Kiggavik Project

Final Environmental Impact Statement

Tier 2 Volume 8: Human Health

September 2014

History of Revisions

Revision Number	Date	Details of Revisions
01	December 2011	Initial release Draft Environmental Impact Statement (DEIS)
02	September 2014	FINAL Environmental Impact Statement

Foreword

The enclosed document forms part of the Kiggavik Project Final Environmental Impact Statement (FEIS) submission, presenting potential environmental and social impacts to determine if the Project should proceed and if so, under what terms and conditions. The submission has been prepared for the Nunavut Impact Review Board by AREVA Resources Canada Inc. to fulfill the requirements of the “Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.’s Kiggavik Project (NIRB File No. 09MN003)”, to include new material or clarity provided during the review of the Draft Environmental Impact Statement, and to address company commitments and direction from the Nunavut Impact Review Board as outlined in the “Preliminary Hearing Conference Decision Concerning the Kiggavik Project (NIRB File No. 09MN003)”.

The FEIS submission consists of a number of documents, as shown in the attached road map. These documents have been categorized into tiers, as follows:

- **Tier 1** document (Volume 1) provides a plain language summary of the Final Environmental Impact Statement.

- **Tier 2** documents (Volumes 2 to 10) contain technical information and provide the details of the assessments of potential Project environmental effects for each environmental compartment. Tier 2 Volume 11 contains executive, popular, and volume summaries in Inuktitut.

- The Tier 2 documents each have a number of technical appendices, which comprise the **Tier 3** supporting documents. These include the environmental baseline reports, design reports, modelling reports and details of other studies undertaken to support the assessments of environmental effects. Management plans are provided as Tier 3 documents.

Volume 1
Main Document

Volume 2 Project Description and Assessment Basis

- Governance and Regulatory Oversight
- Project Description
- Assessment Basis

2A Alternatives Assessment
2B Drilling and Blasting Design
2C Explosives Management Plan
2D Design of Ore and Mine Rock Pads and Ponds
2E Water Diversion and Collection Design
2F Design of Andrew Lake Dewatering Structure
2G Kiggavik-Sissons Road Report
2H Ore Storage Management Plan
2I Water Management Plan
2J Marine Transportation
2K Winter Road Report
2L All-Season Road Report
2M Roads Management Plan
2N Borrow Pits and Quarry Management Plan
2O Mine Site Airstrip Report
2P Occupational Health and Safety Plan
2Q Radiation Protection Plan
2R Preliminary Decommissioning Plan
2S Waste Management Plan
2T Environmental Management Plan
2U Hazardous Materials Management Plan
2V Mine Geotechnical Reports

Volume 3 Public Engagement and Inuit Qaujimajatuqangit

Part 1
- Public Engagement

Part 2
- Inuit Qaujimajatuqangit

3A Public Engagement Documentation
3B Inuit Qaujimajatuqngit Documentation
3C Community Involvement Plan

Volume 4 Atmospheric Environment

Part 1
- Air Quality and Climate Change

Part 2
- Noise and Vibration

4A Climate Baseline
4B Air Dispersion Assessment
4C Air Quality Monitoring Plan
4D Baker Lake Long-Term Climate Scenario
4E Noise and Vibration Assessment
4F Noise Abatement Plan

Volume 5 Aquatic Environment

- Surface Hydrology
- Hydrogeology
- Water and Sediment Quality
- Aquatic Organisms
- Fish and Fish Habitat

5A Hydrology Baseline
5B Geology and Hydrogeology Baseline
5C Aquatics Baseline
5D Groundwater Flow Model
5E Prediction of Water Inflows to Kiggavik Project Mines
5F Mine Rock Characterization and Management
5G Thermal and Water Transport Modelling for the Waste Rock Piles and Tailings Management Facilities
5H Waste Rock Water Balance
5I Hydrology of Waste Rock Piles in Cold Climates
5J Tailings Characterization and Management
5K Historical and Climate Change Water Balance
5L Kiggavik Conceptual Fisheries Offsetting Plan
5M Aquatics Effects Monitoring Plan
5N Hydrology Assessments
5O Sediment and Erosion Control Plan
5P Technical Assessments of Water Withdrawal Locations and Baker Lake Dock Site

Volume 6 Terrestrial Environment

- Terrain
- Soils
- Vegetation
- Terrestrial Wildlife

6A Surficial Geology and Terrain Baseline
6B Vegetation and Soils Baseline
6C Wildlife Baseline
6D Wildlife Mitigation and Monitoring Plan

Volume 7 Marine Environment

- Marine Water and Sediment Quality
- Marine Mammals
- Marine Fish

7A Marine Environment Baseline
7B Underwater Acoustic Modelling

Volume 8 Human Health

- Occupational Dose Assessments
- Human Health Risk Assessment

8A Ecological and Human Health Risk Assessment
8B Radiation Protection Supporting Document

Volume 9 Socio-Economic Environment and Community

Part 1
- Socio-Economic Environment

Part 2
- Heritage Resources

9A Socio-Economic Baseline
9B Archaeology Baseline
9C Human Resources Development Plan
9D Archaeological Resource Management Plan

Volume 10 Accidents, Malfunctions and Effects of the Environment on the Project

- Risk Assessments
- Effects of the Environment on the Project

10A Transportation Risk Assessment
10B Spill Contingency and Landfarm Management Plan
10C Emergency Response Plan

Volume 11 Executive, Popular and Volume Summaries Translated into Inuktitut

KEY:

Tier 1 Document	Tier 2 Document	Tier 3 Document
Main Documents	Environmental Effects Assessment Report	Technical Appendices, Baseline Reports, Technical Development and Management Plans

Executive Summary – Human Health

As per the guidelines issued by the Nunavut Impact Review Board (NIRB 2011), AREVA Resources Canada Inc. (AREVA) has prepared this Tier 2 Volume as part of the Environmental Impact Statement (EIS) to assess the potential effects on human health associated with the Kiggavik Project (the Project).

Scope of the Assessment

The NIRB developed the scope of assessment for the Project based on input from Inuit, government, and other interested stakeholders. Human health-related issues identified through this consultation, as well as engagement activities undertaken directly by AREVA, include concerns about the exposure of the public and workers to both radioactive (EN-KIV OH Oct 2009[1], EN-CH OH Nov 2010[2], EN-CH OH Nov 2010[3]) and non-radioactive materials (EN-RI KIA Apr 2007[4], EN-WC KIA Apr 2007[5]). The assessment addresses worker and public exposures to radioactive materials, hazardous substances and constituents of potential concern (COPCs) through construction, mining, milling, decommissioning and reclamation processes. In order to fully understand the potential effects of the Project on human health, COPCs in the environment are examined holistically in the ecological and human health risk assessments (Tier 3, Technical Appendix 8A). This pathways approach follows the food web concept and considers the interconnectedness of human health with ecological health in order to address community concerns such as *if uranium gets into animals and people eat them, do we get sick* (EN-KUG NTI May 2007)?

From a regulatory perspective, the two main acts informing the human health risk assessment are the federal *Nuclear Safety and Control Act* (protects workers and the public from exposure to radioactive and non-radioactive materials) and the Nunavut *Mine Health and Safety Act* (protects workers from risks to health and safety from mining).

Existing Environment

Regardless of where people live or work, they are exposed to radiation from natural sources; it is present in the air we breathe, the food we eat, the water we drink, and in the construction materials used to build our homes. It comes from outer space (cosmic), the ground (terrestrial), radionuclides in the body from air,

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[1] EN-KIV OH Oct 2009: *If I get a job, how will I know if radiation is affecting me?*

[2] EN-CH OH Nov 2010: *Can you see radiation?*

[3] EN-CH OH Nov 2010: *Are you more sensitive to radiation depending on who you are?*

[4] EN-RI KIA Apr 2007: *Are tailings a health hazard?*

[5] EN-WC KIA Apr 2007: *We eat country food and it should be monitored.*

water and food (internal) and exposure to radon. Worldwide, the normal range of average exposures to natural background radiation has been reported as about 1 to 13 mSv/y (UNSCEAR 2008, Annex B). Levels of natural or background radiation can vary greatly from one location to the next. For example, due to consumption of caribou, the internal dose for people living in the Project area is likely higher than that shown above. Ingestion of caribou in northern Canada has been shown to add 1 to 4 mSv/y of internal exposure for an adult, primarily due to the natural background levels of Po-210.

People are also exposed to the other constituents of potential concern (COPCs) such as arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium and zinc through air, water, soil and food. Generally, the intake from food is the largest contributor to the total exposure to COPCs.

Worker Health

Effects of Hazardous Substances and Constituents of Potential Concern on Worker Health

There are many chemicals used in the mining and milling process, some of which are considered as hazardous. A hazardous chemical can be classified as a physical hazard and (or) a health hazard. A chemical is considered a physical hazard if it has properties of being combustible, compressed, explosive, flammable, oxiding, pyrophoric or unstable. A chemical is considered a health hazard if its exposure has the potential to cause acute or chronic health effects. The hazardous substances examined for the Kiggavik Project are those chemicals used in significant quantities in the construction, mining, milling, decommissioning or reclamation activities that may have a potential health risk to the worker, including intermediary chemicals produced during the milling process, and chemical by-products.

A thorough review of the proposed milling process for the Kiggavik Project was conducted. The reagents used in the process was identified and evaluated to determine if it is a human health risk. In addition, by-products created were evaluated for potential risk and its controls are discussed. The mining and milling process at AREVA's McClean Lake Operation in northern Saskatchewan uses many of the same chemicals that will be used at the Kiggavik mines and mill. The controls for each chemical identified were reviewed and evaluated for adequacy to determine if it is sufficient to control exposures below the Threshold Limit Values (TLVs).

Workers may also be exposed to COPCs existing in the ore and mine rock through inhalation of aerosols (e.g. dusts or mists) during the Project phases. For the purposes of workplace exposure assessments, metals identified as COPCs include arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc.

For COPCs, the constituent concentrations in the ore and mine rock were evaluated and determined to each be a small fraction of the occupational exposure limits when expressed as a concentration of the constituent in respirable dust. Control measures designed to maintain respirable dust levels below occupational exposure limits will generally be adequate to protect workers from individual constituents of concern when mining either ore or mine rock.

Worker exposures to hazardous substances and COPCs conducted for the Kiggavik Project conclude that with the proposed mitigation measures in place, there are no exposures to workplace hazardous substances or COPCs expected to exceed the TLVs established by the American Conference of Governmental Industrial Hygienists (ACGIH).

Effects of Radioactivity on Worker Health

Kivalliq community members had many questions about radiation and the potential effects of radiation on people (EN- CH OH Oct 2012[6], EN-CH OH Oct 2012[7], EN-RB HS Nov 2013[8]). Information sharing and capacity building on the topic of radiation was a priority at many of AREVA's community engagement events (Tier 2, Volume 3, Part 1 Public Engagement).

The amount of radiation which a worker is exposed to is measured in terms of radiation dose, typically in units of millisieverts (mSv). Exposure to radiation has been found to increase the likelihood of detrimental effects occurring in those exposed. For the purposes of radiation protection, a precautionary approach is applied (i.e., it is assumed that the likelihood of detrimental effects is proportional to the dose received, even at low doses below the levels where statistical effects can be observed). Dose limits for individuals have been developed by the national nuclear regulator to protect against the radiation risk.

In Canada, the Canadian Nuclear Safety Commission (CNSC) regulates the nuclear industry. General regulations under the Nuclear Safety and Control Act governing work with uranium mines and mills may be found in the Uranium Mines and Mills Regulations (CNSC 2000a) and regulations regarding radiation protection are outlined in the Radiation Protection Regulations (CNSC 2000b). These regulations specify the limits on exposure to radiation for workers and for members of the general public. Doses to Nuclear Energy Workers (NEWs) must be below 50 mSv per year and 100 mSv per 5 years. Effectively, this means the annual exposure of a NEW should be less than 20 mSv/y on average.

In uranium mining and milling, effective dose is determined from evaluation of radiation exposure from three dose components:

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[6] EN-CH OH Oct 2012: *What is a dangerous amount of radiation?*

[7] EN-CH OH Oct 2012: *What is a dangerous number on the gadgets that would cause you to get sick?*

[8] EN-RB HS Nov 2013: *How dangerous is it itself?*

- Gamma radiation
- Radon and radon progeny
- Long-lived radioactive dust (LLRD)s: These are aerosols (fine materials that can become airborne as dry dust as well as mist) that contain radioactive materials, and may be inhaled or ingested, resulting in an internal exposure.

Exposure to each of these three dose components are converted to units of effective dose, in mSv, and then summed to form a worker's total effective dose for comparison to dose limits.

Mitigation and Project Design

The operating principle of radiation protection is "As Low As Reasonably Achievable (ALARA), social and economic factors considered". The process of radiation dose optimization involves assessing the sources of radiation exposure and designing facilities, processes, equipment, and work practices to minimize radiation doses to workers and the public. Dose rate constraints are established as objectives, below the dose limit, to be achieved during operations. They are useful in the design of facilities and are a practical implementation of the ALARA principle. AREVA has established workplace exposure rate design objectives for the Kiggavik mill, open pit and underground mines for each dose component.

A Radiation Protection Plan (RPP) is implemented at uranium mine sites to effectively mitigate risks from radiation exposure to workers, the public and the environment. The RPP is a multi-faceted approach consisting of a combination of: design features of equipment (e.g. sealed and lead-lined mobile equipment cabs, ventilation), operational practices (e.g. minimize time spent in areas with significant radiation levels, dust suppression) and worker awareness. The Radiation Code of Practice (RCOP) is a document, required by the CNSC under the Uranium Mines and Mills regulations, which describes a set of workplace radiological levels and worker exposure levels used for operational control of radiation doses, referred to as administrative and action levels.

Residual Project Effects

Radiation dose rates to workers were estimated based on experience gained from mining of uranium ores in northern Saskatchewan, particularly the mining of the open pits at AREVA's McClean Lake Operation, as well as through the use of computer programs. Radiation doses were estimated for routine operations in the underground mine, surface mines, mill and transport sections. Average potential radiological exposure to Kiggavik Workers during operation is expected to range from 0.74 mSv/y for open pit miners to 5.2 mSv/y for underground miners under routine activities. The maximum worker radiation dose is expected to be 10.5 mSv/y for underground miners.

These estimates indicate that there are no workers expected to receive radiation doses higher than the dose limits set by the Canadian Nuclear Safety Commission of 50 mSv in a single year or 100 mSv in a 5 year period (an effective annualized dose limit of 20 mSv/year).

Consideration was also given to an occupational worker exposure who is a NEW worker at the Kiggavik site and may also reside in Baker Lake. The additional dose to the worker, who would be present for half of their time at Baker Lake, is estimated to be 0.006 mSv/y. Even with the consideration of this additional exposure, all workers are expected to remain well below the CNSC dose limit.

Although the assessment indicates that radiation dose rates will be below CNSC dose limits, AREVA has heard community concerns about radiation. Community members have expressed that *there is a larger concern that people may become contaminated by the project* (IQ BLE 2009) hence the effects of radiation on both workers and the public has been evaluated and a Community Involvement Plan (Tier 3 Technical Appendix 3C) developed to communicate the results of the assessment. The Community Involvement Plan aims to increase community understanding of assessments and provide a framework for discussing future monitoring results in order to address perceived risks and reduce community concerns.

Residual Cumulative Effects

No cumulative effects were identified for occupational exposure.

Monitoring

Gamma radiation, radon/radon progeny (RnP), and long-lived radioactive dust (LLRD) will be monitored routinely throughout the Kiggavik Project in order to promptly detect potentially abnormal radiological conditions, to estimate worker doses, and to document radiological conditions. Dosimetry monitoring is conducted to document individual worker exposures to radiological components. Results of dosimetry monitoring are used to demonstrate regulatory compliance and contribute to radiation dose optimization strategies.

The radiological monitoring and dosimetric monitoring programs are developed to comply with applicable federal and territorial regulations; describe instrument requirements and sampling methods; refer to administrative levels and mitigative measures; and identify reporting responsibilities and methods.

Effects on Public Health

On several occasions during Inuit Qaujimajatuqangit (IQ) interviews and engagement activities, hunters and Elders discussed the pathways by which contaminants may potentially be released by the Project, travel through the ecosystem, and effect wildlife and subsequently humans. For example, hunters and Elders expressed concerns about *the potential for airborne contamination settling on vegetation and being consumed by caribou* (IQ ARHT 2009) and a community member asked *if uranium goes into the water will it be dangerous for our kids and grandkids* (EN-CI OH Nov 2012)?

The pathways framework used in this assessment involves consideration of various pathways, or routes of exposure, by which humans may be exposed; airborne dust and radon account for the inhalation dose while consumption of water, fish, vegetables, berries, and wildlife account for the ingestion dose. The pathways framework examines the interconnectedness of humans with all aspects of the environment; *the health of Inuit, of wildlife and of the environment are interconnected* (IQ-Nunavut Tunngavik Inc. 2005). This ecosystem approach complements the IQ principle of Avatimik Kamattiarniq/Amiginik Avatimik: people are stewards of the environment and must treat all of nature holistically and with respect, because humans, wildlife and habitat are inter-connected.

In the assessment, levels of COPC in the environment were estimated based on the expected atmospheric and aquatic emissions from the Kiggavik Project. To cover a variety of potential exposure situations a number of different representative individuals were incorporated in the assessment. These include permanent residents of the Baker Lake community (adult, child and toddler family members), hunters at Judge Sissons Lake that take game back to their families and non-nuclear workers (non-NEW) at the project site (e.g. camp cook, security guard). IQ is described as wisdom gained and passed from generation to generation (NTI 2000b). Understanding the importance of knowledge transfer, the potential exposure scenario of the hunter at Judge Sissons Lake also assumed a child would accompany to learn on-the-land skills.

Based on IQ and stakeholder engagement, *hunters described the people as dependent on caribou, fish, seals, ptarmigan, and beluga for food* (IQ RIHT 2009), and that *consuming country food is not considered 'ritual food' but the daily way of life* (IQ CIHT 2009). Caribou and fish were consistently named the primary country food sources for Baker Lake residents and local dietary considerations were accounted for in the human health assessment.

The exposure to Criteria Air Contaminants (CAC), radioactivity and non-radioactive COPC through the various pathways of exposure is estimated and compared to benchmarks that are set to be protective of human health.

Mitigation and Project Design

The design of the Kiggavik Water Treatment Plant (WTP) and Sissons WTP ensures that the effluent will meet all appropriate regulations such as the Metal Mining Effluent Regulation (MMER) as well as site-specific discharge limits derived from ecological risk assessment and surface water quality objectives for the receiving environment. Further detail on the design of the water treatment plants can be found in Volume 2 of the EIS (Project Description and Assessment Basis). Similarly, design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated air emissions and/or the potential effect of project-related emissions. These have been discussed in Volume 4 of the EIS (Atmospheric Environment).

Residual Project Effects

Three general groups of COPC were evaluated: CAC including NOx, SOx and particulate matter (PM) which have respiratory effects; non-radionuclide COPC (including arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc); and, uranium-series radionuclides. The findings are as follows:

- Maximum concentrations of SO_2 will be well within the health-based limits. Similarly, annual NO_2 concentrations will meet applicable criteria.
- There may be infrequent, short-term NO_2 concentrations above the WHO health-based criterion at the Kiggavik camp; however, the levels at Baker Lake are well below any level of concern. Exceedances at the camp can be attributed to potential emissions of NOx from open pit mining activities, including diesel-powered mining equipment and blasting. It should be noted that the concentrations are well below levels that WHO indicates may be a concern in healthy adults. NO_2 concentrations at the Kiggavik Camp do not exceed ambient air quality guidelines nor do they exceed Threshold Limit Values (TLVs) established by American Conference of Governmental Industrial Hygienists. which were developed to be protective of repeated exposure in a working environment.
- In terms of exposure to fine particulate matter (PM), the levels at Baker Lake will be well below any levels of concern. There may be some short-term concentrations at the Kiggavik camp which exceed the health-based value designed to be protective of sensitive individuals (e.g. older adults, pre-existing respiratory disease). The potential for adverse effects related to fine PM exposure is considered to be low.
- Exposures to non-radionuclides were evaluated. The predicted intakes are below levels identified by regulatory agencies such as Health Canada and the US EPA as being safe for individuals. Fish and caribou ingestion are the biggest contributors for most COPC, along with berries.
- The predicted average incremental dose to people from radiation for the Project activities are well below Health Canada's dose constraint value of 0.3 mSv and the CNSC allowable dose for members of the public of 1 mSv.

Community Elders expressed that they *are aware that there have been problems at other mines, and cited instances of caribou eating harmful things at mine sites* (IQ WCE 2009). To address this concern, many cautious assumptions were used in the assessment of potential uptake of contaminants by caribou; for example it was assumed that caribou would typically spend 1% of their time in the Local Assessment Area (LAA), which is near Judge Sissons Lake, and 4.7% of their time in the Regional Assessment Area (RAA). These assumptions are based on an analysis of telemetry data for the caribou herds within the LAA and RAA. As a result of these cautious assumptions, dose related to consuming caribou with elevated Po-210 concentrations, which comprises the majority of the dose for receptors other than the non-NEW site worker, is conservatively overestimated.

In summary, the pathways assessment did not indicate any significant human health effects based on exposure to members of the public from emissions from the Kiggavik Project.

Consideration was also given for a non-NEW worker at the Kiggavik site that may also reside in Baker Lake. The total dose for a person living in Baker Lake and working at the site (as a non-NEW) is estimated to be 0.1 mSv/y, well below the CNSC allowable dose for members of the public and the Health Canada dose constraint.

Residual Cumulative Effects

As the future projects considered in the cumulative effects assessment are located a considerable distance from the Kiggavik Project, there is not expected to be any interactions that would have a measurable effect on human health.

Monitoring

Monitoring plans do not directly assess human health; rather the monitoring programs are focused on environmental components such as air, water, soils, vegetation, and wildlife (e.g. Tier 3, Technical Appendices 4C Air Quality Monitoring Plan, 5M Aquatic Effects Monitoring Plan and 6D Wildlife Mitigation and Monitoring Plan. Results from the environmental monitoring programs can then be used to validate human health risk assessments. AREVA will also monitor community feedback and risk perceptions about human health through the implementation of the Community Involvement Plan. Two-way communication will help to ensure that long-term relationships are built and maintained: community members have opportunities to ask questions about human and animal health while AREVA can provide Project updates and overview of monitoring results.

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ᒪᓕᒃᑕᐅᔪᒃᓴᐃᑦ ᓄᓇᕗᒻᒥ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᕿᒥᕐᕈᔨᖏᓐᓄᑦ (NIRB 2011) ᓴᖅᑭᑕᐅᔪᑦ ᒪᓕᒡᓗᒋᑦ, ᐊᕉᕙᒃᑯᑦ AREVA Resources Canada Inc. ᐊᕉᕙᒃᑯᑦ ᐋᕿᒃᓯᐃᓚᐅᖅᑐᑦ ᑖᑉᓯᒥᙵᑦ Tier 2 ᑎᑎᖅᑲᒥᒃ ᐃᓚᒋᔭᐅᑉᓗᓂ ᐊᕙᑎᒥᒃ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᑎᑎᖅᑲᒧᑦ (EIS) ᖃᐅᔨᓴᕐᓂᐊᕐᓗᒍ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖓᓂᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᓐᓇᖅᑐᓄᑦ ᐊᒃᑐᐊᔪᓄᑦ ᑭᒡᒐᕚᒃ ᐱᓕᕆᐅᒧᑦ Kiggavik Project (ᐱᓕᕆᐊᖅ).

ᖃᓄᐃᑑᓂᖓ ᖃᐅᔨᓴᐃᓂᐅᑉ

NIRB–ᑯᑦ ᐋᕿᒃᓯᓚᐅᖅᑐᑦ ᖃᓄᐃᑑᓂᖓᓂᒃ ᖃᐅᔨᓴᐃᓂᐅᑉ ᐱᓕᕆᐊᒧᑦ ᒪᓕᒡᓗᒋᑦ ᐅᖃᐅᓯᐅᔪᑦ ᐃᓄᖕᓄᑦ, ᒐᕙᒪᒃᑯᑦ, ᐊᒻᒪᓗ ᐊᓯᖏᑦ ᐃᓚᐅᔪᒪᔪᑦ ᐱᖃᖃᑕᐅᔪᑦ. ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖓᓄᑦ–ᐱᔾᔪᑕᐅᔪᑦ ᐃᓕᑕᖅᓯᔪᑦ ᑖᒃᑯᓇ ᐅᖃᖃᑎᖃᑦᑕᐅᑎᓂᒃᑯᑦ, ᐊᒻᒪᓗ ᐱᓕᕆᖃᑎᖃᖅᓱᑎᒃ ᖃᓄᐃᓕᐅᕈᓘᔭᕐᓂᒃᑯᑦ ᐊᕉᕙᒃᑯᑦ ᐱᓕᕆᐊᕆᐸᓗᓂᐅᒃ ᐃᓚᐅᔪᑦ ᐃᓱᒫᓘᑏᑦ ᐃᓄᐃᒃ ᐊᒻᒪᓗ ᐱᓕᕆᔨᐅᔪᑦ ᑕᒪᐃᓐᓄᑦ ᐆᓐᓇᖅᑐᒧᑦ ᐊᒃᑐᖅᑕᐅᔪᓐᓇᕐᓂᕆᓐᓄᑦ (EN-KIV OH Oct 2009[9], EN-CH OH Nov 2010[10], EN-CH OH Nov 2010[11]) and non-radioactive materials (EN-RI KIA Apr 2007[12], EN-WC KIA Apr 2007[13]). ᖃᐅᔨᓴᐃᓂᖅ ᐱᓕᕆᐊᖃᖅᑐᖅ ᐱᓕᕆᔨᐅᔪᑦ ᐊᒻᒪᓗ ᐃᓄᐃᑦ ᐊᒃᑐᖅᑕᐅᔪᓐᓇᕐᓂᕆᑦ ᐆᓐᓇᖅᑐᓄᑦ ᐊᑐᖅᑐᑦ, ᐅᓗᕆᐊᓇᖅᑐᓂᒃ ᐊᒻᒪᓗ ᐃᓚᒋᔭᐅᔪᑦ ᐃᓱᒫᓘᑕᐅᔪᓐᓇᖅᑐᑦ (COPCs) ᓴᓇᔭᐅᕙᓪᓕᐊᑎᓪᓗᒍ, ᐅᔭᕋᕐᓂᐊᖅᑐᓕᕆᓂᕐᒥᑦ, ᓯᖃᓪᓕᑎᕆᑎᓪᓗᒋᑦ, ᓄᖅᑲᖅᑎᑦᑎᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᐅᑎᖅᑎᑎᕆᕙᓪᓕᐊᑎᓪᓗᒋᑦ. ᑐᑭᓯᐊᑎᐊᕐᓂᐊᕐᓗᒍ ᖃᓄᐃᖓᓕᕈᑕᐅᔪᓐᓇᖅᑐᑦ ᐱᓕᕆᐊᒥᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒥᓐᓄᑦ, COPCs ᐊᕙᑎᒥᑦ ᖃᐅᔨᓴᖅᑕᐅᓗᒃᑖᕐᑲᑦᑕᖅᑐᑦ ᓄᓇᐅᑉ ᐊᒻᒪᓗ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒥᓐᓄᑦ ᐅᓗᕆᐊᓇᕐᓂᕐᒧᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ (Tier 3, Technical Appendix 8A). ᑕᒪᓐᓇ ᐊᑐᖅᑕᐅᔪᖅ ᒪᓕᒃᑐᖅ ᓂᕿᓂᒃ ᑕᐅᑐᒡᓗᒋᒃ ᐊᒻᒪᓗ ᐃᓯᒪᒋᔭᐅᑉᓗᓂ ᐊᒃᑐᐊᔾᔪᑎᓂᕐᒥᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒥᑦ ᓄᓇᓗ ᐱᓕᕆᐊᕆᓂᐊᕐᓗᒋᑦ ᐃᓱᒫᓘᑏᑦ *ᓲᕐᓗ ᓄᖑᓯᐃᑐᖅ ᓂᕐᔪᑎᒧᐊᖃᑦᑕᕐᒪᑕ ᐊᒻᒪᓗ ᐃᓄᖕᓄᑦ ᓂᕆᔪᑏᑦ ᓂᕆᔭᐅᕙᒡᓗᑎᒃ, ᐋᓐᓂᐊᓕᖃᑦᑕᖅᐱᑕ?* (EN-KUG NTI May 2007).

ᒪᓕᒐᖃᕐᓂᒃᑯᑦ ᑕᐅᑐᒡᓗᒍ, ᒪᕐᕈᐊᒃ ᐱᕐᑯᔮᒃ ᐅᖃᖅᓯᒪᔪᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒥᓐᓄᑦ ᐅᓗᕆᐊᓇᖅᑐᓂᒃ ᖃᐅᔨᓴᐃᓂᐅᔪᖅ ᐅᑯᐊᒃ, ᑲᓇᑕᒥᑦ *Nuclear–ᒥᑦ ᐊᑦᑕᓇᖅᑐᒦᑦᑕᐃᓕᒪᓂᖅ ᐊᒻᒪᓗ ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᐱᕐᑯᔭᖅ* (ᒥᐊᓂᖅᓯᔪᖅ ᐱᓕᕆᔾᔪᓂᒃ ᐊᒻᒪᓗ ᐃᓄᖕᓂᒃ ᐊᒃᑐᖅᑕᐅᓂᕐᒋᓐᓄᑦ ᐆᓐᓇᖅᑐᒧᑦ ᐊᒻᒪᓗ ᐆᓐᓇᖅᑐᖃᙱᑦᑐᓄᑦ ᐊᑐᖅᑕᐅᕙᒃᑐᓄᑦ) ᐊᒻᒪᓗ ᓄᓇᕗᒻᒥᑦ *ᐅᔭᕋᕐᓂᐊᖅᑐᓕᕆᓂᕐᒧᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖅ ᐊᒻᒪᓗ ᐊᑦᑕᓇᖅᑐᒦᑦᑕᐃᓕᒪᓂᕐᒧᑦ ᐱᕐᑯᔭᖅ* (ᒥᐊᓂᖅᓯᔪᖅ ᐱᓕᕆᔾᔪᓂᒃ ᐅᓗᕆᐊᓇᖅᑐᓂᒃ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ ᐊᒻᒪᓗ ᐊᑦᑕᓇᖅᑐᒦᑦᑕᐃᓕᒪᓂᕐᒧᑦ ᐅᔭᕋᕐᓂᐊᖅᑐᓕᕆᓂᕐᒥᑦ).

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[9] EN-KIV OH Oct 2009: *ᐱᓕᕆᐊᖅᑖᕈᒪ, ᖃᓄᖅ ᖃᐅᔨᒪᓂᐊᖅᐳᖓ ᐆᓐᓇᖅᑐᖅ ᐅᕙᒻᓂᒃ ᐊᒃᑐᖅᓯᓂᖅᑲᖓᓛᖓ?*

[10] EN-CH OH Nov 2010: *ᑕᑯᔭᐅᔪᓐᓇᖅᐸ ᐆᓐᓇᖅᑐᖅ?*

[11] EN-CH OH Nov 2010: *ᐃᒃᐱᒋᓴᕋᐃᓂᖅᓴᐅᕚᑕ ᐆᓐᓇᖅᑐᒧᑦ ᑭᓇᐅᓂᕗᓂᖓ ᐊᑐᖅᓗᒍ?*

[12] EN-RI KIA Apr 2007: *ᐊᒃᑖᑯᓯᕝᕙᕋᓗᐃᑦ ᐅᓗᕆᐊᓇᖅᑑᕙᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ?*

[13] EN-WC KIA Apr 2007: *ᓂᕿᓪᓚᑦᑖᓂᒃ ᓂᕆᖃᑦᑕᕋᑉᑕ ᖃᐅᔨᕆᐊᖅᑕᐅᖃᑦᑕᕆᐊᖃᖅᑐᑦ.*

ᒫᓐᓇᐅᔪᖅ ᐊᕙᑎ

ᓇᓃᑐᐃᓐᓇᖅ ᐃᓄᐃᑦ ᓄᓇᖃᖅᐸᒃ ᐱᓕᕆᐊᖃᖅᐸᒐᓗᐊᓂᑦ, ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖃᖅᑐᑦ ᐆᓐᓇᖅᑐᒥᑦ ᓯᓚᒥᙳᖅᑐᒥᒃ; ᑕᐃᒪᐅᔪᖅ ᐊᓂᖅᖄᖅᑐᖅᑕᑉᑎᓐᓂᑦ, ᓂᕆᔭᑉᑎᓐᓂᑦ, ᐃᒥᖃᑦᑕᖅᑕᑉᑎᓐᓂᑦ, ᐊᒻᒪ ᐃᒡᓗᒋᔭᕗᑦ ᓴᓇᔭᐅᑎᓪᓗᒋᑦ ᐊᑐᖅᑕᐅᕙᒃᑐᓂᑦ. ᑖᒃᑳᓐᕆᑦ ᐊᓂᕐᓂᖅᑲᕆᑦᑐᒥᙳᖅᑐᖅ (ᓯᓚᐃᓐᓇᕐᒥᑦ), ᓄᓇᒥᑦ, radionuclides ᓯᓚᒥᑦ, ᐃᒪᕐᒥᑦ ᐊᒻᒪ ᓂᕿᒥᑦ ᐊᒻᒪ ᐊᒃᑐᖅᑕᐅᓂᖅᑲᖅᑰᑎᒃ radon-ᒧᑦ. ᓄᓇᕐᔪᐊᕐᒥᑦ, ᐊᒃᑐᖅᑕᐅᓂᐅᕚᒃᑐᖅ ᐆᓐᓇᖅᑐᒧᑦ ᐅᖃᐅᓯᐅᓯᒪᔪᖅ 1-ᒥᑦ 13-ᒧᑦ mSv/y (UNSCEAR 2008, Annex B). ᐊᕆᓂᕐᒐ ᐆᓐᓇᖅᑑᑉ ᐊᔾᔩᕆᓐᓂᖃᕐᔪᐊᕈᓐᓇᖅᑐᑦ ᓄᓇᐅᔪᓂᑦ (ᐅᕙᙵᑦ ᐃᑯᕐᒐ). ᐆᒃᑐᑎᕆᓗᒍ, ᓂᕆᖃᑦᑕᖅᑕᑉᑎᕐᓄᑦ ᑐᒃᑐᐃᑦ, ᐊᕆᓂᕆᔭᕐᒐ ᐱᓕᕆᐊᕘᑐᑦ ᐊᕆᓂᖅᓴᐅᑐᐃᓐᓇᕆᐊᖃᖅᑐᑦ ᑖᑉᑳᑯᓇᙵᑦ ᑕᑯᒃᓴᐅᑎᑕᐅᔪᓂᐅᕐᒐᓂᑦ. ᓂᕆᔭᐅᔪᑦ ᑐᒃᑐᐃᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᕐᒐᓂᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᓯᒪᔪᖅ 1-ᒥᑦ 4-ᒧᑦ mSv/y-ᒥᑦ ᐊᒃᑐᐊᓂᕐᒧᑦ ᐃᓐᓇᐅᔪᒧᑦ ᐃᓅᕐᒧᑦ, ᓯᓚᒥᙳᖅᑐᒥᓗᐊᖅ ᐊᕆᓂᖃᔭᕐᒐᓂᑦ Po-210.

ᐃᓄᐃᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᕐᒥᔪᑦ ᐊᓯᕆᓐᓄᑦ ᐃᓱᒫᓘᑕᐅᔪᕐᓇᖅᑐᓄᑦ (COPCs)-ᓄᑦ ᓲᕐᓗ arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, ᓄᕚᓯᐃᑐᖅ ᐊᒻᒪ zinc ᐊᓂᖅᖄᖅᑐᖅᑕᑉᑎᒍᑦ, ᐃᒪᕐᒥᑦ, ᐃᐸᔪᒥᑦ ᐊᒻᒪ ᓂᕿᓂᑦ. ᓂᕆᔭᑉᑎᕐᓂᓗᐊᖅ ᐊᕆᕵᒥᒃ ᑲᑎᕆᓗᑦ COPCs-ᓂᒃ ᐱᖃᑦᑕᖅᑐᒍᑦ.

ᐱᓕᕆᔾᔪᑉ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒐ

ᖃᓄᐃᕐᒐᓕᖅᑎᑦᑎᓂᑦ ᐅᓗᕆᐊᓇᖅᑐᐃᑦ ᐊᒻᒪ ᐃᓗᓕᕆᑦ ᐃᓱᒫᓘᑕᐅᔪᕐᓇᖅᑐᑦ ᐱᓕᕆᔾᔪᑉ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕆᔭᕐᒐᓄᑦ

ᐊᒥᓱᐊᓗᐃᑦ chemical-ᑯᐃᑦ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᑦ ᐅᔾᔨᕐᓂᐊᖅᑐᓕᕆᓂᕐᒥᑦ ᐊᒻᒪ ᓱᖃᓪᓕᑎᕆᑎᓪᓗᒋᑦ, ᐃᓚᕆᑦ ᐅᓗᕆᐊᓇᖅᑑᑎᑦᔭᐅᔪᑦ. ᐅᓗᕆᐊᓇᖅᑑᔪᖅ chemical ᐃᓕᑕᕆᔭᐅᓯᒪᔪᕐᓇᖅᑐᖅ ᑎᒥᒧᑦ ᐅᓗᕆᐊᓇᖅᑑᓂᕐᒐᓂᒃ ᐊᒻᒪ (ᐅᕙᓂᑦ) ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ. Chemical-ᑯᐃᑦ ᐃᓱᒪᕆᔭᐅᔪᑦ ᑎᒥᒧᑦ ᐅᓗᕆᐊᓇᕐᓂᕆᑦ ᐃᓗᓕᖅᐸᑦ ᐃᑭᑦᑐᕐᓇᖅᑐᒥᒃ, ᓯᑎᓪᓕᓴᖅᑕᐅᓯᒪᒃᐸᑦ, ᖄᖅᑕᖅᑑᒃᐸᑦ, ᐃᑯᐊᓪᓚᒍᕐᓇᖅᐸᑦ, oxiding, ᓯᓚᒥᑦ ᐊᒃᑐᖅᓯᒃᐸᑦ ᐃᑭᒃᑐᕐᓇᖅᑑᒃᐸᑦ ᓈᒻᒫᓂᙱᕆᐸᓪᓗᓂᑦ. Chemical ᐃᓱᒪᕆᔭᐅᔪᖅ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ ᐅᓗᕆᐊᓇᖅᑑᓂᕐᒐᓂᒃ ᑕᐃᒪᐅᒃᐸᑦ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ ᒥᑭᑦᑑᒐᓗᐊᒥᒃ ᑕᐃᒪᐅᕆᓐᓇᕐᓂᐊᓕᖅᑐᒦᓪᓗᓂᑦ ᖃᓄᐃᕐᒐᓕᖅᑎᑦᑎᔪᕐᓇᖅᐸᑦ. ᐅᓗᕆᐊᓇᖅᑐᐃᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᑭᒡᒐᖏᒃ ᐱᓕᕆᐊᒧᑦ chemical-ᑯᐃᑦ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᑦ ᐊᒥᓱᑲᓪᓚᐅᑉᐳᕆᑦ ᓴᓇᕙᓪᓕᐊᑎᓪᓗᕆᑦ, ᐅᔾᔨᕐᓂᐊᖅᑐᓕᕆᑎᓪᓗᕆᑦ, ᓱᖃᓪᓕᑎᕆᑎᓪᓗᕆᑦ, ᓄᖅᑲᖅᐸᓪᓕᐊᔪᓕᕆᑎᓪᓗᕆᑦ ᐅᕙᓂᑦ ᐅᑎᖅᑎᑎᕙᓪᓕᐊᑎᓪᓗᕆᑦ ᐱᓕᕆᔾᔪᑉ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒐᓄᑦ ᐊᒃᑐᖅᓯᑐᐃᓐᓇᕆᐊᖃᖅᑐᑦ, ᐃᓚᐅᐸᓗᑎᒃ ᕿᑎᕈᔪᐊᓃᑦ ᓴᖅᑭᑕᐅᔪᑦ ᓱᖃᓪᓕᑎᕆᑎᓪᓗᕆᑦ, ᐊᒻᒪ chemical-ᑯᐃᑦ ᓴᓇᔭᐅᓯᒪᔪᑦ.

ᕿᒥᕈᑦᑎᐊᕐᓂᖅᑕᖃᓚᐅᖅᑐᖅ ᓱᖃᓪᓕᑎᕆᕙᓪᓕᐊᓂᐅᔪᒪᔪᖅ ᑭᒡᒐᖏᒃ ᐱᓕᕆᐊᒧᑦ. ᐊᑐᖅᑕᐅᔪᑦ ᐱᕙᓪᓕᐊᓂᕐᒥᑦ ᐃᓕᑕᕆᔭᐅᓚᐅᖅᑐᑦ ᖃᐅᔨᓴᖅᑕᐅᓗᑎᒡᓗ ᖃᐅᔨᔪᒪᓗᑎᒃ ᐃᓅᑉ ᐋᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒐᓄᑦ ᐅᓗᕆᐊᓇᕐᒪᖔᑦ. ᐊᒻᒪ, ᓴᓇᔭᐅᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓗᑎᒃ ᐅᓗᕆᐊᓇᖅᑑᔪᕐᓇᕐᓂᕆᑦ ᐊᐅᓚᑕᐅᓂᕆᓪᓗ ᐅᖃᐅᓯᐅᓗᑎᒃ. ᐅᔾᔨᕐᓂᐊᕐᓂᖅ ᐊᒻᒪ ᓱᖃᓪᓕᑎᕆᕙᓪᓕᐊᓂᖅ ᐊᓇᕙᒃᑯᑦ McClean Lake-ᒥᑦ ᐊᐅᖀᕐᓂᖃᔭᕐᒐᑦ ᐅᐊᕐᓇᖅᐸᓯᕐᒐᓂᑦ ᓴᑉᑳᑦᓯᐊᓐ ᐊᑐᖃᑦᑕᖅᑐᖅ ᐊᒥᓱᓂᒃ ᐊᔾᔨᕆᓐᓂ chemical-ᓂᒃ ᐊᑐᖅᑕᐅᓂᐊᖅᑐᓂᒃ ᑭᒡᒐᖏᕐᒥᑦ ᐅᔾᔨᕐᓂᐊᕐᖏᕐᒥᑦ ᐊᒻᒪ ᓱᖃᓪᓕᑎᕆᕝᖏᕐᒥᑦ. ᐊᐅᓚᑦᑎᓂᑦ ᐊᑐᓂ chemical-ᓄᑦ ᐃᓕᑕᕆᔭᐅᔪᒧᑦ ᕿᒥᕈᔭᐅᓚᐅᖅᑐᑦ ᐊᒻᒪ ᖃᐅᔨᓴᖅᑕᐅᓗᑎᒃ ᓈᒻᒪᒃᑲᓗᐊᕐᓂᕆᓐᓄᑦ ᖃᐅᔨᓂᕐᒧᑦ ᓈᒻᒪᒃᑲᓗᐊᕐᒪᖔᑦ ᐊᐅᓚᓐᓂᐊᕐᓗᒍ ᐊᒃᑐᖅᑕᐅᔪᕐᓇᕐᓂᕐᒐ ᓈᓴᐅᑏᑦ ᑭᒡᓕᕆᔭᐅᔫᑉ ᐊᑖᓄᑦ (TLVs).

ᐱᓕᕆᓃᒃ ᐊᒃᑐᖅᑕᐅᓂᖅᑐᐃᓐᓇᓇᐊᖃᖅᒥᔪᑦ COPCs−ᓄᑦ ᓄᓇᐅᑉ ᐊᑖᓂᙶᖅᑐᓂᒃ ᐅᔭᖅᑲᓃᑐᓂᒃ ᐊᒻᒪ ᐅᔭᕋᖕᓂᐊᖅᓂᐅᑉ ᐅᔭᖅᑲᖏᓐᓂᑦ ᐊᓂᖅᓵᖅᑐᖅᓗᓂᔾᔪᒃ ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑎᖕᓃᑐᓂᒃ (ᓲᖅᓗ ᐳᔪᖅᑖᕋᓗᐃᑦ) ᐱᓕᕆᐊᖅ ᐊᐅᓛᖅᑎᑕᐅᕙᓪᓕᐊᑎᓪᓗᒍ. ᐱᓕᕆᕝᕕᐅᔪᑦ ᐱᔾᔪᑎᒋᑉᓗᒋᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅᑯᑦ ᖃᐅᔨᓴᐃᓃᑦ, ᓴᕚᑦ ᐃᓕᑕᕆᔭᐅᔪᑦ COPCs−ᖑᑉᓗᑎᒃ ᐃᓚᐅᔪᑦ arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, ᓄᖑᓯᐃᑐᑦ, ᐊᒻᒪ zinc.

COPCs−ᓄᑦ, ᐃᓗᓕᖏᑦ ᑲᑎᓯᒪᔪᑦ ᓄᓇᐅᑉ ᐊᑖᓂᙶᖅᑐᓂᒃ ᐅᔭᖅᑲᓂ ᐊᒻᒪ ᐅᔭᕋᖕᓂᐊᖅᓂᐅᑉ ᐅᔭᖅᑲᖏᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ ᖃᐅᔨᑉᓗᑎᓪᓗ ᐊᑐᓂ ᒥᑭᑦᑐᒥᒃ ᐱᓕᕆᕝᕕᐅᔪᑦ ᐱᑕᖃᖅᓂᖏᓐᓄᑦ ᑭᓪᓕᕆᔭᐅᔪᓂᑦ ᑲᑎᓯᒪᔪᑦ ᐃᓗᓕᖏᑦ ᐳᔪᖅᑖᒦᑐᑦ. ᐊᐅᓚᑦᑎᓂᑦ ᐋᖅᑭᒃᑕᐅᓯᒪᔪᑦ ᖃᓄᐃᑎᐅᓂᖏᓐᓂᒃ ᐊᓂᖅᓵᖅᑐᖅᑕᐅᔪᑦ ᐊᑦᑎᖕᓂᖅᓴᐅᓂᖏᓐᓂᒃ ᑭᓪᓕᕆᔭᐅᔪᓂᒃ ᓈᒻᒪᒃᑑᓂᖏᓐᓂᒃ ᒥᐊᓂᕆᔭᐅᓂᖏᓐᓄᑦ ᐱᓕᕆᔨᐅᔪᑦ ᐃᓗᓕᐅᔪᓂᑦ ᑕᒪᒃᑯᓂᙵᑦ ᐱᓕᕆᐊᖃᖅᑎᓪᓗᒋᑦ ᓄᓇᐅᑉ ᐊᑖᓂᙶᖅᑐᓂᒃ ᐅᔭᖅᑲᓃᑐᓂᒃ ᐊᒻᒪ ᐅᔭᕋᖕᓂᐊᖅᓂᐅᑉ ᐅᔭᖅᑲᖏᓐᓂᑦ.

ᐱᓕᕆᓃᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᔪᑦ ᐅᓗᕆᐊᓇᖅᑐᓄᑦ ᐊᒻᒪ COPCs−ᓄᑦ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᖅ ᑭᒡᒐᕝᕕᒃ ᐱᓕᕆᐊᒍᑦ ᖃᐅᔨᓚᐅᖅᑐᑦ ᐊᖏᕈᐊᖏᑎᒋᐊᖅᑎᑦᑎᓂᐅᔪᒪᔪᖅ ᑕᐃᒪᐅᓕᖅᐸᑦ, ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅᑕᖃᔾᔮᖏᓐᓂᖓᓂᒃ ᐅᓗᕆᐊᓇᖅᑐᓄᑦ ᐱᓕᕆᕝᕕᐅᔪᖅ ᐅᕙᓘᓃᑦ COPCs−ᖑᔪᑦ ᓂᕈᐊᕆᔭᐅᔪᑦ ᐅᖓᑕᐅᑎᓂᐊᖅᓂᖓ TLV−ᒥᒃ ᓴᖅᑭᑕᐅᔪᑦ American Conference of Governmental Industrial Hygienists (ACGIH)−ᑯᓐᓄᑦ.

ᖃᓄᐃᖓᓕᕈᑏᑦ ᐆᓇᖅᑐᓄᑦ ᐱᓕᕆᓃᐅᑉ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖓᓄᑦ

ᑭᕙᓪᓕᐅᑉ ᓄᓇᓕᖏᓐᓂᖅᒥᐅᑕᐃᑦ ᐊᒥᓱᓂᒃ ᐊᐱᖅᑯᑎᖃᓚᐅᖅᑐᑦ ᐆᓇᖅᑑᑉ ᒥᒃᓵᓄᑦ ᐊᒻᒪ ᖃᓄᐃᖓᓕᕈᑕᐅᔪᖕᓇᖅᓂᖓ ᐃᓄᖕᓄᑦ (EN- CH OH Oct 2012[14], EN-CH OH Oct 2012[15], EN-RB HS Nov 2013[16]). ᑐᑭᓯᐅᒪᔾᔪᑎᓂᒃ ᐱᖃᑦᑕᐅᑎᓂᖅ ᐊᒻᒪ ᐃᓂᖃᖅᓂᖅᑯᑦ ᐱᕙᓪᓕᐊᓂᖅ ᐆᓇᖅᑐᑦ ᐱᓕᕆᐊᖑᖃᐅᑕᐅᔭᕆᐊᖃᓚᐅᖅᑐᖅ ᐊᒥᓲᔪᓂᒃ ᐊᕇᕙᒃᑯᑦ ᓄᓇᓕᖕᓂᒃ ᐱᓕᕆᖅᑎᖃᖅᓂᕆᔭᖏᓐᓂᑦ (Tier 2, Volume 3, Part 1 ᐃᓄᖕᓂᒃ ᐱᓕᕆᖅᑎᖃᖅᓂᖅ).

ᖃᓄᑎᒋᐅᓂᖓ ᐆᓇᖅᑑᑉ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᕆᔭᖓ ᐱᓕᕆᓃᐅᑉ ᐆᒃᑐᕋᖅᑕᐅᖃᑦᑕᖅᑐᖅ ᖃᓄᑎᒋᐅᓂᖓᓂᒃ ᐆᓇᖅᑑᑉ, ᐃᒪᓐᓇᐅᑎᒋᑉᓗᑎᒃ millisieverts (mSv). ᐆᓇᖅᑐᒧᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᖅ ᐊᖏᓪᓕᒋᐊᖃᑦᑕᕈᖕᓇᖅᓂᖓ ᓱᖁᐃᓗᑎᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖓ ᐊᒃᑐᖅᑕᐅᔪᓄᑦ. ᒥᐊᓂᖅᓯᓂᖅᒧᑦ ᐆᓇᖅᑐᒥᑦ, ᐅᔾᔨᖅᑐᖅᓂᖅᒥᒃ ᐊᑐᓕᖅᓯᒪᔪᑦ (ᓲᖅᓗ, ᐃᓱᒪᒋᔭᐅᔪᖅ ᓱᖁᐃᓂᖃᖅᑐᒥᒃ ᖃᓄᐃᖓᓕᕈᑎᑕᖃᖅᓂᐊᖅᓂᖅ ᐃᓚᐃᓇᖔᖅᑐᖅ ᖃᓄᑎᒋᐅᓂᖓᓂᒃ ᐱᔪᓄᑦ, ᐊᑦᑎᒃᑑᒐᓗᐊᖅᐸᑦ ᐱᔭᐅᔪᖅ ᐊᑦᑎᖓᓂᖅᓴᐅᓗᓂ ᑭᓪᓕᕆᔭᐅᔪᒥᑦ ᓈᓴᐅᑏᑦ ᖃᓄᐃᖓᓕᖅᓂᖅᒧᑦ ᕿᒥᖅᕈᔭᐅᔪᖕᓇᖅᑐᑦ). ᐱᔭᐅᔭᕆᐊᖃᖅᓂᖓ ᐆᓇᖅᑑᑉ ᐃᓄᖕᒧᑦ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᖅ ᑲᓇᑕᒥᑦ nuclear−ᓄᑦ ᖃᐅᔨᓴᕈᑎ ᒥᐊᓂᖅᓯᔪᖅ ᐆᓇᖅᑐᒧᑦ ᐅᓗᕆᐊᓇᖅᑐᓃᑐᓄᑦ.

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[14] EN-CH OH Oct 2012: *ᓱᓇᑦ ᐅᓗᕆᐊᓇᖅᑑᕙᑦ ᐊᖏᓂᕆᔭᖓ ᐆᓇᖅᑐᑦ?*

[15] EN-CH OH Oct 2012: *ᓱᓇᑦ ᓈᓴᐅᑎᐅᑉ ᖃᑉᓯᐅᓂᖏᑦ ᐅᓗᕆᐊᓇᖅᑑᕙᑦ ᓇᓗᓇᐃᔭᐅᑎᓃᑐᑦ ᐋᓐᓂᐊᓕᕈᑕᐅᔪᖕᓇᖅᑐᑦ?*

[16] EN-RB HS Nov 2013: *ᖃᓄᖅ ᐅᓗᕆᐊᓇᖅᑎᒋᕙ ᑖᒻᓇ?*

ᑲᓇᑕᒥᑦ, ᑲᓇᑕᒥᑦ Nuclear-ᓄᑦ ᐊᑦᑕᓇᖅᑐᒦᑎᑦᑎᑦᑕᐃᓕᒪᓕᕆᔩᒃᑯᖏᑦ (CNSC) ᒪᓕᒐᓕᕆᔩᐅᖃᑦᑕᖅᑐᑦ nuclear-ᓕᕆᕙᒃᑐᓂᒃ. ᒪᓕᒐᐃᑦ ᒪᓕᒃᓱᒋᑦ Nuclear-ᓄᑦ ᐊᑦᑕᓇᖅᑐᒦᑦᑕᐃᓕᒪᑎᑦᑎᓂᖅ ᐊᒪᓗ ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᐱᕐᑯᔭᖏᑦ ᐊᐅᓚᑦᑎᔪᖅ ᐱᓕᕆᐊᖃᕐᓂᕐᒥᒃ ᓄᖑᓯᐃᑐᒥᒃ ᐅᔭᕋᖕᓂᐊᖅᑐᓕᕆᔩᑦ ᐊᒪᓗ ᓯᖃᓪᓕᑎᓇᓂᕐᒧᑦ ᒪᓕᒐᓂᒃ (CNSC 2000a) ᐊᒪᓗ ᒪᓕᒐᓂᒃ ᐆᓇᖅᑐᐃᑦ ᒥᒃᓵᓅᖕᒐᔪᓂᒃ ᓇᒧᓇᐃᖅᓯᓯᒪᔪᑦ ᐆᓇᖅᑐᓄᑦ ᒥᐊᓂᕆᔭᐅᓂᕐᒧᑦ ᒪᓕᒐᓂᒃ (CNSC 2000b). ᑕᒪᒃᑯᐊ ᒪᓕᒐᐃᑦ ᐅᖃᖅᓯᒪᔪᑦ ᑭᓪᓕᒋᔭᐅᔪᓂᒃ ᐆᓇᖅᑐᒧᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᔪᖕᓇᕐᓂᖏᓐᓂᒃ ᐱᓕᕆᔩᐅᔪᑦ ᐃᓄᐃᓪᓗ. ᖃᓄᑎᒋᐅᓂᖓ Nuclear-ᒧᑦ ᐆᒻᒪᖅᑯᑎᓕᕆᓂᕐᒧᑦ ᐱᓕᕆᔩᑦ (NEWs) 50 mSv ᐊᑖᓃᑦᑕᓇᐊᖃᖅᑐᑦ ᐅᑭᐅᒥᒃ ᐊᑕᐅᓯᕐᒥᑦ ᐊᒪᓗ 100 mSv -ᖑᓗᓂ ᐅᑭᐅᓄᑦ ᑕᓪᓕᒪᓄᑦ. ᑐᑭᖃᖅᑐᖅ ᐅᑭᐅᓗᒃᑖᖅ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᐅᔪᓐᓇᖅᑐᖅ NEW-ᒧᑦ 20 mSv/y ᑐᖕᓖᓃᓐᓇᔭᖃᑦᑕᖅᑐᖅ.

ᓄᖑᓯᐃᑐᒧᑦ ᐅᔭᕋᖕᓂᐊᖅᑐᓕᕆᑉᓗᓂ ᓯᖃᓪᓕᑎᓇᓂᕐᓗ, ᓈᒻᒪᒋᔭᐅᔪᖅ ᐊᖏᑎᒋᓂᖓ ᖃᐅᔨᔭᐅᖃᑦᑕᖅᑐᖅ ᖃᐅᔨᓴᖅᓱᒍ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅ ᐆᓇᖅᑐᒧᑦ ᐅᑯᓇᙵᑦ ᐱᖓᓲᔪᓂᑦ:

- ᓯᕿᓂᕐᒥᑦ ᐆᓇᖅᑐᖅ
- Radon ᐊᒪᓗ Radon progeny
- ᐊᑯᓂ-ᐆᒪᔪᖅ ᐆᓇᖅᑐᖅ ᐳᔪᖅᑳᒃ (LLRD): ᑕᒪᒃᑯᐊ ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑎᓐᓅᑐᑦ (ᒥᑭᔫᔪᑦ ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑎᓐᓄᐊᕈᓐᓇᖅᑐᑦ ᐸᓂᖅᑑᓗᓂ ᐳᔪᖅᑳᖑᓗᓂ ᐊᒪᓗ ᑭᓂᖅᑑᓗᓂ) ᐃᓗᓕᖃᖅᑐᑦ ᐆᓇᖅᑐᓂᒃ, ᐊᒪᓗ ᐊᓂᖅᓵᖅᑕᐅᔪᓐᓇᖅᓱᓂ ᐄᔭᐅᓗᓂᓘᓃᑦ, ᑕᐃᒪᓐᓇ ᑎᒥᐅᑉ ᐃᓗᐊᓄᐊᕐᓗᓂ.

ᐊᒃᑐᖅᑕᐅᓂᖅ ᑕᒪᒃᑯᓄᙵ ᐱᖓᓲᔪᓄᑦ ᐋᕿᒃᑕᐅᖃᑦᑕᖅᑐᑦ ᐊᑑᑎᖃᖅᑑᓕᖅᓱᒋᑦ, mSv-ᓂᑦ, ᐊᒪᓗ ᑲᑎᑕᐅᑉᓗᑎᒃ ᐱᓕᕆᔩᐅᔫᑉ ᑲᑎᓱᒋᑦ ᐱᔪᖕᓇᖅᑕᖓᓄᑦ ᐱᔭᐅᔪᓐᓇᖅᑐᑦ ᑕᐅᑐᙳᖅᓱᒋᑦ ᑭᓪᓕᒋᔭᐅᔪᑦ .

ᐊᖏᓗᐊᖏᑎᑦᑎᓂᖅ ᐊᒪᓗ ᐱᓕᕆᐊᑉ ᖃᓄᐃᖓᓂᖓ

ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᒪᓕᒐᐃᑦ ᐆᓇᖅᑐᒧᑦ ᒥᐊᓂᕆᔭᐅᓂᕐᒧᑦ "ᐊᑦᑎᓛᒃᑯᑦ ᐱᔭᐅᔪᓐᓇᖅᑐᖅ (ALARA), ᐃᓄᐃᑦ ᐊᒪᓗ ᐱᕈᖅᐸᓪᓕᐊᓂᕐᒎᕐᓚᔪᑦ ᐃᓱᒪᒋᔭᐅᑉᓗᑎᒃ". ᐱᕙᓪᓕᐊᓂᖅ ᐆᓇᖅᑐᒥᒃ ᓈᒻᒪᒃᓯᑎᓇᓂᕐᒥᑦ ᐃᓚᐅᔪᑦ ᖃᐅᔨᓴᐃᓂᖅ ᓇᑭᙶᕐᓂᐅᔪᓂᒃ ᐆᓇᖅᑐᓂᒃ ᑎᑭᑕᐅᓯᒪᓂᕐᒧᑦ ᐊᒪᓗ ᖃᓄᐃᑑᓂᖏᑦ ᐊᑐᖅᑕᐅᔪᑦ, ᐱᕋᓪᓚᐊᓃᑦ, ᐱᕐᑯᑏᑦ, ᐊᒪᓗ ᐱᓕᕆᓂᐅᖃᑦᑕᖅᑐᑦ ᒥᑭᓛᒃᑯᖅᑎᑦᑎᓂᕐᒥᒃ ᐆᓇᖅᑐᒥᒃ ᐱᖃᑦᑕᕐᓂᕐᒥᒃ ᐱᓕᕆᔩᐅᔪᓄᑦ ᐊᒪᓗ ᐃᓄᖕᓄᑦ. ᐊᖏᓂᖓ ᓴᖅᑭᑕᐅᖃᑦᑕᖅᑐᖅ ᐱᓕᕆᐊᖑᓂᐊᖅᓱᑎᒃ, ᑭᓪᓕᒋᔭᐅᔫᑉ ᐊᑖᓂ, ᑎᑭᐅᑎᓂᐊᕐᓗᒍ ᐊᐅᓛᕐᓂᐅᑎᓪᓗᒍ. ᐊᑑᑎᖃᖅᑐᑦ ᖃᓄᐃᑑᓂᖓᓯᒃ ᐊᑐᖅᑕᐅᔪᑦ ᐊᒪᓗ ᓈᒻᒪᒃᑑᑉᐳᑎᒃ ᐊᑐᓕᖅᑎᑕᐅᓂᖓᓄᑦ ALARA ᒪᓕᒐᒧᑦ. ᐊᕕᑉᑯᑦ ᓴᖅᑭᑎᓚᐅᖅᑐᑦ ᐱᓕᕆᕝᕕᖏᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᐅᑉ ᐊᖏᓂᖓᓄᑦ ᖃᓄᐃᖓᓂᖓᓂᐊᕐᓂᖓᓂᒃ ᑭᒡᒐᕝᕕᐅᑉ ᓯᖃᓪᓕᑎᕝᕕᖓᓂᑦ, ᒪᓂᕋᒥᑦ ᐅᒃᑯᐃᖓᔪᒥᑦ ᐊᒪᓗ ᓄᓇᐅᑉ ᐊᑖᓂᑦ ᐅᔭᕋᖕᓂᐊᕐᕕᖕᓄᑦ ᐊᑐᓂ ᐱᔭᐅᔪᓐᓇᖅᑐᓄᑦ.

ᐆᓇᖅᑐᒧᑦ ᒥᐊᓂᕆᔭᐅᓂᕐᒧᑦ ᐸᕐᓇᐅᑎ (RPP) ᐊᑐᓕᖅᑎᑕᐅᔪᖅ ᓄᖑᓯᐃᑐᓄᑦ ᐅᔭᕋᖕᓂᐊᕐᕕᐅᔪᓂᑦ ᐊᖏᓗᐊᖏᑎᑦᑎᒋᐊᕐᓂᕐᒧᑦ ᐅᓗᕆᐊᓇᖅᑐᑦ ᐆᓇᖅᑐᓄᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᕐᒧᑦ ᐱᓕᕆᔩᓄᑦ, ᐃᓄᖕᓄᑦ ᐊᒪᓗ ᐊᕙᑎᒧᑦ. RPP ᐊᒥᓱᐃᓕᖓᔪᖅ ᐃᓚᐅᑉᓗᑎᒃ ᑲᑎᓯᒪᔪᓂᒃ: ᖃᓄᐃᖓᓂᐊᕐᓂᖓᓂᒃ ᐱᕐᑯᑏᑦ (ᓲᕐᓗ ᓯᒥᒃᓯᒪᓂᖅᑲᖅᑐᑦ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᑦ ᐃᖏᕐᕋᔪᐊᑏᑦ, ᓯᓚᒧᐊᖅᐸᓪᓕᐊᕝᕖᑦ), ᐊᐅᓛᖅᑎᑦᑎᓂᖓ (ᓲᕐᓗ ᒥᑭᓛᒃᑯᓗᑎᑦᑎᓗᒍ ᐆᓇᖅᑐᖃᖅᑐᒦᓐᓂᖅ, ᐳᔪᖅᑳᓕᕐᒦᓐᓂᖅ) ᐊᒪᓗ ᐱᓕᕆᔩᑦ ᐅᔾᔨᕈᓱᒃᑎᓪᓗᒋᑦ. ᐆᓇᖅᑐᓕᕆᓂᕐᒧᑦ ᓇᓗᓇᐃᑯᑏᑦ ᐊᑐᖃᑦᑕᕐᓂᖅ (RCOP) ᑎᑎᖅᑲᐅᔪᖅ, ᐱᔭᕆᐊᖅᑲᖅᑕᕐᓚᑦ CNSC-ᑯᑦ ᒪᓕᒃᓱᒋᑦ ᓄᖑᓯᐃᑐᓄᑦ ᐅᔭᕋᖕᓂᐊᕐᕕᖕᓄᑦ ᐊᒪᓗ ᓯᖃᓪᓕᑎᓇᖕᕕᖕᓄᑦ ᒪᓕᒐᐃᑦ, ᐅᖃᐅᓯᖅᑐᑦ ᐱᓕᕆᕝᕕᖕᓂᑦ ᐆᓇᖅᑐᑦ ᖃᓄᑎᒋᐅᓂᖏᓐᓂᒃ ᐊᒪᓗ ᐱᓕᕆᔩᒧᑦ

ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖓᑕ ᐊᖏᓂᕆᔭᖏᑦ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᖅ ᐊᐅᓛᕐᓂᕐᒧᑦ ᐊᐅᓚᑦᑎᓂᕐᒥᑦ ᐆᓇᖅᑐᓂᒃ ᐱᔭᐅᖃᑦᑕᖅᑐᓂᒃ, ᖃᐅᔨᒪᔭᐅᔪᖅ ᐊᐅᓚᑦᑎᓂᖅ ᐊᒻᒪ ᖃᓄᐃᓕᐅᕆᐊᕈᑏᑦ.

ᕿᒪᒃᑎᕐᑎᓄᑦ ᐱᓕᕆᐊᒥᑦ ᖃᓄᐃᖓᓕᕈᑏᑦ

ᐆᓇᖅᑐᖅ ᐱᔭᐅᖃᑦᑕᖅᑐᖅ ᐱᓕᕆᔨᓄᑦ ᓇᓚᐅᑖᖅᑕᐅᓚᐅᖅᑐᖅ ᐊᑐᖅᓱᑎᒃ ᐱᓕᕆᓂᑯᑖᕆᔭᐅᔪᑦ ᐅᔭᖅᓂᐊᑐᓕᕆᓂᕐᒥᑦ ᓄᖑᓯᐃᑐᓄᑦ ᐅᐊᖓᖅᐸᓯᖓᓂᑦ ᓴᒡᑳᑐᐊᓐ, ᐱᑐᐊᖅᑐᒥᑦ ᐅᔭᖕᓂᐊᖅᑐᓕᕆᓂᖅ ᐅᒃᑯᐃᖓᔪᓂᒃ ᒪᓂᕐᒥᑦ ᐊᓅᕙᒃᑯᑦ McClean Lake-ᒥᑦ ᐊᐅᓚᕝᕕᕆᔭᖓᓐᓂᑦ, ᐊᒻᒪ ᐊᑐᖅᓱᑎᒃ ᖃᕆᑕᐅᔭᓂᒃ. ᐆᓇᖅᑐᑦ ᐱᔭᐅᖃᑦᑕᖅᑐᑦ ᓇᓚᐅᑖᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᐅᓛᕐᓂᕐᒧᑦ ᓄᓇᐅᑉ ᐊᑖᓂᑦ, ᓄᓇᒥᑦ ᐅᔭᖕᓂᐊᕐᕕᖕᓂᑦ, ᓯᖃᑦᑎᕆᕝᕕᖕᓂᑦ ᐊᒻᒪ ᐃᖏᕐᕋᔭᒃᑐᓕᕆᓂᕐᓂᑦ. ᑲᑎᑕᐅᑉᓱᑎᒃ ᖃᓄᑎᒋᐅᓂᖓ ᐆᓇᖅᑐᒧᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᔪᑦ ᑭᒡᒐᕝᕕᖕᒥᑦ ᐱᓕᕆᔩᑦᐅᔪᓄᑦ ᐊᐅᓛᕐᓂᖃᖅᑎᑦᑐᒍ ᓂᕈᐅᕆᔭᐅᔪᖅ 0.74 mSv/y -ᒥᑦ ᐅᒃᑯᐃᖓᔪᒥᑦ ᓄᓇᒥᑦ ᐱᓕᕆᔨᓄᑦ 5.2 mSv/y-ᒧᑦ ᓄᓇᐅᑉ ᐃᑐᐊᓂᑦ ᐱᓕᕆᔪᓄᑦ. ᐊᖏᓛᒃᑯᑦ ᐱᓕᕆᔨ ᐊᒃᑐᖅᑕᐅᓇᔭᕐᓂᖓ ᐆᓇᖅᑐᒧᑦ ᓂᕈᐅᕆᔭᐅᔪᖅ 0.5 mSv/y-ᖑᓂᐊᕐᓂᖓᓂᒃ ᓄᓇᐅᑉ ᐊᑖᓂᑦ ᐅᔭᖕᓂᐊᖅᑎᐅᔪᓄᑦ.

ᑕᒪᒃᑯᐊ ᓇᓚᐅᑖᖅᑕᐅᔪᑦ ᓇᑐᓇᐃᖅᓯᔪᑦ ᐱᓕᕆᔨᐅᔪᑦ ᐊᒃᑐᖅᑕᐅᔪᖅᑲᔸᖏᓐᓂᖏᓐᓂᒃ ᑭᒡᒋᕆᔭᐅᔫᑉ ᐅᖓᑖᓅᖅᑐᒥᒃ CNSC-ᑯᓐᓄᑦ ᐋᕿᒃᑕᐅᔪᑦ ᑭᒡᒋᕆᔭᐅᔭᕆᐊᖃᖅᑐᑦ 50 mSv ᐅᑭᐅᑉ ᐃᑐᐊᓂᑦ ᐅᕙᓘᓃᑦ 100 mSv ᐅᑭᐅᓄᑦ ᑕᓪᓕᒪᓄᑦ (ᓈᒻᒪᕆᔭᐅᔪᖅ ᐅᑭᐅᒧᒃᑖᖅ ᑭᒡᒋᕆᔭᐅᔪᖅ 20 mSv /ᐅᑭᐅᒥᑦ).

ᐃᓱᒪᒋᔭᐅᓚᐅᕐᒥᔪᖅ ᐱᓕᕆᕝᕕᖕᒥᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅ NEW-ᒧᑦ ᐱᓕᕆᔨᐅᔪᖅ ᑭᒡᒐᕝ ᐅᔭᖕᓂᐊᕐᕕᖕᒥᑦ ᐊᒻᒪ ᖃᒪᓂᑦᑐᐊᕐᒥᐅᑕᐅᔪᖕᓇᖅᓱᓂ. ᐆᓇᖅᑐᒧᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖅ ᐱᔭᐅᑲᓐᓂᖅᑐᖅ ᐱᓕᕆᔨᒧᑦ, ᖃᒪᓂᑦᑐᐊᕐᒦᖅᑲᑦᑕᕋᔭᖅᑐᖅ ᓇᑉᐸᖓᓂᒃ ᐱᓕᕆᖅᑲᑦᑕᕐᓂᕆᔭᖓᑕ, ᓇᓚᐅᑖᖅᑕᐅᔪᖅ 0.006 mSv/y-ᖑᓂᖓᓂᒃ. ᐃᓱᒪᒋᔭᐅᓯᒪᑎᓪᓗᒍ ᑕᒪᓇ ᐊᒃᑐᖅᑕᐅᓯᒪᒃᑲᓐᓂᕋᔭᕐᓂᖅ, ᑕᒪᐃᓂᒃ ᐱᓕᕆᔨᐅᔪᑦ ᓂᕈᐅᕆᔭᐅᔪᑦ ᑭᒡᒋᕆᔭᐅᔫᑉ CNSC-ᑯᓐᓂᙶᖅᑐᒥᑦ ᐊᑖᓐᓇᔭᕐᓂᖓᓂᒃ.

ᖃᐅᔨᓴᐃᓂᖅ ᓇᑐᓇᐃᖅᓯᒐᓗᐊᖅᑎᓪᓗᒍ ᐆᓇᖅᑐᒥᒃ ᐱᔭᐅᔪᑦ ᐊᑦᑎᖕᓂᖅᓴᐅᓂᐊᕐᓂᖓᓂᒃ CNSC-ᑯᑦ ᑭᒡᒋᓂᕋᖅᑕᖓᑦᑕ, ᐊᓅᕙᒃᑯᑦ ᑐᓴᓚᐅᖅᑐᑦ ᓄᓇᓕᖕᒥᐅᑦ ᐃᓱᒫᓘᑎᒋᔭᖏᓐᓂᒃ ᐆᓇᖅᑑᑉ ᒥᒃᓵᓄᑦ. ᓄᓇᓕᖕᒥᐅᑦ ᓇᑐᓇᐃᓚᐅᖅᑐᑦ *ᐊᖏᓂᖅᓴᒥᒃ ᐃᓱᒫᓘᑎᑦᑲᕐᓂᖏᓐᓂᒃ ᐃᓄᐃᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᔭᕆᐊᒃᓴᖏᓐᓄᑦ ᐱᓕᕆᐊᒥᙶᖅᑐᒥᑦ*
(IQ BLE 2009) ᑕᒪᐃᓂᑦ ᖃᓄᐃᖓᓕᕈᑕᐅᔪᑦ ᐆᓇᖅᑐᒧᑦ ᐱᓕᕆᔨᓄᑦ ᐃᓄᖕᓄᓪᓗ ᖃᐅᔨᓴᖅᑕᐅᓯᒪᓕᒫᕐᖅᑎᓪᓗᒋᑦ ᐊᒻᒪ ᓄᓇᓖᑦ ᐃᓚᐅᑎᑕᐅᓂᖏᓐᓄᑦ ᐸᕐᓇᐅᑎ (Tier 3 Technical Appendix 3C) ᓴᖅᑭᑕᐅᓚᐅᖅᑐᖅ ᑐᓴᐅᒪᑎᑦᑎᓂᕐᒧᑦ ᖃᓄᐃᖓᓂᕆᔭᖓᓂᒃ ᖃᐅᔨᓴᐃᓂᐅᑉ. ᓄᓇᓖᑦ ᐃᓚᐅᑎᑕᐅᓂᖏᓐᓄᑦ ᐸᕐᓇᐅᑎ ᑐᕌᖓᖃᖅᑐᖅ ᐊᖏᓪᓕᕆᐊᖅᑎᓐᓂᕐᒥᒃ ᓄᓇᓕᖕᒥᐅᑦ ᑐᑭᓯᐊᓂᖓᑦ ᖃᐅᔨᓴᐃᓂᐅᔪᓂᒃ ᐊᒻᒪ ᑐᓂᓯᒪᑐᕆᑦ ᐋᕿᒃᓯᒪᔪᒥᒃ ᐅᖃᐅᓯᖃᕐᓂᖅ ᓯᕗᓂᕐᒥᑦ ᖃᐅᔨᕆᐊᑲᓐᓂᖃᑦᑕᕐᓂᐅᔪᑦ ᖃᓄᐃᖓᓂᖓᔭᖏᓐᓂᒃ ᐱᓕᕆᐊᖓᓂᐊᕐᑐᕆᑦ ᐅᑐᖓᐊᕆᔭᐅᔪᑦ ᐊᒻᒪ ᒥᒃᓵᕆᐊᖅᑎᓪᓗᕆᑦ ᓄᓇᓕᖕᒥᐅᑦ ᐃᓱᒫᓘᑎᖏᑦ.

ᕿᒪᒃᑎᑐᑦ ᑲᑎᑉᐸᓪᓕᐊᓂᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᕈᑏᑦ

ᑲᑎᑉᐸᓪᓕᐊᔪᓂᒃ ᖃᓄᐃᖓᓕᕈᑎᓂᒃ ᐃᓕᑕᕆᔭᐅᔪᖃᓚᐅᖏᑦᑐᖅ ᐱᓕᕆᓃᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖏᓐᓄᑦ.

ᖃᐅᔨᒋᐊᖃᑦᑕᕐᓂᖅ

ᓱᕋᓂᕐᒥᑦ ᐆᓐᓇᖅᑐᖅ, radon/radon progeny (RnP), ᐊᒻᒪ ᐊᑯᓂ-ᐆᒪᔪᖅ ᐆᓐᓇᖅᑐᖅ ᐳᔪᖃᑖᒃ (LLRD) ᖃᐅᔨᒋᐊᖅᑕᐅᖃᑦᑕᕐᓂᐊᖅᑐᖅ ᑭᒡᒐᕚᒃ ᐱᓕᕆᐊᒥᑦ ᖃᐅᔾᖃᑦᑕᕈᒪᓂᕐᒧᑦ ᓈᒻᒪᙱᑦᑐᓂᒃ ᐆᓐᓇᖅᑐᓂᒃ, ᓇᓚᐅᑖᕐᓂᕐᒧᑦ ᐱᓕᕆᔾᐅᔪᑦ ᐊᒃᑐᖅᑕᐅᓂᖓᓐᓂᒃ, ᐊᒻᒪ ᑎᑎᕋᐅᓯᕆᓗᒋᑦ ᐆᓐᓇᖅᑐᑦ ᖃᓄᐃᖓᓂᖕᒋᑦ. ᖃᓄᑎᒋᐅᓂᖓᓂᒃ ᖃᐅᔨᒋᐊᖃᑦᑕᕐᓂᖅ ᑎᑎᕋᐅᓯᕆᓂᐊᕐᓗᒋᑦ ᐃᓄᐃᑦ ᐱᓕᕆᔾᐅᔪᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᓂᖕᒋᑦ ᐆᓐᓇᖅᑐᓂᒃ. ᖃᓄᐃᖓᓂᐅᔪᑦ ᖃᓄᑎᒋᐅᔪᒥᒃ ᖃᐅᔨᒋᐊᖃᑦᑕᕐᓂᖅ ᓇᓗᓇᐃᖅᓯᔪᖅ ᒪᓕᖕᓂᕆᔾᖕᒋᑦ ᒪᓕᒐᓂᒃ ᐊᒻᒪ ᐃᑲᔪᐃᓂᕐᒧᑦ ᐆᓐᓇᖅᑐᒥᒃ ᐱᔾᐅᖃᑦᑕᖅᑐᑦ ᐱᐅᓯᒋᐊᖅᑎᑦᑎᓂᕐᒧᑦ ᖃᓄᖅᑑᕈᑎᓂᒃ.

ᐆᓐᓇᖅᑐᒥᒃ ᖃᐅᔨᒋᐊᖃᑦᑕᕐᓂᖅ ᐊᒻᒪ ᖃᓂᑦᑐᒥᒃ ᖃᐅᔨᒋᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᑐᕌᖓᔪᑦ ᓴᖅᑭᑕᐅᖃᑦᑕᖅᑐᑦ ᒪᓕᖕᓂᕐᒧᑦ ᑲᓇᑕᒥᑦ ᐊᒻᒪ ᓄᓇᕗᒻᒥ ᒪᓕᒋᐅᔪᓂᒃ; ᐅᖃᖅᓯᒪᔪᑦ ᐊᑐᕆᐊᓕᖕᓂᒃ ᐊᒻᒪ ᐆᒃᑐᕋᐃᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᓂᒃ; ᖃᐅᔨᒋᐊᕐᓗᒋᑦ ᐊᐅᓚᓐᓂᕐᒧᑦ ᖃᓄᑎᒋᐅᔪᑦ ᐊᒻᒪ ᐊᖏᓗᐊᖏᑎᑦᑎᓂᕐᒧᑦ ᐱᓕᕆᐊᖑᔪᑦ; ᐊᒻᒪ ᐃᓕᑕᕆᓗᒋᑦ ᐅᓂᑳᓕᐅᕆᓂᕐᒧᑦ ᐱᔾᔮᐅᔪᑦ ᐊᒻᒪ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᑦ.

ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᕈᑏᑦ

ᖃᑉᔾᔫᖅᑕᖅᓗᒋᑦ ᐃᓄᐃᑦ ᖃᐅᔾᒪᔾᑐᖃᖕᒋᓐᓂᒃ ᐊᐱᖅᓱᐃᓃᑦ ᐃᓚᐅᖃᑕᐅᓂᐅᔪᓂᒡᓗ, ᒪᖃᐃᑏᑦ ᐊᒻᒪ ᐃᓐᓇᕆᔾᐅᔪᑦ ᐅᖃᐅᓯᖃᓚᐅᖅᑐᑦ ᐅᓗᕆᐊᓇᖅᑐᑦ ᑕᐃᒪᐅᓕᕈᖕᓇᕐᓂᖕᒋᓐᓂᒃ ᐱᓕᕆᐊᒥᙳᖅᑐᓂᒃ, ᐃᖕᒋᕋᓗᑎᒃ ᓄᓇᒃᑯᑦ ᓂᕆᔾᐅᕙᒃᑐᑎᒍᑦ, ᐊᒻᒪ ᓂᕐᔪᑎᓂᒃ ᐊᒃᑐᖅᓯᓗᑎᒃ ᐃᓄᖕᓄᐊᓕᕐᓗᑎᒡᓗ. ᐆᒃᑑᑎᒋᓗᒍ, ᒪᖃᐃᑏᑦ ᐃᓐᓇᕆᔾᐅᔪᓪᓗ ᐃᓱᓖᓘᑎᒥᖕᓂᒃ ᖃᐅᔨᑎᑦᑎᓚᐅᖅᑐᑦ *ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑎᖕᓂᙶᖅᑐᑦ ᐱᕈᖅᑐᓄᐊᕐᓂᐊᕐᓂᖕᒋᓐᓄᑦ ᓂᕆᔾᐅᕙᒃᑐᓄᑦ ᑐᒃᑐᓄᑦ* (IQ ARHT 2009) ᐊᒻᒪ ᓄᓇᓕᖕᒥᐅᑦ ᐊᐱᕆᑉᓗᑎᒃ *ᓄᖑᓱᐃᑐᖅ ᐃᒪᕐᒧᐊᖅᐸᑦ ᐅᓗᕆᐊᓇᙱᒪᖖᒋᑦ ᓄᑕᖅᑲᑉᑎᖕᓄᑦ ᐃᕐᖑᑕᑉᑎᖕᓄᒡᓗ?* (EN-CI OH Nov 2012).

ᐊᑐᖅᑕᐅᔪᖅ ᖃᐅᔾᓴᐃᓂᕐᒥᑦ ᐃᓚᐅᔪᑦ ᐃᓱᒪᒃᓴᖅᓯᐅᕈᑏᑦ ᐊᔾᔨᒌᖕᒋᑦᑐᓂᒃ ᐊᑐᖅᑕᐅᔪᖕᓇᖅᑐᓂᒃ, ᐅᕙᓃᓐᑦ ᐊᑉᕿᑎᒋᔭᐅᔪᑦ ᐊᒃᑐᖅᑕᐅᓂᕐᒧᑦ, ᐃᓄᐃᑦ ᑎᑭᑕᐅᔪᖕᓇᕐᓂᖕᒋᑦ; ᐳᔪᕐᒥᑦ ᐊᒻᒪ radon-ᒥᑦ ᐱᔾᐅᓗᓂ ᐃᒪᖅᑐᖅᑎᓪᓗᒋᑦ, ᐃᖃᓗᐃᑦ, ᐱᕈᖅᑐᑦ, ᐸᐅᕐᖓᐃᑦ, ᐊᒻᒪ ᓂᕐᔪᑏᑦ. ᑕᒪᓐᓇ ᖃᐅᔾᓴᐃᔪᖅ ᐊᒃᑐᐊᔾᔪᑎᓂᖕᒋᓐᓂᒃ ᐃᓄᐃᑦ ᐊᒻᒪ ᐊᕙᑎᓗᒃᑖᖕᒋᓐᓂᑦ; *ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖕᒋᑦ ᐃᓄᐃᑦ, ᓂᕐᔪᑏᑦ ᐊᒻᒪ ᐊᕙᑎᖓᑦ ᐊᒃᑐᐊᔾᔪᑎᔪᑦ* (IQ-Nunavut Tunngavik Inc. 2005). ᓄᓇᓕᕆᓂᖅ ᐃᓚᐅᑎᑦᑎᔪᖅ ᐃᓄᐃᑦ ᖃᐅᔾᒪᔾᑐᖃᖕᒋᓐᓂᑦ ᒪᓕᒋᐅᔪᓂᒃ 'ᐊᕙᑎᒥᒃ ᑲᒪᑦᑎᐊᕐᓂᖅ/ᐊᒥᒋᓂᒃ ᐊᕙᑎᒥᒃ: ᐃᓄᐃᑦ ᑲᒪᔾᐅᔪᑦ ᐊᕙᑎᒥᒃ ᐊᒻᒪ ᐃᓗᐃᑑᓗᒍ ᐊᕙᑎᓗᒃᑖᖅ ᐃᒃᐱᒋᔭᕆᐊᖃᕐᓂᕐᒥᒃ, ᐃᓄᐃᑦ, ᓂᕐᔪᑏᑦ ᐃᓂᒋᔭᕆᓪᓗ ᐊᒃᑐᐊᖃᑎᖏᖕᓂᖕᒋᓐᓄᑦ.

ᖃᐅᔾᓴᐃᓂᕐᒥᑦ, ᖃᓄᑎᒋᐅᓂᖕᒋᑦ COPC ᐊᕙᑎᒥᑦ ᓇᓚᐅᑖᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᑐᖅᓗᒋᑦ ᓂᕆᐅᒋᔭᐅᔪᑦ ᓯᓚᒧᑦ ᐃᒪᕐᒧᐊᖅᑐᓪᓗ ᑭᒡᒐᕚᒃ ᐱᓕᕆᐊᒥᑦ. ᐱᓕᕆᐊᕆᓂᐊᕐᓗᒋᑦ ᖃᑉᓯᐊᕐᔪᐃᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᔪᖕᓇᖅᑐᑦ ᖃᑉᓯᐊᕐᔪᐃᑦ ᐊᔾᔨᒌᖕᒋᑦᑐᑦ ᐃᓚᐅᑎᑕᐅᓚᐅᖅᑐᑦ ᖃᐅᔾᓴᐃᓂᕐᒥᑦ. ᑕᒪᒃᑯᓇᓂ ᐃᓚᐅᔪᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᐅᑕᐅᖕᒋᓐᓇᖅᑐᑦ (ᐃᓐᓇᐃᑦ, ᓄᑕᖅᑲᑦ ᐊᒻᒪ ᐱᓱᒋᐅᕆᔾᔭᖅᑐᑦ ᖃᑕᙳᑎᒌᑦ), ᒪᖃᐃᑏᑦ Judge Sissons Lake-ᒥᑦ ᐊᙳᑕᒥᖕᓂᒃ ᑎᑭᐅᔾᔨᖃᑦᑕᖅᑐᑦ ᖃᑕᙳᑎᒥᖕᓄᑦ ᐊᒻᒪ ᓄᖑᓱᐃᑐᒥᑦ ᐱᓕᕆᐊᖃᙱᓗᑎᒃ ᐱᓕᕆᔩᑦ (NEW-ᖑᖕᒋᑦᑐᖅ) ᐱᓕᕆᐊᑉ ᐃᓂᖓᓂᑦ (ᓲᕐᓗ ᐃᒐᔨ, ᒥᐊᓂᖅᓯᔨ). ᐃᓄᐃᑦ ᖃᐅᔾᒪᔾᑐᖃᖕᒋᑦ ᐅᖃᖅᓯᒪᔪᖅ ᓯᓚᑐᓂᖅ ᐱᔾᐅᔪᖅ ᐊᒻᒪ ᑐᓂᐅᑕᐅᔪᖅ ᑭᖑᕚᖕᒋᓐᓄᑦ (NTI 2000b). ᑐᑭᓱᐊᓂᖅ ᐱᒻᒪᕆᐅᓂᖓᓂᒃ ᖃᐅᔾᒪᓂᕐᒥᒃ ᑐᓂᓯᓂᖅ, ᐊᒃᑐᖅᑕᐅᓯᒪᑐᐃᓐᓇᕆᐊᓖᑦ ᒪᖃᐃᑕᐅᔪᑦ Judge Sissons Lake-ᒥᑦ ᐃᓱᒪᒋᔭᐅᖕᒥᔪᖅ ᓄᑕᕋᐅᑉ ᐃᓕᑦᑎᔾᔪᑎᒋᓂᐊᕐᓂᖓ ᓄᓇᒥᑦ ᐊᔪᙱᓕᕐᓂᕐᒥᒃ.

ᐃᓄᐃᑦ ᖃᐅᔨᒪᔭᑐᖃᖕᒋᑦᑎᒍᑦ ᐊᒻᒪ ᐱᖃᖃᑕᐅᔪᑦ ᐃᓚᐅᓂᖕᒋᑦᑎᒍᑦ, *ᒪᖃᐃᑏᑦ ᐅᖃᖅᑐᑦ ᐃᓄᐃᑦ ᓂᕿᖃᕐᒪᑕ ᑐᒃᑐᓂᒃ, ᐃᖃᓗᖕᓂᒃ, ᓇᕐᑎᓂᒃ, ᐊᕿᒡᒋᓂᒃ, ᐊᒻᒪ ᕿᓇᓗᒐᓂᒃ* (IQ RIHT 2009), ᐊᒻᒪ *ᓂᕆᔭᐅᔪᑦ ᐃᓄᐃᑦ ᓂᕿᖏᑦ 'ᖃᖓᒃᑯᑐᐃᓐᓇᐅᖕᒋᓐᓂᖕᒪᓂᒃ' ᑭᓱᐊᓂ ᖃᐅᑕᒫᑦ ᐃᓅᓯᖕᒪᓂᒃ ᐱᔭᐅᖃᑦᑕᖅᑐᑦ* (IQ CIHT 2009). ᑐᒃᑐᐃᑦ ᐃᖃᓗᐃᓪᓗ ᓂᑉᓚᐅᑕᐅᒐᔪᓚᐅᖅᑐᑦ ᓂᕿᑭᔭᐅᓗᐊᖅᓂᖕᒋᓐᓄᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᐅᓄᑦ ᐊᒻᒪ ᓄᓇᓕᖕᒥᐅᑦ ᓂᕿᖏᑦ ᐃᓱᒪᒋᔭᐅᐸᓗᑎᒃ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᕐᑕᐃᓕᒪᓂᖕᒋᓐᓄᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ.

ᐊᒃᑐᖅᓯᓂᖅ ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑎᖕᓂᑦ (CAC), ᐆᓇᖅᑐᖅ ᐊᒻᒪ ᐆᓇᙱᑦᑐᖅ COPC ᖃᑉᓯᐊᕐᔭᒃᑎᒍᑦ ᐊᒃᑐᖅᓯᔭᖕᓇᕐᓂᒃᑯᑦ ᓇᓚᐅᑖᖅᑕᐅᔭᖅ ᐊᒻᒪ ᐃᒪᓐᓇᐃᖕᒑᖅᑐᓂᑦ ᑭᒡᓕᐅᔭᓂᒃ ᐋᕐᕿᒃᑕᐅᓯᒪᔪᑦ ᒥᐊᓂᖅᓯᓂᕐᒧᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᕐᑕᐃᓕᒪᓂᖕᒋᓐᓂᒃ.

ᐊᖏᓗᐊᖏᑎᑦᑎᓂᖅ ᐊᒻᒪ ᐱᓕᕆᐊᑉ ᖁᓄᐃᖓᓂᖓ

ᖃᓄᐃᖓᓂᖓ ᑭᒡᓕᕙᖕᒥᑦ ᐃᒪᓕᕆᕝᕙᐅᑉ (WTP) ᐊᒻᒪ Sissons ᐃᒪᓕᕆᕝᕙᐅᑉ ᑖᑉᑯᓄᙵᖅᐸᓪᓕᐊᔪᑦ ᑎᑭᐅᑎᓯᒪᓂᐊᕐᓂᖕᒋᓐᓄᑦ ᒪᓕᒐᐅᔭᓂᒃ ᓲᕐᓗ ᓴᕝᕚᑦ ᐅᔭᕋᕐᓂᐊᕐᕕᖕᒥᑦ ᕿᒪᒃᑎᑦᑐᓄᑦ ᒪᓕᒐᖅ (MMER) ᐊᒻᒪ ᐃᓂᒋᔭᐅᔪᒥᑦ ᕿᒪᒃᑎᑐᓄᑦ ᑭᒡᓕᒋᔭᐅᔪᑦ ᓄᓇᒥᑦ ᐅᓗᕆᐊᓇᖅᑐᓄᑦ ᖃᐅᔨᓴᐃᓂᖅ ᐊᒻᒪ ᐃᒪᐅᑉ ᖄᖓ ᖃᓄᐃᖓᓂᕆᔭᖓᓄᑦ ᐱᓕᕆᐊᖑᔪᑦ. ᓇᓗᓇᐃᒃᑲᓂᖅᓯᒪᔪᑦ ᖃᓄᐃᙶᓂᖓ ᐃᒪᓕᕆᕝᕚᑦ EIS Volume 2-ᖓᓂᑦ ᐱᔭᐅᔭᖕᓇᖅᑐᑦ (ᐱᓕᕆᐊᖅ ᖃᓄᐃᙶᓂᖓ ᐊᒻᒪ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᐊᑐᖅᑐᑦ). ᐊᔾᔨᐸᓗᖓ, ᖃᓄᐃᙶᓂᖓᓄᑦ, ᐊᐅᓛᖅᑐᓕᕆᓃᑦ ᐊᒻᒪ ᐊᓯᖏᑦ ᐊᖏᓗᐊᖏᒋᐊᖅᑎᑦᑎᓃᑦ ᐃᓚᐅᑎᑕᐅᓚᐅᖅᑐᑦ ᓖᓇᐅᔭᖅ ᐱᓕᕆᐊᒧᑦ ᐸᕐᓇᐅᑎᓂᑦ ᒥᑭᓛᑰᖅᑎᑦᑎᓂᐊᖅᑐᑦ ᐱᓕᕆᐊᒨᖕᒐᔪᑦ ᓯᓚᒧᐊᖅᐸᓪᓕᐊᔭᓂᒃ ᐊᒻᒪ/ᐅᕙᓘᓃᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔭᖕᓇᖅᑐᑦ ᐱᓕᕆᐊᒥᙵᖅᑐᓂᑦ ᐊᓂᐊᔭᓂᒃ. ᑕᒪᒃᑯᐊ ᐅᖁᐅᓯᓚᐅᖅᑐᑦ Volume 4-ᖓᓂᑦ EIS (ᓯᓚᐅᑉ ᐊᕙᑎᖓ).

ᕿᒪᒃᑎᑐᓄᑦ ᐱᓕᕆᐊᒥᒃ ᖃᓄᐃᖓᓕᕈᑏᑦ

ᐱᖓᓱᙳᖅᑎᓯᒪᔪᑦ COPC ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ: CAC ᐃᓚᐅᑉᓗᑎᒃ NOx, Sox ᐊᒻᒪ (PM) ᐊᓂᖅᓵᖅᑐᕐᓂᕐᒧᑦ ᖃᓄᐃᖓᓕᕈᑕᐅᔭᓂᒃ ᐱᑕᓖᑦ; radionuclide-ᖃᙱᑦᑐᑦ COPC (ᐃᓚᐅᑉᓗᑎᒃ arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, ᓄᖑᓯᐃᑐᖅ, zinc); ᐊᒻᒪ, ᓄᖑᓯᐃᑐᒥᙵᖅᑐᑦ radionuclide-ᖑᔪᑦ. ᐅᑯᐊ ᖃᐅᔨᓴᐅᓚᐅᖅᑐᑦ:

- ᑲᑎᖅᓱᖅᓯᒪᔪᑦ ᑎᑭᐅᑎᓂᐊᖅᑐᑦ ᐊᑐᓇᐊᖃᕐᓂᐅᔪᓄᑦ.
- ᖃᑯᑎᒃᑰᖃᑦᑕᖅᑐᓂᒃ, ᓇᐃᑐᓂᒃ–ᐊᑯᓂᐅᑎᒋᓂᖓ NO2–ᓂᒃ ᒥᒃᓵᑎᓯᒪᔭᓂᒃ ᖁᑦᑎᓐᓂᖅᓴᓂᒃ WHO ᐋᓐᓂᐊᖃᕐᑕᐃᓕᒪᓂᕐᒨᓕᖕᒐᔭᓂᒃ ᑭᒡᓕᕝᕕᖕᒥᑦ ᐱᑕᖃᖃᑦᑕᕐᓂᐊᖅᑐᒃᓴᐅᔭᖅ; ᑭᓯᐊᓂ, ᐊᖏᓂᖏᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᑦ ᐊᑦᑎᖕᓂᖅᓴᑲᓪᓚᐅᖕᒪᑕ ᐃᓱᓖᓗᖕᓇᙱᑦᑐᑦ. ᐅᖓᑕᐅᑎᓃᑦ ᑭᒡᓕᕝᕕᖕᒥᑦ ᑕᐃᒪᐃᓂᖃᕈᖕᓇᖅᑐᑦ ᐊᓂᐊᕙᓪᓕᐊᔭᓂᑦ NOx–ᒥᑦ ᐅᒃᑯᐃᖓᔭᓂᑦ ᒪᓂᕋᒥᑦ ᐅᔭᕋᖕᓂᐊᖅᑐᓕᕆᓂᕐᒥᑦ, ᐃᓚᐅᑉᓗᑎᒃ ᐅᖅᓯᐊᓗᖕᒥᑦ ᐊᑐᖅᑐᑦ ᐃᑯᒪᐃᑦ ᐊᒻᒪ ᖄᖅᓯᔾᔭᑏᑦ. ᖃᐅᔨᒪᔭᐅᔭᓇᐊᖃᖅᑐᖅ ᒥᒃᓵᑎᖅᓯᒪᔪᑦ ᐊᑦᑎᖕᓂᖅᓴᑲᓪᓚᐅᖃᑦᑕᕐᒪᑕ WHO–ᑯᓐᓄᑦ ᐅᖃᐅᓯᐅᔪᑦ ᐃᓱᓖᓅᑎᒋᔭᐅᔭᓇᐊᖃᑐᐃᓐᓇᕐᓂᖕᒋᓐᓄᑦ ᐋᓐᓂᐊᖃᕐᑕᐃᓕᒪᓂᖕᒋᓐᓄᑦ ᖃᓄᐃᖕᒋᑦᑎᐊᕐᓂᖃᖅᑐᓄᑦ ᐃᓐᓇᕐᓄᑦ. NO2 ᒥᒃᓵᑎᖅᓯᒪᔪᑦ ᑭᒡᓕᕝᕕᖕᒥᑦ ᐅᖓᑕᐅᑎᓯᒪᙱᑦᑐᑦ ᓄᖅᑲᖓᖅᑐᒥᑦ ᐊᓂᖅᓵᖅᑐᖅᑕᑉᑕ ᖃᓄᐃᓐᓂᕆᔭᖏᓐᓄᑦ ᒪᓕᒃᑕᐅᔭᓇᐊᓕᖕᓂᑦ ᐅᖓᑕᐅᑎᙱᓗᑎᒡᓗ ᖃᑉᓯᐅᔭᓇᐊᖃᕐᓂᕐᒧᑦ ᑭᒡᓕᒋᔭᐅᔪᒥᑦ (TLVs)–ᓂᑦ ᓴᖅᑭᑕᐅᔪᑦ American Conference of Governmental Industrial Hygienists (ACGIH)–ᑯᓐᓄᑦ, ᓴᖅᑭᑕᐅᓚᐅᖅᑐᑦ ᒥᐊᓂᖅᓯᓂᕐᒧᑦ ᐊᒃᑐᖅᑕᐅᖃᑦᑕᐃᓐᓇᕐᓂᕐᒧᑦ ᐱᓕᕆᕝᕕᖕᒥᑦ.

- ᐊᒃᑐᖅᑕᐅᖃᑦᑕᖅᓂᖅ ᐅᖃᐅᓯᕆᐸᓗᒍ (PM), ᐊᖏᓂᖏᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᑦ ᐊᑦᑎᖕᓂᖅᓴᒃᓚᐅᓂᐊᖅᑐᑦ ᐃᓱᒫᓗᖕᓇᖅᑎᕆᓗᑎᒃ. ᓇᐃᑐᒥ–ᐊᑯᓂᐅᓂᖕᒐᓂᒃ ᑲᑎᓯᒪᔪᓂᒃ ᐱᑕᖃᑐᐃᓐᓇᕆᐊᖃᖅᑐᖅ ᑮᓇᐅᔾᔭᖕᒥᑦ ᐅᖕᒐᑕᐅᑎᔪᖅ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ ᖃᓄᐃᖕᒐᓂᐅᔪᖅ ᒥᐊᓂᖅᓯᓂᕐᒧᑦ ᐃᑉᐱᕆᓴᕋᐃᑐᓄᑦ ᐃᓄᖕᓄᑦ (ᓲᕐᓗ ᐃᓐᓇᐅᓂᖅᓴᓄᑦ, ᐳᓚᖕᕆᑦᑎᒍᑦ ᐋᓐᓂᐊᕐᓂᕐᑳᓂᒃᑐᓄᑦ). ᐊᖏᔪᒥᒃ ᖃᓄᐃᖕᒐᓕᕈᑎᖃᑐᐃᓐᓇᕆᐊᖃᕐᓂᖅ ᐱᔾᔪᑎᓕᒃ PM–ᒥᑦ ᐊᒃᑐᖅᓯᓂᖃᕐᓂᕐᒧᑦ ᐊᑦᑎᒃᑑᓇᓱᕆᔭᐅᔪᖅ.
- ᐊᒃᑐᖅᓯᓂᖃᕐᓂᖅ radionuclides–ᖃᖕᑎᑦᑐᓄᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ. ᓇᓚᐅᑖᖅᑕᐅᔪᑦ ᐱᔭᐅᖃᑦᑕᖅᑐᑦ ᐊᑦᑎᒃᑑᔪᑦ ᐃᓕᑕᕆᔭᐅᓯᒪᔪᓂᑦ ᒪᓕᒐᓂᒃ ᑲᒪᖃᑦᑕᖅᑐᓂᒃ ᓲᕐᓗ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᔾᔪᓕᕆᔨᑦ ᑲᓇᑕᒥᑦ ᐊᒻᒪᓗ US EPA–ᓄᑦ ᐅᓗᕆᐊᓇᖕᑎᑦᑑᓂᖕᒋᓐᓄᑦ ᐃᓄᖕᓄᑦ. ᐃᖃᓗᖕᓄᑦ ᐊᒻᒪᓗ ᑐᒃᑐᓄᑦ ᓂᕆᔭᐅᔪᑦ ᐊᖏᓛᖑᔪᑦ ᐱᑎᑦᑎᖃᑦᑕᖅᓂᕐᒥᒃ COPC–ᓂᒃ, ᐊᒻᒪᓗ ᐸᐅᕐᖓᐃᑦ.
- ᓇᓚᐅᑖᖅᑕᐅᔪᑦ ᐱᔭᐅᖃᑦᑕᖅᓂᐅᔪᓂᒃ ᐃᓄᖕᓄᑦ ᐆᓇᖅᑐᓂᒃ ᐱᓕᕆᐊᒧᑦ ᖃᓄᐃᓕᐅᕐᓂᕆᔭᖕᒐᓄᑦ ᐊᑦᑎᖕᓂᖅᓴᒃᓚᐅᔪᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᔾᔪᓕᕆᔨᑦ ᑲᓇᑕᒥᑦ ᐱᔭᕆᐊᖃᖅᑎᑕᖕᒋᓐᓂᑦ 0.3 mSv–ᒥᑦ ᐊᒻᒪᓗ CNSC–ᑯᑦ ᐱᔭᕆᐊᖃᕐᓂᖃᖅᑕᖕᒋᓐᓄᑦ ᐃᓄᖕᓄᑦ 1 mSv–ᒥᒃ.

ᓄᓇᓕᖕᒥᑦ ᐃᓐᓇᕆᔭᐅᔪᑦ ᐅᖃᓚᐅᖅᑐᑦ *ᐅᔾᔨᕈᓯᖕᓂᖃᖅᓗᑎᒃ ᓈᒻᒪᙱᓐᓂᖃᕐᓂᖕᒋᓐᓂᒃ ᐅᓯᖃᖕᓂᐊᕐᕖᑦ, ᐊᒻᒪᓗ ᑕᑯᓯᒪᕙᓗᑎᒃ ᑐᒃᑐᐃᑦ ᓂᕆᔪᑦ ᐅᓗᕆᐊᓇᖅᑐᓂᒃ ᐅᓯᖃᖕᓂᐊᕐᕕᐅᐸ ᐃᓂᒋᔭᖕᒐᓂᑦ* (IQ WCE 2009). ᑕᒪᓐᓇ ᐱᓕᕆᐊᕆᓂᐊᕐᓗᒍ, ᐊᒥᓱᑦ ᐅᔾᔨᖅᑐᕐᓃᑦ ᐊᑐᖅᑕᐅᓚᐅᖅᑐᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ ᓂᕆᔭᐅᓯᒪᑐᐃᓐᓇᕆᐊᖃᖅᑐᓂᒃ ᑐᒃᑐᓄᑦ; ᐆᒃᑑᑎᑎᓗᒍ ᐃᓱᒪᕆᔭᐅᓚᐅᖅᑐᖅ ᑐᒃᑐᐃᑦ 1%–ᒥᓪᓗᐊᖅ ᐱᕙᖕᒐᓐᓂᒃ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ (LAA), Judge Sissons Lake ᖃᓂᑭᔭᖕᒐᓂᑦ, ᐊᒻᒪᓗ 4.7%–ᓗᐊᑦ ᐱᕙᑭᔭᖕᒐᓐᓂᑦ ᐅᖕᒐᓯᖕᓂᖅᓴᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ (RAA). ᑕᒪᒃᑯᐊ ᐃᓱᒪᕆᔭᐅᔪᑦ ᐊᑐᖅᓗᓂ ᖃᐅᔨᓴᐃᓂᕐᒥᒃ ᓈᓴᐅᑎᓂᒃ/ᑎᑎᖅᑲᓂᒃ ᑐᒃᑐᐃᑦ ᐊᒥᕐᕋᐅᑎᓪᓗᑎᑦ LAA–ᒥᑦ ᐊᒻᒪᓗ RAA–ᒥᑦ. ᐅᔾᔨᖅᑐᕐᓂᕐᒧᑦ ᐃᓱᒪᕆᔭᐅᔪᓄᑦ, ᐱᖃᖅᑕᖅᑕᖕᑎᑦ ᑐᒃᑐᐃᑦ ᓂᕆᔭᖕᒋᓐᓂᒃ ᐱᔾᔪᑎᓖᑦ Po-210–ᒥᒃ ᑲᑎᓯᒪᔪᓂᒃ ᐊᖏᒡᓕᕆᐊᖅᓯᒪᓂᖃᖅᖢᑎᒃ, ᐊᖏᓛᖑᐸᓗᑎᒃ ᐱᖃᑦᑕᖅᑐᓂᒃ NEW–ᖃᖕᑎᑦᑐᓂᒃ ᐱᓕᕆᔨᐅᑉ ᐊᓯᐊᒍᑦ, ᐅᖕᒐᑎᓗᐊᖕᒐᓄᑦ ᓇᓚᐅᑖᖅᑕᐅᓯᒪᔪᑦ.

ᓇᐃᓈᕐᓗᒍ, ᐊᑉᖁᑎᑎᕆᔭᐅᔪᓄᑦ ᖃᐅᔨᓴᐃᓂᖅ ᓇᓗᓇᐃᖅᓯᓚᐅᖕᒋᑦᑐᖅ ᐊᖏᔪᒥᒃ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖕᒋᓐᓄᑦ ᖃᓄᐃᖕᒐᓕᕈᑕᐅᔪᓂᒃ ᐊᑐᖅᓗᑎᑦ ᐊᒃᑐᖅᓯᓯᒪᓂᖕᒋᑦ ᐃᓄᐃᑦ ᐊᓂᐊᔪᓂᒃ ᑮᓇᐅᔾ ᐱᓕᕆᐊᒥᑦ.

ᐃᓱᒪᕆᔭᐅᓚᐅᕐᒥᔪᖅ NEW–ᖃᖕᑎᑦᑐᒥᒃ ᐱᓕᕆᔨ ᑮᓇᐅᔾᔭᖕᒥᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᐅᑕᐅᑐᐃᓐᓇᕆᐊᖃᖅᑐᖅ. ᑲᑎᖓᓂᑦ ᐱᔭᐅᔪᑦ ᖃᒪᓂᑦᑐᐊᕐᒥᐅᑕᕐᒧᑦ ᐊᒻᒪᓗ ᐱᓕᕆᐸᓗᓂ ᐅᔭᕋᖕᓂᐊᕐᕕᖕᒥᑦ (NEW–ᖃᖕᑎᑦᑐᒥᑦ) ᓇᓚᐅᑖᖅᑕᐅᔪᖅ 0.1 mSv/y–ᖃᕐᓂᖕᒐᓃᓐᓂᖕᒐᓄᑦ, ᐊᑦᑎᖕᓂᖅᓴᒃᓚᒃ CNSC–ᑯᑦ ᐱᔪᖕᓇᖅᑎᑦᑎᓂᖕᒐᓐᓂᑦ ᐃᓄᖕᓄᑦ ᐊᒻᒪᓗ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᔪᓕᕆᔨᒃᑯᓐᓄᑦ ᑲᓇᑕᒥᑦ ᐱᔭᐅᔪᖕᓇᕐᓂᖃᖅᑕᖕᒐᓐᓂᑦ.

ᕿᒪᒃᑎᑦᑐᓄᑦ ᑲᑎᑉᐸᓪᓕᐊᔪᓄᑦ ᖃᓄᐃᖕᒐᓕᕈᑏᑦ

ᐱᓕᕆᐊᒃᓴᐅᕙᓪᓕᐊᓂᐊᖅᑐᑦ ᐃᓱᒪᕆᔭᐅᑎᓪᓗᒋᑦ ᑲᑎᑉᐸᓪᓕᐊᔪᓄᑦ ᖃᓄᐃᖕᒐᓕᕈᑕᐅᓂᕐᒧᑦ ᖃᐅᔨᓴᐃᓂᖅ ᐅᖕᒐᓯᐊᕐᔪᖕᒪᑦ ᑮᓇᐅᔾ ᐱᓕᕆᐊᒥᑦ, ᓂᕆᐅᕆᔭᐅᖕᒋᑦᑐᖅ ᐊᒃᑐᐊᓂᖅᑲᖅᓂᐊᕐᓂᖕᒐᓄᑦ ᖃᓄᐃᓕᖕᒐᓕᕈᑕᐅᓂᕐᒧᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖕᒋᓐᓄᑦ.

ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᖅ

ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑏᑦ ᖃᐅᔨᓴᐃᓂᖃᒻᒪᕆᖕᖏᑦᑐᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖕᖏᓐᓄᑦ; ᑭᓯᐊᓂ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᑐᕌᖕᖓᔪᑦ ᑕᐅᑐᒐᖅᑐᑦ ᐊᕙᑎᒨᓕᖕᖓᔪᓄᑦ ᓲᕐᓗ ᐊᓂᖅᕵᖅᑐᖅᑕᕈᑦ, ᐃᒪᖅ, ᐃᑉᔪᐃᑦ, ᐱᕈᖅᑐᑦ, ᐊᒻᒪᓗ ᓂᕐᔪᑏᑦ (ᓲᕐᓗ Tier 3, Technical Appendices 4C ᐊᓂᖅᕵᖅᑐᖅᑕᕈᑦ ᖃᓄᐃᓐᓂᓇᔭᖕᖓᓂᒃ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑎ, 5M ᐃᒪᕐᒥᐅᑕᓄᑦ ᖃᓄᐃᖕᖓᓕᕈᑕᐅᔪᓂᒃ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑎ ᐊᒻᒪᓗ 6D ᓂᕐᔪᑎᓅᖕᖓᔪᓄᑦ ᐊᖏᓗᐊᖏᑎᑦᑎᓂᕐᒧᑦ ᐊᒻᒪᓗ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑎ. ᖃᓄᐃᖕᖓᓃᑦ ᐊᕙᑎᒥᒃ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒧᑦ ᑐᕌᖕᖓᔪᑦ ᐊᑐᖅᑕᐅᔪᖕᓇᖅᓯᓗᑎᒃ ᓇᓗᓇᐃᖅᓯᓂᕐᒧᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᕐᒧᑦ ᐅᓗᕆᐊᓇᖅᑐᓂᒃ ᖃᐅᔨᓴᐃᓂᐅᔪᓄᑦ. ᐊᓅᕙᒃᑯᑦ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᐊᕐᒥᔪᑦ ᓄᓇᓖᑦ ᑭᐅᔾᔪᑎᖏᓐᓂᒃ ᐊᒻᒪᓗ ᐅᓗᕆᐊᓇᖅᑐᑦ ᑕᐅᒃᑕᐅᔪᑦ ᐃᓄᐃᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᖕᖏᓐᓄᑦ ᐊᑐᓕᖅᑎᑦᑎᓂᒃᑯᑦ ᓄᓇᓕᖕᒥᑦ ᐃᓚᐅᑎᓐᓂᕐᒧᑦ ᐸᕐᓇᐅᑎᒥᑦ. ᒪᕐᕈᐃᓕᖕᖓᔫᒃᑯᑦ ᑐᓴᐅᒪᖅᑲᑦᑕᐅᑎᓂᖅ ᐃᑲᔪᐃᓂᐊᖅᑐᖅ ᑕᑭᔪᒥᒃ–ᐊᑯᓂᐅᔪᒥᒃ ᐱᓕᕆᖃᑎᒌᖕᓂᖅᑕᖃᓕᕐᓂᕐᒥᒃ ᐊᒻᒪᓗ ᑕᐃᒪᐅᖏᓐᓇᖅᑎᓪᓗᒍ: ᓄᓇᓕᖕᒥᐅᑕᐃᑦ ᐱᕕᖃᕐᓂᐊᖅᑐᑦ ᐊᐱᖅᑯᑎᖃᕈᑎᒃ ᐃᓄᐃᑦ ᐊᒻᒪᓗ ᓂᕐᔪᑏᑦ ᐋᓐᓂᐊᖃᖅᑕᐃᓕᒪᓂᓇᔭᖏᓐᓂᒃ ᐊᓅᕙᒃᑯᑦ ᑐᓂᓯᖃᑦᑕᕐᓗᑎᒃ ᐱᓕᕆᐊᒨᖓᔪᓂᒃ ᒫᓇᒨᓕᖓᓕᖓᔪᓂᒃ ᐊᒻᒪᓗ ᑐᓂᓯᓗᑎᒃ ᖃᓄᐃᓂᖓᓂᒃ ᖃᐅᔨᓯᐊᖃᑦᑕᕐᓂᕐᒨᖓᔪᑦ.

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Abbreviations

Units

Bq .... becquerel
Bq/kg .... becquerel per kilogram
Bq/L .... becquerel per litre
Bq/m^2 .... becquerel per square metre
Bq/m^3 .... becquerel per cubic metre
Bq/month .... becquerel per month
Bq/week .... becquerel per week
Bq/y .... becquerel per year
c .... centi – 1/100 of a unit
cm .... centimetre
g/s .... grams per second
Gy .... gray
IQ .... Inuit Qaujimajatuqangit
k .... kilo – 1,000 times a unit
km .... kilometre
km/h .... kilometre per hour
L/s .... litres per second
L/y .... litres per year
lbs .... pounds
m .... milli – 1/1,000 a unit
M .... mega – 1,000,000 times a unit
mg/L .... milligrams per litre
mg/kg .... milligrams per kilogram
mg/m^3 .... milligrams per cubic metre
m/s .... metres per second

m^3/s ... cubic metres per second

mGy ... milligray

mph ... miles per hour

mSv ... millisievert

mSv/y ... millisievert per year

ppm ... part per million

Sv ... sievert

t ... tonne (1000 kg)

µ ... micro - 1/1,000,000 of unit

µg/kg-d ... micrograms per kilogram body weight in a day

µg/m^3 ... micrograms per cubic metre

µGy ... microgray

µm ... micrometre

µSv/d ... microsievert per day

µSv/h ... microsievert per hour

µSv/week ... microsievert per week

µSv/y ... microsievert per year

Acronyms

ACGIH .... American Conference of Governmental Industrial Hygienists

AECB .... Atomic Energy Control Board (replaced by CNSC)

AECL .... Atomic Energy of Canada Limited

ALARA .... As Low As Reasonably Achievable

ALI .... Annual Limit on Intake

ANFO .... Ammonia Nitrate Fuel Oil

APR .... Air-Purifying Respirators

ARCAL .... Aircraft Control of Aerodrome Lighting

ATB .... Air Terminal Building

AQG .... Air Quality Guideline

BEI .... Biological Exposure Indices

CAC .... Criteria Air Contaminants

CCME .... Canadian Council of Ministers of the Environment

CCOHS .... Canadian Centre for Occupational Health and Safety

CED .... Collective Effective Dose

CNSC .... Canadian Nuclear Safety Commission

CO .... Carbon Monoxide

CO_2 .... Carbon Dioxide

COPC .... Constituents of Potential Concern

CMR .... Carcinogens, Mutagens and Reproductive (CMR) Toxins

CSA .... Canadian Standards Association

DAC .... Derived Air Concentration

DPM .... Diesel Particulate Matter

DMS .... Dosimetry Monitoring Strategy

DR .... Dose Rate

DRD .... Direct Reading Dosimeters

EA .... Environmental Assessment

EC .... Environment Canada

EIS .... Environmental Impact Statement

ERAP .... Emergency Response Assistance Plan

FAR .... Fresh Air Raises

Fe .... Iron

HC .... Health Canada

HEO .... Heavy Equipment Operators

HEPA .... High-Efficiency Particulate Air

HHRA .... Human Health Risk Assessment

HS .... Hydrogen Sulphide

IARC .... International Agency for Research on Cancer

IAEA .... International Atomic Energy Agency

ICRP .... International Committee on Radiation Protection

IP .... Industrial Package type

IQ .... Inuit Qaujimajatuqangit

LAA .... Local Assessment Area

LHD .... Load Haul Dump

LLRD .... Long-Lived Radioactive Dust

LNT .... Linear No Threshold

LSA .... Low Specific Activity

MSDS .... Material Safety Data Sheets

NaOH .... Sodium hydroxide

$NaSO_4$ .... Sodium sulphate

NCGIH ....National Conference of Governmental Industrial Hygienists (former name of ACGIH)

NEW .... Nuclear Energy Worker

NIOSH .... National Institute for Occupational Safety and Health

NIRB .... Nunavut Impact Review Board

NO .... Nitric Oxide

NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NORM	Naturally Occurring Radioactive Material
NWT	Northwest Territories
O_2	Oxygen
OLD	Optically Stimulated Luminescent Dosimeters
OSHA	Occupational Safety and Health Administration
PAD	Personal Alpha Dosimeters
PAPR	Powered Air-Purifying Respirators
PM	Particulate Matter
PM_{10}	Particulate Matter <10 µm
$PM_{2.5}$	Particulate Matter <2.5 µm
PPE	Personal Protective Equipment
PSL	Priority Substance List
RAA	Regional Assessment Area
RAR	Return Air Raises
RCOP	Radiation Code of Practice
Rn	Radon
RnP	Radon Progeny
RP	Radiation Protection
RPP	Radiation Protection Plan
RPM	Revolutions Per Minute
SAR	Supplied-Air Respirator
SCBA	Self-Contained Breathing Apparatus
SI	International System of Units (abbreviated from French: Système international d'unités)
SO_2	Sulphur Dioxide
SOx	Sulphur Oxides
TDG	Transportation of Dangerous Goods

TED .... Total Effective Dose

TI .... Transportation Index

TLV .... Threshold Limit Value

TLV-C .... Threshold Limit Value - Ceiling

TLV-CS .... Threshold Limit Value for Chemical Substances

TLV-STEL .... Threshold Limit Value – Short Term Exposure Limit

TLV-TWA .... Threshold Limit Value – Time Weighted Average

TRV .... Toxicity Reference Value

U .... Uranium

U/G .... Underground

UNSCEAR .... United Nations Scientific Committee on the Effects of Atomic Radiation

US EPA .... United States Environmental Protection Agency

VC .... Valued Component

VPSA .... Vacuum Pressure Swing Adsorption

WHO .... World Health Organization

WHMIS .... Workplace Hazardous Materials Information System

WL .... Working Level

WLM .... Working Level Month

WSCC .... Workers' Safety and Compensation Commission

WTP .... Water Treatment Plant

Glossary of Terms

Term	Definition	Reference
Absorption	The process of taking in, as when a sponge takes up water. Chemicals can be absorbed through the skin into the bloodstream and then transported to other organs. Chemicals can also be absorbed into the bloodstream after breathing in or swallowing.	US EPA Air Toxics
Absorbed dose	The energy deposited by ionizing radiation to a suitably small volume of matter divided by the mass of that volume. Unit: gray; symbol Gy	CNSC
Activity	The rate at which nuclear disintegrations occur in a radioactive material. Used as a measure of the amount of a radionuclide present. Unit: becquerel; symbol Bq. 1 Bq = 1 disintegration per second	CNSC
Acute dose	Exposure received within a short period of time (hours or days). The adjective 'acute' relates only to the duration of exposure, and does not imply anything about the magnitude of the doses involved.	CNSC
Adverse effect	Effects from a new development that make life worse. Also known as negative effects.	Baffinland 2010
ALARA	An optimization tool in radiation protection used to keep individual, workplace and public dose limits As Low As Reasonably Achievable (ALARA), social and economic factors being taken into account. ALARA is not a dose limit; it is a practice that aims to keep dose levels as far as possible below regulatory limits.	CNSC
Alpha radiation	One of three types of radiation that comes from uranium. It can be stopped by a layer of paper or our skin. In the past this kind of radiation caused some uranium miners to get lung cancer. 2 protons and 2 neutrons	GN-ILA 2011

Term	Definition	Reference
Baseline	A detailed description of an environment that can be used afterwards to compare with newer information to see if the environment has changed.	Terminology on Climate Change
Becquerel or Bq	The SI unit of radioactivity, equal to one transformation (decay) per second. Supersedes the non-SI unit curie (Ci). 1 Bq = 27 pCi (2.7×10^{-11} Ci) and 1 Ci = 3.7×10^{10} Bq.	CNSC
Benchmark	A standard by which something can be measured or judged.	Dictionary
Beta radiation	One of three types of radiation that comes from uranium.	GN-ILA 2011
Chronic dose	Exposure persisting in time (months or years). The adjective 'chronic' relates only to the duration of exposure, and does not imply anything about the magnitude of the doses involved	CNSC
Constituent of Potential Concern	Chemicals that may pose a threat to the populations within the study area. These are the chemicals which are carried through the risk assessment process	US EPA Air Toxics
Conservative	As used in the term conservative estimates, this is considered a pessimistic or an overestimate of the level, effect or hazard, as the case may be.	
Contaminant	Introduced species, substance or material which was either not previously present or was present in a lesser amount, and that may have a harmful effect on air, water or soil	Mining Terminology
Curie	See Becquerel.	
Decay (Radioactive)	The transformation of a radioactive nuclide into a different nuclide by the spontaneous emission of radiation such as alpha, beta, or gamma rays, or by electron capture. The end product is a less energetic, more stable nucleus. Each decay process has a definite half-life.	CNSC

Term	Definition	Reference
Decay chain	The series of nuclides that form sequentially as radioactive decay progresses.	
Decommissioning	The process of permanently closing a facility/site; includes rehabilitation and plans for future maintenance of affected land and water	Water Management
Dermal	Referring to the skin. Dermal absorption means absorption through the skin.	US EPA Air Toxics
Deterministic effect	Changes in cells and tissues that are certain to occur after an acute dose of radiation (in excess of a threshold value of at least 1000 mSv), below which the radiation effect is not detected.	CNSC
Dispersion	Pollutant or concentration mixing due to turbulent physical processes.	US EPA Air Toxics
Dose	The energy absorbed by tissue from ionizing radiation. One gray is one joule per kg, but is adjusted for the effect of different kinds of radiation, so the sievert is the unit of dose equivalent used in setting exposure standards.	CNSC
Dosimeter	A device for measuring a dose of radiation that is worn or carried by an individual.	CNSC
Dosimetry	A scientific subspecialty in radiation protection and medical physics that focuses on calculating the internal and external doses from ionizing radiation.	CNSC
Effective dose	A measure of dose designed to reflect the amount of radiation detriment. It is obtained by multiplying the equivalent dose of each tissue or organ by an appropriate tissue weighting factor and summing the products. Unit: sievert (Sv).	CNSC

Term	Definition	Reference
Equivalent dose	A measure of the dose to a tissue or organ designed to reflect the amount of harm caused to the tissue or organ. Obtained by multiplying the absorbed dose by a “radiation weighting” factor to allow for the biological effectiveness of the various types of radiation in causing harm to tissue. Unit: sievert (Sv)	CNSC
Exposure	Contact made between a chemical, physical, or biological agent and the outer boundary of an organism.	US EPA Air Toxics
Exposure Assessment	An identification and evaluation of a population exposed to a toxic agent, describing its composition and size, as well as the type, magnitude, frequency, route and duration of exposure.	US EPA Air Toxics
Fate and Transport	A description of how a chemical is carried through and changes in the environment.	US EPA Air Toxics
Food Chain	A series of natural relationships between species in a region based on what different species eat and which species are eaten by others. A lot of the time, a plant is at the bottom and humans are at the top of the progression	Terminology on Climate Change
Gamma radiation	One of three types of radiation that comes from uranium. It can be stopped by concrete and lead walls and steel tanks.	GN-ILA 2011
Gray or Gy	The SI unit of absorbed radiation dose, one joule per kilogram of tissue.	CNSC
Half-life	Time required for a given radionuclide's activity to decrease by half through radioactive decay. Symbol $t_{1/2}$. A shorter life means a more radioactive substance.	CNSC

Term	Definition	Reference
Hazard	Any source of potential damage, harm or adverse health effects on something or someone under certain conditions at work.	CCOHS
Hazardous Waste	Material that, given its quantity, concentration and composition or its corrosive, inflammable, reactive, toxic, infectious or radioactive characteristics, presents a real or potential danger	Mining Terminology
Hereditary effect	Effects that are able to be passed down from one generation to another. Radiation exposure has never been demonstrated to cause hereditary effects in human populations.	UNSCEAR
Human health	A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity	WHO
Incremental	Increase above baseline	
Internal Dose	In exposure assessment, the amount of a substance penetrating the absorption barriers (e.g., skin, lung tissue, gastrointestinal tract) of an organism through either physical or biological processes. (See: absorbed dose)	US EPA Air Toxics
Inuit Qaujimajatuqangit	The traditional, current and evolving body of Inuit values, beliefs, experience, perceptions and knowledge regarding the environment, including land, water, wildlife and people, to the extent that people are part of the environment	NIRB 2011
Ionizing Radiation	Consists of particles or electromagnetic waves that are energetic enough to detach electrons from atoms or molecules	GN-ILA 2011

Term	Definition	Reference
Isotope	Various forms of atoms of the same chemical element, which are distinguished by the number of neutrons in the nucleus. The number of protons remains the same, but the number of neutrons differs. For example, uranium has 16 different isotopes.	CNSC
Mitigation	The steps humans take to avoid negative effects on the environment or to lessen those that can't be prevented. It often means finding ways to reduce the release of gases that cause the warming of the Earth, as well as ways to increase the removal of these gases from the air	Terminology on Climate Change
Model	A mathematical representation of a natural system intended to mimic the behavior of the real system, allowing description of empirical data, and predictions about untested states of the system.	US EPA Air Toxics
Modelling	An investigative technique using a mathematical or physical representation of a system or theory that accounts for all or some of its known properties	US EPA Air Toxics
MSDS - Material Safety Data Sheets	It is intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner	GN-ILA 2011
Natural radiation	Natural background radiation is constantly present in the environment and emitted from a variety of sources. These sources include cosmic rays, terrestrial sources (radioactive elements in the soil), ambient air (radon), and internal sources (food and drink). The annual global per caput effective dose due to natural radiation sources is 2.4 mSv.	CNSC
Non-ionizing radiation	refers to any type of electromagnetic radiation that does not carry enough energy per quantum to ionize atoms	GN-ILA 2011
Non-carcinogenic	Any health effect other than cancer.	US EPA Air Toxics

Term	Definition	Reference
Nuclide	A species of atom characterized by the number of protons and neutrons and the energy state of the nucleus.	CNSC
Particulate Matter	are tiny subdivisions of solid matter suspended in a gas or liquid	US EPA Air Toxics
Pathway	The course a chemical or physical agent takes from a source to an exposed organism. Also called Exposure Pathway.	US EPA Air Toxics
Pathways model	A mathematical method of estimating the transfer of contaminants in the environment and the resulting exposure to humans.	
Potable water	Water safe for human consumption	Water Management
Progeny	Products of radioactive decay.	
Radiation	Any form of electromagnetic energy propagated as rays, waves, or streams of energetic particles. Includes any or all of: alpha, beta, gamma, or x-rays, neutrons, and high-energy electrons, protons, or other atomic particles. Does not include sound or radio waves, or visible infrared, or ultraviolet light (Tilleman, 2005).	GN-ILA 2011
Radiation exposure	A measurement of the amount of radiation encountered	
Radioactive	Exhibiting radioactivity; emitting or relating to the emission of ionizing radiation or particles such as alpha and beta particles, neutrons or gamma rays.	NIRB/CNSC
Radioisotope	An isotope that undergoes spontaneous decay and emits radiation.	CNSC
Radionuclide	A radioactive nuclide.	CNSC

Term	Definition	Reference
Radium	A radioactive metallic element. One isotope of radium (Ra-226) is part of the naturally occurring radioactive decay series of uranium (U-238)	
Radon	A colourless, naturally occurring, radioactive, inert gas formed by radioactive decay of radium atoms in soil or rocks.	GN-ILA 2011
Radon decay products	A term used to refer collectively to the immediate products of the radon decay chain. These include Polonium-218, Lead-214, Bismuth-214, and Polonium-214. They have an average combined half-life of about 30 minutes. Also called radon progeny and radon daughters.	CNSC
Receptor	The entity which is exposed to an environmental stressor	US EPA Air Toxics
Reference Values	A reference value is a value that is used to quantify the degree of risk posed by a constituent. Exposures below this value indicate that the constituent is unlikely to pose a measurable risk or adverse effect. Examples are toxicity reference values (TRVs) for conventional COPC.	
Respirable	Particulates that are small enough to reach the gas exchange region in the lung	ACGIH
Risk	A measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard.	US EPA Terms of Environment
Risk Assessment:	Qualitative and quantitative evaluation of the risk posed to the environment by the actual or potential presence and/or use of specific pollutants.	US EPA Terms of Environment

Term	Definition	Reference
Sensitive Subgroups	Identifiable subsets of the general population that, due to differential exposure or susceptibility, are at greater risk than the general population to the toxic effects of a specific air pollutant (e.g., depending on the pollutant and the exposure circumstances, these may be groups such as subsistence fishers, infants, asthmatics, or the elderly).	US EPA Air Toxics
Shielding	Physical barriers designed to provide protection from the effects of ionizing radiation.	
Shotcrete		
Sievert or Sv	The SI unit of absorbed radiation dose in living organisms modified by radiation type and tissue weighting factors. The sievert is the unit of dose measuring the “equivalent dose” and “effective dose”. It replaces the classical radiation unit the rem. Multiples of sievert (Symbol Sv) used in practice include millisievert (mSv) and microsievert (μSv).	CNSC
Stochastic effect	A term used to group radiation-induced health effects (such as cancer or inheritable diseases) which have a statistical risk. For these diseases, the probability of their occurrence increases proportionally to the radiation dose received: the higher the dose, the higher the probability of occurrence. However, at no time, even for high doses, is it certain that cancer or genetic damage will result.	CNSC
Stope		
Three Types of Radiation	Alpha, beta and gamma	GN-ILA 2011
Threshold	The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed.	US EPA Air Toxics

Term	Definition	Reference
Toxicity	The degree to which a substance or mixture of substances can harm humans or environmental receptors	US EPA Air Toxics
Uptake	The process by which a substance crosses an absorption barrier and is absorbed into the body.	US EPA Air Toxics
Yellowcake uranium concentrate (yellowcake)	Impure uranium oxide obtained during the processing of uranium ore (Barber, 2004).	GN-ILA 2011

1 Introduction

1.1 Background

The Kiggavik Project (Project) is a proposed uranium ore mining and milling operation located in the Kivalliq region of Nunavut approximately 80 kilometres (km) west of the community of Baker Lake (Figure 1.1-1). The Project is operated by AREVA Resources Canada Inc. (AREVA), in joint venture partnership with Japan-Canada Uranium Company Limited (JCU) and Daewoo International Corporation

Within the Kiggavik Project there are two general site areas referred to herein as the Kiggavik site and the Sissons site. The two sites are located approximately 17 km apart. Three uranium ore deposits will be mined at the Kiggavik site: East Zone, Centre Zone and Main Zone. A uranium mill, related facilities, main accommodations, and landing strip will also be located at the Kiggavik site. The Sissons site has two uranium ore deposits to be mined: Andrew Lake and End Grid. Open pit mining will be used to extract the ore from the three Kiggavik deposits as well as the Andrew Lake deposit. Mining of End Grid ore will require underground methods.

All ore extracted from the mine sites will be processed through the Kiggavik mill. Mined out pits at the Kiggavik site will sequentially be used as tailings management facilities (TMFs) with East Zone being the initial TMF. The uranium product will be packaged and transported via aircraft to southern transportation networks. Initially, mill reagents, fuel and other supplies will be transported by barge to Baker Lake and then by truck to the mine site over a winter access road. An all-season road between Baker Lake and the Kiggavik Site is carried through the assessment as an option proposed as a contingency in case the winter road cannot adequately support the Project over its life-span.

Decommissioning of the Project will include demolition of site facilities, clean up and reclamation of any disturbed areas, closure of the TMFs and reclamation of mine rock piles to promote vegetative growth and to provide wildlife access.

Projection: NAD 1983 UTM Zone 14N
Creator: CDC Revised: TL
Date: 9/03/2014 Scale: 1:16,000,000
File:
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Geological Survey of Canada, AREVA Resources Canada Inc.*

FIGURE 1.1-1
GENERAL LOCATION OF PROPOSED KIGGAVIK PROJECT IN CANADA

ENVIRONMENTAL IMPACT STATEMENT
SECTION 1 INTRODUCTION

Kiggavik Project
AREVA

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The Kiggavik Project is subject to the environmental review and related licensing and permitting processes established by the Nunavut Land Claims Agreement (NLCA) (NIRB [Nunavut Impact Review Board] 2011), and to the licensing requirements of the Canadian Nuclear Safety Commission (CNSC). The Minister of Indian and Northern Affairs Canada (now Aboriginal Affairs and Northern Development Canada; AANDC) referred the Kiggavik Project to the NIRB for a Review under Part 5 of Article 12 of the NLCA in March of 2010.

The final NIRB "Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.'s Kiggavik Project (NIRB File No. 09MN003)" (NIRB 2011) were issued in May of 2011. AREVA submitted the Draft Environmental Impact Statement in December 2011 and again in April 2012 with the NIRB determining that the submission successfully conformed to the EIS guidelines in May 2012. Two review periods followed with the Information Request stage completed in January 2013 and the Technical Review stage completed in May 2013. An in-person technical meeting was hosted in Rankin Inlet, Nunavut by the NIRB in May 2013 with a Community Roundtable and a Pre-Hearing Conference (PHC) hosted in Baker Lake, Nunavut shortly after in June 2013. Following the Pre-Hearing Conference the NIRB issued the "Preliminary Hearing Conference Decision Concerning the Kiggavik Project (NIRB File No. 09MN003)" in July 2013.

1.2 Nunavut Impact Review Board Guidelines for the Environmental Impact Statement and Preliminary Conference Decision

The DEIS, including this volume, was determined by the NIRB on May 4, 2012 to have adequately addressed relevant sections of the NIRB "Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.'s Kiggavik Project (NIRB File No. 09MN003)" (NIRB 2011).

Greater clarity, consistency and, in some cases, additional design or assessment were provided within AREVA's responses to information requests in January 2013 and technical comments in May 2013. AREVA commitments for the preparation of the FEIS and regulatory review requirements are listed in the NIRB PHC Decision dated July 2013. Changes from the draft to final EIS including the location of information related to information requests, technical comments, and PHC requirements is noted in the Final Environmental Impact Statement (FEIS) conformity table (Tier 1, Volume 1, Technical Appendix 1A).

1.3 Purpose and Scope

The purpose of this document is to describe the Project components and activities that have the potential to interact with human health and result in a potential effect to human health. Human health-related issues identified through this consultation, as well as engagement activities undertaken directly by AREVA, include concerns about the exposure of the public and workers to both radioactive and non-radioactive materials. The assessment addresses worker and public exposures to radioactive materials, hazardous substances and constituents of potential concern (COPCs) through construction, mining, milling, decommissioning and reclamation processes.

The FEIS has been prepared to fulfil the intent of the NIRB Guidelines and PHC Decision, ultimately providing the information required to confidently proceed with an environmental assessment determination. The assessment has been influenced and reflects input provided from Inuit, Land Claim, Government, community, and other interested stakeholders.

Regulatory considerations pertaining to human health risk assessment especially include the federal Nuclear Safety and Control Act (protects workers and the public from exposure to radioactive and non-radioactive materials) and the Nunavut Mine Health and Safety Act (protects workers from risks to health and safety from mining).

1.4 Report Content and Related Documents

In addition to this introduction (Section 1), this volume consists of the following sections:

- Section 2: An Overview of the Project
- Section 3: A description of the ssessment approach and methodology used to assess potential effects of the Project

Tier 3 documents are appended to this Volume to provide further details and supporting information. The Technical Appendices pertaining to this volume are as follows:

- Technical Appendix 8A: Ecological and Human Health Risk Assessment
- Technical Appendix 8B: Radiation Protection Supporting Document
    - Part 1: Socio-Economic Environment
    - Part 2: Heritage Resources

2 Project Overview

2.1 Project Fact Sheet

Location	• Kivalliq Region of Nunavut, approximately 80 km west of Baker Lake. • The Project includes two sites: Kiggavik and Sissons (collectively called the Kiggavik Project). • The Kiggavik site is located at approximately 64°26'36.14"N and 97°38'16.27"W. • The Sissons site is located approximately 17 km southwest of Kiggavik at 64°20'17.61"N and 97°53'14.03"W. • The Kiggavik and Sissons sites are composed of 37 mineral leases, covering 45,639 acres.
Resources	• The total quantity of resources is currently estimated at approximately 51,000 tonnes uranium (133 million lbs U3O8) at an average grade of 0.46% uranium.
Life of Mine	• Approximately 12 years of production, based on studies to date. It is anticipated that pre-operational construction will require three years while remaining post-operational decommissioning activities will require ten years. • Date of Project construction will be influenced by favorable market conditions, completion of detailed engineering, and successful completion of licensing and other Project approvals.
Mining	• There are five individual mines proposed for the Project: East Zone, Center Zone and Main Zone at the Kiggavik site; End Grid and Andrew Lake at the Sissons site. • The three Kiggavik deposits and the Andrew Lake deposit will be mined by truck-shovel open pit, while End Grid will be an underground mine.
Mine Rock	• Mine rock will be segregated into material suitable for use in construction (Type 1), non-acid generating (Type 2), and potentially problematic material (Type 3). • Type 1, Type 2 and Type 3 rock will be managed in surface stockpiles during operation. • Upon completion of mining, Type 3 mine rock will be backfilled into mined-out pits.
Mill	• The ore will be processed in a mill at the Kiggavik site to produce 3,200 to 3,800 tonnes uranium (8.3 to 9.9 million lbs U3O8) per year as a uranium concentrate, commonly referred to as yellowcake.
Tailings	• The mill tailings will be managed at in-pit tailings management facilities constructed using the mined-out East Zone, Centre Zone and Main Zone open pits at the Kiggavik site. • Administrative and action levels will be used to control and optimize tailings preparation performance for key parameters.
Water Management	• A purpose-built-pit will be constructed at the Kiggavik site to optimize water management, storage, and recycling. • All mill effluent, tailings reclaim, and site drainage will be treated prior to discharge to meet the Metals Mining Effluent Regulations and site-specific derived effluent release targets. • Administrative and action levels will be used to control and optimize water treatment plant performance for key elements.
Site Infrastructure	• Power will be supplied by on-site diesel generators. • The operation will be fly-in/fly-out on a 7 to 14 day schedule with on-site employees housed in a permanent accommodations complex.

Access	• Access to the site will be provided by a winter road between Baker Lake and Kiggavik. An all-season road is assessed as an option should the winter road be unable to adequately support the Project. Supplies will be shipped to a dock facility at Baker Lake during the summer barge season and trucked to Kiggavik via the road. • An airstrip will be constructed and operated at site for transportation of personnel and yellowcake.
Environment	• Site-specific environmental studies have been on-going since 2007 • Public engagement and collection of Inuit Qaujimajatuqangit has been on-going since 2006; this information is integrated into the environmental effects assessment reports • AREVA's approach has been to integrate environmental assessment and decommissioning requirements into the Project design cycle to enhance mitigation of effects by design and to support the development of management, mitigation, and contingency plans to protect the environment
Benefits	• AREVA is negotiating an Inuit Impact Benefit Agreement with the Kivalliq Inuit Association • The total taxes and royalties to be paid on the Kiggavik project would be approximately $1 billion, payable to Nunavut Tunngavik Inc., Government of Nunavut, and Government of Canada. • The Project is expected to employ up to 750 people during construction and 400 to 600 people during operation.

The economic feasibility of the Kiggavik Project depends on 1) the production cost for the uranium concentrate including construction, operation and decommissioning costs and 2) the market value of the final product. The latest feasibility study completed for the Kiggavik Project was in November 2011. The study assessed the technical and economic viability of developing and operating a uranium mine and mill site in the Kiggavik area and estimated the capital cost of the Project at $2.1 billion and the operating cost at $240 million per year. This initial feasibility study will be updated and refined prior to a development decision. The market price for uranium concentrate over the last years has been within the range needed for a reasonable return on investment to its owners, however at the time of FEIS preparation was below the threshold needed for Project advancement. AREVA believes future opportunities are strong enough to encourage Project advancement with the intent of development that will coincide with viable future markets.

2.2 Assessment Basis

To ensure that the potential environmental and socioeconomic effects of the Kiggavik Project are adequately considered in this environmental assessment, it was determined that it would be advantageous to develop a clear "assessment basis" for the Project. The purpose of the assessment basis is to clearly and consistently define how the design parameters detailed in Tier 2 Volume 2 Project Description encompass the more conservative values for various design features and options. It is consistent with the precautionary principle to assess potential environmental effects conservatively to improve confidence that the Project can be realized within the predicted effects and approved environmental assessment.

The assessment basis is summarized in Table 2.2-1 and presented with greater detail in Tier 2 Volume 2 Section 20. For biophysical and some socio-economic effects, the range value with the greatest potential to result in an adverse effect is used. In the case of socio-economic benefits, the range value resulting in the lowest benefit is used.

Table 2.2-1 Project Assessment Basis

Project Activities/Physical Works	Parameter	Units	Parameter / Assumption Values	
			Base Case (PD)	**Assessment Case**
Overall	Production Rate	Tonnes U per year	3,200 – 3,800	3,200 - 4,000
	Mill Feed Rate	Kilotonnes per year	71 - 977	1,000
	Project Operating Life	Years	2 years pre-production 12 years production	25
	Project Footprint	Hectares (ha)	938	1,102
	Access Road Route	Not Applicable	Winter Road	Winter Road All-Season Road
	Dock Site Location	Not Applicable	Site 1	Sites 1,2, Agnico Eagle's Meadowbank Dock Site
Milling	Flowsheet	Not Applicable	Resin in Pulp (RIP)	Resin in Pulp (RIP), possibly solvent extraction (SX) and / or calciner
	Final Product	Not Applicable	Non-calcined uranium concentrate	Non-calcined or calcined uranium concentrate
Tailings Management	Containment volume	Million cubic metres (Mm^3)	28.4	30.0
	Total tailings volume (un-consolidated)	Million cubic metres (Mm^3)	21	30.0
	Design		Natural surround, no drain	Various design contingencies
Water Management	Freshwater requirements – no permeate or site drainage recycle	Cubic metres per day (m^3/day)	7,910	8,000
	Freshwater requirements –	Cubic metres per day (m^3/day)	2,000	8,000

Table 2.2-1 Project Assessment Basis

Project Activities/Physical Works	Parameter	Units	Parameter / Assumption Values	
			Base Case (PD)	Assessment Case
	permeate and site drainage recycle			
	Freshwater requirements - Sissons	Cubic metres per day (m^3/day)	60	60
	Treated effluent discharge at base quality – Kiggavik	Cubic metres per day (m^3/day)	2,707	3,000
	Treated effluent discharge – Sissons	Cubic metres per day (m^3/day)	1,700	1,700
Power Generation	Kiggavik peak load	megaWatt (MW)	13.0	13.0 – 16.8
	Sissons peak load	megaWatt (MW)	3.8	0 – 3.8
Logistics & Transportation	Number of barge trips – 5000t & 250 containers	Barge trips / year	9 - 31	31
	Number of barge trips – 7500t & 370 containers	Barge trips / year	7 - 22	22
	Number of truck trips – 56,000L & 48t	Truck trips / year	328 – 3,233	3,300
	Number of truck trips – 70,000L & 60t	Truck trips / year	243 – 2,405	2,500
	Number of yellowcake flights	Flights / year	310 - 350	355
Decommissioning	Period	Years	10	10

3 Assessment Approach and Methods

3.1 Introduction

This section describes the methods used in the assessment of environmental and socio-economic effects associated with the Kiggavik Project. The methods meet the applicable regulatory requirements while focusing the assessment on the matters of greatest environmental, social, cultural, economic and scientific importance. The methodological approach also recognizes the iterative nature of project-level environmental assessment, considering the integration of engineering design and mitigation and monitoring programs into comprehensive environmental management planning for the life of the Project.

The environmental effects assessment method is based on a structured approach that:

- considers the factors that are required under Nunavut Land Claim Agreement,
- focuses on issues of greatest concern,
- affords consideration of all territorial and federal regulatory requirements for the assessment of environmental effects,
- considers issues raised by the Inuit, regulators, government agencies and public stakeholders, and
- integrates Project design and programs for mitigation and monitoring into a comprehensive environmental planning.

The environmental assessment focuses on specific environmental components called Valued Environmental Components (VECs) or Valued Socio-economic Components (VSECs) that are of particular value or interest to Inuit, regulators, government agencies and stakeholders. The term Valued Components (VCs) refers collectively to VECs and VSECs. Valued Components are selected based on regulatory issues and guidelines, consultation with Inuit, regulators, government agencies and stakeholders, field studies, and professional judgment of the study team. Where a VC has various sub-components that may interact in different manners with the Project, the environmental assessment may consider the environmental effects on individual Key Indicators (KIs).

The term “environmental effect” is used throughout the Application and broadly refers to the response of the biophysical or human system or a component of these systems to a disturbance from a Project action or activity or other regional actions (i.e., projects and activities).

The environmental assessment methods address Project-related and cumulative environmental effects. Project-related environmental effects are changes to the biophysical or socio-economic environment that are caused by the Project or activity arising solely because of the proposed principal works and activities, as defined by the Scope of the Project. This includes consideration of the environmental effects of malfunctions or accidents that may occur in connection with the Project. Cumulative environmental effects are changes to the biophysical or socio-economic environment that are caused by an action of the Project in combination with other past, present and future projects and activities.

In this assessment, Project-related environmental effects and cumulative environmental effects are assessed sequentially. The mechanisms through which a Project-specific environmental effect may occur are discussed first, taking into account Project design measures and mitigation that help to reduce or avoid environmental effects. The residual environmental effect is then characterized taking into account planned mitigation. At a minimum, all Project environmental effects are characterized using specific criteria (e.g., magnitude, geographic extent, duration) that are defined for each VC.

A cumulative environmental effects screening is then conducted to determine if there is potential for the Project residual environmental effect to act in a cumulative manner with similar environmental effects from other projects and activities. If there is potential for the Kiggavik Project to contribute to cumulative environmental effects, the environmental effect is assessed to determine if it has the potential to shift a component of the natural or socio-economic environment to an unacceptable state.

The environmental effects assessment approach used in this assessment involves the following steps:

- ***Scoping***: Scoping of the overall assessment, which includes: issues identification; selection of VCs (and KIs, if required); description of measurable parameters; description of temporal, spatial, administrative and technical boundaries; definition of the parameters that will be used to characterize the Project-related environmental effects and cumulative environmental effects; and identification of the standards or thresholds that will be used to determine the significance of environmental effects.
- ***Assessment of Project-related environmental effects***: The assessment of Project-related environmental effects, which includes: description of the mechanism(s) by which an environmental effect will occur; mitigation and environmental protection measures to reduce or eliminate the environmental effect; and evaluation and characterization of the residual environmental effects (i.e., environmental effects remaining after application of mitigation measures) of the Project on the biophysical and socio-economic environment for each development phase.
- ***Evaluation of cumulative environmental effects:*** The evaluation of cumulative environmental effects, which involves two tasks: screening for potential cumulative environmental effects and, if there is potential for cumulative environmental effects, assessment of cumulative environmental effects. Where an assessment of potential cumulative environmental effects is required, the residual cumulative environmental

effects of the Project are evaluated in combination with other past, present and future projects and activities.

- ***Determination of significance***: The significance of Project-related and cumulative residual environmental effects is determined using standards or thresholds that are defined for each VC.
- ***Monitoring***: Several different types of monitoring may be required to confirm compliance with mitigation measures or Project design features, address uncertainties or verify environmental effects predictions and/or assess the effectiveness of mitigation measures.
- ***Summary***: The last step of the assessment of environmental effects on a VC is the development of summaries on Project and cumulative environmental effects (including combined Project environmental effects and combined cumulative environmental effects), mitigation measures and Project design features, and monitoring.

3.2 Scope of the Assessment

3.2.1 Valued Components, Indicators and Measurable Parameters

Valued Components are defined as broad components of the biophysical and socio-economic environments, which if altered by the Project, would be of concern to regulators, Inuit, resource managers, scientists, and public stakeholders.

VECs for the biophysical environment typically represent major components or aspects of the physical and biological environment that might be altered by the Project, and are widely recognized as important for ecological reasons.

Criteria for selection of VCs include:

- Do they represent a broad environmental, ecological or human environment component that may be altered by the Project?
- Are they vulnerable to the environmental effects of the Project and other activities in the region?
- Have they been identified as important issues of concerns of Inuit or stakeholders, or in other assessments in the region?
- Were they identified by the Nunavut Impact Review Board (NIRB), Inuit organizations or departments within the territorial or federal government?

Key indicators (KIs) are species, species groups, resources or ecosystem functions that represent components of the broader VCs. They are selected using the same criteria as described above for VCs. For practical reasons, KIs are often selected where sufficient information is available to assess the potential Project residual environmental effects and cumulative environmental effects.

For each VC or KI, one or more measurable parameters are selected to quantitatively or qualitatively measure the Project environmental effects and cumulative environmental effects. Measurable parameters provide the means of determining the level or amount of change to a VC or KI. The degree of change in the measurable parameter is used to characterize project-related and cumulative environmental effects, and evaluate the significance of these effects. Thresholds or standards are identified for each measurable parameter, where possible, to assist in determining significance of the residual environmental effect.

3.2.2 Key Issues

Issues identification focuses the assessment on matters of greatest importance related to the Project, and assists in determining which factors and the scope of those factors that will be considered in the assessment.

Issues and concern about the possible biophysical or socio-economic effects of the Project have been identified from a variety of sources, including:

- the regulatory requirements applicable to the Project,
- discussions with technical experts from various territorial and federal government agencies,
- input from Inuit and public stakeholders during engagement activities in relation to the Project,
- existing regional information and documentation regarding environmental components found near the Project,
- baseline and assessment studies conducted in the area of the Project, and
- professional judgment of the assessment team, based on experience with similar projects elsewhere and other mining project and activities in Nunavut.

Key Project-related issues are summarized in the scoping section for each discipline considered in the assessment. For instance, in order to fully understand the potential effects of the Project on human health, constituents of potential concern in the environment are examined holistically in the ecological and human health risk assessments (Tier 3, Technical Appendix 8A). This pathways approach follows the food web concept and considers the interconnectedness of human health with ecological health in order to address community concerns such as *if uranium gets into animals and people eat them, do we get sick* (EN-KUG NTI May 2007)?

3.2.3 Project – Environment Interactions and Environmental Effects

Key Project-related activities that are likely to result in environmental effects are considered for each VC. A matrix of Project activities and environmental components is provided in the scoping section for each discipline to identify where interactions are likely to occur based on the spatial and temporal overlap between Project activities and the VC. Each interaction is ranked according to the potential for an activity to cause an environmental effect. The interactions are ranked according to the following:

- If there is no interaction or no potential for substantive interaction between a Project activity and the VC to cause a potential environmental effect, an assessment of that environmental effect is not required. These interactions are categorized as 0, and are not considered further in the EA. The environmental effects of these activities are thus, by definition, rated not significant.
- If there is likely to be a potential interaction between a Project activity and a VC but not likely to be substantive in light of planned mitigation, the interaction is categorized as 1. Such interactions are well understood and are subject to prescribed mitigation or codified practices. These interactions are subject to a less detailed environmental effects assessment and are rated as not significant. Justification is provided and the mitigation is described for such categorizations. Such interactions can be mitigated with a high degree of certainty with proven technology and practices.
- If a potential interaction between a Project activity and a VC could result in more substantive environmental effects despite the planned mitigation, if there is less certainty regarding the effectiveness of mitigation, or if there is high concern from regulatory agencies, Inuit or stakeholders, the interaction is categorized as 2. These potential interactions are subject to a more detailed analysis and consideration in the environmental assessment in order to predict, mitigate and evaluate the potential environmental effects.

The ranking takes a precautionary approach, whereby interactions with a meaningful degree of uncertainty are assigned a rank of 2 to ensure that a detailed analysis of the potential environmental effect is undertaken.

Justification for ranking the Project-environmental interactions considered for each VC is provided in the scoping section for each discipline.

3.2.4 Assessment Boundaries

Boundaries of the assessment are defined for each VC to allow for a meaningful analysis of the significance of environmental effects. The assessment boundaries are described in terms of temporal, spatial and administrative and technical boundaries.

3.2.4.1 Spatial Boundaries

Spatial boundaries are established for assessing the potential Project-related environmental effects and cumulative environmental effects on each VC. The primary consideration in establishing these boundaries is the probable geographical extent of the environmental effects (i.e., the zone of influence) on the VC.

Spatial boundaries represent the geographic extent of the VC, as they pertain to potential Project-environment interactions. Spatial boundaries are selected for each VC to reflect the geographic extent over which Project activities will or are likely to occur, and as such, they may be different from one VC to another depending on the characteristics of the VC. For this assessment, the spatial boundaries are referred to as 'assessment areas' to differentiate the areas from the local and regional study areas referred to in many baseline studies.

Three assessment areas are defined for each VC.

The ***Project Footprint*** is the most immediate area of the Project. The Project Footprint includes the area of direct physical disturbance associated with the construction or operation of the Project.

The ***Local Assessment Area*** (LAA) is the maximum area within which Project-related environmental effects can be predicted or measured with a reasonable degree of accuracy and confidence. The LAA includes the Project Footprint and any adjacent areas where Project-related environmental effects may be reasonably expected to occur.

The **Regional Assessment Area** (RAA) is a broader area within which cumulative environmental effects on the VC may potentially occur. This will depend on physical and biological conditions (e.g., air sheds, watersheds, seasonal range of movements, population unit), and the type and location of other past, present or reasonably foreseeable projects or activities. For the socio-economic environment, the RAA may be much broader (planning areas, regions, territories etc.) based on the potential geographic extent over which socio-economic effects are likely to occur. It is also the area where, depending on conditions (e.g., seasonal conditions, habitat use, more intermittent and dispersed Project activities), Project environmental effects may be more wide reaching.

3.2.4.2 Temporal Boundaries

The temporal boundaries for the assessment are defined based on the timing and duration of Project activities and the nature of the interactions with each VC. Temporal boundaries encompass those periods during which the VCs and KIs are likely to be affected by Project activities.

For the Kiggavik Project, temporal boundaries include the following Project phases.

- construction
- operations
- final closure
- post closure

The operations phase includes consideration of maintenance, planned exploration and temporary closure (care & maintenance) of the Project. The final closure phase considers decommissioning and reclamation, and post-closure phase includes management of restored sites.

In some cases, temporal boundaries are refined to a specific period of time beyond simply limiting them to a specific phase of the Project. This is carried out as necessary within each environmental effects analysis section. Temporal boundaries for the assessment may reflect seasonal variations or life cycle requirements of biological VCs, long-term population cycles for some biological VECs, or forecasted trends for socio-economic VSECs.

3.2.4.3 Administrative and Technical Boundaries

Administrative and technical boundaries are identified and justified for each VC or KI, as appropriate. Administrative boundaries include specific aspects of provincial, territorial and federal regulatory requirements, standards, objectives, or guidelines, as well as regional planning initiatives that are relevant to the assessment of the Project's environmental effects on the VC. Administrative boundaries may be selected to establish spatial boundaries.

Technical boundaries reflect technical limitations in evaluating potential environmental effects of the Project, and may include limitations in scientific and social information, data analyses, and data interpretation.

3.2.5 Environmental Effects Criteria

Where possible, the following characteristics are described quantitatively for each VC to assist in the assessment of residual environmental effects. Where these residual environmental effects cannot be defined quantitatively, they are described using qualitative terms. If qualitative descriptions are used, definitions are provided for each VC or KI, as appropriate, in the scoping section of the environmental assessment for that VC or KI.

- ***Direction:*** the ultimate long-term trend of the environmental effect (e.g., positive, neutral or adverse)
- ***Magnitude:*** the amount of change in a measurable parameter or variable relative to the baseline case (i.e., low, moderate, high)

- ***Geographical Extent:*** the geographic area within which an environmental effect of a defined magnitude occurs (site-specific, local, regional, territorial, national, international)
- ***Frequency:*** the number of times during the Project or a specific Project phase that an environmental effect may occur (i.e., once, sporadically, regular, continuous)
- ***Duration:*** this is typically defined in terms of the period of time that is required until the VC returns to its baseline condition or the environmental effect can no longer be measured or otherwise perceived (i.e., short term, medium term, long term, permanent)
- ***Reversibility:*** the likelihood that a measurable parameter for the VC will recover from an environmental effect (i.e., reversible, irreversible)
- ***Ecological or socio-economic context:*** the general characteristics of the area in which the Kiggavik Project is located (i.e., undisturbed, disturbed, urban setting)

3.2.6 Standards or Thresholds for Determining Significance

Where possible, threshold criteria or standards for determining the significance of environmental effects are defined for each VC or KI to represent that limit beyond which a residual environmental effect would be considered significant. In some cases, standards or thresholds are also defined for specific environmental effects on a VC or KI.

Standards are recognized federal and territorial regulatory requirements or industry objectives that are applicable to the VC, and that reflect the limits of an acceptable state for that component. Where standards, guidelines or regulatory requirements do not specifically exist, thresholds are defined for the measurable parameters for an environmental effect on a VC based on resource management objectives, community standards, scientific literature, or ecological processes (e.g., desired states for fish or wildlife habitats or populations).

Potential changes in a measurable parameter or VC resulting from residual Project or cumulative environmental effects are evaluated against these standards or thresholds. Environmental effects are rated as either *significant* or *not significant*.

3.2.7 Influence of Engagement on the Assessment

Engagement undertaken to date with regulators, Inuit and public stakeholders in relation to the Project is described in Volume 3. Issues raised during these engagement activities and Inuit Qaujimajatuqangit (IQ) sessions were documented, and were reviewed for consideration in each discipline-specific assessment, including scoping of baseline data collection, selection of VC and KIs, use of TEK and IQ in the environmental effects assessment, mitigation and monitoring.

3.3 Assessment of Project Environmental Effects

3.3.1 Existing Conditions

The existing conditions for each VC are described according to the status and characteristics of the VC within its defined spatial and temporal assessment boundaries. This is based on a variety of sources, including:

- information from past research conducted in the region;
- Inuit Qaujimajatuqangit (IQ); and
- knowledge gained from the collection of baseline data through literature review, qualitative and quantitative analyses, and field programs carried out as part of the environmental assessment.

In general, the description of existing conditions is limited to information directly relevant to the potential VC interactions with the Project to support the environmental effects analysis.

3.3.2 Project Effect Linkages

The mechanisms or linkages through which the Project components and activities could result in an environmental effect on a VC, and the spatial and temporal extent of this interaction is described based on the existing conditions of the VC. Because the assessment focuses on residual environmental effects, effects prior to mitigation are not characterized or quantified and the significance of the effect is not determined.

3.3.3 Mitigation Measures and Project Design

Where Project activities are likely to cause an environmental effect on a VC, mitigation measures are identified to minimize or avoid environmental effects of the Project. This includes measures or strategies that are technically and economically feasible and that would reduce the extent, duration or magnitude of the environmental effect.

Mitigation includes Project design features to change the spatial or temporal aspect of the Project, specialized mitigation, environmental protection measures and protocols, and compensation (habitat compensation, replacement or financial compensation).

Where mitigation is identified, a brief discussion of how the measure(s) will help to minimize the residual environmental effect on the VC is provided. Where possible, this includes a description of how effective the measure is expected to be in minimizing the change in the measurable parameters for the environmental effect.

3.3.4 Residual Project Effects Assessment

Taking into account the mitigation and expected effectiveness of the measure(s), the residual environmental effects of the Project are described according to their probable magnitude, geographic scope, duration, frequency, reversibility and ecological context, where appropriate. The residual effect is characterized in the context of the existing condition for the measureable parameter(s) and how it is likely to change as a result of the Project environmental effect. For some residual environmental effects, the change in the measurable parameter is described relative to each Project phase.

Where possible, the magnitude, geographic extent and duration of the residual environmental effect are quantified. If a residual effect cannot be quantified, qualitative terms are used to describe the attributes of the effect.

3.3.5 Significance of Residual Project Environmental Effects

Significance of a residual Project environmental effect is determined based on standards or thresholds that are specific to the VEC, KI and/or the measurable parameters used to assess the environmental effect. Determination of whether a residual environmental effect is considered to be significant or not significant is based on a comparison of the predicted change in the VC or measurable parameter to the defined threshold or standard. This includes an indication of the likelihood that a residual environmental effect on a VC will occur based on probability of occurrence (i.e., based on past experience) and level of scientific uncertainty.

Determination of significance also includes a discussion of the confidence of the prediction with respect to:

- the characterization of environmental effects, and
- the success of Project design features, mitigation measures, and environmental protection measures in effectively reducing the environmental effect.

Prediction confidence for the environmental effect and the success of mitigation measures is ranked as low, moderate or high.

3.3.6 Monitoring of Residual Project Environmental Effects

Based on analysis of the residual Project environmental effect, it may be necessary to conduct a monitoring program. Monitoring is recommended in cases where there is a need to address Project-related issues of public concern, test the accuracy of the assessment predictions, verify the success of the mitigation measures, or gain additional scientific knowledge related to prediction of the Project environmental effect.

Two types of monitoring are considered: compliance and follow-up environmental monitoring.

Compliance monitoring is undertaken to confirm that Project design features, mitigation measures, environmental protection measures, or benefit agreements are being effectively implemented.

Biophysical and socio-economic monitoring programs are used to:

- verify predictions of environmental effects;
- determine the effectiveness of mitigation measures, environmental protection measures or benefits agreements in order to modify or implement new measures where required;
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects; and
- support environmental management systems used to manage the environmental effects of projects.

Where a monitoring program for a specific VC or KI is identified, the following aspects of the program are defined:

- parameters to be measured,
- methods and equipment to be used,
- location and timing of surveys, and
- how the results of the monitoring will be applied, including consideration of an adaptive management approach.

3.4 Assessment of Cumulative Environmental Effects

3.4.1 Screening for Potential Cumulative Effects

Cumulative environmental effects are only assessed if the following criteria are met for the residual Project effect under consideration:

- The Project will result in a measurable, demonstrable or reasonably-expected residual environmental effect on a component of the biophysical or socio-economic environment,
- The Project-specific residual environmental effect on the component will likely act in a cumulative fashion with the environmental effects of other past or future projects or activities that are likely to occur (i.e., Is there overlap of environmental effects?), and

- There is a reasonable expectation that the Project's contribution to cumulative environmental effects will be substantive, measurable or discernible such as that it will affect the viability or sustainability of the resource.

If, based on these criteria, there is potential for cumulative environmental effects, the effect is assessed further to determine if it is likely to shift the component to an unacceptable state. Where there is no potential for the environmental effect of the Project to spatially or temporally overlap with similar effects of other project and activities, justification for not carrying these environmental effects forward to the assessment of cumulative environmental effects is provided.

3.4.2 Project Inclusion List

The project inclusion list includes all past, present and reasonable foreseeable projects, activities and actions in the region of the Kiggavik Project. Only projects and activities that overlap with the Project residual environmental effects both spatially and temporally are considered in the assessment of potential cumulative environmental effects.

The specific projects, activities and action considered for each environmental effect are described in the assessment for the VC or KI.

3.4.3 Description of Cumulative Environmental Effects

The first step in the assessment of cumulative environmental effects involves describing the environmental effect, the mechanisms by which the Project environmental effect may interact cumulatively with other projects and activities in the RAA (from the Project Inclusion List), and the geographic and temporal scope of the cumulative environmental effect.

For this assessment, cumulative environmental effects are described for four cases. A more detailed description of the assessment cases is provided within the Project Inclusion List (Volume 1, Appendix 1).

- ***Base Case***: the current status of the measurable parameters for the environmental effects at baseline (i.e., prior to the Project). Baseline includes all past and present projects and activities in the RAA that may result in similar environmental effects to the Project environmental effect, including ongoing mineral exploration. Existing projects include projects that have received environmental approval and are in some form of planning, construction and/or commissioning.
- ***Project Case:*** the status of the measurable parameters for the environmental effect with the Project in place, over and above the Base Case. This is usually assessed using the peak environmental effect of the Project or maximum active footprint for the Project.

- ***Future Case:*** the status of the measurable parameters for the environmental effect because of the Project Case, in combination with all reasonable foreseeable projects, activities and actions. Reasonably foreseeable projects are defined as future projects, activities and actions that will occur with certainty, including projects that are in some form of regulatory approval or have made a public announcement to seek regulatory approval.

For this assessment, future projects include proposed mines that are currently under NIRB review:

- Meadowbank
- Doris North 1
- Doris North 2
- Meliadine
- Mary River
- Hackett River
- Back River
- Hackett River
- High Lake

The combination of the Project Case with the Future Case allows determination of the Project's contribution to cumulative effects of all past, present and reasonably-foreseeable projects and activities.

- ***Far Future Case:*** the status of the measurable parameters for the environmental effect because of the Future Case, in combination with possible far future developments in the Kiggavik region.

It is recognized that exploration activities will continue in the vicinity of the Kiggavik Project, and that there is the potential for additional resources to be discovered during the life of the Project. To address such a possibility, a potential far future development scenario was developed. This scenario assumes additional deposits within a 200 km radius of the Kiggavik site, and the development of a non-uranium operation located within the Kiggavik RSA. The Meadowbank gold operation is used as the model for this. It assumes additional resources are found in the Meadowbank area, and that operation of Meadowbank continues. The following projects and activities are included in the development scenario.

Component	Locations
Uranium mines	3 mines within 200 km of Kiggavik
Uranium mills	Kiggavik mill
Gold mines	1 mine within Kiggavik RSA Meadowbank region
Gold mills	Meadowbank region Additional mill within Kiggavik RSA
Access Roads	Meadowbank region Additional mill within Kiggavik RSA
Exploration	Induced exploration near the access road(s) and in the Kiggavik area

Due to the lack of information regarding the specific details of potential future developments (i.e., footprint of projects and activities), the assessment of cumulative environmental effects under this Case is by definition qualitative and is limited to a description of how these projects, activities and actions could affect the magnitude, duration and extent of cumulative environmental effects.

3.4.4 Mitigation of Cumulative Environmental Effects

Mitigation measures that would reduce the Project's environmental effects are described for cumulative environmental effects, with emphasis on measures that should limit the interaction of environmental effects of the Project with similar environmental effects from other projects. Three types of mitigation measures are considered, where appropriate:

- measures that can be implemented solely by AREVA,
- measures that can be implemented by AREVA, in cooperation with other project proponents, government, Aboriginal organizations and/or public stakeholders, and
- measures that can be implemented independently by other project proponents, government, Aboriginal Organizations and/or public stakeholders.

For the latter two types of mitigation, the degree to which AREVA can or cannot influence the implementation of these measures is noted.

Mitigation measures that could assist in reducing potential cumulative environmental effects are identified for each environmental effect, including a discussion of how these measures may potentially modify the characteristics of an environmental effect.

3.4.5 Residual Cumulative Environmental Effects Assessment

Residual cumulative environmental effects are described, taking into account how the mitigation will change the environmental effect. Where possible, cumulative environmental effects are characterized quantitatively or qualitatively in terms of the direction, magnitude, duration, geographic extent, frequency and reversibility. This includes characterization of:

- the total residual cumulative environmental effects based on the Future Case (i.e., the environmental effects of all past, present and reasonably foreseeable project and activities), in combination with the environmental effects of the Project, and
- the contribution of the Project to the total residual cumulative effects (i.e., how much of the total residual cumulative effects can be attributed to the Project).

3.4.6 Significance of Residual Cumulative Environmental Effects

The significance of cumulative environmental effects is determined using standards or thresholds that are specific to the VC, KI and/or measurable parameters used to assess the Project environmental effect. Determinations of significance are made for:

- the significance of the total residual cumulative environmental effect, and
- the significance of the contribution of the Project to the total residual cumulative environmental effect.

The determination of residual cumulative environmental effects includes a discussion of the confidence of the prediction based on scientific certainty relative to:

- quantifying or estimating the environmental effect (i.e., quality and/or quantity of data, understanding of the effects mechanisms), and
- the effectiveness of the proposed mitigation measures.

As for residual Project environmental effects, prediction confidence for the cumulative environmental effect and the success of mitigation measures is ranked as low, moderate or high.

3.4.7 Monitoring of Cumulative Environmental Effects

Based on the evaluation of residual cumulative environmental effects, it may be necessary to conduct monitoring programs. Monitoring programs are designed to:

- confirm the effectiveness of a broad range of approved mitigation techniques,

- determine whether different or an increased level of mitigation is required to achieve the mitigation or reclamation goals, and
- identify and address any cumulative effects that occur but were not predicted.

Two types of monitoring are considered:

- Compliance Monitoring: to confirm that Project design features, mitigation measures, environmental protection measures, or benefit agreements are being effectively implemented.
- Biophysical or Socio-economic Monitoring: to confirm the environmental effect prediction and/or effectiveness of a Project design feature, mitigation measure, environmental protection measure, or benefit agreement.

3.5 Summary of Residual Environmental Effects

Residual Project and cumulative environmental effects are briefly summarized for each VC. This includes a discussion of the overall combined environmental effect of the Project on the VC and its significance, as well as a discussion of the overall combined effect of all cumulative effects on the VC and its significance. For biophysical VECs, this relates to the sustainability of the resource or populations being considered. For socio-economic VSECs, this relates to the ability of the community, the Kivalliq region and/or Nunavut to adapt to or manage the environmental effect. A discussion of the Project's contribution to the combined cumulative effect is also provided.

In addition, this summary section presents an assessment of the effects of climate change on residual Project and cumulative effects. Where possible, the effects are described quantitatively, and include a description of how likely climate changes in the region will likely influence Project and cumulative residual effects.

3.6 Assessment of Transboundary Effects

As required by the NIRB EIS Guidelines, the assessment includes consideration of transboundary effects, where residual environmental effects are likely to extend beyond the Nunavut into federal waters and/or other provincial or territorial jurisdictions. As this is based largely on the cumulative effects assessment, the transboundary effects are characterized qualitatively or semi-quantitatively.

3.7 Summary of Mitigation

A detailed description of the mitigation measures proposed to minimize or avoid project-related and cumulative effects on VCs is provided based on the scoping and effects analyses. This includes:

- relevant Project design features to reduce environmental effects,
- Project policies (e.g., Inuit hiring policy),
- specialized mitigation measures to minimize environmental effects on VECs,
- social or community programs to minimize environmental effects on VSECs,
- Environmental Protection plans,
- broader agreements (e.g., benefits agreements), and
- compensation.

3.8 Summary of Monitoring

Monitoring programs to address uncertainties associated with the environmental effects predictions and environmental design features and mitigation proposed for residual Project effects and cumulative effects are described in detail. This includes all compliance monitoring and environmental monitoring that may be applied during the life of the Project, and that will form the:

- Compliance Monitoring Program Framework,
- Environmental Monitoring Program Framework,
- Socio-Economic Monitoring Program Framework,
- Post-Project Analysis Program Framework, and
- Follow-up Monitoring Programs.

4 Summary of Existing Environment, Human Health

Regardless of where people live or work, they are exposed to radiation from natural sources; it is present in the air we breathe, the food we eat, the water we drink, and in the construction materials used to build our homes. It comes from outer space (cosmic), the ground (terrestrial), radionuclides in the body from air, water and food (internal) and exposure to radon. Worldwide, the normal range of average exposures to natural background radiation has been reported as about 1,000 to 13,000 µSv/y (UNSCEAR 2008, Annex B). Figure 4.1-1 shows the exposure to radiation to some of the common sources of naturally occurring radiation for those living in Canada (AECB 1995). An additional source of radiation to some individuals is through diagnostic medical procedures.

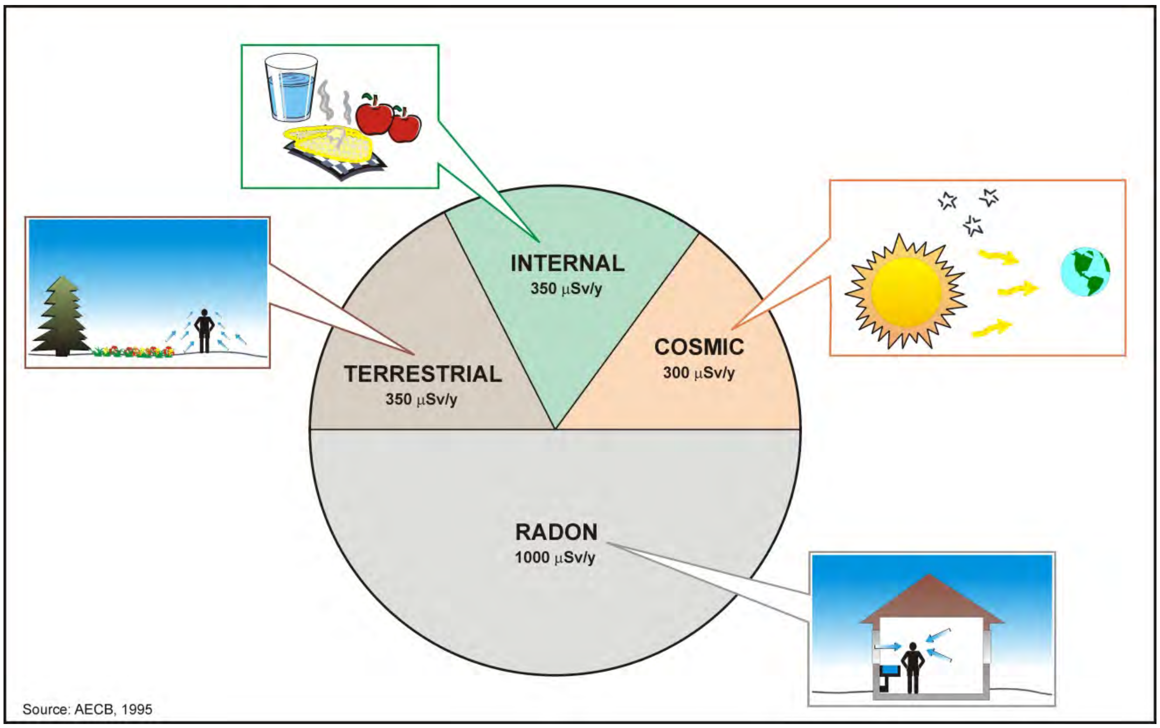


Figure 4.1-1 Typical Distribution of Annual Dose from Natural Radiation

Levels of natural or background radiation can vary greatly from one location to the next. For example, due to consumption of caribou, the internal dose for people living in the Project area is likely higher than that shown above. Ingestion of caribou in northern Canada has been shown to add 1 to 4 mSv/y of internal exposure for an adult, primarily due to the natural background levels of Po-210 (Thomas et al. 2001).

People are also exposed to the other COPC (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium and zinc) through air, water, soil and food. Table 4.1-1 summarizes the typical exposure to these COPC experienced by Canadians; in general, the intake from food is the largest contributor to the total exposure.

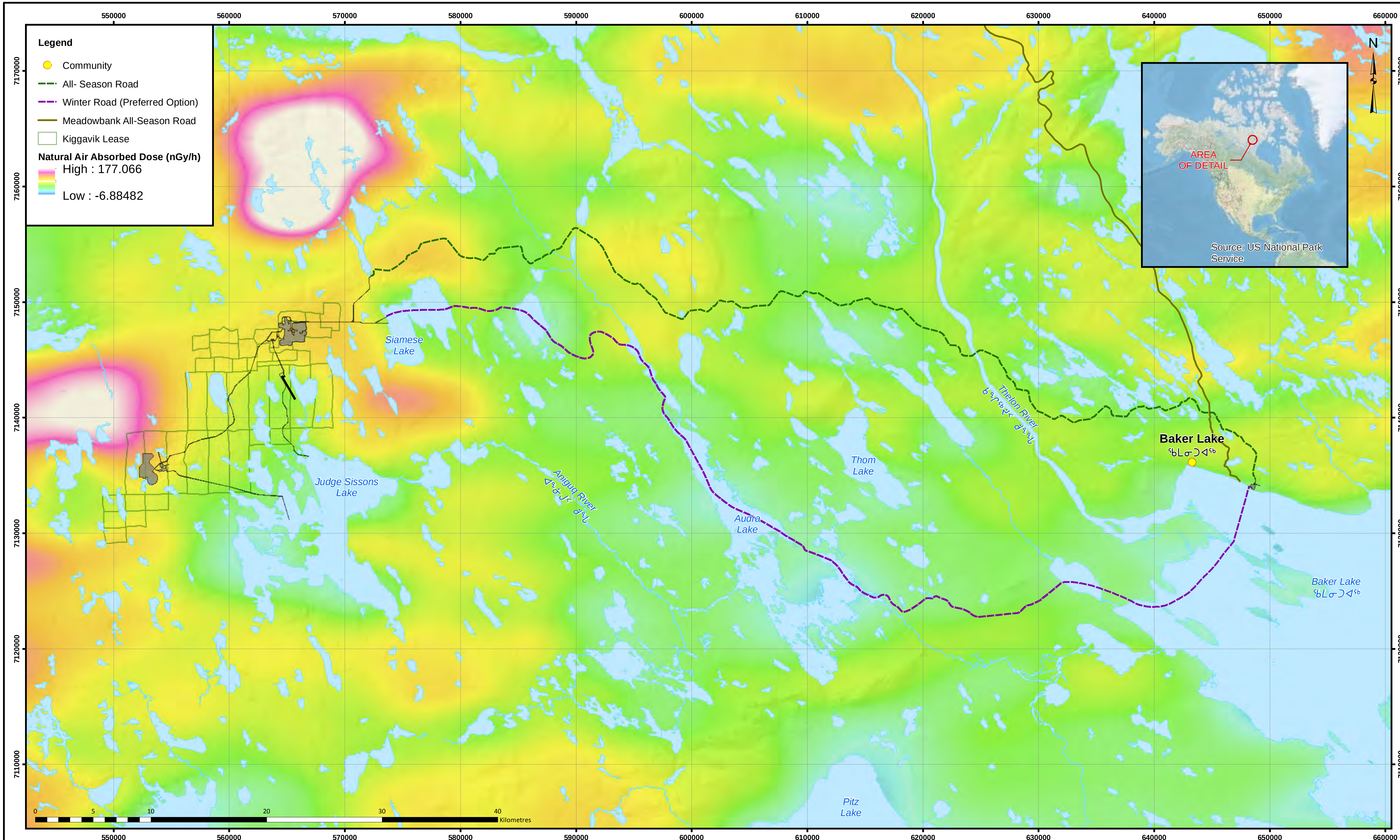
Table 4.1-1 Typical Intake of COPC by Members of the General Public

COPC	Intake (µg/kg-d)			Source
	Adult	Child	Toddler	
Arsenic	0.18	0.41	0.66	EC 1999
Cadmium	0.20	0.48	0.56	PSL 1994 (EC/HC 1994a) - with updated food from HC 2011
Cobalt	0.24	0.45	0.71	HC 2011 + background intake from air, soil, drinking water
Copper	24	46	57	HC 2011 + background intake from air, soil, drinking water
Lead	0.24	0.36	0.60	HC 2011 + background intake from air, soil, drinking water
Molybdenum	2.7	6.2	8.6	HC 2011 + background intake from soil, drinking water
Nickel	4.1	8.3	11	PSL 1994 (EC/HC 1994b) - with updated food from HC 2011
Selenium	1.9	3.4	4.2	CCME 2009
Uranium	0.023	0.052	0.078	CCME 2007
Zinc	184	390	549	HC 2011 + background intake from air, soil, drinking water

Terrestrial Radiation

Terrestrial gamma radiation (groundshine) exposure rates in the Kivalliq region are presented in Figure 4.1-2, as extracted from Natural Resources Canada data (Carson, 2001). Spectral surveys provide estimates of uranium and thorium concentrations in surficial soils, as well as measures of absorbed dose rates.

In the local assessment area, background gamma radiation exposure rates averaged 46 nGy/h and ranged to 92 nGy/h. Figure 4.1-3 below presents gamma radiation exposure rates with Kiggavik lease boundaries indicated. Similarly, preliminary gamma radiation surveys conducted over the proposed mill terrace averaged 56 nGy/h and range to 129 nGy/h, while pre-drilling background gamma radiation levels at drill pad locations were observed to average 53 nGy/h and ranged to 656 nGy/h (AREVA 2011, AREVA 2012).



Projection: NAD 1983 UTM Zone 14N
Compiled: C. CARTER Revised: TL
Date: 08/28/2014 Scale: 1:300,000
File: KI08F087
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Geological Survey of Canada, AREVA Resources Canada Inc.*

FIGURE 4.1-2
GAMMA RADIATION EXPOSURE RATE IN THE KIVALLIQ REGION

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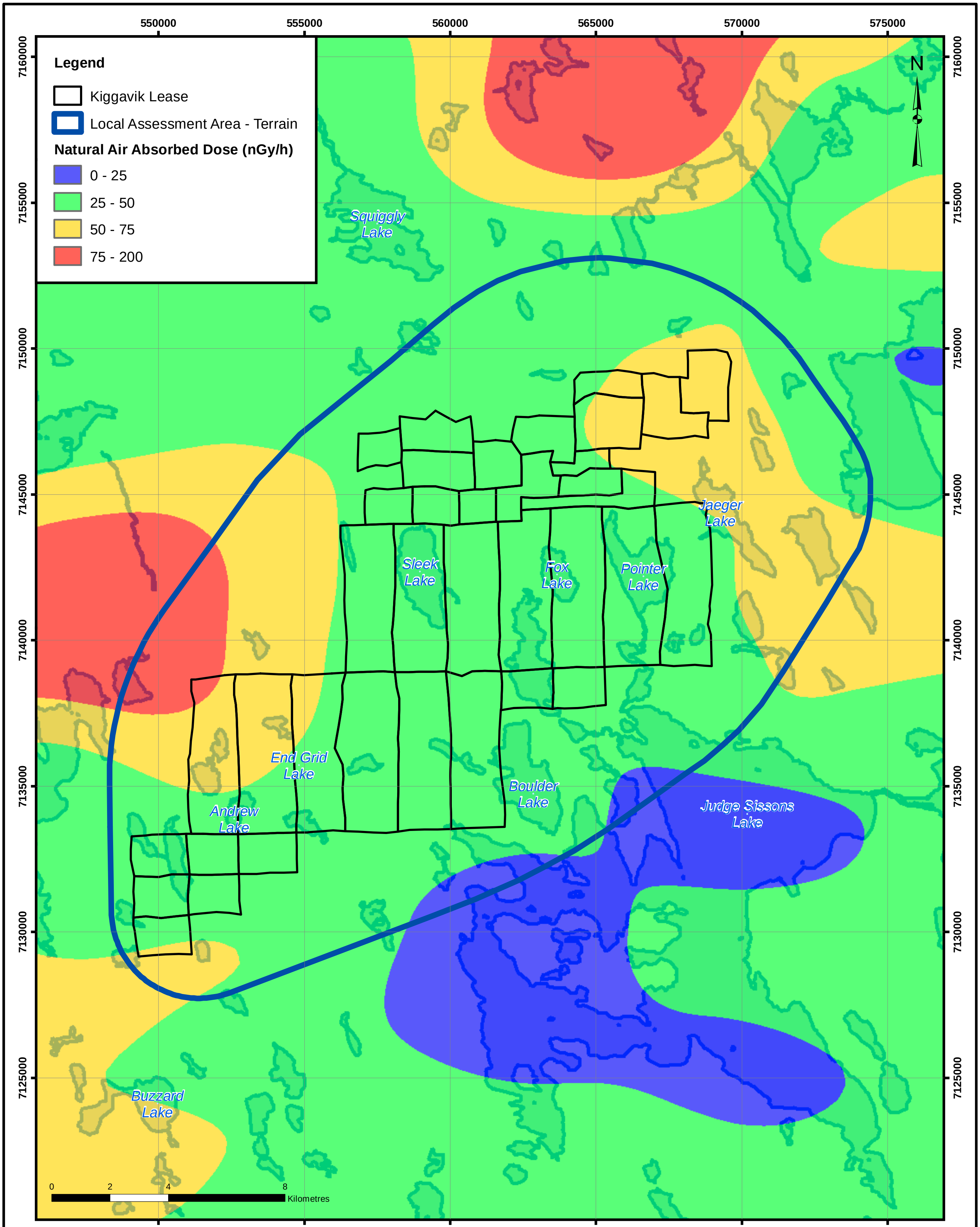

Projection: NAD 1983 UTM Zone 14N
Compiled: C. CARTER Drawn: C. CARTER
Date: 12/11/2012 Scale: 1:175,000
File: KI08F088
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Geological Survey of Canada, AREVA Resources Canada Inc.*

FIGURE 4.1-3
GAMMA RADIATION EXPOSURE RATE IN LOCAL ASSESSMENT AREA (nGy/h)

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In the predictions of external gamma radiation exposures, the groundshine model, discussed in DEIS Tier 3, Volume 8, Human Health, Appendix 8A, uses radionuclide concentrations in the soil layers that are calculated in the soil model. The groundshine model accounts for self-shielding by overlying soil layers and the loss of gamma ray flux via radon emanation and subsequent exhalation to the atmosphere. Using this method, prediction of incremental radiation exposure is not dependent on baseline radiation exposure conditions.

Internal Radiation

Specialized alpha dosimeters were deployed at the Kiggavik and Scissons sites and in the community of Baker Lake for integrated measurements of alpha emissions of short-lived progeny of radon-222 and radon-220, as well as long-lived radioactive decay products of uranium. Data from these monitors deployed from 2008 through 2011 are provided in Table 4.1-2.

Table 4.1-2 Summary of Baseline Environmental Alpha Dosimeter Data

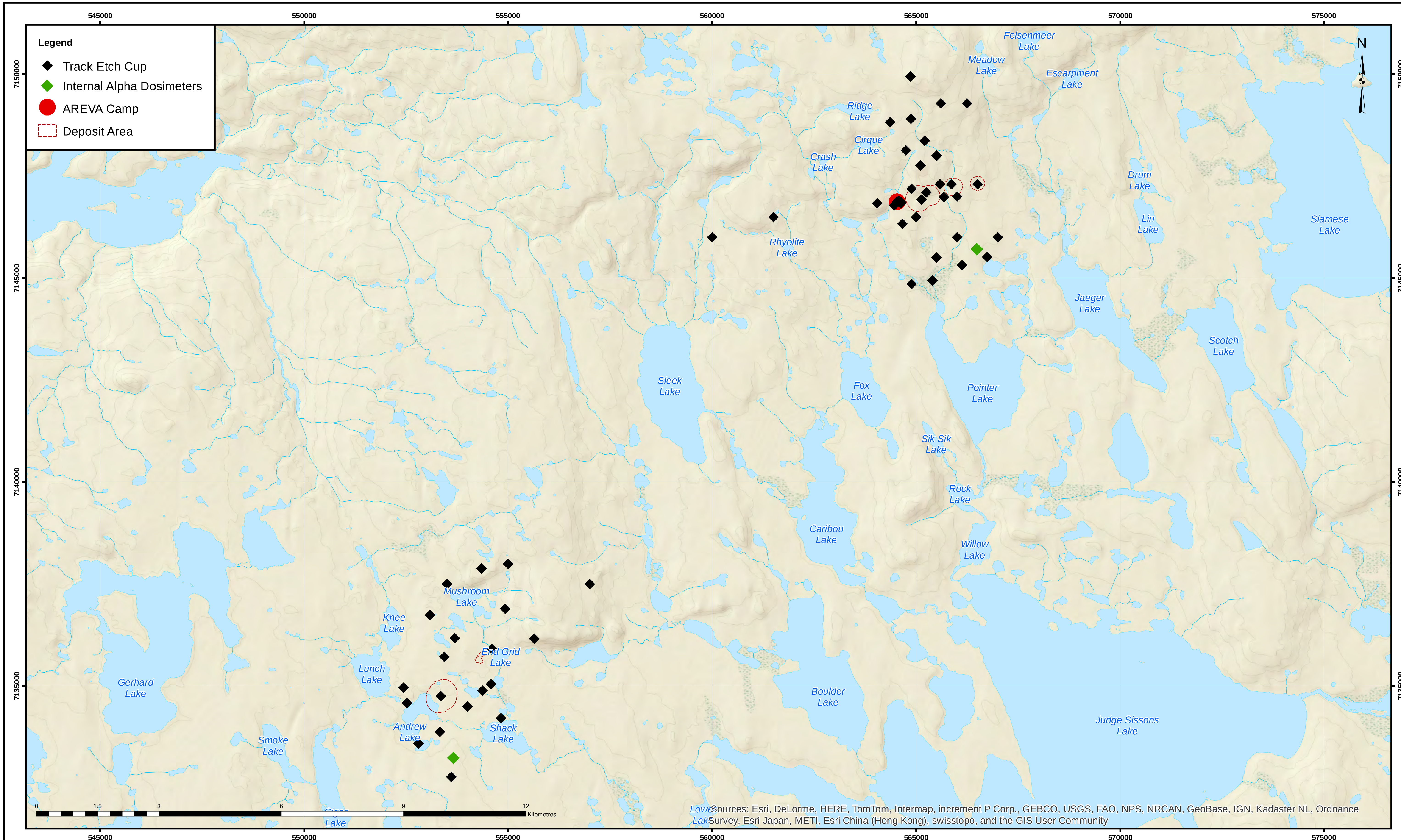
	2008	2009	2010	2011
BAKERLAKE				
EAPRn222 Unit : nJ.m^{-3}	4	5	ND	3
EAPRn220 Unit : nJ.m^{-3}	5	6	ND	3
LLRD Unit : < mBq.m^{-3}	0.2	0.3	ND	0.2
KIGGAVIK				
EAPRn222 Unit : nJ.m^{-3}	6	6	8.5	ND
EAPRn220 Unit : nJ.m^{-3}	5	7	9	ND
LLRD Unit : < mBq.m^{-3}	0.3	0.3	0.3	ND
SISSONS				
EAPRn222 Unit : nJ.m^{-3}	6	6	12	5
EAPRn220	5	6	11	4

Table 4.1-2 Summary of Baseline Environmental Alpha Dosimeter Data

	2008	2009	2010	2011
Unit : $nJ.m^{-3}$				
LLRD Unit : < $mBq.m^{-3}$	0.3	0.2	0.45	0.2

ND = no data

Radon monitors were deployed at several locations at the Kiggavik and Scissons sites to determine both average annual radon concentrations, and average summer-season concentrations. In 2010, radon results for the summer-season track etch cups ranged between a lower limit of detection (LLD) of 14.8 Bq/m^3 and 55.5 Bq/m^3 with an average of 22.2 Bq/m^3 (AREVA 2011). Similarly, in 2011, radon results for the summer-season track etch cups ranged between and LLD of 22.2 Bq/m^3 and 48.1 Bq/m^3 with an average of 24.3 Bq/m^3. The results for the annual track etch cups deployed in July 2010 and retrieved in June 2011 ranged between an LLD of 3.7 Bq/m^3 and 29.3 Bq/m^3 (AREVA 2012). The track etch cup locations are shown in Figure 4.2-1.



Projection: NAD 1983 UTM Zone 14N
Compiled: C. CARTER Drawn: C. CARTER
Date: 12/11/2012 Scale: 1:85,000
File: KI08F086
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, AREVA Resources Canada Inc.*

FIGURE 4.1-4
LOCATION OF RADON, RADON PROGENY, AND RADIOACTIVE DUST MONITORS

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5 Assessment of Project Effects Worker Exposure to Hazardous Substances

5.1 Issues and Concerns Identified During the Inuit and Stakeholder engagement

The NIRB EIS Guidelines for the Project (NIRB 2010) incorporated advice from the public and interested parties on the proposed scope of assessment for Human Health, including the identification of VCs and issues that should be considered in the EIS. Specifically, the guidelines require an assessment of the human health effects due to the mining and milling activities as well as the transport of uranium concentrate by either air or marine shipping.

AREVA recognizes that there are health *concerns from community members regarding workers' exposure to substances associated with milling and mining* (EN-RI NIRB May 2010[17], EN-RI OH Nov 2012[18] EN- BL NIRB Apr 2010[19] EN-RB NIRB April 2010[20]). It is acknowledged that there are hazards associated with mining and milling. However, AREVA is committed to ensuring workers' health and safety are protected. AREVA believes that when proper procedures are followed, workers' exposure to hazardous substances will be minimal and workers will be healthy.

Specific mitigative measures and training will be implemented when the mill has been further designed and developed.

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[17] EN-RI NIRB May 2010: *Kivalliq region has an abundance of minerals (gold, nickel, copper and uranium) and having worked at many exploration companies all over, community member has known someone who became ill after working in the area near the Kiggavik mine site.*

[18] EN-RI OH Nov 2012: *Is it hazardous to mine?*

[19] EN- BL NIRB Apr 2010: *Elder's husband worked at the Rankin Inlet Nickel mine as an underground miner and became ill. What is the plan to protect the people and workers? Would like to see a protection plan put in place for the people, workers, wildlife and land from uranium and uranium mining.*

[20] EN- RB NIRB April 2010: *Uranium mining appears to more dangerous than gold mining (Meadowbank). The chemicals used for both are harmful to wildlife, but chemicals used for uranium is more toxic and of more concern to both wildlife and people.*

The NIRB guidelines specifically require that the Human Health Risk Assessment is to include:

- predicted sources, quantities and points of release from the project emissions and effluents containing radionuclides and COPCs
- Selection process for COPCs
- identification of pathways to human receptors
- identification and characterization of human receptors (workers and the public). Include maps to delineate their locations and the distances of communities, residences, temporary/seasonal residences, etc. to project sites and related infrastructure
- method used to convert radionuclide and hazardous substance exposure and intake by the various human receptors from the various pathways into an exposure or dose (e.g., conversion factors)
- criteria used to determine significance of impact (e.g., percentage of radiation dose limits, exposure relative to lifetime cancer risk limit)

5.2 Introduction to Hazardous Substances and Constituents of Potential Concern

5.2.1 What is a Hazardous Substance?

There have been questions and concerns raised by community members about the hazards of mining (EN-RI OH Nov 2012[21]) as well as questions about how AREVA will ensure that workers are protected (EN-BL NPC Jun 2007[22], EN-BL OH Oct 2012[23]). In this document the various types of hazards a worker for the Kiggavik Project may be exposed to are described with respect to the type of work they may be performing and types of protective measures which will be in place to ensure their health is protected.

The hazardous substances for the Kiggavik Project are defined as chemicals used in significant quantities in the construction, mining, milling or decommissioning and reclamation operation that may have a potential health risk to the worker, including intermediary chemicals produced internally during the milling process and chemical by products.

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[21] EN- RI OH Nov 2012: *Is it hazardous to mine?*

[22] EN-BL NPC Jun 2007: *How are you going to assure the people that we are going to be safe?*

[23] EN-BL OH Oct 2012: *What will you do to protect workers' health?*

There are many chemicals used in the mining and milling process, some of which are considered as hazardous. A hazardous chemical can be classified as a physical hazard and (or) a health hazard. A chemical will be considered a physical hazard if it has properties of being combustible, compressed, explosive, flammable, oxidizing, pyrophoric or unstable. A chemical will be considered a health hazard if its exposure has the potential to cause acute or chronic health effects.

"Acute" effects usually occur rapidly as a result of short-term exposures, and may be of short duration. Some examples of acute effects often observed in overexposure to chemicals include irritation, corrosion and sensitization. "Chronic" effects generally occur as a result of long-term exposure, and may be of long duration. There is a difference in type and severity of effects depending on how rapidly the dose is received (duration) and how often the dose is received (frequency).

Although safety hazards related to the physical characteristics of a chemical can be objectively defined and measured, health hazards definitions are less precise and more subjective. The determination of occupational health hazards is complicated by the fact that many of the signs and symptoms occur commonly in non-occupationally exposed populations, so the effects of exposure are difficult to separate from normally occurring illnesses. In addition, not all people are affected to the same degree by the same chemical. People have different levels of susceptibility depending on a variety of factors including age, sex, genetic predisposition, medication, pre-existing medical conditions and lifestyle choices (smoking, alcohol use, diet).

However, there is an organization known as the American Conference of Governmental Industrial Hygienists (ACGIH) whose mission it is to issue health-based occupational exposure guidelines based on the best available data and, whenever possible, peer reviewed literature on human health effects resulting from industrial, occupational or other exposure situations. They review results from experimental human and animal studies; human epidemiological studies; toxicological studies; and when possible, from a combination of all these sources and create occupational exposure guidelines.

5.2.2 What is a Constituent of Potential Concern?

For the purposes of workplace exposure assessments, metals identified as COPCs include arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc. Workers are exposed to these substances primarily through inhalation of dust during mining operations. Workplace dust exposure concerns have been expressed by community members (EN- RB OH Nov 2012[24]). Mitigative measures for dust control that are put in place to ensure workers are minimally exposed are described in Section 5.3.2.1.

5.2.3 Biological Effects

Many chemicals can have a direct effect on the area which they have contacted such as the skin, eye, and mucous membrane of the nose. There are some chemicals that have an effect on other parts of the body when they are absorbed into the body and can affect such systems as the liver, nervous system and the blood.

There are four primary routes of exposure or ways which chemicals can enter the body. Although injection may be considered another way chemicals can enter the body, it will not be examined in this assessment, as this route of exposure is not probable for mining or milling. Depending on properties of the chemical, it may enter the body in all four ways or it may choose a selective route. By understanding the route of exposure, a person can adequately select the proper protective equipment and develop a safe work plan.

Inhalation - For most chemicals in the form of vapors, gases, mists, or particulates, inhalation is the major route of entry. Chemicals in the air can be inhaled into the body through the mouth or nose. Once inhaled, chemicals are either exhaled or deposited in the respiratory tract. If deposited, damage can occur through direct contact with tissue or the chemical may diffuse into the blood through the lung-blood interface. Upon contact with tissue in the upper respiratory tract or lungs, chemicals may cause health effects ranging from simple irritation to severe tissue destruction. Substances absorbed into the blood are circulated and distributed to organs that have an affinity for that particular chemical. Health effects can then occur in the organs, which are sensitive to the toxicant.

The mucociliary escalator acts as a defence mechanism to the lungs, trapping foreign substances and materials when it reaches the tracheobronchial tree and removing it before it gets to the lungs. The trachea, bronchi, and bronchioles are covered with hair-like projections called cilia. The cells in this area secrete mucous which covers the cilia. As the cilia beat, they move the mucous layer containing the foreign particles, so it can be either swallowed or coughed out. The mucociliary escalator is capable of removing non-soluble particles from the

[24] EN- RB OH Nov 2012: *With milling, is dust safe for people?*

upper airway within hours. Substances such as acute irritant gas exposures or excessive inhaled dust can reduce the effectiveness of the escalator. In situations where the foreign substance is not removed, it can cause damage such as irritation and inflammation when the substance interacts with the lung.

Skin Contact (absorption) - Chemicals can cause direct effects at the point of contact with the skin. Some chemicals can be absorbed into other parts of the body through the skin. Skin (dermal) contact can cause effects that are relatively innocuous such as redness or mild dermatitis; more severe effects include destruction of skin tissue or other debilitating conditions.

Eye Contact (**absorption**) - Chemicals can come in contact with the eyes in the form of dusts, mists, gases, vapours, or liquid splashing into the eye. The eyes are particularly sensitive to chemicals. Even a short exposure can cause severe effects to the eyes or the substance can be absorbed through the eyes and be transported to other parts of the body causing harmful effects.

Ingestion - Chemicals that inadvertently get into the mouth and are swallowed do not generally harm the gastrointestinal tract itself unless they are irritating or corrosive. Chemicals that are insoluble in the fluids of the gastrointestinal tract (stomach, small, and large intestines) are generally excreted. Others that are soluble are absorbed through the lining of the gastrointestinal tract. They are then transported by the blood to internal organs where they can cause damage. In workplaces, common ways in which ingestion of chemicals can result is through inadequate hygiene practices such as hand-to-mouth contact, consuming contaminated food or drink, or smoking cigarettes that have come into contact with a chemical or unclean hands. There are some cases where workplace chemicals can be accidentally swallowed.

Ingestion may also occur as a result of clearance of particles from the mucociliary escalator.

5.3 Scope of the Assessment for Worker Exposure to Hazardous Substances

5.3.1 Regulatory Setting

5.3.1.1 American Conference of Governmental Industrial Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienists is a well-respected, non-governmental organization which deals with industrial hygiene and worker health and safety. The not-for-profit organization was founded in 1938 and originally known as the National Conference of Governmental Industrial Hygienists (NCGIH). In 1946, it changed its name to the American

Conference of Governmental Industrial Hygienists and opened its membership to all industrial hygiene personnel within the agencies as well as to governmental industrial hygiene professionals in other countries. Today, membership is open to all practitioners in industrial hygiene, occupational health, environmental health, and safety.

ACGIH's core purpose is to advance occupational and environmental health. ACGIH's core values include:

- Care for the health and wellbeing of the worker,
- Integrity, and
- Scientific excellence through the pursuit of state of the art knowledge.

ACGIH® has published approximately 400 publication titles offering their expertise on matters such as industrial hygiene, environment, safety and health, toxicology, medical, hazardous materials/waste, workplace controls, indoor air quality, physical agents and ergonomics. In addition to publications, ACGIH® has supported numerous educational activities and conferences that facilitate the exchange of ideas, information, and techniques to improve worker health and safety. Over the years, some of topics of discussion have included workplace control of carcinogens, asbestos identification and measurement, air sampling, industrial ventilation, mining, occupational exposure databases and mold remediation.

There are currently 12 ACGIH committees which focus on a range of topics including agricultural safety and health, air sampling instruments, bioaerosols, biological exposure indices, computer, construction, industrial ventilation, infectious agents, chemical substance Threshold Limit Values, and physical agent Threshold Limit Values.

Threshold Limit Values for Chemical Substances (TLV-CS) Committee

Undoubtedly the best known of ACGIH®'s activities, the Threshold Limit Values for Chemical Substances (TLV®-CS) Committee was established in 1941. This group was charged with investigating, recommending, and annually reviewing exposure limits for chemical substances. It became a standing committee in 1944. Two years later, the organization adopted its first list of 148 exposure limits, then referred to as Maximum Allowable Concentrations. The term "Threshold Limit Values (TLVs®)" was introduced in 1956. Today's list of TLVs® includes 642 chemical substances and physical agents, as well as 47 Biological Exposure Indices (BEIs®) for selected chemicals.

The TLVs and BEI are developed as guidelines to assist in the control of health hazards. These recommendations or guidelines are intended for use in the practice of industrial hygiene, to be interpreted and applied personnel trained in the discipline.

5.3.1.2 Canadian Nuclear Safety Commission (CNSC)

In Canada, the Canadian Nuclear Safety Commission (CNSC) regulates the nuclear industry. The commission was created following a major updating of the Canadian nuclear regulatory system and the implementation of the *Canadian Nuclear Safety and Control Act* and its regulations in 2000.

As set out in the Canadian *Nuclear Safety and Control Act*, the objectives of the CNSC are:

(a) to regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to:

> (i) prevent unreasonable risk, to the environment and to the health and safety of persons, associated with that development, production, possession, or use,
>
> (ii) prevent unreasonable risk to national security associated with that development, production, possession or use, and,
>
> (iii) achieve conformity with measures of control and international obligations to which Canada has agreed; and,

(b) to disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the environment and on the health and safety of persons, of the development, production, possession and use referred to in paragraph (a).

The following excerpt obtained from the CNSC Uranium Mines and Mills Regulations (SOR/2000-206) has specific safety related requirements for any licensee of a uranium mine or mill in Canada:

> “d) in relation to health and safety,
>
> (i) the effects on the health and safety of persons that may result from the activity to be licensed, and the measures that will be taken to prevent or mitigate those effects,
>
> (ii) the proposed program for selecting, using and maintaining personal protective equipment,

(iii) the proposed worker health and safety policies and programs,

(iv) the proposed positions for and qualifications and responsibilities of radiation protection workers,

(v) the proposed training program for workers,

(vi) the proposed measures to control the spread of any radioactive contamination,

(vii) the proposed ventilation and dust control methods and equipment for controlling air quality, and

(viii) the proposed level of effectiveness of and inspection schedule for the ventilation and dust control systems. "

5.3.1.3 Worker Safety and Compensation Commission (WSCC)

The Worker Safety and Compensation Commission in Northwest Territories (NWT) and Nunavut are committed to prevention, and works to improve northern safety cultures through safety education.

In NWT, the Worker's Compensation Board was created in 1977. When Nunavut was created in 1999, the governments of Nunavut and the NWT agreed to a shared Workers' Compensation Board. This arrangement continues to this day.

However on April 1, 2008, with changes to the NWT Workers' Compensation Act and Nunavut Workers' Compensation Act, the WCB became the Workers' Safety and Compensation Commission (WSCC) of the Northwest Territories and Nunavut to further establish their commitment to promoting workplace safety and care for injured workers. In the Northwest Territories and Nunavut, a seven-person Governance Council represents the interests of labour, industry, and the public sector.

There are a number of legislation that has been put forth by the Commission to govern workplace health and safety, including:

- Safety Act*,
- Safety Regulations,
- Mine Health and Safety Act*,
- Mine Health and Safety Regulations, and
- Explosives Use Act*

Within Table 2 of the Consolidation of General Safety Regulations for the Nunavut Territory, occupational exposure limits are established for hazardous substances and constituents of potential concern for 8-hour exposures, 15-minute exposures and exposure ceilings.

5.3.1.4 Nunavut Impact Review Board (NIRB)

The Nunavut Impact Review Board (NIRB) members, appointed by the Government of Canada and Government of Nunavut, are responsible for making recommendations to the responsible federal or territorial Minister regarding the issuance of licenses in the Nunavut Settlement Area. The Board was created by the Nunavut Land Claims Agreement to access the potential impacts of proposed development in the Nunavut Settlement Area prior to approval of the required project authorizations. Both traditional knowledge and recognized scientific methods are used when NIRB assesses the biophysical and socio-economic impact of proposals and makes recommendations and decisions about which project may proceed. The Board may also monitor the impacts of projects that have been reviewed and approved to proceed.

5.3.2 Project-Environment Interactions and Effects

A number of project activities have been identified with potential to interact with human health during construction and commissioning, operations and decommissioning. These activities are ranked according to their potential to interact with the potential source of exposure. Interactions were assigned a ranking as follows:

- **0** = activities are those with no interaction, or no potential for substantive interaction, with the human health assessment.
- **1** = activities are those having a potential interaction with human health assessment, but whose interaction would not result in a significant health effect once planned and proven mitigation methods are applied to the activity.
- **2** = activities are those activities having potential for substantive effects on human health assessment, even after mitigation measures are applied. The potential health effects are addressed further in the health assessment.

Table 5.3-1 Project-Environment Interactions – Worker Exposure to Hazardous Substances

Project Activities/Physical Works	Worker Exposure to Hazardous Substances
Construction	
All associated activities	1

Table 5.3-1 Project-Environment Interactions – Worker Exposure to Hazardous Substances

Project Activities/Physical Works	Worker Exposure to Hazardous Substances
Operation	
Mining	1
Milling	1
Tailings Management	1
Water Management - Collection of site and stockpile drainage	0
Water Management - Water and sewage treatment	1
Water Management - Discharge of treated effluents – including grey water	0
Waste Management	1
General Services – Generation of power	1
General Services - Hazardous materials storage and handling (reagents, fuel and hydrocarbons)	1
General Services - Explosives storage and handling	1
Transportation – Air transport of Uranium concentrates	1
On-going Exploration – Aerial surveys	1
Decommissioning	
On-going treatment and release of water, including domestic wastewater	1

5.3.3 Valued Components, Indicators and Measurable Parameters

Human (worker) health is defined as a valued component (VC) that, if altered by the Project, would be of concern to AREVA, regulators, and the general public. Worker health represents components of worker exposure that may be altered by the Project, and is widely recognized as important to the human environment. In this section, worker exposure to Contaminants of Potential Concern (hazardous substances) in the workplace is specifically addressed.

Table 5.3-2 Measureable Parameters for Worker Exposure to Hazardous Substances

Human Health Effect	Indicator	Measurable Parameter(s)	Selection of the Measurable Parameter
Worker exposure to hazardous substances	Workplace concentrations	Exposure concentrations (mg /m^3)	• TLV-TWA or • 50% of the TLV-C

5.3.4 Spatial Boundaries

5.3.4.1 Project Footprint

The project footprint for the human health assessment for hazardous substances is defined as the milling, open pit mining, underground mining and associated facilities and activities on site.

5.3.4.2 Local Assessment Area

Workers working within the boundaries of Local Assessment Area (LAA) (including the Kiggavik Mill, the open pit mines, underground mine, and all the associated areas and surface facilities within the Project) will be assessed.

5.3.5 Temporal Boundaries

The Human Health effects to workers for the Project were considered for the following phases:

- Construction – project related effects were considered during the construction phase of the surface facilities associated with the Kiggavik Mill while surface mining activities are occurring.
- Operations – project-related effects were considered for the operational period. For the assessment of human health the assessment focused on the period of the highest potential impact.
- Final closure (decommissioning and reclamation) – during decommissioning water treatment is expected to continue and therefore this period is considered in the assessment.

The assessment covers the period of all the phases mentioned above during which Human Health activities will occur (approximately 25 years).

5.3.6 Standards or Thresholds for Determining Significance

The TLVs refer to airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed to daily over a working lifetime without adverse health effects. It is expressed as airborne concentrations in parts per million (PPM) or milligrams per cubic meter (mg/m^3). The TLV also lists the critical effect of the chemical. The TLVs are split into three categories:

1. Threshold Limit Value-Time Weighted Average (TLV-TWA) – this is the time weighted average concentration for a conventional 8 hr, 40hr workweek, to

which is it believed that nearly all workers may be repeatedly exposed day after day for a working life time without any adverse health effect.

2. Threshold Limit Value- Short Term Exposure Limit (TLV-STEL) – a 15-minute TWA exposure that should not be exceeded at any time during a work day, even if the 8 hr TWA is within the TLV-TWA. The TLV-STEL is the concentration that workers can be exposed to continuously for a short period without suffering from irritation, chronic or irreversible tissue damage, dose-rate dependent toxic effects or narcosis of sufficient degree to cause injury, impaired self rescue or reduce work efficiency. Exposures should be less than 15 minutes, should occur no more than 4 times per day and there should be 60 minutes between successive exposures in this range.
3. 50% Threshold Limit Value – Ceiling (TLV-C) – this is the concentration that should not be exceeded during any part of the working exposure.

Within Table 2 of the Consolidation of General Safety Regulations for the Nunavut Territory, occupational exposure limits are established for constituents of potential concern for 8-hour exposures, 15-minute exposures and exposure ceilings. These values are generally adopted from ACGIH.

For the assessment of exposures to hazardous substances and constituents of potential concern, values at or below the lower of the TLV established by ACGIH, or occupational exposure limits within the Consolidation of General Safety Regulations, will be considered not significant.

5.3.7 Influence of Inuit Qaujimajatuqangit and Stakeholder Engagement

Inuit Qaujimajatuqangit (IQ) interviews and engagement activities noted a familiarity with safety in general. Whale Cove Elders described awareness of modern day safety and personal protective equipment: *In the old days, people didn't have all sorts of health and safety protective equipment. Therefore they had to learn to be careful; for example, not to fall off a boat into the sea. Now, people depend on the equipment to save them rather than learning how to survive without it* (IQ-WCE 2009). There has been a shift in safety culture. For instance, *HTO members carry satellite phones and ground positioning system (GPS) devices for safety reasons* (IQ-RIHT 2009) and *young hunters go out in pairs or groups for safety reasons* (IQ-CIYA 2009[25]). Some of this may be due to experience working in an industrial sector and an understanding of health and

[25] IQ-CIYA 2009: *All of these young people go hunting regularly. The main difference between their hunting and their parent's activity is that they hunt in groups. One reason for this is financial, to share fuel costs. Another reason is that some of them don't have their own snow machines. They also go out in groups or pairs for safety reasons.*

safety programs to protect workers. Interviews with Baker Lake rotational workers highlighted the belief that *workers think mining is safer than it used to be* and that *they are not overly worried about occupational health and safety* (IQ-BLRW 2009[26]).

Since Kivalliq community members are familiar with the importance of safety, comments were received concerning protection of workers from hazardous substances and constituents of potential concern (COPCs) through construction, mining, milling, decommissioning and reclamation. This included *concern about oil contamination and other contaminants associated with industrial development* (IQ-McDonald et. al. 1997[27]) and comments that people *worried about worker health and safety (*IQ-RIW 2009[28]*)*. These comments highlight the need to assess worker safety and provide training on proper procedures to mitigate worker's potential exposure to hazardous substances.

5.4 Hazardous Substances and COPC Assessment

5.4.1 Methodology

5.4.1.1 Hazardous substances

All workers in the construction, milling, mining, decommissioning and reclamation process were identified for worker exposure to hazardous substances.

A thorough review of the proposed milling process for the Kiggavik project was conducted. The reagents used in the process was identified as hazardous substances and evaluated to determine if it is a human health risk. In addition, some of the by-products created were evaluated for potential risk and its controls are discussed.

The Material Safety Data Sheets (MSDS) for these chemicals were consulted and the health effects of each chemical were identified. Suppliers and manufacturers are required in Canada to provide information on chemicals through the use of MSDSs. There are nine specific types of information an MSDS must contain; information must include hazardous ingredients, MSDS

[26] IQ-BLRW 2009: *Workers believe that mining is safer than it used to be. They are not worried about occupational health and safety overly.*

[27] IQ-McDonald et. al. 1997: *There is a concern for contamination from oil or other contaminants that may come from development in general.*

[28] IQ-RIW 2009: *The women were also worried about worker health and safety.*

preparation, product information (manufacturer/supplier), physical data, fire or explosion hazard properties, reactivity data, toxicological properties, preventative measures and first aid measures. The health effects listed in the tables below are a summary of the health effects listing the primary health effects as a result of over exposure; the MSDS should be consulted for a full review of potential health effects.

The mining and milling process at McClean Lake Operation in Saskatchewan uses many of the same chemicals that will be used at the Kiggavik mine and mill. The TLV for each chemical was identified. For chemicals that do not have a TLV established by ACGIH, the controls were identified in the MSDS and the recommended controls will be established.

The controls for each chemical identified were reviewed and evaluated for adequacy to determine if it is sufficient to control exposures below the TLV. A discussion on each type of control will follow.

For the Kiggavik project, baseline monitoring will be performed during the post-construction, pre-operation period. A minimum of one area sample will be obtained for each reagent to ensure engineering controls are adequate.

Table 5.4-1 Identification of Hazardous Substances Exposures During Project Activities

Project Activities/ Physical Works	Hazardous Substances																													
	PM_{10} (inhalable fraction)	$PM_{2.5}$ (respirable fraction)	Cement	Diesel	Gasoline	Diesel Particulate Matter	Nitric Oxide (NO)	Nitrogen Dioxide	Carbon Dioxide	Carbon Monoxide	Sulphur Dioxide	Degreasing Solvents	Hydraulic Fluid	Emulsion / Ammonium Nitrate	Sulphuric Acid	oxygen	flocculant	Sodium hydroxide	Sodium sulfate	gypsum	Barium chloride	Hydrogen peroxide	Ammonia	amine	isodecanol	kerosene	Lime (calcium hydroxide)	Sulphur (and H2S)	ferric sulfate	Sodium carbonate
All associated Construction activities	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation																														
Mining	1	1	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Milling	1	0	0	1		0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tailings Management	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	1	0	0	1	1	1	0	0	0	0	1	0	1	0
Water Management - Collection of site and stockpile drainage	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Management - Water and sewage treatment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
Water Management - Discharge of treated effluents – including grey water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste Management	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Services – Generation of power	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.4-1 Identification of Hazardous Substances Exposures During Project Activities

Project Activities/ Physical Works	Hazardous Substances																													
	PM $_{10}$ (inhalable fraction)	PM $_{2.5}$ (respirable fraction)	Cement	Diesel	Gasoline	Diesel Particulate Matter	Nitric Oxide (NO)	Nitrogen Dioxide	Carbon Dioxide	Carbon Monoxide	Sulphur Dioxide	Degreasing Solvents	Hydraulic Fluid	Emulsion / Ammonium Nitrate	Sulphuric Acid	oxygen	flocculant	Sodium hydroxide	Sodium sulfate	gypsum	Barium chloride	Hydrogen peroxide	Ammonia	amine	isodecanol	kerosene	Lime (calcium hydroxide)	Sulphur (and H2S)	ferric sulfate	Sodium carbonate
General Services - Hazardous materials storage and handling (reagents, fuel and hydrocarbons)	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
Explosives storage and handling	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation – Marine transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation – Truck transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation – Air transport of Uranium concentrates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
On-going Exploration – Aerial surveys	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decommissioning																														
On-going treatment and release of water, including domestic wastewater	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0

5.4.1.2 Constituents of Potential Concern to Worker Health

For the purposes of workplace exposure assessments, metals identified as COPCs include arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, uranium, vanadium and zinc. Workers are exposed to these substances primarily through inhalation of dust during mining operations.

Sampling will be based on size fractions: inhalable and respirable dust. Respirable particulate fraction is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. Inhalable particulate fraction is the fraction of a dust cloud that can be breathed into the nose or mouth. An adequate sampling method will be chosen to measure exposure.

5.4.1.3 Other Substances

Asbestos

There have been concerns raised by community members about potential asbestos exposure (EN-CH OH Oct 2012 [29], EN- BL OH Oct 2012[30]). AREVA has a very stringent policy on use and presence of asbestos at their sites. AREVA adheres to AREVA BG Mine Directive, PO ARV 3SE EHS 1, “Asbestos Directive” which ensures that employees will be adequately protected from exposure to asbestos. The directive provides procedures to follow for identification, evaluation and mitigation requirements for asbestos. No asbestos will be used in the construction of mine and mill facilities and all products brought onto site will be asbestos free. There will be no asbestos exposures at the Kiggavik site.

Carcinogens, Mutagens and Reproductive (CMR) Toxins

There are substances that will be used for the Kiggavik project which are classified as Carcinogens, Mutagens and Reproductive (CMR) toxins. These chemicals contain ingredients which can cause carcinogenic, mutagenic or a reproductive health effects. The AREVA BG Mining Group has a specific

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[29] EN-CH OH Oct 2012: *I read in the paper about asbestos in a mine. What is this about? 2) Asbestos was recently found at Meadowbank. This comes with the ore. Concerns about whether asbestos is cancer causing.*

[30] EN- BL OH Oct 2012: *What will you do to protect workers' health? At Meadowbank, they had an issue with asbestos, and management seems slow to do anything. They ended up conducting more dust suppression*.

directive PO ARV SHS HEA 3 EN which has stringent requirements for safe use of these chemicals. AREVA's internal requirements for the control of CMRs are generally more rigorous than the local, provincial or federal legislation. The directive provides a detailed process for the effective management of CMRs which include identification, risk assessment substitution process and evaluation of exposure. Some examples of commonly used substances that are classified as CMRs include aerosol paints, engine oil, gasoline (benzene, the CMR, is naturally found in gasoline) and primers. With mitigation measures and operational controls in place, exposures to CMRs will be non-significant.

Minor Constituents

There are other minor constituents used during the project that will be identified and evaluated in a routine manner during the operating period by site health and safety professionals as part of the Safety Management System. These potentially hazardous chemicals are used in the mining and milling process but used in smaller quantities. With all required mitigation measures and controls in place, it is expected the exposures to these other constituents will be non-significant.

5.4.2 Assessment of Workplace Exposure to COPC

Constituents of potential concern are listed in Table 5.4-2 together with the occupational exposure limits defined within Table 1 of the Consolidation of General Safety Regulations, Nunavut. Occupational exposure limits have also been presented as a percentage of the total inhalable dust limit.

Table 5.4-2 Workplace Occupational Exposure Limits for Selected COPC

Constituent	Units	8-hour Occupational Exposure Limit	15-minute Occupational Exposure Limit	8-hour Occupational Exposure Limit	15-minute Occupational Exposure Limit
Dust (Inhalable Fraction)	**mg/m^3**	**10***	**n/a**	**COPC (mg)/Inhalable Particulate Limits (kg)**	
Dust (Respirable fraction)		**3***	**n/a**		
Arsenic	mg/m^3	0.20	0.60	20000	60000
Cadmium	mg/m^3	0.05	0.20	5000	20000
Cobalt	mg/m^3	0.10	0.30	10000	30000
Copper	mg/m^3	1.0	2.0	100000	200000
Lead	mg/m^3	0.15	0.45	15000	45000
Nickel	mg/m^3	1	n/a	10000	30000
Molybdenum	mg/m^3	5.0	10.0	500000	1000000
Manganese	mg/m^3	0.2	n/a	20000	n/a
Selenium	mg/m^3	0.20	0.60	20000	60000
Uranium	mg/m^3	0.20	0.60	20000	60000
Vanadium	mg/m^3	0.5	1.5	50000	150000
Zinc	mg/m^3	5.0	1.0	500000	100000

Reference: Table 1 of the Consolidation of General Safety Regulations, Nunavut
*ACGIH 2011 TLVs and BEIs

Tables 5.4-3 and 5.4-4 present the concentrations of constituents of potential concern in mine rock and ore respectively. The constituent concentrations in the ore and mine rock are each a small fraction of the occupational exposure limits presented in Table 5.4-2 expressed as a concentration of the constituent in inhalable dust. Control measures designed to maintain respirable dust levels below occupational exposure limits will generally be adequate to protect workers from individual constituents of concern when mining either ore or mine rock.

Table 5.4-3 Concentration of Constituents of Potential Concern In Mine Rock

Parameter	Units	Type 1 Mine Rock (CR)	Type 2 Mine Rock (MR1)			Type 3 Mine Rock (MR2)	
		Kiggavik Rock (28 samples)	Andrew Lake Rock (38 samples)	Kiggavik Rock (36 samples)	Andrew Lake Rock (44 samples)	Kiggavik Rock (57 samples)	Andrew Lake Rock (7 samples)
Arsenic (As)	mg/kg	0.80	3.69	0.92	3.28	0.73	1.92
Cadmium (Cd)	mg/kg	0.05	0.08	0.04	0.09	0.05	0.11
Cobalt (Co)	mg/kg	11.17	3.76	9.63	3.73	10.86	2.63
Copper (Cu)	mg/kg	13.52	7.40	11.96	6.72	45.09	5.64
Lead (Pb)	mg/kg	10.06	7.63	12.41	8.70	30.17	14.12
Nickel (Ni)	mg/kg	26.97	27.05	26.16	28.04	22.19	27.90
Manganese (Mn)	mg/kg	169.81	76.65	141.06	76.33	272.41	78.36
Molybdenum (Mo)	mg/kg	1.90	0.67	1.91	0.69	14.65	0.84
Selenium (Se)	mg/kg	1.13	1.33	1.14	1.28	1.43	1.10
Uranium (U)	mg/kg	5.97	9.70	18.05	13.17	12.45	89.29
Vanadium (V)	Mg/kg	48.27	46.55	56.50	51.47	46.55	63.15
Zinc (Zn)	mg/kg	35.50	13.57	30.14	13.43	35.24	9.95

Table 5.4-4 Concentration of Constituents of Potential Concern in Ore

Parameter	Units	Main Zone	Centre Zone	East Zone	Andrew Lake	End Grid
Arsenic (As)	mg/kg	2.2	20.4	3	7.1	19.4
Cadmium (Cd)	mg/kg	1	1.4	1	1	1.1
Cobalt (Co)	mg/kg	16.8	16.4	8.5	7.1	15.8
Copper (Cu)	mg/kg	38.1	63.5	6.1	13.7	115.9
Lead (Pb)	mg/kg	199.8	226.8	47.5	184.5	114.5
Nickel (Ni)	mg/kg	47.3	69.7	18.9	73.4	80.5
Molybdenum (Mo)	mg/kg	113.5	9.6	1.9	19.7	19.5
Selenium (Se)	mg/kg	3	0.2	1.5	1.2	12.7
Uranium (U)	mg/kg	4,570	5,683	744	4,625	2390.6
Vanadium (V)	mg/kg	484.4	410.0	233.1	526.5	230.8
Zinc (Zn)	mg/kg	26.8	86.6	29.1	20.9	46.3

5.4.2.1 Mitigation

Exposure though inhalation of dust is recognized as a potential worker exposure issue and a potential health concern. Community members raised dust exposure concerns. In the sections below, AREVA provides discussion on how they intend to control dust levels to minimize exposures. Controls include a variety of engineering, administrative practices and personal protective equipment controls to limit the exposure of dust to workers.

Underground Mining

Engineering controls (e.g., ventilation) are established to maintain exposures to all airborne contaminants at levels less than their TLV-TWA or 8-hour exposure limit. Periodic air sampling is conducted to verify the adequacy of engineering controls.

Work practices implemented for the protection of workers from particulate matter, radon and long-lived radioactive dusts as part of a radiation protection program in underground uranium mining are effective at minimizing exposures to other COPCs found in the mine rock and ore.

Open Pit Mining

Open pit mining is conducted using heavy equipment. Operators are enclosed in cabs of equipment, which effectively minimized worker exposure to airborne contaminants.

Work practices implement for the protection of workers from radon and long-lived radioactive dusts as part of a radiation protection program in underground uranium mining are effective at minimizing exposures to other COPCs found in the mine rock and ore.

Milling

Milling involves initial crushing and grinding of ore from the mines. Dust exposure concerns at the mill were also raised by community members (EN - RB OH Nov 2012[31]). There will be numerous control measures to ensure workers are protected. Dust control measures during crushing will include the use of closed-cab equipment, and dust suppression with water as required to minimize dust exposures. Grinding of the ore is a wet process conducted within closed vessels. Conventional dust suppression, routine housekeeping, and good work practices are anticipated to keep COPC exposure levels during milling well below 8-hour exposure values.

5.4.3 Assessment of Workplace Hazardous Substances Exposures – Construction Activities

Groups assessed for potential hazardous substances exposures for the construction of the Kiggavik mill include:

- Construction workers
- Supervisors & Others (Engineers, geotechnical workers, Safety officer)
- Administrative Workers

[31] EN - RB OH Nov 2012: With milling, is dust safe for people?

Workers are expected to be the most likely exposed to such hazardous substances as they are directly handling and working in the vicinity of these chemicals. The exposures of supervisors, engineers and administrative workers are not expected to be significant.

During the construction phase, the chemicals used in the milling process will not be on site. The main constituents of potential concern from an exposure perspective will be cement and fuel (diesel/gasoline).

Workers and supervisors will be trained in WHMIS, wear the appropriate personal protective equipment and required to follow all safe handling procedures. Those workers who will be handling and using the cement will have the highest risk of exposure.

Some chemicals used in smaller quantities during the construction phase include paints, solvents, primers, sealers. These will be specifically assessed and evaluated by the Health and Safety Department to determine safe usage.

Concurrent mining activities conducted while the mill is being constructed are scheduled to take place in waste rock. This is not expected to result in any additional hazardous substances exposures to the construction workers.

Table 5.4-5 Evaluation of Hazardous Substances Exposures for Construction Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Construction Workers	General construction work	Dust (particulates not otherwise classified)	$10 mg/m^3$	Inhalation irritant	• Dust suppression with water • Proper housekeeping/ hygiene practices • Use of dust suppression material to perform housekeeping • PPE required will include gloves, coveralls, adequate footwear, safety glasses with side shields • Respirators are not likely to be required but dust masks are available to minimize nuisance levels of dust particulates	Y
	Handling and application of cement	Cement				Y
Applicable to anyone who uses fuel	Fueling	Diesel Fuel	As total hydrocarbons ($100 mg/m^3$)	• Diesel has been classified by IARC and NIOSH as a possible human carcinogen. • Moderate skin, eye and upper respiratory tract irritant. • Ingestion may cause irritation to the digestive tract. Ingestion may result in central nervous system depression. • Excessive inhalation will cause irritation to respiratory tract and may affect central nervous system.		Y
	Fueling	Gasoline	$525 mg/m^3$	• Gasoline has been classified by IARC (International Agency for Research on Cancer) as a possible human carcinogen because it contains benzene. • Moderate skin, eye and upper respiratory tract irritant. • Ingestion may result in central nervous system depression.	• Fuel tank is enclosed and vented. • Minimal exposure expected as exposure is only probable upon fueling. • WHMIS training • Proper handling procedures and usage of PPE will result in insignificant exposures. • PPE include safety glasses with side shields, coveralls and impervious gloves such as nitrile gloves • Proper hygiene practices	Y

5.4.4 Assessment of Workplace Hazardous Substances Exposures – Open Pit Mining

Open Pit Mining job groups assessed for potential hazardous substances exposures include:

Mining Group	• Heavy Equipment Operators
Mine Maintenance Group	• HD Maintenance Mechanics • HD Welder • HD Shop Supervisors
Drilling/Blasting Group	• Drillers /Blasters
Geology/Surveying	• Geologists • Geology Technicians • Surveyors
Mining Supervision Group	• Mine Engineer • Mine Maintenance • Supervisor • Mine Manager • Pit General Supervisor • Pit Supervisors • Trainer • Office workers

Note that for the Mining Supervision Group are generally not in direct contact with hazardous substances during normal operations.

5.4.4.1 Mitigation Measures: Hazardous Substances

Hazardous substances protection in open pit mining operations consist primarily of conventional operational practices including preventative measures, worker training and awareness, use of PPE, work planning, and ongoing review and follow-up of results. Previous open pit mining experience by AREVA has demonstrated that the worker exposures have been below exposure limits. It is expected that worker hazardous substances exposure during mining of the Kiggavik pits will be controlled to levels below the TLV.

Table 5.4-6 Evaluation of Hazardous Substances Exposures for Open Pit Mining Operations at Kiggavik

Group	Process/ Activity	Hazardous Substances	TLV	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Mining	Heavy Equipment Operation	Dust (particulates not otherwise classified)	10mg/m^3	Inhalation irritant	• Dust suppression with water • Keeping windows in vehicle cabs closed, • Positive ventilation in cab • Air stripping and filtration devices in vehicles • Proper housekeeping/ hygiene practices	Y
		Hydraulic Fluid	5mg/m^3	Prolonged or repeated skin contact may cause irritation	• WHMIS training • Requires minimal contact with hydraulic fluid. If contact required PPE will include oil resistant gloves, safety glasses with side shields, coveralls. • Proper hygiene practices	Y
Applicable to anyone who uses fuel	Fueling	Diesel Fuel	As total hydrocarbons (100mg/m^3)	• Diesel has been classified by IARC and NIOSH as a possible human carcinogen. • Moderate skin, eye and upper respiratory tract irritant. • Ingestion may cause irritation to the digestive tract. Ingestion may result in central nervous system depression. • Excessive inhalation will cause irritation to respiratory tract and may affect central nervous system.		Y
	Fueling	Gasoline	525mg/m^3	• Gasoline has been classified by IARC (International Agency for Research on Cancer) as a possible human carcinogen because it contains benzene. • Moderate skin, eye and upper respiratory tract irritant. • Ingestion may cause irritation to the digestive tract. Ingestion may result in central nervous system depression.	• Fuel tank is enclosed and vented. • Minimal exposure expected as exposure is only probable upon fueling. • WHMIS training • Proper handling procedures and usage of PPE will result in insignificant exposures. • PPE include safety glasses with side shields, coveralls and impervious gloves such as nitrile gloves • Proper hygiene practices	Y
HD Maintenance	Maintenance	Hydraulic Fluid		• Prolonged or repeated skin contact may cause irritation	• WHMIS training • PPE will include oil resistant gloves, safety glasses with side shields, coveralls. • Proper hygiene practices. • Eyewash station in area for emergency use	Y

Table 5.4-6 Evaluation of Hazardous Substances Exposures for Open Pit Mining Operations at Kiggavik

Group	Process/ Activity	Hazardous Substances	TLV	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Geology/Surveying	Surveying work	Dust (Particulates Not Otherwise Classified)	10mg/m^3	• -Inhalation irritant	• Planning work to minimize time spent in dusty conditions • Dust suppression with water • Keeping windows in vehicle cabs closed • Positive ventilation in cab • Air stripping and filtration devices in vehicles • Proper housekeeping/ hygiene practices	Y
Drilling/ Blasting	Mining Explosive	Ammonia Nitrate Fuel Oil (ANFO)	No standard exists for ANFO but TLV for oil mist is 5mg/m3 NOx fumes generated from explosives can be hazardous; see above for health effects	• Stable under normal conditions. Highly reactive explosive, ammonium nitrate will spontaneously decompose at 210°C (410°F). • When detonated or heated to decomposition, this product will evolve highly toxic gases. See above for NOx health effects. • Low to moderate eye irritant • No inhalation hazard is anticipated unless product is heated to decomposition or exploded evolving toxic nitrogen oxides. • Low skin irritant • Ingestion may result in gastrointestinal irritation, nausea and vomiting. Ingestion of large quantities is toxic	• This product is an explosive and is used only under the supervision of trained personnel. • Stored in an isolate area and kept away from open flames, hot surfaces and sources of ignition. The Explosive Management Plan evaluates the safe usage of ANFO. • For handling PPE required include coveralls, tightly fitting safety goggles, and impervious rubber gloves. • In case of insufficient ventilation wear suitable respiratory equipment is required. • ANFO Handling Procedure. • Eyewash in area of handling	Y

5.4.5 Assessment of Workplace Hazardous Substances Exposures – Underground Mining

5.4.5.1 Exposure Assessment

Underground Mining job groups assessed for potential hazardous substances exposures include:

Mining Group	• Production Loader operator • Development Loader operator • Backfill LHD operator • Backfill Truck operators • Production Truck operators • Development Truck operators • Production Jumbo operator	• Development Jumbo operator • Production Bolter operator • Grader operator • Shotcrete Operator • Development helpers • UG Labourers (Vent. Crew) • Batch plant operator
Blasting Group	• Blasters	
Supervising Group	• Supervision	
Surveying & Geology	• Surveyors • Geologists	

The hazardous substances of primary concern for the underground mining of End Grid involve diesel fuel usage and blasting.

Diesel engines are widely used in mining operations because of their high power output and mobility. Many mine operators prefer diesel-powered machines because they are more powerful than most battery-powered equipment and can be used without electrical trailing cables which can restrict equipment mobility. However, the use of diesel produces diesel exhaust which can pose a health risk, especially in underground mining. There are potential acute and long-term health effects associated with over exposure to various constituents of diesel exhaust, which consists of noxious gases and very small particles. The particles in diesel emissions are known as "diesel particulate matter" (DPM). Diesel particulate matter is small enough to be inhaled and retained in the lungs. The particles have hundreds of chemicals from the exhaust adsorbed (attached) onto their surfaces.

The levels of exposure to DPM in underground mines depend upon engine exhaust emissions, the use of exhaust after treatment and its efficiency and ventilation rate and system design. Diesel engine maintenance is the cornerstone of a diesel emission control program. Engine emissions are governed by engine design, work practices, duty cycle, fuel quality and maintenance. Reducing engine emissions will decrease the amount of DPM that needs to be controlled by other means and will reduce the exposure of miners. However, there is no single emission control strategy that removes emissions to acceptable levels and as such, a number of controls are established.

5.4.5.2 Mitigative Measures: Diesel Particulate Matter and Diesel Exhaust Fumes

Vehicles & Fuel

Low emission engines will be used wherever possible, and low sulphur fuels will be used to power the equipment. Exhaust after-treatment devices such as filters and oxidation catalysts, will be in place for each vehicle to reduce equipment operators' exposure to diesel emissions and other particulate matters such as dust. Cabs are also pressurized and use high-efficiency particulate air (HEPA) filters.

Ventilation

A comprehensive ventilation system will be designed to supply fresh air and remove contaminated air. The ventilation system is designed to remove noxious fumes and particulates. The ventilation air flow requirements are based on operating diesel engine requirements and also ensuring adequate radon dilution. Auxiliary ventilation to active mine faces will be fresh air with the exhaust ducted to the mine exhaust. Ventilation air from any potential source of contamination (e.g., sumps, remucks, stockpiles) will be directed to the mine exhaust without contaminating other active workplaces. Each active cross cut will be provided with either a “pull” system, where clean air is fed into the working area and the contaminated air is collected in a duct and directed to a dedicated (unoccupied) exhaust drift, or a flow-through system.

If the ventilation system is interrupted at any time, all vehicle operations will cease until adequate ventilation is resumed.

Maintenance

A preventive maintenance program will be in place to maintain the engine at its specified performance, and maximize vehicle productivity and engine life, while keeping exhaust emissions down. Engine maintenance activities will be performed by mine maintenance personnel and include maintenance of the air intake, cooling, lubrication, fuel injection and exhaust systems. These systems will be maintained according to manufacturer's specifications and on a regularly scheduled basis to keep the system operating efficiently.

Daily checks of engine oil level, coolant, fuel and air filters, water tank, exhaust piping and gauges will also be made. Checks include ensuring the lubrication oil is the correct viscosity and kept at the recommended levels, and that heat exchangers are clean and undamaged. Engine overheating is a frequent cause of premature engine failures.

Training

Equipment operators will be trained to recognize hazards and also trained in the efficient use and care of the equipment, including performing routine inspections and maintenance.

Trained personnel will handle fuel and lubricating oils to prevent contamination from dust, water, or other sources. Dirt and dust are detrimental to engines. Periodic maintenance of the intake air system is required for peak engine performance.

Operators will be trained to avoid lugging, operating the engine at low RPM in high load situations as this increases emissions. Operators will be trained to shift gears to operate the engine at higher speed to lessen the engine load. In addition, operators are trained avoid idling their engines excessively.

Work Planning

Personnel will be advised to plan their work to minimize working around vehicles that are in operation to minimize diesel exhaust exposures.

Blasting – NOx fumes

Handling of emulsion/ANFO will be conducted by trained personnel according to specific handling procedures. This will include the requirement of specified personal protective equipment. They will be trained in accordance with WHMIS and specific explosive handling requirements.

Blasting will occur at scheduled times and all areas that may be affected by the blasting operations are vacated and guarded. All persons are required to be vacated from the area until sufficient time has elapsed for dilution of any toxic gases produced during blasting. If there are any uncertainties, the atmospheric air will be tested prior to entry into the area.

Table 5.4-7 Evaluation of Hazardous Substances Exposures for Underground Mining Operations at Kiggavik

Group	Process/ Activity	Hazardous Substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Mining, Surveying and Geology	Heavy Equipment Operation	Dust (particulates not otherwise classified)	10mg/m^3	• Inhalation irritant	• Dust suppression with water • Mine ventilation • Keeping windows in vehicle cabs closed, • Positive ventilation in cab • Air stripping and filtration devices in vehicles • Proper housekeeping/ hygiene practices	Y
		Hydraulic Fluid	5mg/m^3	• -Prolonged or repeated skin contact may cause irritation	• WHMIS training • Minimal contact with hydraulic fluid. If contact required PPE will include oil resistant gloves, safety glasses with side shields, coveralls. • Proper hygiene practices	Y
	Fueling	Diesel Fuel	As total hydrocarbons (100mg/m^3)	• Inhalation irritant	• All underground diesel powered vehicles are equipped with exhaust gas scrubbers. • Diesel powered vehicles require a WSCC permit issued by the chief inspector for use underground and must meet specified criteria. • Diesel fuel will contain less than 0.25% sulphur by weight and have a closed cup flash point great than 43 ^{o}C. • Undiluted and unscrubbed exhaust gases from diesel powered equipment is less than 1,500 ppm by volume of carbon monoxide • No gasoline or other volatile fuel is used in the starting mechanism of diesel powered equipment underground • Provide adequate ventilation requirements to ensure hazardous substances s are below the TLV • Provide ventilation testing and hazardous substances monitoring including CO and NOx every shift.	Y Y
	Diesel Exhaust	Nitric Oxide (NO)	25ppm	• Exposure to Nitric Oxide gas in low concentrations produces an irritating effect on the mucous membranes of the eyes, nose, throat and lungs, which can include choking, coughing, headache, nausea and fatigue. • -Exposure to high concentrations can result in coma and death.		Y
	Diesel Exhaust	Nitrogen Dioxide (NO_2)	3ppm	• 1 to 13ppm - Irritation of nose and throat • 10 to 20 ppm - Mild irritation of eyes, nose and upper respiratory tract • 80ppm - Tightness in chest after 3 to 5 minutes • 90ppm - Pulmonary edema after 30 minutes		Y
	Diesel Exhaust	Carbon Monoxide (CO)	25ppm	• 200 ppm Slight headache, tiredness, dizziness, nausea after 2 to 3 hrs. • 400ppm -Frontal headache within 1 to 2 hrs. life threatening after 3 hrs. • 800 ppm - Dizziness, nausea and convulsions within 45 minutes. Unconsciousness within 2 hours. Death in 2 to 3 hours.		Y
	Diesel Exhaust	Carbon Dioxide (CO_2)	5000ppm	• At 5000ppm, stimulated respiration • At 7000ppm to 10000ppm, unconsciousness after few minutes of exposure		Y
	Diesel Exhaust	Sulphur Dioxide (SO2)	2ppm	• 20 ppm coughing and irritation of eyes • 50 ppm - Irritation to eyes, lungs, throat • 400 to 500 ppm - Life threatening		Y

Table 5.4-7 Evaluation of Hazardous Substances Exposures for Underground Mining Operations at Kiggavik

Group	Process/ Activity	Hazardous Substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Drilling/ Blasting	Mining Explosive	Ammonia Nitrate Fuel Oil (ANFO)	No standard exists for ANFO but TLV for oil mist is 5mg/m^3 NOx fumes generated from explosives can be hazardous; see above for health effects	• Stable under normal conditions. Highly reactive explosive, ammonium nitrate will spontaneously decompose at 210°C (410°F). • When detonated or heated to decomposition, this product will evolve highly toxic gases. See above for NOx health effects. • Low to moderate eye irritant • No inhalation hazard is anticipated unless product is heated to decomposition or exploded evolving toxic nitrogen oxides. • Low skin irritant • Ingestion may result in gastrointestinal irritation, nausea and vomiting. Ingestion of large quantities is toxic	• This product is an explosive and is used only under the supervision of trained personnel. • Stored in an isolate area and kept away from open flames, hot surfaces and sources of ignition. The Explosive Management Plan evaluates the safe usage of ANFO. • For handling PPE required include coveralls, tightly fitting safety goggles, and impervious rubber gloves. • In case of insufficient ventilation wear suitable respiratory equipment is required. • ANFO Handling Procedure. • Eyewash in area of handling	Y

5.4.6 Assessment of Workplace Hazardous Substances Exposures – Milling

5.4.6.1 Exposure Assessment

Milling job groups assessed for potential hazardous substances exposures include:

Maintenance	• Millwrights • Electrician/Instrumentation • Welders
Utilities	• (Boiler/Oxygen Plant) Utilities Operator • Acid Plant Operator
Operations	• Water Treatment Plant Operator • Control Room Operator • Grinding Operator • Leaching Operator • Reagent Unit Process Operator • Packaging Operator • Precipitation Operator • Mill Feed/Loader/Crusher • Resin In Pulp Operator • Tailings Neutralization Operator
Metallurgy/Chemical Lab	• Chemists • Met. Lab Assistant • Metallurgist
Services	• Plumber • Equipment Operator • General laborer
Other	• Safety Officer/ Radiation Technician/Safety Technician
Office	• Managers • Administrative • Training

Acid Plant

Sulphuric acid (93% H_2SO_4) is produced on site in a 310 t/d acid plant. Acid is supplied to Leaching, Elution, and the Kiggavik and Sissons WTPs. The production of sulphuric acid involves the process of burning sulphur in the presence of dried ambient air, reaction of the products in a catalyst bed, and recovering the reacted components in an air absorption solution to produce sulphuric acid. A sufficient amount of solid sulphur for one year of continuous acid plant operation is shipped annually and stored in cold storage. The acid plant operates 24 hours per day of continuous service. The process involves burning sulphur (S) to form sulphur dioxide (SO_2), combining the sulphur dioxide with oxygen (O_2) to form sulphur trioxide (SO_3) and combining sulphur trioxide with water (H_2O) to form a solution containing sulphuric acid (H_2SO_4),

Sulphur storage has the potential to generate and accumulate hydrogen sulphide. All processing tanks and storage tanks are vented to an exhaust stack to maintain safe atmospheric conditions within the acid plant. In addition, these areas are monitored continuously for any high levels of hydrogen sulphide.

During normal operations, workers other than the acid plant operator must receive permission to prior to entry. Acid plant operators must always carry a two way radio with them. Specific areas in the acid plant which pose a higher risk are shielded, have warning signs posted and also require the donning of additional protective equipment before being permitted to work in the area. There are emergency showers and eyewashes in the area.

There are two processes to control the sulphur dioxide emissions. A cesium-promoted catalyst absorbs excess SO_2 and a scrubber is installed on the exhaust stack to remove particulates, acid mist and excess SO_2. There are also SO_2 monitors installed in the acid plant building in various locations to monitor atmospheric conditions. If levels are above the TLV, the area becomes restricted until the atmosphere is safe to enter.

Oxygen Plant

Oxygen (O_2) for leaching is produced on-site in a Vacuum Pressure Swing Adsorption (VPSA) oxygen plant. The plant is sized to produce the 30 t/d of O_2.

The Oxygen Plant is also a restricted area and permission must be obtained from the Utilities Operator prior to entering. The plant is kept very clean of oils or any combustible materials as a preventative housekeeping because high concentrations of oxygen in open air accelerate combustion and increase the risk of fire and explosion of combustible or flammable materials. There are oxygen monitors in the Oxygen plant to monitor for malfunctions. No special personal protective equipment is required thus standard protective equipment is worn.

Mill

The uranium mill at Kiggavik will use a variety of chemicals to extract uranium and concentrate uranium from raw ore. Many of these chemicals are classified as dangerous and hazardous products. The safety of mill personnel is a key consideration in the design and operation of the mill, in particular the reagent storage and handling circuits. The mill is designed to contain materials during routine operation and in the event of a leak or spill. Tanks are enclosed with berms to contain any spills. Steeply graded floors direct spills into sumps to contain them and minimize worker contact with hazardous materials.

The selection of controls to minimize hazardous substances exposures follows a hierarchical approach. The first attempt is to eliminate the hazard, then engineering controls such as tank design and ventilation are identified if the hazard cannot be eliminated or isolated. Administrative controls will often accompany the engineering controls such as training, developing programs and plans, changing work schedule and maintaining housekeeping. Finally, personal protective equipment is often used to further prevent or minimize any exposure.

The selection of controls is followed up by ongoing evaluations of process and procedures to ensure minimal exposure to hazardous substances, daily checks and inspections of equipment and also preventative maintenance of equipment to ensure controls are maintained.

A discussion of the proposed protective features and operational practices to be put in place to protect workers from hazardous substances will be discussed herein.

5.4.6.2 Mitigation Measures

Control Through Design

The primarily and most effective method to control of exposure to nearly all the chemicals is at the design stage. This includes giving consideration to:

- selection of a suitable chemical giving consideration to potential worker exposure,
- enclosing the entire system or vehicle through appropriate choice of enclosure material,
- Automating the process and control it remotely where possible,
- Venting fumes to scrubbers and to external areas outside the building,
- Preventing leakage of materials and chemicals at joints, areas of connection, valves through adequate engineering and selection of equipment material,
- Provision of a facility of method to remove residual chemical(s) from the system in the event it needs to be taken apart for maintenance, and
- Determining methods for minimal maintenance.

Ventilation

To ensure minimal exposure to fumes and mists released into the atmosphere, process vessels are enclosed and ventilated to exterior of buildings. In situations where ventilation may need to be purposely turned off during activities such as maintenance, the material may be transferred and isolated to other areas or tanks and a combination of general exhaust ventilation, dilution ventilation and local exhaust ventilation may be used to maintain hazardous substances to acceptable levels.

Fresh air introduced into the operating floor flows into the corridors of the lower level and then into the cells from where it is exhausted.

In the event of a power outage, backup systems provide emergency electrical power to maintain ventilation systems.

Maintenance and Housekeeping

Proactive maintenance scheduling minimizes the likelihood of spills and breakdowns. During the planned shutdowns, controls to minimize residual chemical build-up are performed in a controlled manner. The hazardous substances are isolated and removed where feasible; then the equipment or areas may be washed, vacuumed, swept, any residual material may be released into suitable containers for disposal.

Routine housekeeping such as washing areas down and throwing away waste properly will minimize contact and prevent inadvertent exposure to chemicals.

Education and Training

The provision of information through training and instruction is provided for all hazardous substances . Nunavut requires that all workplaces and workers comply with the Workplace Hazardous Materials Information System (WHMIS) as stated in the Nunavut Safety Act, Worksite Hazardous Materials Information System Regulations, 1999.

WHMIS is a comprehensive plan for providing information on the safe use of hazardous materials used in Canadian workplaces. The main components of WHMIS are hazard identification and product classification, labeling, material safety data sheets, and worker training and education.

Suppliers, employers and workers all have specified responsibilities in the Hazardous Products Act as follows:

Suppliers: Canadian suppliers are those who sell or import products. When this product is considered a "controlled product" according to the WHMIS legislation, a supplier must label the product or container, and they must provide a material safety data sheet (MSDS) to their customers. The purpose of the labels is to clearly identify the contents of the hazardous material, and the MSDS is to explain what those hazards are.

Employers: Employers are required to establish education and training programs for workers exposed to hazardous products in the workplace. Employers must also make sure that the products are labelled and that an MSDS is present for each product and that they are readily available to workers.

Workers: Workers are required to participate in the training programs and to use this information to help them work safely with hazardous materials. They may also inform employers when labels on containers have been accidentally removed or if the label is no longer readable.

Personal Protective Equipment (PPE)

This means of protection against exposure to chemicals is considered to be the least effective means of protection as the hazard still exists and should not be considered the only type of control. However, there are situations when it is not technically feasible to control exposure by any other means, for emergency situations (e.g. spills), when other controls have been turned off to facilitate access (e.g. confined space entries) and when there is a risk that needs to be controlled until other means of control are installed or available (e.g. offloading of chemicals or transfer of material from one location to another).

There are many types of PPE available. There were some questions raised by community members on *whether safety clothing will be provided* by AREVA (EN- KIV OH Oct 2009[32]). Personal protective equipment that will be required to be worn by employees and visitors will be provided by AREVA. There were some fears raised by community members on wearing personal protective equipment (EN-KIV OH Oct 2009[33]). All employees and visitors who require to wear PPE will be provided training to ensure the equipment fits, be knowledgeable on how to use it and what is intended to protect and will ensure they are comfortable using it.

[32] EN- KIV OH Oct 2009: *What about safety clothing?*

[33] EN- KIV OH Oct 2009 :*And about the mine in Northern Saskatchewan, the people that travelled there had to wear protective clothing, and I think that was very scary.*

A brief description will follow herein to discuss factors that need to be considered when choosing appropriate PPE, the identification and evaluation of the hazardous substances will dictate the ultimate selection for suitable PPE as there is a wide array of choices available for each type.

Body/Hand/Feet Protection - There are many types of gloves/coveralls/footwear available today to protect against a wide variety of hazards. The nature of the hazard and the operation involved will affect the selection of PPE. It is essential that employees use PPE specifically designed for the hazards and tasks found in their workplace because PPE designed for one function may not protect against a different function even though they may appear to be an appropriate protective device.

The following are examples of some factors that may influence the selection of body/hand/feet protection for a workplace:

- Type of chemicals handled,
- Nature of contact (total immersion, splash, etc.),
- Duration of contact,
- Area requiring protection (hand only, forearm, arm, feet, toes, shins),
- Grip requirements (dry, wet, oily),
- Thermal protection,
- Size and comfort,
- Abrasion/resistance requirements

Inhalation Protection

Workers should use respirators for protection from contaminants in the air only if other hazard control methods are not practical or possible under the circumstances. In many instances, respirators are worn not because levels are in exceedance of the TLV, but as a precautionary measure (e.g. during offloading of reagents).

There will be a detailed written respirator program that describes the proper procedures for selecting and operating respiratory protective equipment. This will include:

- hazard identification and control
- exposure assessment
- respirator selection
- respirator fit-testing
- training program
- inspection and record keeping
- cleaning and sanitizing respirators
- repairing and maintaining respirators

- proper storage of respirators
- health surveillance
- program evaluation.

The two main types are air-purifying respirators (APRs) and supplied-air respirators (SARs).

Air-purifying respirators can remove contaminants in the air that you breathe by filtering out particulates (e.g., dusts, metal fumes, mists, etc.). They are tight-fitting and are available in several forms:

- quarter-mask (covering the nose and mouth),
- half-face mask (covering the face from the nose to below the chin), or
- full facepiece (covering the face from above the eyes to below the chin). Respirators with a full facepiece also protect the eyes from exposure to irritating chemicals.

Examples of Air-purifying respirators (APRs):

- particulate respirators,
- chemical cartridge respirators that can have a combination of chemical cartridges, along with a dust prefilter: this combination provides protection against different kinds of contaminants in the air
- powered air-purifying respirators (PAPRs).

Supplied-air respirators (SARs) supply clean air from a compressed air tank or through an airline. This air is not from the work room area. The air supplied in tanks or from compressors must meet certain standards for purity and moisture content (e.g., CSA Standard Z180.1-00: Compressed Breathing Air and Systems).

Supplied-air respirators may have either tight-fitting or loose-fitting respiratory inlets. Respirators with tight-fitting respiratory inlets have half or full facepieces. Types with loose-fitting respiratory inlets can be hoods or helmets that cover the head and neck, or loose-fitting facepieces with rubber or fabric side shields. These are supplied with air through airlines.

Examples of Supplied-air respirators (SARs):

- self-contained breathing apparatus (SCBA),
- airline supplied-air respirators,

Eye/Face Protection – Each type of face or eye protection is designed to protect against specific hazard. Some factors to consider when choose eye/face protection include:

- type of hazard (chemical or impact or heat)
- is the hazardous substances a dust, mist, liquid, sparks, metal spatter,
- is there a need to protect against infrared or intense radiant heat?

Safety spectacles. These protective eyeglasses have safety frames constructed of metal or plastic and impact-resistant lenses. Side shields are required for all safety glasses.

Goggles. These are tight-fitting eye protection that completely cover the eyes, eye sockets and the facial area immediately surrounding the eyes and provide protection from impact, dust and splashes. Some goggles will fit over corrective lenses. Contact lenses are not permitted.

Welding shields. Constructed of vulcanized fiber or fiberglass and fitted with a filtered lens, welding shields protect eyes from burns caused by infrared or intense radiant light; they also protect both the eyes and face from flying sparks, metal spatter and slag chips produced during welding, brazing, soldering and cutting operations.

Face shields. These transparent sheets of plastic extend from the eyebrows to below the chin and across the entire width of the employee's head. Some are polarized for glare protection. Face shields protect against nuisance dusts and potential splashes or sprays of hazardous liquids but will not provide adequate protection against impact hazards. Face shields used in combination with goggles or safety spectacles will provide additional protection against impact hazards.

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Grinding	Grinding and Crushing	Dust (Particles not otherwise classified)	10mg/m3	• Inhalation irritant	• General exhaust ventilation • Enclosed system and SAG Mill, Ball Mill, Pachucas, Pump Boxes, and Cyclones are all vented to the Grinding Scrubber. • Housekeeping practices such as washing down and keeping area wet. • Using dust suppression compound if sweeping is required • PPE including safety glasses, coveralls, gloves • Respirator available for use if conditions dictate • Proper Hygiene practices	Y
Acid Plant	• Sulphur is burned in dried ambient air to produce sulphuric acid	• Sulphur	• 14mg/m3 (H_2S)	• Very toxic by inhalation. Irritating to respiratory system. Inhalation of vapours containing Hydrogen Sulphide or Sulphur Dioxide can be harmful. • Toxic if swallowed. • May cause skin irritation, especially under repeated or prolonged contact or when moisture is present. • Irritating to eyes • Contains material that can cause target organ damage. Repeated or prolonged contact with dusts may irritate skin, cause dermatitis and lead to allergic reactions. Repeated inhalation exposure to dust may cause bronchitis.	• Process tanks and storage vessels are vented. • H_2S monitoring system in building • Housekeeping practices to keep area free of sulphur. • WHMIS training • PPE including safety glasses, coveralls, gloves • Respirator may be required • All workers carry 2 way radio for communication • Sulphur handling procedure • Emergency shower and eye wash in area for emergency use.	Y
	Intermediary chemical produced when sulphur is burned	Sulphur Dioxide (SO_2)	2ppm	• 20 ppm coughing and irritation of eyes • 50 ppm - Irritation to eyes, lungs, throat • 400 to 500 ppm - Life threatening	• Restricted area to authorized personnel • Atmospheric sulphur dioxide monitors for unsafe conditions. • All workers carry 2 way radio for communication • Exhaust stack scrubbers • cesium-promoted catalyst absorbs excess SO_2 • Respirators may be required if levels are above TLV	Y
-Acid Plant -Leaching -RIP -SX -Water Treatment	- leaching of uranium and metals from the ore removal of impurities pH adjustment	Sulphuric acid	0.2 mg/m3	• Extremely corrosive; causes eye and skin burns, digestive and respiratory tract burns, may be fatal if inhaled, reacts violently with water, may cause permanent lung damage.	• Sulphuric acid at a concentration of 93-98% to reduce its corrosive properties. • Lines, valves and tanks subjected to acid are composed of stainless steel or are coated with an acid resistant liner. Secondary controls include valve and flange covers on sulphuric acid piping that change colors to indicate leakage and areas where additional exposure may occur have additional shielding.	Y

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
Plant				• Workers chronically exposed to sulphuric acid mists may show skin, eye, and other health effects. • Occupational exposure to strong inorganic acid mists containing sulphuric acid is carcinogenic to humans.	• All process tanks and storage tanks in the mill are vented to the outside to minimize worker exposure. • WHMIS training • Administrative controls require that personnel who may contact sulphuric acid to wear rubber boots, chemical gloves and goggles, full face shield, rubber jacket and pants. • All mill personnel are required to wear a two-way radio in the event of an emergency. • Sulphuric Acid Offload Procedure • Eye wash and safety showers in area for emergency use.	
-Tailings Neutralization -Water Treatment Plant	-precipitate arsenic and molybdenum	Ferric Sulphate	1mg(Fe^{3+})/m3	• Minimal risk due to low vapor pressure. Product mists are irritating to mucous membranes, respiratory tract, and lung tissues. • Short duration contact may cause skin irritation. Prolonged contact may cause dermatitis and burns. • Exposure results in pain and corrosive to the eyes. • -Oral ingestion may produce mild to moderately severe oral and • esophageal burns	• All mill ferric lines are composed of high density plastic or stainless steel. Ferric sulphate is directly injected into sealed mix tanks and leach vessels to avoid personnel exposure. • WHMIS training • Personnel who may contact ferric sulphate are required to wear rubber boots, chemical gloves, full face shield, rubber pants and jacket. • Mill personnel are also required to wear a two-way radio in case of an emergency. • Ferric Sulphate Offloading Procedure. • Eye wash and safety showers in area for emergency use.	Y
- - Precipitation -Tailings Neutralization	-in the Uranium Precipitation circuit, hydrogen peroxide is added to precipitate uranium as Uranium concentrate -also added to the tailings neutralization circuit to increase the oxidation-reduction potential (ORP) of the waste streams to precipitate arsenic and molybdenum	Hydrogen Peroxide	1ppm	• -Extremely corrosive to eye, skin, nose, throat and lungs.	• There is an isolated hydrogen peroxide storage building separate from the mill. • Engineering controls implemented to mitigate the hazard of hydrogen peroxide includes fabricating lines, tanks and valves from stainless steel if they are to be subjected to hydrogen peroxide. Hydrogen peroxide is off loaded directly into an isolated vented storage tank. • The solution is stored in compatible covered and vented container in a cool and dry area. The storage container will be located in a containment berm that can accommodate 110% of the largest container. The containment area will have a deluge system for diluting any spillage and leak detection tied into the distributed control system (DCS) and local building alarms. Safety equipment in the building will include detectors for signs of oxidation. • The area is to be kept clean to minimize possible sources of combustion. • Entry to the building is limited to those trained in the safe handling of concentrated peroxide. • WHMIS training • Personnel who may contact hydrogen peroxide are required to wear rubber boots, chemical gloves, chemical goggles, full face	Y

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
					shield, neoprene pants and jacket. • All mill personnel are required to wear a two-way radio in case of an emergency. • Hydrogen Peroxide Unloading Procedure. • Eye wash and safety showers in area for emergency use.	
Oxygen Plant Leaching	Production and use of Oxygen Oxidizer	Oxygen	Not available	• Inhalation of high concentrations of oxygen (>80%) at atmospheric pressure for more than a few hours may cause breathing difficulties, nasal stuffiness, sore –throat, dizziness and chest pain. • Breathing high concentrations of oxygen under pressure may cause the same symptoms in less time. Patients with Chronic Pulmonary Obstructive Disease may experience breathing difficulties if exposed to high oxygen concentrations.	• Oxygen is produced in a fully enclosed system. Exhaust ventilation for the storage vessel. • Oxygen sensors monitor the area in case of any malfunctions with equipment. • Standard PPE include safety glasses with side shields and coveralls are required. • SCBA is worn during an emergency by emergency response personnel	Y
Uranium precipitation Tailings Neutralization Water Treatment Plant	-settle solids (coarse particles) in slurry or slimes (fine particles) in solution	Flocculant	10 mg/m3 (particles not otherwise specified)	• Extremely slippery when wet • May cause eye/skin irritation • Not considered toxic	• Suspending flocculant mixing vessels directly above sumps with a grated walkway to minimize slip hazards. • Hazard signs are posted around flocculant mixing areas to warn personnel of slipping hazard. • WHMIS Training • Personnel who could potentially contact flocculant are required to wear rubber boots, safety glasses or chemical goggles, chemical gloves and a particulate respirator. If repeated contact with the flocculant is likely, a chemical resistant suit is also required. • All mill personnel are also required to wear a two-way radio in case of an emergency. • Flocculant Mixing Procedure	Y
				•	•	
Solvent Extraction	Organic carrier	Kerosene	200mg/m3	• Handling may cause skin irritation • High vapour concentrations are irritating to the eyes, nose, throat and lungs; may cause headaches and dizziness; may be anesthetic and may cause other central nervous system effects. • Ingestion may cause headache, nausea,	• The fire hazards posed by kerosene are minimized by isolating kerosene storage tanks away from the mill. All transfer lines are constructed of steel. SX tanks are fiberglass, which is chemically inert to kerosene. All tanks are electrically grounded to prevent the accumulation of static charge. Tanks are also equipped with a carbon dioxide fire suppression system, and in case of the fire suppression system being activated, the alarmed tank volume and adjacent tanks are evacuated to an emergency underground holding tank. • Local exhaust ventilation to minimize concentration in atmosphere • WHMIS training	Y

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
				abdominal discomfort, vomiting, diarrhea, dizziness, drowsiness, faintness, lack of coordination and unconsciousness	• PPE required in area include chemical goggles and face shield if splashing is expected, impervious gloves such as nitrile gloves are worn during handling, impervious chemical suit is required if splashing is expected and rubber boots • Half face and full face respirators with chemical cartridges are required for situations such as maintenance when other controls may be limited. • SCBA to be worn by emergency response members in an emergency situation. • Eyewash and safety shower in area for emergency use.	
SX	Extracts uranium from the pregnant aqueous solution	Amine	Not available	• skin/eye irritant	• Exposure is limited as amine is contained in enclosed tanks and piping. • WHMIS training • PPE worn during transfer of amine include rubber boots, chemical gloves, splash goggles, a respirator with appropriate cartridge equipped and neoprene pants and jacket. • All Personnel are also required to wear a two-way radio in case an emergency should occur. • Amine handling and transfer procedure • Eyewash station and safety shower in area for emergency use	Y
SX	Phase separation	Isodecanol	Not available	• Skin and eye irritant • Can be hazardous if inhaled or ingested	• Isodecanol exposure is limited as it is stored in isolated self-contained totes. • WHMIS training • Personnel who may contact isodecanol during transfer are required to wear rubber boots, chemical gloves, splash goggles, a cartridge respirator with the appropriate cartridge equipped, neoprene pants and jacket. • All mill personnel are required to wear a two-way radio in case of an emergency. • Isodecanol Transfer and Handling Procedure • Eyewash station and safety shower in area for emergency use	Y
SX	- regenerate the organic carrier by stripping it of gangue metal ions. The contaminated sodium carbonate solution is then transferred to the TN circuit and mixes with residual sulphuric acid present in the SX raffinate. The residual acid decomposes the carbonates to water and carbon dioxide.	Sodium Carbonate	Not available	• May be corrosive to the eye. May cause conjunctivitis, corneal burns and permanent damage. • May cause moderate skin irritation. Prolonged contact may cause more severe irritation, skin sensitization. • Inhalation may cause irritation of the respiratory tract. Prolonged exposure may cause injury to the respiratory tract. • -Ingestion of large doses may be corrosive to the	• Engineering controls in place to minimize the risks of sodium carbonate involve a pneumatic offload system. The sodium carbonate storage silo is equipped with a dust collection system to control dust release during the offload procedure. An automated mixing apparatus is used to minimize exposure to personnel. • Personnel who may contact sodium carbonate are required to wear rubber boots, safety glasses or goggles and chemical gloves. • All mill personnel are required to wear a two-way radio in case of an emergency. • Sodium Carbonate Transfer and Handling Procedure. • Eyewash station and safety shower are in area for emergency use	Y

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
				gastrointestinal tract		
Resin Regeneration Circuit	- used to remove accumulation of silica on resin -pH modifier in the Resin Regeneration and Uranium Precipitation circuits	Sodium Hydroxide	Ceiling 1mg/m^3 (based on 50% ACGIH TLV-C)	• Dusts or mists cause severe irritation of respiratory tract, • contact causes severe burning of skin, • Extremely corrosive to the eyes. • Ingestion causes very serious damage to the mucous membranes and or other tissues in the digestive tract and may be fatal.	• To minimize contact, sodium hydroxide (NaOH) is received in bags and delivered to the Bag Breaker by forklift. A Vibrating Feeder delivers the NaOH to the agitated 15% NaOH Mix Tank. It is further diluted to 5% • WHMIS training • Personnel who may contact sodium hydroxide during transfer are required to wear rubber boots, chemical gloves, face shield, chemical splash suit, respirators may be required. • All mill personnel are required to wear a two-way radio in case of an emergency. • Sodium hydroxide transfer and handling procedure • Eyewash station and safety shower in area for emergency use	Y
Resin Regeneration Circuit	-used in the Resin Regeneration Circuit to replenish the sulphate counter-ion on the resin.	Sodium Sulphate	Not available	• -May cause irritation of skin, eyes and respiratory tract • -Ingestion may cause gastrointestinal irritation, nausea, vomiting and diarrhea	• Sodium sulphate (Na_2SO_4) is received in bags and delivered to the Bag Breaker by forklift. A Vibrating Feeder delivers the Na_2SO_4 to the agitated 15% Na_2SO_4 Storage Tank where it is diluted to 15% with Process Water. • WHMIS training • Personnel who may contact sodium sulphate during transfer are required to wear rubber boots, chemical gloves, face shield, chemical splash suit, respirators may be required. • All mill personnel are required to wear a two-way radio in case of an emergency. • Sodium Sulphate Transfer and Handling Procedure • Eyewash station and safety shower in area for emergency use	Y
-Lime slaking ball mill -Tailings Neutralization Gypsum precipitation -Water Treatment Plant	-used for pH adjustment in Tailings Neutralization, Gypsum Precipitation, the Kiggavik WTP and the Sissons WTP.	Lime (calcium hydroxide)	5mg/m^3	• -Severe irritation of mucous and skin, removes natural skin oils. • -Severe eye irritation, intense watering of the eyes, • - If inhaled in form of dust, irritation of breathing passages, cough, sneezing • - Toxic if ingested	• Minimize direct contact with lime, transfer is performed by offloading lime stored in tote bags into a storage silo using a forklift. A Screw Conveyor feeds the lime to the Lime Slake Ball Mill. Process water is heated with steam and added to the Ball Mill. The Ball Mill discharges to Pump Box and pumped to the Cyclones. • WHMIS training • Personnel who may contact lime are required to wear rubber boots, chemical gloves, neoprene pants and jacket and chemical goggles. • Mill personnel are also required to wear a two-way radio in case of an emergency. • Lime Offload and Slaking System Procedure • Eye wash and safety showers in area for emergency use.	Y
-Reagents -Tailings Neutralization -Water Treatment Plant	- used to treat soluble radium. Barium precipitates with sulphate as barium sulphate. In the presence of radium, it co-precipitates barium-radium sulphate. Barium sulphate precipitates are extremely insoluble and are deposited in	Barium Chloride	0.5 mg (Ba)/m^3	• May cause severe eye irritation • May cause irritation or dermatitis • May cause irritation of mouth, nose and throat • Poisonous if a substantial	• WHMIS training • PPE including safety glasses with side shield or goggles, disposable covers on top of coveralls, rubber gloves, rubber boots, and respirator will be worn when mixing barium. • Proper hygiene practices • Barium Chloride Transfer and Handling Procedure	Y

Table 5.4-8 Evaluation of Hazardous Substances Exposure for the Milling Operations at Kiggavik

Group	Process/ Activity	hazardous substances	TLV-TWA	Health Hazard	Controls	Exposure Expected to be at or below TLV? (Y/N)
	the TMF.			amount is ingested	• Eyewash station and safety shower in area • Antidote available at health center if ingested	
Gypsum Precipitation	Iron adsorption/elution Control sulfate	Gypsum Calcium sulphate dihydrate	10 mg/m^3	• Unlikely under normal conditions of use, but swallowing the powder and dust may result in abdominal discomfort. • Dust can irritate the eyes causing watering and redness and may aggravate pre-existing eye conditions. • skin exposure can cause irritation and dermatitis. • can cause irritation of the nose, throat and lungs. Repeated exposure to the dust may result in increased nasal and respiratory secretions and coughing and may aggravate pre-existing respiratory conditions.	• Work practices should minimize the release of and exposure to dust. General ventilation should be adequate, but local mechanical ventilation may be required if dust is generated, particularly in confined spaces. • WHMIS training • PPE including safety glasses with side shield or goggles, rubber gloves, rubber boots, respirator will be worn if dust levels dictate requirement. • Proper hygiene practices • Gypsum Transfer and Handling Procedure • Eyewash station and safety shower in area	Y

5.4.7 Assessment of Workplace Hazardous Substances Exposures – Decommissioning and Reclamation

During the decommissioning and reclamation phase, the primary chemicals that may need to be used are those for water treatment and also fuel usage. The chemicals include:

- Ferric Sulfate
- Barium Chloride
- Flocculant
- 12% Sodium Hypochlorite (chlorinating potable water system)
- Gasoline (vehicle use)
- Diesel (vehicle use & fuel for back-up generators)

For reclamation, fertilizer may also need to be used and personnel will be required to follow safe handling and storage procedures. They will be trained in WHMIS and wear appropriate PPE which will include impervious gloves, boots, eye protection and coveralls.

Some chemicals that may be used in smaller quantities during the decommissioning phase include solvents, oils and varsol. These will be evaluated in a similar manner by the Health and Safety Department if they are brought to site.

5.5 Summary of Worker Exposure to Hazardous Substances and COPC Assessment

Worker exposures to hazardous substances and COPCs have been conducted for the Kiggavik project. With the proposed mitigation measures in place, there are no exposures to workplace hazardous substances or COPCs expected to exceed Threshold Limit Values established by the ACGIH or 8-hour Occupational Exposure Limits established within Table 2 of the Consolidation of General Safety Regulations.

5.6 Summary of Compliance and Environmental Monitoring for Worker Exposure to Hazardous Substances and COPC Assessment

5.6.1 Workplace Exposure Monitoring

The following monitoring strategy is organized around the Deming Cycle for continuous improvement of Plan, Do, Check, Act.

5.6.1.1 Hazardous Substances - Monitoring

Survey (PLAN)

If a worker is believed to be exposed to a hazardous substance that exceeds the TLV, an assessment of the potential for harmful exposure will be performed. Based on an initial survey of the condition, which may include a walk through and discussion with workers, it may be deemed necessary to reassess exposure levels. Monitoring or sampling of exposure levels to airborne contaminants may be conducted. An initial walkthrough survey including interviews will be conducted to identify the contaminant(s) and who is at risk. A conservative approach will be taken and the worst case scenario will be measured.

There are some issues to identify before air sampling can be conducted:

- what to sample,
- what type of sample to obtain (e.g. air sampling, bulk sampling)
- how many samples to take,
- which workers to sample,
- where to take the sample and
- when to take the sample.

Sampling (DO)

There are a number of sampling methods and instruments used to monitor hazardous substances. The following questions will dictate which methodology that will be selected:

- what hazardous substances is in question,
- what standard is available (e.g. NIOSH Manual of Analytical Methods, OSHA Analytical Methods Manual),
- potential interferences,
- sampling conditions (temperature, relative humidity, pressure),
- detection limit,
- potential for contamination of sampling media,
- stability of sample over time,
- precision and accuracy of method and
- which laboratory is available.

Analysis & Review (CHECK & ACT)

Upon receiving the sample results, an evaluation will be performed to determine if controls are adequate. Any areas requiring improvements will be rectified as required to ensure workers work in safe conditions. A follow-up review will be conducted over a period of time and assessed to confirm adequacy of improvements.

5.7 Noise Exposure

Noise-induced hearing loss occurs after an individual is exposed to high levels of sound, which damage the hearing mechanism. This damage can be either temporary or permanent depending on four main contributing factors; 1) overall noise level, 2) frequency content of the noise, 3) duration of exposure and 4) susceptibility of the individual.

Noise-induced hearing loss is preventable but once acquired, hearing loss is permanent and irreversible. Therefore, for any employee who may be exposed to levels that exceed 80dBA, hearing protection will be provided and prevention measures must be taken to ensure the protection of workers' hearing.

For the Kiggavik Project, noise exposure will be considered during the detailed design phase with design criteria established to control noise exposure. An assessment of workplace exposure to noise and vibration is not possible until the detailed design phase; at the current stage of design an assessment of noise and vibration cannot be conducted as no specific equipment has been selected and no equipment and building layout plans developed. AREVA will consider noise reducing equipment to minimize the noise exposure of workers as removing hazardous noise from the workplace through engineering controls (e.g. building an acoustic barrier) is the most effective way to prevent noise-induced hearing loss. It is however likely that there will be some areas and equipment where the noise levels may be at levels high enough to cause potential hearing loss if protective measures and controls are not used. It is expected that there will be noise exposure of workers during the construction, operational and decommissioning phases.

Controls

The implementation of hearing loss prevention program for the Kiggavik Project will include the following components to ensure a successful hearing loss prevention program:

1. Noise exposure monitoring – The purpose of performing a noise survey is to estimate a worker’s noise dose over a given period. This information is also useful in determining where control of noise levels may be required. Where feasible, a noise dosimeter will be used to estimate a worker’s noise exposure, especially if the worker is exposed to varying degrees of sound levels throughout his or her shift.

2. Engineering and administrative controls - engineers will consider noise reduction when build and design equipment. Personnel purchasing powered mobile equipment will also consider purchasing equipment with noise attenuation. They will consider it is anticipated that there
3. Audiometric evaluation – the health center, together with the hygienist will perform audiometry tests on individuals exposed to noisy conditions to monitor any changes.
4. Use of hearing protection devices- a variety of hearing protection devices including earplugs and earmuffs will be made available to workers. Hearing protection will be provided and will be required to be worn by employees whose daily average noise exposure is greater than 85 dBA or who may be required to work in areas in excess of 90 dBA. Evaluation and selection of acceptable hearing protection will be performed by the Industrial Hygienist.
5. Education - All new employees receive training on the effects of noise hazards and use of hearing protectors. The training can be provided by the Occupational Health Nurse, the Industrial Hygienist or another member of the Safety Group.
6. Record keeping - Training records are documented in each employee's medical file.
7. Program evaluation, and audits – the program will be evaluated on a regular basis.

6 Assessment of Project Effects Worker Exposure to Radioactivity

6.1 Issues and Concerns Identified During Inuit and Stakeholder engagement

The NIRB EIS Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.'s Kiggavik Project, 2011, incorporated advice from the public and interested parties on the proposed scope of assessment for Human Health, including the identification of valued components (VCs) and issues that should be considered in the EIS. Specifically, the guidelines require an assessment of the human health effects due to the mining and milling activities as well as the transport of uranium concentrate by either air or marine shipping.

Project-specific issues and concerns identified during Inuit, government and stakeholder engagement broadly include:

- potential health hazards of uranium (EN-BL HS Nov 2010 [34]EN-CH HS Nov 2010 [35]);
- radiation monitoring of people and areas in the open pits, underground mines and mill (EN-CI OH Nov 2013 [36],EN-RB OH Nov 2010 [37],EN-KIV OH Oct 2009 [38]);
- radiation monitoring off site (EN-CH OH Nov 2010 [39]) e.g. dust levels, concentrations;
- radiation dose limits, reporting and controls in place to protect people (EN-BL OH Oct 2012 [40]);
- background radiation, e.g. properties, occurrence, levels;
- cancer rates in Saskatchewan and Nunavut (EN-CI OH Nov 2010 [41]EN-BL OH Nov 2010[42]);

[34] EN-BL HS Nov 2010: *What can happen to the body after prolonged exposure to radiation?*
[35] EN-CH HS Nov 2010: *What is the main sickness for uranium mining?*
[36] EN-CI OH Nov 2013: *Radiation of underground workers vs open pit?*
[37] EN-RB OH Nov 2010: *How much radiation does a driller receive?*
[38] EN-KIV OH Oct 2009: *Working in the mill, what about radiation?*
[39] EN-CH OH Nov 2010: *Radioactive dust will travel downwind to Rankin Inlet.*
[40] EN-BL OH Oct 2012: *What will you do to protect workers' health?*
[41] EN-CI OH Nov 2010: *When mining uranium are there any examples of cancer?*
[42] EN-BL OH Nov 2010: *What are the cancer rates in Saskatchewan?*

- properties of Uranium concentrates (EN-RB HS Nov 2013 [43]EN-BL NIRB Apr 2010 [44]) e.g. radiation properties, potential hazards, protection of workers and public during transport, storage and transfer of Uranium concentrates;
- history of uranium mining in Canada (EN -WC OH Nov 2013 [45]), worldwide and by ARC;
- properties of uranium (EN-CH OH Oct 2012 [46]), e.g. types of radiation emitted, radon daughters, detection, internal and external hazards, ability to explode, units of measure;
- past uranium miners health studies (EN-KIV OH Oct 2009 [47]):
- Potential by-products of uranium mining and effects to environment and people (EN-RI-KIA Apr 2007 [48]):
- the use of uranium for nuclear weapons (EN-RB NIRB Apr 2010 [49]); e.g. history, present uses, Non-proliferation Treaty;
- alternative uses of Uranium, e.g. medical and cancer treatments;
- regulation of uranium mining in Canada, Nunavut and Northwest Territories (EN-CI KIA Feb 2010 [50]);
- decommissioning and reclamation of land needs to be done properly so that the public can use land without incidents or concerns (EN-CI OH Nov 2012 [51]); and
- Potential impact of uranium entering the food chain (EN-RI KIA Apr 2007 [52],EN-WC KIA Apr 2007 [53]) e.g. plants, caribou, humans.

AREVA has endeavoured to address each of these issues either within this assessment document, or within Tier 3 Technical Appendix 8B: Radiation Protection Supporting Document.

Since AREVA heard community questions about radiation, public engagement events to date have included information on radiation (what is radiation and radiation protection). For instance, radiation demonstrations and poster board displays about the uses of uranium and radiation in general were included in AREVA's Open House community tours (Tier 2, Volume 3 Public Engagement and Inuit Qaujimajatuqangit, Part 1 Public Engagement). Efforts were made to describe radiation in an easy

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[43] EN-RB HS Nov 2013: *How dangerous is it itself?*
[44] EN-BL NIRB Apr 2010: *Concerns about the storage of concentrated uranium at the dock in Baker Lake and potential impacts to people.*
[45] EN-WC OH Nov 2013: *About 20 years ago I heard of uranium miners getting cancer?*
[46] EN-CH OH Oct 2012: *What is a dangerous amount of radiation?*
[47] EN-KIV OH Oct 2009: *Have there been any health studies dones in terms of people who work in the mines?*
[48] EN-RI-KIA Apr 2007: *So the tailings, are they more of a health hazard?*
[49] EN-RB NIRB Apr 2010: *The community would like to know what the uranium will be used for.*
[50] EN-CI KIA Feb 2010: *How often would inspections occur?*
[51] EN-CI OH Nov 2012: *Will the uranium go into the water and be dangerous for our kids and grandkids?*
[52] EN-RI KIA Apr 2007: *I rely on caribou and fish. So does that mean I will get sick more?*
[53] EN-WC KIA Apr 2007: *Are you prepared to mitigate fish contamination?*

to understand way, including analogies between radiation and hockey (Tier 3, Technical Appendix 3A, Public Engagement Documentation).

6.2 Introduction to Radiation Safety

6.2.1 What is Radiation?

Materials which transform spontaneously into other materials through the process of radioactive decay are referred to as radioactive materials. Radioactive decay results in the emission of energy and/or particles from the nucleus of the radioactive substance. The resultant emission of energy and/or particles is known as radiation. There are three kinds of radiation of concern in uranium mining and milling: alpha particle emission, beta particle emission, and gamma ray emission. The rate of spontaneous transformation is measured in terms of its half-life (i.e., the time it takes for one-half of original material to decay to become a new material).

6.2.2 The Discovery of Radiation

Since the appearance of life on our planet and continuing to the present day, all living species, including human beings, have evolved and lived in an environment of radiation.

Some of this ionizing radiation originates in outer space and is called cosmic radiation. Ionizing radiation is also produced by radioactive materials in the Earth's crust. These naturally occurring radioactive materials were created at the same time as the other materials which make up the Earth.

Living species are not equipped to detect ionizing radiation. None of the human biological sensors responds to ionizing radiation at the levels occurring in the environment. In other words, we cannot see or hear or smell ionizing radiation. Because of this, ionizing radiation was completely unknown until the end of the 19th century, when photographic plates became available.

In 1896, in Paris, Henri Becquerel noticed that his photographic plates became fogged when they were placed near his collection of uranium bearing minerals. He assumed from this that some kind of radiation was being emitted by the uranium minerals. These photographic plates provided the first means by which people could detect the ionizing radiation that exists all around them.

6.2.3 Alpha, Beta and Gamma Radiation

Following the discovery of radioactivity by Henri Becquerel, it was soon determined that three different kinds of radiation were being emitted by uranium minerals. These three kinds of radiation were labelled "alpha", "beta" and "gamma", the first three letters of the Greek alphabet. Alpha, beta and gamma radiation will all be addressed in this radiological study.

Alpha and beta radiation consists of high velocity, electrically charged particles, comprised, respectively, of the positive nuclei of helium and of ordinary electrons.

Gamma radiation is similar to visible light, simply more energetic.

All three types of radiation have in common the property of ionizing all traversed media; that is to say, they break up some of the molecules (and atoms) of the medium through which they are travelling, into ions. For this reason, such radiation is known as "ionizing radiation".

6.2.4 Uranium Decay Chain

Many of the radioactive isotopes originally produced by the stars had half-lives that were short, relative to the age of the Earth. Such relatively short-lived radioisotopes disappeared a long time ago, leaving only a few long-lived radioisotopes, such as uranium-238, still in existence.

The on-going decay of these remaining long-lived radioisotopes gives birth to other shorter-lived radioisotopes. In fact, the radioactive disintegration of the uranium-238 atom produces another radioactive atom, which then produces another radioactive atom and so on, until a stable atom of lead is produced. The uranium-238 atom is thus the parent of a chain of 13 unstable atoms, ending in lead which, being stable, does not decay.

This process of the decay of uranium and other unstable atoms which, at the instant of change into another kind of element, give off a burst of radiation, has taken place on our planet from the very beginning of its existence. It is a process that continues all around us, even now.

The radioactive material most relevant to the Kiggavik Project is uranium-238 and the series of radioactive progeny in the radioactive decay series. These include radionuclides such as thorium-230, radium-226, radon-222 and its short-lived decay products, lead-210 and polonium-210. Radioactive decay results in the emission of energy and/or particles from the nucleus of the radioactive substance. The resultant emission of energy and/or particles is known as radiation. The amount of radiation that a worker is exposed to is measured in terms of radiation dose. Of the 13 radiuonuclides in the decay chain, five are monitored to determine receptor doses (i.e., uranium-238, thorium-230, radium-226, lead-210, and polonium-210). These five radionuclides are monitored because they persist in the environment long enough to facilitate monitoring and measuring. The chain of decay is presented in Figure 6.2-1.

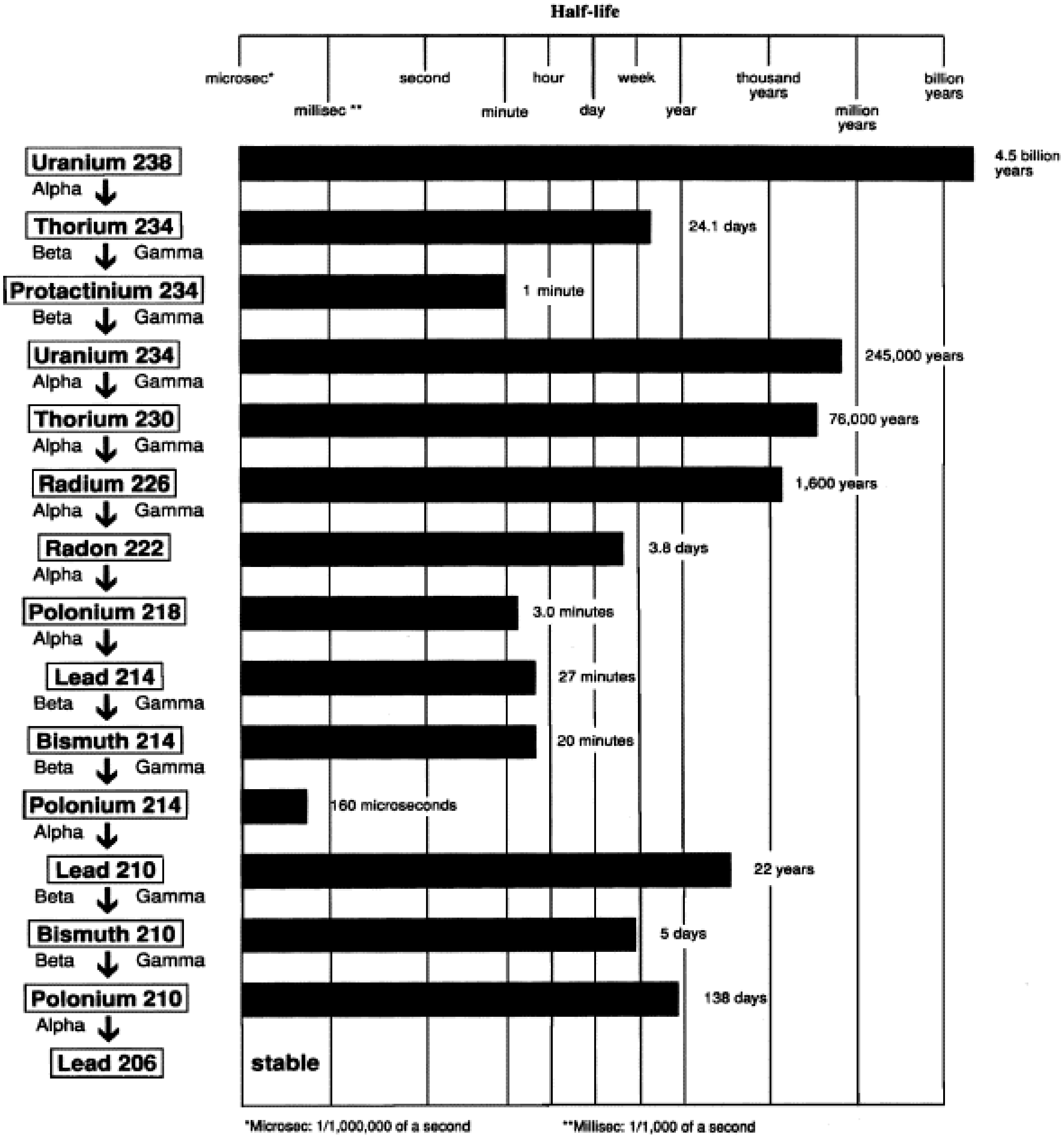

Figure 6.2-1 Uranium Decay Chain

6.2.4.1 Properties of Uranium Ore

In its pure form, uranium is a silvery white metal of very high density, more dense even than lead. Uranium can take many chemical forms, but in nature it is generally found as an oxide, in combination with oxygen. Uranium is one of the most abundant elements found in the Earth's crust. It can be found almost everywhere in soil and rock, in rivers and oceans. A uranium ore deposit is a concentration of uranium in the earth's crust that can be mined economically. Uranium can have several different mineral forms in the ore, including pitchblende and uraninite. The mixture of mineral forms are often referred to generally as U_3O_8.

6.2.4.2 Properties of Uranium Ore Concentrate (Yellowcake)

Uranium ore concentrate is commonly called yellowcake. Uranium ore concentrate is a very fine heavy powder, which can be yellow to slightly orange (non-calcined concentrate) or dark green to near black (calcined concentrate), depending on the processing temperature. For Uranium concentrates, the gamma radiation dose for each unit of uranium is much lower than from the same quantity of uranium as ore because many of the radioactive decay products in the uranium decay chain (from Th-230 downwards) have been removed during the milling process.

6.2.5 Biological Effects of Ionizing Radiation

Public engagement identified that community members *want to further understand radiation exposure and any potential health impacts* (EN–RB OH Nov 2010[54], EN–WC OH Nov 2010[55], EN–CH OH Oct 2012[56],[57], EN-RI OH Nov 2012[58],EN–RB HS Nov 2013[59], EN–BL HS Nov 2010[60]).

There are potential deleterious effects from human exposure to ionizing radiation. In the early days, physicians and scientists who investigated the possible applications of radiation were among the first victims of uncontrolled radiation exposures. Radiation burns and leukaemia were some of the negative effects that were first observed.

[54] EN – RB OH Nov 2010: *What can radiation cause?*
[55] EN – WC OH Nov 2010: *Why is radiation dangerous?*
[56] EN – CH OH Oct 2012: *What is a dangerous amount of radiation?*
[57] EN – CH OH Oct 2012: *What is a dangerous number on the gadgets that would cause you to get sick?*
[58] EN – RI OH Nov 2012: *What does uranium exposure do?*
[59] EN – RB HS Nov 2013: *How dangerous is it itself?*
[60] EN – BL HS Nov 2010: *What will happen to the body after prolonged exposure to radiation?*

Since then, there have been many studies of the effects of ionizing radiation on human beings. These studies have confirmed that chronic exposure to elevated levels of ionizing radiation can cause cancers and other disorders in human populations exposed to such radiation. For example, miners exposed to historical very high concentrations of radon were shown to be an increased risk of lung cancer On the other hand, studies to date have been unable to provide statistically-significant evidence of the existence of a health risk from exposure to lower levels of radiation such as those encountered in modern uranium mines.

The effects of ionizing radiation on humans vary greatly depending on the nature of the radiation, the dose (quantity of energy) received, the duration and means of exposure, and personal factors (age at the time of exposure, sex, and genetic predisposition). For the same dose, the biological effects of ionizing radiation are identical, whether the radiation is natural or artificial. We have been able to gain an understanding of the effects of radioactivity on the human organism through epidemiological studies, experimental research and the analysis of real cases of exposure to irradiation (both accidental irradiation and that due to work or personal activities). There are two categories of biological effects resulting from ionizing radiation:

- Deterministic effects: injury to a population of cells, characterized by a threshold dose and an increase in severity of the reaction as the dose is increased further. These are also referred to as tissue effects. In the absorbed dose range up to 100 mGy no tissues are judged to express clinically relevant functional impairment. (ICRP 103)
- Stochastic effects: Malignant disease and heritable effects for which the probability of an effect occurring, but not its severity, increases with increased dose (ICRP103). There is no clear scientific evidence of any adverse health effects at chronic radiation doses below 100 millisieverts (mSv) (CNSC 2009a). The effects of low doses (e.g., below 100 mSv) are calculated by extrapolating from the effects of high doses, according to two approaches: by animal experiments, and by human epidemiological studies. These involve studying the populations exposed and compiling a statistical assessment of the excess number of cancers compared to a non-exposed population.

The main source of epidemiological data comes from studies on populations exposed to high doses: survivors of the atomic bombs dropped on Hiroshima and Nagasaki in Japan in 1945, highly-exposed populations due to working conditions or past medical practices. Epidemiological studies conducted to assess the health effects of low doses are rare because it is difficult to demonstrate any effects, even in large population groups. Current knowledge does not allow us to confirm with conviction that there is a threshold dose below which radioactivity is harmless. The biological phenomena involved are complex and many mechanisms, such as natural protection and cell repair, are involved.

In light of these two categories of biological effects due to radioactivity, how can we establish radiation protection rules for workers and populations? The protection of humans against the effects of radiation was progressively improved during the 20th century, along with the development of applications and knowledge related to radioactivity. To be on the safe side, the International Commission on Radiological Protection (ICRP) recommends two hypotheses:

- Absence of threshold: all doses are assumed to have an effect on health even if we cannot detect this effect.
- Linear extrapolation of high doses received in “one go” so as to estimate the effects of low doses cumulated over a lifetime (the “dose linear effect” without a threshold). The validity of this hypothesis nevertheless remains scientifically controversial.

These conservative hypotheses give rise to the three main principles that are the foundation of radiation protection today:

- Justify activities involving exposure risk: activities using radiation must provide more advantages than disadvantages, and all activities related to radiation must be justified.
- Limit individual exposure doses: they must remain below the regulatory limits.
- Keep the level of exposure as low as possible, taking into account technical and economic constraints at the time (ALARA principle or “As Low As Reasonably Achievable”).

These radiation protection principles apply to all exposure situations, whether they result from industry, medical activities, research activities, or activities carried out in environments with elevated natural radioactivity (on commercial airlines or in mines). In order to apply these broad principles, radiation protection implements a number of technical and regulatory measures.

6.3 Scope of the Assessment for Worker Exposure to Radioactivity

6.3.1 Regulatory Setting

6.3.1.1 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

UNSCEAR was established by the General Assembly of the United Nations in 1955. Its mandate in the United Nations system is to assess and report levels and effects of exposure to ionizing radiation. Governments and organizations throughout the world rely on the Committee’s estimates as the scientific basis for evaluating radiation risk and for establishing protective measures. The General Assembly has designated 21 countries to provide scientists as members of the Committee.

Since its inception, UNSCEAR has issued 20 major publications. These reports are highly regarded as principal sources of authoritative information on radiation and its effects. The UNSCEAR 2006 Report, “Effects of Ionizing Radiation” contains scientific annexes which discuss epidemiological studies of radiation and cancer, and assessment of radon in homes and workplaces. The scientific information presented by UNSCEAR provides the basis on which the International Commission on Radiological Protection develops its recommendations for radiation protection.

6.3.1.2 International Commission on Radiological Protection

The occurrence of health effects in people exposed to radiation led a group of concerned radiobiologists and physicists to create the International Commission on Radiological Protection (ICRP) in 1928. Since that time, the ICRP has developed, and continues to develop, concepts and philosophies which provide for the safe management of activities involving the use of ionizing radiation.

The ICRP has published a number of documents recommending measures to be incorporated in national regulations on radiological safety and providing practical guidance for users of ionizing radiation. ICRP publications reflect the latest scientific knowledge and evidence about the effects of radiation on living organisms. These ICRP publications are revised periodically as the science of radiation protection advances. The ICRP updated its general recommendations most recently in 2007 (ICRP 2007). It is the ICRP recommendations which establish the basic principles of radiation protection, as well as radiation dose limits for workers and the general public.

Principles of Radiation Protection

The amount of radiation which a worker is exposed to is measured in terms of radiation dose. Exposure to radioactive substances has been found to cause detrimental effects, or to increase the likelihood of detrimental effects occurring, in those exposed. For the purposes of radiation protection, a precautionary approach is applied (i.e., it is assumed that the likelihood of detrimental effects is proportional to the dose received, including low doses below the levels where statistical effects can be observed). Dose limits for individuals have been developed to protect against the risk of unacceptable consequences.

The ICRP has defined three basic principles of radiation protection. They are:

1. Justification: No practice shall be adopted unless its introduction produces a net positive benefit.
2. Optimization: All radiation exposures shall be kept As Low As Reasonably Achievable (ALARA), economic and social factors being taken into account; and,
3. Dose Limitation: The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the ICRP.

In the operation of nuclear facilities the focus of radiation protection practice is centred on the optimization (ALARA) principle. It means that facilities, processes, equipment, and work practices should be designed so that radiation doses to workers, and the public, are minimized.

6.3.1.3 International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) is an agency of the United Nations whose mandate includes development of standards and guidance for radiation protection for use by national authorities. The IAEA bases its safety standards on the recommendations of the ICRP. Regulation in Canada regarding radiation safety is generally adopted from the ICRP recommendations and IAEA safety standards and guidance.

The IAEA serves as an intergovernmental forum for scientific and technical cooperation in the peaceful use of nuclear technology and nuclear power worldwide. The programs of the IAEA encourage the development of the peaceful applications of nuclear technology, provide international safeguards against misuse of nuclear technology and nuclear materials, and promote nuclear safety (including radiation protection) and nuclear security standards and their implementation. IAEA documents, applicable to uranium mining and milling, include:

- IAEA Safety Guide RS-G-1.1, Occupational Radiation Protection, 1999
- IAEA Safety Guide RS-G-1.6, Occupational Radiation Protection in the Mining and Processing of Raw Materials, 2004
- IAEA Safety Requirement TS-R-1, Regulations for the Safe Transport of Radioactive Materials, 2009

6.3.1.4 Canadian Nuclear Safety Commission

In Canada, the Canadian Nuclear Safety Commission (CNSC) regulates the nuclear industry. The commission was created following a major updating of the Canadian nuclear regulatory system and the implementation of the Canadian Nuclear Safety and Control Act and its regulations in 2000. The CNSC replaced the Atomic Energy Control Board, founded in 1946.

As set out in the *Canadian Nuclear Safety and Control Act*, the objectives of the CNSC are:

(a) to regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to:

(i) prevent unreasonable risk, to the environment and to the health and safety of persons, associated with that development, production, possession, or use,

(ii) prevent unreasonable risk to national security associated with that development, production, possession or use, and,

(iii) achieve conformity with measures of control and international obligations to which Canada has agreed; and,

(b) to disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the environment and on the health and safety of persons, of the development, production, possession and use referred to in paragraph (a).

Essentially, from the words set out in the Act, the CNSC's responsibilities involve four major areas:

1. Regulation of the development, production and use of nuclear energy in Canada;
2. Regulation of the production, possession and use of nuclear substances, prescribed equipment and prescribed information;
3. Implementation of measures respecting international control of the use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons; and,
4. Dissemination of scientific, technical, and regulatory information concerning the activities of the CNSC.

General regulations under the Nuclear Safety and Control Act governing work with uranium mines and mills may be found in the Uranium Mines and Mills Regulations (CNSC 2000a) and regulations regarding radiation protection are outlined in the Radiation Protection Regulations (CNSC 2000b). These regulations specify the limits on exposure to radiation for workers and for members of the general public. The general radiation dose and exposure limits set by the CNSC are shown in Table 6.3-1.

Table 6.3-1 General Radiation Dose and Exposure Limits

Person	Period	Effective dose[a] (mSv)[b]
Nuclear Energy Worker, including a pregnant Nuclear Energy Worker	(a) one-year dosimetry period	50
	(b) five-year dosimetry period	100
Pregnant Nuclear Energy Worker	balance of pregnancy	4
A person who is not a Nuclear Energy Worker	one calendar year	1

NOTE:
[a] mSv = millisieverts.
[b] Effective Dose= effective dose is the sum of the weighted equivalent doses in all the organs or tissues of the body as different organs have different susceptibilities to the induction of cancer and genetic defects.

Further to the requirements established by the Radiation Protection Regulations, the CNSC has provided the document, Regulatory Guide G-129 Rev.1 Keeping Radiation Exposures and Doses As Low As Reasonably Achievable (ALARA) (Oct 2004), which is instrumental in the design of facilities and the development of radiation protection programs.

The CNSC regulates the transport of radioactive material through the *Packaging and Transport of Nuclear Substances Regulations* (CNSC 2000c). These regulations govern the way radioactive materials are packaged and transported.

6.3.1.5 Transport Canada

Transport Canada is responsible for transportation policies and programs. It ensures that air, marine, road and rail transportation are safe, secure, efficient and environmentally responsible. Transport Canada administers a number of acts and regulations related to transportation including the Transportation of Dangerous Goods (TDG) Act. The TDG Act and associated regulations provide requirements for manufacturers, shippers, carriers, facility operators, users and government pertaining to dangerous goods movement, including requirements for classifying, packaging, labelling and documenting shipments. For radioactive substances such as uranium ore and concentrates, requirements for transport are described both within the TDG Act and Regulations, as well as the Packaging and Transport of Nuclear Substances Regulations administered by the Canadian Nuclear Safety Commission. These requirements are largely based on transport requirements established by the International Atomic Energy Agency in *IAEA Safety Requirement TS-R-1, Regulations for the Safe Transport of Radioactive Materials*.

Under the Transportation of Dangerous Goods Act dangerous goods, such as uranium concentrate, require an Emergency Response Assistance Plan (ERAP) for handling and transporting the material through Canada. This plan ensures that in the event of an incident involving dangerous goods in Canada, specialized assistance is available to appropriate authorities.

6.3.1.6 Nunavut Impact Review Board (NIRB)

The members of the Nunavut Impact Review Board (NIRB), appointed by the Government of Canada and the Government of Nunavut, are responsible for making recommendations to the responsible federal or territorial Minister regarding the issuance of licences and permits in Nunavut. The Board was created by the Nunavut Land Claims Agreement to access the potential impacts of proposed development in the Nunavut Settlement Area prior to approval of the required project authorizations. Both traditional knowledge and recognized scientific methods are used when NIRB assesses the biophysical and socio-economic impact of proposals and makes recommendations and decisions about which project may proceed. The Board may also monitor the impacts of projects that have been reviewed and approved to proceed.

6.3.1.7 *Worker Safety and Compensation Commission*

The Worker Safety and Compensation Commission (WSCC) administer the Workers' Compensation Acts, the Safety Acts and Regulations, the Mine Health and Safety Acts, and the Explosives Use Acts to protect workers in the Northwest Territories and Nunavut. The WSCC commits to prevention, and works to improve northern safety cultures through safety education.

6.3.2 Project-Environment Interactions and Effects

A number of project activities have been identified with potential to interact with worker exposure to radioactivity during construction and commissioning, operations and decommissioning. These activities are ranked according to their potential to interact with the potential source of exposure. Interactions were assigned a ranking as follows:

- **0** = activities with no interaction, or no potential for substantive interaction, with human health.
- **1** = activities having a potential interaction with human health, but whose interaction would not result in a significant health effect once planned and proven mitigation methods are applied to the activity.
- **2** = activities having potential for substantive effects on human health, even after mitigation measures are applied. The potential health effects are addressed further in the environmental assessment.

Table 6.3-2 Project-Environment Interactions – Worker Exposure to Radioactivity

Project Activities/Physical Works	Worker Exposure to Radioactivity
Construction	
All associated activities	0
Operation	
Mining	1
Milling	1
Tailings Management	1
Water Management - Collection of site and stockpile drainage	1
Water Management - Water and sewage treatment	0
Water Management - Discharge of treated effluents – including grey water	1
Waste Management	0

Table 6.3-2 Project-Environment Interactions – Worker Exposure to Radioactivity

Project Activities/Physical Works	Worker Exposure to Radioactivity
General Services – Generation of power	0
General Services - Hazardous materials storage and handling (reagents, fuel and hydrocarbons)	0
General Services - Explosives storage and handling	0
Transportation – Air transport of Uranium concentrates	1
On-going Exploration – Aerial surveys	0
Decommissioning	
On-going treatment and release of water, including domestic wastewater	1

The radiological risk assessment evaluates exposures to individuals during project activities.

6.3.3 Valued Components, Indicators and Measurable Parameters

Worker health is defined as a valued component that, if altered by the Project, would be of concern to AREVA, the general public, and regulators. Worker health represents components of worker exposure that may be altered by the Project, and is widely recognized as important to the human environment. In this section, worker exposure to radiation in the workplace is specifically addressed.

Table 6.3-3 Measureable Parameters for Protecting Worker Health

Environmental Effect	Indicator	Measurable Parameter(s)	Notes or Rational for Selection of the Measurable Parameter
Worker exposure to radiation	• Dose • Dose rate	• Exposure (mSv) • Exposure rates (µSv/h)	• Regulatory limit and AREVA constraints

6.3.4 Spatial Boundaries

6.3.4.1 Project Footprint

The project footprint for the worker radiological assessment is defined as the milling, open pit mining, underground mining and associated facilities and activities on site as well as the transport of uranium concentrate by air.

6.3.4.2 Local Assessment Area

Boundaries within the Local assessment Area (LAA) include the Kiggavik Mill, the open pit mines, underground mine, uranium concentrate shipping route and all the associated areas and surface facilities within the Project.

6.3.4.3 Regional Assessment Area

The Regional Assessment Area (RAA) of the Project is a broader area within which cumulative effects may potentially occur.

6.3.5 Temporal Boundaries

The worker health effects of the Project were considered for the following phases:

- Construction – project-related effects were considered during the construction phase of the surface facilities associated with the Kiggavik Mill.
- Operations – project-related effects were considered for the operational period. For the assessment of human health, the assessment focused on the period of the highest potential impact.
- Decommissioning – during decommissioning, water treatment is expected to continue and therefore this period was considered in the assessment.
- Post-closure – Worker occupancy of the site will cease following decommissioning; hence, no assessment of worker exposure has been conducted for the post-closure period. A requirement of decommissioning will be to ensure that the public dose limit is not exceeded for future use of the site.

The assessment covers the period of all the phases mentioned above during which worker exposure activities will occur (approximately 25 years).

6.3.6 Administrative and Technical Boundaries

In uranium mining and milling, effective dose is determined from evaluation of radiation exposure from three dose components:

1. **Gamma radiation**: Gamma rays emitted by uranium and its radioactive progeny expose workers. As the source of exposure is external to the body, gamma radiation is referred to as an external exposure hazard. Gamma radiation doses are presented in terms of effective dose in units of sieverts (Sv). Where gamma radiation dose rates in air have been calculated based on uranium ore grades and source and receptor geometries, the reported absorbed dose rates in µGy/h have been converted to units of effective dose according to the recommendations of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2008) using the conversion of 1 Gy = 0.7 Sv.
2. **Radon and radon progeny**: Radon is a gaseous decay product of uranium which is released from uranium ore. Radon and its progeny can be inhaled, giving the recipient an internal source of radiation exposure. In mining, radon progeny levels in workplaces have been typically measured in terms of Working Levels (WL) and exposures calculated in terms of Working Level Months (WLM). (These historical units are still used in Canada and other countries.) Radon exposures have been presented in this report in units of effective dose, in mSv, using the dose conversion factor of 1 WLM = 5 mSv (CNSC 2000b). The ICRP has recently indicated that, based on updates to epidemiological studies, the dose conversion is likely to change by a factor of 2 to approximately 1 WLM = 10 mSv. Assessments are presented using the currently established dose conversion factors, however, the sensitivity to a future change in dose conversions values is discussed. Exposure to radon gas, separate from radon progeny, is calculated using a dose conversion factor of $1.6x10^{8}$ Bq = 20 mSv (Duport 1999)
3. **Long-lived radioactive dust (LLRD):** These are aerosols (fine materials that can become airborne as dry dust as well as mist) that contain radioactive materials, and may be inhaled or ingested, resulting in an internal exposure. Workplace concentrations of radioactive dusts are present in terms of Derived Air Concentrations, DACs. A DAC is the workplace concentration of a contaminant that, if exposed at that level for an entire work year, would result in an exposure equal to the annual limit of intake. For radioactive dusts, an annual limit on intake (ALI) corresponding to an annual dose 20 mSv is used. The dose received from radioactive dusts is dependent on physical and chemical properties of the dust. For example, for uranium ore dust, inhalation by workers of 2800 Bq of LLRD results in a dose of 20 mSv (AECB 1995).

Exposure to each of these three dose components are converted to units of effective dose, in sieverts (Sv), and then summed to form a worker's total effective dose for comparison to dose limits. These dose components have been considered and are discussed further in the assessment.

6.3.7 Dose Limits and Dose Constraints

6.3.7.1 Dose Limits

Dose limits are established by the Canadian Nuclear Safety Commission to control the exposure of individuals to an acceptable level. Radiation doses below this level are considered safe.

The Radiation Protection Regulations (CNSC 2000), issued by the Canadian Nuclear Safety Commission, provide effective dose limits over specific time periods which a licensee must not exceed. Doses to Nuclear Energy Workers (NEWs) must be below 50 mSv per year and 100 mSv per 5 years. Effectively, this means the annual exposure of a NEW should be less than 20 mSv/a on average. In addition, pregnant NEWs must not exceed 4 mSv during the balance of a pregnancy.

The Radiation Protection Regulations (CNSC 2000), issued by the Canadian Nuclear Safety Commission, also provide equivalent dose limits, for skin and extremities, over specific time periods which a licensee must not exceed. Equivalent doses to Nuclear Energy Workers (NEWs) must be below 150 mSv per year (lens of an eye) and 500 mSv per year (skin, hands and feet). These dose limits will be respected. Prediction of equivalent doses has been omitted because in mining and milling uniform gamma radiation fields are observed. Non-uniform exposures necessitating a determination of equivalent dose to the lens of the eye, skin, or extremities are not anticipated to occur in the mining or milling environment however, workers are monitored using dosimeters measuring deep, shallow and beta doses. Further, workers are adequately protected from skin and eye doses through the use of standard personal protective equipment such as coveralls, gloves, and safety glasses. All doses are presented in terms of effective dose.

6.3.7.2 Dose Constraints

The operating principle of radiation protection is “As Low As Reasonably Achievable (ALARA), social and economic factors considered”. The process of radiation dose optimization involves assessing the sources of radiation exposure and designing facilities, processes, equipment, and work practices to minimize radiation doses to workers and the public. Dose and dose rate constraints are established as objectives, below the dose limit, to be achieved during operations. They are useful in the design of facilities and are a practical implementation of the ALARA principle, typically described in the Code of Practice for the facility.

A Radiation Code of Practice (COP) is a document required by the CNSC under the Uranium Mines and Mills regulations which describes a set of workplace radiological levels and worker exposure levels used for operational control of radiation doses, referred to as administrative and action levels. While an “action level” is to be proposed by the licensee and intended to signify the point at which a loss of control has occurred, the action level values typically used throughout the uranium mining industry in Canada are 1 mSv/week and 5 mSv/3 months. These values are designed to ensure the dose limits of 50 mSv/year and 100 mSv/5 years are not exceeded. Effectively, the action level becomes an additional constraint in the design of the project and dose planning during operation.

AREVA has established workplace nominal exposure rate design objectives for the Kiggavik mill, open pit and underground mines for each dose component. The design objectives are as follows.

Kiggavik Mill

- Gamma Radiation – 1.5 µSv/hr
- Radon Progeny – 0.03 WL
- LLRD – 0.1 DAC

Open Pit Mines

- Gamma Radiation – 100 µSv/day and 400 µSv/week
- Radon Progeny – 0.03 WL
- LLRD – 0.1 DAC

Underground Mine

- Total Effective Dose (per Individual) < 10 mSv/year
- Gamma Radiation < 6 mSv/year
- Radon Progeny < 0.6 WLM (or 3 mSv/year)
- Workplace LLRD – 0.1 DAC (or 2 mSv/year)

These objectives limit the exposure to each dose component. The objectives are met through the use of the mine, facilities and equipment design features, and dose control through workplace operational practices. The worker dose estimates given later in this report for future production scenarios have been estimated for the mill, open pits and underground mine considering these values.

6.3.8 Standards or Thresholds for Determining Significance

The Canadian Nuclear Safety Commission has established dose limits to protect workers and the public. The dose limits established by the Radiation Protection Regulations (CNSC 2000c) were set on the basis of recommendations of the International Commission on Radiological Protection which were designed to prevent health effects and to establish an acceptable level of safety for workers and the public.

Radiation doses below the dose limits established by the CNSC are not considered significant.

The radiation dose limits for workers are 50 mSv/year and 100 mSv/ 5 year period. For the purposes of the evaluation, an annualized value of 20 mSv/year is used as the numerical test of significance for the purposes of evaluating worker radiation dose predictions in this document.

6.3.9 Influence of Inuit Qaujimajatuqangit and Stakeholder Engagement

A group of Elders and members of the Hunters and Trappers Organization (HTO) cautioned AREVA that they want a clear understanding on uranium and its danger and also that people will be unhappy if the issues are not clearly explained (both positive and negative) (IQ-RIJ 2011). Volume 8B has been specifically developed, and discussion also provided in Volume 8, to clearly explain issues related to radioactivity. Additionally, AREVA created short videos explaining aspects of radiation and radiation protection and posted them on the Kiggavik Project blog website (http://kiggavik.ca/videos/). Project-specific issues and concerns identified during Inuit, government and stakeholder engagement were identified in Section 6.1. Below, these issues have been listed in Table 6.3-4 together with an identification of the document where the issue is specifically addressed.

Table 6.3-4 Stakeholder Concerns Relating to Radiation and Uranium

Issue	Document
Potential health hazards of uranium;	Volume 8
radiation monitoring of people and areas in the open pits, underground mines and mill;	Volume 8 Appendix 2Q
radiation monitoring off site, e.g. dust levels, concentrations;	Volume 8 Appendix 2Q
radiation dose limits, reporting and controls in place to protect people;	Volume 8
background Radiation, e.g. properties, occurrence, levels;	Volume 8
cancer rates in Saskatchewan and Nunavut;	Volume 9
properties of Uranium concentrates e.g. radiation properties, hazards, protection of workers and public during transport, storage and transfer of Uranium concentrates;	Volume 8
history of uranium mining in Canada, worldwide and by ARC;	Appendix 8B
properties of uranium, e.g. types of radiation emitted, radon daughters, detection, internal and external hazards, ability to explode, units of measure;	Volume 8
details of past uranium miners health studies;	Appendix 8B
Potential by-products of uranium mining and effects to environment and people;	Volume 8
use of uranium for nuclear weapons, e.g. history, present uses, Non-proliferation Treaty;	Appendix 8B

Table 6.3-4 Stakeholder Concerns Relating to Radiation and Uranium

Issue	Document
alternative uses of Uranium, e.g.. medical and cancer treatments;	Appendix 8B
details on regulation of uranium mining in Canada, Nunavut and Northwest Territories;	Volume 8
details on decommissioning and reclamation of land needs to be done properly so that the public can use land without incidents or concerns; and	Volume 8 & Appendix 2R
Potential impact of uranium entering the food chain, e.g. plants, caribou, humans.	Volume 8

6.4 Worker Radiation Dose Assessment

6.4.1 Background Radiation Exposures

Background radiation exposures for workers refer to the existing radiation exposures resulting from natural background radiation and man-made exposure such as medical diagnostic exposures and airline flights. The background exposures for workers are the same as for the general public and have been addressed in Section 4.1. Radiation exposures calculated within this radiation dose assessment section refer to exposures which are incremental to background.

Site radiation exposure measurements are conducted during the post-construction, pre-operation stage to characterize the local baseline conditions in workplaces.

6.4.2 Activities Without Radiation Exposure

The following activities, as identified in Table 6.3-2 Project-Environment Interactions - Worker Exposure to Radioactivity, are not considered to involve exposure to radioactive materials. No further assessment of the activities listed below is conducted.

Construction - The construction period is not expected to result in any incremental worker exposure to radiation. Radioactive materials are not used or encountered during the construction activities of the project. Concurrent mining activities conducted while the mill is being constructed are scheduled to take place in waste rock and will not result in radiation exposures. Confirmatory monitoring of radiological exposures including gamma radiation, radon, radon progeny and long-lived radioactive dust will be conducted during the construction period to validate assumptions on radiation exposures.

Generation of power – Power will be generated using on-site diesel generators. The operation of this equipment does not involve the use of radioactive materials. No incremental exposure is anticipated to workers from this activity.

Explosives storage and handling - The ammonium nitrate storage area, emulsion plant, powder magazine and detonator magazines do not involve the use of radioactive material. No incremental exposure is anticipated to workers from these activities.

On-going Exploration (Aerial surveys) - Radioactive materials are not involved in exploration aerial survey work. Exploration workers, monitored under Exploration's radiation protection program, are expected to receive no incremental dose from exposure to radioactive materials while conducting this activity.

Post-Closure – Decommissioning objectives are established to ensure that post-closure radiation exposures will not exceed the dose limit for the general public (Tier 3, Technical Appendix 2R). No further assessment is conducted of the post-closure conditions as the site end-state must meet public dose limits, which are established for the protection of public health.

The following activities involve limited exposure to radioactive materials. The assessment of exposure to workers during these activities is integrated into the assessment of exposures during mining and milling of uranium ores.

Hazardous materials storage and handling – The handling and storage of hazardous materials is not expected to result in an incremental exposure to workers. Any worker exposure to radioactive contaminated materials being stored has been addressed in the worker dose assessments for the mill and mines and within procedures of the Radiation Protection program.

Water and sewage treatment – Water treatment and waste water management do not encounter radioactive materials in significant quantities. Generally, water treatment facilities are considered low-radiation areas. Exposure is generally from radon which degasses from water in the facility. Exposure of workers within the facility is addressed in an integrated fashion within the worker dose assessment for the mill.

Discharge of treated effluents – As above, the discharge of treated effluents does not contain radioactive material in significant quantities. Exposure of workers is addressed within the worker dose assessment for the mill.

Waste Management - All workers are responsible for participation in waste management on the Kiggavik site. The segregation of radiological contaminated waste involves limited exposure to radioactive materials and is addressed through the worker dose assessments and within procedures of the Radiation Protection program.

Decommissioning – Radioactive materials are managed during the operating period of the project. At the time of final decommissioning, mining of radioactive ores will be completed, materials processed through the mill, and radioactive waste products placed into the tailings management facilities, resulting in minimal residual radioactive materials at the site. Decommissioning activities will be primarily focussed on the demolition of surface facilities and earthworks involving movement of non-radioactive materials. Experience in the decommissioning of uranium mine sites in northern Saskatchewan has demonstrated that radiation exposures during the decommissioning activities are generally a fraction of the exposures during the operating period.

6.4.3 Assessment of Workplace Radiation Exposures – Open Pit Mining

6.4.3.1 Methodology

Local residents have *expressed concern about worker exposures to radiation while mining* (EN–RB OH Nov 2010[61], EN–CI OH Nov 2013[62], EN–BL OH Nov 2013[63]).

AREVA has used operating history and industry experience to develop estimates of worker exposure for the Kiggavik Project. Average uranium ore grades for the Kiggavik Project will be less than 0.5% uranium and will primarily be extracted through open pit methods. AREVA used recent experience in open pit mining as a reference case and developed scaling factors based on workforce and mine characteristics. The mine activities were demonstrated to be sufficiently similar to support this method of estimation. AREVA's experience in similar operations has demonstrated that worker radiation doses from mining open pits are a small fraction of the dose limits when mining substantially higher grade material.

The average grade varies between each open pit and annual results vary year-to-year. Radiation dose assessments attempt to span the range of doses. While dose rates will vary with ore grade, the conclusions of the dose assessments are generally insensitive to small changes in ore grade as

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[61] EN - RB OH Nov 2010: *How much radiation does a driller receive?*
[62] EN – CI OH Nov 2013: *Radiation of underground workers versus open pit workers?*
[63] EN – BL OH Nov 2013: *Will the mine be toxic?*

open pit mining is observed to result in average worker doses being a small fraction of the worker dose limit (<1/20th).

Radiation dose estimation to open pit miners is based on recent experience gained during mining of uranium ores in northern Saskatchewan, particularly the mining of the open pits at AREVA's McClean Lake Operation. At McClean Lake, AREVA has excavated a series of 5 open pit mines and collected detailed information on radiation dose rates, worker radiation exposure and mine production parameters which can be used to predict radiation doses in future open pit mining scenarios.

The experience in mining open pits in Northern Saskatchewan forms a reference case. The reference case establishes reference collective dose values for each mining job group per tonne of uranium mined which can be used to evaluate future doses in open pit mining. For the Kiggavik Project, radiation doses to mine workers have been estimated by applying reference case collective radiation dose values after consideration of the planned production levels and ore grade scenarios in the proposed Kiggavik mining schedule. This methodology is consistent with dose predictions made in various radiation dose assessments conducted by AREVA within environmental impact assessments conducted for open pit mining for the Sue E Project (AREVA 2004), Caribou Project (AREVA 2009) and Midwest Project (AREVA 2011).

The process of estimating doses for Kiggavik open pit mining is summarized as follows:

- The proposed mining at Kiggavik was evaluated to determine the suitability for estimation of radiation doses using established dose per tonne values in the reference case.
- Reference case, base case, and upper bound cases are described.
- Collective effective dose per tonne (CED/t) factors developed for each job category were applied using project-specific production parameters to estimate average annual collective doses for various mine workers for both the base case and the upper bound case.
- Average annual anticipated doses were estimated based on projected staffing levels for both cases.
- Maximum annual anticipated doses were estimated for each case, based on the observed maximums in the reference case scaled for mine production levels.

Reference Case

The reference case was developed from the mining of open pits in Northern Saskatchewan, in particular the Sue C pit at the McClean Lake Operation. The reference case produced 14,100 t of uranium at an average grade of 2.15% U over the span of 4 years (or an average of 3525 T U/a). The reference data is presented in Tables 6.4-1 and 6.4-2. Table 6.4-1 shows the collective worker doses, in mSv, for each 1000 tonne of uranium mined. Each of the individual dose components (i.e.

Gamma, LLRD, & RnP) is presented. Table 6.4-2 shows the annual total effective worker dose (TED), which is the sum of the individual dose components.

In the reference case it is observed that for every 1000 tonnes of U mined, the group of 38 heavy equipment operators (HEO) collectively received a dose from gamma radiation of 8.95 mSv. For an average year of production of 3,525 TU, the average HEO received a dose of 0.90 mSv. As a confirmation on the method used, calculations of radiation exposure rates based on source and shielding characteristics are performed. For example, the gamma radiation dose rate from a 1 m thick slab of uranium ore containing 2.15% uranium is approximately 80 µSv/h (Chambers et al. 1981); shielding in the equipment cabs is observed to reduce the gamma exposure rate by a factor of approximately 4, to approximately 20 µSv/h. In a 1800 hour work year, where the HEOs conducted uranium ore mining for less than 2% of their work time, a dose of approximately 20 µSv/h X 1800 work hours/year x 2% hours in ore = 720 µSv/year, or 0.72 mSv/year. The average observed dose in open pit mining in northern Saskatchewan was 0.90 mSv/year.

Table 6.4-1 Reference Case: Observed Collective Dose/ 1000 tonnes U for Open Pit Mine Workers

	Worker	**Collective Dose/1000 Tonne U**			
Job Category	**Count**	**Gamma**	**LLRD**	**RnP**	**TED**
Geologists / Geo Techs	7	1.54	0.21	0.31	2.05
HD Maintenance General Supervisor	1	0.04	0.05	0.08	0.18
HD Shop Supervisors	2	0.03	0.00	0.00	0.03
Mine Engineer	1	0.02	0.00	0.03	0.05
Mine Maintenance	22	0.90	0.13	0.64	1.67
Mine Superintendent	1	0.02	0.05	0.04	0.12
Pit General Supervisor	2	0.08	0.02	0.06	0.16
Pit Supervisors	6	0.63	0.11	0.40	1.15
Drillers/Blasters	7	1.30	0.19	0.26	1.74
Heavy Equipment Operators	38	8.95	1.33	1.98	12.26
Office workers	1	0.00	0.02	0.06	0.08
Surveyors	3	0.35	0.06	0.11	0.52
Trainer	1	0.01	0.01	0.02	0.04
Total	**92**				

Table 6.4-2 (revised) Reference Case: Annual Average and Maximum Doses for Open Pit Mine

Job Category	Worker	Average Annual Dose (mSv/a)				Maximum Annual Dose (mSv/a)			
	Count	Gamma	LLRD	RnP	TED	Gamma	LLRD	RnP	TED
Geologists / Geo Techs	7	2.39	0.33	0.48	3.20	3.15	0.62	0.83	4.15
HD Maintenance General Supervisor	1	0.15	0.19	0.29	0.63	0.59	0.36	0.71	1.12
HD Shop Supervisors	2	0.40	0.02	0.03	0.45	0.40	0.02	0.03	0.45
Mine Engineer	1	0.30	0.03	0.43	0.76	0.30	0.03	0.43	0.76
Mine Maintenance	22	0.42	0.07	0.30	0.78	1.49	0.14	0.95	2.00
Mine Superintendent	1	0.30	0.74	0.61	1.65	0.30	0.74	0.61	1.65
Pit General Supervisor	2	0.55	0.16	0.43	1.15	0.80	0.18	0.77	1.75
Pit Supervisors	6	1.26	0.23	0.81	2.30	2.20	0.57	1.35	3.47
Drillers/Blasters	7	1.07	0.19	0.22	1.44	3.79	0.50	0.54	4.65
Heavy Equipment Operators	38	2.46	0.39	0.57	3.37	6.65	1.03	1.49	8.31
Sue Office workers	1	0.00	0.07	0.20	0.27	0.00	0.17	0.33	0.50
Surveyors	3	1.63	0.27	0.53	2.44	2.30	0.35	0.65	3.26
Trainer	1	0.10	0.06	0.11	0.27	0.20	0.11	0.17	0.47

Base Case

The base case scenario represents the assessment basis case of 4000 tonnes of uranium (tU) produced annually from mining ore at an average grade of 0.4% U. Uranium ore production will average less than 4% of total material movements.

Upper bound case

The upper bound case has been selected at 20% higher grade and 20% higher production, (i.e. 0.5 %U and 5000 T U/year respectively) than the base case scenario.

Collective doses for each job group were divided by the anticipated job group size to estimate individual worker doses, as was done for the base case. The upper bound case considers a smaller workforce sharing the collective dose during maximum mine production.

6.4.3.2 Exposure Assessment

The assessment of potential radiation exposures has been conducted based on a reference case for both base case and upper bound case scenarios, described in Table 6.4-3.

Table 6.4-2 (Revised) Comparison of Mining Parameters for Cases

Aspect	Reference Case	Open Pit	
		Base Case	**Upper Bound Case**
Ore Grade (%U)	2.15	0.4	0. 5
Uranium Production (Tonnes U/Year)	3,525	4000	5000
Ore production (Tonnes/year)	163,953	1,000,000	1,000,000
Total Material (Tonnes/year)	11,580,624	~ 30,000,000	~ 30,000,000
Ore Production as percentage of total materials moved	1.4%	~ 3.3%	~3.3 %

Radiation doses in mining are observed to relate to the quantity and grade of uranium ore excavated, the mining method used, and the efficiency of the ore excavation. A comparison of these variables is as follows:

- The quantity of uranium to be produced annually from the Kiggavik open pits is similar to the annual quantity removed in the reference case.

- The grade of the ore is lower than that mined in Northern Saskatchewan operations. The average grade of ore mined in the reference case was 2.15 % compared to the projected average ore grade of the Kiggavik open pits of 0.4 % uranium. Uranium grades determine radiation dose rates. Average radiation dose rates are anticipated to be approximately 5 times less at Kiggavik than in the reference case.
- The mining method for the Kiggavik open pit mines will be similar to the reference case, i.e., drill, blast, muck, and haul. The production methods are sufficiently similar to use the reference case as basis for dose estimation for open pit mining at Kiggavik.
- The efficiency of ore mining is lower at Kiggavik than in the base case, i.e. a greater amount of material must be mined at Kiggavik per tonne of uranium production. This parameter increases the proportion of time spent excavating ore. Approximately 5 times more ore material must be excavated to extract the same amount of uranium at Kiggavik than in the reference case.
- The uranium in the Kiggavik pits is more dispersed throughout the volume of material to be mined than in the reference case. This will result in the exposure period at Kiggavik being distributed throughout any given year, rather than concentrated as in the reference case when there were shorter periods of intensive ore mining.

For the purposes of a radiation dose assessment, prediction of radiation doses for the Kiggavik open pit mines based on experience gained at AREVA's Sue C open pit mine will be conservative.

In the reference case, mining began in 1997 and continued into early 2002 with a suspension of mining activities in 1999 for about a nine month period. Radiation doses to workers were determined using dose measuring devices as well as measures of workplace radiological levels paired with workplace occupancy information. In the mining of the open pits at the Northern Saskatchewan operations, radiation dose information for all workers is collected in a database available for analysis of exposures to gamma radiation, radon progeny and long-lived radioactive dusts. The observed radiation dose to each worker in each job category over this period was summed to determine the collective dose for each category, i.e. the total amount of radiation exposure for a category of workers. Job categories included:

- Geologists /Geology Technicians
- HD Maintenance General Supervisor
- HD Shop Supervisors
- Mine Engineer
- Mine Maintenance
- Mine Manager
- Pit General Supervisor
- Pit Supervisors
- Drillers /Blasters
- Heavy Equipment Operators
- Office workers
- Surveyors
- Trainer

In the reference case the collective doses for each job category were divided by the total uranium production over the period to establish the collective effective dose per tonne of uranium production

(CED/t U). This provided an estimate of the amount of radiation exposure a category of workers received for each tonne of uranium mined. The reference case produced 14,100 t of uranium.

Table 6.4-B Worker Dose Calculations shows how each dose component was calculated and includes a Kiggavik Geologist as an example. For each job category, the collective effective dose per tonne of uranium produced in the reference case was multiplied by the anticipated annual uranium production value for the base and upper bound case for Kiggavik open pit mines to establish the estimated collective dose for each job category. The maximum component dose at Kiggavik for a particular job category has been estimated to be equal to the reference maximum dose for the job category, multiplied by the ratio of Kiggavik to Reference average doses.

Table 6.4-B (NEW-IR) Worker Dose Calculations

Worker Dose Calculations	
Average Component Dose for a Job Category:	Dose $_{(Kiggavik)}$ (mSv) = CED/1000 t $_{(reference)}$ x Production$_{(Kiggavik)}$ (t U_3O_8) / # of workers $_{(Kiggavik)}$
Total Effective Dose (*TED*):	$TED\ (mSv/a) = \overline{D}_{\gamma}(mSv/a) + \overline{D}_{RnP}(mSv/a) + \overline{D}_{LLRD}(mSv/a)$
The average component dose at Kiggavik for a particular job category will equal the collective effective dose per tonne for that component in the reference case for the same job category, multiplied be the annual uranium production at Kiggavik, divided by the number of workers in the job category.	
Example: Kiggavik Geologist- Base Case Average Annual Dose (mSv/a)	
Gamma Radiation (*γ*) Dose:	$\overline{D}_{(\gamma)} = 1.54\ person \times \frac{mSv}{1000t} \times \frac{4000\ t/a}{4\ persons} = 1.54\ mSv/a$
Radon Progeny (*RnP*) Dose:	$\overline{D}_{(RnP)} = 0.31 person \times \frac{mSv}{1000t} \times \frac{4000\ t/a}{4\ persons} = 0.31\ mSv/\text{a}$
Long Lived Radioactive Dust (*LLRD*) Dose:	$\overline{D}_{(LLRD)} = 0.21 person \times \frac{mSv}{1000t} \times \frac{4000\ t/a}{4\ persons} = 0.21\ mSv/\text{a}$
Total Effective Dose (*TED*):	$TED_{avg} = 1.54 + 0.31 + 0.21 = \mathbf{2.06\ mSv/a}$
Maximum Worker Dose Calculations	
Maximum Dose (D_{max}):	$Max.Dose_{(Kiggavik)} = Max.Dose\ (Reference) \times \frac{\overline{D}_{(Kiggavik)}}{\overline{D}_{(Reference)}}$
Maximum Total Effective Dose (TED_{max}):	$TED_{max}(mSv) = D_{(\max)\,\gamma}(mSv) + D_{(\max)\,RnP}(mSv) + D_{(\max)\,LLRD}(mSv)$
The maximum dose at Kiggavik is expected to be in a similar proportion to the maximum experienced in the reference case. The maximum component dose at Kiggavik for a particular job category will equal the reference maximum dose for the job category, multiplied by the ratio of Kiggavik to Reference average doses.	
Example: Kiggavik Geologist- Base Case Maximum Annual Dose (mSv/a)	
Gamma Radiation (*γ*) Dose:	$D_{max\ \ (\gamma)} = 3.15 \times \frac{1.54}{2.39} = 2.02\ mSv$
Radon Progeny (*RnP*) Dose:	$D_{max\ \ (RnP)} = 0.83 \times \frac{0.31}{0.48} = 0.53\ mSv$
Long Lived Radioactive Dust (*LLRD*) Dose:	$D_{max\ \ (LLRD)} = 0.62 \times \frac{0.21}{0.33} = 0.40\ mSv$
Total Effective Dose (*TED*) Dose:	$TED_{max} = 2.02 + 0.53 + 0.40 = \mathbf{2.95\ mSv}$

Dose estimates for the base and upper bound case are presented in Table 6.4-4 and Table 6.4-5 respectively.

Table 6.4-4 (Revised-IR) Base Case: Average and Maximum Annual Dose Estimation for Open Pit Mine Workers

Job Category	Count	Average Annual Dose (mSv/a)				Maximum Annual Dose (mSv/a)			
		Gamma	LLRD	RnP	TED	Gamma	LLRD	RnP	TED
Geologists / Geo Techs	4	1.54	0.21	0.31	2.05	2.02	0.40	0.53	2.95
HD Maintenance General Supervisor	1	0.17	0.21	0.34	0.72	0.68	0.41	0.81	1.90
HD Shop Supervisors	5	0.02	0.00	0.00	0.03	0.02	0.00	0.00	0.03
Mine Engineer	4	0.02	0.00	0.03	0.05	0.02	0.00	0.03	0.05
Mine Maintenance	28	0.13	0.02	0.09	0.24	0.45	0.04	0.29	0.78
Mine Superintendent	1	0.09	0.21	0.17	0.47	0.09	0.21	0.17	0.47
Pit General Supervisor	2	0.16	0.05	0.12	0.33	0.23	0.05	0.22	0.50
Pit Supervisors	4	0.63	0.11	0.40	1.15	1.10	0.29	0.67	2.06
Drillers/Blasters	8	0.65	0.09	0.13	0.87	2.29	0.25	0.31	2.85
Heavy Equipment Operators	28	1.28	0.19	0.28	1.75	3.45	0.50	0.74	4.70
Office workers	6	0.00	0.01	0.04	0.05	0.00	0.03	0.06	0.10
Surveyors	12	0.12	0.02	0.04	0.17	0.16	0.02	0.05	0.23
Trainer	2	0.03	0.02	0.03	0.08	0.06	0.03	0.05	0.13
Collective	105	55.49	8.78	15.96	80.23				
Average		0.53	0.08	0.15	**0.76**				
Maximum						3.45	0.50	0.81	**4.70**

Table 6.4-5 (Revised-IR) UpperBound Case: Average and Maximum Annual Dose Estimation for Open Pit Mine Workers

Job Category	Count	Average Annual Dose (mSv/a)				Maximum Annual Dose (mSv/a)			
		Gamma	LLRD	RnP	TED	Gamma	LLRD	RnP	TED
Geologists / Geo Techs	4	1.92	0.26	0.38	2.57	2.52	0.50	0.67	3.69
HD Maintenance General Supervisor	1	0.21	0.26	0.42	0.90	0.85	0.51	1.01	2.37
HD Shop Supervisors	5	0.03	0.00	0.00	0.03	0.03	0.00	0.00	0.03
Mine Engineer	4	0.03	0.00	0.04	0.07	0.03	0.00	0.04	0.07
Mine Maintenance	28	0.16	0.02	0.11	0.30	0.57	0.05	0.36	0.98
Mine Superintendent	1	0.11	0.26	0.22	0.59	0.11	0.26	0.22	0.59
Pit General Supervisor	2	0.20	0.06	0.15	0.41	0.29	0.06	0.27	0.62
Pit Supervisors	4	0.79	0.14	0.50	1.43	1.37	0.36	0.84	2.57
Drillers/Blasters	8	0.81	0.12	0.16	1.09	2.87	0.31	0.38	3.56
Heavy Equipment Operators	28	1.60	0.24	0.35	2.19	4.31	0.63	0.93	5.88
Office workers	6	0.00	0.02	0.05	0.06	0.00	0.04	0.08	0.12
Surveyors	12	0.15	0.02	0.05	0.22	0.20	0.03	0.06	0.29
Trainer	2	0.04	0.02	0.04	0.10	0.07	0.04	0.06	0.17
Collective	105	69.36	10.97	19.96	100.29				
Average		0.66	0.10	0.19	**0.96**				
Maximum						4.31	0.63	1.01	**5.88**

6.4.3.3 *Exposure to Radon Gas*

Doses resulting from radon gas exposure, as separate from radon progeny exposure, are not typically measured in open pit mining as the potential dose from radon gas is below the level at which dose monitoring is expected by nuclear regulators (CNSC 2003d). Radon doses in open pit mining is a small fraction of the dose from radon progeny, which itself is a small fraction of the dose limit. A screening level assessment of potential radon gas doses during open pit mining at Kiggavik is presented for each open pit in Table 6.4-5 for both a base case and a sensitivity case. In the calculation of doses, the maximum radon flux from each open pit, as calculated and presented in *Tier 3 Technical Appendix 4B: Air Dispersion Assessment*, was used to estimate radon concentrations in the open pits. A dose was estimated assuming a worker spends 100% of their 1770-hour work year exposed at the resultant radon concentration. In the sensitivity case, very conservative values for wind speeds and mixing volumes were used. The assessment indicates the potential radon doses for open pit mine workers are small and do not warrant individual estimation or monitoring.

Table 6.4-5: Assessment of Potential Radon Gas Dose in Open Pit Mining at Kiggavik

	Pit Parameters				Base Case (c)				Sensitivity Case (d)			
Open Pit	Pit Area (ha)	Pit Diameter (m)	Pit Depth (m)	Maximum Rn Flux(a) (Bq/s)	Wind Speed(b) (m/s)	Mixing Height (m)	Incremental Rn Conc (e) (Bq/m^3)	Annual Dose (f) (mSv)	Wind Speed(b) (m/s)	Mixing Height (m)	Incremental Rn Conc (e) (Bq/m^3)	Annual Dose (f) (mSv)
Main Zone	39.2	353	235	1.4E+06	4.1	235	24.7	0.01	0.5	118	134.9	0.04
Centre Zone	15	219	110	4.2E+05	4.1	110	33.9	0.01	0.5	55	139.8	0.04
East Zone	8	160	100	1.7E+06	4.1	100	165.9	0.04	0.5	50	852.3	0.23
Andrew Lake	44	374	275	1.6E+06	4.1	275	20.6	0.01	0.5	138	124.4	0.03

a) Maximum radon flux calculated in Volume 4, Appendix 4B
b) Wind speed of 0.5 m/s used for low wind, stagnant air; average wind speed observed at Kiggavik site is 4.1 m/s (Volume 4, Appendix 4B).
c) Base case considers mixing within pit in air with average wind speed of 4.1 m/s, using 50% of pit diameter.
d) Sensitivity case considers mixing within 50% of pit height in stagnant air of 0.5 m/s, using 50% of pit diameter.
e) Rn Conc (Bq/m^3) = Rn Flux (Bq/s) / [(Wind Speed (m/s) x Mixing Height (m) x Diameter (m) x 0.5]
f) Rn dose (mSv)= Rnconc(Bq/m^3) x Breathing rate(m^3/h) x t(h) x DCFRn = Rn Conc (Bq/m^3) x 1.2 m^3/h x 1770h x 20 mSv/1.6x10^8

6.4.3.4 Summary of Exposure Assessment

Radiation protection practices in open pit mining operations consist primarily of operational practices including preventative measures, worker training and awareness, work planning, and ongoing review and follow-up of results. Previous open pit mining of the JEB and Sue deposits at AREVA McClean Lake Operation has demonstrated that the worker exposures have been well below both predicted values and Code of Practice targets. Average annual radiation doses experienced during open pit mining at McClean Lake were less than 1.0 mSv, with maximum annual doses typically less than 3.5 mSv. Average ore grades in the series of 4 Sue pits ranged from 0.41% in Sue A to 2.15% in Sue C, with an overall average grade of 1.37% U. Using the experience at the McClean Lake Operation to evaluate potential doses at Kiggavik (with average ore grade of 0.4% U and maximum of less than 0.8%), average annual doses are similarly expected to be less than 1 mSv. The upper bound case scenario estimated an average annual dose of less than 1 mSv with a maximum value ranging to 5.88 mSv using a maximum uranium production of 5000 TU/year at an ore grade of 0.5%. It is expected that worker radiation exposures during mining of the Kiggavik pits will be controlled to or below those recorded at the McClean Lake Operation.

6.4.3.5 Mitigation Measures

6.4.3.5.1 Protection from External Hazards

In general, the control of worker exposure to external gamma radiation is achieved primarily through design features of heavy equipment and operational practices, and includes the following three methods:

1. Shielding: Lead and steel shielding is applied strategically to attenuate gamma rays, thereby reducing the level of gamma radiation in the workplace.
2. Time: Areas with significant radiation levels are identified and the time spent in such areas is minimized, for example scheduled maintenance work is conducted away from uranium-bearing materials, where practicable; and while working on ore benches, time spent outside vehicles is minimized.
3. Distance: Generally, radiation levels decrease with distance from radioactive material. Where possible, workers and the sources of external gamma radiation are distanced from each other.

6.4.3.5.2 Protection from Internal Hazards

The control of worker exposure to radon and radon progeny, and long-lived radioactive dust is achieved primarily through design features and operational practices and includes the following three methods:

Containment: The containment of internal hazards is achieved through operational practices such as the use of dust suppression with water; controlled blasting in ore zones to minimize throw of ore bearing materials; and proper control of water to prevent radon and particle migration.

Ventilation: Internal hazards in open pit mining are minimized by keeping windows of vehicles closed and using positive pressure ventilation system in vehicle cabs; air filtration devices and weather stripping in vehicles are maintained in good order and building ventilation and containment equipment, such as fans, furnaces, doors, and windows is routinely maintained.

Housekeeping: Operational practices that control worker exposure to internal hazards includes cleaning the interiors of vehicles frequently; cleaning the exteriors of vehicles before maintenance work is conducted; and routine cleaning of shop areas.

6.4.3.5.3 Worker Awareness

During public engagement activities, community members *expressed concerns about workers being monitored and working in a safe environment* (EN– BLNIRB Apr 2010[64] , EN–BL OH Nov 2013[65],[66]EN–RB OH Nov 2010[67] EN–BL NIRB Feb 2010[68]).

The following worker awareness measures will be used at Kiggavik to educate and inform mine workers, on a day-to-day basis, of potential exposures to radioactive materials:

- a copy of the Code of Practice manual available, and explained to workers. The Code of Practice will provide guidance to workers in their activities if key indicator levels are reached;
- area monitoring results will be posted and available to workers through notice boards;
- workers will wear direct reading dosimeters and monitor their accumulated gamma dose throughout the day;
- radiation protection training will be provided to all workers;

[64] EN – BL NIRB Apr 2010: *What is the plan to protect people and workers? Would like to see a protection plan put in place for the people and workers.*

[65] EN – BL OH Nov 2013: *Radiation exposure to workers. How do we keep people safe?*

[66] EN – BL OH Nov 2013: *Radiation: How do you know what reading is dangerous? What if you go over? Does it take long to get a sample back?*

[67] EN – RB OH Nov 2010: *What happens if I receive too much radiation and how do I know?*

[68] EN – BL NIRB Feb 2010: *Do mining companies perform safety inspections to ensure all work is done appropriately? How often would inspections occur?*

- trained radiation protection staff are available to provide guidance and answer questions; and
- radiation protection staff will provide personal dosimeter results to all workers.

Mining staff will plan work in a manner to minimize worker exposure where possible, based on the following procedures:

- regular review meetings will be held with mining and radiation protection staff to review worker doses with respect to past and upcoming work;
- gamma radiation levels will be monitored daily within the pit in areas of potential worker exposure and results and will be reviewed with respect to expected ore grades;
- worker doses, estimated by direct reading dosimeters, will be recorded and reviewed by mine operations supervisors and radiation protection staff daily; and,
- potential radiation exposures not identified in individual worker dose assessments due to workers conducting non-routine activities will be identified, an assessment of potential dose conducted, and a safe work permit issued, as required. The safe work permit describes any constraints (e.g. time duration), and specialized equipment or procedural requirements for the non-routine activity.

6.4.4 Assessment of Workplace Radiation Exposures – Underground Mining

6.4.4.1 Methodology

Communities members have expressed concerns about worker exposures to radiation while mining (EN–RB OH Nov 2010[69], EN–CI OH Nov 2013[70], EN–BL OH Nov 2013[71]).

AREVA has used operation history from Northern Saskatchewan uranium projects and industry experience to develop estimates of worker exposure for the Kiggavik Project. Underground mining of uranium ore using entry methods similar to those proposed for the Kiggavik Project has been conducted successfully by mine operators in Canada for many years. To estimate underground mine worker doses, AREVA evaluated the mine exposure conditions paired with task-time analysis to develop dose estimates. Radiation doses to underground workers are sensitive to mine planning.

[69] EN – RB OH Nov 2010: *How much radiation does a driller receive?*

[70] EN - CI OH Nov 2013: *Radiation of underground workers vs open pit workers?*

[71] EN – BL OH Nov 2013: *Will the mine be toxic?*

AREVA preferred to use a task-time-exposure analysis for underground mine development so that it may be used as a tool in the optimization process throughout the mine lifecycle.

Dose assessments conducted during the feasibility and environmental assessment stages are planning tools, used to determine the ability of an activity to achieve dose objectives below the dose limits. Mining plans will evolve through the detailed design phase and, correspondingly, AREVA anticipates updating dose assessments for underground mining. The dose assessments incorporate planned mitigation during mining, and measurements are carried out during operations, and corresponding controls are in place, to achieve dose objectives. The average grade varies between each underground mine and annual averages will vary year-to-year. Radiation dose assessments attempt to span the range of doses; the conclusions of the dose assessments are generally insensitive to small changes in ore grade.

6.4.4.2 Radiological Design of End Grid Mine

Underground mine workers will be exposed to workplace radiation including chronic low-level exposures to radon & radon progeny, airborne long lived radioactive dust (LLRD) and external gamma radiation. The projected workplace radiation levels and associated worker exposures have been evaluated to ensure that the proposed operations will meet the AREVA dose constraints established for the project and the regulatory dose limits.

The End Grid mine design is focussed on the maximum use of mobile equipment where the worker is encapsulated within a shielded and ventilated cab. While unshielded entries into the ore body will be required, these unshielded entries have been minimized for the purpose of controlling and minimizing worker radiation exposures. The general principle is that workers will prepare for a job in areas outside the ore body, enter the ore body to perform a specific task and then leave.

The basic stope design on a level is presented in Figure 6.4-1. Extraction of the ore will begin at the downwind end of the ore body with successive production stopes retreating towards the fresh air. The completed production stopes will be backfilled to reduce the dead air volumes which would otherwise accumulate radon progeny that could leak into the fresh air stream.

In Figure 6.4-1 the blue arrows out of the stopes depict the ventilation ducting used to exhaust air from the stopes. The clean ventilation air will be drawn down Fresh Air Raises (FAR), through the access drift and into the production stopes. The relatively short distance between the bottom of FARs and the production stopes will ensure that the air arriving at the stope is clean. The ventilation air is expected to become contaminated with radon progeny and LLRD within the stopes. This contaminated air will be ducted directly to the exhaust Return Air Raises (RAR). The minimum rate of ventilation flow will be determined by the diesel requirements however a minimum nominal airflow of 15 m^3 /s has been assumed for each active production stope.

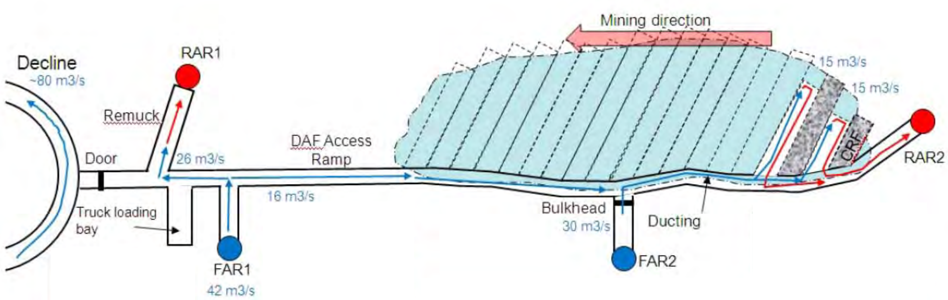

Figure 6.4-1 Conceptual Layout of Production Stopes

The radiological design of the proposed mine includes the use of gamma-shielded and ventilated mobile equipment. While the ventilation airflow in each production stope has been designed to produce acceptable radon progeny levels in the stopes, the cabs of the mobile equipment will be ventilated through HEPA filters in order to further reduce the radon progeny levels within the equipment cabs and to reduce the level of airborne LLRD.

6.4.4.3 Characterization of Gamma Radiation

Gamma radiation exposure will be the primary contributor to effective dose for most workers.

Gamma radiation is an external hazard. The gamma radiation emitted from a source can be estimated knowing the characteristics of the source, such as ore grade, composition, size, and shape. For gamma radiation emitted from uranium ore, the dose rate can be calculated as a function of ore grade and the physical geometry. The effects of geometry and shielding are then modelled to estimate the gamma radiation exposure rate. Where workers are exposed to multiple gamma radiation sources, the exposure rates are summed to give an overall exposure rate. When combined with occupancy information, worker dose can be estimated for each exposure scenario. A gamma radiation simulation program called Javashield has been used to predict gamma radiation exposure rates. Javashield is a product of Environmental Instruments Canada, similar in function to the commonly used radiation modelling software Microshield, designed specifically for the uranium mining industry. Information about uranium ore grades and source and receptor geometries is entered into Javashield to calculate absorbed dose rates in µGy/h. For gamma radiation from uranium ore, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) suggests using the conversion of 1 Gy = 0.7 Sv when converting between absorbed dose and effective dose.

6.4.4.4 Characterization of Long-Lived Radioactive Dust

Airborne long-lived radioactive dust (LLRD) is an inhalation exposure hazard. In underground mining, airborne LLRD is usually produced by work activities such as the movement of muck and the passage of vehicles over ore on the sill of a passageway. Exposure to radioactive dust is primarily controlled by using water sprays to keep muck and passageways damp, careful ventilation where the workers are stationed upwind of sources of LLRD and enclosing workers in filtered ventilated cabs. Where maintenance of contaminated equipment is necessary, operational procedures will provide for the cleaning of potentially contaminated equipment prior to maintenance. In special situations, respiratory protection will be provided to workers, but the use of respirators will be limited to exceptional and specific circumstances. The amount of worker LLRD exposure is difficult to predict theoretically, but past experience has shown that, with good dust control measures, LLRD doses can be maintained at approximately the same level as radon progeny doses (CNSC 2009).

The design target is that worker exposures to LLRD will be controlled operationally to keep the dose to the most exposed worker to less than 2 mSv/a, based on experience at other conventional underground uranium mines operated in Northern Saskatchewan, such at AREVA's Cluff Lake mine.

6.4.4.5 Characterization of Radon Progeny

Radon and radon progeny are an inhalation radiation hazard. Radon is a gas that is present within uranium ore and is released from the rock and from mine water during the mining operation. Radon is a noble gas and generally is not itself an inhalation hazard, except in very high concentrations. It is the short-lived radon decay products, referred to as radon progeny, which are of concern. When radon gas is released into a workplace, it will undergo radioactive decay and produce radon progeny. The level of radon progeny in mine air is primarily controlled by diluting contaminated air with fresh uncontaminated air delivered to the underground workplace by fans. In addition source specific (extraction) ventilation is used to prevent sources of airborne radioactivity from contaminating the air in active workplaces.

All underground mines are required to provide a regulated level of ventilation to control diesel exhaust in the mine air. Experience in Northern Saskatchewan uranium mines has shown that with careful control of the air movement, the regulatory ventilation requirements for diesel equipment underground will be also adequate for the control of radon progeny. The overall volume of ventilation air planned for the End Grid mine is based on the regulatory diesel requirements.

6.4.4.6 Exposure Assessment

Gamma Radiation Exposure Modelling

Workplace gamma radiation levels have been estimated on the basis of the ore grades and workplace configurations. This data was then combined with the time workers will stay in various workplaces to arrive at estimates of the radiation exposures to workers.

The following assumptions were used to model gamma dose rates during mining of the End Grid deposit:

- Average grade of 0.30% U with grades as high as 2% U (80% of the estimated grades are less than 0.30%U).
- Access drift length of 150 m and production stope lengths of 50 m (conservative case)
- Primary stope access drift is in the ore but along the footwall
- Drift dimensions of 5 m wide by 5 m high
- Stopes are backfilled with non-mineralized waste rock and ventilation seals and bulkheads will be provided to inhibit radon entry from mined-out areas
- Barren rock is considered to be less than 30 ppm U.

Approximate dose rates have been calculated for a receptor standing in the middle of drift as presented in Table 6.4-6.

Table 6.4-3 Gamma Dose Rates in Drift (μSv/h)

Dose Point	Ore (0.3% U)	Ore (0.5% U)
Middle of Drift, away from face	25	42
Middle of Drift, 1 m from face	30	50

The above dose rates are calculated for exposure from four walls, and the face as indicated. In practice, only a small percentage of production stopes will have all four walls in mineralization. The majority of primary stope drifts will have unmineralized backfill on the floor and in one wall. The majority of secondary stope drifts will have unmineralized backfill on the floor and on both walls. Where there is backfill on the floor this will reduce the dose rates in the middle of a drift by ~25%.

The footwall access drifts located in the ore body will have waste rock on one wall (the footwall side) and ore on the other three. These drifts will have 10 cm of shotcrete applied to them.

Annual Gamma Dose Rates

The annual worker dose projections are based on a reasonable allotment of worker time for each task. They do not take into account the operational radiation protection that would be provided by the mine Radiation Department and according to the operating Code of Practice. Examples of additional actions that could be taken during operations would include:

- The application of additional shotcrete in localized higher grade zones
- The application of shotcrete to the production stope face where grades are elevated
- The use of movable steel shields at the face while loading holes
- Careful pre-planning of higher hazard work to minimize time spent in exposure areas

Though the average grade of the ore body is about 0.3%, there will be periods when the grades will be higher. The calculation of the gamma radiation doses for 0.5% U provides an indication of the sensitivity of the analysis and demonstrates that 0.5% ore can be mined using this mining method. Extraction of an annual average grade of 0.5% can be considered an upper bound for underground mining at End Grid. Tables 6.4-7 and 6.4-8 list the projected annual gamma radiation dose rates (DR) for grades of 0.3% U and 0.5% U, respectively, together with predictions of annual effective gamma doses to mine workers. For the calculations, it was assumed based on equipment specifications and design requirements that workers in the mobile equipment would be shielded by 4 half-value layers of shielding material (Chambers et al. 1981). This includes the assumption that the production stopes will be covered with a 5 to 10 cm thickness of shotcrete where the walls or back are in ore.

Table 6.4-4 Base Case: Estimated Gamma Radiation Dose Rates for Various Mine Positions (0.3% U grade and 4 half-value layers of shielding)

	Task Analysis (Hours)				Dose (µSv/day)		
Job Category	**Barren Rock**	**Ore (Cab)**	**Ore (no Cab)**	**Total**	**Shielded**	**Unshielded**	**Annual Dose (mSv)**
Production Loader operator	4	4	1	9	8	15	3.2
Development Loader operator	9	0	0	9	0	0	0
Backfill LHD operator	4	4	1	9	8	15	3.2
Backfill Truck operators	8	0	1	9	0	15	2.1
Production Truck operators	3	5	1	9	8	15	3.2
Development Truck operators	9	0	0	9	0	0	0
Production Jumbo operator	4	4	1	9	8	15	3.2

Table 6.4-4 Base Case: Estimated Gamma Radiation Dose Rates for Various Mine Positions (0.3% U grade and 4 half-value layers of shielding)

Job Category	Task Analysis (Hours)				Dose (µSv/day)		Annual Dose (mSv)
	Barren Rock	Ore (Cab)	Ore (no Cab)	Total	Shielded	Unshielded	
Development Jumbo operator	9	0	0	9	0	0	0
Blasters	7	0	2	9	0	30	4.2
Production Bolter operator	4	4	1	9	8	15	3.2
Grader operator	9	0	0	9	0	0	0
Shotcrete Operator	3	5.5	0.5	9	11	8	2.6
Development helpers	6	1	2	9	2	30	4.5
UG Labourers (Vent. Crew)	6	1	2	9	2	30	4.5
Supervision	6	1	2	9	2	30	4.5
Surveyors	6	1	2	9	2	30	4.5
Geologists	6	1	2	9	2	30	4.5

NOTES:

1. Unshielded DR = 15 µSv/h, Shielded DR = 2 µSv/h, Ore Trucking DR = 1.5 µSv/h
2. 12 hour shift (9 working) and 140 working days per year.
3. As the cab shielding is increased, the contribution of radiation through windows is more important
4. Radiation doses have not been calculated for time spent in barren mine rock. Radiation exposure in barren rock are anticipated to be a small fraction of the exposure in ore.

Table 6.4-5 Upper Bound Case: Estimated Gamma Radiation Dose Rates for Various Mine Positions (0.5% U grade and 4 half-value layers of shielding)

Job Category	Task Analysis (hours)				Dose (µSv/day)		Annual Dose (mSv)
	Barren Rock	Ore (Cab)	Ore (no Cab)	Total	Shielded	Unshielded	
Production Loader operator	4	4	1	9	13	25	5.4
Development Loader operator	9	0	0	9	0	0	0.0
Backfill LHD operator	4	4	1	9	13	25	5.4
Backfill Truck operators	8	0	1	9	0	25	3.5

Table 6.4-5 Upper Bound Case: Estimated Gamma Radiation Dose Rates for Various Mine Positions (0.5% U grade and 4 half-value layers of shielding)

Job Category	Task Analysis (hours)				Dose (µSv/day)		Annual Dose (mSv)
	Barren Rock	Ore (Cab)	Ore (no Cab)	Total	Shielded	Unshielded	
Production Truck operators	3	5	1	9	13	25	5.4
Development Truck operators	9	0	0	9	0	0	0.0
Production Jumbo operator	4	4	1	9	13	25	5.4
Development Jumbo operator	9	0	0	9	0	0	0.0
Blasters	7	0	2	9	0	50	7.0
Production Bolter operator	4	4	1	9	13	25	5.4
Grader operator	9	0	0	9	0	0	0.0
Shotcrete Operator	3	5.5	0.5	9	18	13	4.4
Development helpers	6	1	2	9	3	50	7.5
UG Labourers (Vent. Crew)	6	1	2	9	3	50	7.5
Supervision	6	1	2	9	3	50	7.5
Surveyors	6	1	2	9	3	50	7.5
Geologists	6	1	2	9	3	50	7.5

NOTES:

1. Unshielded DR = 25 µSv/h, Shielded DR = 3 µSv/h, Ore Trucking DR = 2.5 µSv/h
2. 12 hour shift (9 working) and 140 working days per year.
3. As the cab shielding is increased, the contribution of radiation through windows is more important.
4. Radiation doses have not been calculated for time spent in barren mine rock. Radiation exposure in barren rock are anticipated to be a small fraction of the exposure in ore.

It is evident from the data in Table 6.4-6 and 6.4-7 that cab shielding has the greatest impact on mitigating gamma doses. The majority of worker gamma radiation exposure within the stopes will be in drifts with 2 walls of mineralization, 5 cm of shotcrete and 2 cm of lead cab shielding. The modelling indicates that these mine production workers could work up to the whole year in this scenario without exceeding a gamma radiation dose objective of 6 mSv/a under routine conditions. Supervisors, development helpers, geologists, surveyors and blaster spend proportionally more time in unshielded conditions and hence have the potential to exceed the AREVA dose objective by approximately 25% per year in the upper bound case. In practice, careful application of a Radiation Code of Practice will control these doses to meet objectives.

Radon and Radon Progeny Modelling

The radon and radon progeny concentrations in a mine depend on the ore grade, the porosity of the rock, amount of water inflow, ventilation air flow rates and radon gas residence time. For this preliminary assessment, consideration was given to a single production stope with the following parameters:

- ore grade of 0.3% U
- stope length of 50 m
- Drift dimensions of 5 m x 5 m
- Average Daily Water Inflow Rate = 50 m^3/day
- 3 sides of drift exposed to ore
- Airflow in stope 13 m^3/s; 37 exchanges/hour ; 0.01 exchanges/s

Radon Release from Mine Water:

E_{Rn222} (minewater) = 3000 gU/tonne x 2.48 tonne/ m^3 x 1.22×10^4 Bq / gU
= 9.0×10^7 Bq/ m^3 Ore x 1 m^3 Ore/ 0.1 m^3 water
= 9.0×10^8 Bq/m^3 water x 50 m^3 water / day x 0.2 (i.e. 20% emanation)
= 9.0×10^9 Bq / day / 24 / 3600
= 1.0×10^5 Bq/s

Radon Release from Walls of Stope:

Exposed Surface Area (Ore) = 50 m x 5 m x 3 sides per drift = 750 m2
U-238 (Ore) = 0.30%

ERn222 (surface flux) = 0.5 Bq/s/m2 x 750 m2 x (1.22x104) Bq Ra226/g U x (0.003) gU/g rock BqRa/grock

= 1.4×10^4 Bq/s

Total Radon Flux to Working Stope:

ERn222 (Total flux) = ERn222 (surface flux) + ERn222 (minewater)
= 1.4x104 Bq/s + 1.0 x105 Bq/s
= 1.14 x105 Bq/s

Radon and Radon Progeny Concentrations at Equilbrium:

Rn (Bq/m3) = Radon Flux (Bq/s) / Air Exchange Rate (s-1) / Volume (m3)
= 1.14 x105 Bq/s / 0.01/s / (50 m x 5 m x 5 m)
= 9,120 Bq/m3

RnP (WL) = 0.078 WL72

Effective Dose Rate from RnP = 0.078 WL x 5 mSv/WLMx 1M/170 h x 1000 µSv/mSv
= 2.2 µSv/h

Effective Dose Rate from Rn73 = 9120 Bq/m3 x 20 mSv/1.6x108Bq x 1000 µSv/mSv
= 1.1 µSv/h

Though the average grade of the ore body is about 0.3%, there will be periods when the grades will be higher. In order to test the sensitivity of the dose calculations for radon progeny, the calculations were repeated for an upper bound annual production ore grade of 0.5% The calculation of the radon progeny doses for 0.5% U provides an indication of the sensitivity of the analysis and demonstrates that 0.5% ore can be mined using this mining method.

As shown in Figure 6.4-1, fresh ventilation air will be provided to each production stope with the contaminated air exhausted directly to the exhaust raise. Therefore the only source of radon gas considered was the radon gas generated within the stope.

The calculation of the generation of radon gas within each stope for 0.3% ore found that each production stope would be subject to an average Rn-222 gas inflow of 1.14×10^5 Bq/s. This radon gas would be generated from the walls of the stope and by the mine water inflow. Increasing the ore grade to 0.5% would increase the radon gas emanating from the sides of the drifts. The calculated rate of Rn-222 gas inflow for 0.5% ore is 1.8×10^5 Bq/s. For all other areas of the mine, the nominal radon progeny concentration value of 0.01 WL has been used for estimation of doses.

Most entries to the production stopes will be by workers within the cabs of mobile equipment. The High Efficiency Particulate Air (HEPA) filters for these cabs will remove the airborne LLRD and any radon progeny in the mine air. However, the radon gas will pass through the HEPA filters and decay to produce radon progeny in the cab. For this assessment it was assumed that:

- The inside volume of the cab on the mobile equipment was 2 m^3

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[72] From solution of Bateman Equations (Evans 1972)

- The airflow into the cab through the HEPA filter was 0.09 m^3/s (200 cfm)
- For simplicity, the efficiency of the HEPA filter was assumed to be 100%. A small amount of leakage through the filter would not materially affect the calculations

Tables 6.4-7 and 6.4-8 lists the projected radon gas and radon progeny levels within the production stopes and within the cabs of the mobile equipment.

Table 6.4-6 Base case: Projected Radon and Radon Progeny Levels for 0.3% Ore

Location	Radon Gas Level (Bq/m^3)	Radon Progeny Level (WL)	Combined Effective Dose Rate (μSv/h)
Production Stope	9120	0.08	3.3
Cab of Equipment in Stope	9120	0.02	1.7

Table 6.4-7 Upper bound case: Projected Radon and Radon Progeny Levels in 0.5% Ore

Location	Radon Gas Level (Bq/m^3)	Radon Progeny Level (WL)	Combined Effective Dose Rate (μSv/h)
Production Stope	14,000	0.12	5.25
Cab of Equipment in Stope	14,000	0.03	2.65

LLRD Modelling

The amount of LLRD exposure is difficult to predict theoretically. However, past experience in Northern Saskatchewan has shown that, with good dust control measures, LLRD exposures can be maintained lower than gamma and radon progeny exposures (CNSC 2009b). Hence the worker LLRD exposures are projected to be the same as the radon progeny exposures. Table 6.4-9 and Table 6.4-10 present the total projected exposures from radon progeny and airborne LLRD for 0.3% and 0.5% ore. In effect the calculated radon and radon progeny exposures have been doubled to account for the inhalation of LLRD.

In underground mining, exposure to radioactive dusts is primarily controlled by using water sprays, enclosing workers, keeping workers upwind of LLRD sources, and allowing time for dusts to settle after dust generating activities. HEPA filters in the cabs of the mobile equipment will reduce radon progeny levels and also be effective in preventing the ingress of airborne LLRD.

Table 6.4-8 Base Case: Projected Total Radon, Radon Progeny and LLRD Dose at 0.3% Ore

Job Category	Worker Number	Time Spent (hours)				Daily Rn &RnP Dose (μSv/d)			Rn, RnP + LLRD Annual Dose (mSv)
		Waste	Inside Cab	Outside Cab	Total	Waste	Inside Cab	Outside Cab	
Production Loader operator	8	4	4	1	9	0.6	2.4	3.3	1.8
Development Loader operator	4	9	0	0	9	1.35	0	0	0.4
Backfill LHD operator	4	4	4	1	9	0.6	6.8	3.3	3.0
Backfill Truck operators	4	8	0	1	9	1.2	0	3.3	1.3
Production Truck operators	8	3	5	1	9	0.45	8.5	3.3	3.4
Development Truck operators	4	9	0	0	9	1.35	0	0	0.4
Production Jumbo operator	8	4	4	1	9	0.6	6.8	3.3	3.0
Development Jumbo operator	4	9	0	0	9	1.35	0	0	0.4
Blasters	4	7	0	2	9	1.05	0	6.6	2.1
Production Bolter operator	8	4	4	1	9	0.6	6.8	3.3	3.0
Grader operator	4	9	0	0	9	1.35	0	0	0.4
Shotcrete Operator	8	3	5.5	0.5	9	0.45	9.35	1.65	3.2
Development helpers	4	6	1	2	9	0.9	1.7	6.6	2.6
UG Labourers (Vent. Crew)	8	6	1	2	9	0.9	1.7	6.6	2.6
Supervision	4	6	1	2	9	0.9	1.7	6.6	2.6
Surveyors	4	6	1	2	9	0.9	1.7	6.6	2.6
Geologists	4	6	1	2	9	0.9	1.7	6.6	2.6

NOTES:

12 hour shift (9 working) and 140 working days per year.

LLRD dose = RnP dose

Table 6.4-9 Upper Bound Case: Projected Total Radon Progeny and LLRD Dose at 0.5% Ore

Job Category	Worker Number	Time (hours) Waste	Inside Cab	Outside Cab	Total	Daily Rn&RnP Dose (µSv) Waste	Inside Cab	Outside Cab	Rn, RnP + LLRD Annual Dose (mSv)
Production Loader operator	8	4	4	1	9	0.6	10.6	5.25	4.6
Development Loader operator	4	9	0	0	9	1.35	0	0	0.4
Backfill LHD operator	4	4	4	1	9	0.6	10.6	5.25	4.6
Backfill Truck operators	4	8	0	1	9	1.2	0	5.25	1.8
Production Truck operators	8	3	5	1	9	0.45	13.25	5.25	5.3
Development Truck operators	4	9	0	0	9	1.35	0	0	0.4
Production Jumbo operator	8	4	4	1	9	0.6	10.6	5.25	4.6
Development Jumbo operator	4	9	0	0	9	1.35	0	0	0.4
Blasters	4	7	0	2	9	1.05	0	10.5	3.2
Production Bolter operator	8	4	4	1	9	0.6	10.6	5.25	4.6
Grader operator	4	9	0	0	9	1.35	0	0	0.4
Shotcrete Operator	8	3	5.5	0.5	9	0.45	14.6	2.6	4.9
Development helpers	4	6	1	2	9	0.9	2.65	10.5	3.9
UG Labourers (Vent. Crew)	8	6	1	2	9	0.9	2.65	10.5	3.9
Supervision	4	6	1	2	9	0.9	2.65	10.5	3.9
Surveyors	4	6	1	2	9	0.9	2.65	10.5	3.9
Geologists	4	6	1	2	9	0.9	2.65	10.5	3.9

NOTES:

12 hour shift (9 working) and 140 working days per year.

LLRD dose = RnP dose

Summary of Worker Radiation Exposures during Underground Mining

The previous sections addressed the primary radiation exposure pathways at the proposed End Grid mine. Each of these exposure pathways has been considered in detail as well as the AREVA program for controlling and minimizing the worker radiation exposures via these exposure pathways. Ultimately, however, AREVA must remain in compliance with the regulatory dose limits which are based on the total effective annual radiation exposures. Table 6.4-11 lists the total projected radiation exposures, both for the average ore grade of 0.3% and for an ore grade of 0.5%. Table 6.4-11 demonstrates that the End Grid ore body can be mined while remaining within the regulatory dose limits and within the AREVA worker dose objectives.

Table 6.4-10 Base and Upper Bound Cases: Estimated Annual Underground Doses

Job Category	Worker Count	Base Case Annual Dose (mSv/a)				Upper Bound Annual Dose (mSv/a)			
		Gamma	Rn &RnP	LLRD	TED	Gamma	Rn &RnP	LLRD	TED
Production Loader operator	8	3.2	0.9	0.9	5.0	4.8	2.3	2.3	9.4
Development Loader operator	4	0.0	0.2	0.2	0.4	0.0	0.2	0.2	0.4
Backfill LHD operator	4	3.2	1.5	1.5	6.2	4.8	2.3	2.3	9.4
Backfill Truck operators	4	2.1	0.6	0.6	3.4	3.1	0.9	0.9	4.9
Production Truck operators	8	3.2	1.7	1.7	6.6	4.1	2.7	2.7	9.4
Development Truck operators	4	0.0	0.2	0.2	0.4	0.0	0.2	0.2	0.4
Production Jumbo operator	8	3.2	1.5	1.5	6.2	4.8	2.3	2.3	9.4
Development Jumbo operator	4	0.0	0.2	0.2	0.4	0.0	0.2	0.2	0.4
Blasters	4	4.2	1.1	1.1	6.3	6.2	1.6	1.6	9.4
Production Bolter operator	8	3.2	1.5	1.5	6.2	4.8	2.3	2.3	9.4
Grader operator	4	0.0	0.2	0.2	0.4	0.0	0.2	0.2	0.4
Shotcrete Operator	8	2.6	1.6	1.6	5.8	3.9	2.5	2.5	8.8
Development helpers	4	4.5	1.3	1.3	7.1	6.6	2.0	2.0	10.5
UG Labourers (Vent. Crew)	8	4.5	1.3	1.3	7.1	6.6	2.0	2.0	10.5
Supervision	4	4.5	1.3	1.3	7.1	6.6	2.0	2.0	10.5
Surveyors	4	4.5	1.3	1.3	7.1	6.6	2.0	2.0	10.5
Geologists	4	4.5	1.3	1.3	7.1	6.6	2.0	2.0	10.5
Collective	92	269	104	104	478	394	166	166	726
Average		2.9	1.1	1.1	**5.2**	4.3	1.8	1.8	7.9
Maximum		4.5	1.7	1.7	7.1	6.6	2.7	2.7	**10.5**

6.4.4.7 Mitigation Measures

The AREVA Radiation Protection Program for underground workers will be a multi-faceted approach consisting of a combination of ventilation controls, sealed and lead-lined mobile equipment cabs and shotcrete applied to the walls and back of the drifts. This section summarizes the overall approach to radiation protection for the End Grid mine.

Radiation Protection by Design

In keeping with the ALARA principle, AREVA has established radiation protection performance objectives for the End Grid Mine. The performance objectives are as follows.

Worker Dose Objectives:

- Total Effective Dose (per Individual) < 10 mSv/year
- Gamma Radiation < 6 mSv/year
- Radon Progeny < 0.6 WLM (or 3 mSv/year)
- Workplace LLRD – 0.1 DAC (or 2 mSv/year)

Protection from Internal Hazards (Radon, Radon Progeny and LLRD)

The ventilation of all production areas will be separated from the main decline by ventilation doors at each level access. All ore headings will be ventilated with fresh air and exhaust air will be pulled through rigid ductwork directly to an exhaust airway so that used air is not re-circulated to other headings. All primary access ways are maintained in fresh air and are located in waste material. The ore stockpile bay at each access level will be ventilated with fresh air to carry dust and radon directly to an exhaust raise connected to the end of these drives. The planned air quantity and velocity in ore drifts will be sufficient to ensure dilution of radon and a continuous supply of fresh air. The general principles used in the design of the End Grid Mine are:

- Auxiliary ventilation to active mine faces will be fresh air with the exhaust ducted to the mine exhaust;
- Ventilation air from any potential source of contamination (e.g., sumps, remucks, stockpiles) will be directed to the mine exhaust without contaminating other active workplaces;
- In general, each active cross cut will be provided with a “pull” system where clean air is fed into the working area and the contaminated air is collected in a duct and directed to a dedicated (unoccupied) exhaust drift; and,
- Equipment cabs will be ventilated through HEPA filters. This will reduce LLRD doses and radon progeny doses.
- The excavation of production stopes will begin at the downwind edge of the ore body on each level. As these stopes are mined out, production will move towards fresh air. This will avoid the contamination of fresh air by radon leaking out of the older mined-out stopes.

Protection from External Hazards (Gamma Radiation)

Shotcrete will be used in all ore drifts to act as a gamma radiation barrier and for ground control. The main ore footwall access drift on each level cut will receive 10 cm of shotcrete. Any portion of the access drift in waste rock, or adjacent to backfill, will be shotcreted as required for ground support reasons. The production ore headings will receive 5 cm of shotcrete applied to all ore surfaces – walls or back. Again, any portion of the production drifts that are in waste rock or adjacent to backfill will only receive shotcrete as required for ground support. The shotcrete will also be applied in the shoulder of these drifts along the backfill interface to ensure that any air gaps between the drift back and the previously backfilled wall is sealed to prevent air leakage.

The shielding factors applied in the gamma dose modeling are as follows:

- 0.6 with 5 cm of regular shotcrete
- 0.3 with 10 cm of regular shotcrete

The application of 5 cm of regular shotcrete will reduce the general gamma radiation levels in the ore stopes to ~15 μSv/h (25 μSv/h x 0.6).

Requirements on the use of shotcrete during mining, based on gamma dose rate critieria, are generally developed as part of mine planning and integrated into the Radiation Protection Program and Code of Practice for underground mining at the time of licensing. Flexibility is required for miners to make wise choices on the use of time, distance, shielding and ventilation. AREVA's experience in underground mining at Cluff Lake, discussed in Appendix 8B, demonstrated that reducing shotcrete requirements optimized protection in some cases. The attenuation abilities of shotcrete have been calculated using software products, such as Microshield, and observed in existing mining operations. Though calculated half-value layers may vary slightly due to composition of shotcrete values will be similar to half-value layers for concrete (Chambers et al. 1981). The assessment generally illustrates that dose objectives can be achieved with application of an achievable thickness of attenuating material. Determining the effectiveness of mitigation measures is a routine part of operational activities during mining.

Mining Procedures and Equipment Shielding

With a practical annual worker gamma dose limit of ~ 6 mSv, a general gamma dose rate of 15 μSv/h in the stopes will necessitate a maximum use of shielded mobile equipment in the production stopes and controls on the time that workers can spend in the stopes when they are not within the shielded cabs of mobile equipment. The use of mobile equipment with heavily shielded cabs will provide shielding for workers from gamma radiation exposure and the time workers spend in the stopes outside of the shielded cabs will be minimized.

All mining equipment will be setup for work within low-dose-rate mobilization areas outside the mineralization (access drifts and declines in waste rock). At these locations workers can assemble their gear and fuel and check their equipment. They would then move to the active workplace, perform their assigned task, and then retreat to the low-dose-rate area. All mobile equipment will be parked in these low-dose-rate areas when not in use.

Mobile equipment cabs will be lined with lead to reduce gamma radiation. This will include drill jumbos, LHD's, trucks, bolters and the shotcrete applicators. Shielding the cabs will require the custom application of lead sheets to the sides, floors and roof of the cabs. It is observed that exposure rates in unshielded cabs are approximately half the exposure rate of workers outside the cab due to the intrinsic shielding provided by the steel construction. Lining the equipment cabs with 1 cm of lead will improve the shielding and reduce gamma exposure by a factor of 4, i.e. the thickness of lead required to reduce gamma exposure by 50 % is approximately 0.5 cm. General gamma fields inside the cab would be reduced to ~ 2 μSv/h from 15 μSv/h, including intrinsic and additional lead shielding.

All mine activities where workers cannot be within shielded cabs, such as explosives loading or changing jumbo drill bits, will be organized in such a way that the minimum practicable time is spent on each part of the cycle. There will be a need for other workers to enter the production stopes for limited periods of time. For example, there will be short entries by geologists and radiation protection technicians.

The most significant time spent in the stopes will be for blasters and workers extending the ventilation ducting and installing auxiliary fans. It is unlikely that the auxiliary ventilation system can be serviced from the shielded cabs of mobile equipment. The installation of ventilation ducting will require careful time management. Preparation and set up for the work will be in the low radiation mobilization area. Once all the equipment preparations are complete, the workers would enter the stope, probably using a mobile scissor lift to hang the ducting, and then exit. In a similar manner, the loading of the holes with explosives will require careful planning with the actual placement of explosives performed expeditiously.

Operational Controls

Feedback receieved through public engagement activities and IQ interviews identified that people *expressed concerns about workers being monitored and working in a safe environment* (EN – BL

NIRB Apr 2010[74] , EN- BL OH Nov 2013,[75],[76],EN - RB OH Nov 2010,[77] , EN CI KIA Feb 2010[78], IQ-BLE 2009[[79]]) .

The previous sections focused on the radiological conditions and on the equipment to be deployed. On site operational controls will also have a profound effect on worker radiation exposures and will constitute an important part of the ALARA program. The operational radiological controls provided at the End Grid mine (and Kiggavik) will consist of:

- The development and implementation of a detailed Radiation Code of Practice to limit worker radiation exposures. The Code of Practice will provide guidance to workers and supervisors on their actions in the event that key radiological indicator levels are reached;
- Daily radiation monitoring by the radiation protection staff with the results posted and available to workers and line supervision;
- Radiation protection staff will monitor the work and provide advice for specific jobs as required;
- Workers will wear direct reading gamma dosimeters when they are working in significant gamma fields. This will allow them to monitor their accumulated gamma dose throughout the shift;
- The provision of radiation protection training to all radiation workers with additional training for line supervision;
- Radiation protection staff will be available 24 hrs/day to provide guidance and answer questions;
- The provision of a complete and comprehensive radiation dosimetry service to all radiation workers; and
- The reporting of quarterly and annual individual worker radiation doses to the workers, mine management and the regulatory agencies.

Mine supervision will organize the work in a manner that minimizes worker radiation exposures, based on the following procedures:

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[74] EN–BL NIRB Apr 2010: *What is the plan to protect people and workers? Would like to see a protection plan put in place for the people and workers.*

[75] EN–BL OH Nov 2013: *Radiation exposure to workers. How do we keep people safe?*

[76] EN–BL OH Nov 2013: *Radiation: How do you know what reading is dangerous? What if you go over? Does it take long to get a sample back?*

[77] EN–RB OH Nov 2010: *What happens if I receive too much radiation and how do I know?*

[78] EN-CI KIA Feb 2010: *Do mining companies perform safety inspections to ensure all work is done appropriately? How often would inspections occur?*

[79] IQ-BLE 2009: *here is a larger concern that people may become contaminated by the Project.*

- Regular review meetings will be held with line supervision and radiation protection staff to review worker doses with respect to past and upcoming work;
- Worker doses, estimated by direct reading dosimeters, will be recorded and reviewed by line supervision and radiation protection staff daily; and,
- For higher-hazard non-routine work, potential radiation exposures will be identified, an assessment of potential dose conducted, and a safe work permit will be required. The safe work permit will describe any constraints (e.g. time duration), and specialized equipment or procedural requirements for the job.

6.4.5 Assessment of Workplace Radiation Exposures – Milling

6.4.5.1 Methodology

Similar to the evaluation of radiation doses in open pit mining, the estimation of future radiation doses to mill workers is based on the experience gained during actual milling of uranium ores at a Northern Saskatchewan operation. For the purposes of this assessment, knowledge gained in the design and operation of the McClean Lake mill is used to inform the assessment of doses for the Kiggavik mill.

The McClean Lake mill was designed to process uranium with ore grade of up to 30% uranium. In contrast, the Kiggavik mill will process low grade ores of approximately 0.4% U with a maximum grade of 0.5% U. The two mills, however, will be comparable from the perspective of radiation protection as both will use radiation protection design criteria in their design and will afford a similar level of worker protection. Though the extensive shielding features at the McClean Lake mill will not be necessary for the Kiggavik mill to provide a similar level of protection, the Kiggavik mill is being designed to meet ALARA design objectives for gamma radiation. In fact, a lower design objective for gamma radiation exposure rates will be achieved at the Kiggavik mill. AREVA has demonstrated that the use of radiation protection design criteria in the design and construction of a uranium mill achieves ALARA-based objectives.

Data collected at the McClean Lake mill combines the actual operating experience in each mill circuit with the observed exposure rates hence the use of the experiential data is considered an improvement on traditional task-time-exposure rate analyses. Doses for the Kiggavik mill have been estimated by adjusting the observed doses at the McClean Lake mill by factors which consider future production levels and ore feed grade scenarios at Kiggavik. In addition, when predicting gamma radiation doses in the grade-sensitive front-end circuits such as grinding, leaching, resin-in-pulp and tailings neutralization, the differences in the gamma radiation shielding features and gamma exposure objectives have been considered. For positions observed to have gamma doses which are sensitive to ore grade doses have been estimated using circuit occupancy data from the reference case concervatively combined with gamma radiation dose rate objectives for the Kiggavik mill; for positions observed to have gamma doses which are insensitive to ore grade, the average gamma dose from the McClean Lake mill has been used. Positions with gamma doses which are insensitive to ore grade generally work in the back-end circuits such as clarification, precipitation, drying and packaging, or work in supervision.

Formulas, used in estimating worker doses, have been provided in Table 6.4-17 along with example calculations.

6.4.5.2 Exposure Assessment

A comparison of the McClean Lake mill and the proposed Kiggavik mill was conducted to identify similarities and differences and assess the amenability of the assessment method. Table 6.4-12 shows a comparison of the radiation protection design features of the existing high grade mill at McClean Lake Operation and the proposed low grade mill at Kiggavik.

Table 6.4-11 Comparison of Radiation Protection Design Features of a High and Low Grade Mill

Design Features	Description of Radiation Protection Mitigation	High Grade Mill: McClean	Low Grade Mill: Kiggavik
Protection from External Hazards	1. Design criterion for gamma radiation	< 5 µSv/h	< 1.5 µSv/h
	2. Shielding features applied to key gamma-sensitive process vessels to achieve criterion.	√	√
	3. Lead shielding wrapped around piping (as required)	√	√
Separation & Containment	1. Shielded elevated slabs separate workers on the operating floor from the high grade radioactive material emitted from components on the lower level	√	X
	2. Steeply graded floors direct spills to sumps, thus containing liquid spills and minimizing worker contact with radioactive material	√	√
	3. Enclosure rooms are used to contain and isolate potential sources of airborne dust from the general work area, eg. drying and packaging rooms	√	√
	4. Process equipment within enclosure rooms are maintained at negative pressure relative to the enclosure rooms and the enclosure rooms are maintained at negative pressure relative to the exterior general area, eg. drying and packaging	√	√
Protection from airborne contaminants	1. Design criteria for radon progeny exposure.	< 0.03 WL	< 0.03 WL
	2. Design criteria for long-lived radioactive dust exposure	< 0.1 DAC	< 0.1 DAC
	3. Air-flow through the mill is from areas of low potential contamination to areas of higher potential contamination.	√	√
	4. Ore containing systems are maintained at lower ventilation pressure than the adjacent atmosphere, thereby preventing leaks of airborne radioactive materials into the working environment	√	√
	5. Backup systems provide emergency electrical power to ventilation	√	√

Table 6.4-11 Comparison of Radiation Protection Design Features of a High and Low Grade Mill

Design Features	Description of Radiation Protection Mitigation	High Grade Mill: McClean	Low Grade Mill: Kiggavik
	systems, if required.		
	6. Process vessels with a potential for airborne releases are equipped with an extraction ventilation system.	√	√

Average and maximum doses for each comparable job category from the McClean Lake mill form the Reference Case for the assessment. The Reference Case is based on dosimetry results, observation and experience from the McClean Lake Operation while processing approximately 6 M lbs of U_3O_8 with a feed grade of 1.75 % U. This Reference Case has been used consistently for several dose assessments for AREVA projects including the Sue E Project (AREVA 2004), Caribou Project (AREVA 2009) and Midwest Project (AREVA 2011) and McArthur Ore Haul Project (AREVA 2011).

The observed average and maximum doses for each job category for the reference case are assembled in Table 6.4-13.

Table 6.4-12 (Revised-PHC) Reference Case: Annual Mill Doses at McClean Lake Operation

Job Category	No. of workers	Average Doses (mSv)				Maximum Doses (mSv)			
		Gamma	RnP	LLRD	TED	Gamma	RnP	LLRD	TED
Boiler/Oxygen	4	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40
Chemist	9	0.00	0.07	0.01	0.08	0.40	0.10	0.03	0.53
Chief Metallurgist	1	0.00	0.49	0.35	0.84	0.40	0.49	0.35	1.24
Control Room	4	0.23	0.24	0.24	0.71	0.60	0.33	0.65	1.58
Electrician	6	0.04	0.22	0.16	0.42	0.40	0.49	0.36	1.24
Grinding	4	1.88	0.36	0.67	2.90	4.70	0.57	1.04	6.31
Instrumentation	4	0.04	0.29	0.16	0.49	0.40	0.52	0.39	1.30
Leaching	4	1.00	0.44	0.60	2.04	2.20	0.70	1.06	3.96
Met Lab Assistant	4	0.00	0.42	0.64	1.07	0.40	0.92	1.27	2.59
Metallurgist	2	0.00	0.35	0.39	0.75	0.40	0.92	1.27	2.59
Mill Feed/Loader	4	3.10	0.23	0.18	3.51	5.80	0.35	0.30	6.45
Mill General Supervisor	1	0.00	0.59	0.43	1.02	0.40	0.61	0.43	1.44

Table 6.4-12 (Revised-PHC) Reference Case: Annual Mill Doses at McClean Lake Operation

Job Category	No. of workers	Average Doses (mSv)				Maximum Doses (mSv)			
		Gamma	RnP	LLRD	TED	Gamma	RnP	LLRD	TED
Mill Maintenance	18	0.56	0.34	0.74	1.65	1.30	0.43	1.02	2.75
Mill Maintenance Supervisor	4	0.05	0.51	0.36	0.92	0.40	0.57	0.39	1.36
Mill Manager	1	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40
Mill Shift Supervisor	6	0.19	0.26	0.37	0.81	0.40	0.42	0.58	1.40
Mill Trainer	2	0.00	0.59	0.39	0.98	0.40	0.59	0.39	1.38
Packaging	2	0.43	0.13	0.12	0.68	0.76	0.31	0.39	1.46
Planner	4	0.00	0.25	0.32	0.57	0.40	0.25	0.32	0.97
Precipitation	4	0.40	0.29	0.66	1.36	0.60	0.35	0.92	1.87
Radiation Techs	6	0.09	0.11	0.07	0.27	0.51	0.26	0.16	0.93
RIP (CCD)	4	0.62	0.44	0.73	1.79	0.71	0.61	1.06	2.38
Safety	3	0.00	0.14	0.10	0.24	0.40	0.46	0.35	1.21
SX	4	0.47	0.41	0.40	1.28	1.00	0.43	0.58	2.01
Tailings Operator	2	0.15	0.18	0.09	0.42	0.40	0.21	0.17	0.78
Utilities (Acid,CX)	8	0.05	0.21	0.15	0.41	0.40	0.30	0.15	0.85
Water Treatment/Reagents	4	0.14	0.30	0.11	0.55	0.60	0.49	0.25	1.34
Environment Techs	5	0.00	0.03	0.02	0.05	0.00	0.05	0.03	0.06
Services	8	0.11	0.12	0.08	0.36	0.40	0.28	0.47	0.90
Nurses	3	0.00	0.01	0.00	0.02	0.00	0.02	0.01	0.03
Office Staff	17	0.00	0.04	0.04	0.08	0.00	0.27	0.23	0.50
Collective dose	**152**	**46.19**	**34.54**	**43.03**	**124.19**	**120.41**	**56.08**	**73.45**	**247.84**
Average		**0.30**	**0.23**	**0.28**	**0.82**				
Maximum						**5.80**	**0.92**	**1.27**	**6.45**

For the assessment of potential radiation exposures a base case Kiggavik milling scenario involves processing an average of 10.4 Mlbs U_3O_8 (4000 TU) at an average grade of 0.4 % U. An upper bound case considers production of up to 13 Mlbs U_3O_8 (5000 TU) from Kiggavik ores with a maximum grade of 0.8% U. Base and upper bound case estimated annual mill doses are described in Table 6.4-17.

Scaling factors were applied, where workplace nominal exposure rate design objectives aligned between the two mills, to predict Kiggavik mill doses for each job category for a base case and upper bound case.

AREVA has established workplace and sanctuary nominal exposure rate objectives for the Kiggavik mill for each dose component.

Mill Workplace Objectives are as follows:

- Gamma Radiation – 1.5 µSv/h
- Radon Progeny – 0.03 WL
- LLRD – 0.1 DAC

Mill Sanctuary Objectives are as follows:

- Gamma Radiation – 0.2 µSv/h
- Radon Progeny – 0.01 WL
- LLRD – 0 DAC

These objectives effectively limit the exposure to each dose component. The objectives will be met through the facility layout as well as the use of facility design features and dose control through workplace practices. Dose estimates for Kiggavik production scenarios have been estimated considering values listed in Table 6.4-15.

Table 6.4-15 (Revised) Aspects Considered for Kiggavik Mill

Aspect	Reference Case	Kiggavik Mill	
		Base Case	**Upper Bound Case**
Ore Grade (%U)	1.75	0.4	0.8
Production Level (TU/year) (M lbs U3O8/year)	2308 6	4000 (10.4)	5000 (13)

It is anticipated that the exposures to each dose component will vary with changes in ore grade and production level generally as follows.

<u>Gamma radiation</u> exposure rates vary with the concentration of gamma emitters in the circuit. In the grinding, leaching, resin in pulp (RIP) and tailings preparation circuits the concentration of gamma emitters is related to ore grade. That is, gamma radiation emissions from process vessels at the Kiggavik mill in these grade sensitive circuits are anticipated to be less than 25% of the emissions observed at McClean Lake for the base case and less than 50% for the upper bound case. In the clarification, solvent extraction, precipitation, drying and packaging circuits, gamma exposure rates are not dependent on ore grades and are relatively constant. For estimation of gamma dose at Kiggavik, the reference case values are used directly.

Radon and Radon progeny exposures at McClean Lake have been found to trend together and vary with production levels, i.e., the amount of radon released relates to the number of atoms of uranium processed. Areas with the highest average radon gas levels (e.g., CCD and grinding) tend to be the areas with the highest RnP levels. The predominant contributor to radiation dose is radon progeny, rather than radon gas, hence radon progeny exposure is monitored for mill workers. For calculation of radon progeny exposure for Kiggavik workers observed doses from the reference case are expected to scale proportionally with ore production, given similar ventilation design criteria applied at both mills. Radon exposure is calculated from the estimated radon prgeny values assuming a ventilation design criteria of four (4) air exchanged per hour.

Long-Lived Radioactive Dust (LLRD) exposures in the grade sensitive circuits (i.e., grinding, leaching, CCD or RIP, and tailings neutralization) will generally increase with ore grade as the radioactivity of the airborne dusts will be reflective of the grade of the material in the circuit. The materials in the back-end circuits (i.e., precipitation, drying and packaging) are of uniform composition so the LLRD exposures in these circuits are expected to vary with production levels. Scaling factors for LLRD follow the same scheme as for gamma radiation.

Scaling factors were developed based on the simple model described above for each process circuit. These scaling factors were applied to the Reference Case data to estimate radiation exposures for future Kiggavik production scenarios wherever workplace nominal exposure rate design objectives aligned between the two mills, (i.e., radon progeny and long lived radioactive dust). The Kiggavik mill has a lower gamma workplace exposure rate design objective than the McClean Lake mill hence estimates of gamma radiation exposure following this scheme are expected to be conservative. Table 6.4-16 provides dose calculations as well as a sample calculation for a front-end Leaching Operator.

Base Case uses the average dose values from the reference case together with the average ore grade of 0.4% and an annual production level of 4000 tU; the upper bound case uses the maximum dose values from the reference case with the maximum ore grade of 0.8% and an annual production level of 5000 tU.

Table 6.4-13 Worker Dose Calculations

Formula
<u>Gamma (γ) Dose Component</u> Front end: Gamma Dose (mSv) = Gamma Dose $_{(Reference)}$ (mSv) x Ore Grade $_{(Kiggavik)}$ % U / Ore Grade $_{(Reference)}$ % U Back end: Gamma Dose (mSv) = Gamma Dose $_{(Reference)}$ (mSv) x Production $_{(Kiggavik)}$ t U / Production $_{(Reference)}$ t U Example: Base Case Leaching Operator Gamma Dose (mSv) = 1 mSv x 0.4%U / 1.75%U = = **0.23 mSv** Example: Base Case Precipitation Operator Gamma Dose (mSv) = **0.4 mSv**
Explanation: The average gamma dose for a particular job category is equal to the gamma dose rate within a given circuit multiplied by the occupancy time within the circuit. Historical data from the reference mill was used to determine worker occupancy time in each circuit (See Table 6.4). Due to process automation, most of a worker's time is spent in control rooms at background gamma radiation levels. The dose rate objective for the Kiggavik mill is less than 1.5 uSv/h.
<u>Radon Progeny (RnP) Dose Component</u> For front-end circuits, RnP doses are calculated by scaling the reference RnP dose according to production level. RnP Dose$_{(Kiggavik)}$ (mSv) = RnP Dose $_{(Reference)}$ (mSv) x Production $_{(Kiggavik)}$ t U / Production $_{(Reference)}$ t U Example: Base Case Leaching Operator RnP Dose$_{(Kiggavik)}$ (mSv) = 0.44 mSv x 4000 t U/ 2308 t U = **0.76 mSv** RnP Dose for occupations not routinely occupying front-end circuits (mSv) = RnP Dose from Reference Case (mSv) Example: Base Case Precipitation Operator RnP Dose (mSv) = **0.29 mSv**
Explanation: The radon progeny dose component for a job category is expected to scale with production levels and occupancy in the front-end radon/radon progeny sensitive circuits, i.e. the amount of radon release is proportional to the amount of uranium processed. For positions not routinely occupying front-end circuits, the RnP dose from the reference case is used.
<u>Radon (Rn) Dose Component</u> Radon Dose$_{(Kiggavik)}$ (mSv) = 0.08 x RnP Dose (mSv) Example: Base Case Leaching Operator Radon = 0.08 x 0.76 = **0.06 mSv**
Explanation: Using similar design criteria for the Kiggavik Mill as for the reference mill, and a planned air exchange rate of 4 air exchanges per hour, the average age of air will be 15 minutes. With an initial radon concentration of 3700 Bq/m^3, RnP in WL can be estimated from the analytical expression WL = 0.023t$^{0.85}$ (Evans 1969). For t=15 minutes, 0.23 WL will result from 3700 Bq/m^3 of radon gas. For comparison, the doses from a 1770 hour exposure to Rn and RnP are calculated as follows: Rn_{dose} (mSv)= Rn_{conc}(Bq/m^3) x Breathing rate(m3/h) x t(h) x DCF_{Rn} = 3700 Bq/m^3 x 1.2 m3/h x 1770h x 20 mSv/1.6x10^8 = 0.98 mSv RnP_{dose} (mSv) = RnP (WL) x t (h) x 1 month/170h x DCF_{RnP} = 0.23 WL x 1770/170 x 5 mSv/WLM = 11.97 mSv Rn_{dose} (mSv) / RnP_{dose} (mSv) = 0.98 / 11.97 = 0.08

Table 6.4-14 Worker Dose Calculations

Formula

Long Lived Radiative Dust (LLRD)Dose Component

LLRD (ore) Dose $_{\text{(Kiggavik)}}$ (mSv) = LLRD (ore) Dose $_{\text{(Reference)}}$ (mSv) x Grade $_{\text{(Kiggavik)}}$ / Grade$_{\text{(Reference)}}$

Example: Base Case Leaching Operator

LLRD (ore) Dose $_{\text{(Kiggavik)}}$ (mSv) = 0.6 mSv x 0.4% / 1.75% = **0.14 mSv**

LLRD (YC) Dose $_{\text{(Kiggavik)}}$ (mSv) = LLRD (YC) Dose $_{\text{(Reference)}}$ (mSv) x Production $_{\text{(Kiggavik)}}$ / Production $_{\text{(Reference)}}$

Example: Base Case Precipitation Operator

LLRD (YC) Dose (Kiggavik) (mSv) = 0.66 mSv x x 4000 t U/ 2308 t U = **1.15 mSv**

Explanation: The long lived radioactive dust dose component at the Kiggavik mill is expected to scale with ore grade in the ore processing front-end circuits, and scale with productions levels in the back-end yellowcake processing circuits of the Kiggavik Mill.

Total Effective Dose (TED)

TED (mSv) = Gamma (mSv) + RnP (mSv) + Rn (mSv) + LLRD (mSv)

Base Case Leaching Operator TED (mSv) = 0.23 + 0.76 + 0.06 + 0.14 = **1.19 mSv**

Table 6.4.17 (Revised- PHC) Base and Upper Bound Case Estimated Annual Mill Doses

Job Category	Count	Base Case					Upper Bound				
		Gamma	RnP	Rn	LLRD	TED	Gamma	RnP	Rn	LLRD	TED
Boiler/Oxygen	4	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Chemist	10	0.00	0.07	0.01	0.02	0.10	0.40	0.10	0.01	0.06	0.57
Chief Metallurgist	2	0.00	0.49	0.04	0.60	1.13	0.40	0.49	0.04	0.76	1.68
Control Room	4	0.23	0.24	0.02	0.42	0.91	0.60	0.33	0.03	1.41	2.37
Electrician	5	0.04	0.22	0.02	0.28	0.55	0.40	0.49	0.04	0.77	1.70
Grinding/Crushing (a)	8	0.43	0.62	0.05	0.15	1.25	2.15	1.23	0.10	0.48	3.95
Instrumentation	5	0.04	0.29	0.02	0.28	0.63	0.40	0.52	0.04	0.84	1.80
Leaching (a)	4	0.23	0.76	0.06	0.14	1.19	1.01	1.51	0.12	0.48	3.12
Met Lab Assistant (a)	4	0.00	0.73	0.06	0.15	0.94	0.18	2.00	0.16	0.58	2.93
Metallurgist	4	0.00	0.35	0.03	0.68	1.06	0.40	0.92	0.07	2.75	4.15
Mill Feed/Loader (a)	6	0.71	0.40	0.03	0.04	1.18	2.65	0.76	0.06	0.65	4.12
Mill General Supervisor (a)	2	0.00	1.03	0.08	0.10	1.21	0.18	1.32	0.11	0.20	1.81
Mill Maintenance (a)	20	0.13	0.59	0.05	0.17	0.94	0.59	0.93	0.07	0.47	2.07
Mill Maintenance Supervisor	6	0.05	0.51	0.04	0.63	1.23	0.40	0.57	0.05	0.85	1.87
Mill Manager	1	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Mill Shift Supervisor (a)	4	0.04	0.44	0.04	0.08	0.61	0.18	0.91	0.07	0.26	1.43
Mill Trainer	2	0.00	0.59	0.05	0.68	1.31	0.40	0.59	0.05	0.85	1.88
Packaging	2	0.43	0.13	0.01	0.21	0.78	0.76	0.31	0.02	0.85	1.94
Planner	4	0.00	0.25	0.02	0.55	0.82	0.40	0.25	0.02	0.69	1.36
Precipitation	4	0.40	0.29	0.02	1.15	1.87	0.60	0.35	0.03	2.00	2.98
Radiation Tech (a)	6	0.02	0.20	0.02	0.01	0.25	0.23	0.57	0.05	0.07	0.92

Job Category	Count	Base Case					Upper Bound				
		Gamma	RnP	Rn	LLRD	TED	Gamma	RnP	Rn	LLRD	TED
RIP (CCD) (a)	4	0.14	0.77	0.06	0.17	1.14	0.33	1.32	0.11	2.29	4.04
Safety (a)	3	0.00	0.24	0.02	0.02	0.28	0.18	1.00	0.08	0.16	1.42
SX	4	0.47	0.41	0.03	0.70	1.61	1.00	0.43	0.03	1.26	2.72
Tailings Operator (a)	4	0.03	0.31	0.03	0.02	0.39	0.18	0.45	0.04	0.08	0.75
Utilities (Acid,CX)	5	0.05	0.21	0.02	0.26	0.54	0.40	0.30	0.02	0.33	1.05
Water Treatment/Reagents	6	0.03	0.30	0.02	0.19	0.55	0.60	0.49	0.04	0.55	1.68
Environment Technicians	6	0.00	0.03	0.00	0.03	0.07	0.00	0.05	0.00	0.07	0.12
Services	14	0.03	0.12	0.01	0.14	0.29	0.40	0.28	0.02	1.02	1.72
Nurses	4	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.00	0.02	0.04
Office Staff	20	0.00	0.04	0.00	0.07	0.11	0.00	0.27	0.02	0.50	0.79
Collective	**177**	19	56	4	37	116	94	102	8	114	318
Average		0.11	0.31	0.03	0.21	**0.66**	0.53	0.58	0.05	0.64	1.80
Maximum		0.71	1.03	0.08	1.15	1.87	2.65	2.00	0.16	2.75	**4.15**

(a) Positions observed to have grade sensitive gamma doses.

6.4.5.3 Mitigation Measures

6.4.5.4 Radiation Protection by Design

Radiation protection practices involved in the Kiggavik mill will consist of a combination of design and equipment features, operational practices, (i.e. including preventative measures, worker training and awareness, and work planning) and ongoing review and follow-up of results. A discussion of the many proposed protective features and operational practices to be put in place to protect workers from radioactivity are discussed below.

Protection from External Hazards

In general, the control of worker exposure to external gamma radiation is achieved primarily through design features of process equipment, the mill and operational practices, and includes the following three methods:

1. Shielding: Lead, concrete and steel are used to attenuate gamma rays, thereby reducing the level of gamma radiation in the workplace.
2. Time: Areas with significant radiation levels are identified and the time spent in such areas is minimized.
3. Distance: Generally, radiation levels decrease with distance from radioactive material. Where possible, workers and the sources of external gamma radiation are kept at a maximum distance from each other.

Protection from Internal Hazards

The control of worker exposure to radon and radon progeny, and long-lived radioactive dust is achieved primarily through design features and operational practices and includes the following three methods:

Containment: The radioactive ore is in a slurry form and contained in pipes and tanks. Under normal operating conditions, radon and long-lived radioactive dusts are not released into the workplace air and do not contaminate accessible areas. The radioactive ore stream is maintained as a wet process from the entry into the grinding circuit to the final drying of the uranium concentrate product.

Ventilation: A well designed ventilation system comprised of fresh, single-pass air to the mill facility as well as a process exhaust system ensure the supply of fresh air and the removal of point source radon and dust emissions.

Housekeeping: When leaks or spills of radioactive material occur in areas occupied by workers, the radioactive material is cleaned up immediately.

Worker Awareness

During public engagement sessions and IQ interviews conducted within Kivalliq communities, people *expressed concern about workers being monitored and working in a safe environment* (IQ- RIW 2009[80], EN - BL NIRB Apr 2010[81], EN - BL OH Nov 2013[82],[83], EN - RB OH Nov 2010[84], EN - BL NIRB Feb 2010[85]).

The following worker awareness measures will be used at Kiggavik to educate and inform mill workers, on a day-to-day basis, of potential exposures to radioactive materials:

- a copy of the Radiation Code of Practice manual will be available, and explained to workers. The Code of Practice will provide guidance to workers in their activities if key indicator levels are reached;
- area monitoring results will be posted and available to workers through notice boards;
- workers will wear direct reading dosimeters and monitor their accumulated gamma dose throughout the day;
- radiation protection training will be provided to all workers;
- radiation protection staff will be available 24 hrs/day to provide guidance and answer questions; and
- radiation protection staff will provide personal exposure results to all Nuclear Energy Workers.

Mill staff will plan work in a manner to minimize worker exposure where possible, based on the following procedures:

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80 IQ- RIW 2009: *The women were also worried about worker health and safety.*

[81] EN - BL NIRB Apr 2010: *What is the plan to protect people and workers? Would like to see a protection plan put in place for the people and workers.*

[82] EN - BL OH Nov 2013: *Radiation exposure to workers. How do we keep people safe?*

[83] EN - BL OH Nov 2013: *Radiation: How do you know what reading is dangerous? What if you go over? Does it take long to get a sample back?*

[84] EN - RB OH Nov 2010: *What happens if I receive too much radiation and how do I know?*

[85] EN - BL NIRB Feb 2010: *Do mining companies perform safety inspections to ensure all work is done appropriately? How often would inspections occur?*

- regular review meetings will be held with mill and radiation protection staff to review worker doses with respect to past and upcoming work;
- worker doses, estimated by direct reading dosimeters, will be recorded and reviewed by mill operations supervisors and radiation protection staff daily; and,
- potential radiation exposures not identified in individual worker dose assessments due to workers conducting non-routine activities will be identified, an assessment of potential dose conducted, and a safe work permit issued, as required. The safe work permit describes any constraints, (e.g. time duration), and specialized equipment or procedural requirements for the non-routine activity.

6.4.6 Assessment of Workplace Radiation Exposures – Transport

6.4.6.1 Methodology

Yellowcake will be transported from the Kiggavik site to Points North (or another destinations with ground link to the south) and then transport to refineries via land route by truck. An airstrip will be constructed at the Kiggavik site (the Pointer Lake airstrip). Truck transportation will be limited to transport from the Kiggavik site to the Pointer Lake airstrip (assumed to be 10 km maximum with no water crossing).

Yellowcake is transported by air and road in 55 - gallon steel drums loaded into 20' sea-containers, which also acts as a secondary containment. The external dose was estimated for four worker scenarios primarily involved with the transportation of yellowcake, and for a member of the public by:

- evaluating the transportation characteristics
- characterising receptor activities and exposure scenarios,
- Calculating external exposure rates using gamma radiation exposure modelling software, and
- Estimating annual doses for exposure scenarios based on activity analysis and exposure rates.

The external dose assessment was performed using MicroShield Version 8.02 (Grove Software 2008). The assumptions used in the MicroShield runs for each scenario are described within the receptor and exposure characteristics.

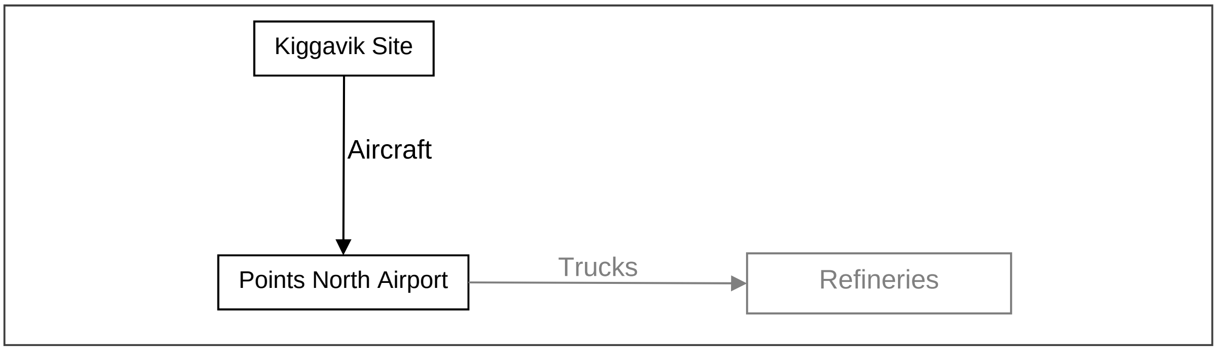
Appendix 10A – Kiggavik Project Transportation Risk Assessment, provides a detailed assessment of risks to workers, public and the environment associated with transportation of yellowcake. The worker and public radiation exposures are summarized in this section.

6.4.6.2 Exposure Assessment

Transportation Characteristic

Uranium Concentrate Transportation Characteristics and Scenarios

Uranium concentrates will be transported from the site to the processing facility via air transportation to Points North and then transport to the refineries via land route by truck.



NOTE: segments shown in grey are not included in the assessment.

Figure 6.4-2 Schematic of Uranium concentrates Transportation

Uranium Concentrate: Material and Containers

Uranium concentrates (yellowcake) will be produced at an on-site mill at Kiggavik through processing of the ore. The uranium concentrates production will amount to 4,000 tonnes of uranium per year as a low-moisture final product. Uranium concentrates would be discharged from the product surge bin to the packaging system, which fills steel drums. The uranium concentrates will be packaged in steel 55-gallon drums and sealed, with each drum holding approximately 400 kg of Uranium concentrates.

According to the IAEA regulations for the safe transport of radioactive material (IAEA 1996) and the Canadian Packaging and Transport of Nuclear Substances Regulations (CNSC 2000) , uranium concentrate is considered Low Specific Activity material (LSA-I) and is to be packaged in Industrial Package Type 1 (IP-1). The main requirements for such a package are that it shall be designed so that it can be transported easily and safely, can be properly secured in or on the conveyance during transport, have robust lifting attachments, nuts, bolts and other securing devices, and can withstand ambient temperature and pressure during air transport. The package is not required to be water-tight.

The site will produce approximately 12,000 drums of uranium concentrates annually, which will be loaded into sea-containers. Limitations apply to the transportation of radioactive goods, and it has been estimated that a maximum of 35 drums may be loaded into a container to maintain a Transportation Index (TI) of less than 6. It is therefore expected that 343 sea-containers will be shipped to the south annually.

Carriers: Aircrafts

For the proposed air transport of Uranium concentrates, the product would be flown using a Hercules aircraft (or similar). One sea-container of 35 drums, within the 18 tonnes payload of the aircraft, would be shipped per flight.

A total production of 4000 tonnes uranium (4800 tonnes of Uranium concentrates) translates to 343 sea-containers to be transported by aircrafts.

Table 6.4-15 Transport by each Carrier

	No. of Containers per Trip	Number or Trips /Year
Material	Aircraft	Aircraft
Uranium concentrates	1	343

Intermodal Sites

Shipments of Uranium concentrates are transported by truck at the Kiggavik site to the Pointer Lake airstrip and loaded onto aircraft for air transport to Points North. These locations, referred to as intermodal sites, include the Kiggavik airstrip and the Points North airport. A brief description of each of these sites is provided below.

Kiggavik Site

At the Kiggavik site, an airstrip would be constructed for the transport of both employees and materials including uranium concentrates to facilitate transport to the refineries. The proposed airstrip includes the following components:

- A runway 2,000 m in length and 45 m in width
- An aircraft turning D on the south end (see Figure 6.4-3)
- A graded area capable of supporting an aircraft on either side of the runway
- A 150 m long Runway End Safety Areas at both ends of the runway

- A taxiway 23 m wide with 6 m graded shoulders
- An apron for two aircrafts with sufficient space for servicing and independent arrival/departure
- A single storey pre-fabricated Air Terminal Building (ATB) to provide shelter

The ATB would also contain the Aircraft Control of Aerodrome Lighting (ARCAL) antenna, aerodrome beacon, aircraft ground power units and apron flood lighting. The ARCAL will allow pilots to control the aerodrome lighting with no assistance from the aerodrome personnel. The selected site will not be stripped or grubbed in order to preserve the permafrost.

Points North Airport

For transport of uranium concentrates, Points North Landing Airport will be used as an intermodal site for shipping Uranium concentrates received from the Kiggavik site to the refineries. Points North airport is located in the continental sub-arctic region of northern Saskatchewan about 20 km west of Wollaston Lake. The airport has a runway approximately 2000 m long, and currently provides regularly scheduled passenger service year round.

Exposure Characterization

Potential impacts of routine operations are limited to external radiation dose to human receptors in close proximity of yellowcake containers. Workers and the public may be exposed during the routine operation of transporting yellowcake from Kiggavik. An exposure assessment has been conducted for four scenarios for operators involved with the transportation of yellowcake, and one representative member of the general public who resides at Points North.

<u>Scenario 1</u>- Forklift operator loading 35 drums of yellowcake into a sea-container which has already been placed on a truck or is on the ground to be loaded into an aircraft

A forklift operator will be exposed to one drum which is being loaded into the sea-container and exposed to drums already in the container when loading the drum into the sea-container. A forklift operator was conservatively assumed to be exposed to a full sea-container.

The estimated exposure time for a forklift operator to move a drum onto the forklift and into the sea-container was two minutes per drum. It was conservatively assumed that one forklift operator operates the forklift to move all the drums for each trip. The operator then spends approximately two minutes in the sea-container to unload the drum from the forklift. Therefore, the estimated exposure time is approximately 140 minutes per trip (i.e., 70 minutes (two minutes per drum x 35 drums) to move a drum onto the forklift and into the sea-container and another 70 minutes to unload the drum from the forklift). A forklift operator was assumed to be 100 cm from the drum. For conservative purposes, a forklift operator was assumed to be located at the centre point of the drum (i.e., half-width and half-height of the source).

A forklift operator will load drums to fill 343 sea-containers which will be transported air.

The dose points for Scenario 1 are shown in Figure 6.4-3. Note that the figure is not to scale and intended to provide a perspective of the dose points with respect to the source.

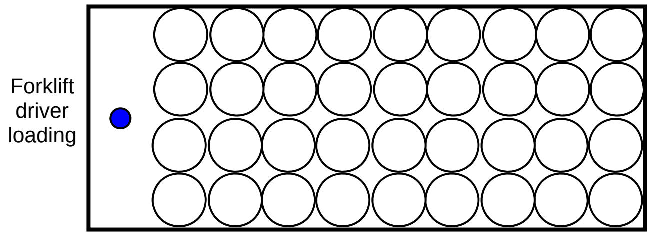


Figure 6.4-3 Dose Point for Scenario 1

The effective doses to a forklift loading 35 drums of yellowcake into a sea-container are shown in Table 6.4-16.

Table 6.4-16 Effective Dose to a Forklift Operator (Scenario 1)

Activity	Hours per trip [a]	Effective Dose Rate (mSv/hr)	Effective Dose (mSv)
Moving a drum into a sea-container which has already been placed on a truck	1.17	1.9E-03 [b]	2.2E-03
Loading a drum into a sea-container which has already been placed on a truck	1.17	8.4E-03 [b]	9.8E-03
		Total Dose per trip [c]	1.2E-02
		Trips per year	343
		Total Dose per year [d]	4.1

NOTES:

a) 2 minute per drum x 35 drums = 70 minutes

b) Antero-posterior geometry (with build-up)

c) Sum of moving and loading effective dose.

d) Total per trip x Trips per year.

Scenario 2- Truck driver transporting a sea-container with 35 drums

A truck driver is expected to make 343 trips per year (i.e., 343 sea-containers); each trip is 10 km and will take 15 minutes assuming an average speed of 40 km/hr. In addition, a truck driver will perform an inspection prior to departure and upon arrival at the destination; each inspection was assumed to take 5 minutes.

During the transport of yellowcake, a truck driver is exposed while driving the trailer and while performing inspections.

During the time spent driving, a truck driver is located in the cab of the truck and is exposed from behind (i.e., the driver's back towards the width of the source). A driver's cabin was assumed to be 100 cm from the trailer. However, it should be noted that the actual distance from the source was 110.45 cm when the thicknesses of the steel wall of the trailer (0.3 cm), wall of the cab (0.15 cm) and the space between the driver and the back wall of the cab (10 cm) are included. For conservative purposes, a truck driver was assumed to be located at the centre point of the shorter side (width) of the trailer (i.e., half-width and half-height of the source).

A driver inspects the truck prior to departure and upon arrival at the destination. During the inspection, a driver was assumed to be 50 cm away from the side of the truck. In addition, for conservative purposes, a truck driver was assumed to be located at the centre point of the longer side (length) of the trailer (i.e., at half-length and half-height of the source).

The dose points for Scenario 2 are shown in Figure 6.4-4. Note that the figure is not to scale and intended to provide a perspective of the dose points with respect to the source.

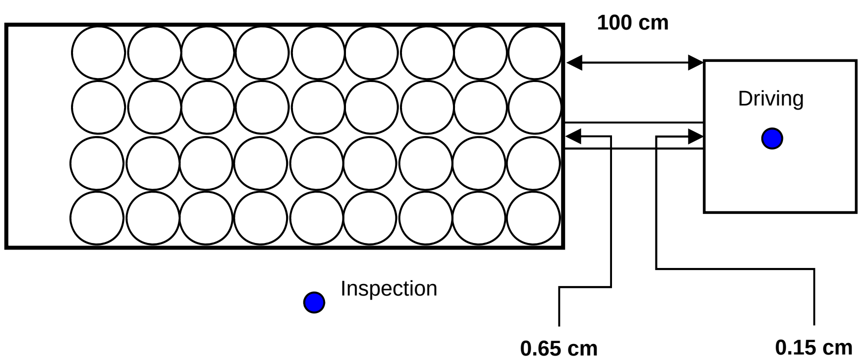


Figure 6.4-4 Dose Points for Scenario 2

The effective dose to a truck driver driving the truck is shown in Table 6.4-19.

Table 6.4-17 Effective Dose to a Truck Driver (Scenario 2)

Activity	Hours per trip	Effective Dose Rate (mSv/hr)	Effective Dose (mSv)
Driving	0.25 [a]	5.5E-03 [c]	1.4E-03
Inspection	0.1 [b]	1.7E-02 [d]	1.7E-03
		Total Dose per trip[e]	3.1E-3
		Trips per year	343
		Total Dose per year[f]	1.1

NOTES:

a) For travelling 110 km at a speed of 80 km/hr

b) 0.25 hours prior to departure and 0.25 hours upon arrival at the destination

c) Postero-anterior geometry (with build-up).

d) Antero-posterior geometry (with build-up).

e) Sum of driving and inspection effective dose.

f) Total per trip x Trips per year.

Scenario 3 - Pilot transporting a sea-container with 35 drums

A pilot of a Hercules cargo plane is expected to make 343 trips per year (i.e., 343 sea-containers), each trip is expected to take 75 minutes assuming an average speed of 602 km/hr (i.e., 374 mph/hr which is the speed of a Hercules C-130, Global Aircraft 2010).

The pilot is assumed to be 10 m from the front of the sea-container, which was approximately 1/3 the length of a Hercules C-130 (29.3 m, Global Aircraft 2010)

The dose points for Scenario 5 are shown in Figure 6.4-5. Note that the figure is not to scale and intended to provide a perspective of the dose points with respect to the source.

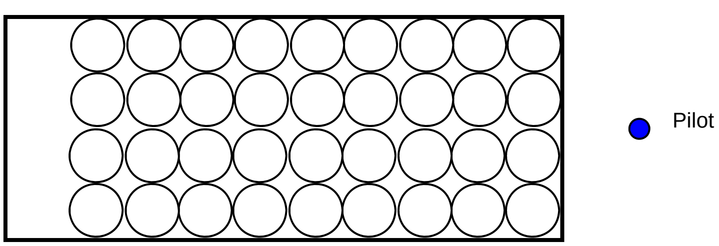


Figure 6.4-5 Dose Point for Scenario 3

The effective dose to a pilot of a Hercules cargo plane is shown in Table 6.4-20.

Table 6.4-18 Effective Dose to Pilot (Scenario 3)

Activity	Hours per trip	Effective Dose Rate (mSv/hr)	Effective Dose (mSv)
Pilot	1.28 [a]	1.2 E-04 [b]	1.5E-04
		Trips per year	343
		Total Dose per year [c]	0.051

NOTES:
a) 770 km/602 km/hr (speed of Hercules C-130)
b) Postero-anterior geometry (with build-up).
c) Total per trip x Trips per year.

The annual dose to the pilot is less than the dose limits for the member of the public (1000 µSv/year).

Scenario 4 - Driver of a heavy duty forklift

A forklift driver in the storage area will be exposed to 14 sea-containers. These 14 sea-containers are in 2 containers (Length) by 7 containers (Width) arrangement. The forklift drivers will spend 140 minutes in the storage area (i.e., 10 minutes per sea-container x 14 sea-containers in the storage area).

A forklift operator will be exposed to 14 sea-containers in the storage area. A forklift operator was assumed to be 1 m from the sea-containers and exposed to 14 sea-containers all the time which is conservative since the sea-containers are gradually moved into and out of the storage area. Another added conservatism is that a forklift operator was assumed to be located at the centre point of the sea-containers (i.e., half-length and half-height of the source).

The effective dose to a forklift operator exposed to 14 sea-containers in the storage area is shown in Table 2.4-21.

Table 6.4-19 Effective Dose to Driver of Heavy Duty Forklift (Scenario 4)

Activity	Hours per operation	Effective Dose Rate (mSv/hr)	Effective Dose (mSv)
Heavy Duty Forklift Driver	0.17 [a]	6.9E-02 [b]	0.11
		Operations per year	343
		Total Dose per year [c]	3.9

NOTES:

a) 10 minutes per sea-container for 60 sea-containers in the storage area.

b) Antero-posterior geometry (with build-up).

c) Total per trip x Trips per year.

Scenario 5 - A member of the public near the storage area

A member of the public (resident worker at Points North Landing) was assumed to live 100 m from the storage area and spend time indoors and outdoors. A member of the public is exposed for four weeks of a year (during which yellowcake is stored at Points North before transport via truck) and spends 6.25% of the time outdoors (adult, Health Canada 2004). When a resident is indoors, a resident was assumed to be shielded by a studded insulated wall with wood sheeting and aluminum siding (which was assumed to be 5 inches thick.

The effective dose to a member of the public is shown in Table 6.4-22.

Table 6.4-20 Effective Dose to Member of the Public (Scenario 5)

Activity	Hours per year	Effective Dose Rate (mSv/hr)	Effective Dose (mSv)
Resident (indoors)	630 [a]	2.8E-05 [c]	0.018
Resident (outdoors)	42 [b]	5.7E-05 [c]	2.4E-3
		Total per year	0.02

NOTES:

a) Based on Health Canada (2004), an adult spends 6.25% of time outdoors and 93.75% of time indoors; exposure duration is three months per year.

b) 1.5 hr/d outdoors (6.25%) for four weeks per year

c) Antero-posterior geometry (with build-up)

Summary

The total effective doses for all transportation scenarios are shown in Table 6.4-23.

The CNSC (2000) radiation dose limit for a member of the public is 1 mSv per year (over natural background levels). The guideline for a NEW is 100 mSv for five years (i.e., an average of 20 mSv/year).

The radiation doses estimated for routine operations are below 1 mSv/y for all members of public, and the pilots.

The forklift operators and truck driver at Kiggavik (Scenarios 1, 2, & 4) will be NEWs; they will not receive radiation doses higher than accepted (i.e. 20 mSv/y) from these operations.

Table 6.4-21 Effective Dose for All Scenarios for Routine Operation

Scenario	Receptor Description	Total Dose (mSv/y)
1	Forklift operator	4.1
2	Truck driver	1.1
3	Pilot (343 trips)	0.051
4	Driver of heavy duty forklift	3.9
5	Member of the public	0.02

For the transportation assessment, the calculated effective doses represent the total dose for the activity, similar to the collective dose for a job category discussed in earlier sections. These values can be considered the upper bound case as they attribute all of the dose for the activity to a single worker for each activity. In practice, the Kiggavik project will be operated with the workforce on a rotational schedule with 1 week of work followed by 1 week at home, resulting in a minimum of 2 persons conducting the work activities. As a base case, exposure levels will be approximately half of those presented in the above table, and the average worker dose for NEWs conducting transportation activities will be approximately 1.5 mSv/year (i.e. [4.1 + 1.1 + 3.9]/6).

6.5 Residual Effects on Worker Exposure to Radioactivity

6.5.1 Summary of Worker Radiation Exposure

The base case and upper bound case radiation doses estimated for routine operations in the underground mine, surface mines, mill and transport sections are presented in Table 6.5-1.

Table 6.5-1 Summary of Potential Radiological Exposure

Project Activities/Physical Works	Base Case Average Worker Radiation Dose (mSv)	Upper Bound Case Maximum Worker Radiation Dose (mSv)
Construction		
All associated activities	NA	NA
Operation		
Mining - Underground	5.2	10.5
Mining - Open Pit	0.76	5.88
Milling	0.66	4.15
General Services – Generation of power	NA	NA
General Services - Hazardous materials storage and handling (reagents, fuel and hydrocarbons	NA	NA
General Services - Explosives storage and handling	NA	NA
Transportation – Air transport of Uranium concentrates	1.5	4.1
On-going Exploration – Aerial surveys	NA	NA
Decommissioning		
On-going treatment and release of water, including domestic wastewater	NA	NA

In the assessment of potential worker radiation doses during underground mining, open pit mining, and milling, input parameters have spanned the range of expected ore grades and production levels under conservative assumptions to demonstrate that mining and milling can be completed safely. There are no workers expected to receive radiation doses higher than the dose limits set by the Canadian Nuclear Safety Commission of 50 mSv in a single year or 100 mSv in a 5 year period. There are no workers expected to receive radiation doses higher than the effective annualized dose limit of 20 mSv/year. Base case and upper bound cases illustrate the sensitivity of projected doses to ore grade and production levels. As projected maximum doses from upper bound cases are anticipated to be a fraction of the dose limit, changes in ore grade and production level are not expected to affect the conclusion that mining and milling can be conducted with resultant worker doses below the dose limit.

6.5.2 Occupational Health Risk From Radiation Exposure in Perspective

The International Commission on Radiological Protection most recently updated its general recommendations with their publication of ICRP 103, “The 2007 Recommendations of the International Commission on Radiological Protection.” The recommendations provide a combined detriment-adjusted risk coefficient for excess cancer and heritable effects of approximately 4% per Sv (5.7% whole population; 4.2% adults), assuming a linear response at low doses.

To look at the estimated worker doses from the perspective of increased individual risk, we start with the basic fact that the overall lifetime risk of fatal cancer in Canada is about 27%; that is, about ¼ of all deaths in Canada are due to cancer. This figure is based on a joint report of Health Canada, Statistics Canada, and the Canadian Cancer Society (Statistics Canada 2009). Considering total cancer incidence, about 45% of men will develop cancer during their lifetimes and 28% will die from it; for females, approximately 40% will develop cancer in their lifetime, and 24% will die from it.

In Canada, the average exposure to background radiation is about 2 mSv per year. This amounts to about 150 mSv (0.15 Sv) over a lifetime of 75 years. With a fatal cancer risk averaged over all ages of 4% per Sv for members of the public (ICRP 2007), a 150 mSv dose would correspond to a theoretical lifetime fatal cancer risk of 0.60% (0.15 Sv x 4% per Sv). This hypothetical risk is based on an assumed linear no threshold (LNT) relationship between dose and risk, and is presumably included in the 27% overall lifetime fatal cancer risk (although it has never been demonstrated that lifetime exposure to background gamma radiation has produced any cancers).

Table 6.5-2 Summary of Radiation Risk Estimate

	Annual Average (mSv)	Annual % Increase in cancer and hereditable effects from radiation exposure	Lifetime Attributable Exposure (mSv)	Lifetime % Increase in cancer and hereditable effects from radiation exposure
Baseline Exposure (75 years)	2	0.01%	150	0.60%
Average Kiggavik Mill Worker (20 years)	0.66	0.003%	13.2	0.053%
Average Kiggavik Open Pit Worker (9 years)	0.76	0.003%	6.66	0.027%
Average Kiggavik U/G Mine Worker (3 years)	5.2	0.02%	15.6	0.06%
Tranporation Worker (20 Years)	1.5	0.006	25	0.10%

6.6 Summary of Compliance Monitoring

A Radiation Protection Plan (RPP) is implemented at uranium mine sites in order to effectively mitigate risks from radiation exposure to workers, the public and the environment. The objective of the Radiation Protection Plan is to fulfill AREVA's Radiation Protection Policy to maintain radiation doses as low as reasonably achievable (ALARA), social and economic factors considered. The RPP describes the program of activities conducted during the operational phase of the Kiggavik Project to manage, control and optimize radiation exposure.

This RPP is organized into five (5) sections. The Administrative Elements describes the principles of radiation protection, classification of workers, and describes a key document in the management of radiation protection: the Code of Practice. The subsequent sections are organized around the Deming Cycle for continuous improvement of Plan, Do, Check, Act.

6.6.1.1 Radiological Levels Area Monitoring

Gamma radiation, radon/radon progeny (RnP), and long-lived radioactive dust (LLRD) will be monitored routinely throughout the Kiggavik Project in order to detect potentially abnormal radiological conditions promptly, to estimate worker doses, and to document radiological conditions.

A network of monitoring locations, parameters and frequencies is established for each of the Kiggavik Mill, Open Pit Mines, Underground Mine, and Associated Facilities in the Routine Radiological Monitoring Schedule procedure. This procedure complies with applicable federal and territorial regulations; states instrument requirements and sampling methods; refers to Administrative Levels and mitigative measures; and identifies reporting responsibilities and methods.

6.6.1.2 Dosimetry Monitoring

Dosimetry monitoring is conducted to document worker exposures to radiological components. The goal of radiation protection is to keep all worker doses below regulatory limits and to maintain worker doses As Low As Reasonable Achievable (ALARA). A procedure for the Kiggavik Project is designed to ensure worker doses from each radiological component are determined (or estimated), recorded, evaluated and monitored in an appropriate manner.

Dosimetry monitoring is required under the Radiation Protection Regulations and the Uranium Mining and Milling Regulations under the Nuclear Safety and Control Act. Licensees are required to record the dose received by and committed to each person who performs duties in connection with any activity that is authorized by the act or who is present at a place where that activity is carried on. Dosimetry monitoring demonstrates compliance with dose limits defined by federal regulations, territorial regulations and other regulatory instruments, e.g., license conditions.

The Dosimetry Monitoring Strategy (DMS) Procedure address all workers for occupational health purposes. This includes both the regular site workforce and other persons (e.g. contractors and visitors) who access “Radiation Areas” of the Kiggavik Project. A distinction is made between Nuclear Energy Workers (NEW) and non-NEW staff. Dosimetry monitoring of NEW staff is a regulatory requirement necessitating routine regulatory reporting. Dosimetry monitoring of non-NEW staff is conducted for internal control purposes; though not routinely reported to regulators, suitable records are maintained on file.

All workers are subjected to a dose assessment, though the DMS, to determine their potential level of radiation exposure and from there they are classified as NEW or non-NEW accordingly. Occupational workers, such as personnel who work at the accommodations complex providing catering and housekeeping services are not anticipated to receive doses which would exceed the dose limit for a member of the general public therefore they are not anticipated to classified as Nuclear Energy Workers. Uranium mining experience at similar facilities in Canada shows that support staff, involved with camp service work, receive little or no incremental dose. Actual workplace levels will be confirmed through monitoring at the time of operation.

This DMS addresses radiation doses from gamma radiation, radon progeny (RnP) and long-lived radioactive dusts (LLRD). Given the current recognized uncertainty of the uranium-in-urine measuring techniques in providing estimates of committed doses, uranium-in-urine monitoring is included as a monitoring tool rather than a dosimetric tool.

Methods of dose monitoring at the Kiggavik Project will include the use of:

- Optically Stimulated Luminescent Dosimeters (OLDs) provided by a dosimetry service provider, licensed by the CNSC, for determination of gamma radiation dose;
- Personal Alpha Dosimeters (PADs) provided by an outside licensed dosimetry service provider for determination of radon progeny (RnP) and long lived radioactive dust (LLRD), used on an individual or group basis;
- Direct reading dosimeters (DRDs) for estimation of gamma radiation dose, used on an individual or group basis;
- Worker occupancy and area monitoring data for estimation of RnP and LLRD dose;
- Dose data from workers conducting similar activities for the estimation of gamma radiation, RnP or LLRD doses;
- Historical occupational information for the estimation of gamma radiation, RnP or LLRD doses; and
- Pre-work dose estimation and planning.

7 Assessment of Project Effects, Human Health – Members of the Public

A Human Health Risk Assessment (HHRA) was conducted to evaluate whether the releases of radionuclides as well as other Constituents of Potential Concern (COPC) from the project would result in any adverse effects on people that live in the area and consume local country food. The completion of an HHRA was specifically identified in the NIRB guidelines.

7.1 Issues and Concerns Identified During the Inuit and Stakeholder engagement

The NIRB EIS Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.'s Kiggavik Project, 2011 incorporated advice from the public and interested parties on the proposed scope of assessment for Human Health, including the identification of VCs and issues that should be considered in the EIS. Project specific issues and concerns identified during Inuit, government and stakeholder engagement that were included in the guidelines broadly include:

- potential health hazards of uranium
- a discussion of the potential effects of changes in air quality on human health
- provide predicted increases in contaminants and radionuclides in groundwater and surface water as a result of the Project
- potential impact to human health due to consumption of fish
- potential impacts on human health from soil ingestion associated with traditional lifestyles where large amounts of country foods are consumed, and from bioaccumulation and take-up of contaminants associated with changes to the level of contaminants loadings in country foods (i.e., wildlife and vegetation consumed by humans)
- predicted radiation exposures (radiation doses) to workers and the public during all phases of the project

In addition, the NIRB guidelines specifically state that the Human Health Risk Assessment is to include:

- predicted sources, quantities and points of release from the project emissions and effluents containing nuclear and hazardous substances
- selection process for COPCs
- identification of pathways to human receptors

- identification and characterization of human receptors (workers and the public). Include maps to delineate their locations and the distances of communities, residences, temporary/seasonal residences, etc. to project sites and related infrastructure
- method used to convert radionuclide and hazardous substance exposure and intake by the various human receptors from the various pathways into an exposure or dose (e.g., conversion factors)
- criteria used to determine significance of impact (e.g., percentage of radiation dose limits, exposure relative to lifetime cancer risk limit)

7.1.1 Complementary Nature of Risk Assessment Process and IQ Values

AREVA does not suggest that the ecological risk assessment and human health risk assessment (ERA/HHRA) were conducted solely because of feedback and comments gathered during Inuit Qaujimajatuqangit (IQ) interviews and engagement activities.

Rather, AREVA would like to explore similarities between the ERA/HHRA process (Tier 3, Technical Appendix 8A) and IQ guiding principles. This includes the complementary nature of the ERA/HHRA approach with the Inuit view of a holistic, interconnected ecosystem which includes humans. The complementary foundation of ecological and human health risk assessments with IQ values are considered here.

7.1.2 Inuit Qaujimajatuqangit Framework and Guiding Principles

Inuit Elders in Nunavut have identified a framework for IQ which is based in four main laws or *maligait* (GN 2007). Implementation of these fours *maligait* contributes towards ‘living a good life’ (Tagalik 2012). The four maligait are:

1. Working for the common good
2. Respecting all living things
3. Maintaining harmony and balance and
4. Continually planning and preparing for the future

The concept of the ERA/HHRA complements these *maligait*, in particular the framework for respecting all living things and continually planning and preparing for the future. The ERA/HHRA process which examine all inputs (e.g. from water, air, soil, plants, animals to humans) shows respect for all living things by acknowledging and embracing the interconnectedness of non-living (soil, water, air) and living things (plants, animals, humans) in a food web or ecosystem. By analyzing data and modelling pathways of constituents of potential concern, AREVA is planning and preparing for the future. The ERA/HHRA model is a tool to predict (model) future changes in the environment and this information is generated to help inform decision making for the Kiggavik Project. In addition to the *maligait*, the ERA/HHRA process shares a foundation with the following subset of IQ guiding principles (from GN 2009 and the Nunavut Wildlife Act).

1. Papattiniq/Munakhinik: obligation of guardianship or stewardship that a person may owe in relation to something that does not belong to the person.

    - The Kiggavik Project is a temporary use of the land for mining and milling. The ERA/HHRA takes timescales into consideration by modelling pathways during construction, operation, decommissioning, and post-decommissioning phases of the Project. Throughout this assessment, AREVA has outlined various mitigation measures in order to minimize effects of the Project on the environment.

2. Avatimik Kamattiarniq/Amiginik Avatimik: concept of environmental stewardship. People are stewards of the environment and must treat all of nature holistically and with respect, because humans, wildlife and habitat are inter-connected and each person's actions and intentions towards everything else have consequences, for good or ill.

    - The interconnectedness of humans and all aspects of the ecosystem is the basis for developing the ERA/HHRA model.

3. Pilimmaksarniq/Ayoikyumikatakhimanik: skills must be improved and maintained through experience and practice.

    - The ERA/HHRA is a living model that will revisited and recalibrated throughout the life of the Project. Environmental monitoring data (e.g. water quality, sediment quality) will be compared to ERA/HHRA predictions as the Project moves through construction, operation and decommissioning phases. A process of continued learning is implicit in the modelling approach.

    - Through IQ interviews and engagement activities to date, AREVA is cooperating and demonstrating an ability to listen to and learn from others. The experience, feedback, and IQ from Inuit has been used to inform various aspects of the Project and the assessment.

4. Qanuqtuurunnarniq/Kaujimatukanut: concept of being resourceful to solve problems. Ability to be creative and flexible and to improvise with whatever is at hand to achieve a purpose or solve a problem.

    - The basic premise of the ERA/HHRA is creativity. The modelling work is done with some assumptions because we cannot know all inputs with 100% certainty.

Scientists use their knowledge and creativity to build the model and also recognize any uncertainty and explain any assumptions made.

- AREVA's resourcefulness is demonstrated through creative approaches to gather community feedback and provide Project information related to human and ecological health, e.g. poster boards explaining radiation using hockey analogies (Tier 3, Technical Appendix 3A, Part 5, Figures B.2-1 to B.2-3).

5. Ikpigusuttiarniq Nirjutilimaanik/Pitiaklugit nekyutit: all wildlife should be treated respectfully.

   - AREVA wants to make sure they understand the potential effects of contaminants of potential concern in the environment. The ERA allows AREVA to look at multiple interactions at once. By understanding the complete picture and looking at a food web rather than just one species at a time, the ERA/HHRA approach is an example of AREVA's respect for wildlife.

As described above, the concept, process, and goal of ecological and human health risk assessments align with IQ framework in a number of ways. In addition, AREVA's commitment to continually revisit and improve the ERA and HHRA highlights the company's priority of continually improving and adapting as required.

7.1.3 Inuit Qaujimajatuqangit and Engagement Data

When Elders tell a story, it may take a while to get to the key message but there is a reason for this style of storytelling. As the story is told, different elements that may appear to have nothing to do with the story are mentioned, such as weather, earlier events, and the mood of people. All of these elements set the tone, environment, senses, and time. An Elder tells a story in this way so the listener gets the holistic view in their mind as to what the story is about: the storyteller wants you to feel as though you are experiencing the event for yourself. You cannot fully understand a piece without some understanding of the whole (IQ-BL EL-13; Kusugak, P. 2013, pers. comm.).

IQ interviews and stakeholder engagement has consistently identified human health as an important consideration. During the consultation activities, concerns were raised by the participants with respect to human health. These concerns included:

- exposure and contamination of local food sources, mainly identified as fish and caribou, and consequences of eating them (EN- BL HTO Aug 2009[86], EN-RI KWB Oct 2009[87], EN-BL NIRB Apr 2010 [88], EN- KUG NTI May 2007[89], EN-RI KIA Apr 2007[90], EN- BL EL Mar 2009[91], IQ- Nunavut Tunngavik Inc. 2005[92], IQ- Nunavut Tunngavik Inc. 2005[93])
- importance of considering ecosystem health and human health in a holistic manner (EN-CI KIA Apr 2007[94], IQ- Nunavut Tunngavik Inc. 2005[95]);
- dust, how far it would travel (IQ-RIE 2009[96], EN-BL EL Oct 2012[97]) and would it affect health (EN-RB NIRB April 2010[98], IQ- ARHT 2009[99]) and
- specific health outcomes including child health (EN-BL HS Nov 2010[100], EN-BL NIRB Apr 2010[101]).

These engagement and IQ comments provide examples of how IQ guiding principles complement and informed the ecological and human health risk assessments.

There are occasional suggestions in the literature that traditional ecological knowledge is “holistic,” in contrast to “reductionist” Western science (Usher 2000). The implication is that these two viewpoints are distinct and have no similarities or overlap. The ERA/HHRA process provides an excellent example of a holistic tool used to consider many pathways and endpoints for constituents of potential concern in the environment. Through implementation of the Community Involvement Plan (Tier 3,

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[86] EN- BL HTO Aug 2009: *Are the fish you catch edible?*

[87] EN-RI KWB Oct 2009: *We rely on country foods and these have to be protected*

[88] EN-BL NIRB Apr 2010: *Concerned about the inability of eating wildlife and fish if contaminated.*

[89] EN- KUG NTI May 2007: *Uranium gets into animals, people eat them, do we get sick?*

[90] EN-RI KIA Apr 2007: *I rely on caribou and fish. So does that mean I will get sick more? Are we more at risk?*

[91] EN- BL EL Mar 2009: *I support the mine because I am concerned about the young people being unemployed. I am also concerned about the environmental assessment and how it is going to be completed, especially with the water testing. The animals drink the water, and it would be best to have all things safe for the animals*

[92] IQ- Nunavut Tunngavik Inc. 2005: *The contamination of wildlife is a concern in itself, not just because of the potential repercussions on country foods; the focus of contaminants research should therefore not focus exclusively on human health*

[93] IQ- Nunavut Tunngavik Inc. 2005: *Not all illnesses in wildlife are caused by contaminants, although they can be a contributing factor*

[94] EN-CI KIA Apr 2007: *Caribou eat off the ground and then we eat the caribou. If they get sick, we get sick. Will we get diseases?*

[95] IQ- Nunavut Tunngavik Inc. 2005: *The health of Inuit, of wildlife and of the environment are interconnected*

[96] IQ-RIE 2009: *Elders expressed concern about the potential effects of uranium dust travelling and affecting many people*

[97] EN-BL EL Oct 2012: *I am pretty sure there will be dust that will spread everywhere. You’ll need wildlife monitors all the time. There will be lots of dust and animals like rabbits and wolves will be affected.*

[98] EN-RB NIRB April 2010: *Concerned with air pollutants travelling by way of dust particles. Dangers associated with the dust to human health and wildlife*

[99] IQ- ARHT 2009: *Hunters and elders expressed concerns about the potential for airborne contamination settling on vegetation and being consumed by caribou.*

[100] EN-BL HS Nov 2010: *What can happen to the body after prolonged exposure to radiation?*

[101] EN-BL NIRB Apr 2010: *Concerns regarding impacts to human health, especially impacts to children.*

Technical Appendix 3D), AREVA Resources Canada Inc. will communicate information on ecological and human health risk assessment results to Kivalliq community members and gather feedback. AREVA is committed to *fostering good relationships by being open and inclusive* (IQ principle Tunnganarniq) while *respecting other and building relationships* (IQ principle Inuuqatigiitsiarniq). Community feedback will inform ERA and HHRA updates which demonstrates AREVA's commitment to *consensus decision-making* (IQ principle Aajiiqatigiingniq).

7.2 Scope of the Assessment for Human Health - Members of the Public

7.2.1 Regulatory Setting

There are no regulations dictating human health risk assessments. General guidance on how to conduct HHRAs is provided by Health Canada (2004a, 2009a) and these guidance documents were considered in this assessment. In addition, the Canadian Standards Association (CSA) has issues a standard that outlines the requirement for risk assessments for uranium mines (N288.6) (CSA 2012).

In Canada, the Canadian Nuclear Safety Commission (CNSC) regulates the nuclear industry. Dose limits for workers and members of public are provided under the Nuclear Safety and Control Act, Radiation Protection Regulations (SOR/2000-203). This act states that the prescribed incremental limit for members of the public is 1 mSv per calendar year.

7.2.2 Project-Environment Interactions and Effects

Project activities and physical works have the potential to interact and affect the surrounding environment. A number of project activities have been identified with potential to interact with exposure to members of the public to radioactivity and other COPC. These activities are ranked according to their potential to interact with exposure to members of the public. Interactions were assigned a ranking as follows:

- **0** = activities are those with no interaction, or no potential for substantive interaction, with the human health assessment.
- **1** = activities are those having a potential interaction with human health assessment, but whose interaction would not result in a significant health effect once planned and proven mitigation methods are applied to the activity.
- **2** = activities are those activities having potential for substantive effects on human health assessment, even after mitigation measures are applied. The potential health effects are addressed further in the health assessment.

Exposure to Criteria Air Contaminants (CAC) was considered separately in the HHRA as the assessment methodology is quite different than the other contaminants. CAC include SO_x, NO_x and particulate matter (PM). Exposure to radioactivity and other COPC is a result of exposure via different pathways including drinking water, inhalation, ingestion of game (e.g., caribou, fish) and gathering of berries and medicinal plants. This results in an integration of the emissions from both the atmospheric and aquatic environments.

Table 7.2.1 presents the ranking of interactions between the Project and the members of the public for the construction, operation and final closure phases of the Project. Each of the environmental interactions ranked as a 2 were carried forward for further assessment. Although those with a ranking of 1 do not necessarily need to be carried forward for a detailed assessment, due to the importance of protection of members of the public a quantitative assessment was conducted for many of these interactions. Those with a ranking of 0 are not carried forward. The rationale for all rankings provided in the table is discussed in more detail below.

Table 7.2.1 Identification of Project-Environmental Effects Interaction for Human Health – Exposure to Members of the Public

Project Component	Project Activities/Physical Works	Exposure to Criteria Air Contaminants	Exposure to Radioactivity and Other COPC
Construction			
Economic Activities	Construction workforce management; Contracts and taxes; Advance training of operations workforce	0	0
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	0	0
	Construct in-water/shoreline structures	0	1
	Water transfers and discharge	0	0
	Freshwater withdrawal	0	0
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing)	1	0
	Road and Airstrip Construction	1	0
	Aggregate Sourcing	1	0
	Construct foundations	0	0
	Construct buildings	0	0
	Install equipment	0	0
	Install and commission fuel tanks	0	0

Project Component	Project Activities/Physical Works	Exposure to Criteria Air Contaminants	Exposure to Radioactivity and Other COPC
	Mill dry commissioning (water only)	0	0
Supporting Activities	Transport fuel and construction materials (transfers, barging)	1	0
	Air transport of personnel and supplies	0	0
	Hazardous materials storage and use	0	0
	Explosives storage and use	0	0
	Waste incineration and disposal	0	0
	Industrial machinery operation	1	0
	Power generation	1	0
Operation			
Economic Activities	Workforce management; Employment; Contracts and taxes	0	0
Mining	Mining ore (blasting, loading, hauling)	1	1
	Ore stockpiling	1	1
	Mining special waste (blasting, loading, hauling)	1	1
	Special waste stockpiling	1	1
	Mining clean waste (blasting, loading, hauling)	1	1
	Clean rock stockpiling	1	1
	Mine dewatering	0	0
	Underground ventilation	1	1
	Backfill production and underground placement	1	1
Milling	Transfer ore to mill	1	1
	Crushing and grinding	1	1
	Leaching and U recovery	1	1
	U purification	1	1
	Yellowcake drying and packaging	1	1
	Tailings neutralization	1	1
	Reagents preparation and use	1	0
Tailings Management	Pumping and placement of tailings slurry	0	0
	Consolidation of tailings	0	0

Project Component	Project Activities/Physical Works	Exposure to Criteria Air Contaminants	Exposure to Radioactivity and Other COPC
	Pumping of TMF supernatant	0	0
Water Management	Create and maintain water levels	0	0
	Freshwater withdrawal	0	0
	Potable water treatment	0	0
	Collection of site and stockpile drainage	0	0
	Water and sewage treatment	0	1
	Discharge of treated effluents (including grey water)	0	1
Waste Management	Disposal of industrial waste	0	0
	Management of hazardous waste	0	0
	Management of radiologically contaminated waste	0	0
	Disposal of domestic waste	0	0
	Incineration and handling of burnables	1	0
	Disposal of sewage sludge	0	0
General Services	Generation of power	1	0
	Operate accommodations complex	0	0
	Recreational activities	0	0
	Maintain vehicles and equipment	0	0
	Maintain infrastructure	0	0
	Operate airstrip	0	0
	Hazardous materials storage and handling (reagents, fuel and hydrocarbons)	0	0
	Explosives storage and handling	0	0
Transportation	Marine Transportation: loading barges, barging, off-loading (fuel, reagents and supplies), Baker Lake and Churchill/Chesterfield, back-haul	1	0
	Truck transportation	1	0
	General traffic (Project-related)	1	0
	Controlled public traffic	0	0
	Air transportation of personnel, goods and supplies	0	0
	Air transportation of yellowcake	0	0

Project Component	Project Activities/Physical Works	Exposure to Criteria Air Contaminants	Exposure to Radioactivity and Other COPC
	General air transportation support	0	0
Ongoing Exploration	Aerial surveys	0	0
	Ground surveys	0	0
	Drilling	0	0
Final Closure			
Economic Activities	Decommissioning Workforce management; Employment; Contracts and taxes	0	0
General	Hazardous materials storage	0	0
	Industrial machinery operation	1	0
	Ongoing withdrawal, treatment and release of water, including domestic wastewater	0	0
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	0	0
	Remove surface drainage containment	0	0
	Remove in-water/shoreline structures	0	1
	Water transfers and discharge	0	0
	Construct fish habitat as per FHCP	0	0
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1	1
	Backfilling	1	1
	Contouring	1	1
	Covering	1	0
	Revegetation	0	0
	Remove foundations	0	0
	Remove buildings	0	0
	Remove equipment	0	0
	Remove fuel tanks	0	0
	Marine Transportation: loading barges, barging, off-loading (fuel, reagents and supplies), Baker Lake and Churchill/Chesterfield, back-haul	0	0

Post Closure			
General	Management of restored site	0	0

NOTES:

0 = If there is no interaction or no potential for substantive interaction between a Project activity and the VEC to cause a potential environmental effect, an assessment of that environmental effect is not required. These interactions are categorized as 0, and are not considered further in the EA. The environmental effects of these activities are thus, by definition, rated not significant.

1 = If there is likely to be a potential interaction between a Project activity and a VEC but not likely to be substantive in light of planned mitigation, the interaction is categorized as 1. Such interactions are well understood and are subject to prescribed mitigation or codified practices. These interactions are subject to a less detailed environmental effects assessment and are rated as not significant. Justification is provided and the proposed mitigation is described for such categorizations. Such interactions can be mitigated with a high degree of certainty with proven technology and practices.

2 = If a potential interaction between a Project activity and a VEC could result in more substantive environmental effects despite the planned mitigation, if there is less certainty regarding the effectiveness of mitigation, or if there is high concern from regulatory agencies, Inuit or stakeholders, the interaction is categorized as 2. These potential interactions are subject to a more detailed analysis and consideration in the environmental assessment in order to predict, mitigate and evaluate the potential environmental effects

As the human health assessment makes direct use of the results of the air dispersion modeling the scoping of project interactions for air emissions to be included in the human health section is based on that provided in the Atmospheric Environment (Volume 4) and additional information can be found in that report.

The activities associated with construction are not expected to result in a significant release of radionuclides or other COPC into the environment. As a result, the potential interactions are ranked 0 and these activities have not been carried forward in the assessment. With respect to CAC, including dust, NO_x and SO_x, the primary sources of air emissions are fugitive dust emissions and exhaust emissions from heavy equipment. Therefore, the interaction with exposure to CAC is ranked as a 1.

During operation, there are activities that can result in changes to radionuclides and COPC including CAC levels in the environment.

- Economic activities are not associated with release of CAC or other COPC and are thus ranked 0 and not carried forward.
- During mining, there are vehicle emissions which contain CAC as well as dust generated that contain radionuclides and other COPC. The dust released will settle and result in changes to soil and vegetation concentrations. Game animals can consume vegetation. Based on these linkages, the interaction between mining and human health are ranked as a 1. The specific activities associated with mining have been accounted for in the air quality assessment. None of the water generated in the mine is directly discharged to the environment, thus there is no interaction with the aquatic environment.

- Similarly, during milling there will be air emissions and thus this interaction is ranked as a 1. The atmospheric environment volume contains details on the specific activities.
- It is not expected that there will be significant air releases (i.e., dust) from the tailings management facility; this is discussed in the atmospheric environment assessment. Treated water from the tailings is considered under water management. Thus, the potential for an interaction between tailings management is ranked as a 0.
- Site-runoff water will be directed to the purpose-built pit and used internally in the mill. All contact water (including runoff from stockpiles) will be intercepted, contained, analyzed and treated when required. Treated water is captured in the WTP effluent, the load from other releases is expected to be minimal and although ranked a 1 were not explicitly included in the quantitative assessment of exposure to members of the public.
- Effluent release from the WTP will have a potential effect on the aquatic environment. As members of the public have linkages to the aquatic environment through drinking water and fish, this interaction is ranked a 1. This interaction has been addressed in the environmental assessment.
- Fugitive and tailpipe emissions of COPC from waste management activities, including disposal and/or management of industrial, domestic, hazardous waste and sewage sludge are minor in comparison to the emissions from the mining and milling operations. As such, these sources have not been carried forward. None of the activities is expected to have a direct release to the aquatic environment.
- The products of fuel combustion are released to the air and contain CAC therefore this interaction is ranked as a 1. As this is not a source of radioactivity or other COPC (e.g., metals) this interaction is ranked as a 0 for exposure to radioactivity and other COPC.
- No significant air emissions are associated with routine hazardous materials storage and handling (reagents, fuel and hydrocarbons). These activities will occur over a very short duration on a daily basis, or as necessary. Thus, they are not considered to be significant and this activity is ranked a 0 for exposure to the public. Under routine operation, this activity is not expected to have a direct release to water.
- No significant air emissions are associated with routine storage and handling of explosives. These activities will occur over a very short duration on a daily basis, or as necessary. Thus, they are not considered to be significant and this activity is ranked a 0 for exposure to the public. Under routine operation, this activity is not expected to have a direct release to water.
- With respect to transportation, vehicle tailpipe exhaust is released to the air and contains dust, metal constituents and gaseous COPC (Criteria Air Contaminants). These activities will occur over a very short duration and are minor compared to other activities and are therefore ranked a 0 for exposure to the public.
- The impacts of ongoing exploration will be limited to the immediate area in the vicinity of the work and are not expected to result in a significant change to the environment.

Final Closure

- On-land activities such as placing covers on waste rock piles and the associated vehicular traffic will emit CAC to the air. These have been ranked as 1 for exposure to CAC. Emissions of other COPC from all remaining on-land decommissioning activities (i.e. removal of foundations, buildings, equipment, fuel tanks, etc.) are minor in comparison to the primary sources.
- The on-going treatment and release of water will have an effect on the aquatic environment and due to the linkages to human health this interaction has been ranked as a 1 and has been addressed in the environmental assessment.

Post Closure

- Once all of the final closure and decommissioning activities have been completed there will be one remaining Project related interaction with the atmospheric environment. Although the clean rock piles will have been contoured and revegetated, they will be a continuous source of radon emissions for many years into the future. The potential effect of this interaction has been ranked as a 1, and was assessed in more detail.

The assessment of the exposure to members of the public does not evaluate individual activities as it is important to consider the total exposure. However, the evaluation approach to exposure to CAC is different than the other COPC and is thus addressed separately. Therefore, two effects are identified to be carried forward for exposure to members of the public: exposure to criteria air contaminants, exposure to radioactivity and other non-radiological COPC.

7.2.3 Valued Components, Indicators and Measurable Parameters

The valued component (VC) selected for human health is the valued socio-economic components (VSEc):

- Human Health – including members of the public

This VSEC have the potential to be affected by the project and have been identified to be important to Inuit, government and stakeholders.

As not every individual can be assessed, selected representative people have been considered in the assessment including:

- Non-Nuclear Energy Worker (non-NEW) at the site such as a camp cook or security guard

- Hunter (adult) at a camp on Judge Sissons Lake (note that the hunter brings game home to feed his/her family, which includes a child and toddler)
- Residents of Baker Lake (adult, child, toddler)

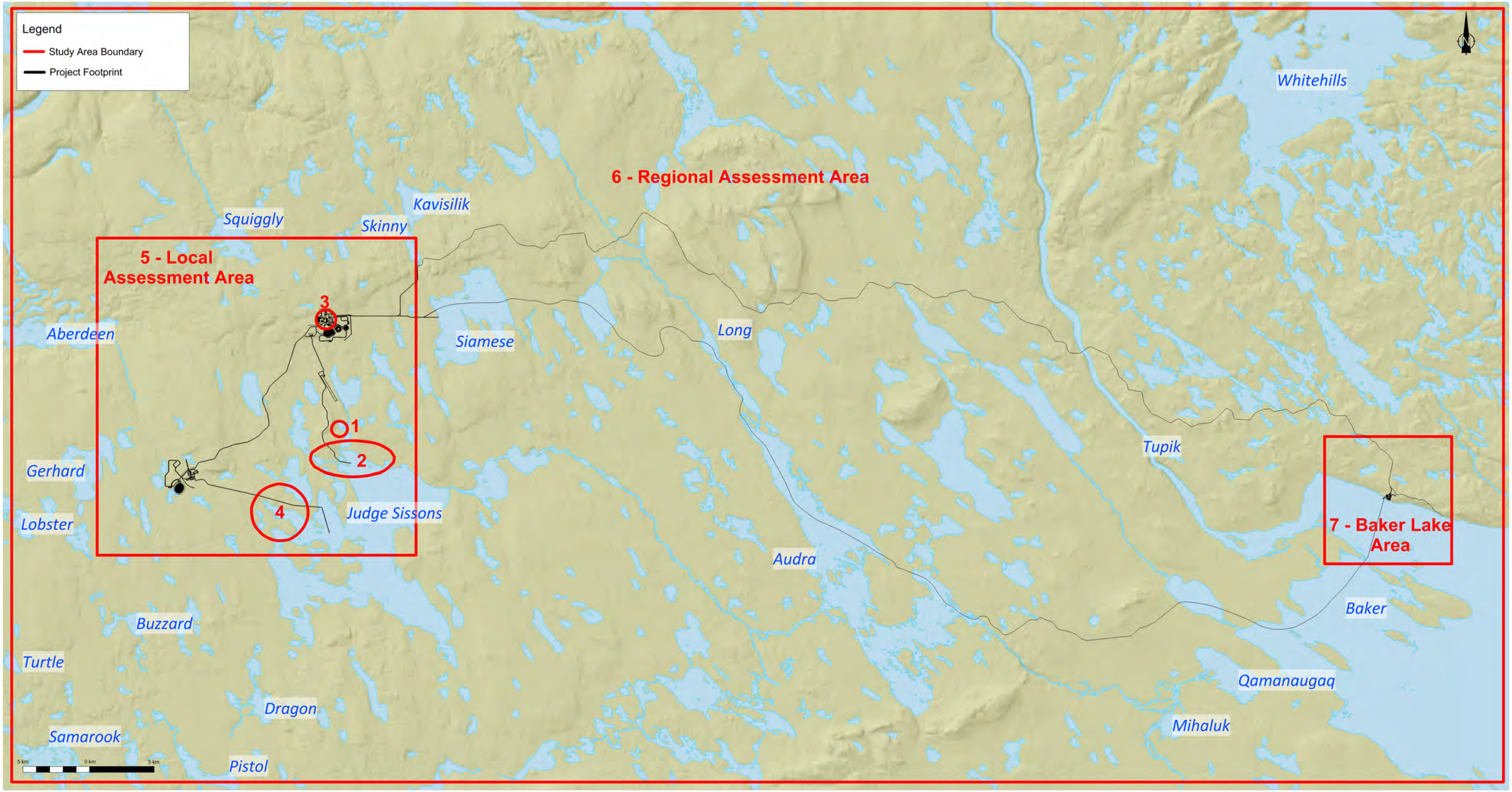
As people reside in the area and are exposed via a number of pathways, the assessment provides linkages to VCs identified for the atmospheric environment, terrestrial environment and aquatic environment. The measurable parameters for human health are summarized in Table 7.2.2.

Table 7.2.2 Measureable Parameters for Human Health - Members of the Public

Environmental Effect	Indicator	Measurable Parameter(s)	Notes or Rationale for Selection of the Measurable Parameter
Exposure to Criteria Air Contaminants	• Non-NEW • Hunter (adult) • Baker Lake residents	• comparison of predicted concentrations of NOx, SOx and particulate matter to health-based benchmarks	• assess potential to affect human health • community, government, stakeholder engagement
Exposure to Radioactivity and Other COPC	• Non-NEW • Hunter and family • Baker Lake residents	• for radioactivity, the incremental dose must remain below 1 mSv/y • for non-radioactive COPC, the total exposure will be compared to a threshold value and/or the incremental cancer risk compared to 1x10-5	• evaluate the potential to affect human health • community, government, stakeholder engagement

7.2.4 Spatial Boundaries

The assessment areas for the evaluation of potential effects for members of the public is shown in Figure 7.2-1.



Projection: NAD 1983 UTM Zone 14N

Compiled: SENES Consultants

Date: 05/05/2014

Data Sources: Natural Resources Canada, Geobase®, Nation Topographic Database, AREVA Resources Canada Inc.

FIGURE 7.2-1

Assessment Areas for Exposure to Members of the Public

ENVIRONMENTAL IMPACT STATEMENT
VOLUME 8: HUMAN HEALTH

KIGGAVIK PROJECT

AREVA

7.2.4.1 Project Area

As members of the public do not have regular access to the site, the Project Footprint is not included in the assessment. However, as discussed previously, a non-NEW that works and resides part time at the on-site accommodation facility (Area 3 on Figure 7.2-1) has been included and is located in the project area.

Note that there is a Dock and Storage Facility, located approximately two and a half kilometres southeast of the community of Baker Lake. As the air quality assessment indicated that the air emissions from this project activity had only a minor effect on air quality (NO_x and particulate matter) at this location where members of the public may be present. Therefore, this location was not considered to be part of the Project Area.

7.2.4.2 Local Assessment Area

The local study area is defined as the maximum area within which Project effects can be predicted or measured with reasonable accuracy. As the evaluation of human health depends on the game species consumed, the local study area is the same as defined in the ecological risk assessment. Due to the strong linkage with air quality, for both the ecological risk assessment and human health risk assessment, the LAA is taken to be the same as used in the Volume 4, Atmospheric Environment.

The hunter at Judge Sissons Lake is assumed to obtain food from the LAA (a 10km square area around the site). With respect to the areas shown on Figure 7.2-1, the hunter is assumed to reside at Baker Lake (Area 7) but spend a portion of year at a camp at Area 2 and obtain food from within Area 5.

7.2.4.3 Regional Assessment Area

Due to the strong linkage with air quality, for both the ecological risk assessment and human health risk assessment, the Regional Assessment Area (RAA) is taken to be the same as used in the Volume 4, Atmospheric Environment. The RAA extends from the facility to the community of Baker Lake. The Baker Lake residents (that reside at Area 7 shown Figure 7.2-1) are assumed to consume game from the RAA (Area 6 on Figure 7.2-1).

7.2.5 Temporal Boundaries

The effects of the Project were considered for the following phases:

- Construction – activities undertaken in this portion of the project can result in the release of Criteria Air Contaminants. As the construction period is not expected to result in a change to the levels of the radioactivity or other non-radiological COPC in the environment this period is not included in the assessment for this effect.
- Operations – the operational period is expected to be 13 years. However, a bounding scenario representing an extended period of operation (25 years), based on the capacity of the TMF, was assessed for the project-related effects. For the assessment of human health, the presentation of results focused on the period of the highest potential impact.
- Final Closure – during decommissioning water treatment is expected to continue and therefore this period is considered in the assessment.
- Post Closure – the recovery of the waterbodies in the area was assessed for the post-decommissioning period. In addition, the impact of a residual radon source was assessed.

7.2.6 Administrative and Technical Boundaries

A technical boundary that was identified is the assessment of effects of multi-stressors (e.g., mixtures of metals). It is recognized that the scientific database of knowledge is not such that a full assessment can be completed. However, considering the low levels of exposure identified and the conservative nature of the approach taken,, this is not expected to be a major limitation of the assessment.

7.2.7 Potential Pathways of Exposure

The potential pathways of exposure to COPC were identified for a Baker Lake resident, hunter at the Judge Sissons Lake areas and a non-NEW, as summarized in Table 7.2.3. The rationale to why a potential pathway is considered or excluded for the specified group is discussed in the Comment section.

Table 7.2.3 Potential Pathways of Exposure for Member of the Public

Potential Pathway of Exposure	Members of the Public			Comment
	Baker Lake Resident	Hunter at Judge Sissons Lake	Non-NEW*	
Incidental Soil Ingestion	Yes	Yes	Yes	Radionuclides and non-radionuclides can be deposited on soil. Therefore, the incremental exposure from incidental ingestion of soil is a potential pathway of exposure.
Dermal contact with soil	Min	Min	Min	Dermal exposure expected to be minimal due to the short season where there is the potential for exposed skin.
Inhalation	Yes	Yes	Yes	Inhalation of particulate containing radionuclides and metals as well as inhalation of radon are potential pathways of exposure.
Immersion in air (dermal exposure)	Min	Min	Min	The dermal exposure to air and external dose from radionuclides in air is not expected to be a significant source of exposure.
Drinking water	Min	Yes	No	Baker Lake obtains drinking water from Baker Lake which is 75km downstream of the Project and the impact of discharge from the site will be insignificant at this location. A hunter at Judge Sissons Lake is assumed to consume water from this lake while in the area. Potable water for the site will be taken from Mushroom and Siamese lakes. The water quality in these lakes will not be impacted by the Project.
Other uses of potable water (e.g. bathing)	Min	Min	No	There will be no significant change in water quality in Baker Lake and water for the camp will be sourced from an un-impacted water body. There is expected to be minimal exposure through secondary exposure pathways of water, such as bathing, for the hunter at Judge Sissons Lake.
Harvest local foods (e.g. berries)	Yes	Yes	Yes	IQ supports that berries are important and it was assumed all receptors would gather berries.
Hunting / Trapping	Yes	Yes	No	Caribou is an important food source. While on site the non-NEW will not consume caribou from local sources.
Fishing	Min	Yes	No	Fish is an important food source. There will be no significant change to water quality in Baker Lake; therefore, fish obtained from this source will not result in any significant exposure. The hunter at Judge Sissons Lake will obtain fish from this lake and take it back for consumption throughout the year by all members of the family. While on site the non-NEW will not consume fish from local sources.

Potential Pathway of Exposure	Members of the Public			Comment
	Baker Lake Resident	Hunter at Judge Sissons Lake	Non-NEW*	
Garden produce ingestion	Min	Min	No	Due to the short growing season it was assumed that there would not be any significant exposure to produce grown in backyard gardens.
Irrigation of vegetation (potable / groundwater / surface water)	No	No	No	Any irrigation water would be sourced from Baker Lake, which is assumed to not have any significance impact. Combined with the low preponderance of gardens, this route of exposure is insignificant.
Livestock	No	No	No	No domestic livestock in the area.
External dose from soil	Yes	Yes	Yes	The incremental external dose from radionuclides deposited on soil is a potential pathway of exposure.
Recreational use of surface water (e.g. swimming[(a)])	Min	Min	No	Due to the climate, it is not expected that there would be any significant use of Judge Sissons or Baker lakes for recreational purposes such as swimming.

Note:
Yes - Potential Pathway
No - Not potential pathway of exposure
Min - Minimal exposure, not significant and will not be quantified

* The non-NEW is assumed to reside in Baker Lake and work for half the time at the site. The pathways identified in this table are for the time spent at the site.
a Includes the pathways of incidental surface water ingestion, immersion in water (dermal exposure and external dose), incidental sediment ingestion, external dose from sediment, dermal contact with sediment

7.2.8 Residual Environmental Effects Criteria

Residual effects were determined by comparison of the exposure or intake to a threshold. For radioactivity, the threshold used to identify a residual effect is the dose constraint of 0.3 millisieverts per year (300 µSv/y) recommended by Health Canada in the Canadian NORM Guidelines (Health Canada 2000). Doses below this level are considered as “unrestricted” and no further action is needed to control doses or materials. For non-radiological COPC two approaches are taken:

- the total exposure (from all pathways) is below the toxicity benchmark to evaluate non-carcinogenic endpoints
- for carcinogenic compounds (arsenic) the incremental risk of cancer over a lifetime is compared to a value of $1x10^{-5}$

Toxicity benchmarks, also call toxicity reference values (TRVs) are intended to protect the most sensitive individuals (i.e., the elderly, pregnant women and children). Table 7.2.4 provides a summary of the TRVs selected for use in the assessment. The TRVs, health effects (toxicological endpoints), and reference sources for each TRV are provided in the table. A discussion of the rationale for selecting the values is provided in Appendix 8A. The inhalation pathway is considered in the Project effects; however, this pathway is only considered in the total exposure evaluation, since the impacts from this pathway alone are very small.

Table 7.2.4 Selected Oral Toxicity Reference Values for Human Receptors

Constituent of Potential Concern	Effect Type [(a)]	Value	Health Effect	Reference [(b)]
Arsenic	C	1.8	Internal cancers (liver, lung, bladder, kidney) (oral, human)	Health Canada (2009b)
	NC	0.001	Not provided	Health Canada Food Directorate (2002)
Cadmium	NC	0.001	Significant proteinuria	Health Canada (2009b) IRIS (U.S. EPA 2011, last updated 1994)
Cobalt	NC	0.01	Haematological effects (polycythemia)	ATSDR (2004)
Copper	NC	0.09	Hepatoxicity	Health Canada (2009b)
Lead	NC	0.0036	Increase in blood lead concentrations in infants	Health Canada (2004b)
Molybdenum	NC	0.005	Increased uric acid levels	IRIS (U.S. EPA 2011, last updated 1993)
Nickel	NC	0.011	Decreased body and organ weights (oral exposure, rats)	Health Canada (2009b)

Table 7.2.4 Selected Oral Toxicity Reference Values for Human Receptors

Constituent of Potential Concern	Effect Type [(a)]	Value	Health Effect	Reference [(b)]
Selenium	NC	0.005	Clinical selenosis	IRIS (U.S. EPA 2011, last updated 1991)
Uranium	NC	0.0006	Degenerative lesions in kidney tubules	Health Canada (2009b)
Zinc	NC	0.3	Diminished copper status (required for protection against free radicals and oxidative stress)	IRIS (U.S. EPA 2011, last updated 2005)

NOTE:

Units: mg/(kg-d) for all except for arsenic carcinogenic (C) TRVs which are in $(mg/(kg\text{-}d))^{-1}$

a = C – Carcinogenic (non-threshold) effect; NC - non-carcinogenic (threshold) effect

b = IRIS - Integrated Risk Information System on-line database (last updated represents year of last significant revision)

ATSDR = Agency for Toxic Substances and Disease Registry

In general, the adverse effects of exposure to CAC are associated with irritation of the tissues of the eyes and upper and lower respiratory systems. Exposures to the gaseous CAC (i.e., SO_2, NO_2) are assessed using air quality guidelines (AQG) values obtained from the WHO. Table 7.2.5 provides a summary of the health-based values used for the assessment of gaseous air pollutants.

Table 7.2.5 Health-Based Values for Gaseous Air Pollutants

Gaseous Air Pollutants		Health-Based Concentration (μg/m^3)	Jurisdiction
NO_2	1 hour	200	WHO (2005)
	Annual	40	WHO (2005)
SO_2	1 hour	500	WHO (2005)
	24 hour	20*	WHO (2005)

NOTE:

* Although the WHO has set the guideline at 20 μg/m^3, it is acknowledged that there will be difficulty in achieving this guideline. As such, a stepped approach has been suggested, using a tier I interim guideline value of 125 μg/m^3 and a tier II interim value of 50 μg/m^3.

There is a growing body of scientific studies linking air pollutants to health effects. Recent assessments of the available health data are implying a stronger link between PM and health effects resulting from short- and long-term exposures. In addition, the effects are estimated to occur at levels that are lower than previously believed. This has motivated some regulators to re-assess the potential impact of particulate matter pollution on public health (CARB 2008).

For PM_{10}, the reference level of 25 µg/m^3, based on a 24 hour averaging time which resulted in consistent associations observed in epidemiological studies with mortality and hospitalizations as well as concerns over links to chronic bronchitis and cardiovascular disease (CEPA/FPAC WGAQOG 1998), was selected as a health-based limit. A threshold value range of 5 to 7 µg/m^3 (CARB 2008) was used as the health-based level for $PM_{2.5}$ (which encompasses ultrafine particles) and the epidemiological evidence related to short-term exposures are the most relevant to consider in this assessment. This threshold range was also considered in this assessment as a health-based limit.

Residual effects that are identified through this process are then placed in context. Table 7.2.6 presents the descriptors used for describing the residual effects of the Project on human health. Professional judgment was used to assign the appropriate classification to the quantitative and qualitative assessment.

Table 7.2.6 Residual Effect Description for Human Health – Members of the Public

Residual Environmental Effects Characteristics	Classification	Description
Direction: the ultimate long-term trend of the environmental effect	N	Neutral (no expected change to human health
	A	Adverse (potential for human health to be affected)
Magnitude: the degree of change in a variable relative to selected threshold	N	Negligible: The predicted exposures are at or below the selected threshold
	L	Low: The predicted exposures are within a factor of 2 of the selected threshold.
	M	Moderate: The predicted exposures are within a factor of 5 of the selected threshold
	H	High: The predicted exposures are greater than a factor of 5 of the selected threshold
Geographical extent: the geographic area within which an environmental effect of a defined magnitude occurs	S	Site-specific: Within Project Boundaries
	L	Local: Within the LAA
	R	Regional: Within the RAA (includes Baker Lake)
Frequency: the number of times during the Project that an	O	Occurs once

Table 7.2.6 Residual Effect Description for Human Health – Members of the Public

Residual Environmental Effects Characteristics	Classification	Description
environmental effect may occur	S	Occurs sporadically at irregular intervals
	R	Occurs on a regular basis and at regular intervals
	C	Continuous
Duration: the period of time that is required until the VEC returns to its baseline condition or the environmental effect can no longer be measured or otherwise perceived	ST	Short term: Less than one year
	MT	Medium term: More than one year, but not beyond the end of project decommissioning
	LT	Long term: Beyond the life of the project
	P	Permanent
Reversibility: the likelihood that the VC will recover from an environmental effect	R	Reversible
	I	Irreversible

7.2.9 Standards or Thresholds for Determining Significance

In Canada, the Canadian Nuclear Safety Commission (CNSC) regulates the nuclear industry. The *Radiation Protection Regulations* (CNSC 2000b) outlines the requirements for radiation protection; as well, the limits on exposure to members of the general public are specified. As discussed previously in Table 6.3-1, the incremental annual dose from the facility to a member of the public must remain below 1 mSv (1000 µSv). Therefore, this regulatory value was used to determine significant effects from radioactivity.

For the other COPC, the determination of the significant effect is based on the consideration of the factors described in Table 7.2.6.

7.2.10 Influence of Inuit Qaujimajatuqangit and Stakeholder Engagement

As discussed in Section 7.1, Inuit Qaujimajatuqangit and stakeholder engagement has consistently identified human health and the protection of members of the public as an important consideration. The alignment of IQ principles and values with the concept of ecological and human health risk assessments is discussed in greater detail in Section 7.1 above.

In order to fully understand the potential effects of the Project on human health, COPCs in the environment are examined holistically in the ecological and human health risk assessments (Tier 3, Technical Appendix 8A). This pathways approach follows the food web concept and considers the interconnectedness of human health with ecological health in order to address community concerns such as *if uranium gets into animals and people eat them, do we get sick* (EN-KUG NTI May 2007)?

To develop the exposure scenarios for use in the human health assessment there must be an understanding of the traditional culture and use of the land. Therefore, this assessment is built on the information collected during engagement activities and IQ interviews conducted by AREVA and supplemented by other sources of information such as CINE workshops (Kuhnlein et al. 2000). These sources of information (discussed in more detail in Tier 3, Technical Appendix 9A) show that traditional activities, including hunting and harvesting, are highly valued. There is a high participation rate in harvesting with most households have people involved in both hunting and fishing (IQ-CIYA 2009[102], IQ-RIHT 2009[103], IQ-BLH 2009[104], IQ-CIHT 2009[105]). The highest percentage of people reported consuming caribou. Fish, particularly trout and char, were also consumed by a large percentage of the population. This information was used to confirm VEC selection and derive the assumptions regarding the diet of people that use the land.

On several occasions, hunters and Elders have discussed the pathways by which contaminants may potentially be released by the Project, travel through the ecosystem, and affect wildlife and subsequently humans. For example, hunters and Elders expressed concerns about the potential for airborne contamination settling on vegetation and being consumed by caribou (IQ-ARHT 2009[106]). Regarding the contamination of potential food sources, comments were heard about concerns that dust from the operations will settle on vegetation and will be consumed by caribou that are hunted (EN-BL NPC Jun 2007[107]). Water quality (EN-BL OH Nov 2013[108]) and fish consumption (EN-KIV OH Oct 2009[109]) were other issues raised.

Based on community feedback, it was important to address concerns *that mining will take away land from hunting grounds* (IQ-BLE 2009[110]) and regarding uptake of radioactivity by caribou and fish and

[102] IQ-CIYA 2009: *All of these young people go hunting regularly.*

[103] IQ-RIHT 2009: *Hunters described the people as dependent on caribou, fish, seals, ptarmigan, and beluga for food.*

[104] IQ-BLH 2009: *Most of the people depend on caribou as a food source*

[105] IQ-CIHT 2009: *The people of Chesterfield continue to primarily depend on caribou, fish and seal. Consuming country food is not considered 'ritual food' but the daily way of life.*

[106] IQ-ARHT 2009" *Hunters and Elders expressed concerns about the potential for airborne contamination settling on vegetation and being consumed by caribou.*

[107] EN-BL NPC Jun 2007: *If there are contaminated lands and cumulative effects, how are we going to be able to maintain our wildlife?*

[108] EN-BL OH Nov 2013: *That water you will use will become contaminated and come to this community and we will get sick.*

[109] EN-KIV OH Oct 2009: *How will uranium affect our water and fish?*

[110] IQ- BLE 2009: *Elders are concerned that mining will take away land from the hunting* grounds

pathways through human consumption of these animals (IQ- BLE 2009[111]). Community Elders expressed that they *are aware that there have been problems at other mines, and cited instances of caribou eating harmful things at mine sites* (IQ-WCE 2009). To address this concern, many cautious assumptions were used in the assessment of potential uptake of contaminants by caribou; for example the assumptions for the amount of time that caribou will spend near the Project.

IQ is described as wisdom gained and passed from generation to generation (NTI 2000). Over 95% of people indicated that harvesting contributed to children's education and was a way to teach children responsibility (Tier 3, Technical Appendix 9A). Therefore, in the human health assessment it was assumed that a child would accompany the adult hunter for a portion of the trip.

Assessment of radiation exposure is traditionally based on the comparison of a dose rate to acceptable benchmarks that are provided by regulatory agencies. However, based on the importance that was raised by stakeholders regarding cancer, cancer risks from radiation exposure were specifically addressed in this assessment.

The human health risk assessment is based on information collected during IQ interviews and engagement events. Community feedback and knowledge has played a key role in the development of the exposure scenario for members of the public. Information gathered by AREVA was fundamental in developing and scoping the human health risk assessment, including: delineation of linkages between environmental components, development of dietary intake characteristics, description of exposure scenarios, inclusion of radiation exposure, determination of residency time for wildlife in a potential exposure area, and inclusion of a child as representative person.

7.3 Residual Project Effects Assessment For Members of the Public

7.3.1 Assessment of Exposure to Criteria Air Contaminants

7.3.1.1 Analytical Methods for Criteria Air Contaminants

Several Project Activities have the potential to release NO_x, SO_x and particulate matter (PM). The CALPUFF/CALMET modelling package was used to predict Project-related incremental ambient air concentrations at a network of receptor locations within the local and regional assessment areas.

[111] IQ- BLE 2009: *Elders are concerned that uranium may escape and contaminate the grounds; especially the land along the Thelon River, or on the south side of Bake Lake.*

The sources of CAC have been detailed in the atmospheric environment report (Volume 4) along with the methodology used to calculate concentrations.

To assist in the assessment, three locations were selected that represent places where members of the public may spend time. These locations are outlined in Table 7.3.1.

Table 7.3.1 Summary of Selected Locations Used in the Assessment of Exposure of CAC to Members of the Public

Assessment Area	Description
Project Assessment Area	Kiggavik Accommodation Complex
Local Assessment Area	Judge Sissons Lake Cabin
Regional Assessment Area	Community of Baker Lake

The estimated concentrations at these locations, for different averaging times (e.g. 24-hour, annual), were then compared to health-based benchmarks to give an indication of the potential for an effect.

7.3.1.2 Baseline Conditions for Criteria Air Contaminants

The available data suggest that baseline concentrations of CAC are very low. This is not unexpected given the remote nature of the Project and the relatively pristine environment of the area. Additional information on the data is provided in Volume 4.

7.3.1.3 Effect Mechanism and Linkages for Criteria Air Contaminants

Human health in members of the public can be affects if people are exposed to CAC at levels that are associated with an effect. In general, the adverse effects of exposure to NOx and SOx are associated with irritation of the tissues of the eyes and upper and lower respiratory systems. The Project-environment interactions and effects described in the Atmospheric Environment (Volume 4) form the basis for the effects mechanisms and linkages. The Project air quality effects relate to emissions of CAC from Project Activities such as materials handling, vehicle exhaust and power generation. These are discussed in greater detail in Volume 4.

7.3.1.4 Mitigation Measures and Project Design for Criteria Air Contaminants

Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions.

Volume 4 (Atmospheric Environment) provides a detailed list of the mitigation measures applied to reduce the changes to ambient air quality. Mitigation measures that have been incorporated to reduce emissions of NOx, SOx and PM include:

- Facilities such as the acid plant, power plant were placed such as to reduce potential air quality impacts
- Low sulphur diesel fuel will be used to reduce emissions associated with diesel fuel combustion
- Scrubbers will be installed on exhaust stacks to remove particulates, acid mist and excess SO_2 from air emissions prior to discharge
- Optimize the use of heavy equipment
- Optimize blasting operations to minimize NOx and particulate emissions
- Apply water or another approved dust suppressant to the surfaces of unpaved mine site roads (including pit ramps) and the Kiggavik-Sissons access road, when possible

7.3.1.5 Residual Effects for Criteria Air Contaminants

In Volume 4, concentrations of CAC were compared to air quality standards, these standards are set based on consideration of a number of factors and are not necessarily health-based. Therefore, for the purposes of this assessment, the maximum incremental concentrations of NO_2 and SO_2 are compared to health-based concentrations as presented in Table 7.3.2. It should be noted that these maximum concentrations do not occur simultaneously. The annual concentrations were obtained from Period 2, which had the highest SO_2 and NO_x emission rates. During this period there is open pit mining of Main Zone West pit at Kiggavik and Andrew Lake at Sissons as well as the milling of ores from East Zone, Centre Zone and Main Zone pits. As the health-based values are expressed as NO_2, the results for NO_x were converted to a NO_2 concentration, assuming NO_2 represents 63% of NO_x.

Table 7.3.2 Assessment of Potential Effects to Members of the Public from Exposure to NO_2 and SO_2

Receptor Name	NO_2 ($\mu g/m^3$)			SO_2 ($\mu g/m^3$)	
	Incremental 1-hr Maximum	Frequency of Exceedances 1-hr Max (hours per year)	Incremental Annual Maximum	Incremental 1-hr Maximum	Incremental 24-hr Maximum
Accommodation Complex	**380.7**	117	10.4	41	15.4
Judge Sissons Lake Cabin	36.5	n/a	0.80	2.7	0.8
Community of Baker Lake	3.8	n/a	0.04	0.16	0.04
Health-Based Benchmark ($\mu g/m^3$)	200	-	40	500	20

As seen from Table 7.3.2, the estimated maximum concentrations of NO_2 and SO_2 at the community of Baker Lake and at the Judge Sissons Lake cabin are well below the health-based benchmarks. In addition, the SO_2 values at the Kiggavik accommodation complex (Camp) are expected to remain below any level of concern. The predicted long-term NO_2 concentrations at the Camp are below any health based concentrations; however approximately 1% of the time (117 hours out of 8760 hours over the year) the short-term concentration of NO_2 may exceed the health-based limit of 200 $\mu g/m^3$. Exceedances can be attributed to large emissions of NO_x from open pit mining activities, including diesel-powered mining equipment and blasting. Although only workers will be present on the site, the NIOSH short-term occupational limit of 1800 ug/m^3 for NO_2 exposure was not applied to the Accommodation Complex since people will be spending a significant amount of time at that location, more than generally accounted for in the derivation of time-weighted occupational limits. The individuals present at the Accommodation Complex are however all adults. It is important to note that the health based limit for NO_2 is set to be protective of sensitive individuals such as asthmatics, particularly in children (additional information on the health effects of NO_2 and the basis of the benchmark can be found in Appendix 8A). It should be noted that the WHO indicates that concentrations in the range of 1880 $\mu g/m^3$ did not result in any adverse respiratory effects in healthy adults. This concentration is similar to the short-term occupational limit, which can be applied to workers at the site. Therefore, given the fact that the work force comprises healthy adults, it is unlikely that adults working at the Camp would experience any health issue related to short-term NO_2 exposure. Simple control measures such as monitoring weather conditions, notifying personnel, and relocating people before a blast can serve to eliminate exposure to the NO_2 and dust during operations.

The predicted incremental concentrations of fine particulate matter (PM_{10} and $PM_{2.5}$) are presented in Table 7.3.3 for the maximum bounding scenario. Also shown in the table are health-based benchmarks for fine particulate matter. As can be seen in the table, concentrations at the Judge Sissons Lake Cabin and at the community of Baker Lake are expected to remain below the health-based benchmark. However, concentrations are above health-based values at the Accommodation Complex. Exceedances can be attributed to large emissions of dust from open pit mining activities, in particular unpaved road dust generated on the in-pit ramps.

Table 7.3.3 Assessment of Potential Effects to Members of the Public from Exposure to Particulate Matter

Discrete Receptor Name	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Incremental 24-hr Maximum	Frequency of Exceedances 24-hr Max (days per year)	24-hr 98th Percentile	Frequency of Exceedances 24-hr Max (days per year)
Accommodation Complex	115.2	35	22.5	34
Judge Sissons Lake Cabin	11.1	n/a	2.0	n/a
Community of Baker Lake	0.6	n/a	0.2	n/a
Health-Based Benchmark (µg/m^3)	25	-	7	-

The values shown in the table are those that have been derived based on protection of the whole population; however the individuals present at the Accommodation Complex are all adult workers. Literature studies suggest that there are people that are more susceptible to the health effects associated with exposure to fine particulate matter. For example:

- Older adults have a greater susceptibility for cardiovascular morbidity with PM exposure.
- Children are at an increased risk of PM-related respiratory effects relative to adults.
- Individuals with underlying cardiovascular and respiratory diseases are more susceptible to adverse effects from PM-exposure.
- Good nutritional status is reported to have protective effects against PM exposure.

Given the above discussion and the fact that the workers present at the camp would be healthy working-age adults with good nutritional status, the probability of adverse effects related to PM exposure is likely to be low.An examination of the potential effects for members of the public from exposure to CAC is provided in Table 7.3.4

Table 7.3.4 Application of Residual Effects Criteria for Exposure of CAC to Members of the Public

Attribute	Description	Rating	Comment
Direction	The ultimate trend of the environmental effect	Adverse	Short-term exposure to CAC may have health-effects on members of the public
Magnitude	Amount of change in a measurable parameter relative to a threshold	Moderate	The predicted exposures are within a factor of 5 of the selected threshold
Geographic Extent	The geographic area within which an environmental effect occurs	Site-specific	The area of potential effect is limited to the individuals that reside at the on-site Accommodation Facility
Frequency	Number of times that an effect may occur over the life of the project	Sporadically	Occurs sporadically at irregular intervals
Duration	Length of time over which the effect is measurable	Medium term	More than one year, but not beyond the end of project decommissioning
Reversibility	Likelihood that VC will recover from an environmental effect to baseline conditions	Reversible	No impact on the long-term health is expected.

7.3.1.6 Determination of Significance for Criteria Air Contaminants

A potential residual effect was identified for exposure to CAC to members of the public, specifically a person who would reside part time at the Kiggavik Accommodation Complex (Camp). A residual effect was identified with respect to NO_2 and fine particulate matter for people at the camp. An assessment of the significance of the residual effect considered the basis of the derivation of the toxicity benchmark, the limited period of exceedances and the fact that workers at the camp are not considered to be sensitive individuals. It is unlikely that adults working at the Camp would be affected.

Overall, there are not expected to be any significant effects on members of the public from exposure to CAC from the Project.

7.3.1.7 Compliance and Environmental Monitoring for Criteria Air Contaminants

No specific monitoring plans have been developed to directly assess human health; rather the monitoring programs outlined in the Atmospheric Environment (Volume 4) is used to evaluate the affect of the Project on exposure to people from CAC. The suggested air quality monitoring program includes particulate matter (including PM_{10} and $PM_{2.5}$) and NOx at relevant locations such as the Accommodation Complex.

7.3.2 Assessment of Exposure to Radioactivity and Other COPC

This section summarizes the Human Health Risk Assessment (provided in Appendix 8A) that examined the potential that releases from the Project to the environment may affect the health of people that live in the area and consume local foods. People in the area may be exposed through the terrestrial environment (e.g., ingestion of berries and medicinal plants), the aquatic environment (e.g., ingestion of fish) or game which could be influenced by both the aquatic and terrestrial pathways. An integrated approach is used to assess the exposure through all pathways.

7.3.2.1 Analytical Methods for Exposure to Radioactivity and Other COPC

Emissions from the Project can affect the concentrations of COPC in the environment (e.g. water, soil, vegetation) which in turn will affect the exposure of members of the public as they consume these items. The COPC included in the assessment include uranium and the uranium-238 decay series (thorium-230, lead-210, radium-226, and polonium-210), arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, and zinc.

There is a high reliance on country foods by Inuit people in the area, particularly caribou and fish (EN-RI KIA Apr 2007[112]). The pathways of exposure for the selected representative people in the area were based on dietary surveys of the Kivalliq community members (Tier 3, Technical Appendix 9A). The specific diet information (e.g., quantity of food ingestion) was also based on data provided in the dietary surveys, with data gaps filled by data from the closest similar communities and characteristics for the general Canadian population. Potential pathways of exposure for human receptors were considered in Section 7.2.7. The identified pathways of exposure for human receptors in the assessment included (Figure 7.3-1):

- exposure to dust, groundshine, and radon
- ingestion of water
- ingestion of ptarmigan
- ingestion of fish
- ingestion of berries
- ingestion of soil
- ingestion of squirrel
- ingestion of caribou

[112] EN-RI KIA Apr 2007: *I rely on caribou and fish.*

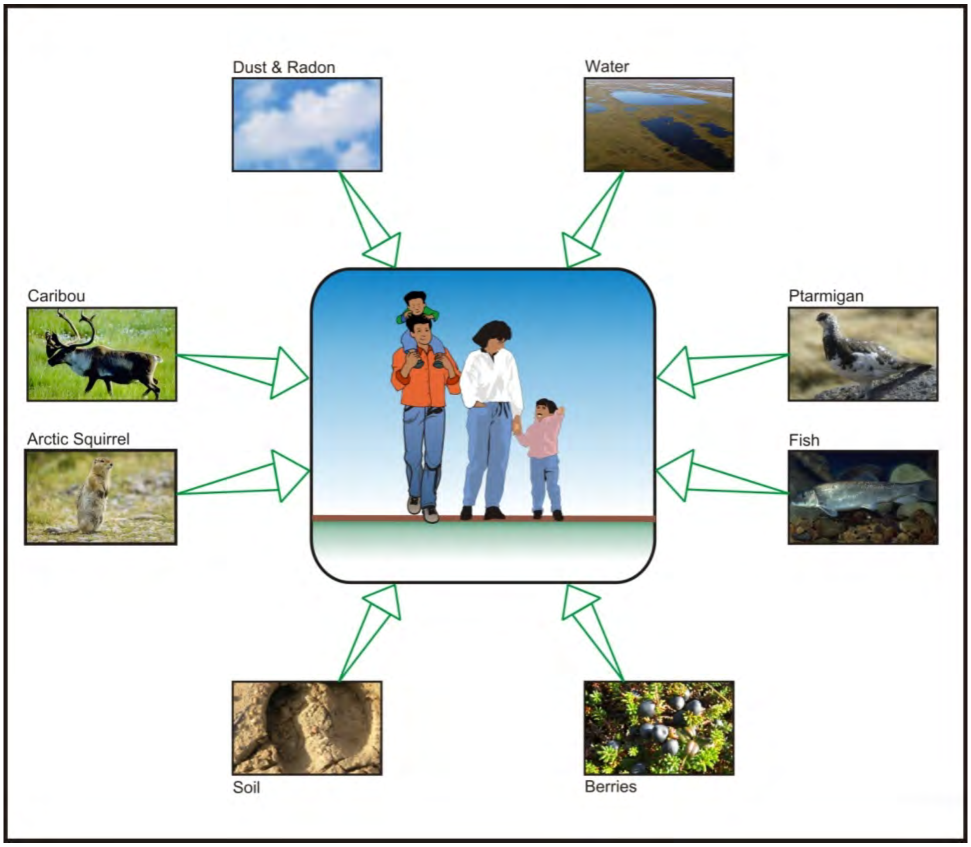


Figure 7.3-1 Representation of Exposure Pathways for Human Receptors

To estimate the exposure by people it is therefore necessary to estimate the concentration in all environmental media that will be consumed (e.g. berries, fish, caribou). Detailed air quality modeling (discussed in Volume 4) and water quality modeling (discussed in Volume 5) are used as inputs into the INTAKE model that estimates the concentration to wildlife and birds (discussed in Volume 6). The INTAKE model then provides estimates of the exposure to people. The concentrations in environmental media (e.g. vegetation) are predicted by using transfer factors that relate the concentration in different media (e.g. soil-to-plant). The transfer factors are based on site-specific information where possible, augmented by literature data. Through this process, the impact of project on country foods (e.g. dust settling on vegetation, which would be consumed by caribou that are hunted by people, IQ- ARHT 2009[113]) is assessed.

The intake of COPC can then be estimated using the predicted concentrations and assumptions about what types of food people consume, how much and from where. Assumptions are made in this regard to provide a cautious estimate of exposure and do not necessarily represent the actual behavior of all individuals. As discussed above, the representative people evaluated include:

- a non-NEW that works and resides part time at the on-site accommodation complex (Area 3 on Figure 7.2-1)
- a hunter at Judge Sissons whom is assumed to obtain food from the LAA (a 10km square area around the site). With respect to the areas shown on Figure 7.2-1, the hunter is assumed to reside at Baker Lake (Area 7) but spend a portion of year (four months) at a camp at Area 2 and obtain food from within Area 5. During the time at the camp sufficient game (caribou, ptarmigan, squirrel, fish) is obtained to last the year and to feed his/her family.
- adult, child and toddler family members in Baker Lake, the closest community to the Kiggavik Project. The Baker Lake residents (that reside at Area 7 shown Figure 7.2-1) are assumed to consume game from the RAA (Area 6 on Figure 7.2-1).

The estimated intakes of non-radioactive COPC are compared to benchmarks that are protective of human health, including sensitivity sub-populations. The total intake is estimated which includes the baseline levels in all environmental media. For estimating radionuclide dose, dose coefficients are used that relate the intake rate in Becquerel (Bq) to an effective dose rate (in sieverts, Sv). For dose, the comparison benchmark is for a Project increment (i.e. above baseline) thus the dose estimates provided are those attributable only to the Project emissions.

The bounding scenario carried through the assessment was based on separate discharges from the Kiggavik water treatment plant and Sissons water treatment plant, an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required. The assessment accounted for the uncertainty and variability in the emissions and the behaviour in the environment. The details are provided in the Human Health Risk Assessment (Appendix 8A).

[113] IQ- ARHT 2009: *Hunters and elders expressed concerns about the potential for airborne contamination settling on vegetation and being consumed by caribou.*

7.3.2.2 Baseline Conditions for Exposure to Radioactivity and Other COPC

Under baseline conditions everyone is exposed to COPC as these constituents are present naturally in the environment. Section 4 discussed typical exposure to people from baseline levels of radioactivity and non-radioactive COPC.

Concentrations of COPC in the environment (e.g. water, fish, berries, caribou tissue) were measured and used in the baseline assessment. This baseline information is presented in Appendix 8A.

7.3.2.3 Effect Mechanism and Linkages for Exposure to Radioactivity and Other COPC

The assessment of potential effects on health depends on the estimated changes in concentrations of environmental media such as vegetation, fish, caribou and soil. These concentrations were derived from the atmospheric and aquatic environment assessments (Volumes 4 and 5).

The Project-environment interactions and effects described in the Atmospheric Environment (Volume 4) and Aquatic Environment (Volume 5) form the basis for the effects mechanisms and linkages. The Project air quality effects relate to emissions of dust containing COPC from open pit and underground mining and supporting activities, milling and vehicle traffic on unpaved roads. The Project water quality effects relate to emissions of COPC from water treatment plants at the Kiggavik and Sissons sites. Complete details about the COPC sources and all assumptions used in the assessments were provided in the atmospheric and aquatic environment assessments.

There linkages between VCs for the atmospheric environment, aquatic environment, terrestrial environment are illustrated in Figure 7.3-2.

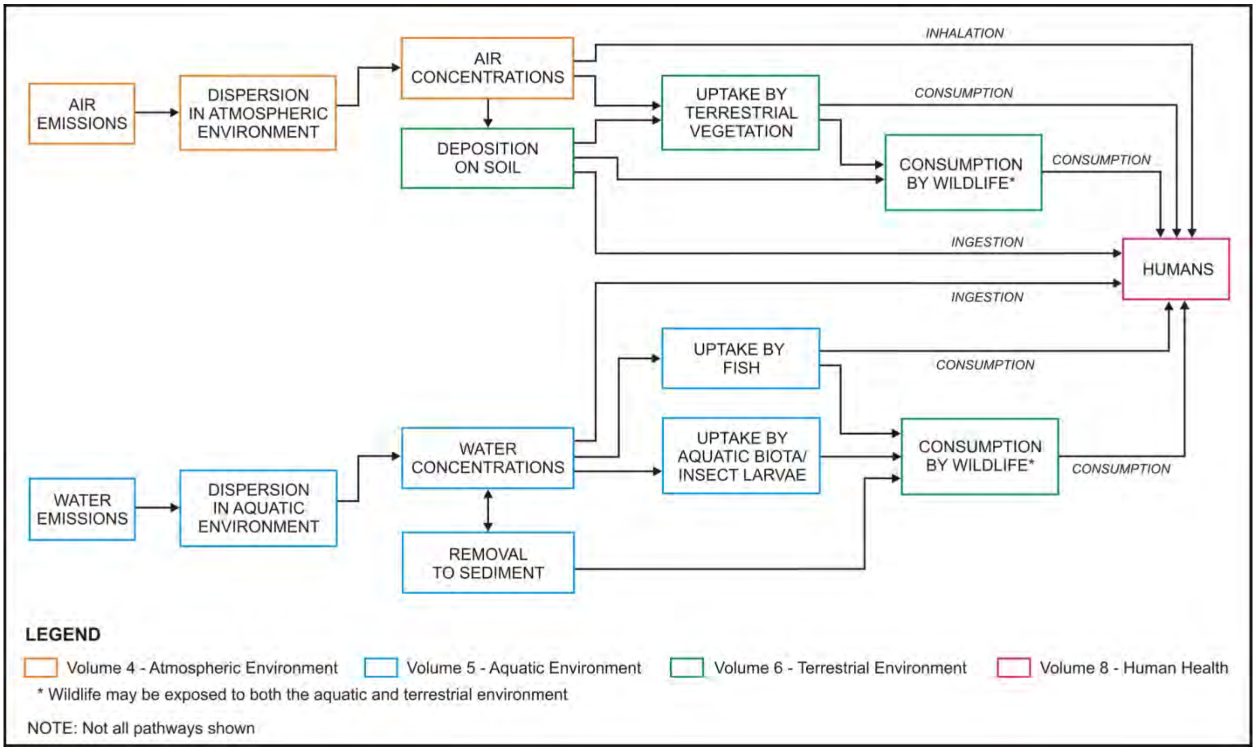


Figure 7.3-2 Linkages Between Human Health and other Environmental Components

7.3.2.4 Mitigation Measures and Project Design for Exposure to Radioactivity and Other COPC

Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize Project-associated emissions and/or the potential effect of project-related emissions.

Volume 4 (Atmospheric Environment) provides a detailed list of the mitigation measures applied to reduce the changes to ambient air quality. Mitigation measures that have been incorporated to reduce emissions of dust containing COPC include:

- Minimize or reduce vehicle speed on unpaved mine site roads (including pit ramps) and the Kiggavik-Sissons access road and enforce speed limits, where possible
- Apply water or another approved dust suppressant to the surfaces of unpaved mine site roads (including pit ramps) and the Kiggavik-Sissons access road, when possible
- Maintain all unpaved road surfaces via grading or other maintenance practices to minimize the amount of silt (i.e., fine particles) present in the roadbed material
- Appropriate air pollution controls will be installed on the exhaust stacks of the mill complex and acid plant (e.g., wet scrubbers, dust collectors)

- Tailings will be released to the TMFs as a slurry below a water surface to avoid tailings dust emissions

The design of the Kiggavik Water Treatment Plant (WTP) and Sissons WTP ensures that the effluent will meet all appropriate regulations such as the Metal Mining Effluent Regulation (MMER) as well as site-specific discharge limits. Environmental considerations were paramount in the selection of the appropriate technology for the WTP. Further detail on the design of the water treatment plant can be found in Volume 2 of the EIS (Project Description and Assessment Basis).

7.3.2.5 Residual Effects for Exposure to Radioactivity and Other COPC

As a result of emissions from the project the exposure of members of the public to radioactivity and other COPC may increase. This is expected to occur throughout the project with some environmental media (soil, lichen, sediment) able to store levels of COPC from one year to the next resulting in a potential cumulative increase at the end of the project. During closure water treatment will continue. At post-closure, there are no direct releases of COPC; however, there is still a small on-going release of radon from the waste rock piles.

One potential route of exposure is through drinking water. A comparison of the predicted water quality and the Canadian Drinking Water Quality Guideline (Health Canada 2010) is shown in Table 7.3.5. This table provides the maximum (throughout the project duration) predicted water concentration (mean and 95th percentile) at the outlet of Judge Sissons Lake. The comparison provided in Table 7.3.5 shows that the water quality is expected to remain well below all health-based Drinking Water Quality Guidelines.

Table 7.3.5 Comparison of Predicted Water Quality and Drinking Water Quality Objectives

Constituent	Units	Baseline WQ	Drinking Water Quality Guidelines[a]	Estimated Maximum Concentrations at Outlet of Judge Sissons Lake	
				Max Mean	Max 95th
Uranium	µg/L	0.064	20	0.2	0.3
Thorium-230	Bq/L	0.006	0.6	0.008	0.010
Lead-210	Bq/L	0.011	0.2	0.014	0.015
Radium-226	Bq/L	0.004	0.5	0.005	0.006
Polonium-210	Bq/L	0.005	0.1	0.006	0.007
Arsenic	µg/L	0.16	10	0.4	0.5
Cadmium	µg/L	0.0015	5	0.1	0.2

Table 7.3.5 Comparison of Predicted Water Quality and Drinking Water Quality Objectives

Constituent	Units	Baseline WQ	Drinking Water Quality Guidelines[a]	Estimated Maximum Concentrations at Outlet of Judge Sissons Lake	
				Max Mean	Max 95th
Cobalt	µg/L	0.06	--	0.1	0.1
Copper	µg/L	0.8	1000 (AO)	1.0	1.0
Lead	µg/L	0.14	10	0.1	0.1
Molybdenum	µg/L	0.09	--	2.5	4.3
Nickel	µg/L	0.6	--	0.8	0.9
Selenium	µg/L	0.06	10	0.2	0.3
Zinc	µg/L	4.0	5000 (AO)	5.0	5.0
Ammonia (un-ionized)	mg/L	0.04	--[b]	0.005	0.007
Chloride	mg/L	0.64	250 (AO)	58.1	83.6
Sulphate	mg/L	0.78	500 (AO)	177	248
TDS	mg/L	24.6	500 (AO)	322	428
Hardness (Ca as $CaCO_3$)	mg/L	2.8	--[c]	132	176

NOTES:

a Drinking Water Quality Guidelines (Health Canada 2010) are health-based unless otherwise noted

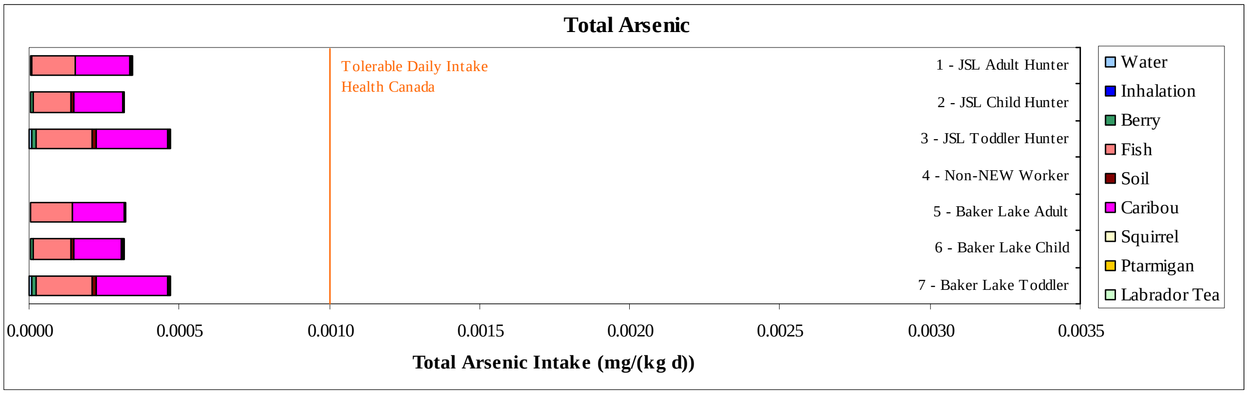
AO aesthetic objective (i.e. not health-based)

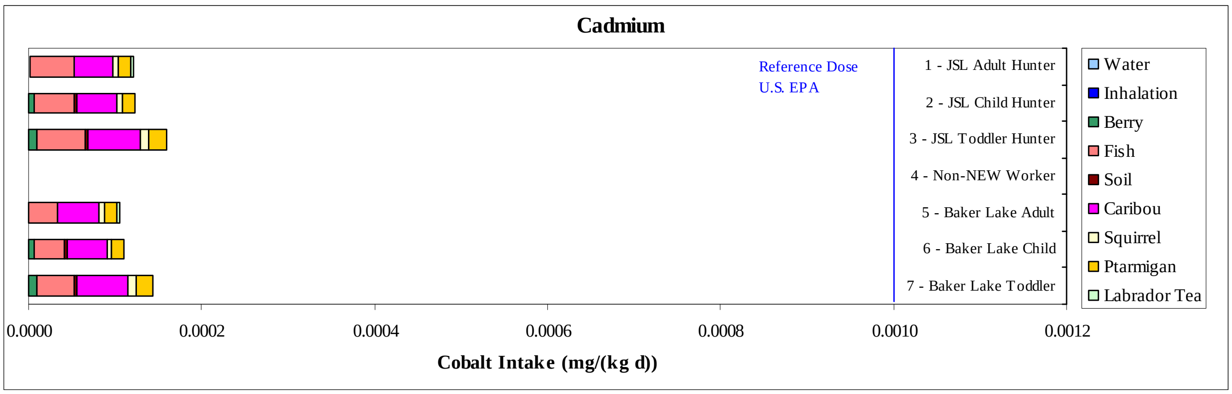
-- no guideline value available

b Ammonia is listed as not having a numerical guideline because current data indicated that it poses no health risk or aesthetic problem at levels generally found in drinking water in Canada

c Generally hardness levels between 80 and 100 mg/L are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable.

In addition to drinking water, members of the public may be exposed to COPC through various pathways as shown in Figure 7.3-1. The intakes of non-radiological COPC from all the pathways are compared to health benchmarks that are set to protect sensitive sub-populations. Figure 7.3-3 presents a graphical summary of the predicted mean intakes for the year of maximum exposure over the assessment period. The figure also indicates the most significant pathways for the total intake of each COPC as well as the appropriate health benchmark. The figure shows that the predicted intakes for all the human receptors are below the applicable health benchmarks for all non-carcinogenic COPC, with the toddler being the most exposed.





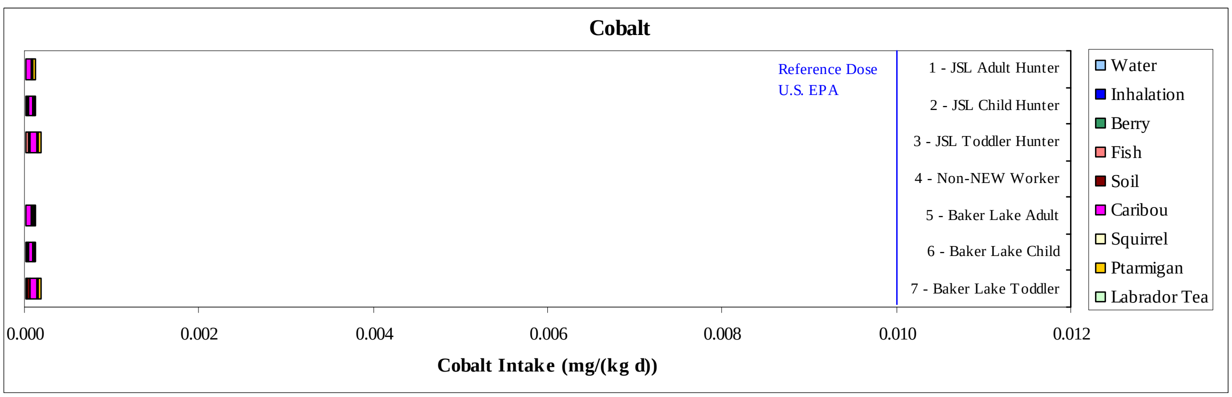


Figure 7.3-3 Predicted Maximum Mean Intakes of Non-Radionuclides by Pathway for Human Receptors

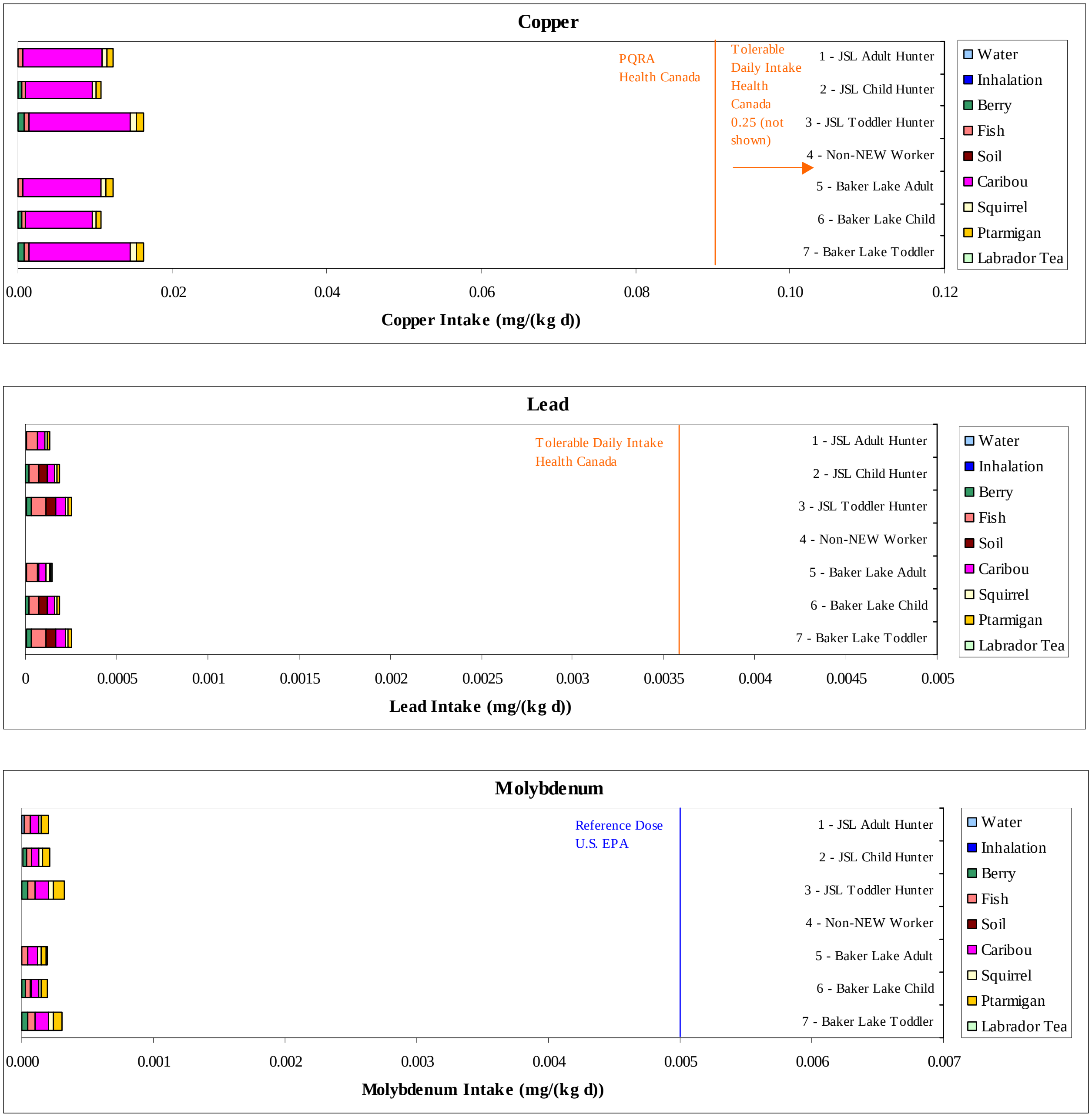


Figure 7.3-3 Predicted Maximum Mean Intakes of Non-Radionuclides by Pathway for Human Receptors

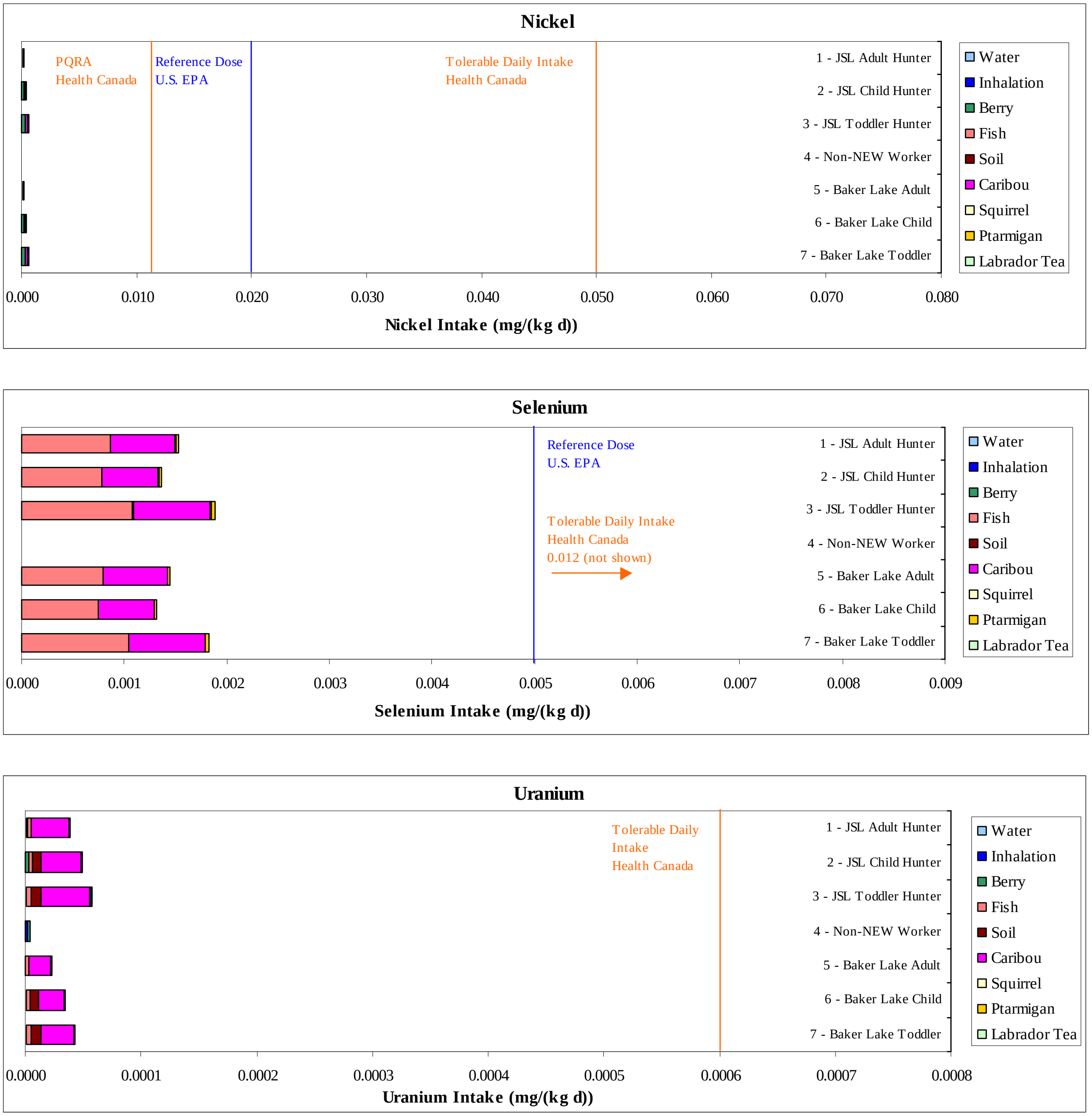


Figure 7.3-3 Predicted Maximum Mean Intakes of Non-Radionuclides by Pathway for Human Receptors

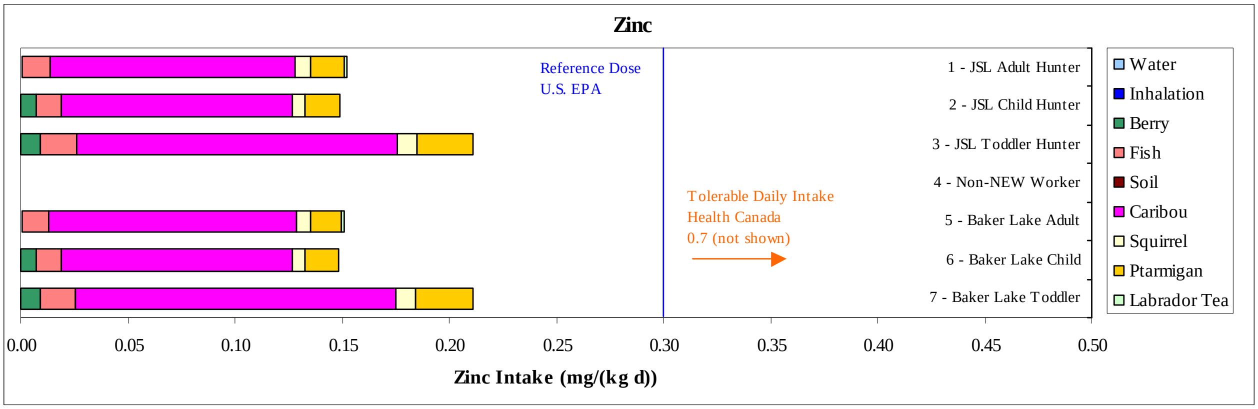


Figure 7.3-3 Predicted Maximum Mean Intakes of Non-Radionuclides by Pathway for Human Receptors

Table 7.3.6 provides a comparison on the intake of the toddler (the most exposed) to intakes that are generally expected for Canadian toddlers. It should be noted that the intakes for the Kiggavik Project and baseline do not account for all pathways of exposure as some supermarket foods (e.g. milk, pasta) are not included. This table shows that the exposure to local toddlers is similar to typical Canadian exposure and below levels of concern.

Table 7.3.6 Assessment of Exposure to Non-Radioactive COPC for Members of the Public (Toddler of Judge Sissons Hunter)

	Health Benchmark (µg/(kg d))	Kiggavik Project + Baseline[a]		General Canadian	
		Intake (µg/(kg d))	% Health Benchmark	Intake (µg/(kg d))	% Health Benchmark
Arsenic	1	0.47	47%	0.66	66%
Cadmium	1	0.16	16%	0.56	56%
Cobalt	10	0.19	2%	0.71	7.1%
Copper	90	16.3	18%	56.8	63%
Lead	3.6	0.25	7%	0.60	17%
Molybdenum	5	0.32	6%	8.59	172%
Nickel	11	0.59	5%	11.5	104%
Selenium	5	1.88	38%	4.2	84%
Uranium	0.6	0.05	10%	0.08	13%
Zinc	300	211	70%	549	183%

NOTE:

a The intakes reflect the total exposure (baseline + Project emissions) for all routes of exposure included in the assessment. Other routes of exposure (e.g. supermarket foods such as milk, grains) have not been included.

Arsenic also has the potential to cause cancer. For carcinogenic compounds, the risk is calculated by multiplying the estimated intake (in mg/(kg-d)) by the appropriate slope factor (in $(mg/(kg\text{-}d))^{-1}$). The calculated risk is then compared to an acceptable risk level. In this assessment, an incremental risk level of 1×10^{-5} (1 in 100,000) was used to assess carcinogenic effects. Health Canada considers this value to represent an "essentially negligible" risk. Risk levels for a composite person, exposed throughout their lifetime from toddler to an adult, are estimated. The estimated risk for the Judge Sisson hunter is 2.2×10^{-6} and the risk for the Baker Lake resident is 1.9×10^{-6}. These risk estimates are considered to be essentially negligible based on Health Canada's acceptable risk level.

For exposure to radionuclides, the incremental dose from the Project was calculated for each receptor. The incremental annual radiation dose resulting from the Project for the seven receptors is summarized in Figure 7.3-4. The highest predicted mean incremental dose is 98 µSv/year for the non-NEW worker. The highest predicted dose for a person located off the site is a toddler of a hunter in the Judge Sissons Lake area with a dose of 59 µSv/year. These doses are all below the Health Canada dose constraint of 300 µSv/year and well below CNSC dose limit of 1,000 µSv/year. The non-NEW is expected to receive most of his/her incremental dose from radon and inhalation of dust.

The majority of the dose for all other receptors is from ingestion of caribou with Po-210. Figure 7.3-5 provides the predicted incremental radiation doses to human receptors considered in the assessment over the phases of the project.

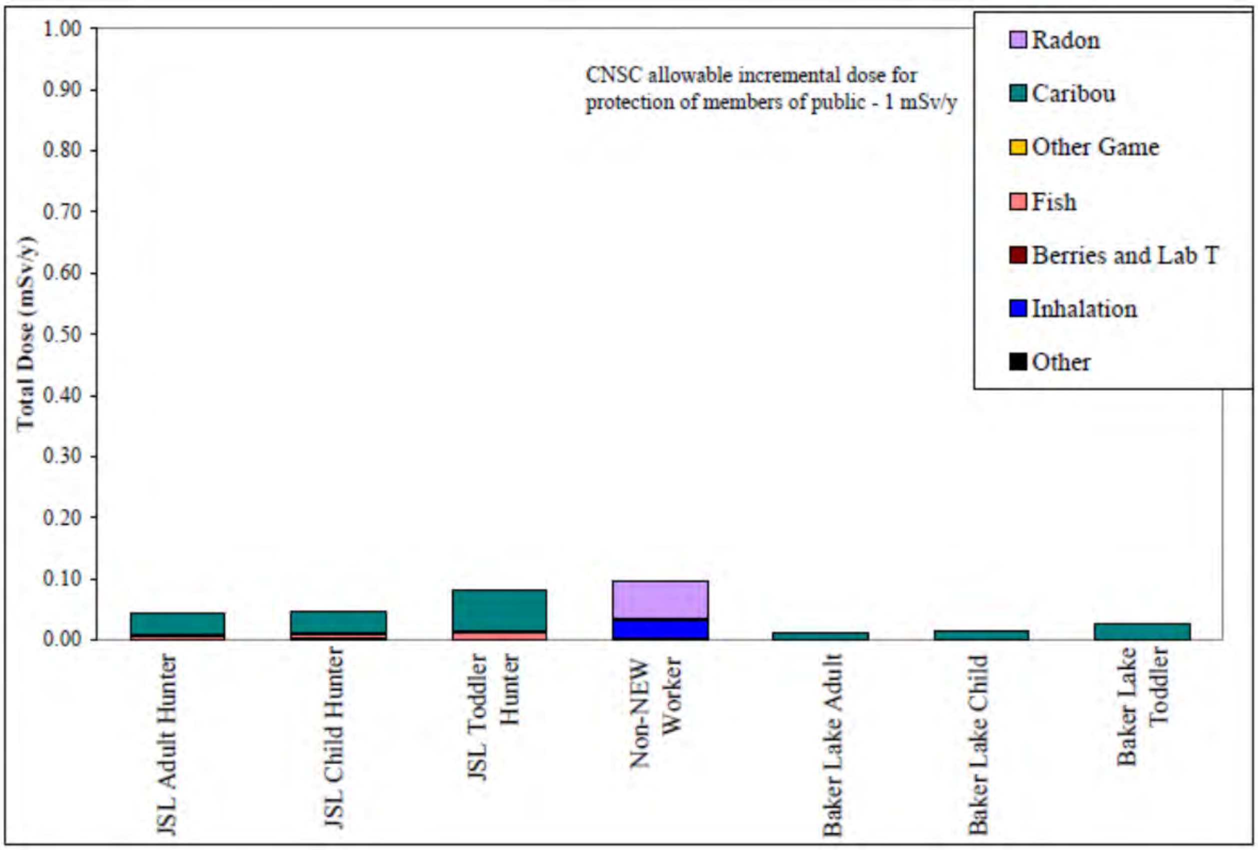
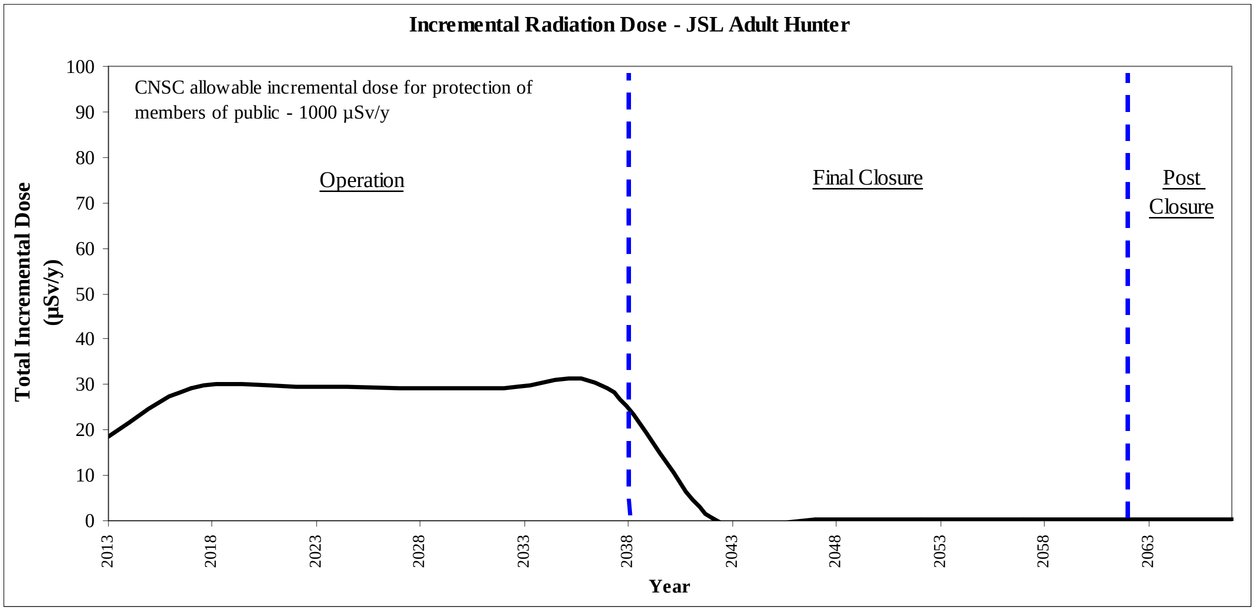
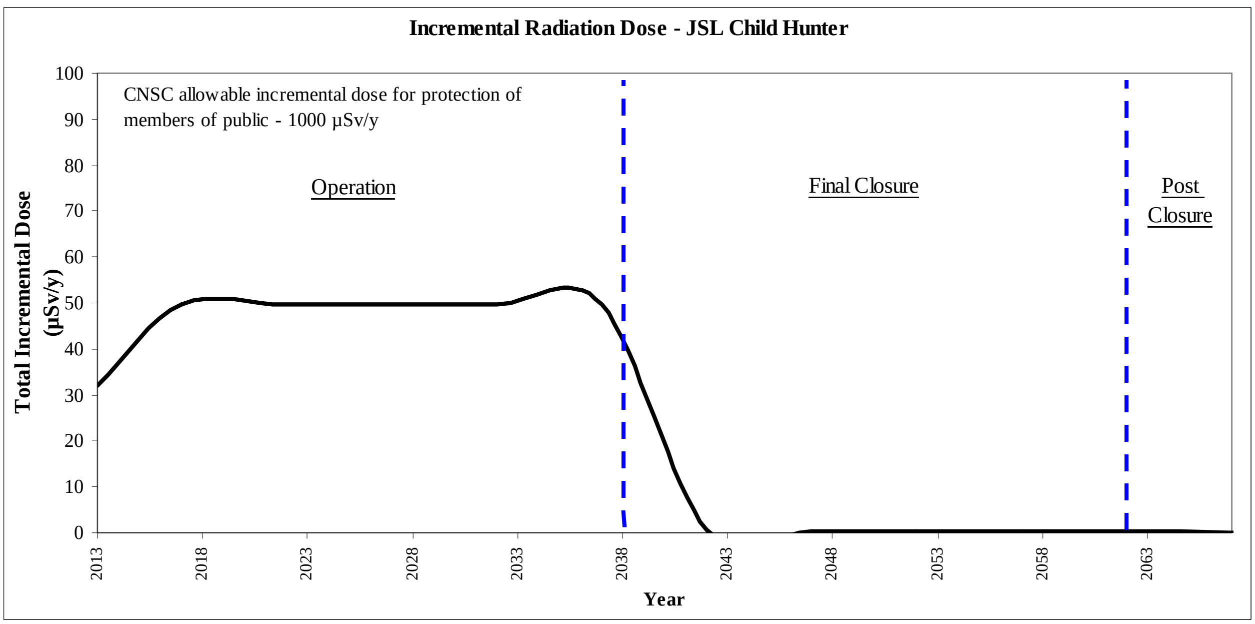
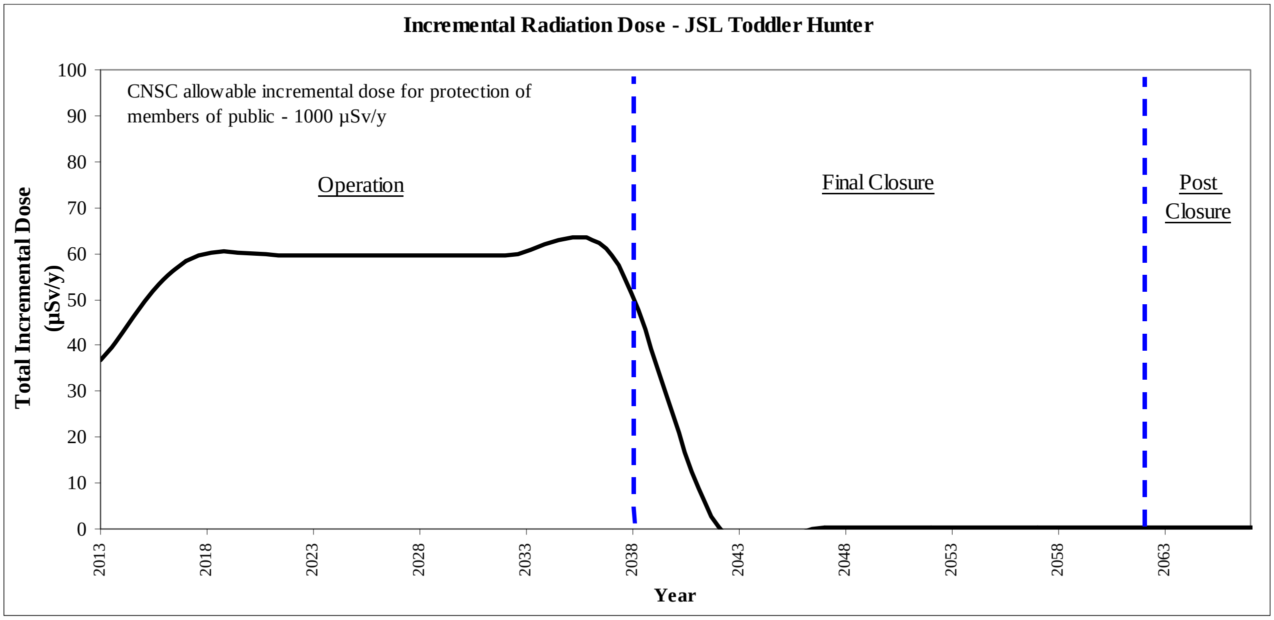
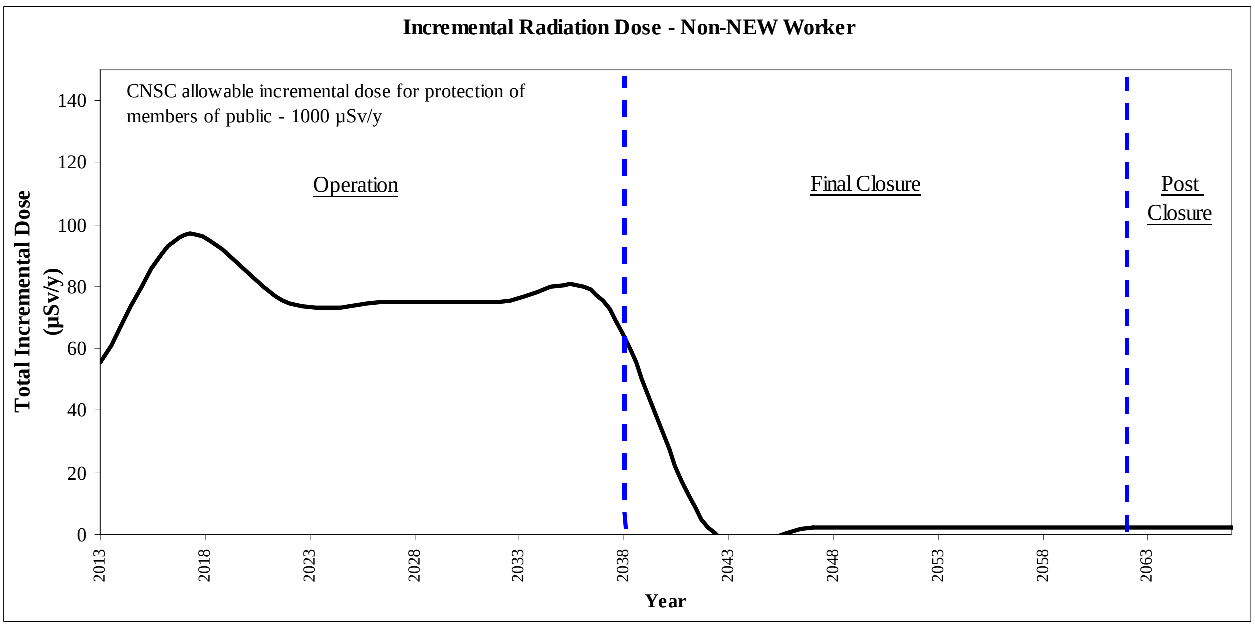


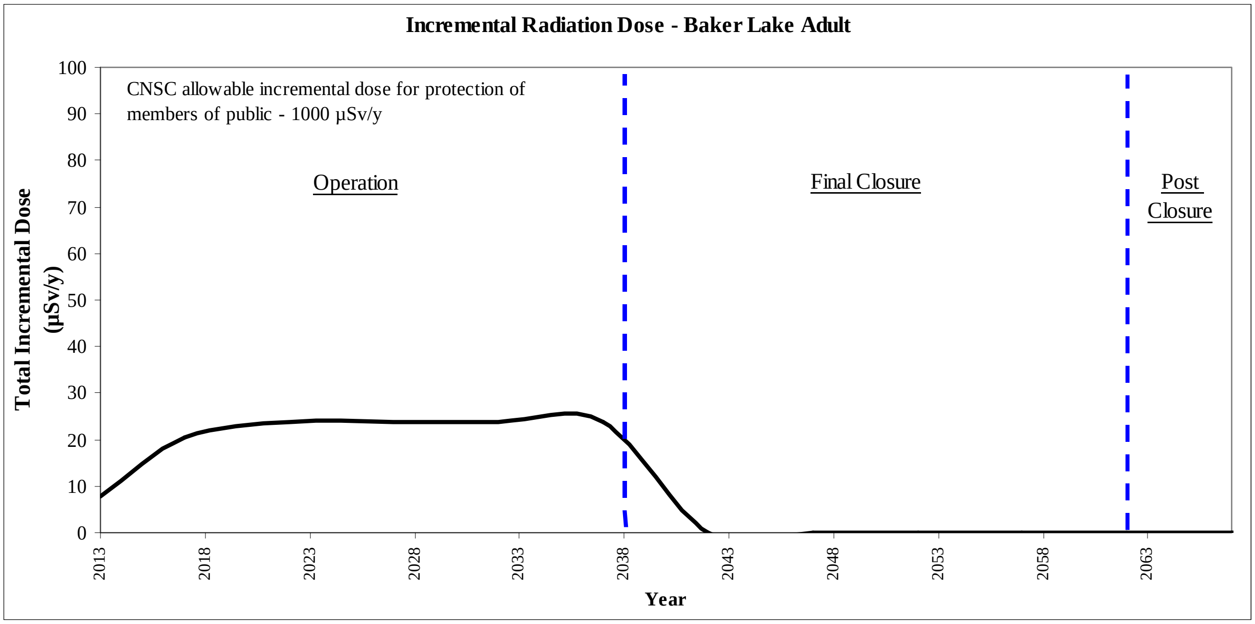
Figure 7.3-4 Breakdown of Incremental Annual Radiation Dose to Members of the Public from the Kiggavik Project

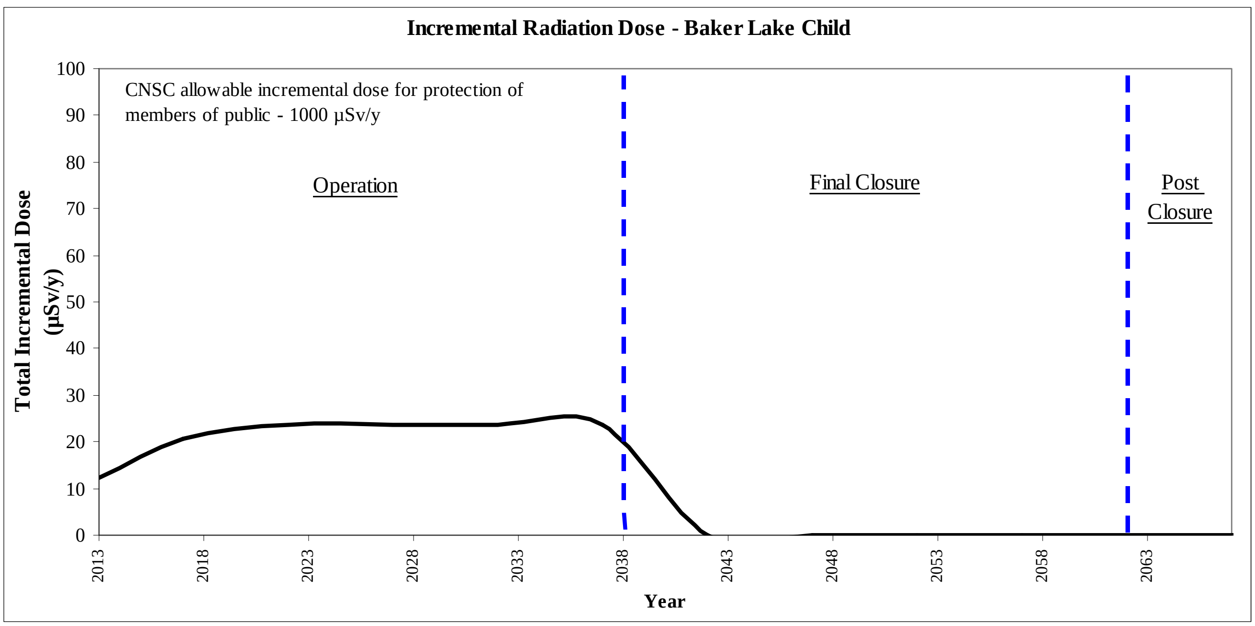

Incremental Radiation Dose - JSL Adult Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - JSL Child Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - JSL Toddler Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
0
10
20
30
40
50
60
70
80
90
100
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - Non-NEW Worker
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
0
20
40
60
80
100
120
140
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - Baker Lake Adult
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
0
10
20
30
40
50
60
70
80
90
100
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063
Year


Incremental Radiation Dose - Baker Lake Child
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
0
10
20
30
40
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60
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Year

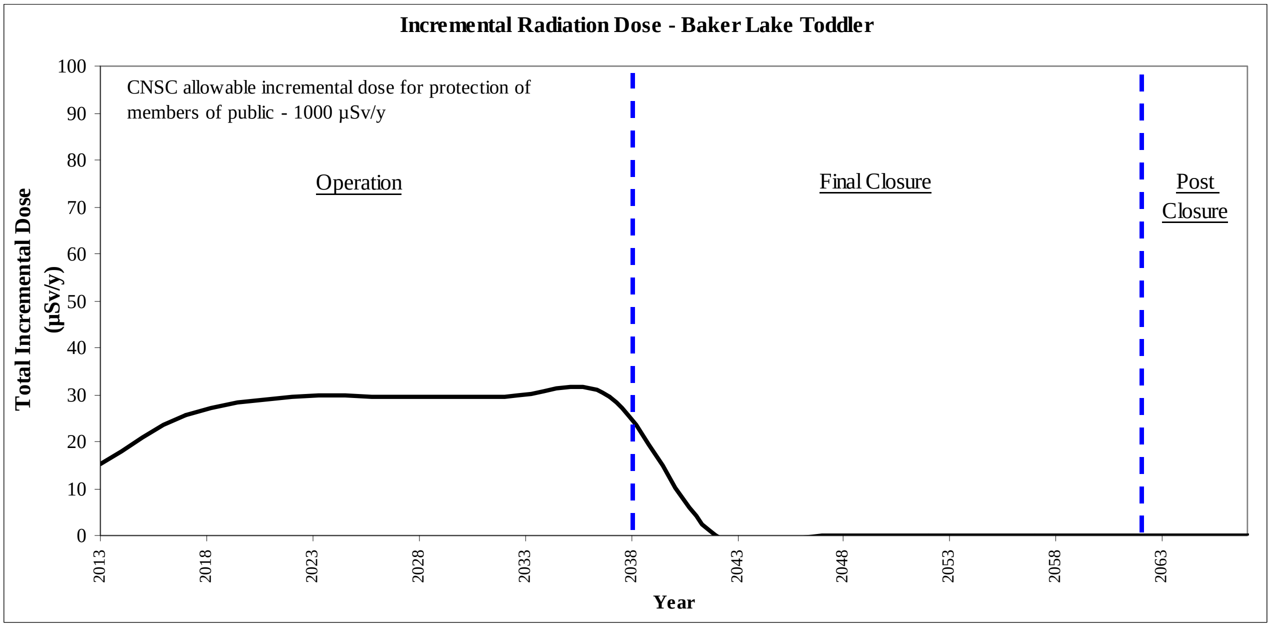

Figure 7.3-5 Incremental Radiation Dose over Time from Kiggavik Project

Additional consideration was given to a non-NEW worker at the Kiggavik site that may also reside in Baker Lake. The total dose for a person living in Baker Lake and working at the site (as a non-NEW) is estimated to be 0.1 mSv/y, well below the CNSC allowable dose for members of the public and the Health Canada dose constraint.

As discussed in Section 6.5.2, the ICRP suggests a risk coefficient for cancer of approximately 5.5% per Sv (based on exposure to all ages, males and females), assuming a linear response at low doses. The dose calculations for the Kiggavik Project were completed for each year of the project to examine the change in air emissions through the life of the project as well as to examine the recovery of the environment once the Project is in closure. Assuming that an individual is born at the beginning of the Kiggavik project and lives in the area for 75 years, the lifetime cancer risk is estimated to be 5.7×10^{-5} for the exposure scenario associated with the Judge Sissons hunter and 2.6×10^{-5} for the exposure scenario associated with the Baker Lake resident. The theoretical cancer risk due to lifetime background exposure is 0.83% (8.3×10^{-3}). This shows that the cancer risk due to releases of radioactivity from the Kiggavik Project is a small fraction of that associated with background exposure.

Overall, no residual effects were identified for exposure to radiation and non-radioactive COPC to members of the public were identified.

7.3.2.6 Determination of Significance for Exposure to Radioactivity and Other COPC

No residual effects were identified for exposure to radioactivity and other COPC for human health for members of the public. Therefore, no significant effects are expected.

7.3.2.7 Compliance and Environmental Monitoring for Exposure to Radioactivity and Other COPC

No specific monitoring plans have been developed to directly assess human health; rather the monitoring programs for the other environmental components (air, water, vegetation) are used to evaluate the affect of the Project has on exposure to people from COPC emissions from the Project.

7.4 Cumulative Effects Analysis for Human Health - Members of the Public

7.4.1 Screening for Cumulative Environmental Effects

Through the inclusion of baseline data collected from the Kiggavik area (e.g. vegetation concentrations, caribou tissue concentrations) any effect from existing projects has been included in the assessment. The measured baseline data includes any exposure that caribou may have to uranium mining operations in northern Saskatchewan.

The only residual effect identified is short-term exposure to NOx and PM for a person at the Accommodation Complex at the Kiggavik site. It is noted that this was a conservative assessment as individuals present at this location are not actually members of the public. The residual effect was only for the short-term exposure and longer term exposure and short-term exposure at other locations was well below any health-based benchmarks. As the future projects considered in the cumulative effects assessment (Section 3.4.3) are located a significant distance from the Project site, there is not expected to be any interactions that would have a measurable effect on human health.

7.5 Summary of Residual effects for Human Health - Members of the Public

7.5.1 Project Effects

The human health risk assessment addressed Criteria Air Contaminants (CAC) such as NO_x, SO_x and particulate matter (PM); non-radionuclide COPC (including arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc); and, radioactivity. The findings are as follows:

- Maximum concentrations of SO_2 will be within the health-based limits. Similarly, annual NO_2 concentrations will meet applicable criteria.
- There may be infrequent, short-term NO_2 concentrations above the health-based criterion at the Kiggavik camp; however, the levels at Baker Lake are well below any level of concern. Exceedances at the camp can be attributed to potential emissions of NO_x from open pit mining activities, including diesel-powered mining equipment and blasting. It should be noted that the concentrations are well below levels that WHO indicates may be a concern in healthy adults. NO_2 concentrations at the Kiggavik Camp do not exceed ambient air quality guidelines nor do they exceed Threshold Limit Values (TLVs) established by American Conference of Governmental Industrial Hygienists.
- In terms of exposure to fine particulate matter (PM), the levels at Baker Lake will be well below any levels of concern. There may be some short-term concentrations at the Kiggavik camp which exceed the health-based value; however as sensitive individuals (children, older adults, pre-existing respiratory disease) should not be present, the probability of adverse effects related to fine PM exposure is expected to be low.
- Exposures to non-radionuclides were evaluated. The predicted intakes are below levels identified by regulatory agencies such as Health Canada and the US EPA as being safe for individuals. Fish and caribou ingestion are the biggest contributors for most COPC, along with berries.
- The maximum mean incremental dose to people from radiation released from the Project is expected to remain below the Health Canada dose constraint as well as the CNSC allowable dose for members of the public. The non-NEW is expected to receive most of his/her incremental dose from radon and inhalation of dust The majority of the dose for all other receptors is from ingestion of caribou with Po-210.

Table 7.5.1 summarizes the residual environmental effects identified for members of the public.

Table 7.5.1 Summary of Project Residual Environmental Effects: Human Health (Members of the Public)

Project Phase	Mitigation/ Compensation Measures	Residual Environmental Effect (Y/N)	Residual Environmental Effects Characteristics: Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context	Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
Exposure of Members of the Public to CAC: Levels of Criteria Air Contaminants may affect individuals that are residing at the Kiggavik camp													
Construction		N								N	L	M	Implement ambient air monitoring program as required
Operation	General mitigation (see atmospheric environment)	Y	N	M	S	MT	S	R	N/A				
Final Closure		N											
Post Closure		N											

KEY

Direction:

P Positive

N Negative

Magnitude:

N Negligible: The predicted exposures are at or below the selected threshold.

L Low: The predicted exposures are within a factor of 2 of the selected threshold.

M Moderate: The predicted exposures are within a factor of 5 of the selected threshold

H High: The predicted exposures are greater than a factor of 5 of the selected threshold

Geographic Extent:

S Site-specific: Within Project Boundaries

L Local: Within 10km from the site

R Regional: Baker Lake

Duration:

Use quantitative measure; or

ST Short term: Less than one year

MT Medium term: More than one year, but not beyond the end of project decommissioning

LT Long term: Beyond the life of the project

P Permanent

Frequency:

Use quantitative measure; or

O Occurs once.

S Occurs sporadically at irregular intervals.

R Occurs on a regular basis and at regular intervals.

C Continuous.

Reversibility:

R Reversible

I Irreversible

Environmental Context:

U Undisturbed: Area relatively or not adversely affected by human activity

D Developed: Area has been substantially previously disturbed by human development or human development is still present

N/A Not Applicable

Significance:

S Significant

N Not Significant

Prediction Confidence:

Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation

L Low level of confidence

M Moderate level of confidence

H High level of confidence

Likelihood:

Based on professional judgment

L Low probability of occurrence

M Medium probability of occurrence

H High probability of occurrence

Cumulative Effects

Y Potential for effect to interact with other past, present or foreseeable projects or activities in RSA

N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RSA

7.5.2 Cumulative Effects

No cumulative effects were identified for exposure to members of the public.

7.5.3 Effects of Climate Change on Project and Cumulative Effects on Human Health - Members of the Public

Determining the effects of climate change on the effect of the Project on Human Health – members of the Public is complicated. The most likely impact would be a change in diet due to availability of game in the area. These effects will likely not be detectable within the approximately 30 year life of the Project. In addition, in the assessment it is assumed that caribou, a species that would reflect changes in the environment from air emissions from the Project due to the consumption of lichen, is a significant source of game. Changes to the diet of local people would therefore likely result in a lower level of exposure. Technical Appendix 5K explored 23 climate change ensembles, which reflect different combinations of models and emission scenarios. Twenty of these twenty three ensembles predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 28% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn. An increase in precipitation could result in a decrease in total suspended particulates and COPCs in the air, as precipitation would wash COPCs out of the air and enhance dust depression. This would lead to a reduction in exposure of caribou to COPCs through lichen. One other change that would be possible is that caribou may spend more time in the area than currently experienced and therefore have greater exposure. However, as a very cautious approach was taken in assessment (e.g. assuming all caribou consumed has spent some time in either the LAA or RAA) these changes are expected to be encompassed by the current assessment.

7.6 Summary of Mitigation Measures for Human Health - Members of the Public

Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans; it was integrated into the Project design that there would be no adverse effects on the health of members of the public.

7.7 Summary of Compliance and Environmental Monitoring for Human Health - Members of the Public

No specific monitoring plans have been developed to directly assess human health; rather the monitoring programs for the other environmental components (air, water, soil, vegetation and wildlife) are used to evaluate the effect of the Project has on exposure to people from COPC emissions from the Project activities. In the development of these monitoring programs, particular emphasis is placed on ensuring that the program addresses issues of relevance to human health. For example, the sampling of fish includes tissue sampling to determine what the levels of metals for species utilized by people. The monitoring of country foods is important (EN-WC KIA Apr 2007[114]) and, in addition to the regular environmental monitoring, AREVA will work collaboratively with local hunters to increase the information available to characterize baseline tissue concentrations for important pathways.

The environmental components such as air, water, soil, vegetation and wildlife, which have an indirect measure on human health will be monitored on a regular scheduled basis. The results of these components will be provided to stakeholders including Government of Nunavut departments in routine report. Upon finalization of the monitoring program at the licensing stage (See Appendix 1D for licensing commitments), AREVA will consult with each stakeholder regarding the types and frequencies of reports to be submitted. These reports will likely be submitted in both electronic and hard copy format. The monitoring programs will be part of the Integrated Management System (IMS) and more details can be found in the Environmental Management Plan in Appendix 2T.

AREVA understands the importance of providing Project updates, gathering feedback, and addressing community concerns throughout the life of the Project. This two-way dialogue will be conducted through the Community Involvement Plan (Tier 3, Technical Appendix 3C), which has been developed to communicate the results of the assessment. The Community Involvement Plan aims to increase community understanding of assessments and provide a framework for discussing future monitoring results in order to address perceived risks and reduce community concerns. Information related to human health and environmental monitoring results will be key components of the Community Involvement Plan.

[114] EN- WC KIA Apr 2007: *We eat country food and they need to be monitored. If it is contaminated it will be everywhere*.

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