2026 Selenium Bioaccumulation Modelling Review

A review of selenium bioaccumulation modelling for Koocanusa Reservoir

June 2026

Ministry of Environment and Parks

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Executive Summary

Concentrations of selenium in water are elevated above background conditions in the Canadian portion of Koocanusa Reservoir due to upstream coal mining inputs from the Elk Valley. Selenium is known to bioaccumulate in aquatic food webs, and at high enough concentrations in fish it has the potential to cause effects to fish and humans who eat fish at certain rates. In 2024, the Minister of Environment and Parks ordered an amendment requiring a review of the Koocanusa Reservoir selenium water quality target established in the Elk Valley Water Quality Plan (Ministerial Order No. 232-2024, Order M232; ENV 2024). The purpose of this report is to explore how a selenium bioaccumulation model could be applied to Koocanusa Reservoir to support review of the selenium target for the Canadian portion of the reservoir.

Selenium bioaccumulation models have been developed by different researchers and jurisdictions for application to Koocanusa Reservoir (Presser & Naftz 2020; MT DEQ 2020). In 2020 and 2021, the British Columbia Ministry of Environment and Parks (ENV) explored modelling selenium bioaccumulation in the reservoir using the Presser and Naftz (2020) framework and in collaboration with Ktunaxa Nation Council (KNC). As a result of these joint efforts, an ENV KNC draft selenium bioaccumulation model was developed in 2021.

In this report, the 2021 ENV KNC model is investigated by ENV with support from an independent subject matter expert for its ability to accurately predict selenium tissue concentrations. Accuracy of the 2021 ENV KNC model was determined through comparison of model predicted tissue selenium concentrations relative to tissue concentrations that were actually measured in the reservoir. Overprediction of the majority of fish tissue selenium concentrations in the Canadian portion of Koocanusa Reservoir by the 2021 ENV KNC model justified calculation of site-specific fish trophic transfer factors (TTF) to increase the accuracy (how well the model predictions match measured values) of the model. Application of the bioaccumulation model for deriving a selenium water quality target would require that the model contain a certain degree of conservatism and confidence to support the protection of aquatic and human receptors. Application of the model using a multiple-scenario distribution approach is one method that could be used to derive a conservative aqueous value from an updated selenium bioaccumulation model. It is therefore recommended that a selenium bioaccumulation model be developed using site-specific fish TTFs and a multiple-scenario distribution approach to more accurately predict fish tissue in the Canadian portion of the Koocanusa Reservoir and support the derivation of aqueous selenium targets that support the protection of human and aquatic health.

Contents

Acronym List

ABMP	Area Based Management Plan
BAP	Bioaccumulation Potential
BC	British Columbia
BC ENV	British Columbia Ministry of Environment and Parks
dw	Dry weight
EC_x	Estimated concentration of a substance causing an x% effect in a measured biological endpoint relative to an untreated control
ECCC	Environment & Climate Change Canada
EMA	Environmental Management Act
EMS	Environmental Monitoring System
EVR	EVR Operations Ltd.
K_d	Environmental partitioning coefficient
KNC	Ktunaxa Nation Council Society
MT DEQ	Montana Department of Environmental Quality
TOR	Terms of Reference
TTF	Trophic Transfer Factor
SPM	Suspended Particulate Matter
US	United States
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
UTM	Universal Transverse Mercator

1 Introduction

The purpose of this report is to explore how a selenium bioaccumulation model could be applied to Koocanusa Reservoir to support review of the Elk Valley Area Based Management Plan (ABMP) selenium target for the Canadian portion of the reservoir. Koocanusa Reservoir lies within ʔamakʔis Ktunaxa (Ktunaxa Nation homelands) and its health is critical to the continued practice of indigenous interests and values of the Ktunaxa Nation. Aqueous selenium is elevated above background conditions in Koocanusa Reservoir due to coal mining in the upstream Elk Valley. Selenium is known to bioaccumulate in aquatic food webs, and at high enough concentrations in fish it has the potential to cause effects to fish, and to humans who eat fish at certain rates. The current selenium target for the Canadian portion of the reservoir is 2 µg/L, which is the BC water quality guideline for selenium for protection of aquatic life (ENV 2014). In the ABMP, it is applied as a monthly average of total selenium at the monitoring station immediately downstream of the Elk River inflow to the reservoir (ENV 2025).

Concentrations of selenium in fish tissue are most directly relevant for assessing impacts to fish and risks to humans who eat fish; however, concentrations of selenium in water are most directly linked to mining activity and are typically used for managing and regulating waste discharges. Concentrations of selenium in water are also easier to measure more frequently and are less invasive in that they do not require fish handling or lethal sampling. For this reason, an accurate, validated bioaccumulation model could be a useful tool for translating concentrations of selenium between these two environmental media in Koocanusa Reservoir. Selenium bioaccumulation models have been developed by different researchers and jurisdictions for application to Koocanusa Reservoir (Presser & Naftz 2020; MT DEQ 2020). In 2020 and 2021, the British Columbia Ministry of Environment and Parks (ENV) in collaboration with Ktunaxa Nation Council Society (KNC), explored modelling selenium bioaccumulation in the reservoir using the Presser and Naftz (2020) framework. As a result of these joint efforts, an ENV KNC draft selenium bioaccumulation model was developed in 2021 (Appendix A). This 2021 model was not finalized or published and is referred to here as the 2021 ENV KNC model. This report describes and builds from ENV and KNC's earlier efforts in modeling selenium bioaccumulation in Koocanusa Reservoir.

In 2024, the Minister of Environment and Parks ordered two amendments to the ABMP (Ministerial Order No. M232-2024, Order M232; ENV 2024). Amendment #1 was completed in July 2025 and resulted in an updated 2025 Elk Valley Water Quality Plan (ENV 2025). Amendment #2 requires ENV to consider new scientific information and review the ABMP selenium water quality target for the Canadian portion of Koocanusa Reservoir. A Terms of Reference (TOR) for the selenium water quality target review has been prepared. To inform the TOR, ENV examined existing tools for understanding selenium bioaccumulation in Koocanusa Reservoir and explored the potential usefulness of these tools for informing a water quality target for the Canadian portion of Koocanusa Reservoir with support from an independent subject matter expert. In support of the Amendment #2 TOR, this report explores the structure, available terms, and performance of the 2021 ENV KNC Koocanusa Reservoir selenium bioaccumulation model.

2 Selenium Bioaccumulation Model – 2021 ENV KNC

The 2021 ENV KNC selenium bioaccumulation model was co-developed by ENV and KNC between 2020 and 2021 for the purpose of deriving a selenium water quality objective for Koocanusa Reservoir, but was never finalized or published (Appendix A). This 2021 ENV KNC model calculated concentrations of total selenium in water (Se_{aqu}) that were predicted to result in concentrations of selenium in fish tissue (Se_{tissue}) protective of designated water uses and values in Koocanusa Reservoir. The basic structure of this model (Equation 1) was developed by USGS researchers and has been adapted for specific applications through selection of relevant model terms (Presser & Luoma 2010; Presser & Luoma 2013; Presser & Naftz 2020; MT DEQ 2020).

The USGS model output is specified as dissolved selenium (Presser & Naftz 2020). The 2021 ENV KNC model was intended to be applied to total selenium in water, recognizing that the presence of volatile reduced organoselenium species can complicate routine testing for total and dissolved selenium, potentially causing bias that results in dissolved selenium exceeding total selenium (ALS 2019). For example, at a Koocanusa Reservoir station upstream of the Elk River inflow (E300095), 44% of dissolved selenium concentrations were equal to or greater than total selenium concentrations measured at the same time between 2015 and 2021.

These models reflect ENV's understanding that dietary exposure is the predominant route of selenium uptake in fish (ENV 2014; DeForest and Adams 2011). Trophic Transfer Factors (TTFs) and diet fractions that characterize the aquatic food web are contained in the Bioaccumulation Potential (BAP) model term. Selenium enters into this food web from water as Suspended Particulate Matter (SPM). The partitioning of selenium in water between dissolved and solid phases is defined as K_d, a partitioning coefficient.

$$\mathrm{Se}_{\mathrm{aqu}} = \frac{\mathrm{Se}_{\mathrm{tissue}}}{\mathrm{BAP} \times (\mathrm{K_d}/1{,}000)}$$

Equation 1. Selenium Bioaccumulation Model

The 2021 ENV KNC model (Equation 2; Table 1) used an aquatic health fish tissue value of 5.6 µg/g dw (whole body) and a human health fish tissue value of 5.2 µg/g dw (whole body). The 2021 ENV KNC model used the median K_d of 4,547 from Presser & Naftz (2020), the site-specific zooplankton TTF (0.85) and macroinvertebrate TTF (1.2) from Thorley (2020), diet fractions of 25% zooplankton and 75% macroinvertebrates informed by Chisholm et al. (1989) and Dalbey et al. (1998), and the fish TTF of 1.1 from Presser & Luoma (2010). The fish TTF was applied twice to model higher trophic fish tissue which were predicted by the model to have higher selenium burdens than lower trophic fish. Additional details on how each model term was selected are provided in Sections 2.1 to 2.3.

$$\mathrm{Se}_{\mathrm{aqu}} = \frac{\mathrm{Se}_{\mathrm{tissue}}}{\mathrm{TTF}_{\mathrm{fish}} \times \mathrm{TTF}_{\mathrm{fish}} \times \left[\left(\mathrm{TTF}_{\mathrm{macro}} \times \text{diet fraction}\right) + \left(\mathrm{TTF}_{\mathrm{zoop}} \times \text{diet fraction}\right)\right] \times \mathrm{K_d}/1{,}000}$$

Equation 2. 2021 ENV KNC Draft Selenium Bioaccumulation Model for Koocanusa Reservoir

Table 1. Model Terms in the 2021 ENV KNC Selenium Bioaccumulation Model for Koocanusa Reservoir

Model Term	Selection	Source or Rational
Human health fish tissue value	5.2 µg/g dw (whole body)	BC human health screening value for fish consumption calculated using the Ktunaxa preferred fish consumption rate of 245 g fish/day and converted from muscle tissue to whole body (ENV 2014; USEPA 2021; Robertson 2020).
Aquatic health fish tissue value	5.6 µg/g dw (whole body)	BC aquatic life guideline for egg/ovary fish tissue converted to whole body (ENV 2014; USEPA 2021).
BAP Structure	Higher trophic fish	Higher trophic fish model is more conservative given the fish TTF value selected.
Low trophic fish diet fractions	75% macroinvertebrate 25% zooplankton	Koocanusa Reservoir low trophic fish diets reported in Chisholm et al. (1989), Dalbey et al. (1998), and Baranowska (2017).
Fish TTF	1.1	Mean of 25 fish TTFs (Presser and Luoma 2010).
Macroinvertebrate TTF	1.2	Site-specific TTF derived from field data (Thorley 2020).
Zooplankton TTF	0.85	Site-specific maximum TTF of monthly values derived from field data (Thorley 2020).
K_d	4,547	Site-specific median K_d value derived from field data (Presser & Naftz 2020).

2.1 Tissue Value

Tissue values can be selected for use in the bioaccumulation model based on protection goals or specific applications of the model. For derivation of a water quality objective for the Canadian portion of Koocanusa Reservoir, ENV and KNC calculated a fish tissue value for the protection of aquatic life and a fish tissue value for the protection of human health. These fish tissue selenium concentrations are numerical representations of tissue selenium levels that are expected to achieve protection of designated water uses and values in Koocanusa Reservoir. Tissue values are presented as whole body fish tissue and not muscle tissue because the Ktunaxa expressed that more than fish muscle is consumed when eating fish.

An aquatic life tissue value of 5.6 µg/g dry weight (dw) whole body fish selenium was derived to protect fish living in Koocanusa Reservoir. This tissue value is based on the BC egg/ovary guideline of 11 µg/g dw which was derived by dividing the lowest available toxicological endpoint, a mean EC_{10} of 22 µg/g dw for rainbow trout, by an uncertainty factor of two (ENV 2014). This egg/ovary value was converted to a fish whole body concentration of 5.6 µg/g dw using the USEPA *Oncorhynchus* egg/ovary to whole body conversion factor of 1.96 (USEPA 2021).

A human health tissue value of 5.2 µg/g dw whole body fish selenium was derived to protect people consuming fish from Koocanusa Reservoir. The tissue value of 5.2 µg/g dw is the BC human consumption screening value (ENV 2014) adjusted to a higher fish consumption rate of 245 g fish muscle/day which is the Ktunaxa preferred fish consumption rate, derived from an internal diet study undertaken by the KNC (Robertson 2020). The resulting fish muscle screening value of 6.6 µg/g dw was converted to a fish whole body concentration of 5.2 µg/g dw using the USEPA *Oncorhynchus* muscle to whole body conversion factor of 1.27 (USEPA 2021). An alternative value calculated with BC's recommended consumption rate for high consumers of fish (220 g/day) instead of the Ktunaxa preferred consumption rate is 5.8 µg/g dw whole body fish tissue. Because 5.2 µg/g dw is more conservative, it was selected as an appropriate tissue value for the purpose of modelling to determine a safe water concentration.

For context, the Montana selenium bioaccumulation model uses the USEPA aquatic life whole body fish tissue criterion for selenium of 8.5 µg/g dw (MT DEQ 2020). This tissue value of 8.5 µg/g dw was derived using toxicity data including that for white sturgeon, the species with the greatest known sensitivity to selenium (USEPA 2021). The USEPA whole body fish tissue criterion of 8.5 µg/g dw selenium is equivalent to the USEPA muscle fish tissue criterion of 11.3 µg/g dw selenium.

2.2 Bioaccumulation Potential

The composition of the Bioaccumulation Potential (BAP) reflects the assumed diet of the intended receptor fish and the Trophic Transfer Factors (TTF) that describe the rates at which selenium moves between trophic levels. Diet fractions can be used to apply different proportions of macroinvertebrates and zooplankton to lower trophic fish diets and multiple fish trophic levels can be applied by using multiple fish TTFs. In general, lower trophic fish consume invertebrates and higher trophic fish consume fish.

2.2.1 Diet Fraction

Regardless of whether a BAP has one or two fish trophic levels, the lower trophic fish are assumed to have a diet of invertebrates. Based on diet studies conducted in Koocanusa Reservoir, lower trophic fish generally consume 75% macroinvertebrates and 25% zooplankton (Chisholm et al. 1989; Dalbey et al. 1998; Baranowska 2017). One notable exception is kokanee, which almost exclusively consume zooplankton. Macroinvertebrates in Koocanusa Reservoir generally have higher selenium burdens than zooplankton. This difference in macroinvertebrate and zooplankton selenium burdens is reflected in the TTFs available for these invertebrate groups. Consequently, models with BAPs that assume higher macroinvertebrate diet fractions result in higher predicted fish tissue selenium for a given water concentration, and a more conservative aqueous selenium concentration. The 2021 ENV KNC model assumed a lower trophic fish diet of 75% macroinvertebrates and 25% zooplankton based on local diet studies (Chisholm et al. 1989; Dalbey et al. 1998; Baranowska 2017). The Montana selenium bioaccumulation model assumes a lower trophic fish diet of 100% macroinvertebrates (MT DEQ 2020).

2.2.2 Trophic Transfer Factors

Trophic Transfer Factors (TTFs) characterize the degree of selenium bioaccumulation between two trophic levels and can be summarized as the concentration of selenium in the higher trophic consumer divided by the concentration of selenium in the lower trophic food source (USEPA 2021). TTFs can be derived from laboratory studies or from paired field measurements.

2.2.2.1 *Invertebrate Trophic Transfer Factor*

Invertebrate TTFs characterize the bioaccumulation of selenium from SPM into macroinvertebrates (TTF_{macro}) or zooplankton (TTF_{zoop}). The 2021 ENV KNC model used site-specific invertebrate TTFs derived from Koocanusa Reservoir data. These site-specific invertebrate TTFs for Koocanusa Reservoir were calculated in Thorley (2020) using concentrations of selenium measured in SPM, macroinvertebrates, and zooplankton collected in Koocanusa Reservoir. Based on these data, a site-specific macroinvertebrate TTF of 1.2 was calculated (Thorley 2020). Monthly zooplankton TTFs were calculated between May and November ranging from 0.36 to 0.85, with the highest TTF occurring in September (Thorley 2020).

The Montana selenium bioaccumulation model uses a macroinvertebrate TTF of 2.8 which is an average of seven aquatic insect TTFs (Presser & Luoma 2010). The Montana selenium bioaccumulation model applies a bioavailability of 60% to the macroinvertebrate TTF of 2.8 to better match observed data (MT DEQ 2020; Presser & Naftz 2020). Presser & Luoma (2010) also present a freshwater composite zooplankton TTF of 1.5.

2.2.2.2 *Fish Trophic Transfer Factor*

Fish TTFs (TTF_{fish}) characterize the bioaccumulation of selenium from fish diets into fish tissue. Species specific fish TTFs are presented in Appendix B of USEPA (2021). Presser and Luoma (2010) present a fish TTF of 1.1 which is a mean TTF of 25 fish species TTFs that range from 0.52 to 1.6. Many of the TTFs used in the calculation of 1.1 are derived from laboratory studies or are TTFs for fish species that are not present in Koocanusa Reservoir. Both the 2021 ENV KNC model and the Montana selenium bioaccumulation model use the Presser and Luoma (2010) fish TTF of 1.1.

2.2.3 BAP Structure

A BAP can be designed to model lower trophic fish tissue by including a single fish TTF (e.g. redside shiner eating macroinvertebrates; Equation 3) or can be designed to model higher trophic fish tissue by including two fish TTFs (e.g. bull trout eating redside shiner eating macroinvertebrates; Equation 4). TTFs are multiplied by the other BAP model terms for each trophic level represented in the equation, so a TTF less than 1 (e.g. 0.5) would result in *decreasing* selenium concentrations when moving up the trophic levels while a TTF greater than 1 (e.g. 1.5) would result in *increasing* selenium concentrations when moving up the trophic levels. Consequently, when the fish TTF is greater than 1, a BAP with two fish TTFs results in a higher predicted concentration of selenium in the final fish receptor (e.g. bull trout) relative to a model with just one fish TTF (e.g. redside shiner). This higher trophic piscivorous fish BAP with two fish TTFs (Equation 4) is used in both the 2021 ENV KNC model and the Montana selenium bioaccumulation model (MT DEQ 2020) because the fish TTF used is 1.1. When the fish TTF is less than 1, a BAP with a single fish TTF (Equation 3) results in a higher predicted concentration of selenium in the final fish receptor (e.g redside shiner) relative to a model with two fish TTFs.

$$\mathrm{BAP} = \mathrm{TTF}_{\mathrm{fish}} \times \left[(\mathrm{TTF}_{\mathrm{macro}} \times \text{macroinvertebrate diet fraction}) + \left(\mathrm{TTF}_{\mathrm{zoop}} \times \text{zooplankton diet fraction}\right)\right]$$

Equation 3. Lower Trophic Fish Bioaccumulation Potential

$$BAP = TTF_{fish} \times TTF_{fish} \times \left[(TTF_{macro} \times \text{macroinvertebrate diet fraction}) + (TTF_{zoop} \times \text{zooplankton diet fraction})\right]$$

Equation 4. Higher Trophic Bioaccumulation Potential

2.3 Environmental Partitioning Coefficient

The environmental partitioning coefficient (K_d) is the ratio of selenium associated with suspended particulate matter (SPM) relative to dissolved selenium in water. The K_d characterizes how much selenium is entering the base of the food web. Presser and Naftz (2020) calculated 87 K_d values from dissolved aqueous selenium and SPM in Koocanusa Reservoir. Dissolved selenium samples were collected by filtering water through a 0.45 µm filter. SPM samples were collected by separating the SPM from large volumes of water through ultracentrifugation. The K_d values were calculated by dividing the concentration of selenium in SPM by the concentration of dissolved selenium in water (Equation 5). The 87 K_d values calculated by Presser and Naftz (2020) ranged from 424 to 7,475 with a median value of 4,547.

$$K_d\left(\frac{kg}{L}\right) = \frac{\text{Concentration of Selenium in SPM }\left(\frac{ug}{g}dw\right)}{\text{Concentration of dissolved Selenium in water }\left(\frac{ug}{L}\right)} \times 1{,}000$$

Equation 5. Environmental Partitioning Coefficient of Selenium Between Water and Suspended Particulate Matter

Spatial and seasonal trends in K_d are apparent in Koocanusa Reservoir with the highest K_d values observed in June in surface samples collected immediately downstream of the Elk River inflow and farther downstream on the US side of the reservoir. The lowest K_d values were observed in deeper samples along the bottom of the reservoir (Presser & Naftz 2020).

The 2021 ENV KNC model used the 50^{th} percentile of the Presser & Naftz (2020) K_d dataset (4,547) (Table 1). The Montana model uses the 75^{th} percentile of the Presser & Naftz (2020) K_d dataset (5,286) (MT DEQ 2020).

3 Model Exploration

To understand how accurate the 2021 ENV KNC model is at predicting tissue selenium in Koocanusa Reservoir and how model accuracy could be improved, model predicted tissue concentrations were compared to tissue concentrations measured in Koocanusa Reservoir. The 2021 ENV KNC model (Appendix A) was used to predict tissue selenium concentrations in Koocanusa Reservoir based on aqueous selenium concentrations measured regularly since 2015. These predicted tissue selenium concentrations were compared to measured fish and invertebrate tissue selenium concentrations from Koocanusa Reservoir.

3.1 Methods

3.1.1 Study Area and Available Data

This analysis focusses on monitoring data collected in the Canadian portion of Koocanusa Reservoir. In the Canadian portion of Koocanusa Reservoir, EVR Operations Ltd. (EVR) conducts monitoring of selenium in surface water, sediment, and biological tissues in accordance with EMA Permit 107517. Sampling in the US portion of the reservoir is undertaken by Montana and US federal agencies.

Monthly water quality samples in the Canadian portion of the reservoir are collected at stations RG_TN, LK2, RG_T4, and RG_GC and have been collected regularly since 2015. Zooplankton and benthic invertebrate tissue samples are collected twice annually at stations RG_TN and RG_T4. Zooplankton and benthic invertebrate tissue samples were collected in 2018 at RG_SC, RG_ER, and RG_GC but invertebrates are not regularly sampled at these stations. Fish tissue samples are collected twice annually in the Kikomun area near RG_SC and RG_TN, in the Elk River area near RG_ER and LK2, and in the Grasmere area near RG_T4 and RG_GC (Table 2, Figure 1).

The primary datasets used in this review are consistent with those used in the Selenium Conditions in the Canadian Portion of Koocanusa Reservoir 2015 – 2025 report and are as follows:

- BC Environmental Monitoring System database (ENV n.d.) including data collected from ECCC/ENV monitoring locations in the Elk River
- Koocanusa Reservoir Data Synthesis Report – 2024 Update, Prepared for EVR Operations Limited by Windward Environmental, February 14, 2025 (Windward 2025)
- Selenium concentrations in food webs of Lake Koocanusa in the vicinity of Libby Dam (MT) and the Elk River (BC) as the basis for applying ecosystem-scale modeling, 2008-2018 data release, Prepared by US Geological Survey, August 11, 2020 (USGS 2020)
- Koocanusa Reservoir Monitoring Program: Annual Data Summary Report – 2024. Prepared for EVR Operations Limited by The Nupqu, Ecoscape and Larratt Aquatic Team, June 30, 2025 (Nupqu, Ecoscape and Larratt Aquatic Team 2025)
- Human Health Evaluation of Selenium in Koocanusa Reservoir Fish Tissue. Prepared for EVR Operations Limited by Ramboll. October 2025 (Ramboll 2025)

Water quality and fish tissue datasets were collated from these sources to support characterization of selenium conditions in the reservoir. The datasets include data available until the end of the calendar year 2025.

Table 2. Sampling Frequency at Koocanusa Reservoir Water Quality and Biological Sampling Stations with Selenium Data

Area	Station (EMS Code)	UTM Zone 11 U	Water Quality	Invertebrate Tissue	Fish Tissue	Description
Kikomun	RG_SC (E328951)	625635 E, 5457301 N	infrequent	infrequent	twice annually	Near Sand Creek and Kikomun Bridge
	RG_TN (E300095 and E328952)	626575 E, 5454366 N	monthly	twice annually		West of Kikomun Provincial Park and downstream of Kikomun Creek
Elk River	RG_ER (E272044)	631458 E, 5446941 N	-	infrequent	twice annually	Immediately downstream of Elk River inflow
	LK2 (E300230)	627031 E, 5445560 N	monthly	-		Downstream of Elk River inflow
Grasmere	RG_T4 (E300092 and E328954)	629326 E, 5441735 N	monthly	twice annually	twice annually	West of Grasmere
	RG_GC (E300093 and E328955)	630811 E, 5439055 N	monthly	infrequent		Upstream of Gold Creek

Notes: EMS = Environmental Monitoring System; UTM = Universal Transverse Mercator

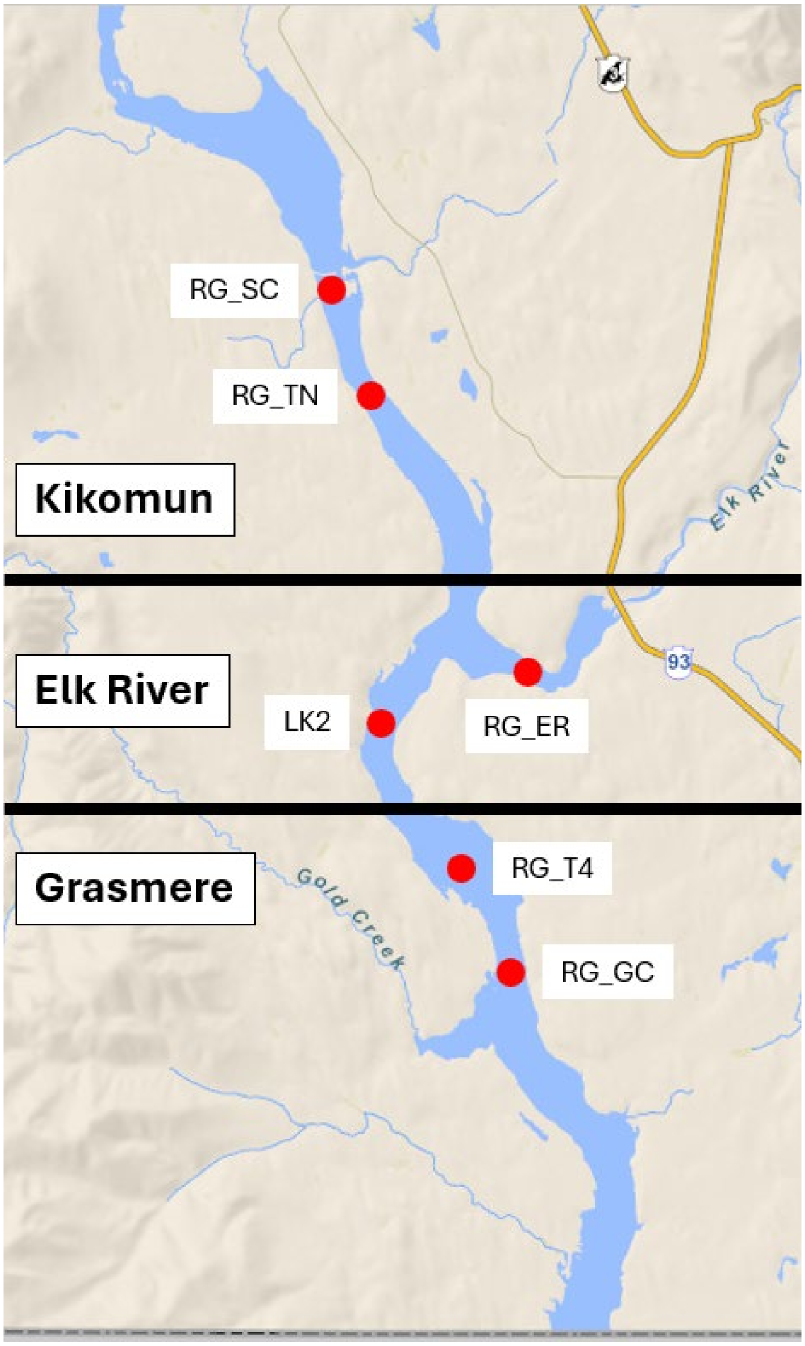

Figure 1. Koocanusa Reservoir Water Quality and Biological Sampling Stations with Selenium Data. Red markers indicate sampling stations. Horizontal black lines delineate the Kikomun, Elk River, and Grasmere areas.

3.1.2 Data Analysis

Data analysis was performed using R Statistical Software (v4.5.2; R Core Team 2026).

3.1.2.1 Data Handling and Sample Averaging

Selenium sampling event averages for zooplankton and macroinvertebrates were both calculated as the mean of samples collected from the same area during the same month. Zooplankton samples were consistently collected with three or more replicates; however, the majority of macroinvertebrate samples were collected as individual samples without replicates. Consequently, many of the macroinvertebrate sampling event averages presented here are individual sample concentrations.

Fish tissue selenium values were assigned to areas according to where each sample was collected (Figure 1). Fish tissue data were available for whole body, muscle, and egg/ovary. Fish muscle tissue concentrations were converted to whole body concentrations using species specific muscle to whole body tissue conversion factors (USEPA 2021). Egg/ovary data were excluded from the dataset due to the seasonal variability of egg/ovary concentrations and lack of ovary ripeness information for available egg/ovary values (Detering et al. 2025). Species specific fish tissue sampling event averages were calculated as the mean of samples collected from the same area, during the same month, and for the same species. Sampling event averages based on three or more individual fish samples were retained for analysis. This sampling event average approach was taken because the BC fish tissue guidelines that the 2021 ENV KNC model tissue values are based on are intended to be applied to “the mean concentration of at least eight samples” (ENV 2014). A substantial portion of the dataset did not have eight samples per average so a minimum of three fish samples per average was deemed sufficient for characterizing selenium concentrations in fish tissue.

Aqueous selenium data were often available for multiple days and depths in a single month for a given station. Monthly averages were calculated as the mean of samples collected from the same station (RG_TN, LK2, or RG_T4), during the same month.

3.1.2.2 High and Low Trophic Fish Designations

Fish tissue data were categorized into high trophic fish values and low trophic fish values based on the diet of each fish species, informed by diet studies conducted in Koocanusa Reservoir (Chisholm et al. 1989; Dalbey et al. 1998; Baranowska 2017). Burbot (*Lota lota*), north pinkeminnow (*Ptychocheilus oregonensis*), and bull trout (*Salvelinus confluentus*) primarily consume fish and were classified as high trophic fish. Westslope cutthroat trout (*Oncorhynchus clarkii*), rainbow trout (*Oncorhynchus mykiss*), kokanee (*Oncorhynchus nerka*), yellow perch (*Perca flavescens*), longnose sucker (*Catostomus Catostomus*), largescale sucker (*Catostomus macrocheilus*), slimy sculpin (*Cottus cognatus*), peamouth chub (*Mylocheilus caurinus*), mountain whitefish (*Prosopium williamsoni*), and redside shiner (*Richardsonius balteatus*) primarily consume invertebrates and were classified as low trophic fish.

3.1.2.3 Tissue Selenium Predictions

Tissue selenium concentrations were predicted with the 2021 ENV KNC model (Section 2) using monthly average aqueous selenium concentrations from the Kikomun (RG_TN), Elk River (LK2), and Grasmere (RG_T4) areas.

Tissue selenium concentrations were calculated using equations 6 to 9 based on the 2021 ENV KNC model (Section 2).

$$\text{Zooplankton Selenium} = \text{Se}_{\text{aqu}} \times \text{K}_{\text{d}}/1{,}000 \times \text{TTF}_{\text{zoop}}$$

Equation 6. 2021 ENV KNC Model Predicted Zooplankton Tissue Selenium

$$\text{Macroinvertebrate Selenium} = \text{Se}_{\text{aqu}} \times \text{K}_{\text{d}}/1{,}000 \times \text{TTF}_{\text{macro}}$$

Equation 7. 2021 ENV KNC Model Predicted Macroinvertebrate Tissue Selenium

$$\text{Low Trophic Fish Selenium} = \text{Se}_{\text{aqu}} \times \text{K}_{\text{d}}/1{,}000 \times (\text{TTF}_{\text{macro}} \times 0.75 + \text{TTF}_{\text{zoop}} \times 0.25\ ) \times \text{TTF}_{\text{fish}}$$

Equation 8. 2021 ENV KNC Model Predicted Low Trophic Fish Tissue Selenium

$$\text{High Trophic Fish Selenium} = \text{Se}_{\text{aqu}} \times \text{K}_{\text{d}}/1{,}000 \times (\text{TTF}_{\text{macro}} \times 0.75 + \text{TTF}_{\text{zoop}} \times 0.25\ ) \times \text{TTF}_{\text{fish}} \times \text{TTF}_{\text{fish}}$$

Equation 9. 2021 ENV KNC Model Predicted High Trophic Fish Tissue Selenium

3.2 Results

3.2.1 Model Predictions Compared to Measured Concentrations

2021 ENV KNC model predicted tissue selenium concentrations (Section 3.1.2.3) were compared to tissue selenium concentrations measured between 2014 and 2024 in the Kikomun, Elk River, and Grasmere areas of Koocanusa Reservoir (Figure 2). Measured concentrations of selenium in zooplankton and macroinvertebrate tissues were similar to 2021 ENV KNC model predicted concentrations; however, the majority of measured fish tissue concentrations were less than 2021 ENV KNC model predicted concentrations (Figure 2).

The 2021 ENV KNC model predicts that concentrations of selenium in tissues increase with increasing trophic level, with the greatest selenium concentrations observed in high trophic fish. In contrast, measured selenium concentrations are greatest in macroinvertebrates and decrease with increasing trophic level, with the lowest selenium concentrations observed in high trophic fish. This observed pattern in selenium bioaccumulation suggests that Koocanusa Reservoir fish TTFs may be less than 1. This finding is supported by a recent study which also found that Koocanusa Reservoir high trophic fish have lower selenium burdens than low trophic fish (Molbert 2026).

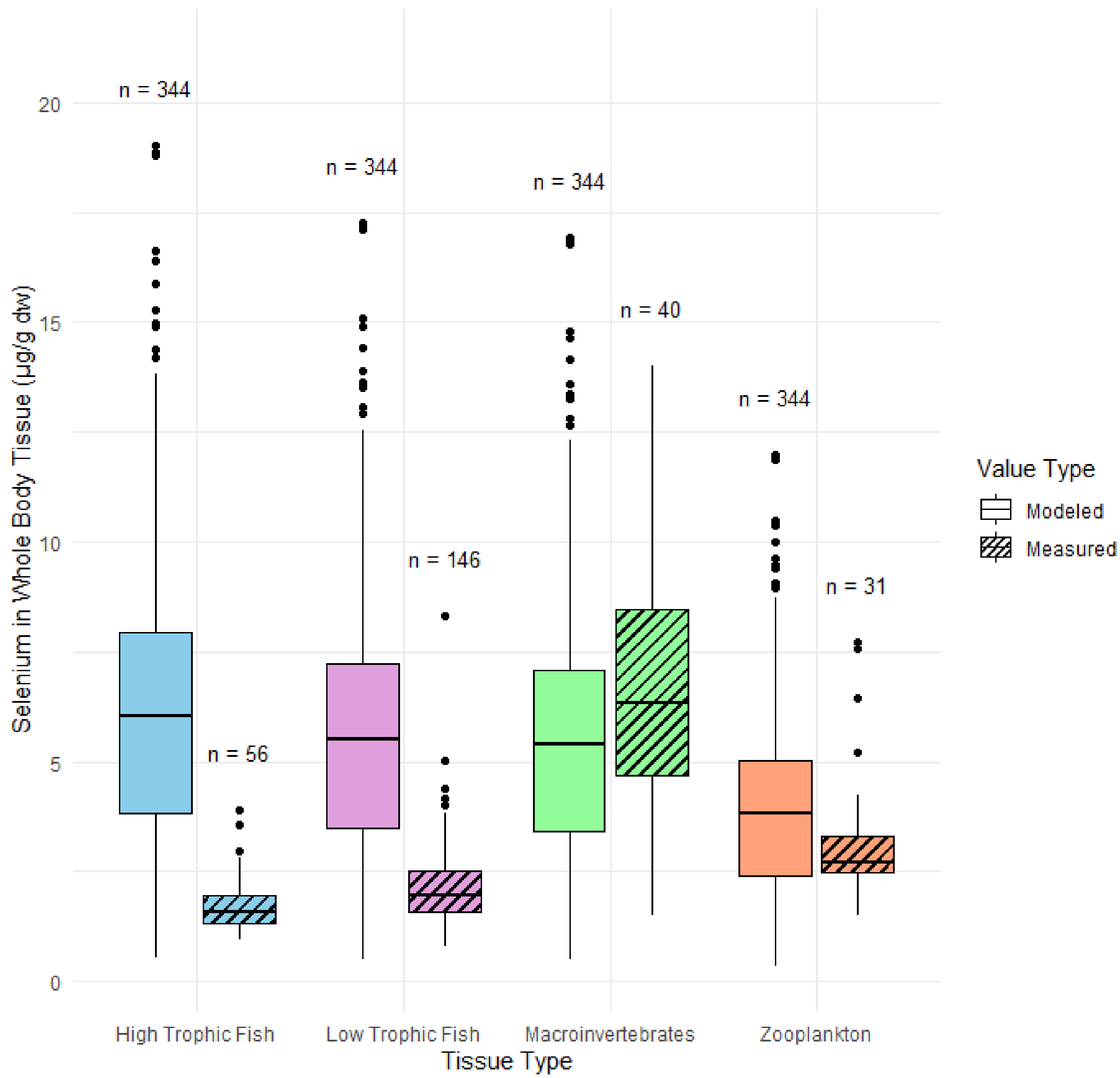

Figure 2. 2021 ENV KNC Model Predicted Tissue Selenium Concentrations and Measured Tissue Selenium Concentrations in Koocanusa Reservoir from 2014 to 2025.

4 Potential Model Updates

Upon review of available model terms and the comparison of the 2021 ENV KNC model predictions to measured concentrations, potential model updates were identified that could increase the accuracy and improve the performance of the model.

4.1 Site-Specific Fish Trophic Transfer Factors

The fish TTF of 1.1 used in the 2021 ENV KNC model is an average of 25 fish TTFs (Presser & Luoma 2010). These fish TTFs were derived using a variety of lab and field studies, many of which were conducted on species not found in Koocanusa Reservoir. Other model terms like K_d and invertebrate TTFs have site-specific values available that were calculated using selenium concentrations measured in Koocanusa Reservoir (Section 2).

2021 ENV KNC model predicted fish tissue selenium appears to be greater than measured fish tissue selenium for the majority of samples. Based on this overprediction of fish tissue selenium by the model, and the observed pattern of selenium bioaccumulation, the fish TTF of 1.1 may be too high for the Canadian portion of Koocanusa Reservoir (Section 3.2). A lower fish TTF derived from site-specific data could allow for the model to better reflect the observed pattern of selenium bioaccumulation, more accurately predicting fish tissue concentrations without underpredicting invertebrate selenium concentrations.

4.1.1 Methods

Site-specific fish TTFs for low trophic fish were calculated using fish and invertebrate selenium concentrations from the Kikomun, Elk River, and Grasmere areas of Koocanusa Reservoir. Low trophic fish tissue sampling event averages of three or more samples (Section 3.1.2.1) were paired with zooplankton and macroinvertebrate data from the same area according to a pairing date range defined for each fish tissue average. The pairing date range used was the average date of each fish tissue average minus one year and plus two months. This date range approach was used in consideration that fish tissue selenium concentrations are influenced by past exposure. Zooplankton and macroinvertebrate averages were calculated from samples that fell within the date range and matched the area of each fish tissue sampling event average. Once fish tissue and invertebrate tissue data were paired, invertebrate selenium averages were applied to fish tissue selenium averages according to each fish species' approximate diet (Chisholm et al. 1989; Dalbey et al. 1998; Baranowska 2017). Kokanee TTFs were calculated using 100% average zooplankton concentrations. TTFs for all other low trophic fish were calculated using 25% average zooplankton concentrations and 75% average macroinvertebrate concentrations (Equation 10).

$$\mathrm{TTF_{fish}} = \frac{\text{Fish Tissue Selenium}}{(\text{Macroinvertebrate Selenium} \times \text{diet fraction}) + (\text{Zooplankton Selenium} \times \text{diet fraction})}$$

Equation 10. Fish Trophic Transfer Factor Formula

4.1.2 Results

Site-specific low trophic fish TTF calculations resulted in 85 values for ten species of fish sampled in Koocanusa Reservoir. Fish TTFs had a mean and median of 0.4 and all values were less than 1 (Figure 3). ENV recognizes that these fish TTF values are lower than those typically reported in the scientific literature (Presser and Luoma 2010; USEPA 2021). Fish TTFs for individual species exhibited high variability with relatively large overlapping ranges between fish species. Larger bodied fish species like cutthroat trout, which exhibit seasonal migratory behavior had the widest ranges of TTFs while smaller bodied fish species that generally have smaller home ranges (peamouth chub and redside shiner) had more narrow ranges of TTFs despite having the two largest sample sizes. This could be evidence that larger bodied fish with larger home ranges are integrating selenium concentrations from larger areas. The tighter distribution of peamouth chub and redside shiner TTFs could be evidence that these smaller bodied fish are primarily feeding on local invertebrates that closely reflect those captured in TTF calculations.

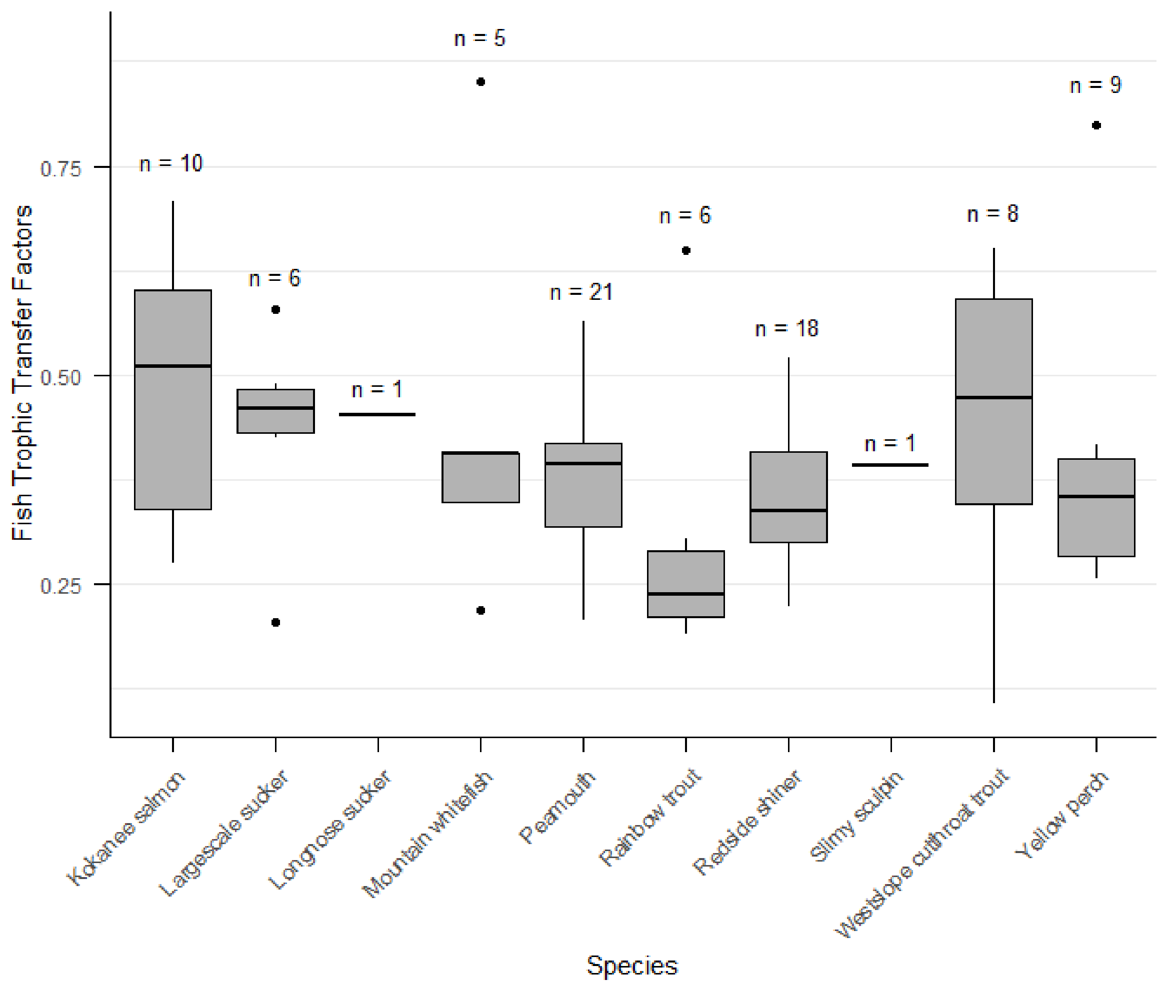

Figure 3. Low Trophic Fish Trophic Transfer Factors. Calculated using fish and invertebrate Selenium concentrations measured in Koocanusa Reservoir.

4.2 Multiple-Scenario Distribution Modeling Approach

Bioaccumulation models can be used to predict a single aqueous selenium concentration expected to result in a single tissue selenium concentration based on the model terms selected. Model terms are often selected as a single representative value from a larger dataset. For example, a dataset of 87 K_d values was derived in Presser & Naftz (2020). The 2021 ENV KNC model uses the 50th percentile K_d and the Montana DEQ bioaccumulation model uses the 75th percentile K_d (MT DEQ 2020). Selenium bioaccumulation models contain multiple model terms, each with its own various assumptions, resulting in the model producing a single aqueous selenium concentration with layers of conservatism that become difficult to quantify and can reduce confidence in this aqueous selenium value. It is possible, for example, for layers of conservative assumptions to compound in the application of the model and cause model predictions to lose accuracy in representing actual conditions.

Rather than assuming model terms are single fixed values, an alternative approach is to allow for variability in model terms by running the model numerous times with varying model terms selected from each model term dataset. This approach would model a broader range of selenium bioaccumulation conditions in Koocanusa Reservoir to produce a distribution of aqueous selenium concentrations from a single tissue selenium concentration. An aqueous selenium concentration could be selected from this range of possible values based on the level of conservatism and protection that is desired. Figure 4 is an example of an aqueous selenium distribution that could be generated through this approach.

Higher selenium concentrations within the distribution, like the 95th percentile, represent low selenium bioaccumulation rate scenarios where relatively high concentrations of selenium in water could result in the fish tissue value of 5.2 µg/g dw (Figure 4). Lower selenium concentrations within the distribution, like the 5th percentile, represent high selenium bioaccumulation rate scenarios where relatively low concentrations of selenium in water could also result in this same fish tissue value of 5.2 µg/g dw. The 5th percentile is the aqueous selenium concentration predicted to result in fish tissue samples being less than the tissue value in 95% of scenarios.

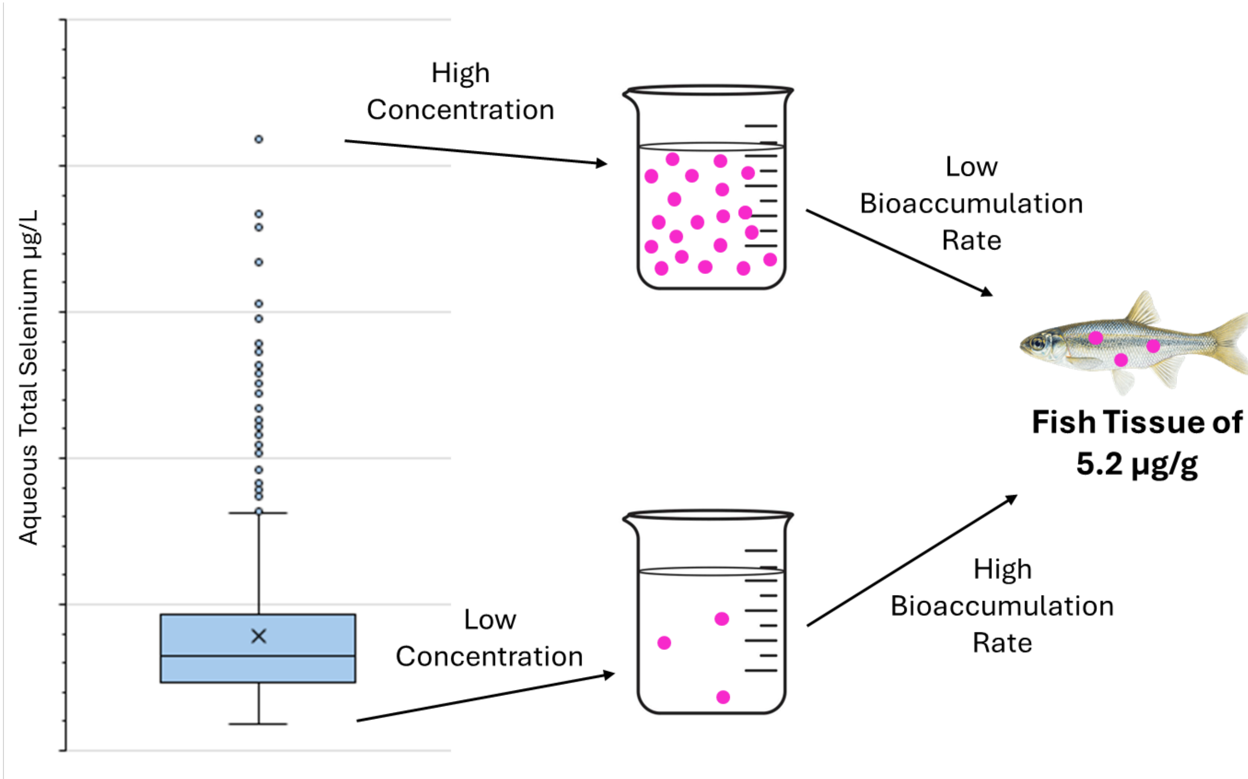

Figure 4. Example distribution of aqueous total selenium concentrations predicted to result in a whole body fish tissue concentrations of 5.2 µg/g dw, the fish tissue value for protection of human health at the Ktunaxa preferred fish consumption rate.

5 Conclusions and Recommendations

To support the Ministry of Environment and Parks review of the ABMP selenium target in the Canadian portion of Koocanusa Reservoir, a site-specific bioaccumulation model for the reservoir could be a useful tool for translating between fish tissue concentrations of interest and aqueous selenium concentrations.

This report describes past work to develop selenium bioaccumulation models, evaluates the accuracy of tissue concentrations predicted with the 2021 ENV KNC model, and suggests modifications that could improve model accuracy and performance. This exploratory exercise led to the following findings:

- The 2021 ENV KNC selenium bioaccumulation model for Koocanusa Reservoir appears to overpredict selenium concentrations in fish tissue collected from the Canadian portion of Koocanusa Reservoir.
- Site-specific fish TTFs calculated from fish and invertebrate selenium concentrations measured in Koocanusa Reservoir could be used to improve predictions of selenium concentrations in fish tissue according to the patterns observed in tissue data reported for the reservoir.

- A distribution approach modeling multiple selenium bioaccumulation scenarios could be a useful method for deriving aqueous selenium targets that would have clear levels of conservatism and protectiveness.

It is recommended that ENV develop and rely on a selenium bioaccumulation model that both accurately predicts fish tissue concentrations in the Canadian portion of Koocanusa Reservoir and that can be applied in a manner that supports the derivation of aqueous selenium targets that support the protection of human and aquatic health with understandable levels of conservatism. Site-specific fish TTFs have the potential to achieve greater bioaccumulation model accuracy. It is therefore recommended that site-specific fish TTFs be developed for use in the model. A multiple-scenario modeling approach could be applied to the bioaccumulation model to allow for selection of aqueous selenium targets with clear levels of conservatism and protectiveness of human and aquatic health. It is therefore recommended that a multiple-scenario modeling approach be developed.

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Appendix A- 2021 ENV KNC Bioaccumulation Model

WATER QUALITY OBJECTIVE SERIES

DRAFT Selenium Water Quality Objective for Koocanusa Reservoir

British Columbia Ministry of Environment & Climate Change Strategy and Ktunaxa Nation Council Lands and Resources Sector

KTUNAXA NATION

BRITISH COLUMBIA

The **Water Quality Objective Series** is a collection of British Columbia (B.C.) Ministry of Environment and Climate Change Strategy water quality objectives reports. Water quality objectives are developed for waterbodies to promote the protection and stewardship of provincially significant water resources. Once approved, water quality objectives constitute formal Ministry policy and must be considered in any decision affecting water quality made within the Ministry of Environment and Climate Change Strategy. For additional information visit: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives.

Cover Photo:

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PREFACE

June 2026

The draft selenium water quality objective (WQO) and supporting documentation in this report were developed collaboratively from 2020 to 2021 by the Ministry of Environment and Parks and the Ktunaxa Nation Council Society (KNC). **The work was not finalized and the draft objective in this report is not an approved Ministry of Environment and Parks policy. This document cannot be cited or quoted as a complete and approved ministry report, nor can the derived numbers be referenced as a ministry policy.**

The Ministry of Environment and Parks has considered the policy framework for the Koocanusa Reservoir watershed and has determined that the Elk Valley Area Based Management Plan (ABMP) is the most appropriate instrument for setting water quality policy for Koocanusa Reservoir and the Elk River watershed. The work previously done towards the draft WQO, including information in this draft report, has been brought into the ABMP process. This includes the baseline datasets, bioaccumulation modelling framework developed by the US Geological Survey, fish tissue thresholds to protect aquatic life and people consuming fish from Koocanusa Reservoir, as well as important Ktunaxa knowledge and understanding.

The Elk Valley ABMP, titled the Elk Valley Water Quality Plan, is a plan to improve water quality in the Elk Valley and Koocanusa Reservoir, recognizing the historical activities and impacts in the watershed from over 100 years of metallurgical coal mining, and in consideration of the importance of mining to the local, regional and broader economy. It was developed in accordance with a Ministerial Order in 2013, and was updated by the Ministry of Environment and Parks in 2025. It provides a strategic framework for decision making, and is a strong policy that guides decision-making towards a long term vision and goals for the watershed which were developed by B.C. and Ktunaxa First Nations.

As part of amending the ABMP, Ministry staff have updated the baseline dataset with recent fish tissue and water chemistry data and compared it with model outputs using the draft bioaccumulation model described here. A review of this draft model revealed opportunities to update the draft selenium bioaccumulation model to improve the accuracy of model predictions relative to measured data. Specifically, using measured selenium in water, the draft bioaccumulation model over-predicts selenium concentrations in fish tissue, especially higher trophic fish, compared to measured concentrations of selenium in fish tissue over the past 10 years.

An updated bioaccumulation model that more accurately predicts measured concentrations of selenium in fish tissue based on measured water quality results will be finalized with input from Ktunaxa, industry, governments, and US agencies and tribes. This new work will be published as part of the second amendment of the ABMP.

Please refer to the Elk Valley ABMP for water quality policies applicable in Koocanusa Reservoir, including target(s) for selenium, which replace the earlier work to develop a water quality objective. Do not cite or quote this document as a completed and approved ministry report or ministry policy.

FOREWORD

Since the time the Ktunaxa risen on ʔamak̓ (Earth), we were given the responsibility to care for ʔamak̓ and wuʔu (water). The Creator told the Ktunaxa, that "you have lost 2 giants on this day, Yawu·nik the water giant and Naɫmuk̓ȼin the land giant. Now it is your duty to care for the wuʔu and ʔamak̓." (https://www.ktunaxa.org/who-we-are/creation-story/). This responsibility stands true today, and will continue to guide us into the future. Being responsible for headwater ecosystems requires that you empathize with the needs of all creations great and small.

The Kootenay River Basin is a tributary to the Columbia River basin, and the Ktunaxa Nation has a responsibility to all those affected by the waters that leave our territory.

The joint work done between Ktunaxa Nation Council and B.C. on the selenium objective for Koocanusa Reservoir reflects the Province's commitment to the *Declaration on the Rights of Indigenous Peoples Act*.

The Koocanusa Reservoir selenium objective was developed through a collaborative process using site-specific information and is based on protecting human health (reflected as the dietary intake of fish to support Ktunaxa eating well, now and in the future, as they did before) and aquatic life. The objective proposed by KNC and B.C. to protect all water uses and values in Koocanusa Reservoir is 0.85 µg/L. Attainment of this objective is expected to protect all kyakxu (fish) in the Reservoir as well as Ktunaxa ʔakɫsmaknik (people).

EXECUTIVE SUMMARY

Section 5(e) of the *Environmental Management Act* (EMA) provides the Ministry of Environment and Climate Change Strategy (ENV) the authority to prepare and publish "policies, strategies, objectives, guidelines and standards for the protection and management of the environment". B.C.'s Water Quality Objectives (WQO) are approved provincial policy statements that apply to specific waterbodies and, although not directly enforceable, must be considered in relevant statutory decisions made within ENV (e.g., waste management permitting decisions under EMA) and guide other processes, such as land use decisions and the establishment of water objectives under the *Water Sustainability Act*. WQOs are derived to protect the most sensitive values of the waterbody being examined. Attainment of WQOs indicates water uses and values are at low risk of adverse effects with respect to a given contaminant. This WQO is specific to selenium (Se) in the Koocanusa Reservoir and has been developed in partnership by ENV and the Ktunaxa Nation Council (KNC) Lands and Resources Sector.

The Koocanusa Reservoir is a transboundary reservoir in southeastern B.C. that was formed with the construction of the Libby Dam in Montana on the Kootenay River. Although the gazetted name is Lake Koocanusa, it is referred to in this document as the Koocanusa Reservoir recognizing it is a man-made, rather than natural, feature. The Kootenay River system, including the Elk River watershed and Koocanusa Reservoir, is the core of ʔamakʔis Ktunaxa (Ktunaxa Nation homelands) and its health is critical to the continued practice of aboriginal interests and values of the Ktunaxa Nation. The water uses and values to be protected under this WQO include human health, aquatic life, wildlife, Ktunaxa cultural and traditional values, recreation and aesthetics, and agriculture (i.e., irrigation and livestock watering).

Selenium is an essential trace element necessary for proper cell function in many organisms; however, excessive levels may result in toxic effects, especially in egg-bearing organisms such as fish and birds. In humans, selenosis results from chronic exposure to elevated Se levels, with symptoms including diarrhea, nausea, fatigue, muscle aches, and hair and nail damage or loss.

Historical and current coal mining activities in the Elk Valley have resulted in increased concentrations of contaminants, including Se, in the Elk River and Koocanusa Reservoir. Teck Coal Ltd. (Teck) and other proponents are seeking regulatory approvals to expand coal mining development in the Elk Valley region. These proposed expansions and new operations have the potential to further increase Se loadings in the Elk River and Koocanusa Reservoir.

B.C.'s Se Water Quality Guideline (WQG) of 2 µg/L (ENV 2014) applies provincially to all fresh surface water. The WQG includes an alert level concentration of 1.0 µg/L to identify and evaluate environments where enhanced Se bioaccumulation may be occurring. As outlined in the WQG, if the alert concentration is exceeded, a series of actions may be triggered to evaluate potential impacts and, if necessary, mitigate the effects of Se contamination.

Selenium concentrations in Koocanusa Reservoir were greater than background concentrations measured upstream in the Kootenay River (maximum of 0.12 µg/L). Above the Elk River inflow, Se concentrations averaged 0.22 µg/L with a maximum concentration of 0.88 µg/L. Downstream of the Elk River confluence, Se concentrations average approximately 1.3 µg/L with a maximum concentration of 2.6 µg/L.

In 2014, the Elk Valley Water Quality Plan (EVWQP) was developed in accordance with Ministerial Order No. 113 to remediate the effects of past coal mining on water quality and guide future development. A long-term Se target of 2 µg/L for Koocanusa Reservoir was established in the EVWQP, reflecting B.C.'s Se WQG. The acceptance of the EVWQP was conditional upon the validation of this target as protective for Koocanusa and required, through the subsequent valley wide permit, that a group be created to carry out this validation.

In 2015, the Lake Koocanusa Monitoring and Research Working Group (LKMRWG) was initiated to address water quality concerns by the State of Montana (MT), KNC, and US EPA which were acknowledged through the development of the EVWQP and required in Teck's valley-wide permit for the Elk Valley. The Working Group was tasked with examining whether a revised Se target was necessary to protect aquatic life and other uses and values of Koocanusa Reservoir. ENV worked closely with the MT Department of Environmental Quality, as co-chairs of this group, to achieve this shared commitment. In 2019, ENV also committed to working collaboratively with the KNC to co-develop a Se WQO for the Koocanusa Reservoir. This report summarizes the results of this collaborative work.

In August 2020, the United States Geological Survey (USGS) provided a peer-reviewed open-source ecosystem model that provided B.C. and MT with a transparent, science-based tool using site-specific data to test independent scenarios. The model calculates the Se concentration in water required to achieve a specified tissue concentration in fish tissue. B.C. and KNC undertook substantive analyses using the USGS model with consideration of input from leading Se experts participating on the Selenium Technical Sub-Committee and the LKMRWG. The Koocanusa Reservoir Se WQO was developed through this collaborative process using site-specific information. Derivation of the Se WQO was based on protecting human health (specifically, the Ktunaxa's preferred dietary intake of fish) and aquatic life as the most sensitive water uses and values.

B.C. and KNC propose a Se WQO of 0.85 µg/L to protect all water uses and values in Koocanusa Reservoir. A Se WQO of 0.85 µg/L is appropriate based on the following key rationale:

1. The USGS model is based on sound, collaborative, and peer-reviewed science with input from leading Se experts;
2. 0.85 µg/L is within the range of current conditions upstream of the Elk River inflow, as described in Section 7.1;
3. Fish muscle and whole-body tissue Se concentrations in Koocanusa Reservoir upstream of the Elk River are below the screening values for the protection of human health (see Sections 7.1 and 7.2, and Appendix 3) indicating that attainment of the WQO should ensure protection of Ktunaxa rights to harvest and consume fish at their preferred rates; and
4. It ensures that the reproduction of sensitive fish species is protected by meeting the 0.91 µg/L threshold identified in Section 8.2.

A Se WQO of 5.2 mg/kg (dry weight, or 1.3 mg/kg wet weight) in fish tissue (whole-body) is also proposed to protect human health of those consuming fish from Koocanusa Reservoir. This value represents a level that is protective at the preferred consumption rate of Ktunaxa communities and the general population.

A water quality monitoring program is recommended to determine attainment of the WQO. Additional fish tissue sampling is recommended to confirm that fish are safe for human consumption and to assess whether fish reproduction may be impaired.

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

BAP	Bioaccumulation potential
B.C.	British Columbia
CSKT	Confederated Salish and Kootenay Tribes of the Colville Indian Reservation
DEQ	Montana Department of Environmental Quality
Dw	Dry weight
EMA	*Environmental Management Act*
ENV	British Columbia Ministry of Environment and Climate Change Strategy
EVWQP	Elk Valley Water Quality Plan
ID	Idaho
K_d	Environmental partitioning factor
KNC	Ktunaxa Nation Council
KToI	Kootenai Tribe of Idaho
LKMRWG	Lake Koocanusa Monitoring and Research Working Group
MT	Montana
MT DEQ	Montana Department of Environmental Quality
OCP	Official Community Plan
RDEK	Regional District of East Kootenay
Se	Selenium
SEA	Strategic Engagement Agreement
SPM	Suspended particulate matter
TFM	Trophic fish model
TTF	Trophic transfer factor
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQO	Water quality objective(s)

1. INTRODUCTION

British Columbia's (B.C.) Water Quality Objectives (WQO) are approved provincial policy statements that apply to specific waterbodies and provide science-based benchmarks for the protection of water uses and values. While not directly enforceable, WQOs must be considered in decisions made within the Ministry of Environment and Climate Change Strategy (ENV) affecting water quality (e.g., decisions under the *Environmental Management Act*). Water Quality Objectives can also guide land and resource management processes, support environmental impact assessments, formalize water quality protection or improvement goals, and promote water sustainability and stewardship.

Water Quality Objectives are derived from the best available information, sound scientific methods and processes, and current technical protocols that define safe levels of contaminants for a waterbody and represent low-risk conditions for designated water uses and values. Attainment of WQOs indicates water uses and values are at low risk of adverse effects with respect to a given contaminant. Following *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia* (ENV 2021), WQOs are derived to protect the most sensitive uses or values of the waterbody being examined. This WQO is specific to selenium (Se) in Koocanusa Reservoir. Water Quality Objectives consider the characteristics of the waterbody, including: the ambient water quality and its assimilative capacity; the aquatic life, wildlife, and related habitat; the hydrology; the sediments; the potential contaminant loadings from point and non-point source waste discharges; and the social and cultural values associated with a waterbody, including those of Indigenous Nations and communities.

The construction of the Libby Dam in Montana (MT) in 1972 resulted in the impoundment of the Kootenay River and the creation of the transboundary Koocanusa Reservoir, crossing the B.C. – MT border. It was built to provide hydroelectric power and flood control in the Kootenay and Columbia River Basins under the Columbia River Treaty between the United States and Canada (Lotic Environmental 2019).

Koocanusa Reservoir is within ʔamakʔis Ktunaxa (Ktunaxa Nation homeland) and specifically within the Ktunaxa district of Ȼaṁna ʔamakis (the land of the woodtick). The Ktunaxa Nation includes four communities in B.C. and two in the US portion of ʔamakʔis Ktunaxa: Ksanka (part of the Confederated Salish and Kootenay Tribes of the Colville Indian Reservation (CSKT)) and Kootenai (Kootenai Tribe of Idaho (KToI)). The water quality of the Kootenay (Kootenai) River is of profound importance to the Ktunaxa Nation. The construction of the Libby Dam and industrial mining development within the watershed have had significant impacts on Ktunaxa rights and values as well as the loss of archaeological and cultural heritage due to flooding and erosion along the banks of the Kootenay (Kootenai) River.

The Elk River is a major tributary to the Kootenay River; there are five coal mines within its watershed boundaries owned and operated by Teck Coal Ltd. (Teck), one of which, Coal Mountain, is no longer actively mining and has entered the "care and maintenance" stage. In April 2013, ENV issued a Ministerial Order under Section 89 of the *Environmental Management Act* (EMA) requiring Teck to develop an Area Based Management Plan for water quality in the Elk Valley, including the Canadian portion of Koocanusa Reservoir, to address increasing concentrations of selenium (Se), cadmium, nitrate, and sulphate, and calcite formation caused by mining activities. Teck responded with the creation of the Elk Valley Water Quality Plan with the following objectives for the designated area:

- Protection of aquatic ecosystem health;
- Management of bioaccumulation of constituents in the receiving environment;
- Protection of human health; and,
- Protection of groundwater.

The goal of the Plan is to improve the overall environmental quality of the Elk Valley over time. The Elk Valley Water Quality Plan was approved by ENV in November 2014 (see Teck 2014a) and has been adopted as ENV policy to be applied to existing and future projects in the designated area. The subsequent EMA permit issued by ENV (also in November 2014) set the selenium limit to the BC WQG value of 2 µg/L (ENV 2014) with a requirement for Teck to participate in a process established by B.C and MT (Section 9.6 of PE 107517) with the intent of establishing site-specific objectives.

In 2015, B.C. and MT established the Lake Koocanusa Monitoring and Research Working Group (LKMRWG) as a forum to develop a Se WQO in B.C. and a Water Quality Standard in MT. The LKMRWG includes representation from ENV, the MT Department of Environmental Quality (DEQ), the Ktunaxa Nation Council (KNC), Teck, the US Environmental Protection Agency, the CSKT, the KToI, other US federal, state, and local government agencies, and select Canadian and U.S. non-governmental organizations.

This document presents a Se WQO for the Canadian portion of Koocanusa Reservoir, co-developed by ENV and KNC, to protect the water uses and values of Koocanusa Reservoir and recognize Ktunaxa cultural values and stewardship principles.

2. REGULATORY CONTEXT

Water quality objectives are not directly enforceable on their own but must be considered in decisions made within the Ministry of Environment and Climate Change Strategy (ENV) affecting water quality. This includes any relevant statutory decisions (e.g., waste management permitting decisions under the EMA) and other processes, such as the setting of water quality targets under the Elk Valley Water Quality Plan.

3. SIGNIFICANCE OF SELENIUM

Selenium is a relatively rare trace element but may be elevated in areas where geological formations originate from marine sedimentary deposits. The movement of Se from land to water occurs from both natural processes (e.g., erosion) and human activities (e.g., mining) either indirectly through overland runoff or directly from industrial discharges. In the aquatic environment, Se accumulates in sediments and biota and can continue to cycle and persist for many years (ENV 2014).

Selenium is an essential trace element necessary for cellular function in many organisms; however excessive amounts may result in toxic effects (see ENV 2014 for a full discussion on Se toxicity). Both the reproductive and non-reproductive toxic effects of chronic Se exposure may be seen in fish including Se-related embryo mortality and developmental deformities. Reproductive effects result from the maternal transfer of Se (i.e., Se in tissue of an organism is concentrated in its eggs), while the non-reproductive effects result primarily from the dietary intake of Se. Birds are susceptible to Se toxicity with the more sensitive chronic effects including reproductive impairment such as decreased fertility, reduced egg hatchability (embryo mortality), and increased incidence of embryo deformity (including eyes, feet, legs, beak, and skull). Other chronic effects include reduced immune function, excess feather loss, liver lesions and necrosis, muscle atrophy, and weight loss (ENV 2014).

Selenium bioaccumulation is key to toxic effects in aquatic ecosystems. Selenium accumulates in biotic and abiotic environmental compartments which contribute, in varying degrees, to elevated Se body burdens. Selenium residues in tissues can vary, even within the same species at the same site, and may not always be predictably correlated with Se in water. Relatively low water column Se concentrations may result in elevated levels of Se in sediments, primary and secondary producers, and higher trophic level consumers, causing reproductive impairment in fish, aquatic birds, and amphibians. In many cases, low water column Se concentrations (≤2 µg/L) will not result in significant accumulation through the food web.

However, there are instances where Se concentrations <1 µg/L have resulted in significant bioaccumulation and apparent chronic effects (ENV 2014). In systems where bioaccumulation is enhanced, relatively low concentrations of Se may lead to elevated body burdens and, therefore, risk.

Ingestion of elemental and organic Se compounds is not known to cause acute toxicity in humans (ENV 2014). However, there is a narrow margin between Se intake that is beneficial and that which is hazardous. Selenosis results from chronic Se intoxication and symptoms include diarrhea, nausea, fatigue, muscle aches, and hair and nail damage or loss. Some environmental health research connects regular consumption of Se above the recommended maximum levels to health issues such as prostate cancer and neurotoxicity (IJC 2020).

4. KTUNAXA NATION

NOTE: *The information contained in the following section is a partial and limited depiction of the dynamic and living system of use and knowledge maintained by Ktunaxa governments, elders, and citizens. The information is provided for the purposes of developing a Se WQO and is specific to Ktunaxa considerations regarding the WQO. It should not be relied upon to inform any other processes, assessments, or decisions except with written consent from the Lands and Resources Council of the KNC. The information provided is summary in nature and does not exhaustively describe, depict, or in any way limit or alter the nature and extent of Ktunaxa title, rights, interests, or concerns*.

The Ktunaxa Nation and its citizens have occupied the lands adjacent to the Kootenay and Columbia Rivers for more than 10,000 years. ʔamakʔis Ktunaxa (Ktunaxa lands) extends from the Arrow Lakes in the west Kootenays, to east of the Rocky Mountains into Alberta, as far north as Yellowhead Mountain (near Valemont B.C.) and south into present day Montana, Idaho (ID), and Washington states. The KNC is the governing body of the Ktunaxa Nation in Canada and is comprised of elected officials from ʔakisq̓nuk (near Windermere), Yaqan Nuʔkiy (Lower Kootenay), ʔaqam (St. Mary's) and Yak̓it ʔaknukⱡiʔit (Tobacco Plains) First Nation communities (Figure 1). There are two Ktunaxa communities in the United States: ʔaq̓anqmi (Kootenai Tribe of Idaho near Bonners Ferry, ID) and k̓upawi¢q̓nuk (Ksanka Band, Confederated Salish and Kootenay Tribes of the Flathead Indian Reservation, near Elmo, MT). The creation of the international border separates the Ktunaxa communities residing in Canada from those residing in the United States of America with separate empowered governments to protect their interests. The KNC holds and exercises management authority over the lands and resources of ʔamakʔis Ktunaxa within Canada.

KNC and the Province of British Columbia implement their government-to-government relationship through a Strategic Engagement Agreement (SEA), most recently renewed in 2019. Regarding the SEA, the KNC Chair has previously stated:

> *Ktunaxa remain unwavering in our role as stewards of this territory. As the Ktunaxa Nation and the Province continue to move towards shared decision-making in relation to land and resources within our territory, we look forward to building upon the successes of the past three years while continuing to develop our government-to-government relationship with the Province. The renewal of the Strategic Engagement Agreement is another positive step forward in this relationship.*

The adoption of the *UN Declaration on the Rights of Indigenous Peoples* and the *Declaration on the Rights of Indigenous Peoples Act*, in addition to the renewed SEA, have furthered the shared decision-making process between KNC and the Province, enabling Ktunaxa to exercise their ancestral laws and rights to ensure that decisions related to resource management adhere to Ktunaxa stewardship principles. Based on these principles, decisions made by the KNC must:

- contribute to the betterment of future generations;
- balance the economic use of land with cultural and spiritual values;
- follow natural law of taking only what is needed;
- ensure that long-term sustainability and ecological integrity take precedence;
- ensure access to and protection of traditional foods, medicines, resources, and spiritual sites;
- maintain, protect, manage, and restore healthy and diverse ecosystems; and,
- ensure land, air, and water are and will be clean and healthy.

It is with these principles as a guide, that KNC participates in this shared decision-making process to develop a WQO for Se in Koocanusa Reservoir.

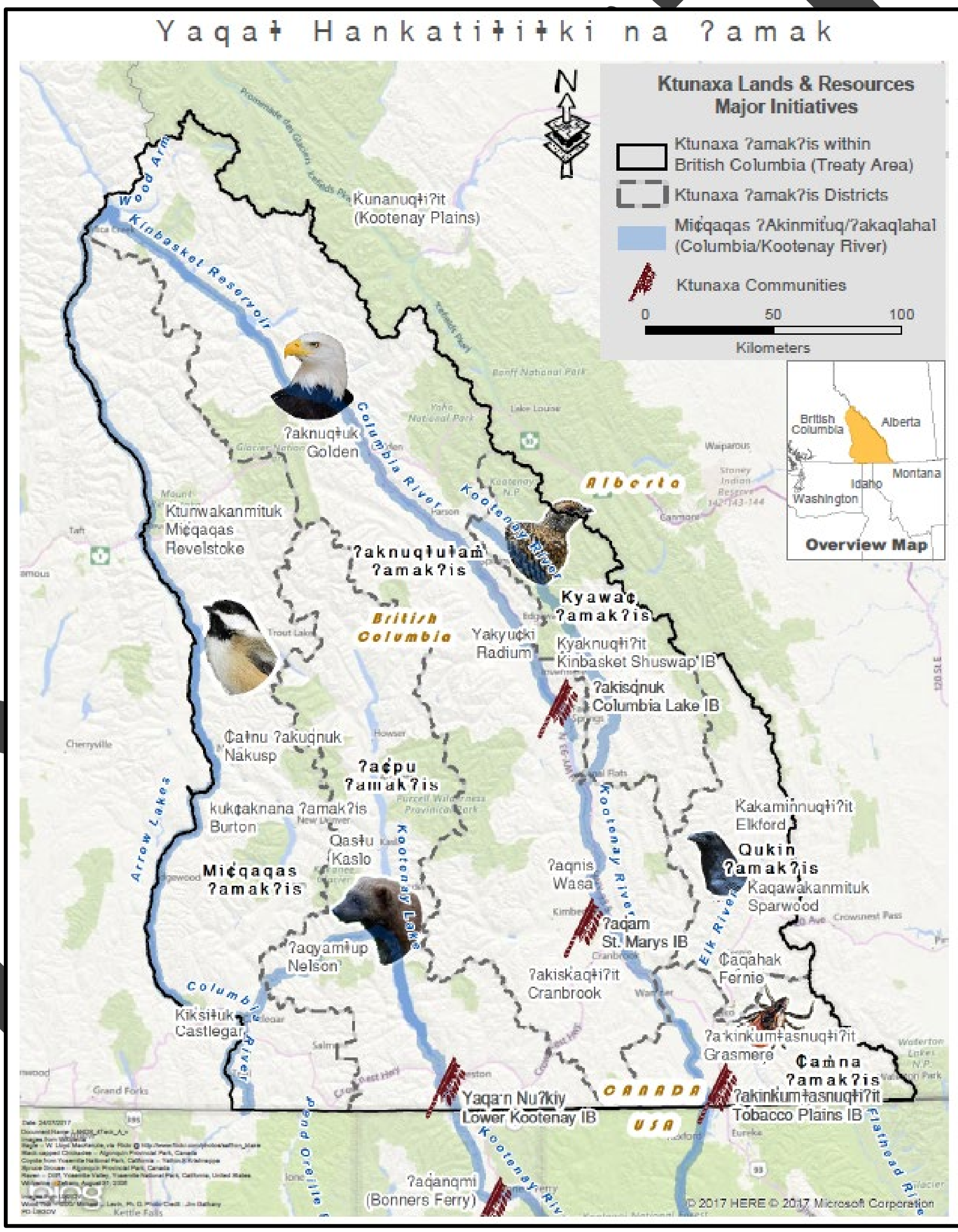

Figure 1: Ktunaxa land districts within British Columbia.

The Kootenay River system, including the Elk River watershed, is the core of ʔamakʔis Ktunaxa and thus our Nation is profoundly interested in and committed to protecting the waters of the Elk and Kootenay Rivers. Ktunaxa remain unwavering in our role, given to us by the Creator, as stewards of this territory:

> *The Ktunaxa have occupied our Territory since time immemorial and we have deep spiritual, cultural, social and socio-economic connections to ʔamak, the land, and wuʔu, the water, within our Territory. Our relationship to the land and water is supported by our oral histories and our teachings. Our Creation Story follows the waterways within our Territory, highlighting the importance of the Columbia and Kootenay Rivers; both being central to our worldview. We were created in interdependence with the land and water, and were given covenants by the Creator to protect, honor and celebrate what the Creator has given us. ʔaknumu¢tiǂiǂ is the Ktunaxa word for a law given to us by the Creator which speaks to why we were put on the land. The land (including water) gives us the resources to survive, and in return, we must protect and not overuse the land. ʔaknumu¢tiǂiǂ is grounded in the fact that all things are connected and must be kept in balance; it is the foundation of our spirituality. The Ktunaxa philosophy of stewardship of the lands and waters is the recognition that we are a part of the land, and that our connectedness to it requires that we have respect for all things as anything that affects one, affects everything else. Ktunaxa believe that we must care for ʔa·kxam̓ is q̓api qapsin, or all living things, and in doing so we must ensure that the water is clean and pure, as it is the giver of life. We also believe that we must ensure that the land is properly stewarded; yaqaǂ hankatiǂiǂki na ʔamak, which translates to "our people care for the land, the land cares for our people".*

The Creation Story tells of the origin of the Ktunaxa people, their homelands, and the natural laws and covenants given to Ktunaxa by the Creator to care for and respect the land and all things on it. Ktunaxa ʔa·qaɬq̓anuxwaɬiʔit (oral histories) and other forms of Ktunaxa knowledge are the foundation of Ktunaxa ways of knowing and being in the world and provide our citizens with context regarding their responsibilities and rights as Ktunaxa ʔakɬsmaknik. Ktunaxa ʔa·qaɬq̓anuxwaɬiʔit affirm that we have lived in their homelands since time immemorial, and were created in interdependence with the land, its living things, and the spirit world. Ktunaxa retain sovereignty over our lands and our lives. With this comes responsibilities to the land and ʔa·kxamis qapi qapsins (all living things).

5. WATERBODY DESCRIPTION

Located in southeastern B.C., Koocanusa Reservoir was formed by the impoundment of the Kootenay River following the construction of the Libby Dam 77 km south of the B.C. – MT border (Figure 2). The Kootenay River flows north to south, with the northernmost portion of the reservoir near Wardner B.C. Downstream of the Libby Dam, the Kootenay/Kootenai River flows west and then north returning to Canada and flowing into Kootenay Lake. The reservoir has a total length of 145 km at full pool. Depending on dam management, the minimum and maximum surface areas range between 59 km^2 and 188 km^2, respectively, and the minimum and maximum volumes are 1.1 km^3 and 7.2 km^3, respectively (Lotic Environmental 2019).

The impoundment of the Kootenay River had a significant impact on native fish species relying on stream environments to complete their life cycle. The change from predominantly lotic (riverine) to predominantly lentic (lacustrine) conditions allowed some native species to thrive (e.g., Peamouth Chub (*Mylocheilus caurinus*), Northern Pikeminnow (*Ptychocheilus oregonensis*)), while other native species, such as Burbot (*Lota lota*), which are now Red-Listed, experienced significant declines (Hardy and

Paragamian 2013). The impoundment also allowed the establishment of non-native species (VAST 2017) and shifted the dominant food sources from benthic macroinvertebrates to zooplankton, contributing to the prolific establishment of Kokanee (*Oncorhynchus nerka*) after an accidental hatchery release in the late 1970's (Hartman and Martin 1987).

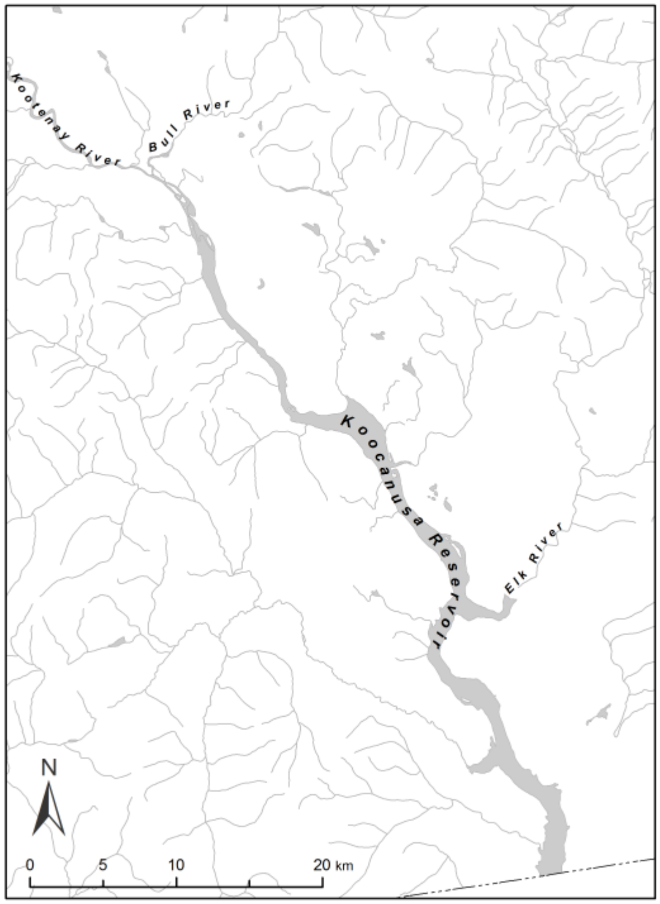

Figure 2. Koocanusa Reservoir and its main tributaries.

The major inputs to Koocanusa Reservoir within B.C. include the Upper Kootenay River, the Bull River, and the Elk River (Figure 2) and are described in detail in Lotic Environmental (2019). The Kootenay River above the Reservoir is 275 km in length with a total drainage area of 11,500 km^2. The Upper Kootenay has high fisheries values and is designated as a Class II Inland Water under B.C.'s Classified Waters Licencing System[1]. The Bull River flows into the Upper Kootenay River near Wardner, B.C. with a drainage area of 1,520 km^2 (Teck 2014b) and a total length of 110 km. The Aberfeldie Dam is located 11 km upstream to provide flow control with negligible storage capacity. The Bull River is also a Class II stream and home to Provincially Blue-Listed fish species, including Bull Trout (*Salvelinus confluentus*) and Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) (listed as a "Species of Conservation Concern" under the federal *Species at Risk Act*).

The Elk River (Figure 3) enters Koocanusa Reservoir approximately 18 km north of the international border. Its total length is 231 km with a drainage area of 4,450 km^2 (Teck 2014b); its major tributaries

[1] The Classified Waters Licencing System was created to protect the unique fishing opportunities provided by certain waters, which contribute significantly to B.C.'s reputation as a world-class fishing destination.

include the Wigwam River as well as the mine-impacted Fording River and Michel Creek. There are natural falls located 18 km upstream of the confluence of the Elk River with Koocanusa Reservoir and a currently non-power generating dam near Elko preventing upstream fish migration. The Elk River is a Class II stream with high fisheries values including Bull Trout, Westslope Cutthroat Trout, and Mountain Whitefish (*Prosopium williamsoni*).

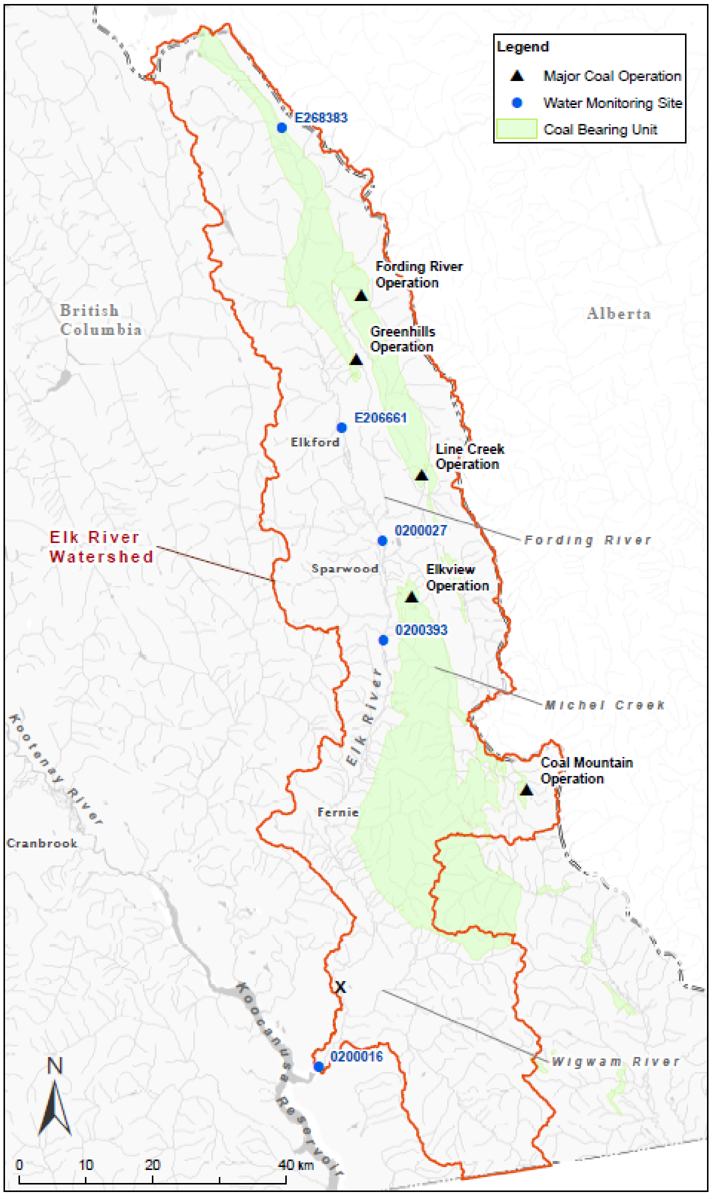

Figure 3. The Elk River watershed and mine-impacted tributaries with sampling locations. X denotes the location of natural falls and a non-operational dam.

The hydrology of the tributary streams, and therefore Koocanusa Reservoir, is driven by spring snowmelt. Flows are generally lowest from August to May and highest in June when peak snowmelt at higher elevations coincides with summer rain events. Water levels are managed to generally follow the same pattern where the reservoir empties throughout the winter and begins to fill in April and May. By July, water levels have peaked and typically remain relatively stable through the summer and fall until they begin to drop in November (Lotic Environmental 2019).

As a functioning reservoir, water levels in the Canadian portion fluctuate approximately 40 m throughout the year in response to flood control, power generation, and downstream fish resources (based on data from 2005 – 2019; Teck 2020a). Over that period of record, there are five to six months of relatively stable pool elevation with July to November typically ranging between approximately 742 m and 750 m. The annual drawdown of the reservoir has prevented the establishment of both riparian vegetation and aquatic macrophytes, resulting in a littoral zone of cobble/mud/sand substrates with limited habitat structure (Lotic Environmental 2019).

6. INFLUENCES ON WATER QUALITY

Elevated Se concentrations resulting from decades of coal mining in the Elk Valley is one of the primary water quality concerns in Koocanusa Reservoir. The Elk River is the primary source of Se inputs to the Reservoir and increased mining in recent years has resulted in increased loadings. Total Se concentrations over time and space are illustrated in Figure 4 and summarized in Table 1. Sampling site locations are illustrated in Figure 3.

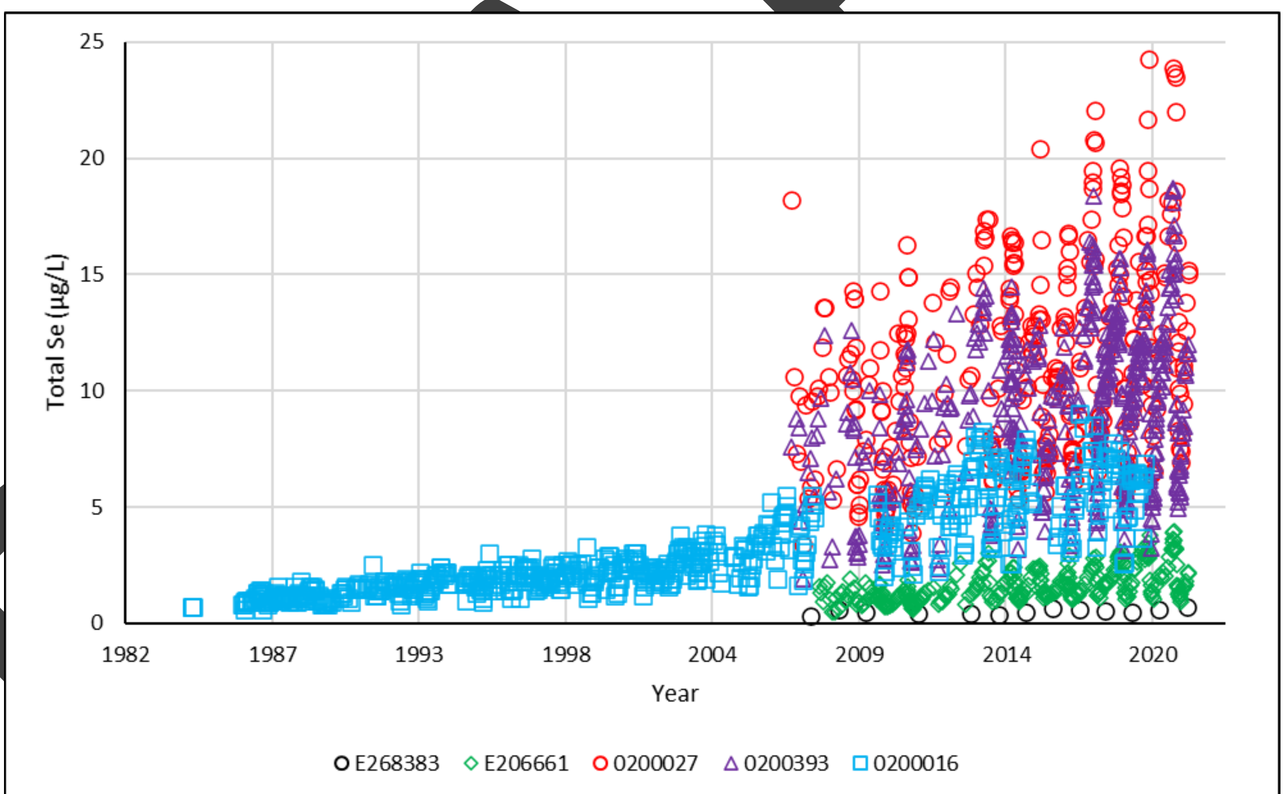

Figure 4. Total selenium concentrations at sites on the Elk River. Sites are ordered upstream to downstream in the legend.

Site E268383 is located upstream of all mining activities and is representative of background conditions in the Elk River. Selenium concentrations are lowest here with a mean concentration of 0.50 µg/L and a 95th percentile concentration of 0.67 µg/L (2007 – 2021). Site E206661 is located below E268383, downstream from one coal mine and upstream of the Fording River (which receives inputs from three mines). Average

Se concentrations increase to 1.66 µg/L at this site (2008 – 2021). Site 0200027 is below the Fording River inflow and shows the highest Se concentrations with an average concentration of 11.51 µg/L and a 95th percentile of 19.50 µg/L (2007 – 2021). Site 0200393 is located further downstream near the confluence of Michel Creek and the Elk River and is under the influence of all upstream mine sites, including Coal Mountain which is not actively being mined and is in the "care and maintenance" (i.e., reclamation) stage. Site 0200393 has the next highest Se concentrations with a mean of 9.34 µg/L and 95th percentile concentration of 15.38 µg/L (2007 – 2021). Finally, site 0200016 is located near the outflow to Koocanusa Reservoir. Selenium concentrations are lower at this point with a mean of 2.98 µg/L and a 95th percentile of 6.86 µg/L (1984 – 2020).

Table 1. Summary statistics for selenium concentrations (µg/L) at sites on the Elk River. Sites are ordered upstream to downstream, left to right.

	E268383	**E206661**	**0200027**	**0200393**	**0200016**
Minimum	0.30	0.50	3.4	1.90	0.60
Maximum	0.70	3.95	28.60	18.70	9.03
Average	0.52	1.66	11.51	9.34	2.98
95th Percentile	0.67	3.03	19.50	15.38	6.86
Sample size	13	313	330	526	637

There are other anthropogenic influences on water quality in the watershed that do not produce Se. Certainteed Gypsum operates a gypsum mine near Canal Flats and is authorized to discharge effluent to the Kootenay River (approximately 90 km upstream of the reservoir), and Paper Excellence operates a pulp mill (Skookumchuck Pulp Inc.) near the confluence of Skookumchuck Creek and the Kootenay River (approximately 70 km upstream of the reservoir). Forestry, agriculture, residential, and commercial development occurs throughout the Upper Kootenay River watershed. Residential development around the reservoir is guided by the Lake Koocanusa Official Community Plan (OCP) (RDEK 2013) with no point sources of pollution. The City of Kimberley's sewage treatment plant and storm sewer system discharge to the St. Mary River, which flows into the Kootenay River approximately 30 km upstream of Koocanusa Reservoir. The City of Cranbrook's sewage treatment plant discharges principally via spray irrigation to land. Other municipal sewage treatment facilities are present in the Elk River watershed including the Town of Fernie (primarily discharges to ground via infiltration), the District of Sparwood (discharges to the Elk River), and the District of Elkford (discharges to ground via infiltration).

Reservoir operations and the resulting changes to water volume and habitat type (i.e., lentic vs lotic) have the potential to influence water quality parameters. The ability of the Reservoir to assimilate wastes is reduced with decreasing volume and studies have shown that some water quality parameters, such as temperature, dissolved oxygen, and pH, are influenced by reservoir depth (Lotic Environmental 2019). The distribution of Se in Koocanusa Reservoir is influenced by the hydrodynamic and source loading conditions of the system (Presser and Naftz 2020). These drivers affect environmental partitioning of Se, especially during rapid flow transitions or when riverine conditions interface with the Reservoir.

Koocanusa Reservoir provides significant recreational opportunities (>100,000 visitors annually) and management of these activities is guided by the Koocanusa Recreation Strategy (Koocanusa Recreation Steering Committee 2017). Significant recreational land-use pressures have recently escalated with unmanaged off-highway vehicle use (e.g., unauthorized "mud-bogging") and uncontrolled camping

(Leschied 2017) resulting in environmental impacts in and around Koocanusa Reservoir. Boating activities (water skiing, house boating, fishing, fueling) also have the potential to contribute to water quality issues on Koocanusa Reservoir if not conducted in a responsible manner.

7. WATER USES AND VALUES

Water Quality Objectives are derived to protect the most sensitive values of the waterbody being examined. Based on the current condition of the reservoir and activities within the watershed, the water uses and values to be protected for Koocanusa Reservoir include human health, aquatic life, wildlife, Ktunaxa cultural values, recreation and aesthetics, and agriculture (i.e., irrigation and livestock watering), as described in the following sections.

7.1 Human Health

The relationship between freshwater environments and humans through the consumption of aquatic foods has cultural, economic, and social significance in Koocanusa Reservoir. The opportunity for Ktunaxa to harvest fish at their preferred rates is a key component to Ktunaxa’s cultural practice of sukiɫ ʔiknaɫa (eating well). The tangible cultural value in harvesting is inextricably linked to the health and well-being of Ktunaxa, as well as honoring the intangible cultural values of balance and stewardship of ʔa·kxamis qapi qapsin (all living things). These important cultural values and practices need to be protected for future generations. The combination of the cultural significance to the Ktunaxa (see Section 7.4) and the recreational fishery (see Section 7.5) supports human health as an important value to protect for the Koocanusa Reservoir.

7.2 Aquatic life

Native species present in Koocanusa Reservoir include the Blue-Listed Bull Trout and Westslope Cutthroat Trout; other native species include Burbot, Mountain Whitefish, Slimy Sculpin (*Cottus cognatus*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*Catostomus catostomus*), Longnose Dace (*Rhinichthys cataractae*), Northern Pikeminnow, Peamouth Chub, and Redside Shiner *(Richardsonius balteatus)*. Introduced species include Kokanee, Brook Trout (*S. fontinalis*), Rainbow Trout (*O. mykiss*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), and Yellow Perch (*Perca flavescens*). These introductions have had some impacts on native species including hybridization (e.g., Brook Trout/Bull Trout, Rainbow Trout/Cutthroat Trout) and increased predation by Largemouth Bass, Pumpkinseed, and Yellow Perch. Downstream of the Libby Dam, KToI have partnered with U.S. federal agencies and the Bonneville Power Administration to operate a conservation aquaculture program for White Sturgeon *(Acipenser transmontanus*) and Burbot and conduct habitat restoration programs.

Amphibian and reptile species occurring in and around Koocanusa Reservoir include Western Toad (*Anaxyrus boreas*), Rocky Mountain Tailed Frog (*Ascaphus montanus*), Northern Leopard Frog (*Lithobates pipiens*), Coeur d’Alene Salamander (*Plethodon idahoensis*), and Painted Turtle (*Chrsemys picta*).

7.3 Wildlife

Koocanusa Reservoir and the surrounding area is home to a variety of wildlife including large mammals (e.g., elk, deer, bear), small mammals (e.g., otter, mink), and birds (e.g., waterfowl, shore birds, raptors). For birds, Koocanusa Reservoir provides a variety of important wildlife habitat features including: staging areas for migrating water birds (e.g., waterfowl, shorebirds, waders); a source of prey for piscivorous birds like osprey, mergansers, loons and grebes and shore birds that feed on invertebrates; and nesting sites for gulls and geese (VAST 2017).

7.4 Ktunaxa Cultural Values

Wuʔu (water) is fundamental to the Ktunaxa Creation Story. It is an essential part of ʔa·kxam̓ʔis q̓api qapsin (all living things) and is considered sacred and living under Ktunaxa law. The responsible stewardship of water, therefore, is a critical component of Ktunaxa's covenant to protect ʔa·kxam̓ʔis q̓api qapsin. Rivers, streams, lakes, and riparian areas provide essential habitat for the many animals and plants on which Ktunaxa harvesters rely. Access to clean drinking water is essential to the ability of Ktunaxa to spend time on the land. It is critical, therefore, that all current and future Ktunaxa have the unrestricted right to access water, from preferred locations, to maintain the continuity of Ktunaxa practice of rights throughout ʔamakʔis Ktunaxa. To that end, the KNC strives to restore and/or maintain natural flow and water quality condition as well as hydrological function, riparian ecosystems, and habitat for fish and other aquatic and aquatic-dependant species. This means:

- rigorous protection of ecologically and hydrologically effective riparian zones;
- protection of the hydrological functioning of wetlands and floodplains;
- general opposition to disposal of any wastes in water and specifically prohibition of waste discharges to water that impair its ecological functions or value for human and animal use;
- prohibiting other water uses that disturb natural stream processes and functioning;
- encouragement of active watershed stewardship by non-Ktunaxa neighbours and basin residents; and,
- protection, maintenance, and restoration of culturally significant, regionally important, and ecologically rare or threatened fish species (Ktunaxa Lands Sector 2011).

The Kootenay River system has been heavily modified, without Ktunaxa consent, by hydroelectric and industrial mining development, which have had enormous impacts on Ktunaxa rights and values. The hydroelectric development on the Columbia and Kootenay River systems resulted in the loss of anadromous salmon in ʔamakʔis Ktunaxa, which led to their removal from the Ktunaxa diet. Other fish species of profound importance to the Ktunaxa Nation have also been affected by hydroelectric and industrial mining development, including endangered White Sturgeon (wiyaǂ), Burbot (ʔaq̓ uǂam), Westslope Cutthroat Trout (qustit) and Bull Trout (tuhuǂ). In addition to the loss of Ktunaxa archaeological and cultural heritage due to flooding and erosion along the banks, the creation of the reservoir has also led to an unregulated increase in recreational users. Outcomes from recent KNC engagement with Ktunaxa citizens resulted in a call to action by citizens to inform and educate recreational users on the Ktunaxa stewardship principles of ʔa·knumuȼtiⱡiⱡ (Natural Law) to protect the continued practice of Ktunaxa rights and values (Firelight Research Inc. 2020).

While the reservoir has significantly impacted the exercise of Ktunaxa rights and values, citizens from all communities, especially Yak̓it ʔaknukⱡiʔit (Tobacco Plains), continue to use the Reservoir and surrounding area to exercise their rights for hunting, fishing, trapping, camping, ceremonial practice, and the transmission of knowledge and identity to future generations. ʔa·kpiȼ̓is is the Ktunaxa concept that refers to the favourite and regular foods eaten by animals, birds, fish, and humans, according to the inherent and interdependent relationships of ʔȧkxam̓is q̓api qapsin and governed by ʔa·knumuȼtiⱡiⱡ. Cultural practices include harvesting ʔaq̓ uǂam (Burbot), <u>kanusq̓upak</u> (<u>Kokanee</u>), q̓ umi (suckers), several trout species (including qustit' and tuhuǂ), and geese. Matit' (Mountain Whitefish) were also harvested in specific areas, but Ktunaxa have identified that current population numbers are unable to support previous levels of harvesting. Much of the floodplain in the surrounding area is considered prime elk habitat, which is an important animal to Ktunaxa for cultural, ceremonial, and subsistence purposes.

The Koocanusa Reservoir and surrounding areas are critical for the ongoing practice of Ktunaxa title, rights, and interests, including hunting, fishing, trapping, camping, ceremonial practice, and transmission of knowledge and identity to future generations. The intergenerational transmission of the unique Ktunaxa language, associated knowledge, and intangible cultural heritage, which is foundational to sense of place and sense of being for Ktunaxa ʔakɬsmaknik (people). The ongoing practice of Ktunaxa title, rights, and interests is especially challenged by a combination of legacy and currently ongoing impacts, especially mining, hydroelectric development, forestry, highways, recreation, and alienation as a result of private land holdings.

Ktunaxa stewardship principles and ʔa·knumuȼtiɬiɬ (Natural Law) recognize the connections between ʔa·kxam̓ is q̓api qapsin (all living things), and the value of biodiversity. Rare species and species at risk are culturally and ecologically important to Ktunaxa – the Ktunaxa language has no word for 'extinct'. The Koocanusa landscape consists of unique ecosystems and many rare and at-risk species of concern rely on the waters of the Kootenay River including: Lewis' woodpecker, western painted turtle, na‡mit̓ (American badger), waq̓a (great blue heron), long-billed curlew, western screech owl, flammulated owl, Townsend's big-eared bat, little brown myotis, and ku·ku (western toad). Many of these species feed in the near shore areas, or feed on aquatic based insects and several are egg laying birds or amphibians. It is therefore critically important to manage water quality to protect ʔa·kxam̓ is q̓api qapsin, including aquatic life and aquatic-dependent wildlife.

7.5 Recreation and Aesthetics

Koocanusa Reservoir has become a regionally important tourism and recreation destination attracting more than 100,000 visitors a year for activities including swimming, fishing, hunting, camping, boating, and wildlife viewing (Koocanusa Recreation Steering Committee 2017). There are several marinas, launch ramps, and campgrounds to support the popular sport fishery. Kokanee are now the most abundant sportfish in the reservoir with a high recreational value (VAST 2017). Bull Trout and Rainbow Trout also have significant recreational value. Because of the high recreational use and the increasing residential development, the aesthetic quality of Koocanusa Reservoir is an important aspect.

7.6 Agriculture

Current agricultural activities within the area covered by the Lake Koocanusa OCP are primarily limited to cattle grazing and production of forage crops. Within the OCP area, 67% of the total land is in the Agricultural Land Reserve. Agricultural OCP objectives include support for agricultural activity within the OCP area, support for local food production, and diversification of agricultural uses. The OCP includes KNC objectives within the Agricultural Land Reserve, which are to support wildlife on Crown lands (RDEK 2013).

8. CURRENT CONDITIONS

8.1 Kootenay River Selenium Concentrations

Background Se concentrations for the Koocanusa Reservoir were assessed using data from site 0200038 (Kootenay River near Fenwick Station) collected between February 2015 and September 2019. Total Se concentrations ranged from below method detection limits (0.01 µg/L) to 0.12 µg/L over that period. Given the lowest concentrations seen in Koocanusa Reservoir occur at times when riverine (lotic) conditions prevail, this site provides an appropriate representation of background conditions as it is located upstream (halfway between Wardner and Fort Steele) of any influence of the Elk River or dam operations.

8.2 Koocanusa Reservoir Se Concentrations

The current conditions in Koocanusa Reservoir, with respect to total Se, were assessed using data collected at five sites (Figure 5) between April 2015 and September 2021 and were compared to the B.C. WQG of 2 µg/L and the alert level of 1 µg/L (ENV 2014). Site E300095 is located approximately 7 km upstream of the Elk River inflow. Site E300230 is 3 km south of the Elk River inflow followed in order by E300092, E300093, and E300094 (8 km, 11 km, and 20 km downstream, respectively). All data for each site were compiled and rolling 30-day average values, based on all results collected in the previous 30 calendar days, were calculated. Daily averages were also calculated for each site. Information on sample depth was not included in this assessment, however limnetic zones were considered as potential drivers for Se modelling inputs (see ENV and KNC 2020). Finally, data were pooled by month for each site to assess seasonal variation in total Se concentrations.

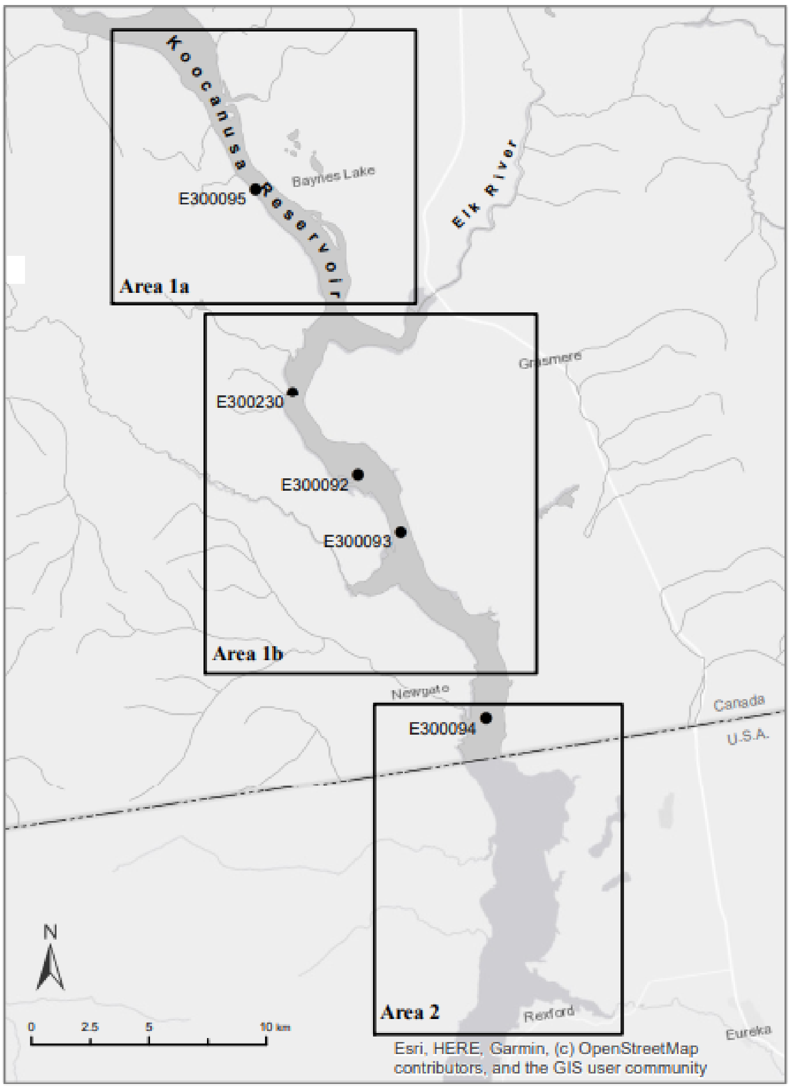

Figure 5. Location of sampling sites on Koocanusa Reservoir. Water quality sample sites are identified by the black circles and site numbers; fish collection areas are identified by the solid black boxes.

The 30-day average concentrations for all reservoir sites are summarized in Figure 6; data from site 0200038 (Kootenay River near Fenwick Station) is included to provide background levels. Thirty-day and daily average concentrations are presented by site in Appendix 1. Summary statistics for the reservoir sites are listed in Table 2. Concentrations at E300095 were below the alert level of 1 µg/L, ranging from 0.08 µg/L to 0.85 µg/L, but greater than background concentrations measured at site 0200038. Total Se concentrations increased south of the Elk River inflow and at times exceeded both the 1 µg/L alert level and the 2 µg/L WQG level; 30-day average concentrations ranged between 1.14 µg/L and 1.20 µg/L. Maximum concentrations decreased from north to south at sites below the Elk River (2.56 µg/L – 2.10 µg/L).

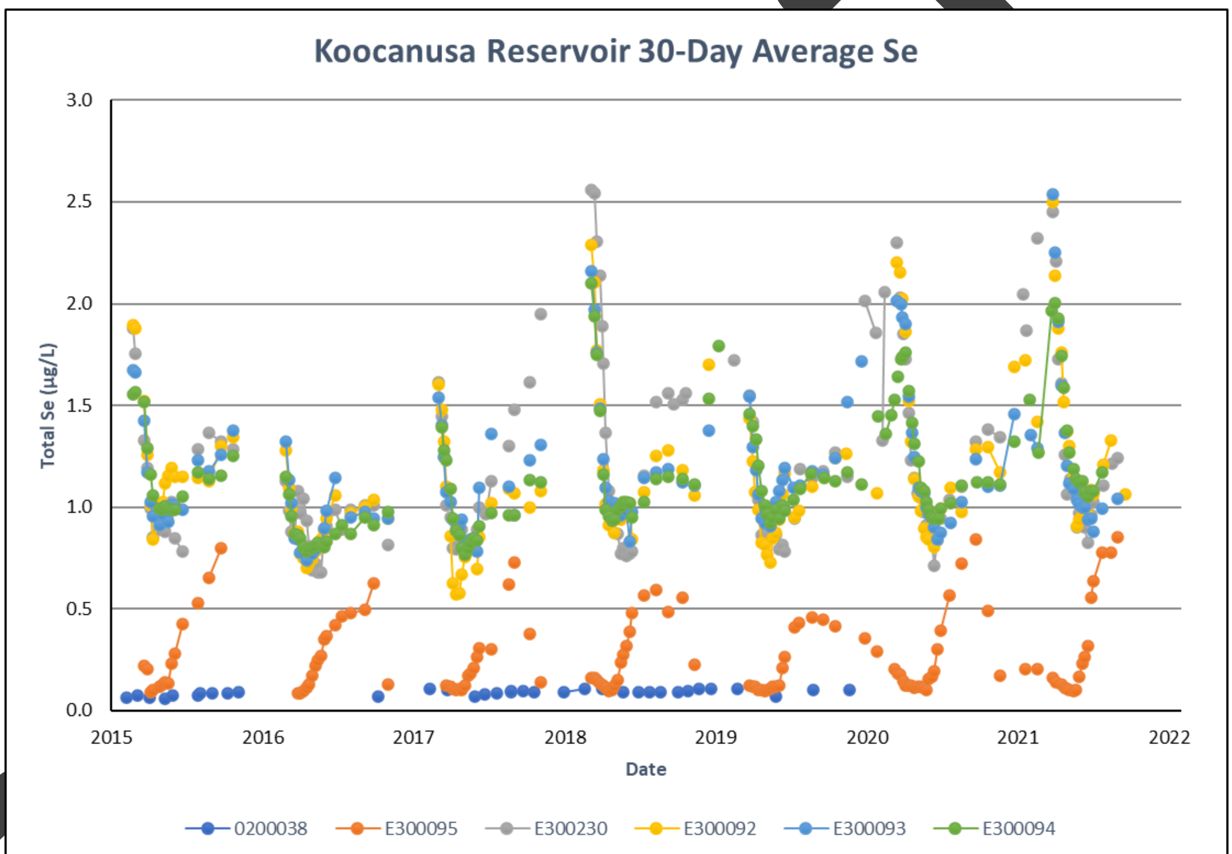

Figure 6. Total selenium (Se) 30-day average concentrations (µg/L) in Koocanusa Reservoir. Sites are presented from north to south with 0200038 representing conditions in the Kootenay River, E300095 representing conditions upstream of the Elk River, and E300092, E300093, and E300094 representing conditions between the Elk River inflow and the Canada/US border.

Selenium concentrations by site and month are summarized in Figure 7. At site E300095, Se concentrations were lowest during May and June. At sites downstream of the Elk River, Se concentrations were greatest from February to May when water levels in Koocanusa Reservoir are generally the lowest. This is likely due to the reduced dilution capacity of the Reservoir to assimilate elevated levels of total Se from the Elk River system.

To summarize, Se concentrations in Koocanusa Reservoir upstream of the Elk River inflow are consistently below the B.C. alert level of 1 µg/L. Downstream of the Elk River, Se concentrations are consistently above the alert level as a result of long-term coal mining activities in the Elk Valley with maximum values above the B.C. WQG level of 2 µg/L. Maximum and 95th percentile values decrease with distance from the Elk River.

Table 2. Summary statistics by site for 30-day average total selenium concentrations (µg/L), April 2015 – September 2021.

	E300095	E300230	E300092	E300093	E300094
Average	0.27	1.20	1.14	1.15	1.15
Minimum	0.06	0.68	0.57	0.74	0.77
Maximum	0.85	2.56	2.50	2.54	2.10
95th Percentile	0.73	2.18	2.02	1.93	1.76
Sample size	129	148	140	139	143

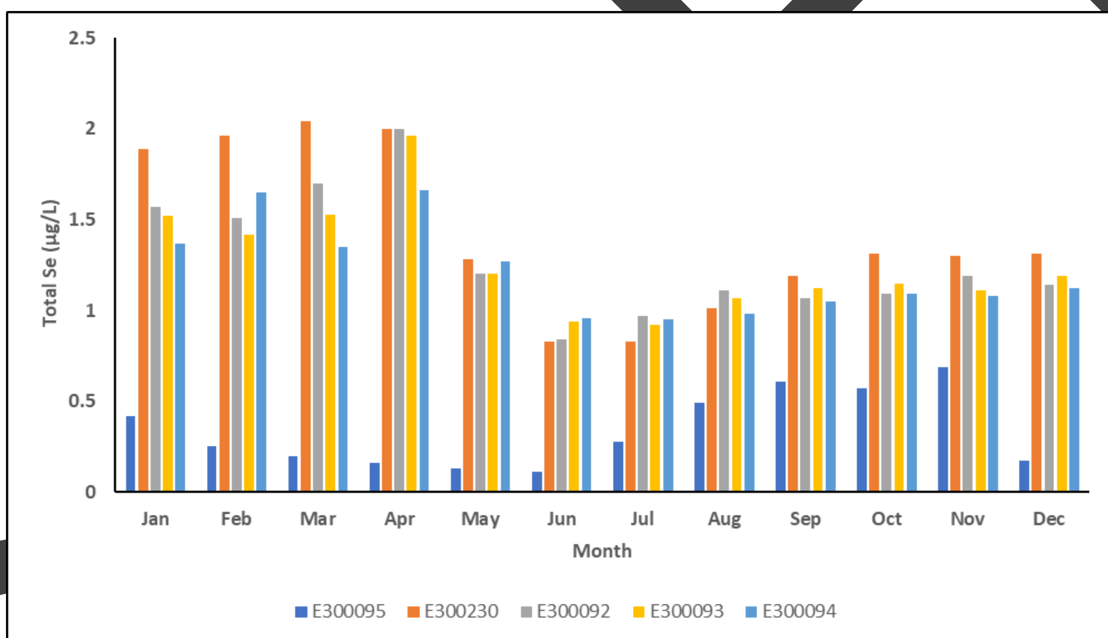

Figure 7. Koocanusa Reservoir average monthly Se concentration (µg/L) (2015 – 2021) by site. Sites are presented from north to south with E300095 representing conditions upstream of the Elk River and E300094 being the most southern site near the Canada/US border.

8.3 Fish Tissue Se Concentrations

Fish tissue Se concentrations were assessed using the following benchmarks:

- 5.2 mg/kg dry weight (dw) (whole-body) – the human health screening value based on the Ktunaxa preferred fish diet of 245 g/day (determined through the KNC Diet Study);
- 7.3 mg/kg dw (muscle) – the human health screening value based on fish intake of 220 g/day (ENV 2014);
- 11 mg/kg dw (egg/ovary) – B.C. water quality guideline for the protection of fish (ENV 2014).

Selenium concentrations in fish tissue are important from a human health perspective. The opportunity for Ktunaxa to harvest fish at their preferred rates is a key component to Ktunaxa's cultural practice of sukiɬ ʔiknaɬa (eating well). The tangible cultural value in harvesting is inextricably linked to the health and well being of Ktunaxa as well as honoring intangible cultural values of balance and stewardship of ʔa·kxamis qapi qapsin. These important cultural values and practices need to be protected for future generations. The Ktunaxa preferred dietary fish intake rate is 245 g/day. Using the Ktunaxa preferred consumption rate and the general equation for determining human health screening values (see ENV 2014), it was determined that the Ktunaxa preferred diet intake rate screening value for fish was 5.2 mg/kg (dw), based on whole-body Se. These values were used as benchmarks for comparing available fish tissue Se data for Koocanusa Reservoir from a human health perspective. Screening values provide general guidance to environmental managers and represent a suggested safe level of a contaminant in fish tissue based on a conservative estimate of a person's daily fish consumption. Exceeding the screening value may indicate the need for further investigations to assess possible health risks. On its own, an exceedance does not imply an immediate risk to human health but should be considered in the context of Se from other food sources to ensure the risk is understood. The B.C. WQGs (ENV 2014) specify a Se screening value for the edible parts of fish of 7.3 mg/kg (dw) for high fish-intake consumers (220 g/day).

To protect sensitive fish species against reproductive effects, ENV (2014) recommends an egg/ovary concentration of 11 mg/kg (dw), which translates to a whole-body concentration of 5.6 mg/kg (dw). The B.C. whole-body WQG of 4.0 mg/kg (dw) was considered lower than warranted by site-specific conditions (ENV and KNC 2020) and 5.6 mg/kg (dw) was selected as the appropriate whole-body benchmark for Koocanusa Reservoir.

Fish tissue Se data were obtained from Lotic Environmental (2019). Fish were collected by gill net and collection areas are described in Presser and Naftz (2020) and illustrated in Figure 5. Collection Area 1A, downstream of Kikomun Creek, represents conditions upstream of the Elk River; Collection Area 1B is south of the Elk River; and Collection Area 2 is near the International Boundary. For muscle and whole-body results, only samples reported as dry weight were included as moisture content could not be accurately estimated. A total of 70 whole-body tissue samples were available (Lotic Environmental 2019). Muscle data were converted to whole-body concentrations using the US EPA (2016) muscle to whole-body conversion factors. The general fish muscle to whole-body conversion factor of 1.27 (US EPA 2016) was applied unless family-specific conversion factors available. A total of 1,287 muscle and whole-body tissue samples were available for the Canadian portion of Koocanusa Reservoir and 168 for the MT portion (Collection Area 2 includes samples collected from both sides of the border). For egg Se data there were 560 results from the Canadian portion and 35 from the MT portion of the Reservoir. Egg Se data for Burbot reported as wet weight were included to supplement the low sample size for this species and converted to dry weight assuming a moisture content of 75%.

Muscle tissue Se concentrations at B.C. sites compared to the human health screening value of 7.3 mg/kg are illustrated in Figure 8. Results for individual sites on Koocanusa Reservoir are summarized in Appendix 3. All muscle Se concentrations measured at Collection Area 1A were below the screening value with Mountain Whitefish and Westslope Cutthroat Trout having the highest average concentrations (5.4 mg/kg and 3.9 mg/kg, respectively). At Collection Area 1B, average concentrations were below the screening value for all species, however there were individual exceedances for Largescale Sucker, Mountain Whitefish, Northern Pikeminnow, Peamouth Chub, and Westslope Cutthroat Trout. The highest muscle Se concentration was measured in Largescale Sucker at 9.9 mg/kg. At Collection Area 2, average concentrations were below the screening value for all species with individual exceedances measured in Burbot, Largescale sucker, Longnose Sucker, Peamouth Chub, and Westslope Cutthroat Trout. The highest individual concentration was measured in Longnose Sucker (10.0 mg/kg). Species-specific exceedances of the screening value were generally seen in data sets with the largest sample size (see Appendix 3) suggesting that these results may be underestimating concentrations. There were no exceedances of the screening value of 14.5 mg/kg for moderate intake fish consumers (ENV 2014) and Se concentrations in popular sportfish, such as Bull Trout, Kokanee, and Rainbow Trout, were consistently below the human health screening levels.

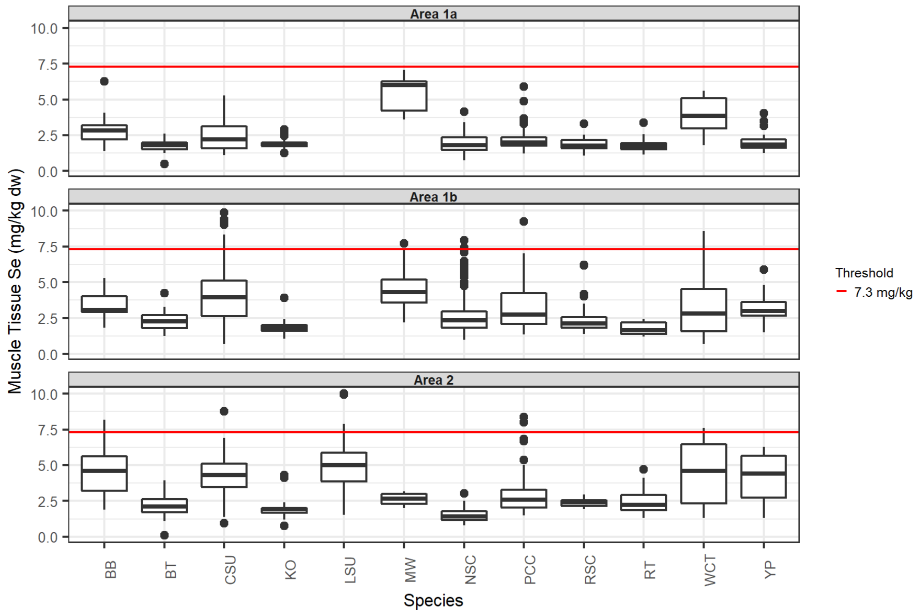

Figure 8. Muscle selenium tissue concentrations for Koocanusa Reservoir fish species compared to the B.C. screening value to protect high fish intake consumers (7.3 mg/kg). Plots are presented north to south, top to bottom. The lower and upper margins of the box represent the 25th and 75th quartiles, respectively. The line within the box represents the median value. The whiskers extend to the largest or smallest value, but no further than 1.5X IQR (inter-quartile range = 75th quartile value – 25th quartile value). Values beyond the whiskers are plotted individually. Species abbreviations: BB – Burbot; BT – Bull Trout; CSU – Largescale Sucker; KO – Kokanee; LSU – Longnose Sucker; MW – Mountain Whitefish; NSC – Northern Pikeminnow; PCC – Peamouth Chub; RSC – Redside Shiner; RT – Rainbow Trout; WCT – Westslope Cutthroat Trout; YP – Yellow Perch.

Whole-body tissue Se concentrations at B.C. sites compared to the Ktunaxa-specific human health screening value of 5.2 mg/kg are illustrated in Figure 9. Results for individual sites on Koocanusa Reservoir are summarized in Appendix 3. The results mirror the muscle tissue results, which is expected as most of the results are based on muscle Se to whole-body Se conversions. The only notable exception was one exceedance at Collection Area 1A for Mountain Whitefish (5.6 mg/kg). Measured whole-body Se concentration data, as opposed to concentrations calculated from muscle data, from all sites are illustrated in Figure 10. On a species-specific basis, measured median Se concentrations tend to be higher than calculated concentrations suggesting the calculated values may underestimate actual whole-body concentrations.

Egg Se concentrations at B.C. sites are summarized by species in Figure 11. All egg Se data are summarized in Appendix 3. At Collection Area 1A, Northern Pikeminnow, Peamouth Chub, Redside Shiner, and Westslope Cutthroat Trout exceeded the WQG of 11 mg/kg. It is important to note that this benchmark is set to protect sensitive fish species such as salmonids (ENV 2014), and that the toxicity thresholds of the other Koocanusa species may be higher. For example, Teck (2020b) recently reported an egg tissue threshold for Redside Shiner of 28 mg/kg (dw). Thresholds for Northern Pikeminnow and Peamouth Chub, however, are not available. At Collection Area 1B, Northern Pikeminnow, Peamouth Chub, Redside Shiner, and Rainbow Trout exceeded the threshold. Redside Shiner had the greatest average concentration (17.2 mg/kg) and the highest individual measurement (77.9 mg/kg). At Collection Area 2, Peamouth Chub, Redsided Shiner and Westslope Cutthroat Trout were the only species to exceed the threshold. Overall, the availability of egg Se data are limited or non-existent, and results should be interpreted with caution. Burbot data are also sparse, although the limited information from Collection Areas 1A and 2 show levels below 11 mg/kg.

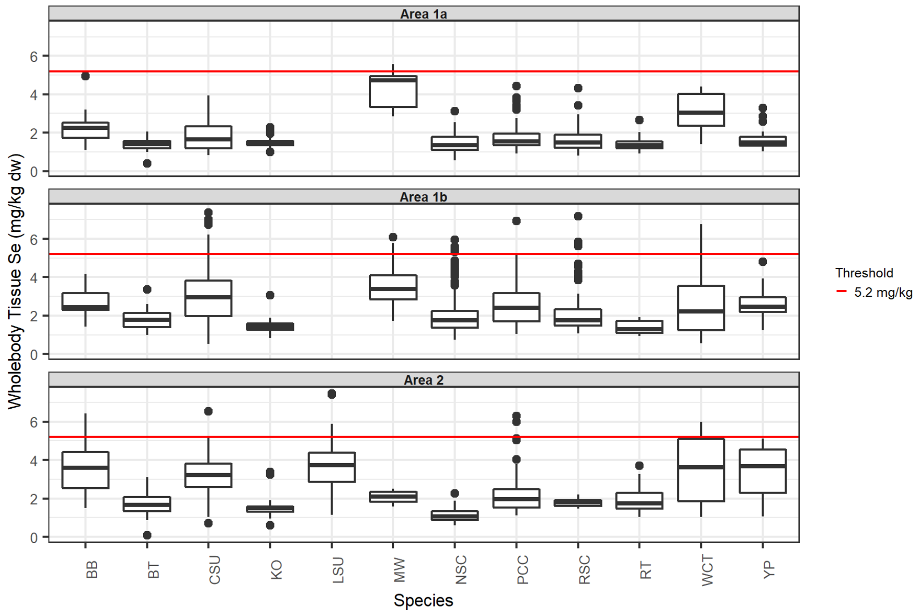

Figure 9. Whole-body selenium tissue concentrations for Koocanusa Reservoir fish species compared to the Ktunaxa-specific human health screening value (5.2 mg/kg). Plots are presented north to south, top to bottom. The lower and upper margins of the box represent the 25th and 75th quartiles, respectively. The line within the box represents the median value. The whiskers extend to the largest or smallest value, but no further than 1.5X IQR (inter-quartile range = 75th quartile value – 25th quartile value). Values beyond the whiskers are plotted individually. Species abbreviations: BB – Burbot; BT – Bull Trout; CSU – Largescale Sucker; KO – Kokanee; LSU – Longnose Sucker; MW – Mountain Whitefish; NSC – Northern Pikeminnow; PCC – Peamouth Chub; RSC – Redside Shiner; RT – Rainbow Trout; WCT – Westslope Cutthroat Trout; YP – Yellow Perch.

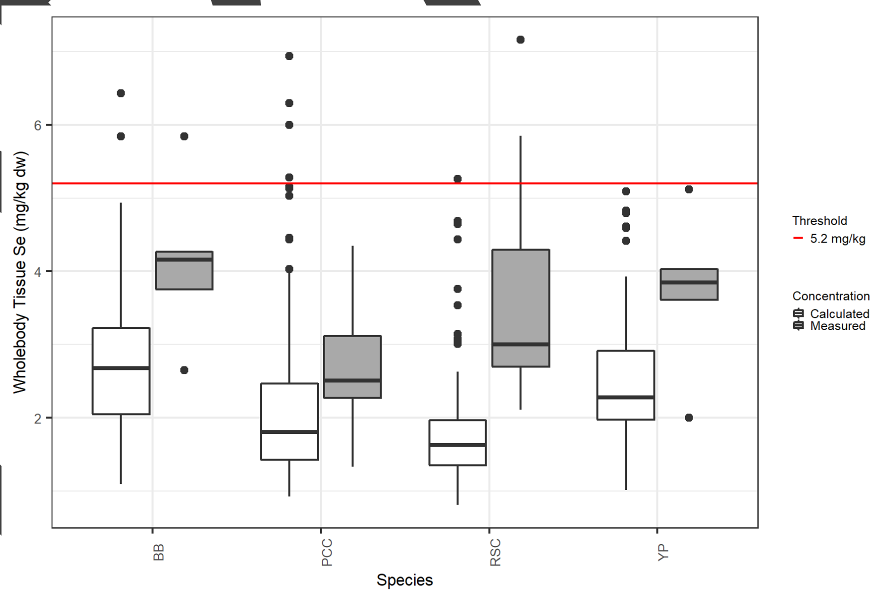

Figure 10. Whole-body tissue selenium concentrations (mg/kg dw) in select Koocanusa Reservoir fish species. Shaded boxes represent measured concentrations; unshaded boxes represent calculated concentrations. Species abbreviations: BB – Burbot; BT – Bull Trout; PCC – Peamouth Chub; RSC – Redside Shiner; YP – Yellow Perch.

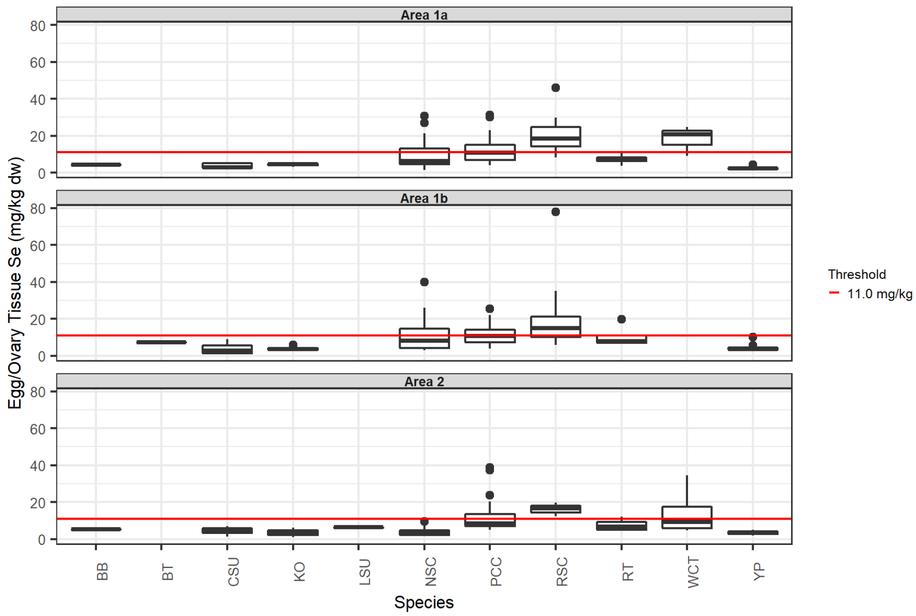

Figure 11. Egg selenium tissue concentrations for Koocanusa Reservoir fish species compared to the B.C. water quality guideline value (11.0 mg/kg). Plots are presented north to south, top to bottom. The lower and upper margins of the box represent the 25th and 75th quartiles, respectively. The line within the box represents the median value. The whiskers extend to the largest or smallest value, but no further than 1.5X IQR (inter-quartile range = 75th quartile value – 25th quartile value). Values beyond the whiskers are plotted individually. Species abbreviations: BB – Burbot; BT – Bull Trout; CSU – Largescale Sucker; KO – Kokanee; LSU – Longnose Sucker; MW – Mountain Whitefish; NSC – Northern Pikeminnow; PCC – Peamouth Chub; RSC – Redside Shiner; RT – Rainbow Trout; YP – Yellow Perch.

While data availability is somewhat limited, some general observations can be made. Fish muscle and wholebody tissue Se concentrations are below the identified thresholds upstream of the Elk River inflow. The only exception was one data point for whole-body Mountain Whitefish which was based on a muscle Se to whole-body Se conversion. Muscle and wholebody tissue Se concentrations in salmonid species (Bull Trout, Kokanee, Rainbow Trout) were below screening values throughout the Reservoir, except for Westslope Cutthroat Trout which exceeded the screening values downstream of the Elk River inflow and at the International Boundary. Burbot followed a similar pattern with all samples below the thresholds except for two data points at Collection Area 2. Exceedances of the muscle and whole-body tissue were generally seen in data sets with the greatest sample size. For example, Northern Pikeminnow muscle Se at Collection Area 1B showed the highest concentration of 7.9 mg/kg with a sample size of 150 while the maximum concentration at Collection Area 1A was 4.2 mg/kg (n = 93) and 3.0 mg/kg (n = 94) at Collection Area 2 (see Appendix 3). In sensitive salmonid species, the egg/ovary threshold was exceeded in most Westslope Cutthroat Trout samples (Collection Areas 1a (66%) and Area 2 (50%)) and one Rainbow Trout sample (Collection Area 1b). Northern Pikeminnow and Peamouth Chub frequently exceeded the egg/ovary threshold (32% and 40%, respectively), however the tolerance of these species to Se has not been quantified. Finally, while it is important to recognize the transitory nature of fish and their movement within the Reservoir could influence the results reported here, exceedances of the tissue Se thresholds tend to occur at sites downstream of the Elk River inflow.

9. <u>SELENIUM WATER QUALITY OBJECTIVES FOR KOOCANUSA RESERVOIR</u>

9.1 Designated Water Uses and Values

Water quality objectives are developed to protect the most sensitive use or value and in doing so, protect all uses and values (ENV 2013a). To determine the most sensitive use or value, the protective level for each must first be defined. Typically, aquatic life represents the most sensitive receptor, but this is not always the case. For Se, it is important to know the tissue concentration required to protect a given use or value which can then be converted to a water column concentration. Starting with aquatic life, the B.C. egg/ovary WQG of 11 mg/kg (dw) (ENV 2014) was converted to a whole-body value, consistent with Presser and Naftz (2020), of 5.6 mg/kg (dw) using a conversion factor of 1.96 (US EPA 2016). The USGS Ecosystem-Scale Selenium Model (Presser and Naftz 2020) was then used to convert the tissue Se concentration to a water column Se concentration specific to conditions in Koocanusa Reservoir. The model estimates the movement of aqueous Se from the water column through the food web to its accumulation in fish to derive a corresponding water column value. A complete overview of the model and the key model inputs is described in the MT DEQ technical support document *Derivation of a Site-Specific Water Column Selenium Standard for Lake Koocanusa* (DEQ 2020). A full description of the selected model inputs for deriving the B.C. WQO is provided in ENV and KNC (2022). The USGS model uses the following equation to derive an aqueous water column concentration:

$$C_{target} = \frac{C_{tissue\ threshold}}{BAP \times (K_d/1{,}000)}$$

Where:

C_{target} = site-specific water concentration (µg/L)
$C_{tissue\ threshold}$ = fish tissue threshold (mg/kg dw)
BAP = bioaccumulation potential (no units of measurement)
K_d = environmental partitioning factor.

The factors influencing bioaccumulation potential (BAP) are food web structure, diet composition, and trophic transfer factors (TTF). The BAP is calculated as the product of the species-specific TTF in each trophic level of the food web of the target fish species related to the tissue threshold; it provides an estimate of Se as it moves from suspended particulate matter (SPM) into the food web to higher trophic levels such as aquatic insects and fish. To assess a maximum Se dietary exposure, the food web selected for Koocanusa Reservoir was the trophic fish model (TFM) with a predatory fish diet comprised of 75% insectivorous prey fish and 25% planktivorous prey fish. Burbot, Bull Trout, and Northern Pikeminnow were identified by Presser and Naftz (2020) as the fish species observed to have this largely piscivorous diet. Waterbody-specific TTFs were derived for invertebrates and fish using an integrated bioaccumulation model based on water, SPM, and invertebrate and fish data collected in the Reservoir (Thorley 2020). Zooplankton appear to bioaccumulate Se less efficiently than aquatic insects and fish with TTFs modelled at 0.85, 1.2, and 1.1, respectively. The BAP equation for the TFM model was:

$$BAP_{TFM} = TTF_{fishTL4} \times TTF_{fishTL3} \times [(TTF_{invert1} * \text{invert1 diet fraction}) + (TTF_{invert2} * \text{invert2 diet fraction})] \times \text{Bioavailability}\ \%$$

The environmental partitioning factor (K_d) characterizes the uptake and transformation of dissolved aqueous Se into SPM at the base of the food web. K_d values represent the ratio of the observed Se concentration in SPM to the observed Se concentration in water and were calculated from co-located SPM and water quality samples collected at the same time. Given the large spatial and temporal variation in K_d values, driven in part by the hydrodynamic nature of reservoir operations, the median K_d value of 4,547 was used.

The above model inputs for the BAP and the K_d, and a whole-body fish tissue threshold of 5.2 mg/kg (see Section 7.2) translates to a water column Se concentration of 0.85 µg/L which is considered protective of human health. A whole-body fish tissue threshold of 5.6 mg/kg results in a water column concentration of 0.91 µg/L and is considered protective of reproduction in sensitive fish species.

Achieving a water column concentration of 0.85 µg/L in Koocanusa Reservoir would be protective of all other uses and values including aquatic life and drinking water. Therefore, human health, with respect to the Ktunaxa preferred dietary rate, is the most sensitive designated use or value in Koocanusa Reservoir.

9.2 Selenium Water Quality Objectives

A Se WQO of 0.85 µg/L, as total Se, is proposed to protect all water uses and values in Koocanusa Reservoir. This value was derived using the USGS model to convert a whole-body fish tissue concentration of 5.2 mg/kg (considered protective of Ktunaxa preferred dietary intake) to a water column concentration.

The Se WQO is considered appropriate for the following reasons:
1. The USGS model used to derive the Se WQO is based on sound, collaborative, and peer-reviewed science with input from leading Se experts.
2. 0.85 µg/L is within the range of current conditions in Koocanusa Reservoir upstream of the Elk River inflow, as described in Section 8.2.
3. Fish muscle and whole-body tissue Se concentrations in Koocanusa Reservoir upstream of the Elk River are below the screening values for the protection of human health (see Section 8.3 and Appendix 3) indicating that attainment of the WQO should ensure protection of Ktunaxa rights to harvest and consume fish at their preferred rates; and
4. It ensures that the reproduction of sensitive fish species is protected by meeting the 0.91 µg/L threshold identified in Section 9.1.

The MT DEQ derived a Se criterion of 0.8 µg/L. The difference from the proposed B.C. WQO is largely due to the MT's model input of an assumed predator fish diet of 100% insectivorous prey fish, while the professional opinion of ENV and KNC biologists was that a predator fish diet of 75% insectivorous/25% planktivorous prey fish was more reasonable based on site-specific food web information. This difference in dietary input resulted in a slightly higher WQO value for BC/KNC compared to MT.

A Se WQO of 5.2 mg/kg (dry weight, or 1.3 mg/kg wet weight) in fish tissue (whole-body) is proposed to protect human health of those consuming fish from Koocanusa Reservoir. This value represents a low-risk level at the preferred consumption rate of Ktunaxa communities and the general population.

9.3 Attainment of Se WQO

Attainment of the Se WQO of 0.85 µg/L, as total Se, is determined from the mean of five evenly spaced daily average concentrations per site collected over 30 days and measured as total Se. Each of the daily averages are calculated from samples collected at the same site and at three depths: at the surface, 1 m above the substrate, and the mid-point of the water column. No more than 20% of the daily averages should exceed the WQO. If the monitoring frequency is insufficient to meet the requirements of the specified averaging period (five daily averages in 30 days), individual samples will be compared directly against the WQO.

Attainment of the Se WQO of 5.2 mg/kg (whole-body) is based on at least one composite sample per site, consisting of a minimum of five individuals per site. If analyzing a small fish species (e.g., <150 mm) a larger sample size may be required to ensure sufficient tissue for analysis. Individual fish must be from the same species and size class, and preferably larger fish. The smallest individual fish submitted for a composite sample must be ≥75% the length of the largest individual for that composite sample.

10. MONITORING RECOMMENDATIONS

To assess attainment of the Se WQO, monthly samples to characterize Se concentrations throughout the year should be collected. Frequency of sampling should increase: 1) when the reservoir is at low pool during the winter and spring months when Se concentrations peak, and 2) during freshet when Se loadings are highest (Teck 2020a). In addition, the Elk River flows along the eastern portion of the reservoir basin until water quality station E300092 where full mixing across the entire basin has been achieved (Teck 2020a). Therefore, stations that are representative of fully mixed reservoir conditions are recommended as listed in Table 3.

Table 3. Recommended water quality monitoring for the Koocanusa Reservoir.

Station	Lat/Long	Frequency and Timing	Parameters to be measured	Station Rationale
E300095 – downstream of Kikomun	49.228980˚/ - 115.261500˚	Monthly samples February – May (low pool): five weekly samples in a 30-day period June – July (freshet): five weekly samples in a 30-day period	Field: Temperature, dissolved oxygen, pH, specific conductivity, turbidity) Lab: Total and dissolved metals, total phosphorus, total mercury, and nitrates	Reference location to assess upstream conditions.
E300092 – west of Grasmere	49.115750°/ - 115.221000°			Represents fully mixed conditions.
E300094 – upstream of Canada/US border	49.014750°/ - 115.175800°			Represents fully mixed conditions before crossing the border.

Recommended monitoring includes fish tissue sampling to confirm that fish are safe for human consumption since the bioaccumulation of Se in organisms is not always predictable from Se concentrations in water (Presser and Luoma 2010). For each fish species that are normally consumed, tissue samples should be collected from five individual fish and the concentrations averaged to determine if the whole-body tissue threshold of 5.2 mg/kg (dw) is being attained (Table 4). Fish should be collected from each of the three sites used for water quality sampling.

Table 4. Recommended fish tissue monitoring for the Koocanusa Reservoir.

Sites	Tissue Type	Frequency and Timing	Parameters to be Measured
• E300095 – downstream of Kikomun • E300092 – west of Grasmere • E300094 – upstream of Canada/US border	Whole body & muscle tissue: (to assess against 5.2 mg/kg human health threshold) - Composite sample of a minimum of 5 individuals, of similar size and age class, per species of interest per site. Whole body, muscle tissue, ripe eggs: (to assess against BC aquatic life guideline) - 8 individuals per species per site.	Whole body and muscle sampling can occur any time of the year. Collection of ripe eggs should align with the spawning window of species of interest.	Field: species, sex, fork length, weight, condition. Lab: Se concentration for whole body, muscle, and egg/ovary tissue. Record gonadosomatic index if assessing against BC aquatic life guideline.

The Se WQO attainment monitoring program should be conducted yearly and follow the methods and quality assurance and quality control protocols provided in ENV 2013b.

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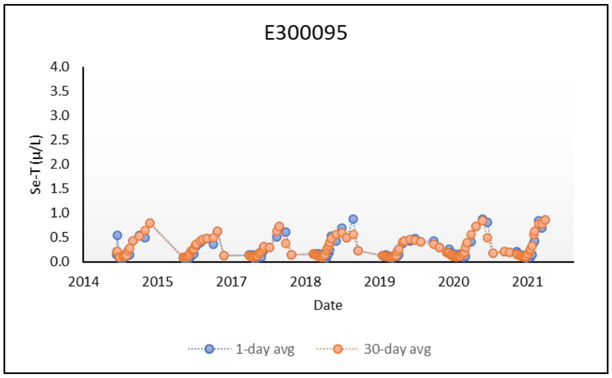
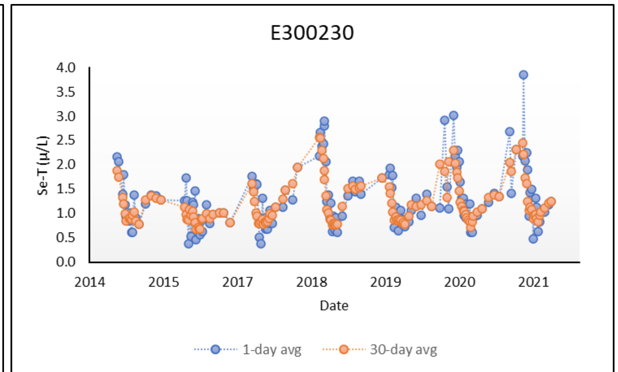
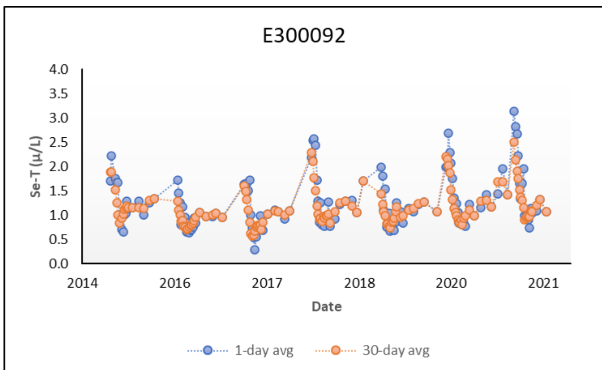
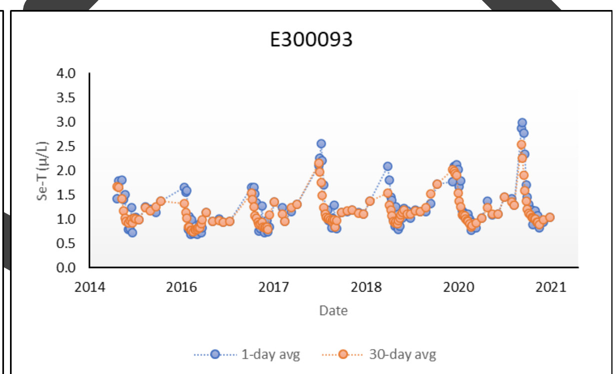
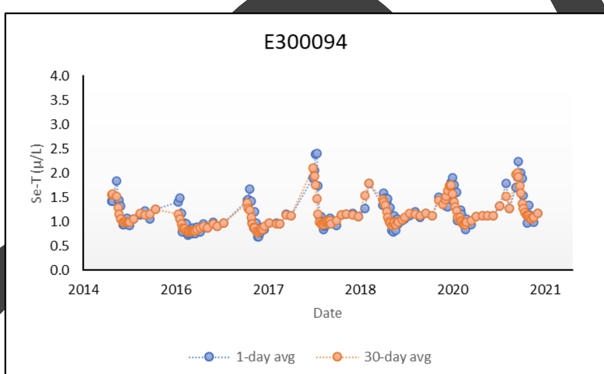
APPENDIX 1. Daily and 30-day average selenium concentrations (µg/L) by site over time.



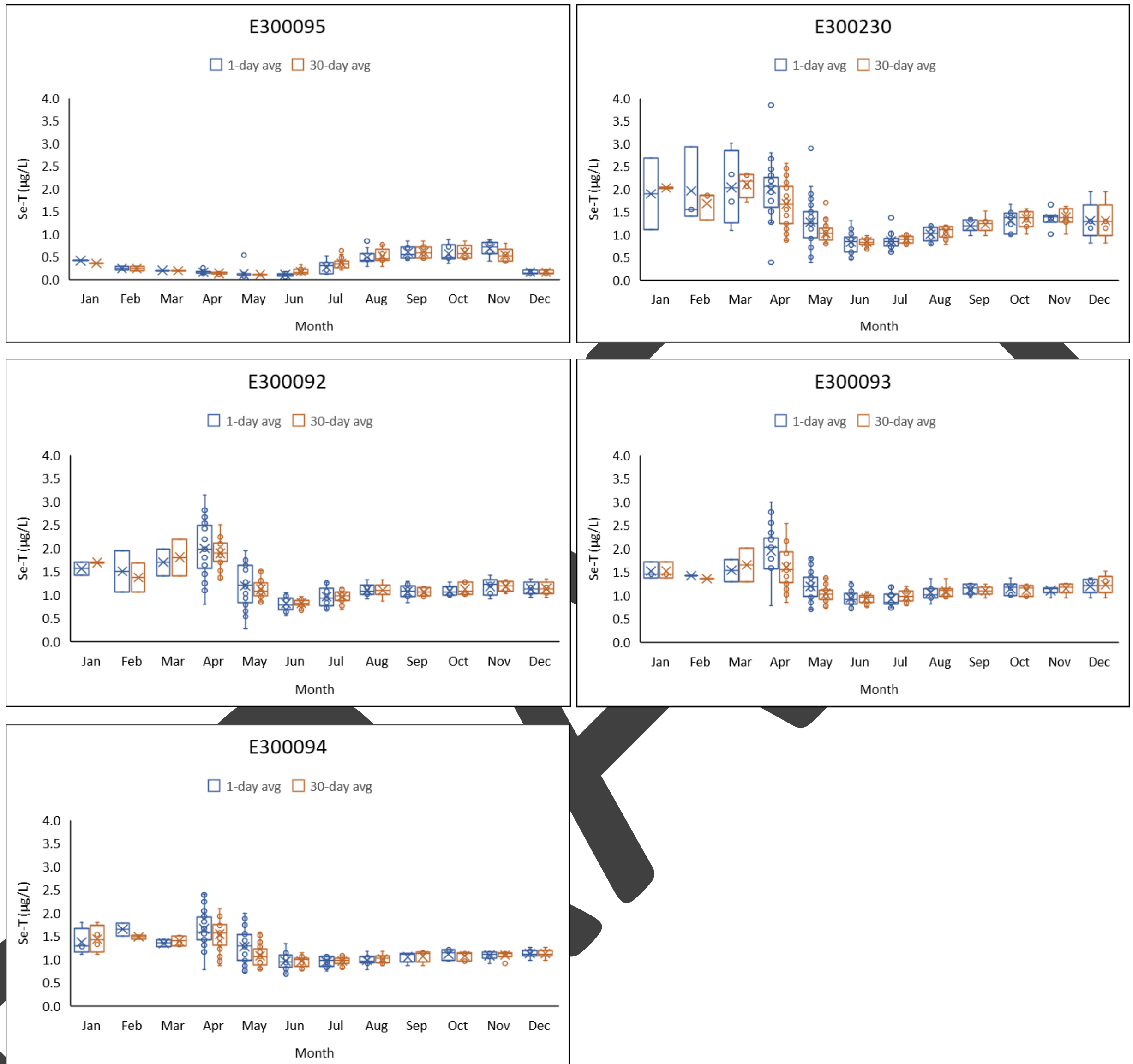






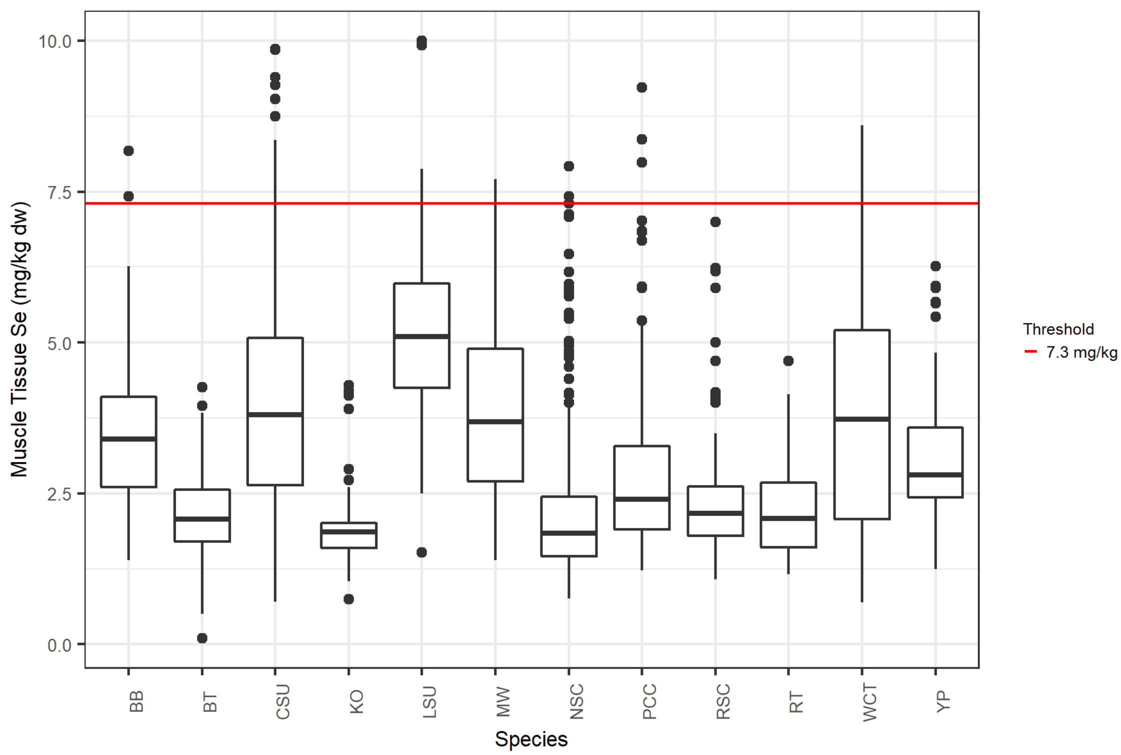


APPENDIX 2. Daily and 30-day average selenium concentrations (µg/L) by month.



APPENDIX 3. Summary of fish tissue selenium concentrations from Koocanusa Reservoir at all sites (B.C. and MT). Muscle tissue concentrations are compared to the B.C. human health screening value to protect high fish intake consumers (7.3 mg/kg); whole-body selenium tissue concentrations are compared to the Ktunaxa-specific human health screening value (5.2 mg/kg); egg selenium concentrations are compared to the B.C. water quality guideline value of 11 mg/kg (ENV 2014). The lower and upper margins of the box represent the 25th and 75th quartiles, respectively. The line within the box represents the median value. The whiskers extend to the largest or smallest value, but no further than 1.5X IQR (inter-quartile range = 75th quartile value – 25th quartile value). Values beyond the whiskers plotted are individually. Species abbreviations are: BB – Burbot; BT – Bull Trout; KO – Kokanee; CSU – Largescale Sucker; LSU – Longnose Sucker; MW – Mountain Whitefish; NSC – Northern Pikeminnow; PCC – Peamouth Chub; RSC – Redside Shiner; RT – Rainbow Trout; WCT – Westslope Cutthroat Trout; YP – Yellow Perch.

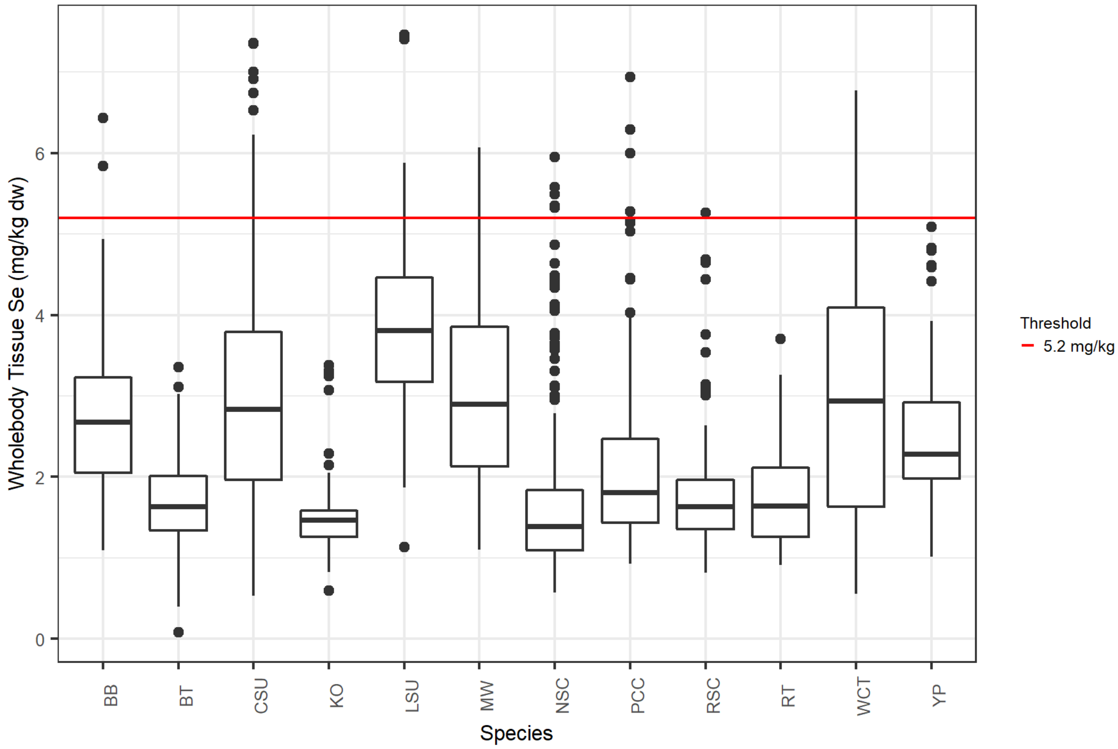
Muscle selenium concentrations:



Muscle tissue selenium concentrations (mg/kg dry weight), by species and site. Sites are listed by location, north to south. Shaded cells denote exceedance of the 7.3 mg/kg human health screening value.

Species	Site	Period	Mean	Minimum	Maximum	n
Burbot	1A (Kikomun)	2014-2016	2.8	1.4	6.3	25
	1B (S of Elk River)	2014-2016	3.3	1.8	5.3	16
	2 (Int. Boundary)	2013-2017	4.7	1.9	8.2	8
	Tenmile	2015-2017	4.3	2.6	5.9	12
	Forebay	2015-2016	3.7	3.5	3.9	4
Bull Trout	1A (Kikomun)	2014-2018	1.7	0.5	2.6	19
	1B (S of Elk River)	2014-2018	2.3	1.3	4.3	27
	2 (Int. Boundary)	2008-2019	2.3	0.1	4.0	59
	Forebay	2013-2018	2.3	1.8	2.8	7
Largescale Sucker	1A (Kikomun)	2014-2020	2.5	1.1	5.3	29
	1B (S of Elk River)	2014-2018	4.2	0.7	9.9	67
	2 (Int. Boundary)	2018-2020	4.2	0.9	8.8	44
	Tenmile	2018	4.4	3.1	5.3	6
	Forebay	2018	4.4	2.9	6.2	14
Kokanee	1A (Kikomun)	2014-2018	1.9	1.3	2.9	46
	1B (S of Elk River)	2014-2019	1.8	1.1	3.9	61
	2 (Int. Boundary)	2008-2019	2.0	0.75	4.2	62
	Tenmile	2018	1.7	1.3	2.6	4
	Forebay	2013-2018	1.8	1.2	2.4	6
Longnose Sucker	Int. Boundary	2008-2018	5.0	1.5	10.0	47
	Forebay	2013-2018	5.4	3.2	6.8	20
Mountain Whitefish	1A (Kikomun)	2016-2018	5.4	3.6	7.1	7
	1B (S of Elk River)	2015-2019	4.5	2.2	7.7	17
	2 (Int. Boundary)	2008-2019	2.6	2.0	3.2	4
	Tenmile	2018	2.1	1.8	2.3	3
	Forebay	2018	2.8	1.4	4.7	7
Northern Pikeminnow	1A (Kikomun)	2014-2020	1.9	0.8	4.2	93
	1B (S of Elk River)	2014-2018	2.9	1.0	7.9	150
	2 (Int. Boundary)	2008-2020	1.5	0.8	3.0	94
	Tenmile	2018	1.3	1.1	1.7	9
	Forebay	2013-2018	1.9	1.1	3.0	21
Peamouth Chub	1A (Kikomun)	2014-2020	2.2	1.2	5.9	58
	1B (S of Elk River)	2014-2018	3.2	1.4	9.2	87
	2 (Int. Boundary)	2008-2020	2.9	1.5	8.4	87
	Tenmile	2018	1.7	1.5	1.8	3
	Forebay	2013-2018	2.6	1.3	4.8	32
Redside Shiner	1A (Kikomun)	2015-2018	1.9	1.1	3.3	26
	1B (S of Elk River)	2015-2019	2.4	1.4	6.2	60
	2 (Int. Boundary)	2018-2019	2.4	1.9	3.0	8
	Forebay	2018	4.6	2.6	7.0	10
Rainbow Trout	1A (Kikomun)	2014-2020	1.8	1.2	3.4	14
	1B (S of Elk River)	2014-2018	1.7	1.2	2.4	9
	2 (Int. Boundary)	2008-2020	2.4	1.3	4.7	56
	Forebay	2018	1.6	1.4	2.0	3
Westslope Cuttroat Trout	1A (Kikomun)	2015-2020	3.9	1.8	5.6	13
	1B (S of Elk River)	2016-2018	3.4	0.7	8.6	16
	2 (Int. Boundary)	2013-2020	4.6	1.3	7.6	12
	Tenmile	2018	2.5	1.7	3.3	2
Yellow Perch	1A (Kikomun)	2014-2018	2.1	1.3	4.0	21
	1B (S of Elk River)	2014-2018	3.2	1.5	5.9	58
	2 (Int. Boundary)	2016-2019	4.1	1.3	6.3	13

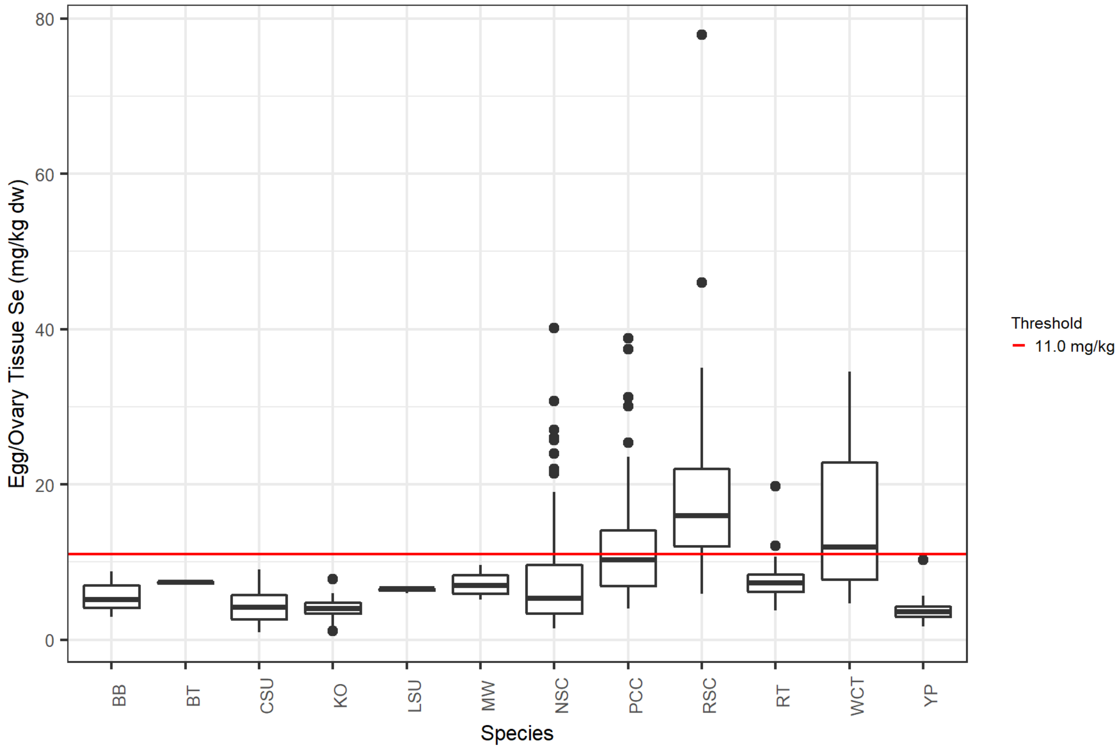
Whole-body selenium concentrations:



Whole-body tissue selenium concentrations (mg/kg dry weight), by species and site. Sites are listed by location, north to south. Shaded cells denote exceedance of the 5.2 mg/kg human health screening value.

Species	Site	Period	Mean	Minimum	Maximum	n
Burbot	1A (Kikomun)	2014-2016	2.2	1.1	4.9	25
	1B (S of Elk River)	2014-2016	2.6	1.4	4.2	16
	2 (Int. Boundary)	2013-2017	3.7	1.5	6.4	8
	Tenmile	2015-2017	3.6	2.0	5.8	15
	Forebay	2015-2016	3.1	2.7	4.3	6
Bull Trout	1A (Kikomun)	2014-2018	1.4	0.4	2.1	19
	1B (S of Elk River)	2014-2018	1.8	1.0	3.4	27
	2 (Int. Boundary)	2008-2019	1.8	0.1	3.1	59
	Forebay	2013-2018	1.8	1.4	2.2	7
Largescale Sucker	1A (Kikomun)	2014-2020	1.9	0.8	3.9	29
	1B (S of Elk River)	2014-2018	3.1	0.5	7.4	67
	2 (Int. Boundary)	2018-2020	3.2	0.7	6.5	44
	Tenmile	2018	3.3	2.3	4.0	6
	Forebay	2018	3.3	2.2	4.6	14
Kokanee	1A (Kikomun)	2014-2018	1.5	1.0	2.3	46
	1B (S of Elk River)	2014-2019	1.4	0.8	3.1	61
	2 (Int. Boundary)	2008-2019	1.5	0.6	3.4	62
	Tenmile	2018	1.3	1.0	2.0	4
	Forebay	2013-2018	1.4	0.9	1.9	6
Longnose Sucker	Int. Boundary	2008-2018	3.7	1.1	7.5	47
	Forebay	2013-2018	4.0	2.4	5.1	20
Mountain Whitefish	1A (Kikomun)	2016-2018	4.2	2.8	5.6	7
	1B (S of Elk River)	2015-2019	3.6	1.7	6.1	17
	2 (Int. Boundary)	2008-2019	2.1	1.6	2.5	4
	Tenmile	2018	1.7	1.4	1.8	3
	Forebay	2018	2.2	1.1	3.7	7
Northern Pikeminnow	1A (Kikomun)	2014-2020	1.4	0.6	3.1	93
	1B (S of Elk River)	2014-2018	2.2	0.8	6.0	150
	2 (Int. Boundary)	2008-2020	1.1	0.6	2.3	94
	Tenmile	2018	1.0	0.8	1.3	9
	Forebay	2013-2018	1.4	0.8	2.3	21
Peamouth Chub	1A (Kikomun)	2014-2020	1.8	0.9	4.4	73
	1B (S of Elk River)	2014-2018	2.5	1.0	6.9	117
	2 (Int. Boundary)	2008-2020	2.2	1.1	6.3	87
	Tenmile	2018	1.3	1.1	1.4	3
	Forebay	2013-2018	1.9	1.0	3.6	32
Redside Shiner	1A (Kikomun)	2015-2018	1.7	0.8	4.3	33
	1B (S of Elk River)	2015-2019	2.2	1.1	7.2	73
	2 (Int. Boundary)	2018-2019	1.8	1.5	2.2	8
	Forebay	2018	3.4	2.0	5.3	10
Rainbow Trout	1A (Kikomun)	2014-2020	1.4	0.9	2.7	14
	1B (S of Elk River)	2014-2018	1.4	0.9	1.9	9
	2 (Int. Boundary)	2008-2020	1.9	1.0	3.7	56
	Forebay	2018	1.3	1.1	1.6	3
Westslope Cuttroat Trout	1A (Kikomun)	2015-2020	3.1	1.4	4.4	13
	1B (S of Elk River)	2016-2018	2.7	0.6	6.8	16
	2 (Int. Boundary)	2013-2020	3.6	1.0	6.0	12
	Tenmile	2018	2.0	1.3	2.6	2
Yellow Perch	1A (Kikomun)	2014-2018	1.7	1.0	3.3	21
	1B (S of Elk River)	2014-2018	2.6	1.2	4.8	58
	2 (Int. Boundary)	2016-2019	3.5	1.1	5.1	18

Egg selenium concentrations:



Egg tissue selenium concentrations (mg/kg dry weight), by species and site. Sites are listed by location, north and south. Shaded cells denote exceedance of the 11.0 mg/kg egg/ovary tissue guideline.

Species	Site	Period	Mean	Minimum	Maximum	n
Burbot	1A (Kikomun)	2014	4.3	4.3	4.3	1
	2 (Int. Boundary)	2016	6.4	5.2	7.7	2
	Tenmile	2017	3.4	3.0	3.8	2
	Forebay	2016	7.5	6.3	8.8	2
Bull Trout	S of Elk River	2016	7.4	7.2	7.6	2
Largescale Sucker	1A (Kikomun)	2015-2020	3.7	2.6	5.2	5
	1B (S of Elk River)	2015-2016	3.6	1.0	9.1	14
	2 (Int. Boundary)	2018-20	4.5	1.2	7.0	29
	Tenmile	2018	5.9	4.2	7.6	2
Kokanee	1A (Kikomun)	2014-2018	4.4	3.1	5.3	12
	1B (S of Elk River)	2014-2018	4.0	3.1	5.8	8
	2 (Int. Boundary)	2018-2019	3.4	1.1	6.0	14
	Tenmile	2018	4.7	2.8	7.8	3
	Forebay	2018	3.7	3.3	4.1	2
Longnose Sucker	2 (Int. Boundary)	2018	6.3	6.0	6.6	2
	Forebay	2018	6.6	6.6	6.6	1
Mountain Whitefish	Tenmile	2018	7.4	5.2	9.6	2
	Forebay	2018	7.0	6.1	7.9	2
Northern Pikeminnow	1A (Kikomun)	2014-2020	9.0	1.5	30.7	44
	1B (S of Elk River)	2014-2018	11.3	3.0	40.1	51
	2 (Int. Boundary)	2018-2020	3.8	1.8	9.5	40
	Tenmile	2018	2.9	1.8	3.8	7
	Forebay	2018	3.0	3.0	3.0	1
Peamouth Chub	1A (Kikomun)	2014-2020	11.8	4.1	31.2	50
	1B (S of Elk River)	2014-2019	11.2	4.0	25.4	81
	2 (Int. Boundary)	2018-2020	11.8	5.1	38.8	34
	Forebay	2018	9.4	4.1	18.2	10
Redside Shiner	1A (Kikomun)	2015-2018	19.9	8.2	46.0	26
	1B (S of Elk River)	2015-2019	17.2	5.9	77.9	58
	Area 2	2019	16.2	12.4	19.7	3
	Forebay	2018	20.9	15.1	26.3	3
Rainbow Trout	1A (Kikomun)	2014-2020	7.2	3.8	10.7	8
	1B (S of Elk River)	2014-2016	10.4	6.4	19.8	4
	Area 2	2020	7.7	5.0	12.1	4
Westslope Cutthroat Trout	Area 1a	2020	18.3	9.2	24.8	3
	Area 2	2019-2020	14.3	4.7	34.5	4
Yellow Perch	1A (Kikomun)	2015-2018	2.5	1.7	4.3	15
	1B (S of Elk River)	2015-2018	4.0	2.7	10.3	45
	Area 2	2019	3.4	1.8	5.0	2

ENVIRONMENTAL QUALITY SERIES

DRAFT Derivation of a Selenium Water Quality Objective for Koocanusa Reservoir: Technical Addendum

Use of a Mechanistic Ecosystem Model to Build a Proposed Objective for Selenium in the Water Column

KTUNAXA NATION

BRITISH COLUMBIA

ISBN:

Citation:

Cover Photograph:

Boat launch at Koocanusa Reservoir and Rocky Mountains in the background. Photo Credit; BC ENV.

<u>Acknowledgements</u>

Special thanks are extended to those who contributed to this document: Ktunaxa Nation Council – Lands and Resources; B.C. Ministry of Environment and Climate Change Strategy - Sheldon Reddekopp, Jessica Penno, and Joe Thorley (Poisson Consulting Ltd.). Thanks are also extended to Teck Resources Ltd. and the Montana Department of Environmental Quality for providing access to data in support of developing the Water Quality Objective.

PREFACE

June 2026

The draft selenium water quality objective (WQO) and supporting documentation in this report were developed collaboratively from 2020 to 2021 by the Ministry of Environment and Parks and the Ktunaxa Nation Council Society (KNC). **The work was not finalized and the draft objective in this report is not an approved Ministry of Environment and Parks policy. This document cannot be cited or quoted as a complete and approved ministry report, nor can the derived numbers be referenced as a ministry policy.**

The Ministry of Environment and Parks has considered the policy framework for the Koocanusa Reservoir watershed and has determined that the Elk Valley Area Based Management Plan (ABMP) is the most appropriate instrument for setting water quality policy for Koocanusa Reservoir and the Elk River watershed. The work previously done towards the draft WQO, including information in this draft report, has been brought into the ABMP process. This includes the baseline datasets, bioaccumulation modelling framework developed by the US Geological Survey, fish tissue thresholds to protect aquatic life and people consuming fish from Koocanusa Reservoir, as well as important Ktunaxa knowledge and understanding.

The Elk Valley ABMP, titled the Elk Valley Water Quality Plan, is a plan to improve water quality in the Elk Valley and Koocanusa Reservoir, recognizing the historical activities and impacts in the watershed from over 100 years of metallurgical coal mining, and in consideration of the importance of mining to the local, regional and broader economy. It was developed in accordance with a Ministerial Order in 2013, and was updated by the Ministry of Environment and Parks in 2025. It provides a strategic framework for decision making, and is a strong policy that guides decision-making towards a long term vision and goals for the watershed which were developed by B.C. and Ktunaxa First Nations.

As part of amending the ABMP, Ministry staff have updated the baseline dataset with recent fish tissue and water chemistry data and compared it with model outputs using the draft bioaccumulation model described here. A review of this draft model revealed opportunities to update the draft selenium bioaccumulation model to improve the accuracy of model predictions relative to measured data. Specifically, using measured selenium in water, the draft bioaccumulation model over-predicts selenium concentrations in fish tissue, especially higher trophic fish, compared to measured concentrations of selenium in fish tissue over the past 10 years.

An updated bioaccumulation model that more accurately predicts measured concentrations of selenium in fish tissue based on measured water quality results will be finalized with input from Ktunaxa, industry, governments, and US agencies and tribes. This new work will be published as part of the second amendment of the ABMP.

Please refer to the Elk Valley ABMP for water quality policies applicable in Koocanusa Reservoir, including target(s) for selenium, which replace the earlier work to develop a water quality objective. Do not cite or quote this document as a completed and approved ministry report or ministry policy.

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

BAP	Bioaccumulation potential
B.C.	British Columbia
DEQ	Montana Department of Environmental Quality
dw	Dry weight
EC_{10}	Effect concentration of a substance where a 10% effect is observed
ENV	British Columbia Ministry of Environment and Climate Change Strategy
IFM	Invertebrate to fish model
K_d	Environmental partitioning factor
KNC	Ktunaxa Nation Council
LKMRWG	Lake Koocanusa Monitoring and Research Working Group
MT DEQ	Montana Department of Environmental Quality
Se	Selenium
SeTSC	Selenium Technical Sub-Committee
SPM	Suspended particulate material
TFM	Trophic fish model
TTF	Trophic transfer factor
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQO	Water quality objective(s)

1. INTRODUCTION

Koocanusa Reservoir is a transboundary reservoir formed by the construction of Libby Dam in Montana. The reservoir receives contaminants, including selenium (Se), from historical and current coal mining in the Elk River Valley in B.C. Technical representatives from the Ktunaxa Nation Council (KNC) and the B.C. Ministry of Environment and Climate Change Strategy (ENV) collaborated in the development of a site-specific water quality objective (WQO) for aqueous Se in Koocanusa Reservoir. Water quality objectives are provincial policy statements that apply to specific waterbodies and provide science-based benchmarks for the protection of water uses and values.

In 2015, the Lake Koocanusa Monitoring and Research Working Group (LKMRWG) was formed to address concerns from communities and governments with both regulatory and stewardship responsibilities related to the Koocanusa Reservoir and the Kootenay/Kootenai watershed. A multi-agency Selenium Technical Sub-Committee (SeTSC) was established to support this work and included technical representatives from both KNC and ENV.

The SeTSC was tasked to facilitate the derivation of a Se benchmark for Koocanusa Reservoir with long-term protection of all fish species adopted as a project goal. The United States Geological Survey (USGS) used a mechanistic ecosystem-scale model (Presser and Luoma 2010) and site-specific data to develop a Se model for Koocanusa Reservoir (Presser and Naftz 2020). The USGS model provided the basis for the Se WQO for the Canadian portion of the Koocanusa Reservoir. Additional analyses were provided by an independent expert (Thorley 2020) to support the selection of appropriate model input values. This report documents how the USGS model was used to derive a B.C. Se WQO for Koocanusa Reservoir.

Presser and Naftz (2020) includes an interactive spreadsheet tool which allows the user to adjust the generic assumptions presented in the model. ENV and KNC are confident that the USGS model and spreadsheet is an effective tool for deriving a Se WQO, especially when informed by additional analyses (e.g., Thorley 2020) and expert recommendations from the SeTSC.

2. SELENIUM MODELING

The implementation of a mechanistic ecosystem-scale Se modeling approach for Koocanusa Reservoir is described in MT DEQ (2020) and provides an overview of the model and key factors incorporated as model inputs. Equation 1 derives an aqueous water column concentration from the model inputs.

EQUATION 1:

$$C_{\text{target}} = \frac{C_{\text{tissue threshold}}}{\text{BAP} \times (K_d/1{,}000)}$$

Where:

C_{target}	= predicted site-specific Se water concentration (µg/L)
$C_{\text{tissue threshold}}$	= fish tissue threshold (µg/g dw)
BAP	= bioaccumulation potential
K_d	= environmental partitioning factor.

The tissue threshold quantifies the protection goal for Koocanusa Reservoir. The bioaccumulation potential (BAP) estimates the relative quantity of Se as it moves from suspended particulate material (SPM) to higher trophic levels such as fish. The BAP is derived by selecting a food web model (either Equation 2 or 3 below), identifying a trophic transfer factor (TTF) value for each taxonomic group in the food web, and multiplying by the estimated percent bioavailability of Se in SPM at the base of the food web.

The two generic food webs provided by Presser and Naftz (2020) are the invertebrate to fish model (IFM) (Equation 2) and the trophic fish model (TFM) (Equation 3).

EQUATION 2 – BAP for IFM

$$BAP_{IFM} = TTF_{fish} \times [(TTF_{invert1}\text{*invert1 diet fraction}) + (TTF_{invert2}\text{*invert2 diet fraction})] \times \text{SPM \% bioavailability}$$

EQUATION 3 – BAP for TFM

$$BAP_{TFM} = TTF_{fishTL4} \times TTF_{fishTL3} \times [(TTF_{invert1}\text{*invert1 diet fraction}) + (TTF_{invert2}\text{*invert2 diet fraction})] \times \text{SPM \% bioavailability}$$

The environmental partitioning factor (K_d) characterizes the uptake and transformation of dissolved Se to particulate Se (e.g., algae) at the base of the food web. The K_d is expressed as the ratio of measured SPM Se concentration divided by the paired aqueous Se concentration. In Equation 1, the K_d is divided by 1,000 to express the resulting aqueous Se concentration in µg/L. K_d values were calculated from 87 sampling events and ranged between 424 and 7,475.

The USGS model output is specified as dissolved Se. ENV and KNC have based the Koocanusa Reservoir Se WQO on total Se, recognizing that the presence of volatile reduced organoselenium species can complicate routine testing for total and dissolved Se, potentially causing bias that results in dissolved Se test results exceeding total Se test results (ALS 2019). For example, at site E300095, 44% of dissolved Se concentrations were equal to or greater than total Se concentrations measured at the same time between 2015 and 2021.

2.1 Model Validation / Calibration

The Presser and Luoma (2010) ecosystem scale model has been rigorously validated to multiple datasets in multiple ecosystems. They describe those model validations and present a set of average TTFs from validated models. For Presser and Naftz (2020), the starting point for modeling was this scientifically robust global model and associated global average model parameter values.

The USGS model (i.e., Presser and Naftz 2020) was not calibrated to Koocanusa using Se concentrations measured in fish. Presser and Naftz (2020) discuss the paucity of site-specific paired data from which to calculate site-specific TTFs, and why they could not conduct a full model validation of the application of global model coefficients to Koocanusa Reservoir. They also present rationale to calibrate the global model to local conditions by modifying the global model parameter values, in this case by adjusting the TTFs with a model factor called the bioavailability percentage. That percentage was estimated through a visual assessment of the measured Se concentrations in invertebrates (benthic invertebrates, aquatic insects, and zooplankton). In this way, they calibrated the model to the invertebrate trophic level by visual comparison of the predicted concentrations to observed ranges.

Table 1 presents the model input values used by Presser and Naftz (2020) to generate the predicted water column concentrations they reported. They use the USEPA (2016) (8.5 µg/g dw) and ENV (2014) (4.0 µg/g dw) whole-body fish tissue criterion as potential protection goals to convert to aqueous water column concentrations by applying global TTFs and each K_d value measured in Koocanusa Reservoir.

ENV compared measured and converted fish tissue concentrations to model predictions as an informative exercise. Due to the lack of tissue (whole-body and other types) Se concentrations in some important fish species in the reservoir, this was considered an exploratory, and not confirmatory, exercise; any such comparison makes significant assumptions about the spatial and temporal homogeneity of Se exposure and the application of USEPA (2016) conversion factors to Koocanusa fish. The lack of data and necessary assumptions supports the USGS decision (Presser and Naftz 2020) to present resource management decision makers with a range of predictions based on the entire set of Kd values.

Table 1. Generic model input values presented in Presser and Naftz (2020).

Protection Goal / Tissue threshold (whole-body, µg/g dw)	**BAP** (Bioaccumulation potential)			**K_d range** (Particulate Se/Water Se)
	Food Web	Trophic Transfer Factors by taxa (TTFs)	Bioavailability percentage	
8.5 (USEPA) or 4.0 (ENV)	Invertebrate to Fish (IFM) or Trophic Fish Model (TFM	TTF_{fish} = 1.1 $TTF_{aquatic\ insects}$ = 2.8 $TTF_{zooplankton}$ = 1.5	60% or 100%	424 – 7,475

The similarity between observed and predicted fish tissue Se concentrations varied with the data sets considered and model parameters used. Each comparison of predicted values to observed data requires choosing the species, timing, and location of the observed tissue data set, and an appropriately paired water column concentration to translate into a predicted mean tissue value. There are comparisons where the model is over predictive, where it predicts in the upper range of observed concentrations, and occasionally where it predicts the average Se concentration.

2.2 Model Uncertainty

The uncertainty related to the transfer of Se into fish (TTF_{fish}) is low. Presser and Naftz (2020) propose a TTF_{fish} of 1.1, which is the average of a relatively narrow range of TTF_{fish} estimates from 25 fish species (0.88 – 1.46, Presser and Luoma 2010). This also approximates the median (1.15) of values from eight resident fish species (USEPA 2016) in Koocanusa Reservoir.

Most of the uncertainty in the model parameters is associated with the environmental partitioning coefficient (K_d). Presser and Naftz (2020) describe the spatial and temporal variation of K_d estimates measured in Koocanusa Reservoir, and the rationale (e.g., insufficient data) for not statistically reducing the dataset to a single K_d estimate for the modeling effort.

The paucity of, and variation in, paired fish, invertebrate, and SPM data prevent defining the range of conditions and times when species are most vulnerable to Se bioaccumulation. Current conditions reflect a system that has integrated decades of elevated Se inputs, with limited understanding of the cycling of dissolved and particulate Se including internal loading, or re-cycling, of Se. Presser and Naftz (2020) cite non-steady state reservoir conditions, survivor bias, maintenance of a currently degraded ecosystem, and normalized toxicity as confounding factors. Koocanusa Reservoir has for decades been, and will be for an indeterminate time, the receiving environment of waters which exceed Se guidelines and effects levels for the fish species present.

2.3 Model Inputs

The uncertainties described above were considered in our selection of model input values. The model inputs are discussed in detail in the following sections with our decisions for each.

2.3.1 Tissue Thresholds

The tissue threshold is the Se concentration in the whole body of fish which quantifies the protection goal for Koocanusa Reservoir. The USGS model (Presser and Naftz 2020) translates this goal into a water column concentration via the ecosystem-scale model.

In B.C., WQOs are derived to protect the most sensitive water use or value. The following water uses have been identified for Koocanusa Reservoir:

- Aquatic life (protection of the most sensitive life stage of the most sensitive species during indefinite exposure)
- Ktunaxa cultural values
- Human health
- Wildlife
- Recreation and aesthetics, and
- Agriculture.

At the outset of the SeTSC work in 2015, the long-term protection of all fish species was adopted as the protection goal for the WQO. The USEPA established a whole-body Se tissue criteria of 8.5 µg/g dw and is considered protective of most aquatic animal species in an aquatic community (USEPA 2016). With respect to aquatic life, this level of protection does not align with ENV's guiding principles (ENV 2019) to protect the most sensitive species, at the most sensitive life stage, over indefinite exposures.

ENV (2014) implements a whole-body (and muscle) Se tissue guideline of 4.0 µg/g dw as a value considered protective of aquatic life. In their recommendations to the SeTSC co-chairs, KNC stated that this threshold may be lower than the site-specific conditions warrant to protect piscivorous fish, based on available data (i.e., TTFs are approximately 1). Teck (2018) presents muscle and whole-body Se tissue concentrations for Longnose Sucker, Westslope Cutthroat Trout, and Mountain Whitefish from lotic and lentic reference sites in the Kootenay River upstream of the reservoir, the Bull River (a tributary to the Kootenay River upstream of Koocanusa Reservoir), and from the Flathead River system. They report muscle and whole-body tissues Se concentrations at or near the tissue guideline of 4.0 µg/g dw at some of these reference locations.

Five of seven participating SeTSC members provided recommendations for tissue thresholds ranging from 4.6 to 7.0 µg/g (dw). This range is supported by rationales to protect to a level consistent with ENV guiding principles (ENV 2019), to address uncertainty regarding the sensitivity of fish species in Koocanusa Reservoir (e.g., Burbot), and to provide assurance that aquatic-dependent wildlife (e.g., avian receptors) would be protected from exposure through consuming fish. For example, Ohlendorf and Heinz (2011) reported an EC_{10} for reduced egg hatchability of 4.9 µg/g in mallards.

Aquatic Life Threshold

ENV's (2014) egg/ovary Se guideline of 11 µg/g dw was calculated by applying an assessment factor of 2 to the lowest endpoint in the toxicological database, an EC_{10} of 22 µg/g dw for *Oncorhynchus* species. USEPA (2016) included additional toxicological data and identified white sturgeon (*Acipenser transmontanus*) as having the lowest reproductive EC_{10} at 15.6 µg/g dw. Recognizing there are fish species in Koocanusa Reservoir, such as Burbot and Peamouth Chub, for which no estimates of sensitivity to Se exposure are available, KNC and ENV agreed the B.C. guideline of 11 µg/g (which is below the EC_{10} for white sturgeon) provides an appropriate estimate of a low-risk concentration. Following Presser and Naftz (2020), the ENV (2014) egg/ovary guideline was converted to a whole-body value using the USEPA (2016) conversion factor of 1.96 for *Oncorhynchus* species (on which the 2014 ENV egg/ovary Se guideline is based). This results in a whole-body threshold of 5.6 µg/g dw which is within the range of thresholds recommended by SeTSC members.

Human Health Threshold

The opportunity for Ktunaxa to harvest fish at their preferred rates is a key component to Ktunaxa's cultural practice of sukiɫ ʔiknaɫa (eating well). The tangible cultural value in harvesting is inextricably linked to the health and well being of Ktunaxa and honors the intangible cultural values of balance and stewardship of ʔa·kxamis qapi qapsin (all living things). These important cultural values and practices must be protected for future generations. Recognizing the importance of food security and the continuity of Ktunaxa cultural rights and practices, KNC evaluated whether Se concentrations in fish tissue would be protective of Ktunaxa citizens consuming fish at their preferred consumption rates. The Ktunaxa preferred consumption rate of 245 g of fish per day is from an internal diet study undertaken by the KNC (Robertson 2020). To meet this threshold, muscle tissue should not exceed the ENV (2014) human consumption screening value, adjusted for the Ktunaxa preferred consumption rate. The adjusted human consumption screening value for muscle tissue is 6.6 µg/g dw (vs 7.3 µg/g dw), which is converted to a whole-body concentration using the generic USEPA (2016) muscle-to-whole body conversion factor of 1.27, resulting in a whole-body tissue threshold of 5.2 µg/g dw. KNC recommended this tissue threshold to the SeTSC co-chairs to protect the health and cultural practices of Ktunaxa citizens consuming fish from Koocanusa Reservoir at their preferred rate.

2.3.2 Bioaccumulation Potential

Bioaccumulation potential (BAP) estimates the relative quantity of Se as it moves from SPM to higher trophic levels such as fish. Selection of the most appropriate food web, diet composition, TTFs, and Se bioavailability drive the BAP value (Equations 2 and 3).

SeTSC members agreed with applying the TFM as it is the most conservative food web model (i.e., results in the most protective aqueous Se concentration, consistent with the pre-defined protection goals). Burbot (*Lota lota*), Bull Trout (*Salvelinus confluentus*), and Northern Pikeminnow (*Ptychocheilus oregonensis*) were identified by Presser and Naftz (2020) as the fish species observed to have a largely piscivorous diet. Bull Trout have a relatively low sensitivity to Se exposure (i.e., are tolerant of Se exposure), while the sensitivity of Northern Pikeminnow and Burbot are currently undocumented in the primary literature. ENV and KNC used the TFM in deriving the Koocanusa Se WQO.

Written recommendations from SeTSC members incorporated a predator fish diet composition of 100% insectivorous prey fish. MT DEQ (2020) also selected a predator fish diet of 100% insectivorous prey fish as the maximum dietary exposure in the TFM food web. ENV and KNC agreed on a predator fish diet composition of 75% insectivorous prey fish and 25% planktivorous prey fish as a more reasonable estimate of maximum dietary exposure in the TFM food web based, on professional opinion and the diet compositions presented in Chisholm et al (1989) and Lotic (2019). Zooplankton in Koocanusa Reservoir, and in general, appear to bioaccumulate Se less efficiently than aquatic insects and we felt this should be considered.

Most SeTSC members agreed with the literature-based values used to represent Se transfer from invertebrates into fish (i.e., TTF_{fish} = 1.1) and no members expressed strong disagreement. Some SeTSC members derived site-specific TTFs ($TTF_{aquatic\ insects}$ and $TTF_{zooplankton}$) directly from data collected from Koocanusa Reservoir. We used site-specific TTFs for invertebrates based on an integrated bioaccumulation model using available water, SPM, and invertebrate and fish tissue Se data (Thorley 2020). This work produced a site-specific TTF for aquatic insects of 1.2 (Figure 1) and site-specific monthly average TTFs for zooplankton ranging between 0.36 and 0.85 (May and September, respectively) (Figure 2). ENV and KNC agreed to use the $TTF_{aquatic\ insect}$ of 1.2 as a best estimate of Se accumulation from particulates to aquatic insects in Koocanusa, and a $TTF_{zooplankton}$ of 0.85 as a best estimate of Se accumulation from particulates to zooplankton. The TTF of 0.85 in zooplankton corresponds to data collected in September, a period in which zooplankton productivity, and therefore Se uptake, is greatest. Conceptually, this relationship is supported with data from Woods (1982) which demonstrated that primary productivity in the Koocanusa Reservoir typically peaks in August; it would therefore be expected that peaks in these primary consumers would follow soon after this period.

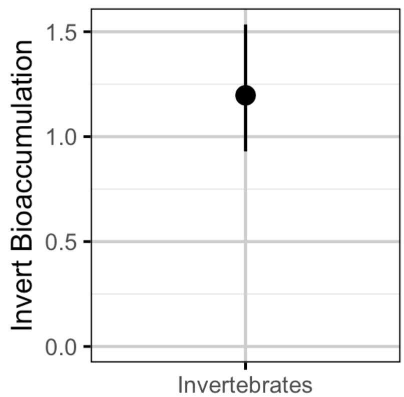


Figure 1. Estimated particulate to benthic invertebrate/aquatic insect selenium trophic transfer factor with 95% confidence intervals (from Thorley 2020).

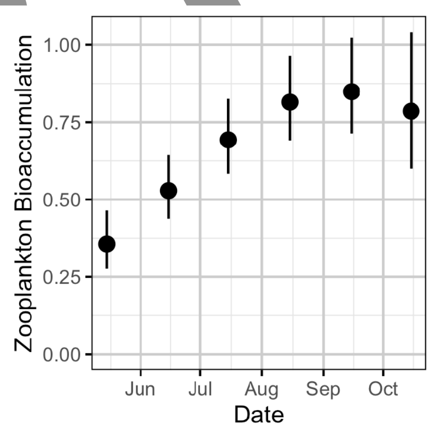


Figure 2. Estimated particulate to zooplankton selenium bioaccumulation rate by date with 95% confidence intervals (from Thorley 2020).

Finally, for Se transfer into invertebrates, some SeTSC members used the bioavailability percentage of 60% suggested by Presser and Naftz (2020). ENV and KNC used TTFs that were derived from Koocanusa Reservoir-specific data (Thorley 2020) and therefore a bioavailability percentage (i.e., correction factor) was not required.

Using the inputs defined above in Equation 3 produced a BAP of 1.35:

$$\mathrm{BAP_{TFM}} = 1.1 \times 1.1 \times \ [(1.2 \times 0.75) + (0.85 \times 0.25)] \ = 1.35$$

2.3.3 Environmental *Partitioning Factor (K_d)*

Presser and Naftz (2020) calculated K_d values from 87 sampling events that ranged between 424 and 7,475 with a median value of 4,547. They did not reduce the data set to a single K_d value because of the large observed variation in K_d values (due in part to data paucity and reservoir operations) and the lack of Se speciation data. For example, they did not remove K_d estimates for a particular depth zone or calculate a summary statistic from the K_d dataset. Their approach produced 87 outputs for each model run, one for each K_d value, and a range of measurements for resource managers to consider.

There appears to be an increasing trend in epilimnetic K_d in recent years, however the bioaccumulation factor approach in Thorley (2020) did not detect a statistically significant trend. Considering the 50 K_d ratios calculated from samples taken at a depth of approximately 3 m (epilimnetic samples), the mean annual epilimnetic K_d values for 2015 – 2019 were 2,456, 4,703, 4,589, 5,482, and 6,046 respectively. However, the trend was not statistically significant if we assumed a consistent relationship between water [Se] and tissue [Se] in the integrated model (Thorley 2020). In fact, no spatial or temporal trends were found to be statistically significant supporting the USGS (Presser and Naftz 2020) approach to present the entire K_d dataset.

There was general agreement amongst the SeTSC members to define a K_d for model application that estimates average exposure throughout the reservoir. An estimate of central tendency balances our understanding of Se integration at different trophic levels with the uncertainty around a representative K_d. Fish integrate Se at a far greater spatial and temporal scale than SPM, therefore it seems reasonable to use an average or median value as opposed to a more protective, higher percentile of the distribution.

In addition to the uncertainties in the data sets described above, we do not know the rate of internal cycling of Se in the reservoir, the uptake of Se into SPM, or the future of upstream Se inputs. These uncertainties indicate the range of conditions and times when fish and aquatic-dependent wildlife are most vulnerable to Se bioaccumulation cannot be defined, therefore it seems reasonable to use an estimate of central tendency as opposed to a higher risk, lower percentile of the distribution. Many SeTSC members recommended the median K_d value (50^{th} percentile) of 4,547.

2.4 Model Results

The predicted water column Se concentrations calculated with the tissue thresholds for aquatic life and human health (5.6 and 5.2 µg/g dw, respectively) are listed in Table 2. The median K_d value was used for both scenarios. The BAP value is a site-specific value (see Thorley 2020) and based on the TTFs and diet composition agreed on by ENV and KNC.

As a final validation of the model, we used Koocanusa-specific data to predict a whole-body tissue concentration which could be compared to actual results. Longnose Sucker muscle tissue concentrations (n = 18) collected in 2017 and 2018 at the international boundary ranged from 4.1 µg/g dw to 10 µg/g dw, with a mean of approximately 5.9 µg/g. This converts to a whole-body range of 3.0 µg/g dw to 7.5 µg/g dw and a mean of 4.4 µg/g using USEPA (2016) muscle to whole-body conversion factors. We assumed a diet of 100% insects for Longnose Sucker and rearranged Equation 1 to solve for $C_{\text{tissue threshold}}$:

$$\mathrm{C_{tissue\ threshold}} = \mathrm{C_{target}} \times \mathrm{BAP} \times (\mathrm{K_d}/1{,}000)$$

and applied the following model inputs:

- C_{target} = 1.10 µg/L (mean of all samples taken at international boundary locations 2017 to 2018)
- BAP = (TTF_{fish}) (TTF_{insect}) = (1.1) (1.2) = 1.32
- K_d = 4,547 (median).

The model predicts a whole-body concentration of 6.6 µg/g dw which is within the the upper range of observed concentrations for this species. We conducted similar comparisons with other species using USEPA egg-ovary to whole-body conversion factors. We converted the predicted whole-body Se concentrations to egg-ovary Se concentrations and found, for some species, a closer match with the average measured egg-ovary Se tissue concentrations.

Table 2. Predicted water column selenium concentrations translated from two ENV/KNC modeling scenarios using Equation 1.

Water Use/Value	Tissue threshold (whole-body, µg/g dw)	BAP (Bioaccumulation potential)	K_d	Predicted water column Se (µg/L)
Aquatic Life	5.6	1.35	4,547 (median)	0.91
Human Health	5.2	1.35		0.85

3. CONCLUSIONS AND FINAL KNC-ENV WQO RECOMMENDATION

To derive a site-specific Se WQO for Lake Koocanusa, we used the most recent site-specific information, the Presser and Naftz (2020) model and supporting information, and technical analyses undertaken by ENV (Thorley 2020). This resulted in protective values lower than the USEPA (2016) criteria of 1.5 µg/L and the ENV (2014) WQG of 2.0 µg/L.

The Ktunaxa preferred consumption rate is slightly higher than the high intake value upon which the previous provincial screening value was derived in ENV (2014), and because of this human health (and the protection of cultural values) is identified as the most sensitive water use in Koocanusa Reservoir. KNC and ENV recommend the following site-specific WQO for aqueous Se in Koocanusa Reservoir:

The 30-day average water quality objective for the protection of human health and aquatic life is 0.85 µg/L determined as the mean of 5 evenly spaced average concentrations measured over 30 days as total Se. Each of the 5 evenly spaced averages will be calculated from samples collected at three evenly spaced depths in the water column. No more than 20% of these averages should exceed the water quality objective. If the monitoring frequency is insufficient to meet the requirements of the specified averaging period, individual samples will be compared against the WQO.

We used Se concentrations measured upstream of the Elk River inflow at ENV monitoring site E300095 (near Kikomun Creek) to assess the appropriateness of the recommended Se WQO relative to more natural conditions. Concentrations measured between April 2015 and September 2021 at site E300095 ranged from 0.08 to 0.85 µg/L, with mean of 0.27 µg/L and 95th percentile of 0.73 µg/L. The recommended Se WQO of 0.85 µg/L is within the upper limit of these upstream in-reservoir concentrations, and the monitoring and modelling efforts conducted in this study suggest the system has some capacity to assimilate Se concentrations above upstream concentrations, therefore the WQO as recommended here is a reasonable estimate of low-risk conditions in Koocanusa Reservoir.

The Koocanusa Reservoir Se WQO is based on the best available information at the time of its derivation. Addressing the following information and data gaps may help reduce the uncertainty associated with the model outputs:

1. Paired measurements of Se in suspended particulate material and the water column at sites of interest (to expand the K_d data set).
2. Site-specific tissue conversion factors for fish species of interest.
3. Diet assessments for fish species and aquatic dependent wildlife species relevant to Koocanusa Reservoir.
4. Ecotoxicological assessments of Se sensitivity in Burbot, Peamouth Chub, and other species with no, or limited, measured sensitivity thresholds.

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