Establishing Selenium Standards for Lake Koocanusa and Kootenai River that Protect Aquatic Life

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Water Pollution Control Advisory Council Meeting

DEQ

Montana Department
of Environmental Quality

Regulatory Background

- Montana's Board of Environmental Review has authority to adopt water quality standards (75-5-301(2), MCA)

- EPA updated its selenium criteria in 2016
    - Montana's current standard dates to 1987 EPA guidance

    - The new guidance recommends states and tribes adopt site-specific selenium standards whenever possible

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Background

- DEQ is proposing these standards using the best available science
- DEQ and BC-ENV goal to co-develop this standard the site-specific water column standard
- BC is currently undergoing their standard setting process right now with goal to adopt in 2020
  - Currently BC is in G to G consultation with the Ktunaxa Nation Council

Addressing Selenium: Timeline

2010	2012	2013	2015	2015	2016
MOUC – Flathead Valley	**Koocanusa Listed for Se**	**BC Ministerial Order** *Remediate water quality effects of past mining activities and guide environmental management of future mining activities in the Elk Valley, including Lake Koocanusa*	**LKMRWG** *Bi-national working group established*	**Selenium Tech. Subcommittee**	**EPA updates national Se criteria recommendations**

Lake Koocanusa Monitoring and Research Working Group

- Formed in 2015 to address transboundary water quality issues
- Semi annual meetings
- Selenium was determined to be the first priority
- Formation of a Selenium Technical Subcommittee
  - Guide data collection and determination of a protective water column standard
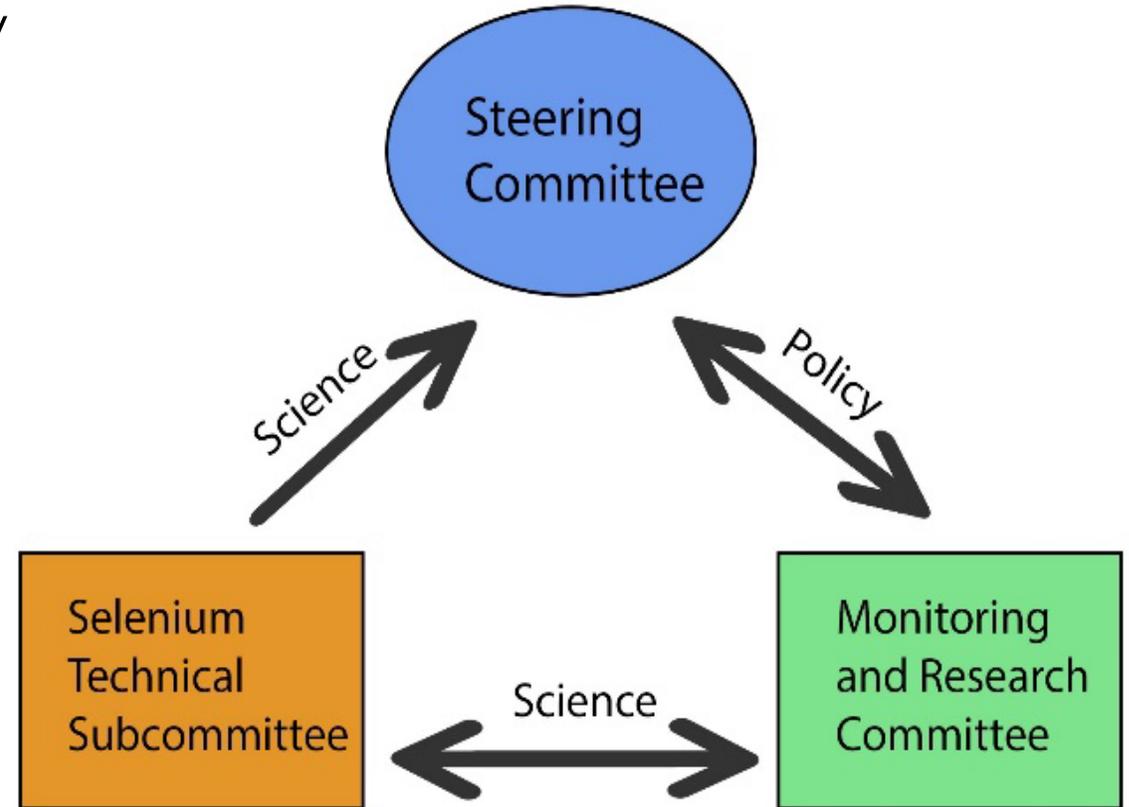
A Multi-National Transboundary Effort

- Six years of coordination with BC-ENV co-leading this effort
- Participation of an engaged Working group consisting of broad ranging entities (state, tribal, federal, industry, etc.)
- Involvement and dedication from top selenium experts in the US, Canada, and the world guiding the development of this standard
- Coordinated transboundary data sharing and data collection
- Public meetings each fall (2017-2019), held alternatively in BC and MT

Overview of proposed standards

To reflect biological uptake through diet, the predominant pathway for selenium toxicity, DEQ is proposing the following standards

Lake Koocanusa

Fish Tissue (mg/kg dry weight (dw))
Egg ovary - 15.1
Muscle - 11.3
Whole body - 8.5

site specific selenium criteria of 0.8 µg/L designed to ensure the tissue criteria are met.

Kootenai River

Fish Tissue (mg/kg dry weight (dw))
Egg ovary - 15.1
Muscle -11.3
Whole body - 8.5

Water column – 3.1 µg/L

Why Now

- 5 years of data collection

- Peer-reviewed modeling report complete

- SeTSC recommendations received

- BC & DEQ co-developed and agreed upon scenarios and protective water column Se

- Uncertainty sows concern

# Kootenai Watershed

Kootenai/Kootenay River

- Originates in SE British Columbia (B.C.)

Lake Koocanusa

- Reservoir created by Libby Dam
- Located in Montana and B.C.
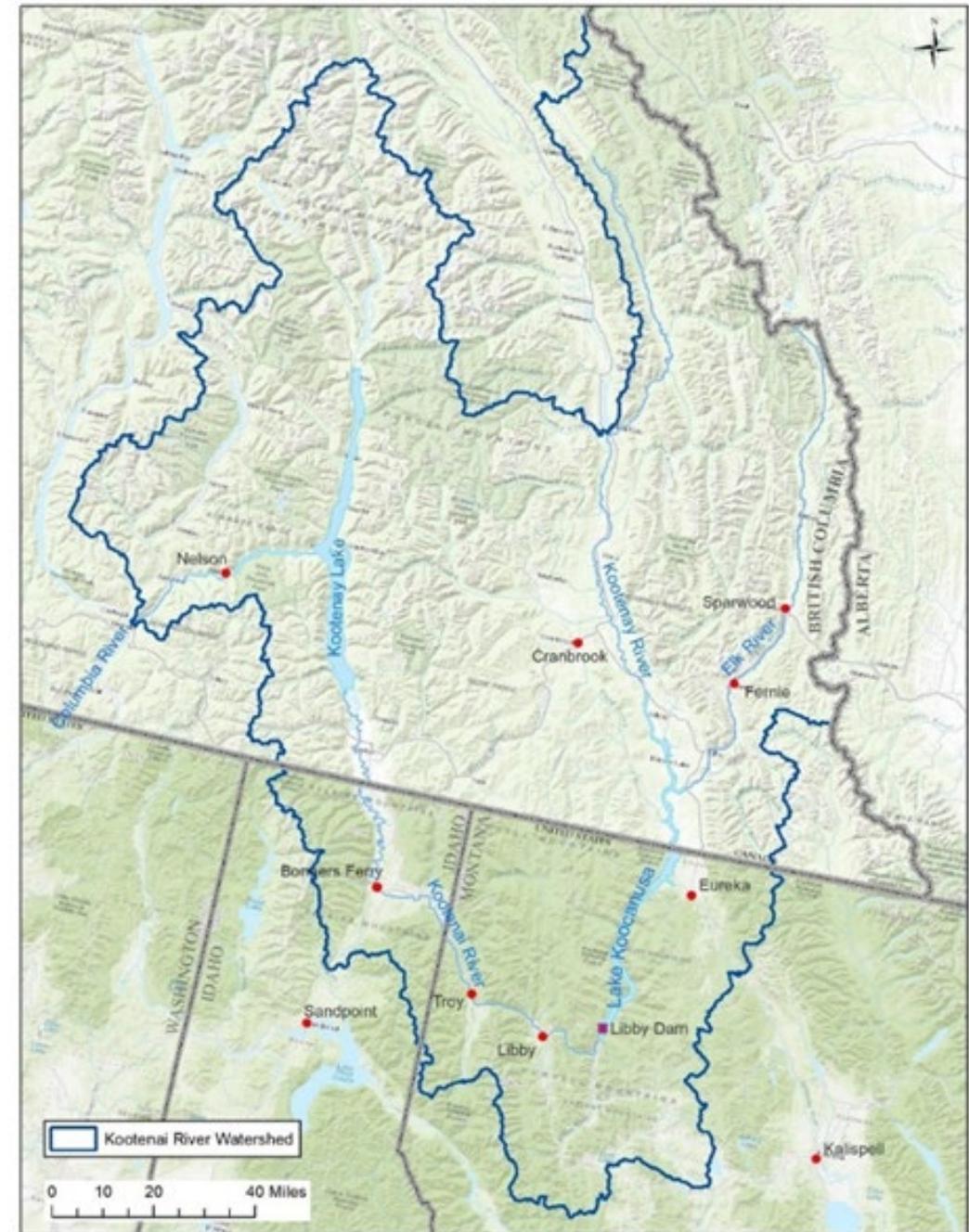
# Selenium increase over time: Elk River, Canada

Elk River at Hwy 93 Crossing (near confluence with Lake Koocanusa)
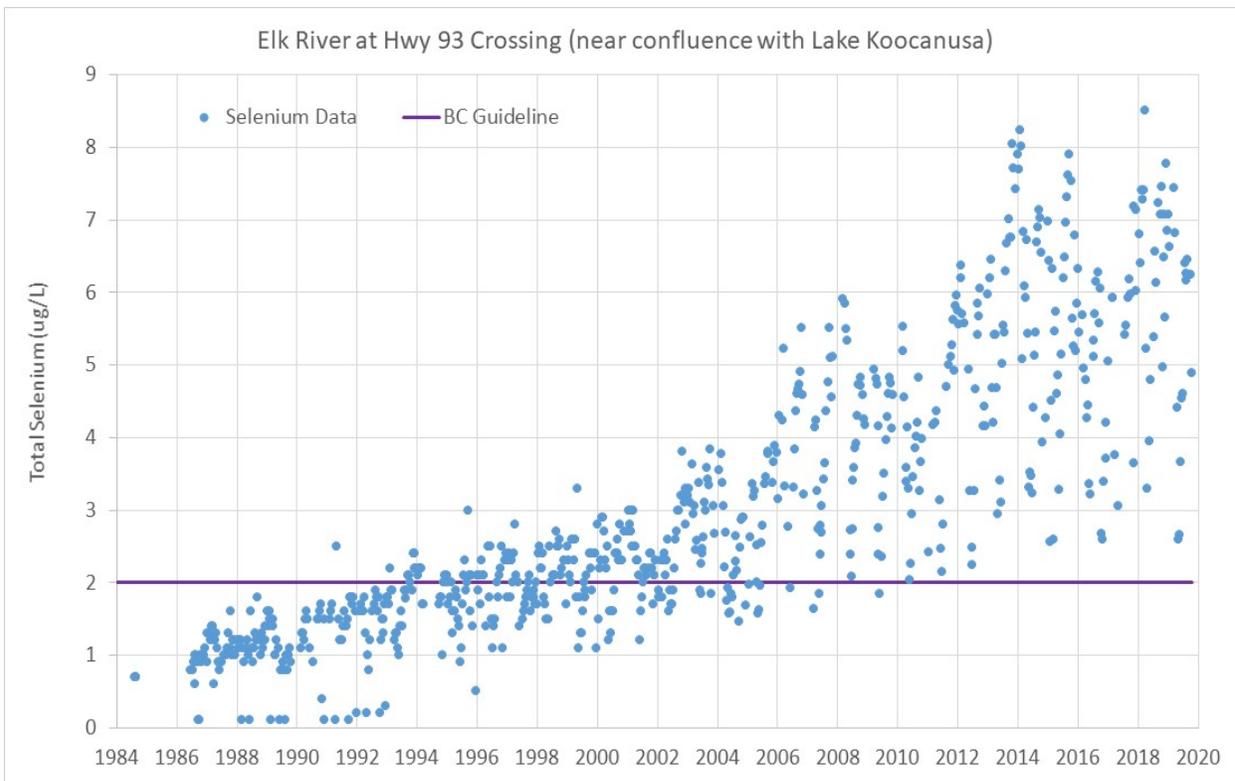
95% of the selenium entering the lake is from the Elk River
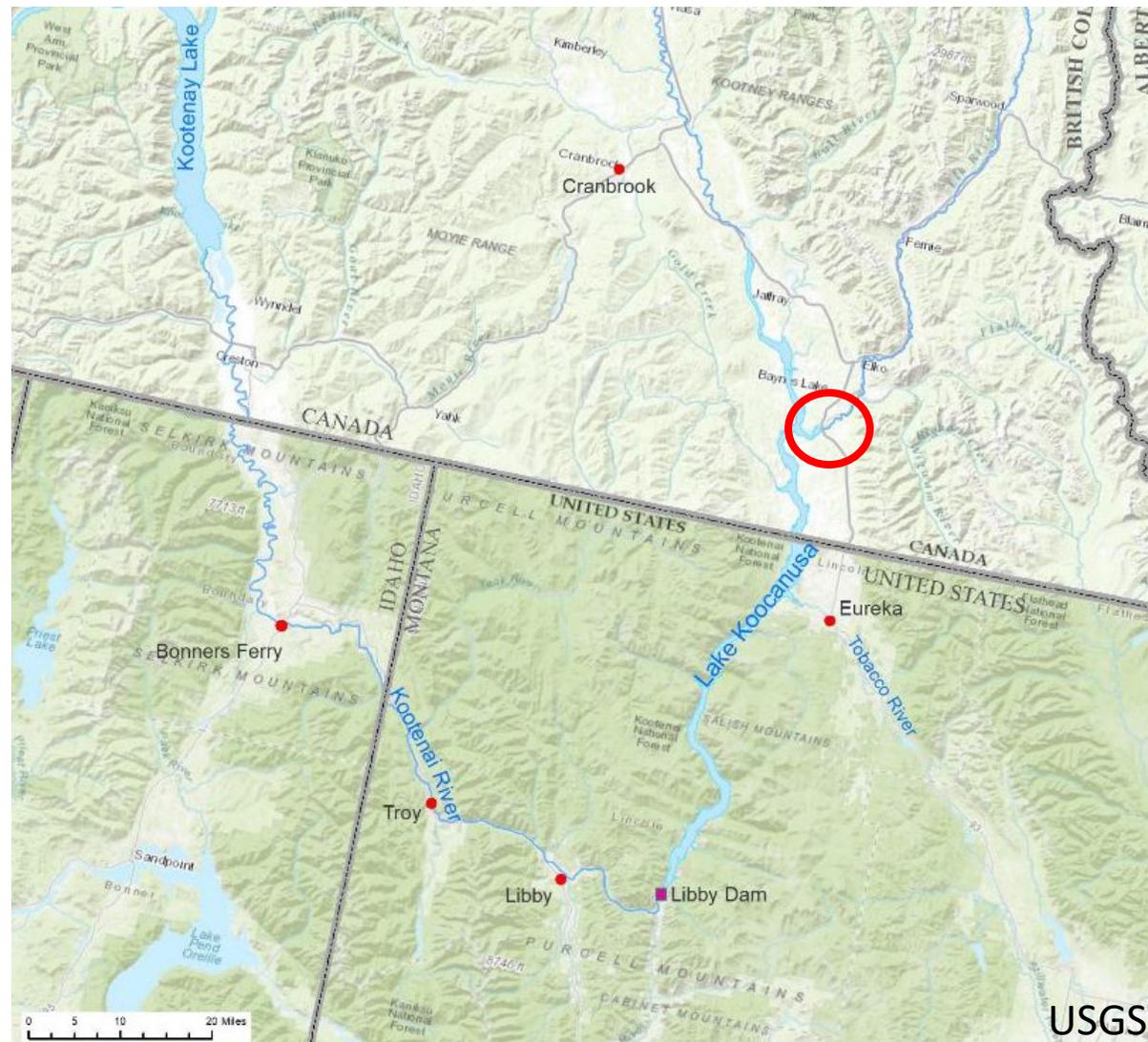
USGS

Selenium Source

- Selenium (Se) is from historic and current coal mining in the Elk Valley, B.C.

- 4 mines in operation.
  - 4 new mines in the environmental assessment (EA) process


Teck, 2019
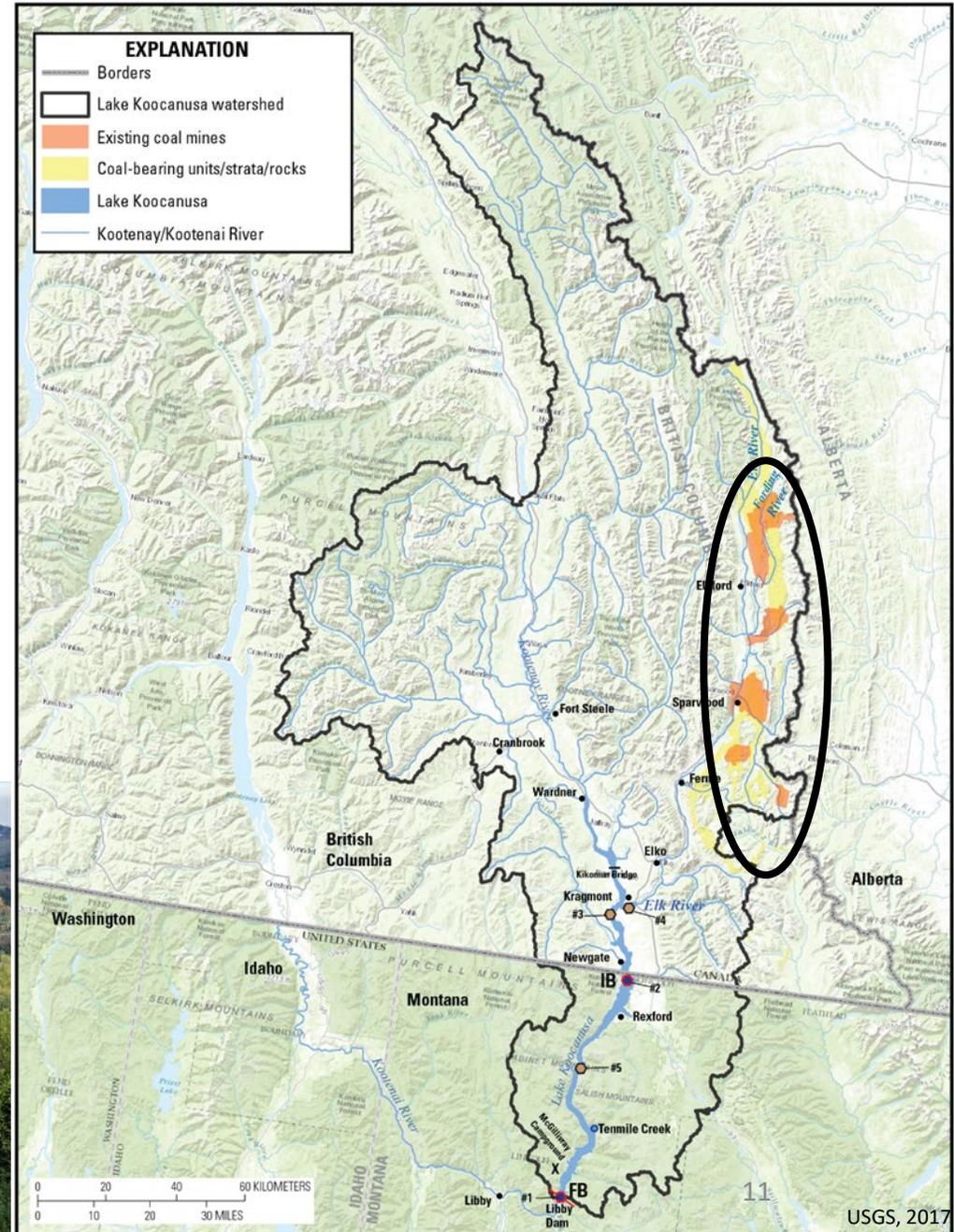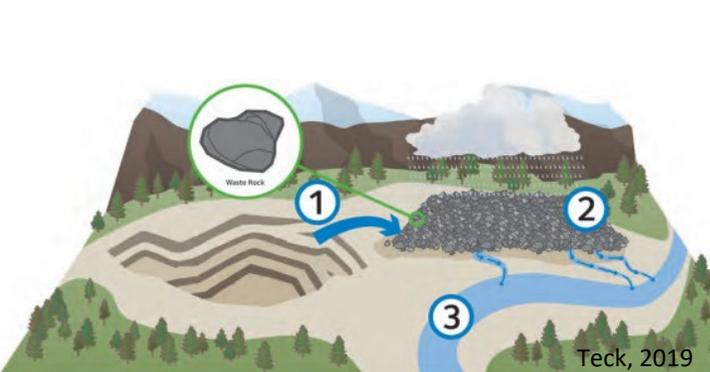
USGS, 2017

Selenium dietary exposure pathway
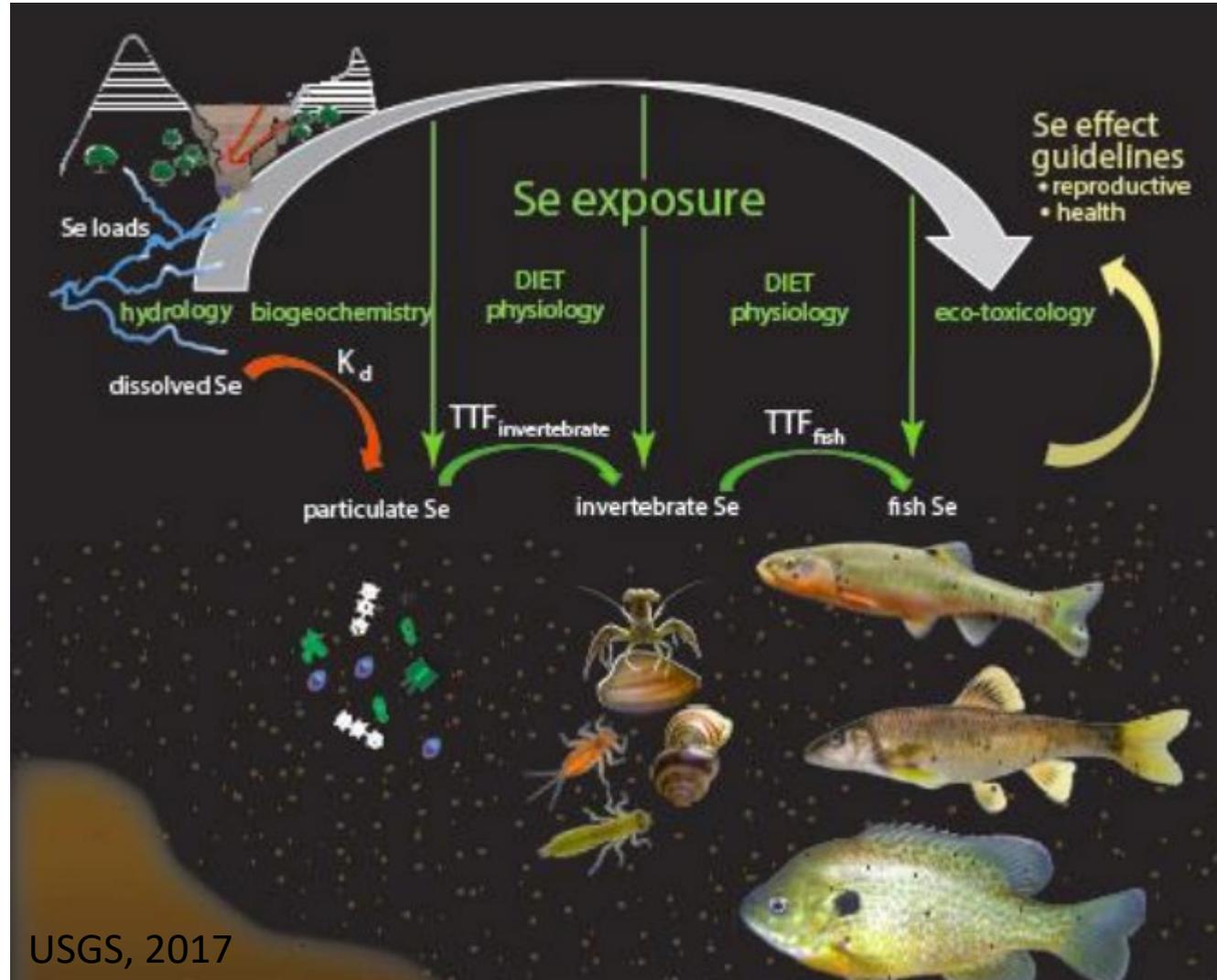
USGS, 2017

Toxicological effects of selenium

- Reduced production of viable eggs
- Reduced growth
- Mortality or deformity
- Altered liver enzyme function
- Winter Stress Syndrome
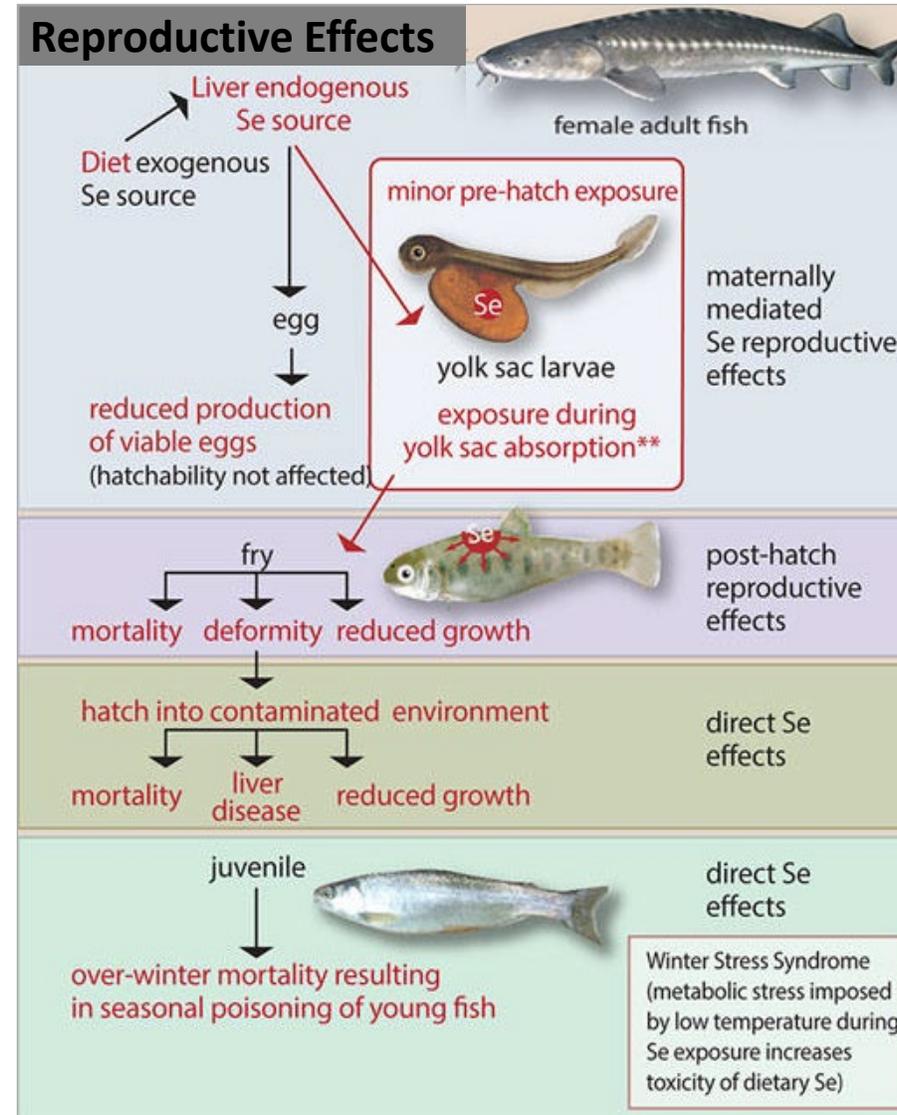
Adapted from Presser and Skorupa, 2019

Exceedances detected in fish tissue at current water Se concentrations

Seleniun Concentrations of Individual Fish in the United States
Reproductive Organ (Egg, Gonad and Ovary)

Egg/Ovary Criteria
11 – BC
15.1 - EPA

Year
2008
2013
2017
2018
2019

Selenium Concentrations (ug/g dw.)

Longnose sucker, Largescale sucker, Peamouth chub, Westslope cutthroat trout, Rainbow trout, Kokanee, Yellow perch, Mountain whitefish, Northern pikeminnow, Redside shiner
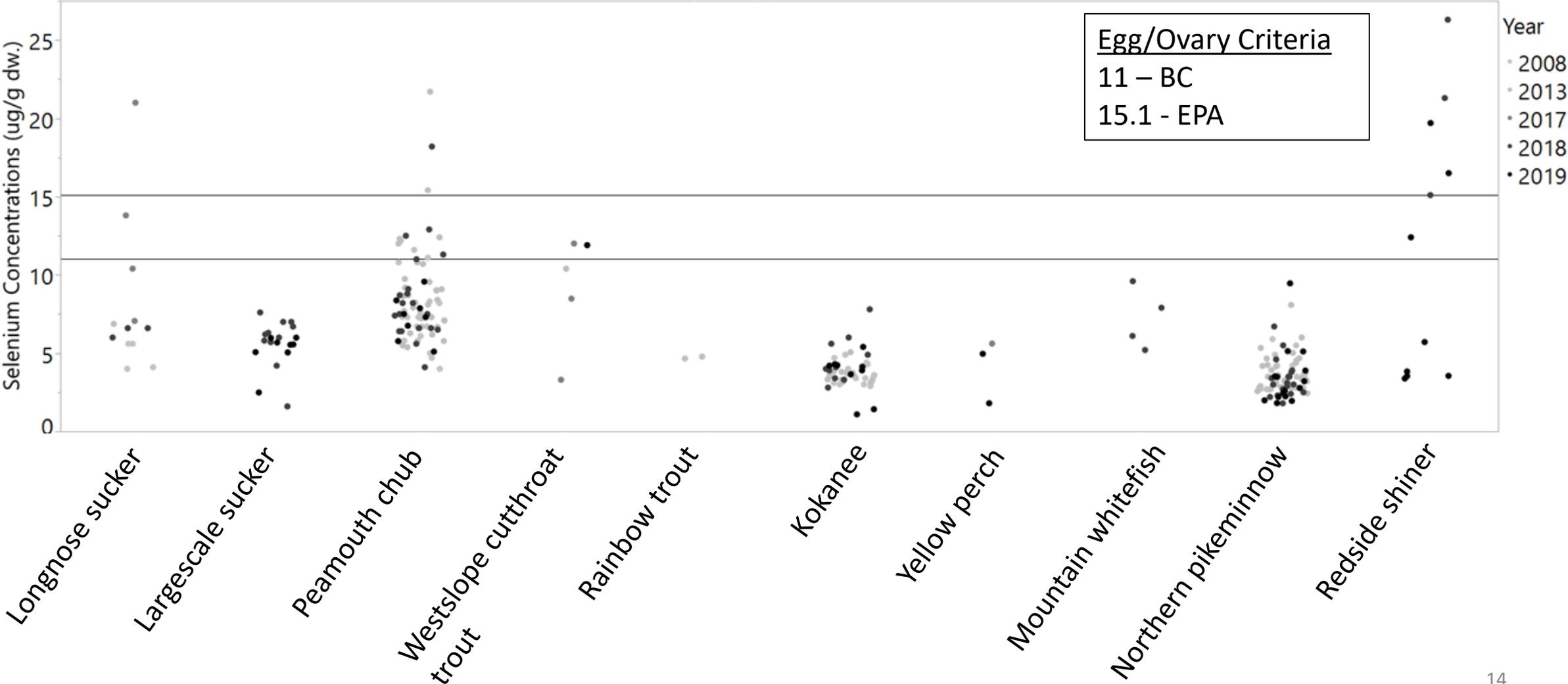
Average selenium levels are currently ~ 1.0 μg/L
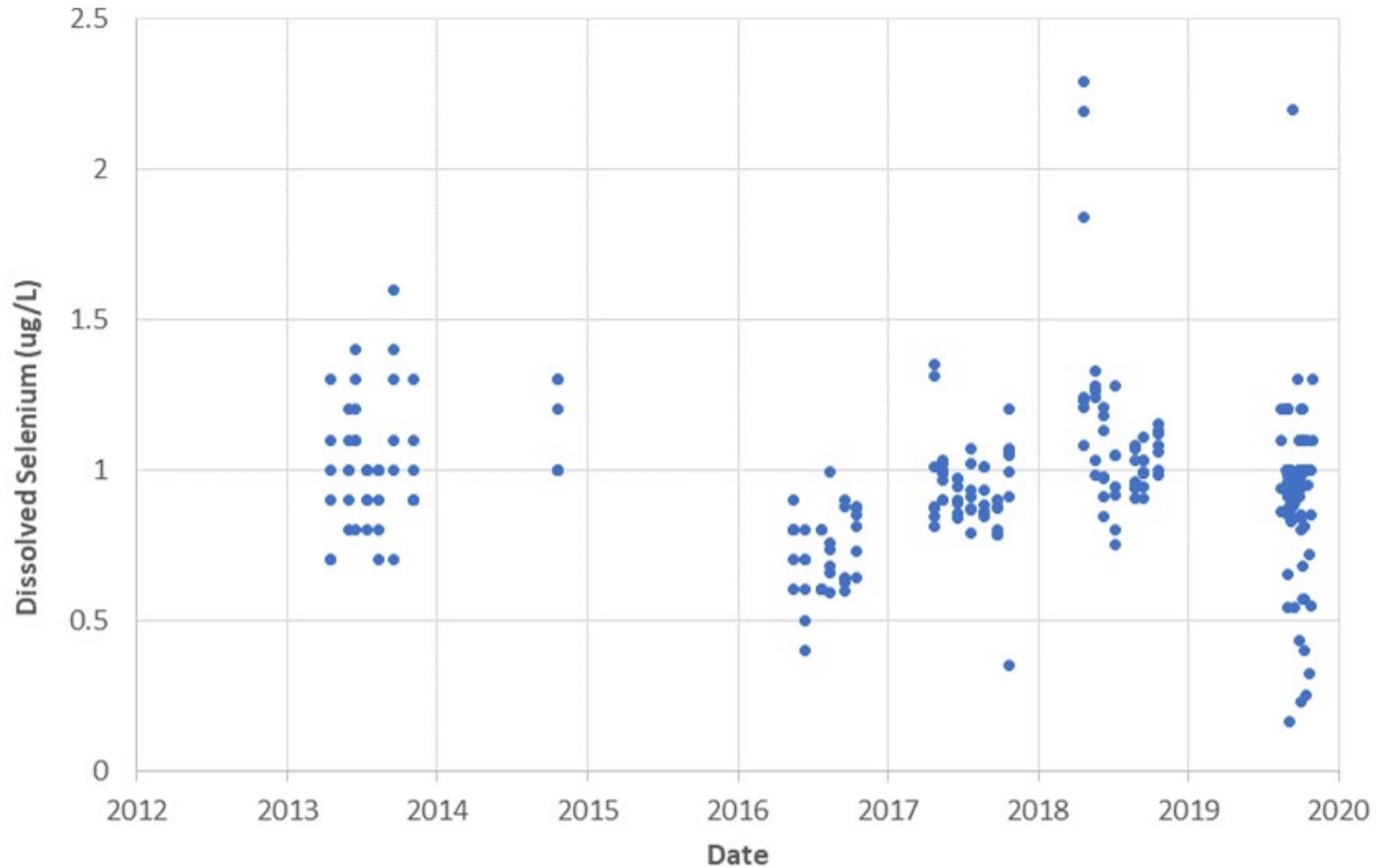
Data collection

MT FWP	MT DEQ	USACE	USGS	USFWS	BC-ENV	Teck

- Water chemistry
- Dissolved Se
- Se speciation
- Particulate (SPM) Se
- Sediment Se
- Periphyton tissue Se
- Invertebrate tissue Se
- Zooplankton tissue Se
- Fish muscle tissue Se
- Fish whole body tissue Se
- Fish egg/ovary Se
- Fish food habits
- Bird egg Se
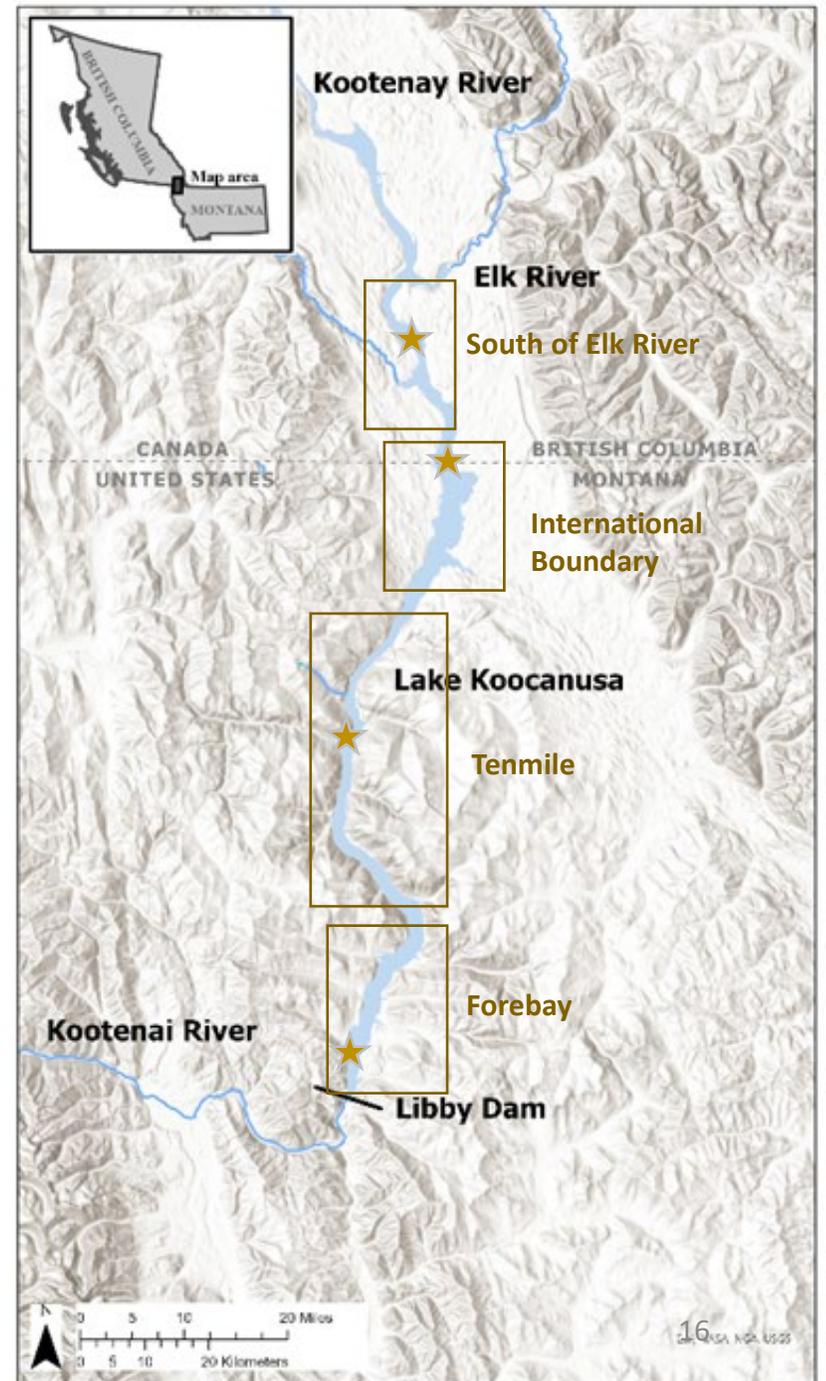
Fish identified by SeTSC for modeling

species (common name)	species (scientific name)	family	origin and utility
Lake Koocanusa			
bull trout	*Salvelinus confluentus*	salmonid	native, game
burbot	*Lota lota*	lotid	native, game
kokanee	*Oncorhynchus nerka*	salmonid	non-native, game
longnose sucker	*Catostomus catostomus*	catastomus	native, non-game
largescale sucker	*Catostomus macrocheilus*	catastomus	native, non-game
mountain whitefish	*Prosopium williamsoni*	salmonid	native, game
Northern pikeminnow	*Ptychocheilus oregonensis*	cyprinid	native, non-game
peamouth chub	*Mylocheilus caurinus*	cyprinid	native, non-game
rainbow trout (wild strain); not claimed in BC	*Oncorhynchus mykiss*	salmonid	native, game
rainbow trout X cutthroat (stocked hybrid)	*Gerrard strain*	salmonid	hatchery strains
redside shiner	*Richardsonius balteatus*	cyprinid	native, non-game
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	salmonid	native, game
yellow perch	*Perca flavescens*	percid	invasive; non-native, non-game

Selenium modeling by

Model Inputs:

- Fish-tissue Se target (mg/kg d.w.)
- Food Web
- TTF & bioavailability
- Kd (Suspended Se/dissolved Se)

→ **Peer-reviewed MODEL** (Presser & Luoma 2010) → **Protective Candidate Criteria (µg/L)**
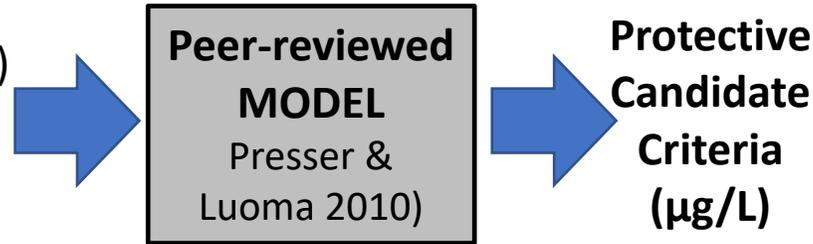
$$C_{target} = \frac{C_{tissue\ criterion\ element}}{TTF^{composite}\ X\ K_d}$$

ABSTRACT

The main route of exposure for selenium (Se) is dietary, yet regulations lack biologically based protocols for evaluations of risk. We propose here an ecosystem-scale model that conceptualizes and quantifies the variables that determine how Se is processed from water through diet to predators. This approach uses biogeochemical and physiological factors from laboratory and field studies and considers loading, speciation, transformation to particulate material, bioavailability, bioaccumulation in invertebrates, and trophic transfer to predators. Validation of the model is through data sets from 29 historic and recent field case studies of Se-exposed sites. The model links Se concentrations across media (water, particulate, tissue of different food web species). It can be used to forecast toxicity under different management or regulatory proposals or as a methodology for translating a fish-tissue (or other predator tissue) Se concentration guideline to a dissolved Se concentration. The model illustrates some critical aspects of implementing a tissue criterion: 1) the choice of fish species determines the food web through which Se should be modeled, 2) the choice of food web is critical because the particulate material to prey kinetics of bioaccumulation differs widely among invertebrates, 3) the characterization of the type and phase of particulate material is important to quantifying Se exposure to prey through the base of the food web, and 4) the metric describing partitioning between particulate material and dissolved Se concentrations allows determination of a site-specific dissolved Se concentration that would be responsible for that fish body burden in the specific environment. The linked approach illustrates that environmentally safe dissolved Se concentrations will differ among ecosystems depending on the ecological pathways and biogeochemical conditions in that system. Uncertainties and model sensitivities can be directly illustrated by varying exposure scenarios based on site-specific knowledge. The model can also be used to facilitate site-specific regulation and to present generic comparisons to illustrate limitations imposed by ecosystem setting and inhabitants. Used optimally, the model provides a tool for framing a site-specific ecological problem or occurrence of Se exposure, quantify exposure within that ecosystem, and narrow uncertainties about how to protect it by understanding the specifics of the underlying system ecology, biogeochemistry, and hydrology. Integr Environ Assess Manag 2010;6:685–710. © 2010 SETAC

Keywords: Selenium Food web Bioaccumulation Site-specific ecological exposure Ecosystem-scale

INTRODUCTION

Effects from Se toxicity have proven dramatic because of extirpations (i.e., local extinctions) of fish populations and occurrences of deformities of aquatic birds in impacted habitats (Skorupa 1998; Chapman et al. 2010). The large geologic extent of Se sources is connected to the environment by anthropogenic activities that include power generation, oil refining, mining, and irrigation drainage (Presser, Piper, et al. 2004). Toxicity arises when dissolved Se is transformed to organic Se after uptake by bacteria, algae, fungi, and plants (i.e., synthesis of Se-containing amino acids de novo) and then passed through food webs. Biochemical pathways, unable to distinguish Se from S, substitute excess Se into proteins and alter their structure and function (Stadtman 1974). The impact of these reactions is recorded most importantly during hatching of eggs or development of young life stages. Thus, the reproductive consequences of maternal transfer are the most direct and sensitive predictors of the effects of Se (Heinz 1996).

Each step in this sequence of processes is relatively well known, but the existing protocols for quantifying the linkage

between Se concentrations in the environment and effects on animals have orders of magnitude of uncertainties. Conventional methodologies relate dissolved or water-column Se concentrations and tissue Se concentrations through simple ratios (i.e., bioconcentration factor, BCF; bioaccumulation factor, BAF), regressions, or probability distribution functions (DuBowy 1989; Peterson and Nebeker 1992; McGeer et al. 2003; Toll et al. 2005; Brix et al. 2005; DeForest et al. 2007). None of these approaches adequately accounts for each of the important processes that connect Se concentrations in water to the bioavailability, bioaccumulation, and toxicity of Se.

In this paper, we present an ecosystem-scale methodology that reduces uncertainty by systematically quantifying each of the influential processes that links source inputs of Se to toxicity. In particular, we emphasize a methodology for relating dissolved Se to bioaccumulated Se. The methodology allows us to 1) model Se exposure with greater certainty than previously achieved through traditional approaches that skip steps, 2) explain or predict Se toxicity (or lack of toxicity) in site-specific circumstances, and 3) translate proposed Se guidelines among media under different management or regulatory scenarios.

Important components of the methodology are 1) empirically determined environmental partitioning factors between water and particulate material that quantify the effects of dissolved speciation and phase transformation, 2) concentrations of Se in living and nonliving particulates at the base

# USGS presented 2 food webs (models) with multiple consumption patterns

Invertebrate to fish model (IFM)

- Insect eating fish
- Zooplankton eating fish
- Mixture of Insect and Zooplankton eating fish

Trophic fish model (TFM)

- Fish eating insectivorous fish
- Fish eating planktivorous fish

Example food webs and Trophic Transfer Factors

Particulate $\xrightarrow{2.8}$ Aquatic Insects $\xrightarrow{1.1}$ fish

Particulate $\xrightarrow{1.5}$ Zooplankton $\xrightarrow{1.1}$ fish

Particulate $\xrightarrow{2.8}$ Aquatic Insects $\xrightarrow{1.1}$ Predator fish $\xrightarrow{1.1}$ Prey fish
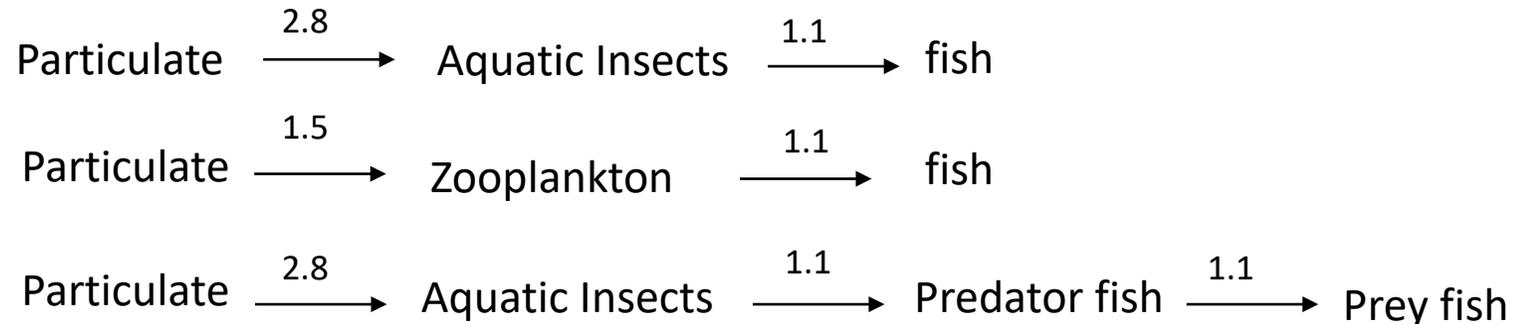
Invertebrate to fish (IFM) model

- IFM model applies for all species consuming only invertebrates or zooplankton
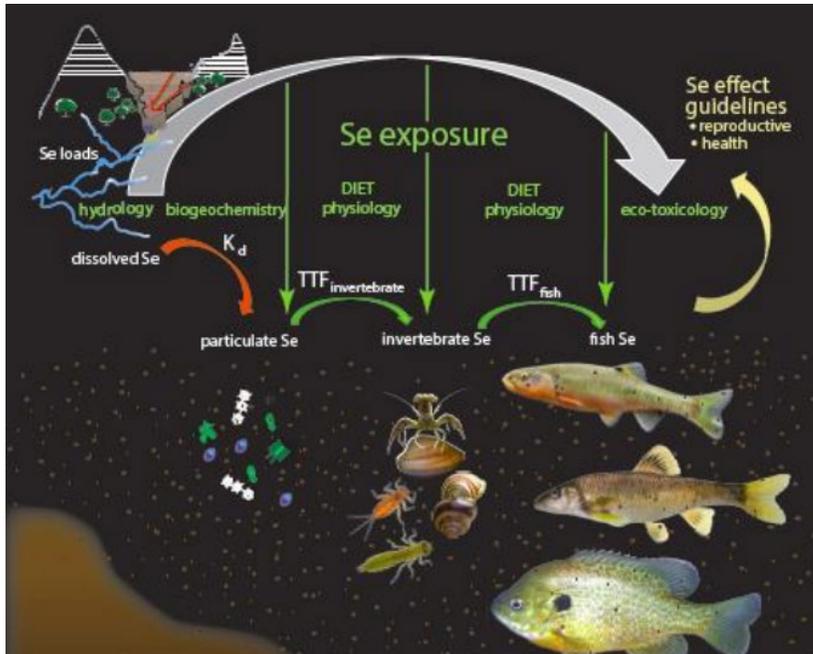
Trophic level fish (TFM) model

- TFM model applies to all predator fish species
- It adds one more step in the food web
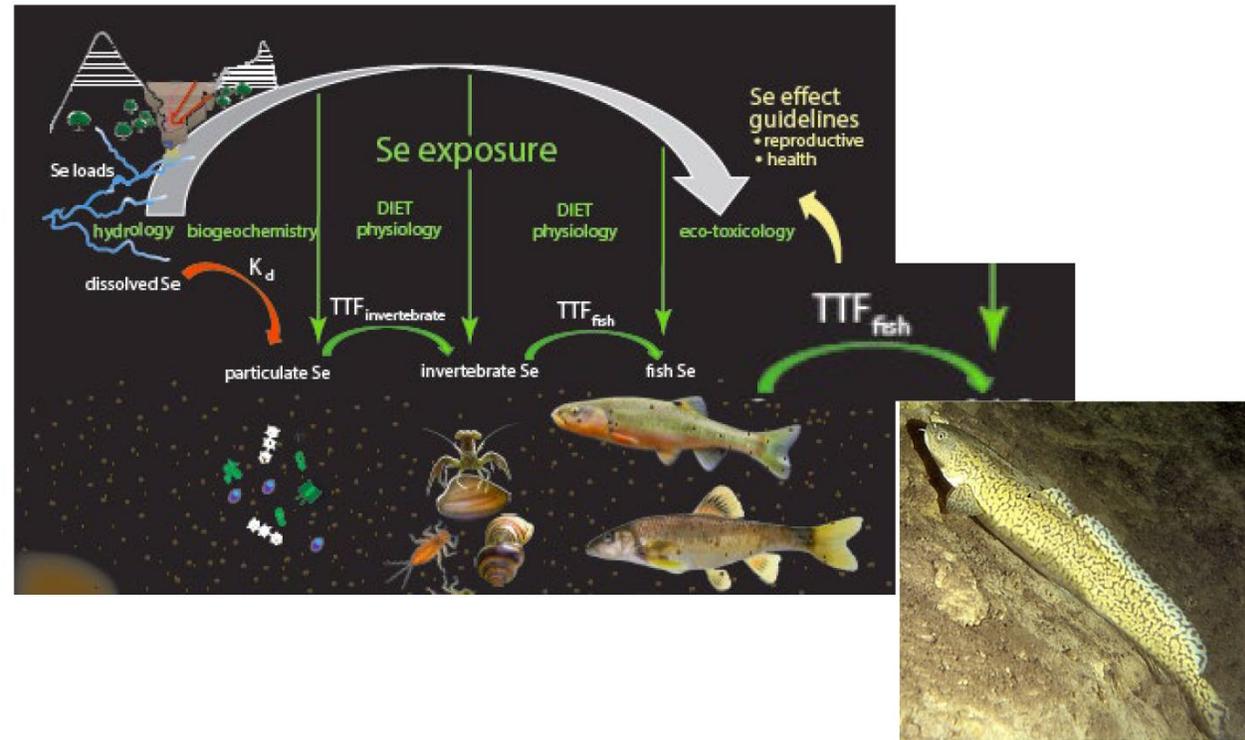
Implication: All K_d values considered as independent scenarios


Kd values from 2015-2019, all locations and depths, sorted from low to high
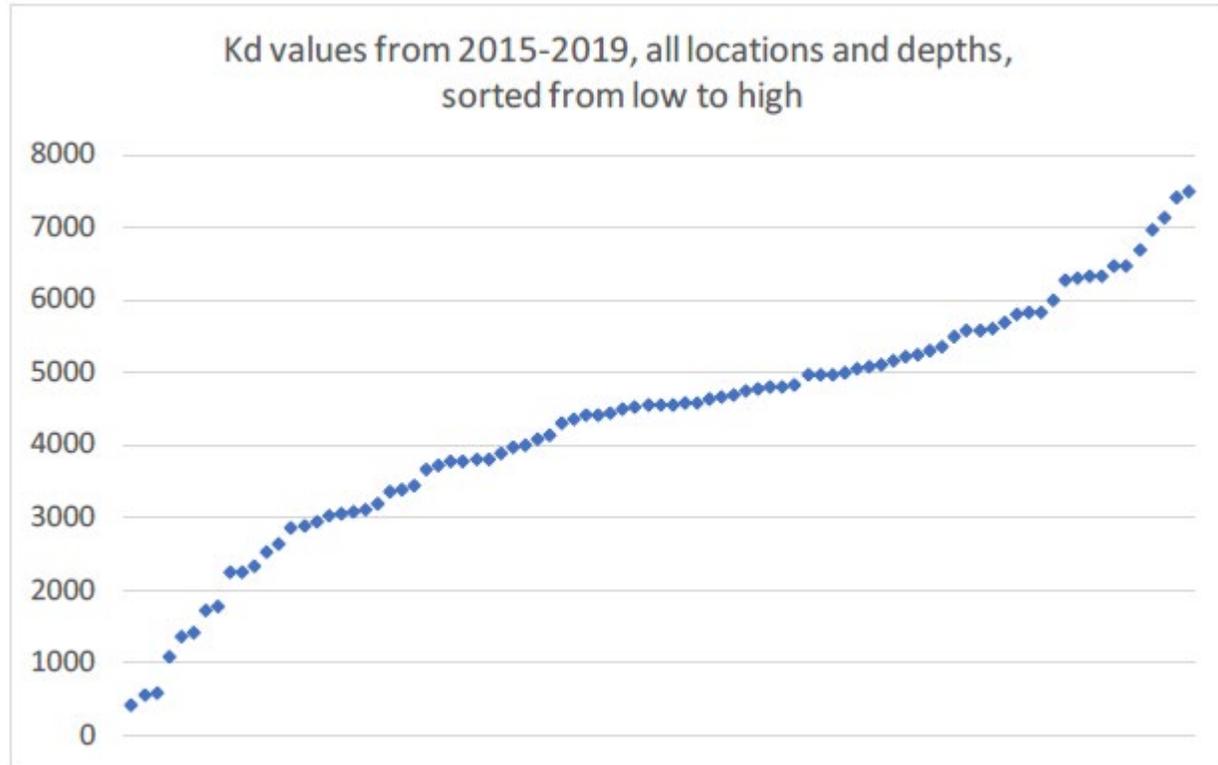
Protective dissolved Se concentration for the specified scenario
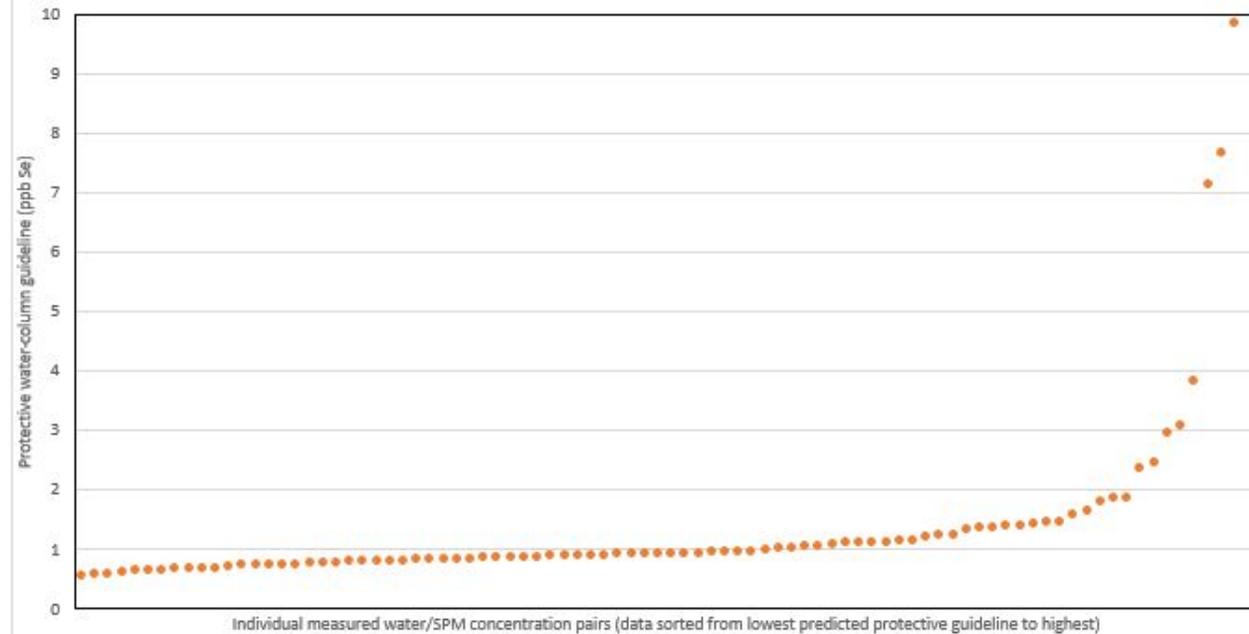
USGS Modeling Results, Conclusions

- USGS modeling was based on EPA national guideline (8.5 mg/kg w. body).

- Values other than 8.5 could be input. Modeling choices and assumptions were guided by goals in the report and previously defined by the SeTSC.

- USGS (Presser and Naftz, 2020) peer-reviewed report provided the foundation from which DEQ and BC-ENV were able to co-develop a protective water column Se standard.

- *Summary of Goals*:
  - Consideration of ecologically significant species and those important to stakeholders
  - Protection of ecosystem during max dietary exposure (feeding in a benthic food web)
  - 100% protection of the fish species in the reservoir assuming a reproductive end point from reproductively mature females feeding in a lentic ecosystem
  - Long-term protection for fish in all parts of the reservoir during all phases of reservoir operation, all Se loading profiles, and all water years

Post Report: DEQ & BC-ENV collaborative analysis

LKMRWG Steering Committee (DEQ & BC-ENV) solicited recommendations from the SeTSC on model inputs and final criteria recommendations

SeTSC members provided recommendations during half day teleconference & written recommendations

DEQ & BC-ENV considered recommendations from SeTSC to develop three additional scenarios

DEQ & BC-ENV agreed upon a narrow range considered protective of the aquatic life beneficial use

SeTSC recommendations

- Whole body tissue:
  - 5/7 members recommended a whole-body tissue value <u>lower than </u>8.5 mg/kg dw
    - Ranged from 4.6 to 7.0 mg/kg
    - 2/7 members recommended 8.5 mg/kg dw

- Food Webs, TTFs, bioavailability:
  - 3/7 members specifically recommended the TFM TL3 at 100% aquatic insect diet; no recommendations for any other food web were presented
  - General agreement that the 60% bioavailability at literature TTFs may be over predictive
    - Recommendations ranged from using 60% at literature TTFs
    - Calculating site specific TTFs – recommendations ranged from 1.1 -1.2 (Aq.Ins) to 0.58-0.85 (zoo)
    - Combining USGS TTFs with EPA TTFs to create a larger database to recalculate

- Kd selection:
  - General agreement that the median (50th percentile) would be appropriate if a lower whole body tissue value is selected, and a more conservative percentile should be selected if 8.5 whole body tissue value is used.

- Final criteria:
  - 4/7 members provided recommendations on a final water column value
    - One member recommended 1.5 ug/L based on EPA 304(a) criteria
    - Three members recommended criteria ranging between 0.6 ug/L and 0.8 ug/L

DEQ & BC-ENV co-developed

Scenario	Whole body tissue threshold (mg/kg dw)	Food Web	diet	TTF Aquatic Insect	TTF Zooplankton	Bioavailability	Kd percentile	Predicted dissolved water column Se (ug/L)
1	5.6	IFM	100% Aquatic Insects	2.8		45%	50th (median)	0.89
2	5.6	TFM TL3	75% Aquatic Insects/ 25% Zooplankton	2.8	1.5	45%	50th (median)	0.91
3	5.6	TFM TL3	100% Aquatic Insects	2.8		45%	50th (median)	0.8

EPA recommendation

Whole body tissue threshold (mg/kg dw)	Food Web	diet	TTF Aquatic Insect	TTF Zooplankton	Bioavailability	Kd percentile	Predicted dissolved water column Se (ug/L)
8.5	TFM TL3	100% Aquatic Insects	2.8		60%	75th	0.8

0.8 ug/L

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Proposed Se standards for Lake Koocanusa

Parameter	Selenium Concentration
Dissolved selenium (µg/L)	0.8
Egg/Ovary (mg/kg dw)	15.1
Muscle (mg/kg dw)	11.3
Whole body (mg/kg dw)	8.5

Proposed Se standards for Kootenai River

Parameter	Selenium Concentration
Dissolved selenium (µg/L)	3.1
Egg/Ovary (mg/kg dw)	15.1
Muscle (mg/kg dw)	11.3
Whole body (mg/kg dw)	8.5

Rulemaking Timeline

- **September 11** - Water Pollution Advisory Council (WPCAC)
- **September 24** -Board of Environmental Review (BER)
  - Request initiation for rulemaking
- **October 9 – November 23** - Public Comment Period
- **November 5** – Public Hearing
- **Dec 11** – Board of Environmental Review (BER)
  - Request adoption of rule