Selenium Conditions in the Canadian Portion of Koocanusa Reservoir 2015-2025

A review of data and assessment of associated risks

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Ministry of Environment and Parks

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Executive Summary

Selenium conditions in the Canadian portion of Koocanusa Reservoir have been influenced by discharges from coal mining in the Elk Valley, natural hydrologic variability, and the operation of Libby Dam in Montana. Using data from 2015 to 2025, this review provides an assessment of selenium concentrations in the reservoir, its accumulation in the food web, and potential risks it poses to aquatic and human health. Under Ministerial Order No. M232-2024, BC ENV will undertake a review of the Area Based Management Plan selenium water quality target for Koocanusa Reservoir, which will rely in part on this report.

Selenium enters the reservoir primarily from the Elk River, which contributes roughly 90% of the annual load. While concentrations in the Elk River increased with continued mining activities and expansion, recent years show a change in trajectory. Climate variation and changing flows are strong influences on loads and concentrations; however, there is growing evidence that water treatment at Elk Valley mines is contributing to observed improvements in water quality. In 2024 and 2025, annual average selenium levels at a key monitoring location in the reservoir near the confluence with the Elk River (LK2) have decreased to 1.19 µg/L and 1.01 µg/L, respectively, which are similar to concentrations observed in 2016. These reductions contrast with the increasing trend in concentration observed between 2015 and 2022.

Short-term seasonal spikes continue to occur, typically in April. These brief elevations in concentration are due to a few factors: rising spring snowmelt with an increase in selenium load from the Elk River, low reservoir volumes at the end of winter, and limited dilution from the Kootenay River. These conditions create a seasonal window where exceedances have occurred in the past, even in years when average selenium concentrations were low. These exceedances appear to be short-lived and are primarily driven by hydrology.

The reservoir is unique with respect to its hydrodynamics, and depending on the time of year, the northern portion of Koocanusa shifts between river-like and lake-like conditions. As the Elk River selenium input does not fully mix across the reservoir until further downstream, localized variability occurs near the confluence. A change to transect based sampling at LK2 in June 2022 has reduced variability in the monitoring data tied to incomplete mixing.

Selenium accumulation in sediments remains low. Only two sediment samples since 2013 have exceeded the provincial alert level, and it appears that the reservoir does not act as a long-term sink for selenium.

Zooplankton have selenium concentrations comparable to reported historical data and are generally below levels associated with risk, except for the 2015 and 2020 averages, which exceeded the guideline. Benthic invertebrates exhibit higher concentrations, as expected in selenium-affected systems, but are like concentrations reported from reference lentic locations in a nearby watershed. While benthic tissue concentrations consistently exceed the BC interim guideline, they have remained below species-specific effects thresholds since 2022.

Nearly 2000 fish muscle tissue samples have been collected since 2002. The results indicate that selenium concentrations in almost all species are below the BC guideline protective of fish health, and there are no exceedances of fish with species-specific effects thresholds. There is no documented evidence of selenium-related impacts to fish in the reservoir. Published bird tissue results exhibit a similar trend, with eggs collected downstream of the reservoir having selenium concentrations below guideline values.

Aqueous selenium concentrations are consistently far lower than the human health drinking water guideline, indicating a negligible risk. Similarly, fish tissue concentrations remain below consumption screening values in the majority of samples. A 2025 human health evaluation concluded that high-frequency consumers, including at the Ktunaxa preferred diet rates, are not at elevated risk from selenium exposure through consumption of reservoir fish.

The overall results from 2015–2025 show that selenium conditions in Koocanusa Reservoir have stabilized and are improving. Water quality is below the Area Based Management Plan selenium target for the majority of the year, and aquatic organisms have tissue concentrations within protective ranges. Neither fish or birds show evidence of selenium-related effects, and the risk to human health is considered low. Continued monitoring remains important, particularly for fish tissue and for filling spatial gaps in sediment and invertebrate datasets. However, based on the full body of evidence, selenium does not appear to pose a significant or increasing risk within the Canadian portion of Koocanusa Reservoir.

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Acronym List

ABMP	Area Based Management Plan
BC	British Columbia
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
EMC	Environmental Monitoring Committee
ENV	British Columbia Ministry of Environment and Parks
EVR	EVR Operations Ltd.
EVWQP	Elk Valley Water Quality Plan
HHRA	Human Health Risk Assessment
HLTH	BC Ministry of Health
HQ	Hazard Quotient
IC_x	Concentration causing an x% inhibition in biological response (e.g., growth rate, cell density) relative to a control
LOEC	Lowest observed effects concentration
MT DEQ	Montana Department of Environmental Quality
TOR	Terms of Reference
TRG	Tissue Residue Guideline
US	United States
US EPA	United States Environmental Protection Agency
WQG	Water Quality Guideline
ww	Wet weight

Introduction

In 2013, the BC Minister of Environment issued Ministerial Order No. M113-2013 (Order M113) under the Environmental Management Act (EMA) to require development of an Area Based Management Plan (ABMP) for managing historical and current waste from multiple coal mines in the Elk River watershed (ENV 2013a). This led to the development of the 2014 Elk Valley Water Quality Plan (EVWQP; Teck 2014), which included a selenium target for Koocanusa Reservoir. When the 2014 EVWQP was approved as the Area Based Management Plan for the Elk Valley, the Minister recognized that new sound science may result in the need to make changes.

In 2024, the Minister of Environment and Parks (ENV) ordered two amendments to the ABMP (Ministerial Order No. M232-2024, Order M232; ENV 2024a). 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 is under development. To inform the TOR, an initial step is to understand the current status and trends of water quality in the reservoir including how current conditions relate to potential risks to aquatic life and human health. It is also important to characterize the factors that influence water quality in the reservoir and understand how well the ABMP Order Station represents reservoir conditions. This is the purpose of the review entitled Selenium Conditions for the Canadian Portion of Koocanusa Reservoir 2015-2025.

By addressing key questions listed below, this review provides the current state of understanding about water quality in the Canadian portion of Koocanusa Reservoir and the factors that are understood to drive measured selenium concentrations. It examines what is known about selenium concentrations in reservoir sediments downstream of mining. It characterizes concentrations of selenium in biota from the lowest trophic levels (zooplankton and benthic invertebrates) and shows how selenium bioaccumulates in higher trophic fish and birds with discussion about the associated risks of impacts. Finally, this review examines risks to human health from the consumption of reservoir fish related to selenium exposure and exposure to other reservoir parameters.

Key Questions

The following key questions are considered in this report. Information, data and analysis are presented in the Current Conditions section and answers are provided in the Conclusions section.

1. Understanding Water Quality and Sediment Quality

What are the current aqueous selenium concentrations and trends in the Canadian portion of the reservoir?

This review provides descriptions of:

- Key influences on Koocanusa Reservoir aqueous selenium concentrations, including:
  - Hydrology of the Elk and Kootenay rivers
  - Managed fluctuations in reservoir water levels
  - Mixing between Elk River and Koocanusa Reservoir waters
  - Concentrations of selenium in the Elk River
  - Selenium load removal by water treatment facilities at the Elk Valley mines
- A comparison of Koocanusa Reservoir selenium concentrations at the ABMP Order Station LK2 to the ABMP aqueous selenium target for the reservoir
- Spatial and temporal water quality variability and trends at the following monitoring locations:
  - LK2 (Downstream of the Elk River)
  - Grasmere
  - Upstream of Gold Creek
  - At the Canada/US Border

What is the concentration of selenium in reservoir sediment?

Characterized by:

- Comparisons of measured sediment quality from the Canadian portion of the reservoir to the relevant sediment quality selenium alert level

2. Understanding Bioaccumulation of Selenium in Biota and Risks to Aquatic Health

What is the current state of selenium bioaccumulation in biota in the Canadian portion of the reservoir?

What are the risks to aquatic health associated with the observed concentrations of selenium in biota?

- Selenium concentrations in zooplankton and benthic invertebrates are compared to BC tissue guidelines and site-specific effects thresholds
- Selenium concentrations in fish tissue are compared to BC tissue guidelines and species-specific effects thresholds
- Selenium concentrations in bird eggs are compared to the BC bird egg selenium guideline
- The risks of impact to biota from guideline and effects threshold exceedances are described

3. Understanding Risks to Human Health

What are the risks to human health from exposure to selenium in the Canadian portion of Koocanusa Reservoir?

Is the water safe to drink?

- Water quality data are compared to the BC selenium drinking water quality guideline

Are the fish safe to eat?

- Measured selenium concentrations in fish tissue are compared to BC fish consumption guidelines for recreational consumers and an equivalent protective threshold using Ktunaxa preferred diet consumption rates
- Fish tissue analyses are compared to the results from a 2025 human health study that examined risks from selenium in Koocanusa Reservoir fish (Ramboll 2025, note: this draft report is currently under review by the Elk Valley Human Health Working Group)
- This review also examines whether other parameters influence risks to human health from the consumption of Koocanusa Reservoir fish

Background

Location and Physical Features

The Kootenay watershed, including the Elk River and the Canadian portion of Koocanusa Reservoir, is situated in ʔamakʔis Ktunaxa, the territory of the Ktunaxa Nation, which extends across international borders. Koocanusa Reservoir (Lake Koocanusa in the BC Gazette) is located in southeast British Columbia and is a transboundary waterbody created by the 1972 construction of the Libby Dam by the United States government on the Kootenai/y River in Montana (spelled Kootenay in Canada and Kootenai in the US). The reservoir is approximately 145 km long, with 68 km in BC and 77 km in Montana, and stores over 7 km^3 of water. It has an average depth of 38 m, with a maximum at the Libby Dam forebay of 106 m. The mean water residence time is 9 months (Easthouse 2008). Most of the reservoir's inflow is supplied by three Canadian rivers: the Kootenay (62%), the Elk (26%) and the Bull (11%) (Minnow 2020a). Reservoir water level drawdown in late winter/early spring provides capacity in the reservoir to capture and store flows from spring freshet. As a result, the reservoir can exhibit lentic (i.e. lake-like) or lotic (i.e. river-like) characteristics in its northern reach, depending on dam operations.

Selenium

Selenium is a relatively rare, naturally occurring trace element. While it is widely distributed across the globe, the presence and concentrations are dependent on the type of parent rock. Generally, it is present in its elemental form as selenide (Se^{2-}), selenate (SeO_4^{2-}; oxygen-rich environments), selenite (SeO_3^{2-}; low-oxygen environments), or as organic selenium (US EPA 2021).

Selenium can enter the environment through anthropogenic or non-anthropogenic sources. Due to its presence in the Earth's crust, processes such as natural weathering of rocks can release selenium into the environment (non-anthropogenic source). It is not directly mined but is a by-product of mining (anthropogenic source). Disturbances during the mining process cause selenium to oxidize to soluble forms, and precipitation moving through tailings and waste rock mobilizes soluble selenium species into surface water and groundwater (ENV 2014).

Following mobilization, selenium can enter the food chain, primarily through uptake by plants and microorganisms. Once in the food chain, selenium undergoes bioaccumulation processes when uptake rates exceed the rate of excretion (ENV 2014). The primary exposure pathway for higher trophic biota, including humans, is through dietary ingestion, not through aqueous exposure (Lemly 2004). In nature, ecotoxicological effects are generally caused by chronic exposure to selenium (Montana DEQ 2020).

Studies have shown lentic waters represent an elevated risk of selenium bioaccumulation, with reducing conditions and higher residence times causing the formation of more bioavailable selenium species (Orr, Guiguer and Russel 2006, US EPA 2021). In contrast, reduced risk of selenium bioaccumulation has been documented in lotic waters due to oxygenated, fast-flowing water and less organic matter (Orr, Guiguer and Russel 2006). However, recent research in the Kootenai River (Mebane et al. 2025) shows that this relationship may not apply to all aquatic systems. For example, downstream of the Libby Dam, greater bioaccumulation was observed in lotic reaches as compared to river reaches with slow moving water.

Selenium is found in trace quantities in most animal and plant tissues and is essential for cellular function. At higher concentrations, selenium can become chronically toxic, and there is generally a narrow range between acceptable and chronic toxicological concentrations. Chronic selenium toxicity in fish leads to reduced growth and reproductive health effects, including increased deformities and higher mortalities in early life stages. In humans, chronic exposure to elevated selenium can cause symptoms of selenosis, which include hair loss, nail damage, and nervous system abnormalities (IJC 2020). Due to a varied diet and diverse food sources, selenium deficiency and toxicity in humans are rare in North America (ENV 2014).

Koocanusa Reservoir Selenium Target

The selenium target in Koocanusa Reservoir, as set out in the EVWQP and Environmental Management Act Permit 107517, is a monthly average total selenium concentration equal to the BC water quality guideline (BC WQG) for the protection of aquatic life of 2 µg/L (see Box 1 below). It applies to all months of the year at a location in the reservoir called LK2.

Box 1. BC Water Quality Guidelines

BC water quality guidelines (BC WGGs) are developed to support assessment and management of the health, safety and sustainability of British Columbia's aquatic resources. They are applicable throughout the province and have been developed for multiple endpoints, including aquatic life, wildlife, agriculture (irrigation and livestock watering), drinking water sources, recreation, and aesthetics (ENV 2014). BC WQGs for aquatic life are designed to protect the most sensitive life-history stages of the most sensitive species (including non-fish species). Guidelines typically include an uncertainty factor. Uncertainty factors are applied as downward adjustments to laboratory-based toxicological effects concentrations and are intended to account for uncertainties associated with translating laboratory-based studies to the field. For example, an uncertainty factor of 5 was used in the derivation of the BC selenium guideline. A lowest observed effects concentration (LOEC) of 10 µg/L selenium was determined through laboratory studies, and application of the uncertainty factory yielded an aqueous guideline of 2 µg/L selenium (ENV 2014). The BC WQG for aqueous selenium was not based on bioaccumulation modelling.

BC WQGs are provincial policies to be considered by decision makers. They are not regulatory limits unless they are established as such in a permit.

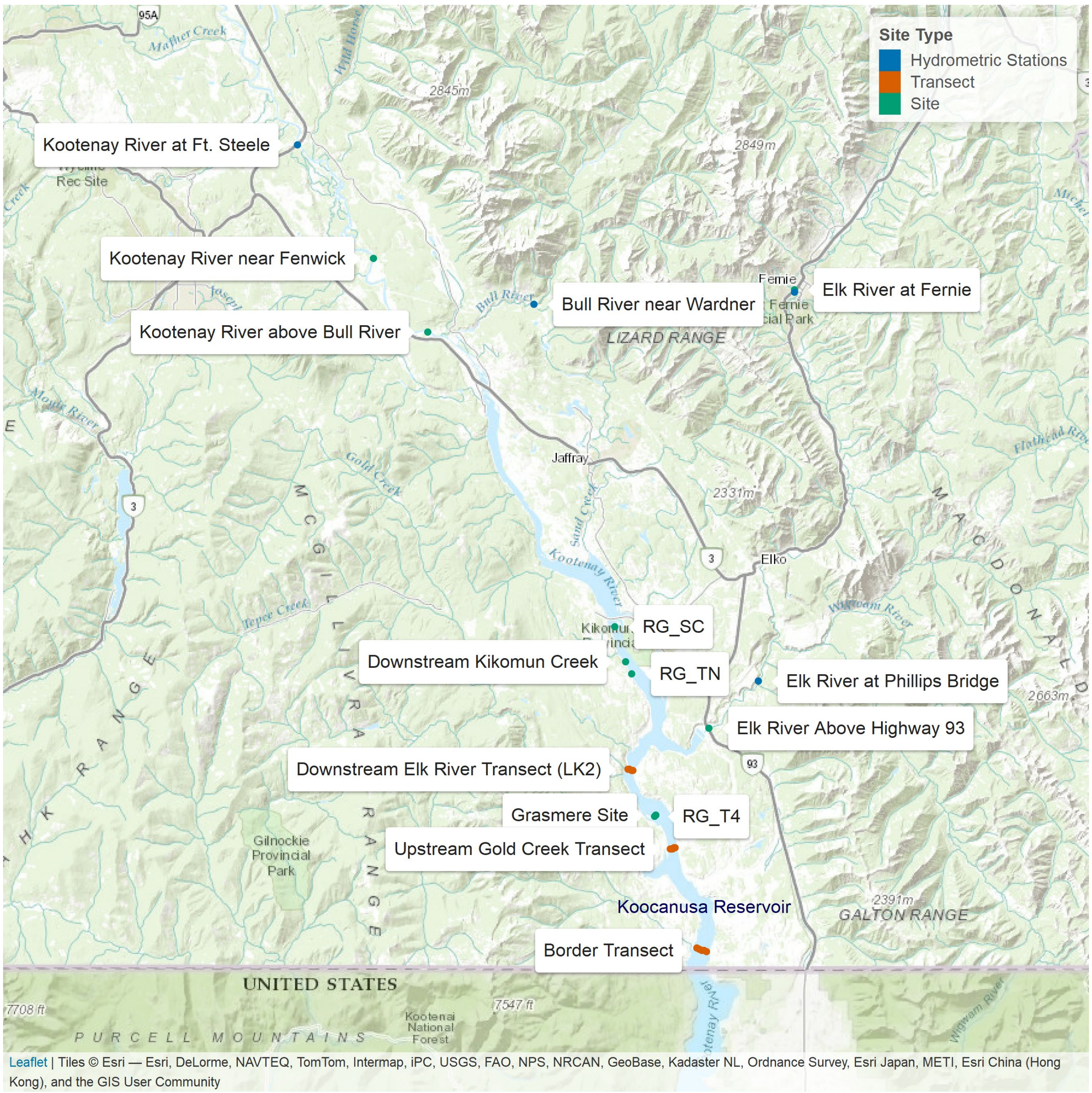
The Koocanusa Reservoir selenium target currently has no tissue-based values and was not set based on an evaluation of the potential risks posed to human consumers of reservoir fish. The target does not account for variations in bioaccumulation owing to site-specific conditions, relationships that could be estimated through bioaccumulation modelling.

Analytical results for selenium can be reported as the total or dissolved fraction. Total (unfiltered) samples include dissolved (a more bioavailable fraction) and selenium sorbed to sediment, biomass or other particles. Both the BC WQG and the ABMP target are based on total aqueous selenium concentrations (ENV 2014) whereas the US EPA lentic criterion is measured as dissolved selenium (US EPA 2021). Total and dissolved test results are not interchangeable measurements or directly comparable. All water quality data analyzed within this review were based on total selenium concentrations to enable comparison to the ABMP selenium target.

The Koocanusa Reservoir selenium target applies at LK2, which is a transect located in the reservoir approximately 6 km downstream of the Elk River confluence and 19 km upstream of the Canada-US border (Figure 1). When the EVWQP was developed in 2013, a point location, DSELK (downstream of the Elk River), was selected where the Elk River waters were expected to be fully mixed with Kootenay River waters and expected to represent average reservoir conditions. The assessment of selenium at DSELK involved averaging samples collected at three depths (near surface, mid depth, near bottom). Monitoring efforts, however, revealed that waters from the Elk and Kootenay rivers are not fully mixed at DSELK. In June 2022, the sampling methodology changed to a five-station transect called LK2 with the assessment of selenium levels involving an averaging of water samples from three depths at each transect station. The intent was to better characterize average concentrations in Koocanusa Reservoir. DSELK is the central sampling station within the LK2 transect.

Attainment of the selenium target at DSELK is not a legal requirement but is an expectation of the EVWQP. Following approval of the 2014 EVWQP as the Elk Valley ABMP, the Koocanusa Reservoir selenium target was set as a Site Performance Objective (SPO) in EMA Permit 107517 to inform the development of legally binding compliance limits in the permit. The SPO ensured a linkage between the permit and the EVWQP, which is the permit's policy foundation. Under the 2025 EVWQP, SPO non-attainment triggers a review of the compliance limits to ensure they are adequate to achieve the ABMP targets.

Figure 1. Water quality sampling sites and transects, and hydrometric stations in the Elk River and downstream of the Elk River in Koocanusa Reservoir.



Monitoring Data

This review focusses on monitoring data collected in the Canadian portion of Koocanusa Reservoir and the primary inflows of the Kootenay and Elk rivers.

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 five stations (Figure 1). Sediment chemistry, zooplankton tissue and community, and benthic invertebrate tissue and community samples are collected annually at two stations (RG_TN and RG_T4). Fish tissues are sampled twice annually at three stations in Koocanusa Reservoir near the confluence of Sand Creek (RG_SC), Elk River (RG_ER), and Gold Creek (RG_GC, Minnow 2024).

There are currently no avian or herptile monitoring programs in the Canadian portion of Koocanusa Reservoir. The most recent avian study with relevant data from the region is a 2025 study on tree swallow eggs that was conducted along the US portion of the reservoir (Balmer et al. 2025).

Data from the Elk River at the Highway 93 bridge near the confluence of Koocanusa Reservoir is collected as a part of a monitoring network managed by the province of British Columbia and Environment and Climate Change Canada.

The primary datasets used in this review are as follows:

- BC Environmental Monitoring System database (ENV n.d. (b)) including data collected from ECCC/ENV monitoring locations in the Elk River.
- Hydrometric data monitored by the Water Survey of Canada (WSC).
- 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 Koocanusa Reservoir 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. Koocanusa Reservoir water elevation data used to contextualize the selenium data were accessed from the US Army Corps of Engineers website (USACE 2025b). The datasets include data available until the end of the calendar year 2025.

Current Conditions

Hydrology

Contributing Flows

To understand concentrations of selenium in Koocanusa Reservoir, it is first helpful to describe the reservoir's source waters. Two main watersheds contribute flow to Koocanusa Reservoir, the Kootenay River and the Elk River. As summarized in Table 1, the combined watersheds of the Kootenay and Elk rivers account for over 75% of the total watershed area upstream of the Libby Dam, and approximately 90% of annual flow from the reservoir.

The seasonal streamflow distribution is similar in both the Kootenay and Elk rivers (Figure 2). The spring snowmelt freshet generally occurs earlier in the Elk River than in the Kootenay River, with the Elk River providing an increased relative proportion of water to Koocanusa Reservoir for a period of the spring (typically in April and May, Figure 2), as compared to other months of the year. The magnitude and timing of this spring increase in proportional flow also differs from year to year. The non-synchronous timing of the spring snowmelt freshet in these two watersheds is a relevant factor for understanding selenium concentrations in the reservoir.

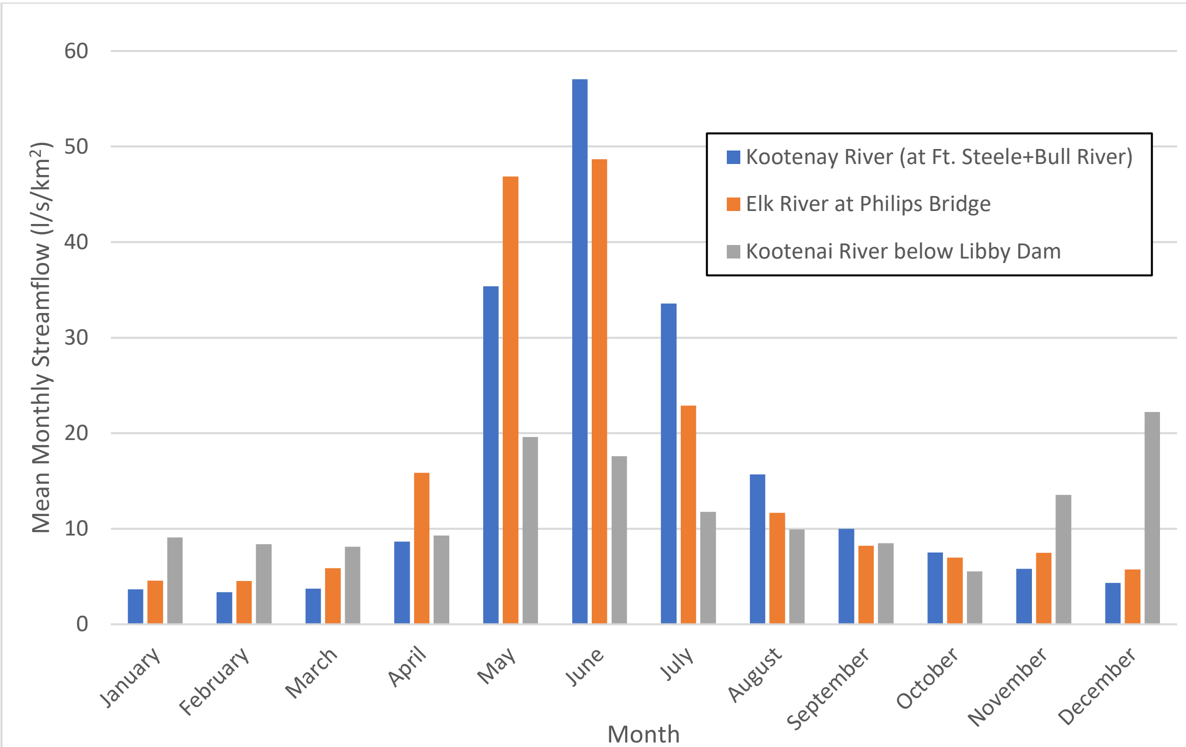
Table 1. Watershed statistics for the Kootenai/y River watershed.

Watershed Statistics			
Watercourse	Drainage Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Unit Runoff ($l/s/km^2$)
Kootenay River Upstream of Koocanusa	13,520	205	15
Elk River	4,380	69	16
Kootenai River Below Libby Dam	23,310	300	13

Notes:

1. Watershed areas calculated using the BC Water Tool (https://nr-bcwat.bcwatertool.ca/)
2. Flow data sourced from Water Survey of Canada (Elk, Kootenay and Bull Rivers; https://wateroffice.ec.gc.ca/index_e.html) and USGS (Kootenai River; https://waterdata.usgs.gov/nwis/uv?site_no=12301933&legacy=1) websites. Data for the 1976-1995 concurrent period of record were used to calculate mean annual flow.
3. Kootenay River Upstream of Koocanusa flow calculated as the sum of Kootenay River at Ft. Steele and Bull River Near Wardner monthly data, prorated by drainage areas.

Figure 2. Mean monthly flow volume per watershed area for the Elk and Kootenay rivers (1964-1995) and Kootenai River (2015-2025).



Reservoir Water Level

The seasonal streamflow distribution in the Kootenai River downstream of the reservoir (in the US) is notably different than the inflow distributions, owing to the regulation of discharge through dam operations (Figure 2). During the snowmelt freshet, reservoir outflows per unit area are much less than inflows. This relationship reverses in the late fall and winter months. This difference is a result of operation of the Libby Dam, which is optimized for flood mitigation, electrical generation, recreation, and White Sturgeon recovery (USACE 2025a). Dam operations were revised in 1995 to improve the flow regime in the Kootenai River to support White Sturgeon recovery, and again in 2006 to improve ecological processes in the river (Rood et al. 2024). Prior data do not represent the modern outflow hydrograph and are not included in Figure 2. Reservoir volume and level are reduced over the winter months by increasing outflows to both produce electricity and to make room to store inflows expected during the following spring snowmelt freshet. During the spring freshet, a portion of the inflows are used to refill the reservoir storage rather than being transferred downstream, which increases the reservoir volume and water level. This is followed by a summer and early fall period where reservoir levels and volumes are more constant and inflows better match outflows. The reservoir is gradually drawn down during the winter months by increasing outflows above inflow rates.

The historical fluctuations in reservoir water level are shown in Figure 3. Seasonal fluctuation in reservoir level is shown in Figure 4, which depicts the range in water levels measured between 2013 and 2018 (Teck 2021).

Figure 3. Koocanusa Reservoir water level at the Libby Dam Forebay, 1975 to 2025.

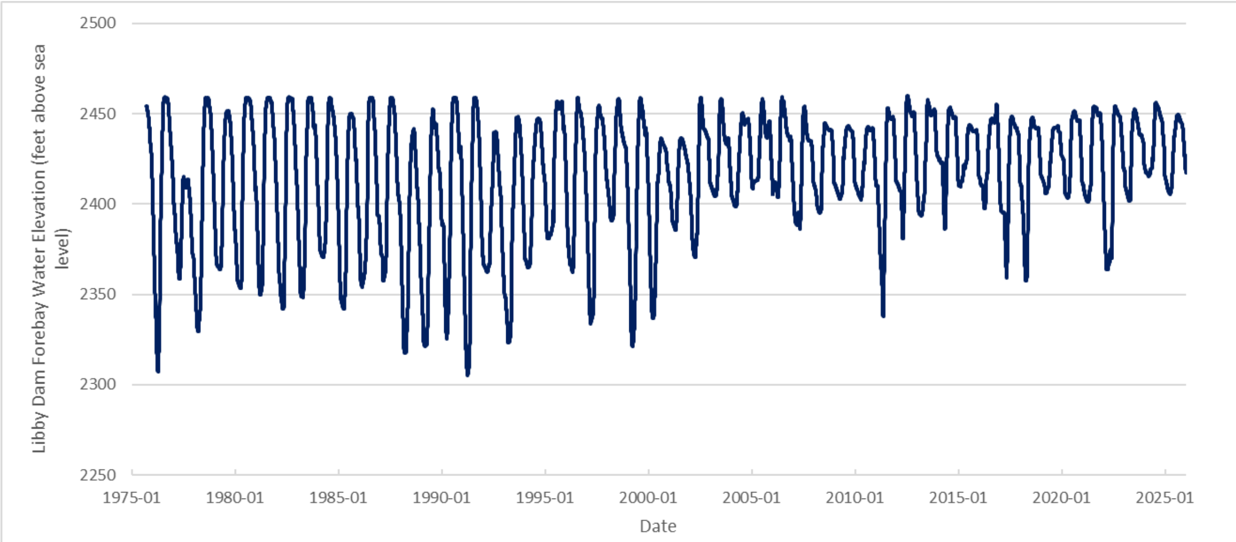
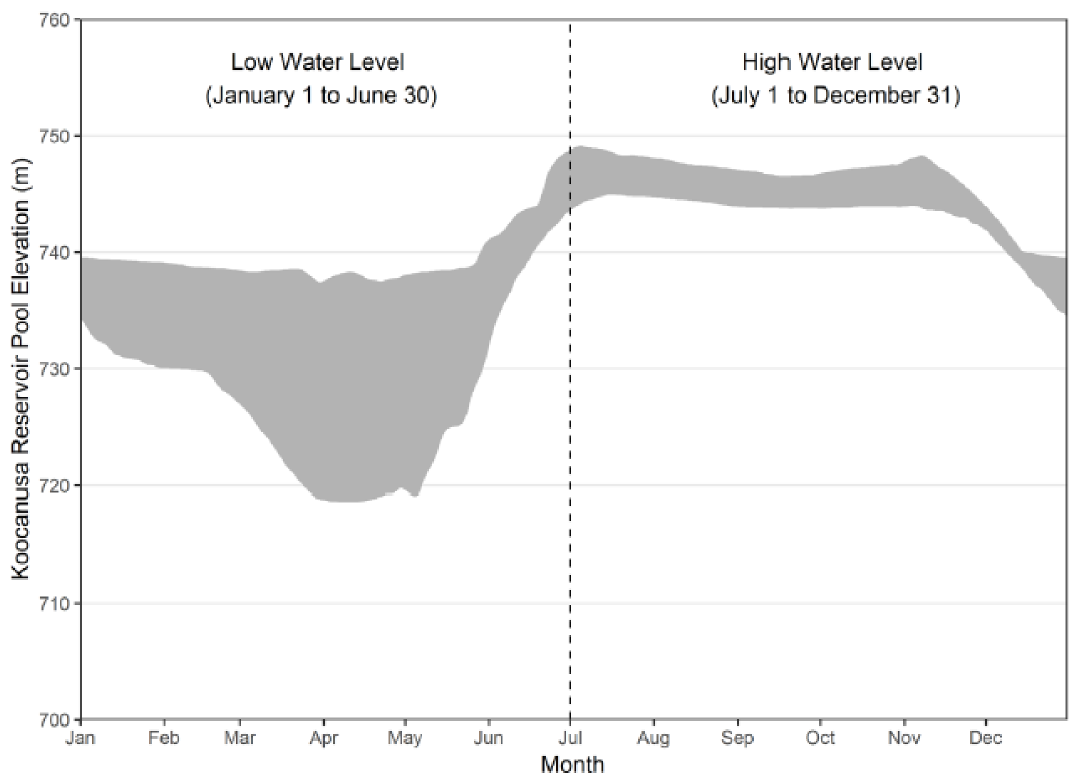


Figure 4. Range of seasonal changes in Koocanusa Reservoir water levels between 2013 and 2018 (Teck, 2021).



Source: Data were obtained from the United States Army Corps of Engineers (USACE 2018).

Figures 4, 5, 8 and 9 are from the *Koocanusa Reservoir Module: Modelling Methods and Calibration* report (Teck 2021), a document that provides detailed characterization of the hydrology and mixing conditions in the reservoir.

Figure 5 depicts the spatial extent of the reservoir surface during high volume/water level conditions in blue-grey and low volume/water level conditions in red. The high-water level conditions are based on Natural Resources Canada imagery while the low-water level conditions are delineated from satellite imagery captured in April 2018. The figure demonstrates how seasonal fluctuations in water volume and level can have a considerable effect on the aquatic habitat conditions in the Canadian portion of the reservoir. This is particularly true upstream of the Grasmere monitoring location. On an annual cycle, the northern reach of the reservoir fluctuates from lacustrine (Figure 6) to riverine (Figure 7), and back to lacustrine conditions in the span of weeks. Further downstream and closer to the international border, conditions are more consistently lake-like throughout the year.

Figure 5. Surface area of Koocanusa Reservoir at high water and low water conditions.

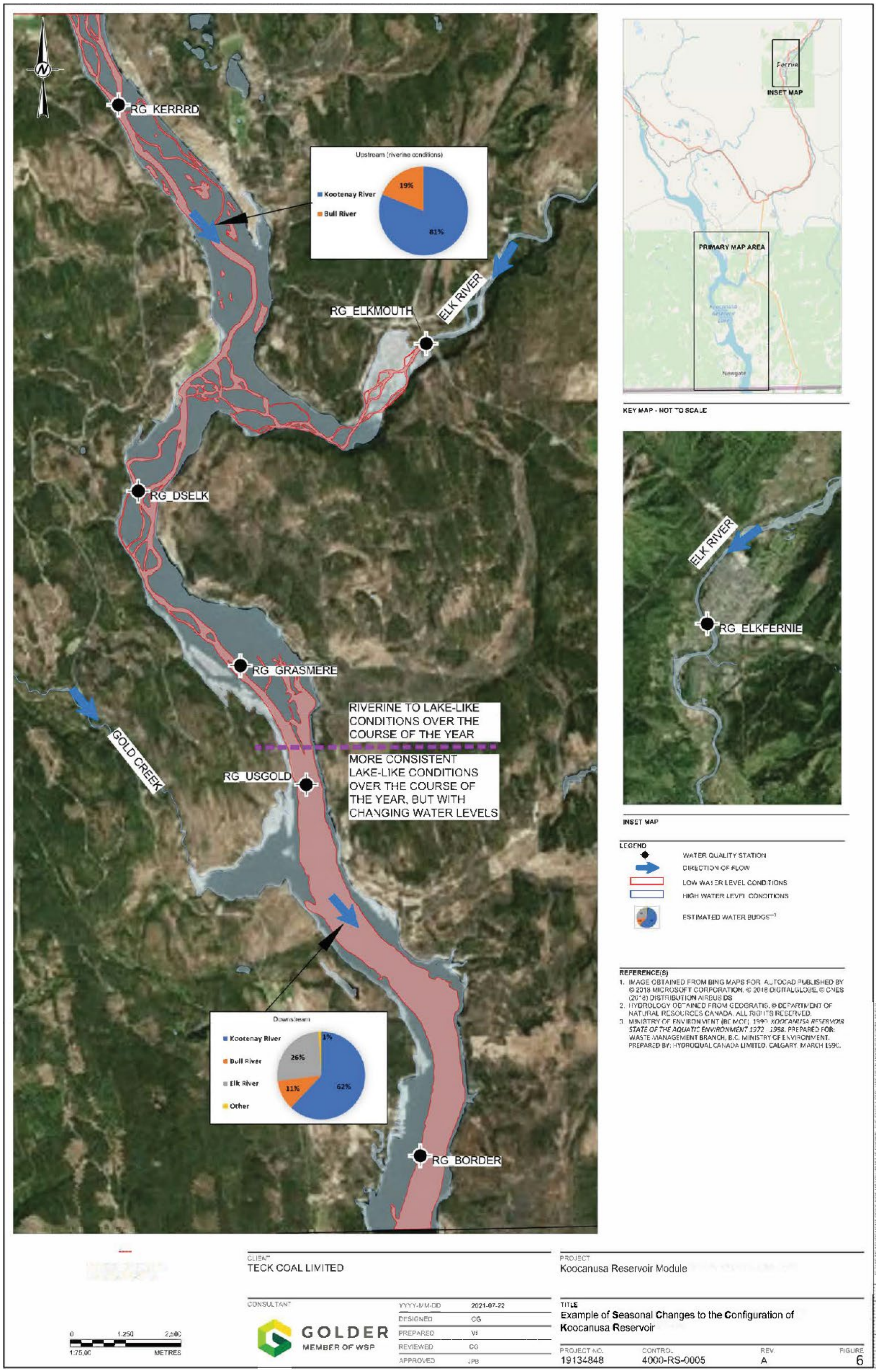


Figure 6. Koocanusa Reservoir at Yaqakxaqłamki Boat Launch during near-full pool conditions (September 23, 2022).

Figure 7. Koocanusa Reservoir at Yaqakxaqłamki Boat Launch during low pool conditions (May 9, 2022).

Mixing in the Canadian Portion of the Reservoir

The seasonal change between riverine and lacustrine conditions also influences how water from the Elk River mixes with the reservoir. Mixing between the Elk River and Koocanusa Reservoir waters is presented graphically in Figures 8 and 9 (Teck 2021). The figures use specific conductivity measured at multiple depths across twenty transect locations to observe how the Elk River water mixes with the reservoir. Specific conductivity was used in the analysis because it can be measured in the field at multiple depths in the water column, and because it can be used as a reliable tracer for Elk River water which has a higher specific conductivity (primarily owing to more soluble parameters from mine waste rock) than the Kootenay River or mixed reservoir waters.

Under riverine conditions (Figure 8), flow from the Elk River rapidly mixes vertically while lateral mixing is gradual and notably incomplete until waters reach the Grasmere monitoring location. Under lacustrine conditions (Figure 9), colder and denser Elk River waters tend to sink below warmer reservoir water. Vertical mixing is slow under lacustrine conditions, with indications of notably incomplete mixing as far south as the Gold Creek monitoring location. Mixing under transitionary and lacustrine conditions can be further influenced by upstream or downstream movement of ambient reservoir water induced by changes in dam operations or strong winds.

Figure 8. Specific conductance profiles of the Koocanusa Reservoir in April 2018.

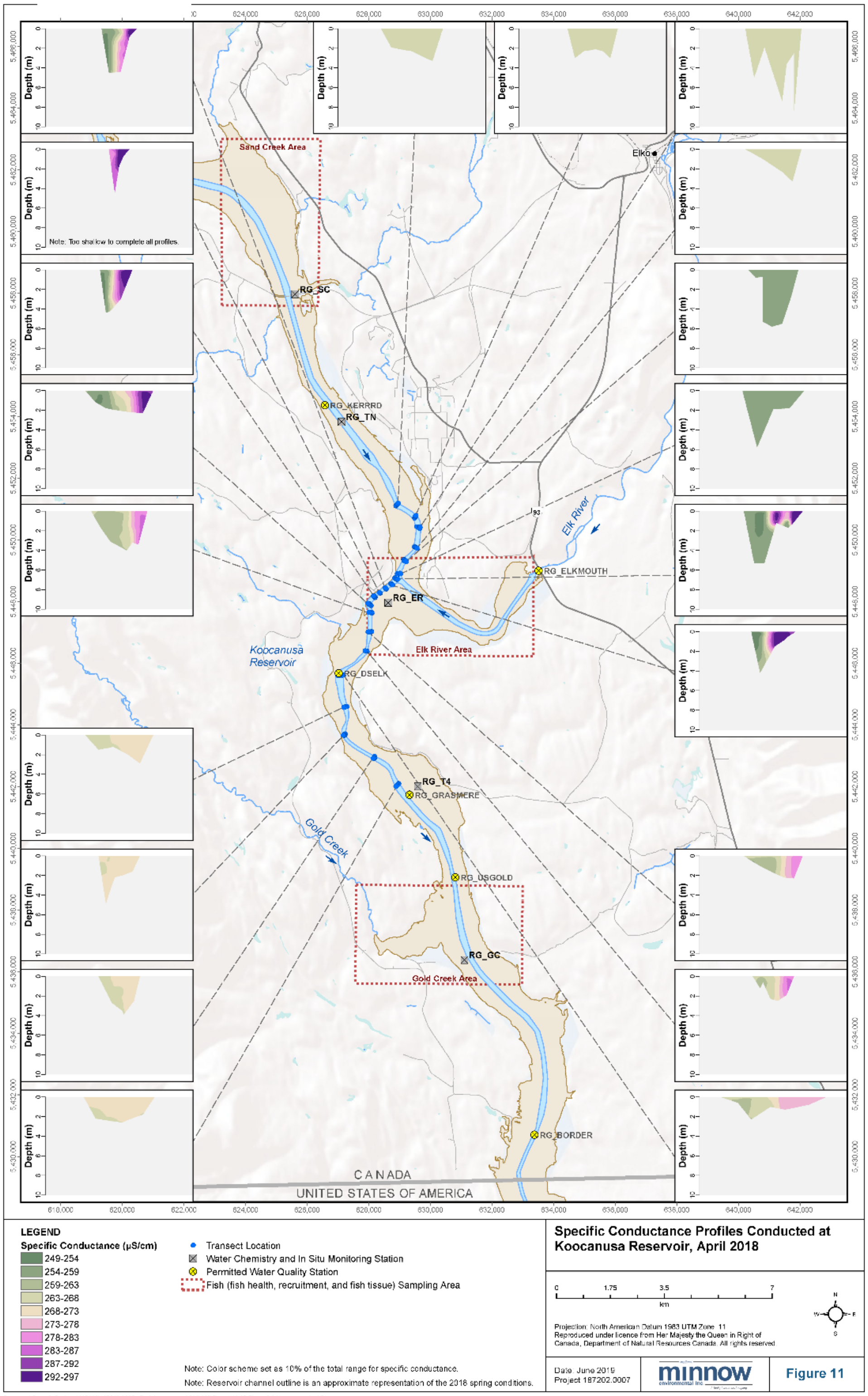
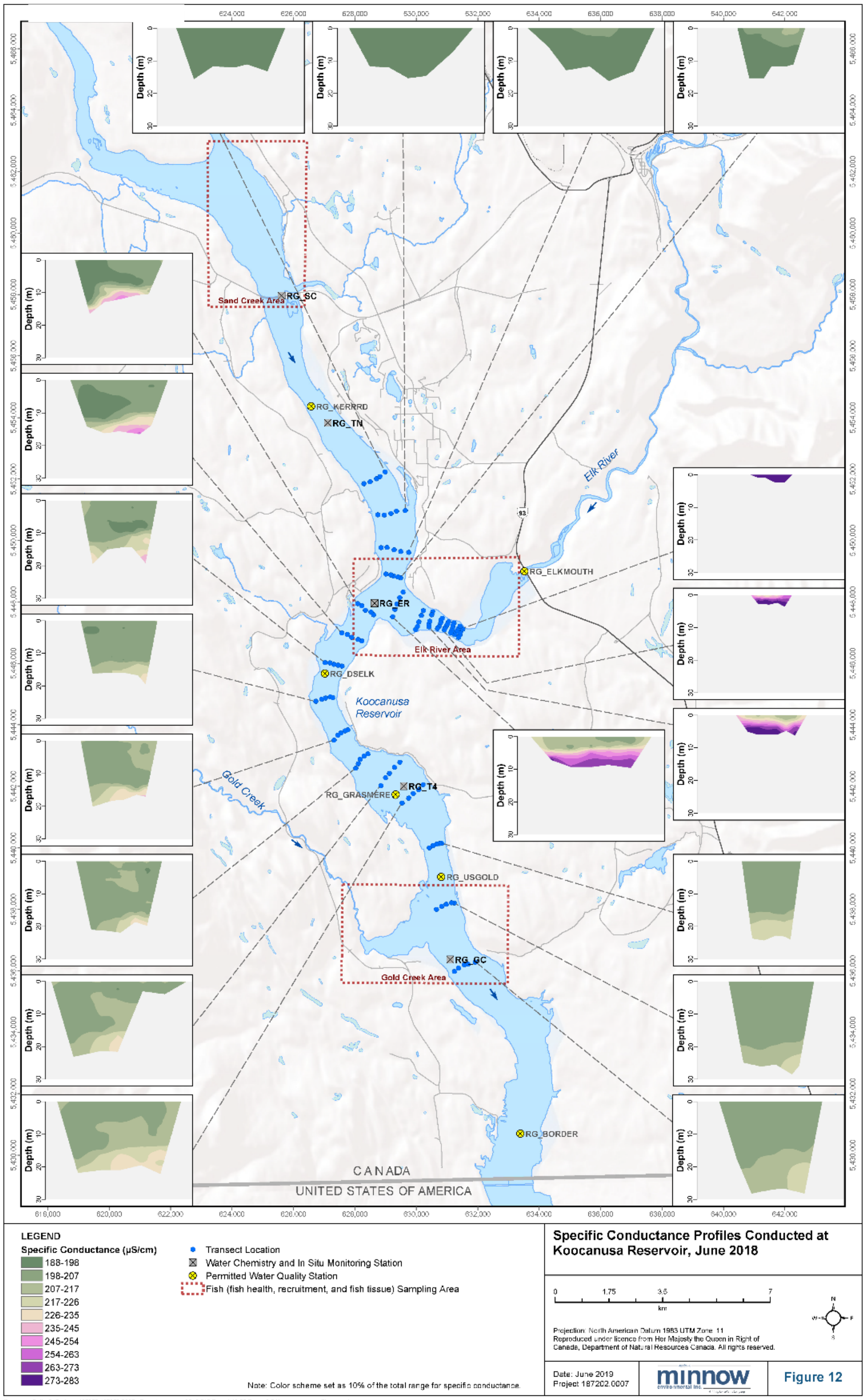


Figure 9. Specific conductance profiles of the Koocanusa Reservoir in June 2018.



On an average annual basis, Elk River watershed drainage represents approximately one quarter of the water in the reservoir, with the Kootenay River making up almost three quarters. Upon entering the reservoir, the Elk River partially mixes with stored reservoir volume and Kootenay River inflows. The influence of both seasonal and interannual variability in dam operations as well as the seasonal and interannual variability in influent streamflow conditions results in a complex hydrologic environment within the Canadian portion of Koocanusa Reservoir, and dynamic and spatially variable mixing between the Elk River and reservoir waters.

During the spring months of April and May, discharge from the Elk River is typically at its highest proportion compared to flow in the Kootenay River. At the same time, particularly in April, reservoir volumes are typically at their lowest. The combination of these two factors, reservoir operations and relative streamflow, typically results in the lowest amount of dilution of Elk River flow.

Water Quality

Water Quality Sampling Locations

Concentrations of selenium have been consistently measured at five locations in the Canadian portion of Koocanusa Reservoir since 2015. Four monitoring stations are located downstream of the Elk River confluence while one location, Kikomun, is located upstream (Figure 1). Selenium concentrations are also monitored upstream of the reservoir at numerous locations throughout the Elk and Kootenay rivers and their tributaries.

The most relevant active stations for understanding selenium inputs to the reservoir are the Elk River monitoring stations at Highway 93 and at Fernie, and the Kootenay River stations at Fenwick and above the Bull River. The Kootenay River and the Elk River at Fernie stations are proximate to Water Survey of Canada (WSC) hydrometric monitoring locations and enable calculation of selenium load (mass per unit time), while the Elk River at Highway 93 monitoring location provides insights into long-term trends and a direct measure of the aqueous selenium concentration entering the reservoir. The locations of monitoring locations are presented in Figure 1, while station metadata are reported in Table 2.

Water quality monitoring in the Elk and Kootenay rivers began prior to 2015. While these records illustrate long-term trends, this review focusses on data from 2015-2025 to characterize current conditions in the reservoir. This period aligns with when the ABMP selenium target was established and concurrent water quality, hydrology and biological data were available.

Table 2. Summary of monitoring data for the Canadian portion of the Kootenay River, Elk River and Koocanusa Reservoir.

Monitoring Location	Date range (Full Years)	Number of samples	Concurrent Hydrometric Data
Kootenay River near Fenwick (ECCC ID: BC08NG0009)	1986-2018	555	Yes; WSC 08NG065 and 08NG002
Kootenay River Above the Bull River (ECCC ID: BC08NG0013)	2021-2024	42	Yes; WSC 08NG065 and 08NG002
Elk River above Highway 93 (ECCC ID: BC08NK0003)	1987-1995 1996-2024	206 607	Yes; WSC 08NK005 No
Elk River at Fernie (EMS ID: E330533)	2015-2025	283	Yes; WSC 08NK002
Kikomun (EMS ID: E300095)	2015-2025	594	No
LK2 (EMS ID: E300230)	2015-2025	246	No
Grasmere (EMS ID: E300092)	2015-2025	236	No
Upstream of Gold Creek (EMS ID: E300093)	2015-2025	235	No
At the Canada/US Border (EMS ID: E300094)	2015-2025	237	No

Selenium Loads

Coal mine development in the Elk Valley is the primary source of selenium to the Elk River (ENV 2013a). As presented in Table 3, the Elk River contributes approximately 90% or more of the total selenium entering the reservoir, with the remaining proportion contributed by the Kootenay River and smaller watersheds which discharge directly to the reservoir. The amount of selenium estimated by ENV to enter the reservoir from these sources compares well with calculations of selenium discharged from the reservoir using data collected by the USGS (Foster et al. 2024). Total 2021-2024 loads leaving the reservoir are 2% less than loads entering the reservoir (Table 3). However, a 2% difference is within the uncertainty of the calculations. The data suggest selenium entering the reservoir remains suspended or in solution and little is retained.

Most of the selenium load enters the reservoir during the May through July snowmelt freshet (Figure 10). In the Kootenay River, the concentration of selenium is relatively constant and the load is proportionate to the flow. In the Elk River, a pulse of selenium load from mine waste rock is released during high flow periods (EVR 2025). Downstream of the reservoir, the load varies positively with the hydrograph (Figure 2).

Because a large portion of annual streamflow occurs during the spring snowmelt freshet, the inter-annual variability in the amount of selenium in the Elk River is correlated with annual streamflow, with relatively more selenium transported in wetter years and less in drier years (Figure 11). Removal of selenium from water treatment facilities at EVR's mines is an emerging influence on the amount of selenium entering the reservoir (Figure 11). Without this removal, selenium loading to the reservoir would be higher than observed (EVR 2025a). The primary factors influencing selenium loadings to the reservoir are: (1) historical and ongoing waste rock placement, which increases the potential amount of selenium that can be released each year; (2) expansions in water treatment, which decreases the amount of selenium released from the mine sites each year; and, (3) and climatic variability, with more selenium transported in freshet and during wetter years.

Figure 10. Distribution of monthly selenium load into and out of the Koocanusa Reservoir from 2021 to 2024.

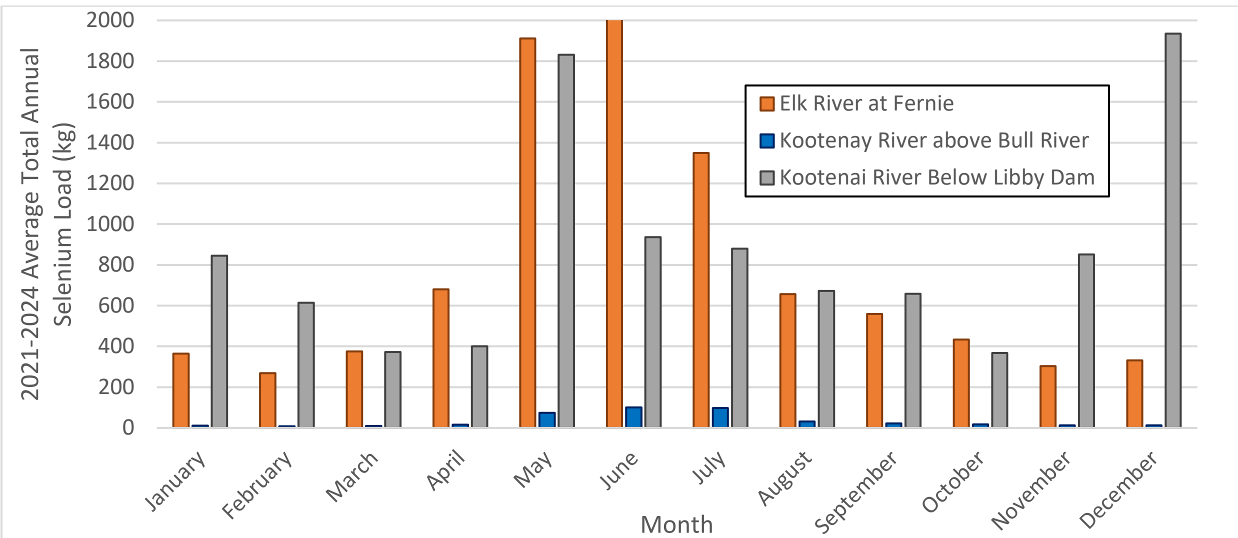


Figure 11. Comparison between annual streamflow, annual selenium load removed by treatment, and annual residual selenium load in the Elk River at Fernie.

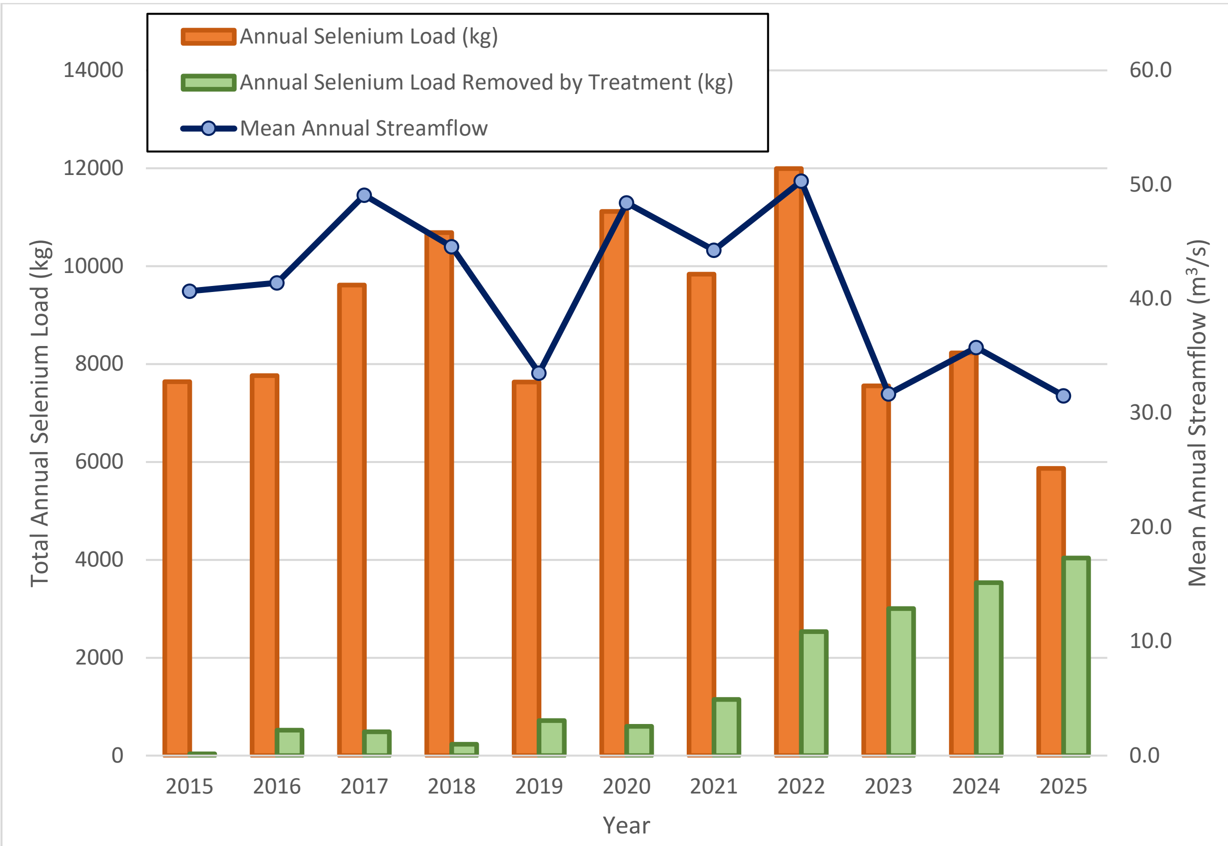


Table 3. Annual selenium load discharged into and out of the Koocanusa Reservoir from 2015 to 2024.

Location	Total Annual Selenium Load (kg)										
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2021-2024 Sum
Elk River at Fernie	7637	7766	9612	10688	7633	11114	9836	11995	7556	8230	37617
Kootenay River*	515	721				611	963	580	725	670	2938
Kootenai River Below Libby Dam							10076	12339	9115	9937	41467
% Difference (In/Out)							7%	2%	-9%	-10%	-2%

Note:

1. Selenium load was calculated using the paired water quality and hydrometric data listed in Table 2. Selenium load for the Kootenai River was calculated using total selenium and flow data from USGS monitoring station 12301933.
2. Load is calculated by multiplying the measured selenium concentration by the average daily streamflow measured on the same date. Resultant daily load values were then averaged for all samples within each month and multiplied by the days in the month to calculate total monthly load. Jan-Dec monthly loads were summed to derive annual totals.
3. Selenium was not measured at the Kootenai River station in April 2021. To calculate annual load, the April 2021 mean daily load was assumed equal to that of March 2021.
4. The Kootenay River values were multiplied by 1.77 to represent the Kootenay River and all non-mining influence watershed area contributing flow to the reservoir from Fernie to Libby Dam ((Kootenai River at Libby Dam area – Elk River at Fernie area)/(Kootenay River at Ft. Steele area) = 1.77).

Aqueous Selenium Concentrations

Concentrations in the Elk River

As the primary source of selenium, understanding conditions in the Elk River is of particular importance to understanding selenium inputs to the reservoir. Between 1986 to 2023, average annual selenium concentrations in the Elk River generally increased in parallel with mine development (Figure 12). In 2024 and 2025, selenium concentrations in the Elk River decreased. This change coincides with the implementation and expansion of water treatment at the Elk Valley coal mines (Figure 11).

Monthly selenium concentrations exhibit a seasonal variation largely inverse to the load distribution (Figure 13), with the highest concentrations occurring in the lower flow winter months and the lowest concentrations occurring during the high flow spring freshet period. These variations in concentration are primarily a result of how water moves through the mine waste rock piles in the Elk Valley and how selenium is transported into the environment. Large waste rock piles release water containing high concentrations of selenium at a relatively steady rate throughout the year. In contrast, the available flows from the surrounding catchment show high seasonal variability (EVR 2025a). The result is proportionally more dilution (and lower total selenium concentrations) but higher total loads during high flows and less dilution (and higher total selenium concentrations) but lower total loads during winter low flows.

However, this distribution may change and show more consistent concentrations throughout the year as more water treatment capacity is added at the Elk Valley mines. Treatment facilities treat proportionally more mine contact water during the lower flow periods (i.e., there is less bypass of mine contact water) and therefore have a greater influence on concentrations during these times of year (EVR 2025b). For example, the January through April 2025 monthly average selenium concentrations plotted in Figure 13 are much lower than the 2015-2024 average and comparable to the 2025 May-July freshet concentrations. These observations do not appear attributable to dilution. Monitoring in the coming years will improve understanding of these emerging relationships.

Figure 12. Aqueous total selenium concentrations in the Elk River at the Highway 93 bridge (1987-2024), at Fernie (2015-2025) and cumulative waste rock volume placed at EVR coal mines from 1987 to 2025 (EVR 2025b).

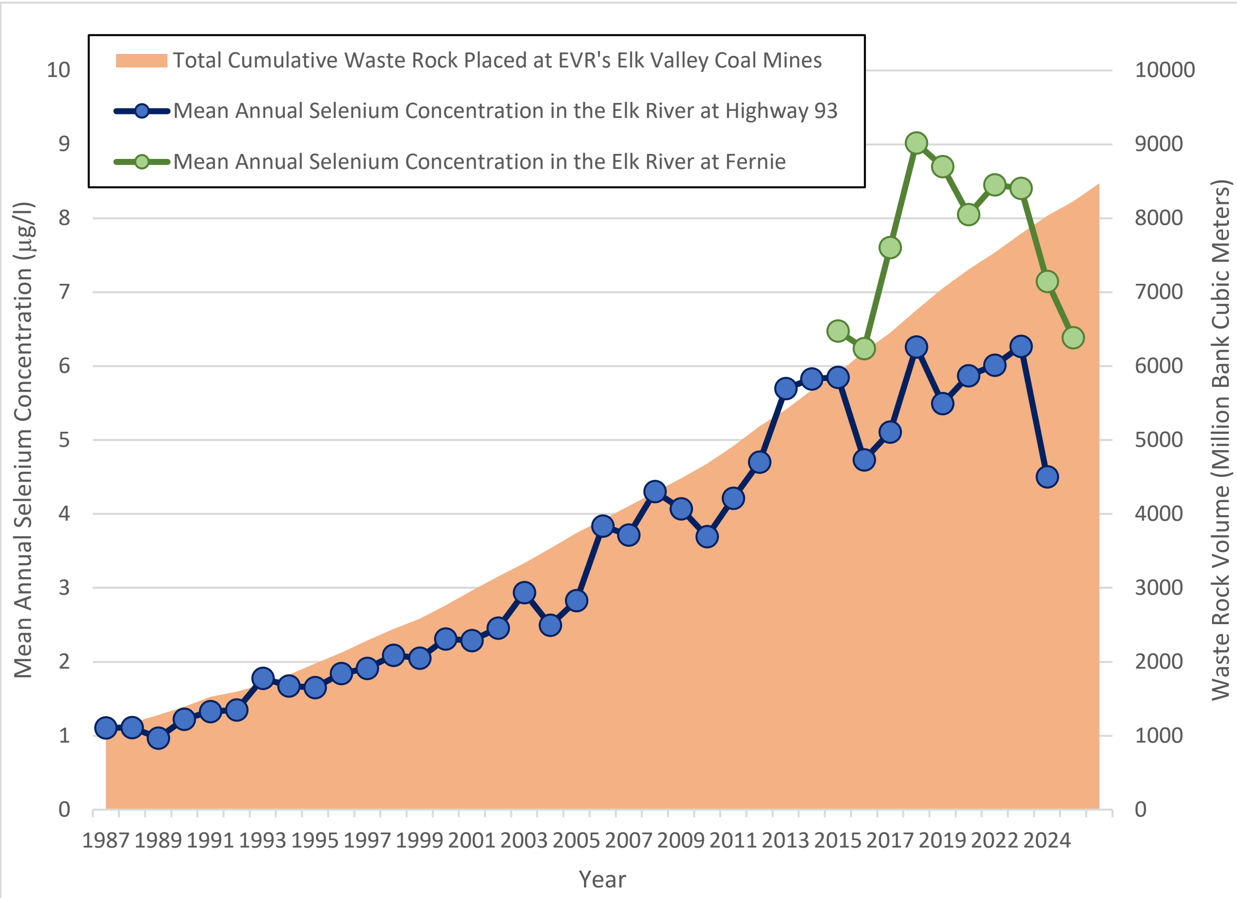
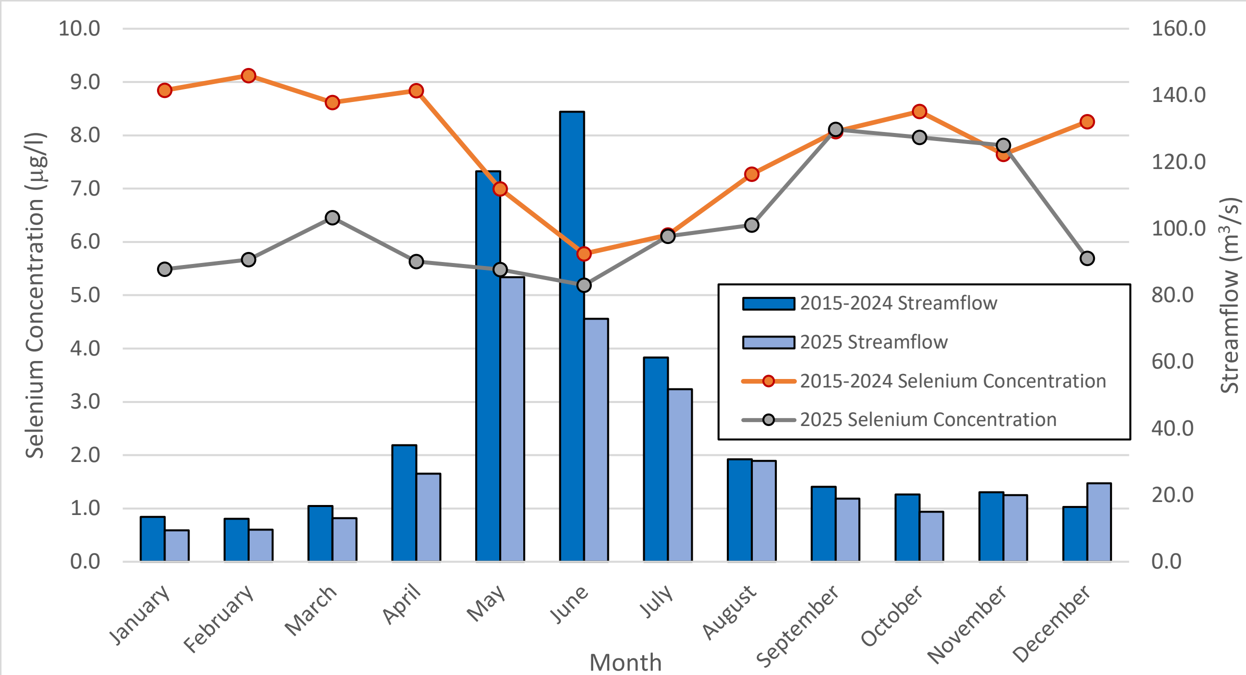


Figure 13. Aqueous mean monthly selenium concentrations in the Elk River at Fernie.



Target Attainment Sampling Methods

Selenium concentrations in Koocanusa Reservoir at LK2 between 2015 and 2025 are presented in Figure 14. The reported concentrations are the average of all monitored values collected in each calendar month. The monitoring values themselves are also calculated and are the average of samples taken at multiple depths at a single monitoring location (2015-May 2022), and the average of all depth-averaged results from five locations across a transect (June 2022-2025). A change to a transect method in June 2022 was designed to improve estimation of average selenium concentrations within the reservoir at the LK2 location and better account for the complex and incomplete mixing between the Elk River and Koocanusa Reservoir at this location. The transect datasets are a valuable tool for understanding how selenium concentrations, and the cross-sectional area of the water column, vary spatially and temporally throughout the reservoir.

Maximum Selenium Concentrations

Maximum selenium concentrations in the reservoir consistently occur in the late winter/early spring, most frequently (although not exclusively) in April. Mean monthly concentrations between 2015 and 2025 have exceeded the Koocanusa Reservoir selenium target of 2 µg/L eleven times (Figure 14) with the most recent exceedance in April 2023. Outside of the late winter/early spring period, concentrations of selenium at LK2 have consistently been below 2 µg/L (Figure 14).

A pattern of short-duration spikes in selenium concentrations in the reservoir are attributed to a combination of three main factors which occur at this time of year:

- a rapid increase in selenium load to the reservoir from the Elk River due to freshet conditions
- low dilution from lower reservoir volumes and lower Kootenay River inflows
- somewhat higher concentrations in the Elk River in April compared to other times of year

A closer examination of these relationships using data from 2023 and 2024 is provided in Box 2.

Box 2. Drivers of selenium concentrations in the Canadian portion Koocanusa Reservoir.

A comparison of concentrations in the reservoir between 2023 and 2024 can help illustrate influences on measured selenium concentrations at LK2. For example, the April 2023 average selenium concentration measured in the reservoir at LK2 exceeded the target of 2 µg/L and was much higher than concentrations measured in any other month that year (Table 4). However, April concentrations in the Elk River were only the 8th highest monthly average measured in 2023. This suggests that the spike in reservoir concentrations was influenced by factors beyond Elk River water quality. The spike aligned with the lowest reservoir levels and lowest Kootenay/Elk River flow ratio of 2023, and it is inferred that the irregularly high selenium concentration in the reservoir was a function of the low-dilution conditions.

The understanding that low dilution drives spring maximum reservoir concentrations is further supported when comparing concentrations between years. For example, the average concentration of selenium in the Elk River in April 2024 was approximately 1.2 µg/L greater than in April 2023 (Table 4), and yet the resultant April peak in reservoir concentration was 34% lower in 2024 than in 2023. Both the reservoir water level and Kootenay/Elk River flow ratios were much higher in 2024 than in 2023, and it is inferred that the lower peak selenium concentration in the reservoir in 2024 reflects increased dilution.

Also apparent in the data record is the pattern of a concentration spike in April, even when the mixing ratio, reservoir level, and Elk River concentrations do not appear to support a spike. For example, the mean April 2024 selenium concentration at LK2 was more than 50% higher than any other month that year. However, the Elk River selenium concentration, reservoir water level and Kootenay/Elk flow ratio were all similar to measurements in January, February and March 2024. Spikes in reservoir selenium concentrations were not observed in these months.

The April 2024 aqueous selenium spike at LK2 is inferred to be a result of the rapid increase in selenium load to the reservoir at that time of year. While complex hydrodynamic and chemical modelling of the reservoir is likely required to better understand this inference, it is nonetheless expected to be an important factor contributing to April spikes in most years. On average, the selenium load entering the reservoir in April doubles as compared to prior low flow months (Figure 11), and this doubling also occurred between March and April 2024. While dilution from the Kootenay River kept pace with the selenium load increase between March and April in 2024, the reservoir volume was largely static, resulting in relatively more load per mixing volume (Kootenay River plus reservoir volume) and a spike in April concentrations, albeit a much lower peak than in the previous four years.

The examples provided in Box 2 show that maximum April concentrations observed in the reservoir are not directly correlated with concentrations in the Elk River. These annual peaks are influenced by a complex interaction between selenium loads and dilution provided by both the reservoir and the Kootenay River.

Figure 14. Monthly selenium concentrations at Koocanusa Reservoir station LK2. Disconnected segments represent months with no samples, typically owing to dangerous site conditions such as thin ice.

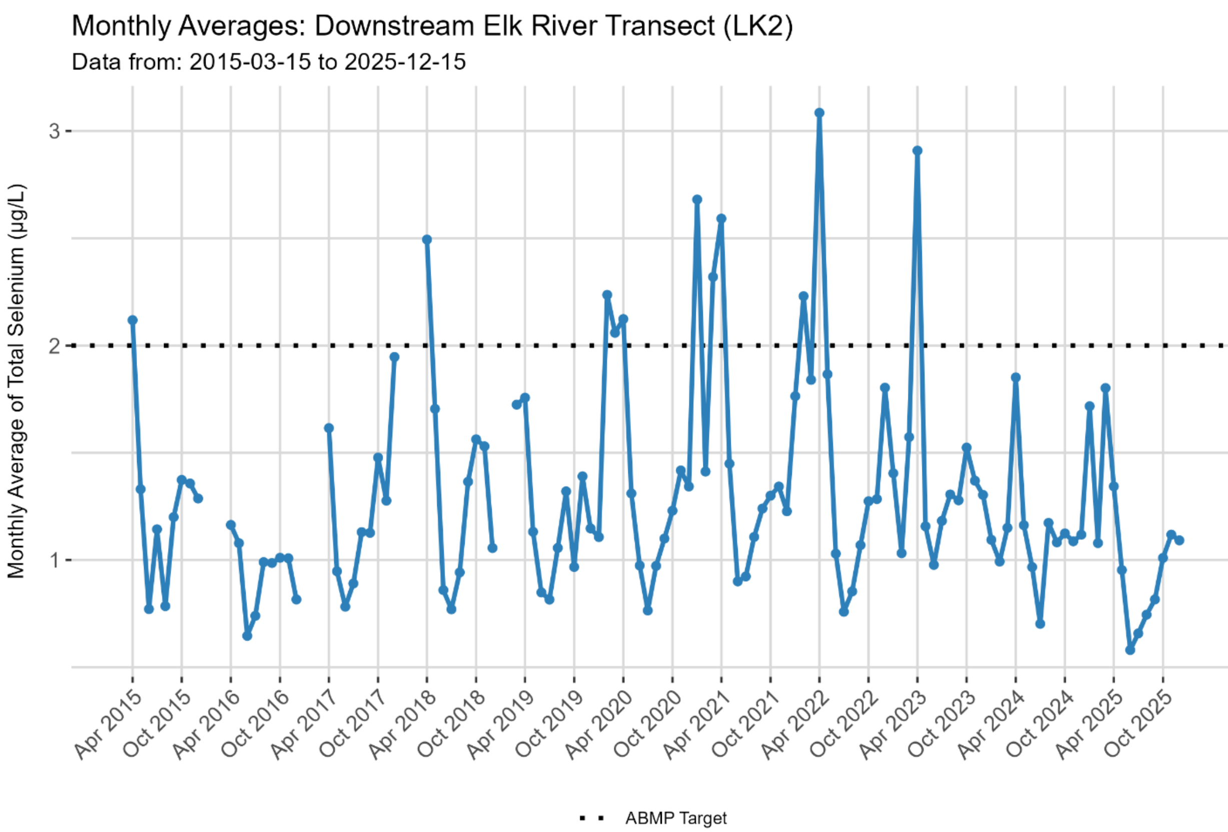


Table 4. Monthly average flow ratios between the Kootenay River and the Elk River and Koocanusa Reservoir water levels in 2023 and 2024.

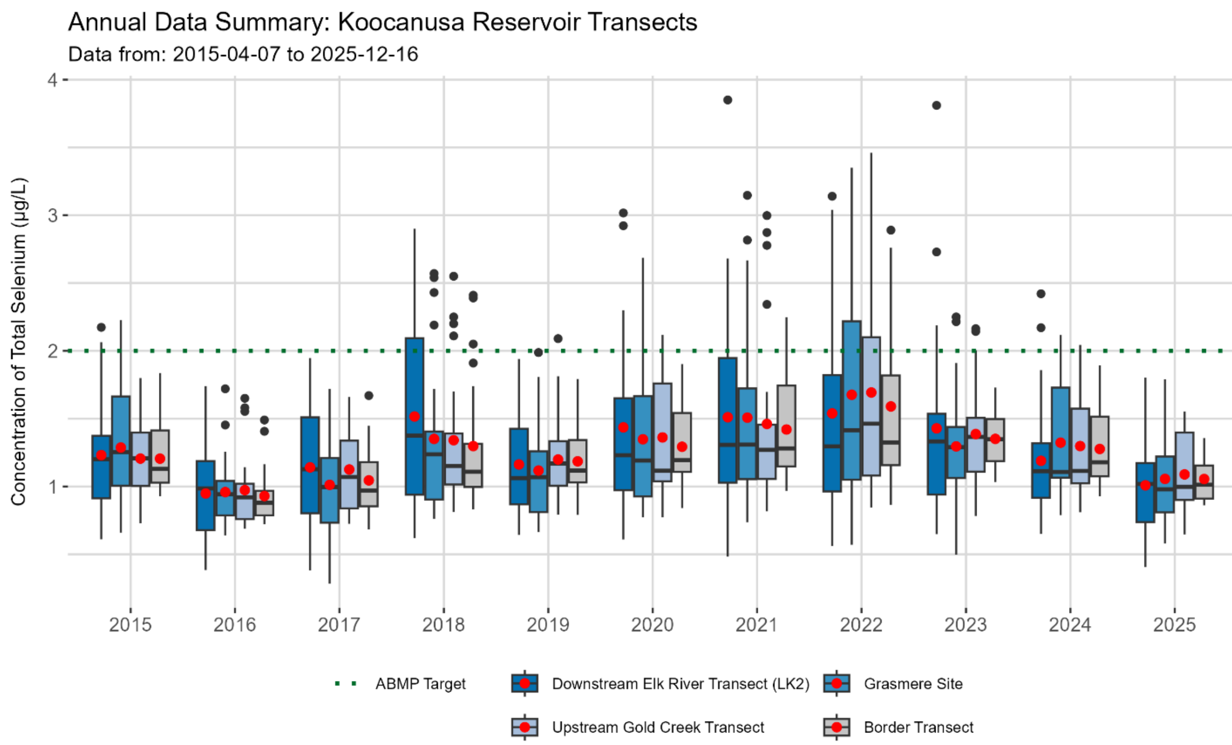
Location	2023 Monthly Averages											
	January	February	March	April	May	June	July	August	September	October	November	December
Selenium Concentration at LK2 (µg/l)	1.4	1.0	1.6	2.9	1.2	1.0	1.2	1.3	1.3	1.5	1.4	1.3
Selenium Concentration in the Elk River at Fernie (µg/l)	10.3	10.1	9.4	7.6	6.6	7.5	7.5	8.8	9.7	8.9	6.6	7.9
Flow Ratio (Kootenay+Bull)/Elk at Fernie	3.1	5.6	2.8	2.7	5.2	6.3	5.5	4.8	4.0	4.8	4.2	3.5
Forebay Water Level (feet above sea level)	2416	2408	2404	2402	2427	2447	2452	2448	2443	2438	2437	2430
	2024 Monthly Averages											
	January	February	March	April	May	June	July	August	September	October	November	December
Selenium Concentration at LK2 (µg/l)	1.1	1.0	1.2	1.9	1.2	1.0	0.7	1.2	1.1	1.1	1.1	1.1
Selenium Concentration in the Elk River at Fernie (µg/l)	8.8	8.8	8.2	8.8	6.8	5.9	5.4	6.1	6.6	7.3	6.6	6.3
Flow Ratio (Kootenay+Bull)/Elk at Fernie	4.5	3.4	3.4	3.6	4.5	4.9	6.0	4.7	4.7	5.5	5.3	4.8
Forebay Water Level (feet above sea level)	2419	2417	2416	2418	2423	2436	2455	2454	2452	2448	2442	2427

Spatial Variability

Selenium concentrations at all monitoring locations in the Canadian portion of the reservoir downstream of the Elk River are summarized in Figures 15 and 16. The stations downstream of the Elk River show similar concentrations across sites with some year-to-year variability (Figure 15). Prior to 2022, the annual mean monthly values at LK2 show higher concentrations than downstream locations for most years. This pattern has changed. Since 2022, mean values at LK2 have been below the downstream

Koocanusa Reservoir sampling stations (Figure 15), and this likely reflects the change from single point location sampling to the transect sampling method. In general, sampling locations further downstream show less variability than upstream locations and this may reflect spatial variability in mixing patterns. Within-site annual variability has reduced since changing to the transect method (spread in box plots from 2015-2022 is generally greater than for 2023-2025), a period that also coincides with the expansion of water treatment in the Elk Valley.

Figure 15. Annual mean daily selenium concentrations at four water quality monitoring stations in Koocanusa Reservoir downstream of the Elk River from 2015 to 2025.

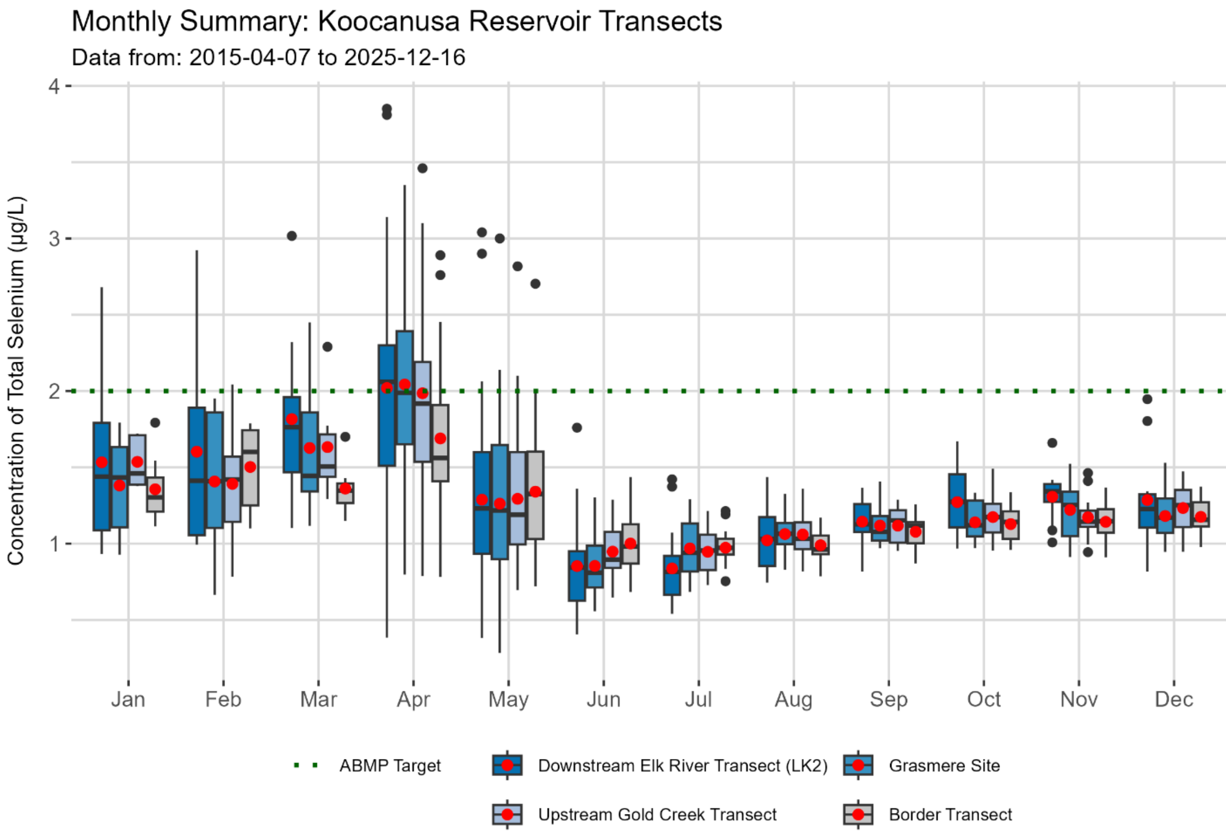


Notes: Red circles represent the mean value, whiskers indicate minimum and maximum values, the box represents 50% of the data, with lines at the 25th (bottom) and 75th (top) quartiles, and median shown as the middle line of the box. Black circles represent outliers. This applies to subsequent figures.

Seasonal Variability

Consistent with LK2, all stations show the highest concentrations in the late winter or early spring when the reservoir volumes and Kootenay River mixing are at their lowest. Concentrations are considerably lower the remainder of the year (Figure 16).

Figure 16. Monthly selenium concentrations at four water quality monitoring stations in Koocanusa Reservoir downstream of the Elk River from 2015 to 2025.



Annual Average Concentrations

To understand changes in selenium concentrations in the Canadian portion of Koocanusa Reservoir it is useful to understand the mechanism and relationships that drive seasonal peak concentrations as discussed. Aqueous selenium is not acutely toxic at concentrations observed in the reservoir. Selenium toxicity to egg-laying vertebrates is generally driven by long-term dietary exposures. Further, selenium toxicity is a function of selenium levels in ovary and egg tissues, which reflect exposures over the ovary developmental period which spans several months and with timing that varies by species (USEPA, 2024). Therefore, it is important to understand levels of selenium using averaging periods in the environment reflecting exposure periods relevant to invertebrates and fish. This review examines annual average concentrations and recognizes that additional analyses of differing averaging periods, such as growing season averages, could be informative.

Selenium concentrations at LK2 and three other downstream sites averaged over the calendar year showed an increasing trend between 2015 and 2022 (Figure 15), which corresponded with monitoring data from the Elk River (Figure 12). These temporal patterns in selenium levels in the Koocanusa Reservoir and downstream were also described in Storb et al. (2023) and Foster et al. (2024). In contrast, annual average concentrations have decreased in the Elk River and Koocanusa Reservoir since 2023 and are now comparable to 2016 (Figures 12 and 15). The average monthly selenium concentration at LK2 from 2020 to 2023 was 1.48 µg/L (Table 5). In 2024, the average monthly selenium concentration was

1.19 µg/L and in 2025, the average was 1.01 µg/L. Similar declines in selenium concentrations were shown by all monitoring stations downstream of LK2 (Figure 15).

Table *5. Average selenium concentration at LK2.*

Date Range	LK2 (µg/L)
Average Monthly Selenium Concentration 2020-2023	1.48
Average Monthly Selenium Concentration 2024	1.19
Average Monthly Selenium Concentration 2025	1.01

Observed reductions in selenium levels in Koocanusa Reservoir are inconsistent with the expectation of increasing selenium concentrations proportionate to cumulative waste rock placement. While recognizing that climate variation and changing flows have a strong influence on selenium loads and concentrations (Figures 11 and 13), there is evidence that water treatment at Elk Valley mines is contributing to observed changes in aqueous selenium concentrations. Flattening of seasonal selenium concentration variability (Figure 13), increasing selenium removal by water treatment facilities, and an emerging separation between Elk River flows and loads (Figures 11) are examples. Improvements to measured selenium concentrations in Koocanusa Reservoir and the Elk River are also consistent with model projections that account for increasing waste rock and water treatment at the Elk Valley coal mines (EVR 2025b).

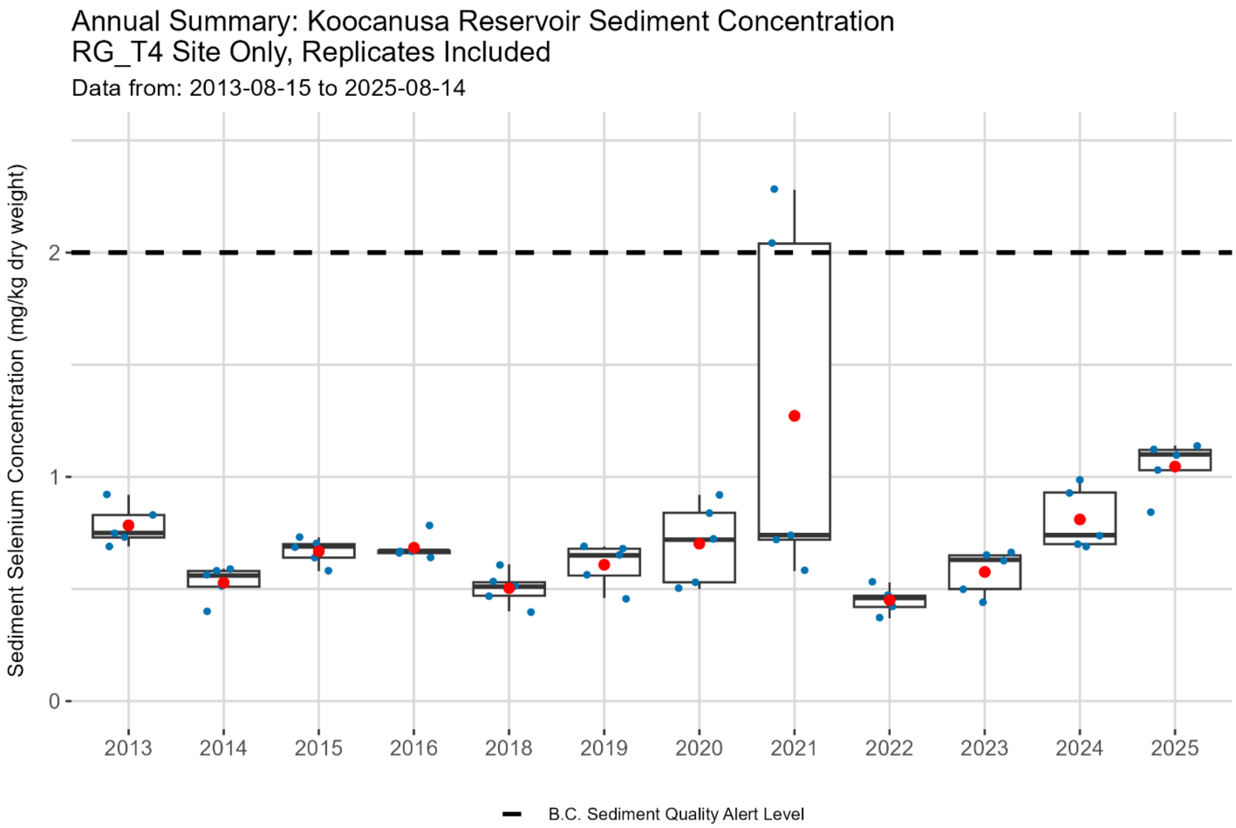
Sediment

Selenium-impacted sediment is a viable pathway into the base of the aquatic food chain. Assimilation by benthic invertebrates living in sediment can lead to trophic transfer and bioaccumulation in higher trophic biota.

BC has adopted an alert concentration for selenium in sediment rather than a guideline due to insufficient supporting studies. An alert concentration is an early-warning indicator that additional assessment and investigation may be required to assess potential risks. Alert levels can promote early detection of potential selenium bioaccumulation and inform management decisions (ENV 2014). The chronic sediment quality selenium alert concentration to protect aquatic life is 2 µg/g dw.

Sediment data is collected in Koocanusa Reservoir each August from transects upstream and downstream of the Elk River as part of EVR's Koocanusa Reservoir Monitoring Program (Minnow 2024). Koocanusa Reservoir sediment data were available from 2013 to 2024. Over this period, 2 out of 105 sediment samples collected downstream of the Elk River at Grasmere (Station T4) had concentrations above the alert level (2.28 and 2.04 µg/g dw), both collected in 2021 (Windward 2025, Figure 17). Sediment concentrations have increased over the past four years; however, they are within the range of variability since 2013 and remain well below the alert level concentration.

Figure 17. Annual selenium concentration in sediments in Koocanusa Reservoir, 2013-2025. Note: sediment was not sampled in 2017.



Note: No data available from 2017. Dashed line indicates the BC alert level. The red dot in the box represents the mean.

A study on selenium loads in the Elk-Kootenai/y watershed concluded that Koocanusa Reservoir was not an important selenium sink (Foster et al. 2024). The Foster study used modelling to determine that most of the selenium load from Elk Valley mines was transported through two riverine reservoirs to the Columbia River with minimal losses over hundreds of kilometers. The research suggested that alkaline and oxidated waters favoured the mobile form of selenium (selenate), potentially contributing to the long-range transport of this substance (Foster et al. 2024).

Data available for the Canadian portion of Koocanusa Reservoir indicate negligible risk from exposure to selenium in reservoir sediment.

Aquatic Health

Koocanusa Reservoir supports a varied and diverse aquatic ecosystem that includes zooplankton, benthic invertebrates, phytoplankton, fish, birds, and other aquatic-dependent life (Baranowska and Robinson 2017). Egg-laying vertebrates such as fish and birds are among the most sensitive receptors to effects from selenium with the main exposure route being diet (ENV 2014). Fish integrate exposure from water, sediment, and food sources, and are centrally located within the food web. They consume benthic invertebrates, phytoplankton, zooplankton, and other fish, and can be consumed by piscivorous birds and mammals. The most reliable indicator of potential effects of selenium to fish is assessing selenium concentrations in fish tissue (Windward 2025) and making comparisons to species-specific effects concentrations.

While zooplankton and benthic invertebrate selenium concentrations can be important supplemental indicators of exposure and risk, fish tissue is the most sensitive metric for evaluating the potential for effects to aquatic health from exposure to selenium in Koocanusa Reservoir. To understand the risks of bioaccumulation to aquatic biota, this review includes a review of measured tissue selenium concentrations in Koocanusa Reservoir zooplankton, benthic invertebrates, fish and birds.

Guidelines and Effects Thresholds

Zooplankton and Benthic Invertebrates

BC has not developed a tissue selenium guideline for the protection of zooplankton or benthic invertebrate health. To estimate risks to benthic invertebrates from selenium bioaccumulation, the 2014 EVWQP (Teck 2014) used a tissue concentration threshold of 13 mg/kg dw selenium based on a review of EC_{10} values in the scientific literature. The EVWQP also proposed a dietary tissue selenium benchmark of 11 mg/kg dw for the protection of fish growth based on a published diet study (Teck 2014). The province developed an interim chronic dietary guideline for invertebrate (and other prey species such as zooplankton) tissue selenium concentrations to protect predator fish and aquatic-dependent wildlife (Table 6, ENV 2014). No uncertainty factor was applied to derive BC's interim chronic dietary guideline of 4 mg/kg dw selenium. For comparison, Table 6 also includes the US EPA criterion.

Table 6. The BC chronic dietary guideline to protect predator fish and aquatic-dependent wildlife and the effects concentration for benthic invertebrate growth, reproduction and survival.

Source	**Guideline, Threshold, or Criterion**	**Derivation**
BC ENV (2014)[(a)]	Interim chronic dietary selenium guideline = 4 mg/kg dw	A review of published dietary thresholds with a focus on the diet of fish and birds
2014 EVWQP (Teck 2014)	IC_{10} for fish diet = 11 mg/kg dw	Juvenile fish growth IC_{10}
2014 EVWQP (Teck 2014)	EC_{10} growth, reproduction, survival of benthic invertebrates = 13 mg/kg dw	Lowest identified EC_{10} or LOEC for benthic invertebrates
US EPA (2021)	Chronic value whole body = 24.2 mg/kg dw	Mayfly biomass LOEC (based on Conley et al. 2009)

(a) Measured as the mean concentration of at least eight composite replicate tissue samples representing appropriate invertebrate or other prey species.

Fish

Regulatory agencies in Canada have developed selenium guidelines for the protection of fish health as summarized in Table 7. This table includes guidelines from the US for comparison.

The BC WQG of 2 µg/L includes an uncertainty factor of five and is based on multiple lowest observed effect concentrations (LOECs) for fish species (ENV 2014). Although the BC water quality guideline includes an element of conservatism in its use of an uncertainty factor, it is similar to the US EPA lentic and lotic water quality criteria calculated as the 20th percentile of water concentration values translated from the egg-ovary toxicity value (US EPA 2021).

Similar to the BC WQG, the BC fish egg and ovary tissue guideline of 11 mg/kg dw was derived by applying an uncertainty factor of two to a mean EC_{10} (10% effect concentration) for rainbow trout (ENV 2014). This BC egg and ovary guideline is similar to the US EPA egg and ovary criterion of 15.1 mg/kg dw which is the 5th percentile of a genus sensitivity distribution in which White Sturgeon (*Acipenser transmontanus*) is the most sensitive receptor (US EPA 2021).

The BC interim whole body and muscle tissue guideline of 4 mg/kg dw was derived from toxicity data for several fish species and using a species sensitivity distribution to calculate an EC_{10} of 8.1 mg/kg dw that was divided by an uncertainty factor of 2 (ENV 2014). The guideline is recommended for sensitive species or for fish species for which there are no toxicity data. The mean of at least eight tissue samples from individual fish collected at a representative area is necessary for making comparisons to the guideline. In assessing fish tissue data for the development of a draft Koocanusa Reservoir Water Quality Objective, ENV and the Ktunaxa Nation Council technical staff converted the BC egg/ovary tissue guideline of 11 mg/kg dry weight (dw) to a whole-body concentration of 5.6 mg/kg dw using a conversion factor of 1.96 (US EPA 2021). The muscle tissue concentration equivalent of this value is 7.1 mg/kg dw and is the concentration used for comparison in this review. This value is more conservative than equivalent US EPA, Montana DEQ, or ECCC selenium tissue guidelines (Table 7).

Table 7. Selenium guidelines for the protection of fish.

Source	Chronic Water Quality Guideline (µg/L)	Tissue Guideline/Criterion (mg/kg dw)		
		Egg/Ovary	Muscle	Whole Body
BC ENV (2014)	2(a)	11(b)	4(c)	4(d)
BC ENV egg to whole-body conversion (Montana DEQ 2020)		11	7.1	5.6(e)
ECCC (2022)	-	14.7(f)	-	6.7(f)
CCME (1987)	1	-	-	-
US EPA (2021)	1.5 lentic, 3.1 lotic(g)	15.1(f)	11.3(f)	8.5(f)
Montana DEQ (2020)	0.8 lentic, 3.1 lotic	15.1	11.3	8.5

(a) Based on multiple LOECs for fish reproductive toxicity of approximately 10 µg/L divided by an uncertainty factor of five.
(b) Based on mean EC_{10} for rainbow trout (22.05 µg/g dw) divided by an uncertainty factor of two.
(c) interim value based on LOEC for fish reproductive toxicity with an uncertainty factor of two and calculated as the mean of a minimum of eight samples from individual fish
(d) Based on EC_{10} for reproductive toxicity using a species sensitivity distribution with an uncertainty factor of two and calculated as the mean of a minimum of eight samples from individual fish
(e) Based on a conversion of the egg/ovary guideline (11 mg/kg dw, which includes an uncertainty factor of two) to whole body using a conversion factor of 1.96
(f) 5th percentile of a genus sensitivity distribution of toxicological endpoints for fish reproductive toxicity.
(g) 20th percentile of the water concentration values translated from the egg-ovary criterion element value.
dw = dry weight; - = value not available

Selenium guidelines and criteria in both Canada and the US have been criticized as being overly conservative for the protection of freshwater fish populations (Gilron et al. 2022). Gilron and others

(2022) provided examples of field studies where fish tissue selenium concentrations exceeded guidelines but population level effects were not observed. The BC guideline was deemed overly conservative due to the use of an uncertainty factor. However, BC's WQGs are not for predicting effects. The BC WQG approach to protecting aquatic life is characterized by preventing effects to individuals and thereby protecting populations (ENV 2019). Exceedance of a BC WQG indicates a potential increase in risk or possibility of effects, whereas exceedance of an effects benchmark or species-specific effects concentration indicates a predicted effect. Species specific effects concentrations are summarized in Table 8.

Table 8. Species-specific effects threshold for fish.

Species	Selenium (mg/kg dw)			Endpoint (Source)
	Egg/Ovary	Muscle	Whole Body	
Oncorhynchus[(a)]	25.3	14.3	11.6	Geometric mean of *Oncorhynchus* EC_{10}s (US EPA 2021)
Rainbow trout (*Oncorhynchus mykiss*)	24.5	12.8	10.0	EC_{10} for edema (US EPA 2021)
Westslope cutthroat trout (*Oncorhynchus clarkii lewisi*)	26.2	16.0	13.3	EC_{10} for alevin mortality (US EPA 2021)
Dolly Varden (*Salvelinus malma*)[(b)]	56.2	44.5	34.9	EC_{10} for total deformities (US EPA 2021)
Mountain whitefish (*Prosopium williamsoni*)	>54 and >33	-	-	EC_{10} for total deformities and larval growth respectively (Brix et al. 2025a)
Redside shiner (*Richardsonius balteatus*)	>28	>22.5	-	EC_{10} for larval survival, growth, and deformities (de Bruyn et al. 2023)
Slimy sculpin (*Cottus cognatus*)	>22	-	-	EC_{10} for reproductive toxicity (Nautilus 2013)

(a) Non-species specific *Oncorhynchus* value that could be applied to *Oncorhynchus* species without species specific values such as Kokanee (*O. nerka*)

(b) *S. malma* is not reported to occur in the Koocanusa Reservoir; however, Bull Trout (*S. confluentus)* does occur in the Koocanusa Reservoir

Birds

Guidelines and criteria for bird egg selenium concentrations have been developed by Canadian and US jurisdictions (Table 9). These were based on multiple studies that examined the effect of selenium on reduced hatchability of Mallard (*Anas platyrhynchos*) eggs.

Table 9. Bird egg selenium guidelines and criteria.

Source	Egg selenium guideline or criterion (mg/kg dw)	Derivation
BC ENV (2014)[(a)]	6	Mallard egg selenium toxicity value of 12 mg/kg dw with an assessment factor of 2
ECCC (2022)	11	US EPA criterion
US EPA (2018)	11.2	EC_{10} for Mallard egg hatchability
Utah Department of Environmental Quality (2008)	12.5	EC_{10} for Mallard egg hatchability

(a) Calculated as the mean concentration of at least eight eggs from eight individual nests in a representative area, reported as dry weight.

Aquatic Health Monitoring Results

Zooplankton

Zooplankton are lower trophic biota that are key contributors to aquatic ecosystems and are important for the diet of many fish species. Kokanee, for example, primarily feed on zooplankton. Zooplankton are collected annually from a location upstream of the Elk River (TN) and downstream west of Grasmere (T4, Minnow 2025). Zooplankton tissue selenium sample numbers are provided in Table 10 for the downstream location near Grasmere.

Table 10. Zooplankton sample number per year at station T4.

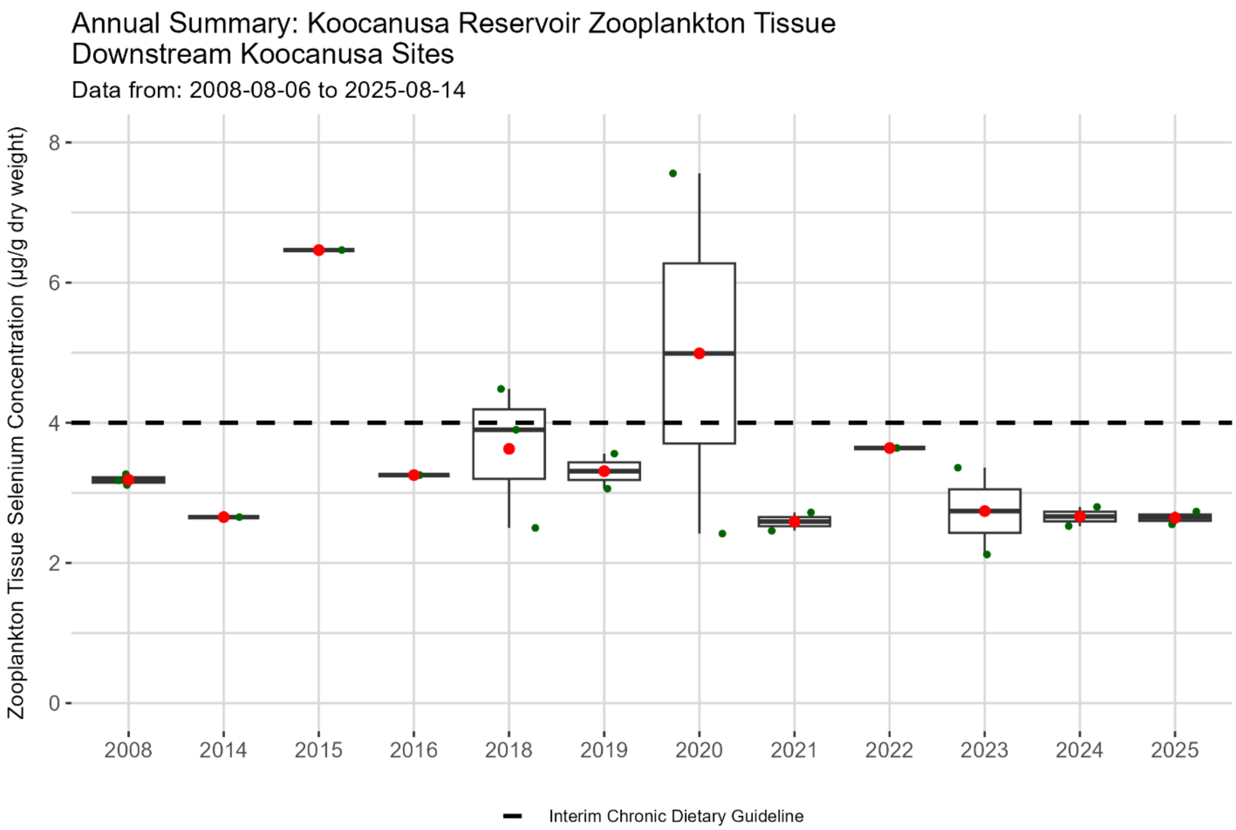
Year	Number of samples
2008	3
2014	1
2015	1
2016	1
2018	3
2019	2
2020	2
2021	2
2022	1
2023	2
2024	2
2025	3

Concentrations of selenium in zooplankton tissue exceeded BC's interim chronic dietary selenium guideline (4 mg/kg dw) in 2015 and 2020 (Figure 18). In all other years, mean zooplankton tissue selenium concentrations remained below the interim guideline. The mean concentration in 2025 (2.64 mg/kg dw) was similar to those reported for Koocanusa Reservoir in 2008 by McDonald (2009) who found an average of 2.89 mg/kg dw at Kikomun (upstream of the Elk River confluence), 3.25 mg/kg dw downstream of the Elk River mouth, and 3.11 mg/kg dw near Gold Creek.

Kokanee muscle tissue did not show a corresponding increase in 2015 or 2020 (Figure 20) and remained below guideline concentrations across all years.

Over the past five years, measured zooplankton tissue selenium concentrations have indicated negligible risk to planktivorous biota from exposure to dietary selenium. This conclusion is supported by low Kokanee tissue selenium concentrations across all years.

Figure 18*1*. Annual zooplankton tissue selenium concentrations at Koocanusa Reservoir station T4 near Grasmere.



Benthic Invertebrates

Table 11 summarizes the number of benthic invertebrate tissue from station T4 (Grasmere) across all years. This station is 10 km downstream of the Elk River confluence. The number of samples collected in each year varies and no year includes eight samples as required for comparison to the interim BC water quality chronic dietary guideline for the protection of aquatic life (4 mg/kg dw).

Table 11. Benthic invertebrate sample number per year at station T4.

Year	Number of samples
2014	2
2015	2

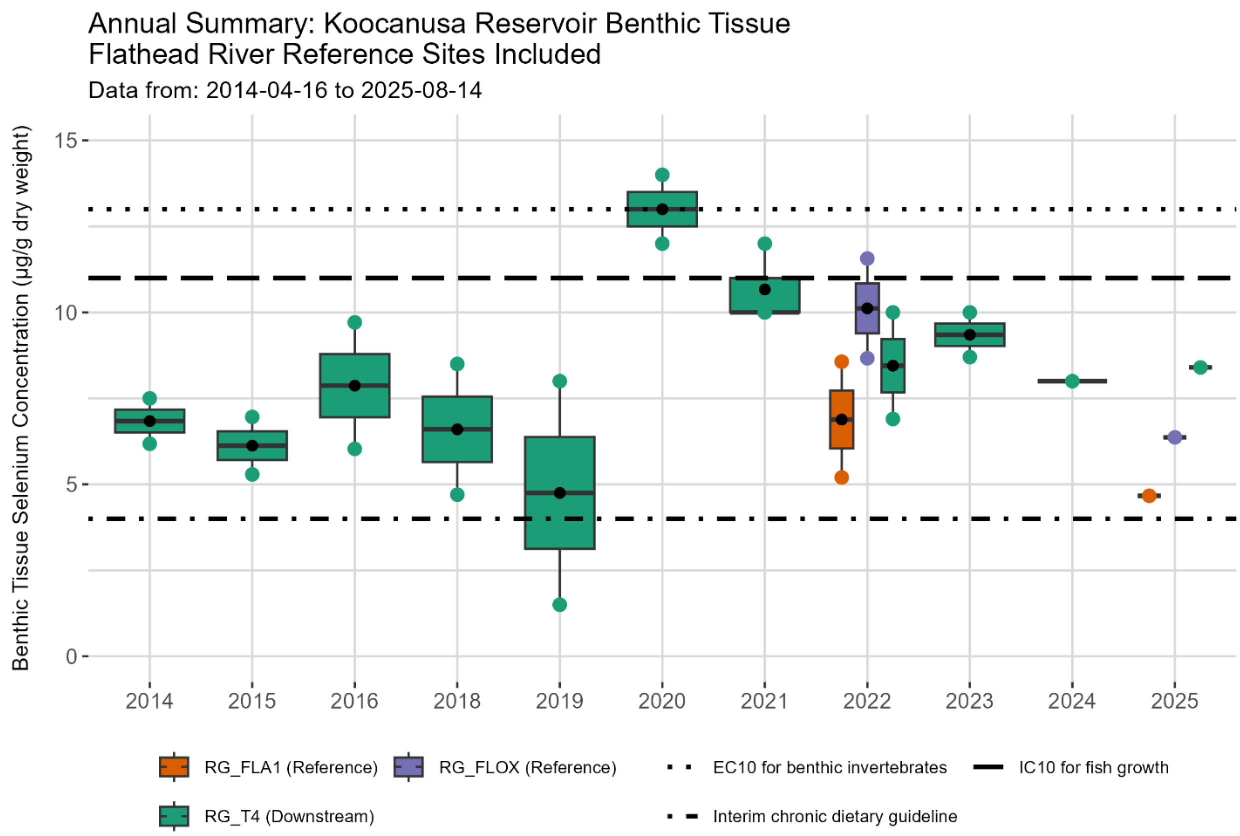
Year	Number of samples
2016	2
2018	2
2019	2
2020	2
2021	3
2022	2
2023	2
2024	1
2025	1

Nearly all benthic tissue selenium measurements were above BC's interim chronic dietary selenium guideline (Figure 19). These results are consistent with exposure to elevated aqueous selenium concentrations, but they are also comparable to tissue concentrations reported from reference lentic waters in the region (Minnow 2023). For example, lentic waters in the Flathead River watershed had average selenium benthic invertebrate tissue concentrations of 6.9 and 10.1 mg/kg dw in 2022 (Figure 19). The mean tissue selenium concentration in 2020 from the Grasmere station was 13 mg/kg dw (Figure 19), which is equal to the EC_{10}, indicating an elevated risk of effect to sensitive species. The benchmark exceedance was reported during a single sampling event in April 2020 (Minnow 2023). The limitations of this observed exceedance, both in magnitude and duration, suggest that it would be difficult to detect an observed effect in benthic invertebrate populations or a response in benthic invertebrate predators from this April benchmark exceedance. All measured tissue concentrations remained below the US EPA Species Mean Chronic Value and Genus Mean Chronic Value for sensitive mayflies of 24.2 mg/kg dw selenium (US EPA 2021). Benthic invertebrate tissue selenium concentrations in Koocanusa Reservoir have been below the dietary 10% Inhibitory Concentration (IC_{10}) for juvenile fish growth of 11 mg/kg dw in all years with exception to 2020 (Figure 19).

Koocanusa Reservoir features a low abundance of benthic invertebrates (Minnow 2018). For example, it typically requires the use of multiple dredges to collect sufficient benthic invertebrate biomass to run a single tissue analysis. Balmer et al. (2025) suggest that the abundance of aquatic insects in Koocanusa Reservoir may be influenced by fluctuations in reservoir elevation (ranging approximately 100 ft or 30 m, Figure 3), which create an "intertidal zone" (Kennedy et al. 2016), an observation documented in other regulated reservoirs and linked to the extirpation of sensitive river-edge species such as mayflies. Fluctuations in surface elevation associated with reservoirs regulated for hydropower are recognized as inhibiting viable populations of aquatic insects (Kennedy et al. 2016).

Benthic invertebrate tissue selenium is a useful supporting indicator that helps to inform understanding of this component of the food web. However, there are challenges for interpreting the level of risk from the present data set. Recognizing that it is technically difficult to obtain samples, the data set is spatially limited and has few total samples. It currently provides information about benthic invertebrate tissue selenium concentrations at one location downstream of the Elk River over an 11-year period. Historical data are available for three additional sites downstream of the Elk River. These locations do not have recent data and were not included in this review. Concentrations of selenium observed in benthic tissues at the Grasmere location in Koocanusa Reservoir are consistently above interim chronic dietary guidelines, a threshold also exceeded in reference areas in the region; however, there is no clear temporal trend. Benthic invertebrate tissue selenium concentrations at the Grasmere location do not appear to respond in a predictable way to total selenium loads (Table 3), annual aqueous concentrations (Figure 15), or sediment concentrations (Figure 17) in the reservoir. Since 2022, benthic invertebrate tissue selenium concentrations at the Grasmere location in Koocanusa Reservoir have been below site-specific effects concentrations for benthic invertebrate health and fish growth.

Figure 19. Annual benthic invertebrate tissue selenium concentrations at Koocanusa Reservoir station T4 near Grasmere and at two lentic reference sites in the Flathead River.



Fish

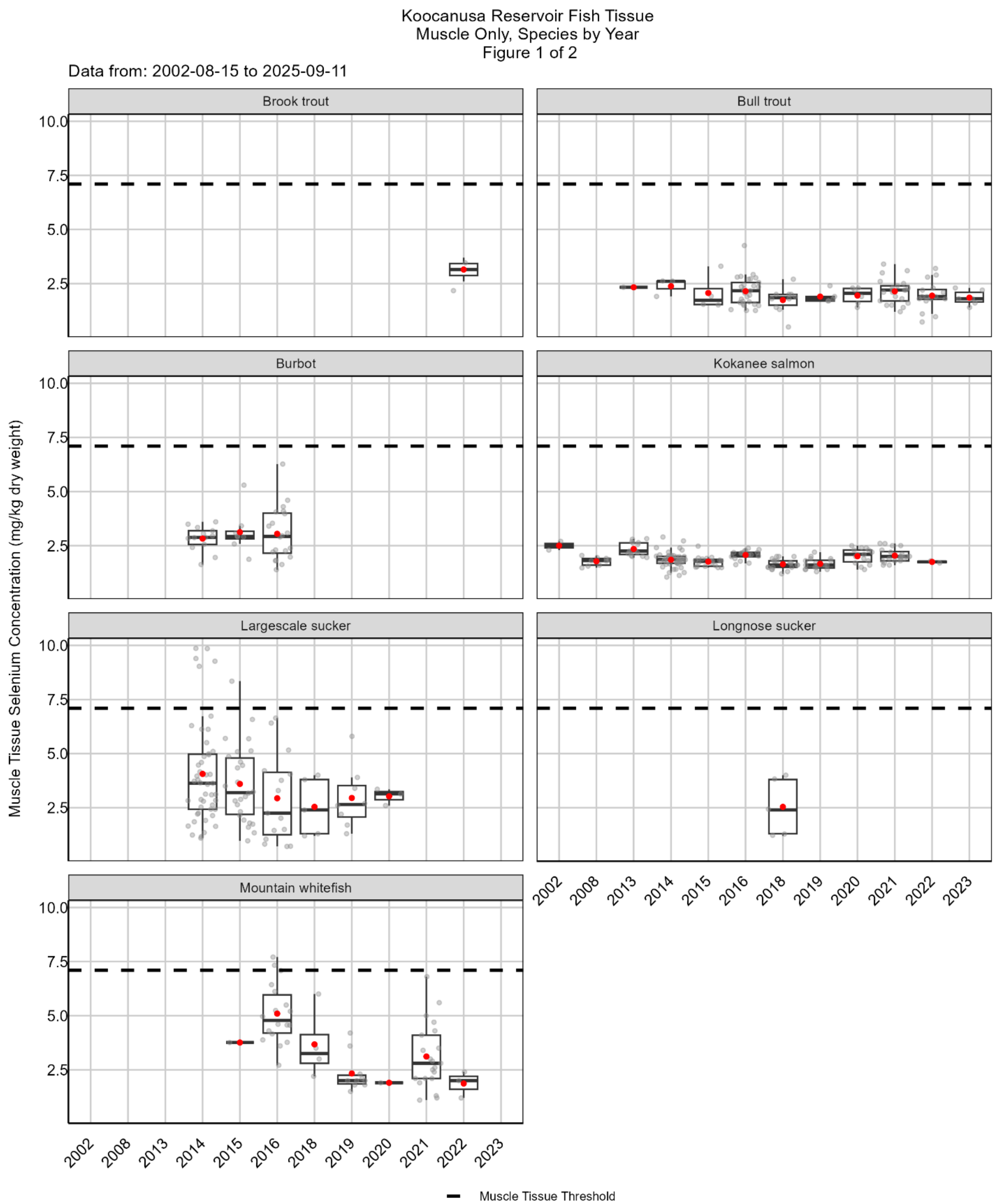
Table 12 summarizes available fish tissue data across all years and grouped by species and tissue type. There are data for eggs, ovaries, and muscle, with muscle tissue being the most prevalent. Palace and others (2024) recommend monitoring fish eggs when available, given the well-documented association of egg selenium to established effects concentrations. While egg selenium concentrations provide the strongest evidence of potential impacts, there is relatively little egg data available because harvesting ripe eggs is logistically challenging, primarily due to challenges in effectively and efficiently capturing gravid females with ripe eggs of different species. Ovary data is often used as a surrogate for egg tissue samples; however, ovary concentrations vary considerably during the spawning season and samples from unripe ovaries are not equal to mature egg concentrations for many fish species (Brix et al. 2025b, Detering et al. 2025). Sampling before ovaries are ripe may result in an overestimation of egg concentrations. Due to concerns around sampling at the appropriate time, distinguishing between ripe and unripe ovaries, and maternal transfer of selenium, there is a higher degree of uncertainty with historical fish egg and ovary data (Brix et al. 2025b, Detering et al. 2025). Muscle tissue can be sampled using a muscle plug without requiring lethal sampling and tends to have lower variability than whole body samples which include tissues and organs with a high variability in constituent concentrations (Stahl, Snyder and McCarty 2021). Established conversion factors allow estimation of egg and whole-body selenium concentration from the muscle tissue samples (ENV 2014, US EPA 2021).

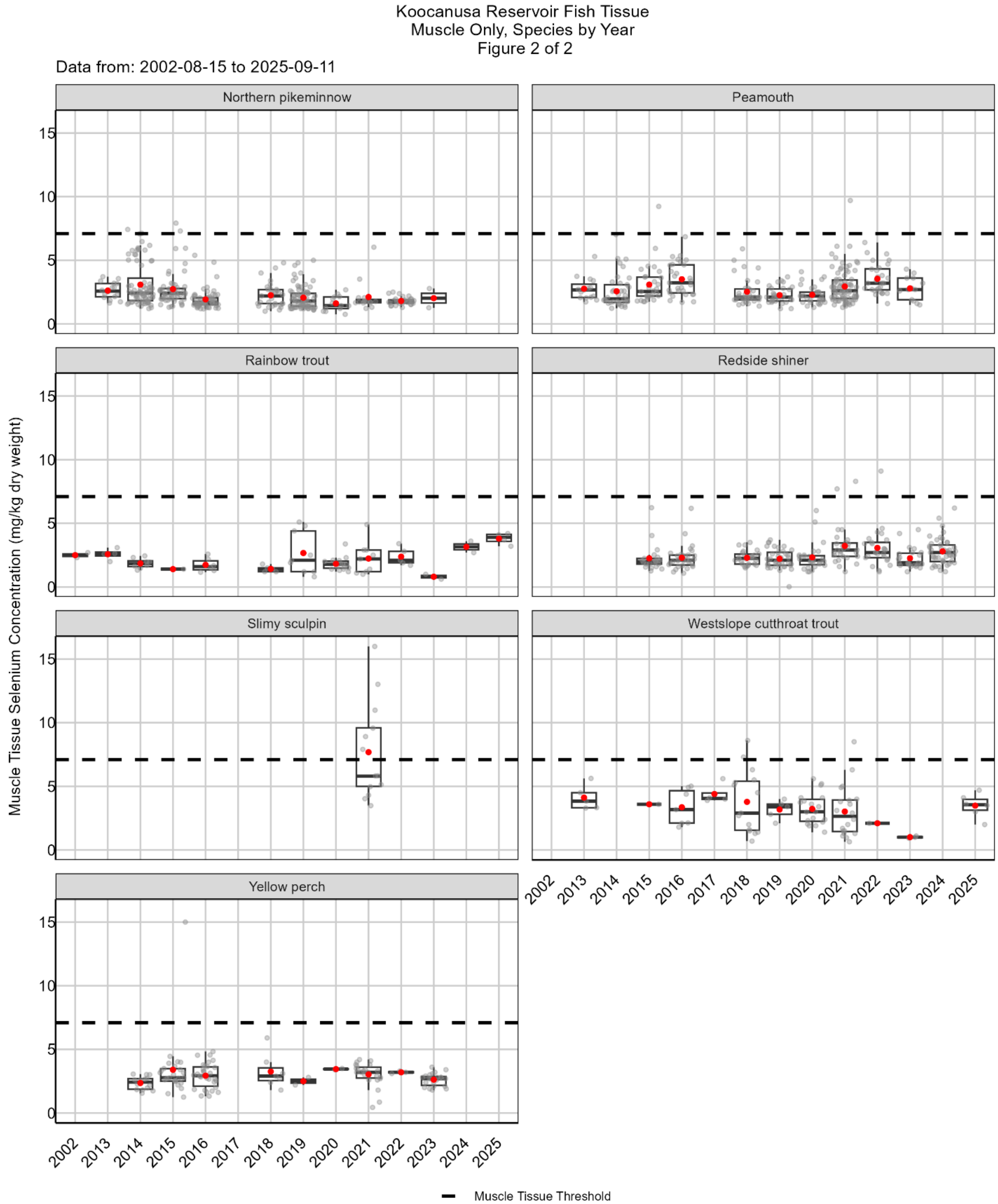
Comparisons to dry weight (dw) are preferred to wet weight (ww) because sample moisture content can change during handling and storage, adding uncertainty to estimates of wet weight concentrations.

Table 12. Number and type of fish tissue samples collected from the Canadian portion of Koocanusa Reservoir.

Fish Species	Common name	Date Range	Number of samples			
			Muscle	Whole Body	Ovary (egg/ovum)	Total
Catostomus catostomus	Longnose sucker	2018	5			**5**
Catostomus macrocheilus	Largescale sucker	2014-2016, 2018-2020	104		19	**123**
Cottus cognatus	Slimy sculpin	2021	13		6	**19**
Lota lota	Burbot	2014-2016	41		1	**42**
Mylocheilus caurinus	Peamouth chub	2013-2016, 2018-2023	360	45	321	**726**
Oncorhynchus clarkii lewisi	Westslope cutthroat trout	2013, 2015-2023	83		4	**87**
Oncorhynchus mykiss	Rainbow trout	2002, 2013-2016, 2018-2024	75		17	**92**
Oncorhynchus nerka	Kokanee salmon	2002, 2008, 2013-2016, 2018-2022	207	10	59	**276**
Perca flavescens	Yellow perch	2014-2016, 2018-2023	134		61	**195**
Prosopium williamsoni	Mountain whitefish	2015-2016, 2018-2022	63		7	**70**
Ptychocheilus oregonensis	Northern pikeminnow	2013-2016, 2018-2023	402		225	**627**
Richardsonius balteatus	Redside shiner	2015-2016, 2018-2024	331	20	267	**618**
Salvelinus confluentus	Bull trout	2013-2016, 2018-2023	105		3	**108**
Salvelinus fontinalis	Brook trout	2022	2			**2**
Total			**1925**	**75**	**990**	**2990**

Figure 20. Muscle tissue selenium concentrations by fish species in the Koocanusa Reservoir from 2002 to 2024. Note: dotted line indicates a muscle tissue concentration of 7.1 mg/kg dw selenium, which is equivalent to the BC ENV fish egg concentration guideline of 11 mg/kg dw.





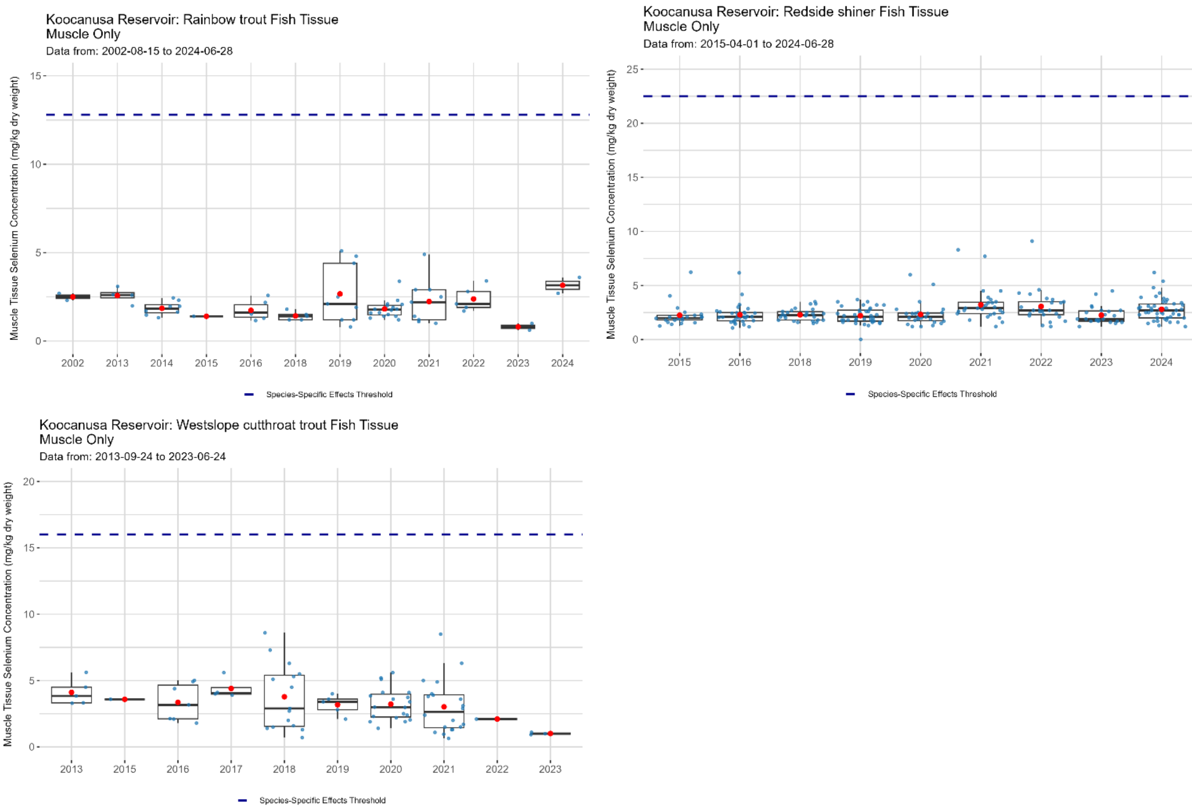
A comparison of fish muscle tissue selenium concentrations by species from 2002 to 2025 showed that most fish had concentrations below a Koocanusa Reservoir site-specific concentration for the protection of fish health (whole body 5.6 mg/kg selenium dry weight, muscle 7.1 mg/kg selenium dry weight (Figure 20). Sampling intensity has varied over this period. In 2024 only two species were sampled:

Rainbow Trout (n=2) and Redside Shiner (n=45, Nupqu et al. 2025). The low number of samples were due to a change in fish sampling methodology in response to concerns raised about bycatch mortalities from short-set gillnetting. In 2022, 15 Bull Trout, 15 Largescale Suckers and a small number of other fish died in gillnets targeting Northern Pikeminnow (DeForest et al. 2023). Short-set gillnets were removed from the sampling methodology in 2023 to mitigate bycatch mortalities and alternative sampling methods were proposed; however, the alternative methods were not as effective for obtaining fish tissue samples. The current sampling plan (2024-2026) being implemented by EVR Operations Ltd. includes targeting tissue samples from up to 8 fish from each of the following species: Westslope Cutthroat Trout, Rainbow Trout, Bull Trout, and Kokanee. Short-set gillnets were reinstated in 2024 for very short durations to target fish tissue samples of Redside Shiner (Minnow 2024).

There are no clear temporal trends in the concentrations of selenium in fish tissue. However, the data suggest that there are species-specific rates of selenium bioaccumulation. For example, Kokanee and Bull Trout appear to accumulate selenium at a lower rate than Mountain Whitefish, Westslope Cutthroat Trout, and Slimy Sculpin. This may reflect differences in diet in addition to differences in seasonal use of various habitats. For example, Mountain Whitefish and Westslope Cutthroat Trout may seasonally inhabit the outflow and lower reaches of the Elk River where they prey on benthic invertebrates exposed to higher aqueous selenium concentrations relative to other parts of the reservoir. Slimy Sculpin is recognized as showing high site fidelity and a benthic invertebrate diet, which may be important factors influencing selenium bioaccumulation in this species.

Species-specific effects thresholds have been reported for three fish species: Rainbow Trout, Redside Shiner and Westslope Cutthroat Trout (Table 8). All species showed tissue concentrations well below their respective effects thresholds (Table 8, Figure 21).

Figure 21. Muscle concentration for fish with species-specific effects thresholds in the Koocanusa Reservoir from 2002 to 2024. Note: the dotted lines correspond to species-specific effect thresholds for selenium in muscle (mg/kg dw).



Since 2002, there has been only one species in only one year that showed a mean muscle tissue selenium concentration in excess of 7.1 mg/kg dw. In 2021, Slimy Sculpin muscle samples collected from Koocanusa Reservoir in the vicinity of Sand Creek, Gold Creek and the Elk River mouth showed a mean concentration of 7.68 mg/kg dw. US EPA (2021) provides a Sculpin muscle to egg/ovary ratio of 1.35. Using this ratio yields a predicted mean egg/ovary concentration of 10.37 mg/kg dw, which is below the reported effects concentration of >22 mg/kg dw (Table 8). This mean muscle concentration and estimated egg/ovary concentration from the Koocanusa Reservoir in 2021 is similar to Slimy Sculpin tissue selenium concentrations observed downstream in the Kootenai River (Mebane et al. 2025). Kootenai River Slimy Sculpin had a mean muscle concentration 6.7 mg/kg dw and a mean egg/ovary concentration of 12.4 mg/kg selenium dw. Applying the muscle to egg ratio observed by Mebane et al. (1.85) results in an estimated egg concentration from the Koocanusa Reservoir Slimy Sculpin of 14. 2 mg/kg dw, which is also below the species-specific effects concentration. A study on the viability of Slimy Sculpin as a potential sentinel monitoring species concluded that the distribution and abundance of this species in the reservoir is insufficient for long-term monitoring owing to changing reservoir levels and the availability of suitable habitat in combination with unfavorable summer temperatures (Minnow 2020b).

Koocanusa Reservoir Fish Studies

A 2022 study on Northern Pikeminnow selenium ecotoxicity using eggs collected from Koocanusa Reservoir showed egg tissue selenium concentrations between 2.3 to 6.5 mg/kg dw while muscle tissue ranged from 1.3 to 2.8 mg/kg dw (DeForest et al. 2023). The study found no adverse effects on larval survival, growth, deformities, or edema that correlated with egg selenium concentrations, which precluded the ability to estimate egg tissue selenium effects concentrations. The study reported a negligible risk of selenium toxicity to Northern Pikeminnow in Koocanusa Reservoir.

In 2019, Redside Shiners were collected from Koocanusa Reservoir, three off-channel lentic areas in the Elk Valley, and a reference location, Loon Lake (de Bruyn et al. 2023). The study examined the potential effects for fish with a range of egg tissue selenium concentrations from 0.7 to 28 mg/kg dw. Embryos hatched and raised in the study showed no adverse effects on survival, deformity, or larval length among the fertilized eggs tested, leading the authors to conclude that reproductive effects threshold may be greater than an egg tissue selenium concentration of 28 mg/kg dw. The study suggested that Redside Shiner have relatively high tolerance for maternal selenium transfer and low egg selenium sensitivity.

Data from Koocanusa Reservoir were collated and used to generate a selenium bioaccumulation model for the purpose of supporting the development of protective guidelines (Presser and Naftz 2020). This biodynamic modelling approach was the foundation of the Montana DEQ site-specific water column selenium standard for Koocanusa Reservoir (Montana DEQ 2020). The model was designed to predict an aqueous selenium concentration that would be protective of fish reproduction, in all parts of the reservoir, during all phases of reservoir operation, and for all fish species inhabiting the reservoir. The model was validated using concurrent zooplankton, benthic invertebrate and water quality data. Fish were excluded from the model validation exercise (Presser and Naftz 2020). To develop the model, key assumptions were made about bioavailability of selenium entering the food web and the transfer of selenium from one trophic level to the next, called trophic transfer. An assumption was made that selenium increases with each step in the food web. However, some of the trophic transfer assumptions used in the model are not supported by tissue and aqueous selenium data from Koocanusa Reservoir or by recent scientific literature. For example, Molbert et al. (2026) showed lower concentrations of selenium in the tissue of higher trophic fish sampled in Koocanusa Reservoir. The disconnect between the model and measured fish tissue data may be explained in part because the model was not validated to measured fish tissue concentrations. Though the model does not align with monitoring data or recent scientific literature, the model framework provides opportunities to better understand relationships between aqueous concentrations and concentrations observed in lower and higher trophic aquatic biota in the reservoir.

A recent study on Koocanusa Reservoir fish focused on the relationships between fish tissue selenium and mercury (Molbert et al. 2026). The study showed the muscle selenium concentrations in all individuals sampled (n=1879) were below US EPA guidelines. Concentrations of selenium and mercury in fish tissue were not linked within fish, among species, or across the food web. The study suggested a link between Elk Valley mining and mercury concentrations in Koocanusa Reservoir fish without providing supporting evidence, while neglecting to include the widely recognized understanding that water management in reservoirs in the region cause elevated fish tissue mercury concentrations (Willacker et al. 2016). Years of fish tissue sampling in the 90 km of aquatic habitat upstream of the reservoir influenced by mine effluent have shown no evidence of mercury bioaccumulation. Mercury bioaccumulation has been documented in reservoirs throughout western North America and is a well-established relationship (Eagle-Smith et al. 2016, Willacker et al. 2016). Molbert et al. (2026) reported the lowest muscle and ovary selenium concentrations in higher trophic level fishes such as Bull Trout and Northern Pikeminnow in Koocanusa Reservoir, indicating that selenium does not biomagnify in reservoir fish. In contrast, large fish showed the highest mercury concentrations, which is consistent with mercury biomagnification reported elsewhere in the scientific literature (e.g., Lavoie et al. 2013).

Monitoring results and studies from the reservoir published to date have shown elevated concentrations of selenium in fish from Koocanusa Reservoir. A small proportion of individual fish tissue samples have exceeded conservative guidelines. However, mean values are well below guideline concentrations for all species with the exception of Slimy Sculpin. Comparisons to species-specific effects thresholds (such as an EC_{10}) do not show exceedances and there has been no documented evidence of selenium-related impacts to fish in the reservoir in either peer-reviewed or unpublished literature. These combined observations strongly indicate that fish in the Koocanusa Reservoir are at low risk of effects related to selenium exposure.

Koocanusa Reservoir Bird Study

A study conducted in 2022 and 2023 on tree swallows (*Tachycineta bicolor*) nesting along the US portion of Koocanusa Reservoir and downstream along the Kootenai River found that concentrations of selenium in eggs ranged from 2.6 to 3.4 mg/kg dw with a mean concentration of 2.8 mg/kg dw in 2022 and 3.2 mg/kg dw 2023 (Balmer et al. 2025). Koocanusa tree swallow eggs were observed to have lower selenium concentrations than six other studies throughout the US. Egg selenium concentrations were lower than EC_{10} values for avian selenium-related reduced hatchability (4.0-12.0 mg/kg dw) and were not expected to exhibit reproductive impacts. No spatial trends in selenium concentrations were observed within the study area. The study concluded that tree swallows have not substantially accumulated selenium in the Kootenai/y River Basin.

Human Health

Guidelines and Dietary Screening Values

The BC's selenium drinking water guideline is 10 µg/L (ENV 2014). The Canadian selenium drinking water guideline set by Health Canada is 50 µg/L (HC 2014).

BC has developed fish tissue selenium screening values to protect human health when consuming fish. The BC fish tissue WQGs are established using a risk-based approach and are based on Health Canada consumption rates. Similar human health screening values have been calculated for the Elk Valley that are based on a Ktunaxa preferred diet rate (Ramboll 2023). The Ktunaxa preferred diet is represented by a rate of fish consumption of 245 grams, or just over 0.5 pounds of fish each day. Exceedance of a screening value may indicate further assessment of human health risk is needed. The screening values are summarized in Table 13.

Table 13. Human health fish tissue selenium screening values.

Population	Consumption rate	Screening Values	Source
Low consumers	30 g/day	18.7 µg/g (ww); 75.0 µg/g (dw) muscle	BC WQG (ENV 2014)
Moderate consumers	111 g/day	3.6 µg/g (ww); 14.5 µg/g (dw) muscle	BC WQG (ENV 2014)
High consumers	>220 g/day	1.8 µg/g (wet weight); 7.3 µg/g (dry weight) muscle	BC WQG (ENV 2014)
Ktunaxa preferred diet	245 g/day	1.3 µg/g (ww); 5.2 µg/g (dw) whole body OR 1.6 µg/g (ww); 6.6 µg/g (dw) muscle	Teck HHRA (Ramboll 2023)

Human Health Monitoring Results

Drinking Water

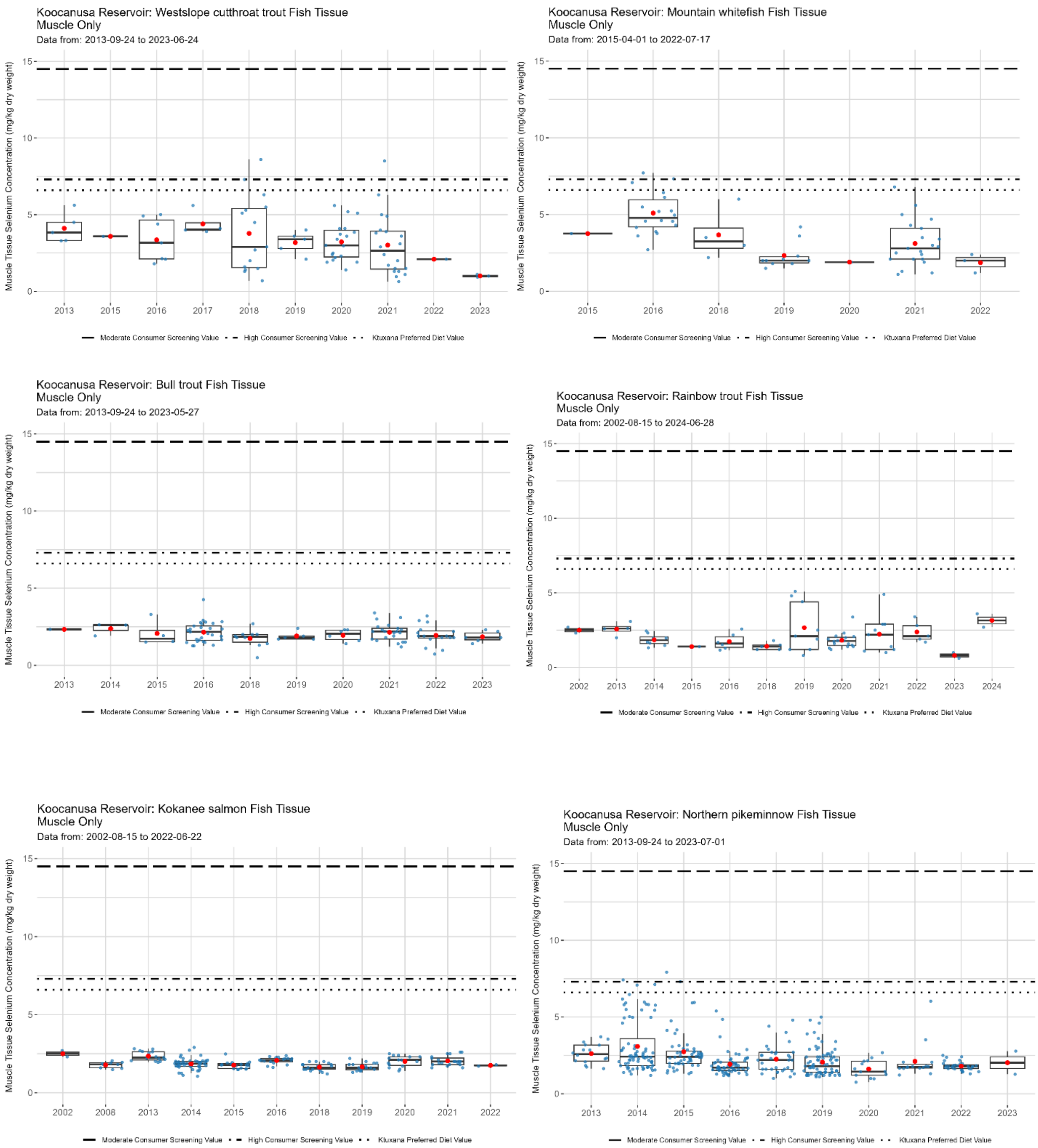
There are no records of concentrations of selenium in Koocanusa Reservoir exceeding the BC drinking water quality guideline of 10 µg/L. The highest daily concentration measured was 3.85 µg/L on April 13, 2021, the highest monthly average concentration at LK2 measured to date was 3.1 µg/L in 2022, and the highest annual average was 1.54 µg/L in the same year. The average selenium concentration in 2025 was 1.01 µg/L, 10 times lower than the drinking water guideline. Monitoring shows that there is no risk of exposure to elevated selenium from drinking water in Koocanusa Reservoir.

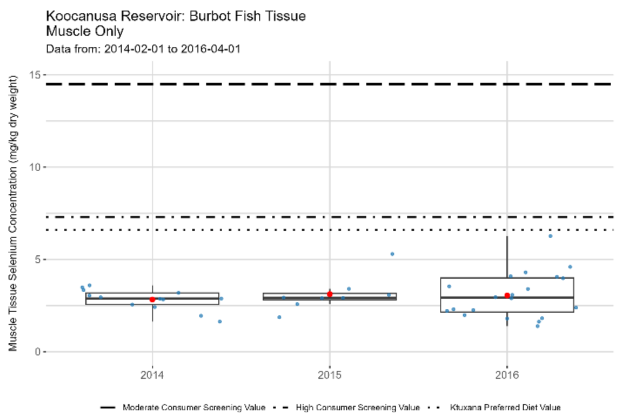
Fish Consumption

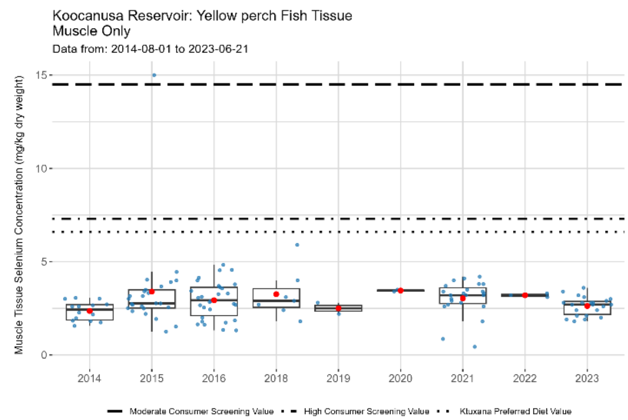
This review evaluated the risks to human health from the consumption of fish by comparing muscle tissue selenium concentrations in Koocanusa Reservoir fish to screening values from Table 13 for moderate fish consumers, high fish consumers and the Ktunaxa preferred diet (Figure 22). While recognizing that some consumers eat more parts of the fish than the fillet, these other parts are a smaller proportion of the fish and pose negligible risk (Ramboll 2023). A comparison to muscle tissue provides a reasonable estimation of exposure risk and is complemented by the abundance of muscle data (1925 samples, Table 12). In contrast, there is considerably less whole-fish data (75 samples). A subset of fish inhabiting the reservoir were identified as those preferentially harvested for consumption: Mountain Whitefish, Westslope Cutthroat Trout, Bull Trout, Rainbow Trout, Brook Trout, Kokanee, Northern Pikeminnow, Burbot and Yellow Perch (Ramboll 2025).

Mean and upper quartile selenium concentrations in muscle tissue were below all screening values for all species and all years (Figure 22). A small number of individual Mountain Whitefish (4), Northern Pikeminnow (5), Westslope Cutthroat Trout (3), and Yellow Perch (1) exceeded the lowest screening value set based on eating fish at the Ktunaxa preferred rate (half a pound of fish every day). This represents 13 out of 1037 sampled fish, or 1.25%. No Burbot, Rainbow Trout, Kokanee or Bull Trout exceeded the Ktunaxa preferred diet screening value from 2013 to 2024. No fish consumption screening values have been exceeded since 2022. To evaluate risk, tissue consumption guidelines are compared to averages of eight or more fish tissue samples (BC ENV, 2014). An evaluation of risk is not based on rare exceedances of tissue guidelines by individual fish.

Figure 22. Annual muscle tissue selenium concentrations in fish from Koocanusa Reservoir. Note: see Table 13 for screening values.







Ramboll (2025) conducted an evaluation of the risk to human health from exposure to selenium from the consumption of Koocanusa Reservoir fish (Ramboll 2025). It relied on Human Health Risk Assessment methodology and calculated Hazard Quotients (HQs) using wet weight concentrations. The evaluation found that a selenium Hazard Quotient of 1 was not exceeded at Ktunaxa preferred dietary rates. A HQ less than 1 means that no adverse effects are expected from exposure through an identified exposure pathway. A HQ of 0.2 (which can be used to evaluate the risk from multiple exposure pathways) could be exceeded by eating fish from reference areas or the reservoir at the preferred dietary rate and concluded that there is no potential elevated risk from selenium associated with eating fish from either the Canadian or the US portions of the reservoir.

An earlier study (Ramboll 2023) identified another constituent present in the Koocanusa Reservoir that posed increased risk to human consumers. The 2023 Elk Valley Human Health Risk Assessment (Ramboll 2023) identified HQs greater than 1 for mercury in reservoir fish at Ktunaxa preferred consumption rates and noted that this is a regional concern relevant to other reservoirs in the area. To further understanding about considerations relevant to fish consumption, a review of recent monitoring results for Koocanusa Reservoir fish tissue mercury concentrations is provided below.

Mercury

Mercury is present in the tissues of Koocanusa Reservoir fish. Some fish sampled from the reservoir show evidence of mercury biomagnification and elevated tissue mercury concentrations (Figure 23).

Health Canada (HC 2007) has established maximum acceptable levels of constituents to protect against the consumption of foods that may pose a health risk. The maximum acceptable level of mercury in the edible portion of retail fish is 0.5 mg/kg wet weight (with limited exceptions based on selected fish species, HC 2007).

Montana Fish and Wildlife (2026) published guidelines for the consumption of fish caught from Koocanusa Reservoir with details about how many fish of a given size can safely be consumed per month owing to the presence of mercury. For example, children and women of childbearing age can safely consume up to eight Burbot between 14-18 inches in length per month, but only one that is greater than 30 inches. The complete consumption guidelines for 11 fish species are available online (Montana Fish, Wildlife and Parks 2026).

A review of water quality constituents in Elk Valley surface waters identified 16 elements linked to mining operations including selenium, nitrate, sulphate, cadmium, nickel, lithium and 10 others (Azimuth

2018). Mercury was not identified as a mine-related constituent. Tissue mercury concentrations in fish caught in the Elk and Fording rivers downstream of the Elk Valley mines are lower than in Koocanusa Reservoir or in regional reference streams (Figure 24), providing additional evidence that mercury in Koocanusa Reservoir fish tissue is not related to coal mining.

Water impoundments such as dams inundate soil and increase microbial conversion of elemental mercury into methylmercury, which rapidly bioaccumulates. Reservoirs throughout western North America are recognized as showing elevated mercury concentrations compared to natural lakes. The source of mercury is understood to be atmospheric deposition and mobilization through soil inundation (Willacker et al. 2016). Twenty-nine reservoirs in Montana have mercury-based fish consumption limits (Montana Fish, Wildlife and Parks 2026).

Figure 23. Total mercury concentrations in fish preferred for consumption from Koocanusa Reservoir, with the Health Canada maximum acceptable level in retail fish plotted (0.5 mg/kg wet weight).

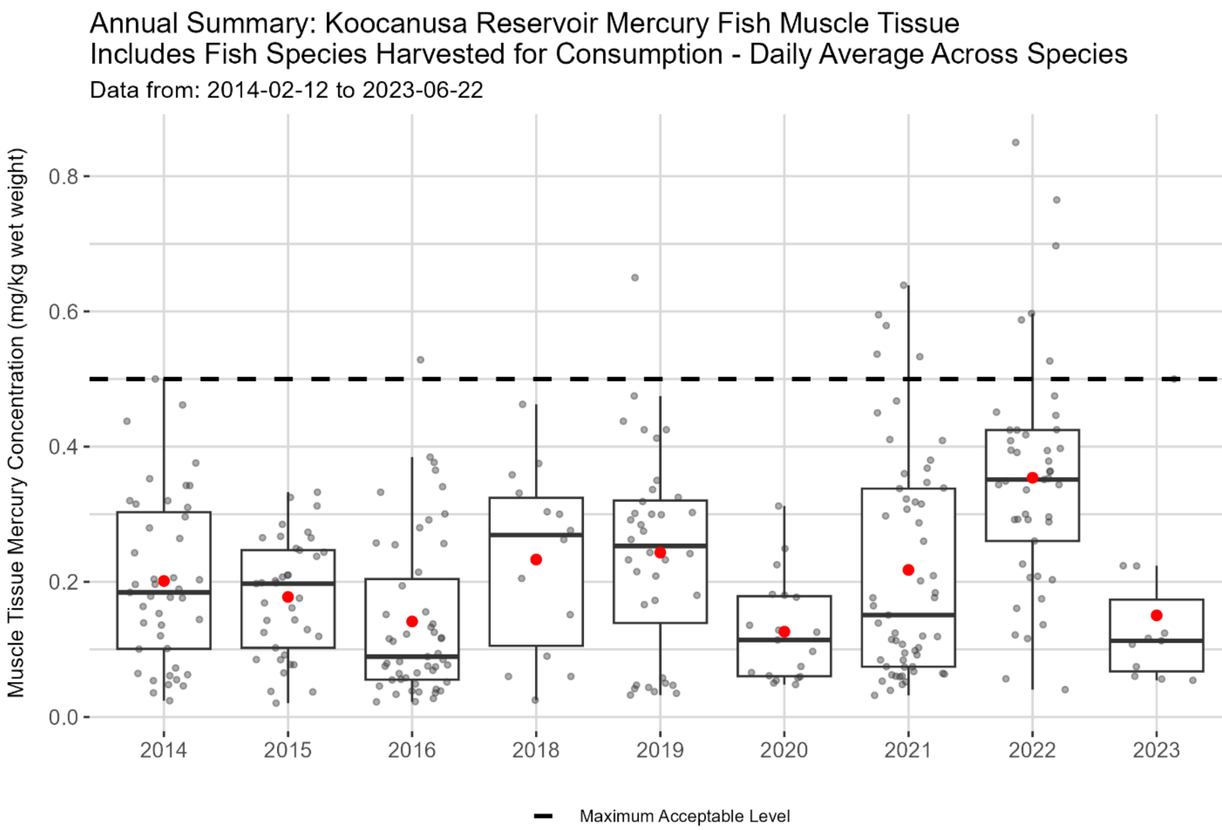
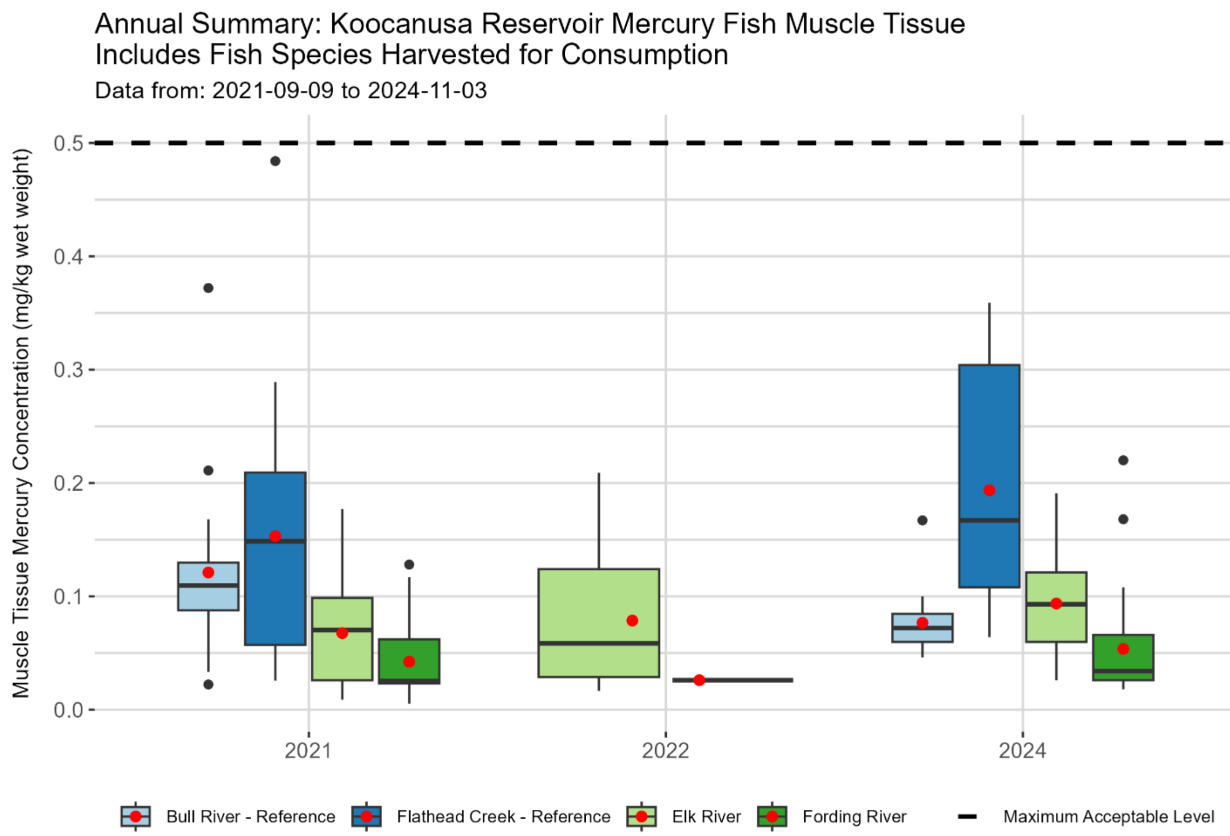


Figure 24. Total mercury concentrations in fish preferred for consumption from the mine influenced waters of the Elk and Fording rivers, and from two reference locations without mine influence (Bull River and Flathead River), with the Health Canada maximum acceptable level in retail fish plotted (0.5 µg/g).



Average annual mercury concentrations in sampled fish muscle tissue from Koocanusa Reservoir are shown in Figure 23. Mean and 75th-percentile fish tissue mercury concentrations were below the Health Canada retail fish maximum acceptable level of 0.5 mg/kg ww; however, individual fish exceeded this threshold. The highest annual mercury concentration observed was in 2022 when the mean tissue concentration was 0.35 mg/kg ww.

Larger fish are recognised as having elevated tissue mercury concentrations relative to smaller fish (Eagles-Smith et al. 2016, Molbert 2026). Frequent consumption, for example at the Ktunaxa preferred rate, of larger fish from the reservoir may increase the risk of exposure to elevated mercury.

Conclusions

Aqueous selenium concentrations in the Canadian portion of Koocanusa Reservoir are below the ABMP target at LK2. They are also below the target value at downstream monitoring locations in the Canadian portion of the reservoir. Selenium in fish tissue is currently at levels protective of fish health and that presents a low or negligible risk to human health (Table 14).

Table 14. A summary of the current state of monitored media in the Canadian portion of Koocanusa Reservoir compared to relevant targets and guidelines.

Media	Relevant Guideline Source	Selenium Guideline or Screening Value	Current Conditions
Surface water	ABMP Target and BC WQG	2 µg/L	Meeting guideline
Drinking water	BC Drinking Water Guideline	10 µg/L	Meeting guideline
Fish muscle tissue concentration (fish protection)	Muscle equivalent of the BC egg tissue guideline	7.1 µg/g dw	Meeting guideline
Fish muscle tissue concentration (human consumption)	Muscle equivalent to the BC fish consumption guideline	6.6 µg/g dw (most conservative – Ktunaxa preferred diet)	Meeting screening value

Water Quality

What are the current selenium concentrations and trends in the Canadian portion of the reservoir?

The annual average concentration of aqueous selenium at LK2 increased from 2015 to 2022. The concentration decreased from an annual average of 1.54 µg/L selenium in 2022 to an annual average of 1.19 µg/L in 2024 and 1.01 µg/L in 2025. Decreasing selenium concentrations since 2022 is evident not only at LK2, but also at all sampling locations in the Canadian portion of Koocanusa Reservoir.

The current Koocanusa Reservoir target of 2 µg/L has been exceeded at LK2 in 11 months since 2015. The most recent exceedance was in April 2023. Short duration, seasonal exceedances reflect complex interactions between selenium inputs from Elk River, the dilution potential provided by Kootenay River flows and the elevation of the reservoir, and climate variability.

When comparing data collected from different sampling locations in the Canadian portion of Koocanusa Reservoir downstream of the Elk River (LK2, Grasmere, Upstream Gold Creek, and Canada/US Border), the monthly and annual mean and median values are comparable; however, there is greater variability at LK2 which shows a broader range of mixing conditions.

The analysis provided in this review supports the understanding that concentrations of selenium measured at LK2 and other locations in the reservoir are primarily driven by the source loads from the Elk Valley mines interacting with the seasonal hydrograph of the Elk and Kootenay rivers and reservoir elevation as controlled by the Libby Dam. Differing temperatures and densities of the combining waters also contribute to complex mixing that varies spatially and temporally. These key drivers influence measured concentrations in Koocanusa Reservoir at LK2, and downstream, and contribute to annual and interannual variability.

Water quality in the Elk River and Koocanusa Reservoir has improved since 2022. Selenium concentrations are currently similar to levels last measured in 2016. While recognizing that climate variation and changing flows are strong influences on loads and concentrations, there is growing evidence that water treatment at Elk Valley mines is contributing to observed improvements in water quality.

What is the concentration of selenium in reservoir sediment?

Two out of 105 sediment samples collected since 2012 showed concentrations above the 2 µg/g dw selenium alert level. With less than 2% exceedance of the alert level, monitoring results indicate a low probability of risk from sediments in Koocanusa Reservoir. This conclusion is supported by a recent load assessment that showed little loss of selenium load throughout the watershed.

Aquatic Health

What is the current state of selenium bioaccumulation in Koocanusa Reservoir?

Monitoring data show that selenium bioaccumulates in aquatic biota inhabiting Koocanusa Reservoir. Certain biota show tissue concentrations above conservative guidelines for specific years; however, recent sampling shows negligible or low risk across all trophic levels.

Over the past five years, zooplankton tissue selenium concentrations indicate a negligible risk to planktivorous biota from exposure to dietary selenium. This is supported by corresponding low tissue selenium concentrations in planktivorous fish such as Kokanee.

Concentrations of selenium observed in benthic tissues in Koocanusa Reservoir are consistently above interim chronic dietary guidelines, a conservative threshold also exceeded in reference areas in the region. There is no clear temporal trend nor are there clear relationships with total selenium load, aqueous concentrations, or sediment concentrations. Since 2022, benthic invertebrate selenium tissues have been below site specific effects concentrations indicating negligible risk to the health of benthic invertebrates and their predators.

Since 2002, fish tissue selenium (n = 1925) concentrations in Koocanusa Reservoir have been below the muscle concentration equivalent to the BC egg/ovary tissue selenium guideline with the exception of Slimy Sculpin sampled in 2021. Comparisons with effects concentrations specific to Slimy Sculpin indicate that observed guideline exceedances were below tissue selenium concentrations known to cause effects to that species.

Tree swallows inhabiting the US portion of the Koocanusa Reservoir have not substantially accumulated selenium.

What are the risks to aquatic health associated with the observed concentrations of selenium in biota?

Monitoring reports and peer reviewed literature have shown evidence of selenium bioaccumulation in Koocanusa Reservoir biota; however, years of extensive monitoring and research have not identified selenium-related impacts. While some individual fish have shown tissue selenium concentrations greater than guidelines, they remain below species-specific effects concentrations. The available data and associated reporting show negligible or low risk to aquatic health from current selenium concentrations in reservoir biota.

Human Health

What are the risks to human health from exposure to selenium in the Canadian portion of Koocanusa Reservoir?

Is the water safe to drink?

There are no records of concentrations of selenium in the reservoir exceeding the BC Drinking Water Quality Guideline for selenium of 10 µg/L. The highest monthly average concentration at LK2 measured to date was 3.1 µg/L in 2022 and the highest annual average was 1.54 µg/L of the same year. The average selenium concentration in 2025 was 1.01 µg/L, 10 times lower than the guideline. There is no elevated risk from exposure to selenium caused by drinking water from Koocanusa Reservoir.

Are the fish safe to eat?

All Burbot, Rainbow Trout, Kokanee, and Bull Trout muscle tissue selenium concentrations from 2013 to 2024 were below consumption-based screening values. In the past 11 years, 1.25% of measured fish (13 out of 1037) showed tissue concentrations higher than the most conservative screening value, which assumes eating half a pound of fish every day. This suggests that eating Koocanusa Reservoir fish, even on a regular basis, presents a negligible risk to human health from exposure to selenium. This finding is in accord with another recent investigation (Ramboll 2025) that reported no elevated risk from selenium when eating fish from the reservoir.

Quality Control/Quality Assurance

The data used to support this review was collected by qualified professionals as required under Permit 107517, the Elk Valley Permit. Sampling followed the BC Field Sampling Manual (ENV 2013b), and analyses were conducted at labs certified by the Canadian Associate for Laboratory Accreditation. ENV collated and reviewed all data.

Data from the Elk River is from the ECCC/ENV site BC08NK0003 (Elk River above Highway 93, E206884) and from BC (Elk River near Fernie, E330533).

Data from Koocanusa Reservoir is from one point location: Lake Koocanusa West of Grasmere (Site E300092), and 3 transect locations: LK2 (Lake Koocanusa South of the Elk; Site E300230), Lake Koocanusa Upstream of Gold Creek (Site E300093), and Lake Koocanusa Upstream of Canada/US Border (Site E300094). Sediment and benthic invertebrate data is from Koocanusa Reservoir near Grasmere, T4 (Site E328954). These data can be downloaded using the listed site ID numbers from BC's Environmental Monitoring System (ENV n.d. (b)).

Recommendations

This review of current data has helped identify monitoring components that are captured by existing programs but that could be enhanced to improve understanding. These are not data gaps per se, as data are available. However, there may be opportunities to reduce uncertainties and better characterize spatial or temporal variability with relatively minor improvements to sampling approaches.

- While there is a robust historical data set, fewer fish tissue samples have been collected in the past two years. Evaluating the influence of water quality on fish tissue selenium concentrations in Koocanusa Reservoir requires samples from multiple fish species. The current monitoring program targets five species with up to eight fish per species. Meeting the sampling targets should provide an adequate dataset for tracking selenium-related risks to fish and fish consumers. Efforts should be made to ensure sampling methods attain sampling targets while seeking ways to minimize unintended mortalities.
- Historical and current monitoring programs are designed to provide substantial data sets for water quality and fish tissue. There are also sediment and benthic invertebrate tissue data represented by smaller sample numbers and limited spatial resolution. Recognizing that there can be technical challenges (for example, abundance and habitat constraints), consideration should be given to sampling sediment, zooplankton and benthic invertebrate tissue at the five established stations (Sand Creek, Elk Mouth, Grasmere, Upstream Gold Creek, and Canada/US Border) in the Canadian portion of Koocanusa Reservoir on an annual basis. These data would provide a more robust understanding of the spatial variability of selenium concentrations in the reservoir and support effectiveness evaluation of regulatory measures.

Consideration should be given to the following recommendations for the Koocanusa Reservoir selenium target review:

- Concerns were identified about variability at the LK2 station transect and how well this location represents average aqueous selenium concentrations in the reservoir. Consideration should be given to reviewing the suitability of the LK2 transect as the Koocanusa Reservoir aqueous selenium target location.
- The Koocanusa Reservoir aqueous selenium target was based on the BC Water Quality Guideline, which was derived from ecotoxicological studies in addition to the application of an uncertainty factor. Selenium bioaccumulation modelling can provide a more refined and site-specific approach to understanding risks from exposure to elevated aqueous selenium concentrations. Recent work on selenium bioaccumulation modelling for the Koocanusa Reservoir should be reviewed to explore how the recently developed model could be adapted for informing a Koocanusa Reservoir aqueous selenium target review.

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