L | 0.90 | 0.82 | 9.8 | <0.04 | <0.04 |
| Silicon | µg/L | 1620 | 1640 | 1.2 | <100 | <100 |
| Silver | µg/L | <0.005 | <0.005 | n/a | <0.005 | <0.005 |
| Stontium | µg/L | 98.4 | 107 | 8.0 | <0.05 | <0.05 |
| Thallium | µg/L | 0.003 | 0.004 | 25.0 | <0.002 | <0.002 |
| Tin | µg/L | <0.01 | <0.01 | n/a | <0.01 | <0.01 |
| Titanium | µg/L | <0.5 | 0.5 | n/a | <0.5 | <0.5 |
| Uranium | µg/L | 0.556 | 0.589 | 5.6 | <0.002 | <0.002 |
| Vanadium | µg/L | <0.2 | <0.2 | n/a | <0.2 | <0.2 |
| Zinc | µg/L | 2.1 | 3.3 | 36.4 | <0.1 | 2.8 |

Exceeds RPD criteria of ± 25% or exceeds Reportable Detection Limit in Blanks

Field QA/QC for biological tissues consisted of duplicate samples for fish axial muscle and ovary intended to evaluate sampling, processing, plus analytical error, for a given analyte. Duplicate axial muscle samples consisted of one sample from either side of the same fish. Duplicate ovary samples consisted of splitting the egg mass in half. No zooplankton duplicates were done in this survey.

Fish tissue field duplicate results are listed in Table IV-2. Based on the same duplicate QC criterion that were employed by Maxxam Analytics (i.e., ± 25% RPD), all fish tissue Se duplicate samples were within control limits.

# Table IV-2. Field QA for Fish Samples

| | | Canadian Reach (E272043) | | | | United States Reach (E273984) | | | | United States Reach (E273984) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish No. (tissue) | | Fish No. (tissue) | | Fish No. (tissue) | | Fish No. (tissue) | | Fish No. (tissue) | | Fish No. (tissue) | |
| **Variable** | **Units** | **KO-10 (muscle)** | **Duplicate** | **KO-10 (ovary)** | **Duplicate** | **KO-40 (muscle)** | **Duplicate** | **KO-40 (ovary)** | **Duplicate** | **PCC-10 (muscle)** | **Duplicate** | **PCC-10 (ovary)** | **Duplicate** |
| Moisture | % | 78 | 78 | 58 | 62 | 84 | 82 | 63 | 61 | 81 | 81 | No result | 67 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 1 | <1 |
| Antimony | 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 |
| Arsenic | mg/kg | 0.03 | 0.03 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.06 | 0.06 | 0.08 | 0.10 |
| Barium | mg/kg | <0.1 | <0.1 | 0.2 | 0.2 | <0.1 | <0.1 | 0.2 | 0.2 | 0.9 | 0.7 | 1.0 | 1.0 |
| Beryllium | 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 |
| Bismuth | 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 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | 0.02 |
| Calcium | mg/kg | 141 | 123 | 510 | 503 | 74 | 108 | 471 | 481 | 759 | 247 | 101 | 128 |
| Chromium | 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 |
| Cobalt | 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 |
| Copper | mg/kg | 0.7 | 0.5 | 13.6 | 14.3 | 0.8 | 0.6 | 10.1 | 11.0 | <0.5 | 0.6 | 1.4 | 1.4 |
| Iron | mg/kg | <10 | <10 | 23 | 21 | <10 | <10 | 17 | 17 | <10 | 10 | 33 | 34 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 257 | 252 | 580 | 580 | 233 | 210 | 468 | 489 | 310 | 263 | 293 | 307 |
| Manganese | mg/kg | <0.1 | <0.1 | 1.2 | 1.2 | <0.1 | <0.1 | 0.8 | 0.8 | 0.3 | 0.2 | 1.6 | 1.8 |
| Mercury | mg/kg | 0.05 | 0.05 | 0.01 | 0.01 | 0.05 | 0.04 | <0.01 | <0.01 | 0.18 | 0.17 | 0.02 | 0.01 |
| Molybdenum | 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 |
| Nickel | mg/kg | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | <0.1 | 0.2 |
| Phosphorus | mg/kg | 2500 | 2340 | 4280 | 4400 | 2360 | 2220 | 3990 | 4050 | 2560 | 2150 | 4740 | 5010 |
| Potassium | mg/kg | 3680 | 3520 | 2750 | 2800 | 3500 | 3260 | 3060 | 3130 | 3800 | 3560 | 2720 | 2770 |
| Selenium | mg/kg | 0.42 | 0.43 | 1.62 | 1.48 | 0.38 | 0.35 | 1.31 | 1.28 | 0.53 | 0.56 | 3.38 | 3.49 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 686 | 590 | 705 | 675 | 784 | 821 | 837 | 894 | 498 | 516 | 541 | 568 |
| Strontium | mg/kg | <0.1 | <0.1 | 0.7 | 0.7 | <0.1 | <0.1 | 0.7 | 0.7 | 0.9 | 0.2 | 0.1 | 0.2 |
| Thallium | 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 |
| Tin | 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 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | 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 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 8.7 | 6.4 | 39.7 | 36.9 | 8.4 | 7.0 | 27.6 | 28.9 | 8.3 | 10.5 | 29.0 | 28.8 |

Exceeds RPD criteria of ± 25%

# Appendix V

# Water Data

# APPENDIX V-A Water Data: Kikomun Bridge

| Sample date: August 5, 2008 | | Replicate 1 | | Replicate 2 | | Replicate 3 | | Replicate 4 | | Replicate 5 | | Surface Average | Bottom Average | Site Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Time** | | 11:45 | | 10:10 | | 12:45 | | 14:30 | | 13:45 | | | | |
| **Variable** | **Units** | **1 m** | **8m** | **1 m** | **8m** | **1 m** | **6m** | **1 m** | **7m** | **1 m** | **7m** | | | |
| pH | | 8.3 | 8.2 | 8.2 | 8.2 | 8.3 | 8.3 | 8.2 | 8.3 | 8.3 | 8.2 | 8.3 | 8.2 | 8.3 |
| Total Hardness | mg/L | 103 | 111 | 110 | 111 | 103 | 110 | 109 | 115 | 99.4 | 108 | 105 | 111 | 108 |
| Total Suspended Solids | mg/L | <4 | 6 | <4 | 5 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | 5 | 4 |
| Total Dissolved Solids | mg/L | 140 | 140 | 150 | 150 | 150 | 130 | 140 | 150 | 120 | 150 | 140 | 144 | 142 |
| Total Alkalinity | mg/L | 94 | 96 | 93 | 95 | 95 | 95 | 93 | 96 | 93 | 94 | 94 | 95 | 94 |
| Sulphate : Diss | mg/L | 21 | 24 | 21 | 24 | 21 | 22 | 21 | 23 | 21 | 22 | 21 | 23 | 22 |
| Chloride: Diss | mg/L | 2.6 | 3 | 2.5 | 3 | 2.5 | 2.7 | 2.5 | 2.8 | 2.6 | 2.9 | 2.5 | 2.9 | 2.7 |
| Ammonia (N) | mg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Nitrite (N) | mg/L | 0.002 | 0.002 | <0.002 | 0.002 | <0.002 | <0.002 | 0.002 | <0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 |
| Nitrate (N) | mg/L | 0.030 | 0.058 | 0.032 | 0.058 | 0.029 | 0.058 | 0.025 | 0.054 | 0.025 | 0.051 | 0.028 | 0.056 | 0.042 |
| Total Organic Nitrogen (N) | mg/L | 0.08 | 0.04 | 0.07 | 0.06 | 0.03 | 0.03 | 0.12 | 0.07 | 0.10 | 0.03 | 0.08 | 0.05 | 0.06 |
| Total Nitrogen (N) | mg/L | 0.11 | 0.1 | 0.1 | 0.12 | 0.06 | 0.09 | 0.15 | 0.12 | 0.13 | 0.08 | 0.11 | 0.10 | 0.11 |
| Orthophosphate (P) | mg/L | 0.001 | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Total Phosphorus (P) | mg/L | 0.004 | 0.005 | 0.004 | 0.004 | 0.004 | 0.006 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.004 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | |
| Calcium | mg/L | 28.1 | 30.0 | 30.2 | 30.1 | 27.9 | 30.1 | 29.7 | 31.2 | 27.1 | 29.2 | 28.6 | 30.1 | 29.4 |
| Magnesium | mg/L | 7.93 | 8.68 | 8.38 | 8.67 | 8.07 | 8.50 | 8.38 | 8.95 | 7.70 | 8.51 | 8.09 | 8.66 | 8.38 |
| Potassium | mg/L | 0.38 | 0.43 | 0.42 | 0.43 | 0.39 | 0.42 | 0.41 | 0.44 | 0.38 | 0.41 | 0.40 | 0.43 | 0.41 |
| Sodium | mg/L | 2.67 | 3.22 | 2.77 | 3.19 | 2.65 | 2.99 | 2.78 | 3.28 | 2.58 | 3.03 | 2.69 | 3.14 | 2.92 |
| Sulphur | mg/L | 8 | 9 | 8 | 9 | 8 | 8 | 8 | 9 | 8 | 9 | 8 | 9 | 8 |
| Aluminium | µg/L | 8.2 | 23.9 | 9.6 | 20.1 | 10.7 | 13.0 | 8.7 | 21.8 | 8.7 | 24.1 | 9.2 | 20.6 | 14.9 |
| Antimony | µg/L | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 |
| Arsenic | µg/L | 0.30 | 0.36 | 0.32 | 0.35 | 0.32 | 0.33 | 0.32 | 0.35 | 0.31 | 0.35 | 0.31 | 0.35 | 0.33 |
| Barium | µg/L | 27.8 | 29.8 | 29.9 | 29.8 | 25.1 | 30.0 | 29.3 | 30.4 | 27.4 | 30.4 | 27.9 | 30.1 | 29.0 |
| Beryllium | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bismuth | µg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Boron | µg/L | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| Cadmium | µg/L | 0.026 | 0.025 | 0.147 | 0.040 | 0.032 | 0.026 | 0.026 | 0.030 | 0.029 | 0.016 | 0.052 | 0.027 | 0.040 |
| Chromium | µg/L | <0.1 | 0.2 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | 0.2 | <0.1 | 0.1 | 0.2 |
| Cobalt | µg/L | 0.026 | 0.051 | 0.031 | 0.051 | 0.029 | 0.025 | 0.025 | 0.047 | 0.021 | 0.053 | 0.026 | 0.045 | 0.036 |
| Copper | µg/L | 0.56 | 0.48 | 0.49 | 0.46 | 0.43 | 0.65 | 0.47 | 0.39 | 0.35 | 0.42 | 0.46 | 0.48 | 0.47 |
| Iron | µg/L | 6 | 32 | 7 | 20 | 6 | 13 | 7 | 30 | 7 | 26 | 7 | 24 | 15 |
| Lead | µg/L | 0.157 | 0.266 | 0.198 | 0.180 | 0.188 | 0.179 | 0.223 | 0.162 | 0.068 | 0.289 | 0.167 | 0.215 | 0.191 |
| Lithium | µg/L | 1.1 | 1.2 | 1.2 | 1.2 | 1.0 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 |
| Manganese | µg/L | 1.10 | 4.50 | 1.24 | 3.43 | 1.03 | 1.79 | 1.14 | 4.01 | 1.23 | 3.41 | 1.15 | 3.43 | 2.29 |
| Molybdenum | µg/L | 0.65 | 0.72 | 0.64 | 0.69 | 0.58 | 0.68 | 0.65 | 0.69 | 0.62 | 0.74 | 0.63 | 0.70 | 0.67 |
| Nickel | µg/L | 5.11 | 4.73 | 5.77 | 6.96 | 6.22 | 2.53 | 2.91 | 2.21 | 1.78 | 5.70 | 4.36 | 4.43 | 4.39 |
| Selenium | µg/L | 0.12 | 0.09 | 0.12 | 0.09 | 0.13 | 0.09 | 0.12 | 0.09 | 0.13 | 0.09 | 0.12 | 0.09 | 0.11 |
| Silicon | µg/L | 1800 | 1890 | 1800 | 1930 | 1860 | 1900 | 1830 | 1810 | 1780 | 1820 | 1814 | 1870 | 1842 |
| Silver | µg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Stontium | µg/L | 111 | 125 | 118 | 126 | 101 | 122 | 114 | 125 | 108 | 125 | 110 | 125 | 118 |
| Thallium | µg/L | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 | 0.004 | 0.002 | 0.003 | 0.002 | 0.003 | 0.002 | 0.003 | 0.003 |
| Tin | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Titanium | µg/L | <0.5 | 0.7 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Uranium | µg/L | 0.581 | 0.648 | 0.624 | 0.635 | 0.529 | 0.618 | 0.593 | 0.645 | 0.565 | 0.651 | 0.578 | 0.639 | 0.609 |
| Vanadium | µg/L | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Zinc | µg/L | 3.8 | 4.3 | 10.3 | 7.3 | 5.7 | 2.9 | 4.4 | 3 | 5.2 | 4.6 | 5.9 | 4.42 | 5.2 |

# APPENDIX V-B Water Data: Elk River

| Variable | Units | Replicate 1 | | Replicate 2 | | Replicate 3 | | Replicate 4 | | Replicate 5 | | Surface Average | Bottom Average | Site Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Time | | 06/08/2008 14:45 | | 07/08/2008 9:15 | | 07/08/2008 10:15 | | 07/08/2008 11:00 | | 07/08/2008 11:45 | | | | |
| | | 1 m | 3m | 1 m | | 1 m | 3m | 1 m | 3.5m | 1 m | 7m | | | |
| pH | | 8.3 | 8.3 | 8.4 | No Sample, Too Shallow | 8.3 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 |
| Total Hardness | mg/L | 98.9 | 118 | 114 | | 110 | 136 | 102 | 125 | 106 | 115 | 106 | 124 | 114 |
| Total Suspended Solids | mg/L | <4 | <4 | <4 | | <4 | 5 | <4 | <4 | <4 | <4 | <4 | <4 | <4 |
| Total Dissolved Solids | mg/L | 130 | 150 | 130 | | 140 | 180 | 130 | 140 | 120 | 160 | 130 | 158 | 142 |
| Total Alkalinity | mg/L | 98 | 110 | 100 | | 99 | 120 | 96 | 110 | 97 | 100 | 98 | 110 | 103 |
| Sulphate : Diss | mg/L | 18 | 25 | 21 | | 20 | 29 | 19 | 25 | 19 | 22 | 19 | 25 | 22 |
| Chloride: Diss | mg/L | 1.9 | 1.8 | 1.9 | | 1.7 | 1.5 | 2.0 | 1.5 | 1.7 | 1.6 | 1.8 | 1.6 | 1.7 |
| Ammonia (N) | mg/L | <0.005 | <0.005 | 0.021 | | 0.030 | <0.005 | 0.012 | 0.007 | 0.008 | 0.010 | 0.015 | 0.007 | 0.016 |
| Nitrite (N) | mg/L | 0.009 | 0.002 | 0.003 | | 0.002 | 0.002 | 0.002 | 0.002 | <0.002 | 0.002 | 0.002 | 0.002 | 0.003 |
| Nitrate (N) | mg/L | 0.069 | 0.181 | 0.096 | | 0.094 | 0.350 | 0.059 | 0.213 | 0.041 | 0.159 | 0.072 | 0.226 | 0.140 |
| Total Organic Nitrogen (N) | mg/L | 0.06 | 0.10 | 0.06 | | 0.03 | 0.03 | 0.06 | 0.03 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 |
| Total Nitrogen (N) | mg/L | 0.14 | 0.29 | 0.18 | | 0.15 | 0.38 | 0.13 | 0.25 | 0.11 | 0.22 | 0.14 | 0.29 | 0.21 |
| Orthophosphate (P) | mg/L | 0.002 | 0.005 | <0.001 | | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.003 |
| Total Phosphorus (P) | mg/L | 0.005 | 0.009 | 0.003 | | 0.005 | 0.003 | 0.003 | 0.003 | 0.002 | <0.002 | 0.004 | 0.004 | 0.004 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | |
| Calcium | mg/L | 27.2 | 32.1 | 31.2 | | 30.3 | 37.1 | 28.0 | 34.3 | 29.1 | 31.4 | 29.2 | 33.7 | 31.2 |
| Magnesium | mg/L | 7.50 | 9.07 | 8.64 | | 8.38 | 10.50 | 7.88 | 9.61 | 8.05 | 8.89 | 8.09 | 9.52 | 8.72 |
| Potassium | mg/L | 0.37 | 0.41 | 0.41 | | 0.40 | 0.43 | 0.40 | 0.42 | 0.40 | 0.40 | 0.40 | 0.42 | 0.40 |
| Sodium | mg/L | 1.96 | 2.05 | 2.15 | | 2.09 | 1.90 | 2.11 | 2.05 | 2.18 | 2.10 | 2.10 | 2.03 | 2.07 |
| Sulphur | mg/L | 8 | 9 | 8 | | 8 | 11 | 7 | 9 | 7 | 9 | 8 | 10 | 8 |
| Aluminium | µg/L | 5.9 | 6.3 | 7.2 | | 5.3 | 7.9 | 5.9 | 6.1 | 7.5 | 7.9 | 6.4 | 7.1 | 6.7 |
| Antimony | µg/L | 0.05 | 0.05 | 0.04 | | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 |
| Arsenic | µg/L | 0.30 | 0.31 | 0.29 | | 0.29 | 0.28 | 0.26 | 0.28 | 0.29 | 0.28 | 0.29 | 0.29 | 0.29 |
| Barium | µg/L | 34.3 | 41.9 | 39.2 | | 37.7 | 54.7 | 35.3 | 46.8 | 34.1 | 41.9 | 36.1 | 46.3 | 40.7 |
| Beryllium | µg/L | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bismuth | µg/L | <0.005 | <0.005 | <0.005 | | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Boron | µg/L | <50 | <50 | <50 | | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| Cadmium | µg/L | 0.013 | 0.016 | 0.025 | | 0.014 | 0.025 | 0.019 | 0.025 | 0.016 | 0.017 | 0.017 | 0.021 | 0.019 |
| Chromium | µg/L | <0.1 | <0.1 | <0.1 | | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cobalt | µg/L | 0.018 | 0.020 | 0.025 | | 0.017 | 0.023 | 0.019 | 0.019 | 0.020 | 0.021 | 0.020 | 0.021 | 0.020 |
| Copper | µg/L | 0.32 | 0.32 | 0.36 | | 0.36 | 0.34 | 0.58 | 0.47 | 0.49 | 0.36 | 0.42 | 0.37 | 0.40 |
| Iron | µg/L | 3 | 8 | 5 | | 4 | 12 | 4 | 9 | 5 | 7 | 4 | 9 | 6 |
| Lead | µg/L | 0.089 | 0.055 | 0.060 | | 0.051 | 0.059 | 0.060 | 0.062 | 0.059 | 0.049 | 0.064 | 0.056 | 0.060 |
| Lithium | µg/L | 1.6 | 2.1 | 1.7 | | 1.7 | 3.2 | 1.5 | 2.5 | 1.4 | 2.0 | 1.6 | 2.5 | 2.0 |
| Manganese | µg/L | 0.75 | 1.70 | 1.05 | | 0.78 | 2.73 | 0.72 | 1.41 | 0.76 | 1.47 | 0.81 | 1.83 | 1.26 |
| Molybdenum | µg/L | 0.61 | 0.68 | 0.65 | | 0.65 | 0.85 | 0.60 | 0.75 | 0.62 | 0.69 | 0.63 | 0.74 | 0.68 |
| Nickel | µg/L | 1.24 | 0.67 | 1.02 | | 0.61 | 0.81 | 0.77 | 0.70 | 0.82 | 0.42 | 0.89 | 0.65 | 0.78 |
| Selenium | µg/L | 0.90 | 1.62 | 0.96 | | 0.99 | 2.73 | 0.72 | 2.16 | 0.58 | 1.32 | 0.83 | 1.96 | 1.33 |
| Silicon | µg/L | 1620 | 1920 | 1510 | | 1480 | 1700 | 1400 | 1970 | 1440 | 1600 | 1490 | 1798 | 1627 |
| Silver | µg/L | <0.005 | <0.005 | <0.005 | | <0.005 | 0.005 | <0.005 | <0.005 | 0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Stontium | µg/L | 98 | 109 | 110 | | 107 | 127 | 105 | 120 | 106 | 113 | 105 | 117 | 111 |
| Thallium | µg/L | 0.003 | 0.004 | 0.003 | | 0.003 | 0.004 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.003 |
| Tin | µg/L | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Titanium | µg/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 |
| Uranium | µg/L | 0.556 | 0.596 | 0.560 | | 0.543 | 0.637 | 0.533 | 0.652 | 0.538 | 0.570 | 0.546 | 0.6 | 0.576 |
| Vanadium | µg/L | <0.2 | <0.2 | <0.2 | | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Zinc | µg/L | 2.1 | 1.7 | 4.2 | | 2.5 | 3.2 | 4.8 | 4.6 | 2.7 | 2.8 | 3.3 | 3.1 | 3.2 |

# APPENDIX V-C Water Data: Gold Creek

| Sample date: August 6, 2008 | | Replicate 1 | | Replicate 2 | | Replicate 3 | | Replicate 4 | | Replicate 5 | | Surface Average | Bottom Average | Site Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Time | | 9:30 | | 10:45 | | 11:30 | | 12:15 | | 13:30 | | | | |
| Variable | Units | 1 m | 23m | 1 m | 14m | 1 m | 30m | 1 m | 25m | 1 m | 25m | | | |
| pH | | 8.4 | 8.2 | 8.3 | 8.2 | 8.4 | 8.2 | 8.4 | 8.1 | 8.5 | 8.2 | 8.4 | 8.2 | 8.3 |
| Total Hardness | mg/L | 115 | 110 | 99.8 | 114 | 98.5 | 110 | 98 | 104 | 97.4 | 115 | 102 | 111 | 106 |
| Total Suspended Solids | mg/L | <4 | 4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 |
| Total Dissolved Solids | mg/L | 140 | 130 | 120 | 140 | 120 | 140 | 120 | 130 | 130 | 140 | 126 | 136 | 131 |
| Total Alkalinity | mg/L | 94 | 96 | 95 | 100 | 95 | 100 | 95 | 97 | 95 | 98 | 95 | 98 | 97 |
| Sulphate : Diss | mg/L | 17 | 17 | 18 | 21 | 18 | 19 | 17 | 17 | 18 | 13 | 18 | 17 | 18 |
| Chloride: Diss | mg/L | 2 | 2.2 | 1.9 | 2.2 | 1.8 | 1.8 | 2 | 1.6 | 2 | 8.7 | 1.9 | 3.3 | 2.6 |
| Ammonia (N) | mg/L | <0.005 | <0.005 | <0.005 | 0.009 | <0.005 | <0.005 | 0.007 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Nitrite (N) | mg/L | <0.002 | <0.002 | <0.002 | 0.002 | 0.002 | <0.002 | 0.002 | <0.002 | 0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Nitrate (N) | mg/L | 0.04 | 0.236 | 0.039 | 0.175 | 0.037 | 0.253 | 0.038 | 0.24 | 0.039 | 0.244 | 0.039 | 0.230 | 0.134 |
| Total Organic Nitrogen (N) | mg/L | 0.09 | 0.03 | 0.1 | 0.02 | 0.05 | 0.04 | 0.07 | 0.04 | 0.03 | 0.06 | 0.07 | 0.04 | 0.05 |
| Total Nitrogen (N) | mg/L | 0.13 | 0.26 | 0.14 | 0.21 | 0.09 | 0.3 | 0.12 | 0.28 | 0.07 | 0.3 | 0.11 | 0.27 | 0.19 |
| Orthophosphate (P) | mg/L | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| Total Phosphorus (P) | mg/L | 0.003 | 0.004 | 0.005 | 0.004 | 0.005 | 0.005 | 0.003 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | |
| Calcium | mg/L | 31.7 | 30.9 | 27.5 | 31.2 | 27.1 | 30.5 | 27.0 | 28.8 | 26.8 | 32.1 | 28.0 | 30.7 | 29.4 |
| Magnesium | mg/L | 8.71 | 8.12 | 7.53 | 8.79 | 7.50 | 8.25 | 7.43 | 7.83 | 7.43 | 8.42 | 7.72 | 8.28 | 8.00 |
| Potassium | mg/L | 0.45 | 0.40 | 0.38 | 0.41 | 0.38 | 0.42 | 0.39 | 0.38 | 0.37 | 0.42 | 0.39 | 0.41 | 0.40 |
| Sodium | mg/L | 2.24 | 1.92 | 2.03 | 2.27 | 1.99 | 2.06 | 1.96 | 1.79 | 1.95 | 1.93 | 2.03 | 1.99 | 2.01 |
| Sulphur | mg/L | 7 | 7 | 7 | 9 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| Aluminium | µg/L | 8.8 | 17.0 | 14.9 | 9.3 | 6.6 | 18.3 | 8.5 | 13.1 | 7.3 | 15.3 | 9.2 | 14.6 | 11.9 |
| Antimony | µg/L | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.06 | 0.04 | 0.05 | 0.04 | 0.06 | 0.04 | 0.05 | 0.05 |
| Arsenic | µg/L | 0.31 | 0.30 | 0.29 | 0.34 | 0.29 | 0.31 | 0.29 | 0.31 | 0.28 | 0.30 | 0.29 | 0.31 | 0.30 |
| Barium | µg/L | 38.6 | 38.9 | 33.8 | 39.0 | 33.6 | 41.7 | 33.7 | 37.0 | 33.8 | 40.9 | 34.7 | 39.5 | 37.1 |
| Beryllium | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bismuth | µg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Boron | µg/L | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| Cadmium | µg/L | 0.021 | 0.035 | 0.024 | 0.026 | 0.011 | 0.024 | 0.011 | 0.014 | 0.007 | 0.033 | 0.015 | 0.026 | 0.021 |
| Chromium | µg/L | 0.1 | <0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.6 | <0.1 | 1.3 | <0.1 | 0.5 | 0.1 | 0.3 |
| Cobalt | µg/L | 0.024 | 0.028 | 0.021 | 0.021 | 0.019 | 0.023 | 0.019 | 0.020 | 0.020 | 0.026 | 0.021 | 0.024 | 0.022 |
| Copper | µg/L | 0.49 | 0.41 | 0.42 | 0.41 | 0.38 | 0.49 | 0.53 | 0.43 | 0.51 | 0.43 | 0.47 | 0.43 | 0.45 |
| Iron | µg/L | 3 | 16 | 7 | 8 | 3 | 13 | 4 | 9 | 3 | 15 | 4 | 12 | 8 |
| Lead | µg/L | 0.132 | 0.142 | 0.055 | 0.087 | 0.043 | 0.090 | 0.062 | 0.052 | 0.077 | 0.078 | 0.074 | 0.090 | 0.082 |
| Lithium | µg/L | 1.5 | 1.6 | 1.4 | 1.9 | 1.3 | 1.8 | 1.4 | 1.6 | 1.4 | 1.7 | 1.4 | 1.7 | 1.6 |
| Manganese | µg/L | 0.73 | 2.46 | 1.31 | 1.77 | 0.65 | 2.00 | 0.68 | 1.14 | 0.80 | 2.20 | 0.83 | 1.91 | 1.37 |
| Molybdenum | µg/L | 0.60 | 0.59 | 0.58 | 0.73 | 0.58 | 0.66 | 0.58 | 0.59 | 0.58 | 0.64 | 0.58 | 0.64 | 0.61 |
| Nickel | µg/L | 1.92 | 1.60 | 0.83 | 2.62 | 0.57 | 0.88 | 0.59 | 0.99 | 0.57 | 1.24 | 0.90 | 1.47 | 1.18 |
| Selenium | µg/L | 0.66 | 0.91 | 0.72 | 0.93 | 0.71 | 0.96 | 0.84 | 1.02 | 0.70 | 0.95 | 0.73 | 0.95 | 0.84 |
| Silicon | µg/L | 1500 | 1980 | 1500 | 1850 | 1520 | 2290 | 1760 | 2270 | 1510 | 2310 | 1558 | 2140 | 1849 |
| Silver | µg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Stontium | µg/L | 107.0 | 102.0 | 95.6 | 116.0 | 94.9 | 107.0 | 94.9 | 95.9 | 97.3 | 107.0 | 97.9 | 105.6 | 101.8 |
| Thallium | µg/L | 0.003 | 0.004 | 0.002 | 0.005 | 0.003 | 0.004 | 0.002 | 0.004 | 0.003 | 0.004 | 0.003 | 0.004 | 0.003 |
| Tin | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Titanium | µg/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 |
| Uranium | µg/L | 0.626 | 0.592 | 0.580 | 0.615 | 0.562 | 0.619 | 0.559 | 0.556 | 0.569 | 0.607 | 0.579 | 0.598 | 0.589 |
| Vanadium | µg/L | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Zinc | µg/L | 3.6 | 5.9 | 2.9 | 3.7 | 1.1 | 4.0 | 1.3 | 2.1 | 1.9 | 7.4 | 2.2 | 4.6 | 3.4 |

# APPENDIX VI-A Total Selenium in Water: Two-Way ANOVA

| | Water Column Total Se (ug/L) | | |
|---|---|---|---|
| Depth | Kikomun | Elk River | Gold Cr |
| surface | 0.12 | 0.90 | 0.66 |
| surface | 0.12 | 0.96 | 0.72 |
| surface | 0.13 | 0.99 | 0.71 |
| surface | 0.12 | 0.72 | 0.84 |
| surface | 0.13 | 0.58 | 0.70 |
| bottom | 0.09 | 1.62 | 0.91 |
| bottom | 0.09 | 2.50 | 0.93 |
| bottom | 0.09 | 2.73 | 0.96 |
| bottom | 0.09 | 2.16 | 1.02 |
| bottom | 0.09 | 1.32 | 0.95 |

(Missing result, estimated value added to balance ANOVA)

Analyse-it v2.12

| | |
|---|---|
| Test | **Compare Groups - 2-way ANOVA** |
| | Data by Sites, Depth |
| Performed by | Les |

Date: 23 October 2008

n: 30

| Sites | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 10 | 0.107 | 0.0058 | 0.0801 | 0.018 |
| Elk River | 10 | 1.448 | 0.2435 | 0.0801 | 0.770 |
| Gold Cr | 10 | 0.840 | 0.0415 | 0.0801 | 0.131 |

| Depth | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| surface | 15 | 0.560 | 0.0871 | 0.0654 | 0.337 |
| bottom | 15 | 1.037 | 0.2311 | 0.0654 | 0.895 |

| Source of variation | Sum squares | DF | Mean square | F statistic | Critical F | p |
|---|---|---|---|---|---|---|
| Sites | 9.017 | 2 | 4.509 | 70.23 | 3.40 | <0.0001 |
| Depth | 1.704 | 1 | 1.704 | 26.54 | 4.20 | <0.0001 |
| Sites × Depth | 2.248 | 2 | 1.124 | 17.51 | 3.40 | <0.0001 |
| Residual | 1.541 | 24 | 0.064 | | | |
| Total | 14.510 | 29 | | | | |

# APPENDIX VI-B Total Selenium in Water: One-Way ANOVA

| Water Column Total Se (ug/L) | | |
|---|---|---|
| Kikomun | Elk River | Gold Cr |
| 0.12 | 0.90 | 0.66 |
| 0.12 | 0.96 | 0.72 |
| 0.13 | 0.99 | 0.71 |
| 0.12 | 0.72 | 0.84 |
| 0.13 | 0.58 | 0.70 |
| 0.09 | 1.62 | 0.91 |
| 0.09 | 2.73 | 0.93 |
| 0.09 | 2.16 | 0.96 |
| 0.09 | 1.32 | 1.02 |
| 0.09 | | 0.95 |

Analyse-it v2.12

| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Groups: Kikomun, Elk River, Gold Cr |
| Performed by | Les |
| Date | 19 December 2008 |

| | |
|---|---|
| n | 29 |

| Groups | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 10 | 0.107 | 0.0058 | 0.1281 | 0.018 |
| Elk River | 9 | 1.331 | 0.2388 | 0.1350 | 0.716 |
| Gold Cr | 10 | 0.840 | 0.0415 | 0.1281 | 0.131 |

| Source of variation | Sum squares | DF | Mean square | F statistic | Critical F | p |
|---|---|---|---|---|---|---|
| Groups | 7.252 | 2 | 3.626 | 22.11 | 3.40 | <0.0001 |
| Residual | 4.263 | 26 | 0.164 | | | |
| Total | 11.515 | 28 | | | | |

| Tukey Contrast | Difference | 95% CI | |
|---|---|---|---|
| Kikomun v Elk River | -1.224 | -1.686 to -0.762 | (significant) |
| Kikomun v Gold Cr | -0.733 | -1.183 to -0.283 | (significant) |
| Elk River v Gold Cr | 0.491 | 0.029 to 0.953 | (significant) |

# Appendix VII Hydrolab Profile Data

| Site | Depth (m) | Temperature (°C) | Conductivity (µS/cm) | DO (mg/L) | Cl *a* (ug/L) |
|---|---|---|---|---|---|
| **Kikomun** | | | | | |
| 1B | 1 | 18.78 | 219 | 9.84 | 0.42 |
| 1B | 8 | 15.51 | 227 | 9.94 | 0.78 |
| 1A | 1 | 18.90 | 219 | 9.86 | 0.40 |
| 1A | 8 | 15.34 | 227 | 9.95 | 0.59 |
| 1C | 1 | 18.79 | 219 | 9.95 | 0.39 |
| 1C | 6 | 16.38 | 223 | 9.45 | 1.21 |
| 1D | | | | | |
| 1D | | | | | |
| 1E | 1 | 19.11 | 219 | 9.86 | 0.47 |
| 1E | 7 | 15.86 | 226 | 10.03 | 1.03 |
| **Gold Creek** | | | | | |
| 3-1 | 1 | 20.40 | 211 | 9.31 | 0.85 |
| 3-1 | 23 | 10.76 | 211 | 8.49 | 0.83 |
| 3-2 | 1 | 20.58 | 211 | 9.21 | 0.95 |
| 3-2 | 14 | 16.69 | 235 | 8.15 | 1.07 |
| 3-3 | 1 | 20.38 | 212 | 9.23 | 0.84 |
| 3-3 | 30 | 9.46 | 220 | 8.19 | 0.72 |
| 3-4 | 1 | 20.24 | 212 | 9.34 | 0.49 |
| 3-4 | 25 | 10.42 | 211 | 8.57 | 0.60 |
| 3-5 | 1 | 20.78 | 212 | 9.26 | 0.79 |
| 3-5 | 25 | 10.52 | 213 | 8.04 | 0.75 |
| **Elk River** | | | | | |
| 2-1 | 1 | 20.96 | 221 | 9.11 | 0.45 |
| 2-1 | 3 | 19.47 | 246 | 9.30 | 0.50 |
| 2-2 | 1 | 19.10 | 271 | 9.07 | 0.74 |
| 2-3 | 1 | 20.15 | 241 | 9.29 | 0.86 |
| 2-3 | 3 | 18.62 | 261 | 9.04 | 0.72 |
| 2-4 | 1 | 20.89 | 217 | 9.35 | 0.99 |
| 2-4 | 3.5 | 19.77 | 250 | 9.38 | 0.72 |
| 2-5 | 1 | 20.44 | 215 | 9.56 | 0.71 |
| 2-5 | 7 | 19.01 | 229 | 9.50 | 0.95 |

# APPENDIX VIII-A Net Zooplankton Data: Kikomun Bridge

| Wet Weights | | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| | Sample Time | 10:10 | 11:45 | 12:45 | 13:45 | 14:30 |
| **Variable** | **Units** | | | | | |
| Moisture | % | 89 | 90 | 93 | 85 | 90 |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 31 | 65 | 28 | 46 | 19 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.28 | 0.29 | 0.19 | 0.41 | 0.23 |
| Barium | mg/kg | 3.4 | 3.6 | 2.9 | 2.8 | 2.7 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | 0.09 | 0.07 | 0.05 | 0.09 | 0.08 |
| Calcium | mg/kg | 5430 | 5770 | 5080 | 3800 | 4120 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | 0.1 | 0.1 | <0.1 | 0.1 | <0.1 |
| Copper | mg/kg | 1.0 | 0.8 | 0.6 | 1.1 | 0.8 |
| Iron | mg/kg | 59 | 118 | 52 | 120 | 41 |
| Lead | mg/kg | 0.08 | 0.11 | 0.05 | 0.16 | 0.06 |
| Magnesium | mg/kg | 203 | 231 | 151 | 243 | 164 |
| Manganese | mg/kg | 6.9 | 7.7 | 5.0 | 7.9 | 5.9 |
| Mercury | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.4 | 0.4 | 0.2 | 0.4 | 0.1 |
| Phosphorus | mg/kg | 1970 | 1850 | 1610 | 1990 | 1820 |
| Potassium | mg/kg | 1150 | 873 | 623 | 1110 | 907 |
| Selenium | mg/kg | 0.36 | 0.29 | 0.19 | 0.37 | 0.31 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 687 | 554 | 407 | 525 | 579 |
| Strontium | mg/kg | 12.2 | 13.1 | 11.4 | 8.3 | 9.2 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | 1 | <1 | 1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 9.3 | 8.1 | 5.9 | 9.6 | 8.9 |

| Dry Weights | | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| | Sample Time | 10:10 | 11:45 | 12:45 | 13:45 | 14:30 |
| **Variable** | **Units** | | | | | |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 282 | 650 | 400 | 307 | 190 |
| Antimony | mg/kg | | | | | |
| Arsenic | mg/kg | 2.55 | 2.90 | 2.71 | 2.73 | 2.30 |
| Barium | mg/kg | 30.9 | 36.0 | 41.4 | 18.7 | 27.0 |
| Beryllium | mg/kg | | | | | |
| Bismuth | mg/kg | | | | | |
| Boron | mg/kg | | | | | |
| Cadmium | mg/kg | 0.82 | 0.70 | 0.71 | 0.60 | 0.80 |
| Calcium | mg/kg | 49364 | 57700 | 72571 | 25333 | 41200 |
| Chromium | mg/kg | | | | | |
| Cobalt | mg/kg | | | | | |
| Copper | mg/kg | 9.1 | 8.0 | 8.6 | 7.3 | 8.0 |
| Iron | mg/kg | 536 | 1180 | 743 | 800 | 410 |
| Lead | mg/kg | 0.73 | 1.10 | 0.71 | 1.07 | 0.60 |
| Magnesium | mg/kg | 1845 | 2310 | 2157 | 1620 | 1640 |
| Manganese | mg/kg | 62.7 | 77.0 | 71.4 | 52.7 | 59.0 |
| Mercury | mg/kg | | | | | |
| Molybdenum | mg/kg | | | | | |
| Nickel | mg/kg | | | | | |
| Phosphorus | mg/kg | 17909 | 18500 | 23000 | 13267 | 18200 |
| Potassium | mg/kg | 10455 | 8730 | 8900 | 7400 | 9070 |
| Selenium | mg/kg | 3.27 | 2.90 | 2.71 | 2.47 | 3.10 |
| Silver | mg/kg | | | | | |
| Sodium | mg/kg | 6245 | 5540 | 5814 | 3500 | 5790 |
| Strontium | mg/kg | 110.9 | 131.0 | 162.9 | 55.3 | 92.0 |
| Thallium | mg/kg | | | | | |
| Tin | mg/kg | | | | | |
| Titanium | mg/kg | | | | | |
| Uranium | mg/kg | | | | | |
| Vanadium | mg/kg | | | | | |
| Zinc | mg/kg | 84.5 | 81.0 | 84.3 | 64.0 | 89.0 |

# APPENDIX VIII-B Net Zooplankton Data: Elk River

| Wet Weights | | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| | Sample Time | 14:45 | 9:15 | 10:15 | 11:00 | 11:45 |
| Variable | Units | | | | | |
| Moisture | % | 89 | 90 | 91 | 92 | 91 |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 11 | 9 | 6 | 7 | 17 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.33 | 0.25 | 0.24 | 0.25 | 0.26 |
| Barium | mg/kg | 1.3 | 2.7 | 1.4 | 1.1 | 3.7 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | 0.19 | 0.20 | 0.14 | 0.12 | 0.13 |
| Calcium | mg/kg | 976 | 1240 | 750 | 968 | 4800 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 1.0 | 0.7 | 0.7 | 0.6 | 0.8 |
| Iron | mg/kg | 27 | 29 | 20 | 20 | 40 |
| Lead | mg/kg | 0.04 | 0.03 | 0.03 | 0.02 | 0.07 |
| Magnesium | mg/kg | 132 | 126 | 91 | 96 | 155 |
| Manganese | mg/kg | 5.6 | 3.8 | 3.4 | 2.7 | 5.9 |
| Mercury | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.1 | <0.1 | <0.1 | <0.1 | 0.1 |
| Phosphorus | mg/kg | 1350 | 1310 | 1060 | 905 | 1950 |
| Potassium | mg/kg | 1200 | 993 | 1080 | 968 | 898 |
| Selenium | mg/kg | 0.35 | 0.34 | 0.27 | 0.24 | 0.33 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 737 | 613 | 664 | 651 | 642 |
| Strontium | mg/kg | 2.3 | 2.9 | 1.8 | 2.2 | 9.3 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 9.3 | 7.7 | 7.1 | 6.2 | 9.0 |

| Dry Weights | | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| | Sample Time | 14:45 | 9:15 | 10:15 | 11:00 | 11:45 |
| Variable | Units | | | | | |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 100 | 90 | 67 | 88 | 189 |
| Antimony | mg/kg | | | | | |
| Arsenic | mg/kg | 3.00 | 2.50 | 2.67 | 3.13 | 2.89 |
| Barium | mg/kg | 11.8 | 27.0 | 15.6 | 13.8 | 41.1 |
| Beryllium | mg/kg | | | | | |
| Bismuth | mg/kg | | | | | |
| Boron | mg/kg | | | | | |
| Cadmium | mg/kg | 1.73 | 2.00 | 1.56 | 1.50 | 1.44 |
| Calcium | mg/kg | 8873 | 12400 | 8333 | 12100 | 53333 |
| Chromium | mg/kg | | | | | |
| Cobalt | mg/kg | | | | | |
| Copper | mg/kg | 9.1 | 7.0 | 7.8 | 7.5 | 8.9 |
| Iron | mg/kg | 245 | 290 | 222 | 250 | 444 |
| Lead | mg/kg | 0.36 | 0.30 | 0.33 | 0.25 | 0.78 |
| Magnesium | mg/kg | 1200 | 1260 | 1011 | 1200 | 1722 |
| Manganese | mg/kg | 50.9 | 38.0 | 37.8 | 33.8 | 65.6 |
| Mercury | mg/kg | | | | | |
| Molybdenum | mg/kg | | | | | |
| Nickel | mg/kg | | | | | |
| Phosphorus | mg/kg | 12273 | 13100 | 11778 | 11313 | 21667 |
| Potassium | mg/kg | 10909 | 9930 | 12000 | 12100 | 9978 |
| Selenium | mg/kg | 3.18 | 3.40 | 3.00 | 3.00 | 3.67 |
| Silver | mg/kg | | | | | |
| Sodium | mg/kg | 6700 | 6130 | 7378 | 8138 | 7133 |
| Strontium | mg/kg | 20.9 | 29.0 | 20.0 | 27.5 | 103.3 |
| Thallium | mg/kg | | | | | |
| Tin | mg/kg | | | | | |
| Titanium | mg/kg | | | | | |
| Uranium | mg/kg | | | | | |
| Vanadium | mg/kg | | | | | |
| Zinc | mg/kg | 84.5 | 77.0 | 78.9 | 77.5 | 100.0 |

# APPENDIX VIII-C Net Zooplankton Data: Gold Creek

**Wet Weights**

| Variable | Units | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| Sample Time | | 9:30 | 10:45 | 11:30 | 12:15 | 13:30 |
| Moisture | % | 91 | 91 | 88 | 90 | 89 |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 29 | 22 | 14 | 39 | 15 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.26 | 0.24 | 0.32 | 0.28 | 0.32 |
| Barium | mg/kg | 2.3 | 2.7 | 3.1 | 2.5 | 2.8 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | 0.09 | 0.10 | 0.14 | 0.11 | 0.12 |
| Calcium | mg/kg | 2580 | 2840 | 4000 | 3290 | 3870 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 0.6 | 0.7 | 0.8 | 0.7 | 0.8 |
| Iron | mg/kg | 49 | 36 | 31 | 72 | 31 |
| Lead | mg/kg | 0.05 | 0.03 | 0.04 | 0.52 | 0.04 |
| Magnesium | mg/kg | 135 | 134 | 168 | 186 | 163 |
| Manganese | mg/kg | 5.8 | 6.1 | 6.6 | 6.0 | 6.1 |
| Mercury | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.2 | <0.1 | 0.2 | 0.2 | 0.1 |
| Phosphorus | mg/kg | 1360 | 1650 | 2200 | 1540 | 1800 |
| Potassium | mg/kg | 810 | 789 | 1070 | 840 | 1060 |
| Selenium | mg/kg | 0.26 | 0.27 | 0.41 | 0.29 | 0.37 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 536 | 462 | 653 | 528 | 691 |
| Strontium | mg/kg | 5.3 | 5.8 | 8.0 | 6.4 | 7.9 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | 1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 7.2 | 7.6 | 10.1 | 7.8 | 8.7 |

**Dry Weights**

| Variable | Units | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|---|
| Sample Time | | 9:30 | 10:45 | 11:30 | 12:15 | 13:30 |
| **Total Metals by ICPMS** | | | | | | |
| Aluminium | mg/kg | 322 | 244 | 117 | 390 | 136 |
| Antimony | mg/kg | | | | | |
| Arsenic | mg/kg | 2.89 | 2.67 | 2.67 | 2.80 | 2.91 |
| Barium | mg/kg | 25.6 | 30.0 | 25.8 | 25.0 | 25.5 |
| Beryllium | mg/kg | | | | | |
| Bismuth | mg/kg | | | | | |
| Boron | mg/kg | | | | | |
| Cadmium | mg/kg | 1.00 | 1.11 | 1.17 | 1.10 | 1.09 |
| Calcium | mg/kg | 28667 | 31556 | 33333 | 32900 | 35182 |
| Chromium | mg/kg | | | | | |
| Cobalt | mg/kg | | | | | |
| Copper | mg/kg | 6.7 | 7.8 | 6.7 | 7.0 | 7.3 |
| Iron | mg/kg | 544 | 400 | 258 | 720 | 282 |
| Lead | mg/kg | 0.56 | 0.33 | 0.33 | 5.20 | 0.36 |
| Magnesium | mg/kg | 1500 | 1489 | 1400 | 1860 | 1482 |
| Manganese | mg/kg | 64.4 | 67.8 | 55.0 | 60.0 | 55.5 |
| Mercury | mg/kg | | | | | |
| Molybdenum | mg/kg | | | | | |
| Nickel | mg/kg | | | | | |
| Phosphorus | mg/kg | 15111 | 18333 | 18333 | 15400 | 16364 |
| Potassium | mg/kg | 9000 | 8767 | 8917 | 8400 | 9636 |
| Selenium | mg/kg | 2.89 | 3.00 | 3.42 | 2.90 | 3.36 |
| Silver | mg/kg | | | | | |
| Sodium | mg/kg | 5956 | 5133 | 5442 | 5280 | 6282 |
| Strontium | mg/kg | 58.9 | 64.4 | 66.7 | 64.0 | 71.8 |
| Thallium | mg/kg | | | | | |
| Tin | mg/kg | | | | | |
| Titanium | mg/kg | | | | | |
| Uranium | mg/kg | | | | | |
| Vanadium | mg/kg | | | | | |
| Zinc | mg/kg | 80.0 | 84.4 | 84.2 | 78.0 | 79.1 |

# APPENDIX IX Selenium in Net Zooplankton: One-Way ANOVA

| (mg Se/kg dry wt.) | | |
|---|---|---|
| **Kikomun** | **Elk River** | **Gold Cr** |
| 3.27 | 3.18 | 2.89 |
| 2.90 | 3.40 | 3.00 |
| 2.71 | 3.00 | 3.42 |
| 2.47 | 3.00 | 2.90 |
| 3.10 | 3.67 | 3.36 |

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| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Zooplankton (mg Se/kg dry wt.): Kikomun, Elk River, Gold Cr |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 15 |

| Zooplankton (mg Se/kg dry wt.) | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 5 | 2.890 | 0.1410 | 0.1284 | 0.315 |
| Elk River | 5 | 3.250 | 0.1282 | 0.1284 | 0.287 |
| Gold Cr | 5 | 3.114 | 0.1147 | 0.1284 | 0.256 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Zooplankton (mg Se/kg dry wt.) | 0.330 | 2 | 0.165 | 2.00 | 0.1774 |
| Residual | 0.989 | 12 | 0.082 | | |
| Total | 1.320 | 14 | | | |

| Tukey Contrast | Difference | 95% CI |
|---|---|---|
| Kikomun v Elk River | -0.360 | -0.844 to 0.124 |
| Kikomun v Gold Cr | -0.224 | -0.708 to 0.260 |
| Elk River v Gold Cr | 0.136 | -0.348 to 0.620 |

# APPENDIX X

# FISH TISSUE ANALYSIS

# Appendix X-A
# Kokanee Whole Body – Canadian Reach (Kikomun to Elk River)

**Kokanee - Whole Body** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-01 | KO-03 | KO-05 | KO-07 | KO-09 | KO-11 | KO-13 | KO-15 | KO-17 | KO-19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 73 | 82 | 77 | 76 | 77 | 75 | 77 | 79 | 76 | 76 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.07 | 0.04 | 0.05 | 0.07 | 0.04 | 0.07 | 0.08 | 0.05 | 0.05 | 0.05 |
| Barium | mg/kg | 0.3 | 0.3 | 0.3 | 0.5 | 0.3 | 0.3 | 0.4 | 0.7 | 0.3 | 0.4 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 |
| Calcium | mg/kg | 2390 | 2920 | 3510 | 4050 | 2800 | 2170 | 3580 | 6310 | 2130 | 5140 |
| Chromium | mg/kg | <0.5 | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 1.8 | 1.5 | 2.2 | 2.6 | 2.6 | 3.5 | 2.1 | 2.5 | 2.7 | 2.8 |
| Iron | mg/kg | 15 | 17 | 17 | 14 | 15 | 15 | 16 | 19 | 14 | 17 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 326 | 255 | 277 | 354 | 298 | 324 | 303 | 334 | 312 | 370 |
| Manganese | mg/kg | 0.5 | 0.6 | 0.6 | 0.9 | 0.7 | 0.7 | 0.7 | 1.1 | 0.7 | 1.0 |
| Mercury | mg/kg | 0.02 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.2 | 0.4 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.5 | 0.1 | 0.2 |
| Phosphorus | mg/kg | 3880 | 3740 | 4480 | 4940 | 4030 | 3780 | 4670 | 5910 | 3810 | 5520 |
| Potassium | mg/kg | 3440 | 3140 | 3380 | 3450 | 3370 | 3230 | 3600 | 3230 | 3260 | 3440 |
| Selenium | mg/kg | 0.50 | 0.44 | 0.53 | 0.52 | 0.62 | 0.57 | 0.54 | 0.52 | 0.62 | 0.59 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 549 | 1000 | 753 | 835 | 949 | 361 | 812 | 1120 | 824 | 945 |
| Strontium | mg/kg | 1.8 | 2.3 | 2.2 | 3.2 | 2.0 | 1.7 | 2.4 | 4.7 | 1.7 | 3.5 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 24.5 | 32.1 | 22.1 | 48.1 | 28.6 | 28.2 | 39.7 | 40.1 | 38.9 | 32.8 |

**Dry Weights**

| Variable | KO-01 | KO-03 | KO-05 | KO-07 | KO-09 | KO-11 | KO-13 | KO-15 | KO-17 | KO-19 |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.26 | 0.22 | 0.22 | 0.29 | 0.17 | 0.28 | 0.35 | 0.24 | 0.21 | 0.21 |
| Barium | 1.1 | 1.7 | 1.3 | 2.1 | 1.3 | 1.2 | 1.7 | 3.3 | 1.3 | 1.7 |
| Calcium | 8852 | 16222 | 15261 | 16875 | 12174 | 8680 | 15565 | 30048 | 8875 | 21417 |
| Copper | 6.7 | 8.3 | 9.6 | 10.8 | 11.3 | 14.0 | 9.1 | 11.9 | 11.3 | 11.7 |
| Iron | 56 | 94 | 74 | 58 | 65 | 60 | 70 | 90 | 58 | 71 |
| Magnesium | 1207 | 1417 | 1204 | 1475 | 1296 | 1296 | 1317 | 1590 | 1300 | 1542 |
| Manganese | 1.9 | 3.3 | 2.6 | 3.8 | 3.0 | 2.8 | 3.0 | 5.2 | 2.9 | 4.2 |
| Nickel | 0.7 | 2.2 | 0.9 | 0.8 | 0.4 | 0.8 | 0.9 | 2.4 | 0.4 | 0.8 |
| Phosphorus | 14370 | 20778 | 19478 | 20583 | 17522 | 15120 | 20304 | 28143 | 15875 | 23000 |
| Potassium | 12741 | 17444 | 14696 | 14375 | 14652 | 12920 | 15652 | 15381 | 13583 | 14333 |
| Selenium | 1.85 | 2.44 | 2.30 | 2.17 | 2.70 | 2.28 | 2.35 | 2.48 | 2.58 | 2.46 |
| Sodium | 2033 | 5556 | 3274 | 3479 | 4126 | 1444 | 3530 | 5333 | 3433 | 3938 |
| Strontium | 6.7 | 12.8 | 9.6 | 13.3 | 8.7 | 6.8 | 10.4 | 22.4 | 7.1 | 14.6 |
| Zinc | 90.7 | 178.3 | 96.1 | 200.4 | 124.3 | 112.8 | 172.6 | 191.0 | 162.1 | 136.7 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-B
# Kokanee Axial Muscle – Canadian Reach (Kikomun to Elk River)

**Kokanee - Axial Muscle** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-02 | KO-04 | KO-06 | KO-08 | KO-10 | KO-12 | KO-14 | KO-16 | KO-18 | KO-20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 81 | 79 | 80 | 73 | 78 | 80 | 81 | 78 | 77 | 79 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.02 | 0.03 | 0.02 | 0.04 | 0.03 | 0.02 | 0.02 | 0.04 | 0.03 | 0.02 |
| Barium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Calcium | mg/kg | 90 | 81 | 95 | 224 | 141 | 186 | 190 | 90 | 146 | 86 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 0.6 | 0.8 | <0.5 | <0.5 | 0.7 | <0.5 | <0.5 | 0.6 | <0.5 | 0.6 |
| Iron | mg/kg | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 243 | 258 | 242 | 279 | 257 | 245 | 263 | 246 | 273 | 258 |
| Manganese | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Mercury | mg/kg | 0.04 | 0.05 | 0.06 | 0.03 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| Phosphorus | mg/kg | 2240 | 2360 | 2260 | 2610 | 2500 | 2280 | 2500 | 2170 | 2330 | 2400 |
| Potassium | mg/kg | 3490 | 3450 | 3510 | 3710 | 3680 | 3470 | 3780 | 3280 | 3440 | 3590 |
| Selenium | mg/kg | 0.34 | 0.39 | 0.41 | 0.42 | 0.42 | 0.32 | 0.37 | 0.41 | 0.34 | 0.38 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 840 | 660 | 450 | 390 | 686 | 609 | 379 | 606 | 458 | 482 |
| Strontium | mg/kg | <0.1 | <0.1 | <0.1 | 0.2 | <0.1 | 0.1 | 0.1 | <0.1 | 0.1 | <0.1 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 7.5 | 6.1 | 3.8 | 9.2 | 8.7 | 5.3 | 9.2 | 6.4 | 6.0 | 6.6 |

**Dry Weights**

| Variable | KO-02 | KO-04 | KO-06 | KO-08 | KO-10 | KO-12 | KO-14 | KO-16 | KO-18 | KO-20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.11 | 0.14 | 0.10 | 0.15 | 0.14 | 0.10 | 0.11 | 0.18 | 0.13 | 0.10 |
| Calcium | 474 | 386 | 475 | 830 | 641 | 930 | 1000 | 409 | 635 | 410 |
| Copper | 3.2 | 3.8 | <2.5 | <1.9 | 3.2 | <2.5 | <2.6 | 2.7 | <2.2 | 2.9 |
| Magnesium | 1279 | 1229 | 1210 | 1033 | 1168 | 1225 | 1384 | 1118 | 1187 | 1229 |
| Nickel | 0.5 | 0.5 | 0.5 | 0.4 | 0.9 | 0.5 | 0.5 | 0.5 | 0.4 | 1.0 |
| Phosphorus | 11789 | 11238 | 11300 | 9667 | 11364 | 11400 | 13158 | 9864 | 10130 | 11429 |
| Potassium | 18368 | 16429 | 17550 | 13741 | 16727 | 17350 | 19895 | 14909 | 14957 | 17095 |
| Selenium | 1.79 | 1.86 | 2.05 | 1.56 | 1.91 | 1.60 | 1.95 | 1.86 | 1.48 | 1.81 |
| Sodium | 4421 | 3143 | 2250 | 1444 | 3118 | 3045 | 1995 | 2755 | 1991 | 2295 |
| Zinc | 39.5 | 29.0 | 19.0 | 34.1 | 39.5 | 26.5 | 48.4 | 29.1 | 26.1 | 31.4 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-C
# Kokanee Ovary – Canadian Reach (Kikomun to Elk River)

**Kokanee - Ovary** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-02 | KO-04 | KO-06 | KO-10 | KO-12 | KO-14 | KO-16 | KO-18 | KO-20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 66 | 66 | 62 | 58 | 60 | 60 | 64 | 59 | 61 |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.03 | 0.03 | 0.06 | 0.04 | 0.03 | 0.03 | 0.03 | 0.06 | 0.04 |
| Barium | mg/kg | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Calcium | mg/kg | 429 | 538 | 408 | 510 | 511 | 442 | 356 | 520 | 498 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 9.0 | 13.3 | 15.9 | 13.6 | 14.6 | 11.7 | 17.5 | 10.7 | 17.1 |
| Iron | mg/kg | 16 | 16 | 19 | 23 | 22 | 18 | 17 | 18 | 18 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 493 | 509 | 510 | 580 | 556 | 490 | 499 | 600 | 581 |
| Manganese | mg/kg | 1.0 | 1.0 | 0.8 | 1.2 | 1.0 | 0.9 | 0.8 | 1.5 | 0.8 |
| Mercury | mg/kg | 0.01 | <0.01 | 0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | <0.1 | 0.1 | 0.1 | 0.1 |
| Phosphorus | mg/kg | 3790 | 3980 | 4240 | 4280 | 4390 | 4160 | 3900 | 4370 | 4280 |
| Potassium | mg/kg | 2400 | 2460 | 2130 | 2750 | 2120 | 2220 | 2360 | 2190 | 2190 |
| Selenium | mg/kg | 1.10 | 1.10 | 1.39 | 1.62 | 1.50 | 1.41 | 1.66 | 1.14 | 1.45 |
| Silver | mg/kg | <0.05 | <0.05 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 979 | 835 | 698 | 705 | 692 | 604 | 770 | 563 | 579 |
| Strontium | mg/kg | 0.5 | 0.7 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | 0.9 | 0.8 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 35.1 | 28.2 | 44.0 | 39.7 | 42.1 | 32.2 | 28.9 | 36.3 | 32.4 |

**Dry Weights**

| Variable | Units | KO-02 | KO-04 | KO-06 | KO-10 | KO-12 | KO-14 | KO-16 | KO-18 | KO-20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | mg/kg | | | | | | | | | |
| Antimony | mg/kg | | | | | | | | | |
| Arsenic | mg/kg | 0.09 | 0.09 | 0.16 | 0.10 | 0.08 | 0.08 | 0.08 | 0.15 | 0.10 |
| Barium | mg/kg | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 |
| Beryllium | mg/kg | | | | | | | | | |
| Bismuth | mg/kg | | | | | | | | | |
| Boron | mg/kg | | | | | | | | | |
| Cadmium | mg/kg | | | | | | | | | |
| Calcium | mg/kg | 1262 | 1582 | 1074 | 1214 | 1278 | 1105 | 989 | 1268 | 1277 |
| Chromium | mg/kg | | | | | | | | | |
| Cobalt | mg/kg | | | | | | | | | |
| Copper | mg/kg | 26.5 | 39.1 | 41.8 | 32.4 | 36.5 | 29.3 | 48.6 | 26.1 | 43.8 |
| Iron | mg/kg | 47 | 47 | 50 | 55 | 55 | 45 | 47 | 44 | 46 |
| Lead | mg/kg | | | | | | | | | |
| Magnesium | mg/kg | 1450 | 1497 | 1342 | 1381 | 1390 | 1225 | 1386 | 1463 | 1490 |
| Manganese | mg/kg | 2.9 | 2.9 | 2.1 | 2.9 | 2.5 | 2.3 | 2.2 | 3.7 | 2.1 |
| Mercury | mg/kg | | | | | | | | | |
| Molybdenum | mg/kg | | | | | | | | | |
| Nickel | mg/kg | 0.3 | 0.3 | 0.3 | 0.5 | 0.3 | <0.3 | 0.3 | 0.2 | 0.3 |
| Phosphorus | mg/kg | 11147 | 11706 | 11158 | 10190 | 10975 | 10400 | 10833 | 10659 | 10974 |
| Potassium | mg/kg | 7059 | 7235 | 5605 | 6548 | 5300 | 5550 | 6556 | 5341 | 5615 |
| Selenium | mg/kg | 3.24 | 3.24 | 3.66 | 3.86 | 3.75 | 3.53 | 4.61 | 2.78 | 3.72 |
| Silver | mg/kg | | | | | | | | | |
| Sodium | mg/kg | 2879 | 2456 | 1837 | 1679 | 1730 | 1510 | 2139 | 1373 | 1485 |
| Strontium | mg/kg | 1.5 | 2.1 | 2.1 | 1.7 | 1.5 | 1.5 | 1.4 | 2.2 | 2.1 |
| Thallium | mg/kg | | | | | | | | | |
| Tin | mg/kg | | | | | | | | | |
| Titanium | mg/kg | | | | | | | | | |
| Uranium | mg/kg | | | | | | | | | |
| Vanadium | mg/kg | | | | | | | | | |
| Zinc | mg/kg | 103.2 | 82.9 | 115.8 | 94.5 | 105.3 | 80.5 | 80.3 | 88.5 | 83.1 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-D
# Kokanee Whole Body – United States Reach (Border to Rexford)

**Kokanee - Whole Body** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-21 | KO-23 | KO-25 | KO-27 | KO-29 | KO-31 | KO-33 | KO-35 | KO-37 | KO-39 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 79 | 76 | 79 | 79 | 74 | 77 | 76 | 82 | 81 | 79 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.04 | 0.07 | 0.10 | 0.04 | 0.07 | 0.05 | 0.06 | 0.04 | 0.06 | 0.05 |
| Barium | mg/kg | 0.5 | 0.6 | 0.6 | 0.4 | 0.4 | 0.4 | 0.3 | 0.5 | 0.3 | 0.4 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Calcium | mg/kg | 5390 | 4380 | 6150 | 3810 | 3860 | 3880 | 2550 | 6000 | 2330 | 3210 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 2.3 | 2.6 | 3.0 | 2.6 | 3.0 | 2.7 | 2.8 | 1.9 | 1.3 | 2.2 |
| Iron | mg/kg | 15 | 19 | 20 | 15 | 19 | 20 | 19 | 18 | 17 | 17 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 |
| Magnesium | mg/kg | 333 | 334 | 378 | 319 | 347 | 352 | 325 | 338 | 237 | 294 |
| Manganese | mg/kg | 1.2 | 1.2 | 1.0 | 0.6 | 0.9 | 0.8 | 0.6 | 1.3 | 0.4 | 0.9 |
| Mercury | mg/kg | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| Phosphorus | mg/kg | 5300 | 5040 | 6280 | 4570 | 4890 | 4760 | 4060 | 5530 | 3410 | 4180 |
| Potassium | mg/kg | 2990 | 3310 | 3660 | 3090 | 3570 | 3080 | 3430 | 2900 | 3190 | 3380 |
| Selenium | mg/kg | 0.51 | 0.56 | 0.67 | 0.59 | 0.64 | 0.66 | 0.61 | 0.46 | 0.46 | 0.53 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 874 | 874 | 808 | 939 | 786 | 967 | 513 | 924 | 1030 | 1020 |
| Strontium | mg/kg | 3.9 | 3.4 | 4.5 | 2.6 | 2.9 | 2.7 | 1.9 | 4.2 | 1.8 | 2.5 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 31.4 | 38.1 | 39.1 | 58.9 | 51.7 | 47.3 | 30.2 | 37.0 | 39.0 | 29.1 |

**Dry Weights**

| Variable | KO-21 | KO-23 | KO-25 | KO-27 | KO-29 | KO-31 | KO-33 | KO-35 | KO-37 | KO-39 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | | | | | | | | | | |
| Antimony | | | | | | | | | | |
| Arsenic | 0.19 | 0.29 | 0.48 | 0.19 | 0.27 | 0.22 | 0.25 | 0.22 | 0.32 | 0.24 |
| Barium | 2.4 | 2.5 | 2.9 | 1.9 | 1.5 | 1.7 | 1.3 | 2.8 | 1.6 | 1.9 |
| Beryllium | | | | | | | | | | |
| Bismuth | | | | | | | | | | |
| Boron | | | | | | | | | | |
| Cadmium | | | | | | | | | | |
| Calcium | 25667 | 18250 | 29286 | 18143 | 14846 | 16870 | 10625 | 33333 | 12263 | 15286 |
| Chromium | | | | | | | | | | |
| Cobalt | | | | | | | | | | |
| Copper | 11.0 | 10.8 | 14.3 | 12.4 | 11.5 | 11.7 | 11.7 | 10.6 | 6.8 | 10.5 |
| Iron | 71 | 79 | 95 | 71 | 73 | 87 | 79 | 100 | 89 | 81 |
| Lead | | | | | | | | | | |
| Magnesium | 1586 | 1392 | 1800 | 1519 | 1335 | 1530 | 1354 | 1878 | 1247 | 1400 |
| Manganese | 5.7 | 5.0 | 4.8 | 2.9 | 3.5 | 3.5 | 2.5 | 7.2 | 2.1 | 4.3 |
| Mercury | | | | | | | | | | |
| Molybdenum | | | | | | | | | | |
| Nickel | 1.0 | 0.8 | 1.4 | 1.0 | 0.8 | 0.4 | 0.8 | 1.1 | 1.1 | 1.0 |
| Phosphorus | 25238 | 21000 | 29905 | 21762 | 18808 | 20696 | 16917 | 30722 | 17947 | 19905 |
| Potassium | 14238 | 13792 | 17429 | 14714 | 13731 | 13391 | 14292 | 16111 | 16789 | 16095 |
| Selenium | 2.43 | 2.33 | 3.19 | 2.81 | 2.46 | 2.87 | 2.54 | 2.56 | 2.42 | 2.52 |
| Silver | | | | | | | | | | |
| Sodium | 4162 | 3642 | 3848 | 4471 | 3023 | 4204 | 2138 | 5133 | 5421 | 4857 |
| Strontium | 18.6 | 14.2 | 21.4 | 12.4 | 11.2 | 11.7 | 7.9 | 23.3 | 9.5 | 11.9 |
| Thallium | | | | | | | | | | |
| Tin | | | | | | | | | | |
| Titanium | | | | | | | | | | |
| Uranium | | | | | | | | | | |
| Vanadium | | | | | | | | | | |
| Zinc | 149.5 | 158.8 | 186.2 | 280.5 | 198.8 | 205.7 | 125.8 | 205.6 | 205.3 | 138.6 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-E
# Kokanee Axial Muscle – United States Reach (Border to Rexford)

**Kokanee - Axial Muscle** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-22 | KO-24 | KO-26 | KO-28 | KO-30 | KO-32 | KO-34 | KO-36 | KO-38 | KO-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 79 | 79 | 78 | 75 | 82 | 80 | 80 | 76 | 76 | 84 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.03 | 0.03 | 0.02 | 0.03 | 0.04 | 0.03 | 0.02 | 0.04 | 0.05 | 0.03 |
| Barium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Calcium | mg/kg | 72 | 87 | 438 | 319 | 485 | 470 | 46 | 85 | 267 | 74 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 0.6 | 0.8 | <0.5 | <0.5 | <0.5 | <0.5 | 0.7 | 0.8 | <0.5 | 0.8 |
| Iron | mg/kg | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 237 | 278 | 260 | 305 | 214 | 242 | 233 | 219 | 296 | 233 |
| Manganese | mg/kg | <0.1 | <0.1 | 0.1 | <0.1 | 0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 |
| Mercury | mg/kg | 0.06 | 0.05 | 0.04 | 0.04 | 0.05 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.3 | <0.1 | <0.1 | 0.1 | 2.0 | 0.1 | 0.1 | <0.1 | 0.2 | 0.1 |
| Phosphorus | mg/kg | 2310 | 2700 | 2540 | 2860 | 2410 | 2400 | 2240 | 2080 | 2750 | 2360 |
| Potassium | mg/kg | 3400 | 3910 | 3530 | 4000 | 3400 | 3460 | 3370 | 3190 | 3920 | 3500 |
| Selenium | mg/kg | 0.41 | 0.40 | 0.34 | 0.49 | 0.41 | 0.37 | 0.34 | 0.36 | 0.44 | 0.38 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 754 | 618 | 458 | 498 | 810 | 550 | 600 | 577 | 330 | 784 |
| Strontium | mg/kg | <0.1 | <0.1 | 0.3 | 0.2 | 0.3 | 0.4 | <0.1 | <0.1 | 0.2 | <0.1 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 6.4 | 8.6 | 5.2 | 7.4 | 8.3 | 6.4 | 9.2 | 6.8 | 9.0 | 8.4 |

**Dry Weights**

| Variable | KO-22 | KO-24 | KO-26 | KO-28 | KO-30 | KO-32 | KO-34 | KO-36 | KO-38 | KO-40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.14 | 0.14 | 0.09 | 0.12 | 0.22 | 0.15 | 0.10 | 0.17 | 0.21 | 0.19 |
| Calcium | 343 | 414 | 1991 | 1276 | 2694 | 2350 | 230 | 354 | 1113 | 463 |
| Copper | 2.9 | 3.8 | <2.3 | <2.0 | <2.8 | <2.5 | 3.5 | 3.3 | <2.1 | 5.0 |
| Magnesium | 1129 | 1324 | 1182 | 1220 | 1189 | 1210 | 1165 | 913 | 1233 | 1456 |
| Nickel | 1.4 | <0.5 | <0.5 | 0.4 | 11.1 | 0.5 | 0.5 | <0.4 | 0.8 | 0.6 |
| Phosphorus | 11000 | 12857 | 11545 | 11440 | 13389 | 12000 | 11200 | 8667 | 11458 | 14750 |
| Potassium | 16190 | 18619 | 16045 | 16000 | 18889 | 17300 | 16850 | 13292 | 16333 | 21875 |
| Selenium | 1.95 | 1.90 | 1.55 | 1.96 | 2.28 | 1.85 | 1.70 | 1.50 | 1.83 | 2.38 |
| Sodium | 3590 | 2943 | 2082 | 1992 | 4500 | 2750 | 3000 | 2404 | 1375 | 4900 |
| Zinc | 30.5 | 41.0 | 23.6 | 29.6 | 46.1 | 32.0 | 46.0 | 28.3 | 37.5 | 52.5 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-F
# Kokanee Ovary – United States Reach (Border to Rexford)

**Kokanee - Ovary** Sample date: September 16, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | KO-22 | KO-24 | KO-26 | KO-28 | KO-30 | KO-32 | KO-34 | KO-38 | KO-40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 61 | 70 | 58 | 61 | 65 | 59 | 60 | 56 | 63 |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.03 | 0.03 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.08 | 0.03 |
| Barium | mg/kg | 0.2 | 0.1 | 0.2 | 0.3 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | 0.05 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 |
| Calcium | mg/kg | 468 | 403 | 527 | 2570 | 547 | 449 | 485 | 497 | 471 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 15.9 | 11.5 | 13.9 | 23.9 | 11.6 | 10.3 | 13.3 | 17.3 | 10.1 |
| Iron | mg/kg | 22 | 20 | 18 | 210 | 17 | 18 | 16 | 27 | 17 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | mg/kg | 549 | 448 | 569 | 300 | 538 | 609 | 573 | 632 | 468 |
| Manganese | mg/kg | 1.3 | 0.9 | 1.1 | 2.5 | 0.9 | 0.8 | 0.8 | 1.6 | 0.8 |
| Mercury | mg/kg | 0.01 | 0.01 | <0.01 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | <0.1 | 0.1 | 0.1 | <0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 |
| Phosphorus | mg/kg | 3990 | 3670 | 4420 | 4130 | 3800 | 4650 | 4720 | 4540 | 3990 |
| Potassium | mg/kg | 2940 | 2860 | 2590 | 3420 | 2860 | 2550 | 2420 | 2410 | 3060 |
| Selenium | mg/kg | 1.37 | 1.44 | 1.72 | 1.84 | 1.16 | 1.44 | 1.37 | 1.97 | 1.31 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 | <0.05 |
| Sodium | mg/kg | 873 | 1020 | 649 | 964 | 747 | 518 | 663 | 589 | 837 |
| Strontium | mg/kg | 0.7 | 0.6 | 0.7 | 1.9 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | 2 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 37.0 | 33.6 | 35.2 | 141.0 | 29.6 | 40.2 | 27.4 | 57.5 | 27.6 |

**Dry Weights**

| Variable | KO-22 | KO-24 | KO-26 | KO-28 | KO-30 | KO-32 | KO-34 | KO-38 | KO-40 |
|---|---|---|---|---|---|---|---|---|---|
| Moisture | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | |
| Aluminium | | | | | | | | | |
| Antimony | | | | | | | | | |
| Arsenic | 0.10 | 0.10 | 0.10 | 0.15 | 0.09 | 0.12 | 0.10 | 0.18 | 0.08 |
| Barium | 0.5 | 0.3 | 0.5 | 0.8 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 |
| Beryllium | | | | | | | | | |
| Bismuth | | | | | | | | | |
| Boron | | | | | | | | | |
| Cadmium | | | | | | | | | |
| Calcium | 1200 | 1343 | 1255 | 6590 | 1563 | 1095 | 1213 | 1130 | 1273 |
| Chromium | | | | | | | | | |
| Cobalt | | | | | | | | | |
| Copper | 40.8 | 38.3 | 33.1 | 61.3 | 33.1 | 25.1 | 33.3 | 39.3 | 27.3 |
| Iron | 56 | 67 | 43 | 538 | 49 | 44 | 40 | 61 | 46 |
| Lead | | | | | | | | | |
| Magnesium | 1408 | 1493 | 1355 | 769 | 1537 | 1485 | 1433 | 1436 | 1265 |
| Manganese | 3.3 | 3.0 | 2.6 | 6.4 | 2.6 | 2.0 | 2.0 | 3.6 | 2.2 |
| Mercury | | | | | | | | | |
| Molybdenum | | | | | | | | | |
| Nickel | <0.3 | 0.3 | 0.2 | <0.3 | 0.9 | 0.2 | 0.3 | 0.2 | 0.3 |
| Phosphorus | 10231 | 12233 | 10524 | 10590 | 10857 | 11341 | 11800 | 10318 | 10784 |
| Potassium | 7538 | 9533 | 6167 | 8769 | 8171 | 6220 | 6050 | 5477 | 8270 |
| Selenium | 3.51 | 4.80 | 4.10 | 4.72 | 3.31 | 3.51 | 3.43 | 4.48 | 3.54 |
| Silver | | | | | | | | | |
| Sodium | 2238 | 3400 | 1545 | 2472 | 2134 | 1263 | 1658 | 1339 | 2262 |
| Strontium | 1.8 | 2.0 | 1.7 | 4.9 | 1.7 | 1.7 | 1.8 | 1.6 | 1.9 |
| Thallium | | | | | | | | | |
| Tin | | | | | | | | | |
| Titanium | | | | | | | | | |
| Uranium | | | | | | | | | |
| Vanadium | | | | | | | | | |
| Zinc | 94.9 | 112.0 | 83.8 | 361.5 | 84.6 | 98.0 | 68.5 | 130.7 | 74.6 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-G
# Peamouth Chub Whole Body – United States Reach (Border to Rexford)

**Peamouth Chub - Whole Body** Sample date: May 14, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | PCC-01 | PCC-03 | PCC-05 | PCC-07 | PCC-09 | PCC-11 | PCC-13 | PCC-15 | PCC-17 | PCC-19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 75 | 72 | 76 | 75 | 74 | 74 | 77 | 77 | 76 | 74 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | 80 | 38 | 9 | 29 | 31 | <1 | 34 | 54 | 56 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.09 | 0.17 | 0.10 | 0.07 | 0.15 | 0.11 | 0.06 | 0.11 | 0.15 | 0.16 |
| Barium | mg/kg | 3.5 | 4.2 | 2.9 | 3.3 | 3.3 | 3.5 | 2.1 | 3.8 | 4.6 | 4.7 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | 0.06 | 0.03 | 0.05 | 0.05 | 0.02 | 0.01 | 0.05 | 0.03 | 0.05 | 0.05 |
| Calcium | mg/kg | 11200 | 8590 | 4850 | 9030 | 5210 | 5730 | 12100 | 6610 | 9710 | 12500 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 0.7 | 1.2 | 1.4 | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 1.4 | 0.9 |
| Iron | mg/kg | 16 | 171 | 87 | 33 | 79 | 74 | 19 | 81 | 112 | 116 |
| Lead | mg/kg | 0.02 | 0.10 | 0.07 | 0.04 | 0.05 | 0.08 | 0.01 | 0.07 | 0.09 | 0.11 |
| Magnesium | mg/kg | 441 | 632 | 412 | 421 | 373 | 389 | 437 | 413 | 461 | 513 |
| Manganese | mg/kg | 2.4 | 7.7 | 4.3 | 3.9 | 2.6 | 3.1 | 1.6 | 3.7 | 5.2 | 5.3 |
| Mercury | mg/kg | 0.10 | 0.09 | 0.14 | 0.17 | 0.11 | 0.08 | 0.14 | 0.17 | 0.13 | 0.07 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.2 | 0.3 | 0.4 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 |
| Phosphorus | mg/kg | 9170 | 6780 | 5080 | 7800 | 5390 | 5260 | 9480 | 5810 | 7760 | 9430 |
| Potassium | mg/kg | 3300 | 3400 | 3190 | 3180 | 3110 | 3130 | 3310 | 3130 | 2990 | 2860 |
| Selenium | mg/kg | 0.92 | 0.88 | 0.75 | 0.59 | 1.08 | 0.90 | 0.63 | 0.85 | 0.87 | 0.98 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 704 | 716 | 651 | 969 | 741 | 728 | 799 | 711 | 698 | 694 |
| Strontium | mg/kg | 12.9 | 10.6 | 6.2 | 11.4 | 5.7 | 7.0 | 14.8 | 7.6 | 12.5 | 13.1 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | 2 | <1 | <1 | 1 | 1 | <1 | <1 | 1 | 2 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 26.8 | 24.2 | 26.2 | 31.2 | 22.0 | 12.6 | 26.7 | 19.2 | 25.7 | 21.3 |

**Dry Weights**

| Variable | PCC-01 | PCC-03 | PCC-05 | PCC-07 | PCC-09 | PCC-11 | PCC-13 | PCC-15 | PCC-17 | PCC-19 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | | | | | | | | | | |
| Antimony | | | | | | | | | | |
| Arsenic | 0.36 | 0.61 | 0.42 | 0.28 | 0.58 | 0.42 | 0.26 | 0.48 | 0.63 | 0.62 |
| Barium | 14.0 | 15.0 | 12.1 | 13.2 | 12.7 | 13.5 | 9.1 | 16.5 | 19.2 | 18.1 |
| Beryllium | | | | | | | | | | |
| Bismuth | | | | | | | | | | |
| Boron | | | | | | | | | | |
| Cadmium | 0.24 | 0.11 | 0.21 | 0.20 | 0.08 | 0.04 | 0.22 | 0.13 | 0.21 | 0.19 |
| Calcium | 44800 | 30679 | 20208 | 36120 | 20038 | 22038 | 52609 | 28739 | 40458 | 48077 |
| Chromium | | | | | | | | | | |
| Cobalt | | | | | | | | | | |
| Copper | 2.8 | 4.3 | 5.8 | 3.2 | 3.1 | 3.1 | 2.6 | 3.5 | 5.8 | 3.5 |
| Iron | 64 | 611 | 363 | 132 | 304 | 285 | 83 | 352 | 467 | 446 |
| Lead | 0.08 | 0.36 | 0.29 | 0.16 | 0.19 | 0.31 | 0.04 | 0.30 | 0.38 | 0.42 |
| Magnesium | 1764 | 2257 | 1717 | 1684 | 1435 | 1496 | 1900 | 1796 | 1921 | 1973 |
| Manganese | 9.6 | 27.5 | 17.9 | 15.6 | 10.0 | 11.9 | 7.0 | 16.1 | 21.7 | 20.4 |
| Mercury | | | | | | | | | | |
| Molybdenum | | | | | | | | | | |
| Nickel | 0.8 | 1.1 | 1.7 | 0.8 | 1.2 | 1.2 | 0.9 | 1.3 | 1.3 | 1.2 |
| Phosphorus | 36680 | 24214 | 21167 | 31200 | 20731 | 20231 | 41217 | 25261 | 32333 | 36269 |
| Potassium | 13200 | 12143 | 13292 | 12720 | 11962 | 12038 | 14391 | 13609 | 12458 | 11000 |
| Selenium | 3.68 | 3.14 | 3.13 | 2.36 | 4.15 | 3.46 | 2.74 | 3.70 | 3.63 | 3.77 |
| Silver | | | | | | | | | | |
| Sodium | 2816 | 2557 | 2713 | 3876 | 2850 | 2800 | 3474 | 3091 | 2908 | 2669 |
| Strontium | 51.6 | 37.9 | 25.8 | 45.6 | 21.9 | 26.9 | 64.3 | 33.0 | 52.1 | 50.4 |
| Thallium | | | | | | | | | | |
| Tin | | | | | | | | | | |
| Titanium | | | | | | | | | | |
| Uranium | | | | | | | | | | |
| Vanadium | | | | | | | | | | |
| Zinc | 107.2 | 86.4 | 109.2 | 124.8 | 84.6 | 48.5 | 116.1 | 83.5 | 107.1 | 81.9 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-H
# Peamouth Chub Axial Muscle – United States Reach (Border to Rexford)

**Peamouth Chub - Axial Muscle** Sample date: May 14, 2008 Sampled by: Montana Fish, Wildlife & Parks

| | | Wet Weights | | | | | | | | | | Dry Weights | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Units | PCC-02 | PCC-04 | PCC-06 | PCC-08 | PCC-10 | PCC-12 | PCC14 | PCC-16 | PCC-18 | PCC-20 | PCC-02 | PCC-04 | PCC-06 | PCC-08 | PCC-10 | PCC-12 | PCC14 | PCC-16 | PCC-18 | PCC-20 |
| Moisture | % | 82 | 80 | 80 | 80 | 81 | 81 | 81 | 81 | 79 | 82 | | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | 1 | <1 | 2 | <1 | | | | | | | | | | |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Arsenic | mg/kg | 0.03 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.04 | 0.06 | 0.04 | 0.05 | 0.17 | 0.20 | 0.35 | 0.20 | 0.32 | 0.26 | 0.21 | 0.32 | 0.19 | 0.28 |
| Barium | mg/kg | 0.5 | 0.2 | 0.3 | 0.3 | 0.9 | 0.5 | 0.3 | 0.2 | 0.6 | 0.4 | 2.8 | 1.0 | 1.5 | 1.5 | 4.7 | 2.6 | 1.6 | 1.1 | 2.9 | 2.2 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | | | | | | | | | | |
| Cadmium | mg/kg | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | | | | | | | | | | |
| Calcium | mg/kg | 559 | 543 | 486 | 698 | 759 | 832 | 503 | 370 | 406 | 1060 | 3106 | 2715 | 2430 | 3490 | 3995 | 4379 | 2647 | 1947 | 1933 | 5889 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | | | | | | | | | | |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Copper | mg/kg | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | | | | | | | | | | |
| Iron | mg/kg | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | | | | | | | | | | |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.01 | | | | | | | | | | |
| Magnesium | mg/kg | 251 | 280 | 300 | 280 | 310 | 251 | 313 | 307 | 270 | 276 | 1394 | 1400 | 1500 | 1400 | 1632 | 1321 | 1647 | 1616 | 1286 | 1533 |
| Manganese | mg/kg | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 1.1 | 1.0 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.1 | 1.4 | 2.2 |
| Mercury | mg/kg | 0.24 | 0.34 | 0.10 | 0.32 | 0.18 | 0.19 | 0.14 | 0.12 | 0.14 | 0.13 | | | | | | | | | | |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Nickel | mg/kg | 0.2 | 0.2 | 0.2 | <0.1 | 0.2 | 0.1 | <0.1 | 0.2 | 0.2 | <0.1 | 1.1 | 1.0 | 1.0 | <0.5 | 1.1 | 0.5 | <0.5 | 1.1 | 1.0 | <0.6 |
| Phosphorus | mg/kg | 2170 | 2260 | 2300 | 2380 | 2560 | 2240 | 2290 | 2390 | 2190 | 2590 | 12056 | 11300 | 11500 | 11900 | 13474 | 11789 | 12053 | 12579 | 10429 | 14389 |
| Potassium | mg/kg | 3280 | 3390 | 3620 | 3610 | 3800 | 3390 | 3570 | 3770 | 3420 | 3620 | 18222 | 16950 | 18100 | 18050 | 20000 | 17842 | 18789 | 19842 | 16286 | 20111 |
| Selenium | mg/kg | 0.42 | 0.35 | 1.07 | 0.52 | 0.53 | 0.44 | 0.83 | 1.22 | 0.49 | 0.50 | 2.33 | 1.75 | 5.35 | 2.60 | 2.79 | 2.32 | 4.37 | 6.42 | 2.33 | 2.78 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | | | | | | | | | |
| Sodium | mg/kg | 401 | 417 | 317 | 574 | 498 | 448 | 399 | 364 | 366 | 438 | 2228 | 2085 | 1585 | 2870 | 2621 | 2358 | 2100 | 1916 | 1743 | 2433 |
| Strontium | mg/kg | 0.7 | 0.6 | 0.5 | 0.9 | 0.9 | 1.0 | 0.5 | 0.3 | 0.4 | 1.2 | 3.9 | 3.0 | 2.5 | 4.5 | 4.7 | 5.3 | 2.6 | 1.6 | 1.9 | 6.7 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | | | | | | | | | |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | | | | | | | | | | |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | | | | | | | | | |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | | | | | | | | | | |
| Zinc | mg/kg | 13.0 | 11.1 | 6.0 | 10.0 | 8.3 | 10.0 | 8.1 | 7.2 | 12.0 | 7.2 | 72.2 | 55.5 | 30.0 | 50.0 | 43.7 | 52.6 | 42.6 | 37.9 | 57.1 | 40.0 |

Exceeds human consumption guideline for >350 g fish/week (0.3 mg/kg ww)

Exceeds human consumption guideline for >525 g fish/week (0.2 mg/kg ww)

Exceeds human consumption guideline for >1050 g fish/week (0.1 mg/kg ww)

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix X-I
# Peamouth Chub Ovary – United States Reach (Border to Rexford)

**Peamouth Chub - Ovary** Sample date: May 14, 2008 Sampled by: Montana Fish, Wildlife & Parks

**Wet Weights**

| Variable | Units | PCC-02 | PCC-04 | PCC-06 | PCC-08 | PCC-10 | PCC-12 | PCC-14 | PCC-16 | PCC-18 | PCC-20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | % | 68 | 64 | 65 | 72 | 67 | 67 | 64 | 65 | 65 | 65 |
| **Total Metals by ICPMS** | | | | | | | | | | | |
| Aluminium | mg/kg | <1 | <1 | <1 | 2 | 1 | 6 | <1 | <1 | 3 | <1 |
| Antimony | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Arsenic | mg/kg | 0.06 | 0.05 | 0.10 | 0.05 | 0.08 | 0.09 | 0.05 | 0.09 | 0.07 | 0.08 |
| Barium | mg/kg | 0.7 | 0.5 | 0.3 | 0.7 | 1.0 | 1.1 | 0.5 | 0.4 | 0.9 | 0.5 |
| Beryllium | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Bismuth | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Boron | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Cadmium | mg/kg | 0.02 | 0.02 | 0.01 | 0.07 | 0.03 | 0.01 | 0.02 | <0.01 | <0.01 | 0.01 |
| Calcium | mg/kg | 114 | 141 | 123 | 219 | 101 | 170 | 85 | 95 | 117 | 100 |
| Chromium | mg/kg | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper | mg/kg | 1.0 | 1.0 | 1.0 | 0.8 | 1.4 | 1.4 | 1.1 | 0.9 | 1.1 | 0.8 |
| Iron | mg/kg | 24 | 24 | 28 | 38 | 33 | 44 | 23 | 25 | 28 | 28 |
| Lead | mg/kg | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | 0.01 | <0.01 |
| Magnesium | mg/kg | 284 | 291 | 295 | 325 | 293 | 307 | 294 | 296 | 306 | 302 |
| Manganese | mg/kg | 1.9 | 2.3 | 1.5 | 2.7 | 1.6 | 2.7 | 2.5 | 1.2 | 3.5 | 2.0 |
| Mercury | mg/kg | 0.02 | 0.03 | <0.01 | 0.03 | 0.02 | 0.02 | <0.01 | <0.01 | <0.01 | 0.01 |
| Molybdenum | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/kg | 0.2 | 0.1 | 0.2 | <0.1 | <0.1 | 0.2 | <0.1 | <0.1 | 0.2 | 0.2 |
| Phosphorus | mg/kg | 3950 | 4240 | 4550 | 3460 | 4740 | 4160 | 4740 | 4710 | 4590 | 4850 |
| Potassium | mg/kg | 2300 | 2520 | 2490 | 2570 | 2720 | 2520 | 2640 | 2440 | 2690 | 2760 |
| Selenium | mg/kg | 1.60 | 2.03 | 3.97 | 2.59 | 3.38 | 1.86 | 3.06 | 3.39 | 2.25 | 2.27 |
| Silver | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Sodium | mg/kg | 433 | 547 | 434 | 731 | 541 | 615 | 487 | 518 | 501 | 601 |
| Strontium | mg/kg | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | 0.2 | <0.1 | <0.1 | 0.2 | 0.1 |
| Thallium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tin | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Titanium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Vanadium | mg/kg | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Zinc | mg/kg | 36.8 | 38.9 | 32.5 | 36.9 | 29.0 | 39.9 | 33.3 | 32.8 | 32.3 | 32.3 |

**Dry Weights**

| Variable | PCC-02 | PCC-04 | PCC-06 | PCC-08 | PCC-10 | PCC-12 | PCC-14 | PCC-16 | PCC-18 | PCC-20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture | | | | | | | | | | |
| **Total Metals by ICPMS** | | | | | | | | | | |
| Aluminium | | | | | | | | | | |
| Antimony | | | | | | | | | | |
| Arsenic | 0.19 | 0.14 | 0.29 | 0.18 | 0.24 | 0.27 | 0.14 | 0.26 | 0.20 | 0.23 |
| Barium | 2.2 | 1.4 | 0.9 | 2.5 | 3.0 | 3.3 | 1.4 | 1.1 | 2.6 | 1.4 |
| Beryllium | | | | | | | | | | |
| Bismuth | | | | | | | | | | |
| Boron | | | | | | | | | | |
| Cadmium | 0.06 | 0.06 | 0.03 | 0.25 | 0.09 | 0.03 | 0.06 | <0.03 | <0.03 | 0.03 |
| Calcium | 356 | 392 | 351 | 782 | 306 | 515 | 236 | 271 | 334 | 286 |
| Chromium | | | | | | | | | | |
| Cobalt | | | | | | | | | | |
| Copper | 3.1 | 2.8 | 2.9 | 2.9 | 4.2 | 4.2 | 3.1 | 2.6 | 3.1 | 2.3 |
| Iron | 75 | 67 | 80 | 136 | 100 | 133 | 64 | 71 | 80 | 80 |
| Lead | | | | | | | | | | |
| Magnesium | 888 | 808 | 843 | 1161 | 888 | 930 | 817 | 846 | 874 | 863 |
| Manganese | 5.9 | 6.4 | 4.3 | 9.6 | 4.8 | 8.2 | 6.9 | 3.4 | 10.0 | 5.7 |
| Mercury | | | | | | | | | | |
| Molybdenum | | | | | | | | | | |
| Nickel | 0.6 | 0.3 | 0.6 | <0.4 | <0.3 | 0.6 | <0.3 | <0.3 | 0.6 | 0.6 |
| Phosphorus | 12344 | 11778 | 13000 | 12357 | 14364 | 12606 | 13167 | 13457 | 13114 | 13857 |
| Potassium | 7188 | 7000 | 7114 | 9179 | 8242 | 7636 | 7333 | 6971 | 7686 | 7886 |
| Selenium | 5.00 | 5.64 | 11.34 | 9.25 | 10.24 | 5.64 | 8.50 | 9.69 | 6.43 | 6.49 |
| Silver | | | | | | | | | | |
| Sodium | 1353 | 1519 | 1240 | 2611 | 1639 | 1864 | 1353 | 1480 | 1431 | 1717 |
| Strontium | 0.3 | 0.3 | 0.3 | 1.1 | 0.3 | 0.6 | <0.3 | <0.3 | 0.6 | 0.3 |
| Thallium | | | | | | | | | | |
| Tin | | | | | | | | | | |
| Titanium | | | | | | | | | | |
| Uranium | | | | | | | | | | |
| Vanadium | | | | | | | | | | |
| Zinc | 115.0 | 108.1 | 92.9 | 131.8 | 87.9 | 120.9 | 92.5 | 93.7 | 92.3 | 92.3 |

Dry weights calculated if more than half the wet weight results exceed the MDL.

# Appendix XI-A Fish Field Data: Kokanee

**Canadian Reach (E272043, Kikomun to Elk River)**

| Fish ID | Length (cm, nose to end of tail) | Weight (g) | Location | Tissue analyzed | Notes |
|---|---|---|---|---|---|
| N-KO-01 | 27.6 | 190 | South of bridge | WB | |
| N-KO-02 | 27.4 | 200 | North of cabin | O, M | |
| N-KO-03 | 27.6 | 172 | North of cabin | WB | |
| N-KO-04 | 28.5 | 194 | South of bridge | O, M | |
| N-KO-05 | 25.5 | 158 | South of bridge | WB | |
| N-KO-06 | 29.8 | 226 | South of bridge | O, M | |
| N-KO-07 | 27.5 | 178 | South of bridge | WB | |
| N-KO-08 | 28.2 | 194 | South of bridge | O, M | Male (ID'd during dissection). Only muscle sampled. |
| N-KO-09 | 26.5 | 170 | North of cabin | WB | |
| N-KO-10 | 28.1 | 180 | Across from campground | O, M | Replicate eggs and muscle from this fish. |
| N-KO-11 | 29.0 | 231 | Across from campground | WB | |
| N-KO-12 | 26.6 | 184 | Across from campground | O, M | |
| N-KO-13 | 28.2 | 180 | Across from campground | WB | |
| N-KO-14 | 25.6 | 139 | Across from campground | O, M | |
| N-KO-15 | 26.9 | 163 | Across from campground | WB | |
| N-KO-16 | 27.8 | 220 | Across from campground | O, M | |
| N-KO-17 | 27.7 | 212 | Across from campground | WB | |
| N-KO-18 | 26.8 | 180 | Across from campground | O, M | |
| N-KO-19 | 28.2 | 213 | Across from campground | WB | |
| N-KO-20 | 26.9 | 170 | Across from campground | O, M | |
| **Mean** | **27.5** | **188** | | | |

**United States Reach (Border to Rexford)**

| Fish ID | Length (cm, nose to end of tail) | Weight (g) | Location | Tissue analyzed | Notes |
|---|---|---|---|---|---|
| S-KO-21 | 27.1 | 177 | S point Tobacco | WB | |
| S-KO-22 | 25.5 | 149 | S point Tobacco | O, M | |
| S-KO-23 | 27.1 | 165 | N point Murray | WB | |
| S-KO-24 | 27.5 | 175 | N point Murray | O, M | Not many eggs - may have already spawned. |
| S-KO-25 | 28.5 | 196 | N point Murray | WB | |
| S-KO-26 | 27.2 | 180 | N point Murray | O, M | |
| S-KO-27 | 26.1 | 165 | N point Murray | WB | |
| S-KO-28 | 29.5 | 212 | N point Murray | O, M | Not many eggs - may have already spawned. |
| S-KO-29 | 27.4 | 172 | N point Murray | WB | |
| S-KO-30 | 26.4 | 170 | N point Murray | O, M | |
| S-KO-31 | 27.1 | 173 | N point Murray | WB | |
| S-KO-32 | 27.0 | 182 | N point Murray | O, M | |
| S-KO-33 | 28.2 | 201 | N point Murray | WB | |
| S-KO-34 | 27.0 | 186 | N point Murray | O, M | |
| S-KO-35 | 28.4 | 190 | Sandhill | WB | |
| S-KO-36 | 27.5 | 172 | Sandhill | O, M | Male (ID'd during dissection). Only muscle sampled. |
| S-KO-37 | 27.0 | 150 | Sandhill | WB | |
| S-KO-38 | 26.6 | 162 | Sandhill | O, M | |
| S-KO-39 | 27.6 | 180 | Sandhill | WB | |
| S-KO-40 | 27.6 | 184 | Sandhill | O, M | |
| **Mean** | **27.3** | **177** | | | |

1. Where possible, scales and otoliths obtained for aging. Many fish absorbing scales so often difficult to obtain. Also, many fish head's were crushed or severed during removal from gill net, so difficult to locate otoliths.
2. Random observation of 10 stomach contents found they were empty or contained well digested brown "gush" - likely digested plankton. No evidence of terrestrial or aquatic invertebrates.

# Appendix XI-B Fish Field Data: Peamouth Chub

**United States Reach (Border to Rexford)**

| Fish ID | Length (cm, nose to end of tail) | Weight (g) | Tissue analyzed | Notes |
|---|---|---|---|---|
| S-PCC-1 | 27.5 | 189 | WB | |
| S-PCC-2 | 27.6 | 180 | O, M | |
| S-PCC-3 | 26.0 | 162 | WB | |
| S-PCC-4 | 28.5 | 201 | O, M | |
| S-PCC-5 | 26.7 | 180 | WB | |
| S-PCC-6 | 27.9 | 211 | O, M | |
| S-PCC-7 | 28.0 | 198 | WB | |
| S-PCC-8 | 27.5 | 173 | O, M | |
| S-PCC-9 | 29.5 | 261 | WB | |
| S-PCC-10 | 28.5 | 211 | O, M | |
| S-PCC-11 | 29.8 | 259 | WB | |
| S-PCC-12 | 28.6 | 203 | O, M | |
| S-PCC-13 | 28.0 | 180 | WB | |
| S-PCC-14 | 27.0 | 192 | O, M | |
| S-PCC-15 | 29.2 | 224 | WB | |
| S-PCC-16 | 27.5 | 200 | O, M | |
| S-PCC-17 | 26.5 | 158 | WB | |
| S-PCC-18 | 24.5 | 157 | O, M | |
| S-PCC-19 | 27.3 | 191 | WB | |
| S-PCC-20 | 28.5 | 209 | O, M | |
| **Mean** | **27.7** | **197** | | |

1. Observation of 10 stomach contents found they were empty or contained well digested brown "gush" - likely digested plankton. No evidence of terrestrial or aquatic invertebrates. Fish stored 5 months frozen prior to dissection.

# APPENDIX XII

# SELENIUM IN KOKANEE
# SITE COMPARISON ANOVA's

# Appendix XII-A Kokanee Sample Sites: Whole Body One-Way ANOVA

Analyse-it v2.12

| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Kokanee: Whole Body Se: Kikomun, Elk River, Rexford |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 20 |

| Kokanee: Whole Body Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 3 | 2.108 | 0.1339 | 0.1291 | 0.232 |
| Elk River | 7 | 2.469 | 0.0525 | 0.0845 | 0.139 |
| Rexford | 10 | 2.614 | 0.0834 | 0.0707 | 0.264 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Kokanee: Whole Body Se | 0.594 | 2 | 0.297 | 5.94 | 0.0110 |
| Residual | 0.849 | 17 | 0.050 | | |
| Total | 1.443 | 19 | | | |

| Tukey Contrast | Difference | 95% CI | |
|---|---|---|---|
| Kikomun v Elk River | -0.362 | -0.758 to 0.034 | |
| Kikomun v Rexford | -0.506 | -0.883 to -0.128 | (significant) |
| Elk River v Rexford | -0.144 | -0.427 to 0.138 | |

## Appendix XII-B Kokanee Sample Sites: Axial Muscle One-Way ANOVA

Analyse-it v2.12

| | |
|---|---|
| Test | Compare Groups - 1-way ANOVA |
| | Kokanee Axial Muscle Se: Kikomun, Elk River, Rexford |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 20 |

| Kokanee Axial Muscle Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 3 | 1.821 | 0.1439 | 0.1406 | 0.249 |
| Elk River | 7 | 1.771 | 0.0646 | 0.0920 | 0.171 |
| Rexford | 10 | 1.890 | 0.0887 | 0.0770 | 0.280 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Kokanee Axial Muscle Se | 0.059 | 2 | 0.030 | 0.50 | 0.6146 |
| Residual | 1.008 | 17 | 0.059 | | |
| Total | 1.067 | 19 | | | |

| Tukey Contrast | Difference | 95% CI |
|---|---|---|
| Kikomun v Elk River | 0.050 | -0.381 to 0.481 |
| Kikomun v Rexford | -0.069 | -0.480 to 0.342 |
| Elk River v Rexford | -0.119 | -0.427 to 0.189 |

# Appendix XII-C Kokanee Sample Sites: Ovary One-Way ANOVA

Analyse-it v2.12

| | |
|---|---|
| Test | Compare Groups - 1-way ANOVA |
| | Kokanee Ovary Se: Kikomun, Elk River, Rexford |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 18 |

| Kokanee: Ovary Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kikomun | 2 | 3.447 | 0.2113 | 0.4025 | 0.299 |
| Elk River | 7 | 3.640 | 0.2140 | 0.2152 | 0.566 |
| Rexford | 9 | 3.933 | 0.1989 | 0.1898 | 0.597 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Kokanee: Ovary Se | 0.566 | 2 | 0.283 | 0.87 | 0.4380 |
| Residual | 4.861 | 15 | 0.324 | | |
| Total | 5.426 | 17 | | | |

| Tukey Contrast | Difference | 95% CI |
|---|---|---|
| Kikomun v Elk River | -0.193 | -1.379 to 0.993 |
| Kikomun v Rexford | -0.486 | -1.642 to 0.670 |
| Elk River v Rexford | -0.293 | -1.038 to 0.452 |

# Appendix XIII-A Selenium in Kokanee versus Peamouth: Whole Body One-Way ANOVA

Analyse-it v2.12

| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Whole Body Se: Kokanee ≠ Peamouth |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 20 |

| Whole Body Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kokanee | 10 | 2.614 | 0.0834 | 0.1334 | 0.264 |
| Peamouth | 10 | 3.376 | 0.1692 | 0.1334 | 0.535 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Whole Body Se | 2.907 | 1 | 2.907 | 16.34 | 0.0008 |
| Residual | 3.203 | 18 | 0.178 | | |
| Total | 6.109 | 19 | | | |

| Tukey Contrast | Difference | 95% CI | |
|---|---|---|---|
| Kokanee v Peamouth | -0.762 | -1.159 to -0.366 | (significant) |

**Appendix XIII-B Selenium in Kokanee versus Peamouth: Axial Muscle One-Way ANOVA**

Analyse-it

| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Axial Muscle Se: Kokanee ≠ Peamouth |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 20 |

| Axial Muscle Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kokanee | 10 | 1.890 | 0.0887 | 0.3500 | 0.280 |
| Peamouth | 10 | 3.304 | 0.4870 | 0.3500 | 1.540 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Axial Muscle Se | 9.996 | 1 | 9.996 | 8.16 | 0.0105 |
| Residual | 22.055 | 18 | 1.225 | | |
| Total | 32.051 | 19 | | | |

| Tukey Contrast | Difference | 95% CI | |
|---|---|---|---|
| Kokanee v Peamouth | -1.414 | -2.454 to -0.374 | (significant) |

## Appendix XIII-C Selenium in Kokanee versus Peamouth: Ovary One-Way ANOVA

Analyse-it v2.12

| | |
|---|---|
| Test | **Compare Groups - 1-way ANOVA** |
| | Ovary Se: Kokanee ≠ Peamouth |
| Performed by | Les |
| Date | 15 December 2008 |

| | |
|---|---|
| n | 19 |

| Ovary Se | n | Mean | SE | Pooled SE | SD |
|---|---|---|---|---|---|
| Kokanee | 9 | 3.933 | 0.1989 | 0.5616 | 0.597 |
| Peamouth | 10 | 7.822 | 0.7103 | 0.5328 | 2.246 |

| Source of variation | Sum squares | DF | Mean square | F statistic | p |
|---|---|---|---|---|---|
| Ovary Se | 71.658 | 1 | 71.658 | 25.24 | 0.0001 |
| Residual | 48.257 | 17 | 2.839 | | |
| Total | 119.914 | 18 | | | |

Tukey

| Contrast | Difference | 95% CI | |
|---|---|---|---|
| Kokanee v Peamouth | -3.889 | -5.523 to -2.256 | (significant) |