Human Health and Ecological Risk Assessment (HHERA)
Nanisivik Mine, Baffin Island, Nunavut

Response to Peer Review Comments

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ATTACHMENT

1.0 INTRODUCTION

Nunavut Water Board has provided CanZinco Limited with peer review comments on the HHERA from a number of sources:

- Indian and Northern Affairs Canada (INAC), who also commissioned the consulting firm EBA Engineering Consultants (Yellowknife, NT), who in turn subcontracted Dr. Robert Lockhart of the consulting firm BC Research (Vancouver, BC);
- Acres International, commissioned by Nunavut Water Board, and Dillon Consulting, subcontracted by Acres International on behalf of Nunavut Water Board;
- AMEC Earth & Environmental (Calgary, AB), commissioned by Nunavut Unngavik Inc. (Cambridge Bay, Nunavut);
- Nunavut Water Board, issues raised by residents of Arctic Bay; and
- Government of Nunavut, Department of Justice (Iqaluit, Nunavut).

This document provides a response to comments on the HHERA. There were a number of comments that were raised by more than one reviewer, and these are addressed in the first section ("Common Review Comments") of this response document. Responses to individual peer review comments ("Individual Review Comments"), which are not otherwise captured in the common comments, are provided in the second section.

Reviewer comments are reproduced in italics, and as much as possible, reference is made to the original review comment, rather than to summaries of the reviews. JWEL text is in normal font. Some re-ordering of comments has been made, to group together comments that are related to each other, or repeat.

Comments that have resulted in modifications to the report and the Soil Quality Remedial Objectives (SQROs) are highlighted in **bold 14 point font** (normal font size is 12 point). All other comments are addressed herein but do not require any report modifications.

2.0 COMMON REVIEW COMMENTS

These comments were raised by more than one peer reviewer of the HHERA.

2.1 Common Comment 1

Does the 1985 soil geochemistry data accurately reflect natural background conditions and is it appropriate for use in the risk assessment?

Comments on the use of the 1985 "background" soils data are common to both the Ecological Risk Assessment (ERA) and the Human Health Risk Assessment (HHRA). This question applies to copper, lead, and zinc as these are the only metals for which 1985 background data were available.

For both the HHRA and the ERA, the 1985 data set was used in the decision tree that provided "rules" to determine which substances should be carried forward in the risk assessment process. Specifically, Box 5 in the decision tree (Figure 4 in JWEL 2003) queries whether the exposure point concentration (EPC) is greater than the expected background concentration for each substance. If so, then the risk assessment proceeds for that substance. However, if the EPC is not greater than the background concentration, then the risk assessment should not proceed, because it is concluded that the substance is present due to a pre-existing natural condition.

Ultimately, it should be noted that none of these metals (copper, lead or zinc) were screened out of consideration based on this data, although it would have been scientifically defensible to do so based on the Canadian Council of Ministers of the Environment (CCME) guidelines for determining site specific soil remediation criteria.

Human Health Risk Assessment

As shown in Table 6.1 (JWEL 2003) for the town site area, both lead and zinc were carried forward in the risk assessment. Copper concentrations based upon the 2002 data did not exceed relevant guidelines for human health, therefore copper was screened out without reference to background data. The EPC for zinc was higher than the background concentration, indicating that zinc concentrations had increased since the 1985 soils survey and therefore this was carried forward. However for lead, the EPC was not significantly different from the background concentration, and was carried forward in any case. This was a decision made based upon professional judgement, and therefore imparts a level of conservatism to the process.

In the general mine area, copper concentrations did not exceed applicable guidelines for human health, so there was no need to compare to background data. Lead and zinc concentrations exceeded generic guidelines for human health, and in both cases the EPC values were higher than the background values. Therefore, both lead and zinc were carried forward in the HHRA.

In the HHRA, the naturally occurring background soil concentrations (BSCs) are also incorporated into the Estimated Daily Intake (EDIvalue used in the risk calculations. Separate BSCs were calculated for the town site, the dock, and the general mine area.

As has been pointed out by several reviewers, and we were aware of, the 1985 data indicates that the lead and zinc levels measured in the townsite and at the dock are elevated relative to the levels in the general mine area. We acknowledge that lead and zinc levels in the town and dock sites were likely impacted by mine operations but we remain confident that the general mine area, away from the town, dock, and roads would not have been impacted and do provide a reliable estimate of natural background conditions. Therefore, in response to this concern, JWEL have modified the HHRA to discard the use of separate background concentrations for each study area and to apply the general mine area background concentrations to all three areas. This change will simplify and clarify the risk assessment process and will hopefully remove any doubt about the applicability of the background data.

Ecological Risk Assessment

The only use of the 1985 soils data in the ERA was in the same decision tree as the HHRA (i.e., Figure 4 in JWEL 2003) to determine whether each heavy metal or trace element should be included in the risk assessment. However, the relevant guidelines for ecological receptors are not the same as for human receptors, so although the underlying decision tree is the same, the selection of chemicals of potential concern (COPCs) is not identical. Table 7.1 in JWEL (2003) provides details of the COPC selection process for ecological receptors at the town site, dock, and general mine areas.

At the town site, the maximum concentrations of copper, lead and zinc in the 2002 data sets all exceeded generic guidelines for soil quality. Reference was subsequently made to the 1985 background data, and it was determined that the EPC values for copper and lead were not significantly higher than the 1985 background values, although zinc was higher. Therefore, zinc was automatically carried forward. As indicated in a footnote to Table 7.1, lead was also carried forward based on a professional judgement to impart additional conservatism into the assessment.

At the dock, there were insufficient data to conduct a statistical comparison between the EPC and the 1985 background data, so comparison was made instead to the Ontario Typical Range (OTR) value for rural parkland. Based upon this comparison, copper, lead and zinc were all carried forward in the ERA.

For the general mine area, the EPC for copper was not significantly different from the 1985 background value. However, copper was carried forward in the ERA, as it was required in order to complete the risk assessment for the much smaller dock area (note that Table 7.1 incorrectly states that copper was not carried forward for the general mine area). In contrast, the lead and zinc concentrations were higher than the 1985 background values, and these two metals were carried forward in the ERA.

To summarize for the ERA, no statistically valid comparison to the 1985 data was possible for the dock area, so all three metals (copper, lead and zinc) were carried forward based upon a conservative comparison to the OTR values. At the town site and general mine areas, both lead and zinc were carried forward, although copper was screened out. Therefore, regardless of whether the 1985 background data are true background or not, the use of lower background values would not have changed any decisions for lead or zinc, and these metals were carried forward in the ERA. Copper is a special case in the ERA, as it was screened out at the town site, based upon comparison to the 1985 background. However, copper was carried forward for the dock area, and a risk-based site specific threshold level (SSTL) was calculated for both the dock and general mine areas. The copper EPC in the town site was much lower (38 mg/kg) than at the dock (835 mg/kg) or in the general mine area (66.7 mg/kg). Therefore since it was concluded that copper did not pose an ecological risk at either the dock or the general mine area, it can logically be concluded that copper does not pose an ecological risk in the town site.

2.2 Common Comment 2

Should potential carcinogenic risks from lead be included in the risk assessment?

Several reviewers commented on the potential for carcinogenic effects of lead exposure, citing the International Agency for Research on Cancer (IARC) monographs, which classify lead in Group 2B (possibly carcinogenic to humans) on the basis of sufficient evidence in animals but inadequate evidence in humans. The IARC monograph cites a number of studies of battery and smelter workers in which excesses of cancers were noted, however, concludes that these excesses were relatively small, showed no clear-cut trend with length or degree of exposure, and could have been confounded by factors such as smoking or exposure to arsenic. We provide a brief review of other sources of information of this subject below:

The United States Environmental Protection Agency (US EPA) Integrated Risk Information System (IRIS) reports sufficient evidence of carcinogenicity in animals (rats and mice) exposed to lead phosphates and acetates but reports inadequate evidence of human carcinogenicity. The US EPA indicate that all of the available human studies lacked quantitative exposure information, as well as information on confounding factors such as smoking and concomitant exposure to other metals such as arsenic, cadmium, and zinc. There was no consistency of site among the various studies and no study showed any dose-response relationship. Thus, the available human evidence was considered to be inadequate to refute or demonstrate any potential carcinogenicity for humans from lead exposure. On this basis, the Carcinogen Assessment Group recommended that a numerical estimate not be used.

The 10th Annual Report on Carcinogens (2002) also reports inadequate evidence of carcinogenicity in humans from lead acetate and lead phosphate.

The Agency for Toxic Substances and Disease Control (ATSDR) publish detailed toxicological profiles for many chemicals. The toxicological profile for lead (1999) reports that there is no proof that lead causes cancer in humans. Kidney tumours have developed in rats and mice given large doses of lead but these studies have been criticized because of the very high doses used. ATSDR indicate that the results of these high dose studies should not be used to predict whether lead may cause cancer in humans. The doses of lead used ranged from 27 mg/kg/day up to 105 mg/kg/day, whereas the predicted intakes to humans at Nanisivik were four to five orders of magnitude lower, in the range of 0.002 mg/kg/day. While it has been determined that lead acetate and lead phosphate may reasonably be expected to be capable of causing cancer, based on sufficient evidence from animal studies, there is inadequate evidence from human studies.

Because of the above uncertainties, neither Health Canada nor the US EPA have developed any quantitative estimates of potential cancer potency of lead or lead compounds. We are unaware of any quantitative toxicity reference values (TRVs) for cancer effects of lead. Therefore, it is not possible to quantitatively assess this potential outcome. It is standard practice of both Health Canada and the US EPA to assess the risks of lead by relating lead intakes to potential increases in body burden and blood lead levels. The US EPA employ their Integrated Exposure and Uptake Biokinetic (IEUBK) model to directly relate lead intakes to predicted blood lead levels in young children. Health Canada employ a Tolerable Daily Intake (TDI) derived by the World Health Organization (WHO) on the basis that there should be no increase in the body burden of lead. The TDI used in the Nanisivik HHERA (3.57 µg/kg/day) is based on studies in infants that showed that a mean daily intake of 3 to 4 µg/kg/day was a No Observable Adverse Effect Level (NOAEL) and was not associated with an increase in blood lead levels or in the body burden of lead. This TDI was extended to all age groups to protect other sensitive population groups, such as women of child bearing age.

Both Health Canada and ATSDR provide some discussion of the blood lead levels at which reproductive or cancer effects have been reported. It is important to note that these levels are elevated relative to a baseline level that would be associated with the TDI used in the HHERA. Increases in stillbirths and miscarriages were reported at blood lead levels in the range of 10-15 µg/dL and potential increases in cancer incidences in smelter workers were associated with blood lead levels ranging from 21 µg/dL up to >100 µg/dL.

On the basis of the above discussion, quantitative assessment of carcinogenic effects of lead is not the approved practice of Health Canada or the US EPA and is not practical due to the lack of any cancer-based TRV for lead. The TDI approved by Health Canada and used in the Nanisivik HHERA is designed to permit no increase in baseline blood lead levels. Importantly, where reproductive or cancer effects have been reported, blood lead levels have been elevated above baseline levels. Therefore, the

Soil Quality Remedial Objectives developed for Nanisivik, based on no increase in blood lead levels, are likely to be over-protective for other potential health effects. It remains our opinion that the consideration given this issue in the HHERA was appropriate and no further assessment is required.

2.3 Common Comment 3

Why are the recommendations for Nanisivik Mine and the recommendations for Polaris Mine different?

Although both mines are in relative proximity and are proceeding through the closure process at the same time, the proposed future land uses in each area are different and therefore so are the two HHERA studies completed for the sites. Comparison of the studies is to some extent an "apples and oranges" comparison, however, to assist the readers in better understanding the differences, we have highlighted the major features below. The HHRA comparison is presented in Table 1; the ERA comparison is presented in Table 2.

The Polaris HHERA does not recommend any SQROs that are specific to ecological receptors. Therefore, it is not possible to conduct a specific comparison of the recommendations for the Polaris and Nanisivik mines. However, a comparison of the methodologies used for the ecological risk assessments can be made, and is also presented in this document.

Table 1 Comparison of Nanisivik and Polaris HHRAs

Issue	Effect
1. Future land use The Polaris HHERA qualitatively states that there will only be occasional transitory use of the land after mine closing and that there will be no significant hunting in the former mine area. However, the quantitative assessment for zinc was not adjusted for transitory use of the site (see below). The Nanisivik HHERA concludes that there will be continued full time residential use of the town site and moderate hunting use of the land in the general mine area.	Because of the limited potential for future exposure at Polaris, the HHERA assessed the potential for acute exposure only (zinc SQRO calculations were based on chronic exposure – see below) The Nanisivik HHERA did not assess acute exposures but assessed chronic long term exposure from more frequent use of the site. Because of this fundamental difference in approach, certain input parameters were different between the two studies.

Table 1 Comparison of Nanisivik and Polaris HHRAs

Issue	Effect
2. Soil Ingestion Rate The Canadian Council of Ministers of the Environment (CCME) default soil ingestion rate for toddlers is 80 mg/day. This ingestion rate is applicable to the assessment of long term chronic exposures and was the value used in the Nanisivik HHERA. For the assessment of short term acute exposures, the Polaris HHERA employed an upper percentile soil ingestion rate from the US EPA Exposure Factors Handbook (1997) of 400 mg/day. This is appropriate for acute exposure assessment as a conservative short term estimate but is not recommended for chronic exposure assessments. As noted by US EPA, "since the study period was short, these values are not estimates of usual intakes".	The soil ingestion rate is one of the most important variables in determining the Soil Quality Remedial Objectives (SQROs) and has an almost direct proportional effect on the outcome of the Polaris HHERA. For instance, at Polaris, soil ingestion accounts for >99% of the lead intake and 83.6% of the zinc intake. The effect on the Nanisivik HHERA would not be as direct due to the added wild game consumption intake that was not required for the Polaris HHERA. If the Polaris HHERA employed the default CCME soil ingestion rate, the lead and zinc SQROs would be approximately 5 times greater than those presented in the report. In an attempt to provide an "apples to apples" comparison, we adjusted the Polaris HHERA to incorporate the default CCME soil ingestion rate and to also adopt a target blood lead level of 10 µg/dL (chronic rather than acute exposure target). This adjustment yields a lead SQRO at Polaris of 3,400 mg/kg which could be compared to the revised lead SQRO for the Nanisivik general mine area of 850 mg/kg (revised based on all review comments received – see below). However, the Polaris SQRO originally derived based on acute exposure (2,000 mg/kg) is the more appropriate objective for that site.
3. TRVs At Polaris a blood lead level of 20 µg/dL was used as an acute exposure limit (for chronic exposure, the recommended safe blood lead level is 10µg/dL). In contrast, the Nanisivik HHERA is based on a TDI designed to result in no increase in baseline blood lead levels. For zinc, no acute TRV is available and the same chronic TRV used at Nanisivik was also employed at Polaris.	Given the different basis for the two studies, the use of acute exposure limits at Polaris and chronic exposure limits at Nanisivik is appropriate. The lack of an acute TRV for zinc and the use of a chronic TRV at Polaris will result in an over estimation of the acute risks. This in turn results in a lower SQRO than would have been derived if an acute TRV had been available. Therefore, given the combination of the acute soil ingestion rate and the chronic TRV, the zinc SQRO derived for Polaris (10,000 mg/kg) is highly conservative. By comparison, the Ontario Ministry of the Environment (OMOE) default residential soil criteria for zinc based on human soil ingestion is 16,000 mg/kg. The revised zinc SQRO for the Nanisivik town site (revised based on all review comments received – see below) is 10,700 mg/kg, also less than the generic OMOE residential criteria.

Table 1 Comparison of Nanisivik and Polaris HHRAs

Issue	Effect
4. Exposure term The exposure term in the risk calculation describes the frequency and duration of exposure at the site, for instance the number of hours per day and days per year that the exposed individual is present on site. Although the Polaris HHERA qualitatively describes an occasional transitory exposure of only a few days per year, the quantitative risk calculations do not include an exposure term. Daily intake is divided by the tolerable daily intake with an implicit exposure term =1, corresponding to full time site occupancy. In effect, the SQROs calculated would equate to residential land use. If an exposure term had been incorporated into the Polaris calculations for zinc, truly reflecting infrequent site visits, the resulting SQRO would have been considerably higher. At Nanisivik, an exposure term was incorporated to account for permafrost conditions and snow cover during the winter months.	Because lead was evaluated directly against an acute exposure limit (blood lead level = 20 µg/dL), incorporation of an exposure term would not be appropriate. Zinc intakes, compared to a chronic TRV, could have been adjusted by an exposure term. For instance, an exposure term of 0.1 (representing 10% site occupancy) would result in a ten-fold increase in the zinc SQRO from 10,000 mg/kg to 100,000 mg/kg. The revised residential lead and zinc SQROs for Nanisivik are 600 mg/kg and 10,700 mg/kg, respectively (revised based on all review comments received – see below). The Nanisivik lead SQROs cannot be directly compared to Polaris due to the differences in acute versus chronic exposure limits, however, the zinc SQROs are both effectively based on full time site occupancy and are comparable.
5. Non-soil related exposures At Nanisivik, the allowable intake from soil is adjusted downwards to account for the fact that we are exposed to other sources of lead and zinc, including ingestion of wild game from the site and other ambient exposures. Where information was not available regarding background exposures (zinc), a soil allocation factor of 20% was employed to permit 80% of a person's exposure to come from other sources. At Polaris, all of the allowable intakes of lead and zinc were assigned to soil contact at the site, thereby assuming zero exposure to non-site related sources. If background exposure to lead and zinc (e.g., water, food, ambient air) are significant, this may result in overestimating the soil SQRO.	To highlight the effect of the other potential sources of exposure, a comparison of the revised lead SQROs for the Nanisivik general mine area and Polaris is given below: Nanisivik — 850 mg/kg Polaris — 2,000 mg/kg Polaris $_{adjusted}$ — 3,400 mg/kg As indicated, the Nanisivik SQRO is more conservative. This difference is partly attributable to the inclusion of a wild game ingestion pathway at Nanisivik, not considered necessary at Polaris, as well as ambient background exposures.

The objectives of the Polaris ERA were:

- to determine whether the on-site soil contamination ... would likely pose risks to indigenous terrestrial wildlife; and
- to identify areas within the site which may potentially require remediation ... and to subsequently determine soil quality remediation objectives ...

In this regard, the objectives of the two studies were similar. A detailed comparison of the two ecological risk assessments is presented in Table 2 below, following the issue: effect format.

Table 2 Comparison of Polaris and Nanisivik ERAs

Issue	Effect
The methodology of the Polaris ERA was based upon CCME, BC MELP, AEP, MOEE and U.S. EPA guidance. The methodology of the Nanisivik ERA was based upon CCME, MOEE and U.S. EPA guidance. Therefore, the two studies were methodologically similar.	No effect
The VECs used in the Polaris ERA included herbivores (lemming, arctic hare and caribou) and carnivores (arctic fox). In this respect, the Polaris ERA was limited to mammals. The Nanisivik ERA considered lemming and arctic fox, and in addition considered Ptarmigan and Gyrfalcon (herbivorous/carnivorous birds).	Nanisivik ERA was broader and considered a wider range of VECS. There was redundancy in the Polaris ERA, since model assumptions for lemming and arctic hare were very similar. Net effects likely neutral.
Exposure pathways for the lemming and fox in the Polaris ERA included ingestion of contaminated soils or dusts; ingestion of contaminated vegetation; dermal contact with soils or dusts; and inhalation of dust. The Nanisivik ERA did not consider dermal contact with or inhalation of dust to be significant pathways, although ingestion of soils and contaminated vegetation were modelled.	The conservative approach that was used in the Nanisivik ERA to model these two pathways was assumed to compensate for ignoring the dermal sorption and inhalation pathways. In the Polaris ERA, inhalation accounted for <0.1% of exposure for lemming and arctic fox. Dermal absorption was more important in the Polaris ERA, but was implicitly accounted for via the ingestion pathway (from grooming or preening activities) in the Nanisivik ERA. Net effects likely neutral.
The Polaris ERA did not consider drinking water to be a pathway, whereas the Nanisivik ERA treated this pathway explicitly for cadmium, lead and zinc.	Nanisivik ERA is more conservative.
Both ERAs involved a screening procedure to evaluate which substances to include as COPCs: in the Polaris ERA the substances retained included cadmium, copper, lead and zinc. In the Nanisivik ERA, the substances retained included cadmium, copper, lead, silver and zinc.	Net effects neutral
The exposure point concentration (EPC) used at Polaris was the geometric mean value; at Nanisivik the EPC was the 95% upper confidence limit for the geometric mean, a more conservative approach that produces a higher EPC value.	Nanisivik ERA more conservative.
Both ERAs focused their assessment endpoints on effects on survival, reproduction or growth, and selected toxicity benchmarks that reflected these measurement endpoints.	Net effect neutral

Table 2 Comparison of Polaris and Nanisivik ERAs

Issue	Effect
The exposure limits or reference toxicity values selected for the two ERAs were similar, except in the case of lead. For lead, the Polaris ERA used lower exposure limits than the Nanisivik ERA. This appears to be a case of high conservatism in the Polaris ERA.	The toxicity of lead varies widely as a function of the chemical form. However, the bioavailability of lead oxides and lead sulfides is generally very low, and hence their toxicity is lower than for more bioavailable forms. Further, the bioavailability and toxicity of lead administered with soils is substantially lower than its bioavailability when administered in a more soluble form (such as lead acetate) with water (ATSDR 1999). The higher reference toxicity value selected in the Nanisivik ERA is appropriate for inorganic lead species in a mining/soil ingestion context. Conservatism is maintained in the Nanisivik ERA by assuming 100% bioavailability of ingested lead in the gut. In the Polaris ERA, only 1% of ingested soil lead was assumed to be bioavailable. The two approaches are different, but the net effect cancels out the differences.
For ecological receptors, the Polaris ERA indicated that unacceptable risks were present to ecological receptors from cadmium, lead and zinc. However, the document went on to conclude that due to conservatism in the model, no real effects were expected on the site. Accordingly, site-specific threshold limits (SSTLs) were not calculated for ecological receptors, and the soil quality remedial objectives (SQROs) were developed based solely on human exposures. In contrast, at Nanisivik, SSTLs were calculated for ecological receptors, but were found to be higher than values that would be protective of human receptors. Therefore, for those metals and areas where human presence was a concern, the SQROs were based on protection of humans; for metals and in areas where human presence was not a concern, the SQROs reflected protection of ecological receptors.	The Nanisivik ERA was more explicit in its calculation of SSTLs and SQROs, but in the end, the SQROs were largely set by the need to ensure protection of humans. Net effect is neutral.

In summary, the revised lead SQROs for Nanisivik mine are lower than the SQRO for the Polaris mine, based on the chronic rather than acute exposure and on the inclusion of wild game consumption as an exposure pathway.

The Polaris zinc SQRO is comparable to the Nanisivik town site zinc SQRO. Despite differences in the details of the approaches, this may be expected given that both SQROs are based on protection of human health. Despite the qualitative statements in the Polaris report describing only transitory occupancy, both HHRAs are effectively based on full time site occupancy. It is acknowledged in the Polaris HHERA that the risks from zinc have been over-estimated due to the use of a chronic TRV.

3.0 INDIVIDUAL REVIEW COMMENTS

Responses to individual peer review comments, which are not otherwise captured in the section "Common Review Comments", are provided here and organized by reviewer.

3.1 Comments from Indian and Northern Affairs Canada (INAC)

Letter to Phyllis Beaulieu (Nunavut Water Board) from Michael Roy (INAC) dated April 25, 2003.

Mr. Roy provides comments on the HHERA, the Phase II Environmental Site Assessment, and the Emergency Response Plan. There were three main comments on the HHERA, and these are are captured in the "Common Comment" section, above. Note that INAC aslo commissioned the consulting firm EBA to undertake a review of the HHERA; the EBA comments are discussed separately, below.

3.2 EBA Review Comments

(From Appendix D of the EBA Final Report, March, 2003).

The EBA review (EBA 2003) was commissioned by Indian and Northern Affairs Canada (INAC). The review comments are summarized by EBA in the main text of their report, however, the review of the human health and ecological risk assessment was subcontracted by EBA to Dr. Robert Lockhart of BC Research Inc. In the interest of accuracy, our response to the review comments is specific to Dr. Lockhart's original review, which was reproduced as Appendix D in EBA (2003).

Comments relating to the human health risk assessment are provided first ("HHRA Comment #"), followed by comments relating to the ecological risk assessment ("ERA Comment #").

3.2.1 HHRA Comments:

HHRA Comment 1

There is an absence of calculations demonstrating derivation of certain exposures and the report therefore poses challenges of comprehension for a non-technical audience.

A similar comment was made by AMEC and we will attempt to accommodate this request by including a sample calculation for lead intakes in the Nanisivik town site in an appendix to the revised report; see attachment to this document. It should be kept in mind however, that the calculation process is in itself a technically complicated procedure and therefore the examples may not achieve the desired clarification.

HHRA Comment 2

The risk of non-cancer health effects from ingestive lead and zinc exposures for an adult should be determined.

It is standard practice in human health risk assessment to assess non-carcinogenic (threshold) risks within specific life stages or age groups. Carcinogenic (non-threshold) risks are amortized over a lifetime of exposure. The toddler age group is generally the most sensitive age group for non cancer health effects because it has the highest intake to body weight ratio. To address the question, a sample calculation for wild game intake is provided below for a toddler and an adult:

$$Intake_{game\ ingestion}\ (mg/kg\text{-}day) = \frac{IR_{game}\ (g/day) \times EF\ (days/year) \times ED\ (years) \times 10^{-3}\ mg/g}{BW\ (kg) \times AT\ (days)}$$

Where:

		Toddler	Adult	
IR_{game}	=	18	74	(Richardson, 1997)
EF	=	365	365	
ED	=	4.5	50	
BW	=	16.5	70.7	(Richardson, 1997)
AT	=	1643	18,250	

Based on the above calculation, the intakes by game ingestion are 0.0011 mg/kg-day and 0.001 mg/kg-day for a toddler and an adult, respectively. Wild game ingestion intakes are essentially the same for an adult and a toddler as both ingestion rate and body weight increase proportionally. Therefore, an adult is at no more risk from wild game ingestion than the toddler. It is also important to remember that total intakes also include soil ingestion and that adult soil ingestion intake rates are 17 times less than toddler soil ingestion intakes. The sum of all intakes (soil ingestion, dermal contact, dust inhalation, and game ingestion) will be lower for an adult than a toddler, confirming that the toddler is the most sensitive receptor.

HHRA Comment 3

Estimated Daily Intakes – the reviewer comments on the dust ingestion portion of the EDI, on the use of the 1985 soils data, and suggests the possibility of using site-specific background data for zinc concentrations in drinking water.

As discussed in previous comments, soil versus dust intakes will be simplified in the revised report to show one combined soil/dust intake. As the concentrations in soil and dust were assumed to be equal, apportionment is not necessary.

Soil/dust background concentrations in the revised report will be taken from the 1985 data for the general mine area (data from the town site and dock site will be excluded as discussed on p.1 of this submission).

The biggest limitation in the calculation of an EDI for zinc is the lack of dietary intake information, hence even with local background soil and drinking water concentrations, an EDI could still not be accurately determined. To account for this, a soil allocation factor of 20% was used for zinc to permit 80% of a person's intake to come from background sources.

HHRA Comment 4

Risk Characterization – Non-Carcinogens: the calculations presented in Appendix C are adequate but are accompanied by inadequate definition of abbreviations.

A sample calculation for lead intakes in the town site will be included in an appendix to the revised report, giving the calculation through to the derivation of a hazard quotient.

HHRA Comment 5

Uncertainty Analysis

The reviewer suggests that the risks from lead and cadmium exposure could be added together as both metals are known to have potential effects on the same target organ (kidney). While this statement is accurate, the blood lead levels that are associated with renal effects (ATSDR, 1999) are considerably higher than would be experienced in Nanisivik as a result of soil exposure. It should be remembered that the human health risk assessment for lead is based on a TRV designed to result in no increase in baseline blood lead levels. In other words, the sum of intakes from all of the exposure pathways assessed would not result in an increased body burden of lead and would not result in renal effects that may occur at much higher blood lead levels. Therefore, for the assessment of exposure levels that would be experienced at Nanisivik, summation of the individual hazard quotients for cadmium and lead is not required.

3.2.2 ERA Comments:

ERA Comment 1

Screening (Table 7.1) shows the EPC (4.05 mg/kg) for the mine area to be above the screening value (0.27 mg/kg) and indicates that silver should move forward to Table 7.2 for inclusion in the risk assessment process.

Silver is clearly noted as "carried forward" in Table 7.1, but is incorrectly omitted from the general mine area in Table 7.2. Despite this typographical error in Table 7.2, silver was carried forward in the ERA for the general mine area (see Tables 7.5 through 7.13).

<u>ERA Comment 2</u>

... model development based on ingestive exposure only will limit the exposure risk assessment for the lemming ... evaluation of exposures through both inhalation and skin contact should be considered.

Section 7.2 (JWEL 2003) addresses this question. All three pathways (ingestion, inhalation, and dermal absorption) were considered in the conceptual model for the ERA. However, it was concluded that inhalation and dermal absorption were relatively minor pathways, and that for the inorganic substances under consideration, it was reasonable to omit them. A significant fraction of inhaled dust is ejected from the lung by ciliary action in the bronchi, and is subsequently swallowed. Similarly, much of the soil that might adhere to fur or skin will be ingested through normal grooming or preening activities (skin is not highly permeable to metals). Therefore, relatively high values for soil ingestion were selected in order to compensate for omitting inhalation and dermal absorption, and it was assumed that 100% of ingested metal was available for uptake across the gut. JWEL also noted that Cantox (2001) included the inhalation pathway for the ERA that was carried out for the closure of the Polaris mine, and concluded that this pathway contributed less than 1% of the ingested dose for lemming, arctic hare, caribou and arctic fox.

<u>ERA Comment 3</u>

... no fish are included as a potential receptor ... uptake of lead, silver, copper, cadmium, zinc for this potential receptor has not been considered. Alternatively, a rationale for not including fish should be presented.

In Section 2.1 (Site Description) of JWEL (2003) it was stated that baseline studies carried out before the mine was developed had indicated that neither Twin Lakes Creek, nor Chris Creek supported fish, and that fish populations were also not present in East Twin Lake or West Twin Lake. Therefore, fish were not included in the risk assessment.

<u>ERA Comment 4</u>

Soil to plant ... uptake factors vary for all of the metals of concern, dependent upon the area: town, dock or mine ... a much more elaborate explanation of the rationale for the differences is required.

Section 7.4.1.1 provides information and references for soil to plant uptake factors. The paper that provided regression equations for soil to plant uptake factors (Efroymson et al., 2001) was published in a noted and widely available scientific journal. Traditionally a constant soil to plant uptake factor has been used in many risk assessments (i.e., the predicted concentration in plants is the product of the soil concentration and a constant uptake factor). However, it has always been known that this is not the case and that at high soil concentrations, uptake factors (for plants and animals) become lower. This may be due to several factors, including:

- fundamental diffusion processes (as plant tissue concentrations increase, diffusion gradients from the soil across the root cell boundaries fall, and uptake is reduced); or
- active adaptation by plants or animals (as metabolic requirements are met for biologically essential metals, uptake is reduced; as concentrations of non-essential or toxic metals increase, biota may adapt to reduce uptake, immobilize, or actively excrete metals).

The availability of reliable and peer-reviewed non-linear uptake models (such as those that have been made available by Efroymson et al. (2001) and Sample et al. (1998)) represents a significant advance in ERA, and JWEL has adopted these models.

<u>ERA Comment 5</u>

The lowest observed adverse effect level (LOAEL) taken from literature sources introduces significant uncertainty ... ingestive exposure of birds to lead may vary between adult and juvenile (HERD note No. 4, December, 2000). ... differences between toxicity reference values for differing bird species ... might dramatically affect metals absorption in the gut. ... Table 7.6 should be adjusted to allow for significant uncertainty in the health outcomes between exposed adult and juvenile members of each of the target species (not just birds).

JWEL has conducted the ERA at a preliminary quantitative level in conformance with CCME and U.S. EPA guidance. The LOAEL values that have been used are based upon chronic exposures (in many cases full life cycle exposures), with an emphasis on reproductive endpoints that will be protective of wildlife populations (not necessarily individuals). The *HERD* reference that is brought forward by the reviewer is a guideline from the State of California, and refers to a more complicated level of risk assessment (i.e., a detailed quantitative risk assessment). This would be appropriate only if risks were identified at lower levels of risk assessment. As outlined by CCME (1996), ERA is intended to be a tiered process, beginning with conservative but simple models, and proceeding to more complex and less conservative models only when an earlier tier of risk assessment has concluded that risk may exist. On the basis of the preliminary quantitative risk assessment, JWEL (2003) has concluded that there are no significant risks to ecological receptors at Nanisivik.

All of the major independent reviews (i.e., Dillon, EBA and AMEC) that have been commissioned for this work have concluded that the risk assessment has been carried out in a conservative and reasonable manner, and that the conclusions are reliable. Therefore, there is no justification for the development of highly sophisticated models to assess potential effects on sub-populations.

<u>ERA Comment 6</u>

Tables 7.8 – 7.11 show HQ data for the four target organisms ... for the General Mine Area ... data on copper is missing from each table. Copper data is similarly missing from Table 7.9 showing findings for the Arctic fox.

The omission of copper data for the general mine area in Tables 7.8 through 7.11 was intentional because copper was not carried forward as a COPC in the general mine area (Table 7.1). However, copper data are reported for the combined dock and general mine areas for Arctic fox (Table 7.9) and Gyrfalcon (Table 7.11), which have large home ranges (estimated at 1,875 and 100,000 hectares respectively). This is not required for Lemming (Table 7.8) or Ptarmigan (Table 7.10), which have small home ranges (estimated at 0.475 and 10.3 ha respectively), and can spend their entire lifespan living within a small area such as the dock.

<u>ERA Comment 7</u>

As the ecological risk assessment does not use reference toxicity values ... it is assumed that target organs are not specified ... the HQ for each organism, for each area (town, dock and mine) should be summed.

The ERA uses reference toxicity dose values (RTD) which are based upon lowest observed adverse effect (LOAEL) values from the literature. The LOAELs are based upon chronic exposures (often lifetime) for birds and mammals, and where possible are referenced to reproductive effects. In addition, where the VECs have a small home range, it is assumed that the biota may spend their entire lifespan within each of the townsite, dock, or general mine areas. Where home ranges are larger, it is assumed that the organisms will occupy a range that includes the most contaminated area, with the balance being made up by the general mine area. Therefore, a further summation of the HQ for each area (town, dock and mine) would not be appropriate.

<u>ERA Comment 8</u>

... for those organisms for which the territory encompasses more than one area ... the HQ values calculated for that organism ... should be summed across all areas.

This is the procedure, as explained above.

ERA Comment 9

Calculation of SSTLeco should be shown. Also later, the comment is made that: *Demonstrated calculations of these values should be shown, including the forward calculation for determining SSTLeco from the HQ values.*

The SSTL values were calculated using a built-in function of the Microsoft Excel software (the "go-seek" function). This procedure was described in Section 7.7 – Site-Specific Threshold Limits. Briefly, the software is instructed to find the EPC that will result in a total ecological hazard quotient of 1.0. These numbers are readily validated by inserting them back into the model.

ERA Comment 10

... there may be a need for actual sampling of metals content in plant tissue.

Sampling of metals concentrations in plant tissues is not essential to the ERA. JWEL has estimated uptake based on the best available models in the literature.

ERA Comment 11

Reassessment of uncertainties related to target organisms, adult vs. juvenile is required ... juvenile[s] ... may also suffer developmental effects due to lead exposure ...

The ERA has considered sub-lethal effects based upon chronic exposures of adult animals, and this is a normal and widely accepted practice. Given the conservatism inherent in the approach that was taken, it is highly unlikely that adverse effects will be occurring to juvenile animals.

ERA Comment 12

... an uncertainty factor needs to be introduced to recognize potential that multiple chemical exposures may affect a target organism in a negative way.

This issue is addressed in Table 7.14, Evaluation of Assumptions and Uncertainties in the Ecological Risk Assessment, and in Section 7.9, Chemical Interactions. JWEL does not believe that there is sufficient evidence to support the position that toxicity for cadmium, copper, lead and zinc is additive, or that there is sufficient scientific information available to define an uncertainty factor to represent the effects of multiple exposures. However, as is noted in Table 7.14, the toxicity for each of these substances alone is likely to be overestimated due to the conservative nature of the risk assessment. Therefore, while we recognize the merit of the argument advanced by EBA/BC Research, we believe that the risk assessment has been performed in a conservative manner, and is appropriately protective of the area ecology.

<u>ERA Comment 13</u>

The SQRO for the dock presented in Table 8.2, should be reviewed as values of 4500 and 4600 mg/kg are quoted.

The inconsistent values of 4,500 and 4,600 mg/kg (lead) are an unfortunate rounding error from the final SSTLeco of 4,569 mg/kg that was presented in Table 7.13. As the value of 4,500 mg/kg is carried forward at the dock (effectively rounding "down" on the safe side), no significant error results.

3.3 Comments from Acres International:

Limited Review Comments as Solicited by the Nunavut Water Board

Acres International Limited subcontracted the review of the Human and Ecological Risk Assessment to Dillon Consulting. This response to review comments is based upon the original memorandum from Bryan Leece and Ulysses Klee (Dillon) to Halim Ramli (Acres) dated March 24, 2003.

Review comments were provided in three sections. The first section presented issues related to the ecological risk assessment (ERA); the second section presented issues related to the human health risk assessment (HHRA); the third section addressed additional questions raised by Acres International. The additional questions Likewise, responses to these comments are provided in three sections below, denoted by "ERA Comment #", "HHRA Comment #", and "Additional Comment #". Comment numbers match those used in the Acres International review document.

3.3.1 ERA Comments:

The Dillon review of the Ecological Risk Assessment notes at the outset that "*the ecological component of the risk assessment for the Nanisivik Mine was conducted properly and in accordance with standard and accepted risk assessment practices ... there were a number of points, however that require further clarification or correction, but it is felt that none of these issues will significantly impact the conclusions of the risk assessment*".

<u>ERA Comment 1.1</u>

... a review of the GLL (2003) document indicates a number of contaminants of concern in addition to those screened in the risk assessment ... [volatile petroleum hydrocarbons, extractable petroleum hydrocarbons, naphthalene, chlorinated ethenes, and cadmium, copper, lead and zinc are indicated] ...

these contaminants should be included in the screening process used to identify Chemicals of Concern, or a rationale needs to be provided for excluding them from the risk assessment.

CanZinco Limited has committed to a full clean-up of all areas where there is hydrocarbon or other organic contamination. These areas are localized and readily identified. These soils will be excavated and placed underground where they will become frozen into the permafrost and encapsulated. Therefore, only heavy metal contamination, which is more widespread, is the subject of the risk assessment.

<u>ERA Comment 1.2</u>

The selection of Valued Ecosystem Components also seems to ignore the information provided in the Phase II Environmental Assessment provided by Gartner Lee. it is advisable to consider a broader range of wildlife ... recommended that caribou, snow geese or eider duck, polar bear and the aquatic ecosystem (freshwater and marine) be included as VECs ...

The selection of Valued Environmental Components is based upon a careful consideration of biota that are likely to be found on the site. The objective is to identify biota at a variety of trophic levels that are maximally exposed to contaminants present on the site. In addition, the specific objective of this risk assessment is to identify soil quality remedial objectives (SQROs) for the site. Wide-ranging or highly migratory biota are generally not included in an ERA because their wide-ranging habits will minimize their exposure to on-site contaminants. The site is not on the migratory pathway for caribou herds, and they are very rarely seen on the site. Polar bear are dependent primarily on the marine environment for their food resources, and have much less exposure to the terrestrial environment. Waterfowl are also migratory. The VECs that were selected (lemming, Ptarmigan, arctic fox and Gyrfalcon) are year-round residents on the site, and rely primarily on terrestrial resources.

<u>ERA Comment 1.3</u>

Data characterizing the unimpacted or background areas are crucial for both screening the chemicals of concern and for quantifying exposure to VECs ... background data was available only for ... copper, lead and zinc ... if surrogates such as the Ontario Typical Range are to be used, some discussion is necessary to support the validity of these values ... it is strongly recommended that a more appropriate source of background information be identified and used.

In the ERA, the background values are used solely to confirm that heavy metal concentrations, which can be present in soils due to entirely natural processes, are in fact elevated. In the absence of site-specific background values, it is not unreasonable to consider a surrogate value. The Ontario Typical Range (OTR) values that were selected are the result of soils surveys in a large and statistically valid sample of soils over a very large geographic area. This kind of data set is simply not available for arctic soils, so the OTR data are considered by JWEL to be the best available.

ERA Comment 1.4

Please provide a reference for the designation of the upper 10 to 15 cm of soil as "surface soil" ... in most jurisdictions the cut-off depth would be 1.5 m ... if permafrost is felt to provide a barrier to soil exposure, then this needs to be documented and explained.

A cutoff of 10 to 15 cm was selected because the contaminants in soils at Nanisivik were deposited onto the surface. If JWEL had selected a soil layer of 1 m or 1.5 m as the basis for the EPC values, then soils concentrations would have been "diluted" by the thick layer of uncontaminated soils below the thin layer of contaminated soils. In Section 3.2.1, this is explained, and it is noted that even taking the surface 30 cm of soil resulted in a lower set of EPC values than the top 15 cm. Since risk is directly proportional to the EPC, it was conservative to restrict soil metals data to the surface 15 cm.

ERA Comment 1.5

As with background soil data, the contaminants studied in the local streams and lakes were limited to cadmium, lead and zinc ... copper was omitted ... where significant data gaps are identified, some discussion is required regarding the use of available data from similar sites, or the use of generic values.

Copper data were simply not available for streams on the site. Copper was a minor risk factor in site soils, and the water ingestion pathway is a minor pathway in comparison with soil and food ingestion. Therefore, the absence of copper data for stream water was not considered to be a serious deficiency.

ERA Comment 1.6

... for the derivation of EPCs, why was the geometric mean used? ... if the geometric mean is appropriate, please provide a reference.

The U.S. EPA has provided guidance for risk assessment at superfund sites. Simply put, the statistical distribution of data should be evaluated to determine whether a normal distribution or a log-normal distribution best fits the data. For the Nanisivik site, as is commonly observed, the soil metals data were typically log-normally distributed. Therefore, the appropriate measure of the central tendency for soil metals data is the geometric mean (rather than the arithmetic mean, which would be appropriate for normally distributed data).

ERA Comment 1.7

... the screening procedure considers only 10 metals while section 3.5.1 indicates that as many as 19 were analyzed in the soil samples. Why were metals ... omitted from the screening procedure?

Although as many as 19 elements were analyzed in the soil samples, many of these elements were simply not of interest from a toxicological perspective. Examples of such metals include calcium, sodium, magnesium, aluminum, etc., which are major mineral forming elements and are environmentally benign.

ERA Comment 1.8

Section 7.2 ... The conceptual model would be more appropriately placed after the discussion regarding ... VECs?

Noted. The conceptual model will be placed after the discussion of VECs in the revised HHERA.

ERA Comment 1.9

Figure 8 ... Sediment from the local streams should also be considered as a source media ... for the marine ecosystem both the surface water and the sediment should be considered ...

Stream sediments from local streams were not considered in this risk assessment for several reasons. First, the streams do not support fish, and have very low abundance and production of benthic invertebrates. Additionally, the streams are high-gradient and high-energy watercourses, with little accumulation of fine-grained sediments. Therefore, sediment based pathways were not considered to be credible for this risk assessment. This HHERA was conducted to determine SQROs for soils at the site, and therefore did not consider the marine environment. The marine environment will be addressed in future investigations that are currently being designed.

ERA Comment 1.10

... to demonstrate an understanding ... of the local ecosystem, some details regarding the local environment ... would be useful. Further explanation is required since the statement, "receptors were selected to be representative of all potential wildlife receptors at the site" is clearly false.

Information on the local environment was presented in Section 2.1 of the report. In addition, information on wildlife on and around the site was presented in Section 4.0 and associated appendices. The VECs that were selected were considered to be representative of other wildlife receptors in the sense that they were as highly or more highly exposed to on-site contaminants as any other biota that might be present on the site. Therefore, risks to other biota are not likely to be higher than risks that were assessed for the VEC organisms.

ERA Comment 1.11

One of the challenges associated with the assessment of Arctic ecosystems is the application of receptor characteristics, exposure factors, and toxicity data developed with animals typical of more temperate climates, to animals that endure the cold, harsh and long winters typical of Canada's northern areas ... some discussion is required that includes: migratory versus non-migratory species ... feast-or-famine feeding habits ... hibernation and other winter survival strategies.

A common procedure in risk assessment is to simplify the approach or model that is used, and to compensate for the simplification by making conservative assumptions. Therefore, in the face of uncertainty about the behaviour of contaminants in arctic ecosystems, it is reasonable to make conservative assumptions about contaminant behaviour, so that risk is not underestimated. The VEC organisms that were selected are non-migratory, so that exposure on-site is maximized. In addition, the selected biota remain active throughout the year, which also tends to maximize exposure.

ERA Comment 1.12

Additional sources of exposure should include terrestrial invertebrates ... and ingestion of sediment from the local streams.

The area under study is a harsh arctic environment with permafrost. Soil invertebrates are expected to be rare, and insectivores, such as shrews, are not present. Therefore, the risk assessment focused on herbivorous and carnivorous food webs. The question of sediment-based pathways was discussed above, and is likewise considered to be of low importance.

ERA Comment 1.13

The paper by Efroymson et al. (2001) provides several equations relating the concentration of the contaminant in the soil to that in the plant ... explain what rationale was used to make the selection.

The paper by Efroymson et al. (2001) provides two basic sets of equations: a set in which plant concentration is related to soil concentration; and a set which includes soil pH as well as soil concentration. Both sets of models were statistically highly significant, and provide strong predictive power. Soil pH was not available for the Nanisivik soil samples, therefore the generic soil to plant uptake equations were chosen.

ERA Comment 1.14

Section 7.5 Exposure Estimates ... it appears that the approach used for the exposure estimate included only the potential for metal intake from the site ... for animals whose home range extends beyond the area of the site, exposure associated with the background must also be included ... this needs to be corrected and will impact both the value of the hazard quotients, and the SSTLs.

For lemming and ptarmigan, home ranges are so small that it is reasonable to assume that they could spend all of their time within the dock or town site areas. For Arctic fox, the home range is larger, so that the home range was assumed to comprise the dock or town site first, with the remainder of exposure coming from the general mine area. Only in the case of the Gyrfalcon was the size of the home range greater than the combined areas of the dock, town site, and general mine area. We agree that a "background" exposure could have been estimated, although this would have required assumptions about "background" soil metal concentrations outside of the general mine area. However, the Gyrfalcon was the least exposed of the four VEC animals, and would not have provided the basis for any of the SSTLs in any case. This deficiency is therefore considered insignificant in the overall outcome of the assessment.

ERA Comment 1.15

Section 7.7 ... The statements "These results indicate that there may be some benefit to ecological receptors if remedial activities are undertaken at areas where the soil metals concentrations (lead and zinc) exceed the SSTLeco" and "however, the overall ERA results indicate that the existing conditions at Nanisivik are not likely to result in adverse effects to exposed biota at the population level" are contradictory ... further discussion and explanation of the results is required.

Simply stated, the ERA has demonstrated that there are no significant risks to on-site biota, however there are some "hot-spot" locations where the measured soil metals concentrations exceeded the SSTLs for ecological receptors. It is therefore reasonable to state that *"there may be some benefit"* in remediating hot-spots during the course of the overall site reclamation work. This would in turn lower the (already safe) EPCs as well as possibly achieving benefits relating to aesthetics and public perception.

ERA Comment 1.16

Section 7.9 Chemical Interactions: The issues associated with chemical mixtures and chemical interactions ... should be discussed as part of the "Model Assumptions and Uncertainties" ... there is a growing body of literature that looks at these interactions ... it is agreed that the uncertainty introduced by chemical interactions is potentially significant ... further clarification is required with specific reference to the site, the COCs and the VECs.

The metals involved in the ERA, primarily cadmium, lead, copper and zinc, have different modes of toxic action, and different physiological behaviour. Copper and zinc are essential elements, that are actively regulated by animals. Cadmium and lead have no known biological function. There is no basis for assuming that the toxicity of these substances should be treated as additive.

The additivity model is appropriate for other classes of compounds, such as dioxins and furans, which as a group have similar chemical structure, similar modes of toxic action, and similar biological and metabolic fate. This is not the case for the heavy metals under consideration.

JWEL has provided a statement of our position on chemical interactions (see Section 7.9) and has addressed the question of chemical interactions versus single chemical exposures in Section 7.8 (Modeling Assumptions and Uncertainties).

3.3.2 HHRA Comments:

The Dillon review of the Human Health Risk Assessment notes at the outset that *"..the human health risk assessment for the Nanisivik Mine was conducted in accordance with standard risk assessment practices…There are some issues that require clarification and/or correction. Addressing these issues may alter the SSTLs from the values that are currently presented in the report. However, these changes are not expected to have a significant effect on the conclusions of the report."*

<u>HHRA Comment 2.1</u>

Identification of Contaminants of Concern…other contaminants of potential concern were identified during the Phase II ESA… should have been considered in the HHRA.

The review points out that the scope of the HHERA was limited to metals and did not include other potential chemicals of concerns (COCs) identified at the site (*e.g*., petroleum hydrocarbons). CanZinco has indicated that soil contamination caused by other potential COCs, including petroleum hydrocarbons, will be remediated as part of the mine reclamation. Therefore, there is no need to include these COCs in the risk assessment process.

<u>HHRA Comment 2.2</u>

Use of bioavailability factors – clarification was requested on how the bioavailability factors were applied in the human health risk assessment.

As indicated in the HHERA report and in the review comment, bioavailability adjustments are made in human health risk assessments to account for the fact that not all metals in soil are absorbed into the body. Bioavailability can be expressed as either *absolute* or *relative* bioavailability. If *absolute* bioavailability is used to adjust the intake from soil ingestion then the toxicity reference value (TRV) must also be adjusted to account for *absolute* bioavailability in the toxicity study. This requires knowledge of the *absolute* bioavailabilities in both soil and the toxicity study, as follows:

3.3.2.1.1 Relative bioavailability = $\frac{\text{absolute bioavailability from soil}}{\text{absolute bioavailability from dosing medium used in toxicity study}}$

In the HHERA report, bioavailabilities were adjusted based on the assumption of 100% absolute bioavailability in the toxicity study. This assumption may not be fully conservative in all cases and upon further consideration we agree to incorporate the reviewer's recommendations and adjust the TRV for bioavailability. Without accurate information on the absolute bioavailability in the toxicity study, this adjustment is most readily accomplished in the risk calculations provided in Appendix C of the report in the following manner:

$$HQ = \frac{(Intake_{soil\ ing} \times AF_{soil\ ing}) + (Intake_{dermal} \times AF_{dermal}) + (Intake_{inh} \times AF_{inh}) + (Intake_{game} \times AF_{game})}{(TDI - EDI) \times AF_{game}}$$

For all metals, AF_{inh} is assumed to be 100%. For cadmium and zinc, $AF_{soil\ ing} = AF_{game}$ hence there is no longer any relative absorption from soil ingestion. This will result in overestimating the intake of both metals by soil ingestion. Literature data available for cadmium indicates that this overestimation may be by a factor of three. Relative absorption factors will now only be applied to soil lead ingestion and dermal uptake, which are well documented and supported in the scientific literature.

HHRA Comment 2.3

Soil ingestion factors for toddlers – why was the CCME default soil ingestion rate not used for assessment of toddlers in the town site?

In order to account for reduced soil contact in the winter months, either the annual average soil ingestion rate or the exposure frequency (days/year of exposure) can be adjusted. In the HHERA, the soil ingestion rate for a toddler in the town site (residential exposure) was adjusted from the CCME default rate of 80 mg/day using a separate calculation that incorporated exposure to household dust in the winter. In this way, the exposure frequency could be left at 365 days/year to reflect year round occupancy.

However, we concur with the reviewer's comment that this leads to some confusion in the interpretation and some lack of internal consistency between the assessment of the town site and the general mine area. Therefore, to clarify and simplify the risk calculations, we have adopted the same soil ingestion rate (CCME default rate) for all areas and adjusted the exposure frequency to reflect winter snow cover and permafrost conditions. The exposure frequency is based on 30 year climate normals for Arctic Bay and Pond Inlet published by Environment Canada which indicate length of snow cover. Potential exposure to household dust in the winter will be included as an additional intake in the risk calculations. It should be noted that the resulting changes to the SQRO's due to this change will be minor.

HHRA Comment 2.4

Apportionment of soil ingestion – clarification was required on how the relative intakes of soil and dust were apportioned between indoors and outdoors based on the assumption that soil and dust concentrations were not equal (indoor dust concentrations are generally some fraction of outdoor soil concentrations).

The comments indicate that the reviewer is confused over the issue of how indoor and outdoor exposures and soil/dust concentrations were apportioned in the report. It is common practice in risk assessments to assume that contaminant concentrations in indoor dust are some fraction of the outdoor soil concentration, hence it becomes important to define what proportion of a person's soil/dust intake is indoors versus outdoors. However, for the assessment of summer exposures at Nanisivik, we assumed that the indoor dust concentration equalled the outdoor soil concentration. This is a conservative measure that likely results in some overestimation of risk but simplifies the calculations and in fact renders the issue of apportionment a moot point that has no effect on the outcome. For the winter months, dust concentrations were defined as a fraction of soil concentrations to account for winter snow cover limiting re-suspension of soil dust. An example calculation for lead in the town site is attached with this document that illustrates this factor.

It should be noted that since the soil and dust concentrations were assumed to be equal, the apportionment of dust versus soil intakes in the calculation of the EDI (Section 6.4.1.5) is also not necessary. To clarify the presentation of this information, only one combined soil/dust intake for lead will be displayed in the revised report (similar to the illustration of the cadmium EDI in Section 6.4.2.5).

HHRA Comment 2.5

Receptor Parameters

i) drinking water consumption rates are not provided

The drinking water consumption rate used for a toddler was 0.2 L/day in accordance with Health Canada guidance. Water intakes used in the calculation of the EDI are for tapwater only since the food data include water-based food composites including beverages and soups prepared and/or re-constituted with tapwater. It should be noted that this factor applies only to the calculation of the EDI and comprises <5% of the total EDI therefore it is considered to have negligible effect on the assessment outcome.

ii) the body weight value used for toddlers…is greater than what is generally accepted by Canadian regulators

The toddler body weight formerly used by CCME of 13 kg dates from a 1994 publication and has been superceded by the values published by Richardson (1997). CCME has adopted the more recent Richardson data in the Canada Wide Standards (CWS) for petroleum hydrocarbons (CCME 2001). Alberta Environmental Protection has adopted the CWS values and all four Atlantic Canadian provinces have adopted the same values in their risk-based contaminated site guidelines. We believe this to be the most up to date estimate of body weight for use in human health risk assessments.

iii) inhalation rates have also been taken from Richardson…and will overstimate inhalation exposures for toddlers

Similarly to the body weight, the 24 hour inhalation rates published by Richardson are the most up to date inhalation rates and better reflect actual research conducted on breathing rates. The US EPA currently recommend a toddler inhalation rate of 8.3 m^3/day and an adult male inhalation rate of 15.2 m^3/day, consistent with the values published in Canada by Richardson. We believe these values to be the best available estimates of inhalation rates.

HHRA Comment 2.6

Review of Calculations

i) calculation of Drinking Water intake for lead…bioavailability factor of 0.5 should have been used

No bioavailability adjustments were made in any of the EDI intake calculations for lead or cadmium. The rationale used for this calculation is the same as discussed in Comment 2.5 i) above.

ii) Section 6.4.1.4: Background Soil/Household Dust…justify the apportion soil ingestion between indoor dust and outdoor soil

The reviewer is correct that no bioavailability adjustments were made in the calculation of the EDI and that the CCME default soil ingestion rate was used. As discussed in Comment 2.4, the soil and dust concentrations were assumed to be equal hence the issue of apportionment of intakes between indoors and outdoors is unnecessary and leads to confusion in the report review. In the revised report, we will show one combined soil/dust intake.

iii) The calculation of the SSTLS for lead and zinc in the town area…do not adjust the toxicity values to correct for bioavailability…soil ingestion rate…

These issues have been discussed and resolved in Comments 2.2 and 2.3, above.

3.3.3 Additional Comments:

<u>Additional Comment 1</u>

3.1 Does HHERA report typically concern only with metals concentrations? Why the report does not contain any assessment (for both human and ecological) for the presence of petroleum hydrocarbon contamination? The Phase II ESA indicates that there are some concerns of hydrocarbon contaminations.

CanZinco Ltd. has committed to the removal and burial of all hydrocarbon contaminated soils as part of the mine decommissioning plan. These contaminants tend to be localized due to their relationship to the locations of oil storage tanks or machinery. Therefore, since there will be no significant residue of hydrocarbons on the site following decommissioning, these were not included in the HHERA.

<u>Additional Comment 2</u>

3.2 This question from Acres was adequately responded to by Dillon. No further response is required from JWEL.

<u>Additional Comment 3</u>

3.3 Table 7.2 on page 52: the discussion for general mine indicates that copper (Cu) is eliminated for consideration, but silver (Ag) is not. However, the table shows otherwise.

There is an error in Table 7.2. Although silver is not shown in this table, silver was carried forward in the ERA for the general mine area. Copper was carried forward only for the dock, not the dock and general mine area as indicated by Table 7.2.

<u>Additional Comment 4</u>

3.4 Ecological risk – surface water assessment. ... EPC is based on mean concentration using 2001 data for metals ... average or mean readings and 95% UCL will be different.

For soils, the EPC was based upon the 95% upper confidence limit (UCL) for the geometric mean. This is a conservative estimator of the central tendency for the soils data, which will remain at high levels (if not remediated) well into the future.

For water, the EPC was based upon the arithmetic mean of recent data (2001). This was chosen as a conservative estimator of the central tendency for future conditions, because the concentration of metals in Twin Lakes Creek is expected to decline following the mine closure and end of operations.

Nanisivik mine collected data for metals at the Twin Lakes Creeks between 1996 to 2001. The average metal concentrations appear to be increasing with time. However, as the mine stops operation, the concentrations may level off or decreasing over time. What concentrations should be used for the analysis? Average over the years, or the latest data?

As the reviewer has pointed out, the average metal concentration did increase marginally over the span of years reviewed. CanZinco advises that this increase is attributed to the reclamation of the sulphide waste rock piles along the creek bank. With this in mind, the selection of the 2001 data was considered to be worse case scenario and therefore conservative in nature.

Additional Comment 5

3.5 *This question from Acres was adequately responded to by Dillon*

Additional Comment 6

3.6 Ecological Risk Assessment: Exposure Point Concentration for metals in surface water (Table 7.3). A) for the town area, data from SNP 159-9 was used in the analysis. Would other data, such as 200-10 and/or NML 28 be more appropriate? B) for the general mining site, should data from SNP 200-1 (located near the mill) be included in the evaluation? This station collect all of the metal loading from the main mining operation site (and including water from WTL and ETL).

Stations were selected based upon proximity to the town or dock areas, or were distributed along the creek as it passed through the general mine area. In the latter case, to be conservative, the highest mean value for the candidate stations was selected.

3.4 Comments from AMEC Earth and Environmental Limited (2003)

Note that the AMEC Earth & Environmental (AMEC) review comments were received in original, as a “plain language” summary, and were further summarized in a letter by Mr. Stefan B. Lopatak of Nunavut Tunngavik Inc. The comments and responses presented here are based on the original AMEC document. Comments on the ERA component of the HHERA (“Part 2” of AMEC 2003) are responded to first, followed by comments on the general HHERA and then the HHRA component (“Part 3” of AMEC 2003).

3.4.1 ERA Comments:

The AMEC document notes that "*Overall, the ERA is well-organized and uses a format that is easily followed. This ERA is conservative in its conclusion, as risk assessments usually are, and this review can find no serious fault with the conclusions. There are a few minor errors or omissions that do not influence the conclusions. There are also several questions raised by some of the statements made in the ERA, but again these have no effect on the conclusions.*" (AMEC, 2003) Also later in the document, it is noted that "*The ecological risk assessment conducted for the Nanisivik Mine is a well-written and organized discussion of the potential for adverse ecological effects due to the presence of various trace elements in the Nanisivik area. This review is in complete agreement with the conclusions.*" Specific review comments are reproduced below in italics, with JWEL responses in normal font.

ERA Comment 1

A sentence or two regarding the lack of significant amounts or the absence of other categories of contaminants (e.g. hydrocarbons) would seem appropriate to get everything else "out of the way" so that the ERA could proceed.

CanZinco Ltd. has committed to full remediation of any residual oil spills or hydrocarbon staining associated with the town site, dock, or general mine area, during decommissioning. Therefore, the only COPCs that will remain following decommissioning of the mine will be trace metals that were distributed in the environment during the mining period.

ERA Comment 2

... the authors of the ERA should probably have given some thought to whether they should be referring to the surface material at Nanisivik as "soil".

We appreciate the discussion that was provided on definitions of "soil", however, the predominantly mineral "soils" that are present at Nanisivik do support some plant growth, and are the substrate that animals walk on and burrow into, and as such can be functionally considered soils.

ERA Comment 3

In Section 7.1.5 (Surface Water) ... EPCs for each metal were calculated as arithmetic mean ... This seems to conflict with the statement made in ... Section 3.6 ... If the trace element concentrations in water were log-normally distributed, the geometric mean should be a better measure of the central tendency than the arithmetic mean.

Trace metal concentrations in soils were found to be nominally lognormally distributed. Therefore, the 95% upper confidence limit of the log-transformed data was considered to be a conservative but reasonable estimate of the upper limit for metals concentrations, now and in the future. In the case of water, the future statistical distribution of metals concentrations in creek water was less predictable, and it seemed reasonable to assume that trace metal concentrations in Twin Lakes Creek will decline once the mine ceases operations, and following decommissioning. Therefore, the arithmetic mean value of concentrations measured over the past few years was considered to be a reasonable but conservative estimator for metal concentrations in creek water after decommissioning.

ERA Comment 4

... shouldn't there be a connection between "surface soil" and "surface water" to account for surface water runoff? Should water associated with the tailings also be identified as a pathway from the solid material to aqueous dissolution in surface water?

This connection exists implicitly, since the trace metal concentrations in water are taken directly from concentrations measured in Twin Lakes Creek. Any possible leaching of trace elements from watershed soils to surface water, including discharges from tailings (which are disposed of in West Twin lake), is directly accounted for in the measurements from Twin Lakes Creek. In addition, there will be a frozen cover for the currently exposed tailings that is intended to reduce trace metal leaching and mobility.

ERA Comment 5

... with respect to the section on exposure assessment ... would the fact that the surface material is frozen reduce the exposure ... to trace elements? ... It would seem to reduce the hazard posed by the specific elements ... to an even greater degree than currently calculated.

Agreed. This is an example of conservatism that is introduced to the risk assessment model by making a simplifying assumption. In this case, it is assumed that animals are exposed to trace metals year-round as if the mine site was under "summer" conditions. Exposure to metals during the winter, when soils are frozen and there is snow cover, will be substantially lower.

ERA Comment 6

One question that is raised ... is the pervasiveness of the contamination. Can the contamination be characterized as slightly elevated over the entire area or highly elevated at a few so-called "hot spots?"

The best answer is probably "both". Wind-borne dispersion of dust from tailings during one period of the mine operations resulted in a slight to moderate increase in trace element concentrations over a relatively wide area. However, there are also “hot spots” that were caused by ore and metal concentrate handling and transportation.

<u>ERA Comment 7</u>

The bioavailability of ingested trace elements was assumed to be 100% in this risk assessment. However, this has been known not to be the case for over 30 years ... In ecological risk assessments, there always exists a high probability that the “worse case” scenario becomes the “impossible case” scenario.

This is another example of conservatism in the risk assessment model. We have assumed that all of the ingested metals are bioavailable, and effectively taken into the body by biota. We know that this is not the case, and that different elements will have varying degrees of bioavailability (but all less than 100%). However, as a first approximation is it acceptable, and incorporation of a certain amount of conservatism into the model in some areas provides flexibility to make simplifying assumptions in other areas, that may partially compensate. For example, ingestion was included in the ERA, with 100% bioavailability. At the same time, it was determined that minor uptake pathways such as dermal absorption and inhalation could be excluded from the model. In this case, a conscious decision was made to ignore the minor processes of dermal absorption and inhalation, but this was compensated for by conservative assumptions in the ingestion pathway (i.e., a high soil ingestion rate, and 100% absorption of ingested metals).

<u>ERA Comment 8</u>

The presence of metallothioneins in mammals should have been at least mentioned, if only in one sentence.

We are aware of the role of metallothioneins as physiological “buffers” and regulators for some heavy metals. The synthesis of metallothioneins by metal-challenged animals is typically very rapid (i.e., the physiological response occurs within hours to days). However, the toxicity database that was developed to provide reference toxicity values for birds and mammals focused on chronic exposures of 100 days or longer. As such, any protection that might be afforded by metallothioneins is implicitly factored into the reference toxicity values. Therefore, there was no need to discuss metallothioneins.

<u>ERA Comment 9</u>

If there is one sentence in this ERA that should be copied and placed much further forward in the text in bold font ... it is the first sentence of the last paragraph of Section 8.0. It gives a perspective that should be realized from the outset. JWEL note: the sentence in question is as follows:

"The physical characteristics of the Nanisivik Mine site (*e.g.*, high arctic climate, natural mineralization, barren terrain) are not representative of a "typical" site envisaged by the CCME."

Note that the CCME reference in question is to the generic Canadian Environmental Quality Guidelines for soil. JWEL is not sure exactly what "perspective" the sentence in question has provided to the reviewers, however, we believe that it directly supports the risk assessment process. The physical and natural environment at Nanisivik is an extreme example of the Canadian environment, and as such, is likely outside the limits of generic Canadian Environmental Quality Guidelines. The appropriate response to this situation is to conduct a site-specific risk assessment in order to develop SQROs for decommissioning (which is what the Nanisivik HHERA is).

ERA Comment 10

Note that Table 8.2 contains an error concerning the final SQRO for lead. It would appear to be 4,600 mg/kg rather than 4,500 mg/kg. The 4,500 mg/kg value is repeated again in Table 8.4.

The inconsistent values of 4,500 and 4,600 mg/kg (lead) are an unfortunate rounding error from the final SSTLeco of 4,569 mg/kg that was presented in Table 7.13. As the value of 4,500 mg/kg is carried forward at the dock (effectively rounding "down" on the safe side), no significant error results.

3.4.2 General HHERA Comments:

General HHERA Comment 1

Explanation of Statistics Used

Section 3.6 of the HHERA report describes the statistics used in the calculation of Exposure Point Concentrations (EPC). A more detailed review of the statistics is provided in the response to peer review comments on the ecological risk assessment.

General HHERA Comment 2

How were concentrations <detection limits dealt with?

Any concentration that was less than the laboratory estimated quantitation limit (EQL) was assumed to equal ½ EQL. This is standard practice methodology.

General HHERA Comment 3

Why was arsenic not included in the quantitative risk assessment?

The reviewer raises some concerns about the use of an Ontario BSC to describe northern background conditions. We do not believe that this use of "southern" data has any negative effect on the outcome of the risk assessment. It is often not possible to obtain background soil data specific to a particular region and it is necessary to substitute data from elsewhere. The *Canadian Soil Quality Guidelines for Arsenic: Environmental and Human Health, Supporting Document*, Environment Canada, 1996 published information on background soil arsenic concentrations in various regions of Canada. Pertinent data from this document are summarized in Table 3, below.

Table 3 Summary of Background Soil Arsenic Concentrations (mg/kg)

Reference	**Arsenic Concentration**	
	Mean	**Range**
World soils (Kabata-Pendias and Pendias, 1984)	8.7	<1 – 95
Canada – literature review	--	4.8 – 13.6
CCME canadian default	10	--
Northwest Territories – Yellowknife area	--	10 – 25
District of Keewatin, Northwest Territories	--	2.4 – 20
Aylmer Lake, District of MacKenzie, Northwest Territories, <0.002 mm	54.5	1 – 224
Aylmer Lake, District of MacKenzie, Northwest Territories, <0.063 mm	11	0.25 – 100
Lac de Gras, District of MacKenzie, Northwest Territories, <0.002 mm	59.4	1 – 154
Lac de Gras, District of MacKenzie, Northwest Territories, <0.063 mm	3.8	1.4 – 25
Winter Lake, District of MacKenzie, Northwest Territories, <0.002 mm	36.4	4 – 200
Winter Lake, District of MacKenzie, Northwest Territories, <0.063 mm	4.4	0.8 – 29
South Melville Peninsula, Northwest Territories, 1990	104	2.5 – 207
South Melville Peninsula, Northwest Territories, 1991	15.5	1 – 520

As indicated, mean background soil concentrations range from 3.8 mg/kg up to 104 mg/kg in canadian soils and glacial tills from northern Canada. The mean arsenic BSC in world soils was 8.7 mg/kg and in Canadian soils was 10 mg/kg. The arsenic BSC used in the Nanisivik HHERA was 11 mg/kg (Ontario rural parkland). All of three of these values are greater than the arsenic EPC for the Nanisivik town site (7.69 mg/kg). Therefore, we conclude that the use of the Ontario BSC has not affected the outcome of the risk assessment and that arsenic was correctly screened out based on the risk assessment framework.

3.4.3 HHRA Comments:

<u>HHRA Comment 1</u>

Why were lead and zinc not evaluated from an inhalation perspective for the toddler?

Lead and zinc were evaluated for inhalation exposure. Please refer to Appendix C for the risk calculation.

HHRA Comment 2

Explain the lower soil ingestion rate for the toddler in the town site.

This issue is addressed above under HHRA Comment 2.3 in the response to Acres International peer review, subcontracted to Dillon Consulting.

HHRA Comment 3

Please provide an explanation of how chemical concentrations were calculated in wild game and subsequently determining the chemical intake in people.

Refer to Section 7.4.1.2 of the HHERA report. Metal uptakes into tissue of wild game were estimated using the empirical relationships derived by Sample et al. (1998) for soil to small mammals uptake factors. The wild game tissue concentrations were then used to calculate daily intakes, using data from Richardson (1997) for wild game ingestion rates by Inuit populations. The intake from ingestion of wild game was then summed with all other intakes to calculate a total daily intake for comparison to the TRV.

HHRA Comment 4

Why were non-carcinogenic risks from cadmium inhalation not assessed?

When a chemical has different modes of action on the human body, it is normal practice to assess those exposures separately. For lead and zinc, the potential health effects are similar whether the exposure is via inhalation, ingestion, or dermal contact. For cadmium, inhalation exposure is potentially carcinogenic and therefore has a different toxic end-point than ingestion and dermal contact. For this reason, inhalation exposure to cadmium is assessed separately for potential carcinogenic risks. JWEL believes that inclusion of cadmium inhalation in the assessment of non-carcinogenic risks would not be appropriate. It should also be noted that if exposure to cadmium by inhalation for non-carcinogenic risks were included, this would have no significant effect on the outcome.

HHRA Comment 5

Please provide a sample calculation

We will include a sample calculation for lead in the town site in an appendix to the revised report; see attachment to this document.

HHRA Comment 6

Why was the cancer assessment based on a composite receptor?

Cancer risks are based on the degree and duration of exposure to a chemical. For this reason, it is normal practice in human health risk assessments to assess risks over an entire lifetime of exposure, rather than just a single life stage (adult or child). We have assessed cancer risks from cadmium inhalation by averaging exposures over five life stages (infant, toddler, child, teen, and adult). In this way we have incorporated the most conservative and protective way of assessing potential cancer risks.

HHRA Comment 7

Has the transcription of soils data used in the risk assessment been adequately validated?

We followed standard practices in conducting our review and validation of the data used in the risk assessment. All data was carefully checked when transcribed and 20% of all the data subsequently independently verified. We are confident that the data represents a complete and correct data set.

HHRA Comment 8

Is the use of a national median drinking water concentration appropriate as a source of background drinking water concentrations?

The intake from drinking water affects only the calculation of the EDI and only comprises less than 5% of the EDI. Therefore, slight variations in the drinking water concentrations would have no significant effect on the outcome of the risk assessment. CanZinco have indicated that the Nanisivik water supply was occasionally tested for metals and that no problems have been reported with the water supply. CanZinco also advises that regular sampling of the potable water system was completed by the DIAND water resources inspector and this data should be available for review to confirm water quality.

3.5 Comments from Nunavut Water Board (NWB),

E-mail from Patrick Duxbury (NWB) to Nanisivik Distribution List (not dated), Subject: Summary of the April 17th, 2003 Public Meeting in Arctic Bay.

The following three questions were brought forward by members of the Hamlet of Arctic Bay, through a memorandum by Mr. Patrick Duxbury, Mine Reclamation Coordinator, Nunavut Water Board, summarizing the April 17th, 2003, Public Meeting.

Comment 1

A hesitation expressed by some residents about the use of some assumptions employed in the HHERA. As some of the assumptions were based on research conducted in southern environments and in southern cultures, there was a sense that the assumptions may somehow underpredict risk, particularly as it relates to exposure of contaminants by both persons and animals.

The HHERA was carried out in a way that included many conservative assumptions (i.e., assumptions that would tend to overestimate risk, rather than to underestimate risk). In addition, members of the community, particularly people who identified themselves as hunters or people who spend a lot to time on the land, were interviewed in the fall of 2002 by Mr. Rob McCullough of JWEL. The purpose of those interviews was to find out directly from the people of Arctic Bay how they use the land, and what resources they harvest from the land. The information that JWEL obtained through these interviews was incorporated into the HHERA so that realistic assumptions, which reflected the arctic environment and culture, could be used. Therefore, we believe that the HHERA will not underpredict risk to people or animals, but will have a tendency to overpredict risk, due to its design.

Comment 2

How the role of the harsh arctic climate may somehow increase risk in a way that was not predicted or taken into account by the consultants authoring the HHERA.

The harsh arctic climate was taken into consideration in the human health risk assessment. During periods when the ground is frozen or snow-covered, there will be less dust in the air to be inhaled, and a reduced tendency for people to ingest soil. These factors were taken into consideration. In the ecological risk assessment, a simplified approach was taken that assumed that animals are exposed to contaminants throughout the year, as if it was summer. This is a conservative assumption, because ingestion of contaminants with soil is the major pathway through which animals and birds are exposed to contaminants like lead, zinc, copper and cadmium. By making this assumption, we ignore the fact that the animals will be less exposed to these metals while the ground is frozen or snow-covered. Therefore, we do not believe that the arctic climate will increase risk in ways that were not considered.

Comment 3

How the behaviour of the animal receptors chosen for the ERA may have not taken fully into account their ability to become exposed to contaminants in ways not predicted. The example was given of arctic fox at the mine site who are found almost everywhere at Nanisivik, including in locations of metal contamination such as the tailings pond or rock dumps.

In the ERA, it was assumed that animals were fully exposed to the most contaminated soils at the dock or town site, before considering their exposure to contaminants in other areas. This is somewhat artificial, but gives a worst-case exposure. At areas such as the tailings dump, or the landfill, cover will be applied so that the wastes are incorporated into the permafrost. It will be impossible for animals, like arctic fox, to come into contact with these wastes once the closure plan has been carried out. The tailings pond is flooded with water, which is the preferred manner of disposal for tailings, and will ensure that the metals remaining in the tailings are immobilized and harmless. All material in rock dumps will be disposed of underground, so there will be no way for wildlife to access these materials after closure. Therefore, it was not necessary to consider these areas in the ERA, because they will be removed or covered during the decommissioning work.

3.6 Comments from the Government of Nunavut

3.6.1 Letter from Susan Hardy (Nunavut Department of Justice) to Mr. Phillippe Di Pizzo (Nunavut Water Board), dated May 1, 2003.

Ms. Hardy provides comments on behalf of the Government of Nunavut. These comments are all directly related to the "Common Comments" for which responses are given earlier in this document.

3.6.2 E-mail message from Susan Hardy (Nunavut Department of Justice) to Nunavut Water Board, dated April 24, 2003.

This e-mail contained Section 6 ("Environmental") of a report commissioned by the Government of Nunavut, conducted by firm FSC Architects and Engineers. This section reported on environmental sampling conducted on four houses in the town site, and was commissioned to address human health concerns in relation to heavy metals.

Comment 1

General risks from lead dust and related assumptions.

The Housing Study completed on four houses at Nanisivik by FSC Architects and Engineers on October 25^{th} and 26^{th}, 2002, indicated that some household dust samples had elevated lead concentrations. Houses 604, 700, and 905 each had two out of six samples collected with lead dust concentrations greater than current US EPA guidance. House 801 had four out of six samples with elevated lead dust concentrations. As suggested by the Mines Inspector (Mr. Martin Van Roy) at the Iqaluit technical meeting, this dust is most likely due to tracking-in of dust from residents/employees during the time of mine operation when ores, concentrates, and tailings were being handled. This issue is separate from the HHERA, which models exposures to dust derived from re-suspension of soil particulates. Dust exposures modelled in the HHERA are based on soil concentrations and do not account for potential historic contamination of the houses from the mining operations. We believe that this is the appropriate approach for the HHERA to ensure that the study accurately portrays potential risks associated with soil concentrations after mine closure when the tailings will be covered and there will be no handling of ores or concentrates.

If specific sampling of the Nanisivik housing stock has indicated elevated dust lead concentrations in the homes, then we agree with the recommendations made by FSC that the houses should be thoroughly cleaned.

> *"We believe that to wash an entire house down to these specifications would take a four-person crew a full day to complete". FSC, March 2003.*

Once cleaned and with the mine no longer operating, the assumptions made in the risk assessment are valid. To bias the HHERA process by assuming that the houses will not be cleaned would be unrealistic.

ATTACHMENT 1

NANISIVIK HUMAN HEALTH RISK ASSESSMENT
SAMPLE CALCULATION

LEAD INTAKES IN THE TOWN SITE

Wild Game Ingestion

Calculation of Wild Game Tissue Concentration

WG_{conc} (mg/kg) = (GF_{site} x ((EXP(-0.6114 + 0.5181(LN(C_{soil})))) x WWCF)) + (GF_{bkgd} x ((EXP(-0.6114 + 0.5181(LN(C_{bkgd})))) x WWCF))

where:

WG_{conc} = 1.95 (wild game tissue concentration, empirical regression equation from Sample et. al. 1998)
GF_{site} = 0.2 (fraction of wild game consumed by local residents that was caught on the Nanisivik mine site)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
WWCF = 0.32 (dry weight to wet weight conversion factor)
GF_{bkgd} = 0.8 (fraction of wild game consumed by local residents that was caught in other areas)
C_{bkgd} = 45 mg/kg (regional soil concentration set equal to the OTR_{98} value for rural parkland)

Calculation of Intake from Wild Game Ingestion

$$WG_{intake} \text{ (mg/kg-d)} = \frac{WG_{conc} \times IR_{game} \times ET_{game} \times AF_{game}}{BW}$$

where:

WG_{intake} = 1.06 x 10^{-3} (intake from ingestion of wild game)
WG_{conc} = 1.95 mg/kg (wild game tissue concentration)
IR_{game} = 0.018 kg/d (amount of wild game consumed daily by a toddler, Richardson 1997)
ET_{game} = 1 (exposure term for wild game ingestion)
AF_{game} = 0.5 (bioavailability factor for food ingestion)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Soil/Dust Ingestion

Calculation of Intake from Soil/Dust Ingestion in the Summer

$$SD_{sum\text{-}ing\ intake} \text{ (mg/kg-d)} = \frac{C_{soil} \times IR_{soil\ ing} \times ET_{soil\ ing\ sum} \times AF_{soil\ ing}}{BW}$$

where:

$SD_{sum\text{-}ing\ intake}$ = 2.90 x 10^{-4} (intake from soil/dust ingestion in the summer)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
$IR_{soil\ ing}$ = 0.00008 kg/d (CCME default soil ingestion rate)
$ET_{soil\ ing\ sum}$ = 0.334 (exposure term for summer soil ingestion = (24 hours/day x 122 days/year)/(24 hours/day x 365 days/year))
$AF_{soil\ ing}$ = 0.3 (bioavailability factor for soil ingestion)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Calculation of Intake from Soil/Dust Ingestion in the Winter

IR_{dust} = SA_{finger} x DA x FR_{soil} x FR_{indoor} x WSF x FME x ET_{dust} x 10^{-6} kg/mg

where:

IR_{dust} = 1.16×10^{-6} kg/day (dust ingestion rate)
SA_{finger} = 8.75 cm^2/event (skin surface area of ½ of one finger, OMOE 1996)
DA = 0.056 mg/cm^2 (dermal loading, OMOE 1996)
FR_{soil} = 0.5 (fraction of dust that comes from soil, Hawley 1985)
FR_{indoor} = 0.75 (fraction of outside dust levels indoors, Hawley 1985)
WSF = 0.1 (factor to account for winter snow cover and permafrost limiting soil dust re-suspension)
FME = 9 events/hour (number of mouthing events per hour, OMOE 1996)
ET_{dust} = 7 hours/day (hours of exposure per day, OMOE 1996)

$$SD_{wint\text{-}ing\ intake}\ (mg/kg\text{-}d) = \frac{C_{soil} \times IR_{dust} \times ET_{dust\ ing\ wint} \times AF_{soil\ ing}}{BW}$$

where:

$SD_{wint\text{-}ing\ intake}$ = 8.39×10^{-6} (intake from soil/dust ingestion in the winter)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
IR_{dust} = 1.16×10^{-6} kg/d (calculated above)
$ET_{dust\ ing\ wint}$ = 0.666 (exposure term for winter dust ingestion = (24 hours/day x 243 days/year)/(24 hours/day x 365 days/year))
$AF_{soil\ ing}$ = 0.3 (bioavailability factor for soil ingestion)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Soil/Dust Dermal Contact

Calculation of Intake from Soil/Dust Dermal Contact in the Summer

$$SD_{summ\ derm\ intake}\ (mg/kg\text{-}d) = \frac{C_{soil} \times SA_{body} \times SAF \times ET_{derm\ summ} \times AF_{dermal} \times 10^{-6}\ kg/mg}{BW}$$

where:

$SD_{summ\ derm\ intake}$ = 3.64×10^{-5} (intake from soil/dust dermal contact in the summer)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
SA_{body} = 3,010 cm^2/day (skin surface area, CCME 2001)
SAF = 0.1 mg/cm^2 (soil to skin adherence factor, CCME 2001)
$ET_{dermsumm}$ = 0.334 (exposure term for summer soil contact = (24 hours/day x 122 days/year)/(24 hours/day x 365 days/year))
$AF_{soil\ ing}$ = 0.01 (bioavailability factor for soil dermal contact, US EPA 1992)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Calculation of Intake from Soil/Dust Dermal Contact in the Winter

$$SD_{wint\ derm\ intake}\ (mg/kg\text{-}d) = \frac{C_{soil} \times SA_{hands} \times SAF \times FR_{soil} \times FR_{indoor} \times WSF \times ET_{derm\ wint} \times AF_{dermal} \times 10^{-6}\ kg/mg}{BW}$$

where:

$SD_{wint\ derm\ intake}$ = 3.89×10^{-7} (intake from soil/dust dermal contact in the winter)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
SA_{hands} = 430 cm^2/day (skin surface area, CCME 2001)
SAF = 0.1 mg/cm^2 (soil to skin adherence factor, CCME 2001)
FR_{soil} = 0.5 (fraction of dust that comes from soil, Hawley 1985)
FR_{indoor} = 0.75 (fraction of outside dust levels indoors, Hawley 1985)
WSF = 0.1 (factor to account for winter snow cover and permafrost limiting soil dust re-suspension)
$ET_{derm\ wint}$ = 0.666 (exposure term for winter soil contact = (24 hours/day x 243 days/year)/(24 hours/day x 365 days/year))
AF_{dermal} = 0.01 (bioavailability factor for soil dermal contact, US EPA 1992)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Soil/Dust Inhalation

Calculation of Intake from Soil/Dust Inhalation in the Summer

TSP (kg/m^3) = Pe x L / U_{air} x ht

where:

TSP = 6.9 x 10^{-10} (total suspended particulate matter)
Pe = 6.9 x 10^{-13} $kg/m^2/s$ (particulate emission rate, ASTM RBCA 1995)
L = 1,000 m (length of soil parallel to wind direction)
U_{air} = 1 m/s (average wind speed)
Ht = 1 m (height of air breathing zone)

$$SD_{summ\ inh\ intake}\ (mg/kg\text{-}d) = \frac{C_{soil} \times FRP \times TSP \times IR_{inh} \times ET_{inh\ summ} \times AF_{inh}}{BW}$$

where:

$SD_{summ\ inh\ intake}$ = 7.75 x 10^{-8} (intake from soil/dust inhalation in the summer)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
FRP = 1 (fraction of the total suspended particulate that is respirable)
TSP = 6.9 x 10^{-10} kg/m^3 (calculated above)
IR_{inh} = 9.3 m^3/day (toddler inhalation rate, CCME 2001)
$ET_{inh\ summ}$ = 0.334 (exposure term for summer soil inhalation = (24 hours/day x 122 days/year)/(24 hours/day x 365 days/year))
$AF_{soil\ ing}$ = 1 (bioavailability factor for soil inhalation)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Calculation of Intake from Soil/Dust Inhalation in the Winter

$$SD_{wint\ inh\ intake}\ (mg/kg\text{-}d) = \frac{C_{soil} \times FRP \times TSP \times IR_{inh} \times FR_{soil} \times FR_{indoor} \times WSF \times ET_{inh\ wint} \times AF_{inh}}{BW}$$

where:

$SD_{wint\ inh\ intake}$ = 5.80 x 10^{-9} (intake from soil/dust inhalation in the winter)
C_{soil} = 597 mg/kg (soil concentration set equal to the SQRO for the sample calculation)
FRP = 1 (fraction of the total suspended particulate that is respirable)
TSP = 6.9 x 10^{-10} kg/m^3 (calculated above)
IR_{inh} = 9.3 m^3/day (toddler inhalation rate, CCME 2001)
FR_{soil} = 0.5 (fraction of dust that comes from soil, Hawley 1985)
FR_{indoor} = 0.75 (fraction of outside dust levels indoors, Hawley 1985)
WSF = 0.1 (factor to account for winter snow cover and permafrost limiting soil dust re-suspension)
$ET_{inh\ wint}$ = 0.666 (exposure term for winter soil inhalation = (24 hours/day x 243 days/year)/(24 hours/day x 365 days/year))
AF_{inh} = 1 (bioavailability factor for soil inhalation)
BW = 16.5 kg (toddler body weight, Richardson 1997)

Sum of all Intake Pathways

$Intake_{total}$ (mg/kg-d) = $WG_{intake} + SD_{sum\text{-}ing\ intake} + SD_{wint\text{-}ing\ intake} + SD_{summ\ derm intake} + SD_{wint\ derm intake} + SD_{summ\ inh\ intake} + SD_{wint\ inh\ intake}$
= 1.40 x 10^{-3}

Calculation of Hazard Quotient

$HQ = Intake_{total} / ((TDI - EDI) \times AF_{game})$

where:

$Intake_{total}$ = 1.40×10^{-3} mg/kg-d
TDI = 3.57×10^{-3} mg/kg-d
EDI = 7.69×10^{-4} mg/kg-d
AF_{game} = 0.5

$HQ = 0.0014 / ((0.00357 - 0.000769) \times 0.5)$
$HQ = 1$

Based on the above sample calculation, a soil concentration of 597 mg/kg results in a hazard quotient equal to 1.

Therefore the Soil Quality Remedial Objective (SQRO) for lead in the town site is rounded to 600 mg/kg.