Environmental Risk Assessment

Cameco Corporation (Cameco) owns (50%) and operates the Cigar Lake Uranium Mining Operation (the Operation) (Figure 1). It is located in northern Saskatchewan, at the eastern edge of the Athabasca basin at the south end of Waterbury Lake, approximately 660 km north of Saskatoon. Development of the Cigar Lake mine began in 1981, and mining was initiated in 2014. Milling of the Cigar Lake ore is being conducted at the McClean Lake site operated by Orano Canada Inc.

In 2017 Cameco completed an environmental risk assessment (ERA) to align with the standardized requirements found in CSA N288.6-12 *ERA at Class I Nuclear Facilities and Uranium Mines and Mills*. An addendum to the ERA was completed in 2019.

Background

An ERA is a systematic process used to identify and assess the potential risk posed by releases from the project to people and the environment. There are two parts to an ERA – an assessment of the exposure and potential risk to people that use the area through a human health risk assessment (HHRA) and an assessment on wildlife and other biota, such as plants, through an ecological risk assessment (EcoRA). The Cigar Lake ERA was completed to address the following question: *Is there potential for significant environmental (i.e., human and/or ecological) effects from current emissions associated with the Operation?*

Additionally, the conclusions of the current assessment were compared to those provided in the 2011 Environmental Impact Statement (EIS).

ERAs follow general guidance provided by CSA and various agencies, such as Health Canada (HC), Environment and Climate Change Canada (ECCC), Canadian Council of Ministers of the Environment (CCME) and the Canadian Nuclear Safety Commission (CNSC).

The first step in conducting an ERA (Figure 2) is to detail the releases from the Operation and to understand how these move in the natural environment. Releases from the Operation have been characterized using the extensive database of available monitoring information and is thus sufficient to support the ERA.

Figure 1. Cigar Lake Uranium Mining Operation

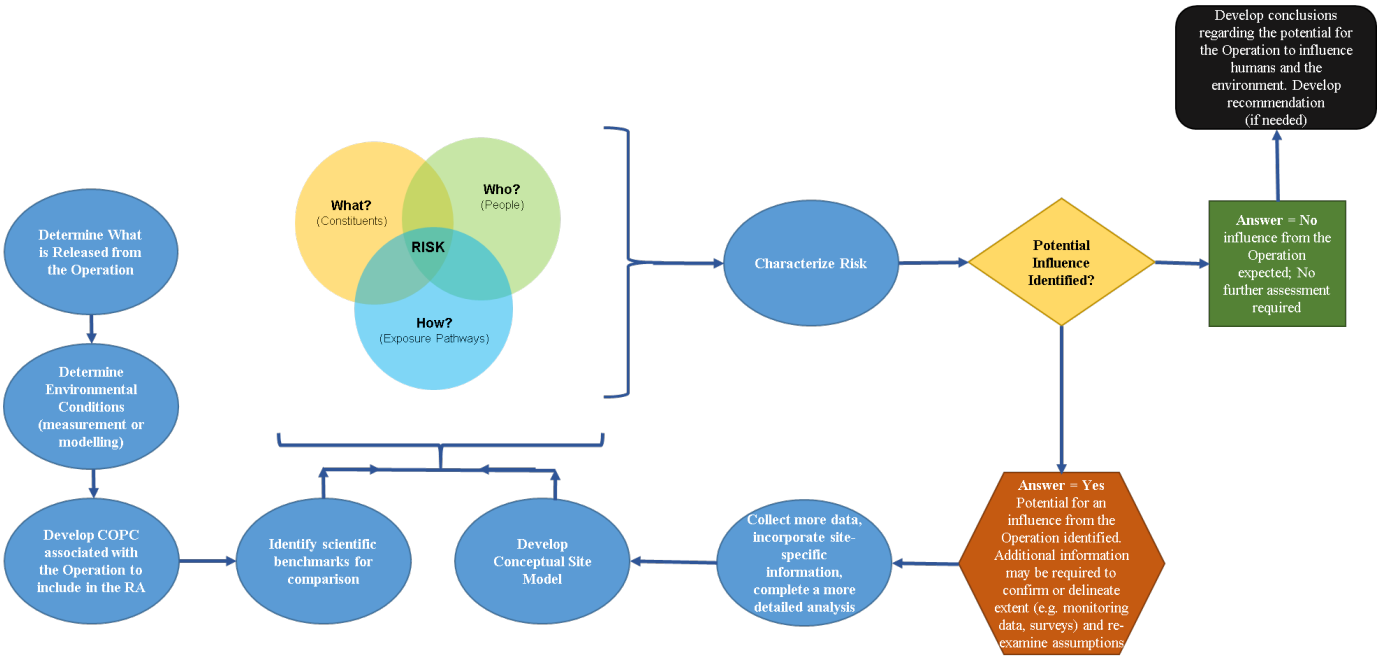


Figure 2. Environmental Risk Assessment Overview

Once the releases are understood, the relevant Constituents of Potential Concern (COPCs) need to be identified. This is a list of the key radiological and non-radiological constituents released to air and water from site operations. It is developed from knowledge of the facility, environmental monitoring data, and feedback from regulators and local land users. In developing the list of COPCs, some constituents are removed from further consideration if they are released in very small quantities, if they are present at or below natural background levels, or if they are determined not to be a concern from a human or ecological health perspective. The concentration(s) of COPCs in the environment (i.e. soil, surface water, air) are determined in the natural areas near the Operation using field measurements, modelling, or a combination of both.

The foundation of the risk assessment is the Conceptual Site Model (CSM). The CSM summarizes how the COPCs are released and are expected to move in the environment as well as identifies who uses the land, including both people and biota (wildlife, plants). This information, together with information on the potential influence of COPCs, are used in the risk assessment. The pathways assessment (also called risk characterization or risk assessment) uses information on What (selected COPCs), Who (identify receptors) and How (exposure pathways) to assess the risk. The CSA standard N288.6 provides a systematic approach and calculations that are used to estimate the exposure of the human or ecological receptor to each of the COPCs. The calculations estimate the uptake of COPCs from the different environmental media and indicate how the COPCs are passed up the food chain. A cautious approach is taken in the assessment using conservative assumptions that are likely to overestimate the exposure. An example of a conservative assumption can be seen regarding the home ranges of the evaluated species. Those species with larger home ranges, such as wolf, moose and caribou, are assumed to spend a significant amount of time in the exposure area; however, it is expected that they would range over a larger area.

Potential influences on the environment are determined using a weight-of-evidence approach. One part of this is to calculate a screening index (SI). In simple terms, an SI is the concentration or exposure level divided by published scientific benchmarks that have been deemed unlikely to adversely influence the receptor (Figure 3). These benchmarks can come from research or field studies, regulatory standards and objectives, scientific literature or other credible sources. If no potential influences are identified (i.e., if SI is less than 1), then influences on the environment are not expected. Due to the cautious nature of the calculations, an SI greater than 1 indicates that further assessment may be required to determine whether there is an influence. This can include more detailed analysis, additional field data and site-specific information.

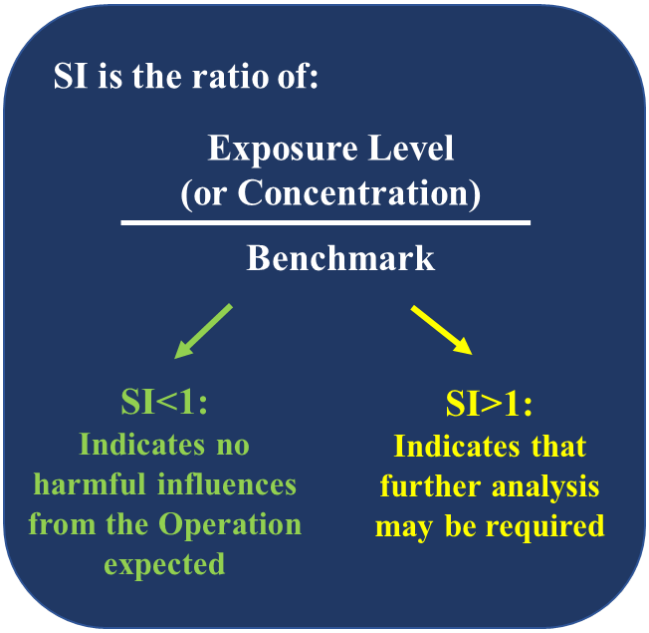


Figure 3. Screening Index (SI) Ratio

In a weight-of-evidence approach, all information is considered to reach an overall conclusion on the potential for a response. For example, for the assessment of aquatic insects that are in sediment, the SI will be considered along with information on the type of insects and how many are present. Once the assessment is complete, a conclusion regarding the potential harm to people or the environment is developed.

The following sections provide more information specifically about the Cigar Lake Operation, the releases into the environment from the Operation, selection of COPCs and receptors, pathway characterization, and results and conclusions of the ERA. The input from the local communities is also highlighted. For example, ecological receptors were selected based on surveys completed in the Operation area as well as other considerations including local resource user interviews and input from local communities.

Site Description

The Cigar Lake Operation is situated near the southern shore of Waterbury Lake between the Aline Creek and Cigar Creek drainages (Figure 4). The Aline Creek system flows into Seru Bay of Waterbury Lake, while the Cigar Creek system flows into Longyear Bay of Waterbury Lake. The aquatic environment study areas considered in the ERA incorporate all of Waterbury Lake, including Seru Bay and Longyear Bay. The terrestrial environment study area includes a 100 km^2 area centered on the Operation.

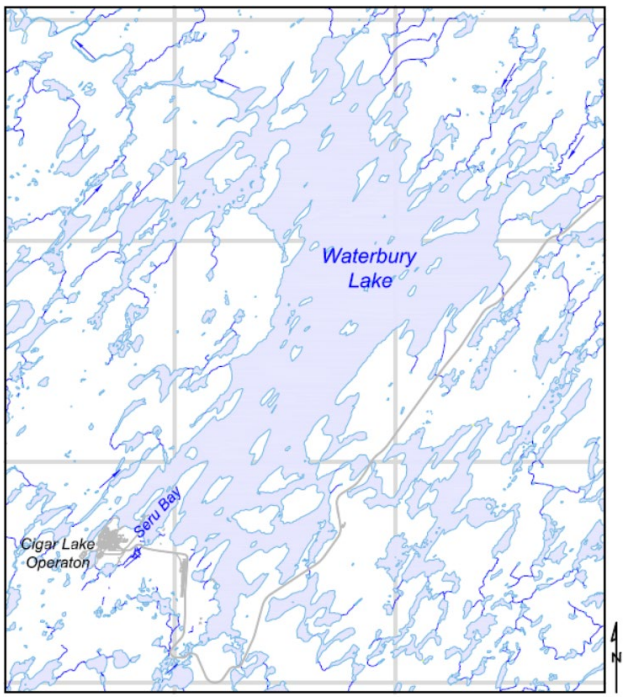


Figure 4. Cigar Lake Operation Study Area

Releases into the Aquatic Environment

Water from the Operation is treated and released through a multi-port diffuser into Seru Bay of Waterbury Lake. The amount and quality of water released were based on the measured data from the water treatment system at the site and on an understanding of the expected changes. Two scenarios were considered for the treated effluent release: an Expected Loading scenario, which represents the current estimate of future effluent flows and concentrations; and a more conservative Upper-bound Loading scenario. To investigate the potential influence of non-routine discharge from inflow events at the Operation, sensitivity case scenarios were run. These sensitivity cases included a non-routine discharge to each of the Expected and Upper-bound Loading scenarios.

The movement of COPCs in the environment was modelled using a computer program called ADEPT (Assessment of the Dispersion and Effects of Parameter Transport), which is a contaminant dispersion and transport model for waterbodies that includes pathways and risk assessment calculations. The model can assess a variety of COPCs and considers numerous lakes/rivers/wetlands/bays and multiple branches of a watershed. As expected, as the Operation proceeds, water and sediment concentrations are predicted to increase. Once the site is decommissioned and treated effluent is no longer released, the concentrations are expected to decline and return to pre-operational conditions.

Releases to the Atmospheric Environment

Air dispersion modelling was used to evaluate the influences of the Operation on ambient air quality over the life of the mine. The emissions from the facility, including mine ventilation, waste rock storage, and road dust were summarized. The CALMET/CALPUFF modelling package was then used to predict concentrations of various COPCs. Overall, it was predicted that the Operation would have only a limited influence on air quality. Within five kilometres of the Operation, all COPCs concentrations are predicted to return to near background levels.

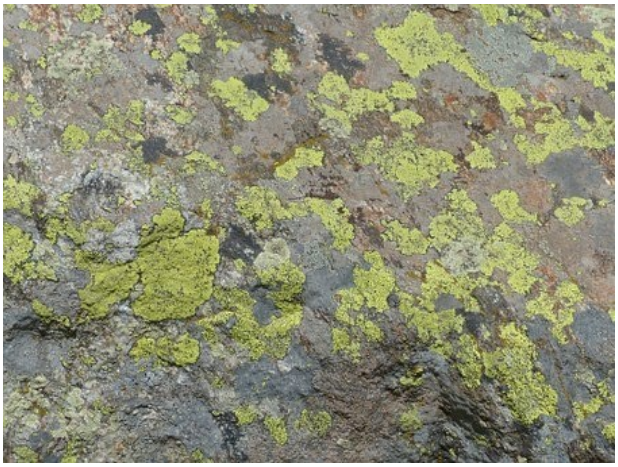


Figure 5. Healthy lichen growth

Selection of COPCs

The final list of COPCs selected for the assessment is provided below:

- Metals (and metalloids): arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc.
- Radionuclides: uranium-238, lead-210, polonium-210, radium-226, and thorium-230
- Total Dissolved Solids (TDS) was included as it represents inorganic salts present in solution in water including calcium, magnesium, sodium, and potassium cations and carbonate, bicarbonate, chloride, sulphate, and nitrate anions.
- Other general chemistry constituents selected for inclusion in the COPCs list are ammonia, chloride, nitrate, and sulphate.
- Additional COPCs selected for inclusion for air quality are TSP (and constituents), PM_{10}, $PM_{2.5}$, NO_x, and radon (Rn-222).

These COPCs were assessed in one or more of the following pathways in the ERA:

- Soil
- Air
- Surface water
- Sediment
- Food items (e.g., fish)
- Gamma radiation

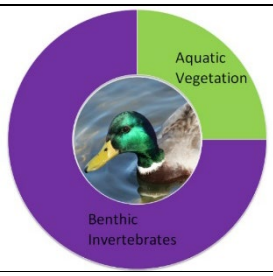
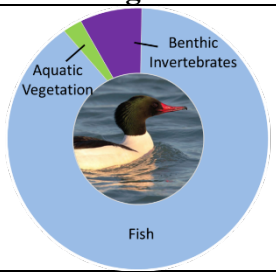
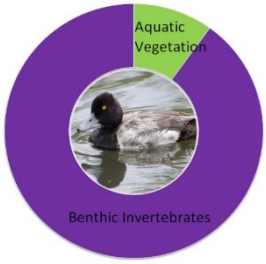
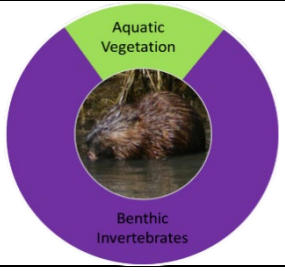
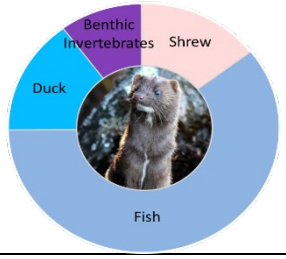
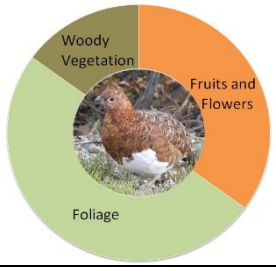
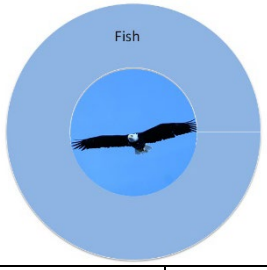
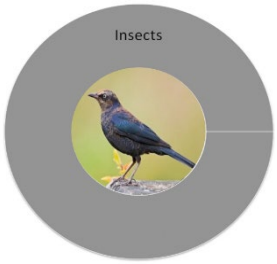
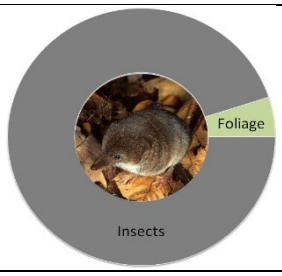
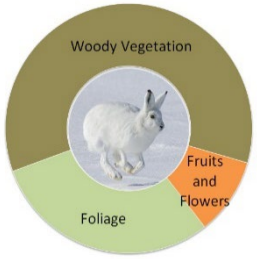
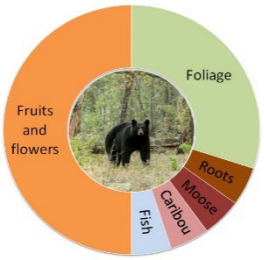
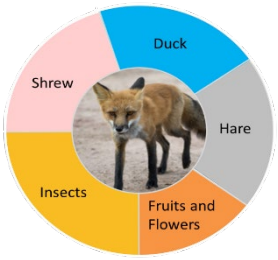
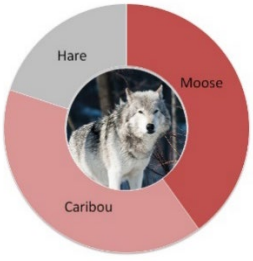
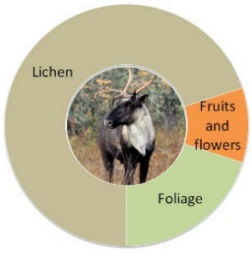
This assessment was undertaken within a pathways framework, which involves consideration of humans, animals, and plants that may be exposed to emissions to the aquatic and atmospheric environment from the Operation.

Selection of Receptors

A number of ecological receptors were selected to represent the range of biota expected to use the area around the Operation. This includes aquatic biota (e.g., benthic invertebrates, fish), terrestrial plants (e.g., foliage, lichen), semi-aquatic animals (e.g., waterfowl, muskrat, beaver), and terrestrial animals (e.g. hare, blackbird, fox, caribou).

Ecological receptors were selected based on surveys in the Operation area as well as other considerations including local resource user interviews and input from local communities. It is also important to determine the presence or absence of species at risk, which can influence the choice of receptor and require a more strict level of protection. Woodland caribou was identified as the only species potentially present in the general area that has special status (threatened). Northern leopard frog and rusty blackbird are both potentially present in the Operation area and are listed as of special concern. An overview of the characteristics of the selected mammals and birds is provided in Table 1.

Table 1. Summary of Selected Mammals and Birds and their Dietary Representation

Waterfowl	**Mallard**	**Merganser**	**Scaup**	
				
Semi-Aquatic Mammals	**Muskrat**	**Beaver**	**Mink**	
				
Terrestrial Birds	**Willow Ptarmigan**	**Bald Eagle** [c]	**Rusty Blackbird**	
				
Mammals	**Masked Shrew**	**Snowshoe Hare**	**Moose**	**Black Bear**
				
	Red Fox	**Grey Wolf**	**Woodland Caribou**	
				

The human receptors were selected to capture a range of people who may live and work in the study area. The selected human receptors are consistent with those from the 2011 EIS and include an adult working at the Operation's camp (e.g., cook, security) and a family living four months a year while working at the Waterbury Lodge (hypothetical receptors). Input from local resource user interviews and the local users was important for defining the appropriate scenarios. For each receptor, exposure estimates are compared to various benchmarks.

Receptor Pathways

Consistent with N288.6, the receptor pathways for the ecological and human health assessments are shown in Table 2 and Table 3, respectively.

Table 2. Ecological Exposure Pathways

Receptor Group	Exposure Pathways			
	Soil	Surface Water	Sediment	Food
Terrestrial plants	✓[a]	NR	NR	NR
Aquatic birds	NR	✓	✓	✓
Terrestrial birds	✓	✓	NR	✓
Semi-Aquatic mammals	NR	✓	✓	✓
Terrestrial mammals	✓	✓	NR	✓
Amphibians[b]	NR	✓	✓	NR
Fish	NR	✓	✓	NR
Aquatic plants	NR	✓	✓	NR
Aquatic invertebrates	NR	✓	✓	NR

Note: VCs were not identified for soil invertebrates, terrestrial plants or reptiles; NR – not relevant; ✓ - assessed; a - exposure to air as well as soil; b - may be assessed using fish as surrogate

Table 3. Human Health Exposure Pathways

Potential Pathway of Exposure	Camp Worker	Waterbury Lodge
Incidental ingestion and direct contact	Yes	Yes
Inhalation	Yes	Yes
Immersion in air	Yes	Yes
Drinking water	Yes	Yes
Other uses of potable water (e.g., bathing)	Min	Min
Harvest local foods (e.g., berries)	Yes	Yes
Hunting / Trapping	No	Yes
Fishing	Yes	Yes
Garden produce ingestion	No	Min
Irrigation of vegetation (potable / groundwater / surface water)	No	Min
Livestock	No	No
External dose from soil (groundshine)	Yes	Yes
Recreational use of surface water (e.g., swimming)	Min	Min

A CSM is a representation of the biological, physical and chemical processes that determine the ways that constituents move from sources through the environmental media to environmental receptors. Figure 6 presents the CSM for the Operation, including pathways considered in the ERA.

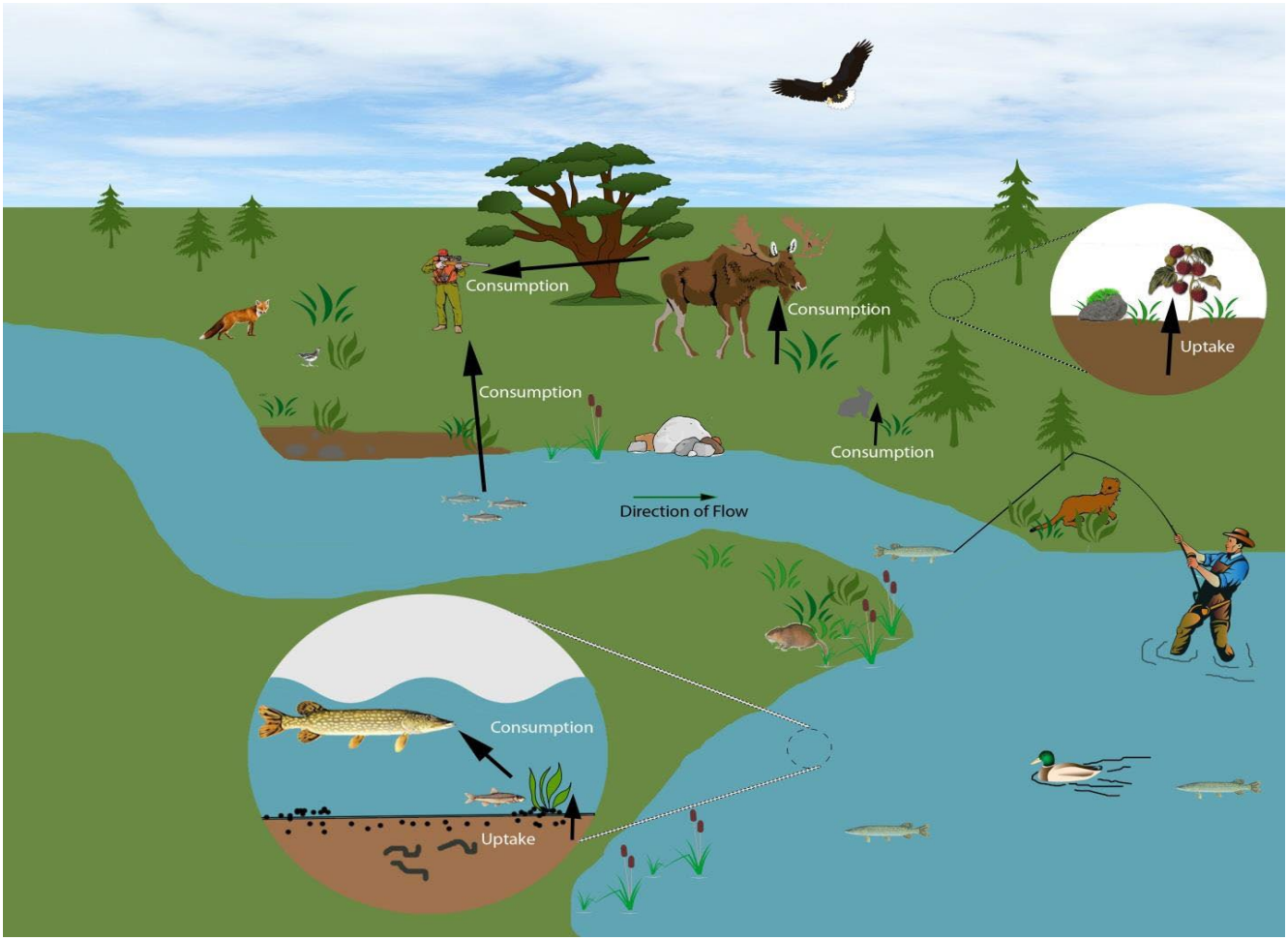


Figure 6. Conceptual Site Model
Note: Figure is conceptual only; not all pathways or receptors are shown.

ERA Conclusion

The results of the ERA for the receiving environment are summarized in Table 4 for the expected future releases. As expected, with the release of treated effluent to Seru Bay, the concentrations of COPCs are predicted to increase; however, only slight changes to the concentrations are expected within Seru Bay and only minimal to no change to the water quality outside of Seru Bay.

Table **5** summarizes the results for the ecological and human health receptors for the expected future releases.

Table 4 Summary of Results to Receiving Environment

Sediment	Surface Water	Air
Predicted concentrations for COPCs are expected to remain below the selected sediment benchmarks, with the exception of lead-210 and polonium-210. Lead-210 and polonium-210 are naturally elevated in Seru Bay and were predicted to exceed the conservative lowest benchmark in this location. Reference (background) concentrations routinely exceed this benchmark in the area.	Surface water levels are predicted to remain below all surface water quality guidelines.	There was no predicted influence on air quality from the Cigar Lake Operation.

Table 5 Summary of Results to Receptors

Stressor Type	Human Receptors	Aquatic Biota	Terrestrial Biota
Scenario	*The HHRA evaluated a Cigar Operation camp worker and a hypothetical Waterbury Lake Lodge operator*	*Assessment for a range of aquatic biota from benthic invertebrates (insects in the sediment at the bottom of the lake) to fish.*	*Assessment for terrestrial plants and wildlife. Selected species at risk (i.e., woodland caribou and blackbird) are protected on an individual basis (versus population basis).*
Radiological	No expected risks to human health from radioactivity related to the Cigar Lake Operation.	No potential influence on aquatic biota are anticipated.	No potential influence on terrestrial biota are anticipated.
Non-Radiological	No expected risks to human health from COPCs released from the Cigar Lake Operation.	No potential influence on populations of aquatic biota are anticipated.	No potential concerns identified for terrestrial vegetation. No potential influence on terrestrial biota are anticipated from exposure to non-radionuclides COPC.

The ERA meets the requirements of CSA N288.6. The results of the 2017 assessment and 2019 addendum are consistent with the findings from the 2011 EIS in that there are no significant risks posed to aquatic, terrestrial, or human receptors situated in the area surrounding the Operation. As such, it can be concluded that the environment and human health in the vicinity of the Cigar Lake Operation will remain protected.

Cameco also completes environment monitoring and summarizes the results in a Comprehensive Aquatic Monitoring Report. The most recent report found that, consistent with the findings from the 2017 ERA and the 2019 Addendum to the 2017 ERA, the Operation remains within the objective of the licensing basis and that human health and the environment in the vicinity of the Operation remain protected.

Summary

The 2017 ERA and the 2019 Addendum to the 2017 ERA demonstrated that human health and the environment in the vicinity of the Operation remain protected.

Further, the ERA and routine monitoring results continue to demonstrate that the site remains within the objective of the licensing basis and previous Environmental Assessment predictions.