A RADIOLOGICAL DOSE ASSESSMENT FOR THE PORT HOPE CONVERSION FACILITY

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ABSTRACT

The Port Hope Conversion Facility (PHCF) receives uranium trioxide for conversion to uranium hexafluoride (UF_6) or uranium dioxide (UO_2). The PHCF Site has a long history of industrial use.

A Radiological Dose Assessment was undertaken as part of a Site Wide Risk Assessment. This assessment took into account all possible human receptors, both workers and members of the public. This paper focuses on a radiological assessment of dose to members of the public.

The doses to members of the public from terrestrial pathways were added to the doses from aquatic pathways to obtain overall dose to receptors.

The benchmark used in the assessment is 1 mSv/y. The estimated doses related to PHCF operations are much lower than the dose limit.

1. INTRODUCTION

This paper summarizes the radiological dose assessment to members of the public that was included as part of the human health risk assessment (HHRA) carried out as part of a larger series of studies for Cameco Corporation's Port Hope Conversion Facility (PHCF) in Port Hope, Ontario. The PHCF is a uranium conversion facility located on a site with a history of industrial use by multiple users, starting in the mid-to-late 1800s. The site is shown in Figure 1.

Figure 1. Cameco Corporation's Port Hope Conversion Facility Site, Port Hope, Ontario.

2. BACKGROUND

The Port Hope Conversion Facility (PHCF) receives uranium trioxide for conversion to either uranium hexafluoride (UF_6) or uranium dioxide (UO_2). Cameco routinely monitors releases of radioactive chemicals to the environment (to air, water and waste) to ensure that they are within regulatory requirements. Cameco also monitors concentrations in the environment (air, soil, water and sediment).

The historic operations on the site were recognized to have resulted in surface and sub-surface contamination on the site and in the surrounding environment at the time Cameco was formed in 1988. A legal agreement exists between the federal government and the municipalities of Port Hope and Clarington for the clean up and long-term safe management of historic low-level radioactive waste. The Port Hope Area Initiative (PHAI) led by Atomic Energy of Canada Limited (AECL) and Cameco's Vision 2010 project are being developed to address this historic contamination in the municipality, including the Port Hope Harbour (Harbour) and site, respectively. The Vision 2010 project involves the removal of several old or under-utilized buildings, the removal of contaminated soils, building materials and stored historical wastes, and the construction of some new buildings where necessary to improve the efficiency of the facility.

Cameco retained SENES Consultants Limited (SENES) to carry out a Site-Wide Risk Assessment (SWRA) based on information readily available as of December 2008 [1]. The SWRA addressed regulatory expectations provided at the start of the project by the Canadian Nuclear Safety Commission (CNSC) and the Ontario Ministry of the Environment (MOE). The SWRA was submitted to the CNSC in June 2009. The SWRA included the fundamental elements of a risk assessment, such as:

- Screening for Contaminants of Potential Concern (COPCs);

- Site Characterization;
- Conceptual Site Model;
- Hazard Assessment and Exposure Assessment; and
- Risk Characterization, etc.

In addition, the SWRA included unique features such as a site-specific hydrodynamic and contaminant transport model and the derivation of Risk-Based Performance Objectives for the site.

The SWRA addressed risks from both radiological and chemical contaminants associated with the PHCF operations. They included scenarios for both present-day soil conditions and post-Vision 2010 soil conditions.

The results of the SWRA were used to provide risk-informed feedback on risk-sensitive information gaps as well as information on the potential need for mitigative and preventative measures to ensure that there is no undue risk associated with PHCF operations.

After the June 2009 SWRA, Cameco and SENES made a number of refinements. Many of these refinements were based on a discussion of uncertainties in the SWRA. The refinements were incorporated into a SWRA Update [2], which was submitted to the CNSC in December 2009.

The June 2009 SWRA has subsequently undergone third party review, on behalf of the Municipality of Port Hope. In response, SENES has formed a disposition of these comments and has identified certain areas for further investigation. As part of this investigation, the radiological dose assessment to members of the public was updated to include additional receptors (SENES 2010 [5]).

3. HUMAN HEALTH RISK ASSESSMENT (HHRA) OBJECTIVES AND SCOPE

The main objectives of the HHRA were to address the following questions:

Q1: What are the potential net effects on humans resulting from current site groundwater loadings to the Harbour and Lake Ontario? This was assessed in the "Incremental" scenarios, where environmental concentrations were calculated from the estimated loadings of the PHCF into the Harbour and the lake. Current loadings took into account the recent removal of contaminated soil as well as the installation of pump and treat wells on-site. Question Q1 addressed the potential issue of Harbour recontamination following sediment cleanup by PHAI.

Q2: What are the potential total effects on humans resulting from several sources, including current contamination levels in the Harbour and current site soil levels and groundwater concentrations and air concentrations? This was assessed in the "Total" scenarios, where environmental concentrations were based on monitoring data.

The radiological dose assessment for the HHRA considered radioactive contaminants for the following off-site members of the public:

- Nearby Resident: residential exposures (all ages) plus fence line walker (all ages);
- Commercial worker: adult working near the facility;
- Yacht Club user: (all ages) either on shore or on moored boat;
- Fisherperson: (all ages);
- Park visitor: (adult and child).

The assessment took into consideration receptor characteristics, exposure pathways and mitigating circumstances. Risk was evaluated using physical site conditions and known characteristics of the people using the site.

The assessment investigated soil at and groundwater below the PHCF site as well as on-site and off-site air quality and surface water and sediment in the Port Hope Harbour. The focus of the radiological dose assessment was risk from soil and groundwater pathways, including the loadings from on-site groundwater to the surface water environment (Port Hope Harbour or Lake Ontario). Other pathways such as air (including deposition) were considered based on readily-available information. Storm water loadings from the site were also included.

4. RADIOACTIVITY RELEASES

The facility releases radiation into the surrounding environment that can result in radioactive dose to members of the public. As a brief summary, the three main exposure pathways are:

(i) uranium released to the air from the PHCF site through various stacks and building vents;

(ii) uranium released from the PHCF site through cooling water discharges to the Turning Basin; and,

(iii) gamma radiation emitted from stored materials.

Uranium (specifically U-238, U-234 and U-235) is the primary source of radioactivity from the facility. Along with uranium, the facility emits additional radionuclides that are short-lived decay products of uranium (e.g. Th-234, Pa-234).

The radioactivity released from PHCF is only that associated with refined uranium (U-238 through U-234 subseries and U-235 and Th-231). Other radionuclides, present in the original ore (e.g. radium-226, thorium-230), will have been removed during milling and refining prior to delivery of uranium to the PHCF as uranium trioxide (UO_3) for conversion to uranium hexafluoride (UF6) or uranium dioxide (UO_2).

5. AIR DISPERSION MODELLING

Air dispersion models use meteorological data, release characteristics (e.g. release rate, height, temperature, etc.) and mathematical models of atmospheric dispersion to predict the annual average air concentrations at locations of interest. In this study, long term average concentrations of uranium-in-air were predicted for individual sources using the corresponding release rates and the AERMOD air dispersion model[1]. Five years of meteorological data were used and the concentrations were predicted at specified discrete receptor locations as well as for a regular grid of points over the nearby area.

6. FATE AND TRANSPORT MODELLING

Fate and transport modelling of contaminants seeping into the Harbour and near-shore Lake Ontario through groundwater and storm water was undertaken as part of the SWRA. A more detailed and more realistic 3D hydrodynamic and contaminant transport model was developed to improve the model used in the June 2009 SWRA. The model was used to estimate the dilution ratios between groundwater and storm water loadings to concentrations in various locations in the Harbour and near-field Lake Ontario and derive contaminant concentrations at receptor locations for the updated SWRA. The hydrodynamic and contaminant transport models used in this SWRA update include the following refinements:

- Extension of the spatial domain to remove artifacts from open boundaries;
- Refinement of the vertical grid;
- Incorporation of MOE current data to calibrate the flow in the near-field Lake Ontario;
- Incorporation of wind shear effects;
- Incorporation of cooling water circulation; and
- Verification and comparison of estimated concentrations to field data.

The refined hydrodynamic and contaminant transport model presented and used in the SWRA Update has been verified by comparison to tracer field data. The estimated tracer (fluoride) concentrations agree well with the field data.

7. DOSE CALCULATIONS

A screening-level (also called Tier 1) dose assessment was carried out for all of the human receptors in the SWRA. This involved conservative assumptions about environmental concentrations, ecological receptor exposure time and hazard assessment parameters. A Tier 2 assessment was carried out for selected receptors. The Tier 2 assessment involved the use of

[1] The ISCST air model was used for the previous DRL study (SENES 2000). Since that time, the Ontario Ministry of the Environment has required that the AERMOD model be used for air dispersion modelling. Although similar in structure and data requirements, the two models for the same emission rate may produce somewhat different concentrations for locations paired in space and time.

more realistic parameters, such as concentrations or transfer factors. Figure 2 shows schematically the Tier 1 and Tier 2 assessment.

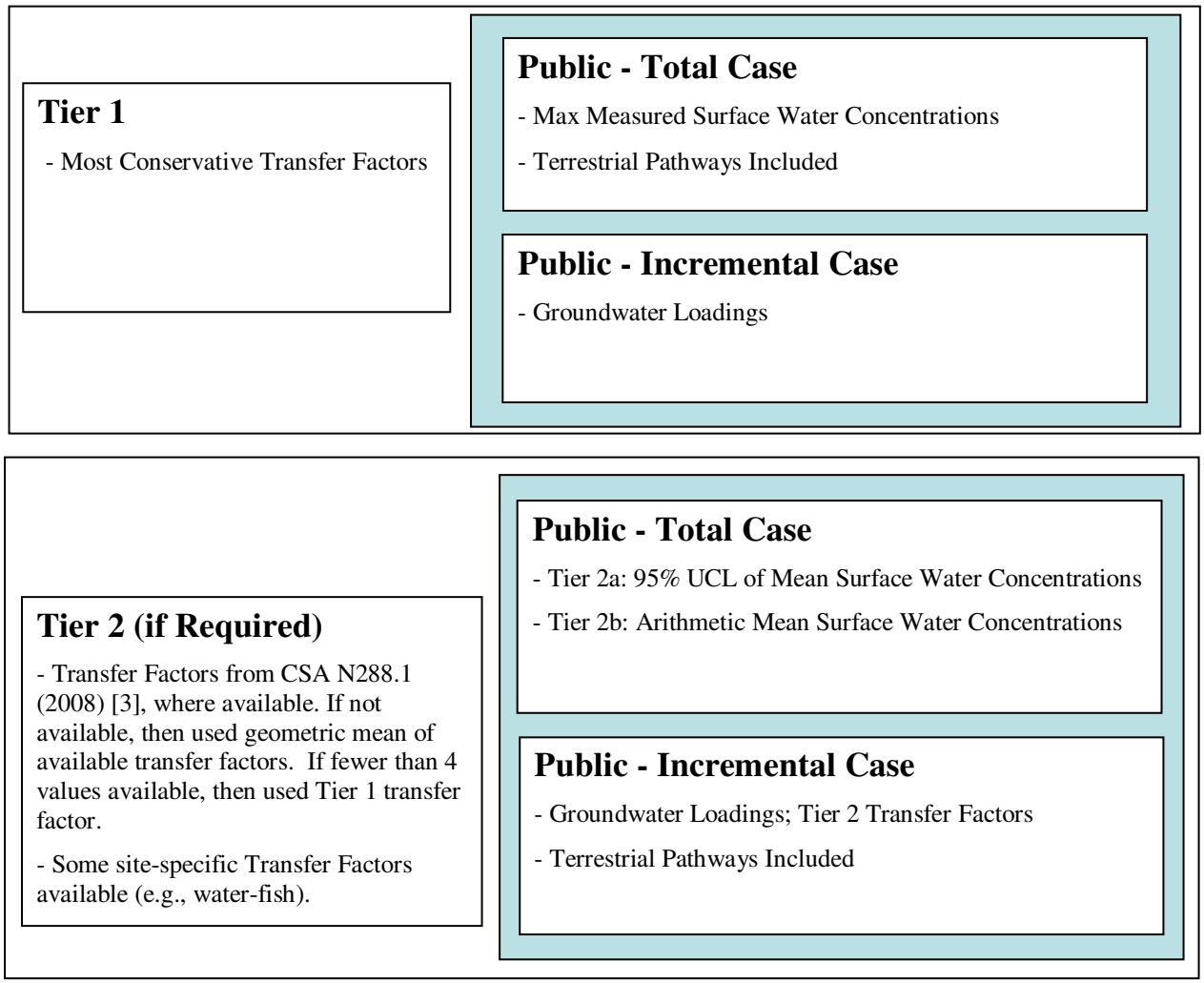

Figure 2. Dose Assessment Tier 1 and 2 Schematic.

Details of the calculations are provided in the SWRA [1],[2]. A brief summary of the methodology is provided in the following sub-sections.

7.1 Conceptual model

Information on the site conditions (including the nature, extent and distribution of the radiological hazards), potential exposure pathways and opportunities for human receptors that will frequent, use or populate the site, were integrated into a Conceptual Site Model (CSM). The CSM for aquatic pathways for the SWRA is shown in Figure 3. Please note that Figure 3 shows the entire CSM for aquatic pathways including workers, while this paper focuses only on members of the public.

In the Total case, air pathways are considered in addition to aquatic pathways as part of the CSM. The air pathways considered are shown in Figure 4.

7.2 Exposure assessment

The exposure assessment comprised three elements:

- frequency and duration of actual and/or potential exposure;
- determination of potential pathways (routes of exposure); and
- estimation of the magnitude of exposure.

Exposure models use measured and estimated media concentrations, as well as receptor characteristics, in order to estimate the doses to humans from radionuclides associated with the facility.

7.3 Hazard assessment

In general, the hazard assessment uses results from animal (and when available, human) studies to determine the likelihood of an adverse health effect occurring as a result of a given exposure. The radiological benchmarks used in the dose assessment are based on dose limits established by the CNSC. It should be noted that an exposure level above a criterion does not mean that an effect will occur, but instead means that there is an increased risk of an adverse effect occurring. These benchmarks were compared to the estimated human doses in order to characterize risk.

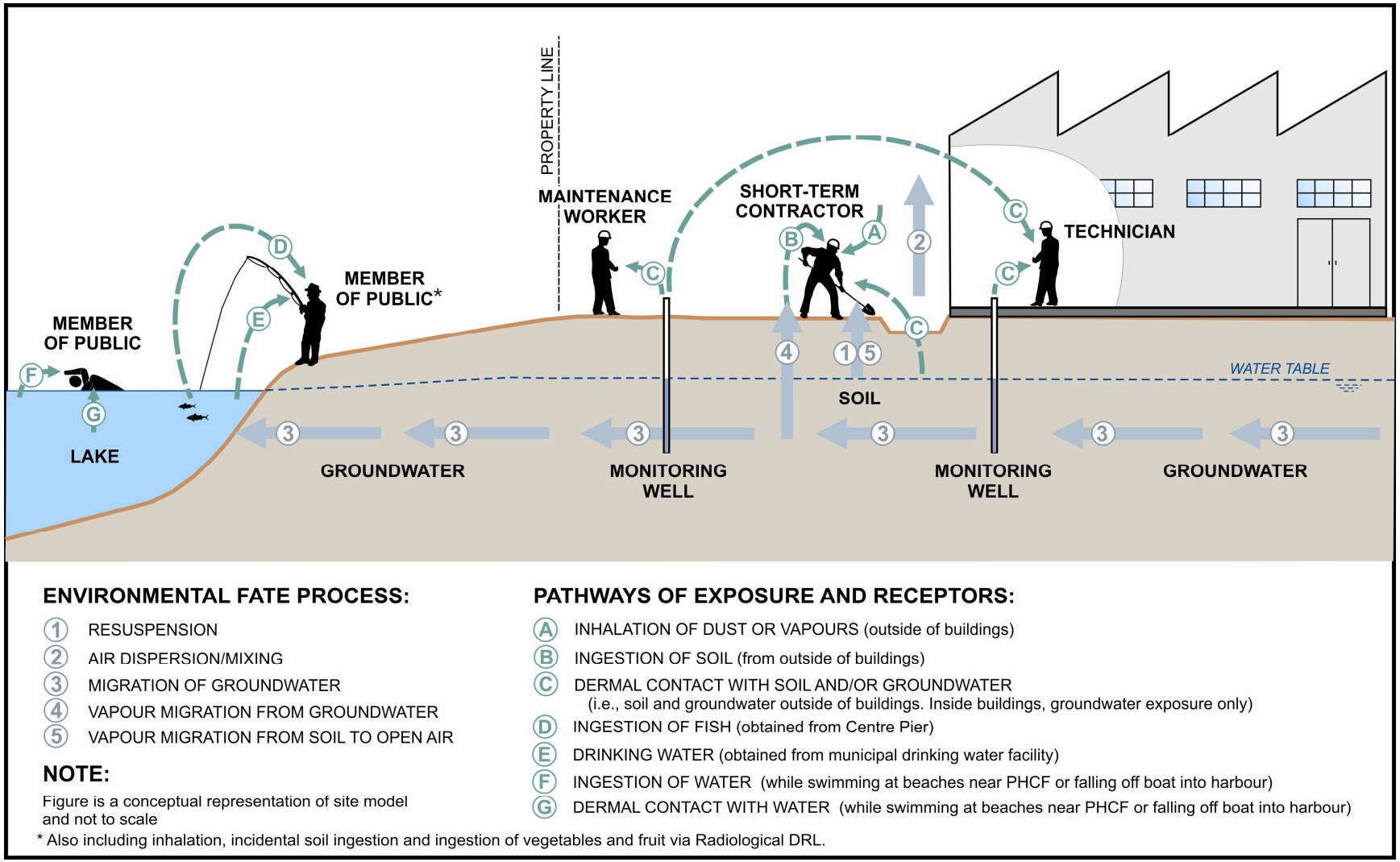

Figure 3. HHRA conceptual site model for aquatic pathways.

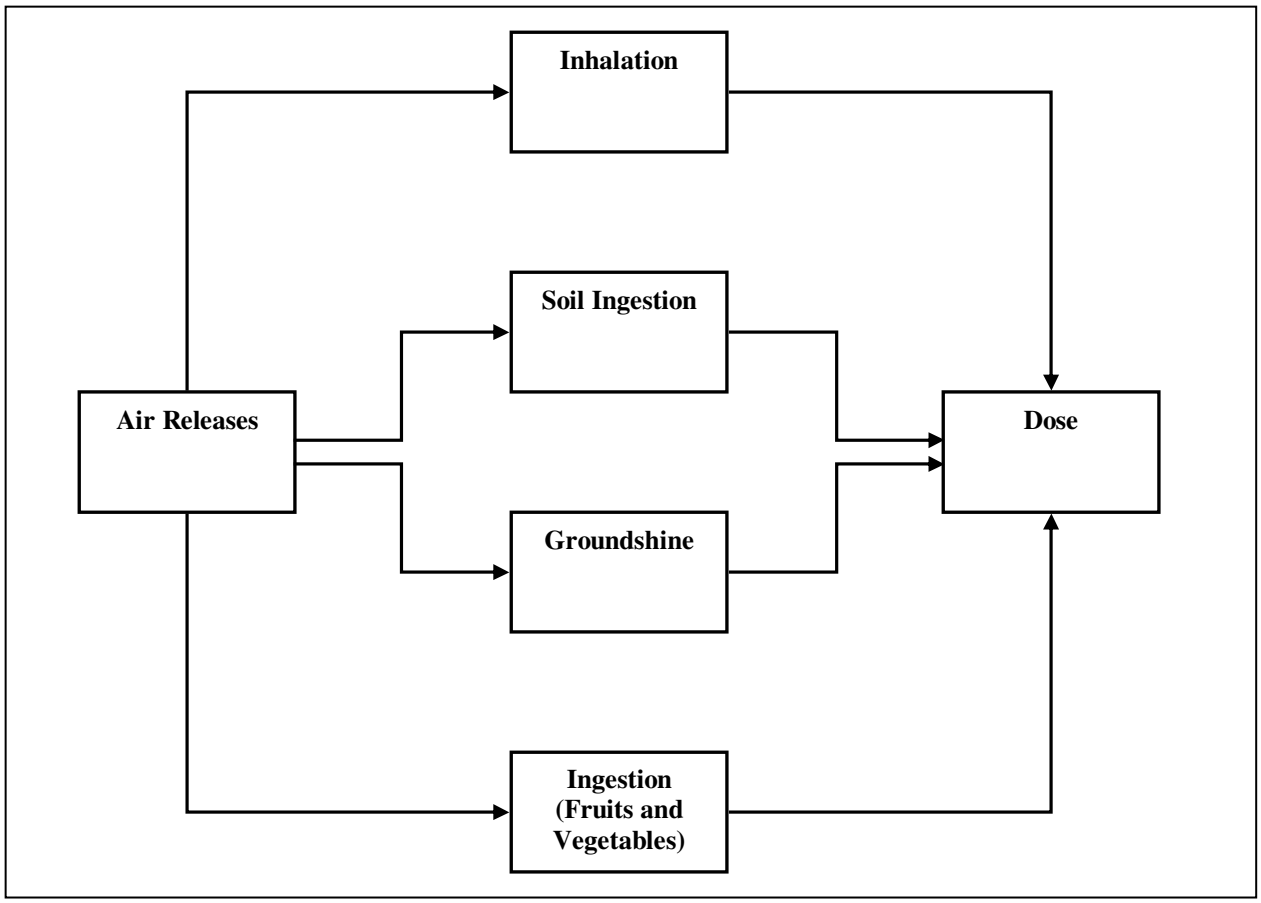

Figure 4. Additional air pathways.

8. DOSE ASSESSMENT RESULTS

The main conclusions from the dose assessment were:

- There is no immediate undue risk to the public due to contamination in the Harbour and near-shore Lake Ontario. This addressed both Questions Q1 ("Incremental") and Question Q2 ("Total") posed above.
- There is no undue risk to human health from exposure to radionuclides for either current conditions (based on the "Total Case") or future net PHCF contribution (based on the "Incremental Case"). It should be noted that only uranium isotopes are associated with current PHCF operations. Consistent with prudent radiological protection principles, Cameco also follows ALARA (i.e., keeping radiation exposure as low as reasonably achievable). This addressed both Questions Q1 ("Incremental") and Question Q2 ("Total").
- Adding additional receptors and pathways (toddler receptors for the fenceline walker, yacht club user and fisherperson receptor categories) did not affect the overall dose assessment results.

For illustration purposes, the following figures show the estimated dose breakdown to members of the public for the worst-case receptors, for incremental case (aquatic only) and total case (with terrestrial doses included):

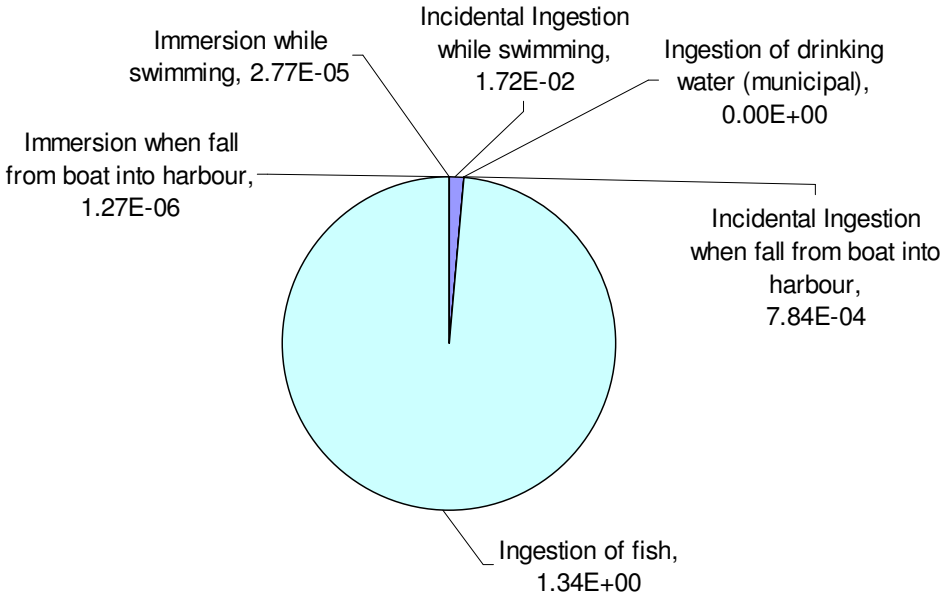

Figure 5. Breakdown of radiological dose intake (µSv/y) for members of the public – tier 1 incremental case, aquatic pathways (child).

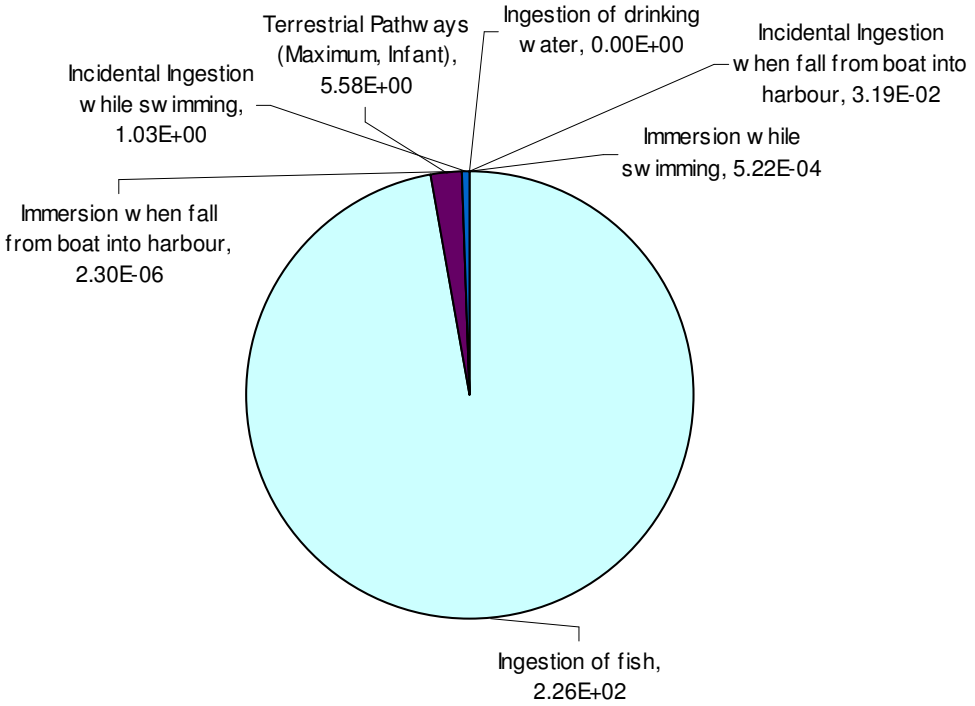

Figure 6. Breakdown of radiological dose intake (µSv/y) for members of the public –total case (tier 1), aquatic and terrestrial pathways (child).

Overall, the conclusions summarized above are consistent with the 2009 CNSC Study entitled "Understanding Heath Studies and Risk Assessments Conducted in the Port Hope Community from the 1950's to the Present"[4].

9. DOSE ASSESSMENT SUMMARY

Table 1 provides a simplified representation of the overall results of the assessment. Results are presented as one of the following:

- ✓ Indicates no adverse effect expected from COPCs associated with PHCF operations.
- ✗ Indicates the potential for adverse effects from COPCs associated with PHCF operations. Mitigation measures to address these issues will be included in the Site-Wide Environmental Management Plan if warranted.

Table 1. Summary of results for radioactive contaminants.

Question	Members of the Public
Q1 (Incremental)	✓
Q2 (Total)	✓

The results shown in Table 1 are supported by extensive site characterization data and a multi-source multi pathways-risk assessment. The results are also supported by toxicity testing and field observations. They are consistent with the 2009 CNSC Health Study [4].

10. REFERENCES

[1] SENES Consultants Limited, "Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 June.

[2] SENES Consultants Limited, "Update: Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 December.

[3] Canadian Standards Association, "CSA Guideline N288.1-08 - Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities", 2008 September.

[4] Canadian Nuclear Safety Commission, "Understanding Health Studies and Risk Assessments Conducted for the Port Hope Community from the 1950s to the Present", INFO-0781, 2009 April.

[5] SENES Consultants Limited, "Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment - Evaluation of Additional DRL Pathways", Prepared for Cameco Corporation, 2010 May.