SECOND DRAFT REPORT ON

ECOLOGICAL AND HUMAN HEALTH SCREENING LEVEL RISK ASSESSMENT FOR THE ANVIL RANGE MINE CLOSURE PLAN DEVELOPMENT

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EXECUTIVE SUMMARY

A Screening Level (Tier 1) ecological and human health risk assessment was carried out for existing conditions at the Anvil Range Mine Complex to assist the project team in the development of closure plans for the site. The ecological and human health risk assessment was undertaken for the explicit purpose of determining whether there are contaminant levels present in the aquatic environment that may have an adverse affect on ecological species or humans that either use, or may potentially use, water bodies downstream of the mine and tailings areas. As such, the assessment focussed on the Rose Creek and Vangorda Creek systems. Both aquatic and terrestrial animals were included in the assessment; however, only aquatic pathways were considered in the exposure assessment, as there was a lack of information on metal levels in terrestrial plants and soils from the study area. Hence, it was not feasible to include terrestrial pathways in the Screening Level Assessment for the terrestrial animals or for humans.

The assessment included the following elements, which are proposed and readily accepted by regulatory agencies such as Environment Canada and the U.S. Environmental Protection Agency:

- receptor characterization;
- exposure assessment;
- hazard assessment; and
- risk characterization.

Measured concentrations of contaminants in water, sediment and fish were used in the assessment. A statistical assessment of water data for 2000 and 2001 was carried out to determine the appropriate concentrations to use in the assessment. It is important to note that many of the detection limits used in the assessment were above current Canadian Council of the Ministers of the Environment (CCME) water quality guidelines. This posed a challenge during the statistical analysis. Sediment concentrations from a 1999 sampling campaign were used to represent Vangorda Creek, whereas Rose Creek sediment concentrations were represented by sediment data from 1995 to 2001. The fish concentrations used in the assessment were based on samples of fish tissue collected in studies from 1974 to 1997.

The ecological component of the assessment considered aquatic receptors from the creek system (e.g. benthic invertebrates, pelagic and benthic fish) in both the upstream and downstream reaches of Rose Creek and Vangorda Creek. The most prevalent fish species found in these creeks are arctic grayling and slimy sculpin. The risks to these species were assessed by comparison of measured metal levels in Rose and Vangorda creeks to appropriate toxicity benchmarks.

In addition, pathways modelling which focused on the aquatic pathways was conducted for several terrestrial receptors to estimate their potential exposure to contaminants in the downstream reaches of these water systems. The terrestrial receptors identified for inclusion in the assessment included bear, caribou, eagle, fox, hare, mink, moose, and Fannin sheep. These receptors were chosen since they provide a range of potential exposures from the aquatic pathways. Ecological impacts in the Screening Level Assessment were determined through a comparison to No Observable Adverse Effects Levels (NOAELs) obtained from literature data.

An assessment of the potential implications to human health from exposure to contaminants in the aquatic environment was also considered for four hypothetical individuals, namely:

- an adult and child (5 to 11 years of age) who live near the Faro town site and drink water and eat fish and wild game obtained from Vangorda Creek (Receptor 1);
- an adult and child who camp near the Anvil Range Mine Complex for three months of the year and consume water, fish and wild game obtained from Rose Creek (Receptor 2).

In the absence of dietary data for First Nations people in the study area, the dietary characteristics for the individuals considered in the human health risk assessment were based on a regional survey in the Northwest Territories. Other exposure information, such as drinking water consumption and body weight was obtained from data on the general Canadian population.

ECOLOGICAL ASSESSMENT

The measured water quality indicated that the concentrations of several contaminants in Rose Creek and Vangorda Creek were above the CCME guideline for the protection of aquatic life. For Rose Creek, measured concentrations of arsenic, cadmium and copper exceed guidelines in the upstream (background) location whereas measured concentrations of arsenic, cadmium, chromium, copper, lead, selenium and zinc exceed the CCME guidelines downstream. For Vangorda Creek, measured concentrations of arsenic, cadmium, chromium, copper and lead exceed the CCME guidelines both upstream and downstream and measured concentrations of zinc exceed the guidelines in the downstream location. These findings indicated that a more detailed examination of the potential impacts on the aquatic environment was required, with consideration of the specific receptors expected to be found in the local area.

The results of the ecological risk assessment showed that for benthic invertebrates, the measured levels of ammonia and zinc at the upper plausible limit (95^{th} percentile) were above the respective toxicity benchmarks in Rose Creek downstream of the mine workings, whereas for Vangorda Creek, only copper at the upper plausible limit (95^{th} percentile) in the upstream location was above the toxicity benchmark. Given that the aquatic invertebrate benchmarks were exceeded only at the upper plausible limit, exposures would be expected to be of short duration and occur only a few times in any year.

For fish such as the arctic grayling, aquatic toxicity benchmarks were exceeded by the mean measured concentrations of ammonia (Rose Creek), copper (Rose and Vangorda creeks) and zinc (Rose Creek). The ammonia exceedence downstream in Rose Creek is expected to be a short-term problem which will quickly disappear. For the upper plausible (95^{th} percentile) concentrations, toxicity benchmarks were exceeded for other metals including cadmium (Rose Creek), chromium (Rose and Vangorda creeks), lead (Rose and Vangorda creeks), and zinc (Vangorda Creek), in some cases both upstream and downstream of the mine and tailings areas. None of the measured concentrations are expected to have an adverse affect on the slimy sculpin community in Rose Creek or Vangorda Creek.

A comparison of Rose Creek sediment levels to appropriate CCME sediment quality guidelines showed that a number of the metals were above both the threshold effects and probable affects levels. This is not surprising given that sediments have been affected by past mining activity and that it is a naturally occurring mineralized area. For Vangorda Creek, measured sediment concentrations also exceed the appropriate sediment guidelines.

Of the eight terrestrial receptors considered in the assessment, no effects toxicity benchmarks were exceeded for arsenic, molybdenum and selenium for bear and mink in both Rose Creek and Vangorda Creek. Exposure to cadmium, chromium and lead at the upper plausible limits (95^{th} percentile concentrations) in Vangorda Creek resulted in toxicity benchmarks being exceeded only for the mink. At the upper plausible limits (95^{th} percentile concentrations) of lead in both Rose Creek and Vangorda Creek watersheds and selenium in Vangorda Creek, the respective toxicity benchmarks for the eagle were found to be exceeded. The exposure of these receptors is dominated by consumption of fish by the bear and eagle and by consumption of fish, sediments and benthic invertebrates by the mink.

Since this is a Screening Level Assessment, a number of very cautious assumptions were made to ensure that exposures for these receptors were not underestimated. These assumptions result in an overestimate of exposures and should be examined more closely in a Tier 2 quantitative risk assessment in which more realistic assumptions are used.

HUMAN HEALTH ASSESSMENT

The human health risk assessment was conducted using assumptions that result in an overestimate of exposure. As noted above, the human receptors were assumed to obtain all their drinking water, fish and wild game from downstream of the mine and tailings areas while in the study area (year round for Receptor 1; 3 months per year for Receptor 2). The estimated exposures (or intakes) by the human receptors were compared to intake levels considered to be protective of human health (i.e. reference doses).

The assessment of the daily intake of total (inorganic and organic) arsenic showed that the reference dose was exceeded for Receptor 1 (a hypothetical resident near Faro) and Receptor 2 (a hypothetical hunter/camper who spends 3 months each year in the Ross Creek watershed). The estimated arsenic intakes were above the range of typical intakes for Canadians living in southern communities which do not have local arsenic issues. The predicted arsenic intakes from the Screening Level Assessment; however, are similar to exposure levels in communities with elevated arsenic levels in the local environment (e.g. Deloro and Wawa, Ontario) where health impacts have not been observed.

From a toxicity perspective, it is important to differentiate between the exposure to total arsenic and inorganic arsenic, as organic arsenic has a much lower toxicity. Speciation measurements on arsenic in fish have demonstrated that nearly all of the arsenic present is in the organic form. Given that the arsenic exposure was dominated by consumption of fish, it is likely that an overestimate of exposure was calculated in the Screening Level Assessment.

Selenium and lead concentrations in Vangorda Creek also resulted in the reference doses for these metals being exceeded for Receptor 1. The main source of these metals was due to the consumption of fish.

The human health assessment results suggested that a more detailed assessment is needed to determine whether the presence of arsenic, lead and selenium will results in any potential adverse impacts.

SUMMARY

A Tier 2 assessment will be needed in order to determine whether impacts on human health and the ecology are likely. However, before this assessment is done, it is recommended that:

- detection limits that are lower than the CCME aquatic guidelines be used in all subsequent monitoring programs;
- bioavailability studies be carried out on sediments to determine whether the metals present in the sediment are available for uptake by biological species;
- metal concentrations in benthic invertebrates be measured;

- a community survey be carried out to determine the time someone from the nearby communities might spend on site once it has been fully remediated and decommissioned, considering past usage of the mine site area; and
- a dietary survey be carried out to determine the amount of country food (e.g. berries, fish and game) that residents in the local area consume and the extent to which these food items are currently, or may in the future be, obtained from the mine site area.

The above information would reduce the uncertainty in carrying out the Tier 2 analysis. Additionally, it is recommended that:

- terrestrial pathways should be included in a Tier 2 assessment to more fully consider the total exposure and risk to both the ecological receptors and human receptors.

1.0 INTRODUCTION

The Interim Receiver commissioned SENES Consultants Limited to carry out a screening level ecological and human health risk assessment for the Anvil Range Mining Complex to assist in the development of closure options for the site. The primary purpose of the assessment was to determine whether there are contaminants present in the water courses in the vicinity of the mine and tailings areas that may have adverse effects on ecological species or humans that either use, or may potentially use, these waters. The assessment was undertaken to provide guidance to the project team in the development of closure plans for the mine site and to identify contaminants of concern and areas that require additional investigation. This report details the methodology and critical assumptions used for the screening level ecological and human health risk assessment.

1.1 ECOLOGICAL RISK ASSESSMENT FRAMEWORK

The Canadian Council of Ministers of the Environment (CCME 1996, 1997) has provided general guidance concerning their views on what constitutes an ecological risk assessment (ERA). The recommended framework is similar to that proposed by Environment Canada (Environment Canada 1997). The CCME recommends three levels of investigation:

1) Screening level assessment (SLA): essentially a qualitative assessment of potential risks to important ecological receptors.
2) Preliminary quantitative risk assessment (PQRA): focuses on filling gaps identified at the screening level.
3) Detailed quantitative risk assessment (DQRA): includes more detailed data and modelling.

Each level of the assessment includes the following elements:

- Receptor Characterization - at this phase of the assessment the potential receptors are identified and the pathways of exposure defined.
- Exposure Assessment - the purpose of this stage is to quantify the contact between the receptor and the contaminant of concern.
- Hazard Assessment - this phase of the ERA examines the potential effects of a contaminant to a receptor.
- Risk Characterization - the risk characterization stage combines the information collected in the exposure assessment and the hazard assessment and the potential for adverse ecological effects is estimated.

The rigour of the risk assessment adopted for a particular situation should be commensurate with the degree and extent of potential harm and may progress to a more stringent level (i.e. from SLA to PQRA or from PQRA to DQRA) depending on the findings at each level. Each level in this tiered approach has the same structure and builds upon the data, information, knowledge and decisions generated from the preceding level. Thus, each level is progressively more rigorous and complex.

Tier 1 Assessment

The initial *screening level assessment* (which is referred to as Tier 1) is intended to identify contaminants that need to be examined in more detail to determine whether an ecological risk is likely. Qualitative and/or comparative methods are used in the assessment. Screening indices are often used in an initial screening assessment to facilitate comparisons. The screening index value is defined as the ratio of the modelled exposure or dose to laboratory toxicity data. Screening assessments, often completed at a species level, involve assumptions that bias estimates of exposure and toxicity towards predicting an ecological impact (i.e. exposure or dose are conservative overestimates of the concentrations required to produce a toxic response and are based on the assumption that 100% of the contaminants are available for intake). If, under these conservative assumptions, a site passes the screening assessment, then reasonable conclusions of minimal ecological risk are supported. The propagation of uncertainty throughout the analysis provides a quantitative measure of the reliability of the assessment and may be useful in identifying major sources of uncertainty for which further refinement of the assessment may be warranted, for example in a site-specific detailed assessment.

For the Anvil Range Mining Complex site, this level of assessment was deemed appropriate at this time.

Tier 2 Assessment

In a Tier 2 assessment, the pessimistic assumptions of the screening level calculations are examined more closely to produce more realistic values of exposure, dose and toxic benchmarks. A combination of field measurements, laboratory experiments, data analysis and ecological modelling are also used to increase the accuracy and precision in estimating exposure and response for the species and contaminants of concern. The results of the preliminary quantitative assessment provide more realistic estimates of expected exposure or dose for comparison to toxicity data. The results of a Tier 2 assessment will either support the conclusion of minimal ecological risk, or indicate that a more detailed quantitative ecological risk assessment may be necessary.

Tier 3 Assessment

For a *detailed quantitative assessment* (which is referred to as Tier 3), it is necessary to introduce as much realism and site-specific detail into the risk assessment as supported by current ecological and toxicological understanding. Sophisticated contaminant transport models and high-resolution ecological models can be combined with rigorously defined spatial-temporal sampling and monitoring programs to produce the most scientifically defensible estimates of ecological risk. The results of the detailed assessment give estimates of ecological risk based on state-of-the-art quantitative systems analysis and modelling using the best available data, or in some instances, requiring new data to be collected. At this point in time, a detailed Tier 3 analysis is not warranted for the Anvil Range Mining Complex site.

1.2 HUMAN HEALTH RISK ASSESSMENT APPROACH

A human health risk assessment (HHRA) evaluates the probability of adverse health consequences to humans caused by the presence of chemical contaminants in the environment. Receptor characteristics (e.g. proportion of time spent in the study area, source of drinking water, composition of diet) and exposure pathways (e.g. inhalation and ingestion) are taken into consideration. Unlike the ERA, which is concerned with population effects, the HHRA focuses on the effects on individuals. In this assessment, the HHRA examined the potential impact of current conditions on adults and children.

Since there are no permanent residences within the immediate Anvil Range Mining Complex area, the potential effects were assessed for a hypothetical human receptor who lives near the Faro Townsite on Vangorda Creek (Receptor 1) and for a hunter/camper who spends 3 months each year in the Rose Creek watershed below the mine and tailings area (Receptor2). Receptor 1 was assumed to live near the Faro Townsite and obtain all his/her drinking water, fish and game from Vangorda Creek. Findings from a survey in the Environmental Baseline Study (Gartner Lee Limited 2002) suggested that individuals have in the past spent time at the mine site. To account for the potential exposure of a hunter/camper (Receptor 2) who could spend time on the watershed downstream of the mine and tailings area, the exposure assessment was undertaken using a conservative assumption that this receptor would obtain all his/her drinking water, fish and game from Rose Creek while at the site for three months of the year.

The assumptions made for the screening level risk assessment are intended to error on the side of caution and therefore to result in over-estimation of contaminant intakes. The level of caution in these assumptions is consistent with the approach typically adopted at the screening stage.

1.3 REPORT STRUCTURE

The report has been structured into several sections, each of which describes specific aspects of the risk assessment. These aspects include:

Section 2 – Site Characterization: Describes the main features of the watersheds surrounding the Anvil Mine Complex. A summary of the most pertinent information from recent surveys of surface water quality, sediment quality, and fish communities in both Rose Creek and Vangorda Creek is provided to establish current (baseline) conditions. These data were used in the subsequent assessment.

Section 3 – Receptor Characterization: Identifies the aquatic and terrestrial species selected for inclusion in the risk assessment, as well as, the human receptors (i.e. adults and children) who may spend time in the study area.

Section 4 – Exposure Assessment: Describes the pathways model used to predict the fate of contaminants (chemical species) in the environment including their uptake by aquatic and terrestrial species. The pathways of exposure of human receptors and their respective dietary characteristics are described.

Section 5 – Hazard Assessment: Details the toxicity benchmarks used in the assessment for each of the chemical species to characterize the risks of potential effects on the health of ecological species and humans.

Section 6 – Risk Characterization: Presents the results of the pathways modelling and risk assessments.

Section 7 – Summary and Conclusions: Provides a synopsis of the basis used for the ERA and HHRA and the findings of these assessments.

Section 8 – References: Lists the reference sources used in this study.

2.0 SITE CHARACTERIZATION

2.1 ANVIL RANGE MINING COMPLEX

The Anvil Range Mining Complex, located about 200 km northeast of Whitehorse, includes the Faro Mine site (in production from 1969 to 1992) and the Vangorda Plateau Mine site (in production from 1986 to 1998). The Faro Mine site is 15 km north of the town of Faro and contains a mill and tailings facilities. The Vangorda Plateau Mine site is 9 km northeast of the town of Faro and includes two open pits and associated mine facilities. The operation produced lead and zinc concentrates. The Faro Mine site is located within the Rose Creek watershed, which is a tributary of the Anvil Creek watershed, and the Vangorda Plateau Mine site is located within the Vangorda Creek watershed. Both watersheds empty into the Pelly River.

2.2 AQUATIC ENVIRONMENT BASELINE INFORMATION

The following section summarizes water and sediment quality, as well as a qualitative discussion of fish and fish habitat, within the Rose Creek and Vangorda Creek watersheds. The discussion presented below is based primarily on a recent report by Gartner Lee Limited (2002). Data were grouped by upstream (not impacted by mining activities) and downstream (potentially impacted by mining activities) for both creeks.

2.2.1 Surface Water Quality

Water measurements for Rose Creek and Vangorda Creek watersheds were restricted in some cases by high method detection limits. This limited the usefulness of the database. For the purposes of this assessment, concentrations measured as less than the detection limit ("<") were considered as equal to ½ the detection limit. For arsenic and selenium, some samples were measured to method detection limits of 0.2 mg/L whereas other samples were measured to detection limits of 0.005 mg/L. It was felt that samples measured to the very high detection limits gave an inaccurate representation of the water quality, since many values were reported at detection limits that were much lower (i.e., < 0.005 mg/L). Therefore, for arsenic and selenium, values reported as < 0.2 mg/L were excluded from the summary statistics.

2.2.1.1 Rose Creek Watershed

Water quality data on pre-mining conditions in Rose Creek are not available, however water chemistry data has been collected throughout the life of the Faro Mine. Stations upstream of the mine are considered to be representative of background water quality conditions and the use of these stations as background water quality is consistent with Gartner Lee Limited (2002). Ten locations are used to monitor surface water quality in Rose Creek (including the North Fork).

Data collected in 2000 and 2001 were considered in the summary of water quality for Rose Creek watershed presented in Table 2.2-1 (upstream of Faro Mine site) and Table 2.2-2 (downstream of Faro Mine site).

From Table 2.2-1, it can be seen that metal concentrations upstream of the mine site were consistently less than the analytical method detection limit (MDL) for antimony, bismuth, cadmium, lead, selenium, silver, tin and tungsten. Comparison of the calculated mean levels to the CCME guidelines for protection of aquatic life suggest that aluminum, arsenic, copper, lead, selenium and thallium exceed the guidelines. These comparisons could be interpreted to imply that Rose Creek has naturally high levels of these elements, however, it is noted that the MDLs were often greater than the CCME guidelines which takes away from the usefulness of the comparison.

At locations downstream of the mine areas (Table 2.2-2), metal concentrations are higher with only silver, bismuth and tungsten concentrations being consistently below the MDL (i.e. in over 95% of the samples). Mean concentrations of aluminum, arsenic, cadmium, chromium, copper, iron, lead, selenium, thallium and zinc all exceed CCME guidelines for protection of aquatic life. This indicates that the Rose Creek system is possibly being affected by activities at the Anvil Mine Complex, although there are limitations to the data as noted above.

2.2.1.2 Vangorda Plateau Mine Site

Water quality is monitored in three sampling locations upstream of the mine area and in four locations in Vangorda Creek downstream of the mine areas. These sampling locations are described in detail in Gartner Lee Limited (2002). Data from 2000 and 2001 were considered in the summary presented in Tables 2.2-3 (upstream) and 2.2-4 (downstream).

At locations upstream on Vangorda Creek, a number of metal concentrations are less than the analytical method detection limit on most (greater than 80%) of the samples. They are antimony, arsenic, bismuth, cadmium, cobalt, lanthanum, lead, selenium, silver and tungsten. Concentrations of aluminum, chromium, copper, selenium, thallium exceed CCME guidelines for protection of aquatic life. While the reported concentrations of these elements may be naturally high, it is also noted that the MDLs were often higher than the guidelines (e.g. cadmium, lead, selenium, silver, thallium). As with Rose Creek, metal concentrations downstream of the mine site are higher with only bismuth, silver and tungsten being at the MDL on all samples. This indicates that Vangorda Creek is possibly affected by activities at the Vangorda/ Grum Mine area.

TABLE 2.2-1
WATER QUALITY SUMMARY - ROSE CREEK UPSTREAM OF FARO MINE SITE

	Parameter	Units	CCME	MDL	Mean	Max	Min	N obs.	N obs < MDL
Total Metals	Ag-Silver	(mg/L)	0.0001	0.0001-0.003	0.001	0.0015	5.00E-05	12	12
	Al-Aluminum	(mg/L)	0.005 to 0.1	0.05	0.130	0.35	0.025	12	1
	As-Arsenic	(mg/L)	0.005	0.001-0.005	0.008	0.068	0.0005	12	9
	B-Boron	(mg/L)		0.002-0.05	0.23	2.26	0.001	12	5
	Ba-Barium	(mg/L)			0.12	0.25	0.05	12	0
	Be-Beryllium	(mg/L)		0.001	0.0004	0.0005	0.0001	12	8
	Bi-Bismuth	(mg/L)		0.001-0.05	0.017	0.025	0.0005	12	12
	Ca-Calcium	(mg/L)			22.4	42	7.4	12	0
	Cd-Cadmium	(mg/L)	0.000017	0.0001-0.001	0.0006	0.003	5.00E-05	12	11
	Co-Cobalt	(mg/L)		0.0002-0.005	0.0035	0.02	0.0001	12	9
	Cr-Chromium	(mg/L)	0.0089	0.0002-0.005	0.0064	0.048	0.0001	12	10
	Cu-Copper	(mg/L)	0.002 to 0.004	0.002	0.006	0.017	0.001	12	2
	Fe-Iron	(mg/L)	0.3		0.24	0.83	0.07	12	0
	K-Potassium	(mg/L)		1	1.08	2	0.36	12	4
	La-Lanthanum	(mg/L)		0.0002-0.005	0.004	0.016	0.0001	12	9
	Mg-Magnesium	(mg/L)			4.7	8.9	1.4	12	0
	Mn-Manganese	(mg/L)		0.01	0.036	0.21	0.005	12	1
	Mo-Molybdenum	(mg/L)	0.073	0.002	0.002	0.008	0.001	12	6
	Na-Sodium	(mg/L)		1	2.8	8	0.5	12	1
	Ni-Nickel	(mg/L)	0.025 to 0.15	0.0002-0.005	0.0023	0.0033	0.0001	12	9
	P-Phosphorus	(mg/L)		0.2-1	0.8	4	0.1	12	9
	Pb-Lead	(mg/L)	0.001 to 0.007	0.001-0.01	0.0035	0.005	0.0005	12	12
	S-Sulfur	(mg/L)		1	2.87	6.07	0.5	9	2
	Sb-Antimony	(mg/L)		0.001-0.03	0.010	0.015	0.0005	12	11
	Se-Selenium	(mg/L)	0.001	0.001-0.005	0.0018	0.0025	0.0005	12	12
	Si-Silicon	(mg/L)			4.3	6.6	2.4	12	0
	Sn-Tin	(mg/L)		0.0004-0.01	0.0034	0.005	0.0002	12	12
	Sr-Strontium	(mg/L)			0.09	0.20	0.03	12	0
	Ti-Thallium	(mg/L)	0.0008	0.005	0.014	0.061	0.0025	12	4
	V-Vanadium	(mg/L)		0.0002-0.005	0.006	0.048	0.0001	12	8
	W-Tungsten	(mg/L)		0.001-0.03	0.010	0.015	0.0005	12	12
	Zn-Zinc	(mg/L)	0.030	0.01	0.019	0.05	0.0035	12	2

<u>Notes:</u> CCME = Canadian Council of Ministers of the Environment. Values given are for protection of aquatic life.

Max = maximum; Min = minimum; N obs = number of observations;

N obs < MDL = number of observations less than method detection limit.

Summary statistics were calculated by setting up values reported as less than method detection limit equal to ½ method detection limit.

Stations: R6 Anvil Creek upstream of Rose.

R7 North Fork of Rose Creek upstream of Faro Creek diversion.

W10 Upper Guardhouse Creek upstream of the Northwest rock dumps.

TABLE 2.2-2
WATER QUALITY SUMMARY – ROSE CREEK DOWNSTREAM OF FARO MINE SITE

	Parameter	Units	CCME	MDL	Mean	Max	Min	N obs.	N obs < MDL
Total Metals	Ag-Silver	(mg/L)	0.0001	0.001-0.01	0.0022	0.039	0.0005	123	121
	Al-Aluminum	(mg/L)	0.005 to 0.1	0.05	0.18	0.66	0.025	123	19
	As-Arsenic	(mg/L)	0.005	0.005	0.006	0.116	0.0025	111	92
	B-Boron	(mg/L)		0.05-0.1	0.15	1.99	0.025	123	71
	Ba-Barium	(mg/L)			0.16	0.28	0.04	123	0
	Be-Beryllium	(mg/L)		0.001-0.005	0.0009	0.003	0.0005	123	96
	Bi-Bismuth	(mg/L)		0.05-0.1	0.03	0.08	0.025	123	122
	Ca-Calcium	(mg/L)			37.0	113.5	2.2	123	0
	Cd-Cadmium	(mg/L)	0.000017	0.001	0.0008	0.007	0.0005	123	105
	Co-Cobalt	(mg/L)		0.005-0.01	0.005	0.043	0.0025	123	97
	Cr-Chromium	(mg/L)	0.0089	0.005-0.01	0.0145	0.176	0.0025	123	89
	Cu-Copper	(mg/L)	0.002 to 0.004	0.002-0.01	0.012	0.25	0.001	123	32
	Fe-Iron	(mg/L)	0.3		0.53	5	0.03	123	0
	K-Potassium	(mg/L)		1-2	1.79	10	0.5	123	57
	La-Lanthanum	(mg/L)		0.005	0.012	0.156	0.0025	111	63
	Mg-Magnesium	(mg/L)			8.0	26	0.7	123	0
	Mn-Manganese	(mg/L)		0.01	0.285	3.52	0.005	123	5
	Mo-Molybdenum	(mg/L)	0.073	0.002-0.01	0.003	0.02	0.001	123	99
	Na-Sodium	(mg/L)		1-2	3.8	16	0.5	123	31
	Ni-Nickel	(mg/L)	0.025 to 0.15	0.005-0.05	0.0077	0.026	0.0025	123	81
	P-Phosphorus	(mg/L)		0.01-1	1.13	26	0.005	123	96
	Pb-Lead	(mg/L)	0.001 to 0.007	0.01-0.05	0.010	0.12	0.005	123	102
	S-Sulfur	(mg/L)		1	14.5	100	0.5	79	4
	Sb-Antimony	(mg/L)		0.03-0.2	0.027	0.1	0.015	123	110
	Se-Selenium	(mg/L)	0.001	0.005-0.2	0.0052	0.071	0.0025	111	99
	Si-Silicon	(mg/L)			4.3	6.37	0.6	123	0
	Sn-Tin	(mg/L)		0.01-0.03	0.011	0.15	0.005	123	109
	Sr-Strontium	(mg/L)			0.17	0.39	0.02	123	0
	Ti-Thallium	(mg/L)	0.0008	0.005-0.01	0.028	0.408	0.0025	123	50
	V-Vanadium	(mg/L)		0.005-0.03	0.026	0.665	0.0025	123	85
	W-Tungsten	(mg/L)		0.03	0.016	0.05	0.015	111	109
	Zn-Zinc	(mg/L)	0.030	0.01	0.065	0.64	0.005	123	12

Notes: CCME = Canadian Council of Ministers of the Environment. Values given are for protection of aquatic life.

Max = maximum; Min = minimum; N obs = number of observations.

N obs < MDL = number of observations less than method detection limit.

Summary statistics were calculated by setting up values reported as less than method detection limit equal to ½ method detection limit.

Stations:
- FAROCR Faro Creek upstream of confluence of the North Fork of Rose Creek.
- NF1 North Fork of Rose Creek upstream of haul road.
- NF2 North Fork of Rose Creek downstream of haul road.
- R8 North Fork of Rose Creek, 100 m downstream of confluence with Faro Creek diversion.
- R9 North Fork of Rose Creek, adjacent to BH-1 & BH-2.
- R10 North Fork of Rose Creek, at least 100 m upstream from maximum elevation of water impounded behind North Fork rock drain and 100 m downstream of R9.
- X2 North Fork of Rose Creek upstream of mine access road.
- X3 North Fork of Rose Creek at the pump house reservoir.
- X10 Rose Creek Diversion Channel, below weirs.
- X14 Rose Creek, downstream of diversion channel.

TABLE 2.2-3
WATER QUALITY SUMMARY - VANGORDA CREEK UPSTREAM OF VANGORDA PLATEAU MINE SITE

	Parameter	Units	CCME	MDL	Mean	Max	Min	N obs.	N obs < MDL
Total Metals	Ag-Silver	(mg/L)	0.0001	0.003	0.0015	0.0015	0.0015	11	11
	Al-Aluminum	(mg/L)	0.005 to 0.1		0.26	0.57	0.08	11	0
	As-Arsenic	(mg/L)	0.005	0.005	0.005	0.022	0.0025	11	9
	B-Boron	(mg/L)		0.05	0.13	0.87	0.025	11	4
	Ba-Barium	(mg/L)			0.18	0.24	0.13	11	0
	Be-Beryllium	(mg/L)		0.001	0.0007	0.002	0.0005	11	8
	Bi-Bismuth	(mg/L)		0.05	0.025	0.025	0.025	11	11
	Ca-Calcium	(mg/L)			35.3	99.8	3.9	11	0
	Cd-Cadmium	(mg/L)	0.000017	0.001	0.0014	0.01	0.0005	11	9
	Co-Cobalt	(mg/L)		0.005	0.008	0.057	0.0025	11	9
	Cr-Chromium	(mg/L)	0.0089	0.005	0.027	0.141	0.0025	11	8
	Cu-Copper	(mg/L)	0.002 to 0.004		0.026	0.10	0.004	11	0
	Fe-Iron	(mg/L)	0.3		0.73	4.44	0.045	11	0
	K-Potassium	(mg/L)		1	1.59	5.51	0.5	11	6
	La-Lanthanum	(mg/L)		0.005	0.006	0.033	0.0025	11	9
	Mg-Magnesium	(mg/L)			11.4	37.8	0.6	11	0
	Mn-Manganese	(mg/L)		0.01	0.057	0.28	0.005	11	3
	Mo-Molybdenum	(mg/L)	0.073	0.002	0.005	0.029	0.001	11	8
	Na-Sodium	(mg/L)			3.6	10	1	11	0
	Ni-Nickel	(mg/L)	0.025 to 0.15	0.005	0.007	0.023	0.0025	11	6
	P-Phosphorus	(mg/L)		1	1.1	4	0.5	11	8
	Pb-Lead	(mg/L)	0.001 to 0.007	0.01	0.0095	0.04	0.005	11	9
	S-Sulfur	(mg/L)		1	6.3	34	0.5	8	3
	Sb-Antimony	(mg/L)		0.03	0.017	0.04	0.015	11	10
	Se-Selenium	(mg/L)	0.001	0.005	0.004	0.023	0.0025	11	10
	Si-Silicon	(mg/L)			4.2	5.7	2.2	11	0
	Sn-Tin	(mg/L)		0.01	0.0086	0.04	0.005	11	9
	Sr-Strontium	(mg/L)			0.16	0.48	0.004	11	0
	Ti-Thallium	(mg/L)	0.0008	0.005	0.023	0.085	0.0025	11	2
	V-Vanadium	(mg/L)		0.005	0.006	0.023	0.0025	11	8
	W-Tungsten	(mg/L)		0.03	0.015	0.015	0.015	11	11
	Zn-Zinc	(mg/L)	0.030	0.01	0.024	0.06	0.005	11	1

<u>Notes:</u> CCME = Canadian Council of Ministers of the Environment. Values given are for protection of aquatic life.

Max = maximum; Min = minimum; N obs = number of observations;

N obs < MDL = number of observations less than method detection limit.

Summary statistics were calculated by setting up values reported as less than method detection limit equal to ½ method detection limit.

Stations: V1 Vangorda Creek upstream of mine activities.

V4 Shrimp Creek

V20 Vangorda Northeast diversion ditch.

TABLE 2.2-4
WATER QUALITY SUMMARY – VANGORDA CREEK DOWNSTREAM OF VANGORDA PLATEAU MINE SITE

	Parameter	Units	CCME	MDL	Mean	Max	Min	N obs.	N obs < MDL
Total Metals	Ag-Silver	(mg/L)	0.0001	0.001-0.01	0.002	0.005	5.00E-04	81	81
	Al-Aluminum	(mg/L)	0.005 to 0.1	0.05	0.40	3.6	0.025	81	6
	As-Arsenic	(mg/L)	0.005	0.005	0.005	0.037	0.0025	72	64
	B-Boron	(mg/L)		0.05-0.1	0.13	3.6	0.025	81	56
	Ba-Barium	(mg/L)			0.18	0.32	0.06	81	0
	Be-Beryllium	(mg/L)		0.001-0.005	0.001	0.003	0.0005	81	62
	Bi-Bismuth	(mg/L)		0.05-0.1	0.029	0.06	0.025	81	78
	Ca-Calcium	(mg/L)			60.0	173	8.2	81	0
	Cd-Cadmium	(mg/L)	0.000017	0.001	0.002	0.094	0.0005	81	67
	Co-Cobalt	(mg/L)		0.005-0.01	0.008	0.28	0.0025	81	66
	Cr-Chromium	(mg/L)	0.0089	0.005-0.01	0.017	0.182	0.0025	81	52
	Cu-Copper	(mg/L)	0.002 to 0.004	0.002-0.01	0.013	0.046	0.001	81	15
	Fe-Iron	(mg/L)	0.3	0.01	0.63	4.75	0.005	81	1
	K-Potassium	(mg/L)		1-2	1.5	5	0.5	81	29
	La-Lanthanum	(mg/L)		0.005	0.015	0.127	0.0025	72	37
	Mg-Magnesium	(mg/L)			24	67	1.9	81	0
	Mn-Manganese	(mg/L)		0.01	0.285	19.04	0.005	81	19
	Mo-Molybdenum	(mg/L)	0.073	0.002-0.01	0.002	0.018	0.001	81	66
	Na-Sodium	(mg/L)		1-2	3.9	12	0.5	81	13
	Ni-Nickel	(mg/L)	0.025 to 0.15	0.005-0.05	0.013	0.425	0.0025	81	53
	P-Phosphorus	(mg/L)		0.01-1	0.78	9	0.005	81	63
	Pb-Lead	(mg/L)	0.001 to 0.007	0.01-0.05	0.01	0.06	0.005	81	69
	S-Sulfur	(mg/L)		1	39.2	244	0.5	57	4
	Sb-Antimony	(mg/L)		0.03-0.2	0.026	0.1	0.015	81	76
	Se-Selenium	(mg/L)	0.001	0.005-0.2	0.004	0.059	0.0025	72	69
	Si-Silicon	(mg/L)		0.2	4.5	9.6	0.1	81	2
	Sn-Tin	(mg/L)		0.01-0.03	0.13	4.82	0.005	81	66
	Sr-Strontium	(mg/L)			0.27	1.23	0.044	81	0
	Ti-Thallium	(mg/L)	0.0008	0.005-0.01	0.016	0.1	0.0025	81	30
	V-Vanadium	(mg/L)		0.005-0.03	0.009	0.052	0.0025	81	57
	W-Tungsten	(mg/L)		0.03	0.015	0.015	0.015	72	72
	Zn-Zinc	(mg/L)	0.030	0.005-0.01	0.035	0.16	0.0025	80	14

Notes: CCME = Canadian Council of Ministers of the Environment. Values given are for protection of aquatic life.
Max = maximum; Min = minimum; N obs = number of observations;
N obs < MDL = number of observations less than method detection limit.

Summary statistics were calculated by setting up values reported as less than method detection limit equal to ½ method detection limit.

Stations:
- V5 West Fork Vangorda Creek
- V8 Lower Vangorda Creek
- V27 Main Stem Vangorda Creek (Upper)
- VGMAIN Main Stern Vangorda Creek (Lower)

2.2.2 Sediment Quality

2.2.2.1 Sediment Quality in Rose Creek Watershed

Sediment data were available for the section of Rose Creek downstream of the Faro Mine site. Samples were collected in October 1999 and analyzed for a number of metals, including arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, selenium and zinc. Table 2.2-5 summarizes the data and provides the CCME Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL) for comparison. The guidelines provide scientific benchmarks for evaluating the potential for observing adverse biological effects on benthic invertebrates in aquatic systems. The Interim Sediment Quality Guideline (ISQG) values represent the concentrations below which adverse biological effects are expected to occur rarely. The Probable Effect Level (PEL) values represent the concentrations above which adverse effects are expected to occur frequently. Further discussion of sediment toxicity benchmarks is provided in Section 5.2. The CCME guidelines are presented here to facilitate the review of the quality of sediments in the study area.

CCME ISQG levels were exceeded for arsenic, cadmium, chromium, copper, lead and zinc in Rose Creek downstream of the Faro Mine site. The measured levels of chromium and copper were below the CCME PEL values. As seen in Table 2.2-5, sediment quality guidelines do not exist for iron, molybdenum, nickel and selenium.

TABLE 2.2-5
SEDIMENT QUALITY IN ROSE CREEK DOWNSTREAM OF FARO MINE SITE

	Units	CCME		Average	Max	Min	N obs	N obs < MDL
		ISQG	PEL					
Total Metals								
Arsenic	mg/kg(DW)	5.9	17.0	29	47	10	8	0
Cadmium	mg/kg(DW)	0.6	3.5	2.3	3.9	1.3	8	0
Chromium	mg/kg(DW)	37.3	90	62	80	52	8	0
Copper	mg/kg(DW)	35.7	197	81	182	42	8	0
Iron	mg/kg(DW)			40000	57900	28700	8	0
Lead	mg/kg(DW)	35.0	91.3	253	788	54	8	0
Molybdenum	mg/kg(DW)			2.8	8.0	2.0	8	6
Nickel	mg/kg(DW)	15.9	42.8	117	350	46	8	0
Selenium	mg/kg(DW)			11.5	32	8	8	6
Zinc	mg/kg(DW)	123.0	315	672	1600	156	8	0

Note: Shading indicates values that exceed Canadian Council of Ministers of the Environment Interim Sediment Quality Guidelines (CCME ISQG).

Measured data are for Rose Creek stations 4401, 4400, 4398, 4396, 4395, 4394, 4397, 4399.

2.2.2.2 Sediment Quality in Vangorda Creek Watershed

Sediment samples from Vangorda Creek watershed were summarized for sampling events from 1995 to 2001. Table 2.2-6 presents the data for the section of Vangorda Creek upstream of the Vangorda Plateau Mine site and Table 2.2-7 presents the data for Vangorda Creek downstream of the site. Each table also provides the CCME Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) values for comparison. As seen in the table, data have only been collected for copper, lead and zinc.

Metal levels in Vangorda Creek sediments upstream and downstream of the mine site exceeded the ISQG for copper (downstream only), lead and zinc at the average and maximum concentrations. In the upstream segment of Vangorda Creek, all metal concentrations are below the PEL value. Downstream of the Vangorda Plateau Mine site, lead and zinc levels are higher and exceed the CCME PEL values. This is not a surprising result since activities at the Vangorda Plateau Mine site focused on mining lead and zinc ores.

TABLE 2.2-6
SEDIMENT QUALITY IN VANGORDA CREEK UPSTREAM OF VANGORDA PLATEAU MINE SITE

	Units	CCME		Average	Max	Min	N obs	N obs < MDL
		ISQG	PEL					
Total Metals								
Copper	mg/kg(DW)	35.7	197	33.4	53	19	5	0
Lead	mg/kg(DW)	35.0	91.3	40.8	58	18	5	0
Zinc	mg/kg(DW)	123.0	315	131	177	58	5	0

Note: Shading indicates values that exceed Canadian Council of Ministers of the Environment Interim Sediment Quality Guidelines (CCME ISQG).

Measured data are for Vangorda Creek reference station V1, 1995 to 2001.

TABLE 2.2-7
SEDIMENT QUALITY IN VANGORDA CREEK DOWNSTREAM OF VANGORDA PLATEAU MINE SITE

	Units	CCME		Average	Max	Min	N obs	N obs < MDL
		ISQG	PEL					
Total Metals								
Copper	mg/kg(DW)	35.7	197	54.2	129	25	15	0
Lead	mg/kg(DW)	35.0	91.3	630	2800	25	15	0
Zinc	mg/kg(DW)	123.0	315	380	921	81	15	0

Note: Shading indicates values that exceed Canadian Council of Ministers of the Environment Interim Sediment Quality Guidelines (CCME ISQG).

Measured data are for Vangorda Creek stations V27, V5, V8, 1995 to 2001.

2.2.3 Fish and Fish Habitat Surveys

Fish tissue samples were collected in the Rose and Vangorda Creek watersheds in 1974, 1975, 1976, 1977, 1992 and 1997. A number of fish species were studied, including: arctic grayling, burbot, chinook salmon, slimy sculpin, longnose sucker and round whitefish. Table 2.2-8 presents a summary of the data for fish collected from Rose Creek and Table 2.2-9 presents a summary for Vangorda Creek (all samples were assumed to be collected from downstream locations). Muscle and whole body samples, as well as fish species, were pooled for the summary statistics. Generally metal concentrations in fish were higher in Vangorda Creek than in Rose Creek.

TABLE 2.2-8
METAL CONCENTRATIONS IN FISH – ROSE CREEK DOWNSTREAM

	Units	Average	Max	Min	N obs	N obs < MDL
Arsenic	mg/kg(ww)	2.2	10.4	0.9	20	20
Cadmium	mg/kg(ww)	0.04	0.1	0.004	15	1
Chromium	mg/kg(ww)	0.8	3.1	0.09	20	10
Copper	mg/kg(ww)	1.0	4.7	0.2	20	3
Iron	mg/kg(ww)	83	476	6.3	20	0
Lead	mg/kg(ww)	2.8	10.4	0.9	20	12
Molybdenum	mg/kg(ww)	0.5	2.1	0.2	20	19
Nickel	mg/kg(ww)	1.1	5.2	0.4	20	19
Selenium	mg/kg(ww)	2.4	10.4	0.9	20	18
Zinc	mg/kg(ww)	27	48	14	20	0

TABLE 2.2-9
METAL CONCENTRATIONS IN FISH – VANGORDA CREEK DOWNSTREAM

	Units	Average	Max	Min	N obs	N obs < MDL
Arsenic	mg/kg(ww)	3.5	10.9	0.6	17	0
Cadmium	mg/kg(ww)	0.2	0.5	0.04	17	1
Chromium	mg/kg(ww)	0.7	5.7	0.06	17	11
Copper	mg/kg(ww)	1.0	4.8	0.4	17	5
Iron	mg/kg(ww)	45	154	8	17	0
Lead	mg/kg(ww)	3.4	10.9	0.3	17	8
Molybdenum	mg/kg(ww)	0.7	2.2	0.1	17	17
Nickel	mg/kg(ww)	1.7	5.4	0.3	17	15
Selenium	mg/kg(ww)	6.3	10.9	1.6	10	5
Zinc	mg/kg(ww)	34	58	13	17	0

3.0 RECEPTOR CHARACTERIZATION

3.1 ECOLOGICAL RECEPTORS

The first step in the assessment of ecological receptors is determination of which ecological receptors should be examined. Ecological receptors are generally chosen to capture various levels of exposure via the different types of diets that they consume. They are also selected if they are considered important: (1) in the functioning of the ecosystem; (2) in the production of food for subsistence; or (3) due to their cultural or medicinal significance. In this assessment, exposure is primarily due to aquatic pathways thus ecological receptors were selected to capture this exposure.

3.1.1 Aquatic Receptors

Aquatic species, which reside in Rose Creek and Vangorda Creek, are potentially the most exposed species. The aquatic species chosen for this assessment cover trophic levels found in the study area creeks and are provided in Table 3.1-1. Chinook salmon have not been observed in Rose Creek although they have been found in Anvil Creek downstream of the confluence with Rose Creek and in the lower reaches of Vangorda Creek. Given that aquatic plants have only been found in very low abundance in the Anvil, Rose and Vangorda Creek systems, they have not been considered in this assessment. The rationale behind the choice of the species identified in Table 3.1-1 is discussed below.

TABLE 3.1-1
AQUATIC SPECIES SELECTED FOR
THE ANVIL MINE ASSESSMENT

Benthic Invertebrates
Chinook Salmon
Arctic Grayling
Slimy Sculpin

Primary Producers

Benthic invertebrates were chosen to represent ecological receptors at the primary producer level. Due to the association of benthic invertebrates with sediments in aquatic ecosystems, they possess the greater risk in terms of sediment contamination. Benthic invertebrates both live and feed within sediments and therefore may be exposed to contaminants through ingestion of sediment bound contaminants and also through exposure to interstitial waters within the sediment.

Chironomidae (midge) larvae are usually the most abundant benthic invertebrate taxa present in aquatic ecosystems in the northern climate. Midge larvae are selected as an ecological receptor due to the important role they play in aquatic ecosystems. Many species are detritivorous and thereby form an important link between the decomposer level and primary consumers. Furthermore, midge larvae are a main food source for small/juvenile fish and larger omnivorous fish. The adults are capable of flight and are frequently consumed by birds and bats. This life stage provides an important link between aquatic and terrestrial ecosystems in the region.

Secondary Consumers

Ecological receptors at the secondary consumer level include arctic grayling and slimy sculpin both of which have been widely observed in Anvil and Rose Creeks. These species feed largely on benthic invertebrates and smaller individuals are an important food source of larger predatory fishes. Arctic grayling are valued since they are an important sport fish.

Tertiary Consumers

Tertiary or terminal trophic level consumers consist of larger predatory fish species, which include chinook salmon. Chinook salmon are considered ecological receptors from both an ecological and socio-economic perspective. As previously noted, chinook salmon have been observed in the lower reaches of Vangorda Creek, but not in Rose Creek although they are present in Anvil Creek downstream of the confluence with Rose Creek.

3.1.2 Terrestrial Receptors

The terrestrial receptors chosen for the assessment of potential impacts from the Anvil Mine site have been obtained from various information sources containing information on the Yukon as well as the baseline study for the Anvil Mine Complex (Gartner Lee Limited 2002) and are presented in Table 3.1-2. There are many other ecological species in the Anvil Plateau Mine area; however, the species presented in this table were selected to provide a range of exposure via aquatic pathways. Since the aquatic pathways are the only source of contamination considered in the current assessment, species which are reliant on terrestrial pathways for most of their food were generally not included, with certain exceptions as noted below.

TABLE 3.1-2
TERRESTRIAL RECEPTORS CHOSEN FOR THE ANVIL MINE ASSESSMENT

Herbivores	Omnivores	Carnivores
Snowshoe Hare	Black bear	Bald Eagle
Moose	Red fox	Mink
Woodland caribou		
Fannin sheep		

All of the species listed in the above table would be potentially exposed to contaminants from the consumption of water from Rose Creek and Vangorda Creek. Some of the species will also be potentialley exposed to contaminants as a result of consumption of benthic invertebrates, river sediments or fish as noted below. The terrestrial species have been chosen for the following reasons:

Black Bear –While berries, herbs and roots are their primary food source, they also consume fish and are thus potentially exposed via the aquatic pathways

Caribou – Caribou consume predominantly lichen, which are mostly impacted by contaminant deposition from the air. Since the aquatic pathways are the predominant pathways, caribou are not a highly exposed species. Caribou are also not typically found in the study area. However, they were chosen since they are the main large game food source for First Nations people who rely heavily on country foods.

Bald Eagle – Eagles consume fish and thus are exposed via food chain effects.

Red Fox - Foxes are predatory species and thus are exposed via food chain effects. They consume benthic invertebrates and fish which are associated with the aquatic pathways.

Snowshoe Hare – The snowshoe hare is chosen as it may be trapped in the area and used as a food source. The only pathway of exposure for hare is from consumption of water from the creeks.

Mink – Mink are found in the Yukon and consume benthic invertebrates and fish and are thus potentially exposed via the aquatic pathways.

Moose – Moose consume primarily aquatic macrophytes and browse and thus are potentially a high exposed species. In this assessment, there are very limited aquatic macrophytes in either

Anvil, Rose and Vangorda Creeks; however, given that moose may serve as a food source they are included in the assessment.

Fannin Sheep - The Faro herd (approximately 80 in the nursery herd) migrate directly through the Vangorda Plateau Mine site and are therefore of particular importance and are considered in this assessment. They are also a protected species.

Each of the terrestrial species mentioned above also consumes water, which may be obtained from either Rose Creek or Vangorda Creek, downstream of potential impacts from the mine areas.

3.2 HUMAN RECEPTORS

This assessment considered the impacts on hypothetical receptors who either reside close to the site or who potentially camp at the site while hunting and fishing. Given that the Ross River First Nations community is in close proximity to the site, it was assumed that individuals from this community would use the site.

Two hypothetical human receptors were considered for the assessment of potential exposures from the Anvil Range Mining Complex. Receptor 1 was defined to be an adult and child who live near the Faro town site in the Vangorda Creek watershed and who were assumed to be exposed to contaminant intakes from drinking water and eating fish and wild game obtained from the watershed. Receptor 2 was characterized as a hunter/camper adult and child who were assumed to use the area downstream of the Faro mine and tailings area for three months of the year and to consume water, fish and wild game from Rose Creek.

Dietary data from a regional survey of First Nations people in the Northwest Territories were used to define the dietary characteristics for these individuals as site-specific data were not available for this assessment. While the data from the Northwest Territories have been used in other risk assessments, it is recognized that they are not necessarily entirely applicable to the study area. It is recommended therefore, that a dietary survey of the communities near the Anvil Range sites be undertaken and that these site-specific data be used in future risk assessment work. Other exposure data, such as drinking water consumption and body weight, were obtained from a survey of the general Canadian population and are acceptable for use in future assessments.

4.0 EXPOSURE ASSESSMENT

The exposure assessment phase of an ecological and human health risk assessment entails identification of pathways of exposure and the quantification of exposure for the selected receptors. As previously noted, the primary pathways of exposure considered in this assessment are related to contaminants (mostly metals) present in surface waters and sediments in the vicinity of the mine and tailing areas. The pathways and assumptions applied in this assessment are described in this section. Detailed equations for the ecological exposure assessment are provided in Appendix A. Calculated intakes are also provided in Appendix A for each of the pathways. The transfer factors used to calculate contaminant concentrations in environmental media and receptors, for which measured levels were not available, are summarized in Appendix B. Appendix C documents the pathways model used in the assessment of contaminant intakes by the human receptors and the detailed results of the exposure assessment by pathway.

4.1 ECOLOGICAL PATHWAYS

The assessment of potential impacts to ecological receptors from the Anvil Range Mining Complex considered exposure from aquatic pathways (Rose Creek and Vangorda Creek). Figure 4.1-1 provides a diagram of the potential pathways of exposure for both aquatic and terrestrial species.

It has been assumed that all species drink water from Rose Creek and Vangorda Creek. In addition to the food sources identified on Figure 4.1-1 for each species, it was assumed that the bear, caribou, eagle, fox, hare and sheep consume soil and that mink and moose consume sediment. It is important to note that all food sources for some of the species are not shown in this diagram (for example, bear, caribou, fox, hare, mink, moose, sheep); this is because the aquatic pathways are the only pathways that are pertinent to this assessment. Details of receptor dietary characteristics are provided in Table 4.1-1. The fractions of a year that each species was assumed to spend in the study area is also provided in Table 4.1-1.

FIGURE 4.1-1
POTENTIAL PATHWAYS OF EXPOSURE FOR ECOLOGICAL RECEPTORS

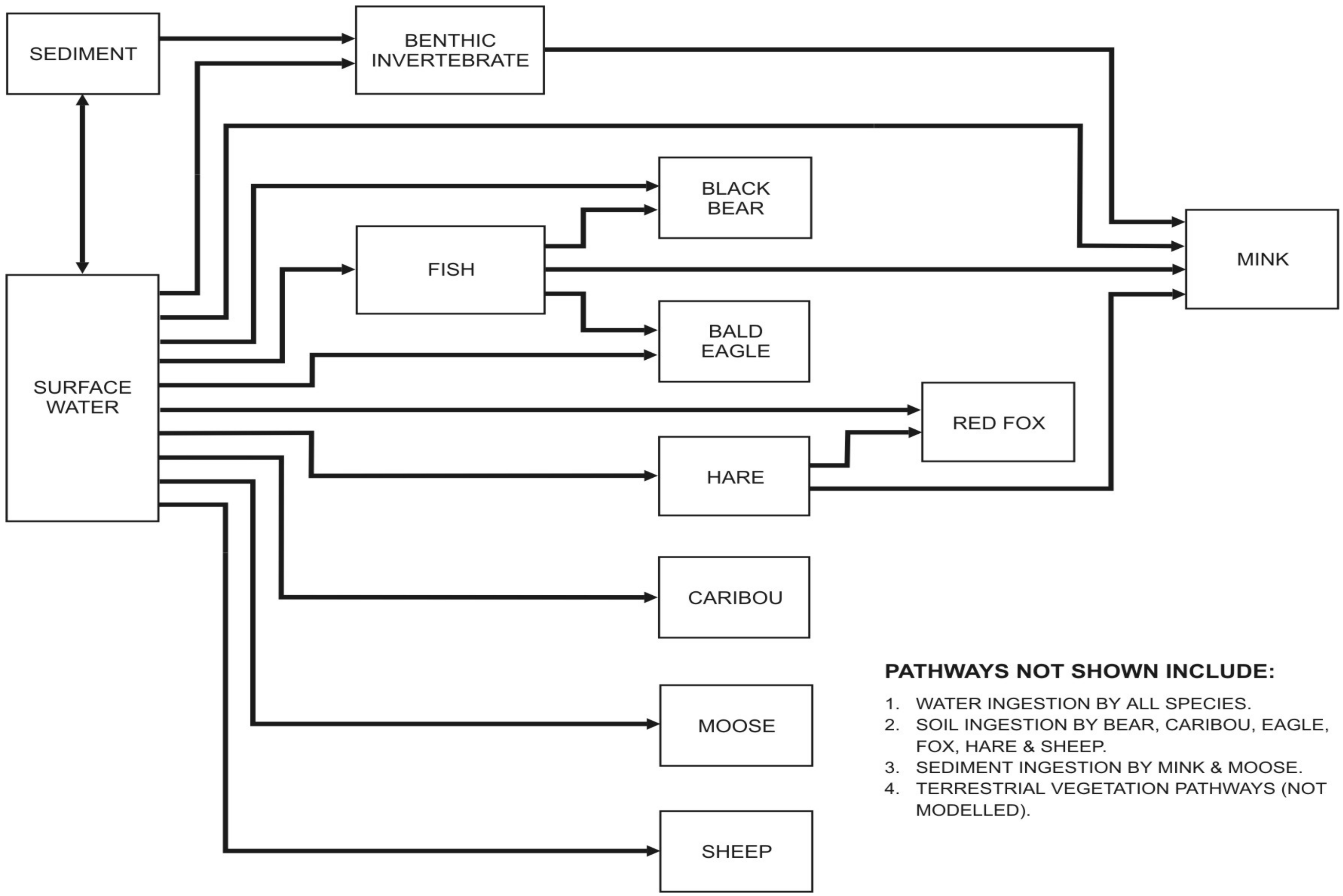


TABLE 4.1-1
TERRESTRIAL ECOLOGICAL RECEPTOR CHARACTERISTICS

	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Body weight (kg)[a]	225	105	3.75	4.5	1.4	1.0	600	70
Fraction of time at site (-)[b]	0.5	0.1	0.25	0.25	1.0	1.0	1.0	0.25
Water Ingestion Rate (L/d)[a]	13	9.5	0.14	0.38	0.14	0.11	32	4.5
Food Ingestion Rate (kg/d)[a]	8.9	8.0	0.45	0.314	0.3	0.13	23	5.8
Fraction of food – benthic invertebrates (-)[b]	0	0	0	0	0	0.08	0	0
Fraction of food – fish (-)[b]	0.25	0	1.0	0	0	0.65	0	0
Fraction of food – hare (-)[b]	0	0	0	0.4	0	0.05	0	0
Sediment Ingestion Rate (kg/d)[c]	0	0	0	0	0	0.002	0.184	0
Soil Ingestion Rate (kg/d)[c]	0.231	0.104	0.007	0.007	0.007	0	0	0.077

Note:
a – From U.S. EPA (1993) except: Canadian Wildlife Service (1997) for bear, moose and sheep, Schmidt & Gilbert (1978) for caribou.
b – Assumed from characteristics or obtained from data presented in U.S. EPA (1993) except: Holcroft and Herrero (1991) for bear, Thomas and Barry (1991) for caribou, Pease et al. (1979) for hare, Canadian Wildlife Service (1997) and Belovsky et al. (1973) for moose.
c – Calculated from Beyer et al. (1994).

4.2 HUMAN EXPOSURE PATHWAYS

4.2.1 Pathways Considered

The human exposure analysis focused on the aquatic pathways as shown on Figure 4.2-1. They include:

- consumption of drinking water from Vangorda Creek or Rose Creek by human receptors;
- uptake by fish of contaminants from the aquatic environment and consumption of contaminated fish flesh by each human receptor;
- uptake by moose of contaminants from sediment and water and consumption of contaminated moose flesh and organs by the human receptors;
- uptake by snowshoe hare of contaminants from water and consumption of contaminated hare flesh by the human receptors; and,
- uptake by caribou of contaminants from water and consumption of contaminated caribou flesh and organs by the human receptors.

It must be noted that the consumption of sheep is not included in the pathways considered. Since the focus is on the aquatic environment, the consumption of sheep will not be affected to a large extent by the aquatic pathways and thus is not considered.

4.2.2 Assumed Dietary Characteristics

The following summarizes information gleaned from available surveys on the dietary characteristics of First Nations communities in the Northwest Territories, as dietary data were not available for the study area. Assumptions regarding the assumed intakes of the adult and child receptors are outlined below.

Table 4.2-1 provides a summary of the location of the various dietary components considered in the assessment. For Receptor 1 (an adult and child who live near the Faro Townsite), it was assumed that all the fish, caribou, moose, small game and drinking water were obtained from Vangorda Creek. It is acknowledged that the use of Vangorda Creek as a drinking water source may be an overly conservative assumption, as it is understood that residents of Faro obtain their drinking water from a well.

For Receptor 2 (a hunter/camper), it is assumed that the adult and child spend 25% of their time on the Anvil Range Mine site in the vicinity of Rose Creek. It was also assumed that all the fish, caribou, moose, small game and drinking water were obtained from the Rose Creek watershed.

TABLE 4.2-1
LOCATION OF THE VARIOUS DIETARY COMPONENTS FOR THE HUMAN RECEPTORS

Dietary Component	Receptor 1 - Local Resident[a]	Receptor 2 - Hunter/Camper[b]
Drinking Water	Vangorda Creek	Rose Creek
Moose	Vangorda Creek watershed downstream of Vangorda/Grum mine areas	Rose Creek watershed downstream of Faro mine and tailings areas
Caribou	Vangorda Creek watershed downstream of Vangorda/Grum mine areas	Rose Creek watershed downstream of Faro mine and tailings areas
Small Game (hare)	Vangorda Creek watershed downstream of Vangorda/Grum mine areas	Rose Creek watershed downstream of Faro mine and tailings areas
Fish[c]	Vangorda Creek	Rose Creek

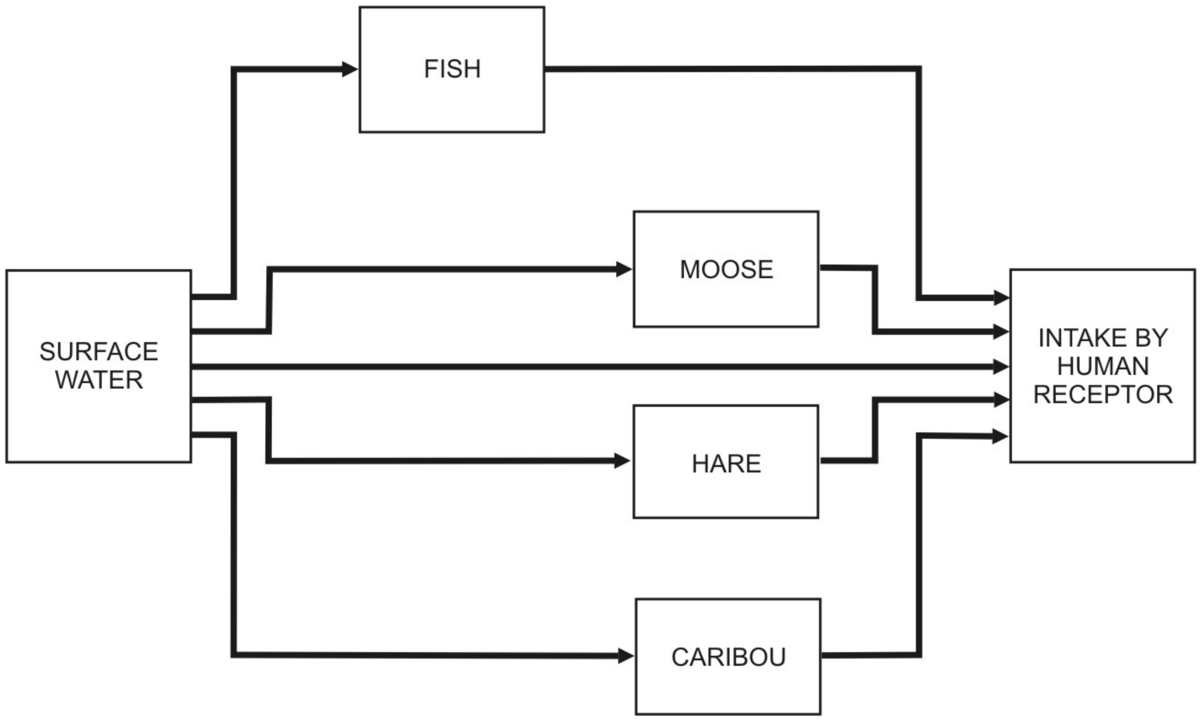
Note:

[a] – It was assumed that Receptor 1 would obtain his/her water from Vangorda Creek. It is acknowledged that this is a conservative assumption.

[b] – It was assumed that Receptor 2 would spend 25% of his/her time (3 months) on the Anvil Mine site in the vicinity of Rose Creek.

[c] - It was assumed that salmon was obtained from Vangorda Creek and arctic grayling from Rose Creek.

FIGURE 4.2-1
POTENTIAL PATHWAYS OF EXPOSURE FOR HUMAN RECEPTORS



Food Consumption

For this assessment, food consumption patterns were based on those of the First Nations people. The sources of traditional food were obtained from a study of a First Nations community in the Canadian North (Receveur *et al*. 1996). The results of this survey were compared to other data collected from First Nations people across Canada (Coad 1994). It was assumed that in the absence of any other data, that the data from these surveys were appropriate for use in the Anvil Mine study. Additionally, the intakes of fish, meat and other foods, fell within the range of the Coad study (1994). For this assessment, it was assumed that all of the traditional foods consumption comprised animal muscle and organs.

There was a lack of information for this study on which to base the diet of a child. Thus, it was assumed that the diet of the children is composed of the same traditional foods as the adults but was adjusted to account for differences in the total intake rate of a child versus an adult. In a Canadian wide survey carried out by Health Canada (Richardson 1997) a ratio of 74% can be derived to account for the difference between an adult and child (aged 5 to 11 years old) intake, this ratio was applied to the intakes from various sources.

The total meat and fish from the regional study is summarized in Table 4.2-2. The values reported in the table are mean consumption rates for typical individuals.

TABLE 4.2-2
TOTAL INTAKE OF MEAT AND FISH USED IN THE ASSESSMENT

	Receptor	
	Adult	**Child**
Meat (g/d)		
Caribou	281	208
Moose	4	3
other small mammals (hare)	3.5	2.6
Fish (g/d)	67	50
Total Meat, Fish and Poultry (g/d)	355.5	263.6

Water Intake

The water intakes for an adult and child were obtained from the *"Compendium of Canadian Human Exposure Factors for Risk Assessment"* (Richardson, 1997). The water intake for an adult is estimated to be 1.6 L/d and the water intake for a child (5 to 11 years of age) is estimated to be 0.86 L/d.

Body Weight

The body weight (bw) of a child and adult are also necessary in order to calculate a daily intake (mg/(kg (bw) d)). In this assessment the body weights used for the child and adult receptors were 35 kg and 70 kg respectively (Richardson 1997).

4.3 METAL BIOAVAILABILITY

Bioavailability of a chemical can be defined as the fraction of an administered dose that reaches the central (blood) compartment, whether through the gastrointestinal tract, skin or lungs (NEPI 2000). This type of bioavailability is known as "absolute bioavailability".

In risk assessments, oral exposures are generally described in terms of an external dose or intake, as opposed to an absorbed dose or uptake. Intake occurs as an agent enters the body of a human or animal without passing an absorption barrier (e.g., through ingestion or inhalation), while uptake occurs as an agent passes across the absorption barrier (IPCS 2000). Not all materials (e.g., metals, nutrients) that enter the body as intake are absorbed into the body as uptake. Many are passed through the body and expelled without effect.

When calculating the intake via the oral route of exposure, it is customary to take into account the food, water and soil pathways. The default bioavailability value used in screening level (Tier 1) calculations is 100%.

5.0 HAZARD ASSESSMENT

The hazard assessment phase of an ecological and/or human health risk assessment involves identification of contaminant concentrations or doses which have been shown to have adverse effects on the receptors (ecological species or humans) of concern. The exposure concentrations or doses are generally determined from controlled laboratory tests or from epidemiology studies and are used to establish toxicity benchmarks which are protective of the receptors.

5.1 AQUATIC TOXICITY EVALUATIONS

Toxicity data for the aquatic ecological receptors have been compiled from reputable sources, such as Suter and Tsao (1996) and the United States Environmental Protection Agency (U.S. EPA) on-line database for aquatic toxicity (U.S. EPA AQUIRE 2002). The toxicity benchmarks, which were used in this assessment are summarized on Table 5.1-1. The benchmarks are either lowest chronic values (EC/LC_{20}) or acute EC/LC_{50} values with an applied safety factor of 10. These represent conservative toxicity benchmarks.

Decision rules for the selection of test species were developed around the available data. For benthic invertebrates, the lowest available toxicity values for any invertebrate test species were used. For the fish species, data were chosen for the closest similar species or species with feeding habits representative of the selected fish. For example, in the absence of toxicity data for the bottom-feeding slimy sculpin, the available toxicity data for other bottom feeding fish, such as white sucker, goldfish and carp, were considered. The lowest toxicity value of these species was chosen. When chronic toxicity values were available, the benchmark was chosen to be the LC/EC_{20}; this assumption follows guidance provided in "*Environmental Assessments of Priority Substances Under the Canadian Environmental Protection Act"* (1997) which indicates that benchmarks for Tier 1 and 2 assessments are LC/EC25's. Copper toxicity benchmarks were generally selected to be LC/EC_{20} values since the application of a safety factor of 10 resulted in benchmarks below the CCME criterion value of 2 µg/L for low hardness waters.

In this assessment, a linear relationship between dose of a contaminant and toxicity was assumed. This tends to be a conservative assumption and most likely results in an over-estimation of the toxic effects. Different models exist for translating chemical exposure (or dose) to toxic responses. In the absence of detailed dose-response functions, a linear approximation can be established with a single toxicity benchmark (e.g. LC_{20}/EC_{20}), assuming zero effect at zero exposure. For exposure concentrations less than the benchmark LC_{20}, this approximation will predict some degree of effect for any non-zero exposure. This linearization is pessimistic since the predicted effect will be greater than that observed using the commonly encountered sigmoidal dose-response function for exposures less than the LC_{20}.

TABLE 5.1-1
AQUATIC TOXICITY BENCHMARKS

Aquatic Receptor	Un-ionized Ammonia (mg/L)				
	Test Species	**LC/EC50**	**Toxicity Benchmark**	**Reference**	**Comments**
Benthic Invertebrates	Cladoceran	1.2	0.12	EC/HC (2001) PSL2	Lowest value for invertebrate species. LC50; applied factor of 0.10 to LC50
Arctic Grayling/ Chinook Salmon	Walleye	0.7	0.07	EC/HC (2001) PSL2	LC50 reported as geometric mean of 4 studies; applied factor of 0.10 to LC50
Slimy Sculpin	White sucker	1.3	0.13	EC/HC (2001) PSL2	LC50 reported as geometric mean of 7 studies; applied factor of 0.10 to LC50

Aquatic Receptor	Arsenic (mg/L)				
	Test Species	**LC/EC50**	**Toxicity Benchmark**	**Reference**	**Comments**
Benthic Invertebrates	Calanus sp.		0.32	Borgmann et al. (1980)	from CCME (1999); 14-d EC20
Arctic Grayling/Chinook Salmon	Rainbow Trout	0.55	0.22	Birge et al. (1979a)	from CCME (1999); 28-d LC50; used an LC20 for a chronic LC50
Slimy Sculpin	Goldfish	0.49	0.196	Birge et al. (1979b)	from U.S. EPA AQUIRE; Only test species for which data exists - 7-d LC50 (mor); used an LC20 for a chronic LC50

Aquatic Receptor	Cadmium (mg/L)				
	Test Species	**LC/EC50**	**Toxicity Benchmark**	**Reference**	**Comments**
Benthic Invertebrates	Chironomus sp.	1.2	0.12	Rehwoldt et al. (1973)	from U.S. EPA AQUIRE; LC50 (mortality) 96-hr; applied factor of 0.10 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.002	Carlson et al. (1982)	from Suter and Tsao (1996); lowest chronic test EC20 – early life stage tests
Slimy Sculpin	Common carp	0.24	0.024	Rehwoldt et al. (1972)	from U.S. EPA AQUIRE; LC50 (mortality) 96-hr; applied factor of 0.10 to LC50

	Chromium (mg/L)				
Aquatic Receptor	**Test Species**	**LC/EC50**	**Toxicity Benchmark**	**Reference**	**Comments**
Benthic Invertebrates	Chironomus sp.	11.0	1.1	Rehwoldt et al. (1973)	from U.S. EPA AQUIRE; LC50 (mortality) 96-h, applied factor of 0.1 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.051	Sauter et al. (1976)	from Suter and Tsao (1996); lowest test EC20 for Cr(VI)
Slimy Sculpin	Goldfish	0.660	0.264	Birge et al. (1979b)	from U.S. EPA AQUIRE; 7-d LC50 (mortality) 7-d; used an LC20 for a chronic LC50

TABLE 5.1-1 (Cont'd)
AQUATIC TOXICITY BENCHMARKS

Valued Ecosystem Component	Copper (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates	Chironomus sp.	0.8	0.08	Hooftman et al. (1989)	from U.S. EPA AQUIRE; LC50 (mortality) 72-hr
Arctic Grayling/ Chinook Salmon	Brook Trout	0.009	0.004	Marr et al. (1999)	LC50 (mor) 96hr; used an LC20 since a factor of 0.1 gives a value < CCME benchmark
Slimy Sculpin	White sucker	0.35	0.14	Munkittrick and Dixon (1987)	from U.S. EPA AQUIRE; LC50 (mor) 6-d; used an EC20 for a chronic EC50

Valued Ecosystem Component	Lead (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates	Tanytarus sp.	224	22.4	Call et al. (1984)	from MOE (1988); 48-hr LC50; applied factor of 0.1 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.022	Sauter et al. (1976)	from Suter and Tsao (1996); lowest chronic test EC20
Slimy Sculpin	Goldfish	1.66	0.16	Birge et al. (1979b)	from U.S. EPA AQUIRE; LC50 (mor) 7-d; applied factor of 0.1 to LC50; lowest value of snakehead catfish and goldfish

Valued Ecosystem Component	Molybdenum (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates					no data available
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.73	0.29	Birge et al. (1979b)	from U.S. EPA AQUIRE; LC50 (mor) 28-d; used an LC20 for a chronic LC50
Slimy Sculpin	Goldfish	60	24	Birge (1978)	from CCME (1999); 7-d LC50; study results had a large CI; used an LC20 for a chronic LC50

Valued Ecosystem Component	Nickel (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates	Chironomus sp.	8.6	0.86	Rehwoldt et al. (1973)	from U.S. EPA AQUIRE; LC50 (mortality) 96-hr; applied factor of 0.1 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.062	Nebeker et al. (1985)	from Suter and Tsao (1996); lowest chronic test EC20, early life stage test
Slimy Sculpin	Carp	10.4	1.04	Rehwoldt et al. (1972)	from U.S. EPA AQUIRE; LC50 (mor) 96-hr; applied factor of 0.1 to LC50

TABLE 5.1-1 (Cont'd)
AQUATIC TOXICITY BENCHMARKS

Valued Ecosystem Component	Selenium (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates	Chironomus sp.	1.8	0.18	Ingersoll et al. (1990)	from U.S. EPA AQUIRE; LC50 (ITX) 48-hr; applied factor of 0.1 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.04	Goettl and Davies (1976)	from Suter and Tsao (1996); lowest chronic test EC20, early life stage tests
Slimy Sculpin	White Sucker	29.0	2.9	Klaverkamp et al. (1983)	from U.S. EPA 1987 Ambient Water Quality Criteria for Selenium; applied factor of 0.1 to LC50

Valued Ecosystem Component	Zinc (mg/L)				
	Test Species	LC/EC50	Toxicity Benchmark	Reference	Comments
Benthic Invertebrates	Chironomus sp.	1.13	0.11	Phipps et al. (1995)	from U.S. EPA AQUIRE; LC50 (mortality) 10-d; applied factor of 0.1 to LC50
Arctic Grayling/ Chinook Salmon	Rainbow Trout		0.048	Spehar (1976)	from Suter and Tsao (1996); lowest chronic test EC20
Slimy Sculpin	Carp	7.8	0.78	Rehwoldt et al. (1972)	from U.S. EPA AQUIRE; LC50 (mor) 96-hr; applied factor of 0.1 to LC50

5.2 SEDIMENT TOXICITY EVALUATIONS

The potential ecological effects of sediment contamination were addressed in part through the examination of potential effects on benthic invertebrates. Toxicity benchmarks are available from the CCME (1999), the Ontario Ministry of the Environment (MOE 1993), Kurias *et al*. (2000), Long *et al*. (1995) and Liber and White-Sobey (2000). The establishment of sediment quality guidelines is a relatively new area of environmental science and many jurisdictions are currently in the process of attempting to evaluate different measurements of sediment quality and toxicity and approaches for converting those measurements into regulatory guidelines/standards. The available sediment benchmarks/guidelines are presented in Table 5.2-1 as an example of the range of sediment quality guidelines that have been developed.

TABLE 5.2-1
SUMMARY OF TOXICOLOGICAL BENCHMARKS FOR SEDIMENTS

Metal	Units	CCME		Ontario MOE		Kurias *et al.*		Long *et al.*		Liber and White-Sobey	
		TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM	NOEC	LOEC
Arsenic	µg/g	5.9	17	6	33	30	570	8.2	70	3.9	39
Cadmium	µg/g	0.6	3.5	0.6	10	-	-	1.2	9.6	-	-
Chromium	µg/g	37.3	90	26	110	-	-	81	370	-	-
Copper	µg/g	35.7	197	16	110	-	-	34	270	-	-
Lead	µg/g	35	91.3	31	250	1	24	46.7	218	-	-
Molybdenum	µg/g	-	-	-	-	25	470	-	-	358	3589
Nickel	µg/g	15.9	42.8-	16	75	5	100	20.9	51.6	21	210
Selenium	µg/g	-	-	-	-	-	-	-	-	-	-
Zinc	µg/g	123	315	120	820	-	-	150	410	-	-

Note: - No data available
TEL – Threshold Effect Level
PEL - Probable Effect Level
LEL - Lowest Effect Level
SEL - Severe Effect Level
ERL - Effects Range Low
ERM - Effects Range Medium
NOEC - No-observed-effect-concentration
LOEC – Lowest-observed-effect-concentration

The national CCME guidelines provide Threshold Effect Levels (TELs) and Probable Effect Levels (PELs). The TEL represents the concentration below which adverse biological effects are expected to occur rarely (i.e. fewer than 25% adverse effects occur below the TEL). The PEL defines the level above which adverse effects are expected to occur frequently (i.e. more than 50% adverse effects occur above the PEL, or above which adverse effects are usually or always observed). The Canadian sediment quality guidelines were developed with the intention to be conservative (CCME 1999). The Ontario MOE provides LELs (lowest effects level) and SELs (severe effects level) developed for the protection of aquatic biological resources. The MOE guidelines provide guidance during decision-making in relation to sediment issues. A sediment concentration above the SEL is a trigger for conducting biological tests to determine whether any adverse effects are present.

The Kurias *et al*. (2000) paper is under revision; however, the results are presented here as additional sediment benchmarks. The screening level concentration (SLC) approach used by Kurias *et al*. has several disadvantages, and issues are apparent with the LEL and SEL numbers calculated as threshold levels that are below baseline levels. Long *et al*. (1995) provides ERLs (effects range-low) and ERMs (effects range-median) concentrations developed from a database of sediment chemistry/biological effects. ERLs represent the lower tenth percentile of effects data and a minimal-effects range in which effects would rarely be observed. ERMs are the median of the effects data and represent a possible-effects range above the ERL. Concentrations above the ERM represent a probable-effects range with the frequent occurrence of effects. The benchmarks presented by Liber and White-Sobey (2000) were developed using whole-sediment bioassays, a method that is considered the most relevant for the assessment of effects from metals associated with bottom sediments.

It is important to note that these benchmarks should only be used for screening purposes. An exceedance of any of these benchmarks does not mean that an adverse effect would be observed rather it means that further investigation is necessary.

5.3 TOXICITY TO WILDLIFE

In the absence of toxicity data for most of the terrestrial animal receptors, data for laboratory animals (generally mice and rats) were used in the risk assessment calculations. The benchmarks for mice and rats, generally No Observable Adverse Effects Levels (NOAELs), were scaled by body weight for the various wildlife, as shown in equation (5.3-1).

$$NOAEL_{wildlife} = NOAEL_{testspecies}\left(\frac{BodyWeight_{testspecies}}{BodyWeight_{wildlife}}\right)^{0.25} \tag{5.3-1}$$

Toxicity benchmarks used to evaluate the terrestrial populations were collected from the U.S. Department of Energy database by Sample *et al*. (1996). The toxicity benchmarks for birds were also obtained from Sample et al. (1996); these were not species-specific, therefore, for the eagle, the toxicity benchmarks were not scaled by body weight. The toxicity data were used in the study are shown in Table 5.3-1.

TABLE 5.3-1
SUMMARY OF TOXICOLOGICAL BENCHMARKS FOR TERRESTRIAL ECOLOGICAL RECEPTORS

Receptor	NOAEL (mg/(kg d))									Body Wt. (kg)
	Arsenic	Cadmium	Chromium	Copper	Lead	Molybdenum	Nickel	Selenium	Zinc	
Bear[a]	0.014	0.19	0.65	3.0	1.6	0.028	7.9	0.04	32	225
Caribou[a]	0.016	0.23	0.79	3.7	1.9	0.034	9.6	0.05	38	105
Eagle[b]	5.1	1.45	1	47	1.13	3.5	77.4	0.5	14.5	3.75
Fox[a]	0.036	0.51	1.7	8.0	4.2	0.07	21.1	0.11	84	4.5
Hare[a]	0.048	0.68	2.3	10.8	5.7	0.10	28.3	0.14	113	1.4
Mink[a]	0.052	0.74	2.5	11.7	6.2	0.11	30.8	0.15	123	1.0
Moose[a]	0.011	0.15	0.51	2.4	1.2	0.02	6.2	0.03	25	600
Sheep[a]	0.018	0.26	0.87	4.0	2.1	0.04	10.6	0.05	43	70
Test Species - mouse	0.136	1.926	6.55	30.4	15.98	0.28	79.89	0.399	319.5	0.022
Test Species – bird	5.1	1.45	1	47	1.13	3.5	77.4	0.5	14.5	

Note: All test species toxicity values are NOAELs from Sample *et al*. (1996) unless noted otherwise. Where multiple forms of the chemical species were available, the lowest (or most conservative) value was chosen.

a – Toxicity values for non-bird species are scaled by body weight from the test species (white-footed mouse) following the accepted equation presented in Sample *et al*. (1996) and shown below:

$$NOAEL_{wildlife} = NOAEL_{test\ specice} \times \left(\frac{BW_{test\ species}}{BW_{wildlife}} \right)^{0.25}$$

b – Toxicity values for bird species are considered equal to the test species NOAEL for all birds and not scaled by body weight.

5.4 TOXICITY TO HUMANS

Toxicity is defined as the ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness or, in extreme cases, death when ingested, inhaled or absorbed by the skin. The purpose of a toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals. As well, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects should be provided.

The toxicity data for each of the contaminants (chemical species) considered in this study are provided in Table 5.4-1.

TABLE 5.4-1
HUMAN TOXICITY – ORAL PATHWAY

Chemical	**Oral**		**Reference**
	Slope Factor (mg/(kg d))-1	**Reference Dose (mg/(kg d))**	
Arsenic	1.5	2×10^{-3}	IRIS; Health Canada
Cadmium	n/a	5×10^{-4}	IRIS
Chromium	n/a	1.5	IRIS (Cr(III))
Copper	n/a	3.7×10^{-2}	HEAST
Lead	n/a	1.85×10^{-3}	MOE
Molybdenum	n/a	5×10^{-3}	HEAST
Nickel	n/a	2×10^{-2}	IRIS
Selenium	n/a	5×10^{-3}	IRIS
Zinc	n/a	3×10^{-1}	IRIS

IRIS Integrated Risk Information System (U.S. EPA, 2002).
HEAST Health Effects Assessment Summary Tables (U.S. EPA, 1997).
NCEA National Center for Environmental Assessment (U.S. EPA, 2001).
MOE Ontario Ministry of the Environment (MOE, 1994).
n/a not applicable.

In the table, data is provided for the following:

- Slope Factor (SF) - (for carcinogens) comprises a plausible upper bound estimate of the probability of a response per unit intake of a contaminant over a lifetime. It is used to evaluate the probability of a cancer developing due to a lifetime of exposure and permits an estimate of the risk for a specified dose (known as a risk specific dose or RSD) to be calculated. For carcinogens, no threshold is assumed to exist (i.e., every dose is assumed to present some risk); or

- Reference Dose (RfD) - (for non-carcinogens) comprises an estimate of the daily exposure level for a chemical for the entire population, including sensitive receptors, that is not anticipated to present an appreciable risk of an adverse effect during a portion of a lifetime.

The various sources of information for the toxicity data were:

- IRIS (Integrated Risk Information System) - The U.S. EPA's on-line database was a prime source of information. This database is regularly updated by the U.S. EPA; and
- HEAST (Health Effects Assessment Summary Tables) - The data contained in HEAST were used to supplement the IRIS toxicological data. These tables are issued bi-annually by the U.S. EPA.

When data were available from more than one information source, a chain of precedence was established. Data from IRIS were generally chosen first, followed by the HEAST database as the next choice. If data were not available in these two sources, then data were obtained from the National Center for Environmental Assessment (NCEA), which is part of the U.S. EPA.

Slope Factors

Carcinogenesis is generally assumed to be a "non-threshold" type phenomenon whereby it is assumed that any level of exposure to a carcinogen poses a finite probability of generating a carcinogenic response. Slope factors are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The slope factor is, therefore, the lifetime cancer risk per unit of dose.

Of the contaminants selected for evaluation in this study, only arsenic is considered to be a human carcinogen or probable human carcinogen. The slope factor used in this assessment represents an upper bound (95^{th} percentile) dose-response estimate. The slope factor is conservative and is meant to protect susceptible members of the public. The slope factor for arsenic was obtained from IRIS (U.S. EPA 2002).

Reference Doses

The remaining contaminants are considered to be non-classifiable with respect to human carcinogenicity, indicating that there are no human or animal data to indicate that they are carcinogens. The contaminants falling into this category include cadmium, chromium, copper, lead, molybdenum, nickel, selenium and zinc.

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect is manifested from chronic exposure to a toxicant. This is known as a "threshold" concept. Non-carcinogens are often referred to as "systemic toxicants" because of their effects on the function of various organ systems. A reference dose (RfD) is the value most often used in the evaluation of non-carcinogenic effects resulting from exposure to toxicants.

6.0 RISK CHARACTERIZATION

The following sections describe the comparison of water quality and sediment quality to available guidelines and the assessment of potential impacts to aquatic and terrestrial ecological receptors. The results of the human health assessment are also presented.

6.1 AQUATIC ENVIRONMENT

6.1.1 Water Quality

Measured mean and 95th percentile water concentrations from 2000 and 2001 in Rose Creek and Vangorda Creek, upstream and downstream, were compared to available guidelines from the CCME for the protection of aquatic life (see Table 6.1-1) and for drinking water (see Table 6.1-2). As seen in the tables, a number of the measured concentrations are above the appropriate guideline.

TABLE 6.1-1
COMPARISON OF MEASURED WATER QUALITY TO GUIDELINES – PROTECTION OF AQUATIC LIFE (mg/L)

Contaminant	CCME Guideline	Mean				95th Percentile			
		Rose Creek		Vangorda Creek		Rose Creek		Vangorda Creek	
	Protection of Aquatic Life	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Ammonia	1.23	0.025	0.0735	0.025	0.025	0.025	0.17	0.025	0.025
Arsenic	0.005	**0.0082**	**0.0057**	**0.0051**	0.0046	**0.068**	**0.024**	**0.022**	**0.022**
Cadmium	0.000017	**0.0006**	**0.0008**	**0.0014**	**0.002**	**0.003**	**0.003**	**0.01**	**0.002**
Chromium	0.0089	0.0064	**0.0145**	**0.0266**	**0.0174**	**0.048**	**0.063**	**0.141**	**0.139**
Copper	0.002	**0.0063**	**0.0121**	**0.0255**	**0.0127**	**0.0167**	**0.03**	**0.103**	**0.034**
Lead	0.002	**0.0035**	**0.0105**	**0.0095**	**0.0103**	**0.005**	**0.03**	**0.04**	**0.025**
Molybdenum	0.073	0.0023	0.0026	0.0054	0.0024	0.008	0.01	0.029	0.006
Nickel	0.065	0.0023	0.0077	0.0072	0.0133	0.0033	0.025	0.023	0.025
Selenium	0.001	**0.0018**	**0.0052**	**0.0044**	**0.0038**	**0.0025**	**0.026**	**0.023**	**0.0025**
Zinc	0.03	0.0188	**0.065**	0.0241	**0.0348**	**0.05**	**0.18**	**0.06**	**0.095**

Notes: **Bold** values indicate that measured water concentration is greater than the CCME guideline.

TABLE 6.1-2
COMPARISON OF MEASURED WATER QUALITY TO GUIDELINES – DRINKING WATER (mg/L)

Contaminant	CCME Guideline	Mean				95th Percentile			
		Rose Creek		Vangorda Creek		Rose Creek		Vangorda Creek	
	Drinking Water	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Ammonia	-	0.025	0.0735	0.025	0.025	0.025	0.17	0.025	0.025
Arsenic	0.025	0.0082	0.0057	0.0051	0.0046	**0.068**	0.024	0.022	0.022
Cadmium	0.005	0.0006	0.0008	0.0014	0.002	0.003	0.003	**0.01**	0.002
Chromium	0.05	0.0064	0.0145	0.0266	0.0174	0.048	**0.063**	**0.141**	**0.139**
Copper	1	0.0063	0.0121	0.0255	0.0127	0.0167	0.03	0.103	0.034
Lead	0.01	0.0035	**0.0105**	0.0095	**0.0103**	0.005	**0.03**	**0.04**	**0.025**
Molybdenum	-	0.0023	0.0026	0.0054	0.0024	0.008	0.01	0.029	0.006
Nickel	-	0.0023	0.0077	0.0072	0.0133	0.0033	0.025	0.023	0.025
Selenium	0.01	0.0018	0.0052	0.0044	0.0038	0.0025	**0.026**	**0.023**	0.0025
Zinc	5	0.0188	0.065	0.0241	0.0348	0.05	0.18	0.06	0.095

Notes: **Bold** values indicate that measured water concentration is greater than the CCME guideline.
Dash (-) indicates that guideline is not available
Values shown for copper and zinc are aesthetic objectives

The measured water quality in Rose Creek and Vangorda Creek is seen to be above the CCME guideline for the protection of aquatic life for a number of contaminants. For Rose Creek, mean measured concentrations of arsenic, cadmium, copper, lead and selenium exceed guidelines in the upstream (background) location whereas measured concentrations of arsenic, cadmium, chromium, copper, lead, selenium and zinc exceed the CCME guidelines downstream. For Vangorda Creek, mean measured concentrations of cadmium, chromium, copper, lead and selenium exceed the CCME guidelines both upstream and downstream and measured concentrations of zinc exceed the guidelines in the downstream location. Arsenic was marginally higher than the guideline at the upstream station whereas it was slightly lower downstream of the mine area. Because there were a number of exceedances of the guidelines, a more detailed examination of the impacts on the aquatic environment was undertaken with consideration of the specific receptors expected to be found in the local area.

6.1.2 Sediment Quality

Measured levels in lake sediments were compared to sediment toxicity benchmarks presented previously in Section 5.2. The benchmarks are intended to be used for evaluation of the potential of observing adverse biological effects in aquatic systems and should not be interpreted to infer that higher levels will necessarily result in toxicity to the benthic invertebrate populations of Rose and Vangorda creeks. To simplify the review, the mean and 95th percentile sediment concentrations, presented on Table 6.1-3, were divided by the toxicity benchmarks to obtain the screening index values presented on Table 6.1-4 (Rose Creek) and Table 6.1-5 (Vangorda Creek). Screening index values less than 1 indicate that the predicted levels are below the corresponding benchmarks. Values greater than 1 suggest that there is potential of observing adverse effects on some species. These numbers are shown as **bold** numbers on Tables 6.1-4 and 6.1-5. It is noted that many factors affect the availability of metals in sediment and hence their toxicity (e.g. grain size distribution and organic content).

TABLE 6.1-3
MEASURED METAL LEVELS IN SEDIMENTS (mg/kg (dw))

Contaminant	Mean				95th Percentile			
	Rose Creek		Vangorda Creek		Rose Creek		Vangorda Creek	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Arsenic	-	28.96	-	-	-	46.65	-	-
Cadmium	-	2.25	-	-	-	3.58	-	-
Chromium	-	62.21	-	-	-	77.05	-	-
Copper	-	81.26	33.4	54.2	-	148.98	50.2	110.1
Lead	-	252.81	40.8	629.53	-	603.57	55.4	2288.6
Molybdenum	-	2.83	-	-	-	6.13	-	-
Nickel	-	117.21	-	-	-	283.28	-	-
Selenium	-	11.46	-	-	-	24.88	-	-
Zinc	-	672.17	131.2	379.6	-	1414.45	169.8	883.9

Note: - no measured data available.

Sediment chemistry data were available on Rose Creek only for stations downstream of the mine facilities. Comparison of the mean and 95th percentile levels to available sediment quality guidelines showed that a number of the contaminants were above both effects levels (see Table 6.1-4). This is not surprising given that sediments have been affected by past mining activity and that it is a naturally occurring mineralized area.

For Vangorda Creek, measured sediment concentrations are available for copper, lead and zinc at both upstream (not influenced by mining operations) and downstream locations. These concentrations also exceed the appropriate sediment guidelines as seen in Tables 6.1-5 and 6.1-6. The fact that the threshold effects levels are exceeded for all three metals at the upstream station confirms that elevated metal levels in the area are a natural occurrence.

TABLE 6.1-4
COMPARISON OF MEASURED METAL LEVELS IN SEDIMENT – ROSE CREEK

	Mean	Screening Index Values Based on Comparison to									
		CCME		Ontario MOE		Kurias *et al.*		Long *et al.*		Liber and Sobey	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM	NOEC	LOEC
Arsenic	29	**4.91**	**1.70**	**4.83**	0.88	0.97	0.05	**3.53**	0.41	**7.43**	0.74
Cadmium	2	**3.75**	0.64	**3.75**	0.23	-	-	**1.88**	0.23	-	-
Chromium	62	**1.67**	0.69	**2.39**	0.57	-	-	0.77	0.17	-	-
Copper	81	**2.28**	0.41	**5.08**	0.74	-	-	**2.39**	0.30	-	-
Lead	253	**7.22**	**2.77**	**8.16**	**1.01**	**252.81**	**10.53**	**5.41**	**1.16**	-	-
Molybdenum	3	-	-	-	-	0.11	0.01	-	-	0.01	< 0.01
Nickel	117	**7.37**	**2.74**	**7.33**	**1.56**	**23.44**	**1.17**	**5.61**	**2.27**	**5.58**	0.56
Selenium	11	-	-	-	-	-	-	-	-	-	-
Zinc	672	**5.46**	**2.13**	**5.60**	0.82	-	-	**4.48**	**1.64**	-	-

	95th Percentile	Screening Index Values Based on Comparison to									
		CCME		Ontario MOE		Kurias *et al.*		Long *et al.*		Liber and Sobey	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM	NOEC	LOEC
Arsenic	47	**7.91**	**2.74**	**7.78**	**1.41**	**1.56**	0.08	**5.69**	0.67	**11.96**	**1.20**
Cadmium	4	**5.97**	**1.02**	**5.97**	0.36	-	-	**2.98**	0.37	-	-
Chromium	77	**2.07**	0.86	**2.96**	0.70	-	-	0.95	0.21	-	-
Copper	149	**4.17**	0.76	**9.31**	**1.35**	-	-	**4.38**	0.55	-	-
Lead	604	**17.24**	**6.61**	**19.47**	**2.41**	**603.57**	**25.15**	**12.92**	**2.77**	-	-
Molybdenum	6	-	-	-	-	0.25	0.01	-	-	0.02	< 0.01
Nickel	283	**17.82**	**6.62**	**17.71**	**3.78**	**56.66**	**2.83**	**13.55**	**5.49**	**13.49**	**1.35**
Selenium	25	-	-	-	-	-	-	-	-	-	-
Zinc	1414	**11.50**	**4.49**	**11.79**	**1.72**	-	-	**9.43**	**3.45**	-	-

TABLE 6.1-5
COMPARISON OF MEASURED METAL LEVELS IN SEDIMENT – VANGORDA CREEK UPSTREAM

	Mean	Screening Index Values Based on Comparison to							
		CCME		Ontario MOE		Kurias *et al.*		Long *et al.*	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM
Copper	33	0.94	0.17	**2.09**	0.30	-	-	0.98	0.12
Lead	41	**1.17**	0.45	**1.32**	0.16	**40.80**	**1.70**	0.87	0.19
Zinc	131	**1.07**	0.42	**1.09**	0.16	-	-	0.87	0.32

	95th Percentile	Screening Index Values Based on Comparison to							
		CCME		Ontario MOE		Kurias *et al.*		Long *et al.*	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM
Copper	50	**1.41**	0.25	**3.14**	0.46	-	-	**1.48**	0.19
Lead	55	**1.58**	0.61	**1.79**	0.22	**55.40**	**2.31**	**1.19**	0.25
Zinc	170	**1.38**	0.54	**1.42**	0.21	-	-	**1.13**	0.41

TABLE 6.1-6
COMPARISON OF MEASURED METAL LEVELS IN SEDIMENT – VANGORDA CREEK DOWNSTREAM

		Screening Index Values Based on Comparison to							
	Mean	CCME		Ontario MOE		Kurias *et al.*		Long *et al.*	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM
Copper	54	**1.52**	0.28	**3.39**	0.49	**-**	**-**	**1.59**	0.20
Lead	630	**17.99**	**6.90**	**20.31**	**2.52**	**629.53**	**26.23**	**13.48**	**2.89**
Zinc	380	**3.09**	**1.21**	**3.16**	0.46	**-**	**-**	**2.53**	0.93

		Screening Index Values Based on Comparison to							
	95th Percentile	CCME		Ontario MOE		Kurias *et al.*		Long *et al.*	
	µg/g	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM
Copper	110	**3.08**	0.56	**6.88**	**1.00**	**-**	**-**	**3.24**	0.41
Lead	2289	**65.39**	**25.07**	**73.83**	**9.15**	**2288.60**	**95.36**	**49.01**	**10.50**
Zinc	884	**7.19**	**2.81**	**7.37**	**1.08**	**-**	**-**	**5.89**	**2.16**

6.1.4 Aquatic Ecology

To assess potential effects to aquatic receptors (e.g., benthic invertebrates, arctic grayling, Chinook salmon and slimy sculpin), measured mean and 95th percentile water concentrations were compared to toxicity benchmarks presented in Section 5.1 for aquatic species. A value greater than one (1) indicates that the toxicity benchmark for an aquatic receptor is exceeded by the measured concentration. The results are presented in Table 6.1-7 for upstream Rose Creek, Table 6.1-8 for downstream Rose Creek, Table 6.1-9 for upstream Vangorda Creek and Table 6.1-10 for downstream Vangorda Creek.

With respect to the benthic invertebrate comparison, the results show that that the measured levels of ammonia and zinc at the 95th percentile were above the toxicity benchmark in Rose Creek downstream of the mine workings. For Vangorda Creek, only the 95th percentile concentration of copper in the upstream location was above the toxicity benchmark for benthic invertebrates. Given that the benthic invertebrate benchmarks were exceeded only at the 95th percentile level, exposures would be expected to be of short duration and occur only a few times in any year.

For the arctic grayling and chinook salmon, the aquatic toxicity benchmark for copper was exceeded at both the mean and 95th percentile levels in Rose and Vangorda creeks both upstream and downstream of the mine areas. Cadmium and zinc 95th percentile concentrations at the upstream locations on Rose Creek exceeded the respective toxicity benchmarks whereas, cadmium, chromium, lead and zinc 95th percentile concentrations were above benchmark values at the downstream location. In Vangorda Creek, cadmium, chromium, lead and zinc exceed the respective toxicity benchmarks for arctic grayling and Chinook salmon at the 95th percentile levels at both upstream and downstream locations. Ammonia benchmarks are only exceeded downstream in Rose Creek, this is expected to be a short-term problem which will quickly disappear. None of the measured concentrations are expected to have an adverse affect on the slimy sculpin community in Rose Creek and Vangorda Creek.

TABLE 6.1-7
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS –
UPSTREAM ROSE CREEK – MEAN VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.04
Slimy Sculpin	Goldfish	0.04

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.30
Slimy Sculpin	Common carp	0.03

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.13
Slimy Sculpin	Goldfish	0.02

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.08
Arctic Grayling/ Chinook Salmon	Brook Trout	**1.58**
Slimy Sculpin	White sucker	0.05

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.16
Slimy Sculpin	Goldfish	0.02

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	< 0.01
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.04
Slimy Sculpin	Carp	< 0.01

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.05
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.17
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.39
Slimy Sculpin	Carp	0.02

Note: nd – no data available

TABLE 6.1-7 (Cont'd)
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – UPSTREAM ROSE CREEK – 95th PERCENTILE VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.21
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.31
Slimy Sculpin	Goldfish	0.35

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.50**
Slimy Sculpin	Common carp	0.13

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.04
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.94
Slimy Sculpin	Goldfish	0.18

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.21
Arctic Grayling/ Chinook Salmon	Brook Trout	**4.18**
Slimy Sculpin	White sucker	0.12

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.23
Slimy Sculpin	Goldfish	0.03

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.03
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.05
Slimy Sculpin	Carp	< 0.01

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.06
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.45
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.04**
Slimy Sculpin	Carp	0.06

Note: nd – no data available

TABLE 6.1-8
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – DOWNSTREAM ROSE CREEK – MEAN VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.61
Arctic Grayling/ Chinook Salmon	Walleye	**1.05**
Slimy Sculpin	White sucker	0.57

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.03
Slimy Sculpin	Goldfish	0.03

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.40
Slimy Sculpin	Common carp	0.03

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.28
Slimy Sculpin	Goldfish	0.05

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.15
Arctic Grayling/ Chinook Salmon	Brook Trout	**3.03**
Slimy Sculpin	White sucker	0.09

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.48
Slimy Sculpin	Goldfish	0.07

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	< 0.01
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.12
Slimy Sculpin	Carp	< 0.01

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.13
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.59
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.35**
Slimy Sculpin	Carp	0.08

Note: nd – no data available

TABLE 6.1-8 (Cont'd)
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – DOWNSTREAM ROSE CREEK – 95th PERCENTILE VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	**1.42**
Arctic Grayling/ Chinook Salmon	Walleye	**2.43**
Slimy Sculpin	White sucker	**1.31**

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.08
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.11
Slimy Sculpin	Goldfish	0.12

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.50**
Slimy Sculpin	Common carp	0.13

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.06
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.24**
Slimy Sculpin	Goldfish	0.24

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.38
Arctic Grayling/ Chinook Salmon	Brook Trout	**7.50**
Slimy Sculpin	White sucker	0.21

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.36**
Slimy Sculpin	Goldfish	0.19

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.03
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.40
Slimy Sculpin	Carp	0.02

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.14
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.65
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	**1.64**
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**3.75**
Slimy Sculpin	Carp	0.23

Note: nd – no data available

TABLE 6.1-9
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – UPSTREAM VANGORDA CREEK – MEAN VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.02
Slimy Sculpin	Goldfish	0.03

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.70
Slimy Sculpin	Common carp	0.06

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.52
Slimy Sculpin	Goldfish	0.10

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.32
Arctic Grayling/ Chinook Salmon	Brook Trout	**6.38**
Slimy Sculpin	White sucker	0.18

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.43
Slimy Sculpin	Goldfish	0.06

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.02
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.12
Slimy Sculpin	Carp	< 0.01

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.11
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.22
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.50
Slimy Sculpin	Carp	0.03

Note: nd – no data available

TABLE 6.1-9 (Cont'd)
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – UPSTREAM VANGORDA CREEK – 95th PERCENTILE VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.07
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.10
Slimy Sculpin	Goldfish	0.11

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.08
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**5.00**
Slimy Sculpin	Common carp	0.42

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.13
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**2.76**
Slimy Sculpin	Goldfish	0.53

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	**1.29**
Arctic Grayling/ Chinook Salmon	Brook Trout	**25.75**
Slimy Sculpin	White sucker	0.74

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.82**
Slimy Sculpin	Goldfish	0.25

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.10
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.37
Slimy Sculpin	Carp	0.02

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.13
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.58
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.55
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.25**
Slimy Sculpin	Carp	0.08

Note: nd – no data available

TABLE 6.1-10
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – DOWNSTREAM VANGORDA CREEK – MEAN VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.02
Slimy Sculpin	Goldfish	0.02

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	1.00
Slimy Sculpin	Common carp	0.08

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.34
Slimy Sculpin	Goldfish	0.07

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.16
Arctic Grayling/ Chinook Salmon	Brook Trout	**3.18**
Slimy Sculpin	White sucker	0.09

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.47
Slimy Sculpin	Goldfish	0.06

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	< 0.01
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.21
Slimy Sculpin	Carp	0.01

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.10
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.32
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.73
Slimy Sculpin	Carp	0.04

Note: nd – no data available

TABLE 6.1-10 (Cont'd)
RESULTS OF ASSESSMENT FOR AQUATIC RECEPTORS – DOWNSTREAM VANGORDA CREEK – 95th PERCENTILE VALUES

Ammonia

VEC	Test Species	Screening Index
Benthic Invertebrates	Cladoceran	0.21
Arctic Grayling/ Chinook Salmon	Walleye	0.36
Slimy Sculpin	White sucker	0.19

Arsenic (mg/L)

VEC	Test Species	Screening Index
Benthic Invertebrates	Calanus sp.	0.07
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.10
Slimy Sculpin	Goldfish	0.11

Cadmium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.02
Arctic Grayling/ Chinook Salmon	Rainbow Trout	1.00
Slimy Sculpin	Common carp	0.08

Chromium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.13
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**2.73**
Slimy Sculpin	Goldfish	0.53

Copper

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.43
Arctic Grayling/ Chinook Salmon	Brook Trout	**8.50**
Slimy Sculpin	White sucker	0.24

Lead

VEC	Test Species	Screening Index
Benthic Invertebrates	Tanytarus sp.	< 0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.14**
Slimy Sculpin	Goldfish	0.16

Molybdenum

VEC	Test Species	Screening Index
Benthic Invertebrates	nd	
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.02
Slimy Sculpin	Goldfish	< 0.01

Nickel

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.03
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.40
Slimy Sculpin	Carp	0.02

Selenium

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.01
Arctic Grayling/ Chinook Salmon	Rainbow Trout	0.06
Slimy Sculpin	White Sucker	< 0.01

Zinc

VEC	Test Species	Screening Index
Benthic Invertebrates	Chironomus sp.	0.86
Arctic Grayling/ Chinook Salmon	Rainbow Trout	**1.98**
Slimy Sculpin	Carp	0.12

Note: nd – no data available

It is important to note that the screening index values are based on laboratory toxicity studies for particular species. The use of laboratory toxicity bioassays to assess the impacts of contaminants does not usually provide an adequate basis for extrapolating the effects on populations, communities, or ecosystems (Levin *et al*. 1989). Effects at higher orders of organization (i.e. populations, communities and ecosystems) can only be predicted with a detailed knowledge of the interactions among species, and the connections between biota and the biochemical processes that maintain ecosystems. Thus, it becomes difficult to measure impacts due to species specific tolerance levels, which are unknown, and complex interactions of biotic and abiotic components (Leland and Kuwabara 1985). The screening index values derived in this assessment therefore are useful only in identifying species and metals that need further investigation.

6.2 TERRESTRIAL ECOLOGY

This section presents the results of the risk characterization for terrestrial receptors assessed in the Anvil Range Mining Complex area. Risks associated with water quality (based on total metal concentrations) and sediment quality in Rose and Vangorda Creeks are discussed.

Potential toxic effects can be measured at different levels of biological and ecological organization. Screening indices provide an integrated description of the potential hazard, the exposure (or dose)-response relationship, and the exposure evaluation (U.S. EPA 1992, AIHC 1992). In this study, ecological impacts to contaminants of concern were characterized by the value of a simple screening index. This index was calculated by dividing the predicted exposure for the discharge scenarios by the benchmark toxicity value for each ecological receptor, as shown in equation (6.2-1).

$$Screening\ Index = \frac{Dose}{Toxicity\ Benchmark} \qquad (6.2\text{-}1)$$

The screening index values reported in this section are not estimates of the probability of ecological impact. Rather, the index values are positively correlated with the potential of an effect, i.e. higher index values imply a greater potential of an effect. Different magnitudes of the screening index have been used in other studies to screen for potential ecological effects. A screening index value of 1.0 has been used in some instances (e.g. Suter 1991). In this study, screening index benchmark values of less than 1 are used to reflect the fact that not all exposure pathways were accounted for in the assessment. Benchmark values were chosen based on the time that each species is assumed to spend at site and the components of the species diet accounted for in the assessment; the index benchmarks used are presented in Table 6.2-1.

TABLE 6.2-1
SCREENING INDEX BENCHMARKS SELECTED FOR THE ASSESSMENT

Receptor	Screening Index Benchmark	Selection Criteria
Black bear	0.2	Water and fish pathways only considered; at site 50% of year
Caribou	0.02	Water pathway only considered; at site 10% of year
Bald eagle	0.25	100% of diet accounted for; at site 25% of year
Red fox	0.1	Water and hare pathways only considered; at site 25% of year
Snowshoe hare	0.2	Water pathway only considered; at site 100% of year
Mink	0.85	85% of diet accounted for; at site 100% of year
Moose	0.4	Water and sediment pathways only considered; at site 100% of year
Fannin sheep	0.05	Water pathway only considered; at site 25% of year

The potential ecological effects of contaminants of concern in measured water and sediments concentrations on Rose and Vangorda creeks downstream of the mine areas were evaluated by comparing the mean and 95th percentile exposures for the selected ecological receptors to a no-effects level toxicity benchmark (NOAEL). The results from the mean and 95th percentile values are presented in Tables 6.2-2 and 6.2-3 for both Rose and Vangorda creeks. A shaded value indicates that a screening index value is above the screening index benchmarks presented in Table 6.2-1.

As seen from Tables 6.2-2 and 6.2-3, the screening index values for cadmium, chromium, copper, nickel and zinc are not exceeded for Rose Creek. The screening index values are not exceeded for cadmium, copper, nickel and zinc in Vangorda Creek. Therefore, the intakes of these metals are not a concern for any of the selected ecological receptors. Caribou, fox, hare, moose and sheep are not impacted by metal concentrations in either of these two water systems. For arsenic and selenium, screening index values for the bear and mink in Rose Creek are greater than the screening index benchmarks presented in Table 6.2-1 for both the mean and 95th percentile concentrations. Screening index values for the eagle are exceeded only at the 95th percentile concentration for selenium. The screening index value for molybdenum is exceeded for the mink. The 95th percentile exposures for molybdenum are above the toxicity benchmarks for the bear. The exceedance of a 95th percentile indicates that there may occasionally be short-term concentrations that are unacceptable to some terrestrial receptors.

In Vangorda Creek, the screening index benchmarks are exceeded by arsenic for the bear and mink. Selenium exposures result in toxicity benchmarks being exceeded for the bear, eagle and mink. Molybdenum exposures exceed benchmarks for the mink at the mean and 95th percentile concentrations and for bear at the 95th percentile only. Lead exposures exceed benchmarks at the 95th percentile concentration only for the eagle and mink. Mink exposures to chromium at the 95th percentile result in the benchmark being exceeded.

A graphical breakdown by pathway is provided in Figures 6.2-1 and 6.2-2 for the contaminant/receptor groups that exceed the screening index benchmarks for Rose Creek and Vangorda Creek. As seen in these figures, consumption of fish by bear, mink and eagle dominate the exposures. Ingestion of sediment and benthic organisms are also important pathways for the mink. Since this is a screening level assessment it was assumed that the mink spends 100% of its time and obtains all its food from downstream of the mine areas and that the bear and eagle are present at the site 50% and 25%, respectively. These assumptions result in an overestimate of exposure.

TABLE 6.2-2
SCREENING INDEX VALUES FOR TERRESTRIAL RECEPTORS – ROSE CREEK

Screening	Mean								95th Percentile							
Index Values	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	**0.83**	< 0.01	0.01	< 0.01	0.01	**5.23**	0.11	0.01	**3.49**	0.01	0.06	0.01	0.05	**18.70**	0.26	0.02
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.06	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.19	< 0.01	< 0.01
Chromium	0.01	< 0.01	0.02	< 0.01	< 0.01	0.20	0.01	< 0.01	0.02	< 0.01	0.06	< 0.01	< 0.01	0.65	0.01	< 0.01
Copper	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.06	< 0.01	< 0.01
Lead	0.01	< 0.01	0.08	< 0.01	< 0.01	0.14	0.01	< 0.01	0.03	< 0.01	**0.25**	< 0.01	< 0.01	0.38	0.02	< 0.01
Molybdenum	0.08	< 0.01	< 0.01	< 0.01	< 0.01	**1.41**	0.01	< 0.01	**0.34**	< 0.01	0.02	< 0.01	0.01	**5.43**	0.03	< 0.01
Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.04	< 0.01	< 0.01
Selenium	**0.33**	< 0.01	0.16	< 0.01	< 0.01	**12.73**	0.02	< 0.01	**1.19**	< 0.01	**0.57**	0.01	0.02	**61.17**	0.07	0.01
Zinc	< 0.01	< 0.01	0.06	< 0.01	< 0.01	0.09	< 0.01	< 0.01	0.01	< 0.01	0.10	< 0.01	< 0.01	0.21	< 0.01	< 0.01

TABLE 6.2-3
SCREENING INDEX VALUES FOR TERRESTRIAL RECEPTORS – VANGORDA CREEK

Screening	Mean								95th Percentile							
Index Values	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	**1.29**	< 0.01	0.02	< 0.01	0.01	**5.91**	0.02	< 0.01	**3.97**	0.01	0.06	0.01	0.05	**18.66**	0.11	0.02
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.16	< 0.01	< 0.01	0.01	< 0.01	0.01	< 0.01	< 0.01	0.18	< 0.01	< 0.01
Chromium	0.01	< 0.01	0.02	< 0.01	< 0.01	0.17	< 0.01	< 0.01	0.02	< 0.01	0.06	< 0.01	0.01	**1.21**	0.01	< 0.01
Copper	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.05	< 0.01	< 0.01
Lead	0.01	< 0.01	0.09	< 0.01	< 0.01	0.29	0.02	< 0.01	0.03	< 0.01	**0.28**	< 0.01	< 0.01	**1.03**	0.06	< 0.01
Molybdenum	0.13	< 0.01	0.01	< 0.01	< 0.01	**1.49**	0.01	< 0.01	**0.39**	< 0.01	0.02	< 0.01	0.01	**4.04**	0.02	< 0.01
Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01
Selenium	**0.79**	< 0.01	**0.38**	< 0.01	< 0.01	**11.59**	0.01	< 0.01	**1.35**	< 0.01	**0.65**	< 0.01	< 0.01	**11.28**	< 0.01	< 0.01
Zinc	0.01	< 0.01	0.07	< 0.01	< 0.01	0.06	< 0.01	< 0.01	0.01	< 0.01	0.12	< 0.01	< 0.01	0.13	< 0.01	< 0.01

FIGURE 6.2-1
EXPOSURE BY PATHWAY FOR ROSE CREEK RECEPTORS

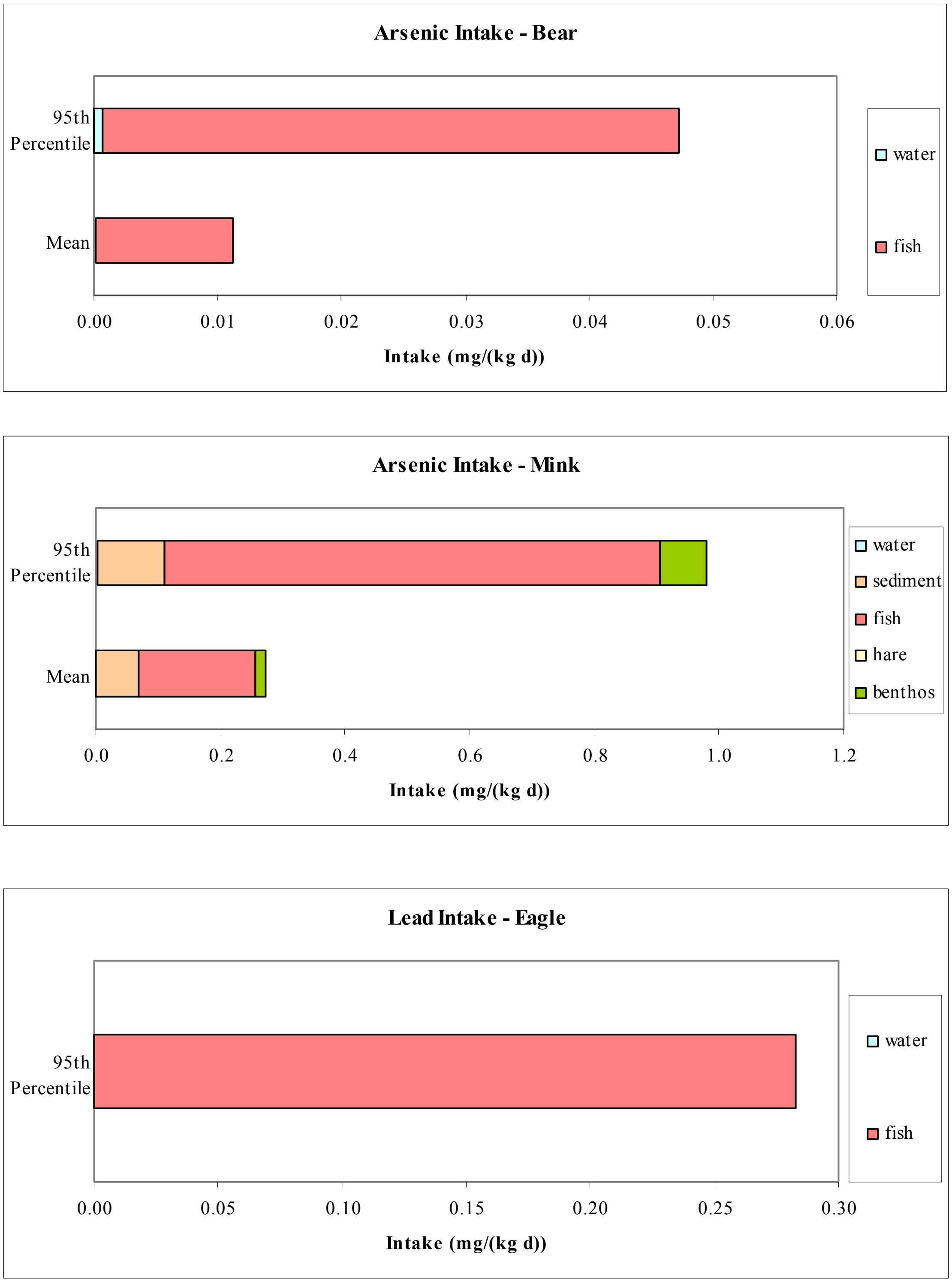
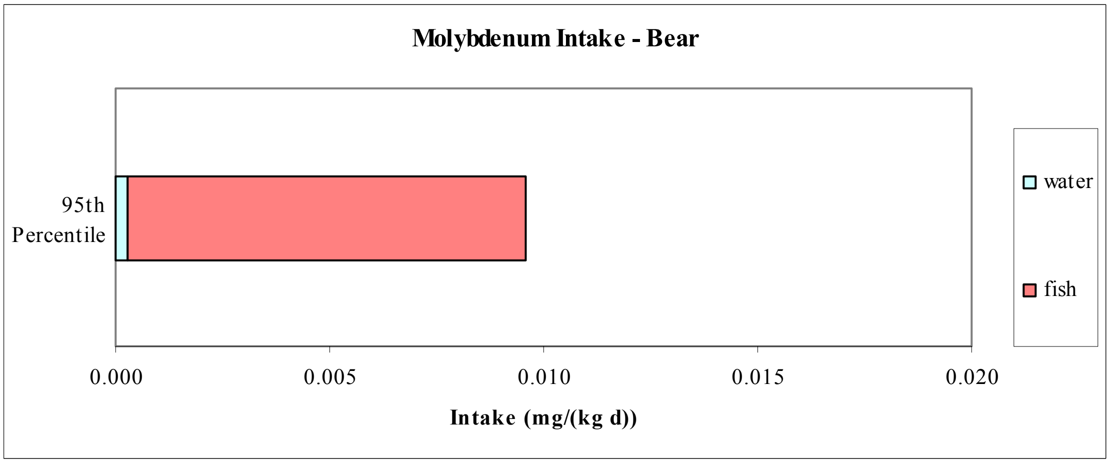


FIGURE 6.2-1 (Cont'd)
EXPOSURE BY PATHWAY FOR ROSE CREEK RECEPTORS



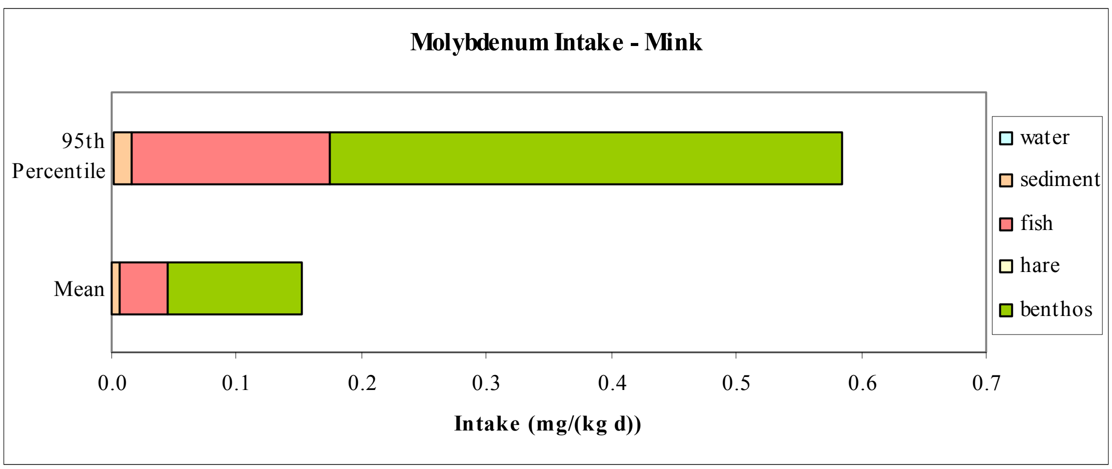
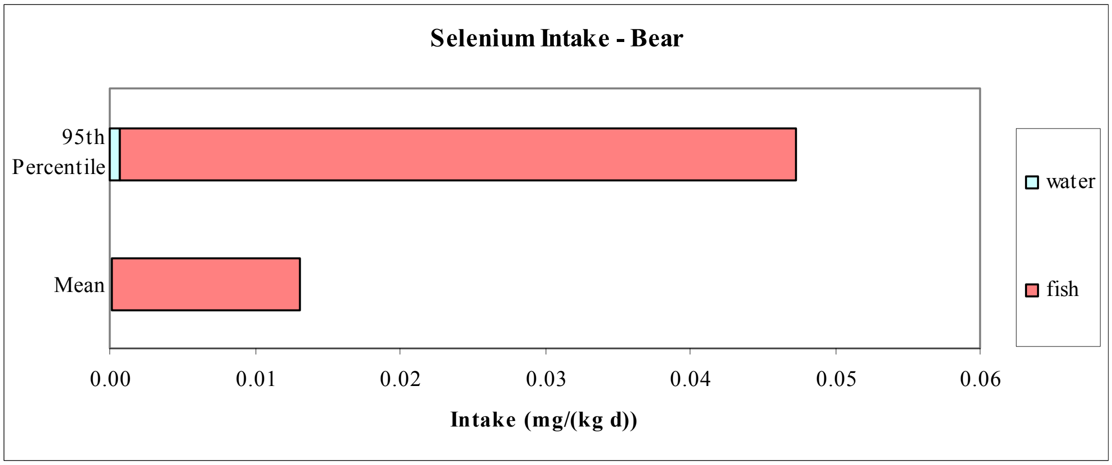
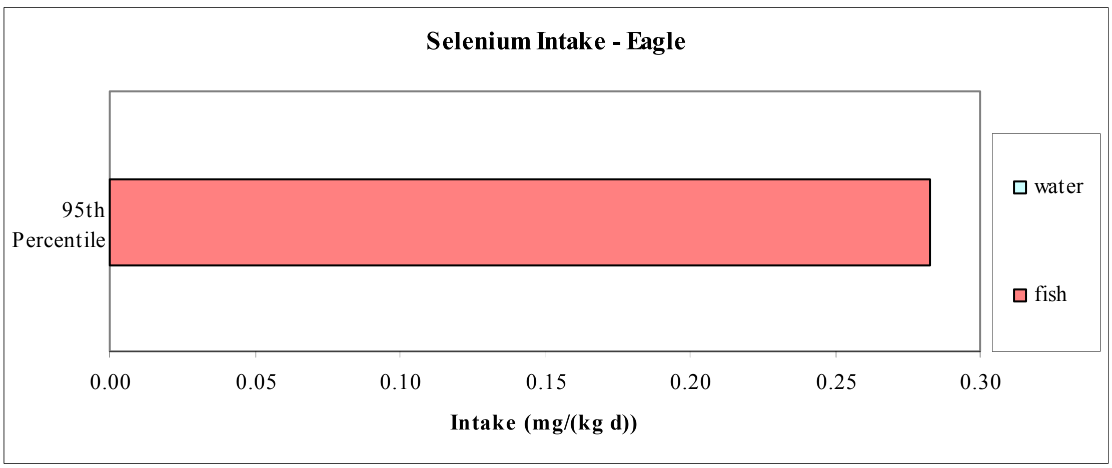


FIGURE 6.2-1 (Cont'd)
EXPOSURE BY PATHWAY FOR ROSE CREEK RECEPTORS





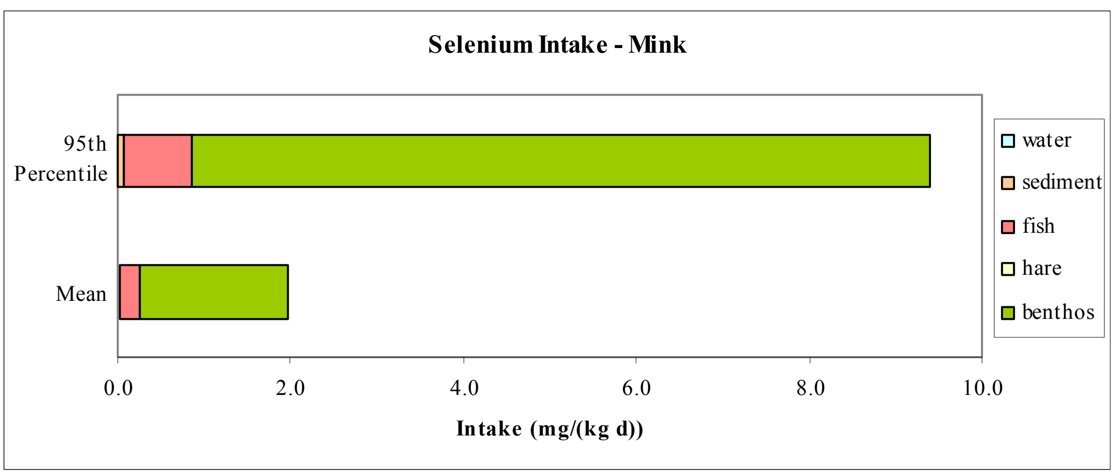
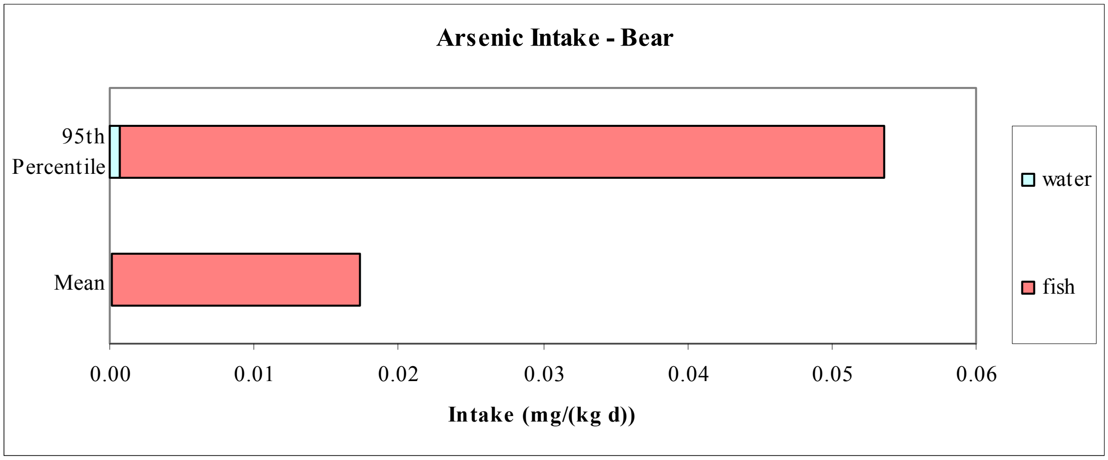
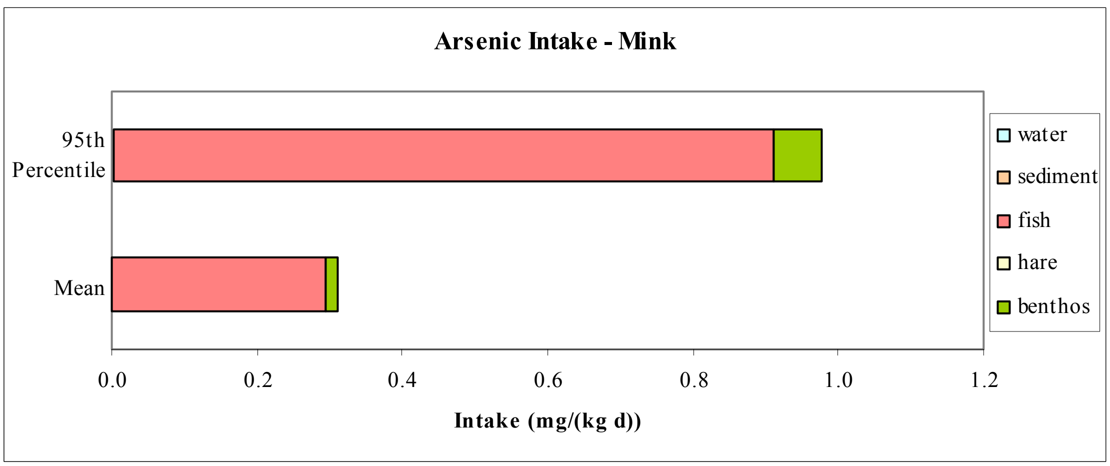


FIGURE 6.2-2
EXPOSURE BY PATHWAY FOR VANGORDA CREEK RECEPTORS





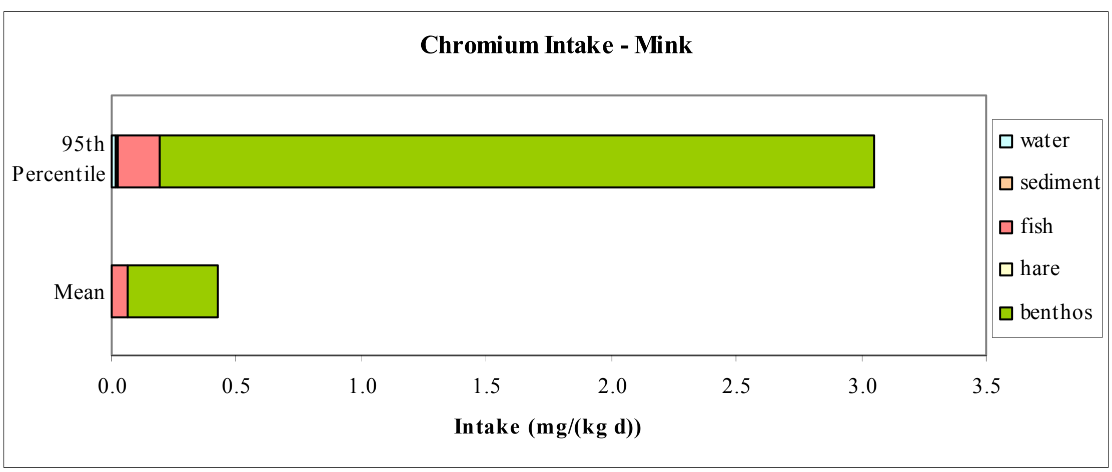
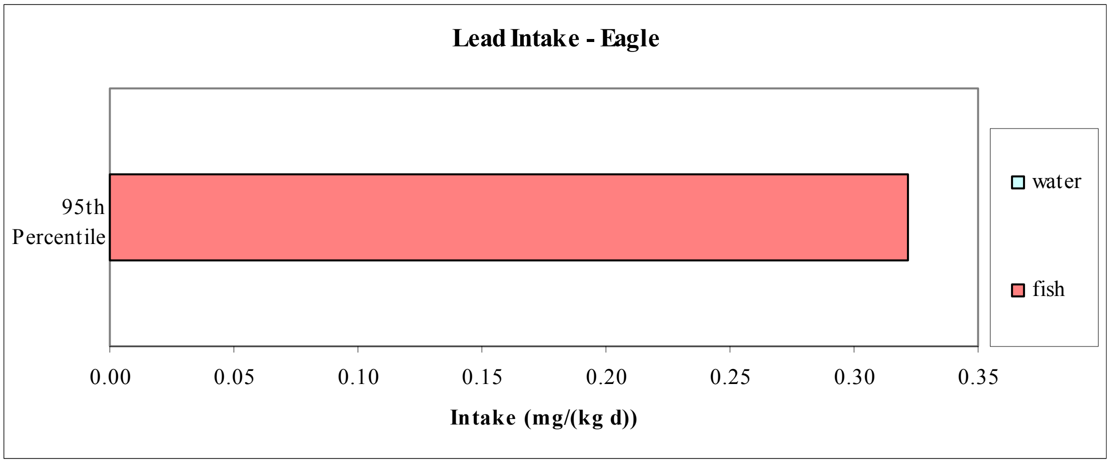


FIGURE 6.2-2 (Cont'd)
EXPOSURE BY PATHWAY FOR VANGORDA CREEK RECEPTORS



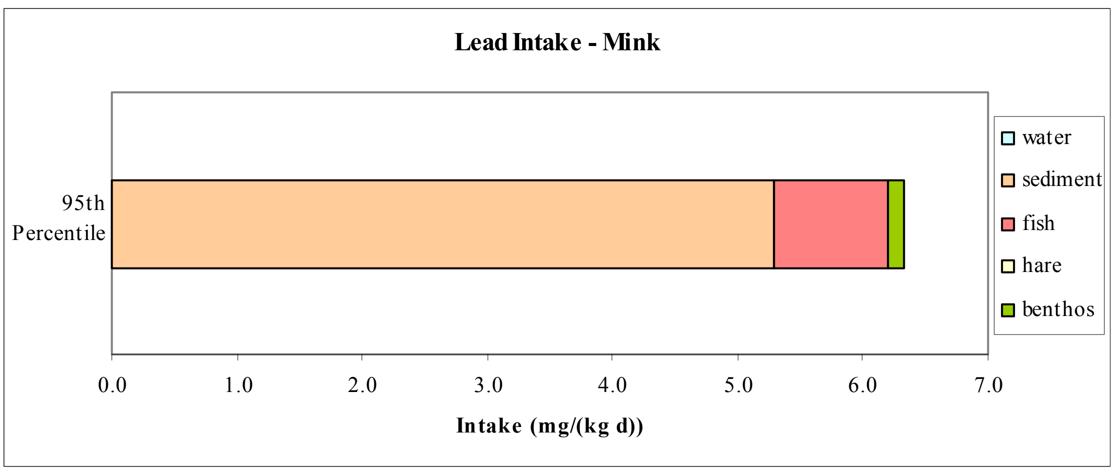
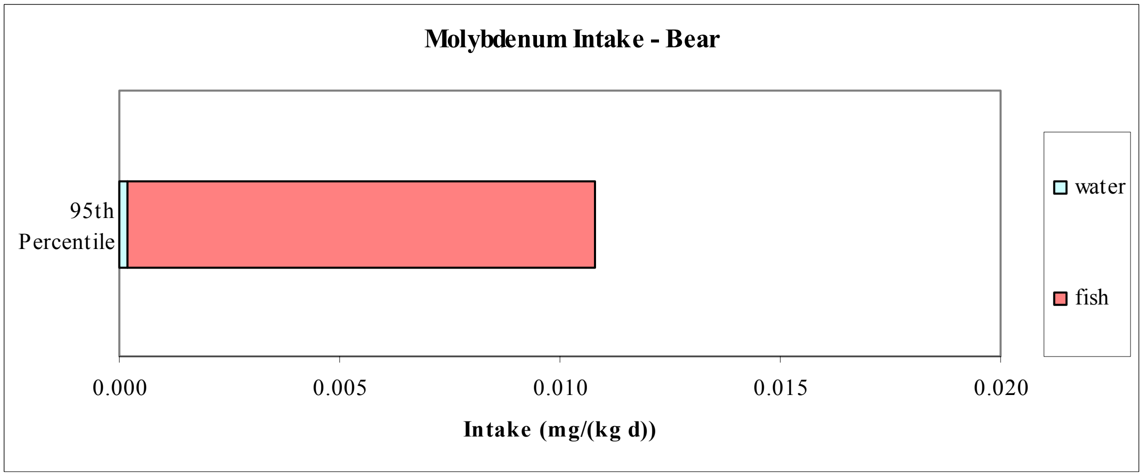


FIGURE 6.2-2 (Cont'd)
EXPOSURE BY PATHWAY FOR VANGORDA CREEK RECEPTORS



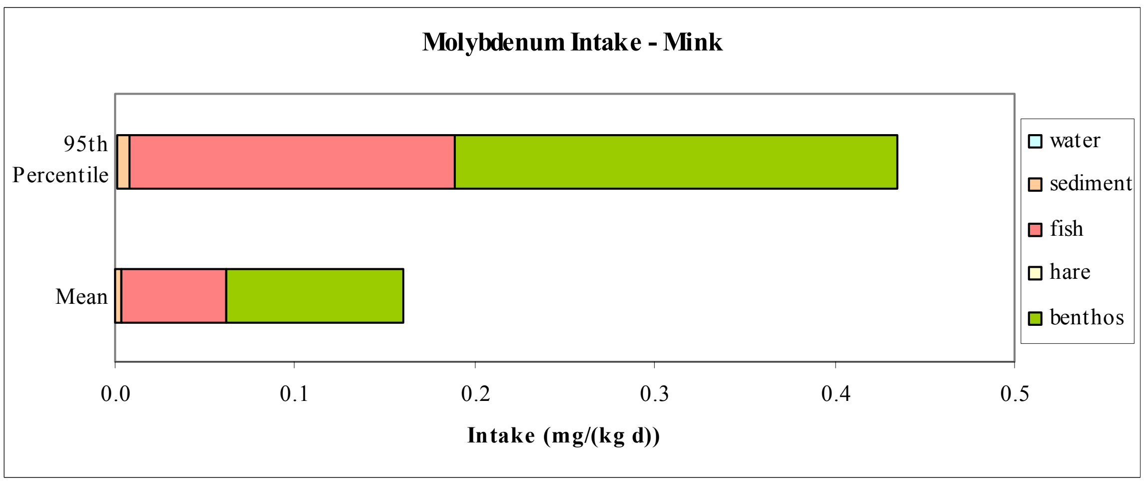
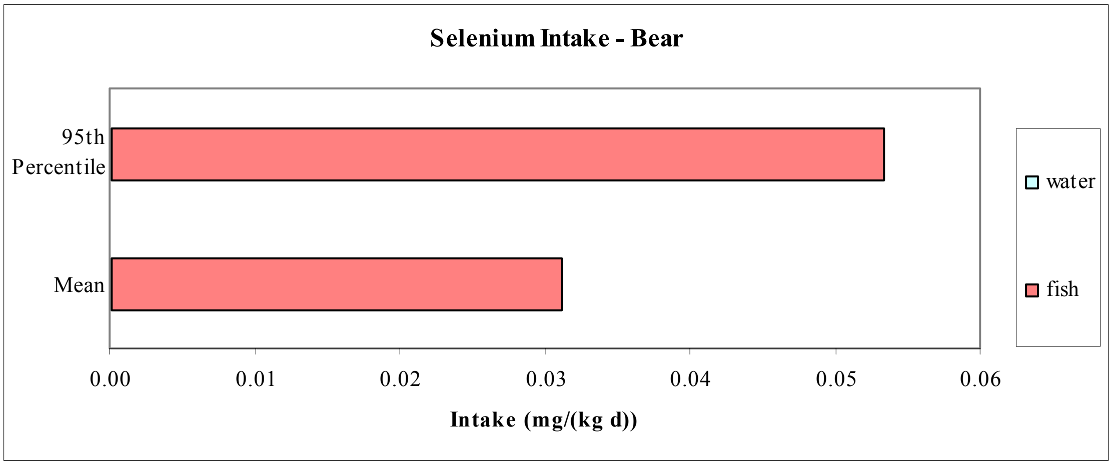
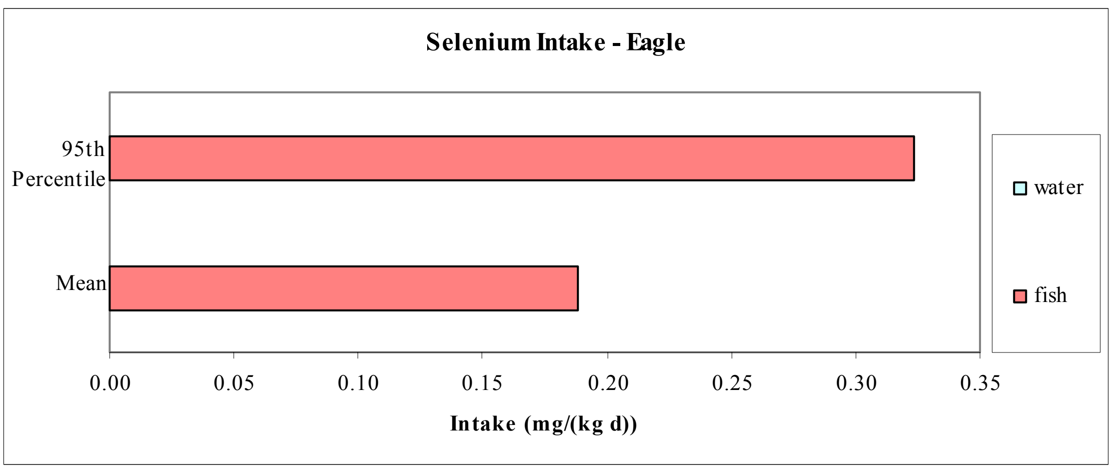
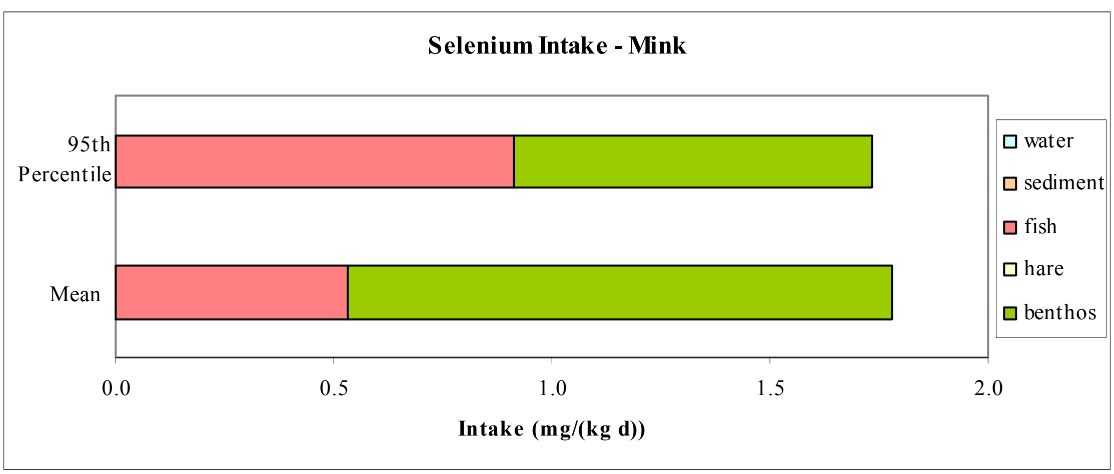


FIGURE 6.2-2 (Cont'd)
EXPOSURE BY PATHWAY FOR VANGORDA CREEK RECEPTORS







6.3 HUMAN HEALTH

This section discusses the potential human health risks associated with exposure to contaminants for the measured mean and 95th percentile total metal concentrations in Rose Creek and Vangorda Creek. The results presented here are separated into two categories: non-cancer (or chronic) effects related to arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, selenium and zinc; and, cancer effects related to a risk value for a lifetime exposure to arsenic. Skin cancer potentially arises from exposure to elevated concentrations of arsenic.

As previously discussed, the human health risk assessment (HHRA) was carried out for a hypothetical adult and child at two separate locations. Receptor 1 was defined as an adult and child who live year round near the Faro townsite in the Vangorda Creek and obtain all their drinking water, fish and wild game from the watershed downstream of the Vangorda/Grum mine area. Receptor 2 was defined as a hypothetical adult and child camper/hunter who spends 3 months each year in the Rose Creek watershed, during which time they obtain all their drinking water, fish and game from the watershed downstream of the Faro mine and tailings area.

6.3.1 Chronic (Non-carcinogenic) Effects

Estimated exposures for the adult and child human receptors were calculated using the human characteristics presented in Section 4.3. These estimates were based on the mean and 95th percentile measured metal concentrations in downstream water, sediment and fish concentrations in Rose Creek and Vangorda Creek and the estimated metal concentrations in hare, moose and caribou from downstream Rose Creek and Vangorda Creek. Estimated exposures were compared to the toxicity benchmarks (RfDs), presented in Section 5.4. It is noted however, that the exposure estimates do not account for all pathways, in particular terrestrial pathways.

Table 6.3-1 summarizes the results for Receptor 1 and Table 6.3-2 summarizes the results for Receptor 2. **Bold** values indicate that the intake of the contaminant exceeds the toxicity benchmark.

TABLE 6.3-1
SCREENING INDEX VALUES FOR RECEPTOR 1 ADULT AND CHILD

Screening Index	Adult		Child	
	Mean	95th Percentile	Mean	95th Percentile
Arsenic	**1.72**	**5.38**	**2.55**	**7.93**
Cadmium	0.41	0.80	0.57	**1.15**
Chromium	< 0.01	< 0.01	< 0.01	< 0.01
Copper	0.04	0.05	0.06	0.07
Lead	0.44	0.62	0.60	0.80
Molybdenum	0.14	0.44	0.21	0.64
Nickel	0.05	0.06	0.07	0.08
Selenium	**1.22**	**2.08**	**1.82**	**3.10**
Zinc	0.09	0.09	0.13	0.14

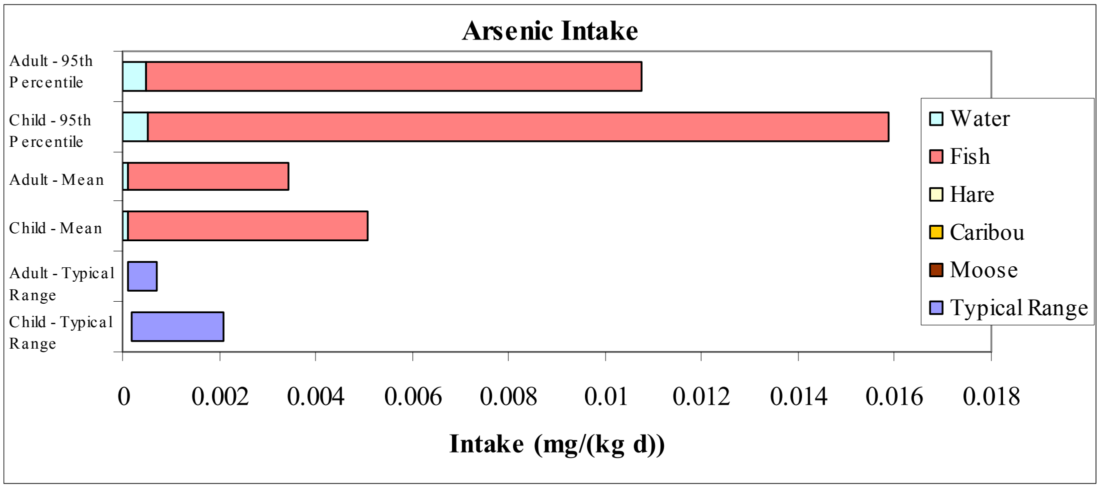
TABLE 6.3-2
SCREENING INDEX VALUES FOR RECEPTOR 2 ADULT AND CHILD

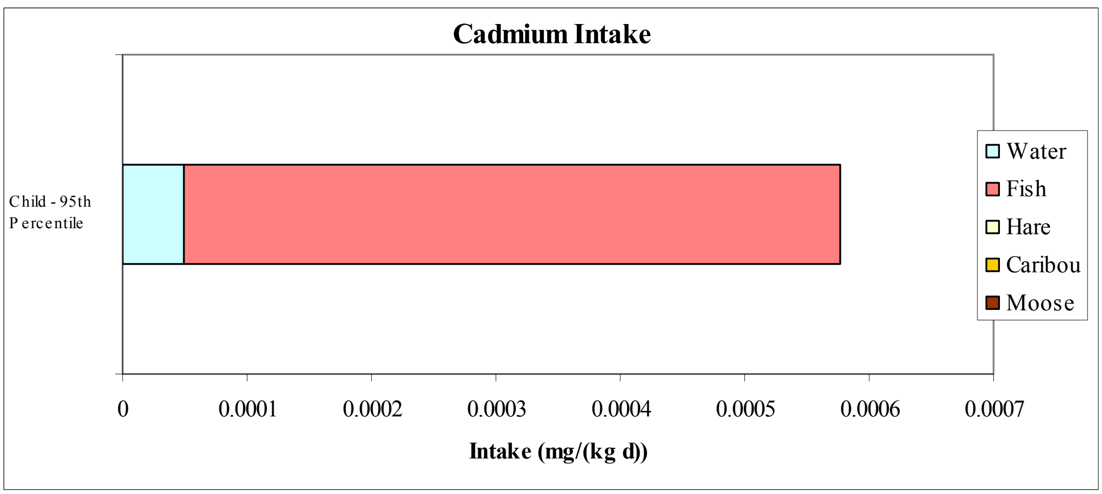
Screening Index	Adult		Child	
	Mean	95th Percentile	Mean	95th Percentile
Arsenic	0.43	**1.35**	0.64	**1.98**
Cadmium	0.10	0.20	0.14	0.29
Chromium	< 0.01	< 0.01	< 0.01	< 0.01
Copper	0.01	0.01	0.01	0.02
Lead	0.11	0.15	0.15	0.20
Molybdenum	0.04	0.11	0.05	0.16
Nickel	0.01	0.02	0.02	0.02
Selenium	0.31	0.52	0.45	0.77
Zinc	0.02	0.02	0.03	0.03

Arsenic, cadmium (95^{th} percentile exposure for the child) and selenium are indicated as a potential concern for Receptor 1 (Table 6.3-1). Figure 6.3-1 shows a breakdown by pathway for these contaminants. For all three metals, fish is the dominant pathway. To assess the likelihood of effects from the intake of arsenic under this scenario, the figures also show the typical arsenic intake levels for an adult and child from baseline levels across Canada (Environment Canada 1993). By comparison, potential exposures for Receptor 1 are above the typical Canadian adult and child. However, it is noteworthy that the exposures to the adult and child are due to the presence of the less toxic organic form of arsenic.

From Table 6.3-2 it can be seen that the estimated intakes for Receptor 2 for all contaminants except arsenic are below the associated toxicity benchmarks. Figure 6.3-2 shows a breakdown by pathway of the intake of arsenic for the camper/hunter. As seen in this figure, consumption of fish dominates the exposure. From a toxicity perspective, it is important to differentiate between the exposure to total arsenic and inorganic arsenic, given that organic arsenic has a much lower toxicity. Speciation measurements on arsenic in fish have demonstrated that nearly all of the arsenic present is in the organic form. Since the arsenic exposure is dominated by consumption of fish, it is likely that exposure to the toxic forms of arsenic has been overestimated. Additionally, mean exposure for the child is well within the typical range for Canadian children living in southern communities that do not have local arsenic issues while the adult arsenic intake is only slightly higher than the typical range.

FIGURE 6.3-1
BREAKDOWN BY PATHWAY – RECEPTOR 1 ADULT AND CHILD





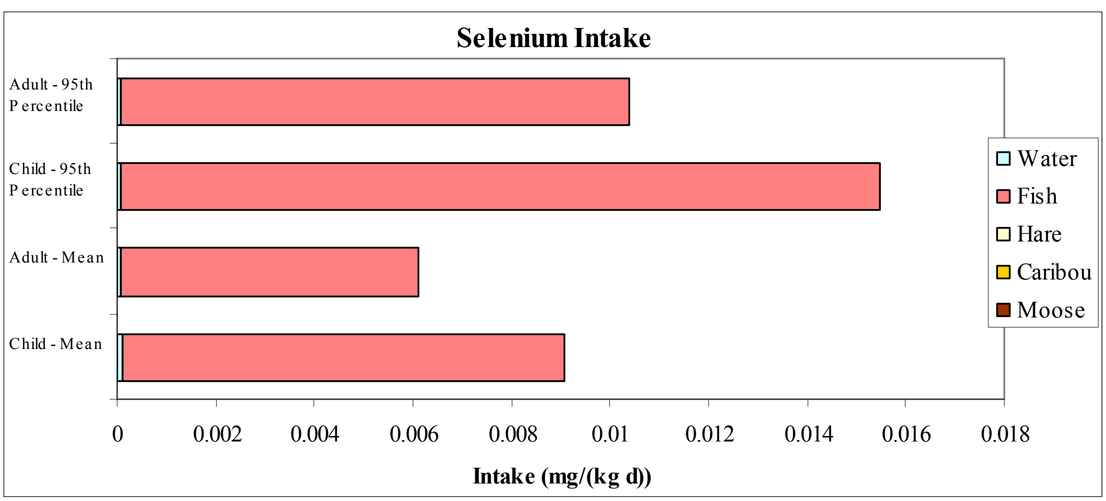
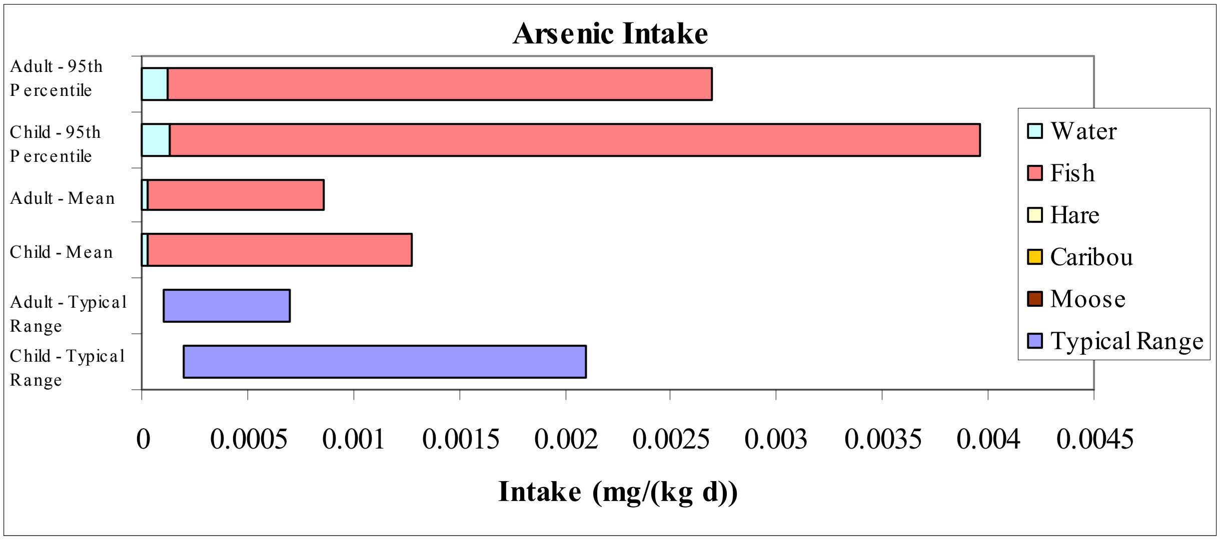


FIGURE 6.3-2
BREAKDOWN BY PATHWAY – RECEPTOR 2 HUNTER/CAMPER



6.3.2 Carcinogenic Effects

The risk levels associated with the carcinogenic effects (skin lesions) of baseline exposure (across Canada) to arsenic range from 7 x 10^{-4} to 1 x 10^{-3} for an adult. These baseline risk levels are higher than generally accepted risk levels (e.g. 1 x 10^{-5} or 1 x 10^{-6}), indicating the conservative nature of the toxicity benchmark (slope factor) provided by the U.S. EPA.

Table 6.3-3 shows the risk levels calculated for the adult and a composite receptor at the Rose Creek and Vangorda Creek locations. A composite person is used to capture the exposure from being resident in the local area over a lifetime (70 years of exposure) spanning the persons childhood and adult years. Equation (6.3-1) shows the method of calculating the carcinogenic risks.

$$Risk = Intake \times SF_o \qquad (6.3\text{-}1)$$

where:

Intake = total intake {mg/(kg d)} (estimated)
SF_o = Slope Factor – oral pathway {$(mg/(kg\ d))^{-1}$} (see Section 5.4)

TABLE 6.3-3
RISKS OF CARCINOGENIC EFFECTS FOR RECEPTORS 1 AND 2 TO ARSENIC EXPOSURE

	Adult		Composite	
	Mean	95th Percentile	Mean	95th Percentile
Receptor 1	5.2×10^{-3}	1.6×10^{-2}	5.5×10^{-3}	1.7×10^{-2}
Receptor 2	1.3×10^{-3}	4.0×10^{-3}	1.4×10^{-3}	4.3×10^{-3}

All values shown in Table 6.3-3 are greater than risk levels associated with baseline exposure. Fish consumption is the largest pathway of exposure (see Figures 6.3-1 and 6.3-2). The risk estimates summarized on Table 6.3-3 are based on the total arsenic intakes and do not account for the fact that most of the arsenic in fish exists in less toxic organic form.

6.4 UNCERTAINTY

Many areas of uncertainty attend a risk assessment. This is due to the fact that assumptions have to be made throughout the assessment either due to data gaps, environmental fate complexities or in the generalization of receptor characteristics. To be able to place a level of confidence in the results, an accounting of the uncertainty, the magnitude and type of which are important in determining the significance of the results, must be completed. In recognition of these uncertainties, some conservative assumptions are used throughout the assessment to ensure that the potential for an adverse effect would not be underestimated. Several of the major assumptions are outlined below.

The measured metal concentrations used to characterize baseline quality were based on the reported concentrations in a given watershed (Gartner Lee Limited 2002). As mentioned previously, method detection limits (MDLs) for a number of the metals were above current CCME criteria resulting in possibly a skewed distribution of the metal concentrations. This distribution could lead to overestimates of exposure.

For the pathways modelling, where data were lacking (e.g. transfer factors, physical chemical parameters, etc.) worst-case values were generally assumed. In the absence of measured data for benthic invertebrates, conservative transfer factors based on information reported in the literature were used. As these transfer factors may vary by several orders of magnitude there is uncertainty in the results. Similarly, feed-to-cow transfer factors were used for all the terrestrial mammal species since no data were available for the specific receptors chosen. There was also a lack of data for feed-to-bird transfer factors; therefore, it was conservatively assumed that these factors were the same as for chickens and in some cases cow data were used. The uncertainty in these assumptions could be reduced by gathering site-specific data.

Toxicity values for the chemicals of concern are obtained from reputable sources (e.g., U.S. DOE and U.S. EPA); however, some assumptions are made in the absence of available data. For aquatic species, toxicity data for indicator species that were most similar to the receptor species were used. Given that no adequate toxicological database is available that determines the concentrations of chemicals that impact all terrestrial ecological species, toxicity data from laboratory species such as rats and mice were used and scaled to the appropriate terrestrial receptor. Additionally, for terrestrial mammals and birds, toxicity information for a chemical was used regardless of its form in the test procedure, even though this may not be the same form used in the assessment (e.g., an oxide form compared to a more soluble form). It is hard to determine the effect of these assumptions.

Another area of uncertainty is the use of a single value for toxicity. The slope factor is selected to be very protective. The slope factor for arsenic used in the human health assessment represent risks from upper bound (95th percentile) dose-response estimates. The reference doses represent an exposure day-after-day for a lifetime. The use of an upper bound for the toxicity values ensures that the risk to humans is not underestimated. Exposures to arsenic may be overestimated since the consumption of fish (mainly the less toxic organic form) dominates the exposure.

It is currently not possible or practical to develop approaches to evaluate the validity of the toxicity benchmark assumptions on the overall assessment. As improvements occur in toxicological/human health research and assessments, the uncertainties may be reduced. However, given that the predicted impacts are not significant, it is not anticipated that these improvements would change the overall conclusion of the assessment.

The dietary characteristics of the human receptors assessed in the study were based on a dietary survey of the Dene/Metis community in the Northwest Territories as similar data were not available for the Yukon study area. It is likely that this assumption does not accurately reflect the dietary characteristics of First Nations people who live near the Anvil Range Mining Complex.

The characteristics (food, water and soil consumption) of ecological receptors were obtained from the literature. These values are generally obtained from animals in captivity and may not be fully representative of free-range animals in the wild. An underestimate of exposure might result from this but there are other conservative assumptions that may compensate (e.g. time spent in area exposed to the highest level of contamination).

Another area of uncertainty in the risk assessment is the effect of multiple contaminants. When dealing with toxic chemicals, there is potential interaction with other chemicals that may be found at the same location. It is well established that synergism, potentiation, antagonism or additivity of toxic effects occurs in the environment. A quantitative assessment of these interactions is outside the scope of this study and, in any event, would be constrained, as there is not an adequate base of toxicological evidence to quantify these interactions. This may result in an underestimate of the risk for some contaminants.

7.0 SUMMARY AND CONCLUSIONS

A Screening Level (Tier 1) risk assessment was carried out for existing conditions at the Anvil Range Mine Complex. The assessment focussed on the Rose Creek and Vangorda Creek systems. Impacts related to the aquatic pathways only were examined. Measured concentrations of contaminants in water, sediment and fish were used in the assessment. A statistical assessment of water data for 2000 and 2001 was carried out to determine the appropriate concentrations to use in the assessment. A summary of sediment concentrations sampled in 1999 was used to represent Rose Creek. Vangorda sediment concentrations were represented by a summary of sediment data from 1995 to 2001. Samples of fish tissue were collected in studies from 1974, 1975, 1976, 1977, 1992 and 1997. A statistical summary of the data was used to represent concentrations in fish for this assessment.

It is important to note that many of the method detection limits (MDLs) used in the assessment were above current Canadian Council of the Ministers of the Environment (CCME) water quality guidelines. This posed a challenge during the statistical analysis. For contaminants measured below the detection limit, it was assumed that they were present at ½ of the detection limit. This is a common rule that is applied in many assessments where there are limitations inherent in the analytical data. For arsenic and selenium, concentrations reported as less than the highest method detection limit of 0.2 mg/L were removed from the database, as there were several measurements of both elements reported at much lower concentrations.

The assessment included the following elements which are proposed and readily accepted by regulatory agencies such as Environment Canada and the U.S. EPA:

- receptor characterization;
- exposure assessment;
- hazard assessment; and
- risk characterization.

The ecological assessment considered aquatic receptors from the creek system (e.g. benthic invertebrates, pelagic and benthic fish). The aquatic ecosystem assessment considered exposure to contaminants present in both the upstream and downstream reaches of Rose Creek and Vangorda Creek. Ecological impacts in the screening level assessment were characterized by the value of a simple screening index which is derived by dividing the exposure or intake value by an appropriate toxicity benchmark. Screening index values of less than 1 are generally considered to indicated low risk of adverse effect.

In addition, pathways modelling which focused on the aquatic pathways was conducted for several terrestrial receptors to estimate their potential exposure to contaminants present downstream in these water systems. The terrestrial receptors identified for inclusion in the assessment included bear, caribou, eagle, fox, hare, mink, moose, and Fannin sheep. These receptors were chosen since they provide a range of potential exposure from the aquatic pathways. Ecological impacts in the Screening Level assessment were determined through a comparison to No Observable Adverse Effects Levels (NOAELs) obtained from literature data.

An assessment of the potential implications to human health from exposure to contaminants in the aquatic environment was also considered for four hypothetical individuals with differing lifestyle characteristics. The pathways modelling was conducted to provide estimates of the potential exposures of both adults and children living in the Vangorda Creek watershed near the Faro town site (Receptor 1) to contaminant intakes from drinking water and eating fish and wild game, which were assumed to be exposed to contaminants in Vangorda Creek. A hunter/camper adult and child (Receptor 2) were assumed to use the area downstream of the Faro mine and tailings area for three months of the year and to consume water, fish and wild game from Rose Creek. As dietary information was not available for residents of the study area, results from a regional survey of First Nations people in the Northwest Territories were used to determine the dietary characteristics for these individuals. A dietary survey of the local communities is recommended to obtain site-specific data prior to updating the human health risk assessment. Other exposure information, such as drinking water consumption and body weight was obtained from data on the general Canadian population.

In human populations, arsenic is considered to possess both carcinogenic and non-carcinogenic properties. In this study, a lifetime carcinogenic risk was estimated and non-carcinogenic impact was characterized by a comparison to the selected reference dose of arsenic. The non-carcinogenic risks associated with other contaminants of concern were also determined via comparison of estimated intakes to appropriate reference doses.

7.1 WATER QUALITY OBSERVATIONS

As discussed above, measured water quality data for the Rose Creek and Vangorda Creek systems were obtained from 2000 and 2001. Data from upstream and downstream of the mine site were analyzed separately. Table 7.1-1 summarizes the water quality predictions, as compared to the CCME water quality guidelines for the protection of aquatic life and for drinking water. As seen in the table, the measured concentrations of several of contaminants were found to be above the appropriate guidelines. However, it is noted that the method detection limits for several of the contaminants (e.g. arsenic, cadmium, chromium, lead and selemium) were equal to or greater than the respective CCME guidelines for protection of aquatic life. Furthermore, a majority of the analytical data reported for these contaminants were less than the detection limits of the contaminants, only copper and zinc were found to be present at detectable levels in a majority of the samples.

TABLE 7.1-1
COMPARISON OF MEASURED WATER QUALITY TO GUIDELINES

Contaminant	CCME Aquatic Guidelines				CCME Drinking Water Guidelines			
	Rose Creek		Vangorda Creek		Rose Creek		Vangorda Creek	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Ammonia	✔	✔	✔	✔	✔	✔	✔	✔
Arsenic	●	●	●	o	o	✔	✔	✔
Cadmium	●	●	●	●	✔	✔	o	✔
Chromium	o	●	●	●	✔	o	o	o
Copper	●	●	●	●	✔	✔	✔	✔
Lead	●	●	●	●	✔	●	o	●
Molybdenum	✔	✔	✔	✔	✔	✔	✔	✔
Nickel	✔	✔	✔	✔	✔	✔	✔	✔
Selenium	●	●	●	●	✔	o	o	✔
Zinc	o	●	o	●	✔	✔	✔	✔

Notes: o - Indicates exceedance of appropriate guideline for the measured 95th percentile only.
● - Indicates exceedance of the appropriate guideline for both the measured mean and 95th percentile values.
✔ - Indicates that measured contaminant concentration in water is below the appropriate guideline.

7.2 SEDIMENT QUALITY OBSERVATIONS

Sediment chemistry data were available on Rose Creek only for stations downstream of the mine facilities. Comparison of the mean and 95th percentile levels to CCME sediment quality guidelines showed that a number of the contaminants were above both the threshold effects and probable effects levels (see Table 7.2-1). This is not surprising given that sediments have been affected by past mining activity and that it is a naturally occurring mineralized area.

TABLE 7.2-1
COMPARISON OF MEASURED SEDIMENT QUALITY IN ROSE CREEK TO CCME GUIDELINES

Contaminant	CCME Guidelines			
	Threshold Effects		Probable Effects	
	Mean	95th	Mean	95th
Arsenic	●	●	●	●
Cadmium	●	●	✔	●
Chromium	●	●	✔	✔
Copper	●	●	✔	✔
Lead	●	●	●	●
Nickel°	●	●	●	●
Zinc	●	●	●	●

Notes: o - Indicates that the nickel guideline is an interim guideline.
● - Indicates exceedance of the appropriate guideline
✔ - Indicates that measured contaminant concentration in water is below the appropriate guideline.

For Vangorda Creek, measured sediment concentrations are available for copper, lead and zinc at both upstream (not influenced by mining operations) and downstream locations. These concentrations also exceed the appropriate sediment guidelines as seen in Table 7.2-2. The fact that the threshold effects levels are exceeded for all three metals at the upstream station confirms that elevated metal levels in the area are a natural occurrence.

TABLE 7.2-2
COMPARISON OF MEASURED SEDIMENT QUALITY IN VANGORDA CREEK TO CCME GUIDELINES

Contaminant	CCME Guidelines							
	Upstream				Downstream			
	Threshold Effects		Probable Effects		Threshold Effects		Probable Effects	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Copper	✔	●	✔	✔	●	●	✔	✔
Lead	●	●	✔	✔	●	●	●	●
Zinc	●	●	✔	✔	●	●	●	●

Notes: ● - Indicates exceedance of the appropriate guideline
✔ - Indicates that measured contaminant concentration in water is below the appropriate guideline.

7.3 ECOLOGICAL ASSESSMENT

A summary of the results of the ecological assessment for all the selected aquatic receptors and contaminants is shown in Table 7.3-1. The measured water quality indicated that the water quality in Rose Creek and Vangorda Creek is above the CCME guideline for the protection of aquatic life for a number of contaminants. For Rose Creek, measured concentrations of arsenic, cadmium, copper, lead and selenium exceed guidelines in the upstream (background) location whereas measured concentrations of arsenic, cadmium, chromium, copper, lead, selenium and zinc exceed the CCME guidelines downstream. For Vangorda Creek, measured concentrations of cadmium, chromium, copper, lead and selenium exceed the CCME guidelines both upstream and downstream and measured concentrations of zinc exceed the guidelines in the downstream location. The arsenic guideline was exceeded at the upstream locations but not at downstream locations. Because there were a number of exceedances of the guidelines, a more detailed examination of the impacts on the aquatic environment was undertaken with consideration of the specific receptors expected to be found in the local area.

The results of the ecological risk assessment showed that that the measured levels of ammonia and zinc at the 95th percentile were above the toxicity benchmarks for benthic invertebrates in Rose Creek downstream of the mine and tailings area. For Vangorda Creek, only the 95th percentile concentration of copper in the upstream location was above the toxicity benchmark for benthic invertebrates. Given that the aquatic invertebrate benchmarks were exceeded only at the 95th percentile level, exposures would be expected to be of short duration and occur only a few times in any year.

For the arctic grayling and chinook salmon, the aquatic toxicity benchmark for copper was exceeded at the mean and 95th percentile levels in both Rose and Vangorda creeks upstream and downstream of the mine areas. The 95th percentile concentrations of cadmium and zinc also exceeded the respective toxicity benchmarks and both upstream and downstream locations in Rose Creek. Chromium and lead similarly were above the toxicity benchmarks in Rose Creek downstream of the mine area at the 95th percentile level. Ammonia benchmarks are only exceeded downstream in Rose Creek, this is expected to be a short-term problem which will quickly disappear. In Vangorda Creek, the 95th percentile concentrations of chromium, lead and zinc also exceed the toxicity benchmarks for arctic grayling and Chinook salmon at both upstream and downstream locations. None of the measured concentrations are expected to have an adverse affect on the slimy sculpin community in Rose Creek and Vangorda Creek.

A summary of the results of the terrestrial ecological assessment is provided in Table 7.3-2. For the terrestrial receptors, the bear and mink exceed the NOAEL values for arsenic, molybdenum and selenium in both Rose Creek and Vangorda Creek. NOAEL values are also exceeded for the mink for exposure to chromium and lead at the 95th percentile level in Vangorda Creek. The 95th percentile concentrations of lead and selenium result in the NOAELs being exceeded by the eagle at both Rose Creek and Vangorda Creek watersheds respectively. As well, the mean selenium intake by eagle exceeds the NOAEL in Vangorda Creek. The exposure of these receptors is dominated by consumption of fish by the bear and eagle and by consumption of fish, sediments and benthic invertebrates by the mink.

Since this is a screening level assessment a number of very conservative assumptions were used to ensure that exposure to these receptors was not underestimated. It was conservatively assumed that the mink spends 100% of its time downstream of the mine and tailings area in Rose Creek and the mine area in Vangorda Creek. It has also been assumed that while the bear and eagle are on site (50% and 25% of the time respectively), they obtain all their food from downstream in Rose Creek and Vangorda Creek. These assumptions result in an overestimate of exposure and should be examined more closely in a Tier 2 quantitative risk assessment in which more realistic assumptions are used.

TABLE 7.3-1
RESULTS OF ECOLOGICAL ASSESSMENT FOR AQUATIC RECEPTORS

	Benthic Invertebrates				**Arctic Grayling**				**Chinook Salmon**				**Slimy Sculpin**			
	Rose Creek U	**Rose Creek D**	**Van. Creek U**	**Van. Creek D**	**Rose Creek U**	**Rose Creek D**	**Van. Creek U**	**Van. Creek D**	**Rose Creek U**	**Rose Creek D**	**Van. Creek U**	**Van. Creek D**	**Rose Creek U**	**Rose Creek D**	**Van. Creek U**	**Van. Creek D**
Ammonia	✓	o	✓	✓	✓	●	✓	✓	✓	●	✓	✓	✓	o	✓	✓
Arsenic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cadmium	✓	✓	✓	✓	o	o	o	✓	o	o	o	✓	✓	✓	✓	✓
Chromium	✓	✓	✓	✓	✓	o	o	o	✓	o	o	o	✓	✓	✓	✓
Copper	✓	✓	o	✓	●	●	●	●	●	●	●	●	✓	✓	✓	✓
Lead	✓	✓	✓	✓	✓	o	o	o	✓	o	o	o	✓	✓	✓	✓
Molybdenum	-	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nickel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Selenium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zinc	✓	o	✓	✓	o	●	o	o	o	●	o	o	✓	✓	✓	✓

<u>Note:</u>

● - Indicates exceedance of appropriate toxicity benchmark for the predicted mean and 95th percentile values.
o - Indicates exceedance of appropriate guideline for the measured 95th percentile only.
✓ - indicates that negative impacts are not expected.
- - not assessed.
Rose Creek U – Rose Creek Upstream of mine site.
Rose Creek D – Rose Creek Downstream of mine site.
Van. Creek U – Vangorda Creek Upstream of mine site.
Van. Creek D – Vangorda Creek Downstream of mine site.

TABLE 7.3-2
RESULTS OF ECOLOGICAL ASSESSMENT FOR TERRESTRIAL RECEPTORS

	Bear		Caribou		Eagle		Fox		Hare		Mink		Moose		Sheep	
	Rose Creek D	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**	**Rose Creek D**	**Van. Creek D**
Arsenic	●	●	✓	✓	✓	✓	✓	✓	✓	✓	●	●	✓	✓	✓	✓
Cadmium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chromium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	o	✓	✓	✓	✓
Copper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lead	✓	✓	✓	✓	o	o	✓	✓	✓	✓	✓	o	✓	✓	✓	✓
Molybdenum	o	o	✓	✓	✓	✓	✓	✓	✓	✓	●	●	✓	✓	✓	✓
Nickel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Selenium	●	●	✓	✓	o	●	✓	✓	✓	✓	●	●	✓	✓	✓	✓
Zinc	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

o - Indicates exceedance of appropriate toxicity benchmark for the measured 95th percentile only.
● - indicates exceedance of appropriate toxicity benchmark for the measured mean and 95th percentile values.
✓ - indicates that negative impacts are not expected.
Rose Creek D – Rose Creek Downstream of mine site.
Van. Creek D – Vangorda Creek Downstream of mine site.

7.4 HUMAN HEALTH ASSESSMENT

A screening level risk assessment was conducted that examined the exposure to contaminants through the aquatic pathways, with consideration of both direct exposure (e.g. drinking water) and indirect (e.g. consumption of fish) pathways of exposure to two hypothetical human (adult and child) receptors. Receptor 1 was assumed to live year round in the Vangorda Creek watershed near the Faro townsite and Receptor 2 was assumed to be a camper/hunter who lives 3 months each year in the Rose Creek watershed. As site-specific data were not available for this assessment on the dietary characteristics of local residents, representative consumption patterns of First Nations people included in a dietary survey in the Northwest Territories were used in the exposure assessment. To encompass the differences in exposure patterns in a lifetime, both an adult and a child (aged 5 to 11 years) were considered. The results of the assessment are presented on Table 7.4-1 together with identification of the sources of the dietary components.

The assessment of the daily intake of total (inorganic and organic) arsenic showed that the toxicity benchmark was exceeded for Receptor 1 at the mean and 95th percentile levels and for Receptor 2 at the 95th percentile level. This is a reflection of the dietary characteristics of these receptors, where a large portion of their food was assumed to be obtained from local sources, in particular fish from Rose and Vangorda creeks. The estimated intakes were above the range of typical intakes for Canadians living in southern communities which do not have local arsenic issues. The predicted arsenic intakes from the screening level assessment; however, are similar to exposure levels in communities with elevated arsenic levels in the local environment. Communities such as Deloro and Wawa in Ontario and other communities in Newfoundland with similar high levels of arsenic do not report high incidence of skin cancer.

From a toxicity perspective, it is important to differentiate between the exposure to total arsenic and inorganic arsenic, as organic arsenic has a much lower toxicity. Speciation measurements on arsenic in fish have demonstrated that nearly all of the arsenic present is in the organic form. Given that the arsenic exposure was dominated by consumption of fish, it is likely that an overestimate of exposure was calculated in the screening level assessment.

In addition to the non-carcinogenic effects, inorganic arsenic is a known carcinogen. An estimate of the incremental lifetime risk was made for each of the receptors. It should be noted that all risk estimates are above the risk associated with the CCME drinking water guideline.

Selenium concentrations in Vangorda Creek also resulted in the toxicity benchmark being exceeded for Receptor 1. This is again due to the consumption of fish.

It must again be emphasized that this is a screening level assessment and that many conservative assumptions were used to ensure that exposures were not underestimated. Some of these assumptions related to obtaining all drinking water downstream of the mine workings in both Rose Creek and Vangorda Creek. Additionally it was assumed that all fish and game were obtained downstream on these two watersheds.

7.5 OVERALL CONCLUSIONS AND RECOMMENDATIONS

Based on the results of a screening level assessment presented in this report, several of the metals were found to pose low risk of adverse effects on ecological or human receptors (i.e. cadmium, chromium, lead, molybdenum, nickel and zinc). Reported levels of arsenic, copper and selenium exceeded toxicity benchmarks for aquatic, terrestrial and/or human receptors however, the assessment of arsenic and selenium exposures were affected by the high method detection limits used in the analysis of surface water quality samples. The lack of resolution in these data may have affected the assessment. A Tier 2 assessment will be needed in order to determine whether impacts are likely. However, based on these results it is recommended that:

- detection limits that are lower than the CCME aquatic guidelines be used in all subsequent monitoring programs;
- bioavailability studies be carried out on sediments to determine whether the metals present in the sediment are available for uptake by biological species;
- metal concentrations in benthic invertebrates be measured. This has been suggested previously and is part of the current field program;
- a community survey be carried out to determine the time someone from the nearby community would spend on site;
- a dietary survey be carried out to determine the amount of country food (i.e. berries, fish and game) that residents in the local area consume and the extent to which these food items are currently or may in the future be, obtained from the local area.

The above information would reduce the uncertainty in carrying out the Tier 2 analysis. Additionally, it is recommended that:

- terrestrial pathways should be included in a Tier 2 assessment to more fully consider the total exposure and risk to the ecological receptors and human receptors.

TABLE 7.4-1
RESULTS OF HUMAN HEALTH ASSESSMENT

	Receptor 1 – Local Resident		**Receptor 2 – Hunter/Camper**	
Dietary Component and Source				
Drinking Water	Vangorda Creek[b]		Rose Creek	
Moose	Vangorda Creek watershed downstream of Vangorda/Grum mine areas		Rose Creek watershed downstream of Faro mine and tailings areas	
Caribou	Vangorda Creek watershed downstream of Vangorda/Grum mine areas		Rose Creek watershed downstream of Faro mine and tailings areas	
Small Game (hare)	Vangorda Creek watershed downstream of Vangorda/Grum mine areas		Rose Creek watershed downstream of Faro mine and tailings areas	
Fish[c]	Vangorda Creek		Rose Creek	
Results of Non-Carcinogenic Effects Assessment				
	Adult	**Child**	**Adult**	**Child**
Arsenic	●	●	o	o
Cadmium	✓	o	✓	✓
Chromium	✓	✓	✓	✓
Copper	✓	✓	✓	✓
Lead	✓	✓	✓	✓
Molybdenum	✓	✓	✓	✓
Nickel	✓	✓	✓	✓
Selenium	●	●	✓	✓
Zinc	✓	✓	✓	✓
Results of Carcinogenic Effects Assessment				
	Adult	**Composite Adult**	**Adult**	**Composite Adult**
Arsenic	>d.w. risk	>d.w. risk	>d.w. risk	>d.w. risk

Notes:

● - Indicates exceedance of appropriate toxicity benchmark for the measured mean and 95th percentile values.

o - Indicates exceedance of appropriate toxicity benchmark for the measured 95th percentile only.

✓ - Indicates that negative impacts are not expected.

d.w.risk - Risk levels associated with CCME Drinking Water Guideline.

Risk levels of $1x10^{-3}$ (i.e. risk of 1 in 1,000) are associated with drinking water containing 25 µg/L arsenic (CCME Drinking Water Guideline).

[a] – It was assumed that the Ross River hunter/camper would spend 25% of the year on the Anvil Mine Site in the vicinity of Rose Creek.

[b] – It was assumed that a resident of Faro obtains his/her water from Vangorda Creek.

[c] – It was assumed that chinook salmon was obtained from Vangorda Creek and arctic grayling from Rose Creek.

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APPENDIX A

DETAILED EXPOSURE CALCULATIONS FOR THE ECOLOGICAL RISK ASSESSMENT

APPENDIX A: DETAILED EXPOSURE CALCULATIONS FOR THE ECOLOGICAL RISK ASSESSMENT

This appendix details the approach taken in the ERA to assess the exposures to contaminants of concern for the aquatic receptors and the intakes of contaminants of concern by the terrestrial receptors. As the exposure assessment for aquatic receptors was straightforward, most of the discussion pertains to the methodology followed to estimate intakes for each of the exposure pathways for terrestrial receptors. Detailed results of the estimated intakes by pathways are also presented.

A.1 AQUATIC ECOLOGICAL RECEPTORS

Potential impacts from metals to aquatic ecological receptors were assessed by the comparison of the measured water and sediment concentrations with toxicity benchmarks (discussed in Section 5.1) for each of the receptors. Therefore, further calculation of exposure to aquatic receptors was not required. A discussion of the predicted impacts and their significance is provided in Section 6.1.

A.2 TERRESTRIAL ECOLOGICAL RECEPTORS

The assessment of metal intakes by terrestrial species considered exposure through the ingestion pathway. Estimated rates of metal ingestion were calculated for the terrestrial receptors, using the environmental concentrations reported in Section 2.2 and receptor characteristics outlined in Section 4.1. Ingestion pathways considered in the assessment included consumption of water, fish, aquatic plants, benthic animals and sediments from Rose Creek and Vangorda Creek. Equation (A-1) shows the calculation for exposure through the ingestion of water, and equations (A-2) and (A-3) show the calculations for the sediment and food ingestion pathways.

For water ingestion:

$$I_{water} = \frac{C_{water} \times R_{water} \times F_{site}}{BW} \qquad \text{(A-1)}$$

where:

I_{water}	=	exposure to contaminant through the water pathway [mg/(kg d)] {summarized in Tables A.2-1}
C_{water}	=	measured water concentration, mean or 95th percentile [mg/L] {see Table 6.1-1}
R_{water}	=	water ingestion rate [L/d] {see Table 4.1-1}
F_{site}	=	fraction of time at site [-] {see Table 4.1-1}
BW	=	body weight [kg] {see Table 4.1-1}

For sediment ingestion:

$$I_{sediment} = \frac{C_{sediment} \times R_{sediment} \times F_{site}}{BW} \qquad \text{(A-2)}$$

where:

$I_{sediment}$ = exposure to contaminant through the sediment pathway [mg/(kg d)] {summarized in Tables A.2-2}

$C_{sediment}$ = measured sediment concentration, mean or 95th percentile [mg/kg] {see Tables 6.1-3}

$R_{sediment}$ = sediment ingestion rate [kg/d] {see Table 4.1-1}

F_{site} = fraction of time at site [-] {see Table 4.1-1}

BW = body weight [kg] {see Table 4.1-1}

For food ingestion:

$$I_i = \frac{C_i \times R_{food} \times F_i \times F_{site}}{BW} \qquad \text{(A-3)}$$

where:

I_i = exposure to contaminant through the pathway i = benthic invertebrates, fish, hare [mg/(kg d)] {summarized in Tables A.2-3 to A.2-5}

C_i = derived concentration for i = benthic invertebrates and hare [mg/kg] {see Appendix B} and measured concentration for fish {see Tables 2.2-8 and 2.2-9}

R_{food} = food ingestion rate [kg/d] {see Table 4.1-1}

F_i = fraction of food that is i = benthic invertebrates, fish and hare [-] {see Table 4.1-1}

F_{site} = fraction of time at site [-] {see Table 4.1-1}

BW = body weight [kg] {see Table 4.1-1}

Table A.2-6 presents the total exposure for each terrestrial receptor, as calculated following the method described.

TABLE A.2-1
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – WATER PATHWAY
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.00016	0.00005	0.00005	0.00012	0.00057	0.00063	0.00030	0.00009	0.00069	0.00022	0.00022	0.00051	0.00240	0.00264	0.00128	0.00039
Cadmium	0.00002	0.00001	0.00001	0.00002	0.00008	0.00009	0.00004	0.00001	0.00009	0.00003	0.00003	0.00006	0.00030	0.00033	0.00016	0.00005
Chromium	0.00042	0.00013	0.00014	0.00031	0.00145	0.00160	0.00077	0.00023	0.00182	0.00057	0.00059	0.00134	0.00630	0.00693	0.00336	0.00101
Copper	0.00035	0.00011	0.00011	0.00026	0.00121	0.00133	0.00065	0.00019	0.00087	0.00027	0.00028	0.00064	0.00300	0.00330	0.00160	0.00048
Lead	0.00030	0.00010	0.00010	0.00022	0.00105	0.00116	0.00056	0.00017	0.00087	0.00027	0.00028	0.00064	0.00300	0.00330	0.00160	0.00048
Molybdenum	0.00008	0.00002	0.00002	0.00006	0.00026	0.00029	0.00014	0.00004	0.00029	0.00009	0.00009	0.00021	0.00100	0.00110	0.00053	0.00016
Nickel	0.00022	0.00007	0.00007	0.00016	0.00077	0.00085	0.00041	0.00012	0.00072	0.00023	0.00023	0.00053	0.00250	0.00275	0.00133	0.00040
Selenium	0.00015	0.00005	0.00005	0.00011	0.00052	0.00057	0.00028	0.00008	0.00075	0.00024	0.00024	0.00055	0.00260	0.00286	0.00139	0.00042
Zinc	0.00188	0.00059	0.00061	0.00138	0.00650	0.00715	0.00347	0.00104	0.00520	0.00163	0.00168	0.00383	0.01800	0.01980	0.00960	0.00289

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.00013	0.00004	0.00004	0.00010	0.00046	0.00051	0.00025	0.00007	0.00064	0.00020	0.00021	0.00047	0.00220	0.00242	0.00117	0.00035
Cadmium	0.00006	0.00002	0.00002	0.00004	0.00020	0.00022	0.00011	0.00003	0.00006	0.00002	0.00002	0.00004	0.00020	0.00022	0.00011	0.00003
Chromium	0.00050	0.00016	0.00016	0.00037	0.00174	0.00191	0.00093	0.00028	0.00402	0.00126	0.00130	0.00295	0.01390	0.01529	0.00741	0.00223
Copper	0.00037	0.00011	0.00012	0.00027	0.00127	0.00140	0.00068	0.00020	0.00098	0.00031	0.00032	0.00072	0.00340	0.00374	0.00181	0.00055
Lead	0.00030	0.00009	0.00010	0.00022	0.00103	0.00113	0.00055	0.00017	0.00072	0.00023	0.00023	0.00053	0.00250	0.00275	0.00133	0.00040
Molybdenum	0.00007	0.00002	0.00002	0.00005	0.00024	0.00026	0.00013	0.00004	0.00017	0.00005	0.00006	0.00013	0.00060	0.00066	0.00032	0.00010
Nickel	0.00038	0.00012	0.00012	0.00028	0.00133	0.00146	0.00071	0.00021	0.00072	0.00023	0.00023	0.00053	0.00250	0.00275	0.00133	0.00040
Selenium	0.00011	0.00003	0.00004	0.00008	0.00038	0.00042	0.00020	0.00006	0.00007	0.00002	0.00002	0.00005	0.00025	0.00028	0.00013	0.00004
Zinc	0.00101	0.00031	0.00032	0.00074	0.00348	0.00383	0.00186	0.00056	0.00274	0.00086	0.00089	0.00202	0.00950	0.01045	0.00507	0.00153

TABLE A.2-2
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – SEDIMENT PATHWAY
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	no path	no path	0.066898	0.000888	no path	no path	no path	no path	no path	no path	0.107762	0.001431	no path
Cadmium	no path	no path	no path	no path	no path	0.005198	0.000069	no path	no path	no path	no path	no path	no path	0.00827	0.00011	no path
Chromium	no path	no path	no path	no path	no path	0.143705	0.001908	no path	no path	no path	no path	no path	no path	0.177986	0.002363	no path
Copper	no path	no path	no path	no path	no path	0.187711	0.002492	no path	no path	no path	no path	no path	no path	0.344144	0.004569	no path
Lead	no path	no path	no path	no path	no path	0.583991	0.007753	no path	no path	no path	no path	no path	no path	1.394247	0.018509	no path
Molybdenum	no path	no path	no path	no path	no path	0.006537	0.000087	no path	no path	no path	no path	no path	no path	0.01416	0.000188	no path
Nickel	no path	no path	no path	no path	no path	0.270755	0.003594	no path	no path	no path	no path	no path	no path	0.654377	0.008687	no path
Selenium	no path	no path	no path	no path	no path	0.026473	0.000351	no path	no path	no path	no path	no path	no path	0.057473	0.000763	no path
Zinc	no path	no path	no path	no path	no path	1.552713	0.020613	no path	no path	no path	no path	no path	no path	3.26738	0.043376	no path

Note: no path - indicates that the pathway is not relevant for a receptor

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	no path	no path	0.000329	0.000004	no path	no path	no path	no path	no path	no path	0.001575	0.000021	no path
Cadmium	no path	no path	no path	no path	no path	0.019866	0.000264	no path	no path	no path	no path	no path	no path	0.019866	0.000264	no path
Chromium	no path	no path	no path	no path	no path	0.001206	0.000016	no path	no path	no path	no path	no path	no path	0.009633	0.000128	no path
Copper	no path	no path	no path	no path	no path	0.125202	0.001662	no path	no path	no path	no path	no path	no path	0.254331	0.003376	no path
Lead	no path	no path	no path	no path	no path	1.454214	0.019306	no path	no path	no path	no path	no path	no path	5.286666	0.070184	no path
Molybdenum	no path	no path	no path	no path	no path	0.002772	0.000037	no path	no path	no path	no path	no path	no path	0.00693	0.000092	no path
Nickel	no path	no path	no path	no path	no path	0.058374	0.000775	no path	no path	no path	no path	no path	no path	0.109725	0.001457	no path
Selenium	no path	no path	no path	no path	no path	0.000019	<0.000001	no path	no path	no path	no path	no path	no path	0.000013	<0.000001	no path
Zinc	no path	no path	no path	no path	no path	0.876876	0.011641	no path	no path	no path	no path	no path	no path	2.041809	0.027106	no path

Note: no path - indicates that the pathway is not relevant for a receptor

TABLE A.2-3
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – FISH PATHWAY
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.011041	no path	0.06699	no path	no path	0.188689	no path	no path	0.046527	no path	0.2823	no path	no path	0.795145	no path	no path
Cadmium	0.000173	no path	0.00105	no path	no path	0.002958	no path	no path	0.000475	no path	0.00288	no path	no path	0.008112	no path	no path
Chromium	0.003817	no path	0.02316	no path	no path	0.065234	no path	no path	0.00978	no path	0.05934	no path	no path	0.167141	no path	no path
Copper	0.004732	no path	0.02871	no path	no path	0.080867	no path	no path	0.010695	no path	0.06489	no path	no path	0.182774	no path	no path
Lead	0.013953	no path	0.08466	no path	no path	0.238459	no path	no path	0.046527	no path	0.2823	no path	no path	0.795145	no path	no path
Molybdenum	0.00225	no path	0.01365	no path	no path	0.038448	no path	no path	0.009305	no path	0.05646	no path	no path	0.159029	no path	no path
Nickel	0.005459	no path	0.03312	no path	no path	0.093288	no path	no path	0.023264	no path	0.14115	no path	no path	0.397573	no path	no path
Selenium	0.012915	no path	0.07836	no path	no path	0.220714	no path	no path	0.046527	no path	0.2823	no path	no path	0.795145	no path	no path
Zinc	0.134983	no path	0.819	no path	no path	2.30685	no path	no path	0.229437	no path	1.39209	no path	no path	3.921054	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.017246	no path	0.10464	no path	no path	0.294736	no path	no path	0.053004	no path	0.3216	no path	no path	0.90584	no path	no path
Cadmium	0.000821	no path	0.00498	no path	no path	0.014027	no path	no path	0.001825	no path	0.01107	no path	no path	0.031181	no path	no path
Chromium	0.003644	no path	0.02211	no path	no path	0.062277	no path	no path	0.009874	no path	0.05991	no path	no path	0.168747	no path	no path
Copper	0.004969	no path	0.03015	no path	no path	0.084923	no path	no path	0.009325	no path	0.05658	no path	no path	0.159367	no path	no path
Lead	0.016737	no path	0.10155	no path	no path	0.286033	no path	no path	0.053004	no path	0.3216	no path	no path	0.90584	no path	no path
Molybdenum	0.003451	no path	0.02094	no path	no path	0.058981	no path	no path	0.010601	no path	0.06432	no path	no path	0.181168	no path	no path
Nickel	0.008623	no path	0.05232	no path	no path	0.147368	no path	no path	0.026502	no path	0.1608	no path	no path	0.45292	no path	no path
Selenium	0.031091	no path	0.18864	no path	no path	0.531336	no path	no path	0.053351	no path	0.3237	no path	no path	0.911755	no path	no path
Zinc	0.167419	no path	1.0158	no path	no path	2.86117	no path	no path	0.275282	no path	1.67025	no path	no path	4.704538	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

TABLE A.2-4
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – BENTHIC INVERTEBRATE PATHWAY
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	no path	no path	0.017562	no path	no path	no path	no path	no path	no path	no path	0.073944	no path	no path
Cadmium	no path	no path	no path	no path	no path	0.032864	no path	no path	no path	no path	no path	no path	no path	0.12324	no path	no path
Chromium	no path	no path	no path	no path	no path	0.29783	no path	no path	no path	no path	no path	no path	no path	1.29402	no path	no path
Copper	no path	no path	no path	no path	no path	0.049707	no path	no path	no path	no path	no path	no path	no path	0.12324	no path	no path
Lead	no path	no path	no path	no path	no path	0.053918	no path	no path	no path	no path	no path	no path	no path	0.15405	no path	no path
Molybdenum	no path	no path	no path	no path	no path	0.106808	no path	no path	no path	no path	no path	no path	no path	0.4108	no path	no path
Nickel	no path	no path	no path	no path	no path	0.007908	no path	no path	no path	no path	no path	no path	no path	0.025675	no path	no path
Selenium	no path	no path	no path	no path	no path	1.708928	no path	no path	no path	no path	no path	no path	no path	8.54464	no path	no path
Zinc	no path	no path	no path	no path	no path	6.6755	no path	no path	no path	no path	no path	no path	no path	18.486	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	no path	no path	0.014173	no path	no path	no path	no path	no path	no path	no path	0.067782	no path	no path
Cadmium	no path	no path	no path	no path	no path	0.08216	no path	no path	no path	no path	no path	no path	no path	0.08216	no path	no path
Chromium	no path	no path	no path	no path	no path	0.357396	no path	no path	no path	no path	no path	no path	no path	2.85506	no path	no path
Copper	no path	no path	no path	no path	no path	0.052172	no path	no path	no path	no path	no path	no path	no path	0.139672	no path	no path
Lead	no path	no path	no path	no path	no path	0.052891	no path	no path	no path	no path	no path	no path	no path	0.128375	no path	no path
Molybdenum	no path	no path	no path	no path	no path	0.098592	no path	no path	no path	no path	no path	no path	no path	0.24648	no path	no path
Nickel	no path	no path	no path	no path	no path	0.013659	no path	no path	no path	no path	no path	no path	no path	0.025675	no path	no path
Selenium	no path	no path	no path	no path	no path	1.248832	no path	no path	no path	no path	no path	no path	no path	0.8216	no path	no path
Zinc	no path	no path	no path	no path	no path	3.57396	no path	no path	no path	no path	no path	no path	no path	9.7565	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

TABLE A.2-5
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – HARE PATHWAY
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Cadmium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Chromium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Copper	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Lead	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Molybdenum	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Nickel	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Selenium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Zinc	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Cadmium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Chromium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Copper	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Lead	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Molybdenum	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Nickel	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Selenium	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path
Zinc	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path	no path	no path	no path	<0.00001	no path	<0.00001	no path	no path

Note: no path - indicates that the pathway is not relevant for a receptor

TABLE A.2-6
TERRESTRIAL ECOLOGICAL RECEPTOR INTAKE – TOTAL
ROSE CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.0112	0.0001	0.0670	0.0001	0.0006	0.2738	0.0012	0.0001	0.0472	0.0002	0.2825	0.0005	0.0024	0.9795	0.0027	0.0004
Cadmium	0.0002	<0.0001	0.0011	<0.0001	0.0001	0.0411	0.0001	<0.0001	0.0006	<0.0001	0.0029	0.0001	0.0003	0.1400	0.0003	<0.0001
Chromium	0.0042	0.0001	0.0233	0.0003	0.0015	0.5084	0.0027	0.0002	0.0116	0.0006	0.0599	0.0013	0.0063	1.6461	0.0057	0.0010
Copper	0.0051	0.0001	0.0288	0.0003	0.0012	0.3196	0.0031	0.0002	0.0116	0.0003	0.0652	0.0006	0.0030	0.6535	0.0062	0.0005
Lead	0.0143	0.0001	0.0848	0.0002	0.0011	0.8775	0.0083	0.0002	0.0474	0.0003	0.2826	0.0006	0.0030	2.3467	0.0201	0.0005
Molybdenum	0.0023	<0.0001	0.0137	0.0001	0.0003	0.1521	0.0002	<0.0001	0.0096	0.0001	0.0566	0.0002	0.0010	0.5851	0.0007	0.0002
Nickel	0.0057	0.0001	0.0332	0.0002	0.0008	0.3728	0.0040	0.0001	0.0240	0.0002	0.1414	0.0005	0.0025	1.0804	0.0100	0.0004
Selenium	0.0131	<0.0001	0.0784	0.0001	0.0005	1.9567	0.0006	0.0001	0.0473	0.0002	0.2825	0.0006	0.0026	9.4001	0.0021	0.0004
Zinc	0.1369	0.0006	0.8196	0.0014	0.0065	10.5422	0.0241	0.0010	0.2346	0.0016	1.3938	0.0038	0.0180	25.6942	0.0530	0.0029

Note: no path - indicates that the pathway is not relevant for a receptor

VANGORDA CREEK DOWNSTREAM

mg/(kg d)	Mean								95th Percentile							
	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep	Bear	Caribou	Eagle	Fox	Hare	Mink	Moose	Sheep
Arsenic	0.0174	<0.0001	0.1047	0.0001	0.0005	0.3097	0.0002	0.0001	0.0536	0.0002	0.3218	0.0005	0.0022	0.9776	0.0012	0.0004
Cadmium	0.0009	<0.0001	0.0050	<0.0001	0.0002	0.1163	0.0004	<0.0001	0.0019	<0.0001	0.0111	<0.0001	0.0002	0.1334	0.0004	<0.0001
Chromium	0.0041	0.0002	0.0223	0.0004	0.0017	0.4228	0.0009	0.0003	0.0139	0.0013	0.0612	0.0030	0.0139	3.0487	0.0075	0.0022
Copper	0.0053	0.0001	0.0303	0.0003	0.0013	0.2637	0.0023	0.0002	0.0103	0.0003	0.0569	0.0007	0.0034	0.5571	0.0052	0.0005
Lead	0.0170	0.0001	0.1016	0.0002	0.0010	1.7943	0.0199	0.0002	0.0537	0.0002	0.3218	0.0005	0.0025	6.3236	0.0715	0.0004
Molybdenum	0.0035	<0.0001	0.0210	0.0001	0.0002	0.1606	0.0002	<0.0001	0.0108	0.0001	0.0644	0.0001	0.0006	0.4352	0.0004	0.0001
Nickel	0.0090	0.0001	0.0524	0.0003	0.0013	0.2209	0.0015	0.0002	0.0272	0.0002	0.1610	0.0005	0.0025	0.5911	0.0028	0.0004
Selenium	0.0312	<0.0001	0.1887	0.0001	0.0004	1.7806	0.0002	0.0001	0.0534	<0.0001	0.3237	0.0001	0.0003	1.7336	0.0001	<0.0001
Zinc	0.1684	0.0003	1.0161	0.0007	0.0035	7.3158	0.0135	0.0006	0.2780	0.0009	1.6711	0.0020	0.0095	16.5133	0.0322	0.0015

Note: no path - indicates that the pathway is not relevant for a receptor

APPENDIX B

CALCULATED ENVIRONMENTAL CONCENTRATIONS AND TRANSFER FACTORS

APPENDIX B: CALCULATED ENVIRONMENTAL CONCENTRATIONS AND TRANSFER FACTORS

This appendix presents the components and calculations for deriving environmental concentrations in media other than the sampled water, sediment and fish. Section B.1 shows the transfer factors used for the assessment, and Section B.2 describes the equations for the calculation. Section B.3 shows the calculations for deriving the contaminant concentrations in hare, moose and caribou flesh.

B.1 TRANSFER FACTORS

The measured concentration of contaminants in water is used to derive the concentration in sediment, benthic invertebrates and fish. Table B.1-1 presents the transfer factors used in this assessment. Concentrations are calculated always for benthic invertebrates and if measured data were not available for sediment and fish.

TABLE B.1-1
TRANSFER FACTORS FOR
SEDIMENT, BENTHIC INVERTEBRATES AND FISH

	Water-to-			Reference		
	Sediment	Benthic Invertebrates	Fish	Sediment	Benthic Invertebrates	Fish
	L/kg (dw)	L/kg (ww)	L/kg (ww)			
Arsenic	31	300	1000	U.S. EPA 1998	Napier et al. 1988	CSA 1987
Cadmium	4300	4000	250	U.S. EPA 1998	U.S. EPA 1979, SENES 1987	U.S. EPA 1998
Chromium	30	2000	200	Bechtel Jacobs 1998	Napier et al. 1988	CSA 1987, NCRP 1996
Copper	28500	400	2500	U.S. EPA 1998	Napier et al. 1988	Napier et al. 1988
Lead	270	500	2000	Bechtel Jacobs 1998	Napier et al. 1988	Napier et al. 1988
Molybdenum	500	4000	10	COGEMA 2000	U.S. EPA 1979	IAEA 1994
Nickel	1900	100	307	U.S. EPA 1998	U.S. EPA 1979	U.S. EPA 1998
Selenium	2.2	32000	130	U.S. EPA 1998	NTIS 1985	IAEA 1994
Zinc	500	10000	2500	IAEA 1994, Bechtel Jacobs 1998	Napier et al. 1988	Napier et al. 1988

B.2 CALCULATIONS FOR SEDIMENT, BENTHIC INVERTEBRATES AND FISH

The following equations show the calculations for deriving the sediment concentration (B-1), the benthic invertebrate concentration (B-2) and the fish concentration (B-3) from measured water concentrations.

$$C_{aq\ veg} = TF_{aq\ veg} \times C_{water} \qquad \text{(B-1)}$$

where:

$C_{aq\ veg}$ = calculated concentration in sediment [mg/kg]

$TF_{aq\ veg}$ = water-to-sediment distribution coefficient [L/kg (dw)] {see Table B.1-1}
C_{water} = measured water concentration [mg/L]

$$C_{benthos} = TF_{benthos} \times C_{water} \tag{B-2}$$

where:
$C_{benthos}$ = calculated concentration in benthic invertebrates [mg/kg (ww)]
$TF_{benthos}$ = water-to-benthic invertebrates transfer factor [L/kg (ww)] {see Table B.1-1}
C_{water} = measured water concentration [mg/L]

$$C_{fish} = TF_{fish} \times C_{water} \tag{B-3}$$

where:
C_{fish} = calculated concentration in fish [mg/kg (ww)]
TF_{fish} = water-to-fish transfer factor [L/kg (ww)] {see Table B.1-1}
C_{water} = measured water concentration [mg/L]

B.3 CALCULATIONS FOR HARE, MOOSE AND CARIBOU CONCENTRATIONS

The concentration of contaminants in hare, moose and caribou flesh are needed for the human health assessment and for food chain effects for terrestrial receptors. Equation (B-4) shows the calculation for deriving the hare, moose and caribou concentrations from their predicted contaminant intakes.

$$C_{flesh} = TF_{food-to-flesh} \times Exposure \times BW \tag{B-4}$$

where:
C_{flesh} = calculated concentration in hare, moose or caribou flesh [mg/kg]
TF = food-to-flesh transfer factor [day/kg] {see Table B.3-1}
Exposure = calculated contaminant ingestion [mg/kg day] {see Table A.2-6}
BW = body weight of hare or duck [kg] {see Table 4.1-1}

TABLE B.3-1
TRANSFER FACTORS FEED-TO-BEEF

	Feed-to-Beef	Reference
	d/kg (ww)	
Arsenic	0.02	NCRP 1996
Cadmium	0.00012	U.S. EPA 1998
Chromium	0.03	NCRP 1996
Copper	0.01	Baes et al. 1994, NCRP 1996
Lead	0.0003	U.S. EPA 1998
Molybdenum	0.001	IAEA 1994
Nickel	0.006	IAEA 1994, Baes et al. 1994, U.S. EPA 1998, NCRP 1996
Selenium	0.015	IAEA 1994, Baes et al. 1994, U.S. EPA 1998, NCRP 1996
Zinc	0.10	NCRP 1996

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APPENDIX C

DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

APPENDIX C: DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

The exposure assessment for metals to humans considered the ingestion pathways only. The individual pathways exposure estimates are shown in Table C-1 for the two hypothetical receptors considered in this assessment.

Intakes by human receptors were calculated following equation (C-1) for the water pathway and equation (C-2) for the food pathway. Total intakes of each of the metals are the sum of the water and food pathways.

For water ingestion:

$$I_{water} = \frac{C_{water} \times R_{water} \times F_{site}}{BW} \tag{C-1}$$

where:

I_{water}	=	exposure to contaminant through the water pathway [mg/(kg d)] {see Table C-1}
C_{water}	=	measured water concentration [mg/L] {see Table 6.1-1}
R_{water}	=	water ingestion rate [L/d] {see Section 4.2}
F_{site}	=	fraction of time at site [-] {see Section 4.2}
BW	=	body weight [kg] {see Section 4.2}

For food ingestion:

$$I_i = \frac{C_i \times R_{food} \times F_i \times F_{site}}{BW} \tag{C-2}$$

where:

I_i	=	exposure to contaminant through the pathway i = fish, hare, moose and caribou [mg/(kg d)] {see Table C-1}
C_i	=	concentration of i = fish, hare, moose and caribou [mg/kg]
R_{food}	=	food ingestion rate [kg/d] {see Table 4.2-2}
F_i	=	fraction of food that is i = fish, hare, moose and caribou [-] {see Section 4.2}
F_{site}	=	fraction of time at site [-] {see Section 4.2}
BW	=	body weight [kg] {see Section 4.2}

For the assessment of risks associated with carcinogenic chemicals (i.e. arsenic), a composite receptor was also considered to capture the exposure over the complete lifetime of a human, growing from a child to an adult at the site. For the composite intake calculation, the intakes of the adult and child receptors were weighted according to assumed duration of exposures, as shown in equation (C-3).

$$I_{composite} = \frac{\left(I_{child} \times D_{child} + I_{adult} \times D_{adult}\right)}{L} \qquad \text{(C-3)}$$

where:

$I_{composite}$	=	total intake for composite human receptor [mg/(kg d)] {see Table C-1}
I_{child}	=	total intake for child human receptor [mg/(kg d)] {see Table C-1}
D_{child}	=	duration of child exposure [yr] {assumed to be 11}
I_{adult}	=	total intake for adult human receptor [mg/(kg d)] {see Table C-1}
D_{adult}	=	duration of adult exposure [yr] {assumed to be 59}
L	=	lifetime duration [yr] {assumed to be 70}

Table C-1 summarizes the estimated metal intakes by pathway for the adult, child and composite receptors.

TABLE C-1
ESTIMATED EXPOSURE TO HUMAN RECEPTORS – RECEPTOR 1, LOCAL RESIDENT

	Mean						95th Percentile					
	Adult Intake (mg/(kg d))						Adult Intake (mg/(kg d))					
	Water	Fish	Hare	Moose	Caribou	Total	Water	Fish	Hare	Moose	Caribou	Total
Arsenic	0.0001	0.0033	<0.0001	<0.0001	<0.0001	0.0034	0.0005	0.0103	<0.0001	<0.0001	<0.0001	0.0108
Cadmium	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	0.0004
Chromium	0.0004	0.0007	<0.0001	<0.0001	<0.0001	0.0011	0.0032	0.0019	<0.0001	<0.0001	<0.0001	0.0051
Copper	0.0003	0.0012	<0.0001	<0.0001	<0.0001	0.0015	0.0008	0.0012	<0.0001	<0.0001	<0.0001	0.0020
Lead	0.0002	0.0006	<0.0001	<0.0001	<0.0001	0.0008	0.0006	0.0006	<0.0001	<0.0001	<0.0001	0.0011
Molybdenum	0.0001	0.0007	<0.0001	<0.0001	<0.0001	0.0007	0.0001	0.0021	<0.0001	<0.0001	<0.0001	0.0022
Nickel	0.0003	0.0007	<0.0001	<0.0001	<0.0001	0.0010	0.0006	0.0007	<0.0001	<0.0001	<0.0001	0.0013
Selenium	0.0001	0.0060	<0.0001	<0.0001	<0.0001	0.0061	0.0001	0.0103	<0.0001	<0.0001	<0.0001	0.0104
Zinc	0.0008	0.0261	<0.0001	<0.0001	<0.0001	0.0270	0.0022	0.0261	<0.0001	0.0001	<0.0001	0.0284
	Composite Adult Intake (mg/(kg d))						Composite Adult Intake (mg/(kg d))					
Arsenic	0.0001	0.0036	<0.0001	<0.0001	<0.0001	0.0037	0.0005	0.0111	<0.0001	<0.0001	<0.0001	0.0116
	Child Intake (mg/(kg d))						Child Intake (mg/(kg d))					
	Water	Fish	Hare	Moose	Caribou	Total	Water	Fish	Hare	Moose	Caribou	Total
Arsenic	0.0001	0.0050	<0.0001	<0.0001	<0.0001	0.0051	0.0005	0.0153	<0.0001	<0.0001	<0.0001	0.0159
Cadmium	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	0.0006
Chromium	0.0004	0.0011	<0.0001	<0.0001	<0.0001	0.0015	0.0034	0.0029	<0.0001	<0.0001	<0.0001	0.0063
Copper	0.0003	0.0019	<0.0001	<0.0001	<0.0001	0.0022	0.0008	0.0019	<0.0001	<0.0001	<0.0001	0.0027
Lead	0.0003	0.0009	<0.0001	<0.0001	<0.0001	0.0011	0.0006	0.0009	<0.0001	<0.0001	<0.0001	0.0015
Molybdenum	0.0001	0.0010	<0.0001	<0.0001	<0.0001	0.0011	0.0001	0.0031	<0.0001	<0.0001	<0.0001	0.0032
Nickel	0.0003	0.0010	<0.0001	<0.0001	<0.0001	0.0014	0.0006	0.0010	<0.0001	<0.0001	<0.0001	0.0016
Selenium	0.0001	0.0090	<0.0001	<0.0001	<0.0001	0.0091	0.0001	0.0154	<0.0001	<0.0001	<0.0001	0.0155
Zinc	0.0009	0.0390	<0.0001	0.0001	<0.0001	0.0399	0.0023	0.0390	<0.0001	0.0002	0.0001	0.0416

Note: the composite intake is only applicable to the assessment for carcinogens, thus only arsenic is assessed

TABLE C-1 (Cont'd)
ESTIMATED EXPOSURE TO HUMAN RECEPTORS – RECEPTOR 2, HUNTER/CAMPER

	Mean						95th Percentile					
	Adult Intake (mg/(kg d))						Adult Intake (mg/(kg d))					
	Water	Fish	Hare	Moose	Caribou	Total	Water	Fish	Hare	Moose	Caribou	Total
Arsenic	<0.0001	0.0008	<0.0001	<0.0001	<0.0001	0.0009	0.0001	0.0026	<0.0001	<0.0001	<0.0001	0.0027
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0001
Chromium	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003	0.0008	0.0005	<0.0001	<0.0001	<0.0001	0.0013
Copper	0.0001	0.0003	<0.0001	<0.0001	<0.0001	0.0004	0.0002	0.0003	<0.0001	<0.0001	<0.0001	0.0005
Lead	0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0003
Molybdenum	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	0.0005
Nickel	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0002	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003
Selenium	<0.0001	0.0015	<0.0001	<0.0001	<0.0001	0.0015	<0.0001	0.0026	<0.0001	<0.0001	<0.0001	0.0026
Zinc	0.0002	0.0065	<0.0001	<0.0001	<0.0001	0.0067	0.0005	0.0065	<0.0001	<0.0001	<0.0001	0.0071
	Composite Adult Intake (mg/(kg d))						Composite Adult Intake (mg/(kg d))					
Arsenic	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	0.0009	0.0001	0.0028	<0.0001	<0.0001	<0.0001	0.0029
	Child Intake (mg/(kg d))						Child Intake (mg/(kg d))					
	Water	Fish	Hare	Moose	Caribou	Total	Water	Fish	Hare	Moose	Caribou	Total
Arsenic	<0.0001	0.0012	<0.0001	<0.0001	<0.0001	0.0013	0.0001	0.0038	<0.0001	<0.0001	<0.0001	0.0040
Cadmium	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0001
Chromium	0.0001	0.0003	<0.0001	<0.0001	<0.0001	0.0004	0.0009	0.0007	<0.0001	<0.0001	<0.0001	0.0016
Copper	0.0001	0.0005	<0.0001	<0.0001	<0.0001	0.0005	0.0002	0.0005	<0.0001	<0.0001	<0.0001	0.0007
Lead	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003	0.0002	0.0002	<0.0001	<0.0001	<0.0001	0.0004
Molybdenum	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0008	<0.0001	<0.0001	<0.0001	0.0008
Nickel	0.0001	0.0003	<0.0001	<0.0001	<0.0001	0.0003	0.0002	0.0003	<0.0001	<0.0001	<0.0001	0.0004
Selenium	<0.0001	0.0022	<0.0001	<0.0001	<0.0001	0.0023	<0.0001	0.0039	<0.0001	<0.0001	<0.0001	0.0039
Zinc	0.0002	0.0098	<0.0001	<0.0001	<0.0001	0.0100	0.0006	0.0098	<0.0001	<0.0001	<0.0001	0.0104

Note: the composite intake is only applicable to the assessment for carcinogens, thus only arsenic is assessed