RIVERSDALE RESOURCES

Joint Review Panel Request for Additional Information Response Package to JRP IR Package 7, Reference Lists and Consolidated Mitigation Tables Addendum 12

Benga Mining Limited
Grassy Mountain Coal Project

June 2020

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SECTION A: JRP PACKAGE 7 INFORMATION REQUESTS

HUMAN AND WILDLIFE HEALTH

Information Request 7.1

Eleventh Addendum to the Environmental Impact Assessment. Response to Information Request 6.25, 6.27 and 6.28. Appendix 6.25-1, Appendix 6.27-1 and Appendix 6.28-1, Figures 6.25-7 and 6.25-7. (CIAR #313).

In response to Information Request (IR) 6.27 (CIAR#313), Benga provided an update to the Human Health Risk Assessment (HHRA) to include water-based exposure pathways in the Local Study Area (LSA), Regional Study Area (RSA), the Oldman Reservoir and the end pit lake in the post-closure landscape (Addendum 11, Appendix 6.27-1).

Benga's response to IR 6.27, which includes Appendix 6.27-1 of Addendum 11, lacked details regarding how water-based exposure pathways were incorporated into the HHRA. For example, Benga did not provide a table containing the concentrations of contaminants of potential concern (COPCs) that were used for each water source (i.e. the sedimentation ponds, end pit lake, Blairmore Creek, Gold Creek, and the Oldman Reservoir) in its modelling for evaluating the risks to human health. Benga also did not provide a description of the methods used to estimate concentrations of COPCs in the end pit lake or the Oldman Reservoir (except for selenium). Finally, Benga did not describe how atmospheric deposition to water was combined with the modelling of mean monthly COPC concentrations in Blairmore Creek and Gold Creek (Appendix 6.25-1 of Addendum 11). In the absence of this information, the Panel is unable to evaluate the level of conservatism used by Benga to incorporate water-based pathways into the HHRA. Although Benga provided the assumptions used to determine the duration and frequency of exposure to water-based pathways, the response does not clearly explain how assumed concentrations of COPCs were derived from the water quality modelling results presented in Appendix 6.25-1 of Addendum 11. Therefore, the Panel cannot assess the significance of the revised hazard quotients.

In response to IR 6.28 (CIAR#313), Benga provided a table containing the concentrations of COPCs that were used for each water source in the modelling for evaluating the risks to wildlife health. However, in the updated Wildlife Health Risk Assessment (WHRA) (Appendix 6.28-1 of Addendum 11), Benga did not explain how the COPC concentrations were derived and did not provide a rationale to demonstrate their suitability and level of conservatism. Furthermore, it is unknown whether the concentrations used for the WHRA are the same as those used in the HHRA.

Therefore, the Panel requires more information to understand and evaluate the assessment conducted by Benga, and have confidence in its conclusions. Information is required regarding the details of how concentrations of COPCs were derived and the level of conservatism represented by the derived concentrations.

a) Provide a table, similar to that provided for the WHRA in Addendum 11, Appendix A of Appendix 6.28-1, that presents the concentrations of COPCs that were used for each water source considered in the revised HHRA (i.e. the sedimentation ponds, end pit lake, Blairmore Creek, Gold Creek, and the Oldman Reservoir);

Response:

The same surface water concentrations were used in both the human health assessment and wildlife assessment. The table in Addendum 11, Appendix A of Appendix 6.28-1 applies for both assessments (Addendum 11, JRP IR 6.28, Appendix 6.28-1 [CIAR #313]).

b) Discuss how the COPC water concentrations used for the sedimentation ponds, end pit lake, Blairmore Creek, Gold Creek, and the Oldman Reservoir for both the HHRA and WHRA were derived, and explain the level of conservatism represented by the derived concentrations. Include the following details to support this discussion:

   i. Identify the statistic selected from the range of monthly predicted concentrations produced by the modelling of water quality in Blairmore Creek and Gold Creek (as per the mean monthly modelling results presented in Appendix 6.25-1) (e.g. annual mean, annual median, or maximum), and present the rationale for the level of conservatism represented by that statistic. For the end pit lake, identify the statistic selected based on data from other end pit lakes used as a surrogate by Benga; and

Response:

The COPCs for the risk assessment were based on water quality model results from a scenario that used "Upper Case" geochemical source terms, as opposed to "Base Case" source terms. Section 7.2 of the Geochemical Characterization Report for the Project (EIA, Appendix 10A [CIAR #42]) includes the following comment on the distinction between the Base Case and the Upper Case geochemical source terms:

> *"7.2 Evaluating Uncertainty*
>
> *Consistent with other studies, uncertainty in geochemical source terms is reflected in two cases referred to as "Base Case" and "Upper Case". The Base Case indicates the most likely outcome combining numerical inputs that reflect typical conditions and scientific judgment for some aspects. The Upper Case is analogous to a boundary condition in that it is considered highly unlikely that concentrations would be exceeded. This deterministic rather than stochastic approach is preferred for contact water source terms is preferred because, in contrast to hydrological inputs to models, the underlying mechanisms are less quantifiable and it is not possible to assign statistical distributions to the inputs and outputs of the calculations."*

According to this qualitative definition, it is highly unlikely that the concentrations used for the risk assessment will materialize. For example, the Base Case (or expected) selenium concentrations in the End Pit Lake is estimated to be approximately 0.006 mg/L, while the Upper

Case concentrations are estimated to be approximately 0.030 mg/L, or about five times higher. The Upper Case concentrations were used for the risk assessments.

The risk assessment was based on the 95th percentile concentrations calculated from monthly concentrations of the 23-year operations and a 57-year post-closure period from the Upper Case model scenario. In other words, the 95th percentile monthly concentrations from a scenario based on highly unlikely source terms were used.

ii. Consider the sensitivity analysis modelling runs presented in Figures 6.25-6 and 6.25-7 for Blairmore Creek and Gold Creek, which assumed that the saturated backfill zone would result in 90% and 95% removal of selenium rather than 99% removal, and comment on the relative effect on the risk characterization when alternative selenium removal assumptions are used.

Addendum 11, JRP IR-6.25, Figures 6.25-6 and 6.25-7 (CIAR #313) provided the requested model results for total selenium concentrations in Blairmore Creek assuming 95% and 90% removal of selenium in the saturated backfill zones, respectively. Water quality in Gold Creek is not affected by the assumed attenuation in the saturated backfill zones because treated effluent is only directed to Blairmore Creek. In Addendum 11, JRP IR-6.25 (CIAR #313) it was presented that under both scenarios, 90% and 95% removal of selenium, the resulting concentrations of selenium in Blairmore Creek would be unacceptable at 70 µg/l and 35 µg/l, respectively.

In preparing these sensitivity analyses, Benga has used several very conservative assumptions including the use of Upper Case selenium concentrations, which, as discussed in part i) above, represents an unlikely worst-case scenario. Other conservative assumptions that are made in the model include that the effect of progressive reclamation to reduce quantities of percolating water through the external rock dumps has not been considered. As a result, it is likely that concentrations actually experienced will be much lower, which would obviously result in more acceptable results even at the lower removal rates of 95% and 90%.

As stated in the response to JRP IR-6.25 (Addendum 11, JRP IR-6.25 [CIAR #313]), selenium levels are not forecast to exceed 10 µg/l, even in the 90% case, until 10 years after the start of operations as the rate of selenium leaching will be proportional to the amount of rock stored in the rock dump, which will increase through the years with mine activity. During these 10 years after mine start-up, Benga will be monitoring the selenium removal rates in the Saturated Backfill Zone (SBZ) as well as selenium concentrations in the surge ponds and raw water pond. If there is an indication that removal rates will not achieve the targeted 99% or that selenium concentrations in untreated water are higher than expected, Benga will have several years to resolve the situation through operational adjustments to the SBZ or to implement another contingency plan to prevent unacceptably high selenium levels in Blairmore Creek.

Regarding the relative effect on the risk characterization when alternative selenium removal assumptions are used it is anticipated that the risk characterization would be unchanged as Benga would ensure approved Project-related water quality limits are met prior to release.

c) Provide detailed examples of how Benga calculated hazard quotients for the multimedia assessment of risk to human health (Tables 7-1 to 7-4 of Appendix 6.27-1) and the exposure ratios for the multimedia assessment of risk to wildlife health (Tables D-1 to D-6 of Appendix D of Appendix 6.28-1) to demonstrate how Benga has integrated both the air and water exposure pathways for the HHRA and WHRA. Worked examples for risk to human health should include calculation of hazard quotients and incremental lifetime cancer risk for fluoranthene, cadmium and arsenic in the end pit lake, Blairmore Creek, Gold Creek and the Oldman Reservoir. Worked examples for risk to wildlife health should include calculations of exposure ratios for Northern River Otter, American Dipper and Mallard Duck calculated for selenium and zinc in the sedimentation ponds, end pit lake, Blairmore Creek, Gold Creek and the Oldman Reservoir.

Amendment to c) (CIAR #355):

The Panel has considered the possible worked examples resulting from 7.1(c), and advises that it does not require all 28 possible worked examples. The Panel requests that Benga provide the following worked examples:

- Human health: worked examples of hazard quotients and incremental lifetime cancer risk for fluoranthene and arsenic in Blairmore Creek and the Oldman Reservoir.
- Wildlife health: worked examples of exposure ratios for Northern River Otter and American Dipper for selenium and zinc in the end pit lake and Blairmore Creek.

Response:

The requested worked examples below are provided in Appendix 7.1-1.

- Human health hazard quotients (HQs) for the Application Case and incremental lifetime cancer risks (ILCRs) for the Project Case for fluoranthene at Blairmore Creek.
  - Regarding impact to the surface water at the Oldman Reservoir: as fluoranthene is not predicted to occur in the surface water *via* the water pathway and the Oldman Reservoir is too far away to receive deposition of COPC in air emissions, zero contribution of this COPC was predicted. Therefore, a worked example for the Oldman Dam was not provided.
- Human health ILCRs for the Project Case for arsenic at Blairmore Creek and Oldman Reservoir.

- Wildlife exposure ratios (ERs) for selenium and zinc for the northern river otter and the American dipper predicted for the end pit lake (EPL) and Blairmore Creek.

Specifically, Equation 7 illustrates where contaminants of concern (COPC) from air and surface pathways were integrated to predict total surface water concentrations. While producing the worked example, it was determined that some input parameters required modification. These were minor and did not result in any changes to the overall conclusion; however, some input errors were identified that required additional assessment. These included: in the Human Health Risk Assessment (HHRA) correction of an arsenic-specific value for assessment of surface water concentrations not associated with air deposition; in the wildlife assessment correction of two non-COPC-specific conversion factors (bulk density sediment unit conversion and wet/dry weight food rate consumption).

With the minor adjustments, there is no change to the assessment conclusions, which indicate there is a very low risk of potential adverse human health effects associated with long-term exposure to the predicted surface water in Blairmore and Gold creeks. The results for the EPL indicate that the predicted concentrations are approaching or exceed Canadian water quality guidelines for arsenic and represent a higher potential for adverse health effects assuming long-term exposures. As stated in the response for Part B i), it is highly unlikely that the concentrations used for the risk assessment will materialize as the 95th percentile monthly concentrations from an Upper Case scenario, based on highly unlikely source terms, were used.

The wildlife results indicate a low potential for adverse effect for piscivorous mammals on Gold Creek; piscivorous birds in the EPL and Gold and Blairmore creeks. The magnitude of predicted risk is slightly higher in the EPL for insectivorous and omnivorous birds. Due to slim margins for exposure that could result in adverse effect, particularly with selenium, focused data collection to refine risk predictions and efforts to limit metal mass migration through surface water and adaptive management are warranted.

Additional discussion of the modifications made, and their outcomes is provided below.

Human Health

The final risk values for fluoranthene are slightly changed from the assessment conducted in February 2020 due to small adjustments of some input parameters. The changes are insubstantial and do not represent any changes in the overall conclusions.

An input error specific to arsenic was identified during the preparation of the arsenic worked example. The error was specific to arsenic and did not affect results of other COPCs. Correction of this error did not change the overall conclusion of the predicted risk associated with the exposure from the air deposition route; the predicted ILCRs were substantially below the acceptable risk of 1 in 100,000 (1×10^{-5}) (Table 7.1-1). It was identified that there were changes to the ILCRs predicted for exposure to the surface water concentrations. Due to the identification of the error, the ILCRs were re-calculated for Gold Creek and the EPL (Table 7.1-1). The ILCRs predicted for the air deposition source, surface source and air plus surface sources (Totals) are provided in Table 7.1-1.

Table 7.1-1 Predicted Risks to Human Receptors from Project Only emissions for the Composite Receptor - Arsenic

Receptor	Deposition from Air Only	Surface Contribution Only (SRK Predictions)	TOTAL ILCR
End Pit Lake	-	**2.75E-04**	**2.75E-04**
Oldman Reservoir	-	1.43E-06	1.43E-06
Blairmore Creek	1.04E-07	**2.05E-05**	**2.05E-05**
Gold Creek	1.04E-07	**1.92E-05**	**1.92E-05**

Note: **Bold** indicates ILCR > 1×10^{-5}

The predicted ILCRs indicate that potential risk associated with exposure to air deposition of Project-related emissions are all below the acceptable risk of 1 in 100,000 ($<1 \times 10^{-5}$). The total ILCR for the Oldman Reservoir is also below a risk of 1×10^{-5}. At Blairmore Creek and Gold Creek the total ILCR were predicted to be slightly higher than the target risk of 1×10^{-5} (2.05×10^{-5} and 1.92×10^{-5}, respectively). The potential risk predicted for the EPL is higher (2.7×10^{-4}).

The HHRA guidance states that an ILCR greater than 1×10^{-5} is an indication that the predicted exposures exceed negligible levels. As some ILCR values were predicted to be greater than 1×10^{-5}, additional assessment was conducted as per Health Canada and Alberta Health HHRA guidance (Government of Alberta 2019; HC 2012, HC 2010a, HC 2010b) to determine whether the result indicates potential risk of adverse health effects, or are the results of conservative assumptions built into the exposure assessment and risk characterization steps of the HHRA. The lines of evidence pursued included:

- Determination of the magnitude of exceedances of the ILCRs with respect to negligible rates. Review of conservative assumptions included in the exposure assessment.
- Comparison of the predicted surface water concentrations to existing Canadian surface water and drinking water guidelines.
- Comparison of the predicted surface water concentrations with current monitoring data from the Grassy Mountain area (Blairmore Creek, Gold Creek, Crowsnest River) and the Rocky Mountain area.

An ILCR greater than 1 x 10^{-5}, is not automatically an indication of potential risk of cancer (Government of Alberta 2019, HC 2012). The ILCR for Blairmore Creek and Gold Creek are equivalent to 2 x 10^{-5} and 1.9 x 10^{-5}. These results are only slightly higher than 1 x 10^{-5} which is much lower than typical Canadian rates reported as 0.4 (HC 2012) and contribute only a small amount to typical Canadian rates (0.4 + 0.00002 = 0.400002). The ILCR for Blairmore Creek and Gold Creek were determined to represent a very low potential risk of adverse health effects. The EPL surface water is 2.7 x 10^{-4} and is an order of magnitude greater than the acceptable risk. It is still small compared to the Canadian background rate (0.400027), however, it was determined that the EPL results indicate a low potential risk of adverse health effects.

As stated in response to Part B (i and ii) overly conservative assumptions built into the exposure assessment of the HHRA results in purposeful overestimation of potential risks. The current HHRA assumed a person lives in the area 100% of their lifetime at each location assessed and surface water was assumed to be the only source of drinking water. This is believed to be overly conservative as there are no residences within the local study area (LSA) and historically human activities have been recreational. These assumptions have overestimated potential exposure and thus overestimated potential risk of adverse health effects.

Although the ILCRs predicted for Blairmore Creek and Gold Creek were greater than 1 x 10^{-5}, the predicted surface water concentrations are lower than the surface water (freshwater aquatic life) and human drinking water guidelines (Table 7.1-2). Arsenic is a naturally occurring compound found in small quantities in rock, soil, water and air throughout Canada. Soil concentrations are often reported greater than Canadian guidelines (HC 2012).

Additional assessment of arsenic included consideration of the baseline surface water concentrations measured at the site and in the surrounding drainage basin, and investigation of typical Albertan background surface water concentrations in the Alberta foothills. Measured surface water collected from creeks and rivers located in the Rocky Mountain Foothills and the Grassy Mountain area are lower than the surface water (freshwater aquatic life) and human drinking water guidelines, whereas a regional study reports a range of concentrations with greater than one or both guidelines (Table 7.1-3). The predicted surface water concentrations for Blairmore Creek and Gold Creek are within the same order of magnitude of measured surface water from the Grassy Mountain area as well as other creeks and rivers monitored in the Rocky Mountain Foothills (Tables 7.1-2 and 7.1-3).

The assessment indicated that existing concentrations at the site and typical background Albertan surface water concentrations are at a similar magnitude to the predicted Project and Application concentrations at Blairmore Creek and Gold Creek (EIA Water and Load Balance, Appendix 10B, CIAR #42). They are primarily below Canadian surface water and drinking water guidelines with a few exceedances. While the concentration predicted for the EPL, exceeds the Alberta Surface Water guideline, it is slightly below the Canadian Drinking Water guideline.

Table 7.1-2 Predicted Surface Water Concentrations Compared to Canadian Water Quality Guidelines

Location		Predicted Surface Water Concentrations (mg/L)	Guidelines: CCME CEGQ (mg/L)	Guidelines: Alberta Surface Water Quality Guidelines (mg/L)	Guidelines: Health Canada Drinking Water Guideline (mg/L)
			5.00E-03	**5.00E-03**	**1.00E-02**
NESP	**Baseline**	1.90E-04	<	<	<
	Maximum (Application)	1.90E-04	<	<	<
	Project	0.00E+00	<	<	<
ESP	**Baseline**	1.90E-04	<	<	<
	Maximum (Application)	1.90E-04	<	<	<
	Project	0.00E+00	<	<	<
End Pit Lake	**Background (Baseline)**	**-**	-	-	-
	Maximum (Application)	**6.91E-03**	**>**	**>**	<
	Project	**6.91E-03**	**>**	**>**	<
Blairmore Creek 95th	**Baseline**	1.90E-04	<	<	<
	Maximum (Application)	4.37E-04	<	<	<
	Project	2.47E-04	<	<	<
Gold Creek 95th	**Baseline**	1.90E-04	<	<	<
	Maximum (Application)	4.22E-04	<	<	<
	Project	2.32E-04	<	<	<
Oldman Reservoir	**Assumed Background**	4.00E-04	<	<	<
	Maximum (Application)	4.17E-04	<	<	<
	Project	1.72E-05	<	<	<

Notes: > Indicates greater than guideline

Table 7.1-3 Arsenic Surface Water Background Concentration (mg/L)

Regional Location	Creek/River Name	Number of samples	Concentration Mean (mg/L)	Range	Mean	Median	Reference
Alberta Surface Water Quality Guidelines (mg/L) CCME CEGQ (mg/L)				**5.00E-03**			
Health Canada Drinking Water Guideline (mg/L)				**1.00E-02**			
Rocky Mountain Foothills Alberta	McLeod River, Whitehorse Creek, Wildhay River, South Berland and Berland Rivers, South Sulphur River, and sites on the Gregg River	12	1.00E-04	0.00010–0.00010	8.67E-05	1.00E-04	Wayland and Crosley, 2006
		9	1.00E-04	0.00005–0.00010			
		6	6.00E-05	0.00004–0.0001			
Grassy Mountain	Blairmore Creek	12	2.20E-04	0.0002-0.00046	2.53E-04	2.00E-04	Collected by Benga, 2016-2020.
		22	2.87E-04	0.00012-0.00063		2.65E-04	Winward Environmental, 2018.
	Crowsnest River	25	2.80E-04	0.0002-0.0003	2.72E-04	2.50E-04	Collected by Benga, 2016-2020.
		14	2.64E-04	0.00024-0.00028		2.75E-04	Winward Environmental, 2018.
	Gold Creek	14	2.03E-04	0.0002-0.00021	1.94E-04	2.00E-04	Collected by Benga, 2016-2020.
		17	1.85E-04	0.00012-0.00043		1.60E-04	Winward Environmental, 2018.
Alberta SW	AB05AA0050 - AB05AA1340	302	1.54E-01	0.0002-7.43	**1.54E-01**	**7.00E-04**	Alberta Environment and Parks, 2020.

Notes: Bold indicates greater than Alberta Surface Water guideline. Underline indicates concentration is greater than Health Canada Drinking Water guideline. Windward Environmental. (2018). Risk-based Evaluation of Predicted Selenium, Sulphate, Cobalt, and Zinc Concentrations Downstream of the Grassy Mountain Coal Mine Project. Alberta Environment and Parks. (2020). Alberta Surface Water Quality Monitoring Data. Retrieved from https://www.alberta.ca/surface-water-quality-data.aspx

The IRLC results indicate there is a very low risk of potential adverse health effects associated with long-term human exposure to the predicted surface water in Blairmore and Gold creeks. The results indicate that the predicted concentrations for the EPL are approaching or exceed Canadian water quality guidelines for arsenic and represent a higher potential for adverse health effects assuming long-term exposures.

Wildlife

The final exposure ratios for selenium and zinc are slightly changed from the assessment conducted in February 2020 due to an adjustment to the units for bulk density used to calculate sediment concentrations (from kg/m^3 to kg/L). This increased the predicted sediment concentration for all COPC, with a change in exposure ratio relative to the wildlife-specific sediment ingestion rate. Overall, the exposure ratios for the wildlife receptors ran from 0.03 to 4.1 for all habitats. These results indicate that predicted exposures are lower or slightly higher than acceptable. For zinc, the largest change in the exposure ratio was for the beaver (due to higher relative sediment ingestion), increasing the exposure ratio by 0.06 in the EPL to a value of 0.075. All updated exposure ratios for zinc are provided in Table 7.1-4. No change to the conclusions for zinc are noted, and a review of copper and thallium which had exposure ratios with higher relative magnitudes indicates no change to conclusions.

Table 7.1-4 Predicted Exposure Ratios for the Multimedia Assessment for Zinc

Receptor Location	Case	Aquatic						
		Mammalian Receptors			Avian Receptors			
		Northern River Otter	Beaver	Little Brown Bat	American Dipper	Goose	Great Blue Heron	Mallard Duck
End Pit Lake	Project	8.5E-02	8.9E-02	2.7E-02	1.8E-02	1.1E-02	1.5E-02	4.9E-02
	Baseline	1.2E-06	5.6E-03	1.1E-03	1.3E-09	1.6E-03	1.4E-06	1.2E-03
	Application	8.5E-02	7.6E-02	2.8E-02	1.8E-02	7.6E-03	1.5E-02	4.6E-02
Oldman Reservoir	Project	4.4E-04	1.6E-04	6.0E-05	4.6E-05	1.4E-05	7.9E-05	1.0E-04
	Baseline	6.5E-03	8.0E-03	2.0E-03	6.9E-04	1.8E-03	1.2E-03	2.8E-03
	Application	6.9E-03	8.1E-03	2.0E-03	7.4E-04	1.8E-03	1.3E-03	2.9E-03
NESP	Project	1.4E-04	8.2E-03	4.6E-05	3.0E-05	9.8E-06	2.5E-05	1.3E-04
	Baseline	1.6E-03	8.8E-03	1.6E-03	3.4E-04	1.7E-03	2.8E-04	2.1E-03
	Application	1.7E-03	1.5E-02	1.6E-03	3.7E-04	1.7E-03	3.0E-04	2.2E-03
ESP	Project	1.4E-04	8.2E-03	4.6E-05	3.0E-05	9.8E-06	2.5E-05	1.3E-04
	Baseline	1.6E-03	8.8E-03	1.6E-03	3.4E-04	1.7E-03	2.8E-04	2.1E-03
	Application	1.7E-03	1.5E-02	1.6E-03	3.7E-04	1.7E-03	3.0E-04	2.2E-03

Table 7.1-4 (continued) Predicted Exposure Ratios for the Multimedia Assessment for Zinc

Receptor Location	Case	Aquatic						
		Mammalian Receptors			Avian Receptors			
		Northern River Otter	Beaver	Little Brown Bat	American Dipper	Goose	Great Blue Heron	Mallard Duck
Blairmore Creek	Project	8.6E-03	1.1E-02	1.2E-03	9.1E-04	2.7E-04	1.5E-03	2.1E-03
	Baseline	4.0E-03	8.9E-03	1.6E-03	4.2E-04	1.7E-03	7.2E-04	2.2E-03
	Application	1.2E-02	1.8E-02	2.7E-03	1.3E-03	2.0E-03	2.2E-03	4.2E-03
Gold Creek	Project	8.7E-03	1.1E-02	1.2E-03	9.2E-04	2.7E-04	1.6E-03	2.1E-03
	Baseline	4.0E-03	8.9E-03	1.6E-03	4.2E-04	1.7E-03	7.2E-04	2.2E-03
	Application	1.2E-02	1.8E-02	2.8E-03	1.3E-03	2.0E-03	2.2E-03	4.2E-03

A second change was made to selenium to account for fish tissue concentration as dry weight. This resulted in an increase to exposure ratios for those receptors that consume fish and was specific only to selenium. Updated selenium exposure ratios for all habitats are provided in Table 7.1-5. Exposure ratios just above 1.0 were predicted for the river otter and great blue heron on Gold and Blairmore creeks.

Table 7.1-5 Predicted Exposure Ratios for the Multimedia Assessment for Selenium

Receptor Location	Case	Aquatic						
		Mammalian Receptors			Avian Receptors			
		Northern River Otter	Beaver	Little Brown Bat	American Dipper	Goose	Great Blue Heron	Mallard Duck
End Pit Lake	Project	9.2E-01	3.4E-01	3.8E-01	1.8E+00	2.8E-01	1.1E+00	4.1E+00
	Baseline	3.3E-08	2.0E-04	5.5E-04	1.7E-09	4.2E-04	2.7E-07	3.2E-04
	Application	9.2E-01	3.2E-01	3.8E-01	1.8E+00	2.5E-01	1.1E+00	4.1E+00
Oldman Reservoir	Project	4.7E-02	2.2E-03	2.6E-03	1.8E-02	1.7E-03	6.2E-02	3.3E-02
	Baseline	4.5E-02	2.3E-03	3.0E-03	1.7E-02	2.0E-03	6.0E-02	3.2E-02
	Application	9.3E-02	4.6E-03	5.6E-03	3.5E-02	3.7E-03	1.2E-01	6.4E-02
NESP	Project	8.3E-05	2.3E-03	3.4E-05	1.6E-04	2.2E-05	9.7E-05	4.8E-04
	Baseline	2.4E-02	9.1E-03	1.0E-02	4.6E-02	6.7E-03	2.8E-02	1.0E-01
	Application	2.4E-02	1.1E-02	1.0E-02	4.6E-02	6.7E-03	2.8E-02	1.1E-01

Table 7.1-5 (continued) Predicted Exposure Ratios for the Multimedia Assessment for Selenium

Receptor Location	Case	Aquatic						
		Mammalian Receptors			Avian Receptors			
		Northern River Otter	Beaver	Little Brown Bat	American Dipper	Goose	Great Blue Heron	Mallard Duck
ESP	Project	8.3E-05	2.3E-03	3.4E-05	1.6E-04	2.2E-05	9.7E-05	4.8E-04
	Baseline	2.4E-02	9.1E-03	1.0E-02	4.6E-02	6.7E-03	2.8E-02	1.0E-01
	Application	2.4E-02	1.1E-02	1.0E-02	4.6E-02	6.7E-03	2.8E-02	1.1E-01
Blairmore Creek	Project	1.0E+00	4.6E-02	5.3E-02	3.7E-01	3.3E-02	1.3E+00	6.7E-01
	Baseline	1.2E+00	9.1E-03	6.5E-02	4.4E-01	1.6E-02	1.6E+00	7.7E-01
	Application	1.0E+00	5.4E-02	5.6E-02	3.9E-01	3.9E-02	1.4E+00	7.1E-01
Gold Creek	Project	1.6E+00	3.3E-02	8.8E-02	6.0E-01	3.3E-02	2.2E+00	1.1E+00
	Baseline	1.2E+00	8.5E-03	6.4E-02	4.4E-01	1.6E-02	1.6E+00	7.7E-01
	Application	1.7E+00	4.1E-02	9.4E-02	6.4E-01	3.9E-02	2.3E+00	1.2E+00

While the magnitude of the predicted exposure ratios is higher for selenium, the overall change to conclusions remains the same. Risk assessment is a tool to indicate potential for impact, it is meant to over-estimate exposure so that if predicted risk is below acceptable thresholds practitioners can have confidence that the potential for impact is negligible. Conversely, predicted risk above acceptable thresholds indicates i) risk assessment methodologies may require increased site-specific precision (*e.g.,* measured tissue data), and ii) it helps highlight where monitoring and potentially adaptive management may be required. As such, reliance on the specific exposure ratio metric rather than overall magnitude and range against baseline is not intended.

Conservatism built into the risk assessment is layered, some of the very conservative assumptions are outlined below:

- Predicted surface water concentrations used in the risk assessment are defined as upper-case, and higher than what is considered probable.
- All trophic transfer values for selenium are thought to be very conservative. For example, the trophic transfer (TTF_{fish}) values for fish in lotic habitats (Blairmore Creek and Gold Creek) applied a value of 1.48 [$C_{Fish} = C_{Invertebrate-lotic} \times TTF_{Fish}$]. This value is believed to be higher than 'typical' fish trophic transfer for species in the evaluated watershed, for example the published TTF_{fish} for the cutthroat trout is 1.1 (US EPA 2016). A TTF_{fish} of 1.1 reduces exposure ratios for the river otter and great blue heron by 0.3 and 0.4, respectively. Selected trophic transfer values make a significant difference for predicted risk and highlight the conservatism applied herein.

Selenium exposure ratios predicted on Table 7.1-5 also indicate that baseline is close to, and in some cases elevated above, the accepted threshold. Again, this indicates the conservatism of the model and also the inhibitory effect of predicted sulphate on selenium uptake during the Project.

The results presented in Table 7.1-5 indicate a low potential for adverse effect for piscivorous mammals on Gold Creek; piscivorous birds in the EPL (likely absent in this habitat due to lack of preferred food), Gold and Blairmore creeks. The magnitude of predicted risk is slightly higher in the EPL for insectivorous and omnivorous birds.

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CLIMATE CHANGE

Information Request 7.2

Eleventh Addendum to the Environmental Impact Assessment. Response to Information Request 6.25. Figure 6.25-1, Figure 6.25-2. (CIAR #313).

In response to IR 6.25 (CIAR #313), Benga stated that Figures 6.25-1 and 6.25-2 portray updated flows for Gold Creek and Blairmore Creek on a mean monthly basis with climate change modelling incorporated in the updated hydrological inputs. In its response, Benga provided a series of figures demonstrating the variability in mean monthly concentrations of contaminants of potential concern (COPCs). As Benga did not provide an accompanying description of how climate change was integrated, it remains unclear how climate change modelling was incorporated into the updated hydrology figures.

Describe how climate change was incorporated into the updated hydrological model, including:

a) The climate change scenario used, and the main results extracted from this scenario which informed Benga's updated hydrology assessment;

Response:

Climate change modelling for the Project was conducted through the compilation of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, which are accessible through Environment Canada, and by completing a probability analysis on the multiple climatic models using a purpose-built script developed by SRK Consulting using R Software (Comprehensive R Archive Network (CRAN), 2015). The results of the analysis provide an expected change of different climatic parameters for a specific longitude and latitude with respect to baseline conditions.

There are five Assessment Reports from the IPCC that present monthly climate change modelling predictions for any location globally:

- Canadian Regional Climate Model (CRCM) (Environment Canada (EC), 2015), also known as First Assessment Report (FAR);
- Second Assessment Report (SAR) (Intergovernmental Panel on Climate Change (IPCC), 1995);
- Third Assessment Report (TAR) (Intergovernmental Panel on Climate Change (IPCC), 2001);
- Fourth Assessment Report (AR4) (Intergovernmental Panel on Climate Change (IPCC), 2007); and
- Fifth Assessment Report (AR5) (Intergovernmental Panel on Climate Change (IPCC), 2014).

Climate change models presented in the Assessment Reports assume the application of radiative forces (energy flux) from different anthropogenic sources that results in discharge of varying concentrations of atmospheric greenhouse gases. These radiative forces are not constant through time, as they are based on global anthropogenic behavior. To eliminate bias when choosing a specific climate scenario, all of the available climate change models are weighted equally during analyses and present a single climate change design parameter based on a rational statistical evaluation of the overall cumulative results.

The climate predictions are presented up to the year 2100, which is deemed the maximum reasonable timeframe in which to extend predictions. Within the projected timeframe, three 30-year periods are applied: (1) from 2011 to 2040, (2) from 2041 to 2070, and (3) from 2071 to 2100.

The analysis produces a series of figures that summarize climatic prediction models and the statistical analysis of the climatic baseline data, which is available from 1975 to 2005. The first analysis summarizes the number of models and predicted change with respect to the set baseline condition. Table 7.2-1 presents the climatic parameters analyzed at Grassy Mountain Project. A sample output graph for a hypothetical site is presented in Figure 7.2-1. The second analysis is presented as a box-whisker plot, as shown in Figure 7.2-2, which is associated with the change in baseline conditions for each individual Assessment Report. Thirdly, a trend analysis is applied using reanalysis (Reanalysis, 2015), which combines satellite information, land records, and numerical models that simulate the earth's climatic conditions. State-of-the-art publicly available reanalysis data for the record period of 1979 to 2015 from ERA-Interim produced by the European Center for Medium-Range Weather Forecast (ECMWF) (2015) was used in this trend analysis. The methods of trend analyses were Ordinary Least Squares (Maidment, 1993), Quantile Regression (Koenker & Bassett, 1978), Mann-Kendall (1945) and Theil Sen (1968), Zhang (2000), and Yue and Pilon (2002). An example of the graph produced for this analysis on a hypothetical site is shown in Figure 7.2-3. The last analysis is presented as a cumulative probabilistic curve, as shown in Figure 7.2-4, created from the combined data available from the Assessment Reports.

Table 7.2-1 Climatic Parameters Used in the Assessment of Climate Change for the Project Area

Climate Parameter	Details
Total Precipitation	Total precipitation including rainfall and snowfall as snow water equivalent.
Days w/rain > 10 mm	Days with rain greater than or equal to 10 mm/day.
Simple Daily Intensity Index	Annual total precipitation / number of precipitation days ≥ 1 mm/day.
Air Temperature	Mean at 2 m above ground.
Dry Days	Max amount of consecutives dry days (precipitation < 1 mm).

In each of the five trend analyses cases, a statistical significance value is produced and if it is greater than 95%, the case with the maximum climate change design parameter is used. If there is no trend with a statistical significance value greater than 95%, then the climate change design parameter is the 50% cumulative probability value. This is also the case if the 50% cumulative probability value is greater than the climate change design parameter values produced through the trend analyses.

To determine the climate change design parameter, the following equation is applied:

$$Recommended\ Climate\ Change\ Design\ Parameter = Max(50\%\ Cumulative\ Probability, Mean\ \{Regression_{stat.sign.\geq 95\%}\})$$

The climate parameters used in the analysis of the Project are summarized in Table 7.2-1.

In the case that there was no climatic information available from regional EC meteorological stations, the baseline values of the climate parameters were set as the ERA-Interim value for the period of 1979 to 2005. In each model produced for the Project, the 50% cumulative probability value was reported, as no trend analysis produced a statistically significant value greater than 95%.

Precipitation

The MAP for the Project site, calculated through a regional linear regression using regional meteorological stations is 628 mm. The MAP calculated using the ERA-Interim data in the statistical climate model is 613 mm. The small discrepancy could be accounted for by comparing the differences in recorded time periods, as well as a difference in methodology. Reanalysis of ERA-Interim data considers identical parameters for a 0.75° latitude x 0.75° longitude grid. This does not encompass the site orographic effect.

Figure 7.2-5, Figure 7.2-6, and Figure 7.2-7 are the output figures from the R script for each projected period in the climate change analysis for total annual precipitation. Table 7.2-2 summarizes the change of the total annual precipitation with respect to the baseline value of 628 mm. The predicted change by the year 2100 is an increase of 33 mm, resulting in a MAP of 661 mm, which is an increase of approximately 5%.

Table 7.2-2 Percent Change of Mean Annual Precipitation with Respect to Baseline Data

Climate Parameter	Projection Period		
	2011-2040	2041-2070	2071-2100
Precipitation - Total (mm/yr)	2%	4.1%	5.2%

As climate change progresses, the change of annual precipitation with respect to baseline conditions progresses along a near-linear trend.

Temperature

The MAAT (mean annual air temperature) for the Project site, calculated through a regional linear regression is 3.2°C. The MAAT calculated for the Project site using ERA-Interim data is 3.21°C.

In the case of temperature change with respect to baseline values, the climate change design parameter is presented as a percent change of temperature in degrees Kelvin. Converting baseline values in degrees Celsius to degrees Kelvin is necessary before applying the climate change design parameter.

Figure 7.2-8, Figure 7.2-9, and Figure 7.2-10 are the output figures from the R script for each projected period in the climate change analysis for MAAT. Table 7.2-3 presents the results of the change of the MAAT with respect to the baseline value of 3.2°C. The MAAT is predicted to increase to 6.24°C by the year 2100, representing a change of 3.04°C.

Table 7.2-3 Percent Change of Mean Annual Air Temperature with Respect to Baseline Data

Climate Parameter	Projection Period		
	2011-2040	2041-2070	2071-2100
Air Temperature - Mean (°K)	0.4%	0.75%	1.1%

As climate change progresses, the change of the MAAT with respect to baseline conditions progresses along a near-linear trend. However, the percent change is much less compared to the change in annual precipitation.

Intensity-Duration-Frequency Curve

Several climate parameters analyzed from ERA-Interim data and the Assessment Reports can be used to estimate a change in the IDF (Intensity-Frequency-Duration) curves for the Project site. Using IDF curves produced by the computerized tool developed by Simonovic *et al.* (2015) for the two most proximal stations available, the estimation made using the climate change design parameters was confirmed.

While there are no direct mathematical relationships between the climate parameters and IDF curves, the climate parameters can provide an understanding about the site conditions and the short storm events that occur. It was estimated that the intensity values plotted for the IDF curves would increase by 15% by the last projection period of the climate models. The percent change between the present and future IDF curves from the Sparwood and Pincher Creek A stations from the computerized tool from Simonovic *et al*. (2015) were calculated in order to compare the values to the estimation of 15%. At each station, 2070 – 2100 was used as the projection period and Scenario RCP 4.5 was used as a moderate scenario. The average percent change of the IDF curves are presented in Table 7.2-4, along with the climate parameters used for the predicted change in the site representative IDF curve.

Table 7.2-4 Percent Change of Various Climatic Parameters and IDF Curves with Respect to Baseline Data

Climate Parameter	Baseline Period (1975-2005)	Projection Period (2071-2100)
Days - Consecutive Dry (days)	29.5	14%
Precipitation - 5 Day Max (mm)	55.6	9.4%
Precipitation - Days >10 mm/day (days)	10.1	28%
Precipitation - Simple Daily Intensity Index (mm/day)	4.78	6.6%
Average Percent Increase in IDF Curve – Sparwood[1]		14.9%
Average Percent Increase in IDF Curve – Pincher Creek[1]		16.7%
Average Percent Increase in IDF Curve – Site Estimation		15%

Source: Simonovic *et al.* (2015)

The intensification of weather patterns can de deduced by the number of consecutive dry days and the precipitation related climate parameters in Table 7.2-4. The results show that precipitation will increase in more concentrated time frames, which also allows for the number of consecutive dry days to rise. The percent increase in the IDF curves also convey the conclusion that there will be more extreme precipitation events.

b) How the selected scenario compares with other generally accepted scenarios in terms of mean annual precipitation and mean annual temperature; and

Response:

The information request does not define what is meant by “other generally accepted scenarios”. The extent of the analysis completed is described in the response to part a).

c) How the updated hydrological model was used to generate the monthly flows shown in Figures 6.25-1 and 6.25-2 of Addendum 11.

Response:

Climate change was incorporated by increasing monthly precipitation (and by extension monthly flows) linearly by factors of 0 to 5.3% starting in 2011 (0% increase) and ending in 2100 (5.3% increase). Strictly speaking, the 5% increase should have been applied to annual precipitation/flow, not monthly precipitation/flow. However, the application of increased precipitation on a monthly timestep was assumed to be a reasonable estimate.

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HYDROLOGY

Information Request 7.3

Tenth Addendum to the Environmental Impact Assessment. Response to Information Request 5.3. (CIAR #251).

Eleventh Addendum to the Environmental Impact Assessment. Response to Information Request 6.13. (CIAR #313).

Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. Fisheries and Oceans Canada. (2013).

A Desk-top Method for Establishing Environmental Flows in Alberta Rivers and Streams. Government of Alberta. (2011).

Guide to Compelling Reasons to not take the 10% Holdback for Water Transfers within the South Saskatchewan River Basin. Government of Alberta. (2015).

Water Conservation Objective Conditions in the New Licence

Benga has applied for a new licence for 185,022 m^3 of surface runoff in the Gold Creek and Blairmore Creek watersheds from the Crown Reservation under the Oldman Water Allocation Order. The South Saskatchewan River Basin (SSRB) Plan requires that any licences issued for applications received after May 1, 2005 be subject to the appropriate Water Conservation Objective (WCO). The Oldman River WCO for Oldman River headwaters will likely apply to the new (Crown reservation) licence, if approved.

Minimum Release Criteria for the Aquatic Environment

Benga is proposing to transfer two licences to the Gold Creek and Blairmore Creek watersheds: one from Crowsnest River and one from York Creek. The SSRB Plan's Matters and Factors state that transfers should have no significant adverse effect on other users and the aquatic environment.

Although the Crowsnest River has an established WCO, neither Gold Creek nor Blairmore Creek have an established instream objective (IO). In order to ensure no significant adverse effect on Gold Creek and Blairmore Creek, as required by the SSRB Plan, specific minimum release criteria for Gold Creek and Blairmore Creek will likely be required as conditions to the licences, if approved. The minimum release criteria will likely be based on either the Fisheries and Oceans Canada (DFO) framework[1] or the Alberta Desktop Method[2].

[1] Available Online: Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013).https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Documents/Fisheries-and-Oceans-Canada-SAR-2013.pdf

[2] Available Online: A Desk-top Method for Establishing Environmental Flows in Alberta Rivers and Streams. Updated April 1, 2011. https://open.alberta.ca/publications/9780778599791

10% Holdback for Water Transfers

Alberta Environment and Parks' (AEP) *Guide to Compelling Reasons to not take the 10% Holdback for Water Transfers within the SSRB*[3] documents past decisions where minimum flow conditions were added to transferred licences instead of withholding the 10% WCO holdback. The guide indicated that successful implementation of minimum release criteria may provide a greater benefit to streams than withholding 10% of the transferred water. In Benga's case, minimum flow conditions will likely be implemented as minimum release criteria/conditions, potentially enabling the transfer of the requested volumes without the 10% WCO holdback.

Alberta Desktop Method and DFO Ecological Flow Framework

In response to IR 6.13 (CIAR #313), Benga stated that Project impacts on Gold Creek are within the 15% limit of the Alberta Desktop Method and the 10% limit of the 2013 DFO Ecological Flow Framework, and indicated that even without releases from the saturated backfill zone, flows in Blairmore Creek would remain at baseline levels. However, Benga has not clearly explained how flows in Blairmore Creek would remain at baseline levels without releases from the saturated backfill zone given the sizable Project footprint in the Blairmore Creek watershed.

Both the Alberta Desktop Method and the DFO framework include Ecosystem Base Flow (EBF) components that define critical flow thresholds below which there should be no Project impacts on flows.

Therefore, to be consistent with these approaches and to ensure that the licences will have no significant adverse effects on the aquatic environment, the licences will likely require specific minimum release criteria when Gold Creek and Blairmore Creek are not meeting the requirements of either the DFO framework or the Alberta Desktop Method, with respect to both the maximum percent reduction and EBF requirements.

Benga has provided the EBF using the Alberta Desktop Method, which are the Q80 values in Addendum 11, IR 6.13 (a) (CIAR #313). However, Benga has not used this information to calculate a minimum release rate from the Project.

The EBF using the DFO framework is defined as 30% of the mean annual discharge in each creek. Benga has provided the mean annual discharges to be 0.669 m^3/s in Gold Creek and 0.235 m^3/s in Blairmore Creek. The EBFs using the DFO framework are therefore 0.201 m^3/s in Gold Creek and 0.071 m^3/s in Blairmore Creek. The EBF minimum release rate will likely be required to be proportional to the Project footprint in each creek's watershed, as illustrated in the sample calculations provided later in this request.

Finally, to meet the minimum release requirement when the Crowsnest River is below its WCO, Benga is likely to be required to release a volume equal to the daily equivalent of the 185,022 m^3 annual allocation (about 500 m^3/day). It should be noted that any release

[3] Available Online: Guide to Compelling Reasons to not take the 10% Holdback for Water Transfers within the SSRB (GoA, 2015). https://open.alberta.ca/publications/esrd-water-quantity-2015-no-1

into either Blairmore Creek or Gold Creek to meet minimum release criteria for these creeks can count towards meeting the WCO on the Crowsnest River.

Water Quality Environmental Protection and Enhancement Act (EPEA) Targets

As Benga has consistently stated that it will not discharge water from the saturated backfill zone to Gold Creek and Benga's environmental assessment is based on this approach, Benga should anticipate that, if approved, the Panel will likely include a condition prohibiting release of water from the saturated backfill zone to Gold Creek.

In response to IR 5.3 (CIAR #251), Benga has also stated that if water from the saturated backfill zone cannot meet EPEA water quality release standards, it will re-direct this water to the saturated backfill zone or the raw water pond. Therefore, Benga will need to be able to meet the minimum release criteria using water that can reliably be expected to meet EPEA criteria, such as water stored in the sedimentation ponds.

a) Explain in detail how Benga concluded that without releases of water from the saturated backfill zone, flows in Blairmore Creek would remain at baseline levels;

b) Confirm that Benga can commit to limit Project impacts on flows in Blairmore Creek to less than 10% without any release of water from the saturated backfill zone; and

c) Confirm and provide a detailed justification to demonstrate that the Project has sufficient water storage capacity from sources other than the saturated backfill zone to support the following minimum daily releases for Gold Creek, Blairmore Creek, and the Crowsnest River. As part of the justification, estimate the amount of time per year when these minimum release requirements are expected to be in place (considering the changes in land use and on-site water storage over the life of the mine). If the Project will not have sufficient water from sources other than the saturated backfill zone to satisfy these requirements, explain what alternatives will be pursued by Benga.

   i. Gold Creek Ecosystem Base Flow:

$$Minimum\ Release\ Rate = Q_{GC}\frac{A_{mine,GC}}{A_{GC}}$$

      a. DFO Framework, when flow in Gold Creek is less than 0.20 m^3/s

      b. Alberta Desktop Method, when flow in Gold Creek is less than the weekly Q80

   ii. Blairmore Creek Ecosystem Base Flow:

$$Minimum\ Release\ Rate = Q_{BC}\frac{A_{mine,BC}}{A_{BC}}$$

a. DFO Framework, when flow in Blairmore Creek is less than 0.07 m^3/s

b. Alberta Desktop Method, when flow in Blairmore Creek is less than the weekly Q80

iii. Crowsnest River WCO:

When flow in Crowsnest River at WSC 05AA008 is below the established WCO, minimum release rate = 500 m^3/day, where the minimum release is the sum of releases to Gold Creek and Blairmore Creek.

Q_{GC} = flow at WSC station 05AA030, Gold Creek near Frank

Q_{BC} = flow at Blairmore Creek near the mouth

$A_{Mine,GC}$ = disturbance area of mine within Gold Creek Watershed

$A_{Mine,BC}$ = disturbance area of mine within Blairmore Creek Watershed

A_{GC} = Area of Gold Creek watershed at WSC station = 63.3 km^2

A_{BC} = Area of Blairmore Creek watershed near the mouth = 48.1 km^2

Response:

The emphasis of this Information Request is to establish whether Environmental Flow Needs will be met on Gold and Blairmore creeks, using the provincial and federal coarse-based desktop methods Alberta Desktop Method (ADM) and the DFO Framework, respectively, under an unscheduled event in which treated contact water is not released into Blairmore Creek from the Saturated Backfill Zone (SBZ).

In this response, we re-introduce the detailed Instream Flow Assessment (IFA) conducted for the Project and presented in the EIA (Addendum 1, Appendix A3, CIAR #44), as originally requested by AER and DFO, to provide a comprehensive assessment of the potential changes to fish habitat due to predicted (scheduled) changes in flow over the life of the mine. For Gold Creek, the IFA predicted modest habitat losses which have been captured in the proposed Detailed Fisheries Offsetting Plan, a draft of which has been submitted (Addendum 8, Appendix B1, CIAR #89) and will be finalized through subsequent permitting with Fisheries and Oceans Canada (DFO). On Blairmore Creek, the IFA predicted habitat gains to occur during scheduled project operations assuming continued discharge and no shut-down. The following information has been compiled to consider the worse-case scenario of a full SBZ-shutdown (*i.e.,* no discharge of effluent).

Benga has organized this response into the following order of sub-categories:

i. Overview of establishing environmental flows, and their applicability to the Grassy Mountain Coal Project;

ii. Grassy Mountain Coal Project detailed Instream Flow Assessment;

iii. Original predicted surface flow and habitat changes due to the Project;

iv. Proposed mitigation for the SBZ–shutdown scenario;
v. Predicted habitat changes under the SBZ-shutdown scenario, with mitigation;
vi. Comparison against provincial and federal desktop thresholds; and
vii. Information Request Summary.

i. Overview of Establishing Environmental Flows and their Applicability to the Grassy Mountain Coal Project

Screening-level (coarse, desktop-based) assessments of Instream Flow Needs (IFN), including the Alberta Desktop Method (ADM) and DFO Framework for Assessing Ecological Flows (2013) (noted in the information request preamble) are conservative thresholds that have been peer reviewed and identified to holistically protect aquatic ecological processes. When these conservative thresholds are exceeded, a more rigorous level of assessment is recommended to evaluate potential effects on ecosystem functions that support fisheries (see DFO 2013). Uncertainties in the changes to fish habitat (suitability, quantity) become amplified, amongst other factors, when there is limited local or regional data available (both in terms of long-term streamflow data, and fisheries information for the focused watercourses), or when there are sensitive or protected species (as is the case the SARA-listed westslope cutthroat trout [WSCT] present on this Project).

For these types of projects, detailed assessments, which include field characterizations of surface flow regimes and how they associate with the suitability of fish habitat, provide the necessary data to generate higher resolution, reach-specific evaluation of potential habitat changes, identify thresholds that provide ecological protection, and support with developing mitigation options and/or habitat offsetting to counterbalance any identified residual effects. The outcomes of these detailed assessments are more fitting than a corresponding desktop method when it comes to providing adequate assessment of effects while defining species-specific thresholds that protect ecological function.

For the Project a detailed Instream Flow Assessment (Addendum 1, CR #6, Appendix A3, CEAR #44) was conducted to investigate predicted changes to WSCT habitat based on changes to hydrological conditions over the life of the mine and inform applicable mitigations and protective thresholds for both Blairmore Creek and Gold Creek. This field-based IFA was requested by Alberta Energy Regulator to address information gaps in the assessment of potential effects on WSCT.

ii. Grassy Mountain Coal Project Detailed Instream Flow Assessment

The Grassy Mountain Project IFA evaluated the potential for flow-related changes on WSCT habitat (suitability, quantity) for five study reaches on Gold Creek and three study reaches on Blairmore Creek. Predictions were made for existing conditions and all hydraulic conditions (stream depth, width, substrate) across defined Project phases. These predictions were then applied to assess for possible changes in WSCT habitat suitability and quantity. Species-specific life-history criteria were used to predict habitat Area Weighted Suitability (AWS), which was calculated by applying WSCT life-stage specific Habitat Suitability Curves (HSCs) to these hydraulic conditions. The percentage change in average monthly AWS, expressed in metres squared per reach, during biologically relevant time-periods (stanzas or bioperiods) was used to assess the potential interaction between predicted flow changes and WSCT habitat during each Project phase relative to baseline. The threshold for no significant effect on WSCT due to predicted flow changes was a <10% reduction in total WSCT AWS during each Project phase (*i.e.,* at least 90% of total WSCT habitat remained available during relevant biological stanzas).

This approach was based on the Instream Flow Incremental Methodology that are applied in both BC and Alberta. These methods assume that habitat for fish and other aquatic species change as a function of flow and that predictive models can be developed to describe this relationship for a given stream.

iii. Original Predicted Surface Flow and Habitat Changes Due to the Project

The Project's water balance model (EIA, Appendix 10B, CIAR #42) was used to predict monthly runoff changes forecast through all Project phases (2018-2099) at several model nodes along Gold and Blairmore creeks to incorporate spatial differences in natural runoff associated with the planned water management infrastructure. Relative to baseline conditions, the model predicted typical runoff losses along Gold Creek of between 3-7% (up to a maximum decrease of 10.4%) and typical runoff gains along Blairmore Creek of between 5-15% (up to a maximum increase of 35.4%). On Gold Creek, these flow losses translated into IFA predicted habitat losses (decreases of AWS) during all Project phases, relative to existing (baseline) conditions, and this information was subsequently used to support the Preliminary Habitat Offsetting Plan (Addendum 1, CR #6, Appendix A4, CEAR #44).

On Blairmore Creek, simulated runoff gains translated into predicted habitat improvements (increases of AWS), but neither the water balance model nor the IFA considered changes due to a potential shutdown of SBZ treated releases into Blairmore Creek. The information presented in ***iv to vii,*** below, considers the SBZ-shutdown scenario and predicts potential changes to AWS without the SBZ discharging to Blairmore Creek.

iv. Proposed Mitigation for the SBZ-Shutdown Scenario

As shown in the IFA study (Addendum 1, CR #6, Appendix A3, Table 3-4, CIAR#44), the baseline monthly streamflow for late summer (August-September) for the two IFA study reaches #3 and #4 (where SBZ discharges occur) requires a base rate of 0.07 m^3/s.

In the unlikely event flow from the SBZ to Blairmore Creek is suspended for a maximum of 55 days (Addendum 11, JRP IR-6.17a), Benga would augment the flows in Blairmore Creek to ensure the 0.07 m^3/s is met by pumping stored water from select sedimentation ponds. As stated in Addendum 8, AER-R2-6 (CIAR #89), additional source water not exposed to selenium would include surface runoff and groundwater interception from the pit, which would be directed towards the west, southwest, and plant site sedimentation ponds. The combined capacity of these three sedimentation ponds is 163,000 m^3, which equates to 27 days of augmentation if the full 0.07 m^3/s base rate needs to be supplied. In addition, intercepted ground water from the pit will continue to be produced into the sedimentation ponds and could even be accelerated to ensure that the 0.07 m^3/s base rate can be maintained for the full SBZ outage.

v. Predicted Habitat Changes Under the SBZ-Shutdown Scenario, with Mitigation

The IFA presented bioperiod-specific flow-habitat relationships for each study reach, as modelled using surface flow and transect-specific (hydraulic and substrate) information collected within each reach. In Blairmore Creek, the results for Reach 4 (containing SBZ releases through BC-07) and Reach 3 (containing SBZ releases through BL-02 near the reach [4 to 3] break), have been pulled from the IFA report and presented as Figure 7.3-1 and Figure 7.3-2, respectively, corresponding to the two study reaches with the highest relative potential for flow reductions during a SBZ shutdown scenario. In the original IFA, these relationships provided the foundation for assessing changes to habitat suitability/quantity through each project phase and corresponding predicted flow alteration excluding the zero-discharge scenario.

While the model outputs in Figure 7.3-1 and Figure 7.3-2 are shown across a wide range of flow conditions (from zero flow to above the highest expected monthly flows), only a proportion of this flow range is used by each bioperiod. The WSCT life stages including rearing adults and juveniles, fry, and invertebrates (food supply) occur over a range of variable flow months, whereas spawning (May-July) and overwintering (October-March) WSCT life-stages are generally restricted to high and low flow months, respectively. Table 7.3-1 summarizes the expected range of Mean Monthly Discharge (MMD) for each bioperiod (and reach) at baseline condition and whether the minimum MMD in each instance (as a proxy for the month with lowest potential AWS, *i.e.,* most highly stressed conditions) falls above or below the potential minimum sedimentation pond discharge rate of 0.07 m^3/s. The results indicate that all life stages, with the exception of the spawning bioperiod, naturally fall below the 0.07 m^3/s threshold during baseline conditions, meaning that flow requirements for these life stages would be met if a minimum pond discharge rate of 0.07 m^3/s was sustained during a maximum-length period of SBZ-shutdown scenario.

Table 7.3-1 Bioperiod-Specific Flow Statistics and Relation to Worst-Case SBZ-Shutdown Pond Release Rates, Reaches 3 to 4 Blairmore Creek

Reach	Bioperiod	Corresponding Months	Corresponding MMD range (m^3/s)	Minimum MMD (in bold) above or below SBZ-shutdown scenario (release rate of 0.07 m^3/s)
Reach 4	Adult Rearing	Apr - Sep	**0.05** – 0.69	Below
	Juvenile Rearing	Apr - Sep	**0.05** – 0.69	Below
	Spawning Adult	May - Jul	**0.22** – 0.69	Above
	Fry	Jul - Sep	**0.05** – 0.22	Below
	Overwintering	Oct - Mar	**0.03** – 0.05	Below
	Food Supply	Jun - Sep	**0.05** – 0.69	Below
Reach 3	Adult Rearing	Apr - Sep	**0.06** – 0.82	Below
	Juvenile Rearing	Apr - Sep	**0.06** – 0.82	Below
	Spawning Adult	May - Jul	**0.26** – 0.82	Above
	Fry	Jul - Sep	**0.06** – 0.26	Below
	Overwintering	Oct - Mar	**0.03** – 0.06	Below
	Food Supply	Jun - Sep	**0.06** – 0.82	Below

Assuming the SBZ-shutdown scenario occurred during the spawning bioperiod, surface flows from outside the project would have to drop to 0.15 and 0.19 m^3/s respectively in Reaches 3 and 4 to trigger the 10% habitat threshold. Benga considers the coincidence of low surface flows from outside the Project footprint during spawning season and a recycling of the SBZ for an extended period to be a low probability event; however, to maintain monthly streamflows to 0.15 m^3/s and 0.19 m^3/s in reaches 4 and 3, respectively, or at approximately 0.2 m^3/s when averaged across the May-July period (when average streamflow is typically much higher than this), Benga would assess the contributing flows from the other portions of the Blairmore Creek watershed and pump the appropriate amount of water from the pit to the sedimentation ponds above the 0.07 m^3/s as needed.

vi. Comparison Against Federal and Provincial Desktop Thresholds

For transparency, the viability of potentially meeting desktop-based Environmental Flow Needs, using the ADM and DFO (2013) are summarized in Table 7.3-2. These results were generated by comparing the number of months, from baseline through to the end-of-Project (in 2100, a period of approximately 1,000 months), where the minimum thresholds established by the desktop methods (*i.e.,* the Environmental Base Flow [Q80] for ADM, and 30% Mean Annual Discharge [MAD] for the DFO Framework) were met during:

- normal operations (SBZ operating as planned); and
- during individual months without SBZ release into Blairmore Creek, as simulated by the Water and Load Balance Model.

For the ADM, Q80 results were generated using long-term synthetic hydrographs for each reach on weekly (existing conditions) flow data, then aggregated into monthly Q80 values. For the DFO Framework, 30% of the MAD predicted for each reach was used as the low-flow threshold in this application (noting that additional changes can also occur at higher flows, when altered flows exceed ±10% difference from existing flows during existing conditions). These results were additionally extended further downstream (outside of the area covered by the detailed IFA), including for Reach 2 (where discharge is released at BC-03) and near the mouth of Blairmore Creek (equivalent to model node BC-01 and near the BC-H01 gauge location).

The results indicate that under typical conditions, when the SBZ operates as it should, approximately 20% of monthly flows would not meet the ADM Q80 threshold, and even more (50%) would not meet the DFO threshold. These low-flow thresholds are considered inappropriate for Blairmore Creek given that flows naturally occur frequently below these thresholds. If the SBZ is not releasing to Blairmore Creek, obviously there are more months that would fall below these thresholds. However, since recycling of the SBZ is expected to be a relatively rare occurrence, in practice the number of months below the thresholds is not materially different than under normal operations.

Table 7.3-2 Proportion of Mine-Life Monthly Flows Not Meeting Desktop-Method EFN Low-Flow Thresholds

Assessment Location	Corresponding Model Node	% Months Not Meeting Desktop Low-Flow Threshold Under Normal Operating Conditions	
		ADM	DFO
Reach 4	BC-07	18%	32%
Reach 3	BL-02	22%	38%
Reach 2	BC-03	6%	6%
BC-01	BC-01	0%	1%

vii. Information Request Summary

A detailed IFA was conducted for the Project (Addendum 1, CR #6, Appendix A3, Table 3-4, CIAR#44), to provide a comprehensive assessment of the potential changes to fish habitat on WSCT due to the predicted changes in flow that are likely to occur during the life of the mine.

In the absence of any shutdown of the SBZ, surface flows and habitat quality (for all life stages of WSCT) were predicted to increase on Blairmore Creek during all Project phases, relative to existing (baseline) conditions. The information presented in this IR response has further considered (and evaluated) the potential for a worse-case (unplanned) full SBZ shutdown scenario on Blairmore Creek.

The minimum monthly streamflow associated with each WSCT life-stage, except spawning, naturally falls within the available sedimentation pond discharge rate (estimated to be 0.07 m^3/s), indicating that there is sufficient water available within the Project's sedimentation ponds that could be pumped into Blairmore Creek to maintain instream flow requirements for these life stages. This represents a worst-case situation in which the shutdown is assumed to occur specifically during the lowest-flow month, when in reality, significant changes to fish habitat would only occur over longer-periods (*e.g.,* if an SBZ shutdown extended across entire duration of various bioperiods); however, this is a very unlikely occurrence as the bioperiods occur over various streamflows that naturally incorporate higher flow months and dilute these worst-case habitat losses on a monthly timescale. With respect to the spawning bioperiod, significant changes (of 10% or more habitat reduction) would be avoided if monthly streamflows were maintained above 0.15 m^3/s and 0.19 m^3/s in reaches 4 and 3, respectively, or above approximately 0.2 m^3/s when averaged across the May-July period (when average streamflow is typically much higher than this).

Response Recap

a) Explain in detail how Benga concluded that without releases of water from the saturated backfill zone, flows in Blairmore Creek would remain at baseline levels;

As indicated above, flows in Blairmore Creek can be maintained above a minimum of 0.07 m^3/s by pumping from sedimentation ponds in the rare event that the SBZ is not discharging to the Creek. All life stages, with the exception of the spawning bioperiod, naturally fall below the 0.07 m^3/s threshold during baseline conditions, meaning that flow requirements for these life stages would be met. Assuming the SBZ-shutdown scenario occurred during the spawning bioperiod, surface flows from outside the Project would have to drop to 0.15 and 0.19 m^3/s respectively in Reaches 3 and 4 to trigger the 10% habitat threshold (*i.e.,* significant effect). Benga considers the coincidence of low surface flows from outside the Project footprint during spawning season and a recycling of the SBZ for an extended period to be a low probability event.

b) Confirm that Benga can commit to limit Project impacts on flows in Blairmore Creek to less than 10% without any release of water from the saturated backfill zone; and

Benga conducted an IFA which evaluated the potential for flow-related changes on WSCT habitat (suitability, quantity) for five study reaches on Gold Creek and three study reaches on Blairmore Creek. Predictions were made for existing conditions and all hydraulic conditions (stream depth, width, substrate) across defined Project phases. These predictions were then applied to assess for possible changes in WSCT habitat suitability and quantity. Species-specific life-history criteria were used to predict habitat Area Weighted Suitability (AWS), which was calculated by applying WSCT life-stage specific Habitat Suitability Curves (HSCs) to these hydraulic conditions. The percentage change in average monthly AWS, expressed in metres squared per reach, during biologically relevant time-periods (stanzas or bioperiods) was used to assess the potential interaction between predicted flow changes and WSCT habitat during each Project phase relative to baseline. The threshold for no significant effect on WSCT due to predicted flow changes was a <10% reduction in total WSCT AWS during each Project phase (*i.e.,* at least 90% of total WSCT habitat remained available during relevant biological stanzas). Benga considers the IFA and these thresholds to be more appropriate than flow thresholds based on desktop models that are less sophisticated and which do not consider local conditions.

c) Confirm and provide a detailed justification to demonstrate that the Project has sufficient water storage capacity from sources other than the saturated backfill zone to support the following minimum daily releases for Gold Creek, Blairmore Creek, and the Crowsnest River. As part of the justification, estimate the amount of time per year when these minimum release requirements are expected to be in place (considering the changes in land use and on-site water storage over the life of the mine). If the Project will not have sufficient water from sources other than the saturated backfill zone to satisfy these requirements, explain what alternatives will be pursued by Benga.

i. Gold Creek Ecosystem Base Flow:

a. DFO Framework, when flow in Gold Creek is less than 0.20 m^3/s

b. Alberta Desktop Method, when flow in Gold Creek is less than the weekly Q80

No flow augmentation is proposed for Gold Creek. Predicted flow reductions, and resultant changes in WSCT habitat suitability/quantity, in Gold Creek are being counterbalanced through the Proposed Habitat Offset Plan, which has been submitted in draft form and will require final approval from DFO. Of note, no SBZ discharge is planned into Gold Creek so the already-filed analysis and Detailed Fisheries Offsetting Plan (Addendum 8, Appendix B1, CIAR #89) are not affected by the SBZ operation.

ii. Blairmore Creek Ecosystem Base Flow:

a. DFO Framework, when flow in Blairmore Creek is less than 0.07 m^3/s

b. Alberta Desktop Method, when flow in Blairmore Creek is less than the weekly Q80

See section iv above.

iii. Crowsnest River WCO:

When flow in Crowsnest River at WSC 05AA008 is below the established WCO, minimum release rate = 500 m3/day, where the minimum release is the sum of releases to Gold Creek and Blairmore Creek.

As noted in the response above, release rates from the Sedimentation Ponds alone, without the SBZ, can at a minimum be maintained at 0.07 m^3/s which is 10 times higher than the Crowsnest minimum release rate of 500 m^3/day.

REFERENCES

DFO (2013) Available Online: Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013). https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Documents/Fisheries-and-Oceans-Canada-SAR-2013.pdf

Alberta Desktop Method: Available Online: A Desk-top Method for Establishing Environmental Flows in Alberta Rivers and Streams. Updated April 1, 2011. https://open.alberta.ca/publications/9780778599791

SECTION B: JRP APRIL 8, 2020 REQUEST:
REFERENCE LISTS AND CONSOLIDATED MITIGATION TABLES

1. REFERENCE LISTS FOR EACH VALUED COMPONENT

Prior to issuing a notice of hearing, the Panel will require Benga to provide the following:

1. **A reference list that indicates where information on each valued component (VC) can be found on the record for the environmental assessment. Benga is asked to identify the specific section(s) of the Environmental Impact Assessment (EIA), or the specific information request response(s) within an Addenda that are relevant to a particular valued component. Clearly indicate where information has been superseded and is no longer the most current information to be considered by the Panel and participants.**

Response:

To provide clarity to participants and the Panel, a reference list has been provided that outlines where each VC is covered in both the EIA and the 12 Addendums. To accomplish this, Benga has provided one reference list table per discipline outlining the places in the EIA where topics were covered, as well as a list of IR responses applicable to those disciplines, with keywords provided. In some places IR responses provide further clarification to previously provided information. In other instances, the IR response supersedes previously provided information. In these cases, this is clearly marked in the tables.

The reference list tables are organized as follows for each VC:

- Table 1-1 Air Quality Reference List
- Table 1-2 Noise Reference List
- Table 1-3 Hydrogeology Reference List
- Table 1-4 Hydrology Reference List
- Table 1-5 Surface Water Quality Reference List
- Table 1-6 Aquatic Ecology Reference List
- Table 1-7 Soil and Terrain Reference List
- Table 1-8 Vegetation and Wetlands Reference List
- Table 1-9 Wildlife Reference List
- Table 1-10 Land and Resource Use Reference List
- Table 1-11 Socio-Economics Reference List
- Table 1-12 Human Health Reference List
- Table 1-13 Historical Resources Reference List
- Table 1-14 Effects on Indigenous Groups Reference List

AIR QUALITY

A reference list has been created to indicate where information on air quality can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-1.

Table 1-1 Air Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.1	Air Quality Environmental Assessment Overview	Information submitted in the 2016 EIA
	Section A.11.1	Air Quality Mitigations and Monitoring Overview	
	Section E.1	Summary of the project wide Air Quality Impact Assessment	
	Consultant Report #1a	Project wide Air Quality Impact Assessment	
	Consultant Report #1b	Detailed Air Quality Assessment of Train Loadout Emissions	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional air quality information provided
Addendum 2 (CIAR #53)	NA	NA	No additional air quality information provided
Addendum 3 (CIAR #54)	NA	NA	No additional air quality information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA IR-2	Model request	Additional Information
	CEAA IR-3	Dust control efficiency (80%)	
	CEAA IR-4	Greenhouse Gases	
Addendum 5 (CIAR #69)	AER-R1-76	Typographical error for density units	
	AER-R1-77	Tier 4	
	AER-R1-78	Emission factor	
	AER-R1-153	Baseline information, dustfall	
	AER-R1-154	Diesel particulate matter	
	AER-R1-155	Emission Factor	
	AER-R1-193	Latex binder	
	AER-R1-197	Dust suppression at the ROM pad	

Table 1-1 Air Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 6 (CIAR #70)	ECCC-R1-10	Canadian Ambient Air Quality Standards for NO_2	Additional Information
	ECCC-R1-11	Canadian Ambient Air Quality Standards for SO_2 and PM	
	ECCC-R1-12	Dust control efficiency (80%)	
	ECCC-R1-13	Fugitive Dust	
	ECCC-R1-14	Inclusion of existing rail line in emissions modelling	
	ECCC-R1-15	Selection of air quality monitoring stations	
	ECCC-R1-16	Locomotive emission factors	Supersedes EIA, Consultant Report #1a, Appendix A, Table A5-1
	ECCC-R1-17	Inclusion of marine and rail emissions (beyond Project boundary) in emissions estimates	Additional Information
	ECCC-R1-18	Use of train load-out	
	ECCC-R1-19	Number of haul trucks	
	ECCC-R1-20	Mitigating emissions from mobile equipment	
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional air quality information provided
Addendum 8 (Part B) (CIAR #89)	ECCC-R2-5	$PM_{2.5}$, 50% Control Efficiency	Additional Information
	ECCC-R2-6	NO_2, Rail Traffic	
	ECCC-R2-7	Canadian Ambient Air Quality Standards	
	HC-R2-1	Diesel particulate matter	
	HC-R2-2	NO_2, risk quotients for receptors	
	HC-R2-3	$PM_{2.5}$, risk quotients for receptors	
Addendum 8 (Part C) (CIAR #89)	AER-R2-1	Dust control	Additional Information

Table 1-1 Air Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (CIAR #89)	Appendix A-1, Section 3.0	Cumulative Effects Assessment, Air Quality	This report supersedes the cumulative effects discussion in Section E.1.4 of the EIA and in Consultant Report #1
Addendum 10 (CIAR #251)	JRP IR-1.1	Latex Binder for dust control	Additional Information
	JRP IR-1.2	Rail Loadout Cladding	
	JRP IR-1.3; Appendix 1.3-1	Draft Air Quality Monitoring and Adaptive Management Plan	
	JRP IR-1.4	$PM_{2.5}$ and TSP Update	
	JRP IR-1.5	Wind Speed	
	JRP IR-1.6	Baseline	
	JRP IR-1.7	Rail and Marine	
	JRP IR-1.8; Appendix 1.8-1	Greenhouse Gas Monitoring Plan	
Addendum 11 (CIAR #313)	JRP IR-6.1	Wind gusts, dust	Additional Information
Addendum 12	Section B, Table 2-1	Air Quality Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

NOISE

A reference list has been created to indicate where information on noise can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-2.

Table 1-2 Noise Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.2	Noise Impact Assessment Overview	Information submitted in the 2016 EIA
	Section A.11.2	Noise Impact Assessment Mitigations and Monitoring Overview	
	Section E.2	E.2A Summary of the project wide Noise Impact Assessment E.2B Summary of the Detailed Noise Impact Assessment on Rail Alignment and Loadout Components	
	Consultant Report #2a	Project wide Noise Impact Assessment.	
	Consultant Report #2b	Detailed Noise Assessment of Rail Siding and Loadout Components	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional noise information provided
Addendum 2 (CIAR #53)	NA	NA	No additional noise information provided
Addendum 3 (CIAR #54)	NA	NA	No additional noise information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA IR-20	Effects on Indigenous ceremonial and community recreational use	The additional information provided in CEAA IR-20, Table 20-2 has since been superseded by Addendum 6, IR HC-R1-20, Table HC 20-1
Addendum 5 (CIAR #69)	AER-R1-47	Model results for the rock disposal areas	Additional information
	AER-R1-48	Noise impacts from blasting	

Table 1-2 Noise Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 6 (CIAR #70)	HC-R1-17	Residential and theoretical receptors	Additional information
	HC-R1-18	Impacts to trapper cabin	
	HC-R1-19	Noise levels during different Project phases	
	HC-R1-20	Updates to changes to % highly annoyed	Table HC 20-1 supersedes Table 20-2 from Addendum 4, CEAA IR-20
	HC-R1-21	Noise impacts from blasting	Additional information
	HC-R1-22	Low frequency noise impacts	
	HC-R1-23	Noise levels at night	
	HC-R1-24	Change in % highly annoyed	
	HC-R1-25	Noise impact assessment of rail loadout	
	HC-R1-26	Road and rail noise	
	HC-R1-27	Noise impact assessment of rail loadout, uncertainty of predictions	
	HC-R1-28	Noise complaint resolution	
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information; it does not supersede.
Addendum 7 (CIAR #72)	NA	NA	No additional noise information provided
Addendum 8 (Part A) (CIAR #89)	CEAA-R2-4	Noise effects of the current mine plan	Additional information
Addendum 8 (Part B) (CIAR #89)	HC-R2-13	10dBA adjustments	
	HC-R2-14	Blasting noise	
	HC-R2-15	Low frequency noise and complaints	
	HC-R2-16	Noise levels at receptors 301, 302	
	HC-R2-17	Rail and loadout	
	HC-R2-18	Noise monitoring	
Addendum 8 (CIAR #89)	Appendix A-1, Section 4.0	Cumulative Effects Assessment, Noise	This report supersedes the cumulative effects discussion in the EIA, Section E.2.4
Addendum 9 (CIAR #185)	NA	NA	No additional noise information provided

Table 1-2 Noise Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 10 (CIAR #251)	JRP IR-1.9	Noise and Proximity of Sensitive Receptors	Additional information
Addendum 11 (CIAR #313)	NA	NA	No additional noise information provided
Addendum 12	Section B, Table 2-2	Noise Mitigation and Commitments Summary Table	Summary of existing information; it does not supersede

HYDROGEOLOGY

A reference list has been created to indicate where information on hydrogeology can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-3.

Table 1-3 Hydrogeology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.3	Hydrogeology Environmental Assessment Overview	Information submitted in the 2016 EIA Refer to notes below for updates regarding Consultant Report #3
	Section A.11.3	Hydrogeology Mitigations and Monitoring Overview	
	Section E.3	Summary of the Hydrogeology Impact Assessment	
	Consultant Report #3	Hydrogeology Impact Assessment	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional hydrogeology information provided
Addendum 2 (CIAR #53)	NA	NA	No additional hydrogeology information provided
Addendum 3 (CIAR #54)	NA	NA	No additional hydrogeology information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA IR-7	Mine Pit Dewatering	Additional Information
	CEAA IR-8	Base Flow Rates	
	CEAA IR-9	Steady State Flow Model	

Table 1-3 Hydrogeology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 5 (CIAR #69)	AER-R1-81	Privately owned water wells, pit dewatering water quality	Additional Information
	AER-R1-82	Seepage capture system	
	AER-R1-214	Karst and underground mine workings	Correction to EIA, Consultant Report #3, Section 5.4.2.1, page 48
	Appendix A-3	Groundwater Seepage Conceptual Plan	Additional Information
Addendum 6 (CIAR #70)	DFO-R1-15	Hydraulic Conductivity	Additional Information
	DFO-R1-16	Limited Hydrogeological Data at Depth	
	DFO-R1-17	Limited Hydrogeological Data at Depth	
	DFO-R1-18	Surficial Geology in Model	
	DFO-R1-19	Simplified Local-Scale Hydrogeology	
	DFO-R1-20	Top of Model Boundary	
	DFO-R1-21	Constant Head and Seepage Nodes	Figure 21-1 supersedes EIA, Consultant Report #3, Appendix C, Figure 3-4
	DFO-R1-22	Constant Head and Seepage Nodes	Additional Information
	DFO-R1-23	Downward Trend in Simulated Heads	
	DFO-R1-24	Drawdown Intercepting Stream Boundary Conditions	
	DFO-R1-25	Simulated Depth to Water Table	Figure 25-1 supersedes EIA, Consultant Report #3, Appendix C, Figure 3-17
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information
Addendum 7 (CIAR #72)	NA	NA	No additional hydrogeology information provided

Table 1-3 Hydrogeology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (Part B) (CIAR #89)	DFO-R2-9	Geologic model	Additional Information
	DFO-R2-10	Surge ponds	
	DFO-R2-11	Model adjustments	
	DFO-R2-12	Change in flux	
	DFO-R2-14	Leakage rates	
	DFO-R2-15	Leakage rates	
	DFO-R2-16	GW movement onsite	
	DFO-R2-17	Model clarifications	
	DFO-R2-18	Model clarifications	
	DFO-R2-19	Model clarifications	
Addendum 8 (CIAR #89)	Appendix A-1, Section 5.0	Cumulative Effects Assessment, Hydrogeology	This report supersedes cumulative effects discussion in the EIA, Section E.3.4, and Consultant Report #3, Section 6.0
Addendum 9 (CIAR #185)	-	Traditional Land Use	Additional Information
Addendum 10 (CIAR #251)	JRP-IR-5.18	Groundwater monitoring plan	Additional Information
	JRP-IR-5.19	Seepage capture feasibility	
	JRP-IR-5.24	Pit dewatering and base flow	
	JRP-IR-5.25	Flow augmentation	
Addendum 11 (CIAR #313)	JRP IR-6.12	Seepage capture options	Additional Information
Addendum 12	Section B, Table 2-3	Hydrogeology Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

HYDROLOGY

A reference list has been created to indicate where information on hydrology can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-4.

Table 1-4 Hydrology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.4	Hydrology Environmental Assessment Overview	Information submitted in the 2016 EIA See below for updates to Consultant Report #4
	Section A.11.4	Hydrology Mitigations and Monitoring Summary	
	Section E.4	Summary of the project wide Hydrology Impact Assessment	
	Consultant Report #4	Project wide Surface Hydrology Baseline and Effects Assessment	
	Appendix 10B	Water and Load Balance Model	
	Section C.5	Water Management	Subsections C.5.1 and C.5.2 have been superseded by Addendum 2
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional hydrology information provided
Addendum 2 (CIAR #53)	Appendix 1D	Fence-line *Water Act* Application	Submission
	Appendix 1E	*Water Act* Licence	Submission
	Errata	An errata to subsections C.5.1 (Water Supply and Source) and C.5.2 (Water Licencing)	This supersedes Sections C.5.1 and C.5.2 from the EIA
Addendum 3 (CIAR #54)	NA	NA	No additional hydrology information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA-IR-8	Recharge rates	Additional Information

Table 1-4 Hydrology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 5 (CIAR #69)	AER-R1-79	Potable water	Additional Information
	AER-R1-80	Sedimentation pond design	
	AER-R1-83	Gauging stations	
	AER-R1-84	Hydrology assessment	Table 84-1 supersedes EIA, Consultant Report #4, Table 12
	AER-R1-97	Reduced creek flows	Additional Information
	AER-R1-189	Raw water pond for dust suppression	
	AER-R1-203	Dam safety, water ponds applications	
	AER-R1-204	Water volumes	
	AER-R1-205	Reject dewatering	
	AER-R1-206	Expected return flows	
	AER-R1-207	Water licences	
	AER-R1-208	Water licences	
	AER-R1-209	Dam on York Creek	
	AER-R1-210	Water shortage response plan	
	AER-R1-211	Proposed transfers and the Approved Water Management Plan for the South Saskatchewan River Basin	
Addendum 6 (CIAR #70)	ECCC-R1-1	Effects of extreme precipitation in hydrological analysis	Additional Information
	ECCC-R1-2	Climate change	
	ECCC-R1-3	Methodology for estimating future changes in evaporation	
	ECCC-R1-4	Effects of extreme flows on hydrological modelling	
	ECCC-R1-5	Impacts of extreme weather on water management ponds	
	ECCC-R1-6	Impact of ice on hydrological curves	
	ECCC-R1-7	Gaps in streamflow data	
	ECCC-R1-8	Uncertainty associated with flow estimates	
	ECCC-R1-9	Effects of flow changes on sediment transport modelling	
	DFO-R1-26	Water and Load Balance Model Report - GoldSim	Additional Information
	DFO-R1-27	Water and Load Balance Model Report – model scenarios	
	DFO-R1-28	Evaporation	

Table 1-4 Hydrology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	DFO-R1-29	Yield Coefficient	
	DFO-R1-30	Load Balance Model and Leakage Rates	
	DFO-R1-31	Water management system linkages: figure	
	DFO-R1-32	Void ratios	
	DFO-R1-33	Water balance and budget	
	DFO-R1-34	Pit lake and groundwater inflows	
	DFO-R1-35	Errata: Water and Load Balance Model Report	Correction to EIA, Appendix 10B to remove a bullet point
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	80	Engineering design details of sedimentation ponds	Additional Information
	84	Hydrological data	
	206	Contingency periods	
	207	Water conservation objective	
Addendum 8 (Part B) (CIAR #89)	ECCC-R2-2	Flows in nearby creeks	Additional Information
	ECCC-R2-3	Flow uncertainty and variability	
	DFO-R2-13	Water balance model assumptions	
	DFO-R2-14	Leakage rates	
	DFO-R2-15	Leakage rates	
	DFO-R2-16	GW movement onsite	
	DFO-R2-17	Model clarifications	
	DFO-R2-18	Model clarifications	
	DFO-R2-19	Model clarifications	
Addendum 8 (Part C) (CIAR #89)	AER-R2-2	Livingstone watershed clarification	Additional Information
	AER-R2-4	Streamflow changes, load balance model	
	AER-R2-5	Precipitation	
	AER-R2-6	Sedimentation pond releases	
	AER-R2-7	Water conservation objective	
	AER-R2-15	SW surge pond, hillside runoff	
	AER-R2-16	Flow rate, sedimentation ponds	
	AER-R2-19	Flow augmentation	
	Appendix C-1	Inflow Design Flood Analysis	

Table 1-4 Hydrology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (CIAR #89)	Appendix A-1, Section 6.0	Cumulative Effects Assessment, Hydrology	This report supersedes the cumulative effects discussion in the EIA, Section E.4.4 and Consultant Report #4, Section 1.3
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information
Addendum 10 (CIAR #251)	JRP-IR-5.15	Streamflow changes, watershed hydrology	Additional Information
	JRP-IR-5.16	Flows in Gold and Blairmore Creeks, water return strategy, instream objectives	
	JRP-IR-5.17	Agricultural water users	
	JRP-IR-5.20	Base flow, stream temperatures	
	JRP-IR-5.24	GW discharge and base flow	
	JRP-IR-5.25	Flow augmentation	
	JRP IR-5.31	Past and Existing Activities related to aquatic resources, surface water and hydrology	
Addendum 11 (CIAR #313)	JRP IR-6.13	IFN, flow augmentation	Additional Information
	JRP IR-6.17	Instream objectives, pond capacity	
	JRP IR-6.25; Appendix 6.25-1	Hydrographs for Gold and Blairmore Creeks, sensitivity analysis for varying model inputs, monthly model predictions	
Addendum 12	JRP IR-7.2	Incorporating climate change into the hydrological model	Additional Information
	JRP IR-7.3	Blairmore Creek flows, water releases	
	Section B, Table 2-4	Hydrology Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

Surface Water Quality

A reference list has been created to indicate where information on surface water quality can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-5.

Table 1-5 Surface Water Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.5	Surface Water Quality Environmental Assessment Overview	Information submitted in the 2016 EIA
	Section A.11.5	Surface Water Quality Mitigations and Monitoring Overview	
	Section C.5	Water Management, subsection C.5.3 Water Treatment including selenium treatment approach	
	Section E.5	Summary of the project wide Surface Water Quality Impact Assessment	
	Consultant Report #5	Surface Water Quality Impact Assessment.	
	Appendix 10A	Geochemistry Source Terms Characterization for Load Balance Model	
	Appendix 10B	Water and Load Balance Model	
	Appendix 10C	Water Quality Management, which summarizes the water quality mitigation measures proposed for the Project.	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional surface water quality information provided
Addendum 2 (CIAR #53)	NA	NA	No additional surface water quality information provided
Addendum 3 (CIAR #54)	NA	NA	No additional surface water quality information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA-5	Use of existing water quality information & historical dataset	Additional Information
	CEAA-6	Selenium concentrations	
Addendum 5 (CIAR #69)	AER-R1-79	Potable water	Additional Information
	AER-R1-80	Sedimentation pond design	
	AER-R1-85	Water management ponds	
	AER-R1-86	Water treatment plant	
	AER-R1-87	Sedimentation pond water release	

Table 1-5 Surface Water Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	AER-R1-88	Nitrate and selenium attenuation	
	AER-R1-89	Residence time in saturated backfill zones	
	AER-R1-90	SW surge pond	
	AER-R1-91	Treatment time in saturated backfill zones, closure	
	AER-R1-92	Release criteria, water management	
	AER-R1-93	Selenium management, source control	
	AER-R1-94	Proposed discharge locations for treated water	
	AER-R1-95	Control of acid generating potential	
	AER-R1-96	Metals treatment plant	
	AER-R1-98	Effluent selenium concentration cap	
	AER-R1-99	Metals treatment plant	
	AER-R1-100; Appendix A-5	Background water quality; Water Quality Data Table	
	AER-R1-101	Water quality model	
	AER-R1-102	Water management at closure	
	AER-R1-103	Capture efficiency, 95%	
	AER-R1-104	Selenium treatment performance	
	AER-R1-105	Phosphorus in water releases	
	AER-R1-107	Calcite	
	AER-R1-108	Site specific selenium guidelines	
	AER-R1-109	Sulphate guidelines, calcite	
	AER-R1-110	Mitigation and monitoring sulphate, methyl mercury	
	AER-R1-193	Fueling of locomotives, spills	
	AER-R1-194	Tanks and storage	
	AER-R1-195	Tanks and storage	
	AER-R1-196	Sewage management	
Addendum 6 (CIAR #70)	ECCC 21	Exposure of aquatic and terrestrial biota to contaminants of concern; monitoring	Additional Information
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional surface water quality information provided

Table 1-5 Surface Water Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (Part C) (CIAR #89)	AER-R2-3	Runoff management in the explosives storage magazine	Additional Information
	AER-R2-7	Water conservation objective	
	AER-R2-10	Management of selenium rich groundwater	
	AER-R2-11	Treatment plant	
	AER-R2-12	Water quality standards, discharge from sedimentation ponds	
	AER-R2-13	Selenium, nitrate, attenuation trials	
	AER-R2-14	Selenium and closure	
	AER-R2-15	SW surge pond, hillside runoff	
	AER-R2-16	Diverting water from sedimentation ponds to saturated zones	
	AER-R2-17	Metals treatment plant discharge locations	
	AER-R2-18	Metals treatment plant	
	AER-R2-19	Flow augmentation	
	AER-R2-20	Discharge locations, mixing zone, selenium, sulphate	
	AER-R2-21	Background water quality, central tendency	
	AER-R2-22	selenium, sulphate, contact water management, closure	
	AER-R2-23	Calcite	
	AER-R2-24	Aquatics monitoring program	
	AER-R2-27	Calcite, flow augmentation	
	AER-R2-28	End pit lake water quality, flow augmentation	
	AER-R2-29	Sulphate, selenium, metals risk-based evaluation	
	AER-R2-31	Calcite	
	AER-R2-32	Methyl mercury, phosphorous	
	Appendix C-2	Selenium Attenuation Barrel Trial	
	Appendix C-3	Risk-Based Evaluation of Predicted Selenium, Sulphate and Metals	

Table 1-5 Surface Water Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (CIAR #89)	Appendix A-1, Section 7.0	Cumulative Effects Assessment, Surface Water	This report supersedes the cumulative effects discussions in the EIA, Section E.5.4 and Consultant Report #5, Section 4.0 (4.1.3, 4.2.3, 4.3.3, 4.4.3, and 4.5.2)
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information
Addendum 10 (CIAR #251)	JRP IR-5.1	Selenium guidelines, risk assessment	Additional Information
	JRP IR-5.2	Holding ponds, metals treatment plant	
	JRP IR-5.3	Calcite, lime addition, mitigation, monitoring	
	JRP IR-5.4; Appendix 5.4-1	Draft Fisheries and Aquatic Monitoring Plan	This draft plan is superseded by Addendum 11, Appendix 6.23-1
	JRP IR-5.5	Saturated backfill zones, SBZ research and development, engineering design, selenium attenuation case studies	Additional Information
	JRP IR-5.6	Selenium and metals treatment technologies, temperature, dissolved oxygen, gravel bed reactors	
	JRP IR-5.7	Selenium bioaccumulation model	
	JRP IR-5.8	Selenium at discharge points	
	JRP IR-5.9	Sulphate, hardness, synergistic effects, selenium	
	JRP IR-5.10	Sulphate site specific guidelines, toxicity studies	
	JRP IR-5.11	Alternative risk assessment for cobalt	
	JRP IR-5.12	Legacy coal piles	
	JRP IR-5.13	Methanol storage facilities	
	JRP IR-5.14	Materials storage and management at the explosives magazine	
	JRP IR-5.21	Dissolved oxygen and temperature	
	JRP IR-5.24	Groundwater discharge, stream temperatures	
	JRP IR-5.25	Flow augmentation	
	JRP IR-5.31	Past and Existing Activities related to aquatic resources, surface water and hydrology	

Table 1-5 Surface Water Quality Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 11 (CIAR #313)	JRP IR-6.16	Site-specific selenium guideline, sulphate, seasonal variation	
	JRP IR-6.17	Instream objectives, pond capacity, off-spec water management	
	JRP IR-6.18	Gravel bed reactors, selenium	
	JRP IR-6.19	Saturated backfill zone references	
	JRP IR-6.20	Geochemistry, selenite, selenate	
	JRP IR-6.21	Technically and economically feasible alternatives for selenium treatment	
	JRP IR-6.22	Saturated backfill zone performance	
	JRP IR-6.23; Appendix 6.23-1	Draft Aquatic Monitoring Plan, adaptive management	This plan supersedes the previous draft in Addendum 10, Appendix 5.4-1
	JRP IR-6.24	Selenium concentrations at model nodes in Blairmore and Gold Creeks	Additional Information
	JRP IR-6.25; Appendix 6.25-1	Hydrographs for Gold and Blairmore Creeks, sensitivity analysis for varying model inputs, monthly model predictions	
	JRP IR-6.26	Risk of selenium loading into the Oldman Reservoir, cumulative effects	
Addendum 12	Section B, Table 2-5	Surface Water Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

AQUATIC ECOLOGY

A reference list has been created to indicate where information on aquatic ecology can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-6.

Table 1-6 Aquatic Ecology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.6	Aquatic Resources Environmental Assessment Overview	Information submitted in the 2016 EIA. This has been superseded by Addendum 1.
	Section A.11.6	Aquatic Resources Mitigations and Monitoring Overview	
	Section E.6	Summary of the project wide Fish and Aquatic Resources Impact Assessment	
	Consultant Report #6	Project wide Aquatic Resources Impact Assessment	
Addendum 1 (CIAR #44)	Updated Consultant Report #6	Project wide Aquatic Resources Impact Assessment	This report supersedes EIA Consultant Report #6
	Consultant Report #6, Appendix A4	Preliminary Habitat Offsetting Plan	This is superseded by Addendum 8, Appendix B-1
	Updated Section E.6	Summary of the Fish and Aquatic Resources Impact Assessment	This section supersedes EIA Section E.6
Addendum 2 (CIAR #53)	Not Applicable (NA)	NA	No additional aquatic resources information provided
Addendum 3 (CIAR #54)	NA	NA	No additional aquatic resources information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA 1	Concordance Tables for information requests	Additional Information
Addendum 4, Attachment 3 (CIAR #55)	CEAA IR-1	Daisy Creek	Additional Information
	CEAA IR-2	Mapping fish habitat	
	CEAA IR-3	Geomorphological changes	
	CEAA IR-4	Westslope Cutthroat Trout Recovery Strategy	
Addendum 5 (CIAR #69)	AER-R1-106	Macroinvertebrates	Additional Information
	AER-R1-107	Calcite	
	AER-R1-111	*Fisheries Act* authorizations	
	AER-R1-112	Riparian buffers	
	AER-R1-198	*Water Act* application	

Table 1-6 Aquatic Ecology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 6 (CIAR #70)	DFO-R1-1	Riparian habitat mitigation	Additional Information
	DFO-R1-2	Flow in Gold Creek, flow augmentation	
	DFO-R1-3	Watercourse crossings	
	DFO-R1-4	Overwintering research	
	DFO-R1-5	Stream temperature	
	DFO-R1-6	Habitat offsetting plan	
	DFO-R1-7	Effectiveness monitoring of habitat offsets	
	DFO-R1-8	Feedback from Indigenous groups	
	DFO-R1-9	Fluvial geomorphology, channel slopes and cross sections	
	DFO-R1-10	Fluvial geomorphology, Shields values, sediment mobility	
	DFO-R1-11	Fluvial geomorphology, bankfull discharge	
	DFO-R1-12	Fluvial geomorphology, mean monthly flows, erosion thresholds	
	DFO-R1-13	Fluvial geomorphology, bed sediment sizes	
	DFO-R1-14	Bank Erosion	
	DFO-R1-36	Substrate size and channel slope methodology	
	DFO-R1-37	Changes in area weighted suitability	
	DFO-R1-38	Baseline flow	
	DFO-R1-39	Baseline flow	
	DFO-R1-40	Benthic invertebrate habitat	
	DFO-R1-41	Integration of data between disciplines	
	Appendix A-2	Cumulative Effects Assessment, Section 3.0 Fisheries	Supersedes previously presented information on cumulative effects for Fish in Addendum 1: Consultant Report #6, Section 4.4; and updated EIA Section E.6, Section 6.4
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information
Addendum 7 (CIAR #72)	NA	NA	No additional aquatic resources information provided

Table 1-6 Aquatic Ecology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (Part B) (CIAR #89)	DFO-R2-1; Appendix B1	Detailed Fisheries Offsetting Plan	Supersedes Addendum 1, Consultant Report #6, Appendix A4
	DFO-R2-2 Appendix B2	Effectiveness Offsetting Monitoring Plan	Additional Information
	DFO-R2-3	Fluvial geomorphology, slope	
	DFO-R2-4	Fluvial geomorphology, spawning substrate size	
	DFO-R2-5	Fluvial geomorphology, monitoring	
	DFO-R2-6	Fluvial geomorphology, intra-annual changes	
	DFO-R2-7	Fluvial geomorphology	
	DFO-R2-8	Fluvial geomorphology, bank erosion	
	DFO-R2-20	Groundwater discharge and spawning	
Addendum 8 (Part C) (CIAR #89)	AER-R2-24	Aquatics monitoring plan	This is superseded by Addendum 11, Appendix 6.23-1,
	AER-R2-27	Calcite, habitat reduction in Gold Creek	Additional Information
	AER-R2-28	End pit lake discharge	Superseded by Addendum 11, JRP IR-6.15
	AER-R2-29	Selenium, sulphate, cobalt risk-based assessment	Additional Information
	AER-R2-34	Significance characterization clarifications	
	AER-R2-35	Habitat type descriptions	
	AER-R2-36	Runoff management and ponds	
	AER-R2-37	Stream temperature modeling	
	AER-R2-38	Habitat loss and buffers	
	Appendix C-3	Risk-Based Evaluation of Predicted Selenium, Sulphate and Metals	

Table 1-6 Aquatic Ecology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (CIAR #89)	Appendix A-1, Section 8.0	Cumulative Effects Assessment, Aquatic Resources	This report supersedes the cumulative effects discussion in: -Addendum 1: Consultant Report #6, Section 4.4; and updated EIA Section E.6, Section 6.4; and -Addendum 6: Appendix A-2, Section 3.0. This is the most current version of the cumulative effects discussion for fish.
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information
Addendum 10 (CIAR #251)	JRP IR-5.1	Selenium guidelines, risk assessment	Additional Information
	JRP IR-5.4; Appendix 5.4-1	Draft Fisheries and Aquatic Monitoring Plan	This is superseded by Addendum 11, Appendix 6.23-1
	JRP IR-5.7	Selenium bioaccumulation model	Additional Information
	JRP IR-5.9	Sulphate, hardness, synergistic effects, selenium	
	JRP IR-5.10	Sulphate site specific guidelines, toxicity studies	
	JRP IR-5.11	Alternative risk assessment for cobalt	
	JRP IR-5.20	Base flow, stream temperatures	
	JRP IR-5.21	Dissolved oxygen and temperature	
	JRP IR-5.22	Overwintering, temperature	
	JRP IR-5.23	Tissue sampling	
	JRP IR-5.24	Groundwater discharge, stream temperatures	
	JRP IR-5.25	Flow augmentation	
	JRP IR-5.26	Critical habitat additions for westslope cutthroat trout	
	JRP IR-5.27	Precautionary approach, Fisheries Offsetting Plan	
	JRP IR-5.28	Effects of blasting	
	JRP IR-5.29	Selenium bioaccumulation, Oldman Reservoir	

Table 1-6 Aquatic Ecology Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	JRP IR-5.31	Past and Existing Activities related to aquatic resources, surface water and hydrology	
Addendum 11 (CIAR #313)	JRP IR-6.14	Discharge locations from sedimentation ponds	Additional Information
	JRP IR-6.15	Sediment pond discharge, stream temperature	Supersedes Addendum 8, AER-R2-28
	JRP IR-6.23; Appendix 6.23-1	Draft Aquatic Monitoring Plan	This supersedes the previous drafts provided in Addendum 8, AER-R2-24 and Addendum 10, Appendix 5.4-1
	JRP IR-6.26	Risk of selenium loading into the Oldman Reservoir, cumulative effects	Additional Information
Addendum 12	Section B, Table 2-6	Aquatic Ecology Mitigation and Commitments Summary Table	Summary of existing information

Soil and Terrain

A reference list has been created to indicate where information on terrain and soils can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-7.

Table 1-7 Soil and Terrain Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.7	Terrain and Soil Environmental Assessment Overview	Information submitted in the 2016 EIA
	Section A11.7	Terrain and Soil Mitigations and Monitoring Overview	
	Section B	Geology and Geotechnical	
	Section E.7	Summary of the project wide Terrain and Soil Impact Assessment	
	Section F	Conservation and Reclamation Plan	
	Consultant Report #7	Terrain and Soil Impact Assessment	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional terrain and soils information provided

Table 1-7 Soil and Terrain Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 2 (CIAR #53)	NA	NA	No additional terrain and soils information provided
Addendum 3 (CIAR #54)	NA	NA	No additional terrain and soils information provided
Addendum 4, (CIAR #55)	NA	NA	No additional terrain and soils information provided
Addendum 5 (CIAR #69)	AER-R1-120	Historic contamination	Additional Information
	AER-R1-121	Soil salvage volume and loss	
	AER-R1-122	Reclamation material stockpiles	
	AER-R1-123	Soil nutrients and placement	
	AER-R1-124	Soil stockpiling and salvage, land capability, landscape integration	Figure 124-1 supersedes EIA, Section F, Figure F.2.1-6
	AER-R1-125	Soil diversity, soil map units	Additional Information
	AER-R1-126	Significance characterization, construction mitigation	
Addendum 6 (CIAR #70)	NRCan-R1-1	Terrain Hazards	Additional Information
	Appendix E-1	Terrain Assessment	
	NRCan-R1-2	Seismicity	
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional terrain and soils information provided
Addendum 8 (Part B) (CIAR #89)	NRCan-R2-1	Seismicity-Faulting	Additional Information
Addendum 8 (Part C) (CIAR #89)	AER-R2-39	Salvage SPRgr1/Mb/Ri (5-6), salvage on steep slopes	Additional Information
	AER-R2-40	Soil nutrient dilution	
	Appendix A-1, Section 9.0	Cumulative Effects Assessment, Soils	This report supersedes the cumulative effects discussion in the EIA, Section E.7.4 and Consultant Report #7, Sections 7.1.2, 7.2.2, 7.3.2, and 7.4.2
Addendum 9 (CIAR #185)	NA	NA	No additional terrain and soils information provided

Table 1-7 Soil and Terrain Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 10 (CIAR #251)	JRP IR-2.6; Appendix 2.6-1	Updated Conservation and Reclamation Plan	Supersedes EIA, Section F (Conservation and Reclamation Plan)
	JRP IR-5.32	Turtle Mountain	Additional Information
	JRP IR-5.33	Cost of Reclamation	
Addendum 11 (CIAR #313)	NA	NA	No additional terrain and soils information provided
Addendum 12	Section B, Table 2-7	Terrain and Soils Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

VEGETATION AND WETLANDS

A reference list has been created to indicate where information on vegetation and wetlands can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-8.

Table 1-8 Vegetation and Wetlands Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.8	Vegetation Environmental Assessment Overview	Information submitted in the 2016 EIA
	Section A.11.8	Vegetation Mitigations and Monitoring Overview	
	Section E.8	Summary of the project wide Vegetation and Wetlands Impact Assessment.	
	Consultant Report #8	Vegetation Impact Assessment.	
	Section F	Conservation and Reclamation Plan	Superseded by Addendum 10, Appendix 2.6-1
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional vegetation and wetlands information provided
Addendum 2 (CIAR #53)	NA	NA	No additional vegetation and wetlands information provided

Table 1-8 Vegetation and Wetlands Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 3 (CIAR #54)	NA	NA	No additional vegetation and wetlands information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA IR-12	Whitebark pine	Additional Information
	CEAA IR-25	Effects of climate change on SARA listed species	
Addendum 5 (CIAR #69)	AER-R1-113	Whitebark pine, wetlands	Additional Information
	AER-R1-114	Rough fescue	
	AER-R1-115	Wetlands	
	AER-R1-116	Reclamation of anthropogenic features	
	AER-R1-117	Seed mix	Revised Table F.3.6.3 supersedes EIA, Section F, Table F.3.6.3
	AER-R1-118	End pit lake littoral zone	Additional Information
	AER-R1-119	Ecosite phases and reclamation	
	AER-R1-127	TEK species	
	AER-R1-128	TEK species in reclamation	
	AER-R1-129	Whitebark pine, significance thresholds and ratings	
	AER-R1-130	Sensitivity to disturbance	
	AER-R1-131	Timelines for recovery of vegetation; fire	
	AER-R1-199	*Alberta Wetland Policy*	
	AER-R1-200	Wetland avoidance	
	AER-R1-201	Wetlands	Revised Table 4.7-2 supersedes EIA, Consultant Report #8, Table 4.7-2
	AER-R1-202	Wetland propagules and soil	Additional Information
	AER-R1-215	Fescue errata: Update to a typographical error in a Figure reference	Correction to a reference in EIA, Section F.3.2.4
	AER-R1-217	Errata: Footprint size was corrected	Correction to EIA, Section F.4.1 for total disturbance area

Table 1-8 Vegetation and Wetlands Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 6 (CIAR #70)	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional vegetation and wetlands information provided
Addendum 8 (Part C) (CIAR #89)	AER-R2-8	Wetlands, littoral zone of end pit lake	Additional Information
	AER-R2-9	Whitebark pine significance rating	
Addendum 8 (CIAR #89)	Appendix A-1, Section 10.0	Cumulative Effects Assessment - Vegetation and Wetlands	This report supersedes the cumulative effects discussion in the EIA, Section E.8.4; and Consultant Report #8, Section 4.0
Addendum 9 (CIAR #185)	-	Traditional Land Use information	Additional Information
Addendum 10 (CIAR #251)	JRP IR-2.1	Common tall manna grass *Glyceria grandis*	Additional Information
	JRP IR-2.2	Reclamation timelines at closure	
	JRP IR-2.3	Whitebark case studies	
	JRP IR-2.4	Rough fescue	
	JRP IR-2.6	Conservation and Reclamation Plan Update	This Plan supersedes EIA, Section F. This is the most current version of the Conservation and Reclamation Plan.
	Appendix 2.6-1		
Addendum 11 (CIAR #313)	NA	NA	No additional vegetation and wetlands information provided
Addendum 12	Section B, Table 2-8	Vegetation Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

WILDLIFE

A reference list has been created to indicate where information on wildlife can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-9.

Table 1-9 Wildlife Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.9	Wildlife Environmental Assessment Overview	Information submitted in the 2016 EIA See below for updates to Consultant Report #12
	Section A.11.9	Wildlife Mitigations and Monitoring Overview	
	Section E.9	Summary of the project wide Wildlife Impact Assessment	
	Consultant Report #9	Wildlife Impact Assessment	
	Consultant Report #12, Section H	Wildlife Screening Risk Assessment	
Addendum 1 (CIAR #44)	-	Wildlife Addendum: Little Brown Bat	Additional Information
Addendum 2 (CIAR #53)	Not Applicable (NA)	NA	No additional wildlife information provided
Addendum 3 (CIAR #54)	NA	NA	No additional wildlife information provided
Addendum 4, Attachment 2 (CIAR #55)	CEAA IR-13	Little brown bat	Additional Information
	CEAA IR-14; Appendix 14A	Wildlife Risk Assessment Update to include ingestion pathways	
	CEAA IR-15	Wildlife Risk Assessment	
	CEAA IR-16	Wildlife Risk Assessment	
	CEAA IR-22	Significance of Project effects and 20% threshold	
	CEAA IR-25	Effects of climate change on SARA listed species	
Addendum 4, Attachment 3 (CIAR #55)	CEAA IR-5; Appendix 5A	Bat Hibernacula Program – Swarming Survey Workplan	Additional Information

Table 1-9 Wildlife Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 5 (CIAR #69)	AER-R1-132	Legislation and Policy	Additional Information
	AER-R1-133	Baseline bird surveys	
	AER-R1-134	Raptor essential habitat nest survey	
	AER-R1-135	Amphibian surveys	
	AER-R1-136	Breeding songbird surveys	
	AER-R1-137	Owl baseline habitat	
	AER-R1-138	Short-eared owl survey	
	AER-R1-139	Raptor nest surveys	
	AER-R1-140	Zone of influence	
	AER-R1-141	Significance criteria for residual effects	
	AER-R1-142	Ungulate seasonal movements	
	AER-R1-143	Migratory birds	
	AER-R1-144	Golf course	
	AER-R1-145	Moose cumulative effects	
	AER-R1-146	Significance criteria for residual effects	
	AER-R1-147	Significance 20% threshold	
	AER-R1-148	Wildlife crossing mitigation at the coal conveyor	
	AER-R1-149	Baseline, seasonal tracking	
	AER-R1-150	Clark’s nutcracker	
	AER-R1-151	Bat survey station location	
	AER-R1-152	Wildlife risk assessment, bioaccumulation, lentic aquatic habitats	
Addendum 6 (CIAR #70)	CEAA-R1-1; Appendix A-1	Bat Hibernacula Report: Field Program	Additional Information
	ECCC-R1-21	Exposure of aquatic and terrestrial biota to contaminants of concern; monitoring	
	ECCC-R1-22	Inclusion of amphibian receptors in the Wildlife Risk Assessment	
	Appendix A-2	Cumulative Effects Assessment, Section 4.0 Migratory Birds and SARA listed Species	This has been superseded by Addendum 8, Appendix A-1

Table 1-9 Wildlife Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional wildlife information provided
Addendum 8 (Part A) (CIAR #89)	CEAA-R2-1	Clark’s Nutcracker	Additional Information
Addendum 8 (Part B) (CIAR #89)	ECCC-R2-4	Little brown myotis hibernacula	Additional Information
Addendum 8 (Part C) (CIAR #89)	AER-R2-74	Common Nighthawk	Additional Information
	AER-R2-75	Planned development case: Golf Course	
	AER-R2-76	Clark's Nutcracker	
Addendum 8 (CIAR #89)	Appendix A-1, Section 11	Cumulative Effects Assessment, Wildlife	This is the most current version of the cumulative effects discussion for wildlife. This report supersedes the cumulative effects discussions in: -EIA, Section E.9.4; -EIA, Consultant Report #9, Section 6.0; -Addendum 6, Appendix A-2, Section 4.0; and -Addendum 5, IR 145
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information
Addendum 10 (CIAR #251)	JRP IR-5.34	Baird’s sparrow and American badger	American badger superseded by Addendum 11, JRP IR-6.9
	JRP IR-5.35	VC selection	Additional Information
	JRP IR-5.36	Significance threshold of 20%	
	JRP IR-5.37	Limiting Habitat Factors	
	JRP IR-5.38	Grizzly road density errata	Supersedes parts of EIA, Consultant Report #9, Sections 3.2.5.4.3 and 4.4.8.3, as noted in the IR
	JRP IR-5.39; Appendix 5.39-1	Wildlife Mitigation and Monitoring Plan	Additional Information

Table 1-9 Wildlife Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	JRP IR-5.40	Plains Bison	
Addendum 11 (CIAR #313)	JRP IR-6.9	American badger	Supersedes Addendum 10, JRP IR-5.34
	JRP IR-6.10	Common nighthawk and bobolink	Table 6.10-1 supersedes EIA, Consultant Report #9, Table 4.6-1
	JRP IR-6.28; Appendix 6.28-1	Wildlife Screen Risk Assessment-Addendum 1 to include water exposure pathways	Additional information to the original WRA (Consultant Report #12, Appendix H) and the first update (Addendum 4, Attachment 2, Appendix 14A)
Addendum 12	JRP IR-7.1	Wildlife risk assessment	Additional Information
	Section B, Table 2-9	Wildlife Mitigation and Commitments Summary Table	Summary of exiting information, it does not supersede

LAND AND RESOURCE USE

A reference list has been created to indicate where information on land and resource use can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-10.

Table 1-10 Land and Resource Use Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.10	Land and Resource Use Environmental Assessment Overview	Information submitted in the 2016 EIA See notes on Addendum 3, 7, and 8 related to the PLA application.
	Section A.11.10	Land Use Mitigations and Monitoring Overview	
	Section E.10	Summary of the project wide Land and Resource Use Impact Assessment	
	Consultant Report #10	Land and Resource Use Impact Assessment	
	Appendix 11	*Public Lands Act* (PLA) Application	

Table 1-10 Land and Resource Use Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional land and resource use information provided
Addendum 2 (CIAR #53)	NA	NA	No additional land and resource use information provided
Addendum 3 (CIAR #54)	-	*Public Lands Act* Applications	Supersedes EIA, Appendix 11, see notes on Addendum 7 and 8 regarding PLA environmental field reports (EFRs).
Addendum 4 (CIAR #55)	NA	NA	No additional land and resource use information provided-
Addendum 5 (CIAR #69)	NA	NA	No additional land and resource use information provided-
Addendum 6 (CIAR #70)	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	IR 1 Appendix A-1	Environmental Field Reports	Additional Information
Addendum 8 (Part C) (CIAR #89)	AER-R2-77	*Public Lands Act*, updated Environmental Field Reports	Supersedes relevant EFRs from Addendum 7
	AER-R2-78	Historical Resources	
	AER-R2-79	*Public Lands Act*, updated Environmental Field Reports	
	AER-R2-80	*Public Lands Act*, updated Environmental Field Reports	
	AER-R2-81	*Public Lands Act*, updated Environmental Field Reports	
	Appendix C-7 to C-10	Updated Environmental Field Reports	
Addendum 8 (CIAR #89)	Appendix A-1, Section 13	Cumulative Effects Assessment, Land Use	Reiterates previously provided information
Addendum 9 (CIAR #185)	-	Consultation Update Report: Traditional Land Use	Additional Information

Table 1-10 Land and Resource Use Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 10 (CIAR #251)	JRP IR-3.3	Livingstone Land Footprint Management Plan	Additional Information
	JRP IR-3.4	Public Lands Application Consents	
	JRP IR-3.5	Access	
	JRP IR-4.5; Appendix 4.5-1	Access Management Plan	
	JRP IR-5.41	Updated figure outlining past activities considered in the cumulative effects assessment	Figure 5.41-2 supersedes Addendum 8, Appendix A-1, Figure 2-2
	JRP IR-5.42	Livingstone Land Footprint Management Plan	Additional Information
Addendum 11 (CIAR #313)	JRP IR-6.2	Consent and clearances	Additional Information
Addendum 12	Section B, Table 2-10	Land Use and Historical Resources Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

Socio-Economics

A reference list has been created to indicate where information on socio-economics can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-11.

Table 1-11 Socio-Economic Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.11	Socio-Economics Assessment Overview	Information submitted in the 2016 EIA See below for updates to Consultant Report #11
	Section A.11.11	Socio-Economics Mitigations and Monitoring Overview	
	Section E.11	Summary of the project side Socio-Economics Impact Assessment	
	Consultant Report #11	Socio-Economic Impact Assessment	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional socio-economic information provided
Addendum 2 (CIAR #53)	NA	NA	No additional socio-economic information provided

Table 1-11 Socio-Economic Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 3 (CIAR #54)	NA	NA	No additional socio-economic information provided
Addendum 4, (CIAR #55)	NA	NA	No additional socio-economic information provided
Addendum 5 (CIAR #69)	AER-R1-49	Regional waste transfer station, municipal infrastructure	Additional Information
	AER-R1-50	Updates to SEIA since 2016	Table 50-1 supersedes the population estimates in EIA, Consultant Report #11, Table 5.2
	AER-R1-51	RSA boundaries, employment	Additional Information
	AER-R1-52	Construction schedule	
	AER-R1-53	Coordination with Teck	
	AER-R1-54	Social services, childcare, school capacity	
	AER-R1-55	Access, trails, TLU areas	
	AER-R1-56	Public access	
	AER-R1-57	Sensitive features	
	AER-R1-58	Access management plan metrics	
	AER-R1-59	Traditional land use	
	AER-R1-60	Commitments to First Nations	
	AER-R1-61	Old Man River, Weasel Valley	
	AER-R1-62	Transportation to site	
	AER-R1-63	Camp	
	AER-R1-64	Temporary accommodations	
	AER-R1-65	Hotel capacity	
	AER-R1-66	Employment	
	AER-R1-67	Revenue sharing	
	AER-R1-68	Royalty forecast	
	AER-R1-69	license fees	
	AER-R1-70	Fly fishing outfitters	
	AER-R1-71	Socio-Economic monitoring	
	AER-R1-72	Assessment of alternative means	
Addendum 6 (CIAR #70)	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede

Table 1-11 Socio-Economic Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 7 (CIAR #72)	NA	NA	No additional socio-economic information provided
Addendum 8 (Part C) (CIAR #89)	AER-R2-42	Sparwood	Additional Information
	AER-R2-43	TLU incorporation into reclamation	
	AER-R2-44	Employment Indigenous groups	
	AER-R2-45	Royalty forecast	
Addendum 8 (CIAR #89)	Appendix A-1, Section 12	Cumulative Effects Assessment, Socio-Economics	This report supersedes the cumulative effects discussion in the EIA, Section E.11.4. Table 12.5 replaces Table 5.2 presented in EIA, Consultant Report #11, Section 5.3.1.2.
Addendum 9 (CIAR #185)	NA	NA	No additional socio-economic information provided
Addendum 10 (CIAR #251)	JRP IR-3.6	Tax and Coal Pricing	Additional Information
	JRP IR-3.7	Municipal infrastructure and Highway 3	
	JRP IR-3.8	Autonomous Vehicles	
Addendum 11 (CIAR #313)	JRP IR-6.3	Price forecasts, projected revenues	Supersedes the previous price forecasts in Consultant Report #11 and E.11.7 of the EIA, and JRP IR-3.6
Addendum 12	Section B, Table 2-11	Socio-Economics Mitigation and Commitments Summary Table	Additional Information

Human Health

A reference list has been created to indicate where information on human health can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-12.

Table 1-12 Human Health Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.12	Human Health Assessment Overview	Information submitted in the 2016 EIA Consultant Report #12 has been superseded by Addendum 10, Appendix 4.9-1
	Section A.11.12	Human Health Mitigations and Monitoring Overview	
	Section E.12	Summary of the Human Health Risk Assessment	
	Consultant Report #12	Human Health Risk Assessment	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional human health information provided
Addendum 2 (CIAR #53)	NA	NA	No additional human health information provided
Addendum 3 (CIAR #54)	NA	NA	No additional human health information provided
Addendum 4, Attachment 2 (CIAR #55)	17	Exceedances NO_2, $PM_{2.5}$, PM_{10}	Additional Information
	18	Food consumption rates	Supersedes EIA, Consultant Report #12, Table 5.1.3-2
	19	Health effects from leachate	Additional Information
Addendum 5 (CIAR #69)	AER-R1-152	Criteria for COPC biomagnification; protecting lentic aquatic habitats	Additional Information
	AER-R1-153	Baseline information	
	AER-R1-154	Diesel particulate matter	
	AER-R1-155	Emission factor	
	AER-R1-156	Regional health services and concerns	
	AER-R1-157	Multimedia assessment	
	AER-R1-158	Traffic	
	AER-R1-159	Hazard Quotient	

Table 1-12 Human Health Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	AER-R1-160	Typographical error in EIA, Consultant Report #12, Table 6.2-3	Correction
	AER-R1-161	Indigenous groups consultation	Additional Information
	AER-R1-162	Health regions	
	AER-R1-163	Drinking water	
	AER-R1-164	Chromium	
	AER-R1-165	Receptors, workers and visitors	
	AER-R1-166	Receptor locations	
	AER-R1-167	Receptors, workers and visitors	
	AER-R1-168	Baseline water and fish tissue	
	AER-R1-169	Toxicity endpoint for lead	
	AER-R1-170	Toxicity endpoint groups, hazard quotients for mixtures	Provided tables supersede EIA, Consultant Report #12, Table 5.3.2-1, Table 6.1-6, Table 6.2-2, 6.3-2,
	AER-R1-171	Hazard Quotients and toxicity endpoint groups	Additional Information; see corresponding supersede note on Addendum 10, JRP IR-4.9
	AER-R1-172	Hazard Quotients	Additional Information
Addendum 6 (CIAR #70)	HC-R1-1	Diesel particulate matter	Additional Information
	HC-R1-2	SO_2 predictions	
	HC-R1-3	Updated NO_2 predictions	Table HC 3-2 supersedes EIA, Consultant Report #12, Table 6.1-2
	HC-R1-4	Benzene, toxicological reference value	Additional Information
	HC-R1-5	Cumulative effects	
	HC-R1-6	$PM_{2.5}$ acute inhalation update, PM from coal dust	Supersedes EIA, Consultant Report #12, Table 5.3.2-1
	HC-R1-7	Vegetation samples	Additional Information
	HC-R1-8	Methylmercury	
	HC-R1-9	Ingestion rates	

Table 1-12 Human Health Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	HC-R1-10	Toxicological reference values	
	HC-R1-11	Benzo(a)pyrene, correction to the chronic oral exposure limit	Correction to EIA, Consultant Report #12, Table 5.3.1-3
	HC-R1-12	Toxicity reference values	Additional Information
	HC-R1-13	Risk quotient of 1.0	
	HC-R1-14	End pit lake	
	HC-R1-15	Drinking water, recreational use, surface and groundwater quality	
	HC-R1-16	Downstream drinking water treatment, emergency response	
Addendum 7 (CIAR #72)	NA	NA	No additional human health information provided-
Addendum 8 (Part A) (CIAR #89)	CEAA-R2-3	Rail traffic emissions, cumulative effects	Additional Information
Addendum 8 (Part B) (CIAR #89)	HC-R2-1	Diesel particulate matter	Additional Information
	HC-R2-2	Updated hazard quotient risk results for NO_2, risk quotients for receptors	Table HC-R2-2-1 supersedes EIA, Consultant Report #12, Table 6.1-2 and Addendum 6, HC-R1-3, Table HC-3-2
	HC-R2-3	$PM_{2.5}$, risk quotients for all receptors	Additional Information
	HC-R2-4	PM_{10} and $PM_{2.5}$ mitigation	
	HC-R2-5	Deposition rates	
	HC-R2-6	Fish ingestion rates	
	HC-R2-7	Fish ingestion rates	
	HC-R2-8	Toxicological Reference Values	
	HC-R2-9	Incremental Lifetime Cancer Risk	
	HC-R2-10	Incremental Lifetime Cancer Risk, hazard quotient	
	HC-R2-11	Reassessing with a hazard quotient of 0.2	
	HC-R2-12	Gold and Blairmore Creek drinking water	

Table 1-12 Human Health Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 8 (Part C) (CIAR #89)	AER-R2-46	Diesel particulate matter	Additional Information
	AER-R2-47	Pre-existing health and lung issues	
	AER-R2-48	Worker definition and exposure, community exposure	
Addendum 8 (CIAR #89)	Appendix A-1, Section 14	Cumulative Effects Assessment, Health	This report supersedes the cumulative effects discussions in the EIA, Section E.12.4
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information
Addendum 10 (CIAR #251)	JRP IR-4.9; Appendix 4.9-1	Updated Health and Wildlife Screening Risk Assessment	This report supersedes EIA, Section E.12 and Consultant Report #12 and incorporates IR clarifications to date.
	JRP IR-4.10	Fugitive dust emissions, constituents of coal dust, silica dust	Additional Information
	JRP IR-4.11	Hazard quotient for naphthalene	
	JRP IR-4.12	Country foods, consultation	
	JRP IR-4.13	Country foods, holistic health	
	JRP IR-4.14	Country foods, manganese	
	JRP IR-4.15	Groundwater pathway	
	JRP IR-4.16	Human health and wildfire	
Addendum 11 (CIAR #313)	JRP IR-6.27; Appendix 6.27-1	Updated Human Health Risk Assessment (HHRA-Addendum 1). This update includes exposure pathways related to water.	This report is supplemental to Appendix 4.9-1 (Addendum 10)
Addendum 12	JRP IR-7.1	Human health risk assessment, COPC water concentrations, detailed calculations	Additional Information
	Section B, Table 2-12	Human Health Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

HISTORICAL RESOURCES

A reference list has been created to indicate where information on historical resources can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-13.

Table 1-13 Historical Resources Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.10.13	Historic Resources Assessment Overview	Information submitted in the 2016 EIA
	Section A.11.13	Historic Resources Mitigations and Monitoring Overview	
	Section E.13	Summary of the Historical Resources Impact Assessment.	
Historical Resources Impact Assessment	-	Historical Resources Impact Assessment submitted to Alberta Culture and Tourism on March 4, 2016.	Not available for public release
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional historical resources information provided
Addendum 2 (CIAR #53)	NA	NA	No additional historical resources information provided
Addendum 3 (CIAR #54)	NA	NA	No additional historical resources information provided
Addendum 4 (CIAR #55)	NA	NA	No additional historical resources information provided
Addendum 5 (CIAR #69)	NA	NA	No additional historical resources information provided
Addendum 6 (CIAR #70)	NA	NA	No additional historical resources information provided
Addendum 7 (CIAR #72)	NA	NA	No additional historical resources information provided
Addendum 8 (Part C) (CIAR #89)	AER-R2-78	Status of the *Historical Resources Act* clearance	Additional Information
Addendum 9 (CIAR #185)	-	Traditional Land Use Studies	Additional Information

Table 1-13 Historical Resources Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 10 (CIAR #251)	NA	NA	No additional historical resources information provided
Addendum 11 (CIAR #313)	JRP IR-6.4; Appendix 6.4-2	Status update of the HRIA and any updates as a result of recent field work along with Alberta Culture's *Historical Resources Act* Requirements: Schedule of Requirements (Issued December 2017)	Additional Information
Addendum 12	Section B, Table 2-10	Land Use and Historical Resources Mitigation and Commitments Summary Table	Summary of existing information, it does not supersede

EFFECTS ON INDIGENOUS GROUPS

A reference list has been created to indicate where information on effects on Indigenous groups can be found on the record within the EIA or specific information request responses within the submitted Addenda. This reference list is provided below as Table 1-14.

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
EIA (CIAR #42)	Section A.9	Aboriginal Consultation Summary	Information submitted in the 2016 EIS Section H is superseded by Addendum 10, Appendix 4.1-1
	Section G	Stakeholder Engagement	
	Section H	Project wide Impact Assessment.	
	Appendix 6	Public Engagement Records	
	Appendix 7	Aboriginal Consultation Records	
Addendum 1 (CIAR #44)	Not Applicable (NA)	NA	No additional Indigenous information provided
Addendum 2 (CIAR #53)	NA	NA	No additional Indigenous information provided
Addendum 3 (CIAR #54)	NA	NA	No additional Indigenous information provided
Addendum 4, (CIAR #55)	NA	NA	No additional Indigenous information provided

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 5 (CIAR #69)	AER-R1-1	Mitigation proposed by First Nations	Additional Information
	AER-R1-2	Concerns and Responses tables: Alberta Aboriginal Consultation Office (ACO) format	
	AER-R1-3	Traditional Use	
	AER-R1-4	TK/TU Studies	
	AER-R1-5	Concerns and Responses tables	
	AER-R1-6	Concerns and Responses tables	
	AER-R1-7	Project footprint overlap with traditional territory	
	AER-R1-8	Consultation activities	
	AER-R1-9	Concerns and Responses tables	
	AER-R1-10	Kainai trapping	
	AER-R1-11	Kainai fishing	
	AER-R1-12	Kainai fishing	
	AER-R1-13	Concerns and Responses tables	
	AER-R1-14	Hunting: Concerns and Responses tables	
	AER-R1-15	Residual Effects Characterization	
	AER-R1-16	Monitoring programs	
	AER-R1-17	Hunting, consultation	
	AER-R1-18	Hunting, consultation	
	AER-R1-19	Eagle trapping	
	AER-R1-20	Reclamation plan input	
	AER-R1-21	Fishing	
	AER-R1-22	Siksika fishing	
	AER-R1-23	Siksika hunting	
	AER-R1-24	Siksika species for harvesting	
	AER-R1-25	Siksika fishing	
	AER-R1-26	Siksika plant species	
	AER-R1-27	Stoney Nation species of interest	
	AER-R1-28	Stoney Nation fishing practices	
	AER-R1-29	Stoney Nation plant species	

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	AER-R1-30	Stoney Nation cumulative effects	
	AER-R1-31	Tsuut'ina TK/TU Study	
	AER-R1-32	Tsuut'ina concerns and responses	
	AER-R1-33	Tsuut'ina TK/TU sites	
	AER-R1-34	Tsuut'ina fishing	
	AER-R1-35	Consultation records	
	AER-R1-36	ACO approved First Nation consultation plan	
	AER-R1-37	Locations of TK/TU sites	
	AER-R1-38	Incorporation of TK/TU information	
	AER-R1-39	Selection of VC fish species	
	AER-R1-40	Input to aquatic monitoring plans	
	AER-R1-41	Current and traditional use	
	AER-R1-42	TEK vegetation mitigation	
	AER-R1-43	TEK vegetation mitigation	
	AER-R1-44	TEK vegetation mitigation	
	AER-R1-45	Wildlife	
	AER-R1-46	Socio-Economic mitigation	
	Appendix A-1	ACO-Specific Concern and Response Tables	Superseded by Addendum 8, Appendix C-4
	Appendix A-2	Chronology of Key Consultation Activities: continuation of Tables in EIA, Section H with additional consultation since EIA submissions in July 2016	Superseded by Addendum 8, Appendix C-5
	AER-R1-217	Errata: Siksika Nation overview, typographical error	Correction to EIA Section H, H.5.1
	AER-R1-218 to 221	Errata: Nation overviews: correction as Treaty 7 Management Corporation no longer exists	Correction to EIA, Section H: H.3.1, H.4.1, H.5.1, H.6.1

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
Addendum 6 (CIAR #70)	Appendix C-1	Piikani Technical Review	Additional Information
	Appendix A-2	Cumulative Effects Assessment, Section 5.0 Aboriginal Groups	Supersedes Section EIA, H Cumulative effects discussion, and is superseded by Addendum 8, Appendix A-1
	Appendix A-3	Summary of Potential Effects, Mitigations, and Impact Ratings	Summary of existing information, it does not supersede
Addendum 7 (CIAR #72)	NA	NA	No additional Aboriginal information provided
Addendum 8 (Part A) (CIAR #89)	CEAA 1	Update on the nature and status of additional work being carried out by Benga with Treaty 7 First Nations and other Indigenous groups	Additional Information
Addendum 8 (Part C) (CIAR #89)	AER-R2-49; Appendix C-4	Updated Concern and response tables (ACO tables); incorporation of concerns into EIA; tables were updated to February 2018	These supersede Addendum 5, Appendix A-1,
	AER-R2-50	TU information and incorporation into EIA	Additional Information
	AER-R2-51	Updated Issues and Concerns Tables	
	AER-R2-52	Effectiveness of mitigation	
	AER-R2-53	Traditional territory	
	AER-R2-54; Appendix C-5	Chronology of Key Consultation Activities; Tables were updated to December 2017	These tables supersede those in Addendum 5, Appendix A-2 and EIA, Section H (Tables H.3.2-1, H.4.2-1, H.5.2-1, H.6.2-1, H.7.2-1)
	AER-R2-55	Concerns related to TK/TU sites	Additional Information
	Appendix C-6	Consultation Issues Tracking Tables	
	AER-R2-56	Hunting	
	AER-R2-57	Concerns and responses and incorporation into EIA	
	AER-R2-58	Conservation and reclamation plan	
	AER-R2-59	Reclamation	
	AER-R2-60	Siksika species for harvesting	

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	AER-R2-61	Traditional harvest	
	AER-R2-62	Stoney Nation species of interest	
	AER-R2-63	Stoney Nation TU report	
	AER-R2-64	Typographic correction to a statement in H.6.3.3 (EIA)	Correction to a sentence in Section H.6.3.3, EIA
	AER-R2-65	Stoney Nation cumulative effects	Additional Information
	AER-R2-66	Tsuut'ina fishing and plant gathering	
	AER-R2-67	Tsuut'ina TK/TU sites	
	AER-R2-68	Maps of TK sites	
	AER-R2-69	Incorporation of TK/TU information	
	AER-R2-70	Aquatic Monitoring Plan consultation	
	AER-R2-71	Treaty 7 Nations input related to TK vegetation	
	AER-R2-72	Mitigation	
	AER-R2-73	Socio-Economic mitigation	
Addendum 8 (CIAR #89)	Appendix A-1, Section 15	Cumulative Effects Assessment, Aboriginal Groups	This report supersedes the cumulative effects discussion in the EIA, Section H, but is superseded by Addendum 10, Appendix 4.1-1
Addendum 9 (CIAR #185)	-	Consultation Update Report, Traditional Land Use studies	Additional Information
Addendum 10 (CIAR #251)	JRP IR-4.1; Appendix 4.1-1	An Updated Assessment of the Potential Effects of the Grassy Mountain Project on Indigenous Groups	Supersedes: -EIA Section H, and -Addendum 8, Appendix A-1, Section 15
	Appendix 4.1-2	Mitigation related to Current Use of Lands and Resources for Traditional Purposes	Additional Information
	JRP IR-4.2	Modern Buffalo Treaty	
	JRP IR-4.3	VC Selection	
	Appendix 4.3-1	Wildlife and Fisheries Identified as Species of Interest by Indigenous Groups	

Table 1-14 Effects on Indigenous Groups Reference List

EIA or Addendum #	Sections/IR#	Topic/Keywords	Notes
	JRP IR-4.4	Cumulative Effects	
	JRP IR-4.5; Appendix 4.5-1	Access Management Plan	
	JRP IR-4.6	Indigenous Rights, Land Use and Culture – View of Indigenous Groups	
	JRP IR-4.7	Consultation	
	JRP IR-4.8	Louis Bull Tribe, Montana First Nation, Erminskin Cree Nation	
Addendum 11 (CIAR #313)	JRP IR-6.4	HRA recommendations and AB Culture HRA Requirements	Additional Information
	JRP IR-6.5	Mitigation for current use of lands and resources for traditional purposes and physical and cultural heritage	
	JRP IR-6.6	Intangible aspects of cultural heritage	
	JRP IR-6.7	Residual effects on current use of lands and resources for traditional purposes and physical and cultural heritage	
	JRP IR-6.8	Cumulative effects on current use of lands and resources for traditional purposes and physical and cultural heritage	

2. SUMMARY TABLES OF COMMITMENTS AND MITIGATION FOR EACH VALUED COMPONENT

2. An updated, comprehensive, and consolidated table of commitments and mitigation measures for each valued component. A template for this table is included as Attachment 1. Benga is encouraged to use this template in responding to this request.

Response:

As outlined in the Panel's letter dated April 8, 2020, summary tables to comply with Section 7 of the *Environmental Impact Statement Guidelines*, under the *Canadian Environmental Assessment Act, 2012* have been previously provided in Appendix 2B, 2C, and 2D in the 2016 EIA (CIAR #42) as well as in Addendum 11, JRP IR-6.5, Tables 6.5-2 through 6.5-7 (CIAR #313) specifically for current use of lands and resources for traditional purposes, and physical and cultural heritage.

In addition, an updated table organized by VC summarizing the potential effects, mitigations and impact ratings for Project VCs was provided as requested in Addendum 6, Section A, CEAA IR 3, Appendix A-3 (CIAR #70).

The following response fulfills the Panel's request for updated summary tables that include mitigation up to the end of Addendum 12. Tables 2-1 to 2-12 provided below addresses request #2 in the Panel's letter dated April 8, 2020 and follows the provided template.

As requested in the letter, the information contained within Tables 6.5-2 through 6.5-7 from Addendum 11, JRP IR-6.5 (CIAR #313) were relied upon to populate the tables for this request. The mitigation contained within the tables provided in response to Addendum 11, JRP IR-6.5 (CIAR #313) will be found within the tables provided here, split into appropriate discipline specific sections. It is important to note, however, that there will be more mitigation in the tables provided here, beyond that contained within Tables 6.5.2 to 6.5-7, because those tables were specific to effects on current use of land and resources for traditional purposes and physical and cultural heritage, whereas this request covers the breadth of the entire Project.

The updated, comprehensive, and consolidated table of commitments and mitigation measures for each VC are organized as follows:

- Table 2-1 Air Quality Mitigation and Commitments Summary Table
- Table 2-2 Noise Mitigation and Commitments Summary Table
- Table 2-3 Hydrogeology Mitigation and Commitments Summary Table
- Table 2-4 Hydrology Mitigation and Commitments Summary Table
- Table 2-5 Surface Water Quality Mitigation and Commitments Summary Table
- Table 2-6 Aquatic Ecology Mitigation and Commitments Summary Table

- Table 2-7 Soil and Terrain Mitigation and Commitments Summary Table
- Table 2-8 Vegetation and Wetlands Mitigation and Commitments Summary Table
- Table 2-9 Wildlife Mitigation and Commitments Summary Table
- Table 2-10 Land Use and Historical Resources Mitigation and Commitments Summary Table
- Table 2-11 Socio-Economics Mitigation and Commitments Summary Table
- Table 2-12 Human Health and Wildlife Health Mitigation and Commitments Summary Table

AIR QUALITY

A consolidated table of commitments and mitigation measures related to air quality has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-1.

Table 2-1 Air Quality (AQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Changes to air quality based on construction and operational activities	Changes in assessed COPCs such as NO_2, SO_2, CO, $PM_{2.5}$, PM_{10}, TSP can result in effect to human health, visibility impairment and/or nuisance effects. Potential particulate sources for the Project include fugitive dust emissions from wheel entrainment and mining and coal processing facility operations as well as from soil and coal handling activities. Fine particulates are also generated by diesel-fired equipment and are created in secondary atmospheric reactions. Small amounts of fugitive VOCs and PAHs and specific metals may be emitted by the diesel combustion equipment. Sources of metals include exhaust emissions from diesel combustion and fugitive emissions from the re-suspension of road dust and material handling in pit operations.	1. Benga's heavy duty mine equipment and fleet will be equipped with Tier 4 engines.	Air Quality Monitoring Plan, (Addendum 10, Appendix 1.3-1, Section 5, CIAR #251) also EIA, Section E.1.4.1, CIAR #42	The magnitude of residual impacts associated with changes to air quality was moderate for combustion-related emissions, including SO_2, NO_2, and CO. For these parameters, actual increases in concentration or deposition were low even when relative increases were large given the isolated nature of the project. Project emissions cease after operations cease. For most air quality emissions associated with mining operations, effects are largest at the source and decrease with distance and are therefore local not regional in nature. Air modelling was conducting assuming mitigation was in place. Blasting resulted in large relative increases in predicted maximum 1-hour concentrations of combustion emissions (SO_2, NO_2, CO) on the eastern pit boundary. For longer averaging periods, the actual and relative increases due to the Project were negligible. The Alberta objectives were met for all averaging periods for SO_2, NO_2 and CO at all locations in the Baseline, Project-only, and Application cases. The 24-hour $PM_{2.5}$ Alberta and Canadian objectives were not exceeded at or beyond the Mine Permit Boundary for any assessment case. PM_{10} daily predictions exceeded the BC objectives for all assessment cases, including the Baseline case, as a result of community and highway emissions. TSP predicted concentrations were above the Alberta objectives in all assessment cases. Exceedances for daily TSP were also predicted at a number of special receptors in Application and Baseline cases, but the Project contribution was not significant. For the Application case, locations of maximums shifted to the eastern bit boundary, as a result of fugitive dust emissions from the haul road which is located very close to the boundary of the pit. Predicted concentrations of all VOCs, PAHs and metals were less than AAAQOs at and beyond the MPB in Baseline and Application cases.	Residual effect not significant
		2. Benga will investigate alternative ammonium nitrate/fuel oil (ANFO) formulations that reduce NO_x emissions during blasting.			
		3. Propane or natural gas will be used for coal plant building heating.			
		4. Blasting occurrences will be spread over two or more hours of the day, or spread out over the course of the week, to reduce hourly blasting emissions in any one hour.	Addendum 10, JRP IR-1.6, CIAR #251		
		5. The mine will have an integrated dispatch system to provide overall control of individual trucks and allocating sequencing and routing to minimize delays and unnecessary idling and fuel wastage. The fleet will also be managed to minimize fuel consumption by minimizing haul road length and gradient. The fleet will be regularly maintained, with one of the goals being to minimize fuel consumption and thereby emissions.	Addendum 8, ECCC-R2-6, CIAR #89 and Air Quality Monitoring Plan, (Addendum 10, Appendix 1.3-1, Section 5, CIAR #251)		
		6. The Project will use low-sulphur diesel for the mining fleet.	Air Quality Monitoring Plan, (Addendum 10, Appendix 1.3-1, Section 5, CIAR #251)		
		7. Benga will systemically apply water to haul roads and the plant access road to minimize dust using a dedicated water truck.	Air Quality Monitoring Plan, (Addendum 10, Appendix 1.3-1, Section 5, CIAR #251) also -EIA, CR #1, Section 6.6, CIAR #42 -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313		
		8.Snow cover will be retained on the road when safe to do so to minimize dust in the winter.			
		9. Gravel or crushed rock will be used as the underlay on the haul roads to minimize dust.			
		10. A grader will be used to maintain the active surface of the mine roads to move the silt particles to the inactive portion (side) of the road or cover the active portion with coarser material.			
		11.Mined areas will be reclaimed progressively and revegetated to reduce windblown fugitive dust emissions from exposed land.			
		12. Trees and bush will be preserved around the mine and plant perimeter to help trap dust emissions from mining activities and reduce dust concentrations farther from mining activities.			
		13. The coal processing plant will be contained within an enclosed building and coal material handling will be *via* covered conveyors.			
		14. Dust generation from transferring coal from the conveyor to the stockpile will be minimized by the use of luffing stackers (those that can lower and raise their boom) to minimize the drop height and drop time of the coal.			
		15. The rail load-out will have full cladding on the sides of the load-out structure to create a wind shelter and will utilize a movable discharge chute located as close as practical to the coal within the rail cars.			
		16. Speeds on mine roads will be limited to 50 km/hr or less.			

Table 2-1 Air Quality (AQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
		17. Benga will use a water-based, non-toxic dust suppression product such as Envirobind DCT (or equivalent) to minimize wind-blown dust from rail cars during transport. The manufacturer has committed to working with Benga's engineers to develop the spray applicator unit for the loadout, to provide guidance on the "make down" unit that mixes the dry product with water for on-site storage and then further mixes it during application, and to monitoring and optimization of the treatment amounts on-site.	Addendum 10, JRP IR-1.1, CIAR #251		
2. Changes to terrestrial and aquatic habitats associated with increased potential acid input (PAI) and nitrogen deposition.	Acidification of soils, vegetation, and waterbodies could affect various valued components within these terrestrial and aquatic environments. Increased nitrogen deposition could result in eutrophication of waterbodies.	1. Potential impacts associated with PAI is mitigated through management of SO_2 and NO_2 emissions. Refer to mitigations AQ-1.1 to AQ-1.17 above which pertain to mitigating effects to air quality and subsequent deposition to terrestrial and aquatic environments.	EIA, CR #1, CIAR #42	The magnitude of residual impacts was low for combustion-related emissions, including VOCs, PAHs, metals, and nitrogen and acid deposition. For these parameters, actual increases in concentration or deposition were low even when relative increases were large given the isolated nature of the project. Project emissions cease after operations cease. For most air quality emissions associated with mining operations, effects are largest at the source and decrease with distance and are therefore local not regional in nature.	Residual effect not significant
		2. Potential impacts of nitrogen deposition is mitigated through the management of NO_x emissions. Refer to mitigations AQ-1.1 to AQ-1.17 above which pertain to mitigating effects to air quality and subsequent deposition to terrestrial and aquatic environments.			Residual effect not significant
3. Changes in ground level concentration of ozone caused by Project emission of ozone precursors, such as NO_x.	Changes in ground level concentration of ozone could result in human health effects.	1. Secondary ozone production is managed by mitigating precursor emissions including NO_x. Refer to mitigations AQ-1.1 to AQ-1.17 above which pertain to mitigating effects to air quality and subsequent deposition to terrestrial and aquatic environments.	EIA, CR #1, CIAR #42	The magnitude of residual effect was low for ozone after mitigation.	Residual effect not significant
4. Changes in ambient odour from mining activities such as blasting and use of diesel equipment.	Changes in odour could be deemed to result in nuisance effects.	1. Mitigation of odours caused by NOx emissions are managed by mitigating NO_x. Refer to mitigations AQ-1.1 to AQ-1.17 above which pertain to mitigating effects to air quality and subsequent deposition to terrestrial and aquatic environments.	EIA, Section E.1.4.1, CIAR #42 -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313	The Project did not change predicted odour frequencies in the community but added a new location with detectable odour on the MPB.	Residual effect not significant
5. Increased greenhouse gas emissions.	Increase in greenhouse gases (*e.g.,* carbon dioxide [CO_2]) will be produced by combustion of diesel from mining equipment and fugitive methane emissions from surface coal mining. Increases in GHG can have potential ecological effects.	1. Emissions due to the mine fleet operation will be managed through operational means such as speed limits, optimizing haul distances, and routine maintenance & upgrades of fleet equipment	GHG Management Plan, Addendum 10, Appendix 1.8-1, CIAR #251	The magnitude of residual effect was low for greenhouse gases after mitigation.	Residual effect not significant
		2. Benga will investigate potential opportunities to increase the fraction of renewable electricity used on site.			
6. Changes in ambient lighting.	Project activities could have an effect on light levels or the visibility of Project operational activities during the day, which may cause nuisance effects to humans or impacts to wildlife.	1. Benga will use low visibility spectrum lights in light stands and on CHPP and rail loadout structures, designed with directional shades to minimize illumination above the lights horizontal line and to direct light to the illuminated feature.	EIA, CR#1, Section 5.16.2, CIAR #42 also -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313	Lighting may cause residual nuisance effects to human and wildlife receptors. Mitigation will reduce but may not eliminate these effects. The magnitude of the residual effect was low for lighting.	Residual effect not significant
		2. An on-demand and adaptive light management strategy will be implemented at the rail loadout during times a train is not onsite for loading during nighttime hours.			
		3. Benga will minimize the amount of train loading during nighttime hours.			
		4. The overland conveyor system will not be equipped with any additional lighting structures.			
		5. Existing vegetation (mature trees) will not be cleared around the perimeter of the Project and along the access road to reduce total viewshed.			
		6. Mobile lighting set ups on the waste rock disposal area will only be used when needed and will be equipped with low visibility spectrum lights positioned (where possible) at the base of existing high points to reduce their associated viewshed.			

NOISE

A consolidated table of commitments and mitigation measures related to noise has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-2.

Table 2-2 Noise (N) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Effects on ambient sounds levels from noise associated with the construction and operation of the mine and mine equipment and the rail loadout.	Changes in noise levels at the surrounding residential and theoretical 1,500 m receptors.	1. Haul trucks will be routed along the western slope of the south disposal area such that the south disposal area itself provides noise shielding between the operating equipment and receptors to the east of the Project.	EIA, Section E.2.5.1, CIAR #42 Addendum 11, JRP IR-6.5, Table 6.5-5, CIAR #313	The noise model assumes the noise mitigation will be in place. The noise modelling results indicate that throughout the life of the Project noise levels during the night-time and day-time, with the addition of the ASLs, will be below the PSLs for all residential and theoretical 1,500 m receptors. The existing noise levels are expected to increase slightly at each receptor when the rail alignment and loadout are operational. Anticipated increases in noise arising from the operating rail alignment and associated loadout components are expected to fall within the range of +5.0 dBA, which is the accepted maximum tolerable increase for residential receptors. The modelling results indicate the possibility of a low frequency tonal noise.	Residual effect not significant
		2. A 15 m tall earthen berm will be built along the eastern edge of the south disposal area. The earthen berm will be constructed and maintained during the day-time and the 15 m earthen berm will be increased in elevation as the height of the south disposal area increases.			
		3. Blasting will occur primarily on weekdays during typical day-time hours and blasting will be minimized during periods of cloud cover.			
		4. Blasting will be limited to smaller more localized blasts to reduce the amount of explosives used at any one time.			
		5. If concerns are raised by local residents regarding noise, Benga will investigate and implement additional noise mitigation measures such as flashing light instead of backup alarm at night, directional backup alarms, *etc.*			
		6. Benga will develop and use a blasting regime that will meet the blasting guidelines contained in Wright and Hopky (1998).	Addendum 10, JRP IR-5.28, CIAR #251 Addendum 1, Updated Section E.6, CIAR #44		
		7. If noise complaint is received, Benga will conduct a comprehensive sound level (CSL) survey in accordance with the requirements of the AER Directive 038.	EIA, Section E, Subsection E.2.5.2, CIAR #42		
		8. Benga will develop a communication protocol with Piikani First Nation, the nearest aboriginal community, for dealing with any complaints or concerns they may have arising from the operation.	Addendum 8, HC-R2-15		

HYDROGEOLOGY

A consolidated table of commitments and mitigation measures related to hydrogeology has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-3.

Table 2-3 Hydrogeology (GW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Effect of Pit Dewatering on Water Quantity Pumping of groundwater out of the open pit will cause the water level (hydraulic head) within the aquifers to decrease. This effect spreads outward as the cone of depression (or drawdown cone) increases with the pit depth and extent with time. This will result in a reduction of hydraulic head in the formation. This could result in a reduction of water available.	Bedrock Aquifers: This could result in a reduction of water available in the adjacent bedrock unit.	1. Pit dewatering is necessary for the mine operations, therefore drawdown of groundwater in the bedrock units will occur during the Project, but effects to bedrock aquifers are predicted to be localized so that no mitigation measures are required.	EIA, Section E, Subsection E.3.5.1, CIAR #42	Results from the numerical models indicate drawdown in the bedrock units associated with pit dewatering will occur within the pit, and will be contained within the LSA and Mine Permit Boundary. Drawdowns at the mine permit boundary are not predicted to be measurable and are expected to be within the natural range of variation. Pit dewatering through sump pumps placed at the bottom of the pit during active mining should have a moderate impact on the quantity of groundwater in bedrock aquifers.	Residual effect not significant
	Downstream water well users: Impacts are not predicted to affect water quality associated with downstream water wells users.	2. No mitigation required for domestic water wells.	EIA, Section E, Subsection E.3.5.1, CIAR #42	Potential effects related to mine dewatering on groundwater quantity in the water wells resulting from Project activities have been assessed as negligible in magnitude.	No residual effect
2. Effects of Mine Waste Rock on Groundwater Quality	Potential water quality effects in Bedrock Aquifer from mine waste rock and mine operations relate to the composition of the coal and waste rock and to the use of explosives for the mining.	1. Monitoring wells will be located downgradient of each waste dump and downgradient of each surge pond. The main focus of the groundwater monitoring program will be on the shallow to intermediate groundwater systems that have the potential to discharge near or into the surface water receptors including Blairmore Creek and Gold Creek.	Addendum 11, JRP IR-6.12, CIAR #313	Mine waste rock and mining operations are assessed to have a low residual impact on the quality of groundwater within bedrock aquifers. Groundwater flow direction patterns for EOM (end-of-mine) and LTC (long-term closure), as predicted by the numerical model, indicate that the pit will capture nearby groundwater towards the pit. It is predicted that the end pit lake will take approximately 13 years to fill. Head distribution indicates that groundwater further away from the pit will flow southward away from Grassy Mountain, but will flow northward from Bluff Mountain. Groundwater accumulating between the two mountains will ultimately discharge to Blairmore and Gold creeks and will therefore be discharged from the groundwater system.	Residual effect not significant
		2. Surface collection of seepage from the toe of the waste rock dumps will be facilitated by grading the foundation to facilitate effective drainage, using end-dumping techniques to establish a coarse permeable layer at the base of the dump, and using collection ditches to capture shallow seepage.	Addendum 10, JRP IR-5.19, CIAR #251 Addendum 11, JRP IR-6.12, CIAR #313		
		3. Installation and pumping of groundwater seepage capture wells will be implemented if ground water quality, as indicated by ground water monitoring, indicates that water quality at receptors such as Gold Creek or Blairmore Creek may be affected.	Addendum 11, JRP IR-6.12, CIAR #313		
	Impacts are not predicted to affect water quality associated with downstream water wells users.	4. No mitigation required for domestic water wells.	EIA, Consultant Report #3, Section 5.3.2.2.2, CIAR #42	Municipal water wells are not predicted to have any groundwater quality impacts associated with mine spoil and mining activities.	No residual effect

Table 2-3 Hydrogeology (GW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
3. Effects of surface facilities on groundwater quality (bedrock aquifers)	Surface facilities relevant to groundwater quality include the wash bay, cold storage, lube storage, fuel farm, potable and wastewater treatment plants, and storage yards. Accidental releases may allow chemicals, either fluids or solids that are dissolved or transported by precipitation events, to seep into the ground where they could alter shallow groundwater quality. The impact to groundwater quality will depend on the volume and type of product released, the characteristics of the surface materials at the release location, the presence of liners, and the underlying groundwater conditions.	1. Refer to mitigations SW-8.1 to SW-8.5 (Table 2-5) that pertain to accidental releases.	EIA, Section E, Subsections E.3.3.1 and E.3.5.1, CIAR #42	As a result of the best management practices for material handling methods, there is a low possibility of potential effects to shallow groundwater quality, except through upset conditions. Surface facilities are assessed to have a low residual impact on groundwater quality within bedrock aquifers.	Residual effect not significant

HYDROLOGY

A consolidated table of commitments and mitigation measures related to hydrology has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-4.

Table 2-4 Hydrology (H) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Effects of Operations and Closure on flow in Blairmore Creek and Gold Creek.	Potential effects on high, average, and low flows in Blairmore Creek and Gold Creek due to changes in the upper reaches of the catchments for both watersheds and increased discharge of treated water to Blairmore Creek.	1. Refer to mitigation AE-1.1 to AE-1.8 (Table 2-6) that pertain to measures and commitments to minimize predicted changes associated with changes in flow on aquatic and/or riparian habitat for fish in Blairmore Creek and Gold Creek.	EIA, Section E, Subsection E.4.5.1, CIAR #42	The Project has developed a water management strategy that facilitates both the management and use of water from the Project. There will be interaction with surface water and groundwater resources during the construction, operation, and closure phases of the Project. The Project has been designed to manage the surface water and groundwater efficiently and to minimize hydrological effects. The magnitude of flow changes are estimated to be low to moderate for Blairmore Creek and low for Gold Creek.	Residual effect not significant
		2. Refer to mitigation AE-2.1 and AE-2.2 (Table 2-6) that pertain to measures and commitments to minimize predicted changes associated with the water management plan on aquatic and/or riparian habitat for fish in Blairmore Creek and Gold Creek.			
		3. In the unlikely event flow from the SBZ to Blairmore Creek is suspended Benga would augment flows in Blairmore Creek to ensure the baseflow is met by pumping stored water from select sedimentation ponds.	Addendum 12, JRP IR-7.3		
2. Effects of Operations and Closure on sediment in Blairmore Creek and Gold Creek.	Effects of increases in sediment concentrations from mining operations on surface water quality and hydrology.	1. Refer to mitigations WQ-1.1 and WQ-1.14 (Table 2-5) that pertain to water management plan, and sediment and erosion control, respectively.	EIA, Section E, Subsection E.4.5.1, CIAR #42	The hydrology effects analysis concluded that the Project's effects on sediment yields and constituent concentrations in receiving watercourses of the LSA due to construction activities will be small and localized.	Residual effect not significant
		2. Refer to mitigations AE-5.1 and AE-5.2 (Table 2-6) that pertain to minimizing changes in fluvial geomorphology (sediment supply and transport mechanisms).			
		3. Sedimentation ponds will be designed to function in a 1:10 year storm event and safely convey up to 1:100-year flood event.			

SURFACE WATER QUALITY

A consolidated table of commitments and mitigation measures related to water quality has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-5.

Table 2-5 Surface Water Quality (WQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Surface water runoff from the Project during construction, operations, closure, and post-closure.	Increased sediment loading and runoff to surface waters could lead to changes in surface water quality.	1.Non-contact water will be directed to sedimentation ponds where it will be treated to remove sediment. Water quality will be checked prior to discharge from the sedimentation ponds to ensure applicable quality guidelines are met.	Addendum 10, JRP IR-5.16, CIAR #251	The hydrology effects analysis concluded that the Project's effects on sediment yields and constituent concentrations in receiving watercourses of the LSA due to construction activities will be small and localized. Sediments re-suspended during watercourse crossing construction will originate from native stream substrates, which are assumed to be uncontaminated. Surface water runoff from mining areas, haul roads, overburden disposal areas and any other disturbed areas, as well as groundwater runoff from the pit, will be collected and directed to sedimentation ponds. Once suspended solids are settled there, water will be discharged to the receiving environment. Based on the planned management of construction activities and runoff waters, the controlled release of water from the sedimentation ponds, elevated sediment inputs and surface runoff waters is predicted to have a negligible effect on surface water quality.	Residual effect not significant
		2. Water from sedimentation ponds will be discharged to Blairmore Creek and Gold Creek in a manner that does not cause erosion, scour or increased sedimentation to downstream areas.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also -Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR-6.5, Table 6.5-3, CIAR #313		
		3. Salvaged topsoil for reclamation purposes will be stored 30 m or more away from headwater tributaries and 100 m away from the mainstems of Blairmore Creek and Gold Creek.			
		4. Appropriate erosion and sediment control measures will be applied to salvaged soil piles to reduce potential erosion and sediment transport off-site. These may include use low areas to trap sediment, silt fences or exfiltration ditches in small, low gradient areas adjacent to soil and stockpiles areas. In addition, cover soil stockpiles will be seeded with suitable vegetation species mix to ensure long term stability of the soil piles, which reduces erosion and the potential for weed establishment.			
		5. Light duty vehicle and heavy-duty vehicle haul road will be designed to contain road surface water runoff and direct it to designated runoff control features.	EIA, Section E, Subsection E.4.5.1, CIAR #42		
		6. Benga will ensure contractor and/or staff minimize surface disturbances, properly install, and maintain the appropriate erosion and sediment control measures.			
		7. Slope grading and stabilization techniques will be adopted. Slopes will be contoured to produce moderate slope angles to reduce erosion risk. Other stabilization techniques used to control erosion include: ditching above the cutslope to channel surface runoff away from the cutslope, leaving buffer (vegetation) strips between the construction site and a watercourse, and placing large rock rip rap to stabilize slopes.	EIA, Section E, Subsection E.5.5, CIAR #42		
		8. Progressive reclamation will be conducted to minimize the amount of disturbed area at any given time. During reclamation, permanent plant cover and revegetation will be established to minimize the time that reclaimed surfaces are left bare and thereby reduce soil erosion.	EIA, CR#5, Section 4.1.1.2, CIAR #42		
		9. Temporary measures to control erosion before vegetation cover is re-established will be employed including diversion ditches, drainage control, check dams, sediment ponds, sumps, and mulches.			
		10. Whenever possible, construction activities in close proximity to watercourses will be carried out during periods of lowest potential impact, typically during the winter months.			
		12. The design and construction of any required watercourse crossings will adhere to the Alberta *Water Act* Code of Practice for Watercourse Crossings.			
		13. Benga will ensure that the surface water runoff collection ditch at the north end of the North Rock Disposal Area (NRDA), and the NRDA itself, do not extend out of the Crowsnest River watershed into the Livingstone River watershed.	Addendum 8, AER-R2-2, CIAR #89		
		14. Benga will ensure that sufficient laboratory measurements of the quality of proposed discharge water will be made before water is released, to ensure water quality meets approved Project-related compliance limits.	Addendum 8, AER-R2-12, CIAR #89		

Table 2-5 Surface Water Quality (WQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
2. Released process water from Project activities associated with operations and closure.	Exposure of waste rock to water and air has the potential for acid rock drainage, metal(s) leaching, and elevated levels of nitrate and selenium, which may cause adverse effects to aquatic life.	1. Benga has, and will continue to, mitigate exposure to waste rock in external dumps through mine design. Waste rock dumps were not located within valleys or directly within major watercourses. In-pit dumping of waste rock was maximized, with external pit waste rock dumps being positioned to the north and south of the pit, avoiding the mainstems of Blairmore Creek or Gold Creek and grading of the waste rock foundations will be done in a manner to facilitate effective drainage and collection of infiltration and prevention of pooling under the waste rock dumps.	Addendum 10, JRP IR-5.1, CIAR #251	Water management is a key design feature for all phases of the Project. The main objective of the water management plan is to ensure water quality (*e.g.,* selenium and other metals) are treated before release to natural watercourses. Modelling was conducted to assess the effectiveness of these mitigation measures. Water quality modelling results indicate that in Gold Creek, the predicted concentrations of all 21 water quality variables with published Alberta guidelines for protection of aquatic life would be below these guidelines throughout construction, operation, closure, and post-closure periods. In Blairmore Creek, with the exception of sulphate, predicted concentrations of all variables were within these guidelines or the proposed site-specific selenium objective.	Residual effect not significant
		2. Benga will implement progressive reclamation of the mine to establish vegetation caps to stabilize subsurface soils and maximize water update to minimize the infiltration of water and therefore the amount and concentration of nitrate and selenium enriched water that requires treatment.			
		3. Benga has incorporated capture (surge) ponds into the Project's water management plan to collect and hold water that has come into contact with waste rock. These ponds do not directly release water into the downstream aquatic environment (designed with no outlet channel). The water will be stored in these ponds prior to use in the coal processing facility and/or prior to a treatment process designed to ensure approved Project-related water quality limits are met prior to release.	EIS, Section C.5.3, CIAR #42		
		4. Nitrate and selenium can be removed from water by making the water anoxic (free of oxygen) and electrochemically reducing. Under reducing conditions, selenium can precipitate or adsorb to mineral particles. The saturated backfill areas planned for the Grassy Mountain Mine can be managed as reducing zones and used for removal of selenium from mine contact water.			
		5. Benga has and will continue to implement testing and other research and development initiatives to progressively develop the detailed engineering parameters for the first phase of the SBZ. After Project approval, Benga will have an opportunity to engage in field scale pilot testing if necessary, to fine tune engineering designs and operational parameters.	Addendum 10, JRP IR-5.5, CIAR #251		
		6. Through its operation, Benga has committed to monitor the SBZs treatment performance.	Addendum 11, JRP IR-6.22, CIAR #313		
		7. In the event monitoring of selenium concentrations in water pumped from the active treatment in the SBZs does not meet regulatory compliance limits, Benga will recirculate the water through the Raw Water Pond and back to the SBZ while adjustments are made to treatment parameters to improve selenium removal rates.	Addendum 10, JRP IR-5.1, CIAR #251		
		8. In the event monitoring indicates that the planned SBZ zones are not effective in reducing selenium concentrations all the way down to approved Project-related water quality limits, to treat the anticipated water balance in the long term, Benga has committed to implementing additional, supporting measures including the use of gravel bed reactors, looking for alternative sites to construct additional SBZ's, and/or constructing an active treatment facility.	Addendum 11, JRP IR-6.22, CIAR #313		
		9. In the event that water quality monitoring results indicate approved Project-related water quality limits cannot be met through source control techniques, the active treatment though SBZs, or additional, supporting measures (GBRs), Benga will construct an additional active selenium treatment process. Together these measures provide a layered approach to selenium management.	Addendum 10, JRP IR-5.1, CIAR #251		

Table 2-5 Surface Water Quality (WQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
3. Changes in released process water parameters from proposed selenium management mitigations.	Elevated water quality parameters, including calcite and some metal(s) may occur as a result of the Saturated Backfill Zone mitigation that could lead to effects on aquatic life.	1. In the event water quality parameters including metals or calcite, exiting the SBZ are found to not meet approved Project-related water quality limits, Benga will ensure any off-specification water will be managed accordingly. This includes redirecting the water to the raw water pond or recirculating back to the SBZ or a gravel bed reactor (GBR) for additional treatment. In the event monitoring trends indicate additional mechanical treatment for specific water quality parameters are required, Benga will construct the appropriate water treatment plant.	Addendum 10, JRP IR-5.3 and IR-5.6, CIAR #251	Different water quality issues due to the Project activities would be addressed by applying these mitigation measures. Effects of process-related water release are predicted on sulphate in the receiving surface water environments. The predicted sulphate concentrations were above the range of hardness-dependent sulphate guideline value. The development of a site-specific sulphate objective based on site water hardness is recommended.	Residual effect not significant
		2. Benga has developed a calcite monitoring approach to document the extent of calcite deposition, the degree to which deposition has occurred, as well as to characterize the calcite depositions in Blairmore and Gold Creek.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also in Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR-6.5, Table 6.5-3, CIAR #313		
		3. Benga will construct a cascade from the discharge point of the SBZ that will promote CO_2 off-gassing and atmospheric equilibration and reduce the volume of calcite precipitates.	Addendum 10, JRP IR-5.3, CIAR #251		
		4. In the event water quality parameters exiting the SBZ, including calcite, are found to not meet water quality compliance limits, Benga will construct a water (metals) treatment plant.	Addendum 10, JRP IR-5.6, CIAR #251		
		5. A site-specific sulphate objective based on site water hardness will be developed and monitoring to validate assessment prediction in Blairmore Creek will be implemented as part of the Aquatics Monitoring Plan.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, CIAR #313)		
4. Nitrogen-based explosives used in Blasting during mine operations	Leaching of blasting residues will generate inorganic nitrogen species which may enhance primary productivity and in turn cause oxygen depletion.	1. Emulsions will be used for wet blasting; ammonium nitrate fuel oil (ANFO) will be used for dry blasting to limit ammonia leaching.	EIA, CR #5, Section 4.2.1.2, CIAR #42	Total ammonia, nitrate and nitrite concentrations were modelled and found below water quality guidelines in the LSA during all mine phases (refer to CR#5, Section 4.2.1.2) due to release of mine process water. For the Project, an assumption that up to 95% of the influent nitrate and nitrite loading could be removed from water routed through saturated backfill zones. It is expected that any residual reduced form of nitrogen will be converted to less harmful nitrate rapidly upon mixing with well-oxygenated natural waters.	No residual effects
		2. All runoff from the ammonium nitrate storage areas, mine pits, and mine rock piles will be contained within the water management system and directed to surge ponds and the SBZ for treatment.			
	Higher concentrations of ammonia, nitrite and nitrate: Broken rock and unconsolidated material will be deposited in piles or be used to backfill previously mined areas. These rock piles and backfilled areas are potential sources of leaching of nitrogenous substances into surface waters.	3. Refer to mitigation WQ-2.4 above as it pertains to the Project's treatment process for nitrate and selenium.			

Table 2-5 Surface Water Quality (WQ) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
5. Domestic wastewater generated from camp operations	Domestic wastewater releases leading to elevated concentrations of nutrients resulting in increased primary productivity and oxygen depletion	1. Domestic wastewater will be collected in storage tanks and transferred to a wastewater treatment facility.	EIA, Section E, Subsection E.5.5, CIAR #42	Based on the expected level of treatment, the anticipated low amounts of domestic wastewater generated and water treatment, no measurable effects on the water quality of nearby surface waters are predicted from the release of treated domestic wastewater from the Project.	No residual effects
		2. Facility sewage will be collected and treated in a sewage treatment package plant located on the MIA pad (Section C.6.13, EIA). Treated effluent will be tested to ensure that its quality meets or exceeds the limits for treated wastewater discharge as be specified in the EPEA approval.			
		3. Excess sludge will be collected for removal from the package treatment plant by vacuum trucks and disposal off site. Sewage and grey water from the Coal Handling and Processing Plant (CHPP) service buildings will be pumped to the water treatment plant for processing and discharge.			
6. Acidification due to air emissions from construction and operations	Mining activities have the potential to affect surface water quality through the release of air emissions that result in increased deposition of sulphate and nitrate. Deposition of sulphate and nitrate can lead to a reduction in pH in acid-sensitive watercourses and water bodies, which in turn might alter other aspects of water chemistry (*e.g.,* the solubility of aluminum), ultimately resulting in adverse effects on water quality as well as aquatic life.	1. Acidification due to air emissions will be mitigated by mitigation of the air emissions. Refer to AQ-2.1 and 2.2 (Table 2-1) mitigations for details.	EIA, CR#5, Section 4.5, CIAR #42	The residual (after mitigation) effects of the acidifying air emissions of the Project on surface water quality are assessed as not significant.	Residual effect not significant
7. Acidification due to water exposure to acid generating rock.	Static geochemical characterization results have shown acid rock drainage potential that will require management.	1. During operations, acid-generating material will be blended with non-acid generating materials or sub-aqueous disposal will be performed to minimize acid concentrations.	EIA, Section E, Subsection E.5.5, CIAR #42	The water quality model assumes that 80% of loadings generated by acidic rock types will be mitigated by these techniques to effectively manage acid generation due to PAG.	Residual effect not significant
		2. During mine closure, all acid-generating pit walls will be actively managed by blending with non-acid-generating materials.			
8. Accidental leaks and spills of hydrocarbons, chemicals and waste products used and stored within the Project footprint	Accidents and Spills - Effects on surface water from elevated concentrations of hydrocarbons, chemicals and waste products.	1. The Project will incorporate design features, management practices and mitigation plans to minimize the potential for accidental spills that might adversely affect soil and surface water quality. Appropriate design features include berms and other forms of containment around potential sources.	EIA, CR #5, Section 4.3.1.2, CIAR #42	Given these regulated measures, it is most likely that the environmental effect from leaks and spills will be minimum. Therefore, the overall environmental consequence of leaks and spills on surface water quality is considered to be negligible.	No residual effects
		2. Spills of untreated water or other potentially hazardous substances will be cleaned up according to emergency response procedures and regulations. Leaks and spills will be reported to AER and AEP as required by regulation.			
		3. The carbon source for the SBZ will be stored per the guidelines set under the Alberta Energy Regulator (AER) Directive 055: Storage Requirements for the Upstream Petroleum Industry or equivalent for the mining industry.	Addendum 10, JRP IR-5.13, CIAR #251		
		4. Only oils, not fuels, will be stored at the Project's explosive magazine. No mixing (preparation of ANFO) will be performed at the explosive magazine facility.	Addendum 10, JRP IR-5.14, CIAR #251		
		5. Fueling and lube maintenance stations will be sited to control drainage would be located outside riparian buffer zones (refer to AE-1.5, Table 2-6).	Addendum 1, CR #6, Table 4.2, CIAR #44		

AQUATIC ECOLOGY

A consolidated table of commitments and mitigation measures related to aquatic ecology has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-6.

Table 2-6 Aquatic Ecology (AE) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Changes to aquatic and/or riparian habitat for fish in Blairmore Creek and Gold Creek associated with implementation of water management, mining, and waste rock placement.	The Project's footprint will result in change to fish habitat in Blairmore Creek and Gold Creek. These potential effects include change to sediment deposition and scour processes in the creeks, changes to flow, and changes to tributary aquatic/riparian habitat.	1. Through proactive and strategic mine planning, avoidance of placing waste rock into valley bottoms will be implemented (requiring the hauling of waste rock up slopes, which is not a common mining practice; however, in this situation will help mitigate riparian habitat loss adjacent to the mainstems of Blairmore Creek and Gold Creek).	Addendum 8, Appendices B1 and B2, CIAR #89	The EIA evaluated interactions between the Project and Aquatic Ecology through a pathways analysis that was used to direct the residual effects assessment (Addendum 1, CR #6, CIAR #44). These mitigations are expected to reduce or minimize potential adverse effects of the Project that may cause changes to aquatic and/or riparian habitat for fish; however, it was identified that a residual effect associated with the permanent loss or alteration to tributary and mainstem aquatic and/or riparian habitat in Blairmore Creek and Gold Creek may exist as a result of the Project footprint. A summary of the quantified residual effects on fish habitat for the Project is provided in Table 5.1 (Addendum 1, CR #6, CIAR #44). As discussed with DFO during the development of the EIA (prior to the establishment of the Panel), an offset plan will be required. As such, Benga has submitted a draft Fisheries Offsetting Plan (and Offsetting Effectiveness Monitoring Plan) that adheres with the goals and objectives of the DFO Fisheries Protection Provisions (FPP), the *Species at Risk Act Permitting Policy*) and the WSCT Recovery Strategy. Benga has committed to the implementation of an approved Fisheries Offsetting Plan, pending Project approval and final consultation with Indigenous groups and DFO. Through mitigation and implementation of the Fisheries Offsetting Plan, the Project is predicted to make a positive contribution to Blairmore Creek and Gold Creek; consequently, through the determination of significance, this pathway of effect was deemed not significant.	Residual effect not significant
		2. The Project footprint will be minimized to the extent possible through storing of waste rock in existing disturbed locations, including the backfilling of mined out pits.	Addendum 1, CR #6, Table 4.2, CIAR #44		
		3. During construction and through operations the Project will ensure appropriate erosion and sediment control features, including properly sized and controlled sedimentation ponds, are in place.	Addendum 1, CR #6, Section 4.3.1, CIAR #44		
		4. Detailed engineering designs for the CHPP facilities, overland conveyor, rail loadout, and rail, will aim to avoid instream works where technically feasible or ensure construction activities adhere to the best management practices associated with the Alberta *Water Act* Code of Practice for Watercourse Crossings.			
		5. The Project will maintain an undisturbed riparian buffer zone, generally 100 m wide, from the mainstems of Blairmore Creek and Gold Creek, and a 30 m setback from associated tributaries.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313)		
		6. As operations progress, if technically feasible, an effort to upgrade existing infrastructure will be made in preference to adding new infrastructure disturbance that may result in the loss of riparian habitat.			
		7. Benga will implement a progressive reclamation plan to expedite revegetation, reforestation and end land uses to provide overhanging cover and shade for watercourses. Refer to Vegetation and Wetland mitigation table (Table 2-8) for details on the Conservation and Reclamation Plan mitigations.			
		8. Benga has committed to the implementation of an approved Fisheries Offsetting Plan, pending Project approval and final consultation with Indigenous groups and DFO.	Addendum 11, Appendix 6.23-1, CIAR #313		

Table 2-6 Aquatic Ecology (AE) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
2. Changes to hydrology in Blairmore Creek and Gold Creek associated with implementation of water management, mining, and waste rock placement.	As a result of the implementation of the water management plan to capture and appropriately treat water prior to release, a change to the drainage patterns and flow characteristics of sub-catchments on the east side of the Blairmore Creek watershed and the west side of the Gold Creek watershed will occur. These changes to hydrology include a predicted increase in flow to Blairmore Creek, and a reduction in flow to Gold Creek.	1. Flow monitoring in Gold Creek will be incorporated into the Aquatic Monitoring Plan to validate the predicted outputs of the Project's water balance model to determine if flow augmentation is required during any phase of the Project. If required, Benga will implement flow augmentation in Gold Creek as an adaptive management mitigation should the flow reductions and/or changes in area weighted suitability (AWS) be greater than what was predicted in the Instream Flow Assessment.	Addendum 10, JRP IR-5.25, CIAR #251	Once all water management features are fully implemented, it is anticipated that predicted flow (runoff) will be increased in the Blairmore Creek watershed and reduced variably at different locations within the Gold Creek watershed. The Project's Instream Flow Assessment (IFA) conducted for the Project considered potential flow changes on fish habitat associated specifically with WSCT during construction, operations, reclamation, and closure phases of the Project. The IFA indicates a portion (530 m^2) of fish habitat (spawning juvenile rearing, adult holding, overwintering) in Gold Creek is predicted to be altered as a result in changes to the Gold Creek hydrological regime, despite implementation of hydrology related mitigations. These habitat losses will be offset and exceeded by gains in habitat attained through the implementation of an approved Fisheries Offsetting Plan required as a component of a Fisheries Act Authorization (FAA). Through mitigation and implementation of the Fisheries Offsetting Plan, the Project is predicted to make a positive contribution to Blairmore Creek and Gold Creek; consequently, through the determination of significance, this pathway of effect was deemed not significant.	Residual effect not significant
		2. An approved Fisheries Offsetting Plan will be developed and implemented to counterbalance predicted loss of fish habitat caused by the reduction in flow to Gold Creek.	Addendum 8, Appendices B1 and B2, CIAR #89		
3. Changes in Water Temperature	Stream temperatures could be modified by the loss of runoff (flow), redirection, storage, or pumping of contact water (treated) or clean water, by all activities associated with site preparation, waste rock placement, the implementation of the site Water Management Plan (WMP), or potentially due to heating or cooling of mine-treated water through a water treatment plant (if deemed necessary). Changes to stream temperatures could affect the thermal regime within Gold or Blairmore creeks such that water temperatures could fall outside of the thresholds tolerated by WSCT, ultimately affecting habitat quantity and suitability.	1. Refer to mitigation AE-1.5 above that pertains to riparian buffer zones.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also -Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR 6.5, Table 6.5-3, CIAR #313	No residual effects. Based on the findings from the predictive water temperature modeling assessment the likelihood and extent of stream temperatures to be altered that will potentially affect key WSCT bioperiods is considered negligible. Therefore, no detectable residual effects on fish habitat due to modifications in stream temperature are predicted throughout mine life (construction, operations, reclamation, closure phases).	No residual effects

Table 2-6 Aquatic Ecology (AE) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
4. Changes in fish food supply	Changes in aquatic and riparian habitat, along with a modification in hydrology can change fish food supply in Blairmore Creek and Gold Creek. A change in food supply can affect fish population sustainability. This effect was deemed to be a secondary linkage pathway effect during the Aquatic Ecology impact assessment.	1. Refer to mitigation AE-1.5 above that pertains to riparian buffer zones.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also -Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR 6.5, Table 6.5-3, CIAR #313	Although the tributary habitat losses that will occur as a result of the Project will affect tributary macroinvertebrate communities and may alter the biomass of invertebrate drift in localized areas of both Gold and Blairmore creeks, the contribution of the affected areas relative to the total invertebrate biomass within each mainstem watercourse is minimal in comparison to the total invertebrate supply of biomass supplied from all reaches and/or other tributaries based on drainage area. This pathway is considered a secondary linkage and is expect to not have a significant effect on fish and fish habitat in Blairmore Creek or Gold Creek.	Residual effect not significant
		2. Refer to mitigation AE-1.7 above that pertains to progressive reclamation.			
		3. Refer to mitigation AE-1.9 above that pertains to a commitment to develop a final Fisheries Offsetting Plan.			
		4. Benga has committed to the finalization of the draft Aquatic Monitoring Plan (AMP) that was prepared using the most current information available regarding mitigation, monitoring, and potential adaptive management options related to the Project. Finalization of the AMP will occur once Project is approved. The AMP will include bioenergetics monitoring, which will be aimed at quantifying the food energy provided to fish and fish condition.	Addendum 11, Appendix 6.23-1, CIAR #313		
5. Changes to fluvial geomorphology (sediment supply and transport mechanisms)	Site preparation, water management, erosion control, open pit development and/or waste rock placement activities can alter sediment supply, transport (*e.g.,* bedload movement), and basin sediment yield, which can affect WSCT habitat quantity and suitability.	1. Refer to mitigation AE-1.5 above.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also -Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR 6.5, Table 6.5-3, CIAR #313	No residual effects Based on the findings from the fluvial geomorphology assessment (Addendum 1, CR #6, Appendix A2: Sections 3.0 and 4.0), the likelihood and extent of physical habitat to be altered in terms of quantity and suitability is considered negligible. Thus, no detectable residual effects to fish habitat, due to modifications in fluvial geomorphological processes (*e.g.,* sediment mobility, bed load movement), proportional to baseline conditions, are expected throughout the mine life (construction, operations, reclamation, closure phases).	No residual effects
		2. Refer to mitigations WQ-1.1 to WQ-1.9 (Table 2-5), that pertain to water management plan, and sediment and erosion control.			
6. Changes to fish health	Changes to surface water quality can affect aquatic resources and fish habitat quantity and suitability and/or survival and reproduction.	1. Refer to mitigations WQ-2.1 to WQ-2.9 (Table 2-5), that pertain to contact water release.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1, CIAR #313) also -Addendum 1, CR #6, Table 4.2, CIAR #44 -Addendum 11, JRP IR 6.5, Table 6.5-3, CIAR #313	Based on the Surface Water Quality Assessment Report (CR #5), the pathway between water quality and WSCT health is classified as a secondary linkage. Given the proposed mitigation and monitoring measures, no significant effects are expected to WSCT health.	Residual effect not significant

Table 2-6 Aquatic Ecology (AE) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
7. Changes in fish habitat due to calcite precipitation	Dissolved calcium carbonate emerging from waste rock dumps can increase the potential for calcite precipitation within downstream receiving environments, which can affect fish habitat quantity and suitability.	1. Refer to mitigations WQ-3.1 to WQ-3.4 (Table 2-5), that pertain to calcite treatment.	Draft Aquatic Monitoring Plan (Addendum 11, Appendix 6.23-1, Table 5.0-1) also in Addendum 1, CR #6, Table 4.2(CIAR #44) -Addendum 11, JRP IR 6.5, Table 6.5-3	The potential for calcite formation to precipitate to the extent where it could affect fish or fish habitat is currently considered low.	Residual effect not significant
		2. Benga has committed to the finalization of the draft Aquatic Monitoring Plan (AMP) that was prepared using the most current information available regarding mitigation, monitoring, and potential adaptive management options related to the Project. The AMP will include calcite precipitation monitoring, which will be aimed at verifying the effectiveness of the calcite mitigations.			
8. The release of spills from hydrocarbons, chemicals and waste products used and stored within the Project footprint	A potential short-term change to surface water and/or aquatic sediment quality, due to an accidental spill or incident that could directly and/or indirectly adversely affect fish and fish habitat.	1. Refer to mitigations WQ-8.1 to WQ-8.4 (Table 2-5), that pertain to accidental spill management.	Addendum 1, CR #6, Table 4.2, CIAR #44	No residual effects Implementation of environmental design features and mitigation actions are expected to reduce the likelihood and extent of a hazardous spill and leaks on-site and along transportation corridors, thus result in no detectable changes in surface water or sediment quality in local watercourses relative to baseline conditions. Thus, this pathway was determined to have no linkage to effects on fish and fish habitat.	No residual effects
9. Improved access and increased workforce in the area as a result of the Project	Improved access could increase fishing pressure and fish harvesting in local fish-bearing watercourses. This could result in a decreased abundance of sportfish if fishing pressure and/or fish harvest were not appropriately managed.	1. Benga will discourage fishing by Project employees in the LSA, conduct awareness training and education to understand the implications of fishing in the LSA, and develop and implement an access control policy to limit public access to the Project area.	Addendum 1, Updated EIA Section E6, Section 6.3.1.1, CIAR #44	No residual effects Implementation of the above-mentioned mitigation and management actions is expected to effectively manage and reduce the likelihood and extent of recreational access to Gold and Blairmore creeks thus result in no detectable changes in WSCT relative abundance due to increased angling pressure relative to baseline conditions. Thus, this pathway was determined to have no linkage to effects on WSCT.	No residual effects
		2. Benga will adhere to the appropriate recommendations in the Livingstone and Porcupine Hills Land Management Policy.	Addendum 10, JRP IR-3.4, CIAR #251		
10. Effects of explosives used in mining activities	Use of explosives can have the potential to create instantaneous pressure changes in the swim bladder of a fish. Explosive vibrations may cause damage to incubating eggs.	1. Benga will implement blasting procedures as follows: • No explosive charge will be detonated near fish habitat that will produce, or is likely to produce, an instantaneous pressure change (*i.e.,* overpressure) greater than 100kPa (14.5 psi) in the swim bladder of a fish. • No explosive charge will be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation. • Explosive weight charge will be limited to one charge per discrete explosion ; • If multiple charges are required, time-delay detonators will be used to reduce the overall detonation to a series of discrete explosions; and • Ground vibration monitoring, using specifically designed instruments, of all blasting activities will be conducted when an explosives charge is used within 300m of fish habitat.	Addendum 1, Updated EIA Section E6, Section 6.3.1.1, CIAR #44 Addendum 10, JRP IR5.28, CIAR #251	No residual effects Implementation of mitigation actions is expected to effectively manage and reduce the likelihood and extent of direct mortality to WSCT that inhabit both Gold and Blairmore creek watersheds. Thus, no detectable changes in WSCT relative abundance due to blasting activities, proportional to baseline conditions, is expected. Thus, this pathway was determined to have no linkage to effects on WSCT.	No residual effects

Soil and Terrain

A consolidated table of commitments and mitigation measures related to soil and terrain has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-7.

Table 2-7 Soil and Terrain (ST) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Effects of construction, operations and closure on soil quality through soil profile disturbance.	Disturbance of the soil profile during development of Project infrastructure, mining of the coal resource, and reclamation has the potential to impact soil quality. Soil salvage, handling, storage (long term and short-term stockpiles) and replacement may impact soil quality. Soil material salvaged from disturbance areas may be chemically and physically impacted through the removal, handling and storage, and replacement during reclamation.	1. Upland surface soil and sufficient subsoil and suitable overburden materials (coversoil) will be salvaged using best management practices. 2. Soil handling activities will be suspended under wet or windy conditions when the degradation of soil quality is a potential. 3. Coversoil material will be stored in a manner to minimize material loss or degradation of quality and located in areas that are accessible and retrievable. 4. During reclamation, varying thicknesses of coversoil will be replaced to assist in creating diversity in the reclaimed landscapes. 5. All reclaimed lands will be initially vegetated using a cover crop upon completion of soil placement to minimize soil loss *via* erosion.	EIA, CR #7, Section 7.1.3.1, CIAR #42	The residual environmental effect of the Project on soil quality as a result of complete disturbance of the soil profile through soil salvage, storage and replacement at reclamation throughout the development is rated as low impact. Soil salvage, handling, progressive reclamation, and monitoring and mitigation efforts will allow for reclaimed soil profiles to evolve over time to provide land capability suitable to meet the desired end land uses.	Residual effect not significant
2. Effects of construction, operations and closure on soil quality through erosion.	Stockpiling of salvaged soil materials during the construction and operation of the Project, both short term and long term, results in potential for soil erosion issues and effects to soil productivity.	1. When stockpiling reclamation material, piles will be placed in strategic locations, to minimize exposure to wind or water. 2. Stockpiles of reclamation material will be seeded with a non-invasive and weed free seed mix that establishes quickly. 3. Erosion control materials (mats, netting, mulches, straw) will be used to reduce soil surface exposure. 4. Reclaimed landscapes will be reseeded with a quick establishing; non-invasive cover crop to minimize the length of time bare soil is exposed to potential wind and water erosion. In addition, reclaimed landscapes that have a moderate to high water erosion risk (*i.e.,* steep side slopes) will have soil stabilizers or other measures implemented to minimize the potential of erosion.	EIA, CR #7, Section 7.1.3.2, CIAR #42	Residual effects of wind and/or water erosion will be localized to the proposed disturbance area and are of concern in areas where the vegetation has been removed and the soil profile disturbed and/or stockpiled. Appropriate soils handling and implementation of erosion control and monitoring of areas (both pre-disturbance and reclaimed landscapes) that are considered to have a moderate to high erosion potential *via* wind or water (after implementation of appropriate mitigation) throughout the life of the of the Project will minimize the potential impacts of erosion.	Residual effect not significant
3. Effects of accidental releases from equipment failures, line failures, tank releases, and surface releases from operations activities on soil quality	Soil loss or degradation of soil quality due to accidental releases. Impacts to soil quality caused by accidental releases and operational incidents within the proposed disturbance area have the potential to alter chemical and physical attributes of soils.	1. Refer to mitigations WQ-8.1 to WQ-8.5 (Table 2-5) that pertain to accidental leaks and spills to the environment.	EIA, CR #7, Section 7.1.3.2, CIAR #42	The magnitude of residual impacts to soil as a result of accidental releases is expected to be low. Implementation of regulatory requirements for containment, facility design and required spill response plans will ensure that impacts or releases are minimized or prevented. In addition, adherence to applicable regulatory requirements relating to soil remediation will ensure any impacted materials are remediated to meet applicable regulations in place. A net neutral contribution is expected. Any releases will be remediated to meet regulatory guidelines. No net loss of soil material is expected.	Residual effect not significant
4. Soil Biodiversity and Ecological Integrity impacts from mining disturbance	Reduced soil biodiversity & ecological integrity: impact of the Project on the spatial distribution of soil patterns and potential changes in soil diversity and ecological integrity post disturbance.	1. Soil salvage, handling, progressive reclamation, and monitoring and mitigation efforts will allow for reclaimed soil profiles, reclaimed landscapes and revegetated lands to evolve over time to provide equivalent capability with a level of biodiversity appropriate for the end land uses.	EIA, CR #7, Section 7.2, CIAR #42	Soil diversity and ecological integrity may be decreased as a result of development but appropriate reclamation will allow for increased reclaimed soil profile diversity over time in the reclaimed landscapes.	Residual effect not significant

Table 2-7 Soil and Terrain (ST) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
5. Various terrain types will be disturbed or removed as a result of Project development	Removal of natural terrain and reconstruction of reclaimed terrain post development can lead to disturbances to the terrain types within the LSA, loss of organic landforms, a reduction in extreme slopes in upland terrain, and changes to natural variability and complexity of the existing terrain.	1. Re-contouring of reclaimed landscapes will be done to provide topography and surface forms that provide appropriate surface drainage, blend with the adjacent undisturbed terrain (*i.e.,* drainage, aspect), remain stable, provide suitable habitat for the formation of diverse reclaimed soil and vegetation patterns in the reclaimed landscape, and meet the desired end land use objectives. In instances where the reclaimed landscape is expected to differ from the original terrain type, the landscape will be designed to ensure that end land use objectives are met. 2. The Conservation and Reclamation plan will include the development of various ecosystem features (wetlands, surface drain ways (swales), and end pit lakes that will function as wetlands) to ensure that a range of diverse terrain and terrain features are created post development. 3. Final re-contouring of depleted mine blocks and appropriate soil replacement will create soil landscape patterns appropriate for the desired end land uses. The landscapes will provide surface water drainage to ensure water movement across disturbed lands, provide surface runoff for constructed wetlands and end pit lakes, as well as establishment of ecosystem patterns appropriate for desired end land uses.	EIA, CR #7, Section 7.3.3, CIAR #42	It is expected that the creation of a range of terrain types during contouring and reclamation will provide a reclaimed terrain that will tie into adjacent undisturbed lands, and provide suitable landscapes for the development of a range of reclaimed soil types and functioning vegetation communities.	Residual effect not significant
6. Land Capability Effects	Achievement of equivalent land capability could be delayed or hindered through unsuitable overburden in root zone. Project development and subsequent materials placement on altered landscape may cause alteration in land capability distribution and delay in achieving equivalent land capability	1. Benga will implement soil salvage activities such that the maximum achievable (technical and safety considerations) volume(s) of reclamation material are salvaged for placement. 2. Upon backfilling and re-contouring of mine blocks, unsuitable overburden will be identified to ensure that sufficient reclamation material is replaced to meet regulatory requirements over all reclaimed lands. 3. Effects will be mitigated with a Reclamation Plan that will result in reclaimed landscapes providing a range of capabilities that will be spatially unique to pre-disturbance conditions.	EIA, CR #7, Section 7.4.3, CIAR #42	It is expected that land capability and end land use post disturbance will not be exactly as the land capability distribution (spatially) that currently exists but the overall reclaimed landscape will provide similar ecological function as the pre disturbance conditions. It is expected that completion of the recommended mitigation and monitoring activities will minimize the potential of unsuitable overburden materials being introduced into the reclaimed soil profile by ensuring appropriate replacement depths and recognition of potential problem areas during, and immediately after, reclamation.	Residual effect not significant

Vegetation and Wetlands

A consolidated table of commitments and mitigation measures related to vegetation and wetlands has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-8.

Table 2-8 Vegetation and Wetlands (VW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Effects on terrestrial vegetation due to physical disturbance	Potential effects of the Project on ecosite phases and ELC classes are related to clearing of vegetation and physical alteration of the landscape for the Project's mine pit and associated waste rock dumps and infrastructure.	1. Benga will implement a Conservation & Reclamation Plan (C&R Plan) aimed at the establishment of target vegetation with equivalent capability through progressive reclamation.	EIA, CR #8, Section 4.1.5.1, CIAR #42; Addendum 10, JRP IR-2.6, CIAR #251	The reclaimed land will support a range of communities with equivalent capabilities to those of the surrounding lands and that existed prior to development. Due to the spatial boundary associated with reclamation, the identified mitigations reduce the impact; however, a residual effect remains.	Residual effect not significant
		2. The C&R Plan will include the establishment of vegetation communities that are locally and regionally limited in distribution where conditions allow.	EIA, CR #8, Section 4.1.5.1, CIAR #42		
		3. The Project will preserve adjacent vegetation communities by limiting disturbance to areas required for development.			
		4. The reclamation plan will include direct placement of soil for provision of propagules.			
		5. Benga will implement a weed management and control program.			
		6. Through the progressive reclamation process, Benga will continue to consult with Indigenous communities to ensure identified traditional use plants are incorporated into the reclamation program.			
		7. Multiple layers of native vegetation (*e.g.,* trees, shrubs and graminoids) will be established to provide initial structure for wildlife habitat and to enhance biodiversity.			
		8. Benga will utilize a native seed mix that has been inspected and certified free of weeds and undesirable species. Part of this seed mix will include wild-harvested native seeds where practicable.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Section 4.3.4.1, CIAR #42		
2. Effects on rare plants due to physical disturbance	Construction and operation of the Project would result in the removal of some rare plants observed within the Project Footprint (Whitebark Pine, native Fescue).	1. The C&R Plan will be designed to establish diverse native vegetation communities (closed conifer forests, moderate mixed forests, natural upland herbaceous grasslands, and treed wetlands) with equivalent pre-disturbance capability.	EIA, CR #8, Section 4.2.6.2, CIAR #42	The project will have a negative contribution for some rare plants removed during clearing and mining as there is no assurance that they will return after reclamation. The project will have a positive contribution for whitebark pine with the establishment of disease resistant trees on the reclaimed landscape and additional creation of habitat with reclamation of historical mine areas. Where reclaimed terrain may support whitebark pine and limber pine, whitebark pine will be preferentially planted as it is more imperiled than limber pine. Project effects on limber pine will be neutral with preservation of genetic diversity but limited reestablishment.	Residual effect not significant
		2. Refer to mitigations VW-1.2 through to VW-1.8 above as it pertains to vegetation community reclamation that are also applicable to rare plant communities.			
		3. Benga will consider avoidance of populations of Whitebark Pine as a criteria for on-going mine footprint planning.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Section 4.2.6.3, CIAR #42		
		4. The Project will adhere to the mitigation approaches outlined in applicable provincial and federal Whitebark and Limber Pine Recovery Plan(s).			
		5. Benga will endeavor to introduce Whitebark Pine (blister rust resistant strains) during reclamation phases using available provincial and federal guidelines.			
		6. Genetic diversity will be preserved, by collecting cones from Whitebark Pine within the disturbance footprint that are healthy and free of disease. Seed will be extracted from the cones and stored until needed as part of the progressive reclamation program.			
		7. Benga will plant approximately three times the number of Whitebark Pine removed from mining.	Addendum 8, AER-R2-8, CIAR #89		
		8. Benga will engage qualified professional contractors to undertake the safe collection of healthy Whitebark Pine cones.	Addendum 5, IR 113, CIAR #69		
		9. Benga will initiate planting trials once suitable reclaimed habitat is available.	Addendum 10, IR 2.3, CIAR #251		
		10. Through mine planning Benga will aim to minimize project disturbance and avoid fescue where possible.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Section 4.3.4.1, CIAR #42		
		11. Benga will identify potential areas on hill crests and southern aspects suitable for transplanting native fescue.			

Table 2-8 Vegetation and Wetlands (VW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
3. Effects on rangeland resources due to physical disturbance	Areas of native montaine grasslands and native subalpine grasslands in the LSA will be impacted by the Project.	1. Refer to mitigations VW-2.10 to VW-2.12 above that pertain to establishment of grasslands species.	EIA, CR #8, 4.3.4.1, CIAR #42	The project will have a neutral contribution. The initial contribution will be negative due to the removal of the rangeland resource during the operational phase. However, the reclaimed land will support a range of communities with equivalent capabilities to those of the surrounding lands and that existed prior to development.	Residual effect not significant
4. Effects on forest resources due to physical disturbance	Potential effects on forestry resources are related to clearing of vegetation and physical alteration of the landscape of the Project.	1. Merchantable timber, both coniferous and deciduous, will be salvaged. 2. Benga will collect locally available cones which will be stored until needed as part of the progressive reclamation program.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Sections 4.4.4.1 and 4.5.4, CIAR #42	Overall project contribution is neutral due to the inclusion of historically disturbed unproductive lands with Project reclamation. Once project operations cease, the more subdued terrain will allow for an increase in the area of forest compared to predisturbance conditions. Reclaimed terrain and soils will support establishment of native forest communities.	Residual effect not significant
5. Effects on old growth forests due to physical disturbance	Potential effects of the Project on old growth forests are related to clearing of vegetation and physical alteration of the landscape of the Project.	1. Benga will include tree species capable of achieving of old growth conditions in the reclamation plan. 2. Refer to mitigation VW-1.3 above as it pertains to preservation of adjacent vegetation communities.	EIA, CR #8, Section 4.5.4, CIAR #42	It is anticipated that the mitigation measures outlined for forest resources would support the return of old growth forests that may be removed during Project activities. Reclaimed terrain and soils will support establishment of native forest communities including communities with high old growth potential.	Residual effect not significant
6. Effects on traditionally used plants due to physical disturbance	The Project would remove ecosite phases that support traditional ecological knowledge (TEK) vegetation potential.	1. The re-vegetation program will aim at re-establishing vegetation communities that are common to the pre-disturbed landscape and that will support TEK vegetation. 2. Benga will provide opportunities for Indigenous communities to identify and collect suitable lodgepole pine for traditional use ceremonies. 3. TEK vegetation species identified through Indigenous community consultation to be established include: Lodgepole pine; Prickly Rose; Ground Juniper; Willow; Aspen; and Balsam Poplar, Saskatoon; Thimbleberry; Bearberry; Dwarf Birch, Subalpine fir; and Dogwood. 4. The C&R Plan will utilize native vegetation species and will not include agronomic invasive species. Agronomic species would only be used as a temporary cover crop until native seed can be established. 5. The C&R Plan will utilize locally collected seed to preserve the legacy of species and of place, where practicable. 6. Benga have and will continue to consult with Indigenous groups on the C&R Plan. The C&R Plan wherever possible will include the use of traditionally important species and incorporate end land use decisions made in consultation with Indigenous groups.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Section 4.6.4.1, CIAR #42; and Addendum 10, Appendix 4.1-2, CIAR #251	Reclaimed terrain and soils will support establishment of a range of native communities that will support TEK species. However, in addition to simple presence, the place where species grow may be important for some TEK species and this may not return. The project will have a neutral contribution with respect to TEK species and communities. The reclaimed land will support a range of communities with equivalent capabilities to those of the surrounding lands and that existed prior to development. The project will not result in the loss of the resource to the communities, the region or the province.	Residual effect not significant

Table 2-8 Vegetation and Wetlands (VW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
7. Effects on wetlands due to physical disturbance	Construction, operation and reclamation of the Project will reduce the types and area of wetlands.	1. Benga will implement wetland construction best practices to maintain the hydrologic regime of mineral soil wetlands.	Updated C&R Plan (Addendum 10, Appendix 2.6-1, Section F.2.8, CIAR #251) also EIA, CR #8, Section 4.7.4.1, CIAR #42	The reclamation plan proposes to increase the total wetland area available by closure. At closure with reclamation, an additional 18.2 ha of treed wetlands (STNN) will be added to the Project Footprint, and potentially another 1.8 ha of shallow open water (WONN) and/or open graminoid marsh will be added in the littoral zone around the end pit lake. This approach to wetland mitigation for the Project is consistent with the *Alberta Wetland Policy*. For the Project, wetlands have been avoided or disturbance minimized where possible and any removed wetlands will be replaced / restored during reclamation activities.	Residual effect not significant.
		2. Appropriate depression wetland areas will be revegetated to mineral soil wetlands, where possible using wetland riparian, emergent, and submergent vegetation species.			
		3. During construction, wetland soil and propagule materials from existing (baseline) wetlands within the Project footprint will be salvaged and stored for replacement during wetland reclamation and reconstruction activities.			
		4. Constructed wetlands will use submergent vegetation species as indicators of wetland health and integrity to be measured in subsequent monitoring programs.			
		5. Benga will use opportunities to directly place wetland soil materials (soils and propagules) from adjacent wetlands, to provide a soil substrate with a propagule source for wetlands, where practicable.			
		6. Where applicable, culverts will be placed within wetlands that may be divided by roads to ensure that water flow between wetlands will not be affected.			
		7. During construction of the rail siding, Benga will implement the following mitigation measures: • construction under dry or frozen conditions using wetland construction best practices to maintain the hydrologic regime of mineral wetlands; • construction activities will be scheduled outside of Restricted Activity Periods (RAP) for wildlife, fish and amphibian habitats (note: the wetland has some connectivity with the Crowsnest River; however, is not deemed a side channel with the river); • ensuring all equipment arrives in a clean condition to mitigate the potential introduction of noxious and prohibited noxious weeds identified under the Alberta *Weed Control Act* or weedy species that are not listed under the *Weed Act* but considered invasive to native vegetation and wetlands; • use of clean material for the sidings rail bed and banks; • installation of culverts along the siding as required to ensure the flow of water between any divisions in the wetlands and to provide connectivity between the portions of the wetlands that may be potentially intersected by the Project; and • installation of silt fences or sediment socks during construction to reduce sedimentation during construction.	Addendum 8, AER-R2-25, CIAR #89		
8. Changes to biodiversity and fragmentation from clearing of vegetation and physical alteration of the landscape	Construction and operation of the Project will result in the removal of vegetation from the Project Footprint and a temporary reduction of native species diversity in the LSA that will result in a reduction in species diversity, community diversity, landscape diversity and fragmentation.	Measures taken to mitigate the reduction in areas of terrestrial vegetation, wetlands, old growth forests, and to attenuate the spread of non-native and invasive species due to the Project will be effective for the Project effects on loss of biodiversity. These measures include: • direct placement of soil salvaged (with propagules) from new mining areas as much as is practicable; • re-establishing native species by planting native trees, native shrub species and native graminoids to provide structural diversity, wildlife habitat and wildlife browse; and • an adaptive re-vegetation strategy to take advantage of opportunities present on the re-contoured lands for establishment of a variety target vegetation communities and wetlands as outlined in the reclamation plan (closed conifer forests, grassland open forests, mixed forests, and treed wetlands); or other vegetation communities that may become more appropriate with knowledge gained from adaptive management.	EIA, CR #8, Section 4.8.4.1, CIAR #42	The Project will reclaim existing anthropogenic disturbances, primarily from previous mining activities, and therefore reduce the existing fragmentation within the Project Footprint. However, residual effects on vegetation and plant communities will occur with the removal of vegetation and alteration of the landscape due to the Project even after reclamation is completed. These residual effects will diminish over time following mitigation as reclaimed plant communities will become more complex and natural processes, such as fire, return to the landscape, and these processes will bring ever-increasing complexity and structure to the reclaimed landscape.	Residual effect not significant

Table 2-8 Vegetation and Wetlands (VW) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
9. Effects on noxious and invasive species due to land disturbance	Noxious and invasive species are present within the proposed Project footprint; however, construction and operations activities may enhance the spread and establishment of these species.	1. As required by the *Weed Control Act* and Regulations, noxious weed populations identified during baseline field sampling will be controlled prior to site disturbance and mine operation to prevent the further spread of weeds.	EIA, CR #8, Section 4.9.4.1, CIAR #42	Following the implementation of mitigation measures (including a weed management and monitoring program), the Project is not expected to have lasting local or regional effects on the establishment and spread of noxious and invasive species.	No residual effects
		2. Noxious weed management will adhere with Weeds on Industrial Development Sites R&R/03-4.			
		3. During the construction and operation phases inspections will be conducted during each growing season to identify the presence of prohibited noxious and noxious weeds listed under the *Weed Control Act* and Regulation.			
		4. Benga will implement progressive reclamation to ensure prompt reclamation and re-vegetation of bare ground upon completion of mining.			
		5. Procedures will be in place to ensure that equipment arriving from offsite is cleaned to remove soil and vegetative material before accessing the study area.			
10. Potential Acid Inputs (PAI) and Nitrogen deposition from Project related emission sources	Potential effects of PAI and nitrogen deposition on vegetation.	1. PAI and Nitrogen deposition are effectively mitigated by measures to mitigate air emissions. Refer to AQ mitigation table (Table 2-1) for details.	EIA, CR #8, Section 4.10.3, CIAR #42	The Project is predicted to increase the area affected by nitrogen deposition, but the extent of area is limited and is not expected to have a discernable impact on the plant communities at either a local or a regional scale.	No residual effects

WILDLIFE

A consolidated table of commitments and mitigation measures related to wildlife has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-9.

Table 2-9 Wildlife (WL) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Changes in wildlife habitat availability through habitat loss or sensory disturbance.	Habitat availability will be altered by the Project, either directly through habitat loss within the Project footprint, or indirectly through wildlife avoidance as a result of sensory disturbance. Land clearing during Project construction creates a direct loss of habitat, which for some species may represent the greatest single effect of the Project. Wildlife with small home ranges and highly specific habitat requirements may be affected at the local level, depending on population size and Project location. Other species with different seasonal requirements, such as toads which require aquatic habitat in spring and summer and upland habitat in winter, may reduce their use of an area if one seasonal habitat is lost. Sensory disturbance associated with Project development (*e.g.,* noise, artificial lighting, blasting, and human activity) will also result in indirect habitat loss. These sensory disturbances, which can be ongoing or periodic, may result in wildlife avoiding otherwise suitable habitat, reduced reproductive success, reduced foraging ability or increased mortality.	1. Benga will minimize the overall disturbance footprint through the mine planning process to avoid critical breeding habitats, nesting and denning sites, and movement corridors to the extent possible.	Wildlife Mitigation and Monitoring Plan (WMMP) (Addendum 10, Appendix 5.39-1, Section 5, CIAR #251) also EIA, CR #9, Section 7.1.3, CIAR #42; Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313	At Mine Year 27, the effects of reclamation are expected to result in greater availability of effective habitat relative to baseline for great grey owl, grizzly bear, moose, and elk. The remaining wildlife VCs are dependent on wetland habitat (amphibians) and mature and old-growth forests (olive-sided flycatcher, little brown myotis, American marten, and Canada lynx). Benga acknowledges that it will take decades for wetlands and mature forests to establish; however, once established the habitat availability for species dependent on them is expected to be greater than at baseline. During construction and operations there may be reduced habitat availability due to sensory disturbances or direct loss of habitat. Implementation of mitigation will reduce, but not eliminate these effects. Residual effects are low in magnitude for habitat availability for all wildlife VCs, except for olive-sided flycatcher, little brown myotis, American marten, Canada lynx where the magnitude is predicted to be moderate.	Residual effect not significant
		2. Remnant forest patches will be preserved within the development areas where feasible to provide habitat, habitat connectivity, ensure that core security areas are provided for wildlife and hide cover for wildlife species.			
		3. Progressives reclamation will be used to retain slash and large woody debris in the salvaged soil to provide microsites for native plant and hide cover for wildlife, establish a variety of vegetation species and communities suitable for wildlife, and encourage structural complexity within the forests by planting native shrubs such as alder and willow.			
		4. Surface water quality will be maintained suitable for wildlife habitat availability through mitigations listed in the Water Quality mitigation section.			
		5. Sight lines will be limited by maintaining mature forest stands as buffers between roads and reclamation areas.			
		6. The existing legacy mining disturbances will be incorporated into the development and reclamation plans for the project so that existing habitat loss, habitat fragmentation, linear disturbance features, and cumulative habitat loss are corrected.			
		7. Pre-disturbance surveys (wildlife sweeps) will be conducted in the development area prior to any construction activities during Project development to determine the occurrence of any important wildlife habitat features such as migratory bird nests, mineral licks, active dens, bat habitat and hibernacula, active raptor nest sites, and essential raptor habitat features that could indicate the presence of species at risk.			
		8. Important wildlife habitat features on the edge of the Project footprint boundary) will be protected with appropriate setback distances or other appropriate measures.			
		9. Disturbance of undisturbed areas within and adjacent to the Project footprint will be avoided.			
		10. Vegetation adjacent to high-activity linear corridors will be retained to reduce the extent of noise and visual sensory disturbances.			
		11. Refer to mitigation WQ-1.5 (Table 2-5) as it pertains to riparian buffer zones.			
		12. Refer to visual impact mitigations (AQ-6.1 to AQ-6.6, Table 2-1) that will be implemented that also apply to minimizing effects to wildlife.			
		13. Refer to noise mitigations (N-1.1 to N-1.8, Table 2-2) that will be implemented that also apply to minimizing effects to wildlife.			
		14. Despite the low occurrence of Clark's Nutcracker in the wildlife LSA, the C&R Plan will include the establishment of Whitebark Pine and other species of pine (as described in the Vegetation mitigation section) to ensure sufficient habitat and other food sources for Clark's Nutcrackers.	Addendum 8, CEAA-R2-2, CIAR #89		

Table 2-9 Wildlife (WL) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
		15. Benga will conduct site-specific surveys, that adhere to the Alberta Sensitive Species Inventory Guidelines (SSIG) for common nighthawk prior to construction and operations to further bolster the baseline to capture the status of common nighthawk in the wildlife LSA.	Addendum 8, AER-R2-74, CIAR #89		
		16. Benga will assess the presence/absence of bats in potential high-quality habitats located within the Project footprint at least one year prior to the initiation of any clearing activities. In the event that any maternal colonies and/or roosting sites are identified, Benga will develop a mitigation plan in consultation with AEP and ECCC personnel.	Addendum 8, ECCC-R2-4, CIAR #89		
		17. Benga will assess the potential for creating roosting sites for bats by constructing and erecting bat houses in habitats adjacent to the Project footprint and in reclaimed areas.			
		18. The wildlife mitigation will be implemented, monitored, and verified through the Project's Wildlife Mitigation and Monitoring Plan and the C&R Plan, which are expected to reduce the effects of the Project on wildlife habitat.	Wildlife Mitigation and Monitoring Plan (WMMP) (Addendum 10, Appendix 5.39-1, Section 5, Section 5, CIAR #251) -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313		
2. Changes in wildlife habitat fragmentation and connectivity from physical barriers or sensory disturbance.	Habitat loss and fragmentation reduce habitat connectivity and thereby can affect daily and seasonal movements and dispersal of wildlife species. Wildlife may move into or through habitats that are physically disturbed but are unlikely to reside there, and they are also prone to acoustic or visual sensory disturbances. Potential obstructions to wildlife movement associated with the Project include: • loss of vegetation and landscape alteration from construction of the open pit mine, infrastructure, and roads; • vehicular traffic activity associated with the mine access road and other mining activities; • coal conveyor infrastructure; and • the railway loop.	1. Benga will incorporate appropriately sized wildlife crossings, strategically placed in locations that will maximize wildlife use, into the design of the covered overland coal conveyor and access road.	WMMP (Addendum 10, Appendix 5.39-1, Section 5, CIAR #251) also -EIA, CR #9, Section 7.1.4, CIAR #42; -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313	Mitigation will reduce, but not eliminate the effects of the Project on wildlife movement. There will some amount of residual effect on movement from the conveyor, rail and roads, and removal of riparian habitat or the fragmentation of forest habitat. After mitigation, these effects are characterized as low magnitude for all wildlife VCs.	Residual effect not significant
		2. Surface water management ponds and ditches will be designed to allow wildlife to move around or cross safely.			
		3. Road plowing and grading will be conducted in a manner that does not restrict wildlife from crossing access roads or accessing wildlife crossings.			
		4. Measures to control dust and other air emissions as described in the Air Quality Section will be implemented to minimize effects on adjacent wildlife habitats (refer to mitigations AQ-1.1 to AQ-1.17, Table 2-1).			
		5. Project-specific mitigations targeted to carnivore species have been incorporated into the C&R Plan. The following mitigations will support habitat connectivity for migratory birds, raptors, and species at risk: • minimizing the overall disturbance footprint through the mine planning process; • preserving remnant forest patches in the development areas to provide essential habitat, habitat connectivity, and hide cover for wildlife species; • retaining slash and large woody debris in the replaced soil landscape; • planting native shrubs early in the reclamation process to initiate hiding cover; • establishing mixed wood forest stands and high-density coniferous tree stands; • providing understory complexity in the reclaimed forests by planting native shrubs such as alder and willow to provide security cover for the carnivores and their prey; • maximizing the amount of ungulate habitat; • prior to final reclamation, disrupting linear disturbances and sight lines by mounding surface soils, piling brush; • limiting sight lines by maintaining mature forest stands or by planting high density coniferous stands to act as buffers between roads, project disturbance boundaries and the reclaimed mine areas.			

Table 2-9 Wildlife (WL) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
		6. Project mitigations that are specifically targeted to grizzly bears and grizzly bear habitat that will support other carnivores and migratory birds, and include: • maintaining a 100 m undisturbed riparian buffer zones around Blairmore Creek and Gold Creek, along with 30 m riparian buffer zones at associated tributaries that are not affected by the Project footprint; • leaving patches of residual forest within and adjacent to the mine footprint; • commencing reclamation early on in mine operations by seeding reclaimable areas with plant species favourable to grizzly bear forage, and by planting shrub and tree species that provide suitable cover (*e.g.,* willow, alder, coniferous trees).			
		7. Project mitigations targeted to migratory birds include: • retaining slash and large woody debris in the salvaged soil to provide microsites for native plant and hide cover and perches for wildlife; • ensuring reclaimed areas promote the re-establishment of woody species and are on a trajectory for reforestation.			
		8. Project mitigations targeted for raptors include: • retaining residual patches of essential habitat and habitat features within and adjacent to the mine footprint (*i.e.,* mature poplar trees, tall conifer trees) to provide perches, nest sites, and hide cover; • minimizing loss of mature and old-growth forest habitat and avoid complex, multi-story mixedwood forest where possible.			
		9. Project mitigation targeted for amphibians and amphibian habitat include: • monitoring to identify other habitable ponds and to identify habitat requirements and constraints; • reclaim upland habitat adjacent to reconstructed breeding ponds; and • avoid habitat destruction and alteration outside of the defined Project footprint to the best extent possible.			
3. Changes to wildlife mortality risk from construction activities or increased human-wildlife interactions.	The Project has the potential to increase mortality risk for wildlife species through several mechanisms. Clearing/removal of natural habitat may result in direct mortality of individuals, particularly chicks located in nests and other animals with limited mobility. Mortality can also result from wildlife-vehicle collisions during Project construction and operation.	1. All access to the mine will be controlled, no uncontrolled access will be permitted, and no new roads will be built as a result of the mine. Common operational practices that will be implemented as part of controlled access include: • prohibiting use of snowmobiles and ATVs within the Mine Permit Boundary; •gated security on the primary access road; • prohibiting hunting or use of firearms within the Project boundary.	WMMP (Addendum 10, Appendix 5.39-1, Section 5, CIAR #251) also EIA, CR #9, Section 7.1.5, CIAR #42; -Addendum 11, JRP IR-6.5, Table 6.5-2, CIAR #313	Mitigation will reduce, but not eliminate the effects of the Project on wildlife mortality. There will still be a residual amount of wildlife mortality during construction and operation of the Project. Effects are characterized as low in magnitude for all wildlife VCs.	Residual effect not significant
		2. Vegetation site clearing activities will occur outside the April 15 to August 31 period to avoid disrupting nesting migratory and resident songbirds and raptors. In the event that vegetation clearing must occur within the restricted activity period, pre-disturbance nesting surveys will be conducted by experienced avian biologists according to established sensitive species inventory guidelines. Benga will establish species-appropriate setback distances around confirmed active nest sites in consultation with the AEP. If the status of a nest cannot be confirmed, or if a nest is found outside of the breeding season, a setback distance will be implemented until such time as the nest status can be confirmed.			
		3. Pre-disturbance denning and roosting (bats) surveys will be conducted as described above prior to vegetation clearing and other high-disturbance activities. Benga will consult with AEP as needed to develop appropriate mitigation and management strategies.			
		4. Pre-disturbance surveys (acoustic surveys and visual searches) will be conducted to identify wetlands and watercourses used by breeding Columbia spotted frogs and western toads.			

Table 2-9 Wildlife (WL) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
		5. Benga will develop and implement active bear management plans for the Project. The plan will be developed in consultation with AEP personnel as part of the Wildlife Mitigation and Monitoring Plan. The plan is expected to be a comprehensive document that outlines operational strategies and best practices for addressing concerns related to not only bear-human conflicts but potential risks to ungulates and other wildlife resulting from attraction of bears to the area.			
		6. A detailed Waste Management Plan will be developed and implemented prior to construction and operational activities to minimize the attraction of wildlife. Benga will follow the Best Management Practices for camps, fences, and barriers as described in Bear Smart: Best Management Practices for Camps, and ensure all waste is stored in wildlife-proof containers and disposed of properly.			
		7. Emergency Spill prevention and response measures will be taken as described in mitigations in WQ-8.1 to WQ-8.5 (Table 2-5) to limit the effect of accidental spills.			
		8. Benga will develop procedures to clear blasting areas of large mammals or birds prior to blasting.			
		9. Benga will enforce speed limits as described in AQ-1.16 (Table 2-1), and will place signs at identified wildlife crossings to minimize wildlife-vehicle collisions.			
		10. Bird collisions with buildings will be mitigated by placing visual markers on windows, and collisions with the proposed power line will be mitigated by installing large 'floats' or other markers.			
4. Effects on wildlife abundance due to changes in mortality, habitat availability, or movement.	Changes in habitat availability, habitat fragmentation and movement, and mortality rates can affect the abundance of wildlife within the Project's study areas. Sustained reductions in abundance at the local population level can ultimately lead to changes in population processes at the landscape level, and survival of species at a broader geographic scale.	1. Effects on wildlife abundance are mitigated through the measures implemented to mitigate habitat loss (WL-1.1 to WL-1.18), movement (WL-2.1 to 2.-9), and mortality risk (WL-3.1 to 3.10) (above).	-	Mitigation will reduce, but not eliminate the effects of the Project on wildlife abundance. There may be a decrease in abundance of wildlife in the WLSA during construction and operations phases of the Project, due to the residual effects on habitat availability, mortality and movement. The residual effect is characterized as low in magnitude for all wildlife VCs.	Residual effect not significant
5. Effects on wildlife health due to Project activities	Chemicals of Potential Concern (COPC) emitted from the Project into the air and deposited on soil and/or surface water within the wildlife regional study area (greatest extent defined as the Grizzly Bear regional study area) can have an effect on wildlife health.	1. Refer to mitigations AQ-1.1 to AQ-1.17 and AQ-2.1 to AQ-2.2 (Table 2-1) that pertain to the implementation of dust and air quality management mitigations, which are relevant to ensuring air quality is suitable for wildlife.	EIA, CR #9, Section 4.1, CIAR #42; Addendum 10, Appendix 4.9-1, CIAR #251;	The results of the Project's wildlife risk assessment indicated that wildlife health effects were likely to be highly localized, Project-related contributions to emissions in the GBRSA would be negligible to small, and the risk of adverse effects associated with Project emissions on the health of wildlife in the study areas would be minimal. It was concluded that the Project will not pose a threat to wildlife health.	No residual effect
		2. Refer to mitigations WQ-2.1 to 2.9 and WQ-3.1 to WQ-3.5 (Table 2-5) that pertain to the implementation of water quality mitigation treatment, which are relevant to ensuring water quality is suitable for wildlife.	Addendum 11, Appendix 6-28-1, CIAR #313		
		3. Implement hazardous materials management and emergency spill response mitigations as described in WQ-8.1 to WQ-8.5 (Table 2-5) to minimize potential risks to wildlife.			

Land Use and Historical Resources

A consolidated table of commitments and mitigation measures related to land use and historical resources has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-10.

Table 2-10 Land Use and Historical Resources (LU/HR)

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Changes to existing land use during construction, operations and closure.	Effects on other existing land uses (land use policies and resources management initiatives, resource development, hunting and trapping, access and utilities, tourism, and outdoor recreation) due to the potential for direct impact due to the development of the Project.	1. Benga has filed a *Public Lands Act* application as part of the project that identifies and provides evidence of applicable agreements or consents with existing land users (grazing leases, oil & gas) regarding the proposed development of the Project.	Addendum 10, Appendix 4.1-2, CIAR #251 -Addendum 11, JRP IR-6.5, Table 6.5-5, CIAR #313	With the implementation of mitigation measures and monitoring, it is expected that the Project will not have a significant impact on land and resource uses with the area. Mitigation will reduce, but not eliminate, the effects related to access, and as such, there is a residual effect.	Residual effect not significant
		2. Benga will not be increasing road or trail access to the mine (primary access will be the existing access road) to adhere with the Livingstone-Porcupine Hills Land Management Framework.	Addendum 10, Appendix 4.1-2, CIAR #251		
		3. Access points and roads will be clearly labelled and documented.	Addendum 10, Appendix 4.1-2, CIAR #251 -Addendum 11, JRP IR-6.5, Table 6.5-5, CIAR #313		
		4. Signage will be used for identifying areas that are not open or accessible for public use.	Addendum 10, Appendix 4.1-2, CIAR #251		
		5. Benga will continue to consult with local stakeholders and Indigenous groups through the life of the Project to identify concerns and proactively address issues when they arise.	EIA, Consultant Report #10, Section 6.0, CIAR#42		
		6. Benga will undertake progressive reclamation and reclaim the area to a landscape that includes provisions for a variety of land uses, including forestry, wildlife habitat, grazing, and recreational use.			
		7. Benga will monitor changes in land use policies and initiatives, and through adaptive management incorporate new requirements into the ongoing development, operation, and reclamation plans.			
		8. Benga will continue to work with Indigenous groups to improve and adhere to the Project's Access Management Plan (AMP) to grant access to non-operational areas of Benga land and crown land being used for the Project. The AMP will control access to authorized persons, will ban employees from accessing fishing locations within the Project boundary, and facilitate access to traditional use areas for Indigenous groups, where feasible. The AMP will include notification of access restrictions during construction required for safety purposes to allow for planning alternate plant gathering locations and access routes.	Addendum 10, Appendix 4.1-2, CIAR #251 -Addendum 11, JRP IR-6.5, Table 6.5-5, CIAR #313		
		9. Benga will allow Indigenous groups to access Benga private land, outside of the Project following the AMP for the purposes of harvesting lodgepole pine and other culturally important plants.			
		10. Benga will engage with the Indigenous groups during construction, operations and reclamation, including review and input into management and monitoring plans, discussion of options to facilitate access for traditional activities and reclamation.			
		11. Where identified by Indigenous groups, sites of cultural and sacred importance within 100 m of Project activity and outside the Project footprint will be marked or otherwise protected prior to land disturbance. If avoidance of any these sites is not possible, Benga will work with Alberta Culture, Multiculturalism and Status of Women (formerly Alberta Culture and Tourism and/or Indigenous groups to develop and plan for mitigation of the site.			
		12. Benga will develop and implement a cultural site discovery contingency plan (or equivalent) in consultation with Indigenous communities for culturally important sites identified during construction and operations.			

Table 2-10 Land Use and Historical Resources (LU/HR)

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
		13. Benga will provide training to all staff and contractors regarding respectful land use and access management and will promote cultural diversity awareness to Benga's employees and contractors.	Access Management Plan (Addendum 10, Appendix 4.5-1, CIAR #251) -Addendum 11, JRP IR-6.5, Table 6.5-5, CIAR #313		
		14. Recreational land use restrictions for employees and contractors will be emphasized to minimize intensive hunting, fishing, and other recreational pressures within the Project boundary.			
		15. Access and use of OHVs on Benga-owned lands and the Project footprint will be controlled through the Project's AMP.			
		16. Benga will return Crown dispositions to the Crown after reclamation is completed.			
2. Changes to historical resources as a result of construction and operational activities.	Construction and operational activities such as blasting, earthworks, and mining could have effects on unique sites and special features associated with areas of the Project footprint.	1. Benga will adhere to the approved Project-specific *Historical Resources Act* recommendations as they pertain to the identified historical resources identified on Grassy Mountain adjacent to or within the Project footprint.	Addendum 11, JRP IR-6.4, Appendix 6.4-1, CIAR #313	Mitigations were designed to reduce or eliminate the potential impact from the proposed Project's construction and operation activities on historical resources. After mitigation, it was deemed there may still be a low residual effect on some historical resources.	Residual effect not significant
		2. Where identified by Indigenous groups, sites of cultural and sacred importance within 100 m of a Project activity and outside the Project footprint will be flagged or marked prior to land disturbance.	Addendum 11, JRP IR-6.5, CIAR #313		
		3. Benga will continue to implement the plan, as submitted to Alberta Culture, Multiculturalism and Status of Women, for mitigation of identified TK/TU features where avoidance is not possible.			
		4. Benga will continue to work with the Indigenous groups to identify ways in which TK can be considered during Project activities and in the development of environmental management plans.			
		5. Benga will adhere to the Guidelines for the New Development in Proximity to Railway Operations.	EIA, Appendix 2D, CIAR #42		

SOCIO-ECONOMICS

A consolidated table of commitments and mitigation measures related to socio-economics has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-11.

Table 2-11 Socio-Economics (SE) Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Changes to regional income.	Construction and operation of the Project may result in a change in income of households and individuals in the region.	1. No mitigations required.	EIA, CR #11, CIAR #42	Project contribution is positive during both construction and operation as the Project will contribute to increased incomes to individuals, households, and businesses in the region.	No adverse residual effect
2. Changes to government revenue.	Construction and operation of the Project may result in a change in government revenue.	1. No mitigations required.	EIA, CR #11, CIAR #42	Project contribution is positive as the Project will contribute increased government revenue to all three levels of government.	No adverse residual effect
3. Changes to regional employment.	Construction and operation of the Project may result in a change in employment in the region.	1. No mitigations required.	EIA, CR #11, CIAR #42	Project contribution is positive during both construction and operation as the Project will create employment opportunities at both the regional and provincial level.	No adverse residual effect
4. Changes to regional population.	Construction and operation of the Project may result in a change in population in the region.	1. Benga will work with the municipalities in the region to keep them informed of its development plans and their timing so that the affected municipalities have sufficient time to plan for changes in the demand for services.	EIA, CR #11, Section 5.4, CIAR #42	The Project is expected to result in a net permanent population increase in the regional study area (RSA).	Residual effect not significant
5. Changes to regional housing.	Construction and operation of the Project may result in a change in demand for housing in the region.	1. Benga will house construction workers in a temporary camp, which has the ancillary effect of reducing the resident population effect of the Project and the anticipated demand for housing.	EIA, CR #11, Section 6.4, CIAR #42	The in-migration anticipated to occur as a result of the Project will increase the need for housing in the RSA.	Residual effect not significant
		2. Benga will work with local governments to facilitate the timely development of residential land and dwellings.			
6. Changes to regional social infrastructure.	Construction and operation of the Project may result in a change in demands on social infrastructure in the region.	1. Benga will develop and implement specific policies regarding employee health and safety, alcohol and drug use, and emergency response.	EIA, CR #11, Section 7.4, CIAR #42	Demand for social infrastructure is expected to change largely in line with population effects. While some service providers might face challenges in meeting increased demand, future growth can also help generate opportunities to address this increased. Growth in a community can also help increase the breadth and nature of social infrastructure services available to local residents.	Residual effect not significant
		2.Benga will provide employees with access to a confidential employee assistance plan, which provides support for families and individuals who may experience difficulty dealing with personal, family, or work-life issues that can affect one's health and well-being.			
		3. Benga will support local programs and initiatives through both financial and in-kind contributions such as a grassroots stewardship program for Gold Creek.			
		4.Benga will work with the provincial and municipal governments on the implementation of relevant planning initiatives and coordination of emergency response procedures.			
7. Changes to municipal infrastructure and services.	Construction and operation of the Project may result in a change in demands on municipal infrastructure and services in the region	1. In order to reduce the impact on municipal infrastructure, the Project will not tie in directly to municipal water or sewer lines in the region and the Project will make use of the regional waste transfer station operated by Crowsnest Pass.	EIA, CR #11, Section 8, CIAR #42	There will be an additional demand for municipal infrastructure requirements driven by the population increase	Residual effect not significant
		2. Benga will construct a work camp during construction as indicated above.			
8. Changes to regional transportation.	Construction and operation of the Project may result in increases in traffic in the region	1. Improvements to the left turn lane storage at intersections within Blairmore, and additional signalization at the 129th Street intersection will be completed by 2021 to accommodate projected increases in background traffic volumes.	EIA, CR #11, Section 10.4, CIAR #42	There will be negative effect during construction and operation as Project-related workforce and activities will increase traffic.	Residual effect not significant
		2. The existing gravel access road to the Project will be upgraded to accommodate Project-related traffic.			
		3. During both construction and operations, Benga and its contractors will use buses and multi-passenger vans to transport personnel to site in order to reduce the total number of vehicles traveling on local roads. Benga will also endeavor to schedule construction deliveries during off-peak hours.			
		4. Benga is committed to maintaining an open dialogue and communicating its development and operational plans, including traffic management plans, with the appropriate agencies such as Alberta Transportation and B.C. Transportation and Infrastructure, if required.			

HUMAN HEALTH

A consolidated table of commitments and mitigation measures related to human health has been created, along with the reference to the location within the EIA or Addenda where the mitigation is discussed, and a description of residual effects. This table is provided below as Table 2-12.

Table 2-12 Human Health Risk Assessment (HHRA) and Wildlife Risk Assessment Mitigation and Commitments Summary Table

Pathway of Effect	Description of the Effect	Description of the Mitigation or Commitment	Reference	Description of Residual Effects	Residual Effects Conclusion
1. Potential health risks to the local human population, associated with exposure to chemicals that could be released to the environment from the proposed Project.	Human health risk was evaluated based on exposure to water, soil, air and food (both plant and animal based) within the LSA, EPL, RSA, Blairmore Creek, Gold Creek, Crowsnest River and the Oldman Reservoir. Reduced environmental quality and exposure to potentially harmful concentrations of chemicals can result in a risk of potential adverse health effects.	1. Benga will implement air monitoring program to confirm that the emitted concentrations of NO_2, $PM_{2.5}$, and PM_{10} in areas accessible to the general public do not exceed the levels predicted by the air dispersion modelling. 2. Benga will implement an Aquatics Monitoring Plan to monitor chemicals of potential concern (COPC) associated with the Project affected watercourses and the end pit lake to confirm that water quality parameters do not exceed predicted levels.	HHRA, Addendum 10, Appendix 4.9-1, CIAR #251 and HHRA: Addendum 1, Addendum 11, Appendix 6.27-1, CIAR #313	The emissions from the Project are not predicted to pose a risk of adverse health effects at the receptor locations accessible to the general public. While risk quotients greater than 1.0 were predicted, they were identified to occur within the Mine Permit Boundary, an area assumed to be inaccessible by the public during construction and operation of the mine, or were within the margins of safety considered within the Human Health Risk Assessment (HHRA) and in most cases relate to naturally elevated concentration measured in background. The risk results outside the regional study area-maximum point of impingement (RSA-MPOI) (within the Project Footprint) were not considered to be indicative of a potential for adverse human health effects. Due to the conservative assumptions applied in the air dispersion modelling, groundwater and surface water transport modelling and within the HHRA itself, the risk results presented for the Blairmore Creek, Gold Creek and the Oldman Reservoir were also not considered to be indicative of a potential risk of adverse human health effects.	No residual effects
2. Potential health risks to wildlife, associated with exposure to chemicals that could be released to the environment from the proposed Project.	Exposure to water, soil, air and food (both plant and animal based) within the local study area (LSA), end pit lake (EPL), RSA, Blairmore Creek, Gold Creek, Crowsnest River and the Oldman Reservoir could result in reduced environmental quality and exposure to potentially harmful concentrations of chemicals can result in a risk of potential adverse health effects.	1. Refer to mitigations HHRA-1.1 and HHRA-1.2 as it relates to air (including deposition to soils & vegetation) and aquatic mitigations, respectively.	HHRA, Addendum 10, Appendix 4.9-1, CIAR #251 and Wildlife Risk Assessment: Addendum 1, Addendum 11, Appendix 6.28-1, CIAR #313	The results of the WRA did not indicate a predicted risk of adverse effect associated with Project emissions on the health of wildlife in the study areas. Risk from other evaluated COPC was not predicted for aquatic wildlife.	No residual effects

3. SUMMARY TABLE OF MITIGATION AND COMMITMENTS NOT SPECIFIC TO A VALUED COMPONENT

3. An updated, comprehensive, and consolidated list of measures and commitments that are not specific to a valued component (such as those may have been made during Indigenous or community consultation). This should include reference to the location (document and page number) on the record where the commitment was made.

Response:

A table of mitigation and commitments has been created (Table 3-1) that covers those that are not specific to a valued component. Table 3-1 incorporates the general mitigation and commitments provided in Addendum 11, JRP IR-6.5 (CIAR #313) that are related to effects on Indigenous groups. The tables provided in the response to JRP IR-6.5 were very comprehensive and extensive and were 26 pages in length. As such, they are not replicated here in their entirety, and the reader is encouraged to refer to those tables for more details on Indigenous residual effects, pathways, or mitigation.

Table 3-1 also includes other non-VC specific mitigation or commitments.

Table 3-1 Mitigation and Commitments Not Specific to a Valued Component

Topic	Description of the Mitigation or Commitment	Reference
Comprehensive mitigation was tabulated for effects on Indigenous groups and documented in the response to JRP IR-6.5 (Addendum 11, CIAR #313), Tables 6.5-2 through 6.5-7. The mitigation and commitments from those tables, that are common to many valued components have been repeated below.		
Mitigation related to current use of lands and resources for traditional purposes, or physical and cultural heritage	Benga will support an Indigenous Environmental Stewardship Committee, one of whose functions will be to provide advice on environmental stewardship, land use values and sites of cultural, spiritual and traditional importance that may arise.	Addendum 11, JRP IR-6.5, CIAR #313; Addendum 10, Appendix 4.1-2, CIAR #251
	Benga will support an Indigenous monitoring program(s) that will include monitoring of a suite of culturally defined environmental attributes, and consideration of cultural heritage impacts and monitoring for cultural sites.	
	Benga will continue to work with the Indigenous community to identify ways in which Traditional Knowledge (TK) can be considered during Project activities and in the development of environmental management plans.	
	Benga will engage with the Indigenous communities during construction, operations and reclamation, including review and input into management and monitoring plans, discussion of options to facilitate access for traditional activities, construction timing and reclamation.	
	Benga will allow access to Benga-owned lands outside the Project footprint within the RSA for traditional use such as hunting and trapping. The Access Management Plan will be used to permit this activity while ensuring safety and environmental protection	Addendum 11, JRP IR-6.5, CIAR #313; Addendum 10, Appendix 4.1-1, Section 18.4.1.1.5, CIAR #251
	Develop and implement a Cultural Site Discovery Contingency Plan in consultation with Indigenous communities for culturally important sites discovered during construction and operations.	

Table 3-1 Mitigation and Commitments Not Specific to a Valued Component

Topic	Description of the Mitigation or Commitment	Reference
	Benga will continue consulting and involving nearby Indigenous groups in the ongoing development of conservation and reclamation (C&R) plans and C&R related monitoring as the Project advances through the construction, operations, and progressive reclamation phases.	Addendum 11, JRP IR-6.5, CIAR #313; Updated Conservation and Reclamation Plan (Addendum 10, Appendix 2.6-1, Section F.2.7, CIAR #251)
	Benga will share information about construction timing to allow for gathering valued vegetation in advance of mining activity.	Addendum 11, JRP IR-6.5, CIAR #313; Addendum 10, Appendix 4.1-1, Section 18.4.1.2.4, CIAR #251
	Benga will implement a cultural competency program for its employees and contractors.	
	Benga will continue to support local and Indigenous cultural events and ceremonies through its Indigenous engagement and initiatives such as its community sponsorship program.	
	Benga has agreed to develop a communication protocol with Piikani First Nation, the nearest aboriginal community, for dealing with any complaints or concerns arising from the operation.	Addendum 8, HC-R2-15, CIAR #89
	Benga has been and will continue to be active in the nearby indigenous communities to provide information about the possible adverse health effects associated with country foods from areas adjacent to the project.	Addendum 10, JRP IR-4.13, #251
	Benga has committed to consider inclusion of measures specific to a possible re-establishment of bison to the area.	Addendum 10, JRP IR-4.2, CIAR #251
The following are mitigations and commitments not related to a specific valued component.		
Visual Impacts	Benga will take various steps to obscure the view of the load-out facility from the community. As part of its Public Consultation Plan, Benga will continue to engage in discussions with the community to address ideas for landscaping and other measures that would diminish concerns related to the visual impact of the load out infrastructure from the community's perspective.	EIA, Section G, Table G.4.0-1 and Section G.5.0, CIAR #42
Waste Management	As part of operational readiness preparation, Benga will develop and implement a comprehensive Waste Management Plan prior to commencing construction and operations.	Addendum 5, AER-R1-75, CIAR #69

4. COLLABORATIVE COMMITMENTS RELATED TO CUMULATIVE EFFECTS

4. A description of any collaborative commitments that Benga has made, or intends to make, with respect to the management of any adverse residual cumulative effects of the Project.

Response:

The Project did not predict any significant adverse cumulative effects. Predicted effects were mitigated at the Project level. Several collaborative commitments have been made, many of which are regional in nature, and will therefore, help mitigate cumulative effects. Some are related to collaborating on research, mitigation or monitoring, and others are related to the management of any adverse residual cumulative effects of the Project. The commitments made to Indigenous groups outlined in Table 3-1 are also collaborative in nature.

Table 4-1 provides a list of collaborative commitments for the Project.

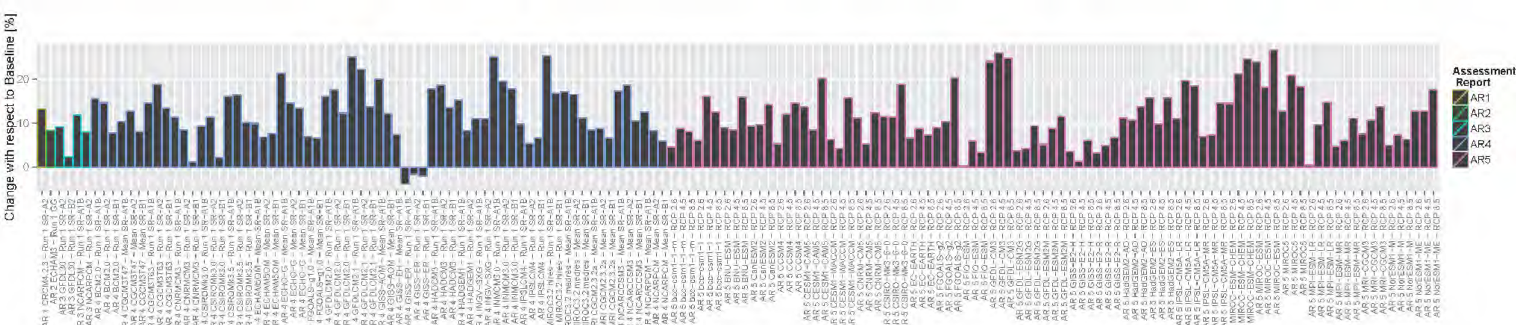
Table 4-1 Collaborative Commitments

Topic	Description of the Mitigation or Commitment	Reference
Reclamation	Benga will work with other operators of coal mines, AEP, AER and local stakeholders, to further develop criteria and monitoring programs that clearly demonstrate progress toward reclaiming environmentally sound sustainable ecosystems.	Addendum 10, Appendix 2.6-1, CIAR #251
Sportfishing	Benga will work closely with AEP (the government resource agency mandated to manage provincial fisheries resources) to ensure fisheries resources in the LSA do not become over-exploited as a result of increased sportfishing.	Addendum 1, Updated Section E.6, Subsection 6.3.1.1 CIAR #44
Research	Benga has partially funded a research project that specifically investigates the quality, extent and use of overwintering habitat by WSCT in Gold and Blairmore creeks. This research is ongoing and is being run through the University of Lethbridge by Dr. Joseph Rasmussen.	Detailed Fisheries Offsetting Plan (Addendum 8, Appendix B-1, Section 2.3.2, CIAR #89)
Country Foods	Benga has been and will continue to be active in the nearby indigenous communities to provide information about the possible adverse health effects associated with country foods from areas adjacent to the Project.	Addendum 10, JRP IR-4.13, CIAR #251
Wildfire Control	Benga will also prepare a Wildfire Control and Prevention Plan that is updated annually for each wildfire season. This plan includes on-site fire prevention and control equipment, communication procedures as well as off-site communication with the public and firefighting authorities (Alberta Agriculture & Forestry) and cooperative efforts in regional fire prevention and control.	EIA, Section C, Subsection C.7.6.3, CIAR #42
Monitoring and Reclamation	Benga will work with other operators of coal mines, AEP, AER and local stakeholders, to further develop criteria and monitoring programs that clearly demonstrate progress toward reclaiming environmentally sound sustainable ecosystems. Benga will use the experience gained during the development of the Project, and other successes by the regional coal operators over the next 24 years, to manage and implement an effective monitoring and reclamation program.	Draft Air Quality Monitoring and Adaptive Management Plan (Addendum 10, Appendix 1.3-1, CIAR #251) Conservation and Reclamation Plan (Addendum 10, Appendix 2.6-1, CIAR #251)
Recreational Use	Benga will continue to work with local recreational users in order to develop measures to mitigate potential impacts of the Project on outdoor recreation in the area.	EIA, Consultant Report #10, Section 5.7, CIAR #42
Wildlife	Benga is committed to mitigating Project effects throughout the construction, operation, and reclamation phases of the Project and collaboratively participating in any regional initiatives with regulators, stakeholders, and other industry partners to minimize the effects of resource development on wildlife on the regional scale.	EIA, Section E, Subsection E.9.4, CIAR #42

Table 4-1 Collaborative Commitments

Topic	Description of the Mitigation or Commitment	Reference
Access	Future versions of the Access Management Plan will be updated with content from the Joint Review Panel (JRP) Report, other provincial authorizations and permits, the federal Decision Statement, future stages of Project planning, and feedback from Indigenous communities and regional stakeholders.	Access Management Plan (Addendum 10, Appendix 4.5-1, CIAR #251)
Monitoring Plans	Finalization of the draft monitoring and mitigation plans will occur following additional consultation with regulators, Indigenous communities and stakeholders and is an anticipated requirement of the *Environmental Protection and Enhancement Act* (*EPEA*) approval condition.	Draft Wildlife Mitigation and Monitoring Plan (Addendum 10, Appendix 2.6-1, CIAR #251)
Bison	Benga has committed to work with Ktunaxa and other Indigenous groups to ensure that Indigenous goals are effectively incorporated into the reclamation planning process and would consider inclusion of measures specific to a possible re-establishment of plains bison to the area.	Addendum 10, JRP IR-4.2, CIAR #251
Turtle Mountain	Should blasting be required (at the golf course road), Benga will be working closely with an expert blast design consultant to ensure the key blasting parameters are managed carefully. Benga will also work closely with the AGS to ensure real time monitoring is in place and comparative data sets are developed. This will help understand the relationship between blast size and design and the vibrations measured on Turtle Mountain and to assist with developing appropriate benchmarks for blast vibration and noise, given that these do not currently exist. Benga will be adopting the latest blasting equipment, products and technology appropriate to its construction and operation requirements and work with the local agencies to ensure all blast related vibration and monitoring data is captured. Benga will also be adopting relatively shallow benches, through seam blasting and using high breakout force equipment (*e.g.*, hydraulic excavators), to ensure blasting powder factors can be minimized while maintaining acceptable levels of productivity.	Addendum 10, JRP IR-5.32, CIAR #251

FIGURES



GRASSY MOUNTAIN COAL PROJECT

RIVERSDALE RESOURCES

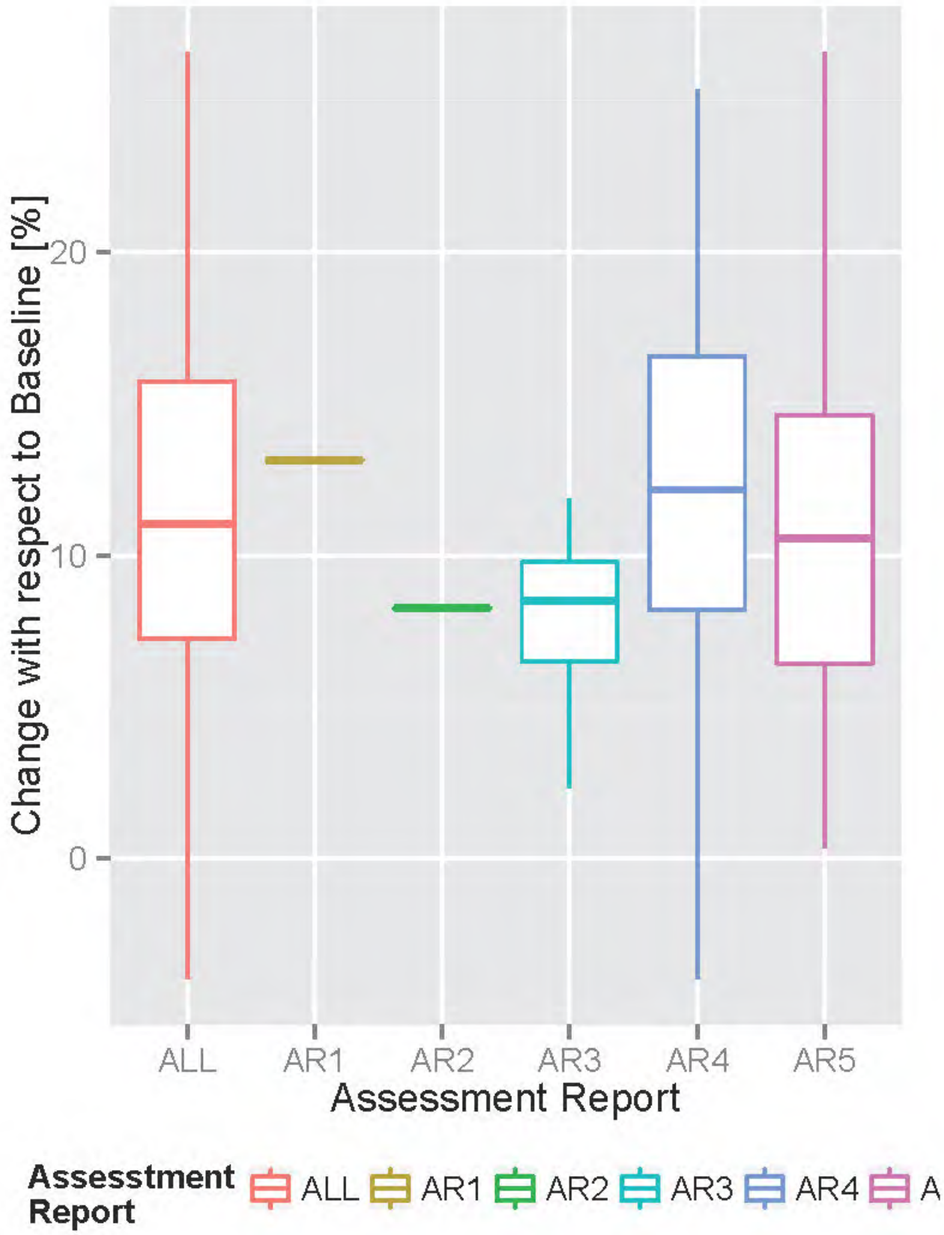
MILLENNIUM EMS SOLUTIONS LTD.

EXAMPLE OUTCOME FOR HYPOTHETICAL SITE SHOWING RESULTS OF CHANGE TO BASELINE CONDITIONS FOR INDIVIDUAL CLIMATE CHANGE MODELS ASSOCIATED WITH EACH OF THE FIVE ASSESSMENT REPORTS FOR A SPECIFIC PROJECTION PERIOD

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE 7.2-1



GRASSY MOUNTAIN COAL PROJECT

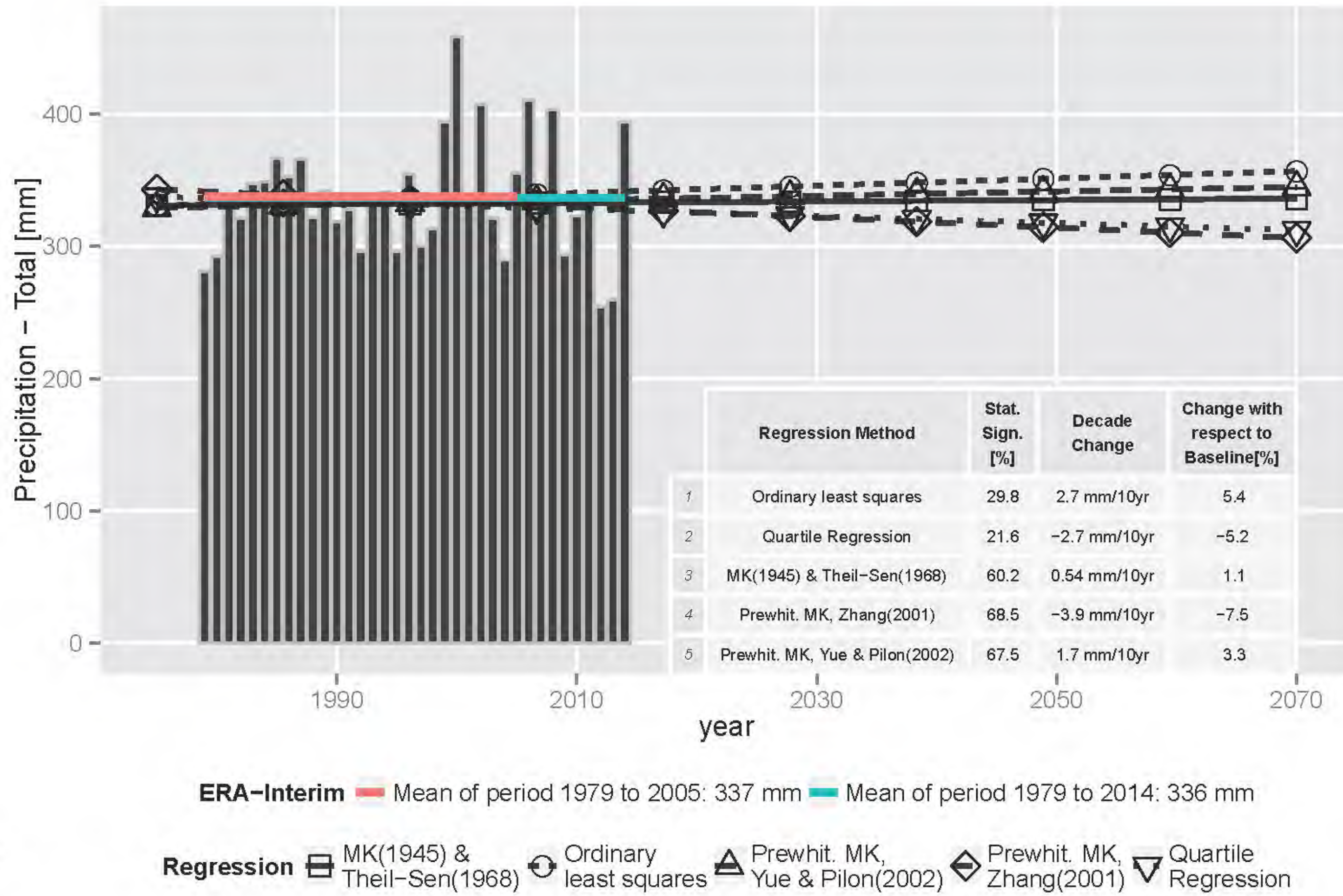
COMBINED BOX-WHISKER PLOT OF CHANGE TO BASELINE CONDITIONS FOR THE INDIVIDUAL CLIMATE CHANGE MODELS

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE 7.2-2

Document Path: K:\Active Projects 2014\AP 14-00201 to 14-00250\14-00201\MXD\Final Figures\Climate\IR 7.2 Climate Change\Fig 7.2-2 Box-Whisker Plot of Change to Baseline Conditions for the Individual Climate Change Models 14-00201.mxd



	Regression Method	Stat. Sign. [%]	Decade Change	Change with respect to Baseline[%]
1	Ordinary least squares	29.8	2.7 mm/10yr	5.4
2	Quartile Regression	21.6	−2.7 mm/10yr	−5.2
3	MK(1945) & Theil−Sen(1968)	60.2	0.54 mm/10yr	1.1
4	Prewhit. MK, Zhang(2001)	68.5	−3.9 mm/10yr	−7.5
5	Prewhit. MK, Yue & Pilon(2002)	67.5	1.7 mm/10yr	3.3

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

TRENDS ANALYSIS OUTCOME BASED ON REANALYSIS EVALUATION FOR HYPOTHETICAL SITE

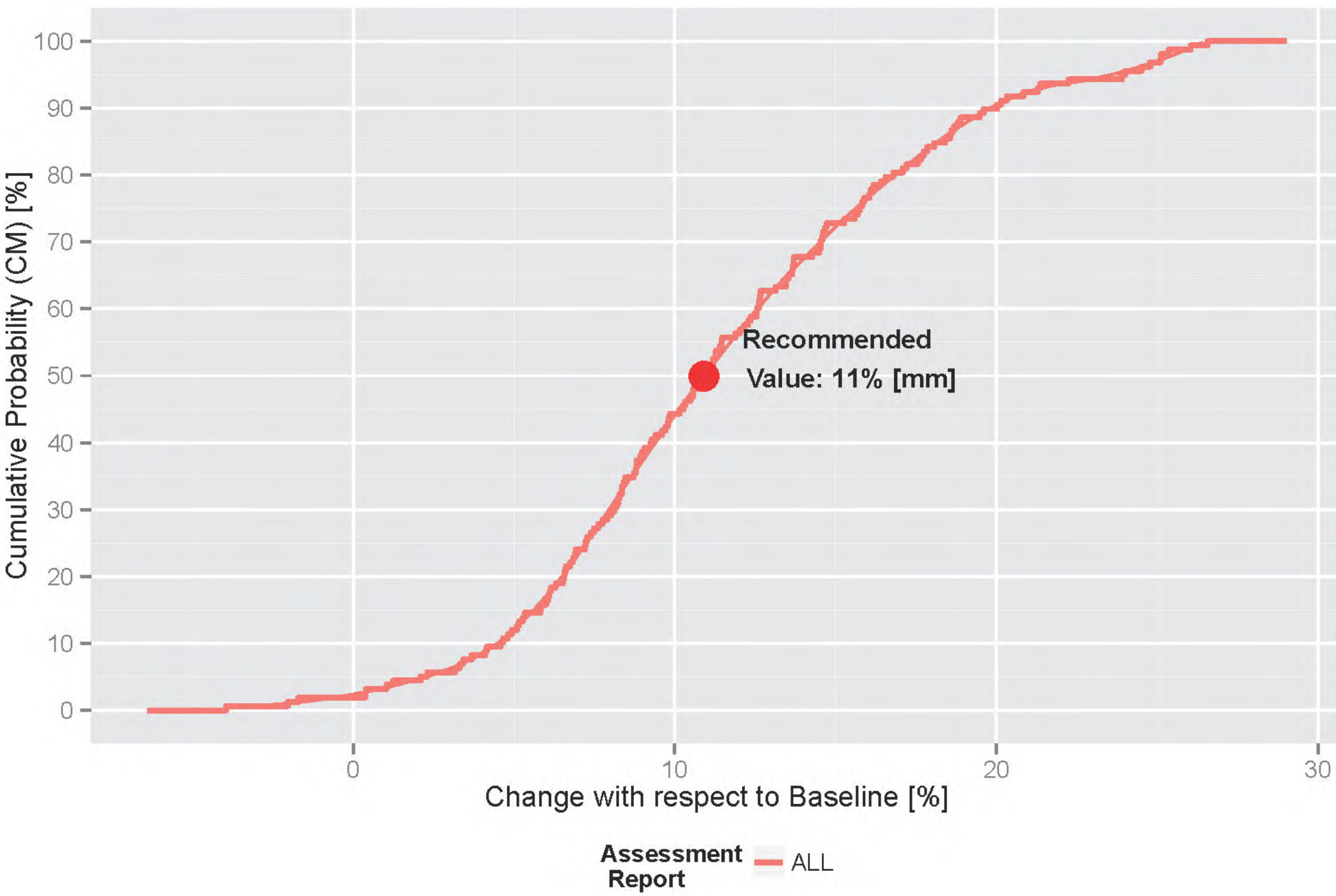
Data Source: SRK, 2020;

MILLENNIUM EMS Solutions Ltd.

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE

7.2-3



RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

MILLENNIUM EMS Solutions Ltd.

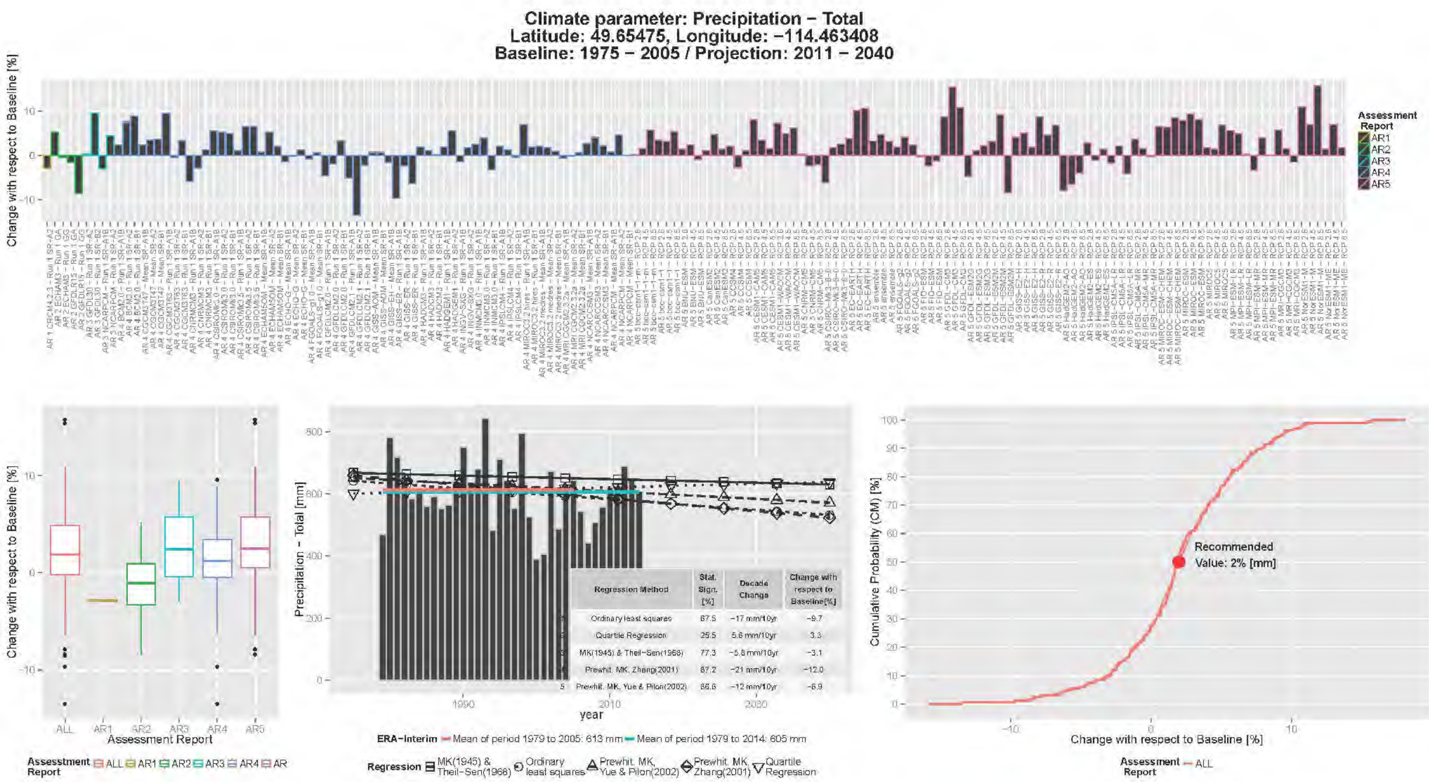
CUMULATIVE PROBABILITY CURVE OF CLIMATE CHANGE PREDICTION MODELS FROM ALL ASSESSMENT REPORTS EXPRESSED AS A PERCENTAGE OF CHANGE AGAINST BASELINE CONDITIONS

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE
7.2-4

Document Path: K:\Active Projects 2014\AP 14-00201 to 14-00250\14-00201\MXD\Final Figures\Climate\IR 7.2 Climate Change\Fig 7.2-4 Cumulative Probability Curve of Climate Change Prediction Models 14-00201.mxd



RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

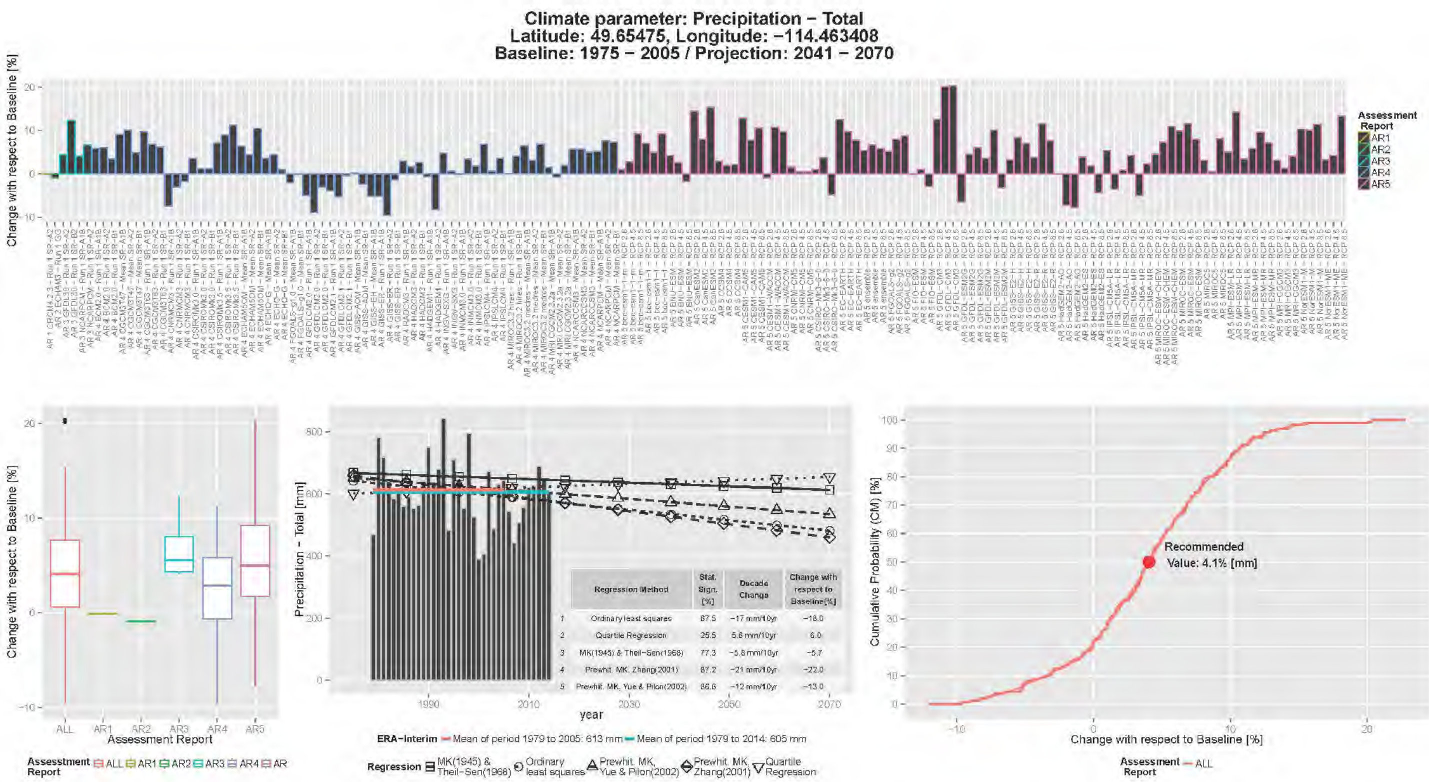
STATISTICAL ANALYSIS OF TOTAL ANNUAL PRECIPITATION FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2011-2040

Data Source: SRK, 2020;

MILLENNIUM EMS SOLUTIONS LTD.

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE
7.2-5



RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

STATISTICAL ANALYSIS OF TOTAL ANNUAL PRECIPITATION FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2041-2070

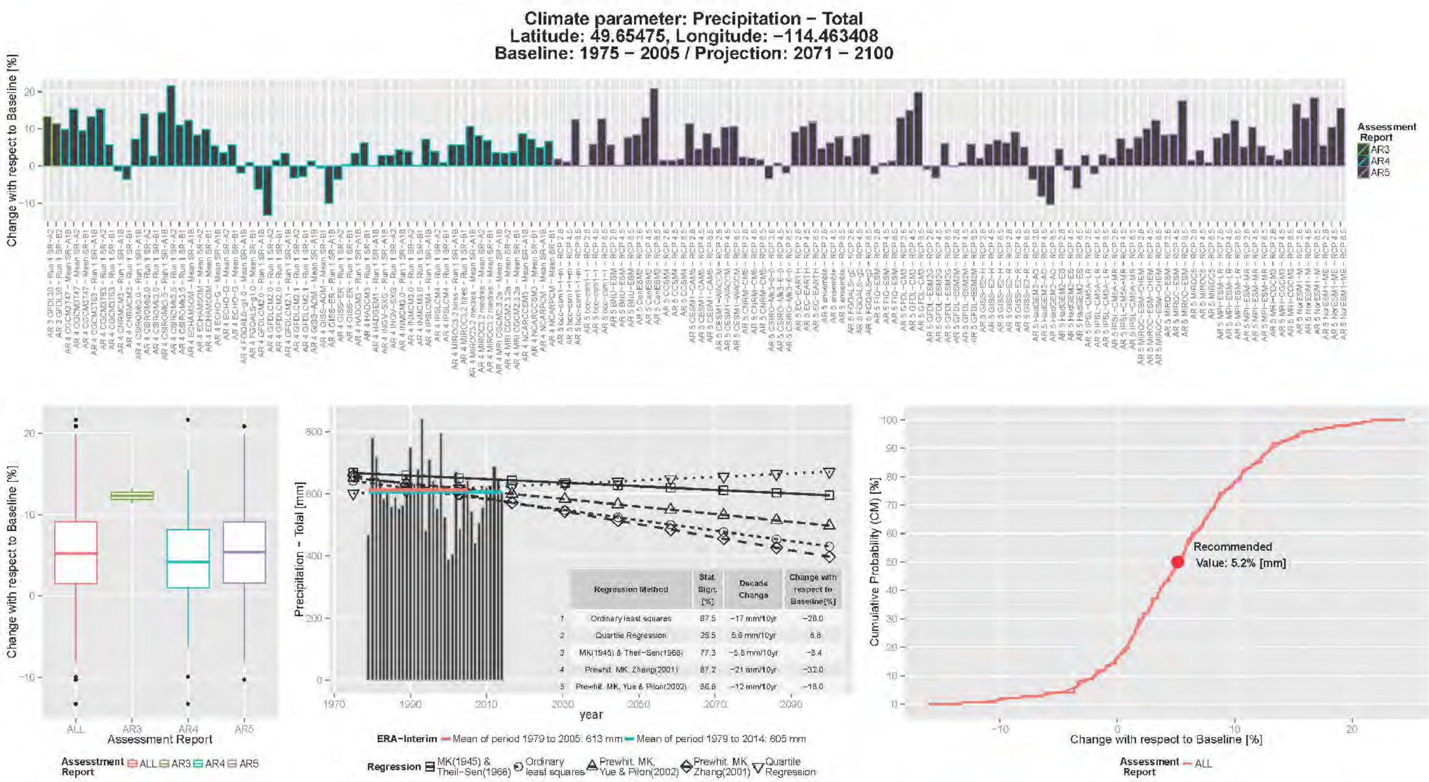
Data Source: SRK, 2020;

MILLENNIUM EMS SOLUTIONS LTD.

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE

7.2-6



RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

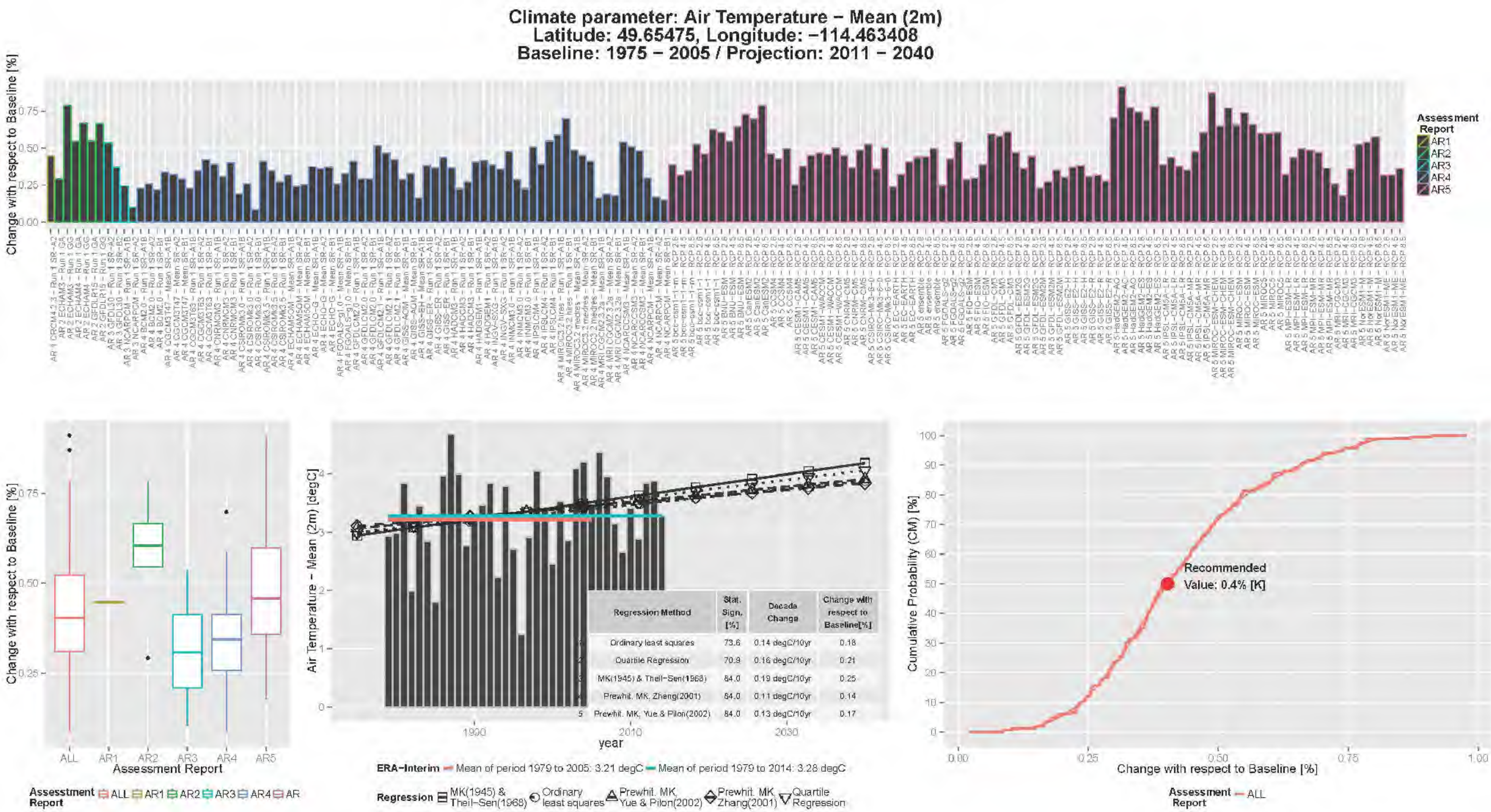
STATISTICAL ANALYSIS OF TOTAL ANNUAL PRECIPITATION FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2071-2100

Data Source: SRK, 2020;

MILLENNIUM EMS SOLUTIONS LTD.

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE
7.2-7



	Regression Method	Stat. Sign. [%]	Decade Change	Change with respect to Baseline[%]
1	Ordinary least squares	73.6	0.14 degC/10yr	0.18
2	Quartile Regression	70.9	0.16 degC/10yr	0.21
3	MK(1945) & Theil–Sen(1968)	84.0	0.19 degC/10yr	0.25
4	Prewhit. MK, Zhang(2001)	84.0	0.11 degC/10yr	0.14
5	Prewhit. MK, Yue & Pilon(2002)	84.0	0.13 degC/10yr	0.17

Document Path: K:\Active Projects 2014\AP 14-00201 to 14-00250\14-00201\MXD\Final Figures\Climate\IR 7.2 Climate Change\Fig 7.2-8 Analysis of Mean Annual Aire Temp with a Projected Time Period of 2011-2040 14-00201.mxd

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

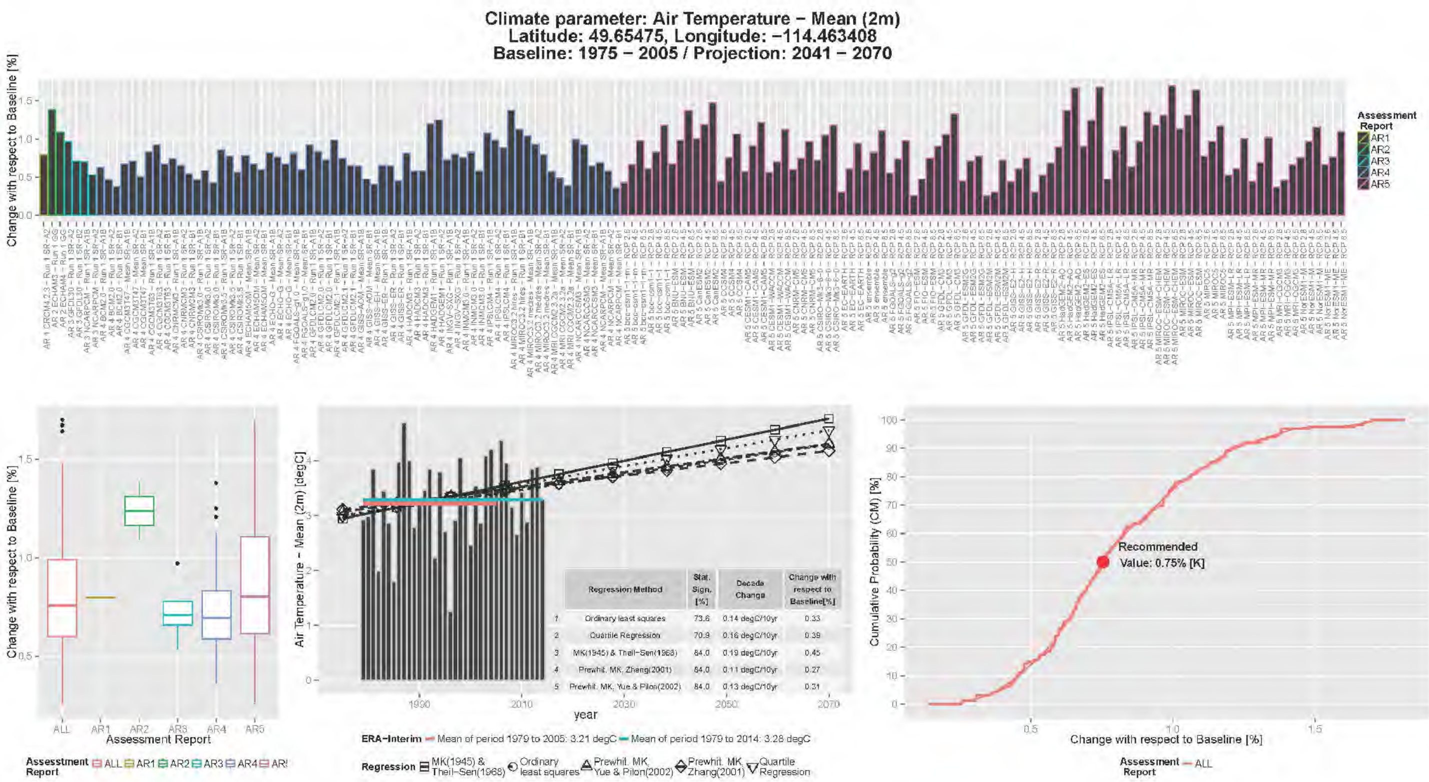
MILLENNIUM EMS Solutions Ltd.

STATISTICAL ANALYSIS OF MEAN ANNUAL AIR TEMPERATURE FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2011-2040

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE 7.2-8



RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

MILLENNIUM EMS SOLUTIONS LTD.

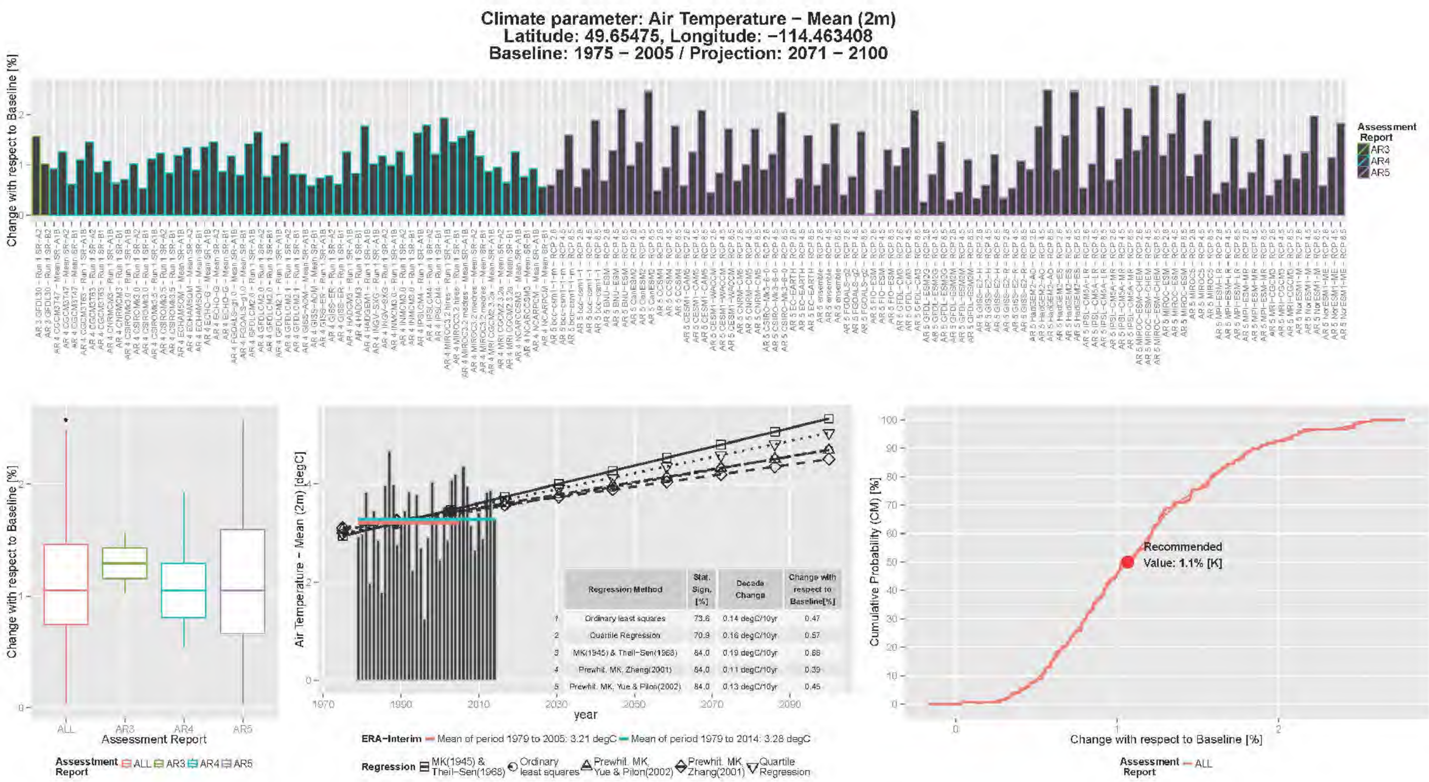
STATISTICAL ANALYSIS OF MEAN ANNUAL AIR TEMPERATURE FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2041-2070

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE

7.2-9



	Regression Method	Stat. Sign. [%]	Decade Change	Change with respect to Baseline[%]
1	Ordinary least squares	73.6	0.14 degC/10yr	0.47
2	Quartile Regression	70.9	0.16 degC/10yr	0.57
3	MK(1945) & Theil–Sen(1968)	84.0	0.19 degC/10yr	0.68
4	Prewhit. MK, Zhang(2001)	84.0	0.11 degC/10yr	0.39
5	Prewhit. MK, Yue & Pilon(2002)	84.0	0.13 degC/10yr	0.45

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

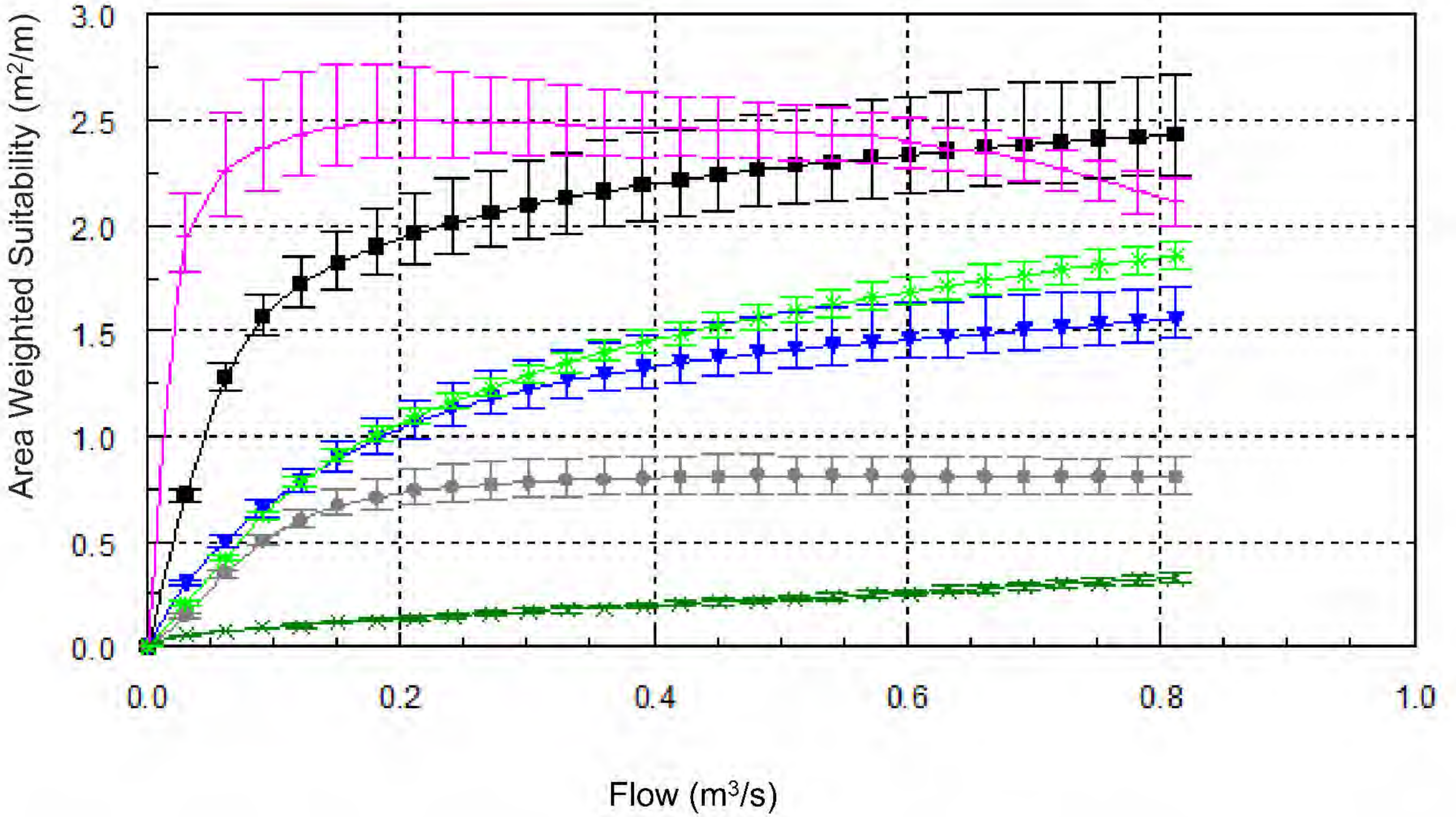
MILLENNIUM EMS SOLUTIONS LTD.

STATISTICAL ANALYSIS OF MEAN ANNUAL AIR TEMPERATURE FOR THE GRASSY MOUNTAIN PROJECT WITH A PROJECTED TIME PERIOD OF 2071-2100

Data Source: SRK, 2020;

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 16, 2020

FIGURE **7.2-10**



Note: For average hydrological conditions during baseline, the MAD is 0.175 m^3/s and MMD range from 0.027 m^3/s (February) to 0.689 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Rearing Adult WSCT; Rearing Juvenile WSCT; Spawning Adult WSCT; Fry WSCT; Overwintering WSCT; Invertebrate Drift

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

MILLENNIUM EMS Solutions Ltd.

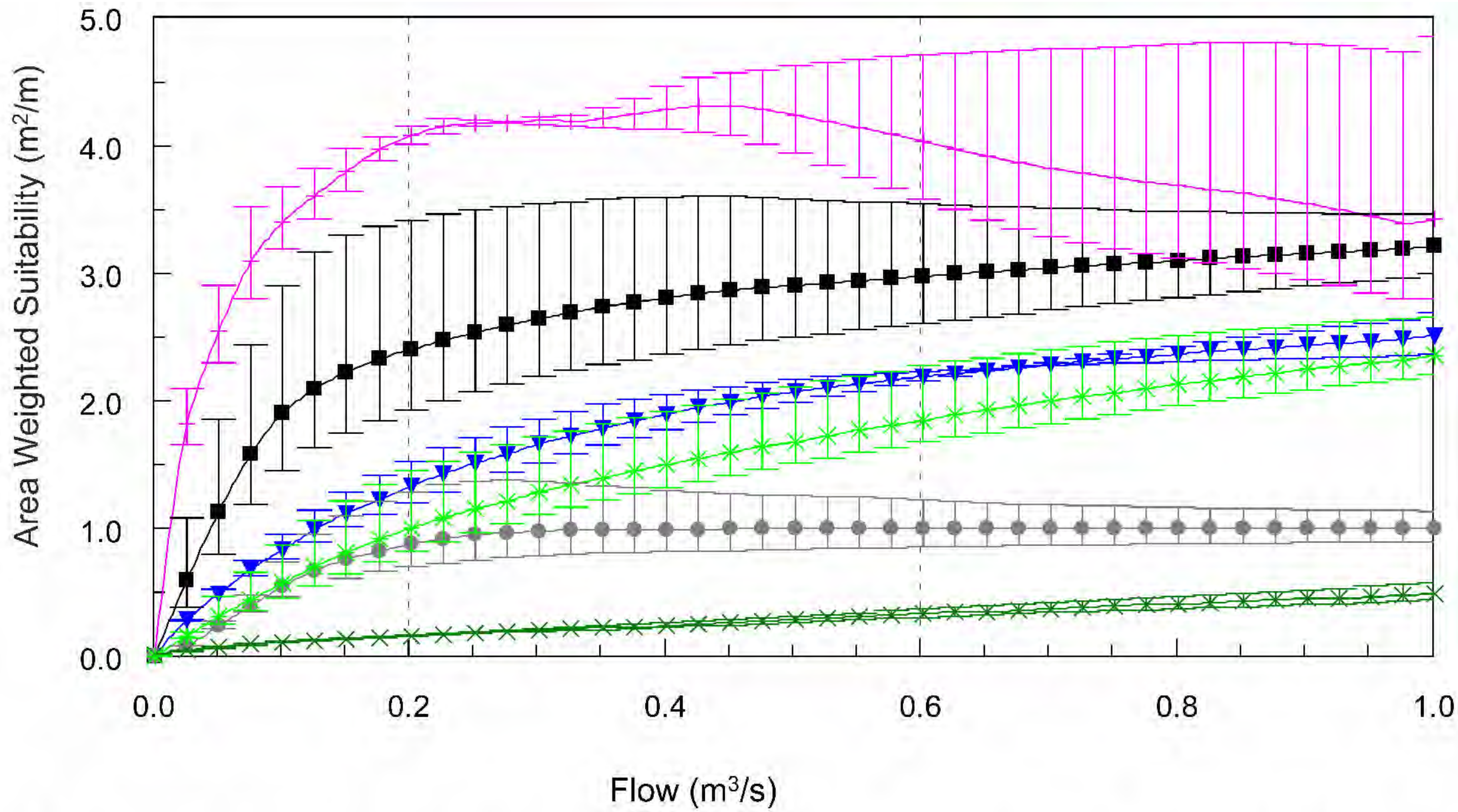
AWS AS A FUNCTION OF FLOW - REACH 4 BLAIRMORE CREEK

PROJECT: 14-00201
DRAWN BY: EPITTMAN
CHECKED BY: TB
DATE: JUNE 17, 2020

Data Source: IFA Fig 4-17, Addendum 1, CR #6, Appendix A3, CIAR #44; SRK, 2020;

FIGURE 7.3-1

Document Path: K:\Active Projects 2014\AP 14-00201 to 14-00250\14-00201\MXD\Final Figures\Hydrology\IR 7.3 Hydrology\Fig 7.3-1 AWS as a Function of Flow - Reach 4 Blairemore Creek 14-00201.mxd



Note: For average hydrological conditions during baseline, the MAD is 0.208 m^3/s and MMD range from 0.032 m^3/s (February) to 0.818 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Rearing Adult WSCT, Rearing Juvenile WSCT, Spawning Adult WSCT, Fry WSCT, Overwintering WSCT, Invertebrate Drift

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

MILLENNIUM EMS Solutions Ltd.

PROJECT: 14-00201

DRAWN BY: EPITTMAN

CHECKED BY: TB

DATE: JUNE 17, 2020

AWS AS A FUNCTION OF FLOW - REACH 3 BLAIRMORE CREEK

Data Source: IFA Fig 4-18, Addendum 1, CR #6, Appendix A3, CIAR #44; SRK, 2020;

FIGURE 7.3-2

Document Path: K:\Active Projects 2014\AP 14-00201 to 14-00250\14-00201\MXD\Final Figures\Hydrology\IR 7.3 Hydrology\Fig 7.3-2 AWS as a Function of Flow - Reach 3 Blairmore Creek 14-00201.mxd

APPENDIX 7.1-1: WALKTHROUGH EXAMPLE CALCULATIONS FOR HUMAN AND WILDLIFE HEALTH

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Grassy Mountain Coal Project
Appendix 7.1-1: Walkthrough Example Calculations for Human and Wildlife Health

Prepared for:
Benga Mining Limited

Prepared by:
Millennium EMS Solutions Ltd.
Suite 202, 701 – 64 Avenue SE
Calgary, Alberta
T2H 2C3

June 2020
File #14-00201-08

Table of Contents

List of Tables

List of Abbreviations

A	area factor (unitless)
AIR	air inhalation rate (m^3/d)
atm	atmosphere
BCF_{PS}	plant-to-soil bioconcentration factor (kg soil / kg plant)
BCF_{WAP}	water-to-aquatic plant bioconcentration factor (L water/kg plant)
BTF	chemical-specific biotransfer factor (mg/kg tissue / mg/d)
BTF_A	adjusted biotransfer factor (mg/kg tissue / mg/d)
BTF_{BM}	breast milk biotransfer factor (µg/kg milk / µg/d intake)
B_V	mass-based air-to-plant biotransfer factor (µg/g plant / µg/g air)
B_{Vol}	volumetric air-to-plant biotransfer factor (unitless)
BW	body weight (kg)
C_{Air}	concentration of COPC in air (µg/m^3)
C_{BM}	concentration of COPC in breast milk (mg/kg)
C_{Dust}	concentration of COPC in dust (µg/m^3)
CF	conversion factor
C_{fish}	concentration of COPC in fish (mg/kg)
C_{Game}	concentration of COPC in wild game (mg/kg)
$C_{Invertebrate}$	concentration in invertebrate tissue (mg/kg dry weight)
$C_{Invertebrate-lotic}$	selenium concentration in invertebrates of lotic habitats (mg/kg dry weight).
C_{lichen}	concentration of COPC in terrestrial plants (mg/kg)
cm^2	centimetres squared
C_{mammal}	concentration of COPC in a surrogate mammal (mg/kg dry weight)
COPC	chemical of potential concern
$C_{Organism}$	concentration of COPC in organism (mg/kg)
C_{PD}	concentration of COPC in plants due to direct deposition (mg/kg)
$C_{periphyton\_lentic}$	selenium concentration (mg/kg dry weight) in periphyton in lentic habitats
$C_{Periphyton-lotic}$	selenium concentration (mg/kg dry weight) in periphyton in flowing lotic habitats
C_{Plant}	concentration of COPC in plants (human consumption; mg/kg)
C_{PR}	concentration of COPC in plant roots (mg/kg)

C_{Prey}	concentration of COPC in prey (mg/kg)
C_{PV}	concentration of COPC in plants due to vapour uptake (mg/kg)
C_{S}	concentration of COPC in soil (mg/kg)
C_{s0}	concentration of COPC in surface soil (mg/kg)
C_{sback}	concentration of COPC in background soil (mg/kg)
C_{Sed}	concentration of COPC in sediment (mg/kg)
C_{SW}	concentration of COPC in surface water (mg/L)
C_{SW_SRK}	application surface water concentration without aerial deposition (mg/L)
C_{SW-Se}	selenium concentration in surface water (µg/L)
C_{SW-SO4}	sulphate concentration in surface water (mg/L)
C_{WPlant}	concentration of COPC in plants (animal consumption; mg/kg)
D_{BS}	depth of benthic sediment (m)
D_{Dry}	dry deposition rate of COPC (mg/m²/yr)
Di	duration of exposure during lifestage "i" (yr)
DL	dust level (kg/m³)
D_{S}	deposition to soil (mg/kg/yr)
D_{s0}	deposition to surface soil (mg/kg/yr)
DTED	daily threshold exposure (mg/kg BW/d)
D_{Tot}	total deposition (mg/m²/yr)
DW	dry weight
D_{WC}	depth of water column (m)
D_{Wet}	wet deposition rate of COPC (mg/m²/yr)
$E_{Air+Dust}$	exposure from dust inhalation adjusted to body weight (mg/kg BW/d)
E_{BM}	exposure from ingestion of breast milk adjusted to body weight (mg/kg BW/d)
EDI_{Adult}	estimated daily intake of adult receptor (mg/d)
E_{Dust}	exposure from dust inhalation adjusted to body weight (mg/kg BW/d)
EF_{Lentic}	enrichment factor, 900 L/kg applied to lentic habitats
E_{Food}	exposure from food ingestion adjusted to body weight (mg/kg BW/d)
ER	predicted hazard from exposure
E_{SC}	exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)
E_{Sed}	exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)
E_{SI}	exposure from soil ingestion adjusted to body weight (mg/kg BW/d)
E_{SwimC}	exposure from contact with surface water adjusted to body weight (mg/kg BW/d)
E_{SwimI}	exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)
E_{Total}	total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{WI}	exposure from water ingestion adjusted to body weight (mg/kg BW/d)
F_{BS}	fraction of total water body COPC concentration in benthic sediment (unitless)
FC	fat content (unitless)
F_{V}	fraction of COPC that is volatile (unitless)
F_{W}	fraction of COPC wet deposition that adheres to plant surfaces (unitless)
F_{Water}	fraction of forage that is water (unitless)
g	gram
H	Henry's law constant (atm m^3/mol)
h	hour
HHRA	human health risk assessment
HQ	predicted hazard from exposure to non-carcinogens (unitless)
ILCR	incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)
$ILCR_{Depositional}$	incremental lifetime cancer risk considering depositional sources (unitless)
$ILCR_{Surface\ Water}$	incremental lifetime cancer risk considering surface water sources (unitless)
IR_{Air}	wildlife air inhalation rate (m^3/d)
IR_{BM}	breast milk ingestion rate (kg/d)
IR_{fish}	ingestion rate of fish (kg/d)
IR_{Game}	ingestion rate of wild game (kg/d)
$IR_{invertebrate}$	ingestion rate of invertebrates (kg/d)
IR_{mammal}	ingestion rate of mammal (kg/d)
IR_{Plant}	ingestion rate of plant type (kg/d)
IR_{Prey}	wildlife prey ingestion rate (kg/d)
IR_{S}	wildlife soil ingestion rate (kg/d)
IR_{Sed}	wildlife sediment ingestion rate (kg/d)
IR_{SW}	wildlife water ingestion rate (L/d)
IR_{WPlant}	wildlife plant ingestion rate (kg/d)
K	Kelvin
K_{D}	sediment partition coefficient (L/kg)
kg	kilogram
K_{OW}	octanol-water partition coefficient (unitless)
K_{P}	plant surface loss coefficient (yr^{-1})
K_{PW}	dermal permeability coefficient (cm/h)
K_{SW}	COPC surface water loss constant (yr^{-1})
K_{T}	soil loss constant for volatilization and biotic and abiotic degradation (yrs^{-1})
L	litre

LA	lake area (m^2)
L_D	deposition loading onto surface water (mg/yr)
L_E	erosion load (mg/yr)
LE	life expectancy (yr)
L_R	runoff load (mg/yr)
L_T	air deposition loading to surface water (mg/yr)
m	metres
m^2	metres squared
m^3	metres cubed
MF	modification factor (unitless)
mg	milligram
MPOI	maximum point of impingement
P_{Air}	density of air (g/L)
P_{Sed}	sediment bulk density (1 kg/L)
PWC	fraction of total water body for mixing (%)
R	gas constant (atm m^3/ mol)
RA	risk adjustment factor (unitless)
RAF	relative dermal absorption factor (%)
R_F	reduction factor (unitless)
RfD	reference dose (mg/kg BW/d)
R_P	intercept fraction of edible portion of plants (unitless)
RsD	risk-specific dose (mg/kg BW/d)
SAH	surface area of hands (cm^2)
SAO	surface area of other exposed skin (cm^2)
SAT	surface area exposed (cm^2)
SedIR	sediment ingestion rate (kg/d)
SEF	swimming exposure factor (h/d)
SIR	soil ingestion rate (kg/d)
SLH	soil loading to hands (g/cm^2 per event)
SLO	soil loading to other exposed skin (g/cm^2 per event)
SWIR	water ingestion rate while swimming (L/h)
T	temperature (K)
T_D	time period over which deposition occurs (yr)
T_P	length of plant exposure (yr)
TTF_{fish}	trophic transfer into fish tissue (unitless)

$TTF_{Invertebrate}$	trophic transfer into invertebrate tissue (unitless)
V_{FR}	average volumetric flow rate through the water body (m^3/yr)
V_{Gag}	empirical correction factor (unitless)
V_{SW}	volume of water body (m^3)
WC	water or moisture content of plant (unitless)
WIR	water ingestion rate (L/d)
WPF	washing and peeling factor (unitless)
Y_P	productivity (kg/m^2)
yr	year
Z_S	soil mixing depth (m)
Z_{s0}	surface soil mixing depth (m)
θ_{BS}	bed sediment porosity (unitless)
P_{Forage}	density of forage (g/L)
ρ_B	soil bulk density (kg/m^3)
µg	microgram

1.0 MULTIMEDIA MODEL WALKTHROUGH EXAMPLES: HUMAN HEALTH

1.1 Introduction

The human health risk assessment (HHRA) included direct and indirect exposure to air and surface emissions of chemicals of potential concern (COPCs) from the Project. Select walkthrough example calculations are presented herein for fluoranthene and arsenic at the the following receptors: Blairmore Creek and Oldman Reservoir.

The predicted hazard quotient (HQ; threshold compounds) for the most sensitive receptor age group (toddler) and incremental lifetime cancer risk (ILCR; non-threshold compounds) for a composite lifetime receptor were calculated in the HHRA. Fluoranthene walkthrough calculations for the Application (threshold effects) and Project (non-threshold effects) cases at Blairmore Creek are shown in Sections 1.3.1 and 1.3.2, respectively. Arsenic walkthrough calculations for the Project (non-threshold effects) cases at Blairmore Creek and Oldman Reservoir, are shown in Sections 1.3.3 and 1.3.4, respectively. Regarding impact to the surface water at the Oldman Reservoir: as fluoranthene is not predicted to occur in the surface water *via* the water pathway and the Oldman Reservoir is too far away to receive deposition of COPC in air emissions, zero contribution of this COPC was predicted. Therefore, a worked example for the Oldman Dam was not provided.

Health risks directly from inhalation were characterized by comparing modelled air concentrations of COPCs modelled using the CALPUFF model in the air quality assessment (EIA, Consultant Report (CR) #1, CIAR #42) with regulatory guidelines considered to be protective of human health. Indirect exposure was predicted through a multimedia exposure model for non-volatile, persistent and bioaccumulative COPCs. Modelling formulas for COPC transport and bioaccumulation were based on United Sates Environmental Protection Agency (US EPA; 2005), and HHRA guidance provided by Health Canada (HC) and the Government of Alberta (GovAB; GovAB, 2019; HC, 2012; HC, 2010a; HC, 2010b).

1.2 Environmental Medial Concentrations

Chemical concentrations were predicted by various technical disciplines and provided for the following media:

- Air (Millennium EMS Solutions Ltd.) (EIA, Consultant Report #1 [CR#1], CIAR#42)
- Surface water *via* water-based pathways (EIA, Appendix 10B, CIAR#42)

Chemical concentrations were estimated for the following media:

- soil;
- dust;
- vegetation;
- wildlife;
- fish; and
- surface water.

The predicted air concentration average wet and dry deposition rates at the maximum point of impingement (MPOI) were assumed for the floranthene Blairmore Creek location. Air concentration and deposition rates for human receptor R9 location were assumed for the arsenic assessment. Input parameters for the Oldman Reservoir were assumed to be zero, as the Oldman Reservoir is sufficiently far away that air deposition is not anticipated.

1.3 Walkthrough Calculations for Human Health

1.3.1 Fluoranthene Calculations for Blairmore Creek (Application Case, Threshold Effects)

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition rate (mg/m²/yr)

D_{Wet} = wet deposition rate of COPC (mg/m²/yr)

D_{Dry} = dry deposition rate of COPC (mg/m²/yr)

Sample Calculation:

$$D_{Tot} = 4.56E^{-04}\ mg/m^2/yr + 3.14E^{-04}\ mg/m^2/yr\ = 7.70E^{-04}\ mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition to surface soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_{s0} = surface soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_{s0} = \frac{7.70E^{-04}\ mg/m^2/yr}{0.02\ m \times 1500\ kg/m^3} = 2.57E^{-05}\ mg/\ kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{7.70E^{-04}\, mg/m^2/yr}{0.2\, m \times 1500\, kg/m^3} = 2.57E^{-06}\, mg/\, kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = C_{sback}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

C_{sback} = concentration of COPC in background soil (mg/kg)

Sample Calculation:

$$C_{s0} = 0.07\, mg/kg$$

Equation 5. Concentration in Soil

$$C_s = C_{sback}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

C_{sback} = concentration of COPC in background soil (mg/kg)

Sample Calculation:

$$C_s = 0.07\, mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (μg/m³)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m³)

CF = conversion factor from mg to μg (unitless)

Sample Calculation:

$$C_{Dust} = 0.07\ mg/kg \times 7.6E^{-10}\ kg/m^3 \times 1000 = 5.32E^{-08} \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{Tot} \times\ LA$$

L_T = air deposition loading to surface water (mg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

LA = lake area (m²)†

$$C_{SW} = \frac{L_T}{(V_{FR}\ \times PWC) + (K_{SW} \times\ V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = air deposition loading to surface water (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m³/yr)

PWC = fraction of total water body for mixing (unitless)

K_{SW} = COPC surface water loss constant (yr⁻¹)

V_{SW} = volume of water body (m³)‡

CF = conversion factor from m³ to L (unitless)

C_{SW_SRK} = Application surface water concentration of COPC without aerial deposition (mg/L)

Sample Calculation:

$$L_T = 7.70E^{-04}\ mg/m^2/yr\ \times 3.25E^{+06}\ m^2 = 2.50E^{+03}\ mg/yr$$

$$C_{SW} = \frac{2.50E^{+03}\ mg/yr}{(2.53E^{+07}\ m^3/yr \times\ 1) + (3.57\ yr^{-1} \times\ 1.63E^{+06}\ m^3\ )} \times 0.001 + 0 mg/L = 8.05E^{-08}\ mg/L$$

Notes:

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}). In its entirety, the calculation also considers deposition loading onto surface water (L_D), runoff loading (L_R), and erosion loading (L_E), in that $L_D = D_{Tot} \times LA$, and $L_T = L_D+L_R+L_E$. However, as L_R and L_E are assumed to be zero, $L_D = L_T$. As such, $L_T = D_{Tot} \times LA$ is appropriate herein.

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body.

‡ Assuming lake area of 3.25E+06 m^2 and depth of 0.5 m, V_{SW} = 1.63E+06 m^3.

Equation 8. Concentration in Aquatic Organisms

Concentrations of the COPC in aquatic plants, aquatic invertebrates, and fish were determined based on the concentration of COPC in surface water (C_{SW}) and a chemical-specific bioconcentration factor (BCF). The concentration of the COPC in terrestrial invertebrates was calculated similarly, only using the concentration of COPC in surface soil (C_{s0}) and BCF. The sample calculation is completed for aquatic plants.

$$C_{Organism} = C_{SW} \times BCF_{WAP}$$

Where:

$C_{Organism}$= concentration of COPC in organism (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

BCF_{WAP}= water-to-aquatic plant bioconcentration factor (L water / kg plant)

Sample Calculation (aquatic plants):

$$C_{Organism} = 8.05E^{-08} mg/L \times 5258\ L\ water/plant\ dry\ weight = 4.23E^{-04}\ mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW} \times F_{BS} \times \frac{K_D}{\theta_{BS} + (K_D \times P_{Sed})} \times \frac{D_{WC} + D_{BS}}{D_{BS}} \times T_D$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC-specific sediment partition coefficient (L water / kg sediment)

θ_{BS} = bed sediment porosity (unitless)

P_{Sed} = sediment bulk density (kg/L)

D_{WC} = depth of water column (m)

D_{BS} = depth of benthic sediment (m)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{Sed} = 8.05E^{-08}\, mg/L \times 1.0 \times \frac{250.5\, L/kg}{0.6 + (250.5\, L/kg \times 1\, kg/L)} \times \frac{1.0\, m + 0.03\, m}{0.03\, m} \times 80\, yr$$

$$C_{Sed} = 2.20E^{-04}\, mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (yr)

Y_P = productivity (kg/m^2)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + (D_{Wet} \times (1 - F_V) \times Fw)\right] \times A \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (unitless)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (unitless)

A = area factor (unitless)

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$A = 0.39 \times \frac{\left[1 - e^{(-18\,yr^{-1} \times 0.16\,yr)}\right]}{2.24\,kg\ DW/m2\ \times 18\,yr^{-1}} = 9.13E^{-03}$$

$$C_{PD} = [3.14E^{-04} mg/m^2/yr \times (1 - 1) + (4.56E^{-04} mg/m^2/yr \times (1 - 1)\ \times\ 0.6)] \times 9.13E^{-03} \times 1 \times (1 - \frac{85\%}{100\%})$$

$$C_{PD} = 0\ mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$C_{PV} = \frac{C_{Air} \times \left(\frac{B_V}{R_F}\right) \times F_V \times V_{Gag}}{P_{Air} \times CF} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (μg/m³)

B_V = mass-based air-to-plant biotransfer factor (μg/g plant / μg/g air)*

R_F = reduction factor (unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (unitless)

P_{air} = density of air (g/L)

CF = conversion factor to mg/kg

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PV} = \frac{1.94E^{-04} \mu g/m^3 \times \left(\frac{2.29E^{+05} \mu g/g\ plant\ /\ \mu g/g\ air}{100}\right) \times 1 \times 0.01}{1.195\ g/L \times 1000} \times 1 \times (1 - \frac{85\%}{100\%})$$

$$C_{PV} = 5.58E^{-07}\ mg/kg$$

Notes:

* The above calculation of C_{PV} relies upon previous calculation of the volumetric air-to-plant biotransfer factor (B_{Vol}) to derive the mass-based air-to-plant biotransfer factor (B_V), such that $B_{Vol} = 10^{(1.065 \times \log Kow - \log(H/[R \times T]) - 1.654)}$, where K_{ow} is the octanol-water partition coefficient (1.66E+05), H is Henry's law constant (8.86E-06 atm m³/mol), R is the gas constant (8.20E-05 atm m³/mol), and T is room temperature (298 K). B_V is then calculated $B_V = (P_{air} \times B_{Vol})/(1-[WC/100\%]) \times P_{forage}$, where P_{forage} is the density of forage (770 g/L). P_{air}, B_{Vol}, WC have been previously defined.

Equation 12. Concentration in Plants due to Root Uptake

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$C_{PR} = C_S \times BCF_{PS} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PR} = concentration of COPC in plant roots (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

BCF_{PS} = plant-to-soil bioconcentration factor (kg soil / kg plant)*

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PR} = 0.07\, mg/kg \times 3.72E^{-02}\, kg\, soil/kg\, plant \times 1 \times (1 - \frac{85\%}{100\%}) = 3.91E^{-04} mg/kg$$

Notes:

* The above calculation relies upon previous calculation of the plant-to-soil bioconcentration factor (BCF_{PS}), such that $BCF_{PS} = 10^{(1.588 - (0.578 \times \log Kow))}$. K_{ow} has been previously defined in Equation 11.

Equation 13. Concentration in Wild Game

Concentrations of the COPC in wild game were determined for the following species: moose, grouse, hare, caribou, and deer. The sample calculation is completed for the moose.

$$C_{Game} = \left(\frac{C_{S0}IR_S + C_{Sed}IR_{Sed} + C_{SW}IR_{SW} + ((C_{Air} + C_{Dust})IR_{Air} \times \mathrm{CF}) + \sum C_{WPlant}IR_{WPlant} + \sum C_{Prey}IR_{Prey}}{BW}\right) \times \mathrm{BTF_A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)*

C_{S0} = concentration of COPC in surface soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)

C_{SW} = concentration of COPC in surface water (mg/L)

IR_{SW} = wildlife water ingestion rate (L/d)

C_{Air} = concentration of COPC in air (µg/m^3)

C_{Dust} = concentration of COPC in dust (µg/m^3)

IR_{Air} = wildlife air inhalation rate (m^3/d)

C_{WPlant} = concentration of COPC in plants (mg/kg)

IR_{WPlant} = wildlife plant ingestion rate (kg/d)

C_{Prey} = concentration of COPC in prey (mg/kg)

IR_{Prey} = wildlife prey ingestion rate (kd/d)

BW = body weight (kg)

BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

CF = conversion factor from µg to mg (unitless)

Sample Calculation (moose):

$$C_{Game} = \frac{\begin{array}{c}(0.07mg/kg \times 0.16kg/d) + (2.20E^{-04}mg/kg \times 0.4kg/d) + (8.05E^{-08}mg/L \times 20L/d) + \\ ((1.94E^{-04}\mu g/m^3 + 5.32E^{-08}\mu g/m^3) \times 65.87m^3/d \times 0.001) + (2.75E^{-03}mg/kg \times 6.4kg/d) \\ +(5.99E^{-04}mg/kg \times 1.6kg/d) + (1.47E^{-04}mg/kg \times 0kg/d) + (2.94E^{-02}mg/kg \times 0kg/d)\end{array}}{400\ kg}$$

$$\times\ 4.04E^{-04}mg/kg\ tissue\ /\ mg/d$$

$$= 3.02E^{-08}mg/kg$$

Notes:

* The above calculation of C_{Game} relies upon previous calculation of the adjusted biotransfer factor (BTF_A; mg/kg tissue / mg/d), which considers the chemical-specific biotransfer factor (0.2127 mg/kg tissue/ mg/d for a moose), fat content of the animal (FC; 0.19), and a modification factor (MF; 0.01 for polycyclic aromatic hydrocarbons, and 1 for volatile organic

compounds), such that BTF_A = BTF × FC × MF, where BTF = $10^{(-0.099*\log Kow^2)+(1.07*\log Kow)-3.56)}$. K_{ow} has been previously defined in Equation 11.

Equation 14. Human Exposure Soil Ingestion

Calculation of human exposure contributions were completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculations for Equations 14 to 21 were completed for the toddler.

$$E_{SI} = \frac{C_{s0} \times SIR \times CF}{BW}$$

Where:

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SIR = soil ingestion rate (g/d)

BW = body weight (kg)

CF = conversion factor from g to kg

Sample Calculation (toddler):

$$E_{SI} = \frac{0.07\ mg/kg \times 0.08\ g/d \times 0.001}{16.5\ kg} = 3.39E^{-07} mg/kg\ BW/d$$

Equation 15. Human Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{WI} = \frac{8.05E^{-08}\ mg/L \times 0.6\ L/d}{16.5\ kg} = 2.93E^{-09}\ mg/kg\ BW/d$$

Equation 16. Human Exposure from Dust Inhalation

$$E_{Dust} = \frac{C_{Dust} \times AIR \times CF}{BW}$$

Where:

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (µg/m³)

AIR = air inhalation rate (m³/d)

BW = body weight (kg)

CF = conversion factor from µg to mg

Sample Calculation (toddler):

$$E_{Dust} = \frac{5.32E^{-08}\mu g/m^3 \times 8.3\ m^3/d\ \times 0.001}{16.5\ kg} = 2.68E^{-11}mg/kg\ BW/d$$

Equation 17. Human Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant}IR_{Plant}\ + \sum C_{Game}IR_{Game})\ \times CF}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{Game} = concentration of COPC in wild game (mg/kg)

IR_{Game} = ingestion rate of wild game (kg/d)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{Food} = \frac{[(3.91E^{-04}mg/kg \times 67g/d) + (1.58E^{-03}mg/kg \times 105g/d) + (2.55mg/kg \times 5g/d) + (1.15mg/kg \times 1g/d) + (5.99E^{-04}mg/kg \times 1g/d)] + [(3.02E^{-08}mg/kg \times 26.50g/d) + (2.25E^{-07}mg/kg \times 14.16g/d) + (2.06E^{-07}mg/kg \times 12.34g/d) + (5.04E^{-08}g/kg \times 15.99g/d) + (4.99E^{-08}mg/kg \times 15.99g/d) + (4.43E^{-06}mg/kg \times 23g/d)] \times 0.001}{16.5kg}$$

$$E_{Food} = 8.54E^{-04}mg/kg\ BW/d$$

Equation 18. Human Exposure from Contact with Surface Water (Swimming)

$$E_{SwimC} = \frac{C_{SW} \times K_{PW} \times SEF \times SAT \times CF}{BW}$$

Where:

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

K_{PW} = dermal permeability coefficient (cm/h)

SEF = swimming exposure factor (h/d)

SAT = surface area exposed (cm^2)

BW = body weight (kg)

CF = conversion factor from cm^3 to L (unitless)

Sample Calculation (toddler):

$$E_{SwimC} = \frac{8.05E^{-08} mg/L \times 3.26E^{-01}\ cm/h \times 0.255 h/d \times 6130 cm^2 \times 0.001}{16.5 kg} = 2.48E^{-09}\ mg/kg\ BW/d$$

Equation 19. Human Exposure from Ingestion of Surface Water (Swimming)

Calculation of human exposure from ingestion of surface water (swimming) was completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculation is completed for the toddler.

$$E_{SwimI} = \frac{C_{SW} \times SEF \times SWIR}{BW}$$

Where:

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

SEF = swimming exposure factor (h/d)

SWIR = water ingestion rate while swimming (L/h)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{SwimI} = \frac{8.05E^{-08} mg/L \times 0.255 h/d \times 0.05 L/h}{16.5 kg} = 6.22E^{-11}\ mg/kg\ BW/d$$

Equation 20. Human Exposure from Contact with Surface Soil

$$E_{SC} = \frac{[(C_{s0} \times SAH \times SLH \times RAF) + (C_{s0} \times SAO \times SLO \times RAF)] \times CF}{BW}$$

Where:

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SAH = surface area of hands (cm^2)

SAO = surface area of other exposed skin (cm^2)

SLH = soil loading to hands (g/cm^2 per event)

SLO = soil loading to other exposed skin (g/cm^2 per event)

RAF = relative dermal absorption factor (%)

BW = body weight (kg)

CF = conversion factor from g to kg

Sample Calculation (toddler):

$$E_{SC} = \frac{[(0.07\ mg/kg \times 430 cm^2 \times 0.0001\ g/cm^2 \times 14.8\%) + (0.07\ mg/kg \times 2580\ cm^2 \times 0.00001\ g/cm^2 \times 14.8\%)] \times 0.001}{16.5\ kg}$$

$$= 4.32E^{-08}\ mg/kgBW/d$$

Equation 21. Human Exposure from Breast Milk Ingestion (Infants Only)

$$C_{BM} = EDI_{Adult} \times BTF_{BM}$$

Where:

C_{BM} = concentration of COPC in breast milk (mg/kg)

EDI_{Adult} = estimated daily intake of adult receptor (mg/d)

BTF_{BM} = breast milk biotransfer factor (µg/kg milk / µg/d intake)

$$E_{BM} = \frac{C_{BM} \times IR_{BM}}{BW}$$

Where:

E_{BM} = exposure from ingestion of breast milk adjusted to body weight (mg/kg BW/d)

C_{BM} = concentration of COPC in breast milk (mg/kg)

IR_{BM} = breast milk ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (toddler):

$C_{BM} = 6.25E^{-02}\ mg/d \times\ 3.32E^{-02}\ \mu g/kg\ milk\ /\ \mu g/d\ intake\ =\ 2.07E^{-03}\ mg/kg$

$$E_{BM} = \frac{2.07E^{-03} mg/kg \times 0\ kg/d}{16.5 kg} = 0\ mg/kg\ BW/d$$

Equation 22. Toddler Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{WI} + E_{Dust} + E_{Food} + E_{SwimC} + E_{SwimI} + E_{SC}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

Sample Calculation:

$$E_{Total} = 3.39E^{-07} mg/kg\ BW/d + 2.93E^{-09} mg/kg\ BW/d + 2.68E^{-11} mg/kg\ BW/d + 8.54E^{-04} mg/kg\ BW/d + 2.48E^{-09} mg/kg\ BW/d + 6.22E^{-11} mg/kg\ BW/d + 4.32E^{-08}\ mg/kg\ BW/d$$

$$E_{Total} = 8.55E^{-04}\ mg/kg\ BW/d$$

Equation 23. Predicted hazard quotient (HQ) from Non-Carcinogenic COPC Exposure

$$HQ = \frac{E_{Total}}{Rfd}$$

Where:

HQ = predicted hazard from exposure to non-carcinogens (unitless)

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

RfD = reference dose (mg/kg BW/d)

Sample Calculation:

$$HQ = \frac{2.14E^{-02}\ mg/kg\ BW/d}{0.04\ mg/kg\ BW/d} = 2.14E^{-02}$$

Equation 24. Predicted ILCR from Carcinogenic COPC Exposure

Calculation of ILCR is not applicable for the assessment of the non-carcinigenic (threshold). See Section 1.3.2 below for a worked example of the calculation of the carcinogenic (non-threshold) effects for fluoranthene.

1.3.2 Fluoranthene Calculations for Blairmore Creek (Project only, Non-Threshold Effects)

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition rate (mg/m²/yr)

D_{Wet} = wet deposition rate of COPC (mg/m²/yr)

D_{Dry} = dry deposition rate of COPC (mg/m²/yr)

Sample Calculation:

$$D_{Tot} = 3.48E^{-04}\ mg/m^2/yr + 1.20E^{-04}\ mg/m^2/yr\ = 4.68E^{-04}\ mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition to surface soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_{s0} = surface soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_{s0} = \frac{4.68E^{-04}\ mg/m^2/yr}{0.02\ m \times 1500\ kg/m^3} = 1.56E^{-05}\ mg/\ kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{4.68E^{-04}\, mg/m^2/yr}{0.2\, m \times 1500\, kg/m^3} = 1.56E^{-06}\, mg/\, kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0} \frac{1 - e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_{S0} = concentration of COPC in surface soil (mg/kg)

D_{S0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for volatilization and abiotic and biotic degradation (yr⁻¹)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{s0} = 1.56E^{-05} mg/kg/yr \times \frac{1 - e^{(-11.9\, yr^{-1} \times 80\, yr)}}{11.9\, yr^{-1}} = 1.31E^{-06}\, mg/kg$$

Equation 5. Concentration in Soil

$$C_s = D_s \frac{1 - e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for volatilization and abiotic and biotic degradation (yr^{-1})

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{s0} = 1.56E^{-06} mg/kg/yr \times \frac{1 - e^{(-11.9\,yr^{-1} \times 80\,yr)}}{11.9\,yr^{-1}} = 1.31E^{-07}\,mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (μg/m³)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m³)

CF = conversion factor from mg to μg (unitless)

Sample Calculation:

$$C_{Dust} = 1.31E^{-06}\,mg/kg \times 7.6E^{-10}\,kg/m^3 \times 1000 = 9.95E^{-13} \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{Tot} \times LA$$

L_T = air deposition loading to surface water (mg/yr)

D_{Tot} = total deposition rate (mg/m^2/yr)

LA = lake area (m^2)†

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = air deposition loading to surface water (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m^3/yr)

PWC = fraction of total water body for mixing (unitless)

K_{SW} = COPC surface water loss constant (yr^{-1})

V_{SW} = volume of water body (m^3)‡

CF = conversion factor from m^3 to L (unitless)

C_{SW_SRK} = Application surface water concentration of COPC without aerial deposition (mg/L)

Sample Calculation:

$$L_T = 4.68E^{-04}\ mg/m^2/yr \times 3.25E^{+06}\ m^2 = 1.52E^{+03}\ mg/yr$$

$$C_{SW} = \frac{1.52E^{+03}\ mg/yr}{(2.53E^{+07}\ m^3/yr \times 1) + (3.57\ yr^{-1} \times 1.63E^{+06}\ m^3)} \times 0.001 + 0mg/L = 4.89E^{-08}\ mg/L$$

Notes:

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}). In its entirety, the calculation also considers deposition loading onto surface water (L_D), runoff loading (L_R), and erosion loading (L_E), in that $L_D = D_{Tot} \times LA$, and $L_T = L_D + L_R + L_E$. However, as L_R and L_E are assumed to be zero, $L_D = L_T$. As such, $L_T = D_{Tot} \times LA$ is appropriate herein.

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body.

‡ Assuming lake area of 3.25E+06 m^2 and depth of 0.5 m, V_{SW} = 1.63E+06 m^3.

Equation 8. Concentration in Aquatic Organisms

Concentrations of the COPC in aquatic plants, aquatic invertebrates, and fish were determined based on the concentration of COPC in surface water (C_{SW}) and a chemical-specific bioconcentration factor (BCF). The concentration of the COPC in terrestrial invertebrates was calculated similarly, only using the concentration of COPC in surface soil (C_{s0}) and BCF. The sample calculation is completed for aquatic plants.

$$C_{Organism} = C_{SW} \times BCF_{WAP}$$

Where:

$C_{Organism}$= concentration of COPC in organism (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

BCF_{WAP}= water-to-aquatic plant bioconcentration factor (L water / kg plant)

Sample Calculation (aquatic plants):

$$C_{Organism} = 4.89E^{-08} mg/L \times 5258\ L\ water/plant\ dry\ weight = 2.57E^{-04}\ mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW} \times F_{BS} \times \frac{K_D}{\theta_{BS} + (K_D \times P_{Sed})} \times \frac{D_{WC} + D_{BS}}{D_{BS}} \times T_D$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC-specific sediment partition coefficient (L water / kg sediment)

θ_{BS} = bed sediment porosity (unitless)

P_{Sed} = sediment bulk density (kg/L)

D_{WC} = depth of water column (m)

D_{BS} = depth of benthic sediment (m)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{Sed} = 4.89E^{-08}\ mg/L \times 1.0 \times \frac{250.5\ L/kg}{0.6 + (250.5\ L/kg \times 1\ kg/L)} \times \frac{1.0\ m + 0.03\ m}{0.03\ m} \times 80\ yr$$

$$C_{Sed} = 1.34E^{-04}\ mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (yr)

Y_P = productivity (kg/m^2)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + (D_{Wet} \times (1 - F_V) \times Fw)\right] \times A \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (unitless)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (unitless)

A = area factor (unitless)

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$A = 0.39 \times \frac{\left[1 - e^{(-18\ yr^{-1} \times 0.16\ yr)}\right]}{2.24\ kg\ DW/m2\ \times 18\ yr^{-1}} = 9.13E^{-03}$$

$$C_{PD} = [1.20E^{-04} mg/m^2/yr \times (1 - 1) + (3.48E^{-04} mg/m^2/yr \times (1 - 1)\ \times\ 0.6)] \times 9.13E^{-03} \times 1 \times (1 - \frac{85\%}{100\%})$$

$$C_{PD} = 0\ mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$C_{PV} = \frac{C_{Air} \times \left(\frac{B_V}{R_F}\right) \times F_V \times V_{Gag}}{P_{Air} \times CF} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (µg/m^3)

B_V = mass-based air-to-plant biotransfer factor (µg/g plant / µg/g air)*

R_F = reduction factor (unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (unitless)

P_{air} = density of air (g/L)

CF = conversion factor to mg/kg

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PV} = \frac{5.29E^{-05}\mu g/m^3 \times \left(\frac{2.29E^{+05}\mu g/g\ plant\ /\ \mu g/g\ air}{100}\right) \times 1 \times 0.01}{1.195\ g/L \times 1000} \times 1 \times (1 - \frac{85\%}{100\%})$$

$$C_{PV} = 1.52E^{-07}\ mg/kg$$

Notes:

* The above calculation relies upon previous calculation of the volumetric air-to-plant biotransfer factor (B_{Vol}) to derive the mass-based air-to-plant biotransfer factor (B_V), such that $B_{Vol} = 10^{(1.065 \times \log Kow - \log(H/[R \times T]) - 1.654)}$, where K_{ow} is the octanol-water partition coefficient (1.66E+05), H is Henry's law constant (8.86E-06 atm m^3/mol), R is the gas constant (8.20E-05 atm m^3/mol), and T is room temperature (298 K). B_V is then calculated $B_V = (P_{air} \times B_{Vol})/(1-[WC/100\%]) \times P_{forage}$, where P_{forage} is the density of forage (770 g/L). P_{air}, B_{Vol}, WC have been previously defined.

Equation 12. Concentration in Plants due to Root Uptake

The sample calculation is completed for the aboveground portion of the garden produce (human consumption).

$$C_{PR} = C_S \times BCF_{PS} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PR} = concentration of COPC in plant roots (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

BCF_{PS} = plant-to-soil bioconcentration factor (kg soil / kg plant)*

WPF = washing and peeling factor (unitless)

WC = water or moisture content of plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PR} = 1.31E^{-07}\, mg/kg \times 3.72E^{-02}\, kg\, soil/kg\, plant \times 1 \times (1 - \frac{85\%}{100\%}) = 7.31E^{-10} mg/kg$$

Notes:

* The above calculation relies upon previous calculation of the plant-to-soil bioconcentration factor (BCF_{PS}), such that $BCF_{PS} = 10^{(1.588 - (0.578 \times \log K_{ow}))}$. K_{ow} has been previously defined in Equation 11.

Equation 13. Concentration in Wild Game

Concentrations of the COPC in wild game were determined for the following species: moose, grouse, hare, caribou, and deer. The sample calculation is completed for the moose.

$$C_{Game} = \left(\frac{C_{S0}IR_S + C_{Sed}IR_{Sed} + C_{SW}IR_{SW} + ((C_{Air} + C_{Dust})IR_{Air} \times \text{CF}) + \sum C_{WPlant}IR_{WPlant} + \sum C_{Prey}IR_{Prey}}{BW}\right) \times \text{BTF}_\text{A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)*
C_{S0} = concentration of COPC in surface soil (mg/kg)
IR_S = wildlife soil ingestion rate (kg/d)
C_{Sed} = concentration of COPC in sediment (mg/kg)
IR_{Sed} = wildlife sediment ingestion rate (kg/d)
C_{SW} = concentration of COPC in surface water (mg/L)
IR_{SW} = wildlife water ingestion rate (L/d)
C_{Air} = concentration of COPC in air (μg/m^3)
C_{Dust} = concentration of COPC in dust (μg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3/d)
C_{WPlant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BW = body weight (kg)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)
CF = conversion factor from μg to mg (unitless)

Sample Calculation (moose):

$$C_{Game} = \frac{\begin{array}{c}(1.31E^{-06} mg/kg \times 0.16 kg/d) + (1.34E^{-04} mg/kg \times 0.4 kg/d) + (4.89E^{-08} mg/L \times 20 L/d) + \\ ((5.29E^{-05} \mu g/m^3 + 9.95E^{-13} \mu g/m^3) \times 65.87 m^3/d \times 0.001) + (4.01E^{-05} mg/kg \times 6.4 kg/d) \\ +(1.12E^{-09} mg/kg \times 1.6 kg/d) + (4.01E^{-05} mg/kg \times 0 kg/d) + (5.49E^{-07} mg/kg \times 0 kg/d)\end{array}}{400\ kg}$$

$$\times 4.04E^{-04} mg/kg\ tissue\ /\ mg/d$$

$$= 3.18E^{-10} mg/kg$$

Notes:

* The above calculation of C_{Game} relies upon previous calculation of the adjusted biotransfer factor (BTF_A; mg/kg tissue / mg/d), which considers the chemical-specific biotransfer factor (0.2127 mg/kg tissue/ mg/d for a moose), fat content of the animal (FC; 0.19), and a modification factor (MF; 0.01 for polycyclic aromatic hydrocarbons, and 1 for volatile organic

compounds), such that BTF_A = BTF × FC × MF, where BTF = $10^{(-0.099*\log Kow^2)+(1.07*\log Kow)-3.56)}$. K_{ow} has been previously defined in Equation 11.

Equation 14. Human Exposure Soil Ingestion

Calculation of human exposure contributions were completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculations for Equations 14 to 21 were completed for the toddler.

$$E_{SI} = \frac{C_{s0} \times SIR \times CF}{BW}$$

Where:

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SIR = soil ingestion rate (g/d)

BW = body weight (kg)

CF = conversion factor from g to kg

Sample Calculation (toddler):

$$E_{SI} = \frac{1.31E^{-06}\ mg/kg \times 0.08\ g/d \times 0.001}{16.5\ kg} = 6.35E^{-12} mg/kg\ BW/d$$

Equation 15. Human Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{WI} = \frac{4.89E^{-08}\ mg/L \times 0.6\ L/d}{16.5\ kg} = 1.78E^{-09}\ mg/kg\ BW/d$$

Equation 16. Human Exposure from Dust Inhalation

$$E_{Dust} = \frac{C_{Dust} \times AIR \times CF}{BW}$$

Where:

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (µg/m³)

AIR = air inhalation rate (m³/d)

BW = body weight (kg)

CF = conversion factor from µg to mg

Sample Calculation (toddler):

$$E_{Dust} = \frac{9.95E^{-13}\mu g/m^3 \times 8.3\ m^3/d\ \times 0.001}{16.5\ kg} = 5.01E^{-16}mg/kg\ BW/d$$

Equation 17. Human Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant}IR_{Plant}\ + \sum C_{Game}IR_{Game})\ \times CF}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{Game} = concentration of COPC in wild game (mg/kg)

IR_{Game} = ingestion rate of wild game (kg/d)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{Food} = \frac{[(1.53E^{-07}mg/kg \times 67g/d) + (2.95E^{-09}mg/kg \times 105g/d) + (2.04E^{-07}mg/kg \times 5g/d) + (4.69E^{-07}mg/kg \times 1g/d) + (1.12E^{-09}mg/kg \times 1g/d)] + [(3.18E^{-10}mg/kg \times 26.50g/d) + (6.20E^{-10}mg/kg \times 14.16g/d) + (9.87E^{-10}mg/kg \times 12.34g/d) + (4.91E^{-10}g/kg \times 15.99g/d) + (4.92E^{-10}mg/kg \times 15.99g/d) + (2.69E^{-06}mg/kg \times 23g/d)] \times 0.001}{16.5kg}$$

$$E_{Food} = 4.48E^{-09}mg/kg\ BW/d$$

Equation 18. Human Exposure from Contact with Surface Water (Swimming)

$$E_{SwimC} = \frac{C_{SW} \times K_{PW} \times SEF \times SAT \times CF}{BW}$$

Where:

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

K_{PW} = dermal permeability coefficient (cm/h)

SEF = swimming exposure factor (h/d)

SAT = surface area exposed (cm^2)

BW = body weight (kg)

CF = conversion factor from cm^3 to L (unitless)

Sample Calculation (toddler):

$$E_{SwimC} = \frac{4.89E^{-08} mg/L \times 3.26E^{-01}\ cm/h \times 0.255 h/d \times 6130 cm^2 \times 0.001}{16.5 kg} = 1.51E^{-09}\ mg/kg\ BW/d$$

Equation 19. Human Exposure from Ingestion of Surface Water (Swimming)

Calculation of human exposure from ingestion of surface water (swimming) was completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculation is completed for the toddler.

$$E_{SwimI} = \frac{C_{SW} \times SEF \times SWIR}{BW}$$

Where:

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

SEF = swimming exposure factor (h/d)

SWIR = water ingestion rate while swimming (L/h)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{SwimI} = \frac{4.89E^{-08} mg/L \times 0.255 h/d \times 0.05 L/h}{16.5 kg} = 3.78E^{-11}\ mg/kg\ BW/d$$

Equation 20. Human Exposure from Contact with Surface Soil

$$E_{SC} = \frac{[(C_{s0} \times SAH \ \times SLH \ \times RAF) + (C_{s0} \times SAO \ \times SLO \ \times RAF)] \ \times \ CF}{BW}$$

Where:

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SAH = surface area of hands (cm^2)

SAO = surface area of other exposed skin (cm^2)

SLH = soil loading to hands (g/cm^2 per event)

SLO = soil loading to other exposed skin (g/cm^2 per event)

RAF = relative dermal absorption factor (%)

BW = body weight (kg)

CF = conversion factor from g to kg

Sample Calculation (toddler):

$$E_{SC} = \frac{[(1.31E^{-06}\ mg/kg \times 430cm^2 \times 0.0001\ g/cm^2 \times 14.8\%) \ + \ (1.31E^{-06}\ mg/kg \times 2580\ cm^2 \times 0.00001\ g/cm^2 \times 14.8\%)] \ \times 0.001}{16.5\ kg}$$

$$= 8.08E^{-13}\ mg/kgBW/d$$

Equation 21. Human Exposure from Breast Milk Ingestion (Infants Only)

$$C_{BM} = EDI_{Adult} \times BTF_{BM}$$

Where:

C_{BM} = concentration of COPC in breast milk (mg/kg)

EDI_{Adult} = estimated daily intake of adult receptor (mg/d)

BTF_{BM} = breast milk biotransfer factor (µg/kg milk / µg/d intake)

$$E_{BM} = \frac{C_{BM} \times IR_{BM}}{BW}$$

Where:

E_{BM} = exposure from ingestion of breast milk adjusted to body weight (mg/kg BW/d)

C_{BM} = concentration of COPC in breast milk (mg/kg)

IR_{BM} = breast milk ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (toddler):

$$C_{BM} = 3.195E^{-07}\ mg/d \times\ 3.32E^{-02}\ \mu g/kg\ milk\ /\ \mu g/d\ intake\ =\ 1.06E^{-08}\ mg/kg$$

$$E_{BM} = \frac{1.06E^{-08} mg/kg \times 0\ kg/d}{16.5 kg} = 0\ mg/kg\ BW/d$$

Equation 22. Toddler Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{WI} + E_{Dust} + E_{Food} + E_{SwimC} + E_{SwimI} + E_{SC}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

Sample Calculation:

$$E_{Total} = 6.35E^{-12} mg/kg\ BW/d + 1.78E^{-09} mg/kg\ BW/d + 5.01E^{-16} mg/kg\ BW/d + 4.48E^{-09} mg/kg\ BW/d + 1.51E^{-09} mg/kg\ BW/d + 3.78E^{-11} mg/kg\ BW/d + 8.08E^{-13}\ mg/kg\ BW/d$$

$$E_{Total} = 7.81E^{-09}\ mg/kg\ BW/d$$

Equation 23. Predicted hazard quotient (HQ) from Non-Carcinogenic COPC Exposure

$$HQ = \frac{E_{Total}}{Rfd}$$

Where:

HQ = predicted hazard from exposure to non-carcinogens (unitless)

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

RfD = reference dose (mg/kg BW/d)

Sample Calculation:

Not applicable for fluoranthene for non-threshold effects.

Equation 24. Predicted ILCR from Carcinogenic COPC Exposure

The following equation was used to calculate the ILCRs for carcinogenic COPCs, when applicable.

$$ILCR = \frac{(E_{Total-infant} \times D_{infant}) + (E_{Total-toddler} \times D_{toddler}) + (E_{Total-child} \times D_{child}) + (E_{Total-teen} \times D_{teen}) + (E_{Total-adult} \times D_{adult})}{RsD \times LE}$$

Where:

ILCR = incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

RsD = risk-specific dose (mg/kg BW/d)

Di = duration of exposure during lifestage "i" (yr)

LE = life expectancy (yr)

$$ILCR_A = \frac{ILCR}{RA}$$

Where:

$ILCR_A$ = adjusted incremental lifetime cancer risk*

ILCR = incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)

RA = risk adjustment factor (unitless)

Sample Calculation:

$$ILCR = \frac{(3.67E^{-09}\,mg/kg\,BW/d \times 0.5\,yr) + (7.81E^{-09}\,mg/kg\,BW/d \times 4.5\,yr) + (6.45E^{-09}\,mg/kg\,BW/d \times 7\,yr) + (4.50E^{-09}\,mg/kg\,BW/d \times 8\,yr) + (4.51E^{-09}\,mg/kg\,BW/d \times 60\,yr)}{0.0014\,mg/kg\,BW/d \times 80\,yr}$$

$$ILCR = 3.47E^{-06}$$

$$ILCR_A = \frac{3.47E^{-06}}{1.0E^{+05}}$$

$$ILCR_A = 3.47E^{-11}$$

Notes:

* The ILCR was divided by the risk adjustment factor (1E+05) so that this adjusted ILCR could be compared to an acceptable risk of 1 in 100,000.

1.3.3 Arsenic Calculations for Blairmore Creek (Project only, Non-Threshold Effects)

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition ($mg/m^2/yr$)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

Sample Calculation:

$$D_{Tot} = 1.32E^{-03}\ mg/m^2/yr + 4.93E^{-03} mg/m^2/yr\ = 6.26E^{-03}\ mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition to surface soil (mg/kg/yr)

D_{Tot} = total deposition ($mg/m^2/yr$)

Z_{s0} = surface soil mixing depth (m)

ρ_B = soil bulk density (kg/m^3)

Sample Calculation:

$$D_{s0} = \frac{6.26E^{-03}\ mg/m^2/yr}{0.02\ m \times 1500\ kg/m^3} = 2.09E^{-04}\ mg/\ kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{6.26E^{-03}\ mg/m^2/yr}{0.2\,m \times 1500\,kg/m^3} = 2.09E^{-05}\,mg/\,kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1 - e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for volatilization and biotic and abiotic degradation (yr^{-1})

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{s0} = (2.09E^{-05}\,mg/kg/yr)\frac{1 - e^{(-468.75yr^{-1} \times 80yr)}}{468.75\ yr^{-1}} = 4.45E^{-07} mg/kg$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1 - e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for volatilization and biotic and abiotic degradation (yr^{-1})

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_S = (2.09E^{-05} mg/kg/yr) \frac{1 - e^{(-468.75\, yr^{-1} \times 80 yr)}}{468.75\, yr^{-1}} = 4.45E^{-08} mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (μg/m³)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m³)

CF = conversion factor from mg to μg (unitless)

Sample Calculation:

$$C_{Dust} = 4.45E^{-07} mg/kg \times 7.6E^{-10}\, kg/m^3 \times 1000 = 3.38E^{-13} \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{Tot} \times LA$$

Where:

L_T = air deposition loading to surface water (mg/yr)

D_{Tot} = total deposition (mg/m²/yr)

LA = lake area (m²)†

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = air deposition loading to surface water (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m³/yr)

PWC = fraction of total water body for mixing (unitless)

K_{SW} = COPC surface water loss constant (0 yr^{-1})

V_{SW} = volume of water body (m³)‡

CF = conversion factor from m³ to L (unitless)

C_{SW_SRK} = concentration of COPC in background surface water (mg/L)

Sample Calculation:

$$L_T = 6.26E^{-03}\ mg/m^2/yr \times 3.25E^{+06}\ m^2 = 2.03E^{+04}\ mg/yr$$

$$C_{SW} = \frac{2.03E^{+04}\ mg/yr}{(2.53E^{+07} m^3/yr \times 1) + (0yr^{-1} \times 1.63E^{+06} m^3)} \times 0.001 + 2.47E^{-04}\ mg/kg = 2.48E^{-04} mg/L$$

Notes:

* The above equation for L_T has been simplified. In its entirety, the calculation also considers deposition loading onto surface water (L_D), runoff loading (L_R), and erosion loading (L_E), in that $L_D = D_{Tot}\ x\ LA$, and $L_T = L_D+L_R+L_E$. However, as L_R and L_E are assumed to be zero, $L_D = L_T$. As such, $L_T = D_{Tot}\ x\ LA$ is appropriate herein. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}).

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body.

‡ Assuming lake area of 3.25E+06 m² and depth of 0.5 m, V_{SW} = 1.63E+06 m³.

Equation 8. Concentration in Aquatic Organisms

Concentrations in aquatic plants, aquatic invertebrates, and fish were determined based on the surface water concentration and a chemical-specific bioconcentration factor (BCF). The sample calculation is completed for aquatic plants.

$$C_{Organism} = C_{SW} \times BCF_{WAP}$$

Where:

$C_{Organism}$= concentration of COPC in organism (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

BCF_{WAP}= water-to-aquatic plant bioconcentration factor (L water / kg plant)

Sample Calculation (aquatic plants):

$$C_{Organism} = 2.48E^{-04}\ mg/L \times 29.3\ L\ water/kg\ plant = 7.27E^{-03} mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW} \times F_{BS} \times \frac{K_D}{\theta_{BS} + (K_D \times P_{Sed})} \times \frac{D_{WC} + D_{BS}}{D_{BS}} \times T_D$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC-specific sediment partition coefficient (L water / kg sediment)

θ_{BS} = bed sediment porosity (unitless)

P_{Sed} = sediment bulk density (kg/L)

D_{WC} = depth of water column (m)

D_{BS} = depth of benthic sediment (m)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{Sed} = 2.48E^{-04}\ mg/L \times 1.0 \times \frac{29\ L/kg}{0.6 + (29\ L/kg \times 1\ kg/L)} \times \frac{1.0\ m + 0.03\ m}{0.03\ m} \times 80\ yr$$

$$C_{Sed} = 6.68E^{-01} mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

The sample calculation is completed for the aboveground portion of forage due to direct deposition (wildlife consumption).

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (yr)

Y_P = productivity (kg/m^2)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + (D_{Wet} \times (1 - F_V) \times Fw)\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (unitless)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{(-18\,yr^{-1} \times 0.12\,yr)}\right]}{0.24\,kg/m^2 \times 18\,yr^{-1}} = 1.02E^{-01}$$

$$C_{PD} = [4.93E^{-03}\,mg/m^2/yr \times (1 - 0.006) + (1.32E^{-03} mg/m^2/yr \times (1 - 0.006)) \times 0.6)\,] \times 1.02E^{-01}$$
$$C_{PD} = 5.83E^{-04}\,mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

The sample calculation is completed for the aboveground portion of forage due to vapour uptake (wildlife consumption).

$$C_{PV} = \frac{C_{Air} \times \left(\frac{B_V}{R_F}\right) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m³)

B_V = mass-based air-to-plant biotransfer factor (μg/g plant / μg/g air)*

R_F = reduction factor (unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (unitless)

P_{Air} = density of air (g/L)

CF = conversion factor to mg/kg

Sample Calculation (wildlife forage):

$$C_{PV} = \frac{1.02E^{-03} \mu g/m^3 \times \left(\frac{0\ \mu g/g\ plant\ /\ \mu g/g\ air}{100}\right) \times 0.006 \times 1}{1.2\ g/L \times 1000} = 0\ mg/kg$$

Notes:

* The above calculation relies upon previous calculation of the volumetric air-to-plant biotransfer factor (B_{Vol}) to derive the mass-based air-to-plant biotransfer factor (B_V), such that $B_{Vol} = 10^{(1.065 \times \log K_{ow} - \log(H/[R \times T]) - 1.654)}$, where K_{ow} is the octanol-water partition coefficient (1.66E+05), H is Henry's law constant (8.86E-06 atm m³/mol), R is the gas constant (8.20E-05 atm m³/mol), and T is room temperature (288 K). B_V is then calculated $B_V = (P_{air} \times B_{Vol})/(1-[F_{water}/100\%]) \times P_{forage}$, where P_{forage} is the density of forage (770 g/L), and F_{water} is the fraction of forage that is water (0.62). P_{air} and B_{Vol} have been previously defined.

Equation 12. Concentration in Plants due to Root Uptake

The sample calculation is completed for the aboveground portion of garden produce due to root uptake (human consumption).

$$C_{PR} = C_S \times BCF_{PS} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PR} = concentration of COPC in plant roots (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

BCF_{PS} = plant-to-soil bioconcentration factor (kg soil / kg plant)*

WPF = washing and peeling factor (unitless)

WC = water or moisture content of the plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PR} = 4.45E^{-08}\ mg/kg \times\ 6.33E^{-03}\ kg\ soil/kg\ plant\ \times 1\ \times (1 - \frac{85\%}{100\%}) = 4.22E^{-11}\ mg/kg$$

Equation 13. Concentration in Wild Game

Concentrations of the COPC in wild game were determined for the following species: moose, grouse, hare, caribou, and deer. The sample calculation is completed for the moose.

$$C_{Game} = \left(\frac{C_{S0}IR_S + C_{Sed}IR_{Sed} + C_{SW}IR_{SW} + ((C_{Air} + C_{Dust})IR_{Air} \times \mathrm{CF}) + \sum C_{WPlant}IR_{WPlant} + \sum C_{Prey}IR_{Prey}}{BW}\right) \times \mathrm{BTF_A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)
C_{S0} = concentration of COPC in surface soil (mg/kg)
IR_S = wildlife soil ingestion rate (kg/d)
C_{Sed} = concentration of COPC in sediment (mg/kg)
IR_{Sed} = wildlife sediment ingestion rate (kg/d)
C_{SW} = concentration of COPC in surface water (mg/L)
IR_{SW} = wildlife water ingestion rate (L/d)
C_{Air} = concentration of COPC in air (μg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3 air/d)
C_{Dust} = concentration of COPC in dust (μg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3/d)
C_{WPlant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BW = body weight (kg)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)
CF = conversion factor from μg to mg (unitless)

Sample Calculation (moose):

$$\sum C_{Plant}IR_{Plant} = [(5.83E^{-04}mg/kg \times 6.4\,kg/d) + (6.48E^{-11}mg/kg \times 1.6\,kg/d)] = 3.73\,E^{-03}\,mg/d$$

$$\sum C_{Prey}IR_{Prey} = 0\,mg/d$$

$$C_{Game} = \frac{(4.45E^{-08}mg/kg \times 0.16kg/d) + (6.81E^{-01}mg/kg \times 0.4kg/d) + (2.48E^{-04}mg/L \times 20L/d) + ((3.87E^{-05}\mu g/m^3 + 3.38E^{-13}\mu g/m^3) \times 65.9m^3/d \times 0.001) + 3.73E^{-03}mg/d + 0\,mg/d}{400\,kg}$$

$$\times 3.80E^{-04}mg/kg\ tissue\ /\ mg/d$$

$$= 2.67E^{-07}mg/kg$$

Notes:

* The above calculation of C_{Game} relies upon previous calculation of the adjusted biotransfer factor (BTF_A; mg/kg tissue / mg/d), which considers the chemical-specific biotransfer factor (BTF; 0.002 mg/kg tissue/ mg/d for a moose), fat content of the animal (FC; 0.19), and a modification factor (MF; 0.01 for polycyclic aromatic hydrocarbons, and 1 for volatile organic compounds), such that BTF_A = BTF × FC × MF.

Equation 14. Human Exposure Soil Ingestion

Calculation of human exposure contributions were completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculations for Equations 14 to 20 were completed for the toddler.

$$E_{SI} = \frac{C_{s0} \times SIR \times CF}{BW}$$

Where:

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SIR = soil ingestion rate (g/d)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{SI} = \frac{4.45E^{-07} mg/kg \times 8.00E^{-2} g/d \times 0.001}{16.5\ kg} = 2.15E^{-12}\ mg/kg\ BW/d$$

Equation 15. Human Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{WI} = \frac{2.48E^{-04}\ mg/L \times 0.6\ L/d}{16.5\ kg} = 9.02E^{-06}\ mg/kg\ BW/d$$

Equation 16. Human Exposure from Dust Inhalation

$$E_{Dust} = \frac{C_{Dust} \times AIR \times CF}{BW}$$

Where:

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (µg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor from µg to mg (unitless)

Sample Calculation (toddler):

$$E_{Dust} = \frac{3.38E^{-13} \mu g/m^3 \times 8.3\ m^3/d \times 0.001}{16.5\ kg} = 1.70E^{-16}\ mg/kgBW/d$$

Equation 17. Human Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{Game} IR_{Game}) \times CF}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{Game} = concentration of COPC in wild game (mg/kg)

IR_{Game} = ingestion rate of wild game (kg/d)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{Food} = \frac{\begin{array}{l}[(7.80E^{-06} mg/kg \times 67 g/d) + (5.34E^{-11} mg/kg \times 105 g/d) + (1.04E^{-05} mg/kg \times 5 g/d) + (2.39E^{-05} mg/kg \times 1 g/d) + \\ (6.48E^{-11} mg/kg \times 1 g/d)] + [(2.62E^{-07} mg/kg \times 26.51 g/d) + (1.32E^{-08} mg/kg \times 14.17 g/d) + (2.27E^{-08} mg/kg \times 12.34 g/d) + \\ (1.23E^{-08} g/kg \times 15.99 g/d) + (1.23E^{-08} mg/kg \times 15.99 g/d) + (7.07E^{-03} mg/kg \times 23 g/d)] \times 0.001\end{array}}{16.5 kg}$$

$$E_{Food} = 9.89E^{-06} mg/kg\ BW/d$$

Equation 18. Human Exposure from Contact with Surface Water (Swimming)

$$E_{SwimC} = \frac{C_{SW} \times K_{PW} \times SEF \times SAT \times CF}{BW}$$

Where:

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

K_{PW} = dermal permeability coefficient (cm/h)

SEF = swimming exposure factor (h/d)

SAT = surface area exposed (cm^2)

BW = body weight (kg)

CF = conversion factor from cm^3 to L (unitless)

Sample Calculation (toddler):

$$E_{SwimC} = \frac{2.48E^{-04} mg/L \times 1.00E^{-03}\ cm/h \times 0.255 h/d \times 6130 cm^2 \times 0.001}{16.5 kg} = 2.35E^{-08} mg/kgBW/d$$

Equation 19. Human Exposure from Ingestion of Surface Water (Swimming)

$$E_{SwimI} = \frac{C_{SW} \times SEF \times SWIR}{BW}$$

Where:

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

SEF = swimming exposure factor (h/d)

SWIR = water ingestion rate while swimming (L/h)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{SwimI} = \frac{2.48E^{-04} mg/L \times 0.255 h/d \times 0.05 L/h}{16.5 kg} = 1.92E^{-07} mg/kgBW/d$$

Equation 20. Human Exposure from Contact with Surface Soil

$$E_{SC} = \frac{[(C_{s0} \times SAH \times SLH \times RAF)+(C_{s0} \times SAO \times SLO \times RAF)] \times CF}{BW}$$

Where:

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SAH = surface area of hands (cm^2)

SAO = surface area of other exposed skin (cm^2)

SLH = soil loading to hands (g/cm^2 per event)

SLO = soil loading to other exposed skin (g/cm^2 per event)

RAF = relative dermal absorption factor (%)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{SC} = \frac{[(4.45E^{-07} mg/kg \times 430cm^2 \times 0.0001g/cm^2 \times 3\%) + (4.45E^{-07} mg/kg \times 2580cm^2 \times 0.00001g/cm^2 \times 3\%)] \times 0.001}{16.5kg}$$

$$E_{SC} = 5.57E^{-14}\, mg/kgBW/d$$

Equation 21. Human Exposure from Breast Milk Ingestion (Infants Only)

$$C_{BM} = EDI_{Adult} \times BTF_{BM}$$

Where:

C_{BM} = concentration of COPC in breast milk (mg/kg)

EDI_{Adult}= estimated daily intake of adult receptor (mg/d)

BTF_{BM} = breast milk biotransfer factor (μg/kg milk / μg/d intake)

$$E_{BM} = \frac{C_{BM} \times IR_{BM}}{BW}$$

Where:

E_{BM} = exposure from ingestion of breast milk adjusted to body weight (mg/kg BW/d)

C_{BM} = concentration of COPC in breast milk (mg/kg)

IR_{BM} = breast milk ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (infant):

$$C_{BM} = 7.60E^{-01} mg/day \times \ 0\mu g/kg\ milk\ \mu g/day \text{ intake} = \ 0\ mg/kg$$

$$E_{BM} = \frac{0\ mg/kg \times 0.664\ kg/d}{8.2\ kg} = 0\ mg/kg\ BW/d$$

Equation 22. Toddler Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{WI} + E_{Dust} + E_{Food} + E_{SwimC} + E_{SwimI} + E_{SC}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

Sample Calculation (Toddler):

$$\begin{aligned} E_{Total} = {} & 2.16E^{-12} mg/kgBW/d \\ & + 9.02E^{-06} mg/kgBW/d \\ & + 1.70E^{-16} mg/kgBW/d \\ & + 9.98E^{-06} mg/kgBW/d \\ & + 2.35E^{-08} mg/kgBW/d \\ & + 1.92E^{-07} mg/kgBW/d \\ & + 5.57E^{-14} mg/kgBW/d \\ & = 1.91E^{-05} mg/kgBW/d \end{aligned}$$

Equation 23. Predicted hazard quotient (HQ) from Non-Carcinogenic COPC Exposure

$$HQ = \frac{E_{Total}}{Rfd}$$

Where:

HQ = predicted hazard from exposure to non-carcinogens

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

RfD = reference dose (mg/kg BW/d)

Sample Calculation: ***Not applicable for arsenic for non-threshold effects***.

Equation 24. Predicted Incremental Lifetime Cancer Risk (ILCR) Quotient from Carcinogenic COPC Exposure

The following equation was used to calculate the ILCRs for carcinogenic COPCs, when applicable.

$$ILCR = \frac{(E_{Total-infant} \times D_{infant)+} (E_{Total-tolder} \times D_{toddler}) + (E_{Total-child} \times D_{child}) + (E_{Total-teen} \times D_{teen}) + (E_{Total-adult} \times D_{adult)}}{RsD \times LE}$$

Where:

ILCR = incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)

E_{Total} = total daily estimated exposure adjusted to body weight at each lifestage (mg/kg BW/d)

RsD = risk-specific dose (mg/kg BW/d)

Di = duration of exposure during lifestage "i" (yr)

LE = life expectancy (yr)

$$ILCR_A = \frac{ILCR}{RA}$$

Where:

$ILCR_A$ = adjusted incremental lifetime cancer risk*

ILCR = incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)

RA = risk adjustment factor (unitless)

$$ILCR_{Total} = \frac{2.06}{1.0E^{+05}} = 2.05E^{-05}$$

Notes:

* The ILCR was divided by the risk adjustment factor (1E+05) so that this adjusted ILCR could be compared to an acceptable risk of 1 in 100,000.

1.3.4 Arsenic Calculations for Oldman Reservoir (Project only, Non-Threshold Effects)

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition ($mg/m^2/yr$)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

Sample Calculation:

$$D_{Tot} = 0\,mg/m^2/yr + 0\,mg/m^2/yr = 0\,mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition to surface soil (mg/kg/yr)

D_{Tot} = total deposition ($mg/m^2/yr$)

Z_{s0} = surface soil mixing depth (m)

ρ_B = soil bulk density (kg/m^3)

Sample Calculation:

$$D_{s0} = \frac{0\,mg/m^2/yr}{0.02\,m \times 1500\,kg/m^3} = 0\,mg/\,kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{0\ mg/m^2/yr}{0.2\ m \times 1500\ kg/m^3} = 0\ mg/\ kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1-e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for volatilization and biotic and abiotic degradation (yr⁻¹)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{s0} = (0\ mg/kg/yr)\frac{1 - e^{(-468.75 yr^{-1} \times 80 yr)}}{468.75\ yr^{-1}} = 0\ mg/kg$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1 - e^{(-K_T \times T_D)}}{K_T}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for volatilization and biotic and abiotic degradation (yr^{-1})

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_S = (0\ mg/kg/yr) \frac{1 - e^{(-468.75\ yr^{-1} \times 80 yr)}}{468.75\ yr^{-1}} = 0\ mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (μg/m^3)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m^3)

CF = conversion factor from mg to μg

Sample Calculation:

$$C_{Dust} = 0\ mg/kg \times 7.6E^{-10}\ kg/m^3 \times 1000 = 0\ \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{Tot} \times LA$$

Where:

L_T = air deposition loading to surface water (mg/yr)

D_{Tot} = total deposition (mg/m²/yr)

LA = lake area (m²)†

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = air deposition loading to surface water (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m³/yr)

PWC = fraction of total water body for mixing (unitless)

K_{SW} = COPC surface water loss constant (0 yr^{-1})

V_{SW} = volume of water body (m³)‡

CF = conversion factor from m³ to L (unitless)

C_{SW_SRK} = concentration of COPC in background surface water (mg/L)

Sample Calculation:

$$L_T = 0\ mg/m^2/yr\ X\ 3.25E^{+06} m^2 = 0\ mg/yr$$

$$C_{SW} = \frac{0\ mg/yr}{(2.53E^{+07} m^3/yr \times 1) + (0 yr^{-1} \times 1.63E^{+06} m^3)} \times 0.001 + 1.72E^{-05}\ mg/kg = 1.72E^{-05} mg/L$$

Notes:

* The above equation for L_T has been simplified. In its entirety, the calculation also considers deposition loading onto surface water (L_D), runoff loading (L_R), and erosion loading (L_E), in that $L_D = D_{Tot}\ x\ LA$, and $L_T = L_D + L_R + L_E$. However, as L_R and L_E are assumed to be zero, $L_D = L_T$. As such, $L_T = D_{Tot}\ x\ LA$ is appropriate herein. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}).

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body.

‡ Assuming lake area of 3.25E+06 m² and depth of 0.5 m, V_{SW} = 1.63E+06 m³.

Equation 8. Concentration in Aquatic Organisms

Concentrations in aquatic plants, aquatic invertebrates, and fish were determined based on the surface water concentration and a chemical-specific bioconcentration factor (BCF). The sample calculation is completed for aquatic plants.

$$C_{Organism} = C_{SW} \times BCF_{WAP}$$

Where:

$C_{Organism}$= concentration of COPC in organism (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

BCF_{WAP}= water-to-aquatic plant bioconcentration factor (L water / kg plant)

Sample Calculation (aquatic plants):

$$C_{Organism} = 1.72E^{-05} mg/L \times 29.3\ L\ water/kg\ plant = 5.05E^{-04} mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW} \times F_{BS} \times \frac{K_D}{\theta_{BS} + (K_D \times P_{Sed})} \times \frac{D_{WC} + D_{BS}}{D_{BS}} \times T_D$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC-specific sediment partition coefficient (L water/kg sediment)

θ_{BS} = bed sediment porosity (unitless)

P_{Sed} = sediment bulk density (kg/L)

D_{WC} = depth of water column (m)

D_{BS} = depth of benthic sediment (m)

T_D = time period over which deposition occurs (yr)

Sample Calculation:

$$C_{Sed} = 1.72E^{-05}\ mg/L \times 1.0 \times \frac{29\ L/kg}{0.6 + (29\ L/kg \times 1\ kg/L)} \times \frac{1.0\ m + 0.03\ m}{0.03\ m} \times 80\ yr = 4.64E^{-02} mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

The sample calculation is completed for the aboveground portion of forage due to direct deposition (wildlife consumption).

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (yr)

Y_P = productivity (kg/m^2)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + (D_{Wet} \times (1 - F_V)\ \times\ Fw)\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg)

D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (unitless)

D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{(-18\ yr^{-1} \times 0.12\ yr)}\right]}{0.24\ kg/m^2 \times 18\ yr^{-1}} = 1.02E^{-01}$$

$$C_{PD} = [0\ mg/m^2/yr \times (1 - 0.006) + (0 mg/m^2/yr \times (1 - 0.006))\ \times\ 0.6)\ ]\ \times\ 1.02E^{-01}$$
$$C_{PD} = 0\ mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

The sample calculation is completed for the aboveground portion of forage due to vapour uptake (wildlife consumption).

$$C_{PV} = \frac{C_{Air} \times \left(\frac{B_V}{R_F}\right) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m^3)

B_V = mass-based air-to-plant biotransfer factor (µg/g plant / µg/g air)

R_F = reduction factor (unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (unitless)

P_{Air} = density of air (g/L)

CF = conversion factors to mg/kg

Sample Calculation (wildlife forage):

$$C_{PV} = \frac{0\ \mu g/m^3 \times \left(\frac{0\ \mu g/g\ plant\ /\ \mu g/g\ air}{100}\right) \times 0.006 \times 1}{1.2\ g/L \times 1000} = 0\ mg/kg$$

Notes:

* The above calculation relies upon previous calculation of the volumetric air-to-plant biotransfer factor (B_{Vol}) to derive the mass-based air-to-plant biotransfer factor (B_V), such that $B_{Vol} = 10^{(1.065 \times \log K_{ow} - \log(H/[R \times T]) - 1.654)}$, where K_{ow} is the octanol-water partition coefficient (4.78), H is Henry's law constant (7.73E-01 atm m^3/mol), R is the gas constant (8.20E-05 atm m^3/mol), and T is room temperature (288 K). B_V is then calculated $B_V = (P_{air} \times B_{Vol})/(1-[F_{water}/100\%]) \times P_{forage}$, where P_{forage} is the density of forage (770 g/L), and F_{water} is the fraction of forage that is water (0.62). P_{air} and B_{Vol} have been previously defined.

Equation 12. Concentration in Plants due to Root Uptake

The sample calculation is completed for the aboveground portion of garden produce due to root uptake (human consumption).

$$C_{PR} = C_S \times BCF_{PS} \times WPF \times (1 - \frac{WC}{100\%})$$

Where:

C_{PR} = concentration of COPC in plant roots (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

BCF_{PS} = plant to soil bioconcentration factor (kg soil / kg plant)*

WPF = washing and peeling factor (1, unitless)

WC = water or moisture content of the plant (%)

Sample Calculation (aboveground plants, human consumption):

$$C_{PR} = 0\ mg/kg \times\ 6.33E^{-03}\ kg\ soil/kg\ plant\ \times 1\ \times \left(1 - \frac{85\%}{100\%}\right) = 0\ mg/kg$$

Equation 13. Concentration in Wild Game

Concentrations of the COPC in wild game were determined for the following species: moose, grouse, hare, caribou, and deer. The sample calculation is completed for the moose.

$$C_{Game} = \left(\frac{C_{S0}IR_S + C_{Sed}IR_{Sed} + C_{SW}IR_{SW} + ((C_{Air} + C_{Dust})IR_{Air}\ \times \mathrm{CF}) + \sum C_{WPlant}IR_{WPlant} + \sum C_{Prey}IR_{Prey}}{BW}\right) \times \mathrm{BTF_A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)

C_{S0} = concentration of COPC in surface soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)

C_{SW} = concentration of COPC in surface water (mg/L)

IR_{SW} = wildlife water ingestion rate (L/d)

C_{Air} = concentration of COPC in air (μg/m³)

IR_{Air} = wildlife air inhalation rate (m³ air/d)

C_{Dust} = concentration of COPC in dust (µg/m³)

IR_{Air} = wildlife air inhalation rate (m³/d)

C_{WPlant} = concentration of COPC in plants (mg/kg)

IR_{WPlant} = wildlife plant ingestion rate (kg/d)

C_{Prey} = concentration of COPC in prey (mg/kg)

IR_{Prey} = wildlife prey ingestion rate (kd/d)

BW = body weight (kg)

BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

CF = conversion factor from ug to mg (unitless)

Sample Calculation (moose):

$$\sum C_{Plant} IR_{Plant} = [(0\ mg/kg \times 6.4\ kg/d) + (0\ mg/kg \times 1.6\ kg/d)] = 0\ mg/d$$

$$\sum C_{Prey} IR_{Prey} = 0\ mg/d$$

$$C_{Game} = \frac{(0\ mg/kg \times 0.16 kg/d) + (4.64E^{-02} mg/kg \times 0.4 kg/d) + (1.72E^{-05} mg/L \times 20 L/d) + ((0 \mu g/m^3 + 0 \mu g/m^3) \times 65.9 m^3/d \times 0.001) + 0 mg/d + 0\ mg/d}{400\ kg}$$

$$\times 3.80E^{-04} mg/kg\ tissue\ /\ mg/d$$

$$= 1.79E^{-08} mg/kg$$

Notes:

* The above calculation of C_{Game} relies upon previous calculation of the adjusted biotransfer factor (BTF_A; mg/kg tissue / mg/d), which considers the chemical-specific biotransfer factor (BTF; 0.002 mg/kg tissue/ mg/d for a moose), fat content of the animal (FC; 0.19), and a modification factor (MF; 0.01 for polycyclic aromatic hydrocarbons, and 1 for volatile organic compounds), such that BTF_A = BTF × FC × MF.

Equation 14. Human Exposure Soil Ingestion

Calculation of human exposure contributions were completed for the following age groups: infant, toddler, child, teen, and adult. The sample calculations for Equations 14 to 20 were completed for the toddler.

$$E_{SI} = \frac{C_{s0} \times SIR \times CF}{BW}$$

Where:

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SIR = soil ingestion rate (g/d)

BW = body weight (kg)

CF1 = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{SI} = \frac{0\, mg/kg \times 8.00E^{-2} g/d \times 0.001}{16.5kg} = 0\, mg/kg\, BW/d$$

Equation 15. Human Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{WI} = \frac{1.72E^{-05} mg/L \times 0.6L/d}{16.5kg} = 6.27E^{-07} mg/kgBW/d$$

Equation 16. Human Exposure from Dust Inhalation

$$E_{Dust} = \frac{C_{Dust} \times AIR \times CF}{BW}$$

Where:

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor from µg to mg (unitless)

Sample Calculation (toddler):

$$E_{Dust} = \frac{0\ \mu g/m^3 \times 8.3\ m^3/d \times 0.001}{16.5kg} = 0\ mg/kgBW/d$$

Equation 17. Human Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{Game} IR_{Game}) \times CF}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{Game} = concentration of COPC in wild game (mg/kg)

IR_{Game} = ingestion rate of wild game (kg/d)

BW = body weight (kg)

CF = conversion factor from g to kg (unitless)

Sample Calculation (toddler):

$$E_{Food} = \frac{\begin{array}{c}[(0\ mg/kg \times 67g/d) + (0\ mg/kg \times 105g/d) + (0\ mg/kg \times 5g/d) + (0mg/kg \times 1g/d) + \\ (0\ mg/kg \times 1g/d)] + [(1.79E^{-08}mg/kg \times 26.51g/d) + (3.38E^{-10}mg/kg \times 14.17g/d) + (6.55E^{-10}mg/kg \times 12.34g/d) + \\ (3.93E^{-10}g/kg \times 15.99g/d) + (3.93E^{-10}mg/kg \times 15.99g/d) + (4.91E^{-04}mg/kg \times 23g/d)] \times 0.001\end{array}}{16.5kg}$$

$$E_{Food} = 6.85E^{-07}mg/kg\ BW/d$$

Equation 18. Human Exposure from Contact with Surface Water (Swimming)

$$E_{SwimC} = \frac{C_{SW} \times K_{PW} \times SEF \times SAT \times CF}{BW}$$

Where:

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

K_{PW} = dermal permeability coefficient (cm/h)

SEF = swimming exposure factor (h/d)

SAT = surface area exposed (cm^2)

BW = body weight (kg)

CF = conversion factor from cm^3 to L (unitless)

Sample Calculation (toddler):

$$E_{SwimC} = \frac{1.72E^{-05} mg/L \times 1.00E^{-3}\ cm/h \times 0.255 h/d \times 6130 cm^2 \times 0.001}{16.5 kg} = 1.63E^{-09} mg/kgBW/d$$

Equation 19. Human Exposure from Ingestion of Surface Water (Swimming)

$$E_{SwimI} = \frac{C_{SW} \times SEF \times SWIR}{BW}$$

Where:

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

SEF = swimming exposure factor (h/d)

SWIR = water ingestion rate while swimming (L/h)

BW = body weight (kg)

Sample Calculation (toddler):

$$E_{SwimI} = \frac{1.72E^{-05} mg/L \times 0.255 h/d \times 0.05 L/h}{16.5 kg} = 1.33E^{-08} mg/kgBW/d$$

Equation 20. Human Exposure from Contact with Surface Soil

$$E_{SC} = \frac{[(C_{s0} \times SAH \times SLH \times RAF) + (C_{s0} \times SAO \times SLO \times RAF)] \times CF}{BW}$$

Where:

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

C_{s0} = concentration of COPC in surface soil (mg/kg)

SAH = surface area of hands (cm^2)

SAO = surface area of other exposed skin (cm^2)

SLH = soil loading to hands (g/cm^2 per event)

SLO = soil loading to other exposed skin (g/cm^2 per event)

RAF = relative dermal absorption factor (%)

BW = body weight (kg)

CF = conversion factor g to kg (unitless)

Sample Calculation (toddler):

$$E_{SC} = \frac{[(0\ mg/kg \times 430cm^2 \times 0.0001g/cm^2 \times 3\%) + (0\ mg/kg \times 2580cm^2 \times 0.00001g/cm^2 \times 3\%)] \times 0.001}{16.5kg} = 0\ \mu g/kgBW/d$$

Equation 21. Human Exposure from Breast Milk Ingestion (Infants Only)

$$C_{BM} = EDI_{Adult} \times BTF_{BM}$$

Where:

C_{BM} = concentration of COPC in breast milk (mg/kg)

EDI_{Adult}= estimated daily intake of adult receptor (mg/d)

BTF_{BM} = breast milk biotransfer factor (µg/kg milk / µg/d intake)

$$E_{BM} = \frac{C_{BM} \times IR_{BM}}{BW}$$

Where:

E_{BM} = exposure from ingestion of breast milk adjusted to body weight (mg/kg BW/d)

C_{BM} = concentration of COPC in breast milk (mg/kg)

IR_{BM} = breast milk ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (infant):

$$C_{BM} = 5.27E^{-05} mg/day \times \ 0 \mu g/kg\ milk\ \mu g/day \text{ intake} = \ 0\ mg/kg$$

$$E_{BM} = \frac{0\ mg/kg \times 0.664 kg/d}{8.2 kg} = 0\ mg/kgBW/d$$

Equation 22. Toddler Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{WI} + E_{Dust} + E_{Food} + E_{SwimC} + E_{SwimI} + E_{SC}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

E_{SwimC} = exposure from contact with surface water adjusted to body weight (mg/kg BW/d)

E_{SwimI} = exposure from ingestion while swimming adjusted to body weight (mg/kg BW/d)

E_{SC} = exposure from contact with surface soil adjusted to body weight (mg/kg BW/d)

Sample Calculation (Toddler):

$$\begin{aligned} E_{Total} &= 0\ mg/kgBW/d \\ &+ 6.27E^{-07} mg/kgBW/d \\ &+ 0\ mg/kgBW/d \\ &+ 6.85E^{-07} mg/kgBW/d \\ &+ 1.63E^{-09} mg/kgBW/d \\ &+ 1.33E^{-08} mg/kgBW/d \\ &+ 0\ mg/kgBW/d \\ &= 1.33E^{-06}\ mg/kgBW/d \end{aligned}$$

Equation 23. Predicted hazard quotient (HQ) from Non-Carcinogenic COPC Exposure

$$HQ = \frac{E_{Total}}{Rfd}$$

Where:

HQ = predicted hazard from exposure to non-carcinogens

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

RfD = reference dose (mg/kg BW/d)

Sample Calculation: ***Not applicable for arsenic for non-threshold effects.***

Equation 24. Predicted Incremental Lifetime Cancer Risk (ILCR) Quotient from Carcinogenic COPC Exposure

The following equation was used to calculate the ILCRs for carcinogenic COPCs, when applicable.

$$ILCR = \frac{(E_{Total-infant} \times D_{infant}) + (E_{Total-toddler} \times D_{toddler}) + (E_{Total-child} \times D_{child}) + (E_{Total-teen} \times D_{teen}) + (E_{Total-adult} \times D_{adult})}{RsD \times LE}$$

Where:

ILCR = predicted risk from exposure to carcinogens

E_{Total} = total daily estimated exposure adjusted to body weight at each lifestage (mg/kg BW/d)

RsD = risk specific dose (mg/kg BW/d)

Di = duration of exposure during lifestage "i" (yr)

LE = life expectancy (yr)

$$ILCR_A = \frac{ILCR}{RA}$$

Where:

$ILCR_A$ = adjusted incremental lifetime cancer risk*

ILCR = incremental lifetime cancer risk; predicted risk from exposure to carcinogens (unitless)

RA = risk adjustment factor (unitless)

$$ILCR_{Total} = \frac{1.43E^{-01}}{1.0E^{+05}} = 1.43E^{-06}$$

Notes:

* The ILCR was divided by the risk adjustment factor (1E+05) so that this adjusted ILCR could be compared to an acceptable risk of 1 in 100,000.

2.0 MULTIMEDIA MODEL WALKTHROUGH EXAMPLES: WILDLIFE HEALTH

2.1 Estimating Exposure *via* Multimedia Modelling

The aquatic Wildlife Risk Assessment (WRA) included direct and indirect exposure to air emissions of chemicals of potential concern (COPCs) from the Project. Concentrations of COPC in environmental media that receptors could be exposed to were predicted through a multimedia model and used to calculate the estimated daily intake (EDI)for surrogate receptors. Air deposition from Project emissions were added to predicted surface water concentrations that included baseline or background exposure, this is defined as the Application case.

Chemical concentrations were predicted by various technical disciplines and provided for the following media:

- Air (Millennium EMS Solutions Ltd.)(EIA, Consultant Report #1 [CR#1], CIAR#42)
- Surface water *via* water-based pathways (EIA, Appendix 10B, CIAR#42)

These provided media concentrations were then used to estimate concentrations in the following media:

- Soil;
- Dust;
- Surface Water (air deposition added to provided surface water concentrations);
- Vegetation (terrestrial and aquatic);
- Periphyton (selenium only);
- Invertebrates;
- Wildlife; and
- Fish.

Modelling formulas for COPC transport and uptake were based on US EPA (2005), unless noted. Ecological receptor characteristics were obtained from Federal Contaminated Sites Action Plan, Ecological Risk Assessment Guidance (FCSAP, 2012), unless noted.

Worked equations for the aquatic WRA are provided herein for selenium and zinc, considering the Application case in Blairmore Creek and the End Pit Lake (EPL). Both the Northern River Otter and American Dipper are presented as receptor surrogates. Wildlife receptor characteristics are presented in Table 2-1.

Table 2-1 Wildlife Receptor Characteristics

Parameter	Small Mammal Food Source	Aquatic Wildlife Receptors						
		Mammalian Receptors			Avian Receptors			
	Meadow Vole	Northern River Otter	Beaver[1]	Little Brown Bat[2,3,4]	American dipper[5,6]	Goose[7]	Great Blue heron	Mallard duck
	Herbivore	Piscivore	Herbivore	Insectivore	Insectivore	Herbivore	Piscivore	Omnivore
Body Mass (kg)	3.49E-02	7.50E+00	2.00E+01	7.50E-03	5.50E-02	3.45E+00	2.30E+00	1.20E+00
Home Range (ha)	6.90E-03	9.00E+02	2.01E+02	1.00E-01	2.24E-01	1.70E+02	1.66E+01	9.20E+00
Food Ingestion Rate (kg-dry weight/kg-bw/day)	1.25E-01	3.00E-02	7.00E-02	2.50E-03	1.20E-02	3.30E-02	4.50E-02	5.00E-02
Food Ingestion Rate (kg/day)	4.38E-03	2.25E-01	1.40E+00	1.88E-05	6.60E-04	1.14E-01	1.04E-01	6.00E-02
Soil Ingestion Rate (kg/kg-bw/day)	3.01E-03	NI	NI	NI	NI	NI	NI	NI
Soil Ingestion Rate (kg/day)	1.05E-04	NI	NI	NI	NI	NI	NI	NI
Sediment Ingestion Rate (kg/kg-bw/day)	NI	6.00E-04	1.40E-03	NI	2.40E-04	6.60E-04	9.00E-04	1.00E-03
Sediment Ingestion Rate (kg/d)	NI	4.50E-03	2.80E-02	NI	1.32E-05	2.28E-03	2.07E-03	1.20E-03
Water Ingestion Rate (L/kg-bw/day)	2.10E-01	8.00E-02	1.00E-01	1.10E-03	8.50E-03	1.89E-01	4.00E-02	6.00E-02
Water Ingestion Rate (L/day)	7.33E-03	6.00E-01	2.00E+00	8.25E-06	4.68E-04	6.51E-01	9.20E-02	7.20E-02
Inhalation Rate (m^3/day)		2.74E+00	6.00E+00	1.03E-02	4.38E-02	1.06E+00	7.60E-01	4.80E-01
Diet Composition:								
- Plants (%)	100	0	75	0	0	0	0	5
- Soil Invertebrates (%)	0	0	0	13	0	0	0	0
- Benthic Invertebrates (%)	0	0	0	0	0	0	0	0
- Vertebrates (%)	0	0	0	0	0	0	0	0
- Aquatic Plants (%)	0	0	25	0	0	99	0	50
- Aquatic Invertebrates (%)	0	15	0	87	75	1	10	40
- Fish (%)	0	80	0	0	25	0	65	5
- Small Mammals (%)	0	5	0	0	0	0	25	0

Unless noted all receptor characteristics are taken from Federal Contaminated Sites Action Plan, Ecological Risk Assessment Guidance - Module 3, 2012

1 - Aleksiuk, M., 1968

2 - US EPA, 1999

3 - Sample *et al.*, 1996

4 - Anthony and Kunz, 1977

5 - Morrissey *et al.*, 2005

6 - Price and Brock, 1983

7 - Ministry of Sustainable Development Environment and Fight against Climate Change, Government of Quebec, 2020

The sediment ingestion rate was calculated as 2% of total food ingestion unless specified in the guidance (FCSAP, 2012)

2.2 Worked Example Selenium - Blairmore Creek (Application Case)

2.2.1 Environmental Media Concentrations

The calculation of environmental media concentrations are presented below in Equation 1 through 13.

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition (mg/m²/yr)

D_{Wet} = wet deposition rate of COPC (mg/m²/yr), 1.03E-3 mg/m²/yr [a]

D_{Dry} = dry deposition rate of COPC (mg/m²/yr), 1.40E-1 mg/m²/yr [a]

a - wet and dry deposition rates were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation:

$$D_{Tot} = 1.03E^{-3}\ mg/m^2/yr + 1.40E^{-1} mg/m^2/yr\ = 1.41E^{-1}\ mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition rate to surface soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_{s0} = surface soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_{s0} = \frac{1.41E^{-1}\ mg/m^2/yr}{0.02\ m \times 1500\ kg/m^3} = 4.69E^{-3}\ mg/\ kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition rate to soil (mg/kg/yr)

D_{Tot} = total deposition rate (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{1.41E^{-1}\ mg/m^2/yr}{0.2\ m \times 1500\ kg/m^3} = 4.69E^{-4}\ mg/\ kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1-e^{(-K_T \times T_D)}}{K_T} + \text{Csback}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition rate to surface soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_{s0} = \left(\frac{4.69E^{-3}mg}{kg/yr}\right)\frac{1 - e^{(-477.19yr^{-1} \times 80yr)}}{477.19\ yr^{-1}} + 8.30E^{-1}mg/kg = 8.30E^{-1}\ mg/kg$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition rate to soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_S = \left(\frac{4.69E^{-4}mg}{kg/yr}\right)\frac{1-e^{(-477.19\times 10^{8}\ yr^{-1}\times 80yr)}}{477.19\ yr^{-1}} + 8.30E^{-1}mg/kg = 8.30E^{-1}\ mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (µg/m³)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m^3)

CF = conversion factor (1000 µg / mg)

Sample Calculation:

$$C_{Dust} = 8.30E^{-1}\frac{mg}{kg} \times 7.6E^{-10}\ kg/m^3 \times 1000\ \mu g/mg = 6.31E^{-7}\mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{tot} \; X \; LA$$

L_T = air deposition loading to surface water (mg/yr)*

D_{Tot} = total deposition rate (mg/m²/yr)

LA = lake area (m²) †

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for.

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body. Assuming lake area of 3.25E+06 m² and depth of 0.5 m, V_{SW} = 1.63E+06 m³.

$$L_T = 1.41E^{-1} \frac{\frac{mg}{m^2}}{yr} X \; 3.25E^{+6} m^2 = 4.57E^{+5} \text{ mg/yr}$$

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = air deposition loading to surface water (mg/yr) ($4.57E^{+5}$ mg/yr)

V_{FR} = average volumetric flow rate through the water body (m³/yr) †

PWC = fraction of total water body for mixing (1.0)

K_{SW} = COPC surface water loss constant (0 yr⁻¹)

V_{SW} = volume of water body (m³)(hypothetical water body with a volume of $1.63E^{+6}$ m³) †

CF = conversion factor (0.001 m³ / L)

C_{SW_SRK} = application surface water concentration without aerial deposition (mg/L)

Sample Calculation:

$$C_{SW} = \frac{4.57E^{+5} mg/yr}{(2.53E^{+7} m^3/yr \times 1) + (0 yr^{-1} \times 1.63E^{+6} m^3)} \times \frac{0.001 m^3}{L} + 4.82E^{-3} mg/L = 4.84E^{-3} mg/L$$

Equation 8. Concentration in Aquatic Organisms

The series of equations calculating the concentrations in aquatic organisms were presented in Addendum 11, Appendix 6.28-1, Appendix B (CIAR#313), which provide the details on the rationale and reference for the selenium specific transfer factors applied to each of the following selenium-specific equations. Note that Blairmore creek is considered a lotic habitat.

Equation 8.1 Concentration in Aquatic Plants

$C_{periphyton\text{-}lotic}$ = Concentration in Aquatic Plants

$$\ln(C_{Periphyton-lotic}) = 0.602 \times \ln(C_{SW-Se}) - 0.409 \times \ln\left(C_{SW-SO_4}\right) + 3.024$$

Where:

$C_{Periphyton\text{-}lotic}$ = selenium concentration (mg/kg dry weight) in periphyton in flowing lotic habitats
$C_{SW\text{-}Se}$ = selenium concentration in surface water (μg/L), 4.84 ug/L – Application
$C_{SW\text{-}SO4}$ = sulphate concentration in surface water (mg/L), 615.4 mg/L – Application

Note, the unitless values in equation 8.1 above are factors within the regression equation specific to uptake in the presence of sulphate.

<u>Worked example (Concentration in aquatic plants)</u>

$\ln(C_{Periphyton-lotic}) = 0.602 \times \ln 4.84 - 0.409 \times \ln(615.4) + 3.024$

$\ln(C_{Periphyton-lotic}) = 3.84$ mg/kg dry weight

Equation 8.2 Concentration in Aquatic Invertebrates

$$C_{Invertebrate-lotic} = 10^{(0.456 \times LOG(C_{Periphyton-lotic})+0.658)}$$

Where:

$C_{Periphyton\text{-}lotic}$ = selenium concentration (mg/kg dry weight) in periphyton in flowing lotic habitats.
$C_{Invertebrate\text{-}lotic}$ = selenium concentration in invertebrates of lotic habitats (mg/kg dry weight).

Worked example (Concentration in aquatic invertebrates)

$C_{Invertebrate-lotic} = 10^{(0.456 \times LOG(3.84)+0.658)}$

$C_{Invertebrate-lotic}$ = 8.41 mg/kg dry weight

Equation 8.3 Concentration in Fish

$C_{Fish} = C_{Invertebrate-lotic} \times TTF_{Fish}$ Equation A.3

Where:

$C_{Invertebrate\text{-}lotic}$ = selenium concentration in invertebrates of lotic habitats (mg/kg dry weight).

C_{Fish} = selenium concentration in whole-body fish tissue (mg/kg dry weight).

TTF_{Fish} = trophic transfer factor (fish)(1.48)

Worked example (Concentration in fish)

$C_{Fish} = 8.41 \frac{mg}{kg} \times 1.48$

$C_{Fish} = 1.24E^{+1}$ mg/kg dry weight

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW}\ X\ F_{BS} \times \frac{K_D}{\theta_{BS}+(K_D \times P_{Sed})} \times \frac{D_{WC}+D_{BS}}{D_{BS}}\ \text{X TD}$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC specific sediment partition coefficient

θ_{BS} = bed sediment porosity (0.6)(unitless)

P_{Sed} = sediment bulk density (1 kg/L)

D_{WC} = depth of water column (1.0 m)

D_{BS} = depth of benthic sediment (0.03 m)

TD = time period over which deposition occurs

Sample Calculation:

$$C_{Sed} = 4.84E^{-3}\ mg/L \times 1.0\ \times \frac{5\ L/kg}{0.6 + (5\ L/kg \times 1\ kg/L)} \times \frac{1.0m + 0.03m}{0.03m} X\ 80\ years = 1.19E^{+1} mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless, 0.5 wildlife forage, 0.39 human consumption)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (0.12 yr wildlife forage, 0.16 yr human consumption)

Y_P = productivity (0.24 kg/m^2 wildlife forage, 2.24 kg/m^2 human consumption)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + D_{Wet} \times (1 - F_V) \times F_W\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

D_{Dry} = overall dry deposition rate ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (1, unitless)

D_{Wet} = overall wet deposition rate ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (0.6, unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{\left(-18yr^{-1} \times 0.12yr\right)}\right]}{0.24kg/m^2 \times 18yr^{-1}} = 1.02E^{-1}$$

$$C_{PD} = [1.40E^{-1}\, mg/m^2/yr \times (1 - 0) + 1.03E^{-3} mg/m^2/yr \times (1 - 0) \times 0.6] \times 1.02E^{-1} = 1.44E^{-2}\, mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

$$B_V = \frac{P_{Air} \times B_{Vol}}{(1 - F_{water}) \times P_{Forage}}$$

Where:

B_V = mass-based air to plant biotransfer factor (µg/g plant / µg/g air)

P_{Air} = density of air (1.2 g/L)

F_{Water} = fraction of forage that is water (0.85 for human intake, 0.62 for wildlife)

P_{Forage} = density of forage (770 g/L)

B_{Vol} = volumetric air to plant biotransfer factor (unitless)

$$C_{PV} = \frac{C_{Air} \times (B_V \div R_F) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m^3), 1.53E-4 ug/m^3 [a]

B_V = mass-based air to plant biotransfer factor (µg/g plant / µg/g air)

R_F = reduction factor (100, unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (1, unitless)

CF = conversion factors (1000L/m^3, 1000µg/mg, 0.001kg/g)

a – air concentrations were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation (wildlife forage):

$$B_V = \frac{1.2 g/L \times 0}{(1 - 0.62) \times 770 g/L} = 0 \text{ µg/g plant/µg/g air}$$

$$C_{PV} = \frac{1.53E^{-4} \mu g/m^3 \times (\ 0.0 \text{ µg/g plant/µg/g/100}) \times 0 \times 1}{1.2\ g/L \times 1000\ L/m^3 \times 1000\ \mu g/mg \times 0.001\ kg/g} = 0\ mg/kg$$

Equation 12. Concentration in Terrestrial Plants – Lichen

$$C_{lichen} = C_{PD} + C_{PV}$$

Where:

C_{lichen} = concentration of COPC in terrestrial plants (mg/kg)

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

Sample Calculation:

$$C_{lichen} = 1.44E^{-2} mg/kg + 0.00\ mg/kg = 1.44E^{-2}\ mg/kg$$

Equation 13. Concentration in Small Mammal (Meadow Vole)

$$\mathrm{BTF_A} = \mathrm{BTF} \times \mathrm{FC} \times \mathrm{MF}$$

Where:

BTF_A = adjusted biotransfer factor (mg/kg tissue / mg/d)

BTF = chemical specific biotransfer factor (mg/kg tissue / mg/d)

FC = fat content (unitless)

MF = modification factor (0.01 for PAHs, 1 for VOCs)

$$C_{Game} = \left(C_S IR_S + C_{Sed} IR_{Sed} + C_{SW} IR_{SW} + ((C_{Air} + C_{Dust}) IR_{Air} \times \mathrm{CF}) + \sum C_{Plant} IR_{WPlant} + \sum C_{Prey} IR_{Prey}\right) \times \mathrm{BTF_A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)

C_{SW} = concentration of COPC in surface water (mg/L)

IR_{SW} = wildlife water ingestion rate (L/d)

C_{Air} = concentration of COPC in air (mg/m^3)

IR_{Air} = wildlife air inhalation rate (m^3 air/d)
C_{Dust} = concentration of COPC in dust (mg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3/d)
C_{Plant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

Sample Calculation (Meadow Vole):

$$\mathrm{BTF_A} = 1.50E^{-2} \times 0.19 \times 1 = 2.85E^{-3} \text{ mg/kg tissue mg/d}$$

$$\sum C_{Plant} IR_{Plant} = 1.44E^{-2} \frac{mg}{kg} \times \frac{4.38E^{-3} kg}{d} = 6.29E^{-5}\ mg/d$$

$$\sum C_{Prey} IR_{Prey} = 0$$

$$C_{Mammal} = \left\{ \left(8.30E^{-1}\ \frac{mg}{kg}\right)\left(\frac{1.05E^{-4} kg}{d}\right) + \left(1.19E^{+1} \frac{mg}{kg}\right)\left(\frac{0\ kg}{d}\right) + \left(4.84E^{-3} \frac{mg}{L}\right)\left(\frac{7.33E^{-3} L}{d}\right) + \left(1.53E^{-4} \frac{ug}{m^3} + 6.31E^{-7} \frac{ug}{m^3}\right)\left(\frac{5.20E^{-2} m^3}{d}\right)\left(\frac{1\ mg}{1000\ ug}\right) + 6.29E^{-5} + (0\ \ mg/d) \right\} \times 2.85E^{-3}\ mg/kg \text{ tissue mg/d} = 5.29E^{-7} mg/kg \text{ tissue}$$

Notes: Meadow vole are herbivores (eat 100% terrestrial plants – assumed to be 100% lichen). Exposure from air and dust assumed to be the same.

2.2.2 Calculation of Exposure Ratio – Northern River Otter, Blairmore Creek

Equation 14a. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR \times CF}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{Sed} = \frac{1.19E^{+1}\frac{mg}{kg} \times 4.50E^{-3}\,kg/d}{7.5kg} = 7.12E^{-3}\ mg/kgBW/d$$

*note there are no reported values for soil or sediment ingestion rate for the Otter, but sediment ingestion was assumed to be 2% of the food ingestion rate, as per guidance (FCSAP, 2012).

Equation 15a. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{WI} = \frac{4.84E^{-3}\,\frac{mg}{L} \times 0.6\ L/d}{7.5kg} = 3.87E^{-4}\ mg/kgBW/d$$

Equation 16a. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (Otter):

$$E_{Air+Dust} = \frac{\left(\frac{1.53E^{-4}\mu g}{m^3} + \frac{6.31E^{-7}\mu g}{m^3}\right) \times 2.74\ m^3/d \ \times 0.001 mg/\mu g}{7.5kg} = 5.61E^{-8} mg/kgBW/d$$

Equation 17a. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{mammal} IR_{mammal} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish})}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{mammal} = concentration of COPC in a surrogate mammal (meadow vole, mg/kg dry weight)

IR_{mammal} = ingestion rate of mammal (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg dry weight)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$\sum C_{Plant} IR_{Plant} = 0\ mg/d$$

$$E_{Food} = \frac{\left[\left(1.51E^{-5}\frac{mg}{kg}\right)\left(\frac{1.13E^{-2}kg}{d}\right)+\left(\frac{8.41\ mg}{kg}\right)\left(\frac{3.38E^{-2}kg}{d}\right)+\left(1.24E^{+1}\frac{mg}{kg}\right)\left(\frac{1.80E^{-1}kg}{d}\right)\right]}{7.5\ kg} = 3.36E^{-1} mg/kg \text{ BW/day}$$

Notes: Otter do not eat plants.

Exposure from air and dust assumed to be the same.

Equation 18a. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (Otter):

$$\begin{aligned} E_{Total} &= 7.12E^{-3} mg/kgBW/d \\ &+ 3.87E^{-4} mg/kgBW/d \\ &+ 5.61E^{-8} mg/kgBW/d \\ &+ 3.36E^{-1} mg/kgBW/d \\ &= 3.44E^{-1} mg/kgBW/d \end{aligned}$$

Equation 19a. Predicted Exposure Ratio – Northern River Otter – Blairmore Creek

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (Otter):

$$ER = \frac{3.44E^{-1}\ mg/kg\ BW/d}{0.33\ mg/kg\ BW/d} = 1.04$$

2.2.3 Calculation of Exposure Ratio – American Dipper

Equations 1-12 are the same as presented for the Otter at Blairmore Creek. The following equations (14b-19b) represent the process of calculating the exposure ratio for the American Dipper at this location.

American Dipper- eat aquatic inverts and fish.

Equation 14b. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)*

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{Sed} = \frac{1.19E^{+1}\frac{mg}{kg} \times 1.32E^{-5}kg/d}{5.50E^{-2}kg} = 2.85E^{-3}\ mg/kg\ BW/d$$

*note there are no reported values for soil or sediment ingestion rate for the American Dipper, therefore sediment ingestion was assumed to be 2% of total food ingestion rate

Equation 15b. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{WI} = \frac{4.84E^{-3}\frac{mg}{L} \times \ 4.68E^{-4}\ L/d}{5.50E^{-2}kg} = 4.11E^{-5}\ mg/kgBW/d$$

Equation 16b. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR\ \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m³)

C_{Air} = concentration of COPC in air (mg/m³)

AIR = air inhalation rate (m³/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/µg)

Sample Calculation (American Dipper):

$$E_{Air+Dust} = \frac{\left(\frac{1.53E^{-4}\mu g}{m^3} + \frac{6.31E^{-7}\mu g}{m^3}\right) \times 4.38E^{-2}\ m^3/d\ \times 0.001mg/\mu g}{5.50E^{-2}kg} = 1.23E^{-7}mg/kgBW/d$$

Equation 17b. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish}}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg dry weight)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$\sum C_{Plant} IR_{Plant} = 0\ mg/d$$

$$E_{Food} = \frac{\left[\left(\frac{8.41\ mg}{kg}\right)\left(\frac{4.95E^{-4}kg}{d}\right) + \left(1.24E^{+1}\frac{mg}{kg}\right)\left(\frac{1.65E^{-4}kg}{d}\right)\right]}{5.50E^{-2}kg} = 1.13E^{-1}mg/kg \text{ BW/day}$$

Notes: American Dipper do not eat plants.

Exposure from air and dust assumed to be the same.

Equation 18b. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (American Dipper):

$$\begin{aligned} E_{Total} &= 2.85E^{-3} mg/kgBW/d \\ &+ 4.11E^{-5} mg/kgBW/d \\ &+ 1.23E^{-7} mg/kgBW/d \\ &+ 1.13E^{-1} mg/kgBW/d \\ &= 1.16E^{-1} mg/kgBW/d \end{aligned}$$

Equation 19b. Predicted Exposure Ratio, American Dipper

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (American Dipper):

$$ER = \frac{1.16E^{-1}\ mg/kg\ BW/d}{0.30\ mg/kg\ BW/d} = 3.86E^{-1}$$

2.3 Worked Example Selenium – End Pit Lake (Application Case)

2.3.1 Environmental Media Concentrations

Equations used in the calculation of environmental media concentrations are presented below in Equation 1 through 13.

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:
D_{Tot} = total deposition (mg/m²/yr)
D_{Wet} = wet deposition rate of COPC (mg/m²/yr), 0 mg/m²/yr [a]
D_{Dry} = dry deposition rate of COPC (mg/m²/yr), 0 mg/m²/yr [a]

a - wet and dry deposition rates were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation:

$$\frac{D_{Tot} = 0\ mg/m^2/yr + 0\,\frac{mg}{m^2}}{yr} = 0\,\frac{\frac{mg}{m^2}}{yr}$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:
D_{s0} = deposition to surface soil (mg/kg/yr)
D_{Tot} = total deposition (mg/m²/yr)
Z_{s0} = surface soil mixing depth (m)
ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_{s0} = \frac{0\ mg/\frac{m^2}{yr}}{0.02\ m \times 1500\,\frac{kg}{m^3}} = 0\,\frac{mg}{kg/yr}$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{0\ mg/\frac{m^2}{yr}}{0.2\ m \times 1500\frac{kg}{m^3}} = 0\frac{mg}{kg/yr}$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs⁻¹)

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_{s0} = \left(0\frac{mg}{kg}\right)\frac{1 - e^{(-477.19yr^{-1} \times 80yrs)}}{477.19\ yr^{-1}} + 8.30E^{-1} = 8.30E^{-1}\frac{mg}{kg}$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_S = \left(\frac{4.69E^{-4}mg}{kg}\right)\frac{1-e^{(-477.19\times10^{8}\ yr^{-1}\times 80yrs)}}{477.19\ yr^{-1}} + 8.30E^{-1} = 8.30E^{-1}\frac{mg}{kg}$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (µg/m^3)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m^3)

CF = conversion factor (1000 µg / mg)

Sample Calculation:

$$C_{Dust} = 8.30E^{-1}\frac{mg}{kg} \times 7.6E^{-10}\ kg/m^3 \times 1000\frac{\mu g}{mg} = \frac{6.31E^{-7}\mu g}{m^3}$$

Equation 7. Concentration in Surface Water

$$L_T = D_{tot}\ X\ LA$$

L_T = air deposition loading to surface water (mg/yr)*

D_{Tot} = total deposition rate (mg/m^2/yr)

LA = lake area (m^2) †

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}).

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on the proposed end-pit lake dimensions. Assuming lake area of 4.44E+04 m^2 and depth of 30 m, V_{SW} = 1.33E+06 m^3.

$$L_T = 0\ \frac{\frac{mg}{m^2}}{yr} X\ 4.44E^{+4}m^2 = 0\ \text{mg/yr}$$

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = total COPC water load (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m^3/yr)

PWC = fraction of total water body for mixing (100%)

K_{SW} = COPC surface water loss constant (0 yr^{-1})

V_{SW} = volume of water body (m^3)

CF = conversion factor (0.001 m^3 / L)

C_{SW_SRK} = application surface water concentration without aerial deposition (mg/L)

Sample Calculation:

$$C_{SW} = \frac{0\frac{mg}{yr}}{\left(\frac{2.43E^{+2}m^3}{yr} \times 1\right) + (0yr^{-1} \times 1.33E^{+6}m^3)} \times \frac{0.001m^3}{L} + 3.03E^{-2} = \frac{3.03E^{-2}mg}{L}$$

Equation 8. Concentration in Aquatic Organisms

The worked example below presents only those calculations that are divergent from previously presented multimedia inputs for concentration in fish and invertebrates. This worked example was presented in Addendum 11, Appendix 6.28-1, Appendix B, CIAR #313. See Appendix B for details on each of the following selenium- specific equations.

End Pit Lake is a lentic habitat, and is assumed to have no fish population.

Equation 8.1 Concentration in Aquatic Plants

$$C_{periphyton_{lentic}} = C_{SW} \times EF_{Lentic}$$
$$C_{periphyton_{lentic}} = 3.03E^{-2} \times 900$$
$$C_{periphyton_{lentic}} = 2.73E^{+1}$$

Where:

$C_{periphyton\_lentic}$ = selenium concentration (mg/kg dry weight) in periphyton in lentic habitats

EF_{Lentic} = enrichment factor, 900 L/kg applied to lentic habitats (post-closure end pit lake, sedimentation ponds, Oldman Reservoir)

C_{SW} = selenium concentration in surface water (mg/L)

$$C_{Invertebrate} = TTF_{Invertebrate} \times C_{Periphyton-lentic}$$
$$C_{Invertebrate} = 2.1 \times 2.73E^{+1}$$
$$C_{Invertebrate} = 5.73E^{+1}$$

Where:

$C_{periphyton\_lentic}$ = selenium concentration (mg/kg dry weight) in periphyton in lentic habitats

$TTF_{Invertebrate}$ = trophic transfer into invertebrate tissue (unitless)

$C_{Invertebrate}$ = concentration in invertebrate tissue (mg/kg dry weight)

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW}\ X\ F_{BS} \times \frac{K_D}{\theta_{BS}+(K_D \times P_{Sed})} \times \frac{D_{WC}+D_{BS}}{D_{BS}} \text{ X TD}$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC specific sediment partition coefficient

θ_{BS} = bed sediment porosity (0.6) (unitless)

P_{Sed} = sediment bulk density (1 kg/L)

D_{WC} = depth of water column (1.0 m)

D_{BS} = depth of benthic sediment (0.03 m)

TD = time period over which deposition occurs

Sample Calculation:

$$C_{Sed} = 3.03E^{-2}\ mg/L \times 1.0\ \times \frac{5\ L/kg}{0.6\ + (5\ L/kg \times 1\ kg/L)} \times \frac{1.0m + 0.03m}{0.03m} X\ 80\ years = \frac{7.43E^{+1}mg}{kg}$$

Equation 10. Concentration in Plants due to Direct Deposition

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless, 0.5 wildlife forage, 0.39 human consumption)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (0.12 yr wildlife forage, 0.16 yr human consumption)

Y_P = productivity (0.24 kg/m^2 wildlife forage, 2.24 kg/m^2 human consumption)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + D_{Wet} \times (1 - F_V) \times F_W\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

D_{Dry} = overall dry deposition rate (mg/m^2/yr)

F_V = fraction of COPC that is volatile (1, unitless)

D_{Wet} = overall wet deposition rate (mg/m^2/yr)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (0.6, unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{(-18yr^{-1} \times 0.12yr)}\right]}{\frac{0.24kg}{m^2} \times 18yr^{-1}} = 1.02E^{-1}$$

$$C_{PD} = \left[\frac{0\frac{mg}{m^2}}{yr} \times (1-0) + 0\frac{\frac{mg}{m^2}}{yr} \times (1-0) \times 0.6\right] \times 1.02E^{-1} = 0\frac{mg}{kg}$$

Equation 11. Concentration in Plants due to Vapour Uptake

$$B_V = \frac{P_{Air} \times B_{Vol}}{(1 - F_{water}) \times P_{Forage}}$$

Where:

B_V = mass based air to plant biotransfer factor (µg/g plant / µg/g air)

P_{Air} = density of air (1.2 g/L)

F_{Water} = fraction of forage that is water (0.85 for human intake, 0.62 for wildlife)

P_{Forage} = density of forage (770 g/L)

B_{Vol} = volumetric air to plant biotransfer factor (unitless)

$$C_{PV} = \frac{C_{Air} \times (B_V \div R_F) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m^3)[a]

B_V = mass based air to plant biotransfer factor (µg/g plant / µg/g air)

R_F = reduction factor (100, unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (1, unitless)

CF = conversion factors (1000L/m^3, 1000µg/mg, 0.001kg/g)

a – air concentrations were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation (wildlife forage):

$$B_V = \frac{\frac{1.2 g/L \times 0}{(1 - 0.62) \times \frac{770g}{L}} = 0\ \mu\frac{g}{g}\text{plant}}{\mu\frac{g}{g}}\text{air}$$

$$C_{PV} = \frac{0\ \mu g/m^3 \times \left(\frac{0.0 \frac{\mu g}{g} \text{plant}}{\frac{\mu g}{g}} \Big/ 100 \right) \times 0 \times 1}{1.2\ g/L \times 1000\ L/m^3 \times 1000\ \mu g/mg \times 0.001\ kg/g} = 0 \frac{mg}{kg}$$

Equation 12. Concentration in Terrestrial Plants – Lichen

$$C_{lichen} = C_{PD} + C_{PV}$$

Where:

C_{lichen} = concentration of COPC in terrestrial plants (mg/kg)

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

Sample Calculation:

$$C_{lichen} = 0 + 0 = 0 \text{ mg/kg}$$

Equation 13. Concentration in Small Mammal (Meadow Vole)

$$\text{BTF}_A = \text{BTF} \times \text{FC} \times \text{MF}$$

Where:

BTF_A = adjusted biotransfer factor (mg/kg tissue / mg/d)

BTF = chemical specific biotransfer factor (mg/kg tissue / mg/d)

FC = fat content (unitless)

MF = modification factor (0.01 for PAHs, 1 for VOCs)

$$C_{Game} = \left(C_S IR_S + C_{Sed} IR_{Sed} + C_{SW} IR_{SW} + ((C_{Air} + C_{Dust}) IR_{Air} \times \text{CF}) + \sum C_{Plant} IR_{WPlant} + \sum C_{Prey} IR_{Prey} \right) \times \text{BTF}_A$$

Where:

C_{mammal} = concentration of COPC in surrogate mammal (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)
C_{SW} = concentration of COPC in surface water (mg/L)
IR_{SW} = wildlife water ingestion rate (L/d)
C_{Air} = concentration of COPC in air (mg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3 air/d)
C_{Dust} = concentration of COPC in dust (mg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3/d)
C_{Plant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

Sample Calculation (Meadow Vole):

$$\mathrm{BTF_A} = 1.50E^{-2} \times 0.19 \times 1 = 2.85E^{-3} \text{ mg/kg tissue mg/d}$$

$$\sum C_{Plant} IR_{Plant} = 0\frac{mg}{kg} \times \frac{4.38E^{-3} kg}{d} = 0\frac{mg}{d}$$

$$\sum C_{Prey} IR_{Prey} = 0$$

$$C_{mammal} = \left\{\left(8.30E^{-1}\ \frac{mg}{kg}\right)\left(\frac{1.05E^{-4} kg}{d}\right) + \left(7.43E^{+1}\frac{mg}{kg}\right)\left(\frac{0\ kg}{d}\right) + \left(3.03E^{-2}\frac{mg}{L}\right)\left(\frac{7.33E^{-3} L}{d}\right) + \left(0\frac{ug}{m^3} + 6.31E^{-7}\frac{ug}{m^3}\right)\left(\frac{5.20E^{-2} m^3}{d}\right)\left(\frac{1\ mg}{1000\ ug}\right) + 0 + (0\ mg/d)\right\} \times 2.85E^{-3}\,\frac{\text{mg}}{\text{kg}}\text{tissue}\,\frac{\text{mg}}{\text{d}} = \frac{8.82E^{-7} mg}{kg}\text{tissue}$$

Notes: Meadow vole are herbivores (eat 100% terrestrial plants – assumed to be 100% lichen). Exposure from air and dust assumed to be the same.

2.3.2 Calculation of Exposure Ratio – Northern River Otter

Equation 14a. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR \times CF}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$Esed = \frac{7.43E^{+1}\frac{mg}{kg} \times \frac{4.50E^{-3}kg}{d}}{7.5kg} = 4.46E^{-2}\frac{mg}{kgBW}$$

*note there are no reported values for soil or sediment ingestion rate for the Otter, but sediment ingestion was assumed to be 2% of the food ingestion rate, as per guidance (FCSAP, 2012).

Equation 15a. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{WI} = \frac{3.03E^{-2}\frac{mg}{L} \times 0.6\ L/d}{7.5kg} = 2.42E^{-3}\ mg/kgBW/d$$

Equation 16a. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (Otter):

$$E_{Air+Dust} = \frac{\left(\frac{0\ \mu g}{m^3} + \frac{6.31E^{-7}\mu g}{m^3}\right) \times 2.74\frac{m^3}{d} \times \frac{0.001mg}{\mu g}}{7.5kg} = \frac{\frac{2.30E^{-10}mg}{kgBW}}{d}$$

Equation 17a. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{mammal} IR_{mammal} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish})}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg dry weight)

IR_{Plant} = ingestion rate of plants (kg/d)

C_{mammal} = concentration of COPC in a surrogate mammal (meadow vole, mg/kg dry weight)

IR_{mammal}= ingestion rate of mammal (kg/d)

$C_{Invertebrate}$= concentration of COPC in invertebrate tissue (mg/kg dry weight)

$IR_{invertebrate}$=invertebrate ingestion rate (kg/d)

C_{fish} = concentration of COPC in fish tissue (mg/kg dry weight)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$\sum C_{Plant} IR_{Plant} = 0 \frac{mg}{d}$$

$$E_{Food} = \frac{\left\{(0\ mg/d) + \left[\left(2.53E^{-5}\ \frac{mg}{kg}\right)\left(\frac{1.13E^{-2} kg}{d}\right) + \left(\frac{5.73E^{+1} k\ mg}{kg}\right)\left(\frac{3.38E^{-2} kg}{d}\right)\right]\right\}}{7.5\ kg} = 2.58 \frac{E^{-1} mg}{kg} \text{BW/day}$$

Notes: Otter do not eat plants, no fish population assumed in the end pit lake.

Equation 18a. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (Otter):

$$\begin{aligned} E_{Total} &= 4.46E^{-2}\ mg/kgBW/d \\ &+ 2.42E^{-3} mg/kgBW/d \\ &+ 2.30E^{-10} mg/kgBW/d \\ &+ 2.58E^{-1} mg/kgBW/d \\ &= 3.05E^{-1}\ mg/kgBW/d \end{aligned}$$

Equation 19a. Predicted Exposure Ratio – Northern River Otter –End Pit Lake

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (Otter):

$$ER = \frac{3.05E^{-1}\ mg/kg\ BW/d}{0.33\ mg/kg\ BW/d} = 9.24E^{-1}$$

2.3.3 Calculation of Exposure Ratio –American Dipper

Equations 1-12 are the same as presented for the Otter at the EPL. The following equations (14b-19b) represent the process of calculating the exposure ratio for the American Dipper at this location.

American Dipper- eat **aquatic inverts** and **fish** (no fish in EPL, so not considered).

Equation 14b. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)*

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{Sed} = \frac{7.43E^{+1}\frac{mg}{kg} \times \frac{1.32E^{-5}kg}{d}}{5.50E^{-2}kg} = 1.78E^{-2}\frac{mg}{kg\ BW/d}$$

*note there are no reported values for soil or sediment ingestion rate for the American Dipper, therefore sediment ingestion was assumed to be 2% of total food ingestion rate

Equation 15b. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{WI} = \frac{3.03E^{-2}\frac{mg}{L} \times 4.68E^{-4}\frac{L}{d}}{5.50E^{-2}kg} = 2.58E^{-4}\frac{mg}{kg\ BW/d}$$

Equation 16b. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \ \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (American Dipper):

$$E_{Air+Dust} = \frac{\left(\frac{0\ \mu g}{m^3} + \frac{6.31E^{-7}\mu g}{m^3}\right) \times 4.38E^{-2}\,\frac{m^3}{d} \times \frac{0.001mg}{\mu g}}{5.50E^{-2}kg} = \frac{\frac{5.03E^{-10}mg}{kgBW}}{d}$$

Equation 17b. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish}}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg dry weight)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$\sum C_{Plant} IR_{Plant} = 0 \frac{mg}{d}$$

$$E_{Food} = \frac{\left[\left(\frac{5.73E^{+1}\,mg}{kg}\right)\left(\frac{4.95E^{-4}kg}{d}\right)\right]}{5.50E^{-2}kg} = \frac{5.16E^{-1}mg}{kg}\text{ BW/day}$$

Notes: American Dipper do not eat plants. There are no fish in the EPL.

Exposure from air and dust assumed to be the same.

Equation 18b. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (American Dipper):

$$\begin{aligned} E_{Total} &= 1.78E^{-2} mg/kgBW/d \\ &+ 2.58E^{-4} mg/kgBW/d \\ &+ 5.03E^{-10} mg/kgBW/d \\ &+ 5.16E^{-1} mg/kgBW/d \\ &= 5.43E^{-1} mg/kgBW/d \end{aligned}$$

Equation 19b. Predicted Exposure Ratio, American Dipper

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (American Dipper):

$$ER = \frac{\frac{5.43\text{E}^{-1}\,\frac{\text{mg}}{\text{kg}}\text{BW}}{\text{d}}}{\frac{0.30\,\frac{\text{mg}}{\text{kg}}\text{BW}}{\text{d}}} = 1.78$$

2.4 Worked Example Zinc - Blairmore Creek (Application Case)

2.4.1 Environmental Media Concentrations

Equations used in the calculation of environmental media concentrations are presented below in Equation 1 through 13.

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:

D_{Tot} = total deposition ($mg/m^2/yr$)
D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$), 1.22E-1 $mg/m^2/yr$ [a]
D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$), 1.49E+1 $mg/m^2/yr$ [a]

a - wet and dry deposition rates were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation:

$$D_{Tot} = 1.22E^{-1}\, mg/m^2/yr + 1.49E^{+1} mg/m^2/yr \ = 1.50E^{+1}\, mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:

D_{s0} = deposition to surface soil (mg/kg/yr)
D_{Tot} = total deposition ($mg/m^2/yr$)
Z_{s0} = surface soil mixing depth (m)
ρ_B = soil bulk density (kg/m^3)

Sample Calculation:

$$D_{s0} = \frac{1.50E^{+1}\ mg/m^2/yr}{0.02\, m \times 1500\, kg/m^3} = 5.01E^{-1}\, mg/\,kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition (mg/m²/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m³)

Sample Calculation:

$$D_S = \frac{1.50E^{+1}\ mg/m^2/yr}{0.2\ m \times 1500\ kg/m^3} = 5.01E^{-2}\ mg/\ kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1-e^{(-K_T \times T_D)}}{K_T} + \text{Csback}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_{s0} = (5.01E^{-1} mg/kg\ yr^{-1})\frac{1 - e^{(-477.19yr^{-1} \times 80yrs)}}{477.19\ yr^{-1}} + 1.44E^{+2} = 1.44E^{+2}\ mg/kg$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_S = (5.01E^{-2}\ mg/kg\ yr^{-1}) \frac{1-e^{(-477.19 \times 10^8\ yr^{-1} \times 80 yrs)}}{477.19\ yr^{-1}} + 1.44E^{+2} = 1.44E^{+2}\ mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust (µg/m^3)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m^3)

CF = conversion factor (1000 µg / mg)

Sample Calculation:

$$C_{Dust} = 1.44E^{+2} \frac{mg}{kg} \times 7.6E^{-10}\ kg/m^3 \times 1000\ \mu g/mg = 1.09E^{-4} \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{tot}\ X\ LA$$

L_T = air deposition loading to surface water (mg/yr)*

D_{Tot} = total deposition rate (mg/m²/yr)

LA = lake area (m²) †

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for in the values provided by SRK (EIA, Appendix 10B – Water and Load Balance, CIAR#42) and is included in the subsequent calculation of the concentration of surface water (C_{SW}).

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on a theoretical water body. Assuming lake area of 3.25E+06 m² and depth of 0.5 m, V_{SW} = 1.63E+06 m³.

$$L_T = 1.50E^{+1}\ \frac{\frac{mg}{m^2}}{yr} X\ 3.25E^{+6} m^2 = \ 4.88E^{+7}\ \text{mg/yr}$$

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC)+(K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = total COPC water load (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m³/yr)($2.53E^{+07}$) †

PWC = fraction of total water body for mixing (100%)

K_{SW} = COPC surface water loss constant (0 yr^{-1})

V_{SW} = volume of water body (m³)(hypothetical water body with a volume of $1.63E^{+6}$ m³)

CF = conversion factor (0.001 m³ / L)

C_{SW_SRK} = application surface water concentration without aerial deposition (mg/L)

Sample Calculation:

$$C_{SW} = \frac{4.88E^{+7}\ mg/yr}{(2.53E^{+7} m^3/yr \times 1)+(0 yr^{-1} \times\ 1.63E^{+6} m^3\ )} \times \frac{0.001 m^3}{L} + 9.25E^{-3} = 1.12E^{-2} mg/L$$

Equation 8. Concentration in Aquatic Organisms

Concentrations of the COPC in aquatic plants, aquatic invertebrates, and fish were determined based on the concentration of COPC in surface water (C_{SW}) and a chemical-specific bioconcentration factor (BCF). The concentration of the COPC in terrestrial invertebrates was calculated similarly, only using the concentration of COPC in surface soil (C_{s0}) and BCF. The sample calculation is completed for aquatic invertebrates and fish, results are produced in dry weight.

$$C_{Organism} = C_{SW} \times BCF$$

Sample Calculation (aquatic invertebrate):

$$C_{invertebrate} = \frac{1.12E^{-2}mg}{L} \times 6.87E^{+2}\,L\frac{water}{kg\ invert\ DW} = 7.68\ mg/kg$$

Sample Calculation (fish):

$$C_{fish} = \frac{1.12E^{-2}mg}{L} \times 2.50E^{+2}\,L\frac{water}{kg\ invert\ DW} = 2.79\ mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW}\ X\ F_{BS} \times \frac{K_D}{\theta_{BS}+(K_D \times P_{Sed})} \times \frac{D_{WC}+D_{BS}}{D_{BS}}\ \mathrm{X\ TD}$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC specific sediment partition coefficient

θ_{BS} = bed sediment porosity (0.6, unitless)

P_{Sed} = sediment bulk density (1000 kg/m^3)

D_{WC} = depth of water column (1.0 m)

D_{BS} = depth of benthic sediment (0.03 m)

TD = time period over which deposition occurs

Sample Calculation:

$$C_{Sed} = 1.12E^{-2}\ mg/L \times 1.0\ \times \frac{1000\ L/kg}{0.6\ + (1000\ L/kg \times 1\ kg/m^3)} \times \frac{1.0m + 0.03m}{0.03m} X\ 80\ years$$
$$= 3.07E^{+1}\ mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless, 0.5 wildlife forage, 0.39 human consumption)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (0.12 yr wildlife forage, 0.16 yr human consumption)

Y_P = productivity (0.24 kg/m^2 wildlife forage, 2.24 kg/m^2 human consumption)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + D_{Wet} \times (1 - F_V) \times F_W\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

D_{Dry} = overall dry deposition rate ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (1, unitless)

D_{Wet} = overall wet deposition rate ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (0.6, unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{\left(-18yr^{-1} \times 0.12yr\right)}\right]}{0.24kg/m^2 \times 18yr^{-1}} = 1.02E^{-1}$$

$$C_{PD} = [1.49E^{+1}\ mg/m^2/yr \times (1 - 0) + 1.22E^{-1} mg/m^2/yr \times (1 - 0) \times 0.6] \times 1.02E^{-1} = 1.53\ mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

$$B_V = \frac{P_{Air} \times B_{Vol}}{(1 - F_{water}) \times P_{Forage}}$$

Where:

B_V = mass based air to plant biotransfer factor (μg/g plant / μg/g air)

P_{Air} = density of air (1.2 g/L)

F_{Water} = fraction of forage that is water (0.85 for human intake, 0.62 for wildlife)

P_{Forage} = density of forage (770 g/L)

B_{Vol} = volumetric air to plant biotransfer factor (unitless)

$$C_{PV} = \frac{C_{Air} \times (B_V \div R_F) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m^3)[a]

B_V = mass based air to plant biotransfer factor (μg/g plant / μg/g air)

R_F = reduction factor (100, unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (1, unitless)

CF = conversion factors (1000L/m^3, 1000μg/mg, 0.001kg/g)

a – air concentrations were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation (wildlife forage):

$$B_V = \frac{1.2g/L \times 0}{(1 - 0.62) \times 770g/L} = 0 \text{ μg/g plant/μg/g air}$$

$$C_{PV} = \frac{1.82E^{-2}\mu g/m^3 \times (\text{ 0.0 μg/g plant/μg/g/100}) \times 0 \times 1}{1.2\ g/L \times 1000\ L/m^3 \times 1000\ \text{μg}/mg \times 0.001\ kg/g} = 0\ mg/kg$$

Equation 12. Concentration in Terrestrial Plants – Lichen

$$C_{lichen} = C_{PD} + C_{PV}$$

Where:

C_{lichen} = concentration of COPC in terrestrial plants (mg/kg)

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

Sample Calculation:

$$C_{lichen} = 1.53\ mg/kg + 0.00 mg/kg\ DW\ = 1.53\ mg/kg$$

Equation 13. Concentration in Small Mammal (Meadow Vole)

$$\mathrm{BTF_A} = \mathrm{BTF} \times \mathrm{FC} \times \mathrm{MF}$$

Where:

BTF_A = adjusted biotransfer factor (mg/kg tissue / mg/d)

BTF = chemical specific biotransfer factor (mg/kg tissue / mg/d)

FC = fat content (unitless)

MF = modification factor (0.01 for PAHs, 1 for VOCs)

$$C_{Game} = \left(C_S IR_S + C_{Sed} IR_{Sed} + C_{SW} IR_{SW} + ((C_{Air} + C_{Dust}) IR_{Air} \times \mathrm{CF}) + \sum C_{Plant} IR_{WPlant} + \sum C_{Prey} IR_{Prey}\right) \times \mathrm{BTF_A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)

C_{SW} = concentration of COPC in surface water (mg/L)

IR_{SW} = wildlife water ingestion rate (L/d)

C_{Air} = concentration of COPC in air (mg/m^3)

IR_{Air} = wildlife air inhalation rate (m³ air/d)
C_{Dust} = concentration of COPC in dust (mg/m³)
IR_{Air} = wildlife air inhalation rate (m³/d)
C_{Plant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

Sample Calculation (Meadow Vole):

$$\mathrm{BTF_A} = 1.00E^{-1} \times 0.19 \times 1 = 1.90E^{-2}\ \text{mg/kg tissue mg/d}$$

$$\sum C_{Plant} IR_{Plant} = 1.53\frac{mg}{kg} \times \frac{4.83E^{-3}kg}{d} = 6.71E^{-3}\ mg/d$$

$$\sum C_{Prey} IR_{Prey} = 0$$

$$C_{mammal} = \left\{\left(1.44E^{-2}\ \frac{mg}{kg}\right)\left(\frac{1.05E^{-4}kg}{d}\right) + \left(3.07E^{+1}\frac{mg}{kg}\right)\left(\frac{0kg}{d}\right) + \left(1.12E^{-2}\frac{mg}{L}\right)\left(\frac{7.33E^{-3}L}{d}\right) + \left(1.82E^{-2}\frac{ug}{m^3} + 1.09E^{-4}\frac{ug}{m^3}\right)\left(\frac{5.20E^{-2}m^3}{d}\right)\left(\frac{1\ mg}{1000\ ug}\right) + 6.71E^{-3} mg/d + (0\ \ mg/d)\right\} \times 1.90E^{-2}\ mg/kg\ \text{tissue mg/d} = 4.16E^{-4} mg/kg\ \text{tissue}$$

Notes: Meadow vole are herbivores (eat 100% terrestrial plants – assumed to be 100% lichen). Exposure from air and dust assumed to be the same.

2.4.2 Calculation of Exposure Ratio – Northern River Otter

Equation 14a. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR \times CF}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{Sed} = \frac{3.07E^{+1}\frac{mg}{kg} \times 4.50E^{-3} kg/d}{7.5kg} = 1.84E^{-2}\ mg/kgBW/d$$

*note there are no reported values for soil or sediment ingestion rate for the Otter, but sediment ingestion was assumed to be 2% of the food ingestion rate, as per guidance (FCSAP, 2012).

Equation 15a. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{WI} = \frac{1.12E^{-2}\frac{mg}{L} \times 0.6\ L/d}{7.5kg} = 8.94E^{-4}\ mg/kgBW/d$$

Equation 16a. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (Otter):

$$E_{Air+Dust} = \frac{\left(1.82E^{-2}\frac{ug}{m^3} + 1.09E^{-4}\frac{ug}{m^3}\right) \times 2.74\, m^3/d \times 0.001 mg/\mu g}{7.5 kg} = 6.69E^{-6} mg/kgBW/d$$

Equation 17a. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{mammal} IR_{mammal} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish})}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

C_{mammal} = concentration of COPC in a surrogate mammal (meadow vole, mg/kg dry weight)

IR_{mammal} = ingestion rate of mammal (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$\sum C_{Plant} IR_{Plant} = 0\ mg/d$$

$$E_{Food} = \frac{\left[\left(4.16E^{-4}\frac{mg}{kg}\right)\left(\frac{1.13E^{-2}kg}{d}\right) + \left(\frac{7.68\ mg}{kg}\right)\left(\frac{3.38E^{-2}kg}{d}\right) + \left(2.79\frac{mg}{kg}\right)\left(\frac{1.80E^{-1}kg}{d}\right)\right]}{7.5\ kg} = 1.02E^{-1} mg/kg\ \text{BW/day}$$

Notes: Otter do not eat plants.

Exposure from air and dust assumed to be the same.

Equation 18a. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (Otter):

$$\begin{aligned} E_{Total} &= 1.84E^{-2}\ mg/kgBW/d \\ &+ 8.94E^{-4} mg/kgBW/d \\ &+ 6.69E^{-6} mg/kgBW/d \\ &+ 1.02E^{-1} mg/kgBW/d \\ &= 1.21E^{-1}\ mg/kgBW/d \end{aligned}$$

Equation 19a. Predicted Exposure Ratio – Northern River Otter – Blairmore Creek

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (Otter):

$$ER = \frac{1.21E^{-1}\ mg/kg\ BW/d}{1.00E^{+1}\ mg/kg\ BW/d} = 1.21E^{-2}$$

2.4.3 Calculation of Exposure Ratio – American Dipper

Equations 1-12 are the same as presented for the Otter at Blairmore Creek. The following equations (14b-19b) represent the process of calculating the exposure ratio for the American Dipper at this location.

American Dipper- eat aquatic inverts and fish.

Equation 14b. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{Sed} = \frac{3.07E^{+1}\frac{mg}{kg} \times 1.32E^{-5}kg/d}{5.50E^{-2}kg} = 7.37E^{-3}\ mg/kg\ BW/d$$

*note there are no reported values for soil or sediment ingestion rate for the American Dipper, therefore sediment ingestion was assumed to be 2% of total food ingestion rate

Equation 15b. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{WI} = \frac{1.12E^{-2}\frac{mg}{L} \times \ 4.68E^{-4}\ L/d}{5.50E^{-2}kg} = 9.50E^{-5}\ mg/kgBW/d$$

Equation 16b. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \ \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (American Dipper):

$$E_{Air+Dust} = \frac{\left(1.82E^{-2}\frac{ug}{m^3} + 1.09E^{-4}\frac{ug}{m^3}\right) \times 4.38E^{-2}\ m^3/d\ \times 0.001mg/\mu g}{5.50E^{-2}kg} = 1.46E^{-5}mg/kgBW/d$$

Equation 17b. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish}}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$\sum C_{Plant} IR_{Plant} = 0\ mg/d$$

$$E_{Food} = \frac{\left[\left(\frac{7.68\ mg}{kg}\right)\left(\frac{4.95E^{-4} kg}{d}\right) + \left(2.79\frac{mg}{kg}\right)\left(\frac{1.65E^{-4} kg}{d}\right)\right]}{5.50E^{-2} kg} = 7.75E^{-2} mg/kg \text{ BW/day}$$

Notes: American Dipper do not eat plants.

Exposure from air and dust assumed to be the same.

Equation 18b. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (American Dipper):

$$\begin{aligned} E_{Total} &= 7.73E^{-3} mg/kgBW/d \\ &+ 9.50E^{-5}\ mg/kgBW/d \\ &+ 1.46E^{-5} mg/kgBW/d \\ &+ 7.75E^{-2} mg/kgBW/d \\ &= 8.50E^{-2}\ mg/kgBW/d \end{aligned}$$

Equation 19b. Predicted Exposure Ratio, American Dipper -Blairmore Creek

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (American Dipper):

$$ER = \frac{8.50E^{-2}\ mg/kg\ BW/d}{6.61E^{+1}\ mg/kg\ BW/d} = 1.29E^{-3}$$

2.5 Worked Example Zinc– End Pit Lake (Application Case)

2.5.1 Environmental Media Concentrations

Equations used in the calculation of environmental media concentrations are presented below in Equation 1 through 13.

Equation 1. Total Deposition Rate

$$D_{Tot} = D_{Wet} + D_{Dry}$$

Where:
D_{Tot} = total deposition ($mg/m^2/yr$)
D_{Wet} = wet deposition rate of COPC ($mg/m^2/yr$), 0 $mg/m^2/yr$ [a]
D_{Dry} = dry deposition rate of COPC ($mg/m^2/yr$), 0 $mg/m^2/yr$ [a]

a - wet and dry deposition rates were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation:

$$D_{Tot} = 0\ mg/m^2/yr + 0\ mg/m^2/yr\ = 0\ mg/m^2/yr$$

Equation 2. Deposition Rate to Surface Soil

$$D_{s0} = \frac{D_{Tot}}{Z_{s0} \times \rho_B}$$

Where:
D_{s0} = deposition to surface soil (mg/kg/yr)
D_{Tot} = total deposition ($mg/m^2/yr$)
Z_{s0} = surface soil mixing depth (m)
ρ_B = soil bulk density (kg/m^3)

Sample Calculation:

$$D_{s0} = \frac{0\ mg/m^2/yr}{0.02\ m \times 1500\ kg/m^3} = 0\ mg/\ kg/yr$$

Equation 3. Deposition Rate to Soil

$$D_S = \frac{D_{Tot}}{Z_S \times \rho_B}$$

Where:

D_S = deposition to soil (mg/kg/yr)

D_{Tot} = total deposition (mg/m^2/yr)

Z_S = soil mixing depth (m)

ρ_B = soil bulk density (kg/m^3)

Sample Calculation:

$$D_S = \frac{0\ mg/m^2/yr}{0.2\ m \times 1500\ kg/m^3} = 0\ mg/\ kg/yr$$

Equation 4. Concentration in Surface Soil

$$C_{s0} = D_{s0}\frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_{s0} = concentration of COPC in surface soil (mg/kg)

D_{s0} = deposition to surface soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_{s0} = (0\ mg/kg)\frac{1-e^{(-477.19 yr^{-1} \times 80 yrs)}}{477.19\ yr^{-1}} + 1.44E^{+2} = 1.44E^{+2}\ mg/kg$$

Equation 5. Concentration in Soil

$$C_S = D_S \frac{1-e^{(-K_T \times T_D)}}{K_T} + C_{sback}$$

Where:

C_S = concentration of COPC in soil (mg/kg)

D_S = deposition to soil (mg/kg/yr)

K_T = soil loss constant for biotic and abiotic degradation (yrs^{-1})

T_D = time period over which deposition occurs (80 years)

C_{sback} = concentration in background soil (mg/kg) (values presented in EIA, CR #12, Appendix G: Baseline monitoring program, CIAR #42)

Sample Calculation:

$$C_S = (0\ mg/kg)\frac{1-e^{(-477.19 \times 10^8\ yr^{-1} \times 80 yrs)}}{477.19\ yr^{-1}} + 1.44E^{+2} = 1.44E^{+2}\ mg/kg$$

Equation 6. Concentration in Airborne Dust

$$C_{Dust} = C_{s0} \times DL \times CF$$

Where:

C_{Dust} = concentration of COPC in dust ($\mu g/m^3$)

C_{s0} = concentration of COPC in surface soil (mg/kg)

DL = dust level (kg/m^3)

CF = conversion factor (1000 µg / mg)

Sample Calculation:

$$C_{Dust} = 1.44E^{+2}\frac{mg}{kg} \times 7.6E^{-10}\ kg/m^3 \times 1000\ \mu g/mg = 1.09E^{-4} \mu g/m^3$$

Equation 7. Concentration in Surface Water

$$L_T = D_{tot}\ X\ LA$$

L_T = air deposition loading to surface water (mg/yr)*

D_{Tot} = total deposition rate ($mg/m^2/yr$)

LA = lake area (m^2) †

* The above equation for L_T has been simplified and considers only the contribution of aerial deposition to surface water. Loading *via* over-land transport is accounted for.

† The values for the average volumetric flow rate (V_{FR}), lake area (LA), and volume of the water body (V_{SW}) were based on the proposed end-pit lake dimensions. Assuming lake area of 4.44E+04 m^2 and depth of 30 m, V_{SW} = 1.33E+06 m^3.

$$L_T = 0\ \frac{\frac{mg}{m^2}}{yr} X\ 4.44E^{+4} m^2 = 0\ \text{mg/yr}$$

$$C_{SW} = \frac{L_T}{(V_{FR} \times PWC) + (K_{SW} \times V_{SW})} \times CF + C_{SW\_SRK}$$

Where:

C_{SW} = concentration of COPC in surface water (mg/L)

L_T = total COPC water load (mg/yr)

V_{FR} = average volumetric flow rate through the water body (m^3/yr)

PWC = fraction of total water body for mixing (100%)

K_{SW} = COPC surface water loss constant (0 yr^{-1})

V_{SW} = volume of water body (m^3)

CF = conversion factor (0.001 m^3 / L)

C_{SW_SRK} = application surface water concentration without aerial deposition (mg/L)

Sample Calculation:

$$C_{SW} = \frac{0\ mg/yr}{(2.43E^{+2} m^3/yr \times 1) + (0 yr^{-1} \times 1.33E^{+6} m^3)} \times \frac{0.001 m^3}{L} + 1.77E^{-1} = 1.77E^{-1} mg/L$$

Equation 8. Concentration in Aquatic Organisms

Concentrations of the COPC in aquatic plants, aquatic invertebrates, and fish were determined based on the concentration of COPC in surface water (C_{SW}) and a chemical-specific bioconcentration factor (BCF). The concentration of the COPC in terrestrial invertebrates was calculated similarly, only using the concentration of COPC in surface soil (C_{s0}) and BCF. The sample calculation is completed for aquatic invertebrates.

$$C_{Organism} = C_{SW} \times BCF$$

Sample Calculation (aquatic invertebrate):

$$C_{invertebrate} = \frac{1.77E^{-1}mg}{L} \times 6.87E^{+2}\ L\frac{water}{kg\ invert\ DW} = 1.22E^{+2}mg/kg$$

Equation 9. Concentration in Lake Sediment

$$C_{Sed} = C_{SW}\ X\ F_{BS} \times \frac{K_D}{\theta_{BS}+(K_D \times P_{Sed})} \times \frac{D_{WC}+D_{BS}}{D_{BS}}\ \text{X TD}$$

Where:

C_{Sed} = concentration of COPC in sediment (mg/kg)

C_{SW} = concentration of COPC in surface water (mg/L)

F_{BS} = fraction of total water body COPC concentration in benthic sediment (unitless)

K_D = COPC specific sediment partition coefficient

θ_{BS} = bed sediment porosity (0.6, unitless)

P_{Sed} = sediment bulk density (1 kg/L)

D_{WC} = depth of water column (1.0 m)

D_{BS} = depth of benthic sediment (0.03 m)

TD = time period over which deposition occurs

Sample Calculation:

$$C_{Sed} = 1.77E^{-1}\ mg/L \times 1.0 \times \frac{1000\ L/kg}{0.6\ + (1000\ L/kg \times 1\ kg/L)} \times \frac{1.0m + 0.03m}{0.03m} X\ 80\ years$$
$$= 4.87E^{+2}mg/kg$$

Equation 10. Concentration in Plants due to Direct Deposition

$$A = R_P \frac{\left[1 - e^{(-K_P \times T_P)}\right]}{Y_P \times K_P}$$

Where:

A = area factor (unitless)

R_P = intercept fraction of edible portion of plants (unitless, 0.5 wildlife forage, 0.39 human consumption)

K_P = plant surface loss coefficient (yr^{-1})

T_P = length of plant exposure (0.12 yr wildlife forage, 0.16 yr human consumption)

Y_P = productivity (0.24 kg/m^2 wildlife forage, 2.24 kg/m^2 human consumption)

$$C_{PD} = \left[D_{Dry} \times (1 - F_V) + D_{Wet} \times (1 - F_V) \times F_W\right] \times A$$

Where:

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

D_{Dry} = overall dry deposition rate ($mg/m^2/yr$)

F_V = fraction of COPC that is volatile (1, unitless)

D_{Wet} = overall wet deposition rate ($mg/m^2/yr$)

F_W = fraction of COPC wet deposition that adheres to plant surfaces (0.6, unitless)

A = area factor (unitless)

Sample Calculation (wildlife forage):

$$A = 0.5 \frac{\left[1 - e^{\left(-18yr^{-1} \times 0.12yr\right)}\right]}{0.24kg/m^2 \times 18yr^{-1}} = 1.02E^{-1}$$

$$C_{PD} = [\ 0\ mg/m^2/yr \times (1 - 0) + 0\ mg/m^2/yr \times (1 - 0) \times 0.6] \times 1.02E^{-1}\ = 0\ mg/kg$$

Equation 11. Concentration in Plants due to Vapour Uptake

$$B_V = \frac{P_{Air} \times B_{Vol}}{(1 - F_{water}) \times P_{Forage}}$$

Where:

B_V = mass based air to plant biotransfer factor (µg/g plant / µg/g air)

P_{Air} = density of air (1.2 g/L)

F_{Water} = fraction of forage that is water (0.85 for human intake, 0.62 for wildlife)

P_{Forage} = density of forage (770 g/L)

B_{Vol} = volumetric air to plant biotransfer factor (unitless)

$$C_{PV} = \frac{C_{Air} \times (B_V \div R_F) \times F_V \times V_{Gag}}{P_{Air} \times CF}$$

Where:

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

C_{Air} = concentration of COPC in air (ug/m^3)[a]

B_V = mass based air to plant biotransfer factor (µg/g plant / µg/g air)

R_F = reduction factor (100, unitless)

F_V = fraction of COPC that is volatile (unitless)

V_{Gag} = empirical correction factor (1, unitless)

CF = conversion factors (1000L/m^3, 1000µg/mg, 0.001kg/g)

a – air concentrations were modelled using the CALPUFF model in the air quality assessment (EIA, CR #1, CIAR #42).

Sample Calculation (wildlife forage):

$$B_V = \frac{1.2g/L \times 0}{(1 - 0.62) \times 770g/L} = 0 \text{ µg/g plant/µg/g air}$$

$$C_{PV} = \frac{0\ \mu g/m^3 \times (\ 0.0 \text{ µg/g plant/µg/g/100}) \times 0 \times 1}{1.2\ g/L \times 1000\ L/m^3 \times 1000\ \text{µg}/mg \times 0.001\ kg/g} = 0\ mg/kg$$

Equation 12. Concentration in Terrestrial Plants – Lichen

$$C_{lichen} = C_{PD} + C_{PV}$$

Where:

C_{lichen} = concentration of COPC in terrestrial plants (mg/kg)

C_{PD} = concentration of COPC in plants due to direct deposition (mg/kg DW)

C_{PV} = concentration of COPC in plants due to vapour uptake (mg/kg)

Sample Calculation:

$$C_{lichen} = 0\ mg/kg + 0\ \ mg/kg\ = 0 \text{ mg/kg}$$

Equation 13. Concentration in Small Mammal (Meadow Vole)

$$\text{BTF}_\text{A} = \text{BTF} \times \text{FC} \times \text{MF}$$

Where:

BTF_A = adjusted biotransfer factor (mg/kg tissue / mg/d)

BTF = chemical specific biotransfer factor (mg/kg tissue / mg/d)

FC = fat content (unitless)

MF = modification factor (0.01 for PAHs, 1 for VOCs)

$$C_{Game} = \left(C_S IR_S + C_{Sed} IR_{Sed} + C_{SW} IR_{SW} + ((C_{Air} + C_{Dust}) IR_{Air}\ \times \text{CF}) + \sum C_{Plant} IR_{WPlant} + \sum C_{Prey} IR_{Prey}\right) \times \text{BTF}_\text{A}$$

Where:

C_{Game} = concentration of COPC in wild game (mg/kg)

C_S = concentration of COPC in soil (mg/kg)

IR_S = wildlife soil ingestion rate (kg/d)

C_{Sed} = concentration of COPC in sediment (mg/kg)

IR_{Sed} = wildlife sediment ingestion rate (kg/d)

C_{SW} = concentration of COPC in surface water (mg/L)

IR_{SW} = wildlife water ingestion rate (L/d)

C_{Air} = concentration of COPC in air (mg/m^3)

IR_{Air} = wildlife air inhalation rate (m^3 air/d)
C_{Dust} = concentration of COPC in dust (mg/m^3)
IR_{Air} = wildlife air inhalation rate (m^3/d)
C_{Plant} = concentration of COPC in plants (mg/kg)
IR_{WPlant} = wildlife plant ingestion rate (kg/d)
C_{Prey} = concentration of COPC in prey (mg/kg)
IR_{Prey} = wildlife prey ingestion rate (kd/d)
BTF_A = adjusted biotransfer factor (mg/kg tissue/ mg/d)

Sample Calculation (Meadow Vole):

$$\mathrm{BTF_A} = 1.00E^{-1} \times 0.19 \times 1 = 1.90E^{-2} \text{ mg/kg tissue mg/d}$$

$$\sum C_{Plant} IR_{Plant} = 0\,\frac{mg}{kg} \times \frac{4.83E^{-3}kg}{d} = 0\,mg/d$$

$$\sum C_{Prey} IR_{Prey} = 0$$

$$C_{mammal} = \left\{\left(1.44E^{+2}\,\frac{mg}{kg}\right)\left(\frac{1.05E^{-4}kg}{d}\right) + \left(4.87E^{+2}\,\frac{mg}{kg}\right)\left(\frac{0\,kg}{d}\right) + \left(1.77E^{-1}\,\frac{mg}{L}\right)\left(\frac{7.33E^{-3}L}{d}\right) + \left(0\,\frac{ug}{m^3} + 1.09E^{-4}\,\frac{ug}{m^3}\right)\left(\frac{5.20E^{-2}m^3}{d}\right)\left(\frac{1\,mg}{1000\,ug}\right) + 0 + (0\ mg/d)\right\} \times 1.90E^{-2}\,mg/kg \text{ tissue mg/d} = 3.12E^{-4}mg/kg \text{ tissue}$$

Notes: Meadow vole are herbivores (eat 100% terrestrial plants – assumed to be 100% lichen). Exposure from air and dust assumed to be the same.

2.5.2 Calculation of Exposure Ratio – Northern River Otter

Equation 14a. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR \times CF}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{Sed} = \frac{4.87E^{+2}\frac{mg}{kg} \times 4.50E^{-3}kg/d}{7.5kg} = 2.92E^{-1}\ mg/kgBW/d$$

*note there are no reported values for soil or sediment ingestion rate for the Otter, but sediment ingestion was assumed to be 2% of the food ingestion rate, as per guidance (FCSAP, 2012).

Equation 15a. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$E_{WI} = \frac{1.77E^{-1}\frac{mg}{L} \times 0.6\ L/d}{7.5kg} = 1.42E^{-2}\ mg/kgBW/d$$

Equation 16a. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/μg)

Sample Calculation (Otter):

$$E_{Air+Dust} = \frac{\left(0\frac{ug}{m^3} + 1.09E^{-4}\frac{ug}{m^3}\right) \times 2.74\ m^3/d \times 0.001 mg/\mu g}{7.5kg} = 3.99E^{-8} mg/kgBW/d$$

Equation 17a. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant} IR_{Plant} + \sum C_{mammal} IR_{mammal} + C_{invertebrate} IR_{invertebrate} + C_{fish} IR_{fish})}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg dry weight)

IR_{Plant} = ingestion rate of plants (kg/d)

C_{mammal} = concentration of COPC in a surrogate mammal (meadow vole, mg/kg dry weight)

IR_{mammal}= ingestion rate of mammal (kg/d)

$C_{Invertebrate}$= concentration of COPC in invertebrate tissue (mg/kg dry weight)

$IR_{invertebrate}$=invertebrate ingestion rate (kg/d)

C_{fish} = concentration of COPC in fish tissue (mg/kg dry weight)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (Otter):

$$\sum C_{Plant} IR_{Plant} = 0\, mg/d$$

$$E_{Food} = \frac{\left(8.94E^{-3}\,\frac{mg}{kg}\right)\left(\frac{1.13E^{-2}kg}{d}\right)+\left(\frac{1.22E^{+2}\,mg}{kg}\right)\left(\frac{3.38E^{-2}kg}{d}\right)}{7.5\,kg} = 5.48E^{-1} mg/kg\ \text{BW/day}$$

Notes: Otter do not eat plants. No fish are predicted in the EPL.

Exposure from air and dust assumed to be the same.

Equation 18a. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (Otter):

$$\begin{aligned} E_{Total} &= 2.92E^{-1}\ mg/kgBW/d \\ &+ 1.42E^{-2} mg/kgBW/d \\ &+ 3.99E^{-8} mg/kgBW/d \\ &+ 5.48E^{-1} mg/kgBW/d \\ &= 8.55E^{-1}\ mg/kgBW/d \end{aligned}$$

Equation 19a. Predicted Exposure Ratio – Northern River Otter –End Pit Lake

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (Otter):

$$ER = \frac{8.55E^{-1}\ mg/kg\ BW/d}{1.00E^{+1}\ mg/kg\ BW/d} = 8.55E^{-2}$$

2.5.3 Calculation of Exposure Ratio –American Dipper

Equations 1-12 are the same as presented for the Otter at the EPL. The following equations (14b-19b) represent the process of calculating the exposure ratio for the American Dipper at this location.

American Dipper- eat **aquatic inverts** and **fish** (no fish in EPL, so not considered).

Equation 14b. Animal Exposure from Sediment Ingestion

$$E_{Sed} = \frac{C_{sed} \times SedIR}{BW}$$

Where:

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

C_{sed} = concentration of COPC in sediment (mg/kg)

SedIR = sediment ingestion rate (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{Sed} = \frac{4.87E^{+2}\frac{mg}{kg} \times 1.32E^{-5}kg/d}{5.50E^{-2}kg} = 1.17E^{-1}\ mg/kg\ BW/d$$

*note there are no reported values for soil or sediment ingestion rate for the American Dipper, therefore sediment ingestion was assumed to be 2% of total food ingestion rate

Equation 15b. Animal Exposure from Water Ingestion

$$E_{WI} = \frac{C_{SW} \times WIR}{BW}$$

Where:

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

C_{SW} = concentration of COPC in surface water (mg/L)

WIR = water ingestion rate (L/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$E_{WI} = \frac{1.77E^{-1}\frac{mg}{L} \times 4.68E^{-4}\ L/d}{5.50E^{-2}kg} = 1.51E^{-3}\ mg/kgBW/d$$

Equation 16b. Animal Exposure from Air and Dust Inhalation

$$E_{Air+Dust} = \frac{(C_{Air} + C_{Dust}) \times AIR \ \times CF}{BW}$$

Where:

$E_{Air+Dust}$ = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

C_{Dust} = concentration of COPC in dust (ug/m^3)

C_{Air} = concentration of COPC in air (mg/m^3)

AIR = air inhalation rate (m^3/d)

BW = body weight (kg)

CF = conversion factor (0.001 mg/µg)

Sample Calculation (American Dipper):

$$E_{Air+Dust} = \frac{\left(0\frac{ug}{m^3} + 1.09E^{-4}\frac{ug}{m^3}\right) \times 4.38E^{-2}\ m^3/d \ \times 0.001mg/\mu g}{5.50E^{-2}kg} = 8.72E^{-8}mg/kgBW/d$$

Equation 17b. Animal Exposure from Food

$$E_{Food} = \frac{(\sum C_{Plant}IR_{Plant} + C_{invertebrate}IR_{invertebrate} + C_{fish}IR_{fish}}{BW}$$

Where:

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

C_{Plant} = concentration of COPC in plants (mg/kg)

IR_{Plant} = ingestion rate of plant type (kg/d)

$C_{invertebrate}$ = concentration of COPC in invertebrates (mg/kg)

$IR_{invertebrate}$ = ingestion rate of invertebrates (kg/d)

C_{fish} = concentration of COPC in fish (mg/kg)

IR_{fish} = ingestion rate of fish (kg/d)

BW = body weight (kg)

Sample Calculation (American Dipper):

$$\sum C_{Plant}IR_{Plant} = 0\ mg/d$$

$$E_{Food} = \frac{\left[\left(\frac{1.22E^{+2}mg}{kg}\right)\left(\frac{4.95E^{-4}kg}{d}\right)\right]}{5.50E^{-2}kg} = 1.10\ mg/kg\ \text{BW/day}$$

Notes: American Dipper do not eat plants. There are no fish in the EPL.

Exposure from air and dust assumed to be the same.

Equation 18b. Animal Total Daily Estimated Exposure

$$E_{Total} = E_{SI} + E_{Sed} + E_{WI} + E_{Air+Dust} + E_{Food}$$

Where:

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

E_{SI} = exposure from soil ingestion adjusted to body weight (mg/kg BW/d)

E_{Sed} = exposure from sediment ingestion adjusted to body weight (mg/kg BW/d)

E_{WI} = exposure from water ingestion adjusted to body weight (mg/kg BW/d)

E_{Dust} = exposure from dust inhalation adjusted to body weight (mg/kg BW/d)

E_{Food} = exposure from food ingestion adjusted to body weight (mg/kg BW/d)

Sample Calculation (American Dipper):

$$\begin{aligned} E_{Total} &= 1.17E^{-1} mg/kgBW/d \\ &+ 1.51E^{-3}\ mg/kgBW/d \\ &+ 8.72E^{-8} mg/kgBW/d \\ &+ 1.10\ mg/kgBW/d \\ &= 1.22\ mg/kgBW/d \end{aligned}$$

Equation 19b. Predicted Exposure Ratio, American Dipper

$$ER = \frac{E_{Total}}{DTED}$$

Where:

ER = predicted exposure ratio

E_{Total} = total daily estimated exposure adjusted to body weight (mg/kg BW/d)

DTED = daily threshold exposure (mg/kg BW/d)

Sample Calculation (American Dipper):

$$ER = \frac{1.22\ mg/kg\ BW/d}{6.61E^{+1}\ mg/kg\ BW/d} = 1.84E^{-2}$$

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