ELK RIVER WATERSHED AND LAKE KOOCANUSA, BRITISH COLUMBIA

Aquatic Environment Synthesis Report 2014

Prepared for

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Executive Summary

Introduction

Under existing *Environmental Management Act* authorizations, numerous environmental monitoring and assessment programs have been conducted within the Elk River watershed over the past twenty years by Teck. Initially, these programs focused on measurement of selenium in water, sediment, and tissues of biota, whereas more recent monitoring has broadened to include evaluation of additional constituents in those media, as well as assessment of benthic invertebrate community and fish population characteristics. Monitoring activities in the BC portion of Lake Koocanusa[1] have also increased. In addition to extensive monitoring activities, numerous supporting investigations have been undertaken to address specific questions about sample types and sampling methods, locations, and timing that will facilitate detection of coal-mine-related effects on aquatic biota. Results of recent monitoring and studies are summarized in this report to inform the study design of a comprehensive monitoring program (i.e., the Regional Aquatic Effects Monitoring Program, or RAEMP) to assess potential mine-related effects in the aquatic environment throughout the Elk River watershed and the Canadian portion of Lake Koocanusa.

This report also responds to an Order issued by the BC Minister of Environment in April 2013. The Order outlined a framework to develop an area-based water quality plan (the Elk Valley Water Quality Plan [EVWQP]) to allow for continued mining development in the Elk Valley while achieving the following outcomes:

- protection of aquatic ecosystem health;
- management of bioaccumulation of contaminants in the receiving environment (including fish tissue);
- protection of human health; and
- protection of groundwater.

The approved Terms of Reference outlining the process for development of the EVWQP include a requirement to evaluate current baseline conditions within the watershed. To satisfy requirements of assessing current conditions as part of the development of the EVWQP, the Designated Area was subdivided into six Management Units (MUs):

- **Management Unit 1 (MU1)** includes the Fording River upstream of Josephine Falls and associated mine-influenced tributaries;
- **Management Unit 2 (MU2)** includes the Fording River downstream of Josephine Falls and associated mine-influenced tributaries;

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[1] For the purpose of this report, and unless otherwise noted, any and all references to Lake Koocanusa are limited to the Canadian portion of the reservoir.

- **Management Unit 3 (MU3)** includes The Elk River upstream from the confluence with the Fording River and associated mine-influenced tributaries;
- **Management Unit 4 (MU4)** includes Michel Creek, as well as the Elk River from the Fording River confluence to immediately downstream from the Michel Creek confluence, plus associated mine-influenced tributaries;
- **Management Unit 5 (MU5)** includes the lower portion of the Elk River to its mouth at Lake Koocanusa; and
- **Management Unit 6 (MU6)** contains the Canadian portion of Lake Koocanusa.

Presentation and interpretation of data within this report have been organized accordingly.

Existing Data

A large amount of environmental information has been collected in the Designated Area during previous studies. This includes summaries of water quality, sediment quality, calcite deposits, tissue residues for aquatic ecological receptors (i.e., plankton, periphyton, benthic macroinvertebrates, fish, and amphibians) and aquatic-dependent birds, as well as invertebrate community structure and fish population characteristics, as summarized below.

Surface Water Quality

Water quality was evaluated for 93 stations monitored by Teck from 2011 to 2013. Each station was categorized as one of the following types: 1) a mine-influenced tributary station, located directly downstream of Teck's operations (e.g., immediately downstream of mining activities or a mine settling pond), 2) a mainstem station receiving inputs from mine-influenced tributaries, or 3) a reference station, representing conditions upstream of mining operations. Water concentrations measured in individual grab samples collected at each station were compared to either water quality guidelines for protection of aquatic life (most constituents) or site-specific benchmarks developed in accordance with the EVWQP under the provincial Order (cadmium, nitrate, selenium, and sulphate). For guidelines or benchmarks that vary based on other water quality factors (such as water hardness), same-sample data were used to derive the relevant guideline/benchmark.

Nitrate, selenium and sulphate were identified as primary constituents of potential concern (COPCs) within the Elk River watershed because more than 10 percent of the samples combined among mainstem receivers and mine-influenced tributaries had concentrations above the site-specific benchmarks. Concentrations of these substances show an increasing trend at most mainstem stations. About 75 percent of the total mine-related loads of these constituents are associated with seven to ten mine-influenced tributaries (depending on the COPC), which are Kilmarnock, Swift and Cataract creeks (MU1); West Line Creek and Line Creek (MU2); Thompson Creek (MU3); and Harmer, Bodie, and Erickson creeks (MU4). In the Elk River downstream from all mining operations, there were no concentrations above benchmarks for nitrate, selenium and sulphate in any samples, and concentrations decreased with distance downstream from mining operations.

Other constituents with at least one sample having a concentration above the WQG or benchmark were identified as COPCs of lesser concern and were each mainly associated with only a few mine-influenced tributaries. These constituents included nitrite, ammonia, aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, thallium, uranium, vanadium, zinc, benzo(a)pyrene, phenanthrene, and pyrene. Samples collected at mainstem receiving stations rarely had elevated concentrations of any COPCs (i.e., <10% of samples per station).

In Lake Koocanusa (MU6), some samples had phosphorus, selenium, or chromium concentrations above benchmarks or WQGs. Elevated phosphorus concentrations did not appear to be a result of Elk River inputs based on results for reservoir stations located upstream of the Elk River. The Elk River has a slight influence on selenium concentrations in downstream areas of Lake Koocanusa, but concentrations did not exceeded the BC MOE WQG of 2 µg/L in any of the samples, except for 2 of 14 samples near the mouth of the Elk River and 1 of 14 samples collected within the reservoir upstream of the Elk River. Chromium was measured slightly above the guideline in only one sample collected at the Elk River mouth.

Sediment Quality

Sediment data were available for both the Elk Valley watershed (2011 and 2013 sampling events) and in Lake Koocanusa (2013). The top 1-2 cm of sediment was analyzed to reflect conditions in the sediment layer containing most benthic organisms. Metals were analyzed on dried samples that had been sieved to remove particles larger than 1-2 mm, and PAH were analyzed on whole, wet sediment samples, consistent with standard laboratory protocols. Sediment metals and PAH data were available for 16 and 26 areas of the watershed, respectively. Two to ten samples were collected per area during each sampling event.

For samples collected within the Elk River watershed, a total of seven constituents (cadmium, nickel, zinc, 2-methylnaphthalene, fluorene, naphthalene, and phenanthrene) were identified as primary COPCs based on concentrations in one or more samples that were above the corresponding high sediment quality guideline (i.e., probable effect level [PEL] or severe effect level [SEL]). Concentrations of cadmium, nickel, and/or zinc were above the high guideline in one or more samples collected at 3 of 16 monitoring areas. One or more PAH was elevated in at least one sample collected at 5 of 26 locations.

Toxicity tests were conducted on a subset of samples in 2013 using the freshwater amphipod *Hyalella azteca* (14-day survival and growth test) and the midge *Chironomus riparius* (10-day survival and growth test). The samples were collected at two reference areas, one settling pond, and three receiving environment areas. The only observed effect was slightly impaired survival of *C. riparius* exposed to some but not all replicate sediment samples collected from a receiving environment located immediately downstream of mining activity (Goddard Marsh in MU4); the observed reduction in survival could not be directly linked to measured differences in sediment chemistry or physical habitat attributes among replicate samples from that area. *Chironomus* growth was not impaired after 10-day exposure to sediment from any areas.

Although the existing data are somewhat limited, they suggest that effects on sediment-dwelling organisms are unlikely at most locations in the Elk Valley watershed based on the relatively small proportion of total samples with metal and/or PAH concentrations greater than the high sediment quality guidelines, as well as available toxicity test results. This could be confirmed by performing toxicity tests on sediments collected from additional depositional areas of the watershed.

Calcite

Calcite ($CaCO_{3(s)}$) precipitation/deposition occurs naturally within the Elk River watershed, but has also been commonly observed downstream of mining activities (e.g., waste rock piles). Precipitation of calcite is governed by a complex system of factors, including stream pH, stream temperature, rates of carbon dioxide off-gassing, kinetic limitations on transformations between inorganic carbon species. Calcite precipitation can affect the physical aquatic habitat and aquatic biota.

Teck initiated a study in 2013 to document calcite deposition in the Elk River watershed using standardized methods. The study was designed to be repeated in three successive years to evaluate changes over time and identify where calcite mitigation may be required. The monitoring program quantifies the degree of calcite deposition using a Calcite Index (CI) that reflects both the presence/absence of calcite and degree of concretion, resulting in scores of 0.0 (no calcite is observed) to 3.0 (streambed is fully concreted). Available data show that most of the watershed reaches assessed (91%) have a Calcite Index of less than 0.5 (i.e., only minimal calcite is observed); about 5% of the assessed reaches have a Calcite Index value greater than 1.0. Beginning in 2014, the study was expanded to also assess benthic invertebrate health and periphyton productivity associated with the range of calcite observed throughout the watershed. The results will be used to inform the future scope of the calcite monitoring program and the RAEMP to ensure that calcite effects on biota are being tracked over time.

Periphyton

Periphyton tissue data were evaluated as part of a screening-level ecological risk assessment (SLERA) of trace element concentrations in aquatic organism tissues. In the SLERA, it was assumed that benthic invertebrates and amphibians may be exposed to trace elements in periphyton via their diet. Manganese, nickel, and zinc were identified as COPCs for invertebrates feeding on periphyton (no COPCs were identified for amphibians that may feed on periphyton). There was considerable uncertainty in the dietary TRVs for benthic invertebrates (dietary toxicity data were not available for closely related taxa) and TRVs for these substances were exceeded in few areas of the watershed. Benthic invertebrate community monitoring will identify if effects to invertebrates are actually occurring, whether due to dietary metal exposure or other causes (such as water toxicity or effects of calcite deposition). Therefore, continued monitoring of metal concentrations in periphyton was not recommended in the SLERA, although measurement of periphyton metal concentrations could be considered as part of a special study at relevant areas if it became important to determine the specific cause of effects.

Periphyton chlorophyll-a data provide an indication of the productivity of chlorophyll-producing algae within the periphyton community. Baseline periphyton chlorophyll-a sampling was initiated in several areas throughout the Elk River watershed (including reference areas) in 2012 and 2013, in support of plans to commission an active water treatment facility at LCO in 2014. Results indicated higher chlorophyll-a concentrations in some receiving environment areas compared to reference areas. With the exception of samples that included bryophytes (which are not traditionally considered a component of periphyton communities), and one sample collected on the Fording River (where calcite was observed), all chlorophyll-a concentrations were well below the in-stream guideline of 100 mg/m^2. Chlorophyll-a concentrations in periphyton varied among substrate types where replicate samples were collected. These data illustrate that natural variation in substrate characteristics can greatly affect chlorophyll-a results, and that the ability to detect mine-related influences depends on how well the characteristics of substrates chosen for sampling are standardized.

A supporting study was implemented by Teck in 2013 to address some of the information gaps related to assessing periphyton community structure in the context of a regulatory monitoring program. A key component of the investigation was an inter-laboratory comparison of taxonomy and enumeration for split samples. Seven periphyton samples collected within the watershed were homogenized and split into quarters, with one quarter of each sample being sent to each of four commercial laboratories specializing in algal community evaluations. Overall, there was very little consistency in community composition data reported by the four laboratories. Rarely was the same species identified by all four laboratories in a given sample and there were even large differences among laboratories for organism abundances reported at a coarse "group" level (i.e., chlorophytes, chrysophytes, cyanophytes, diatoms, and rhodophytes). Another supporting study is planned for 2015 to determine if refinements to sampling design, laboratory analysis and/or data analysis techniques may increase the reliability of periphyton community assessment to detect potential mine-related effects

Benthic Invertebrates

Invertebrate tissue data were evaluated in the SLERA of trace element concentrations in aquatic organism tissues. It was assumed that fish, amphibians, and aquatic-dependent birds may be exposed to trace elements in invertebrates via their diet. In addition, mercury and selenium concentrations in benthic invertebrates were evaluated as indicators of potential toxicity to the benthic invertebrates themselves. Selenium was the only primary COPC identified for invertebrate tissue, which was based on direct toxicity to invertebrates and dietary toxicity to fish and aquatic-dependent birds. The highest hazard quotients (HQs)[2], based on the 95% percentile selenium concentrations in invertebrates for an MU, were 2.2, 2.6, 3.5, and 1.9 for direct toxicity to invertebrates, fish diets, amphibian diets, and aquatic-dependent bird diets, respectively.

A detailed assessment of benthic invertebrate community health in mine-exposed areas relative to reference areas was completed in 2012 based on samples collected from 36 reference and 56 mine-exposed lotic areas. Reference areas were selected to represent a range of natural habitat characteristics exhibited by mine-exposed areas, such as elevation, stream size, catchment area, and catchment gradient, to ensure that each mine-exposed area could be matched with, and statistically compared to, a sub-set of reference areas with similar natural habitat characteristics. Adverse effects to benthic invertebrate communities were indicated at 20 mine-exposed areas, most of which were in mine-influenced tributaries near mine sources. These effects were generally reflected as reductions in the combined proportion of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (i.e., EPT), or the proportion of Ephemeroptera alone; these groups (particularly mayflies and stoneflies) dominated the invertebrate communities in reference areas as well as mine-exposed areas that were considered to be in reference condition. Eighty-six percent of the main stem receiving environments sampled,

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[2] The HQ was the ratio of the trace element concentration in tissue to a corresponding screening value (SV). The SV was typically an effects-based toxicity reference value (TRV), but was based on the 95th percentile reference area concentration for a given constituent and tissue type when the TRV was less than this value.

including all areas sampled along the Elk River, had communities consistent with reference areas. Correlation analysis identified a relationship between the concentrations of mine-related contaminants in water (as summarized by Principal Components Analysis) and various measures of benthic invertebrate community health, suggesting that coal-mining activities contributed to effects on benthic invertebrate communities at locations where effects were observed.

Fish

Fish tissue data were evaluated in the dietary- and tissue-based SLERA. It was assumed that fish, aquatic-dependent birds, and aquatic-dependent mammals may be exposed to trace elements in whole fish or muscle via their diet. In addition, mercury and selenium concentrations in fish tissues were evaluated as indicators of potential direct toxicity to the fish themselves. Selenium was the only primary COPC identified, which was based on direct toxicity to fish (based on ovary/egg selenium concentrations) and dietary toxicity to fish and aquatic-dependent birds and mammals. The highest HQs, based on the 95th percentile selenium concentrations in fish for an MU were 4.5, 4.2, 2.9, and 5.7 based on selenium concentrations in fish ovaries/eggs (direct toxicity), fish diets, and aquatic-dependent bird and mammal diets, respectively. Based on individual fish ovary/egg samples, the highest HQs at each MU were 3.4 (westslope cutthroat trout), 1.5 (mountain whitefish), <1.0, 1.8 (mountain whitefish), and 2.1 (mountain whitefish) for MU1, MU2, MU3, MU4, and MU5, respectively. It should be noted that the mountain whitefish HQs are conservatively high, as the SV used to derive those HQs was based on a "greater than" no-effects threshold (i.e., no effects to mountain whitefish were observed at the highest egg/ovary selenium concentration tested). There were six sampling locations where the maximum egg/ovary selenium HQ was > 1.0 for a species other than mountain whitefish.

Westslope cutthroat trout are commonly found in lotic and lentic habitats throughout the Elk River watershed, and this is the only fish species present in the Fording River upstream of Josephine Falls. In addition to cutthroat trout, bull trout and mountain whitefish are native to the Elk River watershed, although they are usually found only in the main stem and in lower reaches of larger tributaries such as the Fording River, Line Creek, Alexander Creek, and Michel Creek. Rainbow trout are also found within the watershed but are non-native (introduced) species. There are also patchy distributions of several other species, such as longnose sucker and longnose dace, which mainly occupy slow-flowing side channels, oxbows, ponds, and lakes at lower elevations along or near the Elk River downstream of Elkford.

A multi-year study (2012-2015, inclusive) of cutthroat trout in the upper Fording River watershed is underway to assess population status, seasonal movements, and habitat use, which will inform mine mitigation and fish habitat management decisions. Unlike the lower Fording River and the remainder of the Elk River watershed, westslope cutthroat trout in the upper Fording River are isolated from confounding factors (e.g., angling, competition from other fish species, hybridization, and potential effects related to agricultural development) that could affect population stability and fish health. Literature on Population Viability Analyses (PVA) and Recovery Potential Assessments for westslope cutthroat trout has shown that a viable population can range between 470 and 4,600 adults and between 9 and 28 km of stream is required to maintain an isolated population. To date, monitoring of fry, juveniles, sub-adults, and adults indicates that the westslope cutthroat trout population of the upper Fording River is stable at about 3,000 adults having access to 57.6 km of habitat. Based on Fulton’s condition indices, Upper Fording River WCT also appear to be robust and exhibit low rates of deformities.

In 2013, a study of longnose sucker presence/absence, abundance (density), and health was initiated at a variety of lentic areas to inform the design of the RAEMP. No differences in biomass, growth rates or body condition were found among the areas studied. The longnose sucker will be used as a sentinel species in monitoring potential mine-related effects in lentic areas, where they occur. The longnose sucker monitoring program will include assessment of fish health endpoints in a variety of off-channel habitats containing populations of sufficient size that they can be reliably quantified and tracked over time.

Amphibians

Amphibian egg mass data were evaluated in the dietary- and tissue-based SLERA. It was assumed that fish and aquatic-dependent birds may be exposed to trace elements in amphibian egg masses via their diet (direct selenium toxicity to amphibians was not evaluated due to a lack of reliable tissue-based effects data). Selenium was the only primary COPC identified for amphibian egg masses, which was based on dietary toxicity to fish and birds. The highest HQs for an MU, based on the 95th percentile selenium concentrations in amphibian egg masses, were 1.5 and 1.1 for fish and birds, respectively.

Amphibian communities were also surveyed during the breeding season (May) in 2012. In general, the surveys provided an indication of the areas and types of habitat preferred by breeding spotted frogs and western toads in the Elk River valley. While amphibian community surveys may be valuable in identifying species of concern that use a particular area (e.g., for baseline characterization), they are not considered useful for quantitatively monitoring potential mine-related effects on amphibians. This is because the spring breeding surveys do not necessarily correspond to larval or adult use of areas throughout the remainder of the ice-free period. Also, it is challenging to conduct surveys outside of the breeding period because larvae (tadpoles) disperse within the pond/water body and adults disperse away from water and do not vocalize, making them difficult to find and enumerate.

Birds

Bird egg data were evaluated following a step-wise screening process based on the assessment of trace element concentrations in aquatic organism tissues, as described in the dietary- and tissue-based SLERA. Selenium concentrations in bird egg tissue were evaluated as indicators of potential direct toxicity to bird reproduction (i.e., embryo mortality). Selenium was identified as a bird egg COPC because 95th percentile bird egg selenium HQs were > 1.0 at four MUs: 1.9, 1.7, 2.9, and 1.5 for MU1, MU2, MU3, and MU4, respectively.

As with amphibians, breeding bird surveys were completed at several areas throughout the valley in 2012. Again, while the surveys may be valuable in identifying species of concern that may be utilizing a particular area, they are unlikely to be useful for quantitatively monitoring potential mine-related effects on birds. Bird surveys rely primarily on auditory and visual observations of adults and do not include documentation of the number of nests or nesting success. Observations can also be highly weather- and time-dependent (e.g., it is much more difficult to hear/observe birds during heavy rain, birds tend to be less vocal on warm, sunny mornings, and birds are much less active/vocal in afternoons compared to early mornings). Therefore, results can vary substantially among surveys as a result of natural rather than mine-related factors.

Evaluation of Environmental Quality within Each MU

The available aquatic environmental data (summarized above) were compiled for each sampling location within each MU to facilitate an integrated interpretation of conditions within each MU. The lines of evidence considered were water quality, substrate quality (including sediment chemistry and relative calcite deposition), benthic invertebrate community health, and tissue selenium concentrations. Data for each sample type (except calcite) and location were ranked as indicative of "good," "fair," "marginal"[3], or "poor" environmental quality, based on criteria that were defined for each line of evidence.

Management Unit 1

The tributaries that have been sampled in MU1 include those contributing most of the selenium, nitrate, and/or sulphate to the watershed within MU1 (e.g., Henretta, Clode, Kilmarnock, Swift, Cataract, and Greenhills creeks). The tributaries with highest concentrations of mine-related constituents generally reflected poor benthic invertebrate communities and elevated tissue selenium concentrations. Water quality in the upper Fording River is being influenced by contributions from the mine-influenced tributaries, but little or no calcite deposition is occurring along the mainstem river. Also, benthic invertebrate communities and tissue selenium concentrations of most of the upper Fording River are considered indicative of good quality and comparable to conditions observed in reference areas. Biota, such as fish and birds, that are able to move freely between mainstem, tributary, and off-channel areas (including settling ponds) had tissue selenium concentrations ranging from good (low risk of effects) to poor (potential risk). Highest selenium-related risks to invertebrates and vertebrates within MU1 were indicated at the Fording River Oxbow.

Management Unit 2

Water quality in lotic areas of MU2 ranged from good (upstream of the Line Creek rock drain) to poor (immediately downstream of the Line Creek rock drain). Both Line Creek downstream of the rock drain and West Line Creek, which flows into Line Creek just downstream from the rock drain, are major sources of selenium, nitrate, and sulphate to the watershed within MU2. The benthic invertebrate community was considered poor immediately downstream of the rock drain. However, the invertebrate communities in lower Line Creek and in the Fording River upstream and downstream of Line Creek were considered good, as were invertebrate tissue selenium concentrations, in spite of marginal water quality. Calcite levels were low at all areas where other sample types have been collected within MU2. Fish and bird tissues sampled in lotic and off-channel areas of MU2 produced tissue selenium HQs ranging from good to poor. Potential risks of selenium-related effects to invertebrates and/or vertebrates were also indicated in several off-channel areas of MU2.

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[3] This category was used for water and sediment quality indices only, to be consistent with categories defined by CCME (2001a,b; 2007).

Management Unit 3

Water quality was poor in three mine-influenced tributaries in MU3 (Leask, Wolfram, Thompson creeks), and the invertebrate community structure and tissue selenium concentrations were also considered fair to poor at the two tributaries having historical monitoring data (Thompson and Wolfram creeks). Thompson Creek is the dominant source of mine-related constituents to the watershed within MU3. All other tributaries and mainstem (Elk River) locations had invertebrate communities and tissue selenium concentrations considered to be good. Tissue selenium concentrations in off-channel habitats within MU3 (except settling ponds) were also good, with the exception of potential slight risk of selenium effects to piscivorous fish in one off-channel habitat (EROU) where the only fish species captured to date has been a benthivorous one (longnose sucker, for which low selenium-related risk was indicated).

Management Unit 4

Benthic invertebrate communities in lotic areas of MU4 reflected a range of conditions. Poor communities were observed at several mine-influenced tributaries (Corbin, Erickson, Bodie, Otto creeks). Erickson and Bodie creeks are the major mine-related sources of sulphate and nitrate, respectively, to the watershed within MU4 (also sulphate via Harmer Creek). Among all areas that have been sampled in MU4, including off-channel habitats, estimated selenium-related risks to invertebrates and vertebrates were highest at Goddard Marsh, where water quality was also marginal. Benthic invertebrate communities and tissue selenium concentrations were good at most mainstem receiver areas sampled along Michel Creek and the Elk River. Exceptions were fair invertebrate communities sampled in Michel Creek downstream of Corbin Creek (at CMO) and also downstream of EVO inputs to Michel Creek (including ERCK and BOCK).

Management Unit 5

Water quality, benthic invertebrate community structure, and tissue selenium concentrations were ranked as good for all lotic areas sampled within MU5 (based on data for 3, 5, and 8 monitoring areas for the different lines of evidence, respectively). The exceptions were slightly elevated HQs for eastern brook trout at one lotic reference area and mountain whitefish captured in the Elk River downstream of Sparwood; these fish tissue results are inconsistent with low dietary (invertebrate) concentrations at the same locations, suggesting that selenium accumulation by those fish may have occurred elsewhere in the watershed. Slight risk of selenium effects to biota were indicated in several off-channel areas of MU5 (mean HQs were usually 1.5 or less), and 11 of the 16 areas indicated no risk for selenium effects.

Management Unit 6 (Lake Koocanusa)

Fewer monitoring data are currently available for Lake Koocanusa. Available lines of evidence include water and sediment quality and fish tissue selenium concentrations. Water and sediment quality in Lake Koocanusa were ranked as good. Maximum selenium concentrations measured in fish egg/ovary and whole-body/muscle samples collected from the reservoir were well below their respective toxicity thresholds. There was some evidence of increases in whole-body/muscle selenium concentrations for some species. The higher concentrations recently measured (2013) were in samples collected several kilometers upstream of the Elk River mouth, although the potential mobility of the species sampled makes it difficult to determine the locations of their selenium exposure history. Continued monitoring of selenium in fish tissues should determine if tissue concentrations are actually increasing and approaching levels of concern. Three consecutive years of annual monitoring were initiated in 2014 to provide more information regarding current conditions in MU6.

Recommendations for Future Studies and Monitoring

A substantial amount of information has been collected in relation to aquatic environmental conditions in the Designated Area, particularly in the Elk River watershed near and downstream of mining, as presented in previous sections. Data are available for numerous areas within each MU to evaluate multiple lines of evidence regarding environmental quality, including potential direct effects (i.e., benthic invertebrate community structure, fish population characteristics) and potential indirect effects (water quality, sediment quality, calcite, primary productivity, and tissue concentrations in biota). Concentrations of mine-related constituents are routinely monitored at more than 100 stations throughout the Designated Area, which allow for rapid and sensitive detection of changes in mine contributions over time, and comparison to predictions and effects benchmarks identified in the EVWQP. On-going cycles of biological monitoring will allow for verification that aquatic ecosystem conditions are responding as predicted by the EVWQP.

Based on review of the existing information, a number of opportunities have been identified to improve the amount and/or quality of information being collected in aquatic environments downstream of the mines. The following actions listed below are recommended for future studies and monitoring. The status of each activity is identified in square parentheses.

1. Re-evaluate the scope of water quality reporting (i.e., data evaluation and trending, spatial and temporal coverage, frequency, etc.) for informing the RAEMP and adaptive management, and relative to commitments made under the EVWQP. [pending]
2. Consider incorporation of aquatic toxicity tests in the RAEMP using surface water samples from representative locations as an additional direct line of evidence for potential effects. [pending]
3. Evaluate the spatial and temporal variability in calcite deposition and evaluate the effects of calcite on biota. [A regional supporting study of calcite deposition began in 2013 and will continue through 2015. The study was expanded in 2014 to assess calcite effects on benthic invertebrate community health and periphyton productivity. Additional monitoring of both calcite and biota is planned for 2015. The results will inform the scope of long-term calcite and associated biological monitoring within the RAEMP.]
4. Collect sediment samples in additional depositional areas of the watershed for laboratory toxicity testing (along with supporting chemistry and particle size analyses). [This will be done as a supporting study in 2015 to determine if toxicity to biota is occurring as a result of elevated sediment concentrations of mine-related constituents. Results will be used to inform the future scope of the RAEMP.]
5. Monitor periphyton productivity (chlorophyll-a and ash-free dry mass) at representative areas throughout the watershed, particularly downstream of active water treatments facilities involving phosphorus addition. [This will be done as part of the RAEMP and Local Aquatic Effects Monitoring Programs.]

6. Consider opportunities to improve the reliability periphyton community data to reduce uncertainties related to the representativeness (of samples collected in the field and sub-samples analyzed by the laboratory) and accuracy (taxonomic identifications) of reported data. [A supporting study to further evaluate periphyton community data is planned for 2015 which will include reconciliation of 2013 data to an appropriate taxonomic level. This evaluation will be conducted by the taxonomist retained for the supporting study to determine if data collected in 2013 exhibits similar findings to the data collected in 2015. The results will be used to evaluate sensitivity of periphyton community data as an indicator of mine effects and inform scope of long-term monitoring endpoints for the RAEMP.]

7. Continue to monitor benthic invertebrate communities as robust indicators of localized environmental quality and a direct line of evidence of potential mine-related effects. [Included in the 2015 RAEMP monitoring].

8. Sufficient understanding of the westslope cutthroat trout population in the upper Fording River (above Josephine Falls) is required to determine the best sampling locations, sample timing and measurement endpoints for evaluating and tracking of potential mine-related effects to this species over time. The current population study, which will be completed in 2015, should be continued as planned. [Supporting study underway and concluding in 2016.]

9. Monitor longnose sucker populations and tissue selenium concentrations in off-channel habitats containing populations of sufficient size that they can be reliably quantified and tracked over time (e.g., Goddard Marsh). [This will be done as part of the 2015 RAEMP.]

10. Measure selenium in water, periphyton, and invertebrates in off-channel habitats. Based on the results, potential use of off-channel habitats by aquatic or aquatic-dependent vertebrates having invertebrate (dietary) Se HQ>1 should be investigated. The objective would be determine if such areas are of sufficient size and habitat quality to warrant further investigation or long-term monitoring in the RAEMP. [In 2015, selenium will be measured in water, periphyton, and invertebrates at areas that are also targeted for sediment quality evaluation.]

11. Collect biological samples representing different trophic levels within Lake Koocanusa, both upstream and downstream of the Elk River mouth, to assess potential effects related to upstream coal-mining activities. [This was initiated in 2014 and will continue for two additional years. The results will inform the scope of future monitoring in the reservoir as part of the RAEMP.]

12. The ongoing study of selenium effects on spotted sandpiper egg hatchability should be completed. Results will be used to determine if long-term monitoring of potential selenium effects on birds is warranted. [The second and potentially final year of data collection was completed in 2014, and the results will be evaluated and reported in 2015.]

13. Complete a statistical evaluation of effects size and data evaluation methods to inform sample sizes and confidence level for the next cycle of RAEMP. [The data are currently being evaluated for this purpose in collaboration with MOE and KNC.]

14. Develop detailed Standard Operating Procedures (SOPs) for sampling (and laboratory analyses, if appropriate) to standardize approaches used among sampling areas and studies to ensure consistent data quality over time. [pending]

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Acronyms and Abbreviations

Aquatox	Aquatox Testing and Consulting Inc.
AVS	acid volatile sulphide
BC	British Columbia
BLM	biotic ligand model
BOCK	Bodie Creek
CACK	Cataract Creek
CaCO3(s)	calcite
CB	concentration-to-benchmark
CCME	Canadian Council of Ministers of the Environment
CH2M HILL	CH2M HILL Canada Limited
CMO	Coal Mountain Operations
COCK	Corbin Creek
CoI	constituent of interest
COPC	constituent of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSM	conceptual site model
Designated Area	Elk River watershed and the BC portion of Lake Koocanusa
DO	dissolved oxygen
DOC	dissolved organic carbon
DQO	data quality objective
dw	dry weight
ELKO	Elko Reservoir
EMS	environmental monitoring station
EPH	extractable petroleum hydrocarbons
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoperta (caddisflies)
ERCK	Erickson Creek
EVO	Elkview Operations
FOUL	Fording River upstream of Line Creek
FRO	Fording River Operations
GHCKU and GHCKD	Greenhills Creek
GHO	Greenhills Operations

Golder	Golder Associates
HDR	HDR, Inc.
HQ	hazard quotient
HydroQual	HydroQual Canada Limited
IRCL	Interior Reforestation Co. Ltd.
ISQG	interim sediment quality guideline
KICK	Kilmarnock Creek
K_{ow}	octanol-water partition coefficient
KNC	Ktunaxa Nation Council
LCCPL	Line Creek Lower Containment Ponds
LCO	Line Creek Operations
LEL	lowest effect level
Lotic	Lotic Environmental
LSU	Longnose sucker
Nautilus	Nautilus Environmental
MFLNRO	BC Ministry of Forests, Lands and Natural Resource Operations
MFWP	Montana Fish, Wildlife and Parks
MIDCO	Michel Creek
Minnow	Minnow Environmental Inc.
MLE	maximum likelihood estimation
MOE	Ministry of Environment
MU	Management Unit
MU1	Management Unit 1
MU2	Management Unit 2
MU3	Management Unit 3
MU4	Management Unit 4
MU5	Management Unit 5
MU6	Management Unit 6
NHC	Northwest Hydraulic Consultants Ltd
No.	number
OCNM	Otto Creek
ON	Ontario
PAH	polycyclic aromatic hydrocarbon

PEL	probable effect level
PLA	Paine Ledge and Associates
POCK	Porter Creek
PVA	population viability analysis
RAEMP	Regional Aquatic Effects Monitoring Program
Rkm	river kilometre
SARA	*Species At Risk Act*
SEL	severe effect level
SEM	simultaneously extractable metals
SLERA	screening-level ecological risk assessment
SQG	sediment quality guideline
SeQI	sediment quality index
SRK	SRK Consulting (Canada) Inc.
SWCK	Swift Creek
Teck	Teck Resources
THCK	Thompson Creek
THPD	Thompson Settling Pond
TOC	total organic carbon
TRV	toxicity reference value
TSS	total suspended solids
U.S.	United States
u/s	upstream
U/S	upstream
UCL	upper confidence limit
Urban Systems	Urban Systems Ltd.
USEPA	U.S. Environmental Protection Agency
WCT	westslope cutthroat trout
Windward	Windward Environmental LLC
WOCK	Wolfram Creek
WQG	water quality guideline
WQI	water quality index

Units of Measure

°C	degree Celsius
μg/L	microgram per litre
cm	centimetre
cm^2	square centimetre
ha	hectare
km	kilometre
m	metre
m^3	cubic metre
mg/kg	milligram per kilogram
mg/L	milligram per litre
mg/m^2	milligram per square metre
mm	millimetre
Rkm	river kilometre

1 Introduction

Under existing Environmental Management Act authorizations, numerous environmental monitoring and assessment programs have been conducted within the Elk River watershed over the past twenty years by Teck. Historically, these programs focused on water, sediment, and biota tissues; more recent monitoring programs have assessed a broader suite of constituents in those media and include benthic invertebrate community and fish population assessments. In recent years, monitoring activities in the BC portion of Lake Koocanusa[4] also have been increased. In addition to extensive monitoring activities, numerous supporting investigations have been undertaken to address specific questions about sample types and sampling methods, locations, and timing that will facilitate detection of coal-mine-related effects on aquatic biota. Results of recent monitoring and studies are summarized in this report, as requested by the British Columbia (BC) Ministry of Environment (MOE), in the context of designing a comprehensive monitoring program (i.e., the Regional Aquatic Effects Monitoring Program, or RAEMP) that assesses potential effects in the aquatic environment throughout the Elk River watershed and the Canadian portion of Lake Koocanusa.

This report also responds to concerns of increasing water quality concentrations of selenium, cadmium, nitrate and sulphate, as well as calcite formation within watercourses in the Elk Valley, that are the subject of the BC Minister of Environment's Order in April 2013. The Order outlined a framework to develop an area-based water quality plan (the Elk Valley Water Quality Plan [EVWQP]) to allow for continued mining development in the Elk Valley while achieving the following outcomes:

- Protection of aquatic ecosystem health;
- Management of bioaccumulation of contaminants in the receiving environment (including fish tissue);
- Protection of human health; and
- Protection of groundwater.

The approved Terms of Reference outlining the process for development of the EVWQP include a requirement to evaluate current baseline conditions within the watershed.

1.1 Report Objectives

The objectives of this evaluation are to:

- Summarize existing information on chemical, physical, and biological attributes of the Elk River watershed and the Canadian portion of Lake Koocanusa (the Designated Area).

[4] For the purpose of this report, and unless otherwise noted, any and all references to Lake Koocanusa are limited to the Canadian portion of the reservoir.

- Interpret the various lines of evidence separately and together to report upon the current state of the aquatic environment in the Designated Area.
- Refine the conceptual site models (CSMs) developed for the RAEMP, if appropriate, based on available data, to guide future monitoring and special supporting studies.
- Determine critical data gaps or uncertainties that should be addressed in future monitoring cycles or through special supporting studies.
- Make general recommendations for the scope of future RAEMP cycles.

1.2 Technical Approach

RAEMP development is guided by a process commonly referred to as the data quality objective (DQO) process (USEPA 2006). The DQO process follows a logical progression of decisions based on identifying specific information needs (e.g., characterization of the environment and monitoring changes), assembling available information, evaluating the quality of the data, and developing a plan for collecting additional information that will adequately address relevant concerns and uncertainty. The process is not intended to attain the unrealistic goal of resolving all uncertainty; instead, it appropriately identifies, prioritizes, and fills key information needs to address relevant concerns about potential mine-related effects on the downstream aquatic environment.

Although implementation of the RAEMP is the responsibility of Teck Coal Limited (Teck) and its consultants, the program is developed collaboratively among Teck, the BC MOE, and Ktunaxa Nation Council (KNC) through a consensus-based approach to address the following key questions:

- What are the mine-related chemical and physical changes to aquatic ecosystems and where do they occur?
- Are mine-related chemical and physical changes to the aquatic environment resulting in unacceptable[5] biological effects and where do they occur?
- What are the specific mine-related sources of any unacceptable changes to chemical, physical, or biological conditions?
- How are chemical, physical, and biological conditions changing over time?
- What are the consequences of observed biological effects to the aquatic ecosystem?
- Are the mine-related chemical and physical changes, biological effects, or a combination impacting water and aquatic ecosystem uses?

The RAEMP is intended to be a flexible, adaptive, resource-efficient, long-term aquatic monitoring program that involves ecologically sustainable sampling to evaluate spatial patterns and temporal trends of water quality and potential effects on representative biota in the

[5]Conditions that are considered “unacceptable” and necessitate action by Teck will be defined in the Adaptive Management Plan (in preparation).

receiving environment of the Elk River watershed and Lake Koocanusa. Individual components of the RAEMP are designed to be scientifically and statistically defensible in monitoring spatial and temporal effects on water quality, water uses, and aquatic biota representative of the Elk River watershed and Lake Koocanusa. The RAEMP is a multi-year program involving multiple rounds of data gathering and data evaluation, and the RAEMP findings are linked to ongoing management decision-making for the Elk River watershed and Lake Koocanusa through the following operating principles:

1. Coordinate program development, interpretation of data, and reporting with provincial governments and the KNC
2. Use an iterative approach in a risk-based framework
3. Carefully evaluate assumptions and uncertainties associated with data and CSMs
4. Monitor to assess and document environmental conditions
5. Inform site-specific management and mitigation decisions

The resulting technical approach relies upon the initial use of existing data, the DQO process, and an iterative evaluation of data to guide subsequent monitoring and management activities for the Elk River watershed and Lake Koocanusa such that their ecological features and functions are maintained.

2 Overview and Environmental Setting

This section provides an overview of the characteristics of the Elk River watershed and Lake Koocanusa. Major physical characteristics of the watershed and the reservoir as they relate to the aquatic environment are described, with aquatic ecological receptors and communities also discussed. The combined Elk River watershed and Canadian portion of Lake Koocanusa are equivalent to the Designated Area, as defined within Schedule A of Ministerial Order Number (No.) M113. The combined area is referred to as the “Designated Area” or simply as the “study area” when the meaning is clear. When referring to the “Elk River watershed study area” or the “watershed study area,” that means the watershed to the river mouth at Lake Koocanusa. The lake (reservoir) portion of the study area is referred to as the “Lake Koocanusa study area” or the “lake study area.”

2.1 Elk River Watershed and Lake Koocanusa Study Area

The study area, located in the southeastern corner of BC, is situated in the extremely rugged terrain of the Front and Border Ranges of the Rocky Mountains, with peaks up to 3,300 metres (m) in the north and 2,200 m in the south. It spans an area in excess of 490,000 hectares (ha), with the Elk River, a sixth-order tributary to the Kootenay River, bisecting the watershed (Obedkoff 1985). From its headwaters (i.e., Elk Lakes) near the continental divide, the Elk River flows in a southwesterly direction toward its confluence with the Kootenay River/Lake Koocanusa about 20 kilometres (km) upstream from the Canada/United States (U.S.) border (Swain 2007; Kennedy et al. 2000).

The Elk River forms a long, narrow valley that descends from an elevation of about 1,700 m to 720 m at its mouth (Swain 2007; Polzin 1998; Obedkoff 1985). Along this hydrologically dynamic system, numerous tributaries feed into the Elk River, with the largest including the Fording River and Michel Creek, each of which is a fifth-order stream (Hauer and Sexton 2013; NHC 2006; Polzin 1998; Obedkoff 1985) (Map 2.1-1; note that all maps and figures are provided following the text and tables). There are no major lakes in the watershed (Simmons and Brady 1976). However, during the summer and fall months, a long, narrow reservoir (i.e., Lake Koocanusa) is created by Libby Dam in Montana, U.S. (HydroQual 1990; Crozier and Nordin 1983).

The KNC has occupied lands adjacent to, and including, the Kootenay and Columbia Rivers and the Arrow Lakes of BC for more than 10,000 years (KNC 2005). Rivers and streams of the region provide culturally important sources of fish and plants. The Ktunaxa Territory is divided into traditional land districts historically associated with key actors in the Ktunaxa creation story, but also with specific key resources and with specific Ktunaxa individuals or lineages that held particular authority and responsibility for stewardship of resources in those areas (Robertson 2010). The study area, as defined herein, falls within two Ktunaxa traditional land districts, which include Qukin ʔamakʔis (Land of the Raven) and ȼaḿna ʔamakʔis (Land of the Wood Tick).

The Elk River is the most heavily fished river in the Kootenay Region, with populations of westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*), among other species (Swain 2007). The most common resource activities in the watershed are open-pit bituminous coal mining, forestry, tourism, agriculture, transportation, and residential and commercial development. The highest concentration of municipal and agricultural development (e.g., urbanization, farming, and transportation corridors) is located in the valley-bottom, extending from Elkford to Elko (McPherson et al. 2014). The valley-bottom is largely managed by three municipalities (District of Elkford, District of Sparwood, and City of Fernie) and the Regional District of East Kootenay. Occupying a similar range of latitudes at higher elevation to the east is large-scale coal mining, which began in 1970 (Swain 2007). Teck currently operates five mines in the Elk Valley, which include Fording River Operation (FRO), Greenhills Operation (GHO), Line Creek Operation (LCO), Elkview Operation (EVO), and Coal Mountain Operation (CMO) (Map 2.1-3).

Natural and anthropogenic features create barriers to fish migration and limit stream connectivity within the Elk River watershed. The dominant natural feature is Josephine Falls located on the Fording River. Other barriers include Elko Dam located on the Elk River about 16 km upstream of the river mouth at Lake Koocanusa (BC Hydro 2005). Originally built in 1924, Elko Dam is situated on historical falls that limited migration and species distribution of aquatic receptors (e.g., fish) up the Elk River.

Annual precipitation within the Elk River watershed is generally 600 - 900 millimetres (mm) per year, depending on elevation, and is bi-modal in occurrence, with peak snowfall occurring in December and January (mean ≅ 50-60 mm water equivalent monthly) and peak rainfall typically occurring in June (mean ≅ 70 mm). Evapotranspiration is generally asynchronous with precipitation, with up to about two-thirds of precipitation delivered in non-growing-season months (Obedkoff 1985).

2.2 Management Units

To satisfy requirements of assessing current conditions as part of the development of the EVWQP, the Designated Area was subdivided into six Management Units (MUs) (Map 2.2-1). Delineation of MUs is based on geographic features (e.g., confluence with major tributaries), general hydrodynamic characteristics (e.g., natural/anthropogenic features and active water management practices), and expectations regarding principal mechanisms for transport or deposition of constituents of interest (CoIs). General descriptions of the six MUs follow.

Management Unit 1 (MU1): This MU represents the Fording River upstream of Josephine Falls, drains an area of about 42,500 ha, and represents 9 percent of the total study area. Numerous tributaries (e.g., Henretta Creek, Kilmarnock Creek, Swift Creek, Cataract Creek, Porter Creek, Chauncey Creek, Ewin Creek, and Dry Creek) drain into the Fording River within this MU, some of which are influenced by mining. Order Station FR4 (Environmental Monitoring System [EMS]# 0200378 and Teck monitoring station GH_FR1) is located just downstream of Greenhills Creek at the southern edge of MU1. It effectively integrates all inputs to the Fording River from FRO and GHO (plus future input from LCO via Dry Creek); currently active mines within MU1 include FRO and GHO (Map 2.2-2). There are no major urban developments (e.g., urbanization, farming, or transportation corridors) or recreational activities within this MU, although there are active forest management activities throughout the MU.

Management Unit 2 (MU2): The Fording River downstream of Josephine Falls runs along the western limit of MU2, drains an area of about 20,000 ha, and represents 4 percent of the total study area (Map 2.2-3). Tributaries that drain into the Fording River within this MU include

Grace Creek and Line Creek. Order Station FR5 (EMS# 0200028, Teck monitoring station LC_LC5) is located downstream of Line Creek, just before the confluence of the Fording and Elk Rivers. With the exception of LCO and forest management activities, there are no major developments (e.g., urbanization, farming, and transportation corridors) or recreational activities within this MU.

Management Unit 3 (MU3): The Elk River runs along the eastern edge of this MU, drains an area of about 88,400 ha, and represents 18 percent of the study area (Map 2.2-4). Numerous tributaries (e.g., Willow Creek, Wade Creek, Mickelson Creek, Leask Creek, Wolfram Creek, Thompson Creek, Crossing Creek, and Boivin Creek) drain into the Elk River within this MU. Order Station ER1 (EMS# E206661, Teck monitoring station GH_ER1) is located downstream of Thompson Creek and before the District of Elkford. Portions of GHO are associated with this MU (Map 2.2-4).

Management Unit 4 (MU4): This MU drains an area of about 96,900 ha and represents 20 percent of the total study area (Map 2.2-5). Tributaries within this MU include Grave Creek, Harmer Creek, Brule Creek, Otto Creek, Goddard Creek and Marsh, Wilson (Cummings) Creek, and Michel Creek. The northern portion of MU4 is bisected by the Elk River, with Michel Creek joining it at the southern limits of the MU. Unlike other MUs, MU4 contains two Order stations. These stations were strategically positioned to facilitate characterization of the relative potential influences of the Fording River and Michel Creek. Order Station ER2 (EMS# 0200027, Teck monitoring station EV_ER4) is situated in the northern half of MU4 to reflect potential influences from the Fording River and upper Elk River, while Order Station ER3 (EMS# 0200393, Teck monitoring station EV_ER1), located at the southern limit of MU4, is downstream of Michel Creek. Active mines within MU4 include EVO and CMO.

Management Unit 5 (MU5): The highest level of development (e.g., urbanization, farming, and transportation) is located in MU5 and encompasses the District of Sparwood, the City of Fernie, and Elko Dam (Map 2.2-6). Furthermore, MU5 supports a wide range of recreational-based activities (e.g., Sparwood Fish & Wildlife Association Gun Range, Fernie Rod & Gun Club Range, and Fernie Alpine Resort). MU5 drains an area of about 148,000 ha and represents 30 percent of the total study area. The Elk River meanders along the valley-bottom of MU5. Order Station ER4 (EMS# E294312, Teck monitoring station RG_ELKORES) is located at the Elko reservoir. No active coal mines are located within MU5.

Management Unit 6 (MU6): This MU drains an area of about 95,000 ha, represents 19 percent of the total study area, and contains the Canadian portion of Lake Koocanusa (Map 2.2-7). This impoundment started to fill in 1972 and reached full pool in June 1974 (Storm et al. 1982). As detailed by HydroQual Canada Limited (HydroQual) (1990), the reservoir is long and narrow, and undergoes predictable annual fluctuations in water level associated with flood control and hydroelectric power considerations at Libby Dam (Figure 2.2-1). Order Station LK2 (EMS# E294311) is represented by numerous stations within the reservoir (RG_DSELK, RG_Grasmere, RG_Border).

2.3 Habitats and Aquatic Community

2.3.1 Aquatic Habitats

Aquatic habitats of the Elk River watershed are predominantly lotic (flowing), characterized by cold, well-oxygenated water and coarse bottom substrates (e.g., largely cobbles and gravels) (IRCL 2008). Off-channel aquatic habitats have varying degrees of surface or groundwater connectivity to mainstem or tributary habitats, and include side-channels, oxbows, wetlands, ponds, and small lakes. Depending on the degree of surface connectivity to mainstem areas (i.e., usually connected, seasonally inundated, or rarely/never connected), off-channel habitats have characteristics that range from lotic (flowing water, coarse substrates) to lentic (little or no flow, fine substrates). Overall, off-channel habitats represent a small proportion of the total aquatic habitat downstream of Teck's mines, and areas with highly lentic characteristics are uncommon.

Lake Koocanusa, at the terminus of the Elk River, is essentially a widening of the Kootenay River that was created by the Libby Dam in Montana (HydroQual 1990; Minnow 2014b). Although there is visible, channelized water flow in upper portions of the reservoir during the winter, low-elevation period, the reservoir can largely be considered lentic habitat during most of the year, as evidenced by the presence of fine surface sediments throughout most of the Canadian portion of the reservoir, even in early spring.

2.3.2 Aquatic Communities and Species at Risk

2.3.2.1 Elk River Watershed

Benthic invertebrate communities in the Elk River watershed are dominated by Ephemeroptera (mayfly), Plecoptera (stonefly) larvae and Trichoptera (caddisfly), with smaller proportions of other groups, such as Diptera (true flies), Coleoptera (beetles), and Trombidiformes (mites) (Minnow 2014a). These organisms are an important food source for fish, amphibians, and aquatic-dependent birds.

Along the Elk River mainstem, the fish community is primarily composed of westslope cutthroat trout, bull trout, mountain whitefish, longnose dace (*Rhinichthys cataractae*), and longnose sucker (*Catostomus catostomus*) (Minnow 2003; Minnow et al. 2007, 2011; HydroQual 1990; Robinson 2011) (Table 2.3-1). Fish species diversity tends to be lower in the tributaries, particularly at higher elevations, with cutthroat trout being the only species known to inhabit the Fording River above Josephine Falls (Robinson 2011). Brook trout (*Salvelinus fontinalis*) can also be found in some parts of the Elk River basin (Robinson 2011; Minnow 2003). Two fish species previously reported in Elk River watershed studies have special conservation status within the Kootenay region of BC (the Elk River watershed and Lake Koocanusa represent just one portion of the Kootenay region). These include westslope cutthroat trout (blue list) and bull trout (blue list).

Three species of amphibians have been reported in the Elk River watershed, including Columbia spotted frog (*Rana luteiventris*), western toad (*Anaxyrus boreas*), and long-toed salamander (*Ambystoma macrodactylum*) (Minnow 2014a). Of these three species, the western toad is considered to be of "special concern" from a provincial or federal conservation standpoint (Table 2.3-2). Salamanders are relatively uncommon and were found in only one area (Grave

Lake) in a survey of 32 areas of the watershed in 2013 (Minnow 2014a). The presence or absence of breeding amphibians in aquatic habitats of the Elk River watershed is related to the availability and accessibility of habitat with preferred characteristics of each species for breeding, as well as proximity to other habitats (including suitable upland areas) that may be used for other life-cycle functions, such as feeding and overwintering.

A total of 125 bird species were observed in a 2012 survey of 36 areas within the Elk River watershed (Table 2.3-3). Five of the observed species (bald eagle, barn swallow, great blue heron [*herodias* subspecies], long-billed curlew, and olive-sided flycatcher) have special conservation status in the Kootenay District, although the bald eagle is generally considered secure/not at risk by other lists (e.g., BC Yellow List and Committee on the Status of Endangered Wildlife in Canada [COSEWIC]; Table 2.3-4). A long-billed curlew was observed at the mouth of the Elk River at Lake Koocanusa, and great blue herons were observed in two reference areas (in a wetland west of the Elk River upstream of Elkford and at Grave Lake Marsh). No great blue herons were observed at Goddard Marsh, which is the previous location of a heronry; some of the old nests were still visible in the trees, but no herons were observed on the nests during bird surveys in the spring of 2012 (Minnow 2014a). The remaining listed species (barn swallow, bald eagle, and olive-sided flycatcher) observed in the watershed have been found in low numbers (i.e., between one and four individuals) at several mine-exposed and reference areas (Table 2.3-4). The distribution of breeding birds (relative abundance and diversity among areas) appears to be mainly related to the size and diversity of available habitats.

2.3.2.2 Lake Koocanusa

Many of the species described for the Elk River watershed aquatic community (particularly the fish and birds) also occur in Lake Koocanusa, although the fish community is considerably more diverse, including additional game fish species such as kokanee salmon (*Oncorhynchus nerka*) and burbot (*Lota lota*), as well as non-game fish species such as yellow perch (*Perca flavescens*), peamouth (*Mylocheilus caurinus*), northern pikeminnow (*Ptychocheilus oregonensis*), and largescale sucker (*Catostomus macrocheilus*) (Richards 1997; Dunnigan et al. 2009).

Montana Fish, Wildlife and Parks (MFWP) have documented the changes in fish species composition, and in species size and abundance, within Lake Koocanusa since the construction of Libby Dam (Dunnigan et al. 2009). Fish populations within the reservoir are monitored using spring and fall gill netting; recent status of the various species is summarized in Table 2.3-5.

Before Libby Dam was completed in 1972, the fishery in the upper Kootenay River consisted primarily of westslope cutthroat trout, rainbow trout, and mountain whitefish (Richards 1997). Soon after impoundment, both trout species and mountain whitefish were common in gill net catches, but then they began to decline in abundance (Hamilton et al. 1990). Whitefish are now considered rare within the reservoir, but both trout species remain relatively common (Dunnigan et al. 2009). Burbot, redside shiner and longnose sucker have also declined in abundance since construction of the dam, although burbot and longnose sucker are still considered to be relatively common (Chisholm et al. 1989; Dunnigan et al. 2009). In contrast, bull trout, yellow perch, peamouth and northern pikeminnow have increased in abundance since 1972. The presence of kokanee is attributed to inadvertent release from the Kootenay Hatchery during or before 1980 (Richards 1997; Westover 2003), after which this species became one of the most abundant in the reservoir. Yellow perch is also an introduced species.

MFWP also has monitored species composition, abundance, and size of zooplankton within Lake Koocanusa since 1972 (Dunnigan et al. 2009). Zooplankton are an important food source for kokanee and peamouth, as well as trout (Dalbey et al. 1998; McPhail 2007). Inverse correlations between *Cyclops* and *Diaptomus* densities, and between *Daphnia* and *Bosmina* densities, were evident throughout Lake Koocanusa in a study from 1988 through 1996, and were thought to be indicative of a cyclic kokanee population and size-selective fish predation of zooplankton in the reservoir (Dalbey et al. 1998).

Zooplankton abundance, species composition, and size distribution have all been similar since 1997 (Dunnigan et al. 2009). *Cyclops* and *Daphnia* were the first- and second-most abundant genera of zooplankton present in the reservoir during this period. Other lesser-abundant genera in decreasing order of abundance include *Diaptomus, Bosmina, Diaphanosoma, Epischura, and Leptodora*. (*Diaptomus*, *Epischura,* and *Cyclops* are copepods; *Daphnia, Bosmina, Diaphanosoma,* and *Leptodora* are cladocerans.) Zooplankton abundance within the reservoir varied by month, with the monthly abundance peaks over the past 10 years remaining relatively consistent but varying among the different types of zooplankton. The monitoring program found weak evidence that zooplankton abundance differed among the three sampling areas (two sites in Montana and one in BC, between the mouth of the Elk River and the mouth of Kikomun Creek) in 2007.

The order Diptera (primarily chironomids) constituted the predominant group of benthic invertebrates of each reservoir zone during drawdown (shallow, mid, and deep areas that were not dewatered during drawdown) in Lake Koocanusa, averaging about 70 percent of the total number of benthic invertebrates sampled between 1983 and 1987 at the Montana and Canada sites (same sites as mentioned in previous paragraph) (Richards 1997). At the Canadian site, Oligochaeta (freshwater worms) were similar to dipterans in abundance (Chisholm et al. 1989). Thus, the benthic invertebrate community differs substantially from that found in the Elk River watershed (which is dominated by Ephemeroptera, Plecoptera, and Trichoperta [EPT] taxa).

2.4 Chemical Stressors Conceptual Site Models

A CSM provides the framework within which a complex suite of chemical, physical, and biological processes and interactions can be systematically viewed in an organized manner. A CSM typically considers the sources of potential COIs, physical-chemical processes that control chemical fate (i.e., the physical transport and chemical reaction pathways that control concentrations of CoIs over time and space), and exposure pathways relevant to evaluating environmental conditions and receptors. In consideration of the range of stressors within the Elk River watershed and Lake Koocanusa, chemical and physical CSMs (presented in this and the following section) have been developed and ultimately integrated to understand and evaluate potential cumulative effects. CSMs are intended to be dynamic and should be updated, if appropriate, as additional information is obtained.

In developing a CSM for chemical constituents, the first considerations are the different point and nonpoint sources that may release constituents to the environment (i.e., air, surface water, groundwater, soil, and sediment). Once present in the aquatic environment, these constituents are physically transported within and among the various media by processes that result in a range of chemical concentrations to which aquatic organisms (generally referred to as receptors) are potentially exposed. In surface water and sediment, the distribution of these concentrations between the dissolved and particulate phases is relevant in characterizing exposures. However, at a more detailed level, chemical reactions may occur that lead to the formation of a variety of chemical species, particularly for metals/metalloids. These occurrences have important implications for assessing the bioavailability of constituents (e.g., selenium) to aquatic receptors.

A generalized CSM for chemical constituents in the aquatic environment of the Designated Area is provided in Figure 2.4-1, and separate CSMs are provided in Figure 2.4-2 for the Elk River watershed and in Figure 2.4-3 for Lake Koocanusa. Sources, primary and secondary release mechanisms, and transport mechanisms occur/operate primarily in the watersheds of the Elk River and other tributaries, as discussed in the following sections. However, once chemical constituents are present in the surface water, sediment, or porewater, the tertiary release mechanisms, exposure pathways, and aquatic food web receptors are very similar in the Elk River watershed and in Lake Koocanusa. In general, macrophytes are less important in Lake Koocanusa compared to the upstream watershed while plankton are more important in the reservoir than in the watershed. The separate CSMs for the watershed and reservoir are discussed in more detail in the following sections.

2.4.1 Elk River Watershed

The CSM for the Elk River watershed (Figure 2.4-2) broadly characterizes two major aspects of the watershed. Firstly, the physical and chemical processes that influence the transport and fate of mine-related substances within the watershed, and secondly, the relationship between sources (primary and secondary), exposure pathways, and aquatic receptors. Primary sources of chemical stressors within the Elk River watershed include resource activities, such as mining, municipal point and nonpoint sources, agriculture, forestry, and associated transportation networks (Urban Systems 2011). Coal mining in the Elk River watershed began in the late 1890s, with large-scale mining beginning in the late 1960s (Urban Systems 2006). The East Kootenay coalfields have been described as the most important coal fields in BC, having produced over 500 million tonnes of coal since 1898. Currently, there are two active coal bed gas projects in the East Kootenay Basin.

Substances released to the environment by Teck’s operations may originate from waste rock, tailings, coarse coal rejects, and other mine-disturbed surfaces (Figure 2.4-2). A brief description of Teck’s operations is described in the following list, and mine locations are shown in Map 2.1-3:

- FRO is the northern-most and oldest operation, with mining first occurring in 1969. It is located about 29 km northeast of Elkford, covers an area of about 5,200 ha, and has the Fording River and numerous tributaries flowing through the operation.
- GHO is located about 8 km northeast of Elkford, covers an area of about 3,100 ha, sits on the divide between the Fording and Elk Rivers, and has tributaries originating at the operations that drain to both rivers.
- LCO is located about 27 km north of Sparwood and covers an area of about 4,300 ha; Line Creek, a tributary to the Fording River, flows through the operations.
- EVO is located about 15 km from Sparwood and covers an area of about 4,600 ha. Onsite activities associated with EVO have the potential to affect the Elk River directly through its smaller tributaries (Grave, Six Mile, and Otto Creeks) or indirectly via tributaries to Michel Creek (e.g., Harmer, Bodie, and Erickson Creeks).

- CMO is the southern-most operation, located about 30 km southeast of Sparwood. It covers an area of about 1,100 ha and is adjacent to Michel Creek, a tributary to the Elk River.

Mine-related elevations in concentrations of selenium were first observed in the Elk River in 1995 (McDonald and Strosher 2000). Since then, investigations have broadened to include other mine-related chemicals, such as nitrate and sulphate.

Municipal point sources of contaminants within the Elk River watershed include effluent discharges from wastewater treatment plants (e.g., communities of Fernie, Sparwood, and Elkford), while nonpoint sources include stormwater runoff, residential septic fields, and golf courses (e.g., Sparwood Golf Club, Mountain Meadows Golf Club, and Fernie Golf and Country club), agricultural activities and forestry (e.g., Elko sawmill, and CanFor, Jemi Fibre and BC Timber Sales harvesting). In addition, atmospheric chemicals not necessarily tied to a specific point source (e.g., mercury) can be transported to and deposited throughout the watershed from regional or global sources.

Aquatic ecological receptor groups can be exposed to mine-related chemicals through contact with or ingestion of surface water or sediment, through ingestion of tissues of other organisms, and through combinations of environmental media via a specific exposure route (e.g., intentionally or incidentally ingesting water or sediment along with food; Figure 2.4-2). Some receptor groups are exposed primarily through one environmental medium, while others are exposed through more than one.

Receptor groups shown in Figure 2.4-2 are all known to be present, potentially exposed to mine-related chemicals, and representative of the general categories of aquatic plant and animal life found in the Elk River watershed, including periphyton, aquatic macrophytes, benthic macroinvertebrates, fish, amphibians, and aquatic-dependent wildlife (e.g., birds).

Periphyton consists of assemblages of algae, bacteria, moulds, and fungi that live on bottom substrates (e.g., rocks). Some are autotrophs and others are decomposers. Periphyton represents an important source of food for benthic invertebrates, both during the active growing season and the non-growing season when dead tissue and non-photosynthetic components of periphyton will continue to be a food source. Periphyton abundance is influenced by many environmental factors, such as photoperiod, water temperature, and flow. Exposure of periphyton to mine-related chemicals occurs primarily through the water column (Trapp et al. 1990).

Aquatic macrophytes are vascular plants that are rooted in aquatic sediments or float on the water (e.g., duckweed), and can be submerged or emergent. Aquatic macrophytes assimilate mine-related chemicals through their roots via the porewater and through surfaces of stem and leaf cells via the water column (Jackson et al. 1993; Jackson 1998). Factors affecting exposure of aquatic macrophytes include substrate types, hydrology, and light penetration of the water column. Macrophytes are generally not abundant in the Elk River watershed, being found mainly in off-channel habitats having little to no water flow.

Benthic macroinvertebrates can be exposed to mine-related chemicals via surface water, sediment porewater, and ingestion of sediment particles and/or prey (Borgmann et al. 2007; Morrison et al. 1996). Filter feeders (e.g., larvae of many insects) may be exposed to chemicals in dissolved and particulate phases of the water column. Grazers and scrapers (e.g., snails and mayfly larvae) live on the surface of the sediment, rocks, and plants; respire the water; and consume microorganisms and detritus from surfaces of rocks, plants, or other substrate.

Infaunal macroinvertebrates (i.e., oligochaetes and chironomids) typically live in fine sediments and feed on organic matter therein.

Fish inhabiting the Elk River watershed are an integral component of the aquatic food web, feeding primarily on benthic or emergent invertebrates, although some species will also eat other fish (e.g., bull trout). Fish are also prey species for people and piscivorous wildlife (i.e., birds and mammals). Fish are primarily exposed to mine-related chemicals within the water column through gill uptake, diet, and incidental ingestion of sediments during feeding. Exposure pathways of fish can change seasonally based on food availability (e.g., emergent insects are not available in winter), or as their diet changes during development.

Fish and amphibian eggs have layers of semipermeable membranes enclosing the ova (Duellman and Trueb 1994); therefore, the eggs may be exposed to mine-related chemicals in water through contact (diffusion and adsorption) just before egg 'hardening.' Eggs may also contain mine-related chemicals as a result of maternal transfer (Barron 2003). Maternal transfer is generally considered the most important for elements such as selenium. Larvae may be exposed by respiration of water or by ingestion of periphyton and benthic macroinvertebrates.

Aquatic-dependent birds include those species (e.g., spotted sandpipers [*Actitis macularius*] and red-winged blackbirds [*Agelaius phoeniceus*]) that are exposed to mine-related chemicals through diets composed, at least in part (depending on the species), of aquatic organisms (invertebrates or plants), and to a lesser extent, to mine-related chemicals in their drinking water or incidentally ingested sediment (Figure 2.4-2). In addition, species such as the red-winged blackbird are exposed to mine-related chemicals by feeding on emergent aquatic insects or on terrestrial plants or insects.

2.4.2 Lake Koocanusa

The CSM presented here for Lake Koocanusa (Figure 2.4-3) broadly characterizes sources of chemical stressors to the reservoir from resource activities within the watersheds of the Elk River, Kootenay River, Bull River, and other tributaries. They include those already described for the Elk River watershed; with the exception of coal mining, many of the same or similar sources (e.g., forestry, agriculture, and municipal discharges) also occur in the other tributaries to the reservoir.

Abiotic exposure media in the reservoir (i.e., surface water, sediment, and porewater) are the same as those in the Elk River watershed. Tertiary release and uptake mechanisms from those media, as well as exposure pathways by which a mine-related chemical may enter an organism (e.g., ingestion or absorption from direct contact), are also similar to those already discussed. In addition, although the particular species may differ, the groups of aquatic food web receptors are generally similar (Figure 2.4-3). One of the more notable differences is the relative importance of plankton in the reservoir, which are less important in the predominantly flowing habitats of the Elk River watershed.

2.5 Physical Stressors Conceptual Site Models

Physical stressors in the watershed and reservoir can be important in and of themselves (through processes or changes, such as erosion/sediment transport and deposition, barriers to fish migration, and water elevation changes), and also because of the potential interactive effect they may have with chemical stressors (i.e., transport and fate of chemical stressors are affected by hydrodynamic mechanisms and chemical reactions). This section discusses the physical-chemical transport and reaction pathways, human activities, and physical processes or changes that affect aquatic habitat in the Elk River watershed and in Lake Koocanusa. The relative importance of different processes outlined in the CSMs may differ among MUs and may have greater or lesser importance in the watershed versus reservoir.

2.5.1 Elk River Watershed

Fluvial geomorphology (i.e., the processes that operate in river systems and the landforms they create or have created) and hydrology of the Elk River affect erosion, sediment transport, and potential deposition of mine-related chemicals. In the Elk River watershed, hydrodynamic and sediment transport processes vary on a number of relevant space and time scales due to river geomorphology, seasonal patterns of precipitation and snowmelt, and water-level regulation (BC Hydro 2012). Hydrodynamic transport in the Elk River watershed is strongly influenced by weather (e.g., precipitation events, freeze/thaw cycles). With stream elevations ranging from 1,650 m near the headwaters to 720 m at the mouth where the Elk River enters Lake Koocanusa (Polzin 1998), variation in topography/gradient and soil/vegetation cover also influence flow characteristics among tributary and mainstem areas. In addition to surface runoff, the Elk River and its major tributaries contribute to and receive groundwater (NHC 2006; Polzin 1998). Variations in flows continue to dynamically influence stream channels within the watershed, especially during extreme events, resulting in creation of side-channels, oxbows, and braiding.

Once particulate and dissolved mine-related chemicals enter watercourses within the watershed, they are redistributed via the hydrodynamic transport processes of advection and turbulent mixing.

Spring freshet and rain events are dominant factors affecting the processes of sediment erosion, transport, and deposition within the Elk River watershed (NHC 2006; Polzin 1998). Vegetation plays an important role in stream bank stabilization; black cottonwoods, the main riparian trees along the Elk River, have a greater network of roots than plants such as grasses, so they are important in maintaining stream structure. Solids also may enter the system via autochthonous (e.g., algal/plant) production or decomposition of aquatic or terrestrial organic matter.

Sediment transport in streams occurs as a combination of bedload (the coarsest transported material, moving along the bottom), suspended load (those materials lifted well above the bed by the flow and transported in the water column), and washload (the finest-grained fraction of the suspension transport) (Polzin 1998). The hydraulic force of flowing water exerts a dragging action on the stream bed and banks that erodes loosely consolidated materials, such as clay, silt, sand, and gravel. This particulate organic matter and abiotic solids are transported downstream until factors such as decreased gradient, decreased volume (e.g., due to stream flow loss to groundwater recharge), or damming of the channel, cause them to settle to the bottom.

Sediment transport is important because of its effects on physical habitat characteristics (e.g., substrate characteristics), and it also may be an important fate-controlling process for mine-related chemicals because of the tendency of some mine-related chemicals (e.g., metals) to adsorb onto sediment particles.

Natural and anthropogenic features create barriers to fish migration and limit stream connectivity within the Elk River watershed (Figure 2.5-1). The dominant natural feature is

Josephine Falls located on the Fording River. Westslope cutthroat trout is the only fish species known to occur upstream of the falls, and barrier falls have protected this population from hybridization with non-native rainbow trout (Cope et al. 2013). Other barriers within the Elk River watershed include numerous mine-related road culverts and rock drains that are total or partial barriers, railroad tracks or old forestry roads and culverts that also are potential barriers, and Elko Dam, located on the Elk River about 16 km upstream of Lake Koocanusa (BC Hydro 2005). Originally built in 1924, Elko Dam is situated on historical falls that naturally limited the diversity of fish in the upstream portion of the Elk River watershed. Elko Dam is a concrete structure with a crest length of 66 m, a maximum height of 16 m, a headpond surface area of 10 ha, and a storage capacity of 600,000 cubic metres (m^3). The headpond is drawn down twice annually: once in late April–early May for flashboard removal, and again in mid-July for flashboard installation (BC Hydro 2005). Effects associated with these water level fluctuations on sediment mobilization and on aquatic habitat (e.g., fish stranding) are being monitored and evaluated by BC Hydro (2009 and 2011) to develop operational rules for the dam that minimize adverse effects.

Calcite ($CaCO_{3(s)}$) precipitation/deposition occurs naturally within the Elk River watershed, but has also been commonly observed downstream of mining activities (i.e., precipitation is enhanced by water passing through waste rock piles). Precipitation of calcite is governed by a complex system of factors, including stream pH, stream temperature, rates of carbon dioxide off-gassing, kinetic limitations on transformations between inorganic carbon species (in particular, the bicarbonate to carbonic acid conversion), and kinetic barriers to formation of precipitates (SRK 2011). Calcite precipitation can affect the physical aquatic habitat, especially the stream substrate, stream bank vegetation, riparian areas, and channel morphology (Hlushak 2012; Figure 2.5-2). Alterations to those habitat components may directly affect benthic invertebrates and periphyton, and, in turn, may affect other dependent receptors (SRK 2011).

Variation of invertebrate community composition and abundance has been related to a wide-range of environmental variables, such as elevation, latitude, water temperature, water velocity, water depth, light intensity, and substrate characteristics (Jacobsen et al. 1997; Quinn et al. 1994). Substrate size can directly affect the availability of dissolved oxygen (DO), food, and refuge for invertebrates (Boulton et al. 1998). Refuge availability is directly related to the amount of interstitial space, while delivery of DO and food are indirectly affected by the amount of interstitial space. Streambeds with smaller particle sizes typically have reduced interstitial space; thus, they have a reduced rate of hyporheic flow, which may adversely affect DO levels in off-channel habitat, as well as food resources. Substrate size is also important to the migration of invertebrates, as many aquatic invertebrates employ a life history that includes an aquatic larval/nymph stage and a terrestrial adult stage. Given that different invertebrate species have specific substrate requirements, it is reasonable to expect that substrate manipulations (e.g., calcite precipitation) may directly affect the aquatic invertebrate community and indirectly affect aquatic-dependent receptors (e.g., benthivores).

In addition to calcite precipitation having the potential to adversely affect aquatic habitats and communities, work completed by SRK (2011) has found that it inversely affects the availability of mine-related chemicals in the water column. For example, calcite deposits located downgradient of mining activities have been observed to incorporate (i.e., co-precipitate) trace elements such as cadmium, magnesium, manganese, nickel, selenium, and zinc from the water column.

2.5.2 Lake Koocanusa

Human activities (such as mining, forestry, and agriculture) in the upstream watersheds, in combination with natural processes (such as rain events, freezing, snowmelt, and wave action), have a substantial effect on tributary inflow rates, erosion, and sediment transport and deposition in the reservoir (Figure 2.5-3). Those physical processes and environmental changes are greatly affected by the operation of Libby Dam, located downstream on the Kootenay River in Montana. In addition, operation of Libby Dam also has a profound influence on lake elevation and water volume in Lake Koocanusa. Using an area/capacity curve, water depth at the border at full pool is about 40 m, but during annual drawdown it is less than or equal to 10 m (HydroQual 1990; see Figure 2.5-4). Fluctuations within the reservoir are controlled by two primary factors: (1) spring inflow volumes via the Kootenay, Bull, and Elk Rivers; and (2) annual drawdown rate. The Canadian portion of the reservoir experiences the greatest relative change in water elevation (HydroQual 1990). These habitat effects occur because the slopes of the inflowing river channel and the floodplain dictate the amount of area that is flooded versus exposed when elevations change.

Annual fluctuations of reservoir elevation affect aquatic habitats and communities, either directly through disruption of spawning activity, or indirectly through the character of food webs or the quality and availability of habitat (Hardy and Paragamian 2013; Richards 1997; Crozier and Nordin 1983). The most direct effect is the dewatering of littoral habitats with reduced production of species that depend on the littoral region for feeding or spawning (Richards 1997). Figure 2.5-5 illustrates the dramatic effect of annual drawdown on the Canadian portion of Lake Koocanusa (e.g., the barren littoral zone lacking aquatic macrophytes and available aquatic habitat).

2.6 Potential Chemical and Physical Stressors - Conceptual Site Model Summary

The following is a brief summary of chemical and physical stressors that have the potential to cumulatively affect the aquatic environment within the Elk River watershed and in Lake Koocanusa. A number of stressors may contribute to the same effect (e.g., reduced abundance of a species); therefore, investigation of one stressor cannot be made without consideration of others. The relative significance of each of these stressors on the aquatic community should, to the extent possible, be considered when evaluating the state of the aquatic environment. Section 3 provides the existing data for different environmental components, such as water quality, sediment quality, calcite, and biota in the study area, and this information is integrated in Section 4 to provide a cumulative evaluation of ecosystem health in the watershed and Lake Koocanusa. Potential stressors and their general ecological effects are briefly described in this section.

Chemical Stressors. A number of mine-related chemicals (i.e., metals/metalloids and major cations/anions) associated with mine operations or other sources have been detected in waters, sediments, and tissues of aquatic organisms, indicating that organisms are being exposed to multiple mine-related chemicals. These mine-related chemicals, depending on the magnitude and duration of exposure, their bioavailability, the particular biota being exposed (especially their life histories, life stages, and physiologies), can elicit a broad range of effects on growth, survival, and reproduction.

Physical Stressors. In portions of the Elk River watershed, physical stressors, such as hydrodynamic and sediment transport, and calcite precipitation/deposition, may modify aquatic habitats and affect the dispersion, deposition, and bioavailability of mine-related chemicals (e.g., co-precipitation). For chemicals that adsorb to particles, sediment transport is an important fate-controlling process. Natural and anthropogenic features create barriers to fish migration and limit stream connectivity within the Elk River watershed. The dominant natural feature is Josephine Falls located on the Fording River within MU1. Other barriers within the Elk River watershed include numerous mine-related road culverts and rock drains that are total or partial barriers, railroad tracks or old forestry roads that also are potential barriers, and Elko Dam, located on the Elk River about 16 km upstream of Lake Koocanusa. Hydroelectric operations result in annual drawdowns of Lake Koocanusa that perturb all aquatic life dependent upon the littoral zone as habitat; refugia from predators; and for feeding, growing, and reproducing. The annual surface elevation fluctuations move boundary lines for habitats upstream and downstream, as well as desiccate or inundate the shoreline. These habitat disturbances limit their overall biological productivity and preclude use of such habitats by long-lived species that are not able to move about when the water elevation drops (e.g., some benthic invertebrates in the Canadian portion of Lake Koocanusa in MU6).

Others. Biological stressors (such as competition by non-native species and the occurrence of parasites or pathogens) and recreational fishing, although not explicitly reviewed or discussed herein, can strongly affect aquatic communities. The Elk River watershed is known for its world-class recreational fishing opportunities (McPherson et al. 2014) and, as such, fishing pressures have affected fish community structure (Wilkinson 2009). To compound such effects, the Elk River watershed contains non-indigenous fish species that are invasive and have the potential to adversely affect biotic communities. Furthermore, algae (e.g., blue-green), parasites, viruses, and bacteria may cause a variety of diseases, cysts, lesions, and other internal and external abnormalities in fish that can affect fitness.

3 Existing Data

This section provides a summary of the large amount of environmental information collected in the Designated Area during previous studies. This includes summaries of water quality, sediment quality, tissue residues for aquatic ecological receptors (i.e., plankton, periphyton, benthic macroinvertebrates, fish, and amphibians) and aquatic-dependent birds, as well as invertebrate community structure and fish population characteristics.

3.1 Surface Water Quality

Surface water quality has been monitored over the past two decades at monitoring stations located throughout the Elk River watershed, and since 2013 in Lake Koocanusa. Monitoring stations represent mine-influenced tributaries, mainstem receiving waters, and reference[6] environments. Data from 2011 through 2013 were evaluated and constituents of potential concern (COPCs) were identified by comparing surface water concentrations to those at reference stations and to water quality guidelines (WQGs) or site-specific (i.e., Elk Valley) benchmarks for the protection of aquatic life. This section also discusses temporal trends for primary COPCs and summarizes results of toxicity tests conducted using surface water from the Elk and Fording Rivers.

3.1.1 Data and Water Quality Guidelines

3.1.1.1 Available Data

Water quality data used in this evaluation were collected by Teck from 93 stations located throughout the Designated Area (Table A1-1 in Appendix A1; note that all appendices are provided in a separate volume); in addition, data from two stations monitored by the BC MOE were used. Each of these stations has been identified as one of the following: 1) mine-influenced tributary station, located directly downstream of Teck's operations (e.g., immediately downstream of mining activities or a mine settling pond), 2) mainstem station receiving inputs from mine-influenced tributaries, or 3) reference station, representing conditions upstream of mining operations. The stations are shown on maps (Maps 3.1-1 to 3.1-7) as well as on a schematic diagram that presents the spatial relationships of each location to the mining operations and to each other (Figure 3.1-1).

Surface water samples were collected as grab samples by lowering a clean sample bottle supplied by the laboratory into the water, with the opening upstream. When possible, the sample was collected mid-stream. Any necessary filtering or preserving was done as soon as possible after sample collection, typically in the field.

[6] For surface water, reference environments are defined as those located hydrogeologically upgradient of Teck's active mining operations within the Designated Area.

Some monitoring locations have been sampled for more than 10 years, whereas other locations were established more recently and thus have fewer data points. The following evaluation focused on data for the past three years (2011-2013, inclusive) to assess recent conditions, and because analytical detection limits over this period have been fairly consistent and sufficiently low to support comparisons of reported concentrations to WQGs. Summary statistics for monitoring results by station and constituent for January 2011 to December 2013 are presented in Appendix A2.

3.1.1.2 Water Quality Guidelines and Site-Specific Benchmarks

This evaluation used site-specific benchmarks developed for the Elk Valley for cadmium, nitrate, selenium, and sulphate (Golder Associates 2014a,b; HDR 2014). For the remaining constituents, WQGs based primarily on the approved or working BC MOE guidelines for the protection of freshwater aquatic life (Table A3-1 in Appendix A3) were used. BC MOE WQGs are expressed as either maximum concentrations, which should not be exceeded at any time, or as 30-day mean concentrations, which should not be exceeded based on an average of five sample taken over a 30-day period. This evaluation used the 30-day mean WQGs when available, although they were applied to individual sample values, which is more conservative than using a mean over 30 days. If a 30-day mean WQG was not available the maximum WQG was used.

Site-specific benchmarks or WQGs for eight constituents (cadmium, copper, fluoride, lead, manganese, nickel, nitrate, and zinc) depend upon water hardness (Table A3-2 in Appendix A3). In this evaluation, the benchmark or guideline specific to each sample was computed using the hardness value reported for the same sample, or the average hardness for the station if a sample-specific hardness was not available. Similarly, for ammonia, the WQG depends on pH and temperature, and for nitrite, the WQG depends on chloride content (Table A3-1). Sample-specific WQGs for ammonia and nitrite were calculated using pH, temperature, and chloride levels reported for each sample, or using the station average if sample-specific data were not available.

Although WQGs are available for total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), and turbidity, these guidelines were not included in the evaluation because they are based on relatively small variation from reference mean or median concentrations. Waterborne concentrations of these parameters exhibit high seasonal variability even in reference areas, with highest concentrations typically being associated with the spring freshet period from April through July. Therefore, rather than comparing to WQGs, concentrations for these parameters, as well as alkalinity (which has no WQG for elevated concentrations), were compared to reference 95th percentile concentrations calculated for both the freshet and the non-freshet periods (Section 3.1.2.1).

Guidelines were not available for some metals and metalloids, including bismuth, calcium, magnesium, sodium, strontium, and tin. For these constituents, a search was conducted for toxicity benchmarks in the USEPA online ECOTOX database or in the set of toxicological benchmarks compiled by Suter and Tsao (1996). In the selection of benchmarks for use in this evaluation, preference was given to longer-term (i.e., chronic) studies. Benchmarks were identified for bismuth, strontium, and tin from those sources (Table A4-1 in Appendix A4). Benchmarks were not derived for calcium, magnesium, or sodium, as described in Appendix A4.

There are two chronic working BC MOE guidelines for lithium. The higher value of 0.096 mg/L is a final chronic value (FCV) cited by the MOE (BC MOE 2014) as a guideline from the Michigan

Department of Environmental Quality (MDEQ). However, the website for MDEQ currently identifies a FCV for lithium of 0.44 mg/L (ref). The lower working BC MOE guideline for lithium is 0.014 mg/L, which is a secondary chronic value from Suter and Tsao (1996). Since that publication, additional toxicity data have become available, as summarized in Appendix A4.2; the lowest chronic value based on this review was 0.4 mg/L. None of the lithium concentrations in any samples exceeded either the current MDEQ FCV of 0.44 mg/L or the lowest chronic value of 0.4 mg/L from the lithium toxicity review (Appendix A4.2); therefore, lithium was not considered a COPC and was not included in the comparison to WQGs in Section 3.1.2.2.

3.1.2 Elk River Watershed (MU1 – MU5) Surface Water Evaluation

Water quality data were evaluated in a stepwise manner, following the process outlined in Figure 3.1-2. This process is described in detail in this section. In general, the process first selected COPCs and then primary COPCs based on the frequency of concentrations greater than reference as well as WQGs or site-specific benchmarks. Stations in the Elk River watershed (MUs 1 through 5) were evaluated separately from those in the reservoir (MU6) because aquatic habitat differs in the watershed versus the reservoir. All of the reference areas routinely monitored by Teck are located in the watershed upstream of mining and have lotic habitats similar to those found throughout MUs 1 through 5; therefore, comparisons to reference area concentrations were conducted only for these MUs. The methods and results of the reference and WQG comparisons for MUs 1 through 5 are presented in this section. The evaluation for dissolved oxygen (DO) is evaluated separately in this section (i.e., outside of the COPC evaluation) because, although it is potentially influenced by mining, it is not a chemical that is introduced by mining as are the other constituents. Also presented in this section are summaries of results from a previous evaluation of temporal trends (Zajdlick and Minnow 2013) and results for toxicity tests recently conducted using water from the Fording and Elk Rivers.

3.1.2.1 Comparison to Reference Concentrations

This section compares water concentrations at stations downstream of mining conditions to those observed at reference areas to identify mine-related constituents. This section also presents an evaluation of DOC, TOC, turbidity, TSS, alkalinity, and hardness at Order stations compared to reference locations.

Identification of Mine-Related Constituents

Data were pooled across the eight reference locations within MUs 1 through 5 to calculate the upper 95th percentile for all parameters (see Table A5-1 and Figures A5-1 through A5-29 in Appendix A5). These values were considered representative of the upper range concentrations that could be expected to occur naturally within the watershed. Data for each mine-influenced tributary were then compared to the reference 95th percentiles for each constituent (Table A5-2 and Table A5-3).[7]

Constituents were included in the WQG comparison if water quality guidelines or alternative effects-based benchmarks were available (see Section 3.1.1.2), and they were observed at concentrations above the reference 95th percentile in more than 10 percent of samples at any tributary station. Constituents with concentrations greater than the 95th percentile in less than 10 percent of the samples in each of the mine-influenced tributaries were considered to have concentrations within the range of reference area concentrations and were not evaluated further (Figure 3.1-2); only beryllium and mercury fell into this category and therefore were not considered COPCs. There were an insufficient number of reference data points (i.e., 10 samples) for PAHs to calculate 95th percentile reference concentrations, so PAHs were not included in this step of the evaluation, although they were included in the comparison to WQGs.

Evaluation of Additional Parameters

DOC and TOC results for Order stations in MUs 1-4 (GH_FR1 in MU1, LC_LC5 in MU2, GH_ER1 in MU3, and EV_ER4/EV_ER1 in MU4)[8], which are considered representative mainstem locations, were compared to the reference 95th percentiles (Figures A5-33 to A5-42 in Appendix A5). Because DOC and TOC concentrations vary seasonally, 95th percentile concentrations were calculated separately for the freshet period (April through July) and non-freshet period (August through March). As shown in Table 3.1-1, a few samples had TOC concentrations greater than the 95th percentile during the freshet period (1/11 samples at GH_FR1, 1/30 samples at EV_ER4, and 1/31 samples at EV-ER1). None of the DOC concentrations were above the reference 95th percentiles during either the freshet or the non-freshet periods, and none of the DOC or TOC concentrations were below the reference 5th percentiles in any samples. These results indicate that mining has negligible influence on DOC or TOC concentrations.

TSS and turbidity concentrations in 10 and 15 percent, respectively, of all samples combined among mine-influenced tributary and mainstem locations were greater than the reference 95th percentile concentrations (Table 3.1-1). TSS and turbidity tended to be higher and more variable during the freshet period (Figures A5-43 through A5-52). When 95th percentiles were calculated separately for the freshet and non-freshet periods, there were relatively few samples at Order stations that had concentrations exceeding reference concentrations during the non-freshet period (Table 3.1-1). Most of the concentrations greater than reference occurred during the freshet period when variability was high, as shown in Figures A5-43 through A5-52 in Appendix A5. The percentage of samples above reference among the Order stations ranged from 7.1 to 24 percent for TSS and from 7.1 to 15 percent for turbidity (Table 3.1-1). TSS and turbidity naturally tend to increase with distance downstream in a watershed as the catchment area increases, so

[7] The reference comparison focused on mine-influenced tributaries because mine-related constituents were considered more likely to be detected at the highest concentrations in areas closest to the mine operations rather than in downstream mainstem locations where concentrations related to mining would be diluted or confounded by other influences.

[8] The Order station IDs for these locations are FR4 for GH_FR1, FR5 for LC_LC5, ER1 for GH_ER1, ER2 for EV_ER4, and ER3 for EV_ER1.

these results may reflect the larger catchment areas of the Order stations compared to those of most upstream reference areas, rather than mine-related influence.

Water hardness was higher downstream of mining areas compared to reference areas, and concentrations correlated strongly with other mine-related variables (i.e., alkalinity, selenium, nitrate, sulphate; Minnow and PLA 2012). At the Order stations, alkalinity showed strong seasonal variability; peak concentrations occurred at the end of non-freshet period and concentrations decreased during the freshet period (Figures A5-53 to A5-57 in Appendix A). Alkalinity concentrations were higher than the 95th percentile reference concentration during the freshet period at four Order stations (10/24 samples at GH_FR1, 5/12 samples at LC_LC5, 5/30 samples at EV_ER4, and 2/30 samples at EV_ER1). During the non-freshet period alkalinity concentrations were above the 95th percentile reference concentration at only one station (GH_FR1) in 5/23 samples. These results indicate that mining may have an influence on alkalinity at some mainstem locations during the freshet period.

3.1.2.2 Comparison to WQGs and Site-Specific Benchmarks

Constituents with no detected concentrations greater than the long-term WQG or site-specific benchmark in any samples were chloride, fluoride, pH, antimony, bismuth, boron, molybdenum, potassium, strontium, tin, titanium, acenaphthene, anthracene, benzo(a)anthracene, fluoranthene, fluorene, and naphthalene (Table 3.1-2). In addition, none of these constituents had detection limits greater than their respective WQG or site-specific benchmark. As a result, these constituents were not considered COPCs and were not evaluated further. As discussed in Section 3.1.2.1, beryllium and mercury also were not considered COPCs because concentrations in mine-exposed areas were generally within the range observed among reference areas.

Constituents detected in one or more samples at concentrations above the respective WQG or benchmark, including nitrate, nitrite, ammonia, sulphate, aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, thallium, uranium, vanadium, zinc, benzo(a)pyrene, phenanthrene, and pyrene, were considered COPCs (Table 3.1-2).

Nitrate, selenium, and sulphate had concentrations greater than respective benchmarks in more than 10 percent of samples combined among mine-influenced tributaries and mainstem locations, so they were considered primary COPCs (Table 3.1-2). For all other COPCs, less than 10 percent of all samples had concentrations greater than their WQGs or benchmarks.

The number of samples greater than the WQGs or benchmarks by MU and location are presented in Tables 3.1-3 through 3.1-7. Figures 3.1-3 to 3.1-5 show median concentrations for nitrate, selenium, and sulphate at each location, calculated using the 3-year dataset (2011-2013). Figures 3.1-3 to 3.1-5 also show load trends for tributaries that contribute at least 75 percent of total mine loads to the watershed. These results are discussed with an emphasis on sample-specific results, including a discussion of median concentrations to identify locations that have had the highest concentrations in recent years on average, as follows.

MU1

The highest median concentrations of nitrate, selenium, and sulfate were in Swift, Cataract, and Eagle creeks (Figures 3.1-3 to 3.1-5). Nitrate concentrations were greater than the site-specific benchmark in 15 percent of samples collected among tributary and mainstem locations in MU1, whereas selenium and sulphate were more frequently found at concentrations above the site-specific benchmarks among tributary stations (45 and 31%, respectively) than at mainstem stations (6 and 0%, respectively) (Table 3.1.-3). In the Fording River, nitrate, selenium, and sulphate concentrations were generally highest at GH_PC2, downstream of major load sources of Kilmarnock, Swift, and Cataract creeks (FR_SKP2, GH_SC1/GH_SC2, and GH_CC1) (Figures 3.1-3 to 3.1-5).

Nitrite concentrations were frequently elevated at FR_CC1, causing some samples to also be elevated in the Fording River at stations immediately downstream (FR_FRABEC1 and FR_MULTIPLATE). Nitrite concentrations also were frequently elevated at GH_RLP, which infiltrates to ground with no direct discharge to the Fording River. Nitrate concentrations were not elevated at the Fording River station located downstream (GH_FR1) (Table 3.1-3). Other COPCs with concentrations above the WQGs typically occurred in tributary samples, and constituents that were elevated in at least one-third of samples at any station included ammonia (FR_CC1, FR_NL1), cadmium (FR_STPWSEEP, FR_SKP1), uranium (FR_EC1, GH_SC1, GH_CC1), and vanadium (GH_GH1).

MU2

Median concentrations of primary COPCs in MU2 were highest in West Line Creek, and were lower at Line Creek stations located downstream (LC_LC3 and LC_LC4) (Figures 3.1-3 to 3.1-5). Of the primary COPCs, selenium most frequently had concentrations greater than the benchmarks. Although 75 percent of samples collected in lower Line Creek (LC_LC4) had selenium concentrations above the benchmark, the percentage of samples having elevated concentrations in the Fording River downstream of Line Creek (87% at LC_LC5) was similar to upstream (86% at LC_LC6) (i.e., inputs from Line Creek maintain but do not add to concentrations in the Lower Fording River) (Table 3.1-4). Despite concentrations of sulphate, cadmium, and uranium that were frequently above benchmarks or WQGs at stations immediately downstream of LCO (LC_WLC and/or LC_LC3), WQGs were usually met (i.e., more than 90 percent of samples had concentrations below WQGs) at stations in lower Line Creek and in the Fording River both upstream and downstream of Line Creek.

MU3

Nitrate, selenium, and sulphate did not have concentrations above the WQGs or benchmarks at the only mainstem receiving station in the Elk River in MU3 (Table 3.1-5). Nitrate and selenium concentrations were greater than the benchmarks only at Leask, Wolfram, and Thompson creeks (GH_LC2, GH_WC2, and GH_TC1; in 59 to 100% of samples at each location). Sulfate concentrations were above the benchmark only at Wolfram and Thompson creeks (in 19 and 43% of the samples, respectively). Thompson Creek had the highest median concentrations and the highest loads of primary COPCs to the Elk River in MU3 (Figures 3.1-3 to 3.1-5).

MU4

All mine-influenced tributaries to Michel Creek, except CM_SPSP, CM_AG2, and EV_AQ1, had nitrate, selenium, and/or sulphate concentrations that were frequently abovebenchmarks (Table 3.1-6a). However, only 3 of 258 Michel Creek samples had nitrate concentrations above the benchmark, and none of the Michel Creek samples had selenium or sulphate concentrations above the benchmarks. Of the tributaries in MU4 discharging to the Elk River, EV_HC1 and EV_GC2 frequently had concentrations above the site-specific benchmark for selenium, but samples collected at Elk River stations had concentrations that were typically less than the selenium benchmark. Nitrate concentrations in the Elk River were most often observed above the site-specific benchmark at the most upstream station in MU4 (EV_ER4) and concentrations were progressively lower at stations farther downstream, reflecting dominant influence from the Fording River rather than mine sources within MU4. It should be noted that although median nitrate concentrations were lower in the mainstem of the Elk River (e.g., ER_ER4) than they were in the Fording River upstream of the Elk River (e.g., LC_LC5) in MU1, the frequency of concentrations above benchmarks was higher in the Elk River because the site-specific benchmark is lower in the Elk River than in the Fording River (Table A3-2). The lower hardness of surface water in the Elk River compared to the Fording River resulted in lower site-specific benchmarks (Golder 2014a).

Concentrations above WQGs for other COPCs were infrequent at mainstem locations with the exception of chromium in 4.8 to 17 percent of samples at each location (Table 3.1-6b). The tributaries with the most frequent concentrations of chromium above WQGs were EV_MM1 (29%), EV_GC2 (31%), and EV_AQ1 (60%).

Of the remaining COPCs, nitrite concentrations were above the guideline in 24 percent of samples at CM_SPD, but were elevated in a lower percentage (4%) of samples farther downstream at CM_CC1. Other than periodic elevations of aluminum (14 and 15% of samples at EV_SM1 and EV_AQ1, respectively) and cobalt (100% of samples at CM_SPD and 50% of samples farther downstream at CM_CC1), water concentrations usually met WQGs (i.e., 90% or more of samples at each station had concentrations less than the WQGs).

MU5

Concentrations of nitrate, selenium, and sulphate did not exceed the benchmarks at any MU5 locations, all of which are located on the Elk River (Table 3.1-7). Median concentrations of primary COPCs decreased with distance downstream (Figures 3.1-3 to 3.1-5).

Only aluminum (in 7% of samples at BC08NK0003), chromium (16 and 9% of samples at RG_ELKORES and BC08NK0003), and copper (5% of samples from RG_ELKORES) had concentrations above the WQGs. The higher numbers of elevated concentrations of these constituents at RG_ELKORES and BC08NK0003 compared to the upstream station RG_ELKFERNIE indicates sources other than Teck mining operations.

Plots of primary COPC concentrations over time are presented in Appendix A6 for all locations. In addition, plots are presented in Appendix A6 for other COPCs at locations that had at least one exceedance of a benchmark or WQG. For nitrate, selenium, and sulphate, many locations show clear seasonal patterns over time. For example, Figures 3.1-6 to 3.1-8 present data for nitrate, selenium, and sulphate from 2011 to 2013 at Order Station FR_FR2, where concentrations tend to peak at the beginning of the spring/summer freshet period, and decline throughout the freshet and post-freshet period. Most of the other COPCs show the same general seasonal pattern, although the pattern is less evident for some constituents, such as ammonia, chromium, and nitrite as shown for FR_FR2 in Figures 3.1-9 to 3.1-11 (Appendix A6).

3.1.2.3 Evaluation of Dissolved Oxygen

Dissolved oxygen WQGs from BC MOE are based on minimum values below which a concentration should not fall. The DO guidelines pertain to protection of different fish life-stages; the higher 30-day mean WQG of 11 mg/L applies to the most sensitive buried embryo/alevin life stages and the lower 30-day mean WQG of 8 mg/L applies to all other life stages. This evaluation compares DO concentrations to both guidelines, although use of the higher value should be applied to the specific season and locations of spawning for a salmonid species, which is beyond the scope of this evaluation. Therefore the comparison to the higher WQG for sensitive species is a conservative approach. The BC guideline acknowledges that low DO commonly occurs even in natural ambient environments and should be taken into account in evaluating DO conditions. Therefore, this evaluation also compares the mine-exposed DO concentrations to those from reference areas.

DO concentrations at mine-exposed locations were frequently below the conservative WQG for sensitive life stages (11 mg/L), but were also frequently depressed relative to the conservative WQG at reference locations (Table 3.1.8). DO concentrations below the less conservative WQG for other life stages (8 mg/L) and the reference 5th percentile concentration (7.6 mg/L) occurred most frequently in mine-influenced tributaries in MU1 (in 21 to 50% of samples at FR_CC1, FR-EC1, FR_LEESLK, FR_NL1, FR_SP1, FR_STPWSEEP and STPSWSEEP, and GH_RLP), all of which are located downstream of mine-settling ponds (Table 3.1.8). In addition, three mainstem locations in MU1 (FR_FRABEC1, FR_MULTIPLATE, and LC_FRUSDC) and three mine-influenced tributaries in MU4 (EV_OC1, CM_SPSP, and CM_SPD) had concentrations below the conservative WQG and reference 5th percentile in 6.1 to 14% of samples at each station. Otherwise, DO concentrations were infrequently below the lower WQG, and results for exposed stations were similar to those for reference stations.

DO patterns over time for Order stations (Figures A5-58 through A5-62 in Appendix A5) show that the lowest concentrations occur during June through September when water temperatures are highest (reducing the oxygen saturation capacity) and water flow is often low (less turbulent aeration). DO concentrations at Order stations rarely fell below the reference 5th percentile concentrations calculated separately for June-September and October-May.

3.1.2.4 Evaluation of Temporal Trends

A statistical analysis of temporal trends of cadmium, nitrate, selenium, and sulphate concentrations measured at stations in MUs 1-4 was previously conducted for data from 2010 to 2012 (Zajdlik and Minnow 2013). Trends for cadmium, nitrate, selenium, and sulphate at all stations evaluated are presented in Figures 3.1-3 to 3.1-5 and in Table 3.1-9. At most mainstem stations, concentrations of primary COPCs reflected an increasing trend. In mine-influenced tributaries of MUs 2 and 3, most locations also had increasing trends. In mine-influenced tributaries of MU1, about half the locations had increasing trends and half had stable or decreasing trends for each primary COPC. In contrast, most mine-influenced locations in MU4 showed stable or decreasing trends, particularly for cadmium and nitrate. All reference locations (with the exception of one location for sulphate only) had stable or decreasing concentrations for the primary COPCs. Details on the temporal trends analysis are presented in Zajdlik and Minnow (2013), and plots of concentrations over time are presented in Appendix A6.

Zajdlik and Minnow (2013) also evaluated total loads, and estimated that seven to ten major sources contributed at least 75 percent of the mine-related loads of nitrate, selenium, and sulphate to mainstem receiving areas (Figures 3.1-3 to 3.1-5). The stations identified as major sources included Kilmarnock (FR_SKP2), Swift (GH_SC1/SC2) and Cataract (GH_CC1) creeks in MU1; West Line Creek (LC_WLC) and Line Creek (LC_LCUSWLC) in MU2; Thompson Creek (GH_TC1, TC2) in MU3, and/or Harmer (EV_HC1), Bodie (EV_BC1) and Erickson (EV_EC1) creeks in MU4, depending on the constituent. For stations contributing a major load of a given constituent, stable or increasing trends were indicated for all but sulphate at Erickson Creek (decreasing trend) and nitrate, selenium, and sulphate at LC_LCUSWLC (trend not evaluated[9]). The same stations typically also reflected highest median concentrations.

3.1.2.5 Toxicity Test Results

This section summarizes toxicity testing that was conducted on unaltered (ambient) surface water samples collected from the Elk and Fording rivers in 2013 as part of two separate studies (Golder and Nautilus 2013; Nautilus 2014). These unaltered surface water tests were used as controls as part of a site-specific toxicity study for nitrate and sulphate (Nautilus 2014), and as part of the mixture toxicity study for the Line Creek Phase II project (Golder and Nautilus 2013).

In the site-specific toxicity testing study, tests were conducted with two invertebrate species (water flea [*Ceriodaphnia dubia*] and a freshwater amphipod [*Hyalella azteca*]) and two fish species (fathead minnow [*Pimephales promelas*] and rainbow trout) using water from one reference station (GH_ER2), two receiving environment stations in the Elk River (LC_ELKOS and EV_ER1), and two receiving environment stations in the Fording River (GH_FR1 and LC_LC5). In the mixture toxicity study, tests were conducted using one invertebrate species (water flea [*C. dubia*]), one aquatic plant species (duckweed [*Lemna minor*]), one algal species (*Pseudokirchneriella subcapitata*), and one fish species (rainbow trout) using water from one receiving environment station in the Fording River (LC_FRB).

Detailed results from the different toxicity tests are presented in Tables A7-1 and A7-2 in Appendix A7. No significant effects were observed among organisms exposed to the surface water collected from the Elk and Fording Rivers compared to the upstream reference sample. Measured constituent concentrations were below the site-specific benchmark concentrations for sulphate and selenium, and were less than or similar to the benchmark for nitrate (Table 3.1-10).

3.1.3 Lake Koocanusa (MU6) Surface Water Evaluation

For stations in MU6, the Canadian portion of Lake Koocanusa (RG_EASTARM, RG_DSELK, RG_GRASMERE, RG_USELK, and RG_BORDER), the data were evaluated by comparing all sample concentrations to WQGs (all constituents except cadmium) or site-specific benchmarks

[9] Flow data were not available for LC_LCUSWLC to directly calculate loads and assess trends over time. Instead, loads presented in Figures 3.1-3 to 3.1-5 were estimated by subtracting West Line Creek loads from the total loads farther downstream in Line Creek at LC_LC3.

(cadmium). The dataset for MU6 is relatively small because sampling was not initiated until August 2013, yielding 13 to 15 samples at each location for this evaluation. Phosphorus, chromium, and selenium were the only constituents with concentrations greater than their WQGs or site-specific benchmarks in some MU6 samples (Table 3.1-11).

Phosphorus concentrations were above the WQG in 21 to 43 percent of the samples collected at each location, including those upstream of the Elk River in Lake Koocanusa. The lowest frequency of samples above the WQG was at RG_EASTARM, which is the location most likely to be affected by Elk River influences, indicating that elevated phosphorus concentrations in Lake Koocanusa are not a result of Elk River inputs.

Selenium concentrations were above the WQG in 2 of 14 samples at RG_EASTARM and in 1 of the 14 samples from RG_USELK, but were less than the WQG in all other samples from Lake Koocanusa. Median concentrations of selenium were 0.89 μg/L in Lake Koocanusa just upstream of the Elk River mouth (RG_USELK), 6.3 μg/L at the mouth of the Elk River (RG_ELKMOUTH in MU5 where it did not exceed the site-specific benchmark), and 1.35 μg/L downstream of the Elk River mouth (RG_EASTARM), indicating that selenium concentrations in Lake Koocanusa are slightly influenced by Elk River inputs. For chromium, 1 of the 14 samples from RG_EASTARM had a concentration greater than the WQG.

3.1.4 Comparison to 2012 Surface Water Data Evaluation

This evaluation updates a previous analysis of surface water quality (Minnow and PLA 2012). The primary differences in approach between the previous and the current evaluation are as follows:

- Minnow and PLA (2012) used data from 2008 to 2010, whereas this evaluation used data from 2011 to 2013.
- The previous evaluation identified constituents as minor or major mine indicators if more than 10 or 50 percent of samples, respectively, in datasets for both major source tributaries (10 stations combined) and mainstem receiving stations (15 stations combined) had concentrations greater than the 95th percentile of pooled reference samples. This evaluation did not specifically identify mine indicator constituents, but it did eliminate from further evaluation any constituents that did not have concentrations greater than the 95th percentile of pooled reference samples in more than 10 percent of samples in any one of the mine-related tributaries.
- This evaluation used site-specific benchmarks derived in 2014 for the Elk Valley for cadmium, nitrate, selenium, and sulphate, whereas the 2012 evaluation used provincial or federal WQGs for those constituents.

Despite some differences in the datasets and methods used between the two evaluations, the same general conclusions were reached. Minnow and PLA (2012) identified nitrate, selenium and sulphate as the constituents that were most frequently elevated in mine-exposed areas, and by the greatest magnitudes, relative to reference concentrations. These are the same substances identified as primary COPCs in this evaluation. Also, both evaluations found that nitrate, selenium, and sulphate were the constituents with the highest number of median concentrations exceeding the guidelines or benchmarks to which they were being compared. Other constituents identified by both evaluations as having elevated concentrations compared to WQGs in some mine-exposed areas included cadmium, nitrite, and zinc.

3.1.5 Summary

Concentrations of DOC and TOC at Order stations were similar to the range of concentrations observed among reference stations and do not appear to be influenced by mine-related activities. TSS, alkalinity, and turbidity were somewhat elevated compared to reference conditions at some locations during spring freshet, suggesting potential seasonal, mine-related influence on these parameters. However, most reference areas are situated closer to headwaters, where TSS and turbidity would naturally be lower than in higher-order streams situated lower in the watershed (i.e., mine-exposed stations are generally associated with larger catchment areas); therefore, the degree of mine influence, if any, on watershed TSS and turbidity levels remains uncertain.

Nitrate, selenium and sulphate were identified as primary COPCs for MUs 1-5 because more than 10 percent of the samples combined among mainstem receivers and mine-influenced tributaries had concentrations above the benchmarks (summarized in Table 3.1-12). About 75 percent of the total mine-related loads of these constituents are associated with seven to ten mine-influenced tributaries, depending on the COPC. These major sources are Kilmarnock, Swift and Cataract creeks (MU1); West Line Creek and Line Creek (MU2); Thompson Creek (MU3); and Harmer, Bodie, and Erickson creeks (MU4).

Other constituents with at least one sample having a concentration above the WQG or benchmark were identified as COPCs of lesser concern for MUs 1-5 and were each mainly associated with only a few mine-influenced tributaries. These constituents included nitrite, ammonia, aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, thallium, uranium, vanadium, zinc, benzo(a)pyrene, phenanthrene, and pyrene. Samples collected at mainstem receiving stations rarely had elevated concentrations of any COPCs (i.e., <10% of samples per station; Table 3.1-12). However, some mainstem stations reflect the contributions of tributary streams, such as nitrite concentrations at upper Fording River stations FR_FRABEC1 and FR_MULTIPLATE (up to 60% of samples), which were likely influenced by nitrite inputs from tributary station FR_CC1. In MU5, which includes four mainstem locations on the Elk River downstream from all mining operations, there were no concentrations above benchmarks for any of the primary COPCs in any samples, and concentrations decreased with distance downstream from mining operations.

DO concentrations were similar to those in reference areas except at some mine-influenced tributaries primarily in MU1 but also in MU4, and at a few mainstem locations in MU1. At locations other than these, DO concentrations were infrequently below the WQG for less sensitive life stages of fish.

In Lake Koocanusa (MU6), phosphorus, selenium, and chromium had concentrations above benchmarks or WQGs. Elevated phosphorus concentrations did not appear to be a result of Elk River inputs. The Elk River has a slight influence on selenium concentrations in downstream areas of Lake Koocanusa, but concentrations did not exceeded the BC MOE WQG of 2 µg/L in any of the samples downstream of the Elk River in Lake Koocanusa. Chromium was measured slightly above the WQG in only one sample collected at the Elk River mouth.

3.2 Sediment Quality

This section presents an evaluation of sediment data collected from the Elk River watershed (MU1-MU5) and Lake Koocanusa (MU6). This evaluation includes a comparison of sediment data to MOE sediment quality guidelines (SQGs) and reference concentrations to identify sediment constituents of potential concern (COPCs). Additionally, this section includes a comparison of the results from the 2011 study conducted by Lotic (Lotic 2013; and as summarized in Appendix D of Minnow 2014a) and the 2013 study conducted by Minnow (2014a), as well as a review of the available toxicity data.

3.2.1 Data and Sediment Quality Guidelines

This section presents a discussion of the data used in this sediment quality evaluation (Section 3.2.1.1), a summary of the sampling locations (Section 3.2.1.2), and the sediment quality guidelines (SQGs) used for this evaluation (Section 3.2.1.3).

3.2.1.1 Available Data

This evaluation used data collected within the past three years as part of sampling events conducted in the Elk Valley watershed (2011 and 2013) and in Lake Koocanusa (2013) (Table 3.2-1). The three sampling events that were identified as being acceptable for use in this analysis are briefly summarized as follows:

- **Fall 2011 in the Fording River watershed (Lotic 2013; and as summarized in Appendix D of Minnow 2014a)** – This sampling event focused on the collection of surface (top 1 cm) sediments from the Fording River basin. Samples were collected from 6 mine-exposed tributaries, 13 receiving environments (along the Fording and Elk Rivers), and 10 reference areas. At each location, 5 to 10 samples were collected using either a stainless steel spoon or a hand-corer. Each sample was a composite of multiple spoon scoops or core slices until a volume of 500 g was reached. Samples were then divided into two parts and analyzed both as <0.063 mm and as bulk sediment fractions.
- **April and August, 2013, in Lake Koocanusa (Minnow 2014b)** – This sampling event was designed to characterize surface (top 2 cm) sediments in Lake Koocanusa. Samples were collected along seven transects (5 to 7 samples at each transect[10]) across the lake in April at low pool elevation, using a core collar inserted into a petite ponar grab sample (April), or by scooping the surface sediment by spoon from the ponar grab sample (August). Three-subsamples were composited at each station for analysis. Two of the transects were sampled again in August at high pool elevation, primarily to assess the influence, if any, of the June 2013 flood on sediment quality.

[10] For each transect, five samples were collected from submerged areas spaced evenly across the lake (Stations 2 through 6). Additional samples were collected above the waterline on each shoreline (Stations 1 and 7) when sediment was present (if only sand/gravel was present, these stations were not sampled).

- **August 2013 in the Elk River watershed (Minnow 2014a)** – This sampling event was designed to answer various questions about the contaminant concentrations in the Elk Valley watershed that remained after a review of the existing sediment data (e.g., are mine-related chemical/physical changes to sediment occurring?). Three to five surface (top 2cm) sediment samples were collected within each sampling area, each of which was comprised of eight sub-samples that were composited to form the sample. Samples were collected by corer (substrate permitting) or by using a core collar inserted into a petite ponar grab sample.

Analyses were limited to surface sediments to reflect conditions in the sediment layer to which benthic organisms are exposed (i.e., up to 95% of benthic organisms are typically found in the top 1 to 3 cm of sediment (Kirchner 1975)).

Metals were analyzed in the <0.063 mm fraction and/or the bulk fraction (<1 mm or <2 mm) in the three sampling events listed in Table 3.2-1. For purposes of this report, only the results of the bulk sediment samples were evaluated for the following reasons:

- Basis of SQGs – Although BC guidance for mine proponents and operators (BC MOE 2012) specifies analysis of the <0.063 mm fraction, SQGs are based on bulk sediment concentrations (CCME 1999).
- Benthic invertebrate exposure – Bulk sediment samples represent the total environment to which benthic organisms are exposed, whereas the <0.063 mm sediment fraction represented a small proportion of many of the whole-sediment samples collected in 2011 (Appendix F of Lotic 2013).

Additionally, sampling conducted in 2013 targeted areas with fine sediment deposits (i.e., mostly <0.063 mm particles), so observed metal concentrations were similar for the <0.063 mm and bulk sediment fractions (Minnow 2014a, b). Also, polycyclic aromatic hydrocarbons (PAHs) are always analyzed on bulk sediment samples.

Some available data were excluded from the evaluation of sediment quality presented here because of the size fraction of samples analyzed (i.e., <0.063 mm fraction only), the sample type (e.g., subsurface samples are not included in this evaluation), or the location of particular samples (e.g., samples that were collected above the water or samples that were collected from mine works, such as settling ponds). For example, sediment data collected from MU3 through MU6, and from reference areas, as part of the Transboundary Flathead River study, did not report bulk sediment concentration or particle size data (i.e., only the <0.063 mm fraction was analyzed) (Hauer and Sexton 2013), so these data were not used in this evaluation.

In addition, a review of sampling locations resulted in the exclusion of LK01 (located at the mouth of a minor tributary that flows directly into Lake Koocanusa) and LK02 (located at the mouth of the Elk River), because these locations do not exclusively represent conditions in either the reservoir or stream habitats.

3.2.1.2 Sampling Locations

Sampling locations were categorized as representing mine works areas such as settling ponds (i.e., altered or constructed aquatic areas to trap sediment), exposed areas (i.e., areas farther removed from, but potentially influenced by, mining activities), or reference areas (i.e., areas not influenced by mining activities). Sampling locations in each of these area types are listed in Table 3.2-2. Map 3.2-1 shows the spatial distribution of the samples included in the sediment dataset, and Maps 3.2-2 through 3.2-7 show the locations in each MU in more detail. MU6 data (i.e., Lake Koocanusa) are evaluated separately from data collected in MU1 through MU5 (in Section 3.2.3). Additional details regarding the sampling locations are provided in Appendix B (Table B-1).

The sediment quality evaluation focuses on sediment samples collected from exposed areas in comparison with SQGs and concentrations measured at reference locations. The intended purpose of settling ponds (mine works areas) is to trap and retain mobile, upland soils or upstream sediments that are directly influenced by mining activity, and therefore it is expected that concentrations in these areas will be elevated. Therefore, sediment data from settling ponds were not compared to SQGs or reference data as part of this evaluation. Summary statistics and plots graphically showing the data for all samples (including the mine works area samples) are provided in Appendix B (Table B-2 and the figures in Appendix B-2).

3.2.1.3 Sediment Quality Guidelines

Guidelines used to evaluate constituent concentrations in sediment are the working BC guidelines, which are based on the federal CCME SQGs (Table 3.2-3). These guidelines are not based on cause-effect studies, but rather on levels of toxic substances found in the sediment where biological effects have been measured (i.e., results may have been influenced by other co-occurring substances). The low SQGs (i.e., interim sediment quality guideline [ISQG] or lowest effect level [LEL]) represent concentrations below which adverse biological effects would not be expected to occur. In contrast, the high SQGs (i.e., probable effect level [PEL] or severe effect level [SEL]) represent concentrations above which effects are expected to be frequently observed.

In addition to the comparison with low and high SQGs, results for samples from exposed areas were compared to the 95th percentile of concentrations measured in reference area samples. Separate reference areas were identified for the Elk River watershed (i.e., MU 1 through MU5) and for Lake Koocanusa (MU6), as indicated in Table 3.2-2. Thus, Table 3.2-3 presents reference area concentrations for comparison to either the Elk River watershed samples or the Lake Koocanusa samples. Data for all reference areas are presented in graphs in Appendix B. For both the watershed and the reservoir, the reference concentration was used in place of the SQG in the sediment quality evaluation when reference concentrations were greater than the low (for various constituents) or high SQG (i.e., for some PAHs).

Constituents for which no guidelines are available were not included in this evaluation. However, data for these constituents (including conventional parameters and extractable petroleum hydrocarbons [EPHs]) are presented in the summary statistics in Appendix B (Table B-2).

3.2.2 Elk River Watershed (MU1 – MU5) Sediment Quality Evaluation

This section presents the evaluation of sediment quality for samples collected in MU1 through MU5 (i.e., samples collected in the Elk River watershed). This includes the identification of COPCs and primary COPCs (Section 3.2.2.1), a comparison of the 2011 and 2013 data (Section 3.2.2.2), and a summary of the toxicity test results (Section 3.2.2.3).

3.2.2.1 Identification of COPCs and Primary COPCs

The process used to compare sediment concentrations to SQGs and reference concentrations to identify COPCs and primary COPCs is shown in Figure 3.2-1, and summarized as follows:

- **Comparison with low SQG / reference** – Detected concentrations were compared with the higher of either the low SQG or the reference concentration (Table 3.2-3). Constituents for which one or more location had a detected concentration greater than the applicable criteria were identified as COPCs.
- **Comparison with high SQG / reference** – Detected concentrations of COPCs were then compared with the higher of either the high SQG or the reference concentration (Table 3.2-3). Constituents for which one or more locations had a detected concentration greater than the applicable criteria were identified as primary COPCs.

The results of this evaluation are presented in Table 3.2-4. Of the 27 constituents for which SQGs were available, a total of 17 constituents were identified as COPCs (8 metals and 9 PAHs). Of these 17 COPCs, 7 were identified as primary COPCs (3 metals and 4 PAHs). Additionally, for both the comparison to low SQGs/reference and the comparison to high SQGs/reference, Tables 3.2-5 and 3.2-6, respectively, present the locations and constituents for which there are exceedances.

Eleven of 16 exposed locations had concentrations of one or more metals that were above the low SQG and reference concentration and 5 of 26 exposed locations had elevated concentrations of at least one PAH (Table 3.2-5). Based on comparison with high SQGs/reference concentrations, 3 of 16 exposed locations had elevated concentrations of one or more metals and 5 of 26 exposed locations had elevated concentrations of one or more PAH (Table 3.2-6). Detailed results of this evaluation by sampling location are presented in Appendix B (Tables B-3 and B-4) for the comparisons with low SQGs/reference and the comparisons with high SQGs/reference.

The primary difference between this evaluation and the analysis conducted by Minnow (2014a) (which focused primarily on samples collected in 2013), was that with the inclusion of the 2011 data, this evaluation found two additional metals (nickel and zinc) for which detected concentrations were greater than the high SQG and reference 95th percentile value, both occurring in samples collected in Swift Creek (SWI1). The combined data sets for 2011 and 2013 indicated very few areas where sediment concentrations were above both reference and high SQGs for one or more constituents and, even at those locations, the elevated concentrations were often observed in only some of the samples collected (Table 3.2-6).

3.2.2.2 Comparison of 2011 and 2013 Data

Five locations were sampled in both 2011 and 2013; three of these were exposed areas (HE27, FO10, and ELKO) and two were reference areas (LML and FO15). Concentrations of select metals and PAHs (the primary COPCs and selenium[11]) detected during these two events were graphed and reviewed to evaluate differences in the results (Figures 3.2-2 and 3.2-3).

For most locations and constituents, the ranges of concentrations overlap between the two sampling events. Median concentrations appear different in some cases, but the small number of samples is not sufficient to draw conclusions based on these values. Additionally, differences between concentrations in these samples may be the results of natural variability, the re-suspension of fine sediments following the June 2013 flood, differences in sampling methods, and/or differences in within-area sampling locations (e.g., near-shore vs. mid-stream) (Minnow 2014a).

The data collected in 2011 and 2013 generally indicated that 1) concentrations of metals are highest in settling ponds or mine-exposed tributaries (rather than in receiving environments), and 2) few metals were detected at concentrations in receiving environment sediments that would indicate potential toxicity to sediment-dwelling organisms (Minnow 2014a).

3.2.2.3 Summary of Toxicity Test Results

Toxicity testing was conducted on a subset of samples collected from the Elk River watershed in 2013 Minnow (2014a). Sediment toxicity testing was conducted by Aquatox Testing and Consulting Inc. (Aquatox), and included the following tests, as described by Minnow (2014a):

- *Hyalella azteca* – 14-day survival and growth tests were conducted using this freshwater amphipod
- *Chironomus riparius* – 10-day survival and growth tests were conducted using this freshwater chironomid

Statistics on survival and growth endpoints measured as part of sediment toxicity testing are presented in Table 3.2-7, using methods described by Minnow (2014a).

The only observed effect was slightly impaired survival of *C. riparius* exposed to sediment collected from Goddard Marsh (GO13; located in MU4). *Chironomus* growth was not impaired after 10-day exposure to sediment from any areas (Table 3.2-7). Reduced *C. riparius* survival was associated with samples collected at GO13 Stations 1, 2 and 5 Minnow (2014a). Of all stations in GO13, concentrations of metals and PAHs tended to be highest at Stations 1 and 2, but were lowest at Station 5. Also, while Station 1 exhibited much lower DO concentrations and higher TOC than other stations, there was very little difference among Stations 2 through 5 for these variables. Thus, the observed reduction in survival cannot be directly linked to measured differences in sediment chemistry or physical habitat attributes.

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[11] Selenium was selected for evaluation along with the primary COPCs because Minnow (2014a) found that selenium is the constituent most closely associated with the Elk River.

In contrast to *C. riparius,* survival and growth of *H. azteca* did not differ between reference and mine-exposed areas or relative to laboratory controls (Table 3.2-7). Overall, the results of the toxicity tests support the conclusions from sediment chemistry data that few (if any) effects on sediment-dwelling organisms would be expected at the four locations evaluated. Based on the limited number of areas evaluated to date, there is not sufficient toxicity information to make generalized conclusions about the potential for sediment effects on biota in other areas of the Elk River watershed.

3.2.3 Lake Koocanusa (MU6) Sediment Quality Evaluation

As described in Section 3.2.1, data collected from Lake Koocanusa (MU6) were evaluated separately from the data collected in the Elk River watershed (MU1 through MU5). PAHs were not analyzed in the Lake Koocanusa samples, and thus PAHs are not discussed in this section. Using the process outlined in Section 3.2.2.1, the Lake Koocanusa data were compared to SQGs and reference concentrations[12] to determine COPCs. Of the 11 metals with SQGs, four (arsenic, cadmium, manganese, and nickel) had detected concentrations greater than the low SQG or reference concentrations (whichever is higher), and were thus identified as COPCs for Lake Koocanusa (Table 3.2-8). Of these four COPCs, none had concentrations greater than the high SQG,[13] so no primary COPCs were identified.

Of the five exposed locations evaluated in Lake Koocanusa (i.e., Transects 3 through 7), four transects had concentrations of one or more COPCs greater than the corresponding criteria (Table 3.2-9). All four COPCs exceeded the applicable criteria in one or more samples at Transect 4. Concentrations in samples collected downstream of Elk River (Transects 3 through 7) were relatively similar to those measured along the reference transect upstream of Elk River (Transect 2). The same four metals were detected at concentrations above the low SQG/reference concentration in Transect 2 as in the exposed areas, and the magnitude of exceedances were similar (ratio of less than 2 in all cases). Detailed results of this evaluation (i.e., the comparison of samples to the low SQGs/reference concentration) by sampling location are presented in Appendix B (Table B-5). Because no samples had concentrations greater than the high SQG, this comparison is not included in Appendix B.

Despite slightly different methods for data analysis as compared to those used by Minnow (2014b), similar conclusions were reached between the two evaluations:

- Four constituents (arsenic, cadmium, manganese, and nickel) were measured in some Lake Koocanusa samples collected downstream of the Elk River at concentrations greater than the low SQG and upstream concentrations. In general, relatively few samples had concentrations that were elevated relative to the applicable criteria, and the magnitude of the exceedances were low.

[12] Although the sample size for the Lake Koocanusa reference dataset was relatively small (n = 12 samples collected along transects located upstream of the Elk River mouth), a review of the reference area data indicates that the 95th percentile still provides a good measure of the upper range of reference concentrations.

[13] No constituents had reference concentrations greater than the high SQG for Lake Koocanusa.

- No constituents had concentrations greater than the high SQG.

3.2.4 Summary

This section summarizes the evaluation of sediment quality for the Elk River watershed and Lake Koocanusa.

3.2.4.1 Elk River Watershed

As presented in Section 3.2.2, a total of 17 constituents were identified as COPCs for the Elk River Watershed, including 8 metals and 9 PAHs. Of these 17 COPCs, 7 had concentrations higher than the high SQG and reference concentration. Thus, these seven constituents (cadmium, nickel, zinc, 2-methylnaphthalene, fluorene, naphthalene, and phenanthrene) were identified as primary COPCs. The locations with concentrations of primary COPCs detected above the high SQG/reference concentrations are as follows (and shown in Table 3.2-6):

- **Metals (3 locations)** – Upper Lake Mountain Creek (LAK2), Swift Creek near mouth (SWI1), and Michel Creek wetland (MI16).
- **PAHs (5 locations)** – Cataract Creek near mouth (CC1), Upper (LAK2) and Lower (LAK1) Lake Mountain Creek, Line Creek downstream of West Line Creek and upstream of South Line Creek (LC3), and Goddard Marsh (GO13).

These results are similar to those presented by Minnow (2014a). Although the existing data are somewhat limited, they suggest that effects on sediment-dwelling organisms are unlikely at most locations in the Elk Valley watershed based on the relatively low proportion of of samples collected within and among most areas having metal and/or PAH concentrations greater than the high SQGs, even in areas close to active mining (Section 3.2.2.1). This could be confirmed by performing toxicity tests on sediments collected from additional depositional areas of the watershed that were not previously tested.

3.2.4.2 Lake Koocanusa

Four metals (arsenic, cadmium, manganese, and nickel) were identified as COPCs for Lake Koocanusa. No primary COPCs were identified because none of the four COPCs had concentrations higher than the high SQG in Lake Koocanusa samples; the high SQG was used for comparison because all reference concentrations were less than the high SQG. Concentrations of arsenic, manganese, and nickel were relatively similar to reference area (i.e., upstream) concentrations, with only a small number of samples for each constituent detected at concentrations above the 95th percentile reference concentration. These results show that sediment concentrations in Lake Koocanusa were generally similar upstream and downstream of the Elk River, indicating that the Elk River has a negligible to minor influence on Lake Koocanusa sediments, consistent with results presented by Minnow (2014b).

3.3 Calcite

Teck initiated a study in 2013 to document calcite deposition in the Elk River watershed using standardized methods (Robinson et al. 2013). The study was designed to be repeated in three successive years to evaluate the magnitude of change over time and identify where calcite mitigation may be required. The monitoring program quantifies calcite deposition based on a Calcite Index as described briefly below and in more detail by Robinson and MacDonald (2014).

Calcite deposition is measured at one to three 100-m-long areas in numerous reaches defined throughout the watershed, depending on the size of the reach. At each area, a modified Wolman (1954) pebble count procedure is applied involving random selection and measurement of 100 substrate particles ≥ 2 mm in diameter (e.g., gravel or larger) throughout the 100-m area (and distributed in proportion to the habitat types present). The size of each particle is measured (along the intermediate axis; i.e., perpendicular to the longest axis) and the presence (score = 1) or absence (score = 0) of calcite is recorded. In addition, the degree of concretion is assessed by determining if the particle is removed with negligible resistance (not concreted; score = 0), noticeable resistance but removable (partially concreted; score = 1) or, immovable (fully concreted; score = 2).

The results for each area are then expressed as a Calcite Index (CI) based on the following equation:

$$CI = CI_p + CI_c$$

Where:

CI = Calcite Index

CI_p = Calcite Presence Score = $\frac{\text{Number of pebbles with calcite}}{\text{Number of pebbles counted}}$

CI_c = Calcite Concretion Score = $\frac{\text{Sum of pebble concretion scores}}{\text{Number of pebbles counted}}$

For reaches in which multiple areas were sampled, an average CI is computed. The Calcite Index is expressed on a scale from 0.0 (no calcite is observed) to 3.0 (streambed is fully concreted); at 1.0 concretion generally starts to become apparent, and at 2.0 there is significant concretion. Figure 3.3-1 presents an example of the level of detail recorded within each of the surveyed streams and reaches (mine-exposed and references). Proportions of the monitored reaches within the Elk/Fording Rivers and their tributaries that fall into various Calcite Index ranges are summarized in Table 3.3-1. As shown in this table, most of the monitored area has a Calcite Index value of less than 0.5 (i.e., minimal calcite is observed). Data for individual stream reaches are presented in Section 4, where they are used as an information input into the health of the aquatic environment within each of the MUs of the Elk River watershed.

3.4 Periphyton

This section summarizes an evaluation of periphyton tissue data presented in a screening-level ecological risk assessment (SLERA) of trace element concentrations in aquatic organism tissues (Windward 2014; Appendix C). In the SLERA, it was assumed that benthic invertebrates and amphibians may be exposed to trace elements in periphyton via their diet (Figures 2.4-1, 2.4-2, and 2.4-3). This section also presents results of periphyton community and productivity studies (Minnow 2014c, d).

3.4.1 Tissue Chemistry

3.4.1.1 Available Data

Periphyton data summarized in this report were obtained from 10 environmental studies conducted between 1996 and 2013 (Table 3.4-1). Data were collected from 89 mining-exposed areas located among the 6 MUs and from 25 reference areas (Table 3.4-2; Map 3.4-1). Limited data were collected in 1996 and 2001 (five mining-exposed areas each of these years), but more extensive data were collected yearly from 1999 through 2013. The most commonly analyzed elements generally were measured in 217 mining-exposed samples and in 70 reference samples, with selenium being measured in 242 mining-exposed and 81 reference samples (Table 3.4-3). Summary statistics by location (i.e., pooled reference and MU) are provided in Attachment B of the SLERA (Appendix C) and data for all analytes are presented graphically, as box plots, in Attachment D of the SLERA.

3.4.1.2 Screening Evaluation

The screening process is provided as a flow diagram in Figure 3.4-1. The screening value (SV) used for evaluation of tissue constituents was either the toxicity reference value (TRV) for a given constituent and receptor organism or the 95th percentile reference area concentration, whichever was greater (i.e., if the 95th percentile reference area concentration was greater than the TRV, the TRV was considered inappropriately conservative for the study area). Periphyton tissue CoIs were identified on an MU-by-MU basis if the Designated Area-wide[14] maximum concentration exceeded the dietary SV for invertebrates and/or amphibians. CoIs within an MU were further evaluated by comparing the 95th percentile tissue concentration or calculated dietary dose to its respective SV. If the ratio of the 95th percentile constituent concentration in periphyton to the corresponding invertebrate or amphibian dietary SV (referred to as a hazard quotient, or HQ) was greater than 1.0, the constituent was identified as a COPC. For each COPC identified, HQs were further calculated using the maximum and mean constituent concentrations at each sampling location within MUs to better understand the spatial patterns of SV exceedances and to assess whether the COPC concentrations in particular tissues appear to be mine-related. The magnitudes of the COPC HQs and evaluation of spatial patterns of COPC concentrations to mining-related activities, along with consideration of the conservatism in the SVs, were used to identify primary COPCs in tissue (see Section 6 in the SLERA [Windward 2014; Appendix C] for details).

Based on the above considerations, only selenium was identified as a primary COPC for tissues in the study area. Accordingly, this section on periphyton, and subsequent sections on the screening evaluations for other tissues (Sections 3.5-3.8), focus just on selenium. The selenium HQs for amphibians feeding on periphyton ranged from 1.1 to 4.3 in MU1 through MU5 based on 95th percentile periphyton selenium concentrations in each MU (Table 3.4-4). For reference, locations of the periphyton tissue sampling areas are provided in Maps 3.4-2 through 3.4-6 for MU1 through MU5, respectively, and sampling areas with HQs >1.0 are highlighted. It should be

[14] All mine-exposed locations within the Designated Area.

emphasized that the dietary selenium TRV for amphibians (the basis for the SV) was a no-observed-effect concentration (NOEC) of 5.0 mg/kg dw for a diet in which coal ash was added to an algae-based food mixture and fed to frog larvae—this NOEC was considered very conservative because the test organisms performed very similar to, or even better than, control organisms depending on the feeding regime. The lowest observed effect concentration (LOEC; the dietary selenium concentration tested to result in significant [$p < 0.05$] effects on amphibians) was 50 mg/kg dw, so the dietary selenium threshold where adverse effects begin to occur is uncertain. If the geometric mean of the NOEC and LOEC was used as the dietary selenium toxicity threshold for amphibians (i.e., 15.8 mg/kg dw), the 95th percentile HQs would be just 1.1 for MU2 and 1.4 for MU3; the HQs for all other MUs would be < 1.0.

The frequency (as number and percent) of TRV exceedances and maximum and mean HQs for each sampling area were compiled by MU (Table 3.4-5). The highest HQs within each MU were mostly associated with off-channel habitats, including FO10 (Fording River oxbow) in MU1 (Map 3.4-2), R5-9 (Fording river lower reach 5 site 9) in MU2 (Map 3.4-3), GO13 (Goddard Marsh) in MU4 (Map 3.4-5), and R1-18 (Elk River reach 1 site 18) in MU5 (Map 3.4-6); the exception was THCK-R1 (Thompson Creek reach 1) in MU3 (Map 3.4-4). If the dietary selenium toxicity threshold of 15.8 mg/kg dw was used, just FO10, R5-9, GO13, and THCK-R1 would have maximum HQs >1.0 (all of the other 86 locations where periphyton has been sampled would have HQs < 1.0).

3.4.2 Community Structure and Health

Analysis of periphyton is routinely requested by BC MOE as part of baseline monitoring preceding anticipated expansions of Teck's operations, as well as for regional and local aquatic effects monitoring stipulated by EMA permits. Provincial technical guidance exists for collection of samples (BC Ministry of Water Land and Air Protection 2003); however, the guidance is not tightly prescribed, and there are information gaps related to methods for collection and analysis of periphyton, the endpoints to be reported, and how such choices may affect study results and conclusions regarding potential mine-related effects (Minnow 2012, 2013). Also, it is uncertain whether mine-related effects at the food web level of periphyton, if occurring, are reflected at higher levels of organization; if not, the question arises as to the ecological relevance of periphyton observations.

To address these information gaps, a supporting study was implemented by Teck in 2013 (Minnow 2014c). Periphyton was collected in riffle areas of fairly uniform, wetted substrate. Each sample was a composite of scrapings from five different rocks. A thin rubber template with a 4-cm^2 opening in the middle was placed firmly on each rock, and the area within the template was scraped clean using a scalpel. Material on the scalpel was then rinsed into a small pre-labelled plastic jar using de-ionized water. The composite samples (from five rocks) were preserved with Lugol's solution immediately after collection.

A key component of the study was an inter-laboratory comparison of taxonomy and enumeration for split samples. Seven of the preserved periphyton community samples were homogenized and divided into quarters, with one quarter of each sample being sent to each of four commercial laboratories specializing in periphyton taxonomy and enumeration. Overall, there was very little consistency in periphyton community composition data reported by the four laboratories for the seven samples. Even after standardizing algal taxonomy among the laboratories, substantial differences in community composition were reported among laboratories for each sample. For example, the same species was rarely identified by all four laboratories in a given sample (i.e., only one to three species per sample were reported by all four laboratories, despite combined species richness ranging from 30 to 68; Table 3.4-6; locations depicted on Map 3.4-7). Also, the proportion of species identified in an individual sample by one laboratory that was also identified by any other laboratory for the same sample never exceeded 58 percent (Table 3.4-6). That means at least 42 percent of all species identified in a given sample were unique to a specific laboratory. Even when the data were collapsed to genus level, there was still very little agreement among laboratories (i.e., two to seven genera identified by all laboratories per sample, despite combined genus richness ranging from 19 to 38; Table 3.4-7).

In addition to the differences in taxon identifications among laboratories, there were substantial differences in organism densities reported among laboratories. For example, the density of *Hydrurus* sp. reported for LIDSL ranged from 0 to 1,500,000 cells/cm^2 among laboratories (Figure 3.4-2). There were even large difference among laboratories for organism abundances reported at a coarse "group" level (i.e., chlorophytes, chrysophytes, cyanophytes, diatoms, and rhodophytes), providing further evidence of poor reproducibility of results (Figure 3.4-3). In other words, absolute or relative taxon densities reported by different laboratories cannot be reliably compared even at relatively coarse levels of taxonomy.

The data indicate two overarching issues that are currently undermining the utility of periphyton community as an aquatic environmental monitoring tool: (1) lack of standardized methods for laboratory sample handling, analysis, and quality assurance / quality control, and (2) no formal program for independent verification of taxonomic identifications (e.g., a program for taxonomist certification and/or laboratory performance testing). With so little agreement of results among the four laboratories tested, it was not possible to infer which of the laboratories, or associated procedures, provided the most accurate results. Clearly, much additional research will be required by regulators and commercial laboratories toward standardization of laboratory methods and certification programs before periphyton community monitoring and assessment can be confidently incorporated into aquatic effects monitoring programs.

3.4.3 Productivity

Periphyton chlorophyll-a data provide an indication of the productivity of chlorophyll-producing algae within the periphyton community. Baseline periphyton chlorophyll-a sampling was initiated in several areas throughout the Elk River watershed (including reference areas) in 2012 and 2013, in support of active water treatment facility installations. In 2012, periphyton chlorophyll-a samples were collected from rock surfaces in a number of lotic areas, some of which contained bryophytes (i.e., Cataract Creek - CACK and West Line Creek - LILC3; Figure 3.4-4; locations depicted on Map 3.4-8). Rock, sediment and log surfaces were also sampled in two lentic areas (Fording River Oxbow [FO10] and the Fording River Wetland [FO15]). In 2013, sampling specifically targeted rock surfaces in lotic areas, and excluded bryophytes because they are not typically considered part of periphyton assemblages. Results indicated higher chlorophyll-a concentrations in some mine-exposed areas compared to reference areas (Figure 3.4-4), suggesting that productivity may be higher as a result of exposure to mine-related nutrient contributions (i.e., nitrogen levels are often elevated downstream of mine operations due to the use of nitrogen-containing explosives). With the exception of samples that included bryophytes, and the sample collected from FO29 (discussed below), all chlorophyll-a concentrations were well below the in-stream guideline of 100 mg/m^2 (MOE 2001).

In some areas (e.g., FO29), greater periphyton thickness appeared to be associated with calcite deposition, possibly because the rough surface characteristics were more suitable for periphyton attachment and colonization than the rock surfaces commonly found throughout the watershed. Chlorophyll-a concentrations also varied among substrate types in lentic areas where replicate samples were collected from rocks, sediment, and logs. In both FO10 and FO15, the highest chlorophyll-a concentrations were associated with periphyton collected from sediments (by an order of magnitude) compared to those collected from rocks or logs. These data illustrate that natural variation in substrate characteristics can greatly affect chlorophyll-a results, and that the ability to detect mine-related influences depends on how well the characteristics of substrates chosen for sampling are standardized.

3.5 Benthic Invertebrates

This section summarizes the evaluation of invertebrate tissue data presented in the recent SLERA by Windward (2014; Appendix C). It was assumed that fish, amphibians, and aquatic-dependent birds may be exposed to trace elements via dietary intake of invertebrates (Figures 2.4-1, 2.4-2, and 2.4-3). In addition, mercury and selenium concentrations in benthic invertebrates were evaluated as indicators of potential toxicity to the benthic invertebrates themselves. This section also presents results of a recent benthic invertebrate community assessment (Minnow 2014d).

3.5.1 Tissue Chemistry

3.5.1.1 Available Data

Invertebrate data summarized in this report were obtained from 13 environmental studies conducted between 1996 and 2013 (Table 3.4-1). Data were collected from 153 mining-exposed areas located within the 6 MUs and from 67 reference areas (Table 3.5-1; Map 3.5-1). Limited data were collected in 1996 (five areas), 2001 (seven areas), and 2003 (one area), and more extensive data were collected yearly from 2009 through 2013. The most commonly analyzed elements were measured in 274 mining-exposed samples and in 131 reference samples (Table 3.5-2). Summary statistics by location (i.e., pooled reference and MU) are provided in Attachment B of the SLERA (Appendix C), and data for all analytes are presented graphically, as box plots, in Attachment D of the SLERA.

3.5.1.2 Screening Evaluation

Benthic invertebrate tissue CoIs were identified on an MU-by-MU basis if the Designated Area-wide maximum concentration exceeded the dietary SV for fish, amphibians, or birds. CoIs within an MU were further evaluated by comparing the 95th percentile tissue concentration or calculated dietary dose to its respective SV. Benthic invertebrate COPCs were identified on an MU-by-MU basis if the 95th percentile of concentrations measured from the MU exceeded the SV (i.e., HQ >1.0). Cadmium, chromium, copper, mercury, selenium, and zinc were identified as COPCs for invertebrate tissue based on ingestion by fish, amphibians, and/or birds. Selenium was also identified as a COPC for benthic invertebrates based on direct toxicity to the invertebrates themselves. However, as discussed in Section 3.4.1, only selenium was identified as a primary COPC and it, therefore, is the focus of this section (see Section 6 in the SLERA [Windward 2014; Appendix C] for details).

The HQs, based on the 95th percentile of selenium concentrations measured among invertebrate samples collected in each MU are provided in Table 3.5-3. The highest HQs were observed for MU3, which were 2.2 for direct toxicity to invertebrates, 2.6 for fish diets, 3.5 for amphibian diets, and 1.9 and for aquatic-dependent bird diets. The frequency (as number and percent) of TRV exceedances and maximum and mean HQs for each individual sampling area were compiled by MU (Table 3.5-4). For reference, locations of the invertebrate tissue sampling areas are provided in Maps 3.5-2 through 3.5-7 for MU1 through MU6, respectively, and sampling areas with HQs >1.0 are highlighted. For simplicity, Table 3.5-4 and the highlighted HQs in the maps are based on dietary exposures of fish, because fish, along with birds, are the most sensitive taxa to selenium and the dietary selenium TRV for fish is the least uncertain. The highest HQs within each MU were almost exclusively associated with off-channel habitats, including sampling area FO10 (Fording River oxbow) in MU1 (Map 3.5-2), LCCPL (Line Creek Lower Contingency Ponds [mine works]) in MU2 (Map 3.5-3), GO13 (Goddard Marsh) in MU4 (Map 3.5-5), and ELKO (Elko Reservoir) in MU5 (Map 3.5-6). The one exception was Thompson Creek (THCK) in MU3, which was a lotic sampling area that had the highest HQs in this MU (Map 3.5-4).

3.5.2 Community Structure and Health

3.5.2.1 Overview and Methods

A detailed assessment of benthic invertebrate community health in mine-exposed areas relative to reference areas was completed as part of the regional biological monitoring program in 2012 (Minnow 2014d). Community samples were collected in September 2012 from 36 reference and 56 mine-exposed lotic areas for assessment of potential mine-related effects on community composition (Maps 3.5-8 to 3.5-11). Reference areas were selected to represent a range of natural habitat characteristics exhibited by mine-exposed areas, such as elevation, stream size, catchment area, and catchment gradient, to ensure that each mine-exposed area could be matched with, and statistically compared to, a sub-set of reference areas with similar natural habitat characteristics. The reference areas were situated in the Elk River watershed upstream of mining inputs, and also in the upper Kootenay River watershed (B.C.) and in the Oldman River watershed (Alberta), where man-made disturbances were negligible.[15]

Benthic invertebrate sampling in the Elk Valley followed the protocol of the Canadian Biomonitoring Network (CABIN; Environment Canada 2010), which involves a 3-minute travelling kick into a net with a triangular aperture. The samples were sent to Cordillera in

[15] Detailed analyses of reference area data, completed in consultation with technical experts from BC MOE, identified that benthic invertebrate community characteristics were most strongly influenced by natural habitat characteristics and were not measurably influenced by the small amount of historical forestry activity in some reference watersheds (Minnow 2014a).

Summerland, BC, for sorting and taxonomic identification. Two different methods were used to match exposed areas to the appropriate sub-group of reference areas based on habitat similarities: Benthic Assessment of Sediment (BEAST) (Reynoldson et al. 1997) and Assessment by Nearest Neighbour Analysis (ANNA) (Linke et al. 2005). Community endpoints assessed included family richness (i.e., number of families per sample), percent EPT (Ephemeroptera, Plecoptera, and Trichoptera), percent Ephemeroptera, percent Chironomidae, and the scores on the first two axes from non-metric multidimensional scaling (NMDS) ordination. The community in each mine-exposed area was compared to the appropriate group of reference communities using 1) one-sample, non-central, equivalence test, and 2) one-sample, non-central, interval test (Kilgour et al. 1998). This resulted in three possible outcomes: a $p<0.1$ (Interval test) indicated a community endpoint that was outside of the reference condition, a $p>0.9$ (Equivalence test) indicated a community endpoint that was within the reference condition; and a p value between 0.1 and 0.9 was inconclusive with respect to potential difference from the reference condition.

3.5.2.2 Results

Adverse effects (community endpoint that was significantly different from reference conditions) for benthic invertebrate communities were observed for 20 mine-exposed areas, most of which were in mine-influenced tributaries near mine sources (Table 3.5-5). These effects were generally reflected as reductions in the combined proportion of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (i.e., EPT), or the proportion of Ephemeroptera alone; these groups (particularly mayflies and stoneflies) dominated the invertebrate communities in reference areas as well as mine-exposed areas that were considered to be in reference condition. Eighty-six percent of the main stem receiving environments sampled, including all areas sampled along the Elk River, had communities consistent with reference areas. Correlation analysis identified a relationship between the concentrations of mine-related contaminants in water (as summarized by Principal Components Analysis) and various measures of benthic invertebrate community health, suggesting that coal-mining activities contributed to effects on benthic invertebrate communities at locations where effects were observed.

In MU1, adverse effects were observed among five of six discharge tributaries sampled, whereas 2 of 14 areas along the mainstem receiver (upper Fording River) were adversely affected and two others were potentially (inconclusively) affected (Table 3.5-5). The two affected mainstem areas included FOBSC, located downstream of the adversely affected discharge tributary Swift Creek (SWCK), and FO29, downstream of Dry Creek, where calcite deposition was evident at the time of the survey in 2012. Ten of 14 areas sampled in MU1 had communities that were within reference conditions.

In MU2, areas on Line Creek just downstream of LCO were considered adversely affected (LILC3 and LIDSL), but improvement was noted farther downstream at LI8. Potential adverse effects observed on the Fording River upstream of Line Creek (FOUL) contradicted the observations of non-affected communities located farther upstream (FO9) and also downstream (FO23), and occurred where there was no evidence of calcite deposition.

Within MU3 and MU4, no adverse effects were evident at any areas sampled along the Elk River, although effects were evident among communities sampled in some of the mine-influenced tributaries discharging to the Elk River (e.g., WOCK, THCK, HACKDS, GRDS, and OCNM). Adverse effects were also evident on Michel Creek (MIDCO) immediately downstream of Corbin Creek

(COCK, which was also adversely affected) and near the mouth (at MI2, downstream of affected discharge tributaries ERCK and BOCK).

Organisms were typically reasonably abundant, even among adversely affected benthic invertebrate communities (e.g., minimum of 1,003 organisms at Kilmarnock Creek [KICK], which had lowest abundance of all mine-exposed areas, compared to the reference range of 260-22,500 organisms) and represented at least nine families per area (compared to 13-25 families among reference areas). All communities sampled along the Elk River were within reference conditions.

3.6 Fish

This section summarizes the evaluation of fish tissue data described in the dietary- and tissue-based SLERA (Windward 2014; Appendix C). It was assumed that fish, aquatic-dependent birds, and aquatic-dependent mammals may be exposed to trace elements in whole-body fish tissue or muscle tissue via their diet (Figures 2.4-1, 2.4-2, and 2.4-3). In addition, mercury and selenium concentrations in fish tissue were evaluated as indicators of potential direct toxicity to the fish themselves. This section also presents information related to fish community structure and fish health.

3.6.1 Tissue Chemistry

3.6.1.1 Available Tissue Data

Fish tissue data summarized in this report were obtained from 19 environmental studies conducted between 1996 and 2012 (Table 3.4-1). Data were collected from 48 mining-exposed areas located within the 6 MUs and from 31 reference areas (Table 3.6-1; Maps 3.6-1 and 3.6-8 for fish eggs/ovaries and fish whole body/muscle, respectively). Eleven species have been collected almost annually since 1996, including bull trout, brook trout, kokanee, longnose dace, longnose sucker, largescale sucker, mountain whitefish, northern pikeminnow, peamouth chub, rainbow trout, and westslope cutthroat trout. Various fish tissue types have been analyzed among sampling events (whole body, muscle, eggs/ovaries), depending on time of year samples were collected (eggs/ovaries being available only among mature, pre-spawning or spawning females) and restrictions imposed by scientific collector's permits issued by the province. Selenium was the most frequently analyzed constituent in fish tissue, with a total of 1014 whole body/muscle samples and 372 egg/ovary samples collected from mining-exposed areas (Table 3.6-2). A total of 591 whole body/muscle samples and 138 egg/ovary samples were collected from reference areas for selenium analysis. Summary statistics by location (i.e., pooled reference areas and for individual MU) are provided in Attachment B of the SLERA (Appendix C) and data for all analytes are presented graphically, as box plots, in Attachment D of the SLERA.

3.6.1.2 Tissue Screening Evaluation

Fish tissue COPCs were identified on an MU-by-MU basis if the 95th percentile of concentrations measured among samples within the MU exceeded the tissue-based SV for fish (eggs/ovaries) or dietary SVs for fish, birds, and/or mammals (i.e., HQ >1.0). For each constituent evaluated in the SLERA, the SV was selected as the dietary or tissue-based TRV for fish, aquatic-dependent birds or mammals, or the 95th percentile reference area concentration, whichever value was greater. The screening process is provided as a flow diagram in Figure 3.4-1. Chromium, mercury, and selenium were identified as COPCs based on ingestion of fish tissue by fish, amphibians, and/or birds. Selenium was also identified as a COPC for fish eggs/ovaries based on direct toxicity to fish offspring via maternal transfer. However, as discussed in Section 3.4.1, only selenium was identified as a primary COPC for tissues in the study area and it, therefore, is the focus of this section (see Section 6 in the SLERA [Windward 2014; Appendix C] for details). The HQs, based on the 95th percentile selenium concentrations in fish by MU, are provided in Table 3.6-3. The highest HQs for an individual MU were 4.5 based on selenium concentrations in fish eggs/ovaries (direct toxicity), 4.2 for fish diets, and 3.1 for aquatic-dependent bird diets.

The frequency (as number and percent of samples) of TRV exceedances and maximum and mean HQs for each sampling area were also evaluated by location within each MU (Table 3.6-4 for eggs/ovaries and Table 3.6-5 for whole body/muscle). The locations of the fish egg/ovary sampling areas are depicted in Maps 3.6-2 through 3.6-7 for MU1 through MU6, respectively, and the locations of the fish whole body/muscle sampling areas are provided in Maps 3.6-9 through 3.6-14. Those sampling locations with HQs >1.0 are highlighted within the maps.

Based on individual fish egg/ovary samples, the highest HQs at each MU were 3.4, 1.5, 0.9, 4.3, and 2.1 for MU1, MU2, MU3, MU4, and MU5, respectively. The highest HQs within each MU were for westslope cutthroat trout collected from FO10 (Fording River oxbow) and MP1 (Fording River at Multiplate) in MU1 (Map 3.6-2), mountain whitefish collected from FO23 (Fording River d/s Line Creek) in MU2 (although the mean HQ was 1.0; Map 3.6-3), longnose sucker collected from EROU (Elk River upper oxbow) in MU3 (although the mean HQ was <1.0; Map 3.6-4), longnose sucker collected from GO13 (Goddard Marsh) in MU4 (Map 3.6-5), and mountain whitefish collected from EL1 (Elk River d/s of Michel Creek) in MU5 (Map 3.6-6). No fish egg/ovary selenium HQs were >1.0 in MU6 sampling locations. Based on individual fish whole body/muscle samples and assuming a piscivorous fish diet[16], the highest HQs for MU1, MU2, MU3, MU4, and MU5 were 5.1 (FO10; Fording River oxbow), 1.8 (FO23; Fording River d/s of Line Creek), 1.3 (EROU; Elk River upper oxbow), 9.5 (CA1; Carbon Creek), and 2.7 (MC1; Mine Creek) (Maps 3.6-9 through 3.6-14).

Selenium concentrations in fish eggs/ovaries are generally considered the strongest line of evidence in evaluating whether adverse effects may be expected, and egg/ovary selenium toxicity thresholds for fish typically do not vary by more than a factor of 2 (Janz et al. 2010). Accordingly, for those sampling areas with egg/ovary selenium HQs consistently >2 in multiple samples (e.g., FO10, Table 3.6-4), the possibility of adverse effects is more likely. For those areas with just a fraction of HQs slightly exceeding 1.0 (e.g., FO23, Table 3.6-4), the possibility of adverse effects is less likely given the conservative egg/ovary selenium TRV that was used in this evaluation. In fact, for those locations where selenium concentrations were measured in both fish eggs/ovaries and potential prey items (invertebrates, other fish, amphibian egg masses), when the maximum egg/ovary selenium HQ was >1.0, the dietary selenium HQs were also >1.0.

[16] A conservative assumption as westslope cutthroat trout, mountain whitefish, and longnose suckers are largely benthivorous (i.e., they feed on benthic invertebrates) during the period of ovarion development; bull trout are at least partially piscivorous (Minnow et al. 2011).

This indicates that selenium HQs in potential fish prey items may be a good indicator of locations where egg/ovary selenium concentrations could result in HQs >1.0. The data for these locations (i.e., where dietary selenium HQs for fish are >1.0, but where fish eggs/ovaries have not been sampled) could help in targeting future sampling areas for fish eggs/ovaries.

It should also be emphasized that the egg/ovary selenium concentrations, and associated HQs, are not always indicative of selenium exposures at the location where the fish were captured. For example, selenium concentrations in mountain whitefish eggs/ovaries were elevated relative to other fish species captured at both mine-exposed and reference areas, and there was no relationship with gradients of selenium exposure concentrations. As such, mountain whitefish egg/ovary selenium concentrations were considered a weak line of evidence in evaluating overall environmental quality for specific areas within each MU. Interpretation of the fish egg/ovary selenium data relative to other lines of evidence is provided in Section 4.

3.6.2 Community Structure and Health

Westslope cutthroat trout are commonly found in lotic and lentic habitats throughout the Elk River watershed, and this is the only fish species present in the Fording River upstream of Josephine Falls. In addition to cutthroat trout, bull trout and mountain whitefish are native to the Elk River watershed, although they are usually found only in the main stem and in lower reaches of larger tributaries such as the Fording River, Line Creek, Alexander Creek, and Michel Creek (Wilkinson 2009; Robinson 2011). Rainbow trout is a non-native species that generally resides in lakes but spawns in adjacent streams; it was introduced to the Elk River basin through stocking programs at Grave Lake and Summit Lake, and possibly at other locations (Wilkinson 2009). Eastern brook trout is another non-native species; it occurs mostly in the Michel Creek basin, although isolated populations also occur in beaver ponds along the Elk River up to Forsyth Creek (Wilkinson 2009; Robinson 2011). There are also patchy distributions of several other species, such as longnose sucker and longnose dace, which mainly occupy slow-flowing side channels, oxbows, ponds, and lakes at lower elevations along or near the Elk River downstream of Elkford (Robinson 2011; LePage 2013).

Based on this knowledge, cutthroat trout has been identified as a representative species for monitoring mine-related effects on fish in lotic areas of the Elk River watershed. Longnose sucker was identified as a suitable species for monitoring mine-related influences in lentic habitats. In addition to understanding population dynamics, identifying and tracking the health of fish (e.g., growth, condition, and abnormalities) is important for assessing fish population status. Fish population monitoring requires multiple years of study to understand and quantify basic population characteristics and begin to comprehend potential changes over time and relationships to stressors (e.g., mining, angling, extreme weather events). Cutthroat trout and longnose sucker studies were initiated in 2012 and 2013 to collect baseline data to inform the development of future monitoring (e.g., RAEMP) and assess appropriate monitoring endpoints, and to determine what the most effective monitoring methods are to evaluate mine-related influences on population characteristics and fish health.

3.6.2.1 Westslope Cutthroat Trout

A multi-year study (2012-2015, inclusive) of cutthroat trout in the upper Fording River watershed is underway to assess population status, seasonal movements, and habitat use, which will inform mine mitigation and fish habitat management decisions (Cope et al. 2014). Unlike the lower Fording River and the remainder of the Elk River watershed, westslope cutthroat trout in the upper Fording River are isolated from confounding factors (e.g., angling, competition from other fish species, hybridization, and potential effects related to agricultural development) that could affect population stability and fish health. Literature on Population Viability Analyses (PVA) and Recovery Potential Assessments for westslope cutthroat trout has shown that a viable population can range between 470 and 4,600 adults (Cope et al. 2014), depending on the methodology used. Also, between 9 and 28 km of stream is required to maintain an isolated population. To date, monitoring of fry, juveniles, sub-adults, and adults indicates that the westslope cutthroat trout population of the upper Fording River is stable at about 3,000 adults having access to 57.6 km of habitat. Based on Fulton's condition indices, Upper Fording River WCT also appear to be robust and exhibit low rates of deformities.

Evaluation of critical habitats for westslope cutthroat trout in the upper Fording River watershed is in the preliminary stages of investigation. Habitat evaluation and population monitoring are expected to continue over the next few years to provide additional data that will be used to inform the RAEMP. Details related to the MFLNRO westslope cutthroat trout study in the lower Fording and Elk Rivers were not available for inclusion in this report, but will also be considered in the design of future monitoring programs, as appropriate.

Primary goals of the 2013 assessment of juveniles were to identify potentially suitable locations for future monitoring (mine-exposed and reference) and appropriate endpoints for assessing fish health (e.g., body condition, growth and external characteristics) and demographics (e.g., densities and abundance of various age classes) (Robinson 2014). Juveniles were selected for monitoring because they are generally more abundant and less migratory than adults, and they provide an indication of the reproductive success of spawning adults. Preliminary results indicated that juvenile densities, while typically very low, were comparable among mine-exposed (i.e., lower Elk and upper Fording) and reference areas (i.e., Elk and Oldman River). In addition, no differences in body condition were noted among areas, and no abnormalities were found.

Based on the data collected to date, it is anticipated that future westslope cutthroat trout monitoring will focus on assessment of population size and demographics in the upper Fording River (MU1), where mine-related constituents in water are currently highest, and potential mine-related effects could be more readily determined without the confounding influences of angling and competition from other fish species.

3.6.2.2 Longnose Sucker

In 2013, a study of longnose sucker presence/absence, abundance (density), and health was initiated at a variety of lentic areas to inform the design of the RAEMP. No differences in biomass, growth rates or body condition were found among the areas studied (Robinson and Arnett 2014). Of the 13 areas surveyed, eight were recommended for future monitoring based on high densities of longnose sucker and the ability to isolate, and thus quantitatively monitor, populations for density determination (Minnow 2014e).

The longnose sucker will be used as a sentinel species in monitoring potential mine-related effects in lentic areas, where they occur. The longnose sucker monitoring program will include assessment of fish health endpoints in a variety of off-channel habitats containing populations of sufficient size that they can be reliably quantified and tracked over time (Minnow 2014e).

3.7 Amphibians

This section summarizes the evaluation of metal/metalloid concentrations in amphibian egg masses presented in the dietary- and tissue-based SLERA (Windward 2014; Appendix C). It was assumed that fish and aquatic-dependent birds and mammals may be exposed to trace elements in amphibian egg masses via their diet (Figures 2.4-1, 2.4-2, and 2.4-3).

3.7.1 Available Tissue Data

Amphibian egg mass data summarized in this report were obtained from five environmental studies conducted between 2005 and 2012 (Table 3.4-1); they were collected from 12 mining-exposed areas and 8 reference areas (Table 3.7-1; Map 3.7-1). Samples were collected at the mining-exposed areas from 2006 through 2012. Most elements were analyzed in 46 samples collected from mining-exposed areas and 28 samples collected from reference areas, while selenium was analyzed in 56 exposed area and 40 reference area samples (Table 3.7-2). Summary statistics by area are provided in Attachment B of the SLERA (Appendix C) and data for all analytes are presented graphically, as box plots, in Attachment D of the SLERA.

3.7.2 Tissue Screening Evaluation

Amphibian egg mass COPCs were identified on an MU-by-MU basis if the 95th percentile concentrations from the MU exceeded the dietary SVs for fish, birds, and/or mammals (i.e., HQ >1.0). For each constituent evaluated in amphibian egg mass tissue, the SV was selected as the dietary or tissue-based TRV for fish and aquatic-dependent birds or mammals, or the 95th percentile reference area concentration, whichever value was greater. The screening process is provided as a flow diagram in Figure 3.4-1. Chromium, selenium, and vanadium were identified as COPCs for fish and/or birds feeding on amphibian egg masses. However, as discussed in Section 3.4.1, only selenium was identified as a primary COPC for tissues in the study area and it, therefore, is the focus of this section (see Section 6 in the SLERA [Windward 2014; Appendix C] for details).

The selenium HQs, based on the 95th percentile selenium concentrations in amphibian egg masses, are provided in Table 3.7-3. The highest HQ for an MU was 1.5 (MU5) for fish diet. To better understand the spatial extent of TRV exceedances within an MU, the frequency (as number and percent) of TRV exceedances and maximum and mean HQs for each sampling area were compiled by MU (Table 3.7-4). For reference, the locations of the amphibian egg mass sampling areas are provided in Maps 3.7-2 through 3.7-7 for MU1 through MU6, where sampling areas with HQs >1.0 are highlighted. Based on individual amphibian egg mass samples, the highest HQs at MU1, MU2, MU4, and MU5 were 1.6 (SWWL; Swift Wetland), 0.9 (FO15; Fording River wetlands), 3.5 (GO13; Goddard Marsh), and 1.6 (ELKO; Elko Reservoir). No HQs exceeded 1.0 in MU6. Overall, there is considerable conservatism in these HQs (i.e., risk is over-estimated) because it is assumed that fish may feed exclusively on amphibian egg masses over a chronic duration. This line of evidence is weighed with additional lines of evidence, such as selenium concentrations in macroinvertebrate-based diets and fish tissue selenium concentrations, in determining the overall environmental quality of specific sampling areas in Section 4.

3.8 Birds

This section summarizes an evaluation of bird egg data following a step-wise screening process based on the assessment of trace element concentrations in aquatic organism tissues, as described in the dietary- and tissue-based SLERA (Windward 2014; Appendix C). Selenium concentrations in bird egg tissue were evaluated as indicators of potential direct toxicity to bird reproduction (i.e., embryo mortality).

3.8.1 Available Tissue Data

Bird egg data summarized in this report were obtained from seven environmental studies conducted between 2002 and 2013 (Table 3.4-1). Data collected from 36 mining-exposed areas located within the 6 MUs and from 9 reference areas (Table 3.8-1; Map 3.8-1). Eggs were sampled from a total of 6 species, including American dipper, common merganser, killdeer, mallard, red-winged blackbird, and spotted sandpiper. Selenium was analyzed in 273 exposed area samples and 38 reference area samples, while the remaining most commonly analyzed elements were measured in 229 exposed area samples and in 30 reference area samples (Table 3.8-2). However, selenium was the only bird egg constituent evaluated in the SLERA, as bird egg selenium concentrations are considered the most reliable indicator of potential adverse effects (Janz et al. 2010; Ohlendorf and Heinz 2011). Summary statistics by area are provided in Attachment B of the SLERA (Appendix C) and data for all analytes are presented graphically, as box plots, in Attachment D of the SLERA.

3.8.2 Tissue Screening Evaluation

Selenium was identified as a bird egg COPC on an MU-by-MU basis if the 95th percentile concentrations from the MU exceeded the SV for bird eggs (i.e., HQ >1.0). Selenium was identified as a COPC at MU1 (HQ = 1.9), MU2 (HQ = 1.7), MU3 (HQ = 2.9), and MU4 (HQ = 1.5) (Table 3.8-3). To better understand the spatial extent of bird egg selenium TRV exceedances within an MU, the frequency (as number and percent of samples) of TRV exceedances and maximum and mean HQs for each sampling area were compiled (Table 3.8-4). For reference, the locations of the bird egg sampling areas for MU1 through MU6 are provided in Maps 3.8-2 through 3.8-7, where sampling areas with HQs >1.0 are highlighted. Based on individual bird egg samples, the highest HQs at MU1, MU2, MU3, MU4, and MU5 were 2.2 (FO10; Fording River oxbow), 2.7 (LCCPL; Line Creek Lower Containment Ponds), 3.4 (THPD; Thompson Settling Pond), 1.7 (GO13; Goddard Marsh), and 1.0 (ELKO U/S; Elk River u/s Morrissey Creek), respectively. This line of evidence is weighed with additional lines of evidence, such as selenium concentrations in macroinvertebrates, in determining the overall environmental quality of specific sampling areas in Section 4.

4 Evaluation of Environmental Quality

This section summarizes the current understanding of environmental quality within each of the management units (MUs), considering both the chemical and the physical pathways of mine-related influences on the downstream aquatic environment. These pathways are illustrated in the conceptual model for cumulative effects (Figure 4.1-1) and described in more detail in Figures 2.4-1, 2.4-2, 2.4-3, and 2.5-1. Figure 4.1-1 integrates components of the chemical and physical stressor models to describe relations among chemical and physical processes that may be affected by Teck or other sources (such as forestry, agricultural, municipal, and mining); such processes can cause chemical or physical changes to media (including water, sediment or tissue and aquatic habitat) and may affect aquatic food web receptors. These pathways and receptors must be considered when designing routine monitoring programs and supporting studies.

Generally, routine monitoring data are expected to identify the areas within the watershed where biological effects are occurring (if any), but the data may not specifically identify the chemical or physical stressor responsible for the effects. Indeed, it may not always be necessary to precisely identify the stressor(s); for example, confirmation of the source or general category of stressor(s) is sometimes sufficient basis for developing and implementing a remediation plan. In other cases, however, it may be necessary to better understand the mechanisms of effects, and supporting studies may be necessary to distinguish the specific cause(s).

The following sections summarize and discuss the existing monitoring data for different media and receptors in the designated area, supported by material in Appendices C, D, and E. These are the same data presented and discussed in Section 3 except that the data are grouped across sample types within each sampling area in each MU. This was done to identify the areas most influenced by mining, based on direct assessment of effects to biota (e.g., effects on benthic invertebrate communities) and indirect lines of evidence for potential effects (e.g., water, sediment, calcite, tissue selenium concentrations). This information can be used to highlight areas of the watershed that may require further investigation and provides a baseline against which future conditions can be compared.

4.1 Approach

As described in more detail in Appendix E, the various types of data previously collected throughout the Designated Area were summarized for individual monitoring areas within each MU. Lines of evidence considered were water quality, substrate quality (including sediment chemistry and degree of calcite deposition), benthic invertebrate community structure, and tissue selenium concentrations indicative of risks to benthic invertebrates or their consumers. Data for each sample type (except calcite) and location were ranked as indicative of "good," “fair,” “marginal”[17], or “poor” environmental quality, as explained in Appendix E and summarized in Table 4.1-1.

There were numerous examples among all of the MUs of vertebrate tissue selenium concentrations that were inconsistent with other lines of evidence for the same areas. For example, at 7 of 26 locations among all MUs for which invertebrate community and tissue selenium data as well as vertebrate tissue selenium data were available, hazard quotients (HQs)[18] for selenium measured in vertebrate tissues were categorized as fair or poor (including two reference areas), even though invertebrate community health and invertebrate tissue selenium concentrations (in terms of both direct effects to invertebrates and dietary effects to vertebrate consumers) were categorized as good. These observations were taken as evidence that vertebrate tissue concentrations are not always reliable indicators of conditions in the specific areas where the biota are sampled, due to their ability to freely move (and feed) among reference and mine-exposed areas. In some cases, such as spotted sandpipers nesting between settling ponds and receiving environments, egg selenium concentrations were intermediate between those of invertebrates in each habitat type; this suggested that the birds fed in both areas, even though the settling pond may have been identified as the sampling location (i.e., the data do not strictly reflect conditions in the settling pond). Therefore, vertebrate tissue selenium concentrations were not included as a line of evidence for evaluating conditions at specific locations within each MU and instead are discussed separately for each MU.

Based on the wide variability in habitat characteristics among off-channel areas (i.e., ranging from lotic to lentic conditions), and thus the inability to adequately control for habitat variability in statistical comparisons of reference and mine-exposed areas, benthic invertebrate community structure has not been evaluated in off-channel habitats. Also, water quality is not routinely monitored in most of these areas (except at mine settling ponds). As noted in Section 2.3, off-channel habitats represent a small proportion of the total aquatic habitat downstream of Teck’s mines (Interior Reforestation 2008), and areas with highly lentic characteristics are uncommon. Generally, it would be expected that mine-related effects on biota in off-channel habitats would be comparable to or less than those associated with nearby lotic areas (based on comparable or lower water concentrations of mine-related variables; Golder 2014b), with the exception that some such areas have potential for higher food web selenium accumulation than may be occurring in nearby lotic habitats (Orr et al. 2012; Golder 2014a,b; Minnow 2014). Therefore, data for off-channel habitats in each MU are discussed separately from data pertaining to lotic habitats. Some off-channel areas are also conducive to settling and accumulation of fine particles, so sediment quality data are presented, where available.

[17] This category was used for water and sediment quality indices only, to be consistent with categories defined by CCME (2001a,b; 2007).

[18] Hazard quotient is a ratio of the measured tissue concentration to the toxicity reference value, with values above 1.0 being indicative of potential effects.

4.2 Management Unit 1

MU1 includes the upper Fording River extending as far downstream as Josephine Falls. This MU includes a variety of tributaries that are currently influenced by mine operations at FRO and GHO. Aquatic environmental data have been collected in numerous lotic tributary and mainstem areas, as well as a variety of off-channel areas of MU1. The associated data are presented in Appendix E (Tables E.4a and E.4b) and discussed below.

4.2.1 Localized Conditions in Lotic Areas

Benthic invertebrate community data, plus at least one indirect line of evidence for evaluating potential effects (water, sediment, calcite, and/or tissue data) were available for a total of 5 reference areas, 14 mainstem receiving areas, and 7[19] tributaries in MU1 (Appendix Table E.4a). These areas were well-distributed throughout MU1 (Map 4.2-1).

Reference areas evaluated within MU1 had good water quality, lack of visible calcite deposits, good benthic community health, and invertebrate tissue selenium concentrations less than those expected to affect the invertebrates themselves or their consumers (Appendix Table E.4a).

Of all 14 lotic mine-exposed areas of the Fording River in MU1 with multiple lines of evidence, 11 had benthic invertebrate communities that were similar to reference area communities and thus ranked as good (Appendix Table E.4a). Water quality at the same locations ranged from marginal to good (water quality index [WQI] of 49 to 100). Swift water flows in lotic habitats of the watershed preclude accumulation of fine sediments, so sediment quality has been reported for only a single lotic (reference) area within MU1 (i.e., good sediment quality at Dry Creek). There was little or no evidence of calcite deposition (calcite index [CI] of 0.0 to 0.7) at mining-exposed areas of the Fording River, and invertebrate tissue selenium concentrations were below those associated with direct effects on the invertebrates themselves or dietary effects to invertebrate-eating fish or birds. The only exception was one marginally elevated HQ (1.1) for dietary selenium exposure to fish based on the maximum invertebrate tissue concentration for areas of the Fording River downstream of Porter Creek and upstream of Chauncey Creek (i.e., sampling areas FODPO and FO22).

The benthic invertebrate community in the Fording River near the Multiplate crossing (MP1) was ranked as fair based on slightly reduced EPT proportion; however, most of the EPT group was represented by Ephemeroptera (i.e., the latter being an indication of good quality). Water quality at this location was also considered good and there was no visible calcite deposition. Invertebrate selenium concentrations were also below those expected to have effects on invertebrates or their consumers. Future sampling should confirm if there are slight mine-related effects at MP1 or if the slight reduction in EPT proportion observed in 2012 was an anomaly.

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[19] In the context of this section Greenhills Creek was considered one discharge tributary, although two areas were evaluated, located upstream and downstream of the GHO settling pond.

The Fording River between Swift and Cataract creeks (FOBSC) was also concluded to have a fair benthic invertebrate community (Appendix Table E.4a). Water quality was considered marginal based on frequently elevated nitrate and selenium concentrations. However, there was no evidence of calcite deposition and selenium concentrations in invertebrates were below those associated with risks to the invertebrates themselves or to the vertebrates that feed on them.

The third area on the Fording River having a fair invertebrate community was located downstream of Dry Creek and upstream of GHO (at FO29). Water quality was ranked at the upper end of the fair range (WQI=78), well above the WQI values of some other areas in the Fording River where invertebrate communities were unaffected (e.g., WQI as low as 49 were associated with benthic invertebrate communities that were similar to reference communities). Also, invertebrate selenium concentrations at FO29 were good (i.e., HQs less than 1.0), similar to the other areas along the Fording River. Therefore, the observed effect on the benthic invertebrate community may have been attributable to a calcite deposit observed at FO29 during the 2012 benthic invertebrate community assessment, even though no calcite was observed in this area in 2013. These results suggest there may be year-to-year differences in the degree of calcite deposition at some locations. Inter-annual variability in calcite deposition is being evaluated over three consecutive years of monitoring (2013-15) in the calcite study (Robinson and MacDonald 2014). In 2014 and 2015, benthic invertebrate communities are being sampled at a sub-set of areas representing a range of calcite deposition to determine the level of calcite that is associated with benthic invertebrate community effects (Minnow 2014b). The results will facilitate better understanding of the relationship between calcite levels and benthic invertebrate community health.

Data for multiple lines of evidence were also available for seven mine-influenced tributaries within MU1. Most lines of evidence for two of the tributaries (Henretta Creek and lower Lake Mountain Creek; Map 4.2-1) reflected good quality. The other five tributaries (Kilmarnock, Swift, Cataract, Porter, and Greenhills[19] creeks) all had benthic invertebrate communities ranked as poor, and at least one additional line of evidence (water quality and/or tissue selenium concentrations) that was also ranked as poor. All five tributaries with poor environmental quality have been characterized as having elevated aqueous selenium, nitrate, and/or sulphate concentrations and four of these locations (Kilmarnock, Swift, Cataract, Porter, and Greenhills creeks) account for most of the mine-related loads of these constituents to receiving waters in MU1 (Figures 3.1-3 to 3.1-5).

The data discussed above demonstrate that conditions have been assessed in the tributaries contributing most loads of mine-related constituents to MU1, and throughout the upper Fording River upstream and downstream of each of the major source tributaries.

4.2.2 Localized Conditions in Off-Channel Areas

Variable amounts and types of information were available for 31 off-channel habitats located within MU1 (Appendix Table E.4b; Map 4.2-2). Four of the areas for which data were available were mine works (i.e., settling ponds such as Clode, Swift, Kilmarnock and Greenhills ponds), which are generally the only off-channel locations where water quality is routinely monitored[20]. At those four locations, water quality was marginal to poor, as it was for some of the mine-influenced tributaries listed at the bottom of Table E.4a where biota were sampled immediately downstream of mine settling ponds (and the associated water monitoring stations). Sediment quality was good in 4 of 6 off-channel areas where it was evaluated, including two mine settling ponds. Sediment quality was poor at one of the mine settling ponds and was marginal at reference area Lake Mountain Lake, which has naturally elevated sediment concentrations of polycyclic aromatic hydrocarbons (PAHs).

Excluding mine settling ponds, invertebrate tissue selenium concentrations have been measured in 21 off-channel areas of MU1. At six of these, potential selenium effects to invertebrates and to invertebrate-eating fish or birds were indicated. Potential selenium effects to amphibians were indicated for seven additional off-channel areas based on dietary periphyton and/or invertebrate exposure (Table E.4b). HQs were highest (i.e., greatest risk of selenium effects) at the Fording River Oxbow, located adjacent the Fording River upstream of Chauncey Creek (Map 4.2-2).

4.2.3 Risks Based on Vertebrate Tissue Selenium Concentrations

Some fish tissue selenium concentrations at two reference areas of MU1 (Chauncey Creek and Dry Creek; Maps 4.2-3 and 4.2-4) were high enough to suggest potential dietary effects on fish feeding exclusively on other fish (Appendix E, Table E.5); however, cutthroat trout, which feed mainly on invertebrates (Minnow et al. 2011), is the only fish species found in MU1. Potential selenium-related risks were also indicated for fish-eating mammals at the same two reference areas and at reference area FO26. However, dietary selenium risks to fish and birds consuming invertebrates were low in all of these reference areas. All three reference areas are readily accessible to fish from mining-exposed areas of the Fording River, which suggests that the elevated HQs for fish-eating vertebrates were based on fish that migrated to these reference areas from mining-exposed areas. For this reason, the fish from these (and similar such) reference areas were not included in data sets used to describe reference tissue selenium concentrations in the screening-level risk assessment (Windward 2014; Appendix C) or the associated summaries presented in Section 3.0 of this report.[21]

[20] Water quality at Henretta Creek, near Henretta Lake, and Fording River at Fording River bridge, near the Fording River off-channel sampling area referred to as FO29W, are also monitored. This explains the availability of WQI values for Henretta Lake and FO29W, even though water quality is not specifically monitored in those areas.

[21] Reference area fish tissue sampling locations included Alexander Creek, Barnes Lake, Bull River, Cabin Creek, Connor Lake, Elk Lakes, Elk River (non-mine-influenced reaches far upstream), Flathead Lake, Flathead Pond, Flathead River, Foisey Creek, Hartley Lake, Harvey Creek, Howell Creek, Kootenay River, Leach Creek Oxbow, Lodgepole Creek, McCool Creek, McEvoy Creek, McLatchie Creek, Middlepass Creek, O'Rourke Lake, Pollock Creek, and Transmission Creek.

Generally, across all MUs, poor HQs based on invertebrates as the dietary source of selenium were corroborated by fair or poor HQs for direct (egg/ovary) selenium measurements of fish and birds. However, fair or poor HQs based on vertebrate tissue selenium measurements were sometimes associated with areas having good dietary invertebrate selenium levels. This was the case in MU1, where HQs based on measurement of selenium in fish and/or bird tissues sometimes indicated risks of effects (either direct effects or to consumers of such tissues) even though invertebrate selenium concentrations for the same area were below levels expected to affect either the invertebrates or the animals that consumer them. These results suggest that vertebrates with elevated tissue selenium concentrations that were sampled in the Fording River (where invertebrate selenium concentrations were low) likely had previous exposure to higher dietary selenium levels in mine settling ponds or other off-channel habitats of MU1. These observations, and the reference area examples discussed in the previous paragraph, illustrate the issue discussed in Section 4.1 that vertebrate tissue selenium concentrations do not always reflect localized conditions in the areas where they are sampled (due to their mobility).

Excluding mine settling ponds, highest mean HQs for fish egg/ovary and bird egg selenium effects were associated with Fording River Oxbow, which was consistent with the pattern of HQs among areas that were based on invertebrate selenium concentrations.

4.3 Management Unit 2

MU2 includes the lower portion of the Fording River, downstream of Josephine Falls, as well as Line Creek, which is a major tributary to the Fording River. Line Creek is directly influenced by mine operations at LCO, while the portion of the Fording River that is included in MU2 is influenced by inputs from Line Creek as well as GHO and FRO discharges farther upstream (in MU1). Aquatic environmental conditions within MU2 are summarized below.

4.3.1 Localized Conditions in Lotic Areas

Benthic invertebrate community structure and tissue selenium concentration data were available for eight areas in MU2. These included two reference areas, two mine-influenced tributaries, and four mainstem receiver areas (Appendix Table E.6; Map 4.3-1). Calcite deposition was generally low among all areas, with CIs ranging from 0.0 to 0.5. Line Creek downstream of the LCO rock drain and West Line Creek had elevated concentrations of selenium, nitrate, and sulphate and represent major sources of these substances to the Elk River watershed (Figures 3.1-3 to 3.1-5). Consistent with this condition, Line Creek immediately downstream of the confluence with West Line Creek (LILC3) was categorized as having a poor benthic invertebrate community and poor water quality. However, the benthic invertebrate community improved to fair downstream of South Line Creek (LIDSL) and to good farther downstream at LI8, despite water quality continuing to be marginal. Similarly, the Fording River had good benthic invertebrate communities and tissue selenium concentrations at two locations upstream of Line Creek (FO9, FOUL) and at the monitoring location downstream of Line Creek (FO23), despite marginal water quality.

The available data provide good spatial coverage of MU2 relative to major sources mine-related constituents in water (along Line Creek), and also in the Fording River upstream and downstream of Line Creek.

4.3.2 Localized Conditions in Off-Channel Areas

Water quality is routinely monitored at three mine settling ponds (ranging from good to poor quality) for which biological data also are available, and sediment has been assessed at one settling pond (poor quality) (Appendix E, Table E.6). Tissue selenium concentrations were measured at a total of 10 off-channel habitats within MU2, including the 3 mine settling ponds. Of the 7 off-channel areas that are not mine works, all had invertebrate or periphyton selenium concentrations in the range for potential effects to vertebrate consumers.

4.3.3 Risks Based on Vertebrate Tissue Selenium Concentrations

As observed for MU1, fish and bird tissues sampled in lotic and off-channel areas of MU2 produced tissue selenium HQs ranging from good to poor, and the results did not necessarily correspond with selenium HQs based on benthic invertebrates sampled in the same areas (Appendix E, Table E.5; Map 4.3-1). Excluding mine settling ponds, highest HQs for fish egg/ovary and bird egg selenium effects were associated with mountain whitefish sampled in the lower Fording River (at FO23). However, as noted in Section 3, whitefish exhibit a pattern of atypically high ovary selenium concentrations relative to all other fish species sampled in the Elk River watershed and do not reflect the gradient of selenium exposure concentrations among capture areas. Mean HQs based on other vertebrate tissues samples collected in MU2 were generally less than or close to 1.0 suggesting low risk of effects.

4.4 Management Unit 3

MU3 includes the portion of the Elk River that is directly influenced by mining activities at GHO and extends downstream to the mouth of the Fording River. Aquatic environmental conditions within this management unit are summarized below.

4.4.1 Localized Conditions in Lotic Areas

Water quality was good at all mainstem areas and at mine-influenced tributaries in MU3, except near mine settling ponds along Leask, Wolfram, and Thompson creeks (Appendix E, Table E.7; Map 4.4-1). A total of nine lotic areas had multiple lines of data that included benthic invertebrate community structure and tissue selenium concentrations. These areas included three reference areas, two mine-influenced tributaries, and four mainstem receiver areas on the Elk River downstream of mine activities. There was little or no calcite deposition at these areas (CI of 0.0 to 0.3). Both mine-influenced tributaries (Wolfram and Thompson creeks) had poor water quality, benthic invertebrate communities, and invertebrate tissue selenium concentrations that indicated potential effects to the invertebrates and the animals that feed on them. Thompson Creek is also the dominant source of mine-related selenium, nitrate, and sulphate to the Elk River watershed within MU3 (Figures 3.1-3 to 3.1-5). All three reference areas within MU3 and the four mining-exposed areas evaluated along the Elk River downstream of Thompson Creek had good water quality, benthic invertebrate community health and tissue selenium concentrations (Appendix Table E.7). The available data provide good spatial coverage of MU3, including the tributary that is the dominant source within MU3 of mine-related constituents released to the watershed.

4.4.2 Localized Conditions in Off-Channel Areas

Excluding mine settling ponds, none of the nine off-channel areas sampled within MU3 had invertebrate tissue selenium concentrations that would indicate potential for direct effects on the invertebrates themselves or to vertebrates that eat them (Appendix Table E.7; Map 4.4-1).

4.4.3 Risks Based on Vertebrate Tissue Selenium Concentrations

Mountain whitefish sampled well upstream of coal mining (at EL12), had mean egg/ovary selenium concentrations potentially associated with effects (Appendix Table E.7). However, as noted previously, this species has shown unusually high ovary selenium concentrations relative to other species and regardless of sampling location. Potential selenium effects on spotted sandpiper were indicated at Thompson Settling Pond (mine works) based on mean egg selenium HQ of 1.9 (poor) and dietary invertebrate selenium concentrations that also ranked as poor (Appendix E, Table E.5). Slight risk of selenium effects to piscivorous fish was indicated at the Upper Elk River Oxbow (EROU) based on maximum (but not mean) HQ greater than 1.0. However, none of the Elk Valley fish species is exclusively piscivorous. Also only longnose sucker (a benthivore) has been observed at EROU to date and the available data indicate low risk of selenium effects to benthivorous fish.

4.5 Management Unit 4

MU4 includes the Elk River from the Fording River confluence to just downstream of the Michel Creek confluence, as well as Michel Creek itself. Aquatic environmental conditions have been monitored in numerous lotic tributary and mainstem areas and a variety of off-channel areas in MU4. Associated data are summarized in Appendix E, Tables E.5 and E.8, and discussed below.

4.5.1 Localized Conditions in Lotic Areas

Benthic invertebrate community structure and at least one additional line of evidence (e.g., water quality, calcite index, invertebrate tissue selenium concentrations and/or vertebrate tissue selenium concentrations) were available for 21 lotic areas within MU4, including 4 reference areas, 8 mine-influenced tributaries, and 10 mainstem receiver areas (Appendix E, Table E.8; Map 4.5-1).

Consistent with reference areas within the other management units, reference areas within MU4 had good water quality, low calcite, a healthy benthic invertebrate community, and invertebrate tissue selenium concentrations less than those expected to affect the invertebrates themselves or the fish and wildlife feeding on them (Appendix Table E.8).

Mine-influenced tributaries reflected a range of conditions (Appendix Table E.8). Benthic invertebrate communities considered to be poor were observed at Bodie Creek (BOCK) and Erickson Creek (ERCK). These are major mine-related sources of nitrate (Bodie Creek) or sulphate (Erickson Creek) to the watershed, with elevated concentrations of the main mine-related constituents (selenium, nitrate, sulphate; Figures 3.1-3 to 3.1-5) resulting in poor water quality in both creeks (Appendix E, Table E.8). ERCK also had a relatively high calcite index of 1.8. Corbin Creek (COCK), a tributary at CMO, had a poor benthic invertebrate community, elevated calcite, and poor water quality. A poor benthic invertebrate community was also observed at the EVO mine-influenced tributary Otto Creek (OCNM), but water quality was good and there was little calcite (CI of 0.02); the difference in benthic community structure at this location is likely attributable to the difference in habitat (slow, meandering channel through wetland) compared to the other streams sampled throughout the watershed (riffle habitats). Harmer Creek, which is another major source of sulphate to the watershed (Figure 3.1-5), was categorized as having a good benthic invertebrate community upstream of Harmer settling pond (i.e., at HACKUS), but a fair benthic invertebrate community and fair water quality were observed downstream of the pond (at HACKDS).

Although four of six mine-exposed areas evaluated along mainstem receiver Michel Creek had benthic communities similar to reference communities (i.e., good), the communities located immediately downstream of Corbin Creek (MIDCO) at CMO and downstream of Bodie Creek at EVO (MI2) were considered fair (Table E.8). All four areas along the Elk River had good benthic invertebrate communities, although water quality ranged from good to marginal. Invertebrate tissue selenium concentrations were below those expected to affect invertebrates or their consumers at all areas sampled along Michel Creek and the Elk River in MU4.

The available data provide good spatial coverage of MU4, including tributaries that are the dominant sources within MU4 of mine-related constituents released to the watershed as well as mainstem areas upstream and downstream of the tributaries.

4.5.2 Localized Conditions in Off-Channel Areas

Sediment quality was fair in three of six off-channel areas that were evaluated in MU4, including two mine settling ponds; the other areas had good sediment quality (Appendix E, Table E.8; Map 4.5-2). Potential effects to invertebrates or their consumers were indicated for 8 of 17 off-channel habitats evaluated in MU4 where invertebrate selenium concentrations have been measured. Highest risks were indicated in Goddard Marsh, where water quality was considered marginal and sediment quality was fair.

4.5.3 Risks Based on Vertebrate Tissue Selenium Concentrations

Potential risks associated with tissue selenium accumulation were indicated for fish, amphibians, and/or birds at seven lotic areas in MU4, including three reference areas (Appendix E, Table E.5; Map 4.5-1). The elevated HQs for piscivorous fish at reference areas Carbon (CA1) and Snowslide (SN1) creeks are suspect based on implausibly high (laboratory-reported) percent moisture values (88% to 99%) that were used to convert measured wet-weight muscle plug selenium concentrations to dry-weight values. Also, the fish in these creeks, and in Wheeler Creek (WH1), were sampled close enough (e.g., about 1 km) to mine-exposed Michel Creek that previous exposure to elevated selenium concentrations cannot be ruled out. For these reasons, the cutthroat trout in these reference areas were not included in data sets used to describe reference cutthroat trout tissue selenium concentrations in the screening-level risk assessment (Windward 2014; Appendix C) or the associated summaries in Section 3.0 of this report.

Potential effects of selenium accumulation were indicated for one or more vertebrate groups at 7 of 10 off-channel areas sampled in MU4. This included the reference area Leach Creek Oxbow, which is almost 6 km from mine-related influence (Michel Creek), and contains sufficient habitat for fulfilment of fish life-cycle functions, such that previous exposure to mining influences by fish captured at this location is unlikely. Among all off-channel areas that have been investigated in MU4, estimated risks of selenium effects to vertebrates associated (based on relative HQs) were highest at Goddard Marsh (GO13) (Appendix E, Table E.5). Highest potential selenium-related risks to invertebrates were also indicated at GO13 (Appendix E, Table E.8).

4.6 Management Unit 5

MU5 includes the Elk River downstream of Sparwood to its mouth at Lake Koocanusa. There are no additional active mine-related inputs to the watershed within this MU. Aquatic environmental conditions within this management unit are summarized below.

4.6.1 Localized Conditions in Lotic Areas

Benthic invertebrate community data and tissue selenium concentrations were monitored at one reference area (Wigwam River) and five mine-exposed areas of the Elk River in MU5 (Appendix E, Table E.9; Map 4.6-1). Tissue selenium data (but no invertebrate community data) were available for several other areas. All benthic invertebrate communities that were assessed were ranked as good, based on similarity to reference communities, and tissue selenium concentrations were below levels expected to be associated with adverse effects on biota. Water quality in the Elk River, measured at Fernie, Elko, and at the mouth, was also good.

4.6.2 Localized Conditions in Off-Channel Areas

Sediment quality was good in the four off-channel areas that have been sampled within MU5. Invertebrate samples collected at two off-channel areas, R2-108 and the Elko reservoir, indicated slight risk for selenium effects to the invertebrates themselves and to vertebrates that eat them (mean HQ of 1.2 or less; Appendix Table E.9). Potential dietary selenium risk to amphibians (based on consumption of periphyton or invertebrates) was indicated at three additional off-channel areas, but maximum HQs were 1.5 or less at those three locations (i.e., relatively low risk). The other 11 off-channel areas sampled in MU5 had periphyton and benthic invertebrate selenium concentrations below levels expected to result in direct effects to invertebrates or to vertebrate consumers.

4.6.3 Risks Based on Vertebrate Tissue Selenium Concentrations

Brook trout captured at reference area Mine Creek had slightly elevated tissue selenium concentrations that resulted in an HQ greater than 1 for egg/ovary selenium effects (single-sample HQ of 1.2) and effects to piscivorous fish (maximum and mean HQ of 2.7 and 1.1), despite low dietary (invertebrate) concentrations at those areas (Appendix E, Table E.5). Also, the fish samples from the two mine-exposed lotic areas sampled in MU5 consisted exclusively of mountain whitefish (ELK_MS) or predominantly mountain whitefish plus smaller numbers of westslope cutthroat trout (EL1). As noted in Section 3, whitefish exhibit a pattern of atypically high ovary selenium concentrations relative to all other fish species sampled in the Elk River watershed and do not reflect the gradient of selenium exposure concentrations among capture areas. Therefore, elevated selenium concentrations in brook trout and whitefish may be attributable to dietary exposure in locations other than where they were sampled. Slight risk of selenium effects to piscivorous fish was indicated for off-channel area EROL, but only longnose sucker (a benthivorous species) has been captured at that location to date. Slight selenium-related risk was also indicated to piscivorous mammals at EROL (maximum and mean HQ of 1.6 and 1.0, respectively), although similar HQs were associated with reference area Hartley Lake (maximum and mean HQ of 1.3 and 1.1), where pre-exposure of fish to mine influences is unlikely. Birds sampled in MU5 had egg selenium concentrations below those expected to cause effects.

4.7 Management Unit 6

MU6 is the Canadian portion of Lake Koocanusa. Because past monitoring has focused mainly on conditions in the Elk River watershed, closer to mine sources, fewer monitoring data are available for Lake Koocanusa. Available lines of evidence include water and sediment quality and fish tissue selenium concentrations. Water and sediment quality are summarized in Appendix Table E.10, while tissue selenium concentrations are presented in Appendix E, Figures E.1 to E.3. The results are discussed below. Three consecutive years of annual monitoring were initiated in 2014 to provide more information regarding current conditions in MU6.

Water quality monitoring in Lake Koocanusa began in 2012 and data are available for five stations in the reservoir and one at the mouth of the Elk River. Water quality was fair at the Elk mouth station, but good at the other stations within the reservoir. Sediment quality was good along six transects across the reservoir that were sampled in 2013.

Most of the tissue selenium data collected from MU6 are for fish. A total of 89 fish egg/ovary samples were collected for five species (kokanee, longnose sucker, largescale sucker, northern pikeminnow, and peamouth chub) from 2008-2013, and a total of 297 whole-body/muscle samples were collected for nine species (these same five plus bull trout, mountain whitefish, rainbow trout, and westslope cutthroat trout) from 2007-2013. For comparison to the MU6 data, fish tissue selenium concentrations from reference areas were also compiled. These data were collected from a variety of habitat types, including ponds, lakes, creeks, and rivers in or near the Elk River watershed.[22] Although many of the reference areas have different habitat than Lake Koocanusa, this is unlikely to have an important influence on reference selenium concentrations that were used as points of comparison to selenium concentrations in MU6 fish.

Given that fish samples were generally collected over broad sampling regions in Lake Koocanusa, along with the potentially high mobility of most species sampled, it was not possible

[22] Reference area fish tissue sampling locations are listed in Section 4.2.3.

to link the fish tissue data to discrete locations within MU6. Thus, the fish tissue selenium data for Lake Koocanusa (MU6) were pooled by species and compared to toxicity thresholds.

The fish egg/ovary selenium data, which represent the strongest line of evidence in assessing whether selenium may be adversely affecting fish (Janz et al. 2010), were compared to an egg/ovary selenium toxicity threshold of 18 mg/kg dw. This toxicity threshold is based on brown trout and is the lowest effect threshold (EC10[23]) identified for fish (Golder 2014c; Windward 2014). This EC10 was used to interpret egg/ovary selenium data for all fish species (although no brown trout are present in the watershed) because no species-specific toxicity data are available for the fish species for which egg/ovary selenium data are available for MU6.

The whole-body/muscle selenium data were compared to a dietary selenium threshold of 11 mg/kg dw,[24] which is applicable to potential effects on piscivorous fish; while bull trout and northern pikeminnow diets may contain a high proportion of fish, other fish species are likely to feed more on invertebrates. Since benthic invertebrate densities in Lake Koocanusa appear to be very low (S. Weech, personal communication), zooplankton may be an important dietary source for fish. Zooplankton samples for selenium analysis are limited to five samples collected from three locations in 2008, including one location far upstream of the Elk River mouth that was considered a reference area (McDonald 2009). Selenium concentrations at all three locations were well below the dietary Se threshold of 11 mg/kg dw for fish (Appendix E, Figure E.1).

None of the egg/ovary selenium concentrations measured in Lake Koocanusa samples exceeded the egg/ovary selenium toxicity threshold of 18 mg/kg dw (Appendix E, Figure E.2). The highest mean and maximum egg/ovary selenium concentrations were 7.2 and 11.6 mg/kg dw, respectively, for peamouth chub. The mean egg/ovary selenium concentration measured in peamouth chub collected from reference areas was 7.3 mg/kg dw. Temporal patterns in fish egg/ovary selenium concentrations in MU6 could not be evaluated because egg/ovary selenium data were generally not available within a species over time.[25] Overall, the existing data do not indicate that fish in MU6 are at risk of effects from selenium accumulation.

As for fish eggs/ovaries, whole-body/muscle selenium concentrations measured in Lake Koocanusa did not exceed the dietary selenium toxicity threshold of 11 mg/kg dw for fish (Appendix E, Figure E.3). Mean whole-body/muscle selenium concentrations were ≤4.0 mg/kg dw for all species among all sampling years. In general, mean whole-body/muscle selenium concentrations in samples collected from MU6 were similar to mean concentrations measured in reference area fish. One exception was peamouth chub, which had an overall mean whole-

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[23] The chemical concentration estimated to cause an effect to 10% of an exposed population of organisms.

[24] The dietary selenium threshold of 11 mg/kg dw for fish is a benchmark recommended in Golder (2014); this was an EC10 for juvenile chinook salmon growth (Hamilton et al. 1990) and a no-observed-effects concentration for juvenile Yellowstone cutthroat trout survival and growth (Hardy et al. 2010).

[25] The one exception was for kokanee, for which egg/ovary selenium data were available from 2008 and 2013. The mean±SD (n) selenium concentrations were 3.7±0.55 mg/kg dw (29) in 2008 and 4.5±0.81 mg/kg dw (17) in 2013.

body/muscle selenium concentration of 2.8 mg/kg dw at MU6 locations, compared to a mean of 1.5 mg/kg dw at reference area locations (all reference area samples for peamouth chub were from Flathead Lake, MT, USA). However, selenium concentrations in all peamouth chub whole-body/muscle samples were still well below 11 mg/kg dw. Data collected over time suggest an increase in whole-body/muscle selenium concentrations for bull trout, kokanee, northern pikeminnow, and rainbow trout (Appendix E, Figure E.3). For bull trout, the maximum selenium concentration was measured in 2013, based on a single sample. This maximum selenium concentration was almost equal to the mean concentration measured in bull trout collected from reference areas. For northern pikeminnow, the mean selenium concentration in 2013 (2.6 mg/kg dw) was double the mean concentration measured in 2007 and 2008 (1.3 mg/kg dw). The 2013 data were all collected by the Montana Fish, Wildlife & Parks at K01KOOCL35, which is about 9 km upstream of the Elk River mouth. It is uncertain whether the higher mean whole-body/muscle selenium concentrations for some of the fish species in 2013 are due to factors related to sampling location or sampling and analytical methods, or whether the data reflect actual increases in tissue selenium accumulation for these species. Further sampling in future years will be needed to confirm whether there truly is an increasing pattern.

In summary, water and sediment quality in Lake Koocanusa are good. Maximum selenium concentrations measured in fish egg/ovary and whole-body/muscle samples collected from the reservoir were well below their respective toxicity thresholds. There is some evidence of increases in whole-body/muscle selenium concentrations for some species. The higher concentrations recently measured (2013) were in samples collected several kilometers upstream of the Elk River mouth, although the potential mobility of the species sampled makes it difficult to determine the locations of their selenium exposure history. Continued monitoring of selenium in fish tissues should determine if tissue concentrations are actually increasing and approaching levels of concern.

4.8 Summary Of Environmental Conditions

4.8.1 Integrated Lines of Evidence (Elk River Watershed)

This section summarizes the various lines of evidence related to aquatic environmental quality that were presented in Sections 4.2 to 4.7 for each of the MUs.

4.8.1.1 Management Unit 1

The tributaries that have been sampled in MU1 include those contributing most of the selenium, nitrate, and/or sulphate to the watershed within MU1 (e.g., Henretta, Clode, Kilmarnock, Swift, Cataract, and Greenhills creeks). The tributaries with highest concentrations of mine-related constituents tend to reflect poor benthic invertebrate communities and elevated tissue selenium concentrations. Water quality in the upper Fording River is being influenced by contributions from mine-influenced tributaries, but little or no calcite deposition is occurring along the mainstem river. Also, benthic invertebrate communities and tissue selenium concentrations of most of the upper Fording River are considered indicative of good quality and comparable to conditions observed in reference areas. Biota, such as fish and birds, that are able to move freely between mainstem, tributary, and off-channel areas (including settling ponds) had tissue selenium concentrations ranging from good (low risk of effects) to poor (potential risk). Highest selenium-related risks to invertebrates and vertebrates within MU1 were indicated at the Fording River Oxbow.

4.8.1.2 Management Unit 2

Water quality in lotic areas of MU2 ranged from good (upstream of the Line Creek rock drain) to poor (immediately downstream of the Line Creek rock drain). Both Line Creek downstream of the rock drain and West Line Creek, which flows into Line Creek just downstream from the rock drain, are major sources of selenium, nitrate, and sulphate to the watershed within MU2. The benthic invertebrate community was considered poor immediately downstream of the rock drain. However, the invertebrate communities in lower Line Creek and in the Fording River upstream and downstream of Line Creek were considered good, as were invertebrate tissue selenium concentrations, in spite of marginal water quality. Calcite levels were low at all areas where other sample types have been collected within MU2. Fish and bird tissues sampled in lotic and off-channel areas of MU2 produced tissue selenium HQs ranging from good to poor Potential risks of selenium-related effects to invertebrates and/or vertebrates were also indicated in several off-channel areas of MU2.

4.8.1.3 Management Unit 3

Water quality was poor in three mine-influenced tributaries in MU3 (Leask, Wolfram, Thompson creeks), and the invertebrate community structure and tissue selenium concentrations were also considered fair to poor at the two tributaries having historical monitoring data (Thompson and Wolfram creeks). Thompson Creek is the dominant source of mine-related constituents to the watershed within MU3. All other tributaries and mainstem (Elk River) locations had invertebrate communities and tissue selenium concentrations considered to be good. Tissue selenium concentrations in off-channel habitats within MU3 (except settling ponds) were also good, with the exception of potential slight risk of selenium effects to piscivorous fish in one off-channel habitat (EROU) where the only fish species captured to date has been a benthivorous one (longnose sucker, for which low selenium-related risk was indicated).

4.8.1.4 Management Unit 4

Benthic invertebrate communities in lotic areas of MU4 reflected a range of conditions. Poor communities were observed at several mine-influenced tributaries (Corbin, Erickson, Bodie, Otto creeks). Erickson and Bodie creeks are the major mine-related sources of sulphate and nitrate, respectively, to the watershed within MU4 (also sulphate via Harmer Creek). Among all areas that have been sampled in MU4, including off-channel habitats, estimated selenium-related risks to invertebrates and vertebrates were highest at Goddard Marsh, where water quality was also marginal. Benthic invertebrate communities and tissue selenium concentrations were good at most mainstem receiver areas sampled along Michel Creek and the Elk River. Exceptions were fair invertebrate communities sampled in Michel Creek downstream of Corbin Creek (at CMO) and also downstream of EVO inputs to Michel Creek (including ERCK and BOCK).

4.8.1.5 Management Unit 5

Water quality, benthic invertebrate community structure, and tissue selenium concentrations were ranked as good for all lotic areas sampled within MU5 (based on data for 3, 5, and 8 monitoring areas in MU5, respectively). The exceptions were slightly elevated HQs for eastern brook trout at one lotic reference area and mountain whitefish captured in the Elk River downstream of Sparwood; these fish tissue results are inconsistent with low dietary (invertebrate) concentrations at the same locations, suggesting that selenium accumulation by those fish may have occurred elsewhere in the watershed. Slight risk of selenium effects to biota were indicated in several off-channel areas of MU5 (mean HQs were usually 1.5 or less), and 11 of the 16 areas indicated no risk for selenium effects.

4.8.2 Direct Evidence of Effects (Elk River Watershed)

Evaluation of benthic invertebrate community structure provides direct evidence of ecological conditions, whereas the other monitoring data (water and sediment quality, calcite deposition, and tissue selenium concentrations) provide indirect evidence of potential effects. Benthic invertebrate communities reflect the integrated (cumulative) effects of water quality, substrate quality (sediment, calcite), and dietary quality (including potential effects associated with dietary selenium accumulation) over time. Also, their limited mobility makes benthic invertebrates reliable indicators of localized conditions in each sampling area, as compared to species with large home ranges. In this respect, benthic invertebrate community data provide a particularly strong line of evidence respecting the degree of mine-related effect on aquatic biota in different parts of the watershed. This section provides a summary of the benthic invertebrate community health across management units within the Elk River watershed.

Communities were evaluated for 15 reference areas, 20 mine-influenced tributaries, and 36 mainstem areas within the Elk River watershed. Most (65%) mine-influenced tributaries evaluated throughout the watershed had poor community (Table 4.8-1), but sampling programs mainly targeted the tributaries known to have high concentrations of mine-related constituents and contribute the highest loads of the same constituents to the Elk River watershed. The following tributaries were in this category:

- Kilmarnock (KICK), Swift (SWCK), Cataract (CACK), Porter (POCK), and Greenhills (GHCKU, GHCKD) creeks in MU1;
- Line Creek immediately downstream of the LCO rock drain and West Line Creek (LILC3) in MU2;
- Wolfram (WOCK) and Thompson (THCK) creeks in MU3; and
- Otto (OCNM), Corbin (COCK), Erickson (ERCK), and Bodie (BOCK) in MU4.

Of these, Kilmarnock Creek, Swift Creek, and Cataract Creek together contribute about 50 percent of the total mine-related selenium and nitrate loads and about 30 percent of the total sulphate load to the watershed. The other mine-influenced tributary areas evaluated had either fair (3 areas) or good (4 areas) benthic invertebrate communities.

All 15 reference areas had good benthic invertebrate communities (Table 4.8-1). In addition, 31 areas along the mainstem receivers (Elk River, Fording River, Line Creek, and Michel Creek) had good benthic invertebrate communities (i.e., 86% of all receiver areas evaluated). Fair communities were observed at 3 of 14 (21%) mainstem receiver areas evaluated in the upper Fording River (MU1), and at 2 of 9 (22%) of those evaluated in MU4. All areas evaluated in MU5 (lower Elk River) had good benthic invertebrate communities.

Minnow (2014a) reported a significant negative correlation between concentrations of mine-related constituents in water (as summarized by Principal Components Analysis of water chemistry data) and both percent EPT (mayflies, stoneflies, caddisflies) and percent Ephemeroptera (mayflies) alone; these results provided evidence that mine-related influences on water quality have adversely affected benthic invertebrate communities in many tributaries located near mine disturbances and to a lesser degree in some mainstem areas located immediately downstream of the tributaries that are major sources of mine-related constituents.

Overall, the benthic invertebrate community data provided extensive characterization of conditions among reference areas in the region that have comparable habitat characteristics to mine-influenced areas of the Elk River watershed. The benthic invertebrate community data for mine-exposed areas effectively identified the areas of the watershed where aquatic biota are most affected, which provides perspective for managing future mining activities to protect aquatic resources and for monitoring of potential effects.

4.8.3 Lake Koocanusa

Surface water quality, sediment quality, and selenium concentrations in aquatic organism tissues (zooplankton, fish) have been monitored at multiple locations throughout Lake Koocanusa. Overall, water and sediment quality were categorized as good. Selenium concentrations in zooplankton were less than dietary toxicity thresholds for fish, and selenium concentrations in fish eggs/ovaries (89 samples) and whole-body/muscle (292 samples) were below effect levels in 97.8 percent and 94.2 percent of the samples, respectively.

5 Recommendations for Future Studies and Monitoring

A substantial amount of information has been collected in relation to aquatic environmental conditions in the Designated Area, particularly in the Elk River watershed near and downstream of mining, as presented in previous sections. Data are available for numerous areas within each MU to evaluate multiple lines of evidence regarding environmental quality, including potential direct effects (i.e., benthic invertebrate community structure, fish population characteristics) and potential indirect effects (water quality, sediment quality, calcite, primary productivity, and tissue concentrations in biota). Concentrations of mine-related constituents are routinely monitored at more than 100 stations throughout the Designated Area, which allow for rapid and sensitive detection of changes in mine contributions over time, and comparison to predictions and effects benchmarks identified in the EVWQP. On-going cycles of biological monitoring will allow for verification that aquatic ecosystem conditions are responding as predicted by the EVWQP.

Based on review of the existing information, a number of opportunities have been identified to improve the amount and/or quality of information being collected in aquatic environments downstream of the mines. The following actions listed below are recommended for future studies and monitoring. The status of each activity is identified in square parentheses.

15. Re-evaluate the scope of water quality reporting (i.e., data evaluation and trending, spatial and temporal coverage, frequency, etc.) for informing the RAEMP and adaptive management, and relative to commitments made under the EVWQP. [pending]
16. Consider incorporation of aquatic toxicity tests in the RAEMP using surface water samples from representative locations as an additional direct line of evidence for potential effects. [pending]
17. Evaluate the spatial and temporal variability in calcite deposition and evaluate the effects of calcite on biota. [A regional supporting study of calcite deposition began in 2013 and will continue through 2015. The study was expanded in 2014 to assess calcite effects on benthic invertebrate community health and periphyton productivity. Additional monitoring of both calcite and biota is planned for 2015. The results will inform the scope of long-term calcite and associated biological monitoring within the RAEMP.]
18. Collect sediment samples in additional depositional areas of the watershed for laboratory toxicity testing (along with supporting chemistry and particle size analyses). [This will be done as a supporting study in 2015 to determine if toxicity to biota is occurring as a result of elevated sediment concentrations of mine-related constituents. Results will be used to inform the future scope of the RAEMP.]
19. Monitor periphyton productivity (chlorophyll-a and ash-free dry mass) at representative areas throughout the watershed, particularly downstream of active water treatments facilities involving phosphorus addition. [This will be done as part of the RAEMP and Local Aquatic Effects Monitoring Programs.]
20. Consider opportunities to improve the reliability periphyton community data to reduce uncertainties related to the representativeness (of samples collected in the field and sub-

samples analyzed by the laboratory) and accuracy (taxonomic identifications) of reported data. [A supporting study to further evaluate periphyton community data is planned for 2015 which will include reconciliation of 2013 data to an appropriate taxonomic level. This evaluation will be conducted by the taxonomist retained for the supporting study to determine if data collected in 2013 exhibits similar findings to the data collected in 2015. The results will be used to evaluate sensitivity of periphyton community data as an indicator of mine effects and inform scope of long-term monitoring endpoints for the RAEMP.]

21. Continue to monitor benthic invertebrate communities as robust indicators of localized environmental quality and a direct line of evidence of potential mine-related effects. [Included in the 2015 RAEMP monitoring].

22. Sufficient understanding of the westslope cutthroat trout population in the upper Fording River (above Josephine Falls) is required to determine the best sampling locations, sample timing and measurement endpoints for evaluating and tracking of potential mine-related effects to this species over time. The current population study, which will be completed in 2015, should be continued as planned. [Supporting study underway and concluding in 2016.]

23. Monitor longnose sucker populations and tissue selenium concentrations in off-channel habitats containing populations of sufficient size that they can be reliably quantified and tracked over time (e.g., Goddard Marsh). [This will be done as part of the 2015 RAEMP.]

24. Measure selenium in water, periphyton, and invertebrates in off-channel habitats. Based on the results, potential use of off-channel habitats by aquatic or aquatic-dependent vertebrates having invertebrate (dietary) Se HQ>1 should be investigated. The objective would be determine if such areas are of sufficient size and habitat quality to warrant further investigation or long-term monitoring in the RAEMP. [In 2015, selenium will be measured in water, periphyton, and invertebrates at areas that are also targeted for sediment quality evaluation.]

25. Collect biological samples representing different trophic levels within Lake Koocanusa, both upstream and downstream of the Elk River mouth, to assess potential effects related to upstream coal-mining activities. [This was initiated in 2014 and will continue for two additional years. The results will inform the scope of future monitoring in the reservoir as part of the RAEMP.]

26. The ongoing study of selenium effects on spotted sandpiper egg hatchability should be completed. Results will be used to determine if long-term monitoring of potential selenium effects on birds is warranted. [The second and potentially final year of data collection was completed in 2014, and the results will be evaluated and reported in 2015.]

27. Complete a statistical evaluation of effects size and data evaluation methods to inform sample sizes and confidence level for the next cycle of RAEMP. [The data are currently being evaluated for this purpose in collaboration with MOE and KNC.]

28. Develop detailed Standard Operating Procedures (SOPs) for sampling (and laboratory analyses, if appropriate) to standardize approaches used among sampling areas and studies to ensure consistent data quality over time. [pending]

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7 Glossary

Acid volatile sulphide (AVS)—A fraction of the sulphides in sediment that form a complex with heavy metals, like copper, lead, and zinc.

Algae—Simple, rootless, unicellular plants containing chlorophyll that grow in sunlit waters in proportion to the amount of available nutrients.

ANNA—See "Assessment by nearest neighbour analysis."

Assessment by nearest neighbour analysis (ANNA)—An approach for defining groups of areas based on habitat similarities.

Assimilation—The process by which ingested food and nutrients are absorbed and used in the metabolism of an organism.

Autotroph—An organism capable of self-nourishment by using inorganic materials as a source of nutrients and using photosynthesis or chemosynthesis as a source of energy, such as most plants and certain bacteria.

Bacteria—Single-celled microorganisms that lack chlorophyll.

Basin—The area drained by a river and its tributaries.

Benthic—The living organisms found at or near the bottom (i.e., sediments) of the Elk River watershed.

Benthivores—Animals that feed from the benthos/substrate.

Bioavailability—The extent to which bioaccessible metals absorb onto, or into, and across biological membranes of organisms, expressed as a fraction of the total amount of metal the organism is proximately exposed to (at the sorption surface) during a given time and under defined conditions.

Biotic ligand model (BLM)—An analysis tool used to evaluate differences in the availability and toxicity of metals that occur as a result of changes in water chemistry from site to site, and at a given site over time.

Constituent of potential concern (COPC)—A chemical that may pose an unacceptable risk to a certain receptor group under a certain set of conditions.

Chronic value—Typically derived as the geometric mean of the no-observed-adverse-effect concentration and lowest-observed-adverse-effect concentration determined in the same test.

Conceptual site model (CSM)—A written description and visual representation of the known, expected, and predicted relationships between the site chemicals and the ecological receptors.

Community—An assemblage of populations of different species living together in space and time.

Daphnia—A genus of sensitive zooplankton within the family Daphniidae. One of the planktonic species consumed by a number of fish in the Elk River watershed.

Detritus—Suspended or deposited organic matter resulting from the decomposition of plants and animal tissues or waste products.

Dissolved organic carbon (DOC)—The concentration of organic (not inorganic) carbon dissolved in water or porewater.

Drawdown—The distance that the water surface of the reservoir is lowered from a given elevation as water is released from the reservoir.

Effect concentration—The concentration resulting in a specific biological effect in a certain percentage of organisms. For example, an EC20 in a growth experiment indicates the concentration where 20 percent of the test organisms experienced reduced body weight.

Epilithon—The aggregation of bacteria, fungi, algae, other microorganisms, and entrenched particles and detritus attached to rock surfaces, usually as a thin layer.

Epipelon—The aggregation of bacteria, fungi, algae, other microorganisms, and entrenched particles and detritus attached to bottom substrate (sediment).

Family—A taxonomic rank in the classification of organisms between genus and order.

Fluvial geomorphology—The science devoted to understanding processes that operate in river systems and the landforms they create or have created.

Food chain—Series of organisms, each eating or decomposing the preceding one (with the exception of food producers that obtain their food by assimilation of inorganic nutrients). The succession of trophic levels through which energy flows.

Food web—Complex network of many interconnected food chains and feeding interactions.

Habitat—A place where the physical and biological elements of ecosystems provide a suitable environment, including the food, cover, and space resources needed for plant and animal livelihood.

Hyalella azteca (*H. azteca)*—A 0.6-cm-long crustacean that is common in aquatic systems and widely used in standard sediment toxicity tests.

In situ—Latin phrase meaning in its original position or place.

Lacustrine—Pertaining to or living in lakes or ponds.

Lentic—Standing or still waters, such as lakes, reservoirs, or ponds. In this study, the definition is broadened to include relatively slow-flowing habitats (see also Lotic).

Lotic—Actively moving water or any flowing aquatic system, such as rivers or streams. In this study, the definition is more narrowly applied to relatively fast-flowing habitats typical of much of the Elk River watershed (see also Lentic).

Lowest-observed-adverse-effect concentration / Lowest-observed-adverse-effect level—The lowest dose evaluated in a toxicity test that has a statistically significant adverse effect on the exposed organisms compared with unexposed organisms in a control or reference site.

Macrophyte—Large, rooted, or floating aquatic plants that may bear flowers and seeds. Some plants, like duckweed and coontail, are free-floating and are not attached to the bottom.

Macroinvertebrate—Organisms without backbones that are visible to the eye without the aid of a microscope.

Management Unit (MU)—One of six units of the Elk River watershed based on geographic features, general hydrodynamic characteristics, and expectations regarding principal mechanisms for transport or deposition of particulate constituents of potential concern

No-observed-adverse-effect concentration / No-observed-adverse-effect level—The highest effect dose evaluated in a toxicity test that has no statistically significant adverse effect on the exposed organisms compared with unexposed organisms in a control or reference site.

Order—The taxonomic level between class (such as Insecta) and family (such as Chironomidae); the order name is often used for important benthic invertebrate groups, such as Ephemeroptera, Plecoptera, and Trichoptera.

Organic matter—The components of live or dead plant or animal matter possessing a carbon-hydrogen structure.

Periphyton—The aggregation of algae and other organisms that form on stones and other substrates on streambeds and the lake bottom (see also Epilithon and Epipelon).

Phytoplankton—Small, usually microscopic plants (such as algae), found in lakes, reservoirs, and other bodies of water.

Piscivore—An animal that eats fish for its main food.

Porewater—Water that fills the interstitial space between sediment grains in sedimentary deposits. Porewater may be displaced due to the activities of benthic fauna (animals), or by physical processes, such as compaction.

Reference area—A geographic area (that is not the focus of the risk assessment) consisting of similar physical and chemical characteristics (i.e., of natural or anthropogenic origins) as the area under investigation. The primary difference is that the reference area does not receive inputs from the primary contaminant source(s) that are the focus of the risk assessment.

Richness—The number of species identified in a sample or area.

Simultaneously extractable metals (SEM)—The dissolved concentrations of certain divalent metals extracted from sediment using a weak acid. SEM analyses are completed in conjunction with analyses of AVS.

Substrate—The supporting surface on which an organism grows. The substrate may simply provide structural support, or may provide water and nutrients. A substrate may be inorganic, such as rock or soil, or it may be organic, such as wood.

Taxa—Plural of taxon, representing any group or rank in a biological classification into which related organisms are classified.

Taxonomy—The classification of organisms into groups on the basis of shared characteristics.

Total organic carbon (TOC)—The concentration of organic (not inorganic) carbon measured in sediment or a particle.

Total suspended solids (TSS)—The portion of the sediment load suspended in the water column. The grain size of suspended sediment is usually less than 1 millimetre in diameter (clays and silts). High TSS concentrations can adversely affect primary food production and fish feeding efficiency. Extremely high TSS concentrations can impair other biological functions, such as respiration and reproduction.

Trophic level—The position occupied by an organism within a food web.

Watershed—The natural geographic region drained by one or more watercourses and their tributaries.

Wetland—Area of vegetation that is transitional between land and water bodies, and ranges from being permanently wet to intermittently water covered.

Zooplankton—Microscopic and macroscopic animals that swim in the water column. These invertebrates include chiefly three groups: rotifers, cladocerans, and copepods.

Tables

Table 2.3-1. Fish species that utilize habitat within the Elk River watershed and Lake Koocanusa and associated conservation status

Area	English name	Scientific name	Provincial (BC)[a]	COSEWIC[b]	SARA[c]	Conservation framework (1–6, 6 being highest priority)
Elk River Watershed	westslope cutthroat trout	*Oncorhynchus clarkii lewisi*	blue	SC (2006)	1-SC (2010)	2
	bull trout	*Salvelinus confluentus*	blue	SC (2012)	-	2
	rainbow trout	*Oncorhynchus mykiss*	yellow	-	-	6
	eastern brook trout	*Salvelinus fontinalis*	exotic	-	-	6
	mountain whitefish	*Prosopium williamsoni*	yellow	-	-	6
	longnose sucker	*Catostomus catostomus*	yellow	-	-	6
	longnose dace	*Rhinichthys cataractae*	yellow	-	-	6
	torrent sculpin[d]	*Cottus rhotheus*	yellow	-	-	2
Lake Koocanusa	westslope cutthroat trout	*Oncorhynchus clarkii lewisi*	blue	SC (2006)	1-SC (2010)	2
	bull trout	*Salvelinus confluentus*	blue	SC (2012)	-	2
	rainbow trout	*Oncorhynchus mykiss*	yellow	-	-	6
	eastern brook trout	*Salvelinus fontinalis*	exotic	-	-	6
	lake trout	*Salvelinus namaycush*	yellow	-	-	2
	Kokanee salmon	*Oncorhynchus nerka*	yellow	E (2003)[e]	-	2
	mountain whitefish	*Prosopium williamsoni*	yellow	-	-	6
	burbot (lower Kootenay population)	*Lota lota*	red	-	-	2
	largemouth bass	*Micropterus salmoides*	exotic	-	-	6
	yellow perch	*Perca flavescens*	unknown	-	-	not assessed
	northern pike	*Esox lucius*	yellow	-	-	6
	longnose sucker	*Catostomus catostomus*	yellow	-	-	6
	largescale sucker	*Catostomus macrocheilus*	yellow	-	-	6
	northern pikeminnow	*Ptychocheilus oregonensis*	yellow	-	-	6
	peamouth chub	*Mylocheilus caurinus*	yellow	-	-	5
	redside shiner	*Richarsonius balteatus*	yellow	-	-	6
	pumpkinseed	*Lepomis gibbosus*	exotic	-	-	6

Table 2.3-2. Amphibian species that utilize habitat within the East Kootenay District of British Columbia and have special conservation status (from BC Conservation Data Centre 2012)

English name	Scientific name	Provincial (BC)[a]	COSEWIC[b]	SARA[c]	Conservation framework (1-6, with 6 being highest priority)
Coeur d'Alene salamander	*Plethodon idahoensis*	Yellow	SC (Nov 2007)	1-SC (Jun 2003)	2
Columbia spotted frog[1]	***Rana luteiventris***	Yellow	NAR (May 2000)	-	2
Long-toed salamander[1]	***Ambystoma macrodactylum***	Yellow	NAR (April 2006)	-	4
Northern leopard frog	*Lithobates pipiens*	Red	E (Apr 2009)	1-E (Jun 2003)	1
Rocky mountain tailed frog	*Ascaphus montanus*	Red	E (May 2000)	1-E (Jun 2003)	2
Western toad	***Anaxyrus boreas***	Blue	SC (Nov 2002)	1-SC (Jan 2005)	2
Wood frog[1]	***Lithobates sylvaticus***	Yellow	-	-	2

Notes:

Species in **bold** were observed during amphibian surveys in 2012 or other field programs.

[1] Species was not found in a search for the East Kootenay District because region-specific searches are restricted to Red, Blue, and Legally Designated species.

Source: http://a100.gov.bc.ca/pub/eswp/search.do (Search Constrained to the East Kootenay Regional District - accessed on January 30, 2012)

[a] **BC List**

Red: Includes any indigenous species or subspecies that have- or are candidates for- Extirpated, Endangered, or Threatened status in British Columbia. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Not all Red-listed taxa will necessarily become formally designated. Placing taxa on these lists flags them as being at risk and requiring investigation.

Blue: Includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.

Yellow: Includes species that are apparently secure and not at risk of extinction. Yellow-listed species may have Red- or Blue-listed subspecies.

[b] **COSEWIC (Committee On the Status of Endangered Wildlife In Canada)**

E = ENDANGERED: A species facing imminent extirpation or extinction.

T = THREATENED: A species that is likely to become endangered if limiting factors are not reversed.

SC = SPECIAL CONCERN: A species of special concern because of characteristics that make it is particularly sensitive to human activities or natural events.

NAR = NOT AT RISK: A species that has been evaluated and found to be not at risk.

C = CANDIDATE: A species that is on the short-list for upcoming assessment.

[c] **SARA (Species At Risk Act)**

Schedule 1 - Species status confirmed based on 1999 COSEWIC criteria.

Schedule 2 - Species status to be reassessed to 1999 COSEWIC criteria (i.e. schedule 1).

Schedule 3 - Species status to be reassessed to 1999 COSEWIC criteria (i.e. schedule 1).

Table 2.3-3. Avian census results, 2012. Maximum number of individuals of a species observed in any single visit to a particular area is presented (based on combined visual and auditory observations)

Ref vs Exp:	Reference				Exposed																															
Area code:	REFF	LML	CHCK	DRCK	FO15	LI24	GLM	AL4	CL11	FO51	KSP	FO52	CACK	SWCK	FOXL/ FO10	F022	FO29	THPD	WOPD	LEPD	GHPD	LCCPU/L	LI8	FO23	EL19	HA7	GO13	OTTO	GAPD	BOPD	MI2	MI16	MIWW	EL1	ELKO	LK02
American coot	1	1	-	-	8	-	7	-	2	1	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-
American crow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	3	-	1
American dipper	-	-	-	1	-	-	-	5		1	1	-	-	-	-	-	1	-	-	-	-	4	1	-	-	3	-	-	-	-	-	-	-	-	-	-
American goldfinch	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American kestrel	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
American pipit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American redstart	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	6	-	2	-	-	-	-	-	-	1	-	-	-	5	-	-	-	1	-
American robin	5	-	6	4	2	1	6	9	8	2	9	-	5	1	>20	5	4	3	3	7	6	3	1	3	3	4	3	1	1	-	4	5	5	7	3	3
American tree sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
American widgeon	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bald eagle	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	1		2		1		-	-	-	-	-	1	-	1
Bank Swallow	-	-	-	-	-	-	>20	-	16	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	200	-	-
Barn swallow	-	-	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Barrow's goldeneye	-	-	-	-	-	-	-	-	-	-	3	2	1	-	4	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Belted kingfisher	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-billed magpie	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-capped chickadee	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-
Blue-winged teal	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Boreal chickadee	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brewer's blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
Brown creeper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown-headed cowbird	2	-	-	1	-	-	3	1	8	-	3	-	-	-	2	-	1	12	-	1	4	-	-	9	1	2	-	-	-	-	3	3	3	1	4	-
Canada goose	-	-	-	-	2	-	-	1	38	1	15	-	-	-	-	-	-	-	-	-	5	1	-	-	-	-	-	-	-	-	1	-	-	13	-	33
Cassin's finch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cassin's vireo	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cedar waxwing	2	-	1	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18		1	-	-	-	-	1	7	24	1	2
Chipping sparrow	2	-	3	2	2	-	3	3	2	2	4	-	1	3	>20	3	3	2	4	1	3	2	2	2	7	4	1	-	1	-	3	-	-	4	3	2
Cinnamon teal	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Clark's nutcracker	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cliff swallow	-	-	-	-	-	-	12	30	-	-	-	-	-	-	-	-	-	-	-	-	2	12	-	-	-	-	-	-	20	-	-	6	-	-	-	1
Common goldeneye	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common loon	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Common merganser	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	15	-
Common raven	1	-	2	1	1		2	1	1		1		1	1	2		2			1	2	2	5	4	3	-	1		1		4	-	1	6	1	-
Common snipe	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-		1	-	-	-	-	-	-	-	-
Common yellowthroat	1	-	-	-	3	-	>20	-	-	-	-	-	-	-	3	-	-	-	-	-	1	-	-	-	-	-	5	1	-	-	-	1	1	-	1	-
Dark-eyed junco	4		2	2	2	2		2	-	1	1	-	1	2	3	4	2	2	1	2	-	-	-	5	5	-	-	-	-	-	1	1	-	-	-	-

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Downy woodpecker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-
Dusky flycatcher	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	1	1	1	-	-
Eastern kingbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	1	-
European starling	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-	4	-	-
Evening grosbeak	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gadwall	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Golden-crowned kinglet	1	-	1	1	-	2	-	3	-	3	1	-	1	-	>20	1	1	-	-	2	-	1	6	4	3	2	1	-	-	-	-	1	-	1	1	-
Gray jay	-	-	-	-	-	-	1								-	-	2	-	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Great blue heron	1	-	-	-	-	-	1								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Great horned owl	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater yellowlegs	-	-	-	-	1	-	-	-	-	-	-	1			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Green-winged teal	-	-	-	-	-	-	2				3	2			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hairy woodpecker	1	-	-	-	-	-		1							1	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-
Hammond's flycatcher	-	-	-	-	-	-		2							-	-	1	-	-	1	-	3	2	6	2	1	-	-	-	-	-	-	-	-	-	-
Harlequin duck	-	-	-	-	-	-				1					-	-	-	-	-	-	-	7	-	-	-	3	-	-	-	-	6	-	-	-	-	-
Hermit thrush	1	-	-	-	-	-		2										1	-	1	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-
Hooded merganser	-	-	-	-	-	-													-	-	-	-			-	-	-	-	-	-	-	-	-	2	1	-
House wren	-	-	-	-	-	-	3												-	-	-	-			1	-	-	-	-	-	-	-	-	2	-	-
Killdeer	-	-	-	-	-	-				1	3								-	-	3	-			-	-	1	-	-	-	1	-	-	1	-	-
Least flycatcher	-	-	-	-	-	-	6	1											-	-		-			1	-	-	-	-	-	-	2	2	-	-	-
Lesser yellowlegs	-	-	-	-	-	-						2							-	-		-			-	-	-	-	-	-	-	-	-	-	-	-
Lesser scaup	-	-	-	-	1														-	-	2	-			-	-	-	-	-	-	-	-	-	-	-	-
Lincoln's sparrow	5	1	-	6	1		6		1		1			1	1	1	5	1			1					1	1						1	1	2	
Lincoln's warbler															1																					
Long-billed curlew																																				1
MacGillivray's warbler	1			3			1	1					1		1							1	1		1										1	
Mallard	2				17						10				2		3	1			1				1					3	2	6	1		5	
Marsh wren	1																																			
Merlin																															1					
Mountain bluebird							2	1	1		3	4									2				2											2
Mountain chickadee	5	1	1	2			3		1		2				5		1	1	1						3											
Mourning dove																								1												
Northern flicker			1				2	1	2		4		1	1	1		1	1			3	1			1						3		2	1	1	2
Northern rough-winged swallow	1				1		1				2																					2	2	2		
Northern shoveler												10									1															
Northern waterthrush	2		1	2	4			2	2		3		1	1	2		3	2		2		1	2		1		2				6	3	1	6	6	

Table 2.3-3. Avian census results, 2012. Maximum number of individuals of a species observed in any single visit to a particular area is presented (based on combined visual and auditory observations)

Ref vs Exp:	Reference				Exposed																															
Area code:	REFF	LML	CHCK	DRCK	FO15	LI24	GLM	AL4	CL11	FO51	KSP	FO52	CACK	SWCK	FOXL/ FO10	F022	FO29	THPD	WOPD	LEPD	GHPD	LCCPU/L	LI8	FO23	EL19	HA7	GO13	OTTO	GAPD	BOPD	MI2	MI16	MIWW	EL1	ELKO	LK02
Olive-sided flycatcher		1		3				1			1		1					1																		1
Orange-crowned kinglet				1																																
Orange-crowned warbler	2			1											1										1	1										
Osprey	1																							1									1			
Peregrine falcon																									1											
Pied billed grebe																		1																		
Pigmy owl				1																1																
Pileated woodpecker				1			1						1					1									1				1					
Pine grossbeak																				1																
Pine siskin	7	1	5	22	1	1	3	12	25	2	14		13	3	>20	2	11	38	3	1	6	9	9	3	16	60	5		40		5	4	8	18	12	1
Purple finch								1																												
Red crossbill	5																																			
Redhead												18																								
Red-breasted nuthatch	2							1			1		2				1	1	1	1				1		3					3	2			3	
Red-eyed vireo					1			5	1									2												1	1			1	1	
Red-naped sapsucker	4						1													1					2						1	2		2		
Red-tailed hawk					1						2		2		1				3			1	1	1								2			1	1
Ring-necked duck		4			2		1					2						1																		
Red-winged blackbird					6		15	2	5	4					2			2			6						3	8	9	2		4	4	2		
Ruby-crowned kinglet	3	3	5	4	1	2	2	4	1	2	3		1	3	6	5	3	2	2	1	1	1		3	6		7				2	2	1	1	2	
Rufus hummingbird															1											1	1					1		1		
Savannah sparrow									8			10									1	1					1			1						
Sharp-shinned Hawk																								1												
Slate-coloured fox sparrow													1	1																						
Solitary sandpiper									1																											
Song sparrow	1						6	5		1			1		2						1	1	1			2	4		1		3	2	2	4	9	1
Sora					6		14								1												1					1				
Spotted sandpiper	2		2	2				6	11	2	8			1		2	7	3		1	3	12	4	9	7	4			6		11	2	2	10	8	10
Stellar's jay																	1			1																
Swainson's thrush	15	2	5	6	1	3	7	5		1	1		1	4	2	2	3	2	2	1			2	2	3	2	1				3	3	1		2	1
Townsend's solitaire	1			1				1						1			1						2													
Townsend's warbler	3	1	2	5		1		3		1	2		2	1	2		2	1	1	2				8		3						1	1			
Tree swallow	3			1	6		12	5	4	3	6				9	1		1			2	5			1			1	1	5		4	2	1		

Table 2.3-3. Avian census results, 2012. Maximum number of individuals of a species observed in any single visit to a particular area is presented (based on combined visual and auditory observations)

Ref vs Exp:	Reference				Exposed																															
Area code:	REFF	LML	CHCK	DRCK	FO15	LI24	GLM	AL4	CL11	FO51	KSP	FO52	CACK	SWCK	FOXL/ FO10	F022	FO29	THPD	WOPD	LEPD	GHPD	LCCPU/L	LI8	FO23	EL19	HA7	GO13	OTTO	GAPD	BOPD	MI2	MI16	MIWW	EL1	ELKO	LK02
Three-toed woodpecker	2																																			
Turkey vulture																																			1	
Varied thrush			1	2	1			2			2		3	2		1	4			3	1						1				1					
Veery																															7			3	3	
Vesper sparrow																									1											
Violet-green swallow							2																								1			1	1	
Warbling vireo	4		5	3	1		6	4			5		2			1	1	2	3		1	3	3		6	4					5	1	1	7	1	3
Western meadowlark																																				1
Western tanager							1											2		1												1			1	
Western wood-pewee	3			1			2											1													1	2	1		1	
White-breasted nuthatch	1																																			
White-crowned sparrow	2	1	1	1				6	4	2	2					2	1	2			3	1	2	1	1			1	1	1		4				
Willow flycatcher	4			7	2		4								4		1	2		1	2					1	1		1		4	5	3	6	3	
Wilson's snipe				1			7								>20																			1		
Wilson's warbler	3		1	2	1			3	2		2		2	1	3	3		1		1	1						2		1		2	2		1		
Winter wren											1							1					1													
Wood duck																																			2	
Yellow rumped warbler	4		4	5	20	2		11	1	4	30		3	1	5	3	5	3	2	3	2	4	1	3	1	3	1				1	3		1	4	2
Yellow warbler		2			1		9	3						3			2								1		1			1	5	2	2	4	4	1
Total number of species	**44**	**11**	**19**	**33**	**30**	**8**	**42**	**41**	**25**	**21**	**37**	**11**	**24**	**18**	**32**	**17**	**29**	**33**	**14**	**26**	**33**	**24**	**19**	**20**	**35**	**19**	**26**	**8**	**12**	**7**	**35**	**35**	**25**	**39**	**36**	**23**
Total observations	**118**	**18**	**49**	**97**	**99**	**14**	**227**	**154**	**147**	**38**	**160**	**56**	**49**	**31**	**169**	**40**	**74**	**103**	**33**	**44**	**74**	**80**	**47**	**69**	**115**	**104**	**49**	**22**	**83**	**14**	**106**	**84**	**56**	**349**	**108**	**83**

Source: Minnow (2014a)

Table 2.3-4. Bird species observed during spring 2012 sampling that have special conservation status within the East Kootenay District of British Columbia (BC Conservation Data Centre 2012)

Name category	English name	Scientific name	Provincial (BC)[a]	COSEWIC[b]	SARA[c]	Conservation framework (1-6, with 6 being highest priority)	Total number of visual and auditory observations at each site during any single visit																
							Reference					Exposed											
							REFF	LML	DRCK	GLM	AL4	CL11	FO51	KSP	CACK	THPD	GHPD	LCCPU/L	LI8	EL19	GO13	EL1	LK02
Bird	American avocet	*Recurvirostra americana*	Red	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	American bittern	*Botaurus lentiginosus*	Blue	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bald eagle	***Haliaeetus leucocephalus***	Yellow	NAR (May 1984)	-	6	-	-	-	-	-	-	1	2	-	-	-	-	1	2	1	1	1
	Barn swallow	***Hirundo rustica***	Blue	T (May 2011)	-	2	-	-	-	2	-	1	-	2	-	-	1	2	-	-	-	-	4
	Black tern	*Chlidonias niger*	Yellow	NAR (May 1996)	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bobolink	*Dolichonyx oryzivorus*	Blue	T (Apr 2010)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great blue heron, *herodias* subspecies	***Ardea herodias herodias***	Blue	-	-	2	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Le Conte's sparrow	*Ammodramus leconteii*	Blue	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lewis's woodpecker	*Melanerpes lewis*	Red	T (Apr 2010)	1-SC (Jun 2003)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Long-billed curlew	***Numenius americanus***	Blue	SC (May 2011)	1-SC (Jan 2005)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Olive-sided flycatcher	***Contopus cooperi***	Blue	T (Nov 2007)	1-T (Feb 2010)	2	-	1	3	-	1	-	-	1	1	1	-	-	-	-	-	-	1
	Rusty blackbird	*Euphagus carolinus*	Blue	SC (Apr 2006)	1-SC (Mar 2009)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sandhill crane	*Grus canadensis*	Yellow	NAR (May 1979)		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Short-eared owl	*Asio flammeus*	Blue	SC (Mar 2008)	3 (Mar 2005)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Swainson's hawk	*Buteo swainsoni*	Red	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Upland sandpiper	*Bartramia longicauda*	Red	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Western screech-owl, *macfarlanei* subspecies	*Megascops kennicottii macfarlanei*	Red	E (May 2002)	1-E (Jan 2005)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Minnow (2014a)

Source of listed species in East Kootenay Regional District: http://a100.gov.bc.ca/pub/eswp/search.do (accessed on January 30, 2012).

Notes:

Bold font indicates species that were observed in 2012.

[a] **BC List**

Red: Includes any indigenous species or subspecies that have- or are candidates for - Extirpated, Endangered, or Threatened status in BC. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Not all Red-listed taxa will necessarily become formally designated. Placing taxa on these lists flags them as being at risk and requiring investigation.

Blue: Includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in BC. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.

Yellow: Includes species that are apparently secure and not at risk of extinction. Yellow-listed species may have Red- or Blue-listed subspecies.

[b] **COSEWIC (Committee On the Status of Endangered Wildlife In Canada)**

E = ENDANGERED: A species facing imminent extirpation or extinction.

T = THREATENED: A species that is likely to become endangered if limiting factors are not reversed.

SC = SPECIAL CONCERN: A species of special concern because of characteristics that make it is particularly sensitive to human activities or natural events.

NAR = NOT AT RISK: A species that has been evaluated and found to be not at risk.

C = CANDIDATE: A species that is on the short-list for upcoming assessment.

[c] **SARA (Species At Risk Act)**

Schedule 1 - Species status confirmed based on 1999 COSEWIC criteria.

Schedule 2 - Species status to be reassessed to 1999 COSEWIC criteria (i.e. schedule 1).

Schedule 3 - Species status to be reassessed to 1999 COSEWIC criteria (i.e. schedule 1).

Table 2.3-5. Recent relative abundance of fish species in Lake Koocanusa

Common name	Scientific name	Relative abundance	Abundance trend	Native*
Game Fish Species				
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	C	D	Y
Rainbow trout	*Oncorhynchus mykiss*	C	D	Y
Bull trout	*Salvelinus confluentus*	C	I	Y
Brook trout	*Salvelinus fontinalis*	R	U	N
Lake trout	*Salvelinus namaycush*	R	U	N
Kokanee salmon	*Oncorhynchus nerka*	A	U	N
Mountain whitefish	*Prosopium williamsoni*	R	D	Y
Burbot	*Lota lota*	C	D	Y
Largemouth bass	*Micropterus salmoides*	R	U	N
Northern pike	*Esox lucius*	R	U	N
Nongame Fish Species				
Pumpkinseed	*Lepomis gibbosus*	R	U	N
Yellow perch	*Perca flavescens*	C	I	N
Redside shiner	*Richardsonius balteatus*	R	D	Y
Peamouth	*Mylocheilus caurinus*	A	I	Y
Northern pikeminnow	*Ptychocheilus oregonensis*	A	I	Y
Largescale sucker	*Catostomus macrocheilus*	A	S	Y
Longnose sucker	*Catostomus catostomus*	C	D	Y

Notes:

Current relative abundance (A = abundant, C = common, R = rare) and

Abundance trend from 1975 to 2000 (I = increasing, S = stable, D = decreasing, U = unknown) of fish species present in Lake Koocanusa.

* Native species are designated Y, and non-natives N

Source: Dunnigan et al. (2009)

Table 3.1-1. Comparison of DOC, TOC, TSS, turbidity, and alkalinity concentrations at Order stations to 95th percentile reference concentrations

Parameter and time period	Number (and percent) of samples > 95th percentile of reference concentrations / total number of samples[a]				
	GH_FR1 (MU1)	LC_LC5 (MU2)	GH_ER1 (MU3)	EV_ER4 (MU4)	EV_ER1 (MU4)
Dissolved Organic Carbon					
Freshet	0/11 (0%)	0/12 (0%)	0/13 (0%)	0/30 (0%)	0/30 (0%)
Non-freshet	0/21 (0%)	0/23 (0%)	0/26 (0%)	0/31 (0%)	0/31 (0%)
Total Organic Carbon					
Freshet	1/11 (9%)	0/13 (0%)	0/12 (0%)	1/30 (3.3%)	1/31 (3.2%)
Non-freshet	0/21 (0%)	0/22 (0%)	0/27 (0%)	0/31 (0%)	0/30 (0%)
Total Suspended Solids					
Freshet	4/46 (9%)	7/47(15%)	10/47 (21%)	10/42 (24%)	10/42 (24%)
Non-freshet	0/26 (0%)	0/29 0%)	0/30 (0%)	0/33 (0%)	3/35 (9%)
Turbidity					
Freshet	6/46 (13%)	4/47 (8.5%)	7/46 (15.2%)	3/42 (7.1%)	4/42 (9.5%)
Non-freshet	0/23 (0%)	0/29 (0%)	0/28 (0%)	0/32 (0%)	3/34 (8.8%)
Alkalinity					
Freshet	10/24 (42%)	5/12 (42%)	0/25 (0%)	5/30 (17%)	2/30 (6.7%)
Non-freshet	5/23 (22%)	0/23 (0%)	0/25 (0%)	0/31 (0%)	0/31 (0%)

Notes:

[a] The Order station IDs for these locations are FR4 for GH_FR1, FR5 for LC_LC5, ER1 for GH_ER1, ER2 for EV_ER4, and ER3 for EV_ER1.

Table 3.1-2. Identification of COPCs and primary COPCs

Constituent	No. Locations with at least one detected concentration > benchmark or WQG / total no. locations	Percent of all mining-exposed samples with detected concentrations > benchmark or WQG[a]	Constituent identified as a COPC?	Constituent identified as a primary COPC?
Non-metals				
Chloride	0/71	0	no	no
Fluoride	0/70	0	no	no
Nitrate	31/71	22	yes	yes
Nitrite	22/71	4.9	yes	no
Ammonia	7/71	1.2	yes	no
pH[b]	0/71	0	no	no
Sulphate	21/71	19	yes	yes
Metals and Metalloids				
Aluminum	24/71	1.4	yes	no
Antimony	0/71	0	no	no
Arsenic	4/71	0.19	yes	no
Barium	4/71	0.19	yes	no
Bismuth	0/71	0	no	no
Boron	0/71	0	no	no
Cadmium	6/71	2.7	yes	no
Chromium	53/71	7.4	yes	no
Cobalt	9/71	3.9	yes	no
Copper	19/71	0.90	yes	no
Iron	4/71	0.14	yes	no
Lead	1/71	0.03	yes	no
Manganese	1/71	0.03	yes	no
Molybdenum	0/71	0	no	no
Nickel	2/71	0.35	yes	no
Potassium	0/70	0	no	no
Selenium	31/71	35	yes	yes
Silver	7/71	0.39	yes	no
Strontium	0/71	0	no	no
Thallium	3/71	0.23	yes	no
Tin	0/71	0	no	no
Titanium	0/70	0	no	no
Uranium	6/71	5.7	yes	no
Vanadium	23/71	1.9	yes	no
Zinc	4/71	0.13	yes	no
PAHs				

Table 3.1-2. Identification of COPCs and primary COPCs

Constituent	No. Locations with at least one detected concentration > benchmark or WQG / total no. locations	Percent of all mining-exposed samples with detected concentrations > benchmark or WQG[a]	Constituent identified as a COPC?	Constituent identified as a primary COPC?
Acenaphthene	0/27	0	no	no
Anthracene	0/27	0	no	no
Benzo(a)anthracene	0/27	0	no	no
Benzo(a)pyrene	2/27	0.71	yes	no
Fluoranthene	0/27	0	no	no
Fluorene	0/27	0	no	no
Naphthalene	0/27	0	no	no
Phenanthrene	4/27	2.4	yes	no
Pyrene	3/27	2.4	yes	no

Notes:

[a] All non-detected concentrations were assumed to be below the benchmark or WQG.

[b] For pH, represents the number of locations with a value above the upper WQG and below the lower WQG.

Table 3.1-3. Locations in MU1 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs																			
	Nitrate		Selenium		Sulphate		Nitrite		Ammonia		Aluminum		Barium		Cadmium		Chromium		Cobalt		Copper		Uranium		Vanadium		Zinc	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers in Fording River																												
FR_FR1	0/49	0.0	0/53	0.0	0/50	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	2/49	4.1	0/49	0.0	0/49	0.0	0/49	0.0
FR_FRABEC1	0/15	0.0	0/48	0.0	0/15	0.0	9/15	60	0/15	0.0	0/15	0.0	0/41	0.0	0/15	0.0	1/41	2.4	0/41	0.0	0/41	0.0	0/41	0.0	0/41	0.0	0/41	0.0
FR_MULTIPLATE	0/17	0.0	0/51	0.0	0/18	0.0	8/17	47	0/17	0.0	0/17	0.0	0/44	0.0	0/17	0.0	1/44	2.3	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0
FR_BXLBDG	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0	0/2	0.0
FR_FR2	0/77	0.0	0/84	0.0	0/78	0.0	3/77	3.9	0/76	0.0	0/77	0.0	0/77	0.0	0/77	0.0	4/77	5.2	0/77	0.0	1/77	1.3	0/77	0.0	1/77	1.3	0/77	0.0
GH_FR3	2/45	4.4	0/43	0.0	0/47	0.0	3/45	6.7	0/45	0.0	0/29	0.0	0/30	0.0	0/29	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0
GH_FR	7/103	6.8	13/109	12	0/105	0.0	9/103	8.7	0/102	0.0	1/88	1.1	0/89	0.0	0/88	0.0	5/89	5.6	0/88	0.0	0/89	0.0	0/89	0.0	1/89	1.1	0/89	0.0
GH_PC2	24/30	80	17/52	33	0/33	0.0	0/30	0.0	0/31	0.0	0/27	0.0	0/28	0.0	0/27	0.0	0/28	0.0	0/28	0.0	0/28	0.0	0/28	0.0	0/28	0.0	0/28	0.0
FR_FR5	25/44	57	5/44	11	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0	0/44	0.0
LC_FRUSDC	10/37	27	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0	2/37	5.4	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0	0/37	0.0
LC_FRB	5/18	28	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0	1/18	5.6	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0	0/18	0.0
GH_FR1	0/47	0.0	0/45	0.0	0/49	0.0	0/47	0.0	0/47	0.0	1/31	3.2	0/32	0.0	0/31	0.0	2/32	6.3	0/32	0.0	0/32	0.0	0/32	0.0	0/32	0.0	0/32	0.0
Total Mainstem Receivers	**73/484**	**15**	**35/586**	**6.0**	**0/496**	**0.0**	**32/484**	**6.6**	**0/483**	**0.0**	**2/434**	**0.46**	**0/491**	**0.0**	**0/434**	**0.0**	**16/491**	**3.3**	**0/490**	**0.0**	**3/491**	**0.61**	**0/491**	**0.0**	**2/491**	**0.41**	**0/491**	**0.0**
Mine-Influenced Tributaries																												
FR_HC2	0/65	0.0	0/65	0.0	0/66	0.0	0/65	0.0	0/65	0.0	0/65	0.0	0/65	0.0	0/65	0.0	3/65	4.6	0/65	0.0	1/65	1.5	0/65	0.0	0/65	0.0	0/65	0.0
FR_HC1	0/67	0.0	0/67	0.0	0/68	0.0	1/67	1.5	0/66	0.0	0/67	0.0	0/67	0.0	0/67	0.0	1/67	1.5	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0
FR_CC1	68/73	93	74/74	100	0/74	0.0	53/73	73	25/73	34	0/73	0.0	2/74	2.7	0/73	0.0	1/74	1.4	6/74	8.1	0/74	0.0	0/74	0.0	0/74	0.0	0/74	0.0
FR_NGD1	0/67	0.0	0/67	0.0	0/68	0.0	1/67	1.5	0/67	0.0	1/67	1.5	0/67	0.0	0/67	0.0	1/67	1.5	0/67	0.0	1/67	1.5	0/67	0.0	0/67	0.0	0/67	0.0
FR_EC1	1/81	1.2	88/88	100	78/82	95	1/81	1.2	2/81	2.5	0/81	0.0	0/82	0.0	0/81	0.0	1/82	1.2	2/82	2.4	0/82	0.0	63/82	77	0/82	0.0	0/82	0.0
FR_LEESLK	0/10	0.0	0/10	0.0	6/10	60	1/10	10	0/10	0.0	0/10	0.0	0/10	0.0	0/10	0.0	1/10	10	0/10	0.0	0/10	0.0	0/10	0.0	0/10	0.0	0/10	0.0
FR_NL1	2/4	50	0/4	0.0	0/5	0.0	0/4	0.0	2/4	50	0/4	0.0	0/4	0.0	0/4	0.0	0/4	0.0	0/4	0.0	0/4	0.0	0/4	0.0	0/4	0.0	1/4	25
FR_SP1	0/66	0.0	1/66	1.5	8/67	12	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	1/66	1.5	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0
FR_STPWSEEP	0/22	0.0	0/29	0.0	2/22	9.1	0/22	0.0	0/22	0.0	0/22	0.0	0/22	0.0	8/22	36	0/22	0.0	0/22	0.0	0/22	0.0	0/22	0.0	0/22	0.0	0/22	0.0
FR_STPSWSEEP	0/27	0.0	0/34	0.0	2/27	7.4	0/27	0.0	0/27	0.0	0/27	0.0	0/27	0.0	0/27	0.0	1/27	3.7	0/27	0.0	0/27	0.0	0/27	0.0	0/27	0.0	0/27	0.0
FR_SKP1	21/21	100	9/20	45	4/21	19	6/21	29	0/21	0.0	0/20	0.0	0/20	0.0	7/20	35	0/20	0.0	0/20	0.0	0/20	0.0	0/20	0.0	0/20	0.0	0/20	0.0
GH_SC1	0/22	0.0	22/22	100	20/22	91	4/22	18	0/22	0.0	0/10	0.0	0/11	0.0	0/10	0.0	0/11	0.0	0/11	0.0	0/11	0.0	1/11	9.1	0/11	0.0	0/11	0.0
GH_SC2	4/31	13	29/29	100	34/34	100	0/31	0.0	0/32	0.0	0/27	0.0	0/27	0.0	0/27	0.0	1/27	3.7	0/27	0.0	0/27	0.0	23/27	85	0/27	0.0	0/27	0.0
FR_SKP2	16/16	100	9/16	56	0/16	0.0	3/16	19	0/16	0.0	0/16	0.0	0/16	0.0	3/16	19	0/16	0.0	0/16	0.0	0/16	0.0	0/16	0.0	0/16	0.0	0/16	0.0
GH_CC1	0/54	0.0	52/52	100	56/57	98	0/54	0.0	0/55	0.0	0/38	0.0	0/39	0.0	0/38	0.0	0/39	0.0	0/39	0.0	0/39	0.0	32/39	82	0/39	0.0	0/39	0.0
GH_PC1	0/53	0.0	31/51	61	1/56	1.8	0/53	0.0	0/54	0.0	0/37	0.0	0/38	0.0	0/37	0.0	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0
GH_RLP	0/32	0.0	0/30	0.0	0/33	0.0	31/32	97	6/31	19	0/28	0.0	0/29	0.0	0/28	0.0	1/29	3.4	0/29	0.0	0/29	0.0	0/29	0.0	10/29	34	0/29	0.0
GH_GH1	0/54	0.0	36/52	69	33/57	58	0/54	0.0	0/55	0.0	0/38	0.0	0/39	0.0	0/38	0.0	5/39	13	0/39	0.0	0/39	0.0	0/39	0.0	4/39	10	0/39	0.0
Total Mine-Influenced Tributaries	**112/765**	**15**	**351/776**	**45**	**244/785**	**31**	**101/765**	**13**	**35/767**	**4.6**	**1/696**	**0.14**	**2/703**	**0.28**	**18/696**	**2.6**	**17/703**	**2.4**	**8/703**	**1.1**	**2/703**	**0.28**	**119/703**	**17**	**14/703**	**2.0**	**1/703**	**0.14**

Table 3.1-3. Locations in MU1 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs																				
	Nitrate		Selenium		Sulphate		Nitrite		Ammonia		Aluminum		Barium		Cadmium		Chromium		Cobalt		Copper		Uranium		Vanadium		Zinc	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
TOTAL Mainstem Receivers and Mine-Influenced Tributaries	**185/1,249**	**15**	**386/1,362**	**28**	**244/1,281**	**19**	**133/1,249**	**11**	**35/1,250**	**2.8**	**3/1,130**	**0.27**	**2/1,194**	**0.17**	**18/1,130**	**1.6**	**33/1,194**	**2.8**	**8/1,193**	**0.67**	**5/1,194**	**0.42**	**119/1,194**	**10**	**16/1,194**	**1.3**	**1/1,194**	**0.08**
Reference																												
FR_CH1	0/39	0.0	0/40	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	1/39	2.6	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0
FR_HC3	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0
FR_KC4	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0	0/13	0.0
FR_UFR1	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/68	0.0	0/67	0.0	0/67	0.0	0/67	0.0	2/67	3.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0
LC_DC1	1/33	3.0	0/30	0.0	0/33	0.0	1/33	3.0	0/33	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	1/30	3.3
Total Reference	**1/201**	**0.50**	**0/199**	**0.0**	**0/201**	**0.0**	**1/201**	**0.50**	**0/202**	**0.0**	**0/198**	**0.0**	**0/198**	**0.0**	**0/198**	**0.0**	**3/198**	**1.5**	**0/198**	**0.0**	**0/198**	**0.0**	**0/198**	**0.0**	**0/198**	**0.0**	**1/198**	**0.51**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-2 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

COPC – constituent of potential concern

MU – management unit

WQG – water quality guideline

Table 3.1-4. Locations in MU2 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs													
	Nitrate		Selenium		Sulphate		Nitrite		Cadmium		Chromium)		Cobalt		Copper		Uranium		Vanadium	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers in Fording River																				
LC_LC6	8/64	13	25/29	86	0/64	0.0	0/64	0.0	0/28	0.0	2/29	6.9	0/29	0.0	0/29	0.0	0/29	0.0	0/29	0.0
LC_LC5	5/81	6.2	34/39	87	0/81	0.0	0/81	0.0	0/39	0.0	2/39	5.1	0/39	0.0	1/39	2.6	0/39	0.0	0/39	0.0
Total Mainstem Receivers	**13/145**	**9.0**	**59/68**	**87**	**0/145**	**0.0**	**0/145**	**0.0**	**0/67**	**0.0**	**4/68**	**5.9**	**0/68**	**0.0**	**1/68**	**1.5**	**0/68**	**0.0**	**0/68**	**0.0**
Mine-Influenced Tributaries Discharging to Line Creek																				
LC_WLC	0/83	0.0	83/83	100	66/83	80	0/83	0.0	34/79	43	0/83	0.0	0/83	0.0	0/83	0.0	54/83	65	0/83	0.0
Line Creek																				
LC_LC2	0/84	0.0	1/43	2.3	0/84	0.0	0/84	0.0	0/42	0.0	1/43	2.3	0/42	0.0	0/43	0.0	0/43	0.0	0/42	0.0
LC_LC3	28/82	34	69/69	100	0/82	0.0	2/82	2.4	28/66	42	5/69	7.2	2/69	2.9	0/69	0.0	0/69	0.0	3/69	4.3
LC_LC4	4/81	4.9	61/81	75	0/81	0.0	0/81	0.0	0/80	0.0	1/81	1.2	0/81	0.0	1/81	1.2	0/81	0.0	0/81	0.0
Total Mine-Influenced Tributaries	**32/330**	**10**	**214/276**	**78**	**66/330**	**20**	**2/330**	**0.61**	**62/267**	**23**	**7/276**	**2.5**	**2/275**	**0.73**	**1/276**	**0.36**	**54/276**	**20**	**3/275**	**1.1**
TOTAL Mainstem Receivers and Mine-Influenced Tributaries	**45/475**	**9.5**	**273/344**	**79**	**66/475**	**14**	**2/475**	**0.42**	**62/334**	**19**	**11/344**	**3.2**	**2/343**	**0.58**	**2/344**	**0.58**	**54/344**	**16**	**3/343**	**0.87**
Reference																				
LC_GRCK	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0	2/38	5.3	0/38	0.0	0/38	0.0	0/38	0.0	0/38	0.0
LC_LC1	0/41	0.0	1/19	5.3	0/41	0.0	0/41	0.0	1/19	5.3	1/19	5.3	0/19	0.0	0/19	0.0	0/19	0.0	0/19	0.0
LC_SLC	0/32	0.0	0/32	0.0	0/32	0.0	0/32	0.0	0/32	0.0	1/32	3.1	0/32	0.0	0/32	0.0	0/32	0.0	0/32	0.0
Total Reference	**0/111**	**0.0**	**1/89**	**1.1**	**0/111**	**0.0**	**0/111**	**0.0**	**1/89**	**1.1**	**4/89**	**4.5**	**0/89**	**0.0**	**0/89**	**0.0**	**0/89**	**0.0**	**0/89**	**0.0**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-3 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

COPC – constituent of potential concern

MU – management unit

WQG – water quality guideline

Table 3.1-5. Locations in MU3 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs																									
	Nitrate		Selenium		Sulphate		Nitrite		Ammonia		Aluminum		Arsenic		Chromium (Total)		Cobalt		Copper		Iron		Silver		Vanadium		Zinc	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers in Elk River																																
GH_ER1	0/53	0.0	0/53	0.0	0/56	0.0	0/53	0.0	0/56	0.0	1/40	2.5	0/40	0.0	6/40	15	0/40	0.0	0/40	0.0	0/40	0.0	0/40	0.0	0/40	0.0	0/40	0.0
Mine-Influenced Tributaries																																
GH_WILLOW	0/55	0.0	0/55	0.0	0/56	0.0	0/55	0.0	0/56	0.0	4/31	13	0/31	0.0	2/31	6.5	0/31	0.0	1/31	3.2	0/31	0.0	0/31	0.0	0/31	0.0	0/31	0.0
GH_WADE	0/32	0.0	0/32	0.0	0/33	0.0	0/32	0.0	0/33	0.0	2/21	10	0/21	0.0	4/21	19	0/21	0.0	1/21	4.8	0/21	0.0	0/21	0.0	1/21	4.8	0/21	0.0
GH_WILLOW_S	0/6	0.0	0/6	0.0	0/7	0.0	0/6	0.0	0/7	0.0	1/6	17	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0
GH_COUGAR	0/17	0.0	0/17	0.0	0/18	0.0	0/17	0.0	0/18	0.0	1/10	10	0/10	0.0	1/10	10	0/10	0.0	0/10	0.0	0/10	0.0	1/10	10	0/10	0.0	0/10	0.0
GH_MC1	0/36	0.0	0/36	0.0	0/37	0.0	0/36	0.0	0/37	0.0	1/23	4.3	0/23	0.0	3/23	13	0/23	0.0	0/23	0.0	0/23	0.0	0/23	0.0	0/23	0.0	0/23	0.0
GH_LC2	34/34	100	20/34	59	0/35	0.0	3/34	8.8	0/35	0.0	2/24	8.3	0/24	0.0	3/24	13	1/24	4.2	0/24	0.0	1/24	4.2	0/24	0.0	2/24	8.3	0/24	0.0
GH_WC2	40/40	100	33/40	83	8/42	19	5/40	13	4/42	10	1/28	3.6	1/28	3.6	7/28	25	9/28	32	1/28	3.6	0/28	0.0	1/28	3.6	5/28	18	0/28	0.0
GH_TC1	42/43	98	43/43	100	20/46	43	0/43	0.0	0/46	0.0	0/29	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/30	0.0	0/29	0.0	0/30	0.0	0/30	0.0	0/30	0.0
Total Mine-Influenced	**116/263**	**44**	**96/263**	**37**	**28/274**	**10**	**8/263**	**3.0**	**4/274**	**1.5**	**12/172**	**7.0**	**1/173**	**0.58**	**20/173**	**12**	**10/173**	**5.8**	**3/173**	**1.7**	**1/172**	**0.58**	**2/173**	**1.2**	**8/173**	**4.6**	**0/173**	**0.0**
TOTAL Mainstem Receivers and Mine-Influenced Tributaries	**116/316**	**37**	**96/316**	**30**	**28/330**	**8.5**	**8/316**	**2.5**	**4/330**	**1.2**	**13/212**	**6.1**	**1/213**	**0.47**	**26/213**	**12**	**10/213**	**4.7**	**3/213**	**1.4**	**1/212**	**0.47**	**2/213**	**0.94**	**8/213**	**3.8**	**0/213**	**0.0**
Reference																																
GH_BR_F	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	0/6	0.0	4/6	67	0/6	0.0	3/6	50	0/6	0.0	1/6	17	0/6	0.0	0/6	0.0	0/6	0.0	2/6	33
GH_ER2	0/44	0.0	0/44	0.0	1/45	2.2	0/44	0.0	0/45	0.0	0/31	0.0	0/31	0.0	2/31	6.5	0/31	0.0	1/31	3.2	0/31	0.0	0/31	0.0	0/31	0.0	0/31	0.0
GH_WOLF	0/32	0.0	0/32	0.0	0/33	0.0	0/32	0.0	0/33	0.0	3/21	14	0/21	0.0	3/21	14	0/21	0.0	1/21	4.8	0/21	0.0	0/21	0.0	1/21	4.8	0/21	0.0
Total Reference	**0/82**	**0.0**	**0/82**	**0.0**	**1/84**	**1.2**	**0/82**	**0.0**	**0/84**	**0.0**	**7/58**	**12**	**0/58**	**0.0**	**8/58**	**14**	**0/58**	**0.0**	**3/58**	**5.2**	**0/58**	**0.0**	**0/58**	**0.0**	**1/58**	**1.7**	**2/58**	**3.4**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-4 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

COPC – constituent of potential concern

MU – management unit

WQG – water quality guideline

Table 3.1-6a. Locations in MU4 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs															
	Nitrate		Selenium		Sulphate		Nitrite		Ammonia		Aluminum		Arsenic		Barium		Cadmium		Chromium		Cobalt	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers in Elk River																						
EV_ER4	32/67	48	3/67	4.5	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	9/67	13	0/67	0.0
EV_ER3B	19/68	28	0/68	0.0	0/68	0.0	0/68	0.0	0/68	0.0	1/68	1.5	0/68	0.0	0/68	0.0	0/68	0.0	11/68	16	0/68	0.0
EV_ER2	8/60	13	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	9/60	15	0/60	0.0
CM_MC2	3/84	3.6	0/81	0.0	0/87	0.0	0/84	0.0	0/88	0.0	0/55	0.0	0/82	0.0	0/82	0.0	0/55	0.0	14/82	17	2/82	2.4
CM_MCTM	0/42	0.0	0/42	0.0	0/43	0.0	0/42	0.0	0/45	0.0	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	2/42	4.8	0/42	0.0
EV_MC3	0/66	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	1/67	1.5	0/67	0.0	0/67	0.0	0/67	0.0	7/67	10	0/67	0.0
EV_MC1	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	2/66	3.0	0/66	0.0	0/66	0.0	0/66	0.0	10/66	15	0/66	0.0
EV_ER1	1/68	1.5	0/68	0.0	0/68	0.0	0/68	0.0	0/68	0.0	2/68	2.9	0/68	0.0	0/68	0.0	0/68	0.0	9/68	13	0/68	0.0
Total Mainstem Receivers	**63/521**	**12**	**3/519**	**0.58**	**0/526**	**0.0**	**0/522**	**0.0**	**0/529**	**0.0**	**6/493**	**1.2**	**0/520**	**0.0**	**0/520**	**0.0**	**0/493**	**0.0**	**71/520**	**14**	**2/520**	**0.38**
Mine-Influenced Tributaries Discharging to Elk River																						
EV_HC1	0/62	0.0	58/62	94	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	2/62	3.2	0/62	0.0
EV_SM1	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	0/49	0.0	7/49	14	0/49	0.0	0/49	0.0	0/49	0.0	14/49	29	0/49	0.0
EV_GC2	8/70	11	80/80	100	0/70	0.0	0/70	0.0	0/70	0.0	1/70	1.4	0/80	0.0	0/80	0.0	0/70	0.0	25/80	31	0/80	0.0
EV_OC1	0/63	0.0	0/63	0.0	0/63	0.0	0/63	0.0	0/63	0.0	1/63	1.6	0/63	0.0	0/63	0.0	0/63	0.0	3/63	4.8	0/63	0.0
Mine-Influenced Tributaries Discharging to Michel Creek																						
CM_SPSP	0/35	0.0	0/19	0.0	0/38	0.0	0/35	0.0	0/39	0.0	1/18	5.6	0/19	0.0	0/19	0.0	0/18	0.0	2/19	11	0/19	0.0
CM_SPD	37/50	74	0/49	0.0	38/53	72	12/50	24	0/54	0.0	1/32	3.1	2/49	4.1	2/49	4.1	0/32	0.0	7/49	14	49/49	100
CM_CC1	62/97	64	1/95	1.1	52/100	52	4/97	4.1	0/101	0.0	1/67	1.5	2/96	2.1	1/96	1.0	1/67	1.5	4/96	4.2	49/96	51
CM_AG2	0/39	0.0	0/39	0.0	0/40	0.0	0/39	0.0	0/42	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	1/39	2.6	0/39	0.0
EV_EC1	67/67	100	67/67	100	67/67	100	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0
EV_SP1	52/53	98	52/53	98	46/53	87	1/53	1.9	0/53	0.0	0/53	0.0	0/53	0.0	0/53	0.0	0/53	0.0	4/53	7.5	0/53	0.0
EV_MG1	0/47	0.0	47/47	100	11/47	23	2/47	4.3	1/47	2.1	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	3/47	6.4	0/47	0.0
EV_GT1	39/39	100	39/39	100	33/39	85	0/39	0.0	0/39	0.0	1/39	2.6	0/39	0.0	0/39	0.0	0/39	0.0	3/39	7.7	0/39	0.0
EV_AQ1	0/20	0.0	0/20	0.0	0/20	0.0	0/20	0.0	0/20	0.0	3/20	15	1/20	5.0	1/20	5.0	0/20	0.0	12/20	60	2/20	10
EV_BC1	67/67	100	67/67	100	60/67	90	4/67	6.0	2/67	3.0	0/67	0	0/67	0.0	0/67	0.0	0/67	0.0	3/67	4.5	0/67	0.0
Total Mine-Influenced Tributaries	**332/758**	**44**	**411/749**	**55**	**307/768**	**40**	**23/758**	**3.0**	**3/773**	**0.39**	**16/693**	**2.3**	**5/750**	**0.67**	**4/750**	**0.53**	**1/693**	**0.1**	**83/750**	**11**	**100/750**	**13**
TOTAL Mainstem Receivers and Mine-Influenced Tributaries	**395/1,279**	**31**	**414/1,268**	**33**	**307/1,294**	**24**	**23/1,280**	**1.8**	**3/1,302**	**0.23**	**22/1,186**	**1.9**	**5/1,270**	**0.39**	**4/1,270**	**0.31**	**1/1,186**	**0.1**	**154/1,270**	**12**	**102/1,270**	**8.0**
Reference																						
CM_AG1	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0

Table 3.1-6a. Locations in MU4 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Primary COPCs						Other COPCs															
	Nitrate		Selenium		Sulphate		Nitrite		Ammonia		Aluminum		Arsenic		Barium		Cadmium		Chromium		Cobalt	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
CM_MC1	0/82	0.0	0/80	0.0	0/84	0.0	0/82	0.0	0/86	0.0	4/55	7.3	0/81	0.0	0/81	0.0	0/55	0.0	5/81	6.2	0/81	0.0
CM_PC1	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0
CM_WC1	0/9	0.0	0/9	0.0	0/9	0.0	0/9	0.0	0/9	0.0	1/9	11	0/9	0.0	0/9	0.0	0/9	0.0	1/9	11	0/9	0.0
Total Reference	**0/110**	**0.0**	**0/108**	**0.0**	**0/112**	**0.0**	**0/110**	**0.0**	**0/114**	**0.0**	**5/83**	**6.0**	**0/109**	**0.0**	**0/109**	**0.0**	**0/83**	**0.0**	**6/109**	**5.5**	**0/109**	**0.0**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-5 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

COPC – constituent of potential concern

MU – management unit

WQG – water quality guideline

Table 3.1-6b.Locations in MU4 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Other COPCs																					
	Copper		Iron		Nickel		Silver		Thallium		Uranium		Vanadium		Zinc		Benzo(a)pyrene		Phenanthrene		Pyrene	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers in Elk River																						
EV_ER4	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	1/67	1.5	0/67	0.0	0/27	0.0	0/27	0.0	0/27	0.0
EV_ER3B	0/68	0.0	1/68	1.5	0/68	0.0	0/68	0.0	0/68	0.0	0/68	0.0	3/68	4.4	0/68	0.0	0/28	0.0	0/28	0.0	0/28	0.0
EV_ER2	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	0/60	0.0	1/60	1.7	0/60	0.0	0/23	0.0	0/23	0.0	0/23	0.0
CM_MC2	1/82	1.2	0/55	0.0	0/82	0.0	0/82	0.0	0/82	0.0	0/82	0.0	0/82	0.0	0/82	0.0	na	na	na	na	na	na
CM_MCTM	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	0/42	0.0	na	na	na	na	na	na
EV_MC3	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/28	0.0	0/28	0.0	0/28	0.0
EV_MC1	2/66	3.0	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	0/66	0.0	3/66	4.5	1/66	1.5	0/27	0.0	0/27	0.0	0/27	0.0
EV_ER1	2/68	2.9	0/68	0.0	0/68	0.0	0/68	0.0	0/68	0.0	0/68	0.0	2/68	2.9	1/68	1.5	0/28	0.0	0/28	0.0	0/28	0.0
Total Mainstem Receivers	**5/520**	**1.0**	**1/493**	**0.20**	**0/520**	**0.0**	**0/520**	**0.0**	**0/520**	**0.0**	**0/520**	**0.0**	**10/520**	**1.9**	**2/520**	**0.38**	**0/161**	**0.0**	**0/161**	**0.0**	**0/161**	**0.0**
Mine-Influenced Tributaries Discharging to Elk River																						
EV_HC1	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/62	0.0	0/28	0.0	0/28	0.0	0/28	0.0
EV_SM1	1/49	2.0	1/49	2.0	0/49	0.0	1/49	2.0	0/49	0.0	0/49	0.0	5/49	10	0/49	0.0	0/21	0.0	0/21	0.0	0/21	0.0
EV_GC2	0/80	0.0	0/70	0.0	0/80	0.0	0/80	0.0	0/80	0.0	0/80	0.0	1/80	1.3	0/80	0.0	2/29	6.9	7/29	24	8/29	28
EV_OC1	1/63	1.6	0/63	0.0	0/63	0.0	0/63	0.0	0/63	0.0	0/63	0.0	1/63	1.6	0/63	0.0	1/25	4.0	1/25	4.0	1/25	4.0
Mine-Influenced Tributaries Discharging to Michel Creek																						
CM_SPSP	0/19	0.0	0/18	0.0	0/19	0.0	0/19	0.0	0/19	0.0	0/19	0.0	1/19	5.3	0/19	0.0	na	na	na	na	na	na
CM_SPD	2/49	4.1	0/32	0.0	10/49	20	2/49	4.1	2/49	4.1	0/49	0.0	2/49	4.1	0/49	0.0	na	na	na	na	na	na
CM_CC1	3/96	3.1	0/67	0.0	0/96	0.0	2/96	2.1	2/96	2.1	0/96	0.0	2/96	2.1	0/96	0.0	na	na	na	na	na	na
CM_AG2	1/39	2.6	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	na	na	na	na	na	na
EV_EC1	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/28	0.0	0/28	0.0	0/28	0.0
EV_SP1	0/53	0.0	0/53	0.0	0/53	0.0	1/53	1.9	0/53	0.0	3/53	5.7	1/53	1.9	0/53	0.0	0/19	0.0	0/19	0.0	0/19	0.0
EV_MG1	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	0/47	0.0	0/23	0.0	0/23	0.0	0/23	0.0
EV_GT1	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	0/39	0.0	1/39	2.6	0/39	0.0	0/21	0.0	1/21	4.8	1/21	4.8
EV_AQ1	4/20	20	1/20	5.0	1/20	5.0	4/20	20	3/20	15	0/20	0.0	7/20	35	1/20	5.0	0/7	0.0	1/7	14	0/7	0.0
EV_BC1	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	0/67	0.0	1/67	1.5	0/67	0.0	0/27	0.0	0/27	0.0	0/27	0.0
Total Mine-Influenced	**12/750**	**1.6**	**2/693**	**0.29**	**11/750**	**1.5**	**10/750**	**1.3**	**7/750**	**0.93**	**3/750**	**0.40**	**22/750**	**2.9**	**1/750**	**0.13**	**3/228**	**1.3**	**10/228**	**4.4**	**10/228**	**4.4**
TOTAL Mainstem Receivers and Mine-Influenced Tributaries	**17/1,270**	**1.3**	**3/1,186**	**0.25**	**11/1,270**	**0.87**	**10/1,270**	**0.79**	**7/1,270**	**0.55**	**3/1,270**	**0.24**	**32/1,270**	**2.5**	**3/1,270**	**0.24**	**3/387**	**0.78**	**10/389**	**2.6**	**10/389**	**2.6**
Reference																						
CM_AG1	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	0/11	0.0	na	na	na	na	na	na

Table 3.1-6b.Locations in MU4 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Other COPCs																					
	Copper		Iron		Nickel		Silver		Thallium		Uranium		Vanadium		Zinc		Benzo(a)pyrene		Phenanthrene		Pyrene	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
CM_MC1	1/81	1.2	0/55	0.0	0/81	0.0	0/81	0.0	0/81	0.0	0/81	0.0	1/81	1.2	2/81	2.5	na	na	na	na	na	na
CM_PC1	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	0/8	0.0	na	na	na	na	na	na
CM_WC1	1/9	11	0/9	0.0	0/9	0.0	0/9	0.0	0/9	0.0	0/9	0.0	0/9	0.0	1/9	11	na	na	na	na	na	na
Total Reference	**2/109**	**1.8**	**0/83**	**0.0**	**0/109**	**0.0**	**0/109**	**0.0**	**0/109**	**0.0**	**0/109**	**0.0**	**1/109**	**0.92**	**3/109**	**2.8**	**na**	**na**	**na**	**na**	**na**	**na**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-5 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

COPC – constituent of potential concern

MU – management unit

na – not analyzed

WQG – water quality guideline

Table 3.1-7. Locations in MU5 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Aluminum		Chromium		Copper	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Mainstem Receivers						
RG_ELKFERNIE	0/9	0.0	0/9	0.0	0/9	0.0
RG_ELKORES	0/19	0.0	3/19	16	1/19	5.3
RG_ELKMOUTH	0/19	0.0	0/19	0.0	0/19	0.0
BC08NK0003	3/44	6.8	4/44	9.1	0/44	0.0
Total Mainstem Receivers	**3/91**	**3.3**	**7/91**	**7.7**	**1/91**	**1.1**

Notes:

Only constituents with a concentration > WQG or benchmark in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-6 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

MU – management unit

WQG – water quality guideline

Table 3.1.8. Comparison of dissolved oxygen concentrations to WQGs and 5th percentile reference

Station[a]	Mean WQG for sensitive life stages (11 mg/L)		Mean WQG for other life stages (8 mg/L)		5^{th} percentile of pooled reference samples (7.6 mg/L)	
	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]
MU1 - Mainstem Receivers						
FR_FR1	13/39	33	2/39	5.1	2/39	5.1
FR_FRABEC1	3/7	43	1/7	14	1/7	14
FR_MULTIPLATE	4/9	44	1/9	11	1/9	11
FR_BXLBDG	1/2	50	0/2	0	0/2	0
FR_FR2	24/61	39	4/61	6.6	2/61	3.3
GH_FR3	18/48	38	1/48	2.1	1/48	2.1
GH_FR	51/121	42	1/121	0.83	1/121	0.83
GH_PC2	60/80	75	1/80	1.3	1/80	1.3
FR_FR5	12/25	48	1/25	4.0	1/25	4.0
LC_FRUSDC	17/34	50	3/34	8.8	3/34	8.8
LC_FRB	10/18	56	0/18	0	0/18	0
GH_FR1	25/68	37	0/68	0	0/68	0
MU1 – Mine-influenced Tributaries						
FR_HC2	11/48	23	1/48	2.1	1/48	2.1
FR_HC1	28/50	56	0/50	0	0/50	0
FR_CC1	46/52	88	13/52	25	10/52	19
FR_NGD1	21/51	41	4/51	7.8	4/51	7.8
FR_EC1	45/53	85	11/53	21	5/53	9.4
FR_LEESLK	6/6	100	3/6	50	3/6	50
FR_NL1	3/4	75	1/4	25	1/4	25
FR_SP1	43/47	91	17/47	36	13/47	28
FR_STPWSEEP	19/21	90	9/21	43	7/21	33
FR_STPSWSEEP	22/23	96	11/23	48	8/23	35
FR_SKP1	6/22	27	1/22	4.5	1/22	4.5
GH_SC1	12/36	33	0/36	0	0/36	0
GH_SC2	11/42	26	1/42	2.4	0/42	0
FR_SKP2	3/13	23	0/13	0	0/13	0
GH_CC1	37/80	46	0/80	0	0/80	0
GH_PC1	31/79	39	2/79	2.5	2/79	2.5
GH_RLP	45/52	87	17/52	33	8/52	15
GH_GH1	40/80	50	1/80	1.3	1/80	1.3

Table 3.1.8. Comparison of dissolved oxygen concentrations to WQGs and 5th percentile reference

Station[a]	Mean WQG for sensitive life stages (11 mg/L)		Mean WQG for other life stages (8 mg/L)		5[th] percentile of pooled reference samples (7.6 mg/L)	
	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]
MU1 - Total Exposed Stations	**667/1271**	**52**	**107/1271**	**8.4**	**77/1271**	**6.1**
MU1 - Reference						
FR_CH1	3/25	12	1/25	4.0	1/25	4.0
FR_HC3	5/32	16	1/32	3.1	1/32	3.1
FR_KC4	1/3	33	0/3	0	0/3	0
FR_UFR1	13/51	25	3/51	5.9	3/51	5.9
LC_DC1	8/29	28	0/29	0	0/29	0
MU1 - Total Reference	**30/140**	**21**	**5/140**	**3.6**	**5/140**	**3.6**
MU2 - Mainstem Receivers						
LC_LC6	9/55	16	0/55	0.0	0/55	0
LC_LC5	14/63	22	2/63	3.2	2/63	3.2
MU2 – Mine-influenced Tributaries						
LC_WLC	10/66	15	1/66	1.5	0/66	0
LC_LC2	20/63	32	1/63	1.6	1/63	1.6
LC_LC3	20/67	30	2/67	3.0	0/67	0
LC_LC4	8/64	13	1/64	1.6	1/64	1.6
MU2 - Total Exposed Stations	**81/378**	**21**	**7/378**	**1.9**	**4/378**	**1.1**
MU2 - Reference						
LC_GRCK	9/35	26	0/35	0	0/35	0
LC_LC1	9/33	27	1/33	3.0	1/33	3.0
LC_SLC	7/30	23	0/30	0	0/30	0
MU2 - Total Reference	**25/98**	**26**	**1/98**	**1.0**	**1/98**	**1.0**
MU3 - Mainstem Receivers						
GH_ER1	43/70	61	0/70	0.0	0/70	0.0
MU3 – Mine-influenced Tributaries						
GH_WILLOW	59/92	64	0/92	0	0/92	0
GH_WADE	35/54	65	0/54	0	0/54	0
GH_WILLOW_S	13/17	76	0/17	0	0/17	0
GH_COUGAR	16/35	46	0/35	0	0/35	0
GH_MC1	33/58	57	0/58	0	0/58	0
GH_LC2	31/56	55	0/56	0	0/56	0
GH_WC2	38/66	58	1/66	1.5	1/66	1.5

Table 3.1.8. Comparison of dissolved oxygen concentrations to WQGs and 5th percentile reference

Station[a]	Mean WQG for sensitive life stages (11 mg/L)		Mean WQG for other life stages (8 mg/L)		5[th] percentile of pooled reference samples (7.6 mg/L)	
	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]
GH_TC1	42/69	61	1/69	1.4	0/69	0
MU3 - Total Exposed Stations	**310/517**	**60**	**2/517**	**0.39**	**1/517**	**0.19**
MU3 - Reference						
GH_BR_F	7/16	44	1/69	1.4	0/16	0
GH_ER2	28/69	41	0/16	0	0/69	0
GH_WOLF	29/52	56	0/52	0	0/52	0
MU3 - Total Reference	**64/137**	**47**	**1/137**	**0.73**	**0/137**	**0.0**
MU4 - Mainstem Receivers						
EV_ER4	13/64	20	0/64	0	0/64	0
EV_ER3B	12/64	19	1/64	1.6	0/64	0
EV_ER2	15/59	25	1/59	1.7	1/59	1.7
CM_MC2	24/77	31	1/77	1.3	1/77	1.3
CM_MCTM	8/38	21	1/38	2.6	1/38	2.6
EV_MC3	12/64	19	0/64	0	0/64	0
EV_MC1	10/63	16	1/63	1.6	1/63	1.6
EV_ER1	12/64	19	0/64	0	0/64	0
MU4 - Mine Influenced Tributaries						
EV_HC1	10/59	17	0/59	0	0/59	0
EV_SM1	23/49	47	0/49	0	0/49	0
EV_GC2	19/68	28	0/68	0	0/68	0
EV_OC1	46/63	73	6/63	9.5	3/63	4.8
CM_SPSP	19/33	58	2/33	6.1	0/33	0
CM_SPD	36/51	71	4/51	7.8	1/51	2.0
CM_CC1	39/93	42	0/93	0	0/93	0
CM_AG2	7/35	20	0/35	0	0/35	0
EV_EC1	13/65	20	0/65	0	0/65	0
EV_SP1	11/54	20	1/54	1.9	0/54	0
EV_MG1	13/45	29	0/45	0	0/45	0
EV_GT1	21/38	55	0/38	0	0/38	0
EV_AQ1	2/18	11	0/18	0	0/18	0
EV_BC1	21/65	32	0/65	0	0/65	0
MU4 - Total Exposed Stations	**386/1229**	**31**	**18/1229**	**1.5**	**8/1229**	**0.65**

Table 3.1.8. Comparison of dissolved oxygen concentrations to WQGs and 5th percentile reference

Station[a]	Mean WQG for sensitive life stages (11 mg/L)		Mean WQG for other life stages (8 mg/L)		5th percentile of pooled reference samples (7.6 mg/L)	
	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]	Ratio[b]	Percent[c]
MU4 - Reference						
CM_AG1	0/9	0	0/9	0	0/9	0
CM_MC1	19/78	24	1/78	1.3	1/78	1.3
CM_PC1	4/7	57	0/7	0	0/7	0
CM_WC1	0/8	0	0/8	0	0/8	0
MU4 - Total Reference	**23/102**	**23**	**1/102**	**1.0**	**1/102**	**1.0**

Notes:

Highlighted cells indicate location and constituent with at least one concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-6 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

Highlighted cells indicate any location and constituent with at least one concentration greater than the WQG or 5th percentile.

WQG – water quality guideline

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
MU1 - Mainstem Receivers									
FR_FR1	Fording River downstream of Henretta Creek	0.02	-39.5	1.8	12.7	7.9	9.9	46	4.4
FR_FRABEC1	Fording River upstream of Eagle Pond discharge (EC1)	0.02	nst	7.7	na	28	nst	109	na
FR_MULTIPLATE	Fording River multiplate culvert on Greenhills access	0.03	-53.1	8.5	na	36	nst	141	na
FR_FR2	Fording River upstream of Kilmarnock Creek	0.09	nst	7.6	8.0	29	12.5	141	nst
GH_FR3	Fording River upstream of Swift Creek	0.11	25.5	9.9	28.0	35	15.6	204	5.3
GH_FR	Fording River downstream of Swift Creek, upstream of Cataract Creek	0.11	7.7	8.3	11.7	41	9.8	168	3.1
FR_FR5	Fording River downstream of Chauncey Creek	0.03	na	15.8	29.4	56	42.8	230	23.7
GH_PC2	Fording River100m downstream of Porter Creek	0.04	na	19.0	na	72	16.9	289	na
GH_FR1	Fording River downstream of Greenhills Creek	0.03	nst	10.0	14.3	40	11.1	189	6.1
LC_FRUSDC	Fording River upstream of Dry Creek	0.03	nst	9.6	nst	35	26.0	155	nst
LC_FRB	Fording River at highway bridge	0.03	na	8.6	na	34	na	129	na
MU1 - Mine-Influenced Tributaries									
FR_HC2	Henretta Creek upstream of McMillan Creek	0.01	-51.8	5.5	15.1	25	16.9	121	4.6

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
FR_HC1	Henretta Creek upstream of Fording R	0.02	-26.9	6.1	14.1	28	15.6	124	5.9
FR_CC1	Clode Creek mouth, decant from settling pond	0.31	nst	33.8	7.8	108	2.4	272	nst
FR_NGD1	Lower Lake Mountain Creek	0.04	-18.1	1.0	-2.6	24	-1.8	122	-2.1
FR_EC1	Eagle Settling Pond discharge	0.15	-22.2	42.9	-3.1	318	2.5	1430	nst
FR_NL1	North Loop Pond decant	0.16	nst	8.9	nst	9.5	nst	115	nst
FR_SP1	Smith Ponds decant	0.31	-10.7	0.14	-5.6	9.6	-11.3	269	nst
FR_STPWSEEP	Seepage from west dam of south tailings pond	0.61	nst	4.3	nst	0.41	-26.8	391	nst
FR_STPSWSEEP	Seepage from southwest dam of south tailings pond	0.12	na	8.5	52.9	0.61	-31.7	407	nst
FR_SKP1	South Kilmarnock Ponds Phase 1	0.46	na	25.3	9.3	56	nst	116	nst
FR_SKP2	South Kilmarnock Ponds Phase 2	0.48	na	32.8	nst	69	nst	149	nst
GH_SC1	Swift Creek sediment pond decant	0.64	nst	27.2	7.0	396	9.5	862	9.3
GH_SC2	Swift Creek bypass	0.73	nst	63.6	11.7	701	17.3	1660	12.3
GH_CC1	Cataract Creek sediment pond decant	0.65	17.4	34.5	5.2	576	13.8	1610	15.3
GH_PC1	Porter Creek at pond discharge	0.02	nst	1.5	nst	70	nst	428	6.0
GH_RLP	Rail Loop Pond decant	0.14	nst	2.0	-24.5	8.5	-22.1	303	-14.8
GH_GH1	Greenhills Creek sediment pond decant	0.08	18.9	5.3	21.4	151	18.8	616	11.1

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
MU1 - Reference									
FR_UFR1	Fording River upstream of Henretta Creek	0.01	-28.1	0.02	-2.2	0.59	-3.7	27	2.2
FR_HC3	Henretta Creek upstream of Fording River	0.01	nst	0.17	nst	0.76	nst	43	nst
FR_KC4	Kilmarnock upstream of FRO	0.02	na	0.12	nst	0.55	-13.2	16	nst
FR_CH1	Chauncey Creek at Highway	0.01	na	0.07	nst	0.65	nst	22	nst
LC_DC1	Dry Creek at railway culverts	0.04	nst	0.03	nst	1.6	nst	7.69	nst
MU2 - Mainstem Receivers									
LC_LC6	Fording River upstream of Line Creek	0.02	nst	7.0	13.3	32	8.9	125	3.6
LC_LC5	Fording River downstream of Line Creek	0.04	-12.1	6.6	12.6	35	8.2	128	4.0
MU2 - Mine-Influenced Tributaries									
LC_LC2	Line Creek upstream of rock drain	0.01	-13.0	0.43	-3.1	7.7	8.7	44	3.4
LC_LC12	North Horseshoe Creek	0.19	nst	9.0	20.0	35	15.5	135	13.6
LC_LCUSWLC	Line Ck downstream rock drain, upstream West Line Ck	0.37	nst	10.5	14.1	36	11.1	158	7.7
LC_WLC	West Line Creek	1.2	nst	30.2	nst	499	3.2	1040	5.1
LC_LC3	Line Creek downstream of West Line Creek	0.53	nst	12.7	10.0	77	7.9	235	6.2
LC_LC4	Line Creek downstream of LCO, upstream of process plant	0.17	nst	5.7	10.9	33	6.3	113	5.6

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
MU2 - Reference									
LC_GRCK	Grace Creek	0.01	-11.6	0.03	nst	1.9	-3.9	46	nst
LC_LC1	Line Creek upstream of LCO	0.01	-16.5	0.13	nst	1.3	nst	15	nst
LC_SLC	South Line Creek	0.01	nst	0.06	nst	1.2	nst	47	nst
MU3 - Mainstem Receivers									
GH_ER1	Elk River downstream of GHO, upstream of Fording River and Boivin Creek	0.01	nst	0.19	10.9	1.31	nst	21	1.0
MU3 - Mine-Influenced Tributaries									
GH_Willow	Willow North Creek at culvert	0.02	nst	0.12	nst	0.89	-8.8	20	19.9
GH_Wade	Wade Creek at culvert	0.03	nst	0.47	24.2	1.2	nst	21	nst
GH_Cougar	Cougar Creek at culvert	0.05	nst	0.07	nst	0.55	nst	11	-6.3
GH_MC1	Mickelson Creek at culvert	0.05	nst	0.19	nst	0.87	nst	71	4.0
GH_LC2	Leask Creek culvert at road	0.06	23.0	29	24.7	38	27.2	227	16.5
GH_WC2	Wolfram Creek culvert at road	0.29	25.5	18	29.7	44	25.9	399	16.1
GH_TC1	Thompson Creek culvert at bridge	0.04	nst	13	44.2	116	34.0	509	19.8
MU3 - Reference									
GH_ER2	Elk River upstream of GHO	0.01	nst	0.04	-3.1	0.74	-3.1	16	-1.2
GH_Wolf	Wolf Creek at culvert	0.02	nst	0.08	nst	0.64	nst	17	nst
MU4 - Mainstem Receivers									
CM_MC2	Michel Creek downstream of Corbin Creek	0.06	nst	1.4	12.2	4.3	7.8	168	5.4

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
CM_MCTM	Michelle Creek below Tent Mountain	0.02	nst	0.89	12.9	3.0	3.2	145	4.9
EV_ER4	Elk River downstream of Fording River, upstream of Grave Creek	0.02	nst	2.7	8.2	12	3.7	69	3.3
EV_ER3B	Elk River upstream of Lindsay Creek	0.02	nst	2.4	9.1	12	6.7	70	5.7
EV_ER2	Elk River near Highway 43 bridge, downstream of pumphouse	0.02	nst	2.1	7.5	9.9	7.0	64	4.5
EV_ER1	Elk River~1km downstream of Michel Creek at Sparwood	0.02	nst	1.6	1.8	9.1	3.4	67	4.7
EV_MC3	Michel Creek upstream of Erickson Creek	0.03	-5.3	0.12	-6.6	1.0	nst	35	5.4
EV_MC1	Michel Creek ~1km upstream of Highway 43 bridge at Rothels	0.03	-6.2	1.0	-2.9	8.6	nst	82	4.1
MU4 - Mine-Influenced Tributaries									
CM_SPSP	7 Pit Pond decant	0.01	na	0.05	na	0.15	na	324	na
CM_CCPD	Corbin Pond Decant	0.64	21.5	6.6	6.6	28	15.8	709	5.2
CM_PC2	Pengelly Creek downstream	0.05	nst	0.14	-8.8	1.2	-8.2	14	-5.1
CM_SPD	Main Pond decant	0.17	na	7.2	na	6.4	na	738	na
CM_CC1	Corbin Creek downstream of CMO	0.13	nst	4.4	9.2	14	8.3	557	5.3
CM_AG2	Andy Good Creek downstream of CMO	0.01	nst	0.12	nst	1.1	-11.4	12	-5.1
EV_DC1	Dry Creek Decant	0.05	nst	5.7	1.5	165	6.3	707	nst

Table 3.1-9. Surface water concentrations (2010-2012) and trends for cadmium, nitrate, selenium, and sulphate (from Zajdlik and Minnow 2013)

Station	Description	Cadmium		Nitrate		Selenium		Sulphate	
		Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L as N)	Trend (%)	Median concentration[a] (µg/L)	Trend (%)	Median concentration[a] (mg/L)	Trend (%)
EV_HC1	Harmer Creek at dam/spillway	0.02	nst	1.1	nst	33	3.0	180	3.3
EV_SM1	6-Mile Creek Pond decant	0.02	nst	0.06	-10.9	2.2	-2.2	65	2.3
EV_GC2	Lower Goddard Pond decant	0.07	nst	1.6	-11.0	12	-17.2	175	-4.7
EV_OC1	Otto Creek near mouth, ~60m upstream of confluence	0.04	nst	0.12	-5.1	2.3	nst	61	5.4
EV_EC1	Erickson Creek at CPR Mainline, near mouth	0.01	-7.7	7.9	-7.6	98	-5.3	556	nst
EV_SP1	South Pit Pond decant	0.11	nst	7.3	nst	145	16.7	631	11.7
EV_MG1	Milligan Pond #2 discharge	0.19	nst	0.53	-16.4	72	3.1	407	2.3
EV_GT1	Gate Creek Pond decant	0.15	nst	20.8	-8.2	142	6.2	675	4.8
EV_BC1	Gate Creek Pond decant	0.13	-16.6	66.1	-8.2	344	8.3	908	9.2
MU4 – Reference									
CM_MC1	Michel Creek upstream of CMO	0.01	-22.0	0.01	-10.6	0.21	-7.1	9.4	-0.9
CM_PC1	Pengelly Creek upstream of CMO	0.02	nst	0.03	nst	0.24	-33.2	4.9	nst
CM_AG1	Andy Good Creek upstream of CMO	0.01	-12.7	0.17	-8.6	1.3	-14.1	17	-6.1
CM_WC1	Wheeler Creek	0.03	nst	0.05	nst	0.90	-9.6	5.8	nst

Notes:

Orange highlight indicates increasing trend, green indicates decreasing trend, and blue indicated no significant increasing or decreasing trend.

[a] Median concentration calculated using the 3-year dataset from 2010 to 2012.

na – not analyzed

nst – no significant trend

Table 3.1-10. Chemistry results from toxicity test samples compared to site-specific benchmarks for surface water

Constituent[a]	Unit	Concentration				
		Reference location (GH_ER2)	Fording River locations (GH_FR1, LC_LC5, LC_FRB)		Elk River locations (LC_ELKOS, EV_ER1)	
			Measured	Site-specific benchmark	Measured	Site-specific benchmark
Nitrate	mg/L as N	0.038 – 0.155	9.38 – 14.3	10.5 – 12.7	1.66 – 3.45	3
Sulphate	mg/L	15.4 – 18.4	55.2 – 182.5	481	148 - 244	481
Selenium	µg/L	na	46.5 - 47	70	na	19

Notes:

[a] Cadmium was not detected in water from the Fording River location that was used for toxicity tests and analyzed for cadmium (LC_FRB).

na - not analyzed

Table 3.1-11. Locations in MU6 with detected concentrations of constituents greater than the WQG or site-specific benchmark

Station[a]	Phosphorus		Chromium		Selenium	
	Ratio[b]	%[c]	Ratio[b]	%[c]	Ratio[b]	%[c]
Upstream of Elk River Mouth						
RG_USELK	6/14	43	0/14	0.0	1/14	7.1
Elk River Mouth						
RG_EASTARM	3/14	21	1/14	7.1	2/14	14
Downstream of Elk River Mouth						
RG_DSELK	5/15	33	0/15	0.0	0/15	0.0
RG_GRASMERE	5/13	38	0/13	0.0	0/13	0.0
RG_BORDER	4/13	31	0/13	0.0	0/13	0.0
Total Downstream of Elk River Mouth	**23/69**	**33**	**1/69**	**1.4**	**3/69**	**4.3**
Reference						
BC08NG0009	na	na	3/30	10	0/32	0.0
RG_WARDB	10/10	100	0/10	0	0/10	0.0
Total Reference	**10/10**	**100**	**3/40**	**7.5**	**0/42**	**0.0**

Notes:

Only constituents with a concentration > WQG in one or more samples are shown in this table. Highlighted cells indicate location and constituent with at least one detected concentration > WQG or benchmark.

[a] Station descriptions are presented in Table A1-1; station locations are presented on Maps 3.1-1 and 3.1-7 and shown schematically in Figure 3.1-1.

[b] The number of samples with detected concentrations > WQG or benchmark divided by the total number of samples.

[c] The percentage of samples with detected concentrations > WQG or benchmark.

MU – management unit

na – not analyzed

WQG – water quality guideline

Table 3.1-12. Locations with concentrations of primary COPCs above site-specific benchmarks or guidelines in MUs 1-5

Primary COPC	No. locations with detected concentrations > benchmark / total no. locations (percent of samples)				
	MU1	MU2	MU3	MU4	MU5
Nitrate					
Mainstem receivers	6/12 (15%)	2/2 (9.0%)	0/1 (0%)	5/8 (12%)	0/4 (0%)
Mine-influenced tributaries	6/18 (15%)	2/4 (10%)	3/8 (44%)	7/14 (44%)	na
Selenium					
Mainstem receivers	3/12 (6.0%)	2/2 (87%)	0/1 (0%)	1/8 (0.58%)	0/4 (0%)
Mine-influenced tributaries	10/18 (45%)	4/4 (78%)	3/8 (37%)	8/14 (55%)	na
Sulphate					
Mainstem receivers	0/12 (0%)	0/2 (0%)	0/1 (0%)	0/8 (0%)	0/4 (0%)
Mine-influenced tributaries	11/18 (31%)	1/4 (20%)	2/8 (10%)	7/14 (40%)	na

Notes:

na – not applicable

Table 3.2-1. Summary of recent sediment sampling events

Sampling event	Sampling period	Sampling areas
Lotic Environmental Sampling (Lotic 2013; and as summarized in Appendix D of Minnow 2014a)	October/ November 2011	MU1, MU2, MU4, MU5, MU6 (Lake Koocanusa), and reference areas
Minnow Environmental Lake Koocanusa Sampling (Minnow 2014b)	April/August 2013	MU6 (Lake Koocanusa)[a]
Minnow Environmental Elk River Watershed Sampling (Minnow 2014a)	August 2013	MU1, MU2, MU3, MU4, MU5, and reference areas[b]

Notes:

[a] Samples were collected from seven transects across Lake Koocanusa, two upstream of the Elk River and five downstream.

[b] Toxicity tests, in addition to chemical analyses, were done with sediment from a subset of six areas.

MU - management unit

Table 3.2-2. Summary of sediment samples

Area type	MU	Sampling Locations: No. of locations[a]	Sampling Locations: List of location IDs[b]	Number of samples
Exposed	MU1	12	CC1, FMUCK, FO10 (FOX1), FOR3, FR d/s DRCK, FR u/s DRCK, FR4 (FR4a), FR5, HE27 (HEN1), LAK1, LAK2, SWI1	71 (3-10 per location)
	MU2	2	LC3, LC5	7 (2-5 per location)
	MU3	1	EROU	5
	MU4	5	ELWDGC, ER4, GO13, MI16, MIWW	21 (3-5 per location)
	MU5	6	ELK1, ELKO (ELK2), ER1, EROL, ERWSF, SPW	36 (3-10 per location)
	MU6 (Lake Koocanusa)[c]	5	Transects 3, 4, 5, 6, 7	35 (5-12 per location)
Mine works[c]	MU1	3	CL11, GHPD, NGC1	15 (5 per location)
	MU2	1	LCCPL	5
	MU3	1	THPD	5
	MU4	2	GAPD, HA7	8 (3-5 per location)
Reference[c]	Lake Koocanusa[d]	1	Transect 2	12
	For comparison to the Elk River watershed	15	CHCK, DRCK, ER2, FL17, FO15 (FORW), GLMS, GRLK, HC3, KC4, LC1, LCHO, LML (LAK3), LOLA, REFF, UFR1	69 (3-8 per location)

Notes:

[a] Not all constituents were analyzed at all locations.

[b] Areas sampled in both 2011 and 2013 are identified by the 2013 location ID, with the 2011 location ID shown in parentheses.

[c] Mine works and reference area locations were not included in the evaluation of sediment quality presented here, but were evaluated in Appendix D as part of the sediment quality index.

[d] MU6 (Lake Koocanusa) is evaluated separately. Transect 1, upstream of the Elk River, was not used as a reference location because physical characteristics were more riverine (i.e., shallow water with sandy substrate) than those of Transects 3 through 7 in Lake Koocanusa.

d/s – downstream

u/s - upstream

MU - management unit

Table 3.2-3. Selected sediment quality guidelines (SQGs) and reference concentrations

Constituent	Sediment quality guidelines (mg/kg dw)		95^{th} percentile reference concentration[a] (mg/kg dw)	
	Low	High	Elk Valley watershed	Lake Koocanusa
Metals				
Arsenic	5.9 (ISQG)	17 (PEL)	6.13	7.66
Cadmium	0.6 (ISQG)[b]	3.5 (PEL)	2.58	0.491
Chromium	37.3 (ISQG)	90 (PEL)	17.8	24.3
Copper	35.7 (ISQG)	197 (PEL)	24.0	21.1
Iron	21,200 (LEL)[c]	43,766 (SEL)[c]	15,500	25,400
Lead	35 (ISQG)	91.3 (PEL)	11.1	17.4
Manganese	460 (LEL)[c]	1,100 (SEL)[c]	518	635
Mercury	0.17 (ISQG)	0.486 (PEL)	0.086	0.046
Nickel	16 (LEL)[c]	75 (SEL)[c]	28.2	27.9
Selenium	2[d]	na	6.63	0.454
Zinc	123 (ISQG)	315 (PEL)	125	91.9
PAHs				
2-Methylnaphthalene	0.0202 (ISQG)	0.201 (PEL)	2.98	nd
Acenaphthene	0.00671 (ISQG)	0.0889 (PEL)	0.20	nd
Acenaphthylene	0.00587 (ISQG)	0.128 (PEL)	0.075	nd
Anthracene	0.0469 (ISQG)	0.245 (PEL)	0.091	nd
Benzo(a)anthracene	0.0317 (ISQG)	0.385 (PEL)	0.15	nd
Benzo(a)pyrene	0.0319 (ISQG)	0.782 (PEL)	0.20	nd
Benzo(g,h,i)perylene	0.17 (LEL)[c]	3.2 (SEL)[ce]	0.15	nd
Benzo(k)fluoranthene	0.24 (LEL)[c]	13.4 (SEL)[ce]	0.15	nd
Chrysene	0.0571 (ISQG)	0.862 (PEL)	0.31	nd
Dibenzo(a,h)anthracene	0.00622 (ISQG)	0.135 (PEL)	0.075	nd
Fluoranthene	0.111 (ISQG)	2.355 (PEL)	0.19	nd
Fluorene	0.0212 (ISQG)	0.144 (PEL)	0.47	nd
Indeno(1,2,3-c,d) pyrene	0.2 (LEL)[c]	3.2 (SEL)[ce]	0.15	nd
Naphthalene	0.0346 (ISQG)	0.391 (PEL)	0.70	nd
Phenanthrene	0.0419 (ISQG)	0.515 (PEL)	1.78	nd
Pyrene	0.053 (ISQG)	0.875 (PEL)	0.18	nd

Sources: Unless otherwise noted, SQGs are from Nagpal et al. (2006) and CCME (2014).

Notes:

Shaded reference area concentrations indicate values that are greater than the low and/or high sediment quality guidelines.

[a] The 95^{th} percentile reference concentrations for the Elk Valley watershed and Lake Koocanusa were calculated using data from the locations identified as representing reference areas in Table 3.2-2.

[b] Value currently in draft (CCME 2012)

[c] Value based on working MOE guidelines (LEL, SEL) (Persaud et al. 1993; Ontario Ministry of Environment and Energy 1993; Nagpal and Howell 2001; Nagpal et al. 2006)

[d] Value based on April 2014 selenium guidelines (Beatty and Russo 2014). This value is considered a "low" SQG because it is conservative for several reasons. This concentration represents the upper end of the typical range of selenium concentration in background freshwater sediment as reported in Skorupa (1998). Additionally, based on a survey of several western North American waters, there is no evidence of observed or predicted effects of selenium on fish or birds at sites with sediment selenium concentrations as low as 2 mg/kg dw (Van Derveer and Canton 1997).

[e] Working MOE guideline is dependent on TOC fraction; reported criterion assumes 1% TOC in sample (Persaud et al. 1993); the guideline for this constituent assumes 1% TOC which is expected to be conservative based on the available sediment chemistry data from Elk Valley sampling locations (Minnow 2014a).

CCME - Canadian Council of Ministers of the Environment

dw - dry weight basis

ISQG - Interim Sediment Quality Guideline

LEL - Lowest Effect Level

MOE - British Columbia Ministry of the Environment

na - not available

nd – no data

PEL - Probable Effect Level

SEL - Severe Effect Level

TOC - total organic carbon

Table 3.2-4. Identification of COPCs and primary COPCs for the Elk River watershed

Constituent	COPC Identification		Primary COPC Identification	
	No. locations having at least one sample with detected concentration > criterion[a] / total no. locations	Constituent identified as a COPC?	No. locations having at least one sample with detected concentration > criterion[b] / total no. locations	Constituent identified as a primary COPC?
Metals				
Arsenic	6 / 16	YES	0 / 16	no
Cadmium	3 / 16	YES	3 / 16	YES
Chromium	0 / 16	no	-	-
Copper	1 / 16	YES	0 / 16	no
Iron	1 / 16	YES	0 / 16	no
Lead	0 / 16	no	-	-
Manganese	7 / 16	YES	0 / 16	no
Mercury	0 / 16	no	-	-
Nickel	6 / 16	YES	1 / 16	YES
Selenium	3 / 16	YES	0 / 16	no
Zinc	5 / 16	YES	1 / 16	YES
PAHs				
2-Methylnaphthalene	4 / 26	YES	4 / 26	YES
Acenaphthene	0 / 26	no	-	-
Acenaphthylene	0 / 26	no	-	-
Anthracene	0 / 26	no	-	-
Benzo(a)anthracene	3 / 26	YES	0 / 26	no
Benzo(a)pyrene	0 / 26	no	-	-
Benzo(g,h,i)perylene	0 / 26	no	-	-
Benzo(k)fluoranthene	0 / 26	no	-	-
Chrysene	2 / 26	YES	0 / 26	no
Dibenzo(a,h)anthracene	1 / 26	YES	0 / 26	no
Fluoranthene	1 / 26	YES	0 / 26	no
Fluorene	3 / 26	YES	3 / 26	YES
Indeno(1,2,3-c,d) pyrene	0 / 26	no	-	-
Naphthalene	4 / 26	YES	4 / 26	YES
Phenanthrene	4 / 26	YES	4 / 26	YES
Pyrene	3 / 26	YES	0 / 26	no

Notes:

Shaded cells indicate constituents identified as a COPC and/or primary COPC.

[a] The criterion used for the identification of COPCs was the higher of either the low SQG or the reference concentration (see Table 3.2-3).

[b] The criterion used for the identification of primary COPCs was the higher of either the high SQG or the reference concentration (see Table 3.2-3).

COPC - constituent of potential concern

MU - management unit

SQG - sediment quality guideline

Table 3.2-5. Locations in Elk River watershed with COPC concentrations in at least one sample greater than the low SQG and reference 95th percentile

Location[a]	Number of samples with detected concentrations > criterion / total number of samples per location																
	Metals (16 locations evaluated)								PAHs (26 locations evaluated)								
	Arsenic	Cadmium	Copper	Iron	Manganese	Nickel	Selenium	Zinc	2-Methylnaphthalene	Benzo(a)anthracene	Chrysene	Dibenzo(a,h)anthracene	Fluoranthene	Fluorene	Naphthalene	Phenanthrene	Pyrene
MU1																	
CC1 – Cataract Creek near mouth	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	2/5	-	-	-	-	3/5	1/5	3/5	1/5
FMUCK – Fording Meadow near Chauncey Creek	-	-	-	-	-	2/3	-	-	-	-	-	-	-	-	-	-	-
FO10 – Fording River Oxbow	-	-	-	-	-	-	4/10	-	-	-	-	-	-	-	-	-	-
LAK1 – Lower Lake Mtn Creek	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	2/5	-	1/5	-	-	-	5/5	-	-
LAK2 – Upper Lake Mtn Creek	-	5/5	-	-	-	3/5	5/5	5/5	-	1/5	-	-	-	-	-	2/5	-
SWI1 – Swift Creek near mouth	-	5/5	-	-	-	5/5	2/5	5/5	-	-	-	-	-	-	-	-	-
MU2																	
LC3 – Line d/s West Line, u/s South Line	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	1/2	1/2	1/2	-	-	1/2	1/2	1/2	1/2
MU3																	
EROU – Elk River Upper Oxbow	5/5	-	-	-	5/5	1/5	-	1/5	-	-	-	-	-	-	-	-	-
MU4																	
ELWDGC – Elk River wetland d/s of Grave Creek	1/3	-	-	-	3/3	-	-	-	-	-	-	-	-	-	-	-	-
GO13 – Goddard Marsh	3/5	-	-	-	5/5	2/5	-	2/5	1/5	1/5	-	1/5	1/5	1/5	1/5	1/5	1/5
MI16 – Michel Creek wetland	3/5	2/5	1/5	1/5	1/5	2/5	-	3/5	-	-	-	-	-	-	-	-	-
MU5																	
EROL – Elk River Lower Oxbow	1/5	-	-	-	1/5	-	-	-	-	-	-	-	-	-	-	-	-
ERWSF – Elk River wetland south of Fernie	1/3	-	-	-	1/3	-	-	-	-	-	-	-	-	-	-	-	-
SPW – Sparwood Wetland	-	-	-	-	2/3	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

Dashes indicate that no COPCs had concentrations greater than the applicable criteria at this location.

[a] Only locations for which one or more COPCs had concentrations greater than criteria are shown in this table.

[b] No data were available for metals at this location.

COPC - constituent of potential concern

MU - management unit

PAH – polycyclic aromatic hydrocarbon

Table 3.2-6. Locations in Elk River watershed with primary COPC concentrations in at least one sample greater than the high SQG and reference 95th percentile

Location[a]	Number of samples with detected concentrations > criterion / total number of samples per location						
	Metals (16 locations evaluated)			PAHs (26 locations evaluated)			
	Cadmium	Nickel	Zinc	2-methyl naphthalene	Fluorene	Naphth alene	Phenan threne
MU1							
CC1 – Cataract Creek near mouth	-[b]	-[b]	-[b]	2/5	3/5	1/5	3/5
LAK1 – Lower Lake Mountain Creek	-[b]	-[b]	-[b]	2/5	-	5/5	-
LAK2 – Upper Lake Mountain Creek	5/5	-	-	-	-	-	2/5
SWI1 – Swift Creek near mouth	5/5	5/5	5/5	-	-	-	-
MU2							
LC3 – Line d/s West Line, u/s South Line	-[b]	-[b]	-[b]	1/2	1/2	1/2	1/2
MU4							
GO13 – Goddard Marsh	-	-	-	1/5	1/5	1/5	1/5
MI16 – Michel Creek wetland	1/5	-	-	-	-	-	-

Notes:

Dashes indicate that no primary COPCs had concentrations greater than the applicable criteria at this location.

[a] Only locations for which one or more primary COPCs had concentrations greater than criteria are shown in this table. No locations in MU3 or MU5 had concentrations of primary COPCs greater than the applicable criteria.

[b] No data were available for metals at this location.

COPC - constituent of potential concern

MU - management unit

Table 3.2-7. Results of sediment toxicity tests using *H. azteca* and *C. riparius*

Endpoint	Units	Statistic	Lab control	Reference areas		Mine works (settling pond)	Exposed areas		
				GRLK	FL17	HA7 (in MU4)	FO10 (in MU1)	GO13 (in MU4)	ELKO (in MU5)
Hyalella azteca									
Survival	%	average	92	100	70	100	98	100	98
		SD	*11*	*0*	*30.8*	*0*	*4.5*	*0*	*4.5*
Growth	mg	average	0.204	0.237	0.224	0.225	0.256	0.213	0.285
		SD	*0.04*	*0.03*	*0.06*	*0.04*	*0.03*	*0.06*	*0.05*
Chironomus riparius									
Survival	%	average	100	98	100	92	90	76[a]	98
		SD	*0*	*4.5*	*0*	*8.4*	*11.5*	*23*	*4.5*
Growth	mg	average	2.265	2.503	2.398	1.976	2.716	2.393	2.137
		SD	*0.10*	*0.11*	*0.48*	*0.45*	*0.29*	*0.29*	*0.65*

Notes:

Sediment toxicity results shown here are based on the results presented by Minnow (2014a). Sediment toxicity tests were conducted at six locations (including 2 reference areas, 1 area in MU1, 2 areas in MU4, and 1 area in MU5).

[a] Toxicity endpoint was significantly different than in laboratory controls and reference area samples (Minnow 2014a).

MU - management unit

SD - standard deviation

Table 3.2-8. Identification of COPCs and primary COPCs for Lake Koocanusa

Constituent	COPC identification		Primary COPC identification	
	No. transects having at least one sample with detected concentration > criterion[a] / total no. transects	Constituent identified as a COPC?	No. transects having at least one sample with detected concentrations > criterion[b] / total no. locations	Constituent identified as a primary COPC?
Arsenic	2 / 5	YES	0 / 5	no
Cadmium	2 / 5	YES	0 / 5	no
Chromium	0 / 5	no	-	-
Copper	0 / 5	no	-	-
Iron	0 / 5	no	-	-
Lead	0 / 5	no	-	-
Manganese	2 / 5	YES	0 / 5	no
Mercury	0 / 5	no	-	-
Nickel	1 / 5	YES	0 / 5	no
Selenium	0 / 5	no	-	-
Zinc	0 / 5	no	-	-

Notes:

Reference concentrations were based on Lake Koocanusa Transect 2 samples only (n = 12).

[a] The criterion used for the identification of COPCs was the higher of either the low SQG or the reference concentration (see Table 3.2-3).

[b] The criterion used for the identification of primary COPCs was the higher of either the high SQG or the reference concentration (see Table 3.2-3).

COPC - constituent of potential concern

MU - management unit

SQG - sediment quality guideline

Table 3.2-9. Number of samples greater than the low SQG and reference 95th percentile for COPCs in Lake Koocanusa transects

Location	Number of samples with detected concentrations > criterion / total number of samples per transect			
	Arsenic	Cadmium	Manganese	Nickel
Downstream of Elk River				
Transect 3	-	1/7	-	-
Transect 4	3/12	5/12	6/12	3/12
Transect 5	1/6	-	-	-
Transect 6	-	-	-	-
Transect 7	-	-	1/5	-
Upstream of Elk River (reference)				
Transect 2	1/12	1/12	1/12	1/12

Notes:

Dashes indicate that no COPCs had concentrations greater than the applicable criteria at this location.

COPC – constituent of potential concern

SQG – sediment quality guideline

Table 3.3-1. Stream kilometre estimates by Calcite Index (*CI*) ranges. Percentages are of the total 352 km classified

	Reference				Exposed			
	Fording and Elk Rivers		Tributaries		Fording and Elk Rivers		Tributaries	
***CI* Ranges**	**km**	**%**	**km**	**%**	**km**	**%**	**km**	**%**
0.00 - 0.50	21.8	6.2	42.9	12.2	143.0	40.6	111.5	31.7
0.51 - 1.00	0.0	0.0	0.0	0.0	4.7	1.3	9.4	2.7
1.01 - 1.50	0.0	0.0	0.0	0.0	0.0	0.0	5.1	1.4
1.51 - 2.00	0.0	0.0	0.0	0.0	0.0	0.0	6.3	1.8
2.01 - 2.50	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.8
2.51 - 3.00	0.0	0.0	0.0	0.0	0.0	0.0	4.7	1.3
Total	**21.8**	**6.2**	**42.9**	**12.2**	**147.7**	**42.0**	**139.8**	**39.7**

Table 3.4-1. Study summary table

Sample year(s)	Environmental study / data source or provider	Study objectives	Periphyton	Zooplankton	Invertebrate	Fish WB/muscle	Fish eggs/ovaries	Amphibian egg masses	Bird eggs	Analytes	Ecosystem	General areas studied	No. locations	Data category
1996	McDonald and Strosher 1998	Water, sediment, and tissue chemistry; fish size, age, and stomach contents	X		X	WCT, MWF, BT	MWF			selenium	lotic	Elk River, Fording River, Line Creek, Michel Creek	8	E, R
1998	Kennedy et al. 2000	Effects of selenium on cutthroat trout				WCT	WCT			selenium	lentic, lotic	Connor Lake, Fording River	2	E, R
2001-2002	EVS 2005	Water and tissue chemistry; periphyton and BI community; fish size, age, and stomach contents	X		X	WCT, MWF	WCT, MWF			selenium, arsenic, mercury, vanadium	lotic	Elk River, Fording River, Line Creek, Michel Creek, Alexander Creek	15	E, R
2002	Harding and Paton 2003	Effects of selenium on American dippers and sandpipers			X				AMDI, SPSA	selenium, arsenic, mercury, vanadium	lotic	Fording River, Alexander Creek, Line Creek, Boivin Creek, Gold Creek, Lynx Creek	6	E, R
2002	Minnow 2003	Water, sediment, and tissue chemistry				EB, LND, LNS, WCT	WCT			selenium	lentic	Elk River Oxbow, Fording River Oxbow, Leach Creek Barnes Lake, Clode Pond, Goddard Marsh	9	MW, E, R
2003	Minnow 2004b	Selenium bioaccumulation			X	WCT				selenium	lentic, lotic	Fording River, Alexander Creek, Line Creek, Clode Pond	6	MW, E, R
2003, 2005	SciWrite 2007	Effects of selenium on red-winged blackbirds							RWBL	selenium	lentic	Michel Creek Wetlands	1	MW
2004	Minnow 2004a	Selenium bioaccumulation					LNS			selenium	lentic	Elk River Oxbow, Goddard Marsh	2	E
2005	Minnow 2006	In situ assessment of hatch success and deformities						CSF		selenium, sulfur	lentic	Elk River Oxbow, Fording River Wetlands	2	R
2005	Minnow and PLA 2006	In situ assessment of hatch success and deformities					LNS			selenium	lentic	Elk River Oxbow, Goddard Marsh	2	E
2005	Rudolph 2006	Effects of selenium on WCT				WCT	WCT			selenium	lentic	Clode Pond, O'Rourke Lake	2	MW, R
2006	Minnow et al. 2007	Monitoring selenium tissue levels in lentic and lotic habitats			X	BT, LNS, MWF, WCT	WCT, MWF	CSF	RWBL, SPSA	full suite of trace elements	lentic, lotic	Elk River, Fording River, Michel Creek, Alexander Creek, Line Creek, Fording River Wetlands, Michel Creek Wetlands, Elk Lakes, Barnes Lake, Clode Pond, Flathead Wetlands, Goddard Marsh, Harmer Pond, Henretta Lake	33	MW, E, R
2007-2008	MT DEQ 2010	Monitoring selenium tissue levels in fish				BT, KKN, LNS, NPM, MWF, PMC, RBT, WCT				selenium	lentic, lotic	Elk River, Michel Creek, Lake Koocanusa	3	E
2008	Montana Fish, Wildlife, and Parks	Monitoring mercury and selenium concentrations in fish tissues				BRB, BT, KKN, LNS, NPM, MWF, PMC, RBT, WCT	KKN, LNS, NPM, PMC, RBT, WCT			selenium, mercury	lentic	Lake Koocanusa	1	E, U.S.
2008	Nautilus 2011	Development of egg-based selenium toxicity threshold for westslope cutthroat trout				WCT	WCT			full suite of trace elements	lentic, lotic	Fording River, Clode Creek, Clode Pond, Connor Lake	6	MW

Table 3.4-1. Study summary table

Sample year(s)	Environmental study / data source or provider	Study objectives	Periphyton	Zooplankton	Invertebrate	Fish WB/muscle	Fish eggs/ovaries	Amphibian egg masses	Bird eggs	Analytes	Ecosystem	General areas studied	No. locations	Data category
2008	McDonald 2009	Evaluation of risks to aquatic environment based on comparison of water and tissue chemistry to water quality guidelines and tissue-based thresholds		X		KKN, PMC	KKN, PMC			full suite of trace elements	lentic	Lake Koocanusa (Canada Reach 1 and 2, U.S. Reach, Elk River, Gold Creek, Kikomun Bridge)	6	E, R, U.S.
2008	Delray et al. 2011	Baseline mercury and selenium concentrations in fish tissue, fish species distribution, and genetic status of WCT				BT, KKN, LNS, LT, LWT, MWF, NPM, PMC, RBT, SCU, WCT	KKN, LNS, MWF, NPM, PMC			selenium, mercury	lotic	Elk River, Lake Koocanusa, Flathead River, Cabin Creek, Foisey Creek, Harvey Creek, Howell Creek, Lodgepole Creek, McEvoy creek, McLatchie Creek, Middlepass Creek, Pollock Creek, Flathead Lake (BC)	15	R
2008-2009	Minnow et al. 2011	Monitoring selenium tissue levels in lentic and lotic habitats	X		X	BT, MWF, WCT	BT, LNS, MWF, WCT	CSF	RWBL	full suite of trace elements	lentic, lotic	Elk River, Fording River, Michel Creek, Alexander Creek, Line Creek, Fording River Wetlands, Michel Creek Wetlands, Elk Lakes, Clode Pond, Flathead Wetlands, Goddard Marsh, Harmer Pond, Henretta Lake, O'Rourke Lake, Unamed Upper Elk Wetland	35	MW, E, R
2009	Teck 2011	Baseline metals concentrations in biota to support environmental assessment	X		X	LSS, PMC, MWF, WCT	LSS, MWF, WCT			full suite of trace elements	lentic, lotic	Fording River, Dry Creek, ELKO Reservoir, Lake Koocanusa (at Elk River and Sand Creek)	5	E, R
2010	Lotic 2010	Monitoring selenium and metals tissue levels biota	X		X	WCT		CSF, WT	RWBL, SPSA	full suite of trace elements	lentic, lotic	Elk River, Fording River, Cataract Creek, Dry Creek, Henretta Creek, Lake Mountain Creek, Swift Creek, ELKO Reservoir, Lake Koocanusa, Lake Mountain Lake, Swift Wetland, Fen in Stormcat Area	28	E, R
2012	Golder 2013	Monitoring selenium and metals tissue levels in periphyton in lotic habitats	X							full suite of trace elements	lotic	North Thompson Creek, Thompson Creek Reach 1 and 4	3	E
2012	Minnow 2014d	Monitoring selenium and metals tissue levels biota	X		X	LNS, MWF, WCT	LNS, MWF	CSF, WT	AMDI, COME, KD, MALL, RWBL, SPSA	full suite of trace elements	lentic, lotic	Elk River and Fording River and tributaries, ELKO Reservoir, Lake Koocanusa, numerous lakes, ponds, wetlands, marshes, and settling ponds	148	MW, E, R
2012	Teck 2013b (GHO)	Monitoring selenium and metals tissue levels periphyton and benthic invertebrates in lotic habitats	X		X					full suite of trace elements	lotic	Thompson Creek, Leask Creek Settling Pond, Wolfram Pond	5	MW, E, R

Table 3.4-1. Study summary table

Sample year(s)	Environmental study / data source or provider	Study objectives	Periphyton	Zooplankton	Invertebrate	Fish WB/muscle	Fish eggs/ovaries	Amphibian egg masses	Bird eggs	Analytes	Ecosystem	General areas studied	No. locations	Data category
2012	Teck 2013 MW	Monitoring selenium in periphyton, benthic invertebrates, and fish tissues from lotic habitats	X		X	EB, WCT	EB, MWF			full suite of trace elements	lotic	Michel Creek, Alexander Creek, Carbon creek, Fir Creek, Leach Creek, Mine Creek, Snowslide Creek, Transmission Creek, Wheeler Creek	17	E, R
2013	Minnow unpublished data	Monitoring selenium tissue levels in bird eggs and invertebrates, and sandpiper nesting success			X				SPSA	full suite of trace elements	lentic, lotic	Elk River, Fording River, Michel Creek, Alexander Creek, Line Creek, Wigwam River, Chauncy Creek, Clode Pond, Gatehouse Pond, Greenhills Settling Pond, Harmer Pond, MSA-North Pond, NoName Pond, Thompson Settling Pond, Kilmarnock Settling Pond, ELKO Reservoir	26	MW, E, R
2013	Golder 2014c	Collection of biological and chemical data from lentic habitats (habitat assessment, water and tissue chemistry, selenium bioaccumulation)	X		X					full suite of trace elements	lentic, lotic	Elk River, Fording River, Chauncey Creek Dry Creek, McCool Creek, Graves Lake Marsh, Unnamed Elk River Wetland	69	E, R

Notes:
AMDI - American dipper
BI - benthic invertebrates
BRB - burbot
BT - bull trout
CSF Columbia spotted frog
E - exposed
EB - brook trout
GHO - Greenhills Operation
KKN - kokanee
LNS - longnose sucker
LSS - largescale sucker
LT - lake trout
LWF - lake whitefish
MALL - mallard
MW - mine works
MWF - mountain whitefish
NPM - northern pikeminnow
PMC - peamouth chub
R- reference
RBT - rainbow trout
RWBL - red-winged blackbird
SCU - sculpin
SPSA - spotted sandpiper
U.S. - United States
WB – Whole body
WCT - westslope cutthroat trout
WT - western toad

Table 3.4-2. Periphyton tissue sampling area descriptions

Management unit or reference	Area	Description
MU1 Exposed	CACK	Cataract Creek
	FO10	Fording River Oxbow
	FO22	Fording River u/s Chauncey Creek
	FO28	Fording River u/s Dry Creek
	FO29	Fording River d/s Dry Creek
	FOUFO	Fording River
	FR1	Fording River d/s Cataract Creek
	FR2	Fording River d/s Lake Mountain Creek
	FR3	Fording River u/s of Henretta Creek
	FRDFB	Fording River
	HE27	Henretta Lake
	LkMtn1a	Lake Mountain Creek d/s culvert
	LkMtn1b	Lake Mountain Creek u/s culvert
	LkMtn1c	Lake Mountain Creek d/s Lake Mountain Lake
	MP1	Fording River at Multiplate
	NGD1	Lower Lake Mountain Creek
	R5-1	Fording River Lower Reach 5 Site 1 (40m adjacent)
	R6-12	Fording River Upper Reach 6 Site 12 (20m adjacent)
	R6-14	Fording River Upper Reach 6 Site 14 (10m adjacent)
	R6-15	Fording River Upper Reach 6 Site 15 (40m adjacent)
	R6-34	Fording River Upper Reach 6 Site 34
	R6-35	Fording River Upper Reach 6 Site 35
	R6-36	Fording River Upper Reach 6 Site 36 (10m adjacent)
	R6-44	Side channel of Fording River with flowing water and a back water off the channel
	R7-109	Isolated pond and perennially flooded drainage channel from Clode Pond
	R7-114	Perennially flooded back water off a drainage channel from Clode Pond
	R7-119	Channel-like pool off side channel of Fording River
	R7-47	Fording River Upper Reach 7 Site 47 (25m adjacent)
	R7-48	Fording River Upper Reach 7 Site 48 (150m adjacent)
	R7-49	Fording River Upper Reach 7 Site 49 (90m adjacent)
	R7-51	Fording River Upper Reach 7 Site 51 (500m adjacent)
	R7-64	Fording River Upper Reach 7 Site 64
	SW1, SWCK	Swift Creek d/s of first barrier
MU2 Exposed	FO23	Fording River d/s Line Creek
	FO9	Fording River d/s Josephine Falls, u/s Grace Creek
	FOULC	Fording River u/s of Line Creek
	LI8	Line Creek d/s LCO
	LILC3	Line Creek d/s West Line Creek, u/s South Line

Table 3.4-2. Periphyton tissue sampling area descriptions

Management unit or reference	Area	Description
	R5-10	Fording River Lower Reach 5 Site 10
	R5-17	Fording River Lower Reach 5 Site 17
	R5-4	Fording River Lower Reach 5 Site 4 (25m adjacent)
	R5-5	Fording River Lower Reach 5 Site 5
	R5-9	Fording River Lower Reach 5 Site 9
MU3 Exposed	ELUFO	Elk River u/s Fording River
	ERBC	Elk River Above Boivin Creek
	NT1	North Thompson Creek
	R4-160	Elk River Reach 4 Site 160
	R4-162	Elk River Reach 4 Site 162
	R4-163	Elk River Reach 4 Site 163
	R4-164	Elk River Reach 4 Site 164 (315m adjacent)
	R4-165	Elk River Reach 4 Site 165
	THCK-R1	Thompson Creek Reach 1
	THCK-R4	Thompson Creek Reach 4
	WOCK	Wolfram d/s pond
MU4 Exposed	EL19	Elk River d/s Fording River, u/s Grave Creek
	ELDFR2	Elk River downstream Fording River
	ELDGR	Elk River d/s Grave Creek (side channel)
	GO13	Goddard Marsh
	MI2	Michel Creek d/s EVO
	MI3	Michel Creek u/s Erickson Creek
	MICH1	Michel Creek - Reach 1
	MICH2	Michel Creek - Reach 2
	MICH3	Michel Creek - Reach 3
	R3-127	Elk River Reach 3 Site 127
	R3-129	Elk River Reach 3 Site 129
	R3-137	Elk River Reach 3 Site 137 (270m adjacent)
	R3-138	Elk River Reach 3 Site 138 (140m adjacent)
	R3-145	Elk River Reach 3 Site 145 (Anthropogenic)
	R3-153	Elk River Reach 3 Site 153
	R3-157	Elk River Reach 3 Site 157
MU5 Exposed	EL1	Elk River d/s of Michel Creek
	ELELKO	Elk River u/s Elko
	ELKO	Elko reservoir
	ELKO U/S	Elk River u/s Morrissey Creek (side channel)
	ER3	Elk River between Michel Creek and Fernie
	LK02	Lake Koocanusa at Elk River
	R1-18	Elk River Reach 1 Site 18

Table 3.4-2. Periphyton tissue sampling area descriptions

Management unit or reference	Area	Description
	R1-2	Elk River Reach 1 Site 2
	R1-29	Elk River Reach 1 Site 29
	R1-44	Elk River Reach 1 Site 44 (475m adjacent)
	R1-76	Elk River Reach 1 Site 76
	R2-101	Elk River Reach 2 Site 101
	R2-108	Elk River Reach 2 Site 108 (450m adjacent)
	R2-113	Elk River Reach 2 Site 113 (Anthropogenic)
	R2-122	Elk River Reach 2 Site 122
	R2-124	Elk River Reach 2 Site 124
	R2-80	Elk River Reach 2 Sites 80A & 80B
	R2-92	Elk River Reach 2 Site 92
	RG_R2-122	Elk River Reach 2 Sites 122A & 122B
Reference	AL4	Alexander Creek
	AX1	Alexander Creek
	CA1	Carbon Creek
	CHCK	Chauncey Creek
	DRCK	Dry Creek
	EL12	Elk River d/s Cadorna Creek
	EL14	Elk Lakes
	ELUCA	Elk River u/s Cadorna Creek
	ELUQU	Elk River u/s Quarrie Creek
	ELUWE	Elk River u/s Weary Creek
	EWCK	Ewin Creek
	FL17	Flathead Wetland
	FO15	Fording River wetland
	FO26	Upper Fording River (F026)
	FR4	Fording River u/s of Swift Project
	GLM	Graves Lake marsh
	HECK	Henretta Creek
	HENUP	Henretta Creek u/s all mine operations
	LE1	Leach Creek
	LI24	Line Creek u/s LCO
	LK01	Lake Koocanusa at Sand Creek
	LkMtn2	Lake Mountain Lake
	MC1	Mine Creek
	RL1	O'Rourke Lake
	WH1	Wheeler Creek

Table 3.4-3. Analytes and sample sizes for periphyton tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Aluminum	217	70	287
Antimony	217	70	287
Arsenic	222	74	296
Barium	217	70	287
Beryllium	217	70	287
Bismuth	217	70	287
Boron	217	70	287
Cadmium	217	70	287
Calcium	217	70	287
Cesium	207	60	267
Chlorine	10	10	20
Chromium	217	70	287
Cobalt	217	70	287
Copper	217	70	287
Gallium	109	56	165
Iron	217	70	287
Lead	217	70	287
Lithium	217	70	287
Magnesium	217	70	287
Manganese	217	70	287
Mercury	145	46	191
Molybdenum	217	70	287
Nickel	217	70	287
Phosphorous	217	70	287
Potassium	217	70	287
Rhenium	109	56	165
Rubidium	207	60	267
Selenium	242	81	323
Silicon	10	10	20
Silver	27	23	50
Sodium	217	70	287
Strontium	217	70	287
Sulfur	10	10	20
Tellurium	190	47	237
Thallium	217	70	287

Table 3.4-3. Analytes and sample sizes for periphyton tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Thorium	119	66	185
Tin	217	70	287
Titanium	119	66	185
Uranium	217	70	287
Vanadium	222	74	296
Yttrium	109	56	165
Zinc	217	70	287
Zirconium	207	60	267

Table 3.4-4. Summary of HQs based on 95th percentile of periphyton tissue selenium concentrations for all samples collected within each MU

CoI	Tissue type	Receptor	HQs					
			MU1	MU2	MU3	MU4	MU5	MU6
Selenium	Periphyton	Amphibian	**2.4**	**3.6**	**4.3**	**2.8**	**1.1**	0.73

Notes:
CoI – constituent of interest
HQ - hazard quotient
MU - management unit

Table 3.4-5. Exceedances of selenium TRV for amphibians feeding on periphyton by area

Management unit	Area	Ecosystem	# of samples	# of samples > amphib diet TRV	% of samples > amphib diet TRV	Maximum HQ	Mean HQ[a]
MU1	CACK	Lotic	6	0	0%	0.7	-
	FO10	Lentic	5	4	80%	16.7	6.4
	FO22	Lotic	3	0	0%	0.6	-
	FO28	Lotic	3	3	100%	2.2	1.6
	FO29	Lotic	1	1	100%	2.3	2.3
	FOUFO	Lotic	1	0	0%	0.9	-
	FR1	Lotic	5	1	20%	1.2	0.8
	FR2	Lotic	5	1	20%	1.2	0.9
	FR3	Lotic	5	0	0%	0.4	-
	FRDFB	Lotic	1	0	0%	0.6	-
	HE27	Lentic	1	0	0%	0.9	-
	LkMtn1a	Lotic	5	5	100%	2.7	2.3
	LkMtn1b	Lotic	5	3	60%	1.4	1.1
	LkMtn1c	Lotic	5	0	0%	0.7	-
	MP1	Lotic	1	0	0%	1.0	-
	NGD1	Lotic	1	1	100%	1.5	1.5
	R5-1	Off-channel	2	0	0%	0.4	-
	R6-12	Off-channel	1	0	0%	0.4	-
	R6-14	Lentic	1	0	0%	0.2	-
	R6-15	Lentic	1	0	0%	0.5	-
	R6-34	Off-channel	1	0	0%	0.5	-
	R6-35	Off-channel	1	0	0%	1.0	-
	R6-36	Lentic	2	1	50%	1.1	1.1
	R6-44	Off-channel	2	0	0%	0.6	-
	R7-109	Off-channel	1	0	0%	0.6	-
	R7-114	Off-channel	2	0	0%	0.7	-
	R7-119	Off-channel	1	1	100%	1.2	-
	R7-47	Lentic	1	0	0%	0.4	-
	R7-48	Off-channel	1	0	0%	0.3	-
	R7-49	Off-channel	1	0	0%	0.3	-
	R7-51	Off-channel	1	0	0%	0.2	-
	R7-64	Lentic	1	1	100%	1.9	-
	SW1	Lotic	10	7	70%	1.7	1.3
	SWCK	Lotic	1	0	0%	0.9	-

Table 3.4-5. Exceedances of selenium TRV for amphibians feeding on periphyton by area

Management unit	Area	Ecosystem	# of samples	# of samples > amphib diet TRV	% of samples > amphib diet TRV	Maximum HQ	Mean HQ[a]
MU2	FO23	Lotic	3	1	33%	1.8	0.9
	FO9	Lotic	1	0	0%	0.3	-
	FOULC	Lotic	2	1	50%	1.8	1.3
	LI8	Lotic	2	0	0%	0.8	-
	LILC3	Lotic	1	1	100%	3.6	-
	R5-10	Lentic	1	0	0%	0.5	-
	R5-17	Off-channel	1	0	0%	0.5	-
	R5-4	Off-channel	1	0	0%	0.6	-
	R5-5	Off-channel	1	0	0%	0.1	-
	R5-9	Off-channel	4	3	75%	6.2	2.8
MU3	ELUFO	Lotic	1	0	0%	0.2	-
	ERBC	Lotic	1	0	0%	0.1	-
	NT1	Lotic	5	5	100%	1.3	1.2
	R4-160	Off-channel	1	0	0%	0.3	-
	R4-162	Off-channel	1	0	0%	0.5	-
	R4-163	Lentic	1	0	0%	0.2	-
	R4-164	Lentic	2	0	0%	0.2	-
	R4-165	Off-channel	1	0	0%	0.2	-
	THCK-R1	Lotic	5	5	100%	4.5	3.7
	THCK-R4	Lotic	5	5	100%	1.9	1.5
	WOCK	Lotic	1	0	0%	0.9	-
MU4	EL19	Lotic	1	0	0%	0.5	-
	ELDFR2	Lotic	1	0	0%	0.6	-
	ELDGR	Lotic	5	2	40%	1.2	1.0
	GO13	Lentic	3	3	100%	3.7	3.4
	MI2	Lotic	4	0	0%	0.7	-
	MI3	Lotic	1	0	0%	0.3	-
	MICH1	Lotic	6	0	0%	0.4	-
	MICH2	Lotic	5	0	0%	0.5	-
	MICH3	Lotic	5	0	0%	0.5	-
	R3-127	Off-channel	2	0	0%	0.1	-
	R3-129	Lentic	1	0	0%	0.3	-
	R3-137	Off-channel	1	0	0%	0.7	-
	R3-138	Lentic	3	0	0%	0.4	-

Table 3.4-5. Exceedances of selenium TRV for amphibians feeding on periphyton by area

Management unit	Area	Ecosystem	# of samples	# of samples > amphib diet TRV	% of samples > amphib diet TRV	Maximum HQ	Mean HQ[a]
	R3-145	Lentic	1	0	0%	0.3	-
	R3-153	Off-channel	4	0	0%	0.5	-
	R3-157	Off-channel	1	0	0%	0.2	-
MU5	EL1	Lotic	5	0	0%	0.7	-
	ELELKO	Lotic	2	1	50%	1.2	0.8
	ELKO	Lentic	5	0	0%	1.0	-
	ELKO u/s	Lentic	5	0	0%	0.3	-
	ER3	Lotic	1	1	100%	0.0	-
	LK02	Lentic	11	0	0%	0.8	-
	R1-18	Off-channel	1	0	0%	1.5	1.5
	R1-2	Off-channel	3	0	0%	0.0	-
	R1-29	Off-channel	3	1	33%	0.7	-
	R1-44	Lentic	3	0	0%	1.1	1.1
	R1-76	Lentic	3	0	0%	0.7	-
	R2-101	Off-channel	3	0	0%	0.3	-
	R2-108	Lentic	6	0	0%	0.6	-
	R2-113	Off-channel	1	0	0%	0.4	-
	R2-122	Off-channel	4	0	0%	0.2	-
	R2-124	Off-channel	3	0	0%	0.6	-
	R2-80	Off-channel	9	0	0%	0.4	-
	R2-92	Off-channel	3	0	0%	0.1	-
	RG_R2-122	Off-channel	2	0	0%	0.1	-

Notes:
[a] Mean HQs are provided when maximum HQ is >1.0.
TRV - toxicity reference value
HQ - hazard quotient

Table 3.4-6. Summary of periphyton species counts reported among laboratories for split samples

Area	Criteria	Laboratory A	Laboratory B	Laboratory C	Laboratory D	Combined species richness (all laboratories)	Instances where all 4 laboratories identified same species
AL4	Total # of species identified	10	15	19	13	40	1
	At least one match with another lab	3	6	9	4		
	% of spp. identified that were also counted by at least one other lab	30%	40%	47%	31%		
BUUQ	Total # of species identified	13	22	31	30	68	1
	At least one match with another lab	3	11	10	9		
	% of spp. identified that were also counted by at least one other lab	23%	50%	32%	30%		
SLINE-R2	Total # of species identified	8	8	12	14	30	1
	At least one match with another lab	3	3	5	5		
	% of spp. identified that were also counted by at least one other lab	38%	38%	42%	36%		
WIHR	Total # of species identified	16	18	21	26	53	2
	At least one match with another lab	9	5	10	10		
	% of spp. identified that were also counted by at least one other lab	56%	28%	48%	38%		
FODPO	Total # of species identified	13	13	22	16	41	2
	At least one match with another lab	7	7	7	5		
	% of spp. identified that were also counted by at least one other lab	54%	54%	32%	31%		
LI8-R2	Total # of species identified	11	17	20	23	47	3
	At least one match with another lab	4	5	8	8		
	% of spp. identified that were also counted by at least one other lab	36%	29%	40%	35%		
LIDSL-SHR2	Total # of species identified	13	19	25	21	49	3
	At least one match with another lab	7	11	14	8		
	% of spp. identified that were also counted by at least one other lab	54%	58%	56%	38%		

Table 3.4-6. Summary of periphyton species counts reported among laboratories for split samples

Area	Criteria	Laboratory				Combined species richness (all laboratories)	Instances where all 4 laboratories identified same species
		A	B	C	D		
Combined Stations	Average number of species identified per sample	12	16	21	20	-	-
	Average number of times that the species identified agreed with at least one other lab	5	7	9	7	-	-
	Average number of times species was only identified by one lab	6	8	11	11	-	-
	Total number of unique species identified by each lab	33	46	67	41	-	-

Table 3.4-7. Summary of periphyton genus counts reported among laboratories for split samples

Area	Criteria	Laboratory				Combined genus richness (all laboratories)	Instances where all 4 laboratories identified same species
		A	B	C	D		
AL4	Total # of genera identified	9	13	12	11	24	3
	At least one match with another lab	6	9	9	9		
	% of genera identified that were also counted by at least one other lab	67%	69%	75%	82%		
BUUQ	Total # of genera identified	13	17	19	23	38	4
	At least one match with another lab	9	13	14	15		
	% of genera identified that were also counted by at least one other lab	69%	76%	74%	65%		
SLINE-R2	Total # of genera identified	7	6	7	13	19	2
	At least one match with another lab	5	4	5	7		
	% of genera identified that were also counted by at least one other lab	71%	67%	71%	54%		
WIHR	Total # of genera identified	14	10	12	21	27	6
	At least one match with another lab	12	8	11	13		
	% of genera identified that were also counted by at least one other lab	86%	80%	92%	62%		
FODPO	Total # of genera identified	11	10	13	13	22	6
	At least one match with another lab	9	9	10	7		
	% of genera identified that were also counted by at least one other lab	82%	90%	77%	54%		
LI8-R2	Total # of genera identified	11	13	12	20	28	4
	At least one match with another lab	10	9	11	13		
	% of genera identified that were also counted by at least one other lab	91%	69%	92%	65%		
LIDSL-SHR2	Total # of genera identified	12	13	15	19	27	7
	At least one match with another lab	10	11	13	13		
	% of genera identified that were also counted by at least one other lab	83%	85%	87%	68%		

Table 3.4-7. Summary of periphyton genus counts reported among laboratories for split samples

Area	Criteria	Laboratory				Combined genus richness (all laboratories)	Instances where all 4 laboratories identified same species
		A	B	C	D		
Combined Stations	Average number of genera identified	11	12	13	17	-	-
	Average number of times that the genus identified agreed with at least one other lab	9	9	10	11	-	-
	Average number of times genus was only identified by one lab	2	3	2	6	-	-
	Total number of unique genera identified	28	26	33	31	-	-

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
MU1 Exposed	CACK	Cataract Creek
	FO10	Fording River Oxbow
	FO22	Fording River u/s Chauncey Creek
	FO28	Fording River u/s Dry Creek
	FO29	Fording River d/s Dry Creek
	FO52	Fording u/s Kilmarnock
	FOBC	Fording River beside Clode Pond
	FOBCP	Fording River btw Cataract and Porter Creeks
	FOBKS	Fording River btw Kilmarnock and Swift Creeks
	FOBSC	Fording River d/s Swift, u/s Cataract
	FODGH	Fording River d/s GHO
	FODHE	Fording River d/s Henretta Creek
	FODPO	Fording River d/s Porter, u/s Chauncey Creek
	FOFR2W	Wetland South of Fording Tailings
	FOUEW	Fording River d/s Chauncey, u/s Ewin
	FOUFO	Fording River
	FOUKI	Fording River u/s Kilmarnock Creek
	FOUNGD	Fording River u/s NGD
	FOUSH	Fording River u/s Shandley Creek
	FOXL	Fording River Oxbow Lower
	FR1	Fording River d/s Cataract Creek
	FR2	Fording River d/s Lake Mountain Creek
	FR3	Fording River u/s of Henretta Creek
	FRDFB	Fording River
	GHCKD	Greenhills Creek d/s of settling pond
	GHCKU	Greenhills Creek u/s of settling pond
	HE27	Henretta Lake
	HECK	Henretta Creek
	HENFO	Henretta Creek u/s Fording River
	KICK	Kilmarnock Creek
	LkMtn1a	Lake Mountain Creek d/s culvert
	LkMtn1b	Lake Mountain Creek u/s culvert
	LkMtn1c	Lake Mountain Creek d/s Lake Mountain Lake
	MP1	Fording River at Multiplate
	NGD1	Lower Lake Mountain Creek
	POCK	Porter Creek
	R5-1	Fording River Lower Reach 5 Site 1 (40m adjacent)
	R5-2	Fording River Lower Reach 5 Site 2 (20m adjacent)
	R6-12	Fording River Upper Reach 6 Site 12 (20m adjacent)

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
	R6-14	Fording River Upper Reach 6 Site 14 (10m adjacent)
	R6-15	Fording River Upper Reach 6 Sites 15A & 15B
	R6-2	Fording River Upper Reach 6 Site 2 (Anthropogenic)
	R6-35	Fording River Upper Reach 6 Site 35
	R6-36	Fording River Upper Reach 6 Site 36 (10m adjacent)
	R6-44	Fording River Upper Reach 6 Site 44
	R7-109	Fording River Upper Reach 7 Site 109 (100m adjacent)
	R7-114	Fording River Upper Reach 7 Sites 114A & 114B
	R7-47	Fording River Upper Reach 7 Site 47 (25m adjacent)
	R7-48	Fording River Upper Reach 7 Site 48 (150m adjacent)
	R7-49	Fording River Upper Reach 7 Site 49 (90m adjacent)
	R7-51	Fording River Upper Reach 7 Site 51 (500m adjacent)
	R7-64	Fording River Upper Reach 7 Site 64
	SW1, SWCK	Swift Creek d/s of first barrier
	SWWL	Swift Wetland
MU2 Exposed	FO23	Fording River d/s Line Creek
	FO9	Fording River d/s Josephine Falls, u/s Grace Creek
	FOUL	Fording River d/s Grace, u/s Line
	FOULC	Fording River u/s of Line Creek
	LC8	d/s of culvert, u/s of LCCPL
	LCCPL	Line Creek Lower Cont. Ponds
	LI8	Line Creek d/s LCO
	LIDSL	Upper Line Creek, u/s South Line
	LILC3	Line Creek d/s West Line Creek, u/s South Line
	MSAN	MSA-North Pond
	NNP (Benthos)	NoName Pond
	R5-10	Fording River Lower Reach 5 Site 10
	R5-17	Fording River Lower Reach 5 Site 17
	R5-3	Fording River Lower Reach 5 Site 3 (110m adjacent)
	R5-4	Fording River Lower Reach 5 Site 4 (25m adjacent)
	R5-5	Fording River Lower Reach 5 Site 5
	R5-9	Fording River Lower Reach 5 Site 9
MU3 Exposed	EL20	Elk River d/s Thompson & GHO
	ELDEL	Elk River d/s Elkford
	ELUEL	Elk River u/s Elkford
	ELUFO	Elk River u/s Fording River
	ER1	Upper Elk River above the Fording River confluence
	ERBC	Elk River Above Boivin Creek
	EROU	Elk River Upper Oxbow

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
	NT1	North Thompson Creek
	R4-159	Elk River Reach 4 Site 159
	R4-160	Elk River Reach 4 Site 160
	R4-161	Elk River Reach 4 Site 161
	R4-162	Elk River Reach 4 Site 162
	R4-163	Elk River Reach 4 Site 163
	R4-164	Elk River Reach 4 Site 164
	R4-165	Elk River Reach 4 Site 165
	THCK	Thompson Creek
	THCK-R1	Thompson Creek Reach 1
	THCK-R4	Thompson Creek Reach 4
	WOCK	Wolfram d/s pond
MU4 Exposed	AQCK	Aqueduct Creek
	BOCK	Bodie Creek d/s Bodie Pond
	COCK	Corbin Creek
	EL19	Elk River d/s Fording River, u/s Grave Creek
	ELDFR2	Elk River downstream Fording River
	ELDGR	Elk River d/s Grave Creek (side channel)
	ELUSP	Elk River d/s Otto Creek, u/s Sparwood and Michel Creek
	ELWDGC	Elk River Wetland d/s Grave Creek
	ERCK	Erickson Creek
	GO13	Goddard Marsh
	GRCK	Grace Creek d/s Harmer
	GRDS	Grave Creek near mouth at Elk
	HACKDS	Harmer Creek d/s Pond
	HACKUS	Harmer Creek u/s Pond
	MI16	Michel Creek Wetland
	MI2	Michel Creek d/s EVO
	MI3	Michel Creek u/s Erickson Creek
	MI5	Michel Creek d/s CMO
	MICH1	Michel Creek - Reach 1
	MICH2	Michel Creek - Reach 2
	MICH3	Michel Creek - Reach 3
	MIDAG	Michel Creek d/s Andy Good Creek
	MIDCO	Michel Creek d/s Corbin, u/s Andy Good Creek
	MIUCO	Michel Creek u/s Corbin
	MIWW	Lower Michel Wetland
	OCNM[1]	Otto Creek Near Mouth
	OTTO	Otto Creek Wetlands

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
	R3-127	Elk River Reach 3 Site 127
	R3-129	Elk River Reach 3 Site 129
	R3-137	Elk River Reach 3 Site 137
	R3-138	Elk River Reach 3 Site 138
	R3-139	Elk River Reach 3 Site 139
	R3-145	Elk River Reach 3 Site 145
	R3-153	Elk River Reach 3 Site 153
	R3-157	Elk River Reach 3 Site 157
MU5 Exposed	EL1	Elk River d/s of Michel Creek
	EL18	Elk River near Fernie
	ELDFE	Elk River d/s Fernie
	ELELKO	Elk River u/s Elko
	ELH93	Elk River u/s Hwy 93 Bridge
	ELKO	Elko reservoir
	ELKO U/S	Elk River u/s Morrissey Creek (side channel)
	ELUFE	Elk River u/s Fernie
	ER3	Elk River between Michel Creek and Fernie
	EROL	Elk River Lower Oxbow
	ERWSF	Elk River Wetland south of Fernie
	LK02	Lake Koocanusa at Elk River
	R1-15	Elk River Reach 1 Site 15
	R1-18	Elk River Reach 1 Site 18
	R1-2	Elk River Reach 1 Site 2
	R1-20	Elk River Reach 1 Site 20 (115m adjacent)
	R1-29	Elk River Reach 1 Site 29
	R1-44	Elk River Reach 1 Site 44 (475m adjacent)
	R1-61	Elk River Reach 1 Site 61
	R1-76	Elk River Reach 1 Site 76
	R2-101	Elk River Reach 2 Site 101
	R2-108	Elk River Reach 2 Site 108 (450m adjacent)
	R2-110	Elk River Reach 2 Site 110
	R2-113	Elk River Reach 2 Site 113 (Anthropogenic)
	R2-122	Elk River Reach 2 Sites 122A & 122B
	R2-124	Elk River Reach 2 Site 124
	R2-80	Elk River Reach 2 Sites 80A & 80B
	RG_R2-122	Elk River Reach 2 Sites 122A & 122B

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
Reference	AC	Alexander Creek
	AGCK	Andy Good Creek u/s CMO
	AL4	Alexander Creek
	ALB	Albert River u/s Palliser River
	AX1	Alexander Creek
	BA6	Barnes Lake
	Boivin Creek	Boivin Creek
	BU40	Bull River 40 km Bridge
	BUUQ	Bull River u/s Quinn Creek
	CA1	Carbon Creek
	CADCK	Cadorna Creek u/s Elk River
	CHCK	Chauncey Creek
	CRUKO	Cross River u/s Kootenay
	DACK	Daisy Creek
	DRCK	Dry Creek
	DUCK	Dutch Creek
	EL12	Elk River d/s Cadorna Creek
	EL14	Elk Lakes
	ELUCA	Elk River u/s Cadorna Creek
	ELUGH	Elk River u/s Branch
	ELUQU	Elk River u/s Quarrie Creek
	ELUWE	Elk River u/s Weary Creek
	EWCK	Ewin Creek
	Fen	Fen in StormCat area
	FI1	Fir Creek
	FL17	Flathead Wetland
	FO15	Fording River wetland
	FO21	Upper Fording River (F021)
	FO26	Upper Fording River (F026)
	FR4	Fording River u/s of Swift Project
	GLM	Graves Lake marsh
	Gold Creek	Gold Creek
	GRUHA	Grave Creek u/s Harmer Creek
	HENUP	Henretta Creek u/s all mine operations
	KODCR	Kootenay River d/s Cross River
	KOUCR	Kootenay River u/s Cross River
	KOUVE	Kootenay River u/s Vermillion River
	LE1	Leach Creek

Table 3.5-1. Invertebrate sampling area descriptions

Management unit or reference	Area	Description
	LI24	Line Creek u/s LCO
	LK01	Lake Koocanusa at Sand Creek
	LkMtn2	Lake Mountain Lake
	Lynx Creek	Lynx Creek
	MC1	Mine Creek
	MI25	Michel Creek u/s CMO confluence
	MMCR	McCool Creek
	OLDDU	Oldman River d/s Dutch Creek
	OLDLI	Oldman River d/s Livingstone Creek
	OLDLOW	Lower Oldman River u/s Reservoir
	OLUP	Upper Oldman River
	PADAL	Palliser River d/s Albert River
	PAUKO	Palliser River d/s Kootenay River
	RACK	Racehorse Creek
	REFF	Unnamed Wetland near Elk River North of Elkford
	RL1	O'Rourke Lake
	SKUKO	Skookumchuck River
	SLINE	South Line Creek
	SN1	Snowslide Creek
	TRCK	Transmission Creek
	UM1	Unnamed Tributary to Michel Creek
	VEUKO	Vermillion River u/s Kootenay River, d/s Simpson
	VEUP	Vermillion River Upper u/s Simpson River
	VICK	Vicary Creek
	WH1	Wheeler Creek
	WIHR	Wild Horse River
	WWR	Wigwam River
	WWR (Beaver Pond)	Wigwam River (Beaver Pond)
	WWRL	Lower Wigwam River

[1] OCNM is the same location as OTTO in the maps.

Table 3.5-2. Analytes and sample sizes for invertebrate tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Aluminum	274	131	405
Antimony	274	131	405
Arsenic	281	136	417
Barium	274	131	405
Beryllium	274	131	405
Bismuth	274	131	405
Boron	274	131	405
Cadmium	274	131	405
Calcium	274	131	405
Cesium	264	121	385
Chlorine	0	5	5
Chromium	274	131	405
Cobalt	274	131	405
Copper	274	131	405
Gallium	196	114	310
Iron	274	126	400
Lead	274	131	405
Lithium	274	131	405
Magnesium	274	131	405
Manganese	274	131	405
Mercury	114	70	184
Molybdenum	274	131	405
Nickel	274	131	405
Phosphorous	274	131	405
Potassium	274	131	405
Rhenium	196	114	310
Rubidium	264	121	385
Selenium	322	163	485
Silicon	10	10	20
Silver	117	61	178
Sodium	274	131	405
Strontium	274	131	405
Sulfur	0	5	5
Tellurium	157	70	227
Thallium	274	131	405

Table 3.5-2. Analytes and sample sizes for invertebrate tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Thorium	206	124	330
Tin	274	131	405
Titanium	206	124	330
Uranium	274	131	405
Vanadium	281	136	417
Yttrium	196	114	310
Zinc	274	131	405
Zirconium	264	121	385

Table 3.5-3. Summary of HQs based on 95th percentile of invertebrate tissue selenium concentrations for all samples collected within each MU

CoI	Tissue type	Receptor	HQs					
			MU1	MU2	MU3	MU4	MU5	MU6
Selenium	Invertebrate	Invertebrate	**2.1**	**1.9**	**2.2**	**1.6**	**1.2**	0.55
		Fish	**2.5**	**2.3**	**2.6**	**1.9**	**1.4**	0.65
		Amphibian	**3.4**	**3.0**	**3.5**	**2.6**	**1.9**	0.87
		Bird	**1.9**	**1.7**	**1.9**	**1.4**	1.0	0.48

Notes:
CoI – constituent of interest
HQ - hazard quotient
MU - management unit

Table 3.5-4. Exceedances of selenium TRV for fish feeding on invertebrates by area

Management unit	Area	Ecosystem	# of samples	# of samples > invert tissue TRV	% of samples > invert tissue TRV	Maximum HQ	Mean HQ[a]
MU1 Exposed	CACK	Lotic	1	1	100%	2.4	2.4
	FO10	Off-channel	6	6	100%	5.6	3.6
	FO22	Lotic	5	2	40%	1.1	0.9
	FO28	Lotic	1	0	0%	0.8	-
	FO29	Lotic	7	0	0%	0.9	-
	FO52	Lotic	1	0	0%	0.7	-
	FOBC	Lotic	1	0	0%	0.8	-
	FOBCP	Lotic	1	0	0%	0.7	-
	FOBKS	Lotic	1	0	0%	0.8	-
	FOBSC	Lotic	1	0	0%	0.8	-
	FODGH	Lotic	1	0	0%	0.8	-
	FODHE	Lotic	1	0	0%	0.8	-
	FODPO	Lotic	1	0	0%	0.6	-
	FOFR2W	Lentic	1	0	0%	0.4	-
	FOUEW	Lotic	1	0	0%	0.8	-
	FOUFO	Lotic	1	0	0%	0.9	-
	FOUKI	Lotic	1	0	0%	0.8	-
	FOUNGD	Lotic	1	0	0%	0.7	-
	FOUSH	Lotic	1	0	0%	0.7	-
	FOXL	Lentic	3	0	0%	0.1	-
	FR1	Lotic	5	5	100%	1.1	1.1
	FR2	Lotic	5	5	100%	1.1	1.1
	FR3	Lotic	5	1	20%	1.2	1.0
	FRDFB	Lotic	1	0	0%	0.7	-
	GHCKD	Lotic	1	1	100%	1.3	1.3
	GHCKU	Lotic	1	0	0%	0.9	-
	HE27	Lentic	2	0	0%	1.0	-
	HECK	Lotic	5	0	0%	0.5	-
	HENFO	Lotic	1	0	0%	0.7	-
	KICK	Lotic	1	0	0%	0.4	-
	LkMtn1a	Lotic	5	5	100%	1.7	1.5
	LkMtn1b	Lotic	5	0	0%	1.0	-
	LkMtn1c	Lotic	5	0	0%	0.9	-
	MP1	Lotic	2	0	0%	0.8	-
	NGD1	Lotic	1	0	0%	0.6	-
	POCK	Lotic	1	0	0%	0.5	-
	R5-1	Off-channel	1	1	100%	3.2	3.2

Table 3.5-4. Exceedances of selenium TRV for fish feeding on invertebrates by area

Management unit	Area	Ecosystem	# of samples	# of samples > invert tissue TRV	% of samples > invert tissue TRV	Maximum HQ	Mean HQ[a]
	R5-2	Lentic	1	0	0%	0.3	2.0
	R6-12	Off-channel	1	0	0%	0.7	-
	R6-14	Lentic	1	1	100%	2.1	2.1
	R6-15	Lentic	2	0	0%	0.7	-
	R6-2	Lentic	1	1	100%	2.8	2.8
	R6-35	Off-channel	1	1	100%	2.3	2.3
	R6-36	Lentic	2	0	0%	0.5	-
	R6-44	Off-channel	1	1	100%	1.9	1.9
	R7-109	Off-channel	1	0	0%	0.9	-
	R7-114	Off-channel	2	0	0%	0.8	-
	R7-47	Lentic	1	0	0%	0.1	-
	R7-48	Off-channel	1	0	0%	0.1	-
	R7-49	Off-channel	1	0	0%	0.4	-
	R7-51	Off-channel	1	0	0%	0.2	-
	R7-64	Lentic	1	0	0%	0.8	-
	SW1, SWCK	Lotic	6	6	100%	2.5	2.2
	SWWL	Lentic	1	1	100%	1.8	1.8
MU2 Exposed	FO23	Lotic	5	0	0%	1.0	-
	FO9	Lotic	4	0	0%	0.9	-
	FOUL	Lotic	1	0	0%	0.7	-
	FOULC	Lotic	1	1	100%	1.2	1.2
	LC8	Lentic	1	0	0%	1.0	-
	LCCPL	Lentic	1	1	100%	3.3	3.3
	LI8	Lotic	8	0	0%	1.0	-
	LIDSL	Lotic	1	0	0%	0.7	-
	LILC3	Lotic	1	0	0%	0.6	-
	MSAN	Lentic	1	0	0%	0.6	-
	NNP (Benthos)	Lentic	1	0	0%	0.6	-
	R5-10	Lentic	2	0	0%	0.9	-
	R5-17	Off-channel	1	1	100%	1.3	1.3
	R5-3	Off-channel	1	1	100%	2.0	1.1
	R5-4	Off-channel	1	1	100%	1.1	-
	R5-5	Off-channel	1	0	0%	0.9	-
	R5-9	Off-channel	1	0	0%	0.7	-

Table 3.5-4. Exceedances of selenium TRV for fish feeding on invertebrates by area

Management unit	Area	Ecosystem	# of samples	# of samples > invert tissue TRV	% of samples > invert tissue TRV	Maximum HQ	Mean HQ[a]
MU3 Exposed	EL20	Lotic	3	0	0%	0.8	-
	ELDEL	Lotic	1	0	0%	0.6	-
	ELUEL	Lotic	1	0	0%	0.7	-
	ELUFO	Lotic	2	0	0%	0.5	-
	ER1	Lotic	1	0	0%	0.6	-
	ERBC	Lotic	1	0	0%	0.3	-
	EROU	Lentic	3	0	0%	0.4	-
	NT1	Lotic	5	5	100%	2.1	1.6
	R4-159	Lentic	1	0	0%	0.3	-
	R4-160	Off-channel	1	0	0%	0.4	-
	R4-161	Lentic	1	0	0%	0.3	-
	R4-162	Off-channel	1	0	0%	0.6	-
	R4-163	Lentic	1	0	0%	0.5	-
	R4-164	Lentic	1	0	0%	0.2	-
	R4-165	Off-channel	1	0	0%	0.3	-
	THCK	Lotic	1	1	100%	3.2	3.2
	THCK-R1	Lotic	2	2	100%	2.8	2.6
	THCK-R4	Lotic	5	5	100%	1.6	1.4
	WOCK	Lotic	2	1	50%	1.5	0.8
MU4 Exposed	AQCK	Lotic	1	1	100%	1.4	1.4
	BOCK	Lotic	1	1	100%	1.0	-
	COCK	Lotic	1	0	0%	0.4	-
	EL19	Lotic	6	0	0%	0.9	-
	ELDFR2	Lotic	1	0	0%	0.7	-
	ELDGR	Lotic	6	5	83%	1.7	1.4
	ELUSP	Lotic	1	0	0%	0.6	-
	ELWDGC	Lentic	1	0	0%	0.7	-
	ERCK	Lotic	1	0	0%	0.6	-
	GO13	Lentic	6	6	100%	6.9	2.8
	GRCK	Lotic	1	0	0%	0.8	-
	GRDS	Lotic	1	0	0%	0.7	-
	HACKDS	Lotic	1	0	0%	0.6	-
	HACKUS	Lotic	1	0	0%	0.8	-
	MI16	Lentic	5	0	0%	1.0	-
	MI2	Lotic	7	0	0%	1.0	-
	MI3	Lotic	4	0	0%	0.6	-
	MI5	Lotic	3	0	0%	0.5	-

Table 3.5-4. Exceedances of selenium TRV for fish feeding on invertebrates by area

Management unit	Area	Ecosystem	# of samples	# of samples > invert tissue TRV	% of samples > invert tissue TRV	Maximum HQ	Mean HQ[a]
	MICH1	Lotic	6	0	0%	0.7	-
	MICH2	Lotic	5	0	0%	0.6	-
	MICH3	Lotic	5	0	0%	0.6	-
	MIDAG	Lotic	1	0	0%	0.6	-
	MIDCO	Lotic	3	0	0%	0.4	-
	MIUCO	Lotic	1	0	0%	0.6	-
	MIWW	Lentic	1	0	0%	0.6	-
	OCNM[1]	Lotic	1	0	0%	0.4	-
	OTTO	Lentic	3	2	67%	2.5	1.6
	R3-127	Off-channel	1	0	0%	0.2	-
	R3-129	Lentic	1	0	0%	0.8	-
	R3-137	Off-channel	1	0	0%	0.1	-
	R3-138	Lentic	2	0	0%	0.6	-
	R3-139	Off-channel	1	1	100%	1.2	1.2
	R3-145	Lentic	1	1	100%	1.4	1.4
	R3-153	Off-channel	1	1	100%	1.1	1.1
	R3-157	Off-channel	1	0	0%	0.6	-
MU5 Exposed	EL1	Lotic	9	0	0%	0.7	-
	EL18	Lentic	1	0	0%	0.4	-
	ELDFE	Lotic	1	0	0%	0.6	-
	ELELKO	Lotic	2	0	0%	0.6	-
	ELH93	Lotic	1	0	0%	0.4	-
	ELKO	Lentic	9	2	22%	1.6	0.9
	ELKO U/S	Lentic	5	4	80%	1.4	1.2
	ELUFE	Lotic	1	0	0%	0.6	-
	ER3	Lotic	1	0	0%	0.6	-
	EROL	Lentic	3	0	0%	0.5	-
	ERWSF	Lentic	1	0	0%	0.3	-
	LK02	Lentic	11	0	0%	0.7	-
	R1-15	Off-channel	1	0	0%	0.4	-
	R1-18	Off-channel	2	1	50%	1.0	-
	R1-2	Off-channel	1	0	0%	0.2	-
	R1-20	Lentic	1	0	0%	0.4	-
	R1-29	Off-channel	1	0	0%	0.3	-
	R1-44	Lentic	1	0	0%	0.4	-
	R1-61	Lentic	1	0	0%	0.3	-
	R1-76	Lentic	1	0	0%	0.5	-

Table 3.5-4. Exceedances of selenium TRV for fish feeding on invertebrates by area

Management unit	Area	Ecosystem	# of samples	# of samples > invert tissue TRV	% of samples > invert tissue TRV	Maximum HQ	Mean HQ[a]
	R2-101	Off-channel	1	0	0%	0.3	-
	R2-108	Lentic	2	2	100%	1.3	1.2
	R2-110	Off-channel	1	0	0%	0.8	-
	R2-113	Off-channel	1	0	0%	0.4	-
	R2-122	Off-channel	1	0	0%	0.3	-
	R2-124	Off-channel	1	0	0%	0.8	-
	R2-80	Off-channel	2	0	0%	0.5	-
	RG_R2-122	Off-channel	1	0	0%	0.8	-

Notes:

TRV - toxicity reference value

HQ - hazard quotient

[1] OCNM is the same location as OTTO in the maps.

Table 3.5-5. Results of the 2012 benthic invertebrate community assessment (adapted from Minnow 2014a)

Management unit	Area code	Area description	Area type	Adversely affected based on statistical comparisons of community endpoints to habitat-matched reference areas?	Percent ephemeroptera (mayflies), plecoptera (stoneflies), trichoptera (caddisflies)[a]	Percent ephemeroptera (mayflies)[a]
1	FODHE	Fording d/s Henretta	Mainstem Receiver	No	95	81
	FOUNGD	Fording u/s NGD	Mainstem Receiver	No	79	60
	MP1	Fording Multiplate d/s Eagle Ponds	Mainstem Receiver	Potentially	64	57
	FOUSH	Fording u/s Shandley Creek	Mainstem Receiver	No	79	70
	FOUKI	Fording u/s Kilmarnock Creek	Mainstem Receiver	No	84	75
	FOBKS	Fording between Kilmarnock & Swift	Mainstem Receiver	No	79	70
	FOBSC	Fording d/s Swift, u/s Cataract	Mainstem Receiver	Yes	63	49
	FOBCP	Fording between Cataract & Porter	Mainstem Receiver	No	84	73
	FODPO	Fording d/s Porter, u/s Chauncey	Mainstem Receiver	No	73	34
	FO22	Fording u/s Chauncey Creek	Mainstem Receiver	Potentially	56	30
	FOUEW	Fording d/s Chauncey, u/s Ewin	Mainstem Receiver	No	80	52
	FO28	Fording u/s Dry Creek	Mainstem Receiver	No	93	61
	FO29	Fording d/s Dry, u/s GHO & Hwy Bridge	Mainstem Receiver	Yes	59	51
	FODGH	Fording River d/s GHO	Mainstem Receiver	No	88	59
	HENFO	Henretta u/s confluence with Fording	Mine-influenced tributary	No	82	61
	NGD1	Lower Lake Mountain Creek	Mine-influenced tributary	No	71	59
	KICK	Kilmarnock u/s road crossing near mouth	Mine-influenced tributary	Yes	8	3
	SWCK	Swift Creek near mouth	Mine-influenced tributary	Yes	65	1
	CACK	Cataract Creek near mouth	Mine-influenced tributary	Yes	2	0
	POCK	Porter Creek near mouth	Mine-influenced tributary	Yes	39	0
	GHCKU	Greenhills Creek u/s of settling pond	Mine-influenced tributary	Yes	7	5
	GHCKD	Greenhills Creek d/s of settling pond	Mine-influenced tributary	Yes	3	0
2	FO9	Fording d/s Josephine falls, u/s Grace & Line	Mainstem Receiver	No	80	48
	FOUL	Fording d/s Grace, u/s Line	Mainstem Receiver	Potentially	84	29
	LI8	Line Creek d/s LCO	Mainstem Receiver	Potentially	72	28
	FO23	Fording d/s Line Creek	Mainstem Receiver	No	76	29
	LILC3	Line d/s West Line, u/s South Line	Mine-influenced tributary	Yes	8	2
	LIDSL	Upper Line Creek, d/s South Line	Mine-influenced tributary	Yes	49	32
3	EL20	Elk River d/s Thompson & GHO	Mainstem Receiver	No	93	48
	ELUEL	Elk River u/s Elkford	Mainstem Receiver	No	94	58
	ELDEL	Elk River d/s Elkford sewage ponds	Mainstem Receiver	No	93	48
	ELUFO	Elk River just u/s Fording	Mainstem Receiver	No	71	36
	WOCK	Wolfram d/s pond	Mine-influenced tributary	Yes	12	2
	THCK	Thompson d/s pond	Mine-influenced tributary	Yes	68	1

Table 3.5-5. Results of the 2012 benthic invertebrate community assessment (adapted from Minnow 2014a)

Management unit	Area code	Area description	Area type	Adversely affected based on statistical comparisons of community endpoints to habitat-matched reference areas?	Percent ephemeroptera (mayflies), plecoptera (stoneflies), trichoptera (caddisflies)[a]	Percent ephemeroptera (mayflies)[a]
4	EL19	Elk River d/s Fording, u/s Grave	Mainstem Receiver	No	92	63
	ELDGR	Elk River d/s Grave	Mainstem Receiver	No	88	47
	ELUSP	Elk d/s Otto, u/s Sparwood & Michel	Mainstem Receiver	No	85	58
	MIUCO	Michel u/s Corbin Creek	Mainstem Receiver	No	87	46
	MIDCO	Michel d/s Corbin, u/s Andy Good	Mainstem Receiver	Yes	58	28
	MIDAG	Michel d/s Andy Good	Mainstem Receiver	No	86	63
	MI5	Michel d/s CMO	Mainstem Receiver	No	71	43
	MI3	Michel u/s Erickson Creek	Mainstem Receiver	No	82	51
	MI2	Michel Creek d/s EVO.	Mainstem Receiver	Yes	52	16
	HACKUS	Harmer Creek u/s Harmer Pond	Mine-influenced tributary	No	76	32
	HACKDS	Harmer d/s Pond near mouth at Grave	Mine-influenced tributary	Yes	46	30
	GRCK	Grave Creek d/s Harmer	Mine-influenced tributary	No	81	53
	GRDS	Grave Creek near mouth at Elk	Mine-influenced tributary	Yes	61	29
	OCNM	Otto Creek near mouth	Mine-influenced tributary	Yes	38	13
	COCK	Corbin Creek near Mouth	Mine-influenced tributary	Yes	44	3
	ERCK	Erickson at CPR main line near mouth	Mine-influenced tributary	Yes	93	6
	BOCK	Bodie Creek d/s Bodie Pond	Mine-influenced tributary	Yes	28	1
5	EL1	Elk d/s Sparwood & Michel	Mainstem Receiver	No	79	44
	ELUFE	Elk u/s Fernie	Mainstem Receiver	No	74	51
	ELDFE	Elk d/s Fernie	Mainstem Receiver	No	81	59
	ELELKO	Elk River u/s Elko	Mainstem Receiver	No	85	54
	ELH93	Elk River u/s Hwy 93 Bridge	Mainstem Receiver	No	77	46
Reference Areas	**36 Areas Negligibly Disturbed by Mining or Other Man-Made Influences**		**Summary Statisticas, All Reference Areas Combined[b]**	**Minimum**	64	12
				5th Percentile	71	31
				Mean	86	49
				95th Percentile	97	67
				Maximum	97	82

Notes:
[a] Values less than the 5th percentile or less than the minimum of the combined reference areas are shaded light blue or dark blue, respectively. Also see footnote #2.
[b] For general comparative purposes, summary statistics are presented for all reference areas combined, but each mine-exposed areas was statistically compared to a sub-group of reference areas based on similar habitat characteristics. Details are presented in Minnow (2014).

Table 3.6-1. Fish sampling area descriptions

Management unit or reference	Area	Description
MU1 Exposed	CHCK	Chauncey Creek
	DRCK	Dry Creek
	FO10	Fording River Oxbow
	FO26	Fording River u/s Henretta Creek
	FOBKS	Fording River b/t Kilmarnock & Swift
	FOUEW	Fording River u/s Chauncey Creek, d/s Ewin
	HE27	Henretta Lake
	HECK	Henretta Creek
	LkMtn1	Lake Mountain Creek
	LkMtn1c	Lake Mountain Creek d/s Lake Mountain Lake
	MP1	Fording River at Multiplate
	NGD1	Lower Lake Mountain Creek
	PC	Fording River u/s Porter Creek
MU2 Exposed	FO23	Fording River d/s Line Creek
	FO9	Fording River d/s Josephine Falls, u/s Grace Creek
	LI8	Line Creek d/s LCO
MU3 Exposed	EROU	Upper Elk River Oxbow
MU4 Exposed	CA1	Carbon Creek
	EL19	Elk River d/s Fording River, u/s Grave Creek
	FI1	Fir Creek
	GO13	Goddard Marsh
	GRCK	Grave Creek d/s Harmer Creek
	HA7	Harmer Pond
	LE1	Leach Creek
	MI2	Michel Creek d/s EVO
	MI3	Michel Creek u/s Erickson Creek
	MI5	Michel Creek d/s CMO
	MIC_MS	Michel Creek
	MICH1	Michel Creek - Reach 1
	MICH2	Michel Creek - Reach 2
	MICH3	Michel Creek - Reach 3
	Michel Creek	Michel Creek
	SN1	Snowslide Creek
	UW1	Unnamed Tributary to Wheeler Creek
	WH1	Wheeler Creek
MU5 Exposed	EL1	Elk River d/s of Michel Creek
	Elk River	Elk River (area type unknown)
	ELK_MS	Elk River
	ELKO	Elko Reservoir
	EROL	Elk River Lower Oxbow

Table 3.6-1. Fish sampling area descriptions

Management unit or reference	Area	Description
	LK02	Lake Koocanusa at Elk River
	MC1	Mine Creek
MU6 Exposed	K01KOOCL35	Lake Koocanusa
	KOO_KOK	Lake Koocanusa
	Koocanusa	Lake Koocanusa
	LK01	Lake Koocanusa at Sand Creek
	LK-CAN1	Koocanusa - Canadian Reach 1
	LK-CAN2	Koocanusa - Canadian Reach 2
Reference	AC	Alexander Creek
	AL4	Alexander Creek
	AX1	Alexander Creek
	BA6	Barnes Lake
	BU2	Bull River
	BU40	Bull River 40 km Bridge
	CAB	Cabin Creek
	Connor Lake	Connor Lake
	EL12	Elk River d/s Cadorna Creek
	EL14	Elk Lakes
	ELUCA	Elk River u/s Cadorna Creek
	ELUQU	Elk River u/s Quarrie Creek
	ELUWE	Elk River u/s Weary Creek
	FHL	Flathead Lake
	FL17	Flathead Pond
	FOI	Foisey Creek
	FR	Flathead River (BC)
	HART	Hartley Lake
	HOW	Howell Creek
	HV	Harvey Creek
	K01	Kootenay River
	LCO	Leach Creek Oxbow
	LPO	Lodgepole Creek
	MCCR	McCool Creek
	MCE	McEvoy Creek
	MCL	McLatchie Creek
	MIP	Middlepass Creek
	NFR	North Fork Flathead River
	POL	Pollock Creek
	RL1	O'Rourke Lake
	TRCK	Transmission Creek

Table 3.6-2. Analytes and sample sizes for fish tissue

Analyte	Whole body/Muscle			Egg/Ovary		
	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Aluminum	408	77	485	104	19	123
Antimony	405	77	482	104	19	123
Arsenic	472	107	579	148	28	176
Barium	408	77	485	104	19	123
Beryllium	408	77	485	104	19	123
Bismuth	408	77	485	104	19	123
Boron	321	74	395	84	19	103
Cadmium	408	77	485	104	19	123
Calcium	372	77	449	104	19	123
Cesium	246	52	298	48	15	63
Chromium	408	77	485	104	19	123
Cobalt	408	77	485	104	19	123
Copper	408	77	485	104	19	123
Gallium	246	52	298	15	48	63
Iron	321	74	395	84	19	103
Lead	408	77	485	104	19	123
Lithium	333	55	388	68	15	83
Magnesium	372	77	449	104	19	123
Manganese	408	77	485	104	19	123
Mercury	388	62	450	106	13	119
Molybdenum	408	77	485	104	19	123
Nickel	408	77	485	104	19	123
Phosphorous	285	74	359	84	19	103
Potassium	285	74	359	84	19	103
Rhenium	246	52	298	48	15	63
Rubidium	246	52	298	48	15	63
Selenium	1014	591	1605	372	138	510
Silver	237	74	311	79	19	98
Sodium	285	74	359	84	19	103
Strontium	408	77	485	104	19	123
Tellurium	62	0	62	5	0	5

Table 3.6-2. Analytes and sample sizes for fish tissue

Analyte	Whole body/Muscle			Egg/Ovary		
	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Thallium	403	72	475	104	19	123
Thorium	251	57	308	48	15	63
Tin	408	77	485	104	19	123
Titanium	319	74	393	79	19	98
Uranium	408	77	485	104	19	123
Vanadium	467	102	569	148	28	176
Yttrium	251	57	308	48	15	63
Zinc	403	72	475	104	19	123
Zirconium	246	52	298	47	15	62

Table 3.6-3. Summary of HQs based on 95th percentile of fish tissue selenium concentrations for all samples collected within each MU

CoI	Tissue type	Receptor	HQs					
			MU1	MU2	MU3	MU4	MU5	MU6
Selenium	fish eggs/ovaries	fish (direct toxicity)	**4.5**	**2.3**	0.81	**3.1**	**2.7**	0.76
	fish whole body/muscle	fish (dietary toxicity)	**3.8**	**1.2**	**1.1**	**4.2**	**1.3**	0.46
		bird (dietary toxicity)	**2.8**	0.87	0.78	**3.1**	0.92	0.34

Notes:

CoI – constituent of interest

HQ - hazard quotient

MU - management unit

Table 3.6-4. Exceedances of selenium TRV for fish eggs/ovaries

Management unit	Area	Ecosystem	Species	# of samples	# of samples > fish egg/ovary TRV[a]	% of samples > fish egg/ovary TRV[a]	Maximum HQ[a]	Mean HQ[a,b]
MU1 Exposed	DRCK	Lotic	WCT	4	0	0%	0.5	-
	FO10	Lentic	WCT	7	7	100%	3.4	2.5
	FOBKS	Lotic	WCT	6	0	0%	0.8	-
	HE27	Lentic	WCT	3	0	0%	1.0	-
	MP1	Lotic	WCT	9	1	11%	3.4	0.9
	PC	Lotic	WCT	17	2	12%	3.3	0.8
MU2 Exposed	FO23	Lotic	BT	5	1	20%	1.1	0.8
			MWF	30	9	30%	1.5	1.0
			WCT	8	1	13%	1.1	0.6
	FO9	Lotic	WCT	3	0	0%	0.6	-
	LI8	Lotic	WCT	17	0	0%	0.9	-
MU3 Exposed	EROU	Lentic	LNS	20	0	0%	0.9	-
MU4 Exposed	GO13	Lentic	LNS	27	25	93%	4.3	2.3
	MI2	Lotic	MWF	20	13	65%	1.8	1.1
			WCT	10	0	0%	0.5	-
	MI3	Lotic	MWF	5	4	80%	1.3	1.2
			WCT	6	0	0%	0.5	-
	MI5	Lotic	WCT	4	0	0%	0.6	-
	MICH1	Lotic	MWF	5	1	20%	1.1	0.8
MU5 Exposed	EL1	Lotic	BT	1	0	0%	0.9	-
			MWF	23	14	61%	2.1	1.1
			WCT	15	0	0%	0.7	-
	ELK_MS	Lotic	MWF	8	4	50%	1.4	1.1
	ELKO	Lentic	MWF	10	4	40%	1.3	1.0

Table 3.6-4. Exceedances of selenium TRV for fish eggs/ovaries

Management unit	Area	Ecosystem	Species	# of samples	# of samples > fish egg/ovary TRV[a]	% of samples > fish egg/ovary TRV[a]	Maximum HQ[a]	Mean HQ[a,b]
	EROL	Lentic	LNS	6	0	0%	0.9	-
	LK02	Lentic	MWF	7	0	0%	0.7	-
			WCT	6	0	0%	0.7	-
	MC1	Lotic	EB	1	1	100%	1.2	1.2
MU6 Exposed	K01KOOCL35	Lentic	KKN	17	0	0%	0.3	-
	KOO_KOK	Lentic	KKN	20	0	0%	0.3	-
			LNS	4	0	0%	0.3	-
			NPM	18	0	0%	0.3	-
			PMC	20	0	0%	0.6	-
	LK01	Lentic	LSS	1	0	0%	0.2	-
	LK-CAN1	Lentic	KKN	2	0	0%	0.2	-
	LK-CAN2	Lentic	KKN	7	0	0%	0.3	-

Notes:

[a] TRV of 25 mg/kg dw used for WCT and TRV of >33 mg/kg dw used for MWF; TRV of 18 mg/kg dw used for all other fish species.

[b] Mean HQ provided when maximum HQ is >1.0.

HQ - hazard quotient

TRV - toxicity reference value

MU - management unit

BT - bull trout

EB - brook trout

KKN - kokanee

LNS - longnose sucker

LSS - largescale sucker

MWF - mountain whitefish

WCT - westslope cutthroat trout

Table 3.6-5. Exceedances of selenium TRV for fish feeding on other fish by area

Management unit	Area	Ecosystem	# of samples	# of samples > fish dietary TRV	% of samples > fish dietary TRV	Maximum HQ	Mean HQ[a]
MU1 Exposed	CHCK	Lotic	4	2	50%	1.2	0.7
	DRCK	Lotic	21	3	14%	1.1	0.9
	FO10	Lentic	21	21	100%	5.1	3.1
	FO26	Lotic	5	0	0%	0.8	-
	FOBKS	Lotic	22	3	14%	1.5	0.8
	FOUEW	Lotic	3	0	0%	0.8	-
	HE27	Lentic	12	4	33%	1.2	0.8
	HECK	Lotic	1	0	0%	0.6	-
	LkMtn1	Lotic	10	10	100%	3.3	2.1
	LkMtn1c	Lotic	9	0	0%	0.8	-
	MP1	Lotic	14	4	29%	5.0	1.2
	NGD1	Lotic	4	4	100%	3.5	2.5
	PC	Lotic	17	7	41%	3.7	1.2
MU2 Exposed	FO23	Lotic	53	5	9%	1.8	0.6
	FO9	Lotic	6	0	0%	0.9	-
	LI8	Lotic	43	8	19%	1.5	0.8
MU3 Exposed	EROU	Lentic	22	2	9%	1.3	0.6
MU4 Exposed	CA1	Lotic	4	3	75%	9.5	3.9
	EL19	Lotic	5	2	40%	1.4	0.5
	FI1	Lotic	8	0	0%	0.7	-
	GO13	Lentic	27	26	96%	7.3	3.6
	GRCK	Lotic	5	2	40%	1.3	1.0
	HA7	Lentic	5	2	40%	1.0	-
	LE1	Lotic	14	0	0%	0.7	-
	MI2	Lotic	50	1	2%	1.1	0.5

Table 3.6-5. Exceedances of selenium TRV for fish feeding on other fish by area

Management unit	Area	Ecosystem	# of samples	# of samples > fish dietary TRV	% of samples > fish dietary TRV	Maximum HQ	Mean HQ[a]
	MI3	Lotic	33	0	0%	1.0	-
	MI5	Lotic	8	0	0%	0.5	-
	MIC_MS	Lotic	16	0	0%	0.5	-
	MICH2	Lotic	9	2	22%	2.3	0.8
	MICH3	Lotic	9	4	44%	3.1	1.4
	Michel Creek	Lotic	16	0	0%	0.5	-
	SN1	Lotic	3	2	67%	3.1	1.6
	UW1	Lotic	8	0	0%	0.5	-
	WH1	Lotic	10	1	10%	1.7	0.8
MU5 Exposed	EL1	Lotic	74	0	0%	1.0	-
	Elk River	Lotic	20	0	0%	0.8	-
	ELK_MS	Lentic	30	0	0%	0.8	-
	ELKO	Lentic	30	10	33%	1.9	0.9
	EROL	Lentic	20	5	25%	1.3	0.7
	LK02	Lentic	31	1	3%	1.4	0.5
	MC1	Lotic	16	7	44%	2.7	1.1
MU6 Exposed	K01KOOCL35	Lentic	62	0	0%	0.5	-
	KOO_KOK	Lentic	97	0	0%	0.5	-
	Koocanusa	Lentic	97	0	0%	0.5	-
	LK01	Lentic	20	0	0%	0.3	-
	LK-CAN1	Lentic	6	0	0%	0.2	-
	LK-CAN2	Lentic	14	0	0%	0.2	-

Notes:
[a] Mean HQ is provided when maximum HQ is >1.0.
HQ - hazard quotient
TRV - toxicity reference value
MU - management unit

Table 3.7-1. Amphibian tissue sampling area descriptions

Management unit	Area	Description
MU1 Exposed	F.Oxbow	Fording River Oxbow
	FO29	Fording River d/s Dry Creek
	FOFR2W	Wetland south of Fording tailings
	SWWL	Swift Wetland
MU2 Exposed	FO15	Fording River Wetlands
MU4 Exposed	ELWDGC	Elk River Wetland d/s Grave Creek
	GO13	Goddard Marsh
	MI16	Michel Creek Wetlands
	OTTO	Otto Creek Wetland
MU5 Exposed	ELKO	Elko Reservoir
	ELKO u/s	Elk River u/s Morrissey Creek
	LK02	Lake Koocanusa at Elk River
Reference	DRCK	Dry Creek (off-channel lentic habitat)
	DRCKW	Dry Creek Wetland
	EROU	Elk River Oxbow Upper
	Fen	Fen in Stormcat Area
	FO15	Fording River Wetlands
	GLM	Graves Lake Marsh
	LkMtn2	Lake Mountain Lake
	REFF	Unnamed Upper Elk Wetland

Table 3.7-2. Analytes and sample sizes for amphibian tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Aluminum	46	28	74
Antimony	46	28	74
Arsenic	46	28	74
Barium	46	28	74
Beryllium	46	28	74
Bismuth	46	28	74
Boron	46	28	74
Cadmium	46	28	74
Calcium	46	28	74
Cesium	46	28	74
Chromium	46	28	74
Cobalt	46	28	74
Copper	46	28	74
Gallium	46	28	74
Iron	46	28	74
Lead	46	28	74
Lithium	46	28	74
Magnesium	46	28	74
Manganese	46	28	74
Molybdenum	46	28	74
Nickel	46	28	74
Phosphorous	46	28	74
Potassium	46	28	74
Rhenium	46	28	74
Rubidium	46	28	74
Selenium	56	40	96
Silver	29	22	51
Sodium	46	28	74
Strontium	46	28	74
Sulfur	0	8	8
Tellurium	17	6	23
Thallium	46	28	74
Thorium	46	28	74
Tin	46	28	74
Titanium	46	28	74

Table 3.7-2. Analytes and sample sizes for amphibian tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Uranium	46	28	74
Vanadium	46	28	74
Yttrium	46	28	74
Zinc	46	28	74
Zirconium	46	28	74

Table 3.7-3. Summary of HQs based on 95th percentile of amphibian egg mass selenium concentrations for all samples collected within each MU

CoI	Tissue type	Receptor	HQs					
			MU1	MU2	MU3	MU4	MU5	MU6
Selenium	amphibian egg masses	Fish	**1.3**	0.95	na	**1.4**	**1.5**	0.41

Notes:
CoI – constituent of interest
HQ - hazard quotient
MU - management unit
na - no data available

Table 3.7-4. Exceedances of TRVs for fish feeding on amphibian egg masses by area

Management unit	Area	Ecosystem	# of samples	# of samples > fish diet TRV	% of samples > fish diet TRV	Maximum HQ	Mean HQ[a]
MU1 Exposed	F.Oxbow	Lentic	3	3	100%	1.2	1.1
	FO29	Lentic	2	1	50%	1.1	0.7
	FOFR2W	Lentic	3	0	0%	0.5	-
	SWWL	Lentic	6	2	33%	1.6	1.0
MU2 Exposed	FO15	Lentic	2	0	0%	0.9	-
MU4 Exposed	ELWDGC	Lentic	6	2	33%	1.3	0.9
	GO13	Lentic	5	5	100%	3.5	1.4
	MI16	Lentic	9	0	0%	0.7	-
	OTTO	Lentic	10	1	10%	1.3	0.5
MU5 Exposed	ELKO	Lentic	4	3	75%	1.6	1.2
	ELKO u/s	Lentic	2	0	0%	0.5	-
	LK02	Lentic	2	0	0%	0.4	-

Notes:
[a] Mean HQ is provided when maximum HQ is >1.0.
HQ - hazard quotient
TRV - toxicity reference value
MU - management unit

Table 3.8-1. Bird egg tissue sampling area descriptions

Management unit or reference	Area	Description
MU1 Exposed	CHCK	Chauncey Creek
	CL11	Clode Pond
	F.Oxbow	Fording River Oxbow u/s Dry Creek
	FO10	Fording River Oxbow u/s Dry Creek
	FO29	Fording River d/s Dry Creek
	FO52	Fording River at Kilmarnock
	FOXL	Fording River Oxbow Lower
	FPC	Fish Pond Creek
	FR1	Fording River d/s of Cataract Creek
	FR2	Fording River d/s Lake Mountain Creek
	GHPD	Greenhills Settling Pond
	KSP	Kilmarnock Settling Pond
	MP1	Fording River - Multiplate
	NGD1	Lake Mountain Creek
MU2 Exposed	FO23	Fording River d/s Line Creek
	FO9	Fording River d/s Josephine Falls, u/s Grace Creek
	LCCPL	Line Creek Lower Cont. Ponds
	LI8	Line Creek d/s LCO
	MSAN	MSA-North Pond
	NNP	NoName Pond
MU3 Exposed	EL20	Elk River d/s Thompson & GHO
	THPD	Thompson Creek Settling Pond
MU4 Exposed	BODP	Bodie Pond
	EL19	Elk River d/s Fording
	GAPD	Gatehouse Pond
	GO13	Goddard Marsh
	HA7	Harmer Pond
	MI16	Michel Creek Wetlands
	MI2	Michel Creek d/s EVO
	MIWW	Lower Michel Wetland
	OTTO	Otto Creek Wetland
MU5 Exposed	EL1	Elk River d/s of Michel Creek
	ELKO	Elko Reservoir
	ELKO U/S	Elk River u/s Morrissey Creek
	ERWSF	Elk River Wetland south of Fernie
	LK02	Lake Koocanusa at Elk River

Table 3.8-1. Bird egg tissue sampling area descriptions

Management unit or reference	Area	Description
Reference	AL4	Alexander Creek
	Boivin Creek	Boivin Creek
	DRCK	Dry Creek
	FO15	Fording River Wetlands
	GLM	Graves Lake Marsh
	LK01	Lake Koocanusa at Sand Creek
	WWR	Wigwam River
	WWR (Beaver Pond)	Wigwam River (Beaver Pond)
	WWRL	Lower Wigwam River

Table 3.8-2. Analytes and sample sizes for bird egg tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Aluminum	229	30	259
Antimony	229	30	259
Arsenic	238	32	270
Barium	229	30	259
Beryllium	229	30	259
Bismuth	229	30	259
Boron	229	30	259
Cadmium	229	30	259
Calcium	229	30	259
Cesium	229	30	259
Chlorine	110	10	120
Chromium	229	30	259
Cobalt	229	30	259
Copper	229	30	259
Gallium	229	30	259
Iron	229	30	259
Lead	229	30	259
Lithium	229	30	259
Magnesium	229	30	259
Manganese	229	30	259
Mercury	119	12	131
Molybdenum	229	30	259
Nickel	229	30	259
Phosphorous	229	30	259
Potassium	229	30	259
Rhenium	229	30	259
Rubidium	229	30	259
Selenium	273	38	311
Silicon	110	10	120
Silver	195	23	218
Sodium	229	30	259
Strontium	229	30	259
Sulfur	125	11	136
Tellurium	110	10	120
Thallium	229	30	259

Table 3.8-2. Analytes and sample sizes for bird egg tissue

Analyte	Number of samples from mining-exposed locations	Number of samples from reference locations	Total number of samples
Thorium	229	30	259
Tin	229	30	259
Titanium	229	30	259
Uranium	229	30	259
Vanadium	238	32	270
Yttrium	229	30	259
Zinc	229	30	259
Zirconium	229	30	259

Table 3.8-3. Summary of HQs based on 95th percentile of bird egg selenium concentrations for all samples collected within each MU

CoI	Tissue type	Receptor	HQs					
			MU1	MU2	MU3	MU4	MU5	MU6
Selenium	aquatic bird eggs	Birds	**1.9**	**1.7**	**2.9**	**1.5**	0.63	0.63

Notes:

CoI – constituent of interest

HQ - hazard quotient

MU - management unit

Table 3.8-4. Exceedances of selenium TRV for aquatic-dependent bird eggs by area

Management unit	Area	Ecosystem	Species	# of samples	# of samples > bird egg TRV	% of samples > bird egg TRV	Maximum HQ	Mean HQ[a]
MU1	CHCK	Lotic	SPSA	3	0	0%	0.8	-
	CL11	Lentic	RWBL	8	4	50%	2.0	1.1
			SPSA	8	5	63%	2.1	1.3
	F.Oxbow	Lentic	RWBL	1	1	100%	1.9	1.9
	FO10	Lentic	RWBL	5	5	100%	2.2	1.4
	FO29	Lotic	SPSA	9	0	0%	1.0	-
	FO52	Lotic	SPSA	13	1	8%	1.4	0.7
	FOXL	Lentic	MALL	2	0	0%	0.8	-
	FPC	Lotic	SPSA	1	0	0%	0.4	-
	FR1	Lotic	SPSA	5	0	0%	0.6	-
	FR2	Lotic	SPSA	4	1	25%	1.5	0.8
	GHPD	Lentic	MALL	1	1	100%	1.7	1.7
			RWBL	2	0	0%	0.7	-
			SPSA	3	1	33%	1.1	0.8
	KSP	Lentic	SPSA	2	1	50%	1.3	1.0
	MP1	Lotic	SPSA	1	0	0%	0.5	-
	NGD1	Lotic	MALL	2	1	50%	1.1	0.9
MU2	FO23	Lotic	SPSA	15	1	7%	1.7	0.5
	FO9	Lotic	SPSA	8	0	0%	0.9	-
	LCCPL	Lentic	SPSA	3	3	100%	2.7	2.1
	LI8	Lotic	AMDI	1	0	0%	0.6	-
			SPSA	10	0	0%	0.5	-
	MSAN	Lentic	SPSA	7	1	14%	1.1	0.8
	NNP	Lentic	SPSA	2	0	0%	0.7	-
MU3	EL20	Lotic	SPSA	3	0	0%	0.3	-
	THPD	Lentic	SPSA	4	4	100%	3.4	1.9
MU4	BODP	Lentic	MALL	2	0	0%	0.3	-
	EL19	Lotic	SPSA	7	0	0%	0.5	-
	GAPD	Lentic	RWBL	4	0	0%	0.6	-
			SPSA	6	0	0%	0.5	-
	GO13	Lentic	COME	3	0	0%	0.6	-
			RWBL	8	8	100%	1.7	1.4
	HA7	Lentic	AMDI	1	0	0%	0.8	-
			SPSA	6	3	50%	1.4	1.1
	MI16	Lentic	RWBL	12	0	0%	1.0	-
			SPSA	3	0	0%	0.3	-
	MI2	Lotic	SPSA	24	0	0%	0.4	-
	MIWW	Lentic	RWBL	3	1	33%	1.0	-
	OTTO	Lentic	COME	3	0	0%	0.8	-
			RWBL	7	0	0%	0.6	-

Table 3.8-4. Exceedances of selenium TRV for aquatic-dependent bird eggs by area

Management unit	Area	Ecosystem	Species	# of samples	# of samples > bird egg TRV	% of samples > bird egg TRV	Maximum HQ	Mean HQ[a]
MU5	EL1	Lotic	KD	3	0	0%	0.6	-
			SPSA	12	0	0%	0.6	-
	ELKO	Lentic	SPSA	19	0	0%	0.7	-
	ELKO U/S	Lentic	RWBL	3	1	33%	1.0	-
	ERWSF	Lentic	RWBL	3	0	0%	0.4	-
	LK02	Lentic	RWBL	4	0	0%	0.5	-
			SPSA	17	0	0%	0.7	-

Notes:
[a] Mean HQ provided when maximum HQ is >1.0.
HQ - hazard quotient
TRV - toxicity reference value
MU - management unit
AMDI - American dipper
COME - common merganser
KD - killdeer
MALL - mallard
RWBL - red-winged blackbird
SPSA - spotted sandpiper

Table 4.1-1. Categorization of environmental conditions.

Data Type	Good	Fair	Marginal	Poor
Water Quality[a]	80 ≤ WQI ≤ 100	65 ≤ WQI ≤ 79	45 ≤ WQI ≤ 64	0 ≤ WQI ≤ 44
Sediment Quality[a]	80 ≤ SeQI ≤ 100	65 ≤ SeQI ≤ 79	45 ≤ SeQI ≤ 64	0 ≤ SeQI ≤ 44
Benthic community[b]	EPT[c] proportion ≥71% and E[d] proportion ≥31%	EPT proportion ≥ 64% and E proportion ≥ 12%, and also EPT < 71% or E <31% (i.e., data that did not meet criteria for "good" or "poor" categories).	not applicable	EPT proportion <64% or E proportion <12%.
Tissue Selenium[e]	Maximum Se HQ[f] ≤ 1.0	Maximum Se HQ > 1.0, but mean Se HQ ≤ 1.0		Mean Se HQ > 1.0

Notes:
[a] Water and sediment quality categories are based on the Canadian Water Quality and Sediment Quality Indices (WQI and SeQI) , as defined by CCME (2001a,b, 2007), described in detail in Appendix D and summarized in Appendix E, Section E.1.
[b] Based on data from Minnow (2014), as described in Appendix E, Section E.3 and summarized in Table 3.5-5.
[c] EPT - Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
[d] E - Ephemeroptera (mayflies) only
[e] Based on data in Screening-Level Risk Assessment by Windward (2014). Full report is presented in Appendix C and approach for categorizing tissue data is presented in Appendix E, Section E.4.
[f] HQ - Hazard Quotient computed as a ratio of tissue concentration to relevant benchmark (Windward 2014) (Appendix C).

Table 4.8-1. Summary of benthic invertebrate quality at lotic areas assessed in Management Units 1-5 of the Elk River Watershed.

Management Unit	Total Number of Areas Assessed	Area Type	Number of Areas				Percent of Total Areas Assessed within Each MU			
			Good	Fair	Poor	Total	Good	Fair	Poor	Total
1 (Upper Fording River)	27	Reference	5	0	0	5	19	0	0	19
		Discharge Tributaries	2	0	6	8	7	0	22	30
		Mainstem Receivers	11	3	0	14	41	11	0	52
2 (Lower Fording River and Line Creek)	8	Reference	2	0	0	2	25	0	0	25
		Discharge Tributaries	0	1	1	2	0	13	13	25
		Mainstem Receivers	4	0	0	4	50	0	0	50
3 (Elk River upstream of Fording River)	9	Reference	3	0	0	3	33	0	0	33
		Discharge Tributaries	0	0	2	2	0	0	22	22
		Mainstem Receivers	4	0	0	4	44	0	0	44
4 (Michel Creek and Elk River between Fording River and Michel Creek)	21	Reference	4	0	0	4	19	0	0	19
		Discharge Tributaries	2	2	4	8	10	10	19	38
		Mainstem Receivers	7	2	0	9	33	10	0	43
5 (Elk River between Sparwood and mouth)	6	Reference	1	0	0	1	17	0	0	17
		Discharge Tributaries	0	0	0	0	0	0	0	0
		Mainstem Receivers	5	0	0	5	83	0	0	83
Total, All MUs	71	Reference	15	0	0	15	21	0	0	21
		Discharge Tributaries	4	3	13	20	6	4	18	28
		Mainstem Receivers	31	5	0	36	44	7	0	51
Percentage of All Areas within Each Area Type with Communities Categorized as Good, Fair, or Poor		**Reference**	**100**	0	0	100				
		Discharge Tributaries	**20**	**15**	**65**	100				
		Mainstem Receivers	**86**	**14**	0	100				

Figures

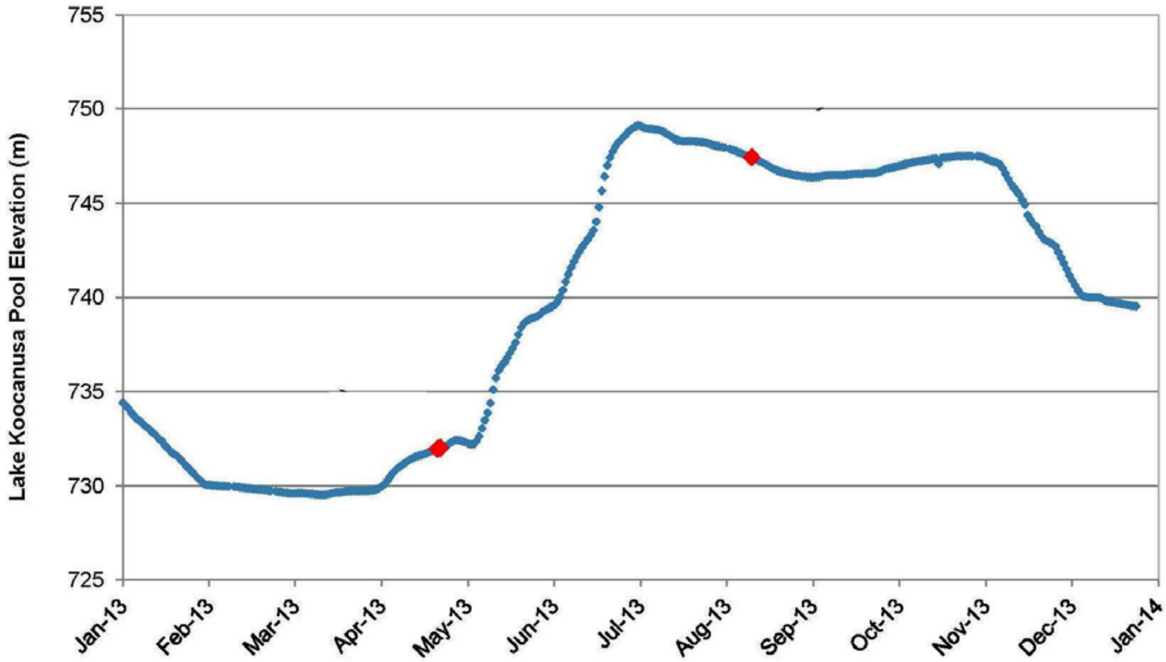


Figure 2.2-1. Typical annual elevation fluctuations observed in Lake Koocanusa reservoir.
Data from United States Army Corps of Engineers, 2014.

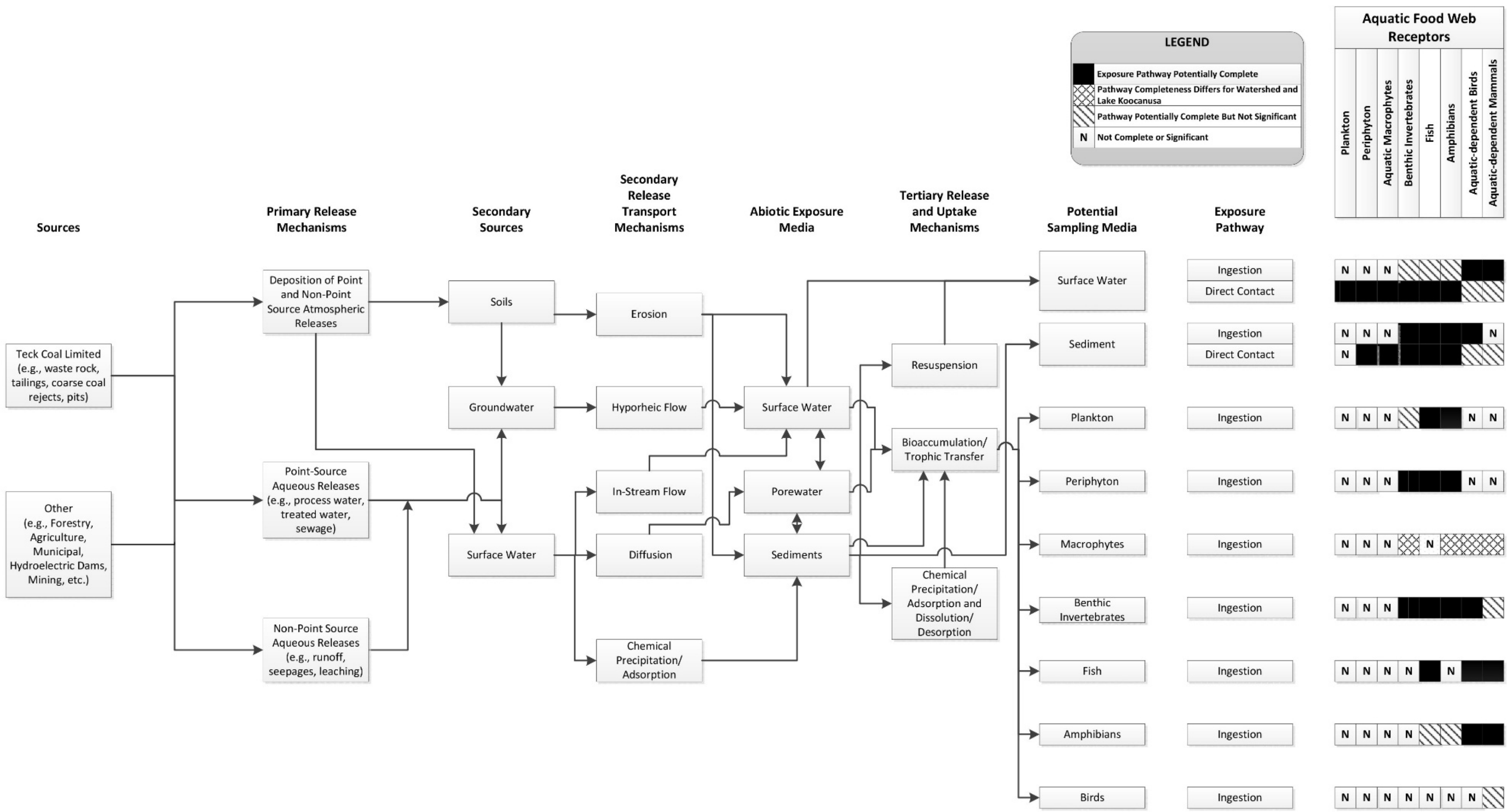


Figure 2.4-1. Conceptual model for chemical stressors in the Designated Area

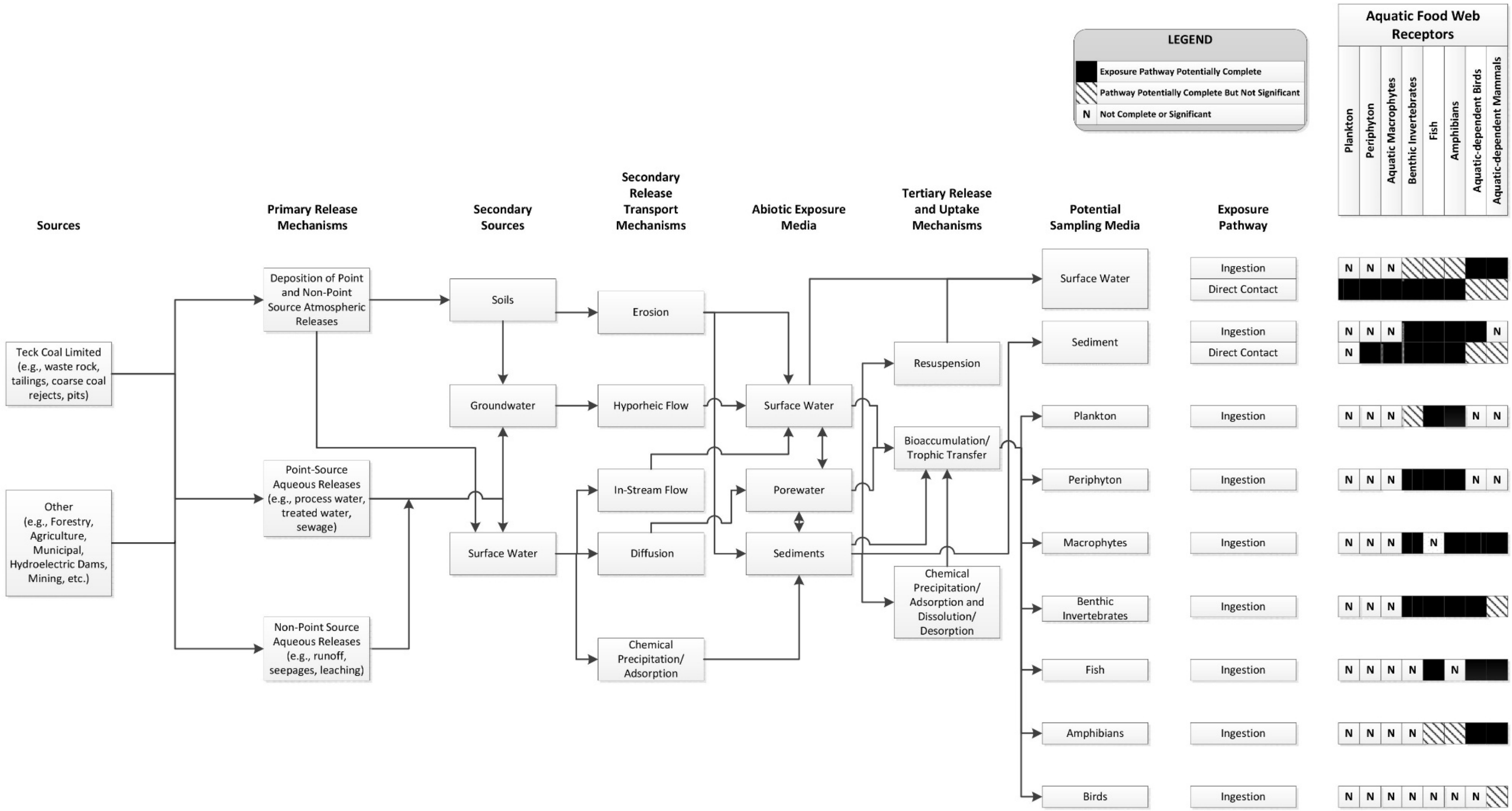


Figure 2.4-2. Conceptual model for chemical stressors in the Elk River watershed (Management Units 1 through 5)

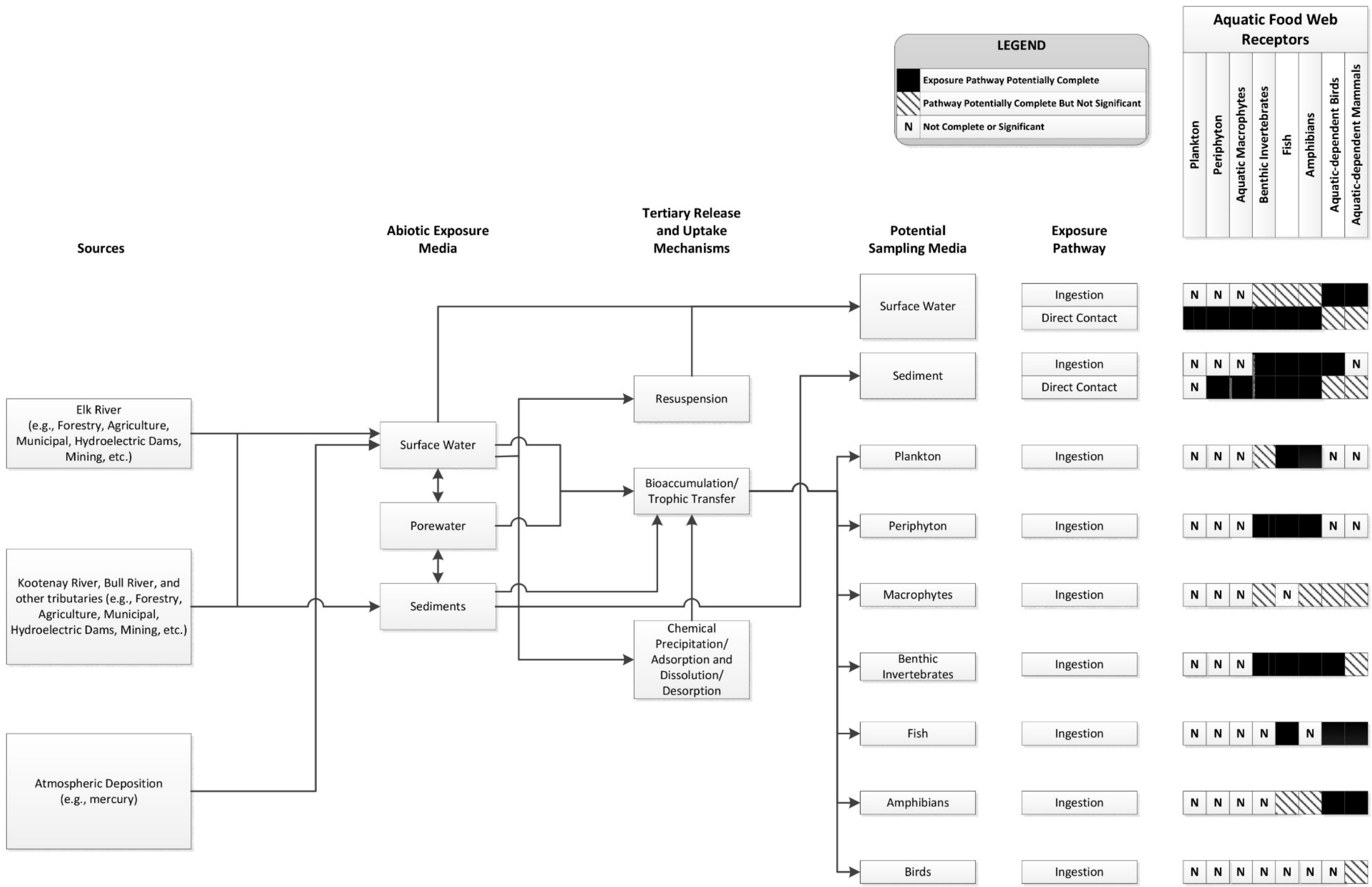


Figure 2.4-3. Conceptual model for chemical stressors in Lake Koocanusa (Management Unit 6)

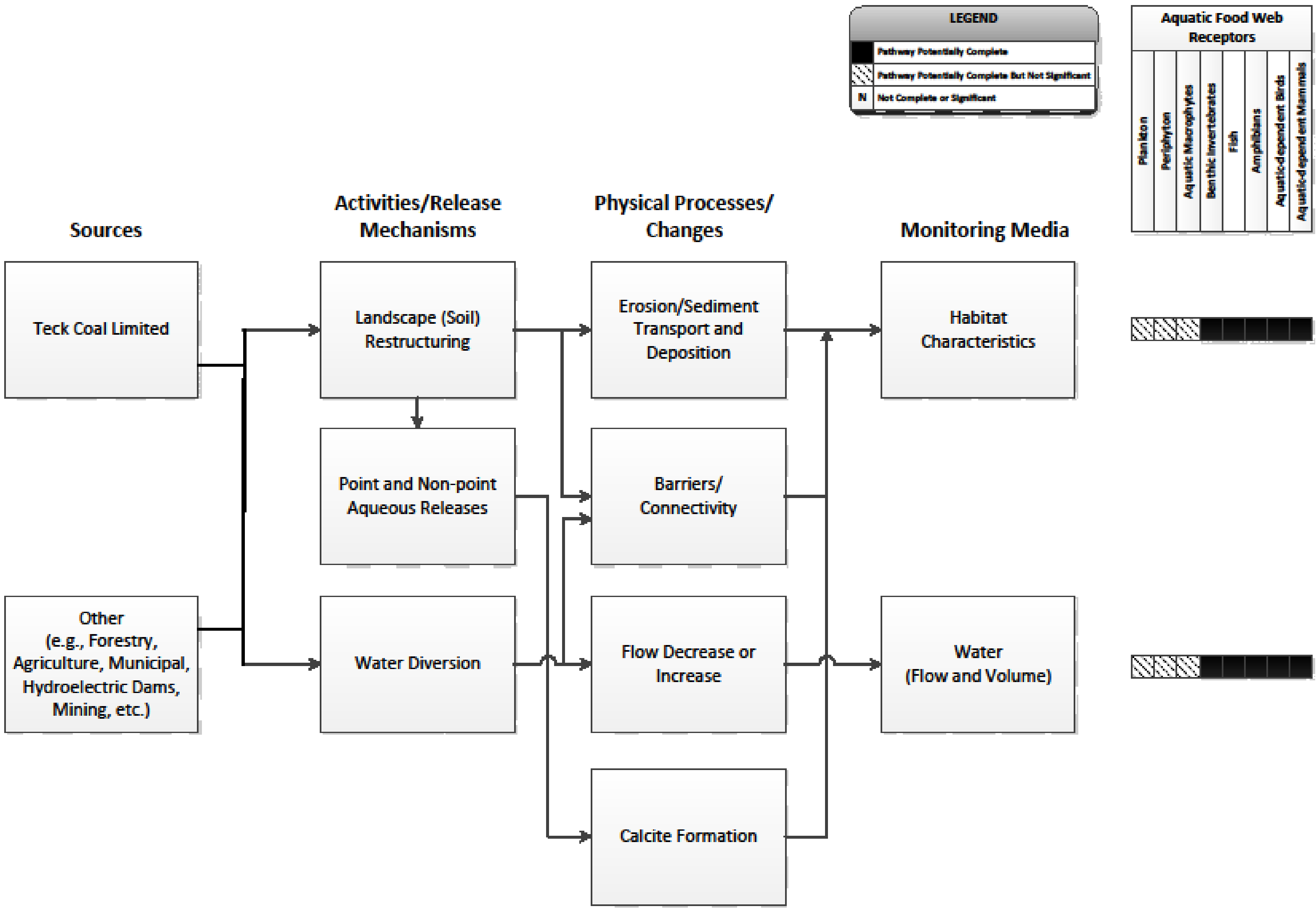


Figure 2.5-1. Conceptual model for physical stressors in the Elk River watershed (Management Units 1 through 5)

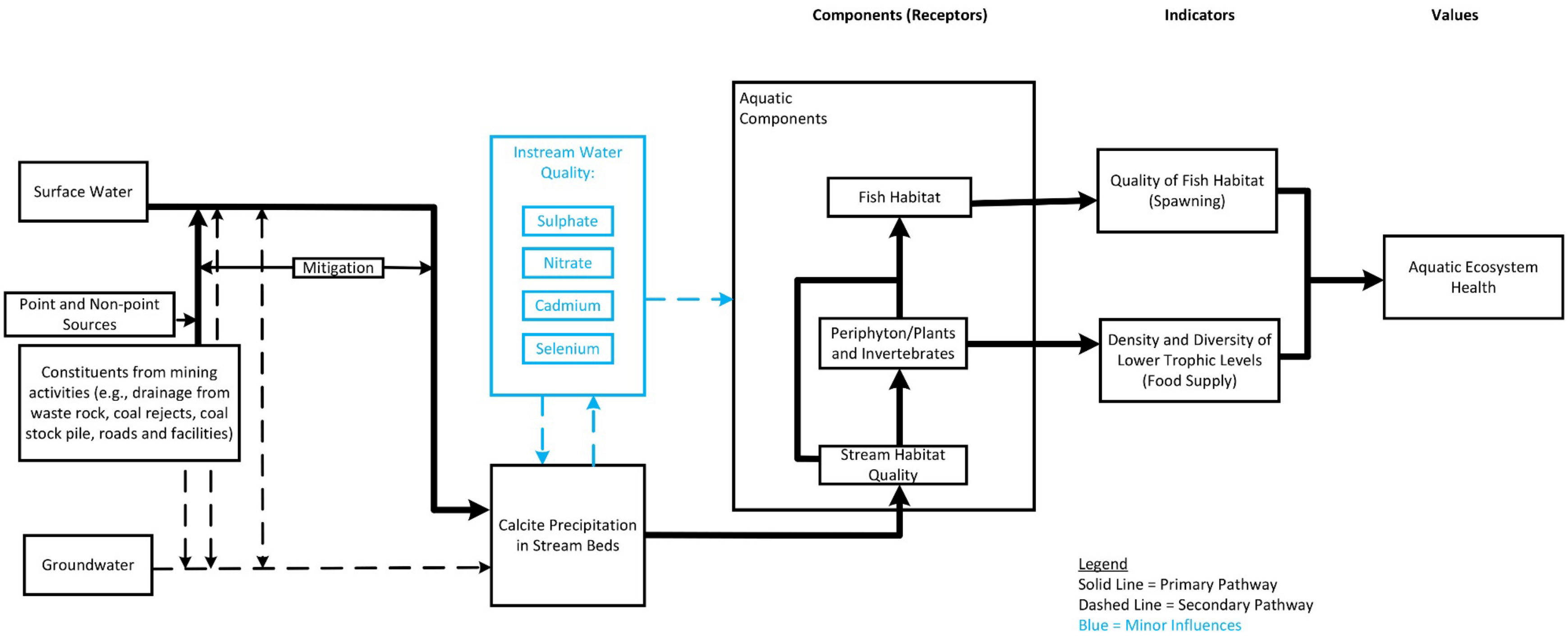


Figure 2.5-2. Calcite precipitation influence diagram – ecological effects linkages

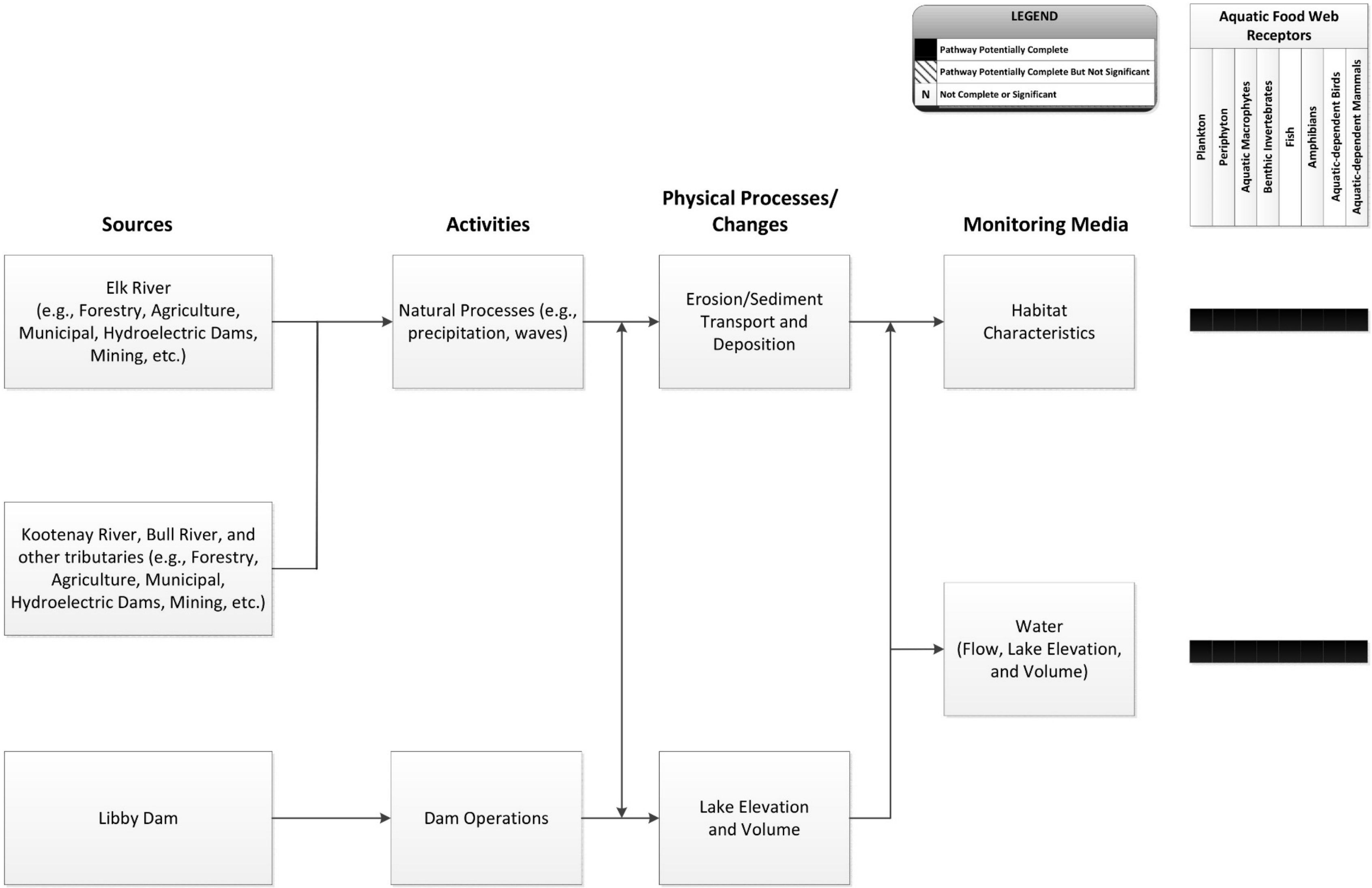


Figure 2.5-3. Conceptual model for physical stressors in Lake Koocanusa (Management Unit 6)

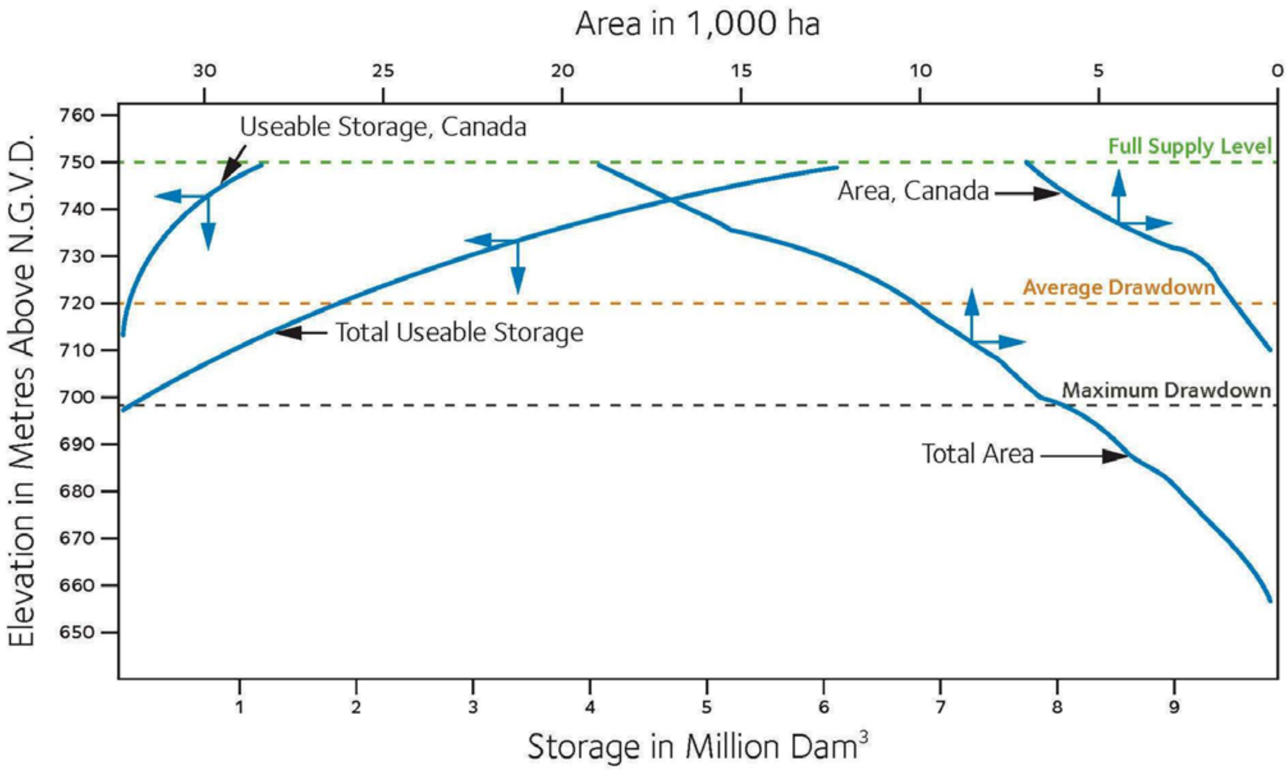


Figure 2.5-4. Area/capacity curve for Lake Koocanusa.
Notes: Redrawn from HydroQual Canada Limited (1990).
N.G.V.D = National Geodetic Vertical Datum; Dam^3 = cubic decameter (1 dam^3 = 1000 m^3); ha = hectare.

Figure 2.5-5. Effect of reservoir drawdown on the littoral zone within the Canadian portion of Lake Koocanusa.

The yellow dot represents the approximate location of the photograph. The base layer map was accessed from Microsoft Bing (2013).

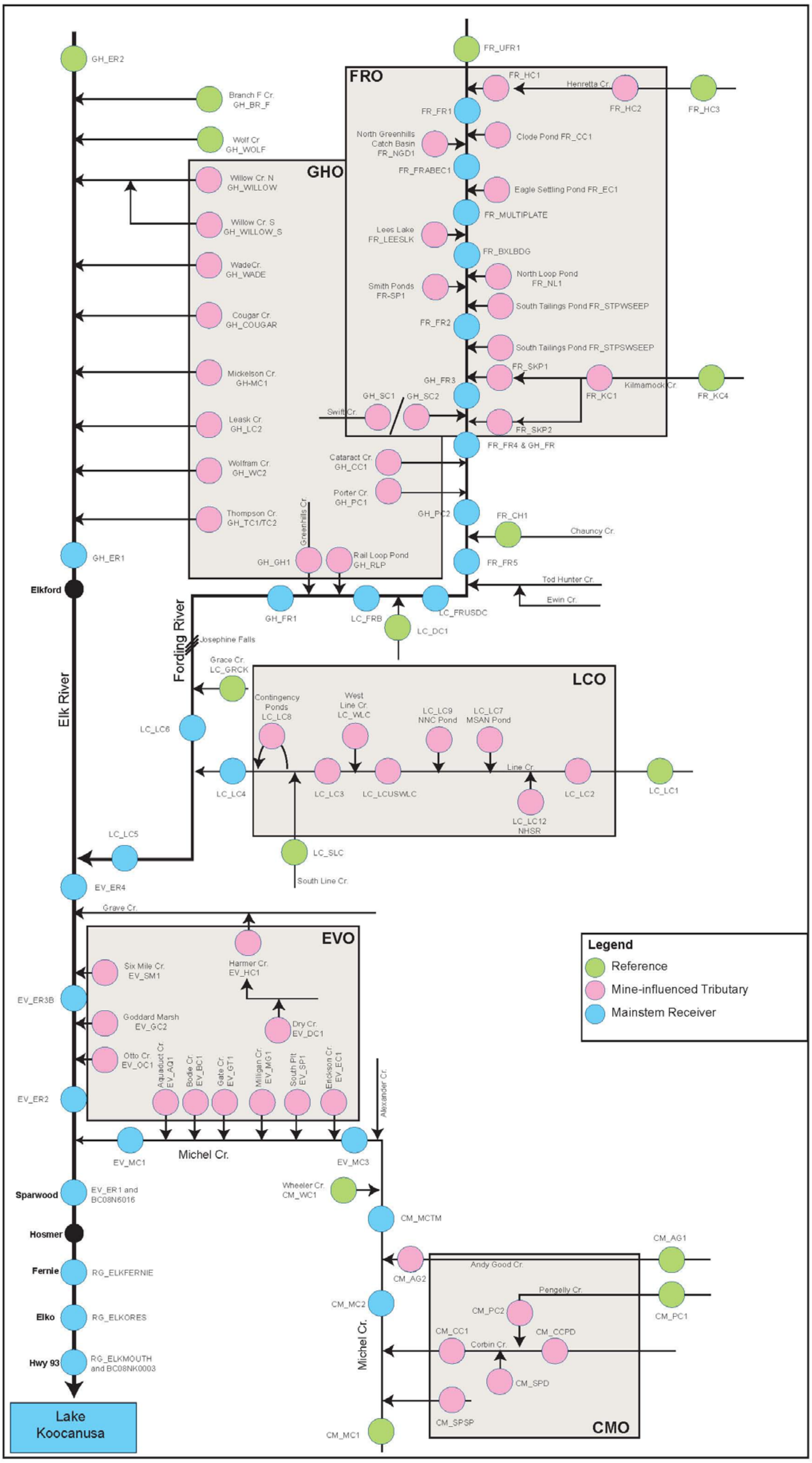


Figure 3.1-1. Schematic diagram of locations used in the surface water evaluation

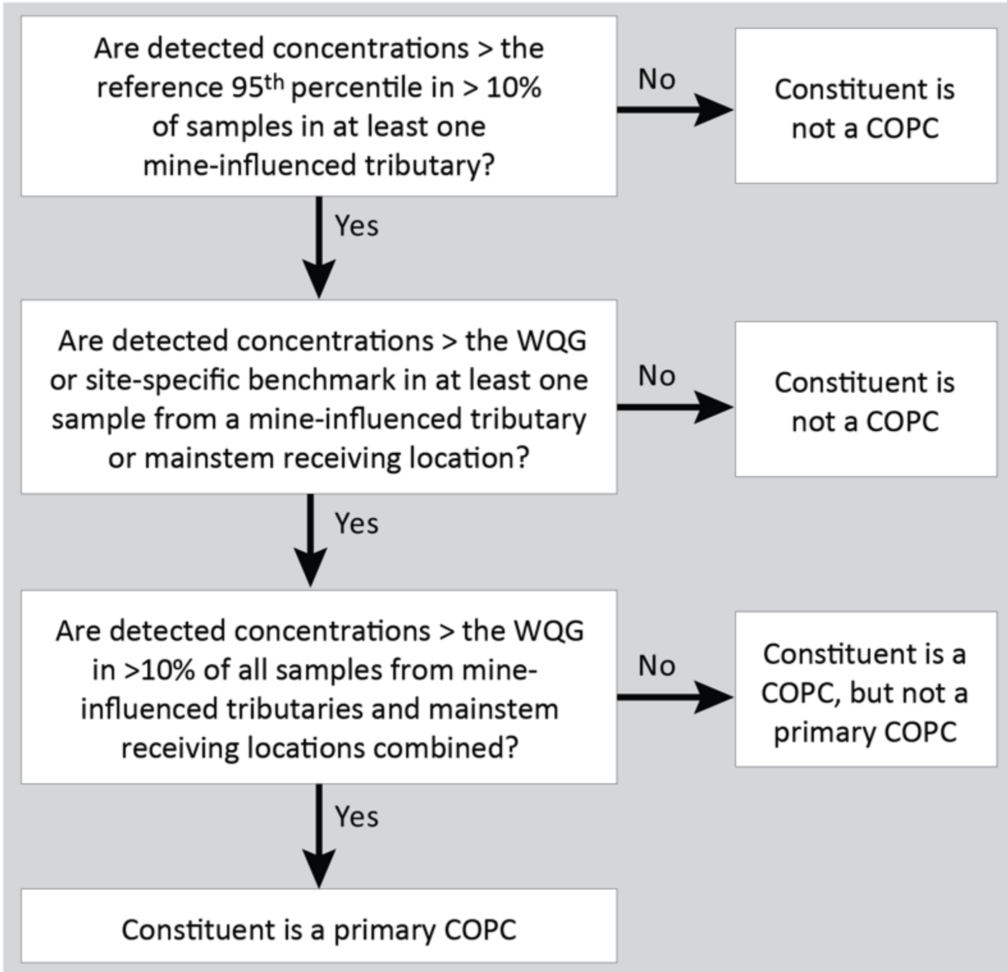


Figure 3.1-2. Process for identification of COPCs and primary COPCs

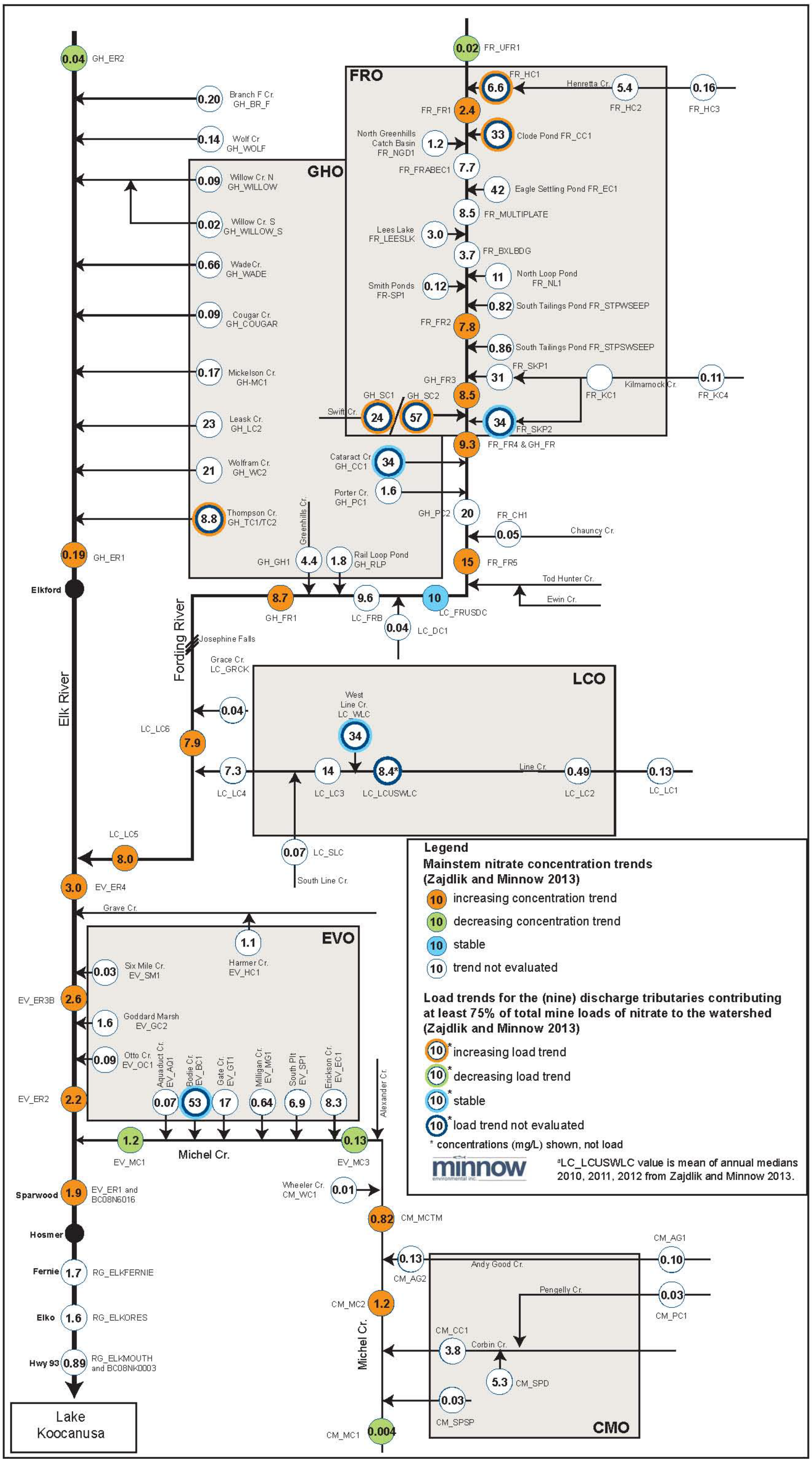


Figure 3.1-3. Schematic diagram of median nitrate concentrations (2011-2013), concentration trends for mainstem stations, and load trends for major sources

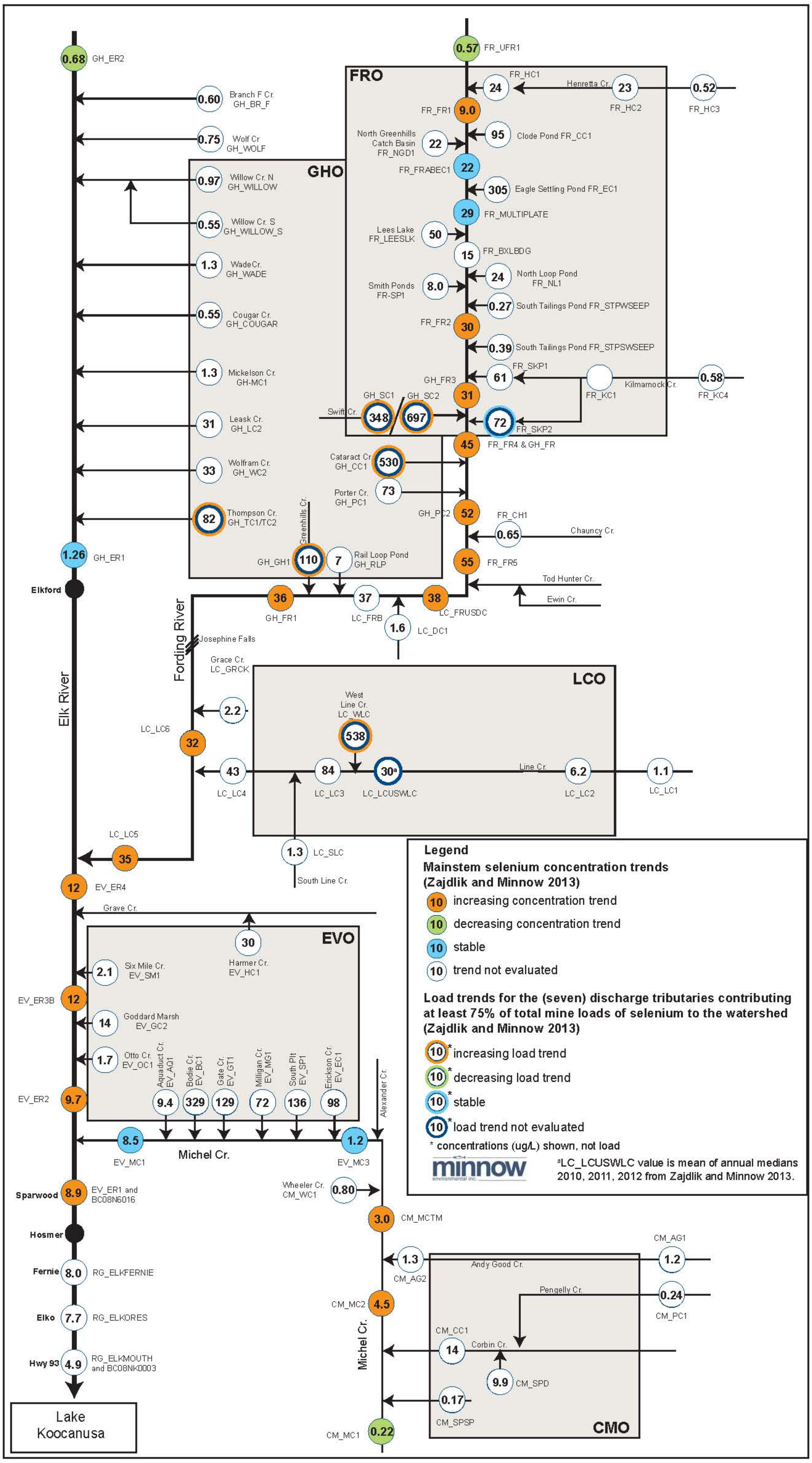


Figure 3.1-4. Schematic diagram of median selenium concentrations (2011-2013), concentration trends for mainstem stations, and load trends for major sources

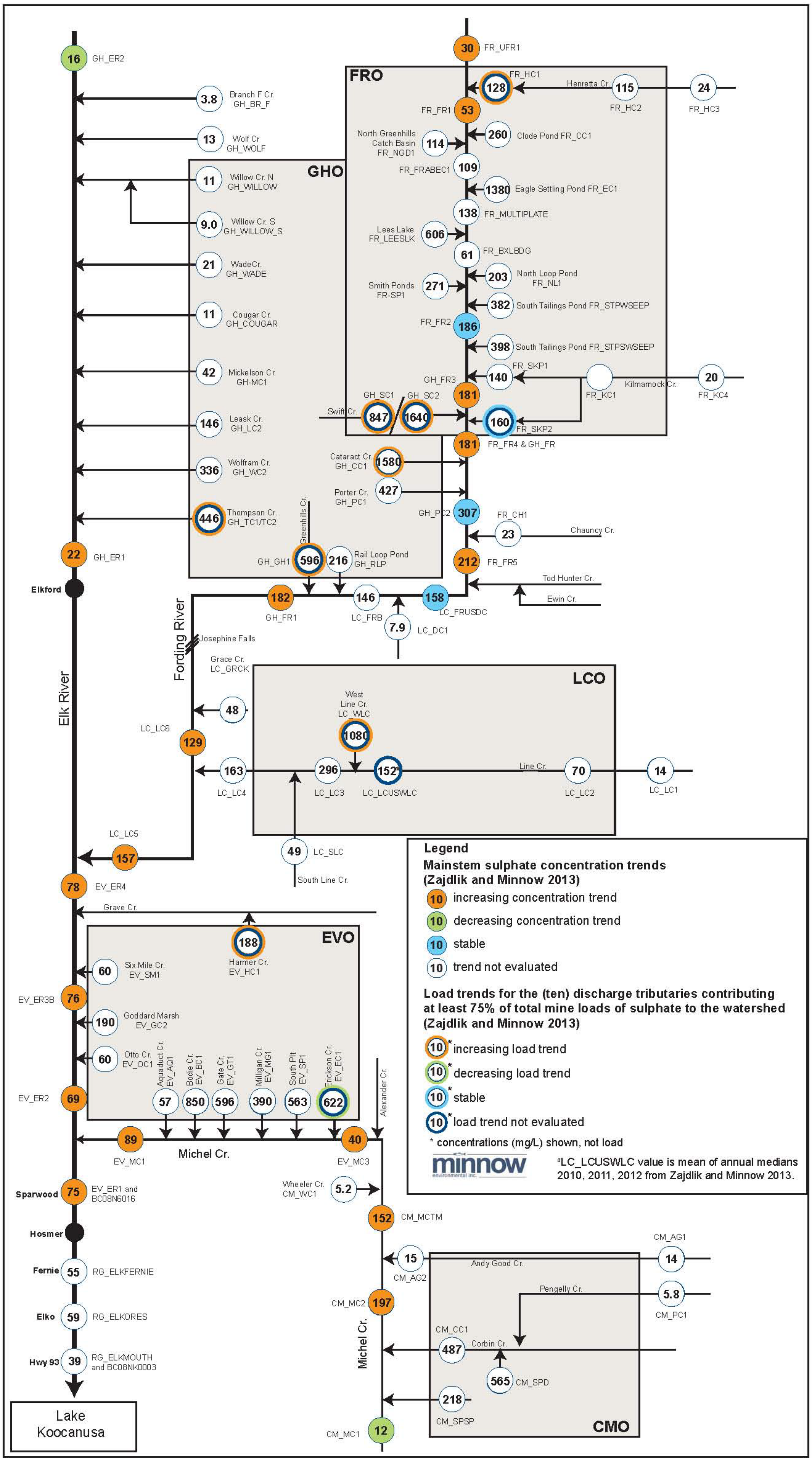
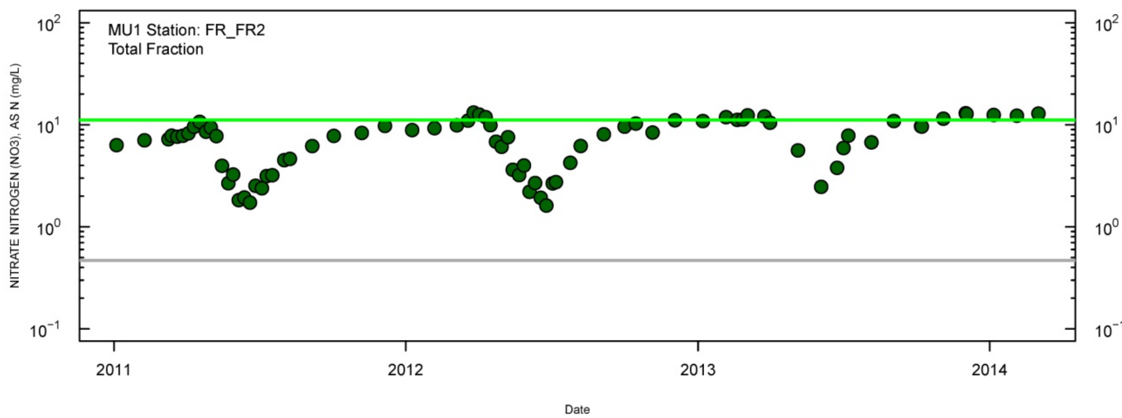
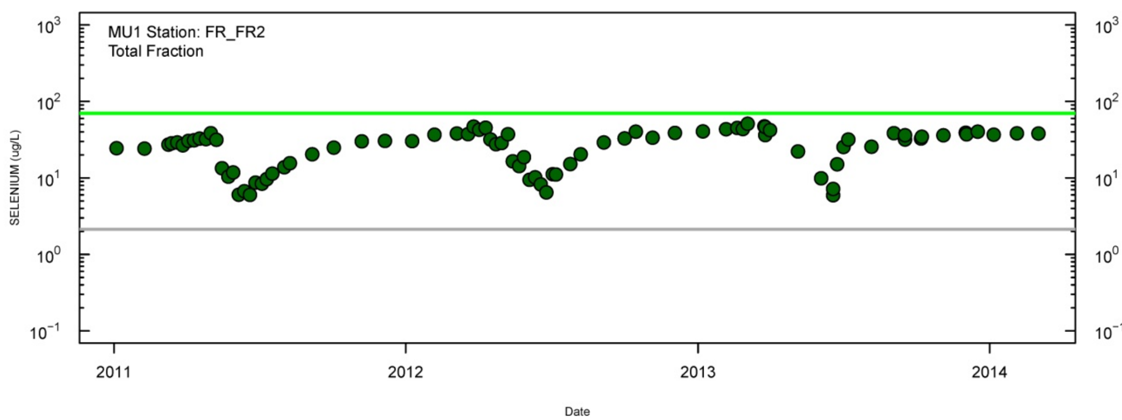


Figure 3.1-5. Schematic diagram of median sulphate concentrations (2011-2013), concentration trends for mainstem stations, and load trends for major sources



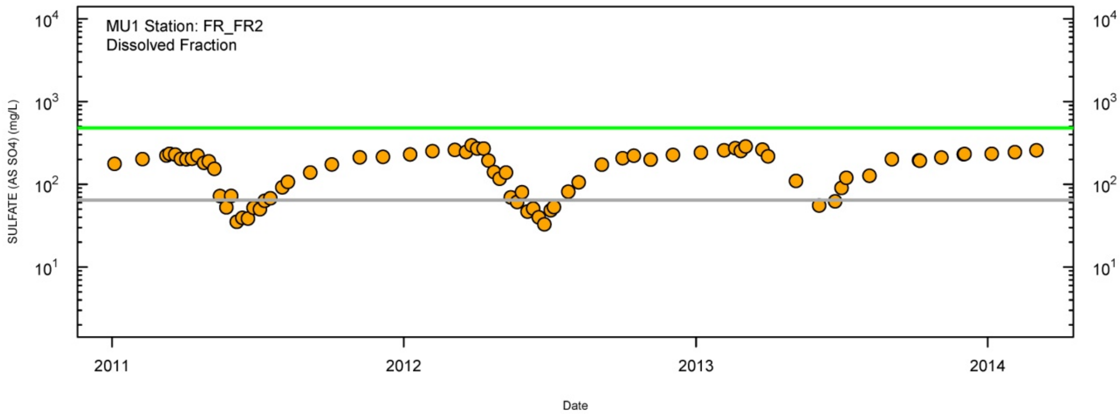
Note: Green line is the benchmark and grey line is the reference 95th percentile

Figure 3.1-6. Nitrate concentrations from 2011 to 2013 at FR_FR2



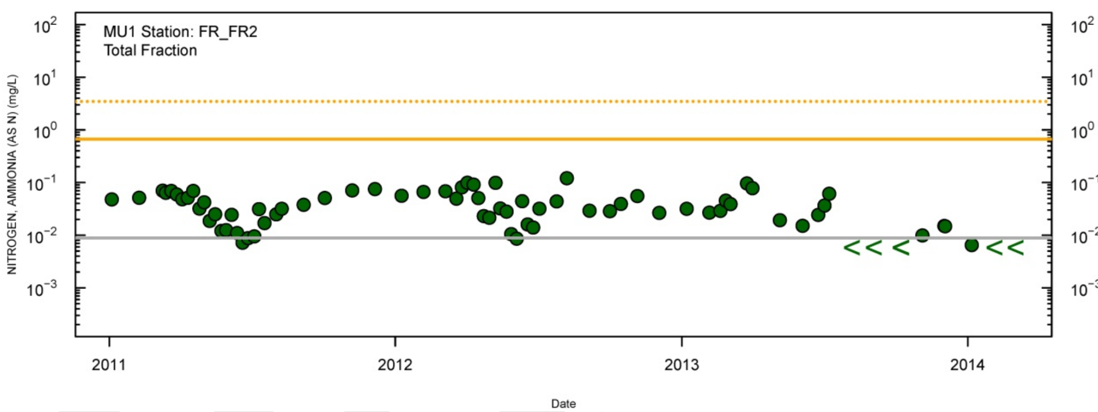
Note: Green line is the benchmark and grey line is the reference 95th percentile

Figure 3.1-7. Selenium concentrations from 2011 to 2013 at FR_FR2



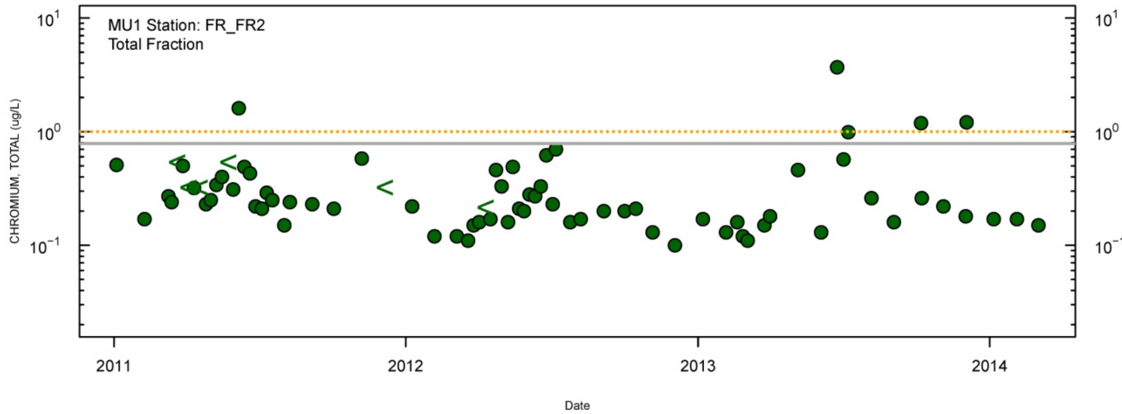
Note: Green line is the benchmark and grey line is the reference 95th percentile

Figure 3.1-8. Sulphate concentrations from 2011 to 2013 at FR_FR2



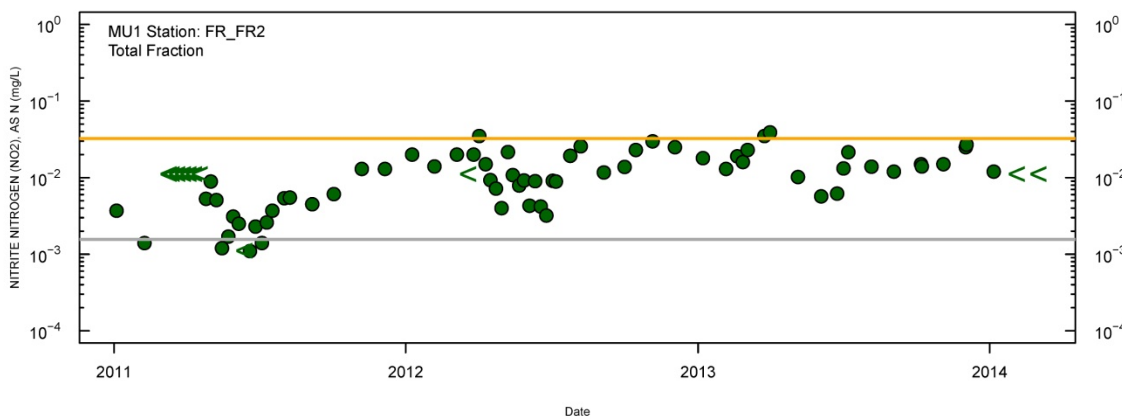
Note: Solid orange line is the 30-day mean WQG, dotted orange line is the maximum WQG, and solid grey line is the reference 95th percentile

Figure 3.1-9. Ammonia concentrations from 2011 to 2013 at FR_FR2



Note: Dotted orange line is the maximum WQG and solid grey line is the reference 95th percentile

Figure 3.1-10. Chromium concentrations from 2011 to 2013 at FR_FR2



Note: Orange line is the 30-day mean WQG and grey line is the reference 95th percentile

Figure 3.1-11. Nitrite concentrations from 2011 to 2013 at FR_FR2

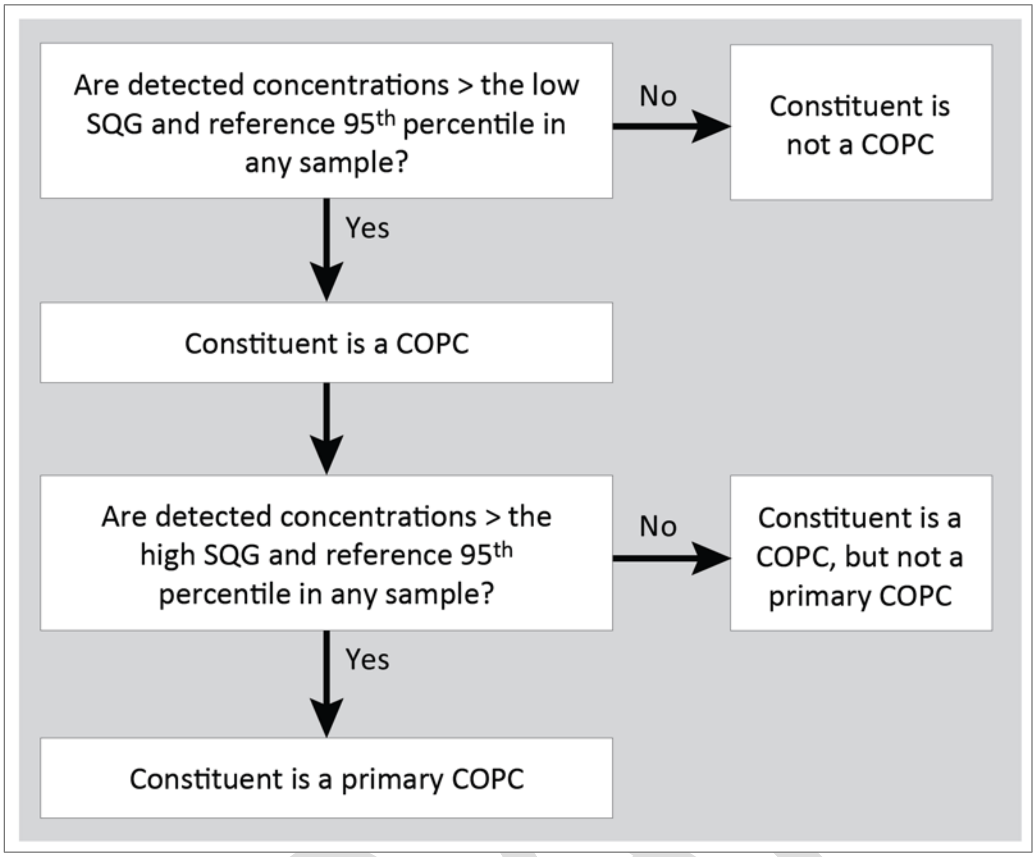
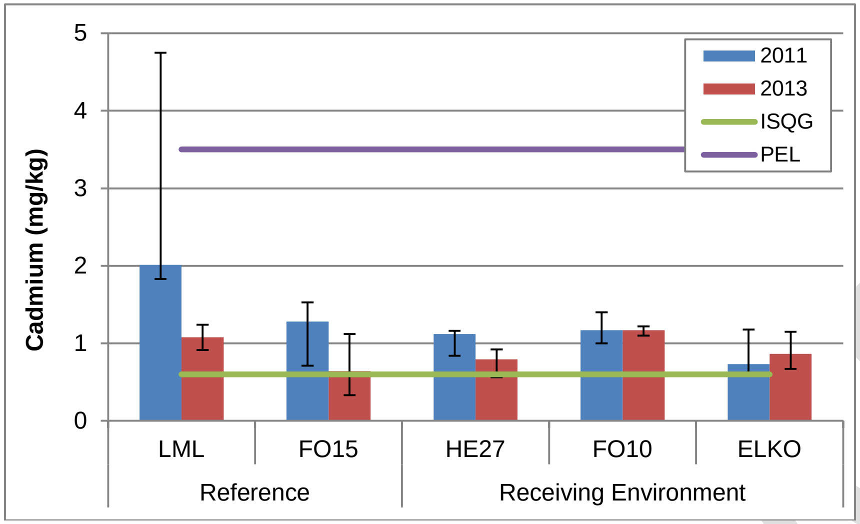
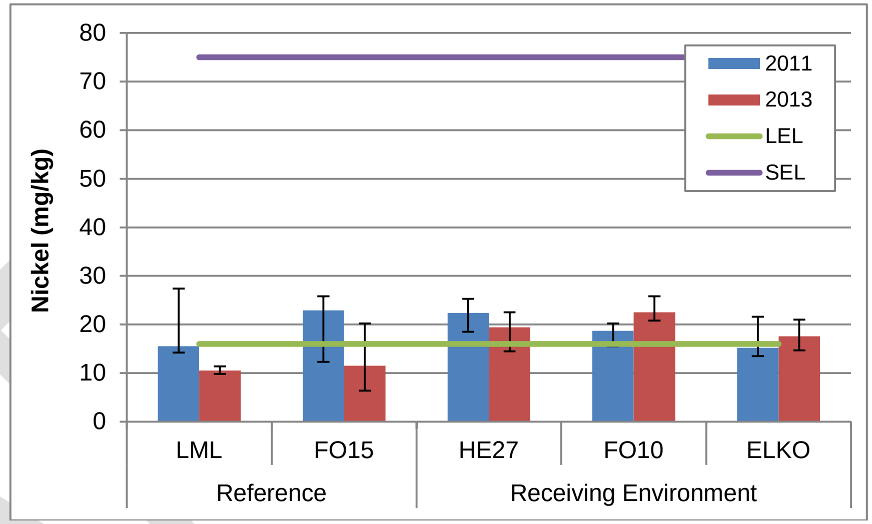


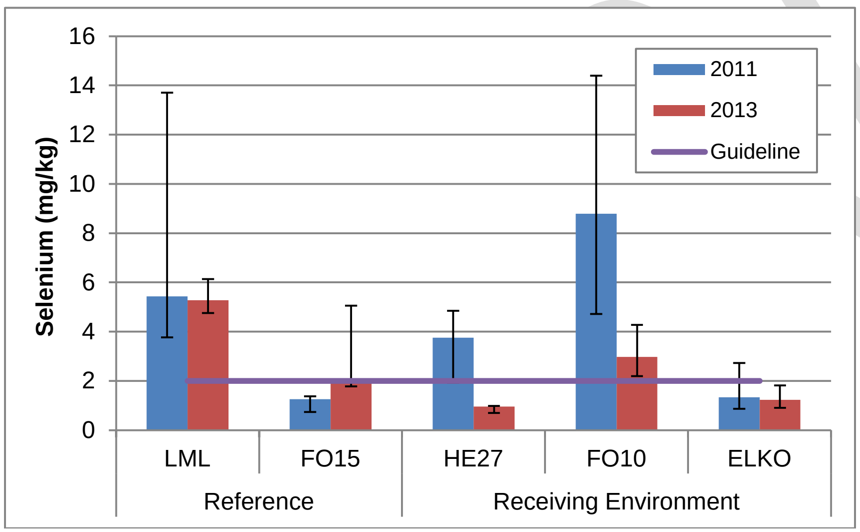
Figure 3.2-1. Sediment quality evaluation flowchart



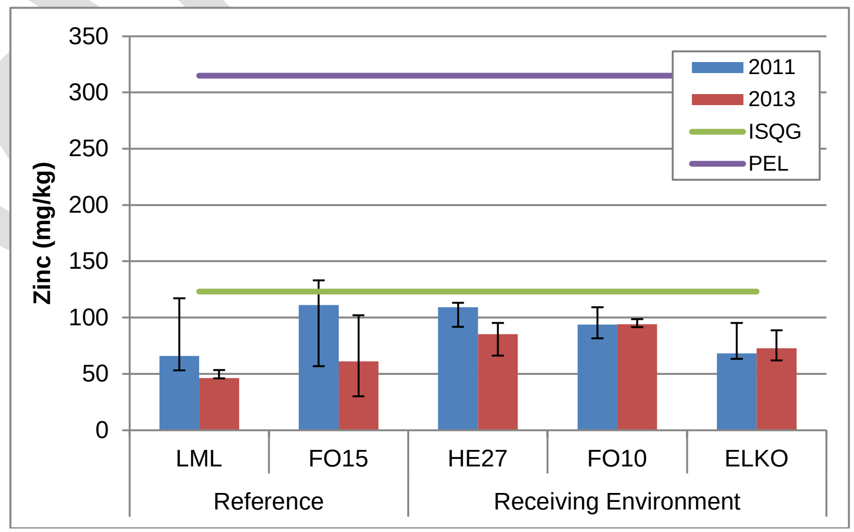
Cadmium



Nickel

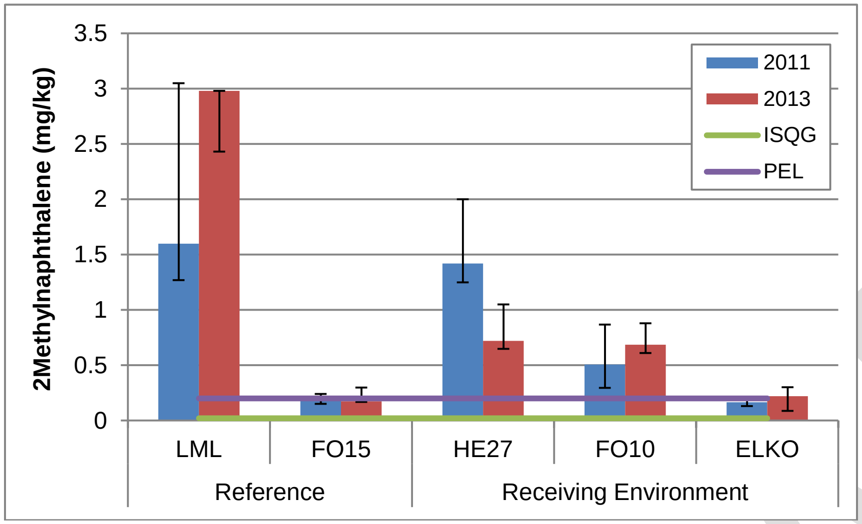


Selenium

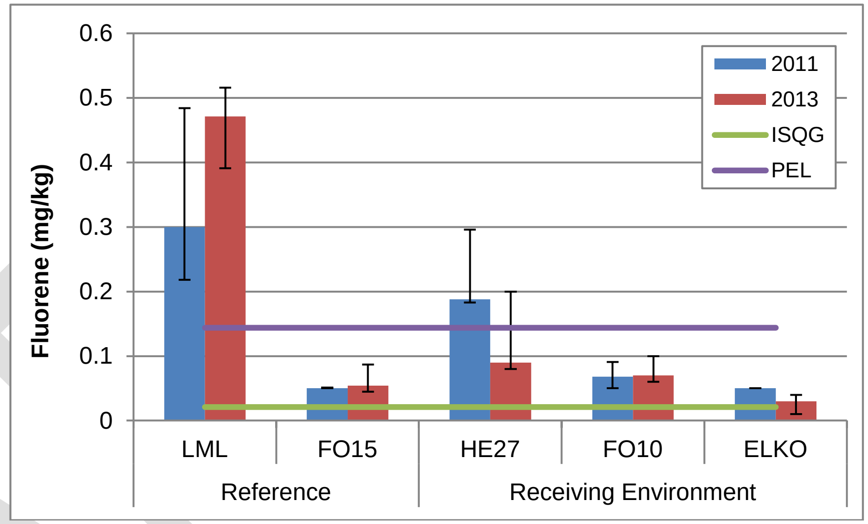


Zinc

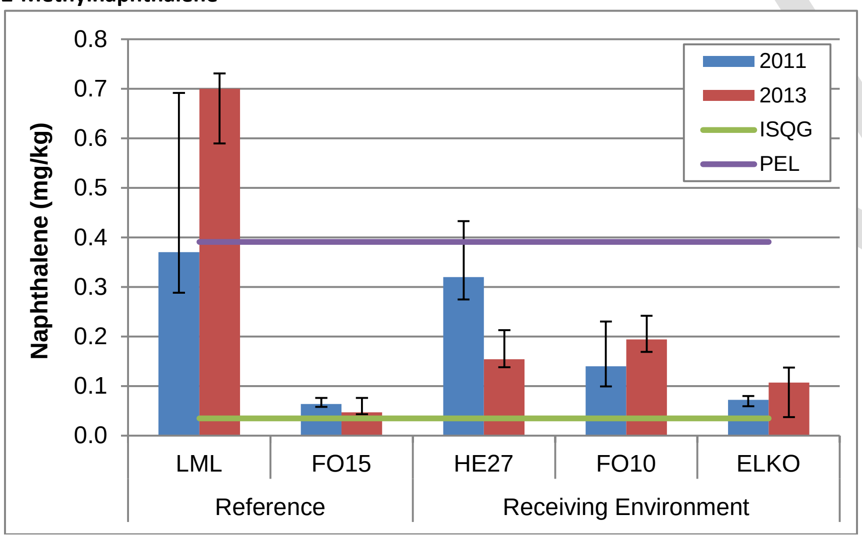
Figure 3.2-2. Median (and range) of sediment concentrations of selected metals observed at locations sampled in both 2011 and 2013.



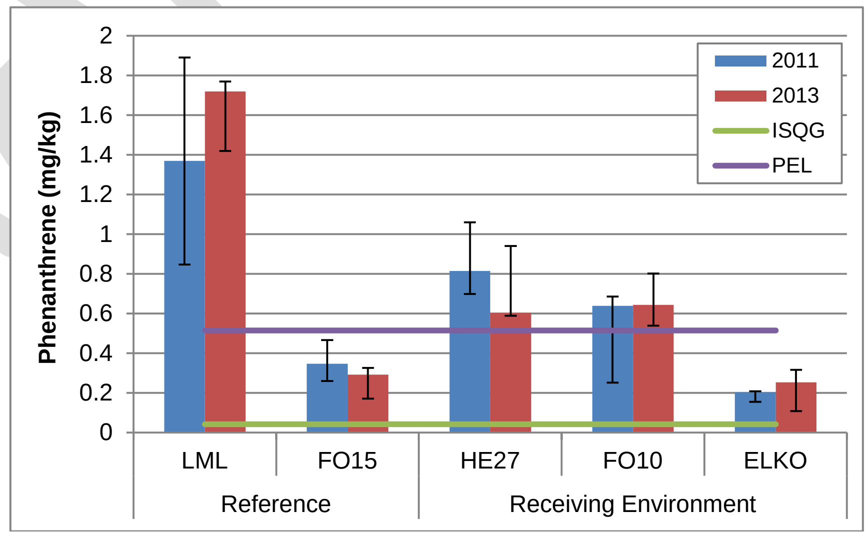
2-Methylnaphthalene



Fluorene



Naphthalene



Phenanthrene

Figure 3.2-3. Median (and range) of sediment concentrations of selected PAHs in locations observed at locations sampled in both 2011 and 2013

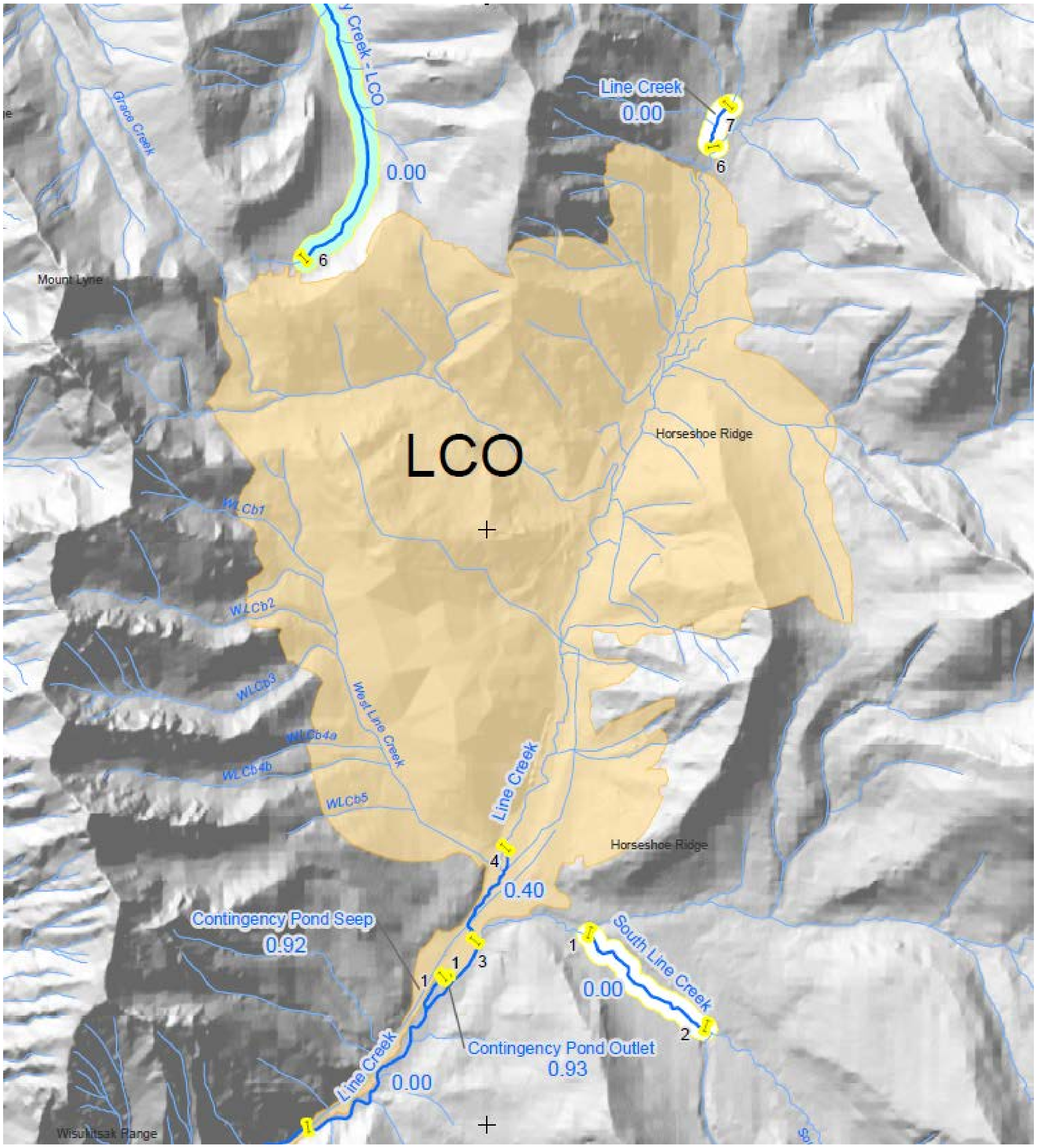
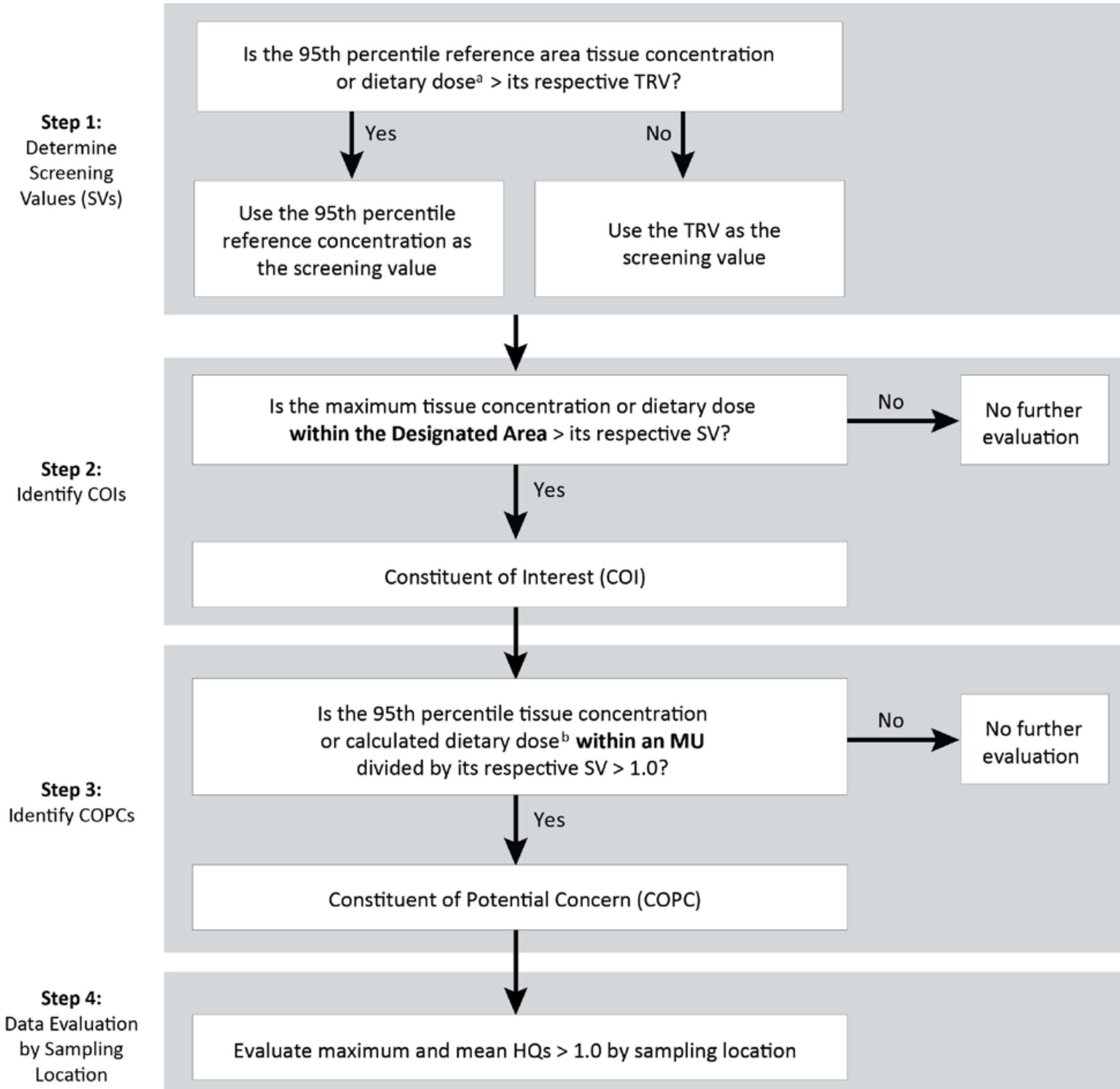


Figure 3.3-1. Calcite Index results from streams surveyed near Line Creek Operations in 2013. Note: Mine-exposed reaches (in blue), reference reaches (white outline), and reaches which are expected to be mine-exposed in the future (green outline).



[a] the reference dietary dose is calculated using the 95th percentile reference tissue concentration
[b] the dietary dose used to calculate the HQ is based on the 95th percentile tissue concentration

Figure 3.4-1. Tissue screening evaluation process

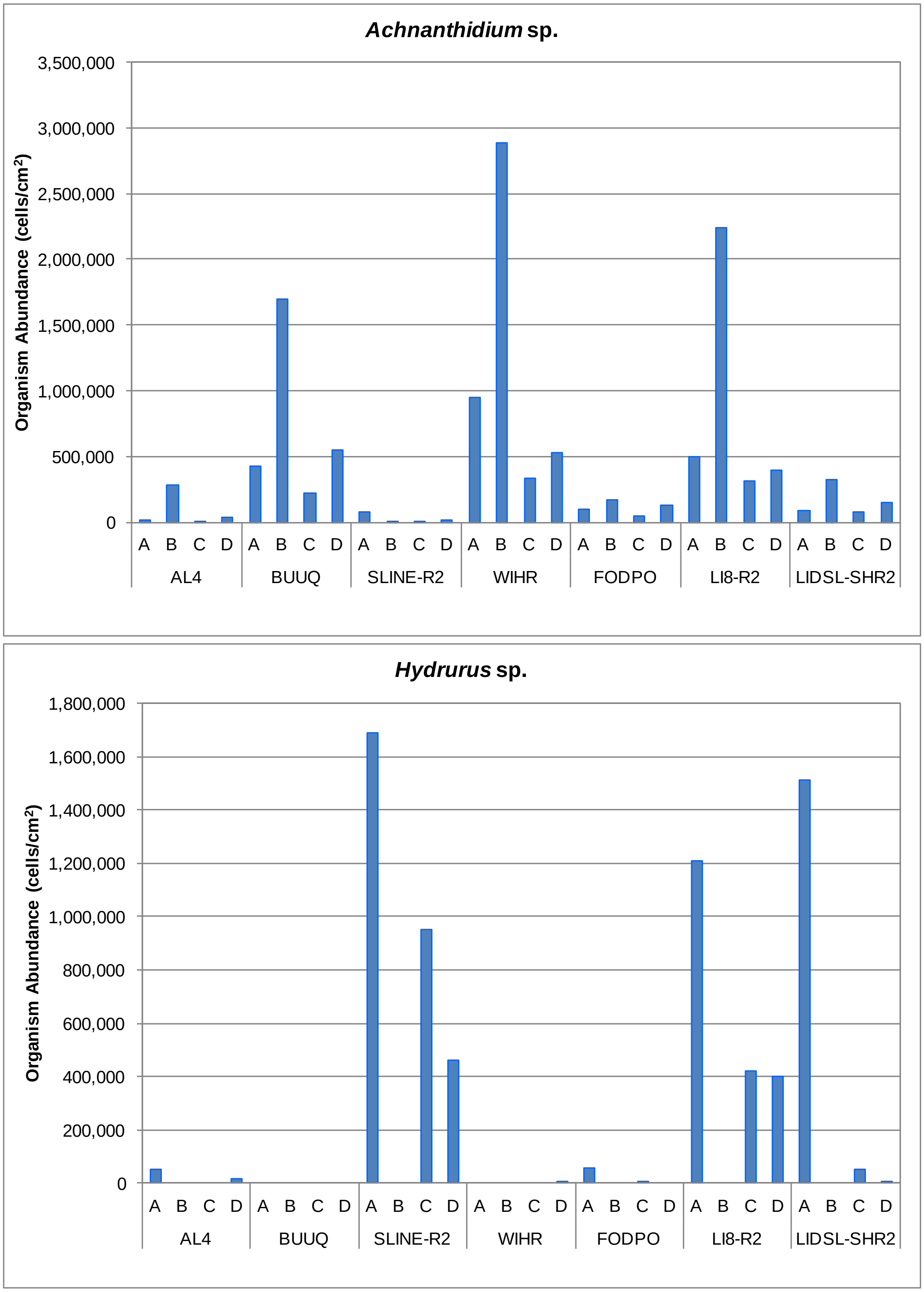


Figure 3.4-2. Densities of *Achnanthidium* sp. (diatom) and *Hydrurus* sp. (chrysophyte) reported for split samples in inter-laboratory comparison, September 2013.

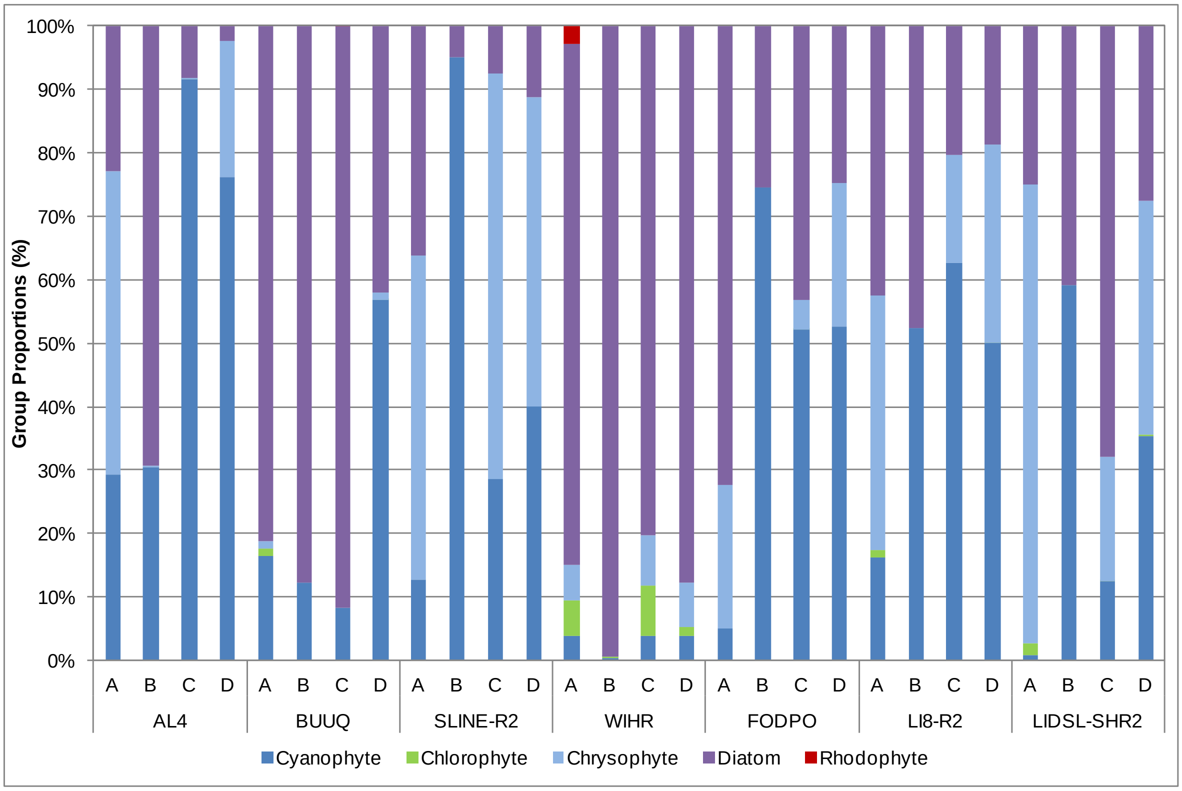


Figure 3.4-3. Periphyton group proportions reported for split samples in inter-laboratory comparison, September 2013.

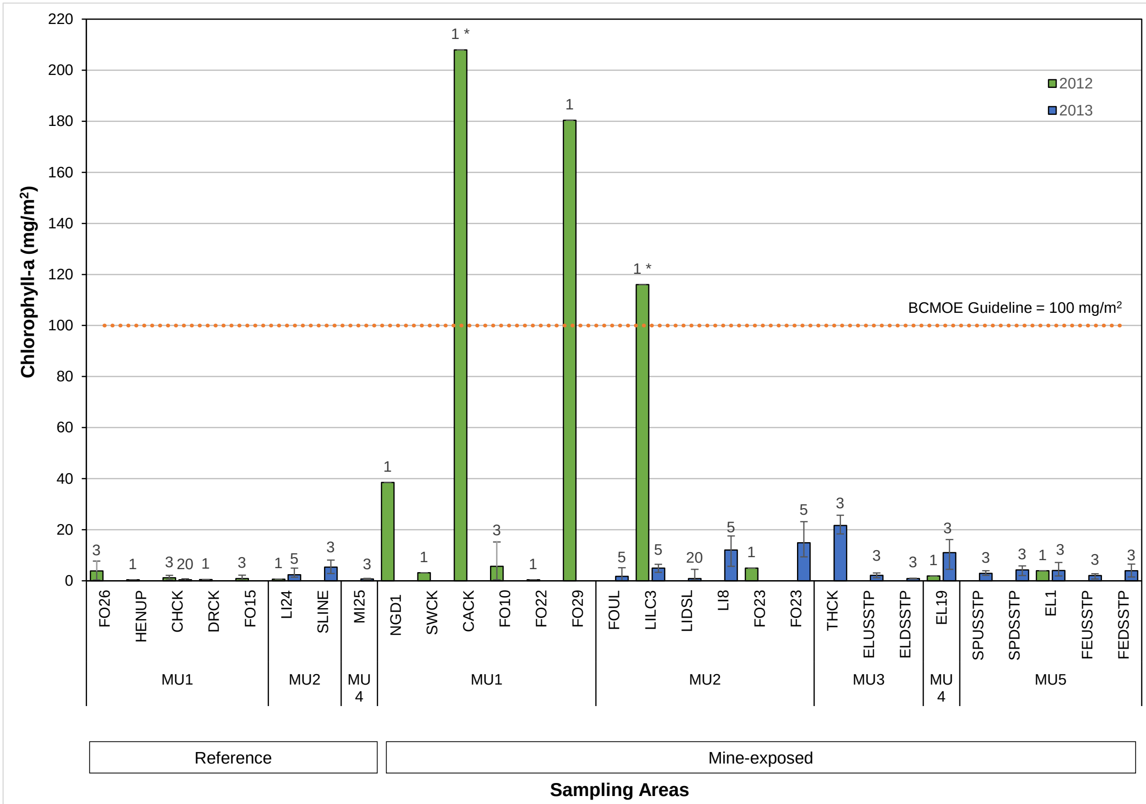


Figure 3.4-4. Periphyton chlorophyll-a concentrations (mean ± range) in September 2012 and 2013. Number of replicates sampled at each area is shown above the data bars.
Asterisk (*) indicates that bryophytes were present in the sample.

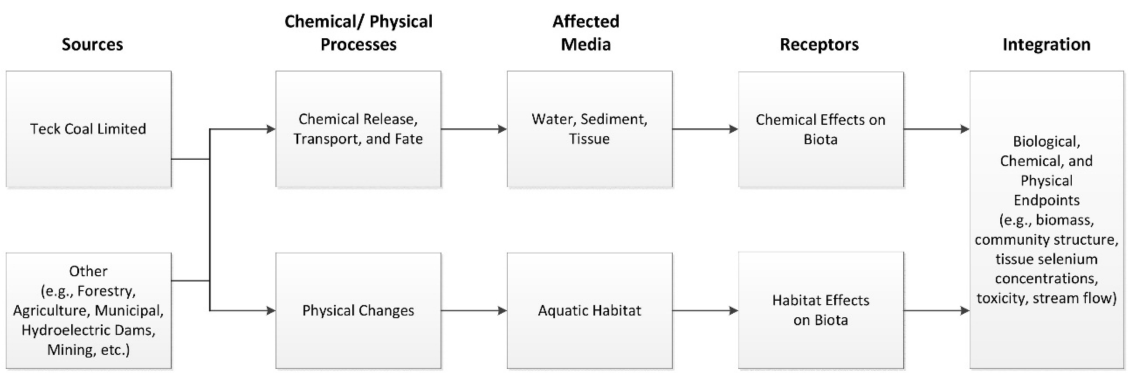


Figure 4.1-1. Cumulative effects model for chemical and physical stressors in the Elk River watershed and Lake Koocanusa