STRATEGY FOR AQUATIC ECOLOGICAL RISK ASSESSMENT AT TECK COMINCO'S KIMBERLEY OPERATIONS, BC

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ABSTRACT

The overall objective of this predictive aquatic ecological risk assessment (ERA) is to assess contaminant-related risks after implementation of Teck Cominco's closure plan for the site. The first stage of the ERA, problem formulation (PF), was conducted to identify the most likely risk drivers for the site to help focus subsequent aquatic ERA investigations. This paper summarizes the key findings of the PF and presents an overview of the main components of the aquatic ERA. The terrestrial component of the ERA is presented in a separate paper (Allard et al., 2004).

OVERVIEW

Approximately a century of mining has been conducted at the Kimberley Operations site (along with a handful of other industrial activities for various durations). Teck Cominco Metals Ltd. (Teck Cominco) has been planning the decommissioning and closure of the Kimberley Operations site for over a decade. Regulatory requirements for mine closure in British Columbia changed over this time (see Higgins et al., 2004), resulting in a request by the BC Ministry of Water, Land and Air Protection (BCWLAP) to undertake a Human Health and Ecological Risk Assessment (HH/ERA) under the province's *Contaminated Sites Regulation* (CSR)[1] to confirm the effectiveness of Teck Cominco's Decommissioning and Closure Plan (Teck Cominco, 2000)

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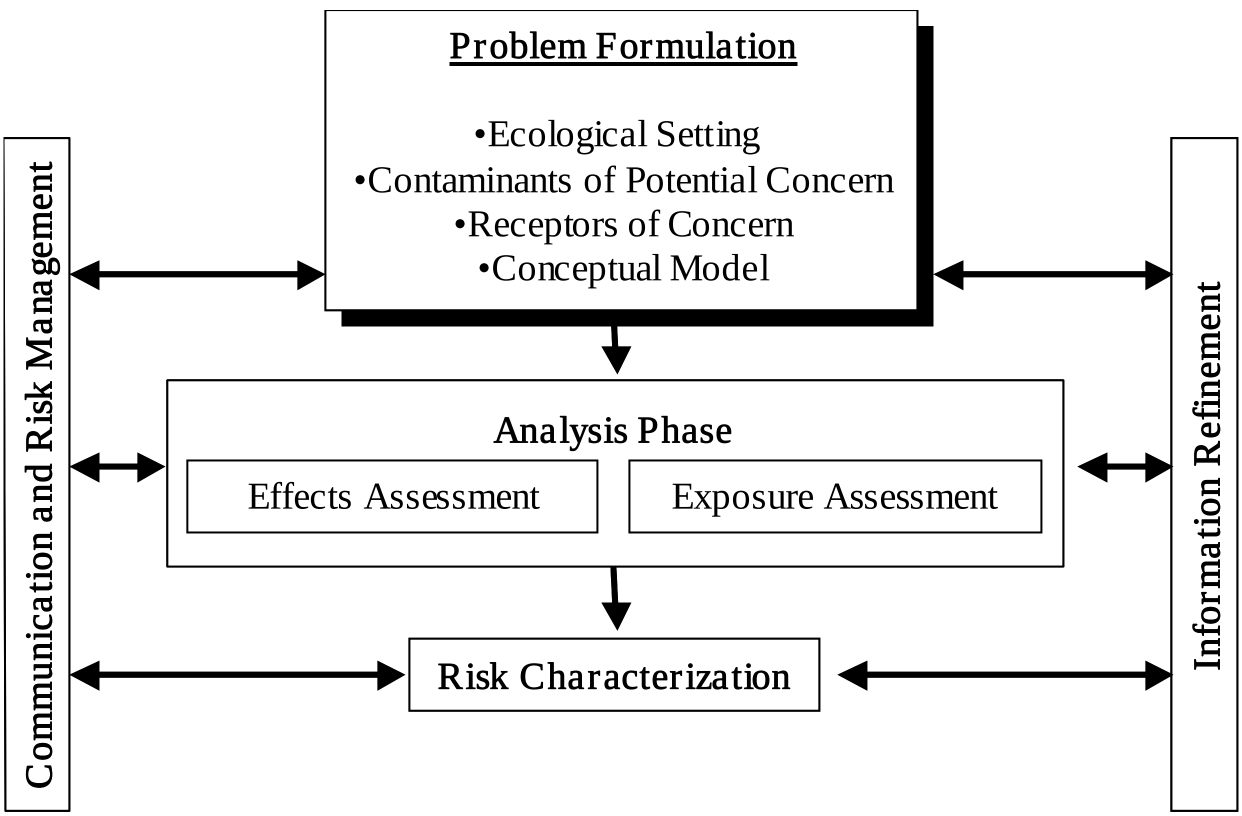
[1] Waste Management Act, *Contaminated Sites Regulation*, BC Reg. 375/96, deposited December 16, 1996, O.C. 1480/96, effective April 1, 1997 (includes amendments BC Reg. 244/99, deposited July 19, 1999 and BC Reg. 17/2002, deposited February 4, 2002).

This paper describes the problem formulation (PF) for the aquatic environment portion of the ERA. In addition to the typical components included in a PF (Figure 1), a screening-level analysis was conducted using available data to help focus the subsequent ERA on the contaminants, exposure pathways and receptor combinations of greatest potential risk at the Kimberley Operations site. The objectives of the PF were to:

- Characterize the general ecological setting of the site.
- Identify contaminants of potential concern (COPCs) for the site.
- Identify ecological receptors of concern (ROCs) for the site and document protection goals for each.
- Integrate information on COPC sources, transport/exposure pathways and ROCs into the development of a conceptual model.
- Conduct a screening-level assessment of potential risks to aquatic receptors[2].
- Describe the key study components used to assess risks in the ERA.

Figure 1. Problem Formulation overview for aquatic environment.



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[2] This paper focuses only on aquatic plants, invertebrates and fish. Amphibians, reptiles, birds, and mammals relying on the aquatic environment are addressed in Allard et al., 2004.

ECOLOGICAL SETTING

The Kimberley Operations site either encompasses or is adjacent to numerous freshwater bodies varying in size and ecological importance. These water bodies are subject to various degrees of contaminant inputs related to the site via surface water and/or groundwater. Some receiving environments (e.g., the St. Mary River) are regionally important aquatic ecosystems, while others (e.g., Sullivan Creek) have been exposed to high levels of mine-related discharges for decades and are now used for mitigation purposes to reduce ARD-related discharges to more important receiving environments. Ongoing reclamation efforts should result in further improvements to water quality in both primary and secondary receiving environments over the next decade or more.

The relative importance of various receiving environments was subjectively categorized as either “primary” or “secondary”. based on both human and ecological values. Ultimately, receiving environments are valued primarily from a human perspective, based on water quality (e.g., as drinking water), aesthetics and visibility in a community setting (e.g., Kimberley and Mark Creek), ability to support a fish and/or a fishery, and usefulness for recreational purposes.

Given these criteria, the St. Mary River ranks high and is the most important primary receiving environment. In addition, based on its size, habitat diversity and geographic area, the St. Mary River is an extremely important receiving environment for many fish and wildlife species. Mark Creek is also considered a primary receiving environment. Anecdotal information and historical data indicate that the creek was largely an industrial sewer until the last few decades when concerted efforts were made to reduce discharges from the Kimberley Operations site. The improvements to the ecology of the creek resulting from these efforts, its proximity and aesthetic value to the City of Kimberley, and its direct link to the St. Mary were considered sufficient justification for its classification. Secondary receiving environments were also identified based their proximity to the Sullivan Mine and communities of Kimberley and Marysville, as potential pathways for waste streams (either via surface or groundwater), and as potential wildlife habitat. In order of relative ecological importance, these are Luke Creek, Lois Creek, Cow Creek, and Sullivan Creek.

CONTAMINANTS OF POTENTIAL CONCERN (COPCs)

Water quality data for the primary receiving environments from Teck Cominco’s routine monitoring program were screened against provincial ambient water quality criteria to identify COPCs. While over a decade of data was available, the screening considered only the results from 2001 through 2003 to provide the best representation of post-closure conditions. Teck Cominco has implemented numerous remedial actions over the past decade to improve improve water quality. However, since the full benefits of these and other planned actions have not likely been fully realized, consideration of only three years of data is considered conservative.

The screening targeted two monitoring stations in Mark Creek. The first, MY-16, is located immediately downstream of the Lower Mine Yard and was included to represent worst-case conditions in Mark Creek. The second, MY-12, is located upstream of Teck Cominco’s operations and is considered a background station[3]. Only those parameters that (1) exceeded water quality criteria and (2) exceeded background conditions were retained as COPCs. Two groups of COPCs were identified based on the magnitude and frequency of exceedences in the screening process: primary COPCs included aluminum, cadmium, cobalt and zinc; secondary COPCs included copper, fluoride, manganese and sulphate. The Hydrological/Geochemical Assessment Team developed a model to look at the relative contributions of COPC sources to loadings to Mark Creek and the St. Mary River.

RECEPTORS OF CONCERN (ROCs)

The ROCs for this study were chosen based on a number of scientific and human value considerations (e.g., ecological or recreational importance). The main aquatic receptor groups are plants (i.e., algae), invertebrates and fish. Rather than identifying individual plant or invertebrate species, their entire communities were included as ROCs. Westslope cutthroat trout, the only native species for most of Mark Creek, was selected as the ROC for fish. Once the ROCs were selected, protection goals (i.e., level of protection afforded each receptor; higher protection typically afforded to listed species), assessment endpoints (i.e., formal statement of what ROC characteristics will be evaluated) and measurement endpoints (i.e., measurable responses to COPC exposure that are linked to the assessment endpoints) were developed for each ROC (Table 1).

Table 1. Receptors, protection goals and endpoints for Aquatic ERA.

ROC Groups (Representatives)	Protection Goals	Assessment Endpoints	Measurement Endpoints
Aquatic plants (periphyton – algae)	Moderate priority at community level; low priority at population or individual level.	Maintenance of healthy plant community capable of supporting local invertebrate and vertebrate populations.	✓ Water quality screen ✓ Preliminary toxicity testing • Detailed toxicity testing • Detailed community survey
Aquatic Invertebrates (primarily insect larvae)	Moderate priority at community level; low priority at population or individual level.	Maintenance of healthy benthic invertebrate community capable of supporting local fish populations.	✓ Water quality screen ✓ Preliminary toxicity testing ✓ Preliminary community survey • Detailed toxicity testing • Detailed community survey
Fishes (Westslope cutthroat trout)	High priority at population level; low priority at individual level	Maintenance of healthy fish populations not carrying unacceptable body burdens of bioaccumulative substances.	✓ Water quality screen ✓ Preliminary toxicity testing ✓ Qualitative habitat survey • Detailed toxicity testing • Detailed biological and chemical (body burden) assessment

Note: Measurement endpoints shown with a check indicate the were considered in the SLRA; those shown with regular bullets will be included in the detailed ERA.

[3] Metals concentrations at MY-12 are somewhat elevated relative to the furthest upstream station on Mark Creek. The sources of the metals are considered to be natural mineralization and/or small-scale historical mining activity.

CONCEPTUAL MODEL

A conceptual model is a graphical or textual representation of the key characteristics relevant to understanding how a COPC might affect an ROC. One of the important elements of the conceptual model is the identification of important exposure pathways for each ROC. For the aquatic ecosystem at the Kimberley Operations site, the following pathways were considered most relevant:

- Direct exposure to site-related COPCs in surface water for aquatic plants.
- Direct exposure to site-related COPCs in surface water and food resources for aquatic invertebrates.
- Direct exposure to site-related COPCs in surface water and ingestion of food with elevated COPC concentrations for fishes.
- Indirect exposure via ingestion of food with elevated COPC concentrations for aquatic birds and mammals (see Allard et al., 2004).

The conceptual model for the aquatic environment is presented in Figure 2.

SCREENING-LEVEL RISK ASSESSMENT

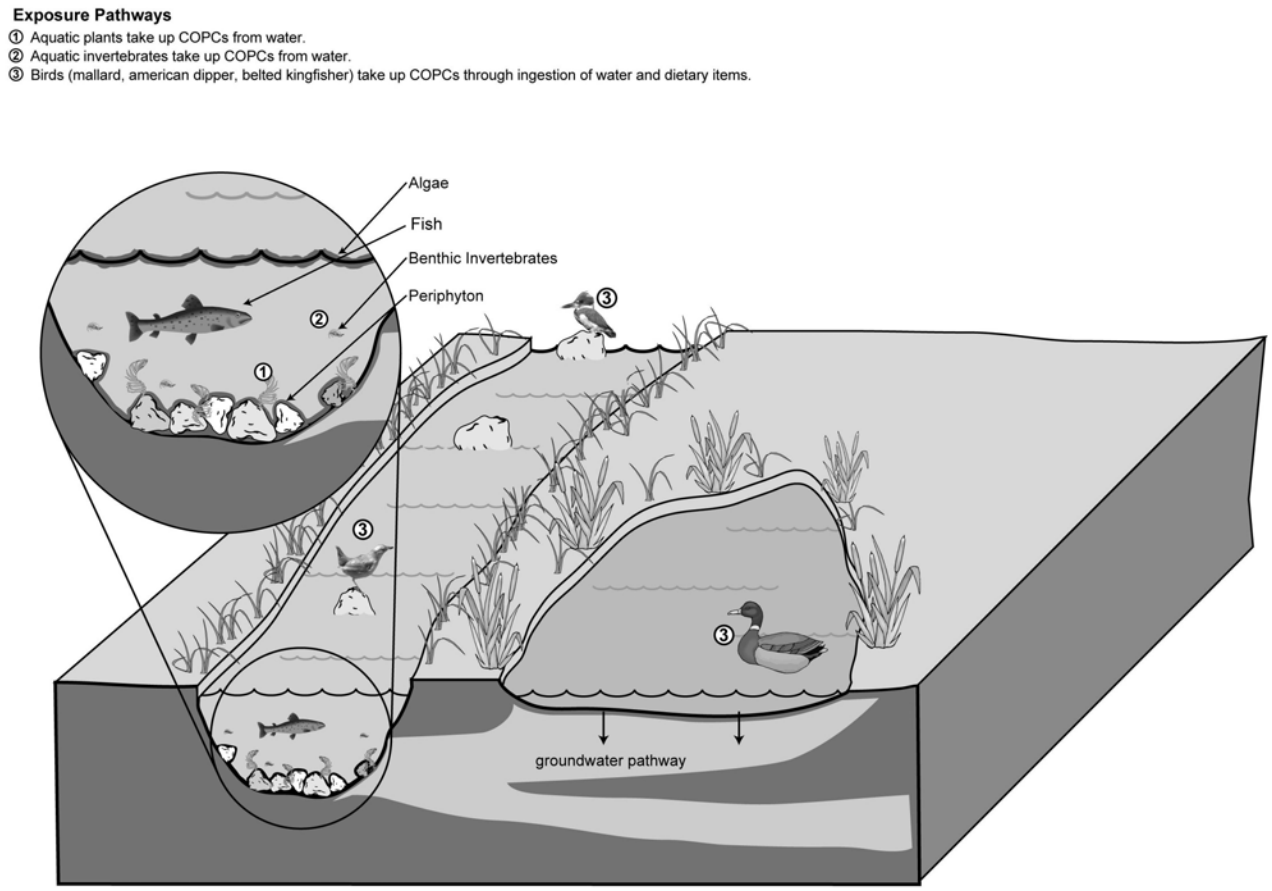
The screening-level risk assessment (SLRA) was conducted to determine which COPC/ROC combinations potentially pose unacceptable risks and should be retained for further evaluation in the detailed risk assessment.

Approach

The approach for the SLRA was to compile available information on COPC-related effects for each major receptor group at the Kimberley Operations site. Two types of site-specific information are available relating to potential effects at the site:

- Laboratory toxicity studies evaluating lethal and sublethal responses to COPCs.
- Field studies addressing population or community responses to the COPCs.

Figure 2. Conceptual model for Aquatic ERA.



While some site-specific information was available from historical studies, the majority was collected during the 2001 Problem Formulation Reconnaissance Sampling Program, which was designed to fill basic data gaps related to aquatic receptors at the Kimberley Operations site. The program included chemical, biological and toxicological components.

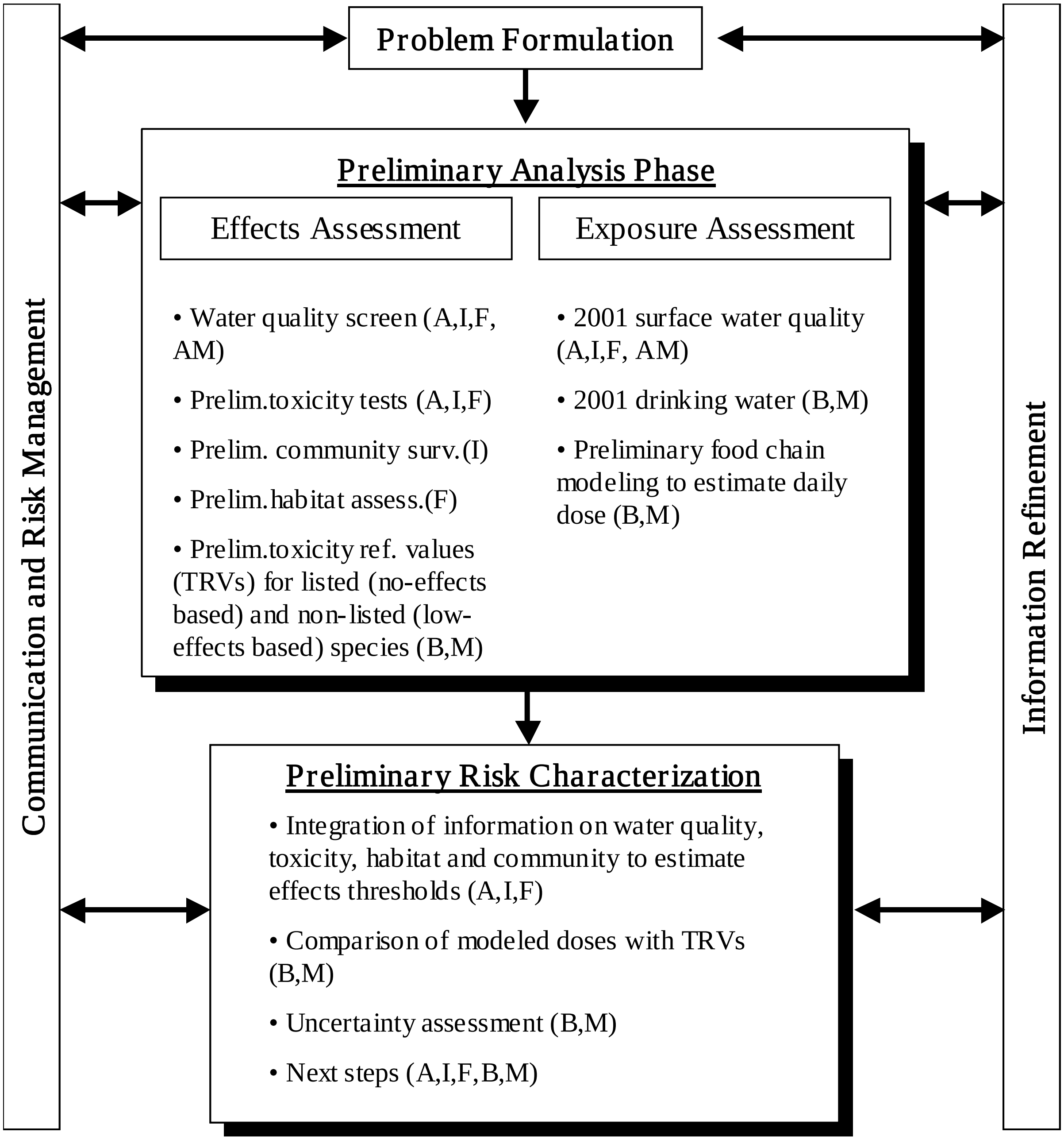
The information was interpreted in a hierarchical way, with more emphasis being placed on results from field studies over laboratory toxicity testing results. The reason that field studies get a higher weighting is that COPC toxicity is controlled by a variety of factors that may not be fully accounted for in laboratory studies. Laboratory studies, however, were particularly useful in determining the types of effects expected and approximate threshold COPC concentrations associated with the onset of unacceptable adverse effects. An overview of the SLRA is presented in Figure 3.

Findings

The main results of the SLRA are summarized below:

- Aquatic Plants – The only available information on potential risks is from toxicity tests on the algal species *Selenastrum capricornutum*. Adverse effects were observed in the laboratory for certain samples collected immediately downstream of the Lower Mine Yard. The observed toxicity was linked to zinc. Recommendations were provided for follow-up ERA investigations.
- Aquatic Invertebrates – Benthic community structure was assessed at the five routine monitoring water quality stations on Mark Creek during the 2001 Reconnaissance Sampling Program. No major differences were observed among stations. Toxicity testing showed adverse effects to invertebrates (the water flea, *Ceriodaphnia dubia*) in the laboratory using water collected from the Lower Mine Yard; follow-up investigation identified zinc as the likely toxicant. Recommendations were provided for more intensive follow-up ERA investigations.
- Fish – Anecdotal information indicates that mining-related contaminants and habitat alterations virtually eliminated fish from Mark Creek below the Kimberley Operations. However, recent data shows fish have returned to Mark Creek. The toxicity testing (on rainbow trout, *Oncorhynchus mykiss*) conducted as part of the 2001 Reconnaissance Sampling Program did not show any adverse effects, but testing was limited in nature. Recommendations were provided for follow-up ERA investigations.

Figure 3. Screening-level Risk Assessment for aquatic environment.



• A = algae • B = birds

• I = invertebrates • M = mammals

•F = fish • AM = amphibians

Note: Details on amphibians, birds and mammals can be found in Allard et al. (2004).

KEY ERA COMPONENTS

The SLRA results identified potential COPC-related risks to aquatic ROCs in Mark Creek and/or the St. Mary River. A series of questions were identified to focus ERA investigations. These included general questions regarding COPC toxicity to be answered using laboratory toxicity testing and ROC-specific questions to be addressed with field investigations. The questions and corresponding investigation components are presented in Table 2.

Table 2. Aquatic ERA field investigation components.

ROC Groups (Representatives)	Guiding Questions	Investigation Components
General Toxicity	How is zinc toxicity affected by water hardness? What is the sensitivity of native species relative to cultured laboratory organisms? Are any other COPCs present in Mark Creek at concentrations that may result in adverse effects? What is the degree of toxicity of Mark Creek water in the Lower Mine Yard during the period immediately prior to freshet?	• Toxicity tests conducted with each ROC group and primary COPCs to determine influence of key modifying factors. • Toxicity testing conducted on native species. • Spiking toxicity tests conducted for all primary COPCs to determine threshold effect concentrations for each ROC group. • Seasonal testing for each ROC group.
Aquatic plants (periphyton – algae)	Are their any ecologically significant changes to the periphyton community structure or biomass related to the COPCs in Mark Creek? If so, would these likely extend to the St. Mary River?	• Detailed community survey in Mark Creek conducted in 2002 and 2003.
Aquatic Invertebrates (insect larvae)	Are there any ecologically significant alterations to the community related to the COPCs? If so, would these likely extend to the St. Mary River? What changes in the community occur due to freshet? Are the changes (if any) related to chemical (i.e., COPCs) or physical (i.e., high flows) factors?	• Recon survey conducted in 2001; detailed community surveys conducted in Mark Creek in 2002 and 2003. • Detailed surveys conducted in April, June and July 2003.
Fishes (Westslope cutthroat trout)	Are COPC concentrations in fish from the St. Mary River higher downstream of inputs from the Kimberley Operations site relative to an upstream reference area? Fish - If so, are the elevated COPCs causing any measurable adverse effects to fish in the St. Mary River? Fish - Are COPCs accumulating into any recreationally important fish species in the St. Mary River?	• Detailed fish (mountain whitefish and cutthroat trout) investigations conducted in St. Mary River. Tissue chemistry compared between reference and exposure areas. • EEM-style biological assessment conducted to evaluate potential COPC-related effects. • Cutthroat trout tissue sampled for chemistry; results addressed in human health risk assessment.

The results of these investigation components for each ROC will be combined with other information (e.g., water quality monitoring results and hydrogeochemical modelling) to assess COPC-related risks in the Aquatic ERA. Ultimately, a weight-of-evidence approach (i.e., consideration of all available lines of evidence regarding potential risks) will be used to make risk conclusions.

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