Canada's Nuclear Regulator

Environmental Protection Review Report:
Cameco Fuel Manufacturing Inc.

August 2022

e-Doc: 6672296 (Word)
e-Doc: 6758831 (PDF)

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

Environmental Protection Review Report: Cameco Fuel Manufacturing Inc.

Cat. No. CC172-241/2022E-PDF
ISBN 978-0-660-43768-2

Également publié en français sous le titre : Rapport d'examen de la protection de l'environnement : Cameco Fuel Manufacturing Inc.

Document availability
This document can be viewed on the CNSC website. To request a copy of the document in English or French, please contact:

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, ON K1P 5S9
CANADA

Tel.: 613-995-5894 or 1-800-668-5284 (in Canada only)
Fax: 613-995-5086

Email: cnsc.info.ccsn@canada.ca

Website: nuclearsafety.gc.ca
Facebook: facebook.com/CanadianNuclearSafetyCommission
YouTube: youtube.com/cnscccsn
Twitter: @CNSC_CCSN
LinkedIn: linkedin.com/company/cnsc-ccsn

Revision History

The following table identifies the revision history of this document.

Revision number	Change	Summary of changes	Date
000	Initial release	N/A	July 2022
001			

EXECUTIVE SUMMARY

The Canadian Nuclear Safety Commission (CNSC) conducts environmental protection reviews (EPRs) for all nuclear facilities with potential project–environmental interactions, in accordance with its mandate under the *Nuclear Safety and Control Act* (NSCA) to ensure the protection of the environment and the health of persons. An EPR is a science-based environmental technical assessment conducted by CNSC staff. The fulfillment of other aspects of the CNSC's mandate, such as regulating safety and security, are met through other oversight activities.

This EPR report was written by CNSC staff as a stand-alone document, describing the scientific and evidence-based findings from CNSC staff's review of Cameco Corporation's (Cameco's) environmental protection (EP) measures. Under its current fuel facility operating licence FFOL-3641.00, Cameco is licenced to produce nuclear fuel bundles using uranium dioxide at its Cameco Fuel Manufacturing Inc. (CFM) facility in Port Hope, Ontario. The CFM facility lies within the traditional territory of the Wendat, Anishinabek Nation, and the territory covered by the Williams Treaties with the Michi Saagiig and Chippewa Nations.

CNSC staff's EPR report focuses on items that are of Indigenous, public and regulatory interest, such as potential environmental releases from normal operations, as well as risk of radiological and hazardous substances to the receiving environment, valued components and species at risk.

This EPR report includes CNSC staff's assessment of documents submitted by the licensee from 2012 to 2021, such as, but not limited to, the following:

- the results of Cameco's environmental monitoring, as reported in the annual compliance monitoring and operational performance reports
- Cameco's 2016 *Environmental Risk Assessment for the Cameco Fuel Manufacturing Facility*
- Cameco's 2021 *Review of the Environmental Risk Assessment for Cameco Fuel Manufacturing*
- Cameco's preliminary decommissioning plan
- the results of the CNSC's Independent Environmental Monitoring Program
- the results from other environmental monitoring programs and/or health studies (e.g., completed by other levels of government) conducted near the CFM facility
- Cameco's licence renewal application for the Cameco Fuel Manufacturing licence (FFL-3641.0/2023)
- Cameco's *Justification for Licence Term and Production Increase for Cameco Fuel Manufacturing*

Based on CNSC staff's assessment and evaluation of Cameco's documentation and data, CNSC staff have found that the potential risks from radiological and hazardous releases to the atmospheric, terrestrial, aquatic and human environments are low to negligible and tend to be similar to natural background. Further, the potential risks to human health are not impacted by operations at the CFM facility and are indistinguishable to health outcomes found in the general public. CNSC staff have also found that Cameco continues to implement and maintain effective EP measures to adequately protect the environment and the health of persons. CNSC staff will

continue to verify Cameco's environmental protection programs (EPPs) through ongoing licensing and compliance activities.

The information provided in this EPR report summarizes CNSC staff's findings that may inform and support staff recommendations to the Commission in future licensing and regulatory decisions. CNSC staff's findings do not represent the Commission's conclusions, as the Commission is an independent, quasi-judicial administrative tribunal and court of record. The Commission's decision making will be informed by submissions from CNSC staff, the licensee, Indigenous Nations and communities, the public, and any interventions heard during public hearings on licensing matters.

For more information on the CFM facility, visit the CNSC's web page and Cameco's web page. References used throughout this document are available upon request, and requests can be sent to ea-ee@cnsc-ccsn.gc.ca.

TABLE OF CONTENTS

1.0 INTRODUCTION 5
1.1 Purpose 5
1.2 Facility overview 7
1.2.1 Site description 8
1.2.2 Facility operations 10
2.0 REGULATORY OVERSIGHT 11
2.1 Environmental protection reviews and assessments 11
2.1.1 Previous EAs completed under CEAA 1992 12
2.2 Planned end state 13
2.3 Environmental regulatory framework and protection measures 13
2.3.1 Environmental protection measures 14
2.3.2 Environmental management system 15
2.3.3 Environmental risk assessment 16
2.3.4 Effluent and emissions control and monitoring 16
2.3.5 Environmental monitoring program 17
2.4 Reporting of airborne emissions under other federal or provincial legislation 18
2.4.1 Greenhouse gas emissions 18
2.4.2 Other environmental compliance approvals 19
3.0 STATUS OF THE ENVIRONMENT 20
3.1 Releases to the environment 20
3.1.1 Licensed release limits 22
3.1.2 Airborne emissions 23
3.1.2.1 Findings 26
3.1.3 Waterborne effluent 26
3.1.3.1 Findings 28
3.2 Environmental effects assessment 29
3.2.1 Atmospheric environment 29
3.2.1.1 Meteorological conditions 29
3.2.1.2 Ambient air quality 29
3.2.1.3 Findings 30
3.2.2 Terrestrial and aquatic environment 31

3.2.2.1 Groundwater quantity and quality 32
3.2.2.2 Surface water quality 34
3.2.2.3 Soil quality 35
3.2.2.4 Assessment of potential effects on non-human biota 36
3.2.2.5 Findings 37
3.2.3 Human environment 37
3.2.3.1 Exposure to radiological substances 37
3.2.3.2 Exposure to hazardous substances 38
3.2.3.3 Findings 39
3.3 Cameco's proposed production increase and its impacts on Environmental protection 40
4.0 CNSC INDEPENDENT ENVIRONMENTAL MONITORING PROGRAM 42
4.1 IEMP at Cameco Fuel Manufacturing 42
4.2 Indigenous participation in the IEMP 43
4.3 Summary of results 43
5.0 HEALTH STUDIES 45
5.1 Population and community health studies and reports 45
5.1.1 Community health profile of the Haliburton, Kawartha, Pine Ridge District ..45
5.1.2 Ontario Cancer Profiles (Cancer Care Ontario) 46
5.1.3 Findings 46
5.2 Current scientific understanding of radiation health effects 46
5.2.1 Radiation epidemiology 46
5.2.2 International Nuclear Worker Study (INWORKS) 47
5.2.3 Findings 47
5.3 Studies of radiation health effects – Living near or working at CFM 47
5.3.1 Health studies of populations living near nuclear processing facilities 47
5.3.1.1 Use of a weight of evidence approach to determine the likelihood of adverse effects on human health from the presence of uranium facilities in Port Hope, Ontario 47
5.3.1.2 An ecological study of cancer incidence in Port Hope, Ontario from 1992–2007 . 48
5.3.1.3 Findings – Health studies of populations living near nuclear processing facilities 48
5.3.2 Health studies of uranium processing workers 48
5.3.2.1 Mortality (1950–1999) and cancer incidence (1969–1999) of workers in the Port Hope cohort study exposed to a unique combination of radium, uranium and gamma-ray doses 48

5.3.2.2 International Pooled Analysis of Uranium Processing Workers study 49
5.3.2.3 Canadian Uranium Workers Study 49
5.3.2.4 Findings – Health studies of uranium processing workers 50
5.4 Findings – Health studies 50
6.0 OTHER ENVIRONMENTAL MONITORING PROGRAMS 51
6.1 National Pollutant Release Inventory 51
6.2 Health Canada's Canadian Radiological Monitoring Network and Fixed Point Surveillance Program 51
7.0 FINDINGS 53
7.1 CNSC staff's follow-up 53
7.2 CNSC staff's findings 53
ABBREVIATIONS 54
ACRONYMS 54
REFERENCES 56

LIST OF TABLES

Table 2.1: Federal EAs completed for the CFM facility 11
Table 2.2: Status of EP measures to implement regulatory documents and standards 14
Table 3.1: Exposure-based release limits for the CFM facility 23
Table 3.2: Total average and maximum uranium discharged to the air from all CFM stacks compared with the action level (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] 24
Table 3.3: Average and maximum building ventilation rates from CFM in g/hr compared with applicable action levels (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] 25
Table 3.4: Total uranium discharged to the air from CFM in kilograms compared with applicable release limits (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] 26
Table 3.5: Annual waterborne releases from CFM compared with the applicable action levels (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] 28
Table 3.6: Total uranium discharged to the sewer from CFM in kilograms compared with applicable release limits (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] 28
Table 3.7: Annual concentrations of uranium (µg/m^3) in ambient air as measured at Hi-Vol stations around the CFM facility [10,11] 30
Table 3.8: Ecological receptors identified for the 2016 ERA for the CFM facility [12] 31
Table 3.9: Soil monitoring results (µg/g) at the CFM facility (0–5 cm depth) [10] 36
Table 3.10: Estimated annual public doses for the CFM facility [10, 11] 37

Table 6.1: Annual external gamma doses (mSv/year[1]) for 2021 at the FPS network monitoring stations near CFM [80] 52

LIST OF FIGURES

Figure 1.1: EPR framework 6

Figure 1.2: Aerial view of the CFM facility [16] 9

Figure 3.1: Conceptual model of the environment around the CFM facility 21

Figure 3.2: Groundwater flow directions at the CFM facility [47] 33

Figure 3.3: Uranium concentrations in groundwater in monitoring wells TW-32-2, TW-41-1 and TW-41-2 [47] 34

Figure 4.1: Overview of the 2020 sampling locations 43

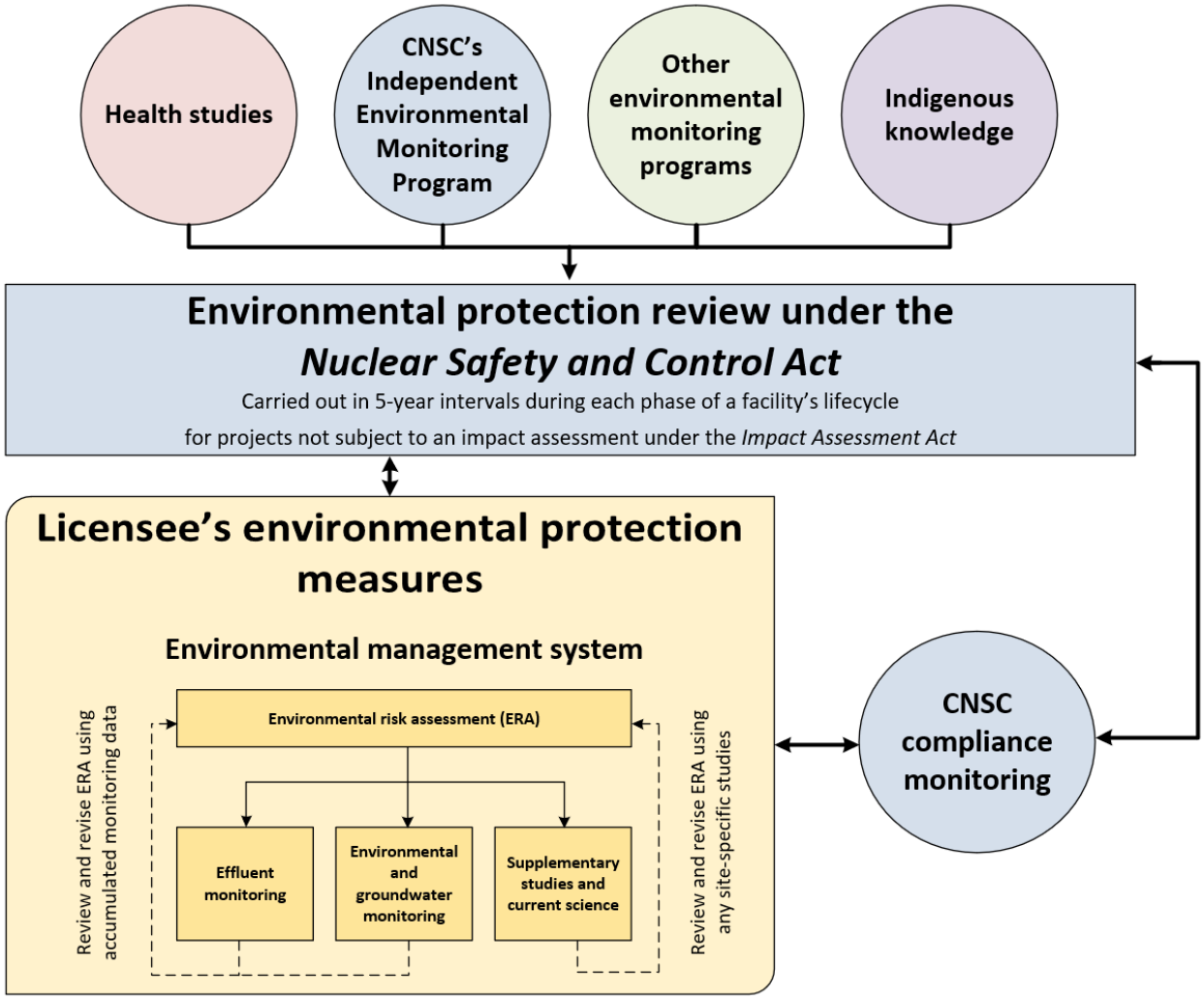
1.0 INTRODUCTION

1.1 Purpose

The Canadian Nuclear Safety Commission (CNSC) conducts environmental protection reviews (EPRs) for all nuclear facilities with potential interactions with the environment, in accordance with its mandate under the *Nuclear Safety and Control Act* (NSCA). CNSC staff assess the environmental and health effects of nuclear facilities and/or activities at every phase of a facility's lifecycle. As shown in figure 1.1, an EPR is a science-based environmental technical assessment conducted by CNSC staff to support the CNSC's mandate for the protection of the environment and human health as set out in the NSCA. As per the CNSC's Indigenous Knowledge Policy Framework the CNSC recognizes the importance of considering and including Indigenous knowledge in all aspects of the CNSC's regulatory processes, including in environmental protection assessments. CNSC staff are committed to working directly with Indigenous Nations and communities and knowledge holders on integrating their knowledge, values, land use information and perspectives in the CNSC's EPRs where appropriate and when shared with the licensee and CNSC. The fulfillment of other aspects of the CNSC's mandate, such as safety and security, are met through other regulatory oversight activities and are outside the scope of this report. EPRs are typically conducted every 5 years and are informed by outcomes of a licensee's environmental protection (EP) program and documentation submitted by licensees as per regulatory reporting requirements.

The purpose of this EPR is to document the outcome of CNSC staff's assessment of Cameco Corporation's (Cameco's) EP measures and CNSC staff's environmental compliance activities for the CFM facility. This review serves to assess whether Cameco's EP measures at the Cameco Fuel Manufacturing Inc (CFM) facility adequately protect the environment and health of persons.

Figure 1.1: EPR framework



CNSC staff's findings may inform and support future recommendations to the Commission in licensing and regulatory decision making, as well as inform CNSC staff's compliance and verification activities. CNSC staff's findings do not represent the Commission's conclusions. The Commission's conclusions and decisions are informed by information submitted by CNSC staff, the licensee, Indigenous Nations and communities, the public, and any interventions heard during public hearings on licensing matters. The information in this EPR report is also intended to inform Indigenous Nations and communities, members of the public and interested stakeholders. EPR reports are posted online for information and transparency, allowing interested Indigenous Nations and communities and members of the public additional time to review EP-related information ahead of any licensing hearings or Commission decisions. CNSC staff may use the EPR reports as reference material when engaging with interested stakeholders.

This EPR report is based on information submitted by Cameco, compliance and technical assessment activities completed by CNSC staff from 2012 to 2021, as well as the following:

- regulatory oversight activities (section 2.0)
- CNSC staff's review of Cameco's preliminary decommissioning plan (PDP) [1] (section 2.2)
- CNSC staff's review of Cameco's annual compliance monitoring and operational performance reports for EP [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
- CNSC staff's review of Cameco's 2016 *Environmental Risk Assessment for the Cameco Fuel Manufacturing Facility* [12] (section 3.2)
- CNSC staff's review of Cameco's 2021 *Review of the Environmental Risk Assessment for Cameco Fuel Manufacturing* [13] (section 3.2)
- Independent Environmental Monitoring Program (IEMP) results (section 4.0)
- health studies with relevance to the Cameco Fuel Manufacturing facility (section 5.0)
- other environmental monitoring programs near the CFM facility (section 6.0)
- Cameco's licence renewal application for Cameco Fuel Manufacturing (FFL-3641.0/2023) [14]
- Cameco's *Justification for Licence Term and Production Increase for Cameco Fuel Manufacturing* [15]

This EPR report focuses on topics related to the environmental performance of the facility, including atmospheric (emission) and liquid (effluent) releases to the environment, the potential transfer of contaminants of potential concern (COPCs) through key environmental pathways and associated potential exposures and/or effects on valued components (VCs), including human and non-human biota. VCs refer to environmental biophysical or human features that may be impacted by a project. The value of a component relates not only to its role in the ecosystem, but also to the value people place on it. For example, it may have scientific, social, cultural, economic, historical, archaeological or aesthetic importance. The focus is on radiological and hazardous substances associated with activities undertaken at the CFM facility, with additional information provided on other topics of Indigenous, public and/or regulatory interest, such as greenhouse gas (GHG) emissions. CNSC staff also present information on relevant regional environmental or health monitoring, including studies conducted by the CNSC (e.g., IEMP) or other governmental organizations. The topics included in the report were selected based on those that have historically been of interest to Indigenous Nations and communities, members of the public and the Commission.

1.2 Facility overview

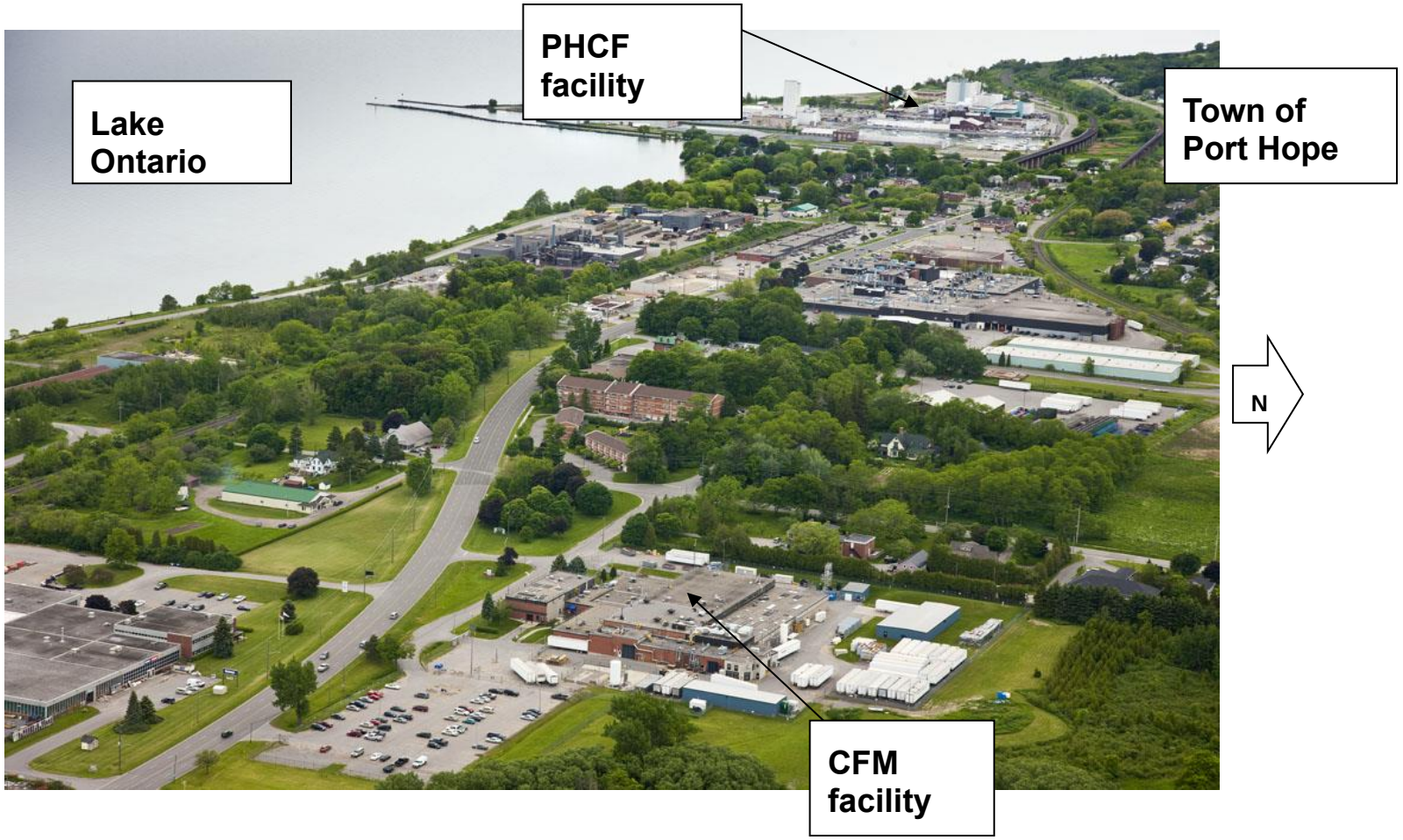
This section of the report provides general information on the CFM facility, including a description of the site location and a basic history of site activities and licensing. This information is intended to provide context for later sections of this report, which discuss completed and ongoing environmental and regulatory oversight activities.

1.2.1 Site description

The CFM facility lies within the traditional territory of the Wendat, Anishinabek Nation, and the territory covered by the Williams Treaties with the Michi Saagiig and Chippewa Nations. The facility is located in the Municipality of Port Hope, situated on the north side of Lake Ontario. Cameco also owns 12 hectares of property to the north and east of the licensed facility. This land is undeveloped and is not actively used by Cameco at this time. The surrounding area is predominantly urban.

The CFM facility comprises the main manufacturing building and 3 steel pre-fabricated buildings: the waste storage building, the maintenance storage building, and the fuel storage building. There are also miscellaneous smaller outbuildings and storage trailers located on the licensed site [14]. Figure 1.2 shows an aerial overview.

Figure 1.2: Aerial view of the CFM facility [16]



1.2.2 Facility operations

The fuel fabrication facility in Port Hope has been manufacturing commercial fuel bundles since the late 1950s. The facility was acquired by Cameco in 2006 and renamed Cameco Fuel Manufacturing Inc. in 2008. The CFM facility manufactures nuclear pellets from uranium dioxide powder and assembles nuclear reactor fuel bundles. The finished fuel bundles are primarily shipped for use in Canadian CANDU reactors.

Uranium dioxide pellet operations

The uranium dioxide pellet operations at CFM can be summarized by the following steps. Pre-compaction, granulation and blending operations are used to condition the uranium dioxide powder for the pellet pressing operation. The conditioned powder is then compressed using conventional pharmaceutical tablet presses. Next, the pressed pellet is passed through an electrically heated sintering furnace within a hydrogen atmosphere to reduce the pellet compact to stoichiometric uranium dioxide composition. Grinders are then used to produce pellets with the required specifications for diameter and surface finish. The ground pellets are then washed, dried and inspected.

Bundle assembly operations

The stacks of uranium dioxide pellets are inserted into zirconium tube subassemblies. Ambient air within the tube is purged with helium as a zirconium alloy end cap is welded to each end of the subassembly. Individual fuel elements are assembled into a fixture that holds them in the required configuration while the zirconium alloy end plates are permanently attached to the element ends by resistance welding to create fuel bundles. Completed bundles are inspected through a series of non-destructive visual and dimensional tests. Accepted bundles are placed into an approved shipping container and then moved to a secured storage area to await shipment.

2.0 REGULATORY OVERSIGHT

The CNSC regulates nuclear facilities and activities in Canada to protect the environment and the health and safety of persons in a manner that is consistent with applicable legislation and regulations, environmental policies and Canada's international obligations. The CNSC assesses the effects of nuclear facilities and activities on human health and the environment at every phase of a facility's lifecycle. This section of the EPR report discusses the CNSC's regulatory oversight of Cameco's EP measures for the CFM facility.

To meet the CNSC's regulatory requirements and according to Cameco's licensing basis for the CFM facility, Cameco is responsible for implementing and maintaining EP measures that identify, control and (where necessary) monitor releases of radiological and hazardous substances, and the effects on human health and the environment. These EP measures must comply with, or have implementation plans in place to comply with, the regulatory requirements found in Cameco's licence and licence conditions handbook (LCH). The relevant regulatory requirements for the CFM facility are outlined in this section of the report.

2.1 Environmental protection reviews and assessments

To date, two federal environmental assessments (EAs) have been carried out for the CFM facility, as indicated in table 2.1 below. Subsection 2.1.1 provides a description of the most recent EAs conducted under the *Canadian Environmental Assessment Act* (CEAA 1992) [17], predecessor to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) [18]. In 2019, the *Impact Assessment Act of Canada* (IAA) [19] came into force replacing CEAA 2012. Cameco's current activities do not require an impact assessment under the IAA's Physical Activities Regulations. The purpose of any one of these assessments is to identify the possible impacts of a proposed project or activity and to determine whether those effects can be adequately mitigated to protect the environment and the health and safety of persons.

Similarly, an EPR under the NSCA was not previously conducted for the CFM facility, and as such, this report is the first developed for the CFM facility.

Table 2.1: Federal EAs completed for the CFM facility

Project	Applicable EA process and/or legislation	EA start date	EA decision date
Zircatec Precision Industries Fuel Fabrication Facility in Port Hope, Ontario	*Canadian Environmental Assessment Act*	1995	1995
SEU CANDU Fuel Production at Zircatec's Facility in Port Hope, Ontairo	*Canadian Environmental Assessment Act*	2006	2008

2.1.1 Previous EAs completed under CEAA 1992

Zircatec Precision Industries Fuel Fabrication Facility in Port Hope, Ontario

In 1995, the previous licensee for the facility, Zircatec Precision Industries Inc. (Zircatec), applied to the CNSC's predecessor, the Atomic Energy Control Board (AECB), to seek approval for the renewal of their licence to possess and use uranium and thorium-containing materials and to operate a nuclear facility. At the time of the EA, the facility manufactured nuclear power reactor fuel containing natural uranium dioxide, and processed small quantities of special material fuel containing low enriched or depleted uranium compounds.

As a Responsible Authority under CEAA 1992 the AECB conducted a screening level environmental assessment pursuant to section 18 of CEAA 1992 [17]. An EA screening report was prepared in accordance with the requirements of CEAA 1992 [20].

Following review of the AECB staff's EA Screening Report in 1995, the Board made a determination in support of AECBs staff's conclusion that the proposed activities are not likely to cause significant adverse environmental effects with the proposed mitigation measures in place [21].

It was determined that Zircatec's monitoring programs allowed for verification of the accuracy of the predicted environmental effects from the EA, including measurement of radiation doses of persons exposed, water sample collection from sanitary systems, air quality sampling at the facility perimeter, and soils sample collection in the vicinity of the plant [20].

SEU CANDU Fuel Production at Zircatec's Facility in Port Hope, Ontario

In the spring of 2006, Zircatec applied to the CNSC to seek approval for the production of slightly enriched uranium (SEU) CANDU fuel bundles at its facility located in Port Hope, Ontario. At the time of the EA, the facility produced natural uranium fuel bundles, and was proposing to construct and operate 2 enriched uranium fuel bundle assembly lines using a similar process. The proposal did not require an expansion of the existing facility but would involve an increase in the quantity of enriched uranium handled at the facility as a result of the new production lines. The components of the project included the storage arrangements for the feed material and final products, the enriched uranium processing lines, and the waste recovery facilities.

CNSC staff reviewed the application and determined that pursuant to section 5 of CEAA 1992 [17], a screening EA of this project was required in order for the project to proceed because the Commission might amend Zircatec's existing licence under subsection 24(2) of the NSCA [22]. An EA screening report was prepared in accordance with the requirements of CEAA [23].

Following the Commission's consideration of the EA Screening Report in 2008, including public concerns expressed about the project, and CNSC staff recommendations [24], the Commission rendered its decision on the EA, stating that the project, taking into account implementation of mitigation measures identified in the EA screening report, was not likely to cause significant adverse environmental effects and that it would proceed to consider the application for a licence amendment under the provisions of the NSCA [25].

It was determined that a follow-up program to verify the accuracy of the EA and/or determine the effectiveness of any measures taken to mitigate the adverse environmental effects was

required for this project. The proposed project did not go forward; therefore, follow-up program requirements were no longer applicable [26].

2.2 Planned end state

The following section provides high-level information with respect to the end state of the CFM facility following decommissioning activities. This section is informed by Cameco's *Cameco Fuel Manufacturing Preliminary Decommissioning Plan* [1]. The PDP is important to consider as part of CNSC staff's ongoing oversight of environmental and health effects of nuclear facilities and activities at every phase of a facility's lifecycle.

A PDP is developed by the licensee and submitted to the CNSC for review and acceptance as early as possible in the lifecycle of the facility or the conduct of the licensed activities. The PDP is progressively updated, where needed, to reflect the appropriate level of detail required for the respective licensed activities. The PDP is developed for planning purposes only and the associated cost estimate is used to develop dedicated decommissioning funding in the form of a financial guarantee. The PDP does not authorize decommissioning and does not provide sufficient details for the assessment of environmental impacts during decommissioning. This information is required to be submitted at a later date in support of an application for a licence to decommission.

The PDPs for nuclear facilities are updated every five years, or in light of notable changes relevant to decommissioning, by the licensee and reviewed by CNSC staff. The decommissioning strategy and end-state objectives for the CFM facility are documented in the CFM PDP [1]. Cameco's preliminary decommissioning strategy for the CFM facility is for prompt removal of all radioactive materials from the facility. As part of Cameco's decommissioning plan, radioactive material, contaminated wastes and hazardous chemical materials will be dispositioned to waste management facilities or suppliers. All equipment will be decontaminated, disassembled, packaged and dispositioned. Process areas will also be cleaned and surfaces tested to verify no radioactive materials remain. Remaining waste might be sent to a licenced waste managed facility, like the proposed facility at the Blind River Refinery site. The building will be left in a condition acceptable for unrestricted future non-licensed industrial use.

Cameco submitted an update of the CFM PDP in May 2021. The revised PDP was reviewed and accepted by CNSC staff in September 2021 [27].

2.3 Environmental regulatory framework and protection measures

The CNSC has a comprehensive EP regulatory framework that includes both radiological and hazardous substances; physical stressors (such as noise); and the protection of people and the environment. Public dose is considered under the EP framework, as well as from a radiation protection standpoint. The focus of this section of the EPR report is on the EP regulatory framework and the status of Cameco's environmental protection program (EPP) for CFM. The results derived from this EPP are detailed in section 3.0 of this report.

The EPP at Cameco's CFM facility was designed and implemented in accordance with regulatory document REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (2020) [28], and the Canadian Standards Association (CSA) Group environmental protection standards listed below. The EPP includes derived release limits (DRLs) and public dose modelling.

In 2020, Cameco was required to update its EPP to meet the current version of REGDOC 2.9.1 [28] and the current versions of the associated CSA standards. CNSC staff confirm that CFM has implemented programs according to the relevant EP regulatory documents or standards listed in table 2.2.

Table 2.2: Status of EP measures to implement regulatory documents and standards

Regulatory document or standard	Status
CSA N288.1-14, *Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities* [29]	Implemented
CSA N288.4-10, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [30]	Implemented
CSA N288.5-11, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [31]	Implemented
CSA N288.6-12, *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills* [32]	Implemented
CSA N288.7-15, *Groundwater Protection Programs at Class 1 Nuclear Facilities and Uranium Mines and Mills* [33]	Implemented
CSA N288.8-17, *Establishing and Implementing Action Levels for Releases to the Environment from Nuclear Facilities* [34]	Implemented
CNSC REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*, version 1.2 (2020) [28]	Implemented

Licensees are also required to regularly report on the results of their EPPs. Reporting requirements are specified in REGDOC-3.1.2, *Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills* [35]; the *Radiation Protection Regulations* [36] (e.g., for action levels (ALs) or dose limit exceedances); the licensees' approved programs and manuals; or the LCH [37].

Cameco is required to submit annual compliance monitoring and operational performance reports as per REGDOC-3.1.2 [35]. These reports are reviewed by CNSC staff for compliance and verification, as well as trending. The reports are publicly available and can be viewed on Cameco's website [16].

CNSC staff report on licensee performance to the Commission for activities conducted at CFM. For example, if there was an unplanned spill resulting in potential releases to the environment, it may be reported to the Commission through an Event Initial Report. Regulatory oversight reports (RORs) are one of the mechanisms for updating Indigenous Nations and communities, the public and the Commission on the operation and regulatory performance of licensed facilities. Previous RORs are available on the CNSC's website [38].

2.3.1 Environmental protection measures

To meet the CNSC's regulatory requirements under REGDOC-2.9.1 (2020) [28], Cameco is responsible for implementing and maintaining EP measures that identify, control and monitor releases of radioactive and hazardous substances, and the effects on human health and the

environment, from CFM. EP measures are an important component of the overall requirement of licensees to make adequate provisions to protect the environment and the health of persons.

This, and the following subsections, provide a brief summary of Cameco's EPP for CFM and the status of each specific EP measure relative to the requirements or guidance outlined in the latest regulatory document or CSA standard. Section 3.0 of this EPR report summarizes the results of these programs or measures against relevant regulatory limits and environmental quality objectives or guidelines, and discusses, where applicable, any interesting trends.

Cameco's EPP includes the following components to meet the requirements and guidance as outlined in REGDOC-2.9.1 (2020) [28]:

- environmental management system
- environmental risk assessment
- effluent and emissions control and monitoring
    - derived release limits and operating release limits
    - air emissions and liquid effluent monitoring
- environmental monitoring program
    - ambient air monitoring
    - soil monitoring
    - surface water and stormwater monitoring
    - groundwater monitoring
    - gamma monitoring

2.3.2 Environmental management system

An environmental management system (EMS) refers to the management of an organization's environmental policies, programs and procedures in a comprehensive, systematic, planned and documented manner. It includes the organizational structure as well as the planning and resources to develop, implement and maintain an EP policy. An EMS requires facilities to continuously improve their EPP, including periodic updates to the environmental risk assessment (ERA). The results from the ERA update determines whether the facility's effluent and environmental monitoring programs (EMP) are effective. The EMS serves as a management tool to integrate all of a licensee's EP measures in a documented, managed and auditable process, in order to:

- identify and manage non-compliances and corrective actions within the activities, through internal and external inspections and audits
- summarize and report the performance of these activities both internally (licensee management) and externally (Indigenous Nations and communities, the public, and the Commission)
- train personnel involved in these activities
- ensure the availability of resources (i.e., qualified personnel, organizational infrastructure, technology and financial resources)
- define and delegate roles, responsibilities and authorities essential to effective management

Cameco established and implemented an EMS for all its fuel services facilities, including CFM, in accordance with REGDOC-2.9.1 (2020) [28], and is also registered and certified under the International Organization for Standardization (ISO) standard 14001:2015. ISO 14001:2015 is a standard that helps an organization achieve the intended outcomes of its EMS. CNSC staff review Cameco's annual internal audits; management reviews; and environmental goals, targets and objectives to ensure compliance with REGDOC-2.9.1(2020) [28]. While formal ISO certification is not solely considered by the CNSC as meeting the requirements of REGDOC-2.9.1, the results of these third-party audits are reviewed by CNSC staff as part of the compliance program. CNSC staff also review the status of CFM's annual goals, targets and objectives and the implementation of the EMS as part of their review of the annual reports on EP.

The results of these reviews demonstrate that Cameco's EMS for CFM meets CNSC requirements as outlined in REGDOC-2.9.1 (2020) [28]. The implementation of the EMS ensures that Cameco continues to improve environmental performance at CFM.

2.3.3 Environmental risk assessment

An ERA of nuclear facilities is a systematic process used by licensees to identify, quantify and characterize the risk posed by contaminants and physical stressors in the environment on human and other biological receptors, including the magnitude and extent of the potential effects associated with a facility. The ERA serves as the basis for the development of site-specific EP control measures and EMPs. The results of these programs, in turn, inform and refine future revisions of the ERA.

In 2016, Cameco submitted to the CNSC an ERA for CFM [12]. The ERA included an ecological risk assessment and a human health risk assessment (HHRA) for radiological and hazardous contaminants and physical stressors. CNSC staff reviewed Cameco's ERA and found it to be compliant with CSA N288.6-12, *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills* [32].

In 2021, Cameco submitted a review of the ERA for CFM [13] in accordance with the requirements set out in CSA N288.6-12 [32] to review and revise its ERA every 5 years. The 2021 review of the ERA was submitted to support Cameco's application for a 1-year renewal of the CFM facility operating licence. CNSC staff agreed with the licensee's conclusion that no new risks have emerged since the 2016 ERA and, therefore, that the 2016 ERA conclusions and recommendations are still valid: meaningful human health and ecological effects attributable to CFM operations are unlikely. CNSC staff found the 2021 review of the ERA to be acceptable and that the update addressed staff's technical comments and recommendations on the 2016 ERA.

2.3.4 Effluent and emissions control and monitoring

Controls on environmental releases are established to provide protection to the environment and to respect the principles of sustainable development and pollution prevention. The effluent and emissions prevention and control measures are established based on industry best practice, the application of optimization (e.g., in design) and *as low as reasonably achievable* (ALARA) principles, the Canadian Council of Ministers of the Environment (CCME) guidelines, and results of the licensee's ERAs.

The latest version of CFM's EPP [39] was reviewed and approved by CNSC staff in September 2021. It contains site-specific DRLs, operating release limits, and ALs to control radiological and hazardous effluents and emissions.

- DRLs represent the maximum acceptable level of emitted contaminants from the processes at CFM. DRLs are based on the most-exposed person receiving a radiological dose of 1 mSv per year from radiological releases at CFM during normal operations. This most-exposed person is a person who would have a higher dose than the average member of the public due to a combination of factors, such as location, lifestyle and food consumption. This person is determined from site-specific surveys and can be based on an actual or hypothetical person.
- Operating release limits were CNSC licensed limits, put in place to ensure that CFM continues to operate within its licensing basis and are considerably lower than the DRLs. The operating release limits were derived using the DRL methodology but using an annual dose target of 0.05 mSv instead of 1 mSv.
- CFM has established ALs which may indicate a loss of control of part of the licensee's EPP. ALs are expected to occasionally be exceeded, as they are used to indicate a potential loss of control of the environmental protection program. Exceeding an AL is evidence that they are set correctly. Exceedance of an AL is not a non-compliance; however failure to inform the CNSC, complete an investigation and implement corrective actions is a non-compliance.

In the most recent CFM licence [40] issued on February 17, 2022, operating release limits have been replaced by Exposure Based Release Limits (EBRLs). More information about EBRLs is found in section 3.1.1.

For the purposes of reporting emissions and releases against limits, comparisons are made against the limits that were in place during the 2012-2022 licence period. Also, comparisons are made against newly established EBRLs where appropriate.

CFM's effluent monitoring program has been reviewed and approved by CNSC staff and is in compliance with REGDOC-2.9.1 (2020) [28] and the relevant standards, including CSA N288.5-11, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [31].

Based on compliance and technical assessment activities, CNSC staff have found that the effluent monitoring program currently in place for CFM continues to protect human health and the environment.

2.3.5 Environmental monitoring program

The CNSC requires licensees to design and implement an EMP that is specific to the monitoring and assessment requirements of the licensed facility and its surrounding environment. The EMP is part of the EPP and it is required to:

- measure contaminants in the environmental media surrounding the facility or site
- determine the effects, if any, of the facility or site operations on people and the environment

- serve as a secondary support to emission monitoring programs to demonstrate the effectiveness of emission controls

More specifically, the program must gather the necessary environmental data to calculate public dose and demonstrate compliance with the public dose limit (1 mSv per year). The program design must also address the potential environmental interactions identified at the facility or site. Uranium is the major contaminant of interest at CFM. Cameco's EMP for CFM consists of the following components:

- ambient air monitoring
- soil monitoring
- surface water and stormwater monitoring
- groundwater monitoring
- gamma monitoring

Monitoring frequency is specified in the EMP and is elaborated further in section 3.2.

Cameco is required to maintain its EMP so that it is in compliance with REGDOC-2.9.1 (2020) [28] and relevant standards, including CSA N288.4-10, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [30].

Based on compliance activities and technical assessments, CNSC staff have found that the EMP currently in place for CFM continues to protect the environment and human health.

2.4 Reporting of airborne emissions under other federal or provincial legislation

A core element of the CNSC's requirement for an EMS is the identification of all regulatory requirements applicable to the facility, whether pursuant to the NSCA or other federal or provincial legislation. The EMS must ensure that programs are in place to respect these requirements.

2.4.1 Greenhouse gas emissions

While there are a range of broadly applicable federal environmental regulations (e.g., petroleum products storage tanks, environmental emergency regulations), the management of GHG emissions has been identified as a national priority.

Under the federal *Canadian Environmental Protection Act, 1999* [41], Cameco is required to monitor GHG emissions [42] and report them to the Ministry of the Environment, Conservation and Parks (MECP) if they are above a threshold as per Ontario Regulation 390/18: *Greenhouse Gas Emissions: Quantification, Reporting and Verification* [43]. Nuclear facilities that emit more than the emission reporting threshold (i.e., 10,000 tons of CO_2 equivalent) on an annual basis must report its GHG emissions to Environment and Climate Change Canada (ECCC). Cameco's CFM facility has continually been below the GHG emission threshold and is therefore not required to report these numbers to the MECP and ECCC.

The CNSC maintains a collaborative working relationship with ECCC through a formal memorandum of understanding [44], which includes a notification protocol. An exceedance of the GHG emission threshold would be included under this notification protocol. This ensures that

a coordinated regulatory approach is achieved to meet all federal requirements associated with EP, including GHGs.

2.4.2 Other environmental compliance approvals

Cameco holds an environmental compliance approval (ECA) for CFM issued by the Ontario MECP. This ECA includes requirements for pollutants released to air, as well as noise. As part of this approval, CFM is required to submit to the MECP annual updates of its acoustic assessment report to confirm that it is in compliance with the MECP's requirements for noise. As part of the ECA, CFM is also required to submit to the MECP annual updates of its air emissions summary and dispersion modelling report. Air emissions from CFM throughout the current licensing period have been in compliance with the facility's ECA and the CNSC's regulatory requirements, and more information can be found in section 3.1.2 of this report.

With respect to water takings, CFM has an MECP Permit to Take Water to operate its groundwater recovery system. In 2020, Cameco's maximum daily water intake volume was within the daily permits of it's Permit to Take Water.

3.0 STATUS OF THE ENVIRONMENT

This section provides a summary of the status of the environment around CFM. It first includes a description of the radiological and hazardous releases to the environment (section 3.1), followed by a description of the environment surrounding CFM and an assessment of any potential effects to the different components of the environment as a result of exposure to these contaminants (section 3.2).

It should be noted that CNSC staff regularly review the potential effects to environmental components through annual reporting requirements and compliance verification activities, as detailed in other areas of this report. This information is reported to the Commission in the EP safety and control area of licensing commission member documents (CMDs) and annual RORs. Annual compliance monitoring and operational performance reports submitted by Cameco for CFM are made publicly available and can be viewed on Cameco's website [16].

3.1 Releases to the environment

Radioactive and hazardous substances that have the potential to cause an adverse effect to ecological or human receptors are identified as COPCs. Figure 3.1 below illustrates a conceptual model of the environment around a generic nuclear processing facility site to show the relationship between releases (airborne emissions or waterborne effluent) and human and ecological receptors or exposure pathways. The movement of the releases through the environment to the receptors is termed the exposure pathway. This graphic is meant to provide an overall conceptual model of the releases, exposure pathways and receptors for CFM, and thus, should not be interpreted as an exact depiction of the CFM site and its surrounding environment. The specific releases and COPCs associated with CFM are explained in detail in the following subsections.

Figure 3.1: Conceptual model of the environment around the CFM facility

3.1.1 Licensed release limits

In June 2020, CNSC staff requested that Cameco establish EBRLs at identified release points at the CFM facility. The EBRLs would replace the operating release limits. EBRLs create a release limit that is based on the objective of ensuring that releases to the receiving environment stay below certain levels, or endpoint parameters, in order to meet desired human health or environmental quality criteria in the areas of radiotoxicity, chemical toxicity, and protection of aquatic life. In general, liquid and air EBRLs would be established for contaminants that require control as part of a screening level assessment. The lowest and limiting endpoint parameter is selected when calculating the EBRLs. The protection of human health and the most sensitive freshwater aquatic receptors is the principle applied, and existing federal or provincial guidelines are identified and used when calculating the EBRLs.

Cameco submitted its proposed EBRLs in April 2021. For liquid releases to the sewer, Cameco derived an EBRL based on the CCME - *protection of aquatic life guidelines* for uranium and a dilution factor determined from modelling releases through the sewage treatment plant (STP) and into Lake Ontario.

For releases to air, Cameco harmonized with the provincial air quality standard for uranium under Ontario Regulation 419/05: *Air Pollution – Local Air Quality* and derived an EBRL that applies to all atmospheric release points (i.e., process stacks and building ventilation emission), based on meeting the applicable air quality standards at the point of impingement. The point of impingement is the nearest point where air contamination emitted by a source has a potential effect on a receptor. This is where the highest concentration of a contaminant from a facility is expected to occur.

CNSC staff reviewed the submission and verified that Cameco derived the EBRLs in accordance with CNSC staff's methodology in draft REGDOC-2.9.2, *Controlling Releases to the Environment*. Therefore, CNSC staff accepted Cameco's EBRLs in July 2021. The new EBRLs are in the updated CFM LCH and are listed below in table 3.1. The EBRLs have been implemented at CFM since March 2022 and replaced the previous operating release limits for the facility.

Table 3.1: Exposure-based release limits for the CFM facility

Source	Parameter	Release limits			
		2012–2022 Release limit[1]	Averaging period	New EBRLs	Averaging period
Water – Releases to sewer	Uranium	475 kg	Annual	1.7 mg/L[2]	Twice weekly, composite discharge
Air – Process stacks and building ventilation emissions	Uranium	14 kg	Annual	10.5 kg	Annual

[1] These were the operating release limits for CFM during the 2012 – 2022 period. They have been replaced by the EBRLs.

[2] It should be noted that the new release limit (i.e. EBRL) of 1.7 mg/L is equivalent to about 62 kg/yr based on CFM's current average release volumes.

3.1.2 Airborne emissions

Cameco controls and monitors airborne emissions from CFM to the environment under its EPP. This program is based on CSA N288.5-11, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [31], and includes monitoring of both radiological and hazardous emissions.

At CFM, there are 2 sources of airborne releases of uranium: the process stacks and the building exhaust ventilation. CFM uses a variety of pollution control equipment, including baghouses, HEPA filtration and scrubbers, to control and reduce emissions to air.

At each of the process stacks, sampling is conducted continuously using an isokinetic sampler. The filter is analyzed by alpha-counting at CFM or by another analytical methodology at the Port Hope Conversion Facility (PHCF) lab or accredited contract laboratory. A daily emission rate of uranium is calculated using the stack flow rate, operating hours, and the daily filter uranium concentration.

At the building exhaust ventilation, in-plant uranium in air concentration is measured using continuous and/or fixed air sampling systems at various locations throughout CFM in-plant production area. Filters from the fixed air sampling stations are analyzed by alpha-counting. A daily emission rate of uranium is calculated using the in-plant uranium in air concentration and the exhaust discharge rate. The exhaust in the Powder Preparation area uses HEPA filtration; thus, an efficiency factor is applied in the calculation.

A summary of the air emissions from all of the stacks at CFM is provided in table 3.2. A summary of the building ventilation emission rates is provided in table 3.3 Total releases of uranium from CFM are provided in table 3.4 and compared against the operating release limits, or licence limits. The licence limit is based on loadings and applies to the total uranium discharge from all stacks. In addition to licence limits, CFM has established air emission ALs and internal control levels. The ALs are based on concentration and are applied to each stack. Exceedances of licence limits and ALs are reported to the CNSC, documented and investigated, and appropriate corrective action is taken where warranted. Air emissions of uranium have been consistently several orders of magnitude below licence limits throughout the current licensing period.

As seen in table 3.2, in 2016, there was one exceedance of the AL for the overall stack emissions. The HEPA filter for the stack servicing the new automated grinder was not clamped down properly during installation. As the filter became loaded, it shifted and caused an abnormal release of uranium. This was detected during daily stack sampling. The stack and the associated equipment were immediately shutdown. CFM reported the incident to the CNSC, performed an investigation, implemented corrective actions to prevent a recurrence, and submitted a follow-up report to the CNSC. CNSC staff reviewed the incident, verified that the corrective actions were properly implemented, and concluded that CFM took the appropriate actions in response to the action level exceedance.

Table 3.2: Total average and maximum uranium discharged to the air from all CFM stacks compared with the action level (2012–2021)[2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

	Action level (µg/m³)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Overall annual average from all stacks (µg/m³)	2.0	0.1	0.1	0.0	0.1	0.1	0.03	0.02	0.02	0.04	0.04
Overall annual maximum from all stacks (µg/m³)		1.5	1.5	0.8	1.5	9.5	1.8	0.55	1.51	1.48	1.69

As seen in table 3.3, in 2012, there was one exceedance of the AL for the building ventilation. The AL exceedance occurred where there was a production area powder spill caused by equipment failure during the transfer of uranium dioxide powder. CFM reported the incident to

the CNSC, performed an investigation, implemented corrective actions to prevent a recurrence, and submitted a follow-up report to the CNSC. CNSC staff reviewed the incident, verified that the corrective actions were properly implemented, and concluded that CFM took the appropriate actions in response to the AL exceedance.

Table 3.3: Average and maximum building ventilation rates from CFM in g/hr compared with applicable action levels (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

	Action level (g/hr)		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Uranium emissions from pelleting area	1.0	Avg	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
		Max	1.9	0.5	0.4	0.6	0.9	0.6	0.9	0.5	0.5	0.3
Uranium emissions from PP2 area[1]	0.5	Avg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Max	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

[2] It should be noted that the PP2 action level was reduced to 0.4 g/hr in 2020

Table 3.4: Total uranium discharged to the air from CFM in kilograms compared with applicable release limits (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

	Release limit (kg/yr)[1]	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total uranium discharge through stacks (kg/year)	14	0.02	0.03	0.01	0.01	0.03	0.01	0.01	0.004	0.01	0.01
Total uranium discharge through building exhaust ventilation (kg/year)		0.57	0.48	0.40	0.45	0.70	0.57	1.25	1.09	0.92	0.89

[3] The current atmospheric release limit, effective March 01, 2022, is 10.5 kg U/yr as discussed in section 3.1.1

3.1.2.1 Findings

Based on CNSC staff's review of the results of CFM's EPP, CNSC staff have found that Cameco's reported air emissions to the environment from CFM have remained below CNSC-approved licence limits throughout the reported period, and that the EPP continues to provide adequate protection of people and the environment from air emissions.

3.1.3 Waterborne effluent

Cameco controls and monitors liquid (waterborne) effluent from CFM to the environment under its implementation of the EPP. This program is based on CSA N288.5-11, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [31], and includes monitoring of radiological and hazardous releases.

Cameco routinely monitors uranium and pH in effluent released from the CFM. Cameco also monitors other municipal sewer bylaw parameters on a non-routine basis. Liquid effluent from CFM's operations is collected and treated using an evaporator process. The condensed liquid is sampled and analyzed prior to being released to the sanitary sewer in a controlled procedure. If the uranium concentration in the effluent is below the AL and the pH is within the acceptable range, the effluent is discharged to the municipal sanitary sewer system. Otherwise, it is pumped back to the waste treatment tanks for re-evaporation. Groundwater treatment system effluent is also discharged to the sanitary sewer system upstream of the compliance monitoring location. There is no direct discharge of liquid effluent from CFM to the environment.

CFM has an automated sampler that takes a sample from a facility discharge point to the municipal system at regular intervals 24 hours per day. A composite sample is created from these individual samples. This composite sample is taken twice a week and is analyzed for uranium concentration. The composite sample is representative of the liquid effluent that is discharged from the facility.

Table 3.5 summarizes the concentrations of liquid effluent discharged to the sewer over a 10-year period from 2012 to 2021. CFM has established liquid effluent ALs and internal control levels. CFM's ALs are based on concentration and the licence limit is based on loadings. Exceedances of limits and ALs are reported to the CNSC, documented and investigated, and appropriate corrective action is taken where warranted.

As seen in table 3.5, in 2014 and 2018, there were exceedances of the AL for the waterborne releases. In 2014, the results of the composite sewer sample indicated that the uranium concentration in the sewer exceeded the AL. CFM notified CNSC staff and conducted an investigation that determined that the probable cause of the incident was maintenance work being performed to clear the furnace sanitary sewer lines. This maintenance work caused a release of historical uranium that collected in the lines. The results from the investigation were detailed with corrective actions identified and submitted to the CNSC.

In 2018, the results of an effluent sample indicated that the uranium concentration exceeded the AL. CFM notified CNSC staff of the exceedance and conducted an investigation to identify the cause. Following the investigation, CFM submitted the event report to the CNSC, concluding that the elevated measurement was likely due to recent equipment modifications at the facility. For both the 2014 and 2018 AL exceedances, CNSC staff reviewed the incident, verified that the corrective actions were properly implemented, and concluded that CFM took the appropriate actions in response to the action level exceedance.

Table 3.5: Annual waterborne releases from CFM compared with the applicable action levels (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

Parameter	Uranium (mg/L)		pH	
	Minimum	Maximum	Minimum	Maximum
Action levels [39]	2012-2017 = 0.20 2018-2020 = 0.10		6.5	9.0
2012	0.03	0.06	7.4	8.2
2013	0.03	0.07	7.3	8.6
2014	0.05	0.54	7.3	8.3
2015	0.04	0.10	7.3	8.2
2016	0.02	0.06	6.9	8.5
2017	0.02	0.10	7.3	8.1
2018	0.02	0.11	7.3	8.4
2019	0.01	0.03	7.4	8.2
2020	0.01	0.05	7.3	8.9
2021	0.01	0.03	6.8	8.9

Table 3.6 contains the total uranium discharged to the sewer. The effluent data shows that the liquid effluent from the facility remained consistently well below the applicable licensed release limit of 475 kg/year over the 2012–2022 licence period.

Table 3.6: Total uranium discharged to the sewer from CFM in kilograms compared with applicable release limits (2012–2021) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

2012-2022 Release limit (kg/yr)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
475	0.95	0.83	1.58	1.24	0.85	0.64	0.84	0.39	0.34	0.29

3.1.3.1 Findings

CNSC staff have found that Cameco's reported liquid effluent discharged to the sewer from CFM remained below CNSC's approved licence limits throughout the reported period from 2012 to 2021.

CNSC staff are satisfied that Cameco continues to provide adequate protection to the people and the environment from effluent to the sewer.

3.2 Environmental effects assessment

This section presents an overview of the assessment of predicted effects from licensed activities on the environment and the health of persons. CNSC staff reviewed Cameco's assessment of current and predicted effects on the environment and health of persons due to licensed activities included in the ERA (see subsection 2.3.3). The ERA was performed in a stepwise manner as described in CSA N288.6-12, *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills* [32].

To inform this section of the report, CNSC staff reviewed Cameco's ERA submitted in 2016 [12], along with the 2021 update of the ERA [13], and the annual compliance monitoring and operational performance reports submitted between 2012 and 2021, inclusively [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

While CNSC staff conducted a review for all environmental components, only a selection of components is presented in detail in the following subsections. The environmental components were selected based on licensing requirements, as well as those that have historically been of interest to the Commission, Indigenous Nations and communities, and the public.

3.2.1 Atmospheric environment

An assessment of the atmospheric environment requires Cameco to characterize both the meteorological conditions and the ambient air quality at the CFM facility.

3.2.1.1 Meteorological conditions

Meteorological conditions, such as temperature, wind speed, wind direction and precipitation, are needed in order to assess the extent of the atmospheric dispersion of contaminants emitted to the atmosphere and the rates of contaminant deposition, and to determine predominant wind directions, which are used to identify critical receptor locations from the air pathway. The 2021 review of the ERA presents meteorological data gathered from Cobourg (surface data) and Buffalo, New York, (upper air data) between 2013 and 2017, and compared with a 5-year period between 1997 and 2001 previously used in the 2016 ERA. Although these data sets were slightly different, this is not expected to affect the conclusions of the 2016 ERA.

3.2.1.2 Ambient air quality

Ambient air monitoring

Ambient air monitoring is used to confirm that ambient air quality, as a result of atmospheric emissions from the facility's operation, remains at levels protective of the environment and human health.

As part of Cameco's EPP, an ambient air monitoring program is implemented using high volume air samplers (Hi-Vols). The Hi-Vols are placed at 4 corners within the CFM fenceline to measure concentrations of uranium in ambient air from stack and fugitive emissions. The Hi-Vols operate continuously for 24 hours per day. The filters are changed weekly and are analyzed for uranium. Over the 6-year period from 2016 to 2021, the results from these monitoring locations show that

uranium concentrations have remained consistently low as summarized in table 3.7. The highest annual average concentration of uranium in ambient air measured among the sampling stations was 0.0019 μg/m^3, well below the MECP's standard for uranium in ambient air of 0.03 μg/m^3, based on an annual average [45].

Table 3.7: Annual concentrations of uranium (μg/m^3) in ambient air as measured at Hi-Vol stations around the CFM facility [10,11]

Hi-Vol station		2016[1]	2017	2018	2019	2020	2021	Ontario standard [45]
East	Average	0.0014	0.0002	0.0002	0.0002	0.0003	0.0003	0.03
	Maximum	0.0050	0.0009	0.0005	0.0008	0.0014	0.0039	
North	Average	0.0019	0.0003	0.0002	0.0003	0.0004	0.0004	
	Maximum	0.0092	0.0008	0.0005	0.0014	0.0024	0.0050	
North West	Average	0.0017	0.0002	0.0002	0.0003	0.0003	0.0003	
	Maximum	0.0071	0.0006	0.0006	0.0016	0.0012	0.0042	
South West	Average	0.0019	0.0002	0.0002	0.0003	0.0004	0.0004	
	Maximum	0.0078	0.0010	0.0005	0.0015	0.0014	0.0056	

[4] 2016 samples were analyzed using alpha monitoring detection equipment; data collected after that used ICP-MS detection method

ERA Predictions

In the 2016 ERA, Cameco predicted and assessed the potential impacts to ambient air quality at the CFM facility by using air dispersion modelling, based on uranium emissions data from the facility. The releases to air from 26 stacks as well as from building ventilation were modelled as sources of uranium emissions for various receptors, including 4 discrete receptors placed at the locations of Hi-Vols at the corners within the CFM fenceline. The comparison of modelled concentrations with Hi-Vol monitoring data at the 4 respective locations demonstrated that modelling predictions were very conservative. In fact, the predicted levels were 3 to 10 times higher than monitoring data which is above the value of 2 recommended for well performing models. The CNSC requested Cameco to update the air dispersion modelling in the next revision of the ERA.

The 2021 review of the ERA addressed the CNSC request and provided the results of updated air dispersion modelling based on the 2013–2017 meteorological dataset, the most recent stack source information, the Hi-Vol monitoring data from 2015–2019, and the revised ventilation emission rates. The CNSC accepted the updated model and agree with Cameco's conclusion that modelling predictions were conservative.

3.2.1.3 Findings

Based on the review of Cameco's ERA and the results of the atmospheric monitoring program for CFM, CNSC staff have found that airborne emissions from the facility remain significantly

below the provincial standard and within the ERA predictions; therefore, ambient air quality remains at levels protective of human health and the environment.

3.2.2 Terrestrial and aquatic environment

An assessment of potential effects on non-human biota at the CFM facility and the surrounding area consists of characterizing local habitat and ecological receptors and assessing the possibility of their exposure to gamma radiation as well as to radiological and hazardous substances in groundwater, surface water, sediment and soil.

The CFM facility is situated in the Municipality of Port Hope, approximately 430 m from the north shore of Lake Ontario. The majority of the developed site area consists of a combination of buildings and hard surfaces (either concrete or asphaltic pavement), including parking areas and access roads as can be seen in figure 3.2. North and east of the facility, the remaining area of the site contains a combination of landscaped natural area (lawns), as well as natural tree canopy. A small creek (a tributary to Gages Creek) is located east of the CFM facility. An agricultural field is located farther east of the site. Immediately to the south of the site is landscaped natural area. A similar section of land is located to the southeast of the facility, also containing some limited tree canopy.

In the 2016 ERA, Cameco selected a total of 14 ecological receptors for the assessment based on knowledge of the CFM site and surrounding environment, relevant environmental studies, field observations and accessibility of the environmental media. The receptors listed in table 3.8 reflect a variety of diets or feeding habits, cover a variety of trophic levels, and are representative of the potential species present in the area.

Table 3.8: Ecological receptors identified for the 2016 ERA for the CFM facility [12]

Aquatic receptors	Terrestrial receptors
Forage/benthic fish	Earthworms
Predator/pelagic fish	Grass
Benthic invertebrates	American robin
Macrophytes	Great horned owl
Lesser scaup	Yellow warbler
Horned grebe	Red fox
	Eastern cotton-tail rabbit
	Meadow vole

In the 2006 EA study conducted on the proposed facility modifications to replace a portion of the natural uranium feed with SEU [46], there were no species with statuses of concern identified within the surrounding area, and the 2016 ERA for CFM did not identify any listed species. The 2021 review of the ERA stated that there is a wide margin of safety for the protection of individual ecological receptors from radiological and hazardous substances and, thus, adverse impacts to any species at risk (SAR) are unlikely. CNSC staff agree with Cameco's conclusion that there are safety measures in place to protect SAR.

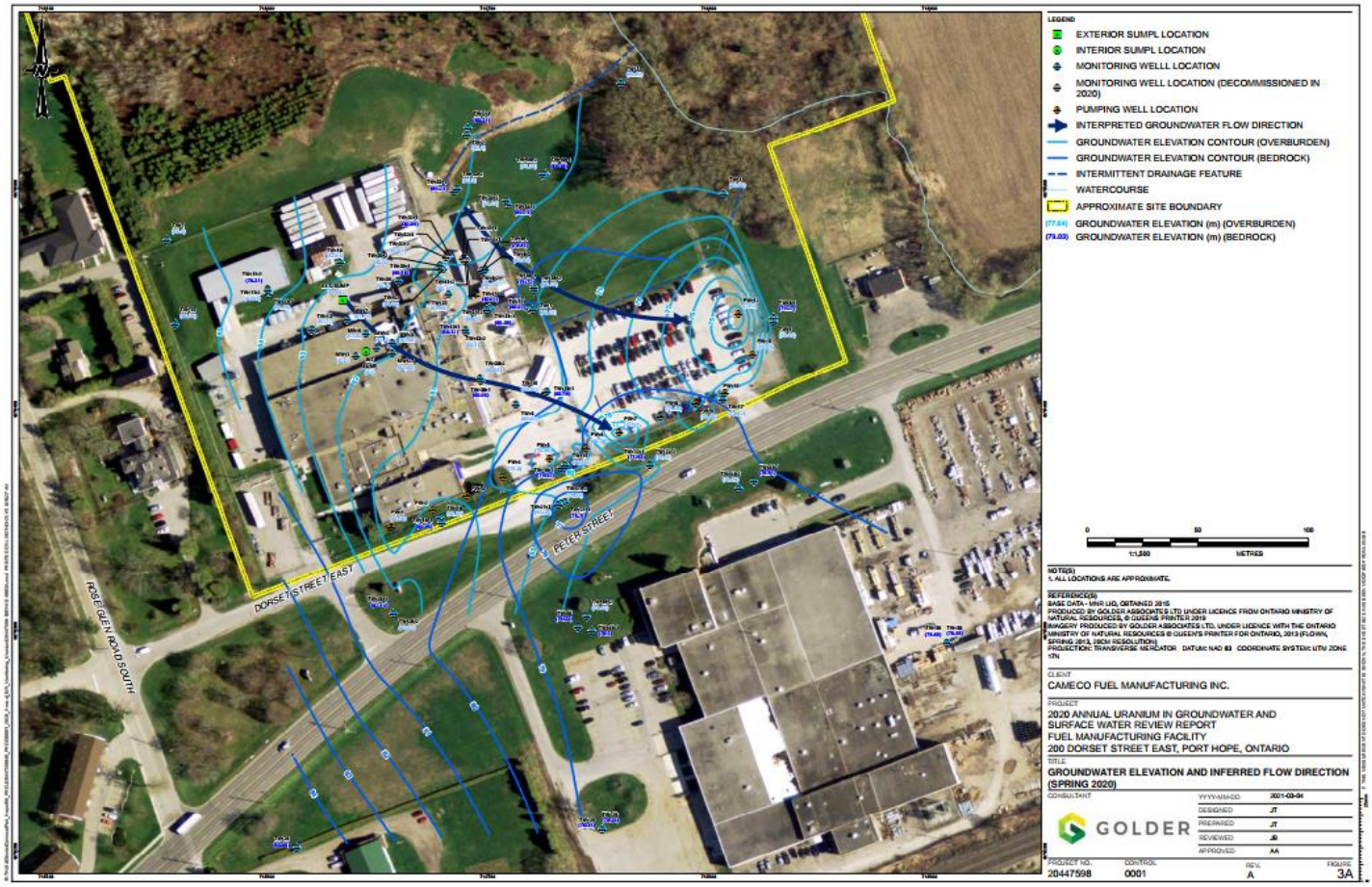
Cameco has identified that a thorough identification and description of both federally and provincially listed species potentially present at the CFM site should occur. CNSC staff expect this review will be done through the next ERA revision.

3.2.2.1 Groundwater quantity and quality

The CFM facility is located on a slight topographic high, with the property generally sloping to the southeast. Most of the developed property adjacent to the licensed area consists of a combination of hard surfaces (either concrete or asphalt), such as parking areas and access roads. The developed portion of the site is drained to a combination of storm sewers and intermediate drainage features (ditches), which either discharge to a tributary to Gages Creek, located approximately 150 m to the east of the licensed area, or the municipal storm sewer system at Peter Street.

The regional groundwater flow direction in both the overburden and bedrock is inferred to be to the south to southeast towards Lake Ontario, which is located approximately 430 m south of the facility. The depth to groundwater has historically ranged from approximately 1 to 4 m below ground surface in the monitoring wells completed within the overburden, and from less than 1 to more than 7 m below ground surface in monitoring wells completed in the shallow bedrock. Groundwater in the overburden enters the facility from the west and northwest and flows towards the east and southeast in the direction of Gages Creek. Bedrock groundwater flow is generally interpreted to follow a similar flow path, from west to east; however, there is a southerly trend in the flow direction, south of the parking area. The groundwater flow direction at the CFM facility can be seen in figure 3.2 below.

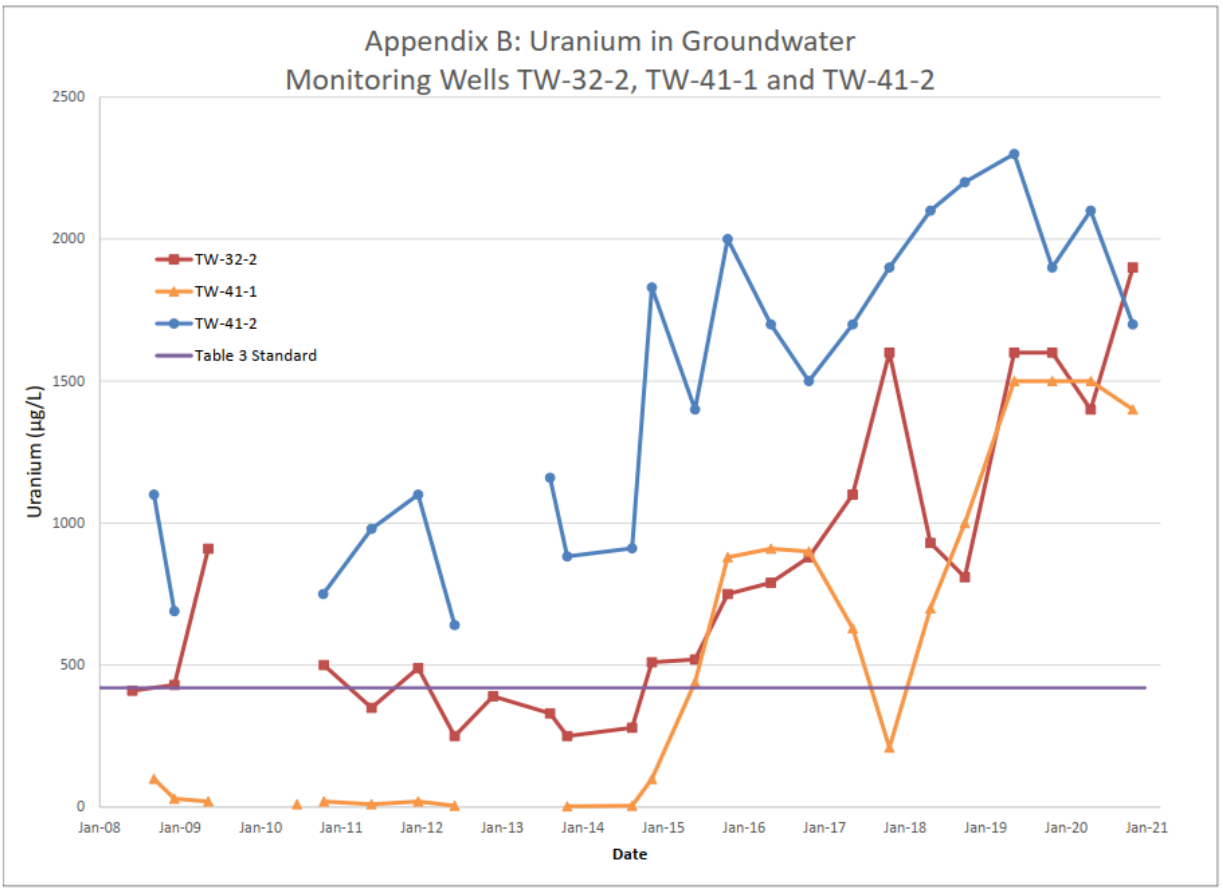
Figure 3.2: Groundwater flow directions at the CFM facility [47]



Groundwater has been monitored at the site twice per year since 1999. The active monitoring well network currently consists of 70 monitoring wells. The groundwater monitoring results confirmed that current operations are not contributing to the concentrations of uranium in groundwater on the licensed property.

In 2020, Uranium concentrations in groundwater satisfied MECP Table 3 Standards (420 ug/L) with the exception of monitoring wells TW-32-2, TW-41-1 and TW-41-2 [48]. Uranium concentration exceedances were detected at TW-32-2 and TW-41-2 since 2008 and at TW-41-1 since 2015 as can be seen in figure 3.3. These wells have more recently been abandoned and replaced with improved well construction details and the replacement monitoring wells have been monitored as of the spring 2021 monitoring program.

Figure 3.3: Uranium concentrations in groundwater in monitoring wells TW-32-2, TW-41-1 and TW-41-2 [47]



March 2021 Golder Associates Ltd. 20447598 (2020U)

Cameco conducted a comprehensive borehole investigation in the north east corner of the facility where the 3 groundwater monitoring wells were experiencing exceedances and concluded that the elevated uranium concentrations were caused by historic site soil impacts. The impact is localized to the site and groundwater monitoring wells are not used for water consumption. Therefore, there has been no adverse impact to human or surface water receptors.

In response to a request from the MECP, in 2000, Cameco's predecessor installed and commissioned a pump-and-treat system that includes pumping wells and sumps to remove the historical chlorinated volatile organic compounds (VOCs) in the groundwater. The pumping well locations and associated depression cones in the groundwater table created by their operation are as shown in figure 3.2.

3.2.2.2 Surface water quality

The main surface water bodies that could be affected by releases from CFM are Lake Ontario and Gages Creek. Liquid effluent releases are routinely monitored in accordance with operating licence requirements. Site sanitary sewer discharges are directed to the municipal sewer system, which is piped to the Port Hope STP, and combined with sewer releases from other sources. The

STP releases treated effluent to Lake Ontario via an outfall diffuser located offshore. The 2016 ERA assessed the potential risks to humans and the environment associated with concentrations of uranium and trichloroethylene (TCE) in surface water near the municipal outfall and in the Port Hope harbour water. This assessment was further described in the 2021 review of the ERA using the more recent (2015–2020) effluent data. The results demonstrate that the conclusions regarding the surface water quality due to CFM operations remain valid and conservative.

Within the site boundary the surface water environment is limited to that of a tributary to Gages Creek, located to the east of the facility. The tributary to Gages Creek receives discharges from site drainage ditches and remaining site storm sewer drainage reports to the municipal storm sewer system at Peter Street. In 2020, Cameco collected surface water and stormwater samples at 9 locations in April, August and October, both within a tributary Gages Creek and drainage ditches at the developed site boundaries. The uranium concentrations generally met the interim Provincial Water Quality Objective (PWQO) [49] and the CCME short-term and long-term uranium guidelines [50] with the exception of select drainage ditch samples. The risk to the environment from the drainage ditch exceedances is expected to be negligible due to the conservative assumptions and safety factors that were used to derive the guidelines.

3.2.2.3 Soil quality

Cameco collects soil samples at least every 3 years in order to assess soil quality in the vicinity of the CFM facility and to verify that there is no significant build-up of uranium in surface soil due to deposition of airborne uranium released from the facility. Soil samples are taken at 23 locations outside of the CFM facility perimeter and sent to an external laboratory to determine concentrations of uranium.

MECP has established the upper limits of typical background concentrations for many substances in soils that are not contaminated by point sources [48]. CNSC staff use this standard to determine if soil concentrations near the nuclear facility are the result of contamination from the facility operations. For uranium, the upper limit of typical background is 2.5 µg/g for residential land use, derived from the 0-5 cm soil horizon.

To enable the comparison with the standard, the soil data for CFM are provided in table 3.9. The average soil concentrations of uranium measured near CFM are above the MECP background for Ontario. It is highly unlikely, however, that this can be attributable to CFM operations due to historical contamination of soil in Port Hope which has long been recognized and continues to be the focus of cleanup activities. Between 2009 and 2019, neither average nor maximum soil concentrations of uranium increased in the top soil horizon near the facility. This indicates that there is no accumulation of uranium in surface soil due to current uranium emissions from CFM. The results for all samples were below the most conservative CCME soil quality guideline of 23 µg/g of soil for residential/parkland land use and, therefore, are not expected to result in any adverse consequences to human and environmental receptors [51].

Table 3.9: Soil monitoring results (µg/g) at the CFM facility (0–5 cm depth) [10]

Parameter	2009	2010	2013	2016	2019	CCME guidelines [51]
Average uranium concentration	6.8	5.6	4.7	3.0	2.9	23
Maximum uranium concentration	17.0	21.1	17.4	10.2	7.6	

3.2.2.4 Assessment of potential effects on non-human biota

The most recent assessment of potential effects on terrestrial biota near the CFM facility was provided in the 2016 ERA [12] and the 2021 review of the ERA [13]. As discussed in subsection 2.3.3, the ERA fully complied with the requirements of CSA N288.6-12, *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and mills* [32], and incorporated recent environmental monitoring data. The most recent 2021 review of the ERA fulfilled the requirements under CSA N288.6-12 to review and update the ERA and to support the CFM licence renewal application. The 2021 review demonstrated that no new risks have emerged since the 2016 ERA and, therefore, ecological risks attributable to CFM operations are negligible.

The potential radiological effects to ecological receptors were assessed by comparing the estimated radiation dose received by each ecological receptor from uranium isotopes through all applicable pathways (i.e., external and internal exposure due to radionuclides in air, soil, water, sediment, and gamma radiation) to the recommended benchmark values (i.e., dose limits to non-human biota).

Based on the 2014 quarterly fenceline gamma monitoring data, maximum potential external exposure of the ecological receptors to gamma radiation at the boundary of the facility was estimated to be 0.023 mGy/d (0.96 µGy/h). This level of exposure is well below the most conservative screening criterion for non-human biota of 10 µGy/h and, therefore, is below the values known to cause adverse effects.

The overall radiation dose (including all internal and external doses from all exposure pathways) was significantly below the radiological dose benchmarks recommended in CSA N288.6-12 [32] – 100 µGy/h for terrestrial receptors and 400 µGy/h for aquatic non-human biota. This indicates no potential for adverse effects and no need for further (detailed) assessment.

The 2016 ERA assessed the potential effects of several hazardous substances (specifically uranium, TCE and its degradation by-products) on terrestrial and aquatic receptors. The estimated risks for all receptors based on maximum concentrations of uranium in each environmental media were below the respective benchmark values [32] except for benthic invertebrates, which showed screening index results for uranium greater than 1 (1.89). Tier 2 calculations were undertaken in accordance with CSA N288.6-12 [32] using a dilution factor for CFM effluent in total STP effluent. Given that this resulted in a screening index of less than 1 (0.27), it has been found that there is no residual risk for benthic invertebrates from uranium levels in surface water due to CFM operations. For all ecological receptors (terrestrial and aquatic), the estimated risks from maximum concentrations of TCE and its degradation by-products were well below the respective benchmark values.

In the 2021 review of the ERA, Cameco indicated that the approach to the evaluation of aquatic receptors has evolved since the completion of the 2016 ERA and that some toxicity values have changed. CNSC staff found Cameco's revised approach to be acceptable. These changes do not result in changes to the 2016 ERA conclusions.

3.2.2.5 Findings

Based on the review of the 2016 ERA, 2021 review of the ERA and the results of the EMP for the CFM facility, CNSC staff have found that the terrestrial and aquatic environments remain protected from radiological and hazardous releases from the facility.

3.2.3 Human environment

An assessment of the human environment at the CFM site consists of identifying representative persons located within or in proximity to the site, and determining whether radiological or hazardous COPCs could impact their health by breathing the air, being on the land, drinking and swimming in surface water, and eating plants, fish and wildlife from the CFM area. In general, human receptors may be exposed to contaminants through 4 primary routes: dermal (i.e., skin), inhalation, incidental ingestion (e.g., soil) and ingestion of food and water. Representative persons are those individuals who, because of their location and habits, are likely to receive the highest exposures to radiological or hazardous substances from a particular source.

The 2016 ERA [12] included a HHRA to assess the risk to humans from both radioactive and hazardous substances released from activities at the CFM facility. A total of 8 human receptor groups were identified to be the most exposed for potential radiological and hazardous contaminant exposures, including onsite and offsite workers and offsite residents. Cameco indicated that no First Nation groups were present in the study area and exposure factors for the HHRA were based on the values recommended by Health Canada [32].

3.2.3.1 Exposure to radiological substances

The CNSC's *Radiation Protection Regulations* [36] prescribe radiation dose limits to protect workers and the public from exposure to radiation from licensed activities. Doses are either monitored by direct measurement or by estimation of the quantities and concentrations of any nuclear substance released as a result of the licensed activities. The annual effective dose limit for a member of the public is 1 mSv per year.

The annual doses to residents in the vicinity of the CFM facility have been calculated based on environmental monitoring data as well as from measurements of airborne and liquid emissions from the facility. These residents are assumed to spend time indoors and outdoors, and to reside year-round while being exposed to emissions and effluent from CFM and to gamma radiation from materials on site. They are also assumed to be engaged in gardening and fishing activities, so their backyard produce and caught fish comprise a portion of their diet. These residences are supplied with municipal drinking water, and therefore it is assumed that groundwater and surface water are not used as drinking water. Residents include all age groups: infant, toddler, child, teen and adult.

Table 3.10 shows the estimated doses to the public from the CFM facility during the period from 2016 to 2021. The public dose estimates reported by CFM prior to 2020 were calculated using the same methodology and remained below 5% of the 1 mSv/year regulatory dose limit during

that time period. In 2021, CFM submitted revised DRLs which included an update to the public dose calculation formulas in accordance with CSA N288.1-14 [29]. The revisions include the incorporation of airborne and liquid emissions in the calculation, and a new location for the critical receptor. These changes were made to obtain a more conservative estimate of dose to the public, and accordingly resulted in a substantial increase to the dose reported in 2021 (i.e., 0.306 mSv) relative to previous years. The most significant change to the public dose estimate methodology introduced in the 2021 DRL report, is a change to the physical location of the critical receptor upon which the public dose estimate is based. The new location is a palliative care facility which began operating from a residence located on the west side of the CFM facility in 2014. This location is in closer proximity to the fuel storage building than the location used to support public dose estimates in previous years. At the time the palliative care facility began operating (i.e., 2014), CFM carried out an assessment of dose implications using the previous methodology. No changes to the receptor location for public doses were recommended at that time as CFM concluded that dose rates would remain similar to the current dose estimates.

As a result of the changes to the methodology and the critical receptor location used for the 2021 public dose estimate, a direct comparison of the 2021 value to previous years is not appropriate. However, recognizing that the palliative care facility has been operating at the current location since 2014, CNSC staff have verified that public dose estimates remained below the 1 mSv regulatory public dose limit using the current the methodology from 2014 to 2020. Based on reviews of quarterly and annual compliance reporting during the previous licence period, CNSC staff confirm that there has not been an actual increase in emissions or dose to the public from CFM.

The public dose reported by CFM in 2021 is considered a very conservative estimate and remains well below the 1mSv annual regulatory dose limit applicable to a member of the public. As part of its ALARA initiatives, CFM has indicated it plans to implement additional measures to reduce public dose, such as increased shielding from the fuel storage building, beginning in 2023.

Table 3.10: Estimated annual public doses for the CFM facility [10, 11]

Gamma dose to critical receptor (mSv)						
Public dose limit (mSv)	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1	0.023	0.022	0.030	0.027	0.020	0.306

3.2.3.2 Exposure to hazardous substances

The hazardous HHRA for the CFM facility encompassed an approach consistent with that described in CSA N288.6-12 [32]. Human receptors assessed included onsite and offsite workers, and offsite members of the public such as residents. Based on a preliminary screening of contaminants, the 2016 ERA identified the following hazardous COPCs for further assessment: uranium, TCE and its degradation by-products.

In general, human receptors may be exposed to the contaminants through 4 primary routes: dermal (skin), inhalation, incidental ingestion (e.g., soil), and ingestion of contaminated food and water. Effects on human health were assessed using an approach encompassing a semi-

quantitative pathways analysis to determine if there was a likelihood for members of the public to be exposed through air, groundwater, surface water, soil or ingested food items.

The 2016 ERA presents the assessment of exposure to hazardous substances for workers and members of the public based on respective environmental media and exposure locations. Tier 1 estimates are based on maximum concentrations in environmental media (i.e., groundwater, surface water, soil and air). If estimated risk exceeded corresponding toxicity reference values, Tier 2 calculations were performed. Tier 2 estimates are based on 95th percentile concentrations in the appropriate environmental media. The assessment identified no residual risks for offsite members of the public.

The conservative assessment showed that there were exceedances of the toxicity benchmarks for some receptors (onsite and offsite workers who perform sub-surface activities) due to oral and dermal exposure to TCE and its degradation products in groundwater. The potential risks posed to these receptors are effectively mitigated and/or eliminated through the implementation of specific health and safety procedures and equipment at the site. This includes, for example, wearing full coveralls and waterproof gloves, keeping food out of all work areas, and wearing goggles for applicable tasks.

Risk from inhalation of uranium in onsite indoor air, assessed while assuming that no protective equipment is used, exceeded the respective benchmark pertaining to the exposure of onsite maintenance workers. This risk is effectively mitigated (eliminated) through use of respirators for duties when air sampling indicates presence of uranium or jobs when workers could be exposed to airborne contaminants in certain areas. These procedures also apply to any non-nuclear energy workers and contractors who perform maintenance-type activities at the CFM facility.

It was noted in the 2021 review of the ERA that the evaluation of oral and dermal exposure pathways from groundwater for sub-surface workers is unrealistic as workers would not be permitted into a trench with water. Furthermore, in the 2016 ERA, the evaluation of uranium in indoor air exposures to onsite workers incorrectly used benchmarks protective of members of the public rather than occupational exposure benchmarks. Cameco indicated that this will likely result in a further reduction of the relevant risks identified in the 2016 ERA. CNSC staff find this rationale to be reasonable and acceptable.

3.2.3.3 Findings

In the last 6 years (2016 to 2021), the estimated annual radiological doses for the public at CFM have remained below the regulatory annual dose limit for the public (1 mSv). This indicates that radiological releases from the facility pose a negligible risk to human health (i.e., potential risk to humans is similar to health outcomes in the general public).

With respect to hazardous substances, CNSC staff's review of the HHRA indicated that operations at CFM pose a negligible risk to offsite residents (i.e., potential risk to humans is similar to health outcomes in the general public). The potential risks to workers are effectively eliminated through the implementation of specific health and safety procedures and equipment.

Based on assessments conducted for the CFM facility, including the 2016 ERA, the 2021 review of the ERA, and annual environmental monitoring data, CNSC staff have found that impacts to

the human environment from radiological and hazardous substances released from the facility are negligible, and that people living near the facility and working in the facility remain protected.

3.3 Cameco's proposed production increase and its impacts on environmental protection

In October 2021, Cameco submitted its application for renewal of CFM's operating licence for a period of 20 years, which is subject to a Commission decision [14]. In this application, Cameco is requesting to increase the annual production limit to reflect the production capacity of CFM. To support its application, Cameco submitted a letter providing justification for licence term and production increase for CFM [15].

Proposed changes

In its application for renewal, CFM has requested to change to an annual production limit of 1,650 tonnes of uranium as uranium dioxide pellets. The production limit represents an approximate 24% increase from the limit currently specified in the CFM LCH. This proposed production limit reflects the actual production capacity of CFM and can be achieved with the current installed equipment configuration by increasing the number of operating hours per year.

Impact of Cameco's proposed production increase on DRLs and EBRLs

Cameco noted that there are no anticipated changes of the existing equipment configuration of the CFM facility to support the increase of production. Since the facility is expected to maintain its current configuration, there will be no impact on the DRLs and EBRLs for the facility.

The EBRLs for both air and water at CFM are described in section 3.1.1. The EBRL for air is determined using the worst case scenario (i.e. the daily maximum discharge rate at each emission source) in the emission summary dispersion model. Both the locations of stacks and discharge points at CFM and the daily emission rate are anticipated to be the same since CFM is maintaining its current configuration and solely increasing its number of operating days. Therefore, the proposed production increase will have no impact on the EBRL for air. The EBRL for water was derived independent of CFM operational data and therefore remains appropriate to use with the production increase.

The DRL for CFM is determined primarily from the gamma component. The gamma measurements at the fenceline of CFM are due to the storage configuration and shielding of nuclear material at the site. Since the production increase will not change the existing storage locations, there will be no impact on the DRL for CFM.

Impact of Cameco's proposed production increase on air and water emissions

As part of its justification for a production increase, Cameco evaluated the impact on air emissions. Cameco applied a 25% increase factor (25% is used for modelling purposes as a 24% production increase results in a 25% increase in operating days) to the annual average and maximum concentration of uranium in air and to the annual average and maximum uranium loadings over the current licensing period. The results show that the extrapolated uranium stack concentrations (0.04 $\mu g/m^3$ – 0.1 $\mu g/m^3$) would remain well below the AL of 2 $\mu g/m^3$. In addition, the extrapolated uranium loadings for all sources (0.9375 kg/yr – 1.6125 kg/yr) would remain well below the licence period DRL of 380 kg/yr and EBRL of 10.5 kg/yr.

Cameco also evaluated the impact of the proposed production increase on the discharge to the sanitary sewer. Cameco applied a 25% increase factor on the annual average and maximum concentration of uranium and to the annual average and maximum uranium loadings over the current licensing period. The results show that the extrapolated uranium concentrations (0.03 mg/L – 0.0625 mg/L) remain below the action level of 0.1 mg/L. In addition, the extrapolated uranium loadings (1.06 kg/yr – 1.975 kg/yr) remain below the current DRL of 331 kg/yr and EBRL of 62 kg/yr.

Impact of Cameco's proposed production increase on uranium soil concentrations

In March 2022, Cameco provided a letter which evaluated the impact of the proposed production increase on uranium soil concentrations [52]. Cameco modelled the predicted uranium concentrations in the soil using a 25% increase factor of the emission rate over a 20-year licence term. The results show that any significant changes in uranium soil concentrations near CFM due to the proposed production increase are unlikely.

Cameco's proposed production increase and the ERA

CNSC staff's assessment of the predicted effects of licensed activities on the environment and the health of persons is provided in section 3.2. Cameco assessed the impacts of the production increase in their justification document [15] by reviewing Cameco's 2016 ERA [12] and the 2021 review of the ERA [13]. Cameco notes that a review/update of the ERA is not required given that [32]:

- The production increase does not require physical modifications to the facility.
- There is limited monitoring data given the recency of the ERA update which was submitted in May 2021.
- There are no other changes which would trigger a review or update of the ERA.

CNSC staff concur with Cameco's assessment that no incremental risks were identified or calculated that required an update to the ERA based on the production increase.

Findings

CNSC staff have reviewed the justification document for Cameco's request to increase CFM's annual production limit by approximately 24%. CNSC staff agree with Cameco's conclusion that the increase in production will have no impact on the DRLs and EBRLs as a result of maintaining the existing equipment configuration. Further, CNSC staff have found that the proposed production increase would generate air emissions and effluent that would remain well below the licence limits. Additionally, CNSC staff agree with Cameco's conclusion that the proposed increase of production will not result in any significant changes in uranium soil concentrations near CFM. Lastly, CNSC staff note that Cameco will not need to update their ERA to reflect the proposed production increase.

4.0 CNSC INDEPENDENT ENVIRONMENTAL MONITORING PROGRAM

The CNSC has implemented its Independent Environmental Monitoring Program (IEMP) as an additional verification that Indigenous Nations and communities, the public and the environment around licensed nuclear facilities are protected. It is separate from, but complementary to, the CNSC's ongoing compliance verification program. The IEMP involves taking samples from public areas around the facilities and analyzing the amount of radiological and hazardous substances in those samples. CNSC staff collect the samples and send them to the CNSC's laboratory for testing and analysis.

4.1 IEMP at Cameco Fuel Manufacturing

CNSC staff conducted IEMP sampling around CFM in 2014, 2015, 2017 and 2020. The sampling plan focused on uranium and took into consideration Cameco's site-wide EMP and the CNSC's regulatory knowledge of the site.

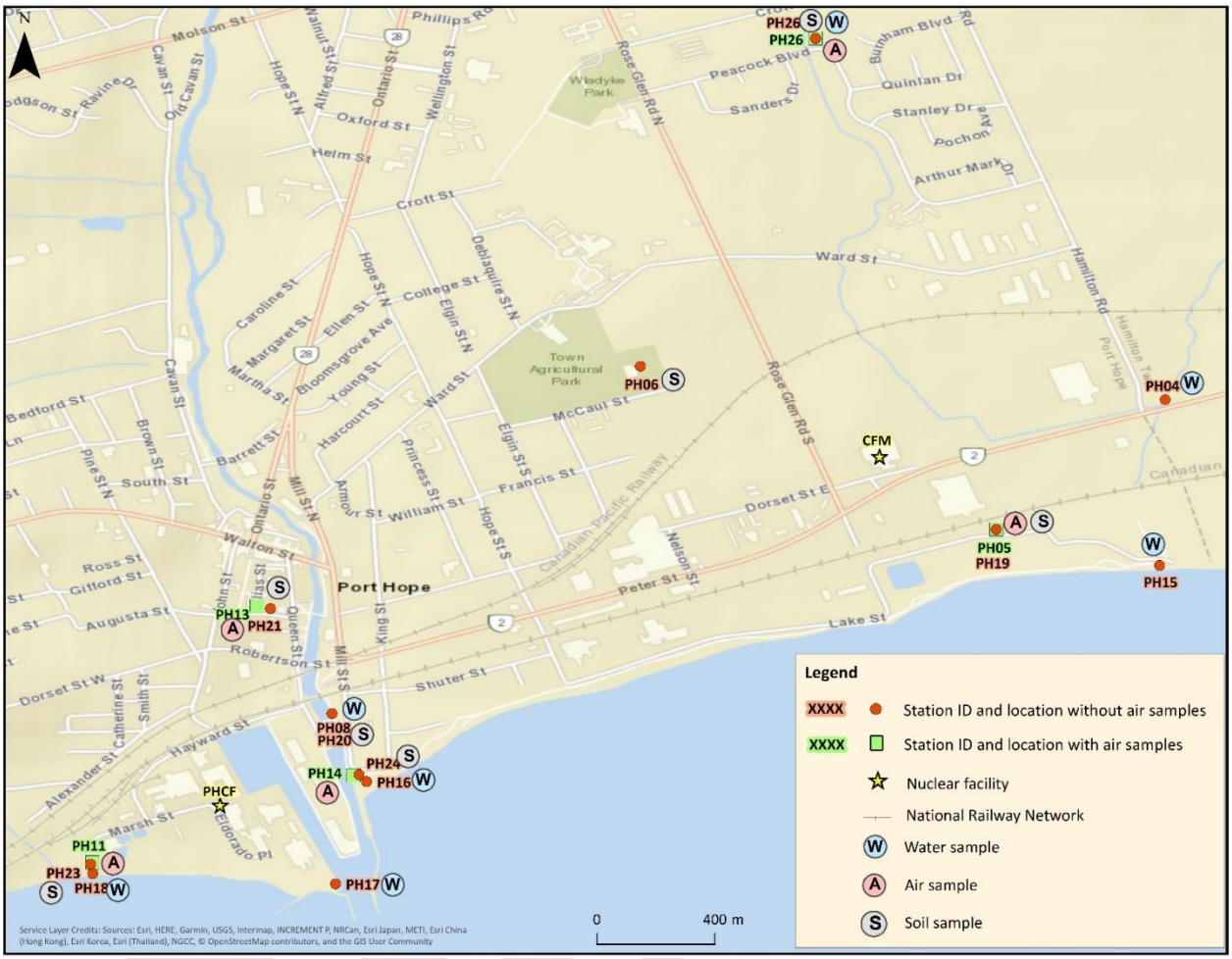
In 2020, the most recent campaign, CNSC staff collected the following samples in publicly accessible areas outside the perimeter of CFM:

- air (2 locations)
- water (4 locations)
- soil (4 locations)

Samples were analyzed by qualified laboratory specialists in the CNSC's laboratory in Ottawa, using appropriate analytical protocols. CNSC staff measured uranium in the collected samples.

Figure 4.1 provides an overview of the sampling locations for the 2020 IEMP sampling campaign around CFM. The figure also includes the sampling locations that were taken at the nearby PHCF. The sample taken at Town Agricultural Park is located between CFM and PHCF and could be considered the exposure location for both facilities. The IEMP results are published on the CNSC's IEMP web page [53].

Figure 4.1: Overview of the 2020 sampling locations



4.2 Indigenous participation in the IEMP

It is a priority for the CNSC that IEMP sampling reflect Indigenous traditional land use, values and knowledge, where possible. In 2020, in advance of the IEMP sampling campaign at CFM, notification emails were sent to the following Indigenous Nations and communities located near CFM: Williams Treaties First Nations, Mohawks of the Bay of Quinte First Nation and Métis Nation of Ontario. CNSC staff invited the Indigenous Nations and communities to provide suggestions for species of interest, valued components or potential sampling locations where traditional practices and activities may take place. CNSC staff did not receive any comments about the 2020 IEMP at CFM. CNSC staff will continue to engage with Indigenous Nations and communities to ensure that IEMP sampling incorporates Indigenous knowledge in future sampling.

4.3 Summary of results

The levels of uranium in all of the samples measured during the 2020 IEMP sampling campaign were below available guideline levels and were similar to the range of results from the 2014,

2015 and 2017 IEMP sampling campaigns at CFM. Results for all campaigns are published on the CNSC's website [53].

The IEMP results are consistent with the results submitted by Cameco, supporting the CNSC's assessment that the licensee's environmental protection program is effective. The results add to the body of evidence that people and the environment in the vicinity of Cameco's CFM are protected and that there are no anticipated health impacts.

5.0 HEALTH STUDIES

The following section draws from the results of regional health studies, reports and publications to provide further independent verification on whether the health of people living near the CFM facility in Port Hope, Ontario, is protected. Various organizations in Ontario, such as Cancer Care Ontario; Public Health Ontario; and the Haliburton, Kawartha, Pine Ridge District Health Unit, monitor the health of people living near CFM. In addition, disease rates around CFM are compared to similar populations to detect any potential health outcomes that may be of concern.

To complement our regulatory oversight, CNSC staff continuously work towards strengthening relationships with the various health units and offices. CNSC staff keep abreast of any new publications and data related to the health of populations living near nuclear facilities. Lastly, CNSC staff conduct health studies on select populations through their research on the effects of low dose (and low dose-rate) exposures. Select publications are discussed and highlighted below. For additional information on health studies related to nuclear facilities, visit the CNSC's web page on health studies [54].

5.1 Population and community health studies and reports

5.1.1 Community health profile of the Haliburton, Kawartha, Pine Ridge District

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit routinely monitors the prevalence of known risk factors and the health status of residents within the health district, which includes Port Hope where the CFM facility is located. Existing provincial cancer incidence, mortality and risk factor databases are used for disease and risk factor surveillance and health planning.

The most recent community health summary [55] and health profile [56] examine health outcomes and factors that affect the health of people living in areas serviced by the HKPR District. Reports use data from a variety of sources, including from the Ontario Ministry of Health and Long-Term Care, Public Health Ontario, the Canadian Cancer Registry, and the Canadian Community Health Survey. The leading causes of mortality in 2015 for the HKPR District and for Ontario were cancers and circulatory and respiratory diseases. Circulatory diseases include heart attack, heart disease and stroke. Respiratory diseases include influenza, pneumonia and chronic obstructive pulmonary disease. Chronic disease mortality in 2015 for the HKPR District was higher than in Ontario for cardiovascular disease, respiratory disease, and injuries. The age-standardized mortality rate from overall preventable causes in 2015 in the HKPR District was higher than in Ontario for preventable injury mortality, but not significantly different for preventable cancer mortality. This may reflect limited medical access (e.g., screening) given the rural characteristics of much of the area. While cancer incidence rates were similar to the rates for Ontario, higher lung cancer incidence was observed between 2012 and 2015. This may be due to generally higher smoking rates in the HKPR District compared to Ontario.

5.1.2 Ontario Cancer Profiles (Cancer Care Ontario)

Ontario Cancer Profiles [56] provides interactive map-based dashboards, which display key public health indicators such as cancer incidence, mortality and risk factors. Regional statistics are available by public health unit and Local Health Integration Network (LHIN). The CFM facility lies with the Central East LHIN.

In 2018, the Central East LHIN and the HKPR District Health Unit had similar incidence and mortality rates for all cancers combined compared to Ontario. Incidence rates for lung cancer for both sexes and lung cancer mortality rates in females were higher in the HKPR District Health Unit. Between 2015 and 2017, the rates for alcohol consumption and sedentary behaviour were higher for the HKPR District Health Unit than for Ontario. Rates for smoking and overweight (body mass index (BMI) ≥25) and obesity (BMI ≥30) were significantly higher for the HKPR District Health Unit, particularly among women. Inadequate fruit and vegetable consumption was also slightly higher in males within the HKPR District Health Unit compared to Ontario.

Excess body weight, smoking, alcohol consumption, sedentary behaviour and poor diet are linked to increased of cancer incidence and mortality for various cancer types. Smoking is also a major risk factor for lung cancer incidence and mortality.

5.1.3 Findings

The review of health reports is an important component to ensure that the health of people living near nuclear facilities is protected. The population and community health studies and reports indicate that common causes of death among the population of the HKPR District Health Unit are cancers, circulatory diseases and respiratory diseases. Mortality data among the population of the HKPR District Health Unit are similar to the rest of Ontario and Canada, where heart disease and cancer are the 2 leading causes of death [58]. Lung cancer incidence and mortality rates are higher in the HKPR District Health Unit compared to Ontario; however, risk factors for cancer mortality, such as smoking, excess body weight and alcohol consumption, are also higher within the region.

5.2 Current scientific understanding of radiation health effects

The current scientific knowledge of the sources, effects and risks of ionizing radiation is reviewed and published by international experts at the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [59]. This information comes from many population studies, animal and cell studies, and clinical investigations. These studies build the foundation of the knowledge about the relationship between radiation exposure and health effects, such as cancer. This knowledge, in turn, informs the recommendations of the International Commission on Radiological Protection, which are focused on the protection of human health [60].

5.2.1 Radiation epidemiology

The epidemiological evidence of radiation-related health effects comes from several main research populations. These populations include the atomic bomb survivors, people involved in the Chernobyl disaster, patients treated with radiotherapy for cancer and non-cancer diseases, miners exposed to radon and radon decay products [61, 62], and nuclear energy workers [63, 64, 65, 66, 67, 68].

Two major findings are consistent within all of these studies:

1) Excess risk of cancer increases as radiation dose increases.
2) Statistically significant population effects are typically observed at doses above approximately 100 mSv (either acutely or chronically exposed).

Importantly, the absence of statistically significant data does not indicate the absence of risk. To put these findings into perspective, 100 mSv is much higher than the average Canadian natural background of 1.8 mSv per year, which varies between 1 and 4 mSv/year [69]. Similarly, 100 mSv is much higher than the average annual effective doses experienced by workers at CFM (0.4 mSv/year for 2020) and the public living nearby (0.02 mSv/year for 2020) [10].

5.2.2 International Nuclear Worker Study (INWORKS)

The largest and most relevant study on nuclear energy workers is the International Nuclear Worker Study (INWORKS), a multinational cohort study that assessed cancer risk from 1943 to 2005 in 308,297 workers from the nuclear industry in France, the United Kingdom, and the United States [70, 71, 72, 73]. This series of studies provides strong evidence of a linear relationship between low dose radiation exposures and cancer. The results were consistent with the current radiation protection system, whereby the risk is assumed to be proportional to dose.

5.2.3 Findings

Experts worldwide study radiation health effects to provide objective scientific evidence to support environmental and radiation protection programs, ensuring that workers and members of the public are protected. The international understanding is that low doses of radiation are associated with low and/or indiscernible risks to health. CNSC staff are confident that those living and working near the CFM facility are adequately protected.

5.3 Studies of radiation health effects – Living near or working at CFM

5.3.1 Health studies of populations living near nuclear processing facilities

Several environmental and epidemiological studies have been conducted to assess the potential contamination effects in the Port Hope community over the last 70 years. The lines of evidence from these studies support each other and reveal that the levels of exposure in local area residents and workers are low, and there is no evidence of adverse health effects as a result of past and present nuclear operations or activities in the region. These findings are consistent with the international scientific understanding of radiation effects on human health and with other studies examining similar populations worldwide.

5.3.1.1 Use of a weight of evidence approach to determine the likelihood of adverse effects on human health from the presence of uranium facilities in Port Hope, Ontario

In 2011, CNSC staff used a weight of evidence approach to assess the types and levels of contaminants of concern in the environment and the potential human exposure to these contaminants [74]. Their toxicological and radio-toxicological properties were also assessed to determine their potential health effects. The results of these assessments were further compared to findings of earlier epidemiological studies of Port Hope residents and nuclear industry workers.

The conclusions of this study indicated that levels of exposure to radioactive and hazardous contaminants in Port Hope are below levels known to cause adverse health effects. Further, epidemiological studies provide no evidence of health effects as a result of past and present activities of the Port Hope nuclear industries. The conclusions of the ERAs completed for nuclear facilities in Port Hope and the epidemiological studies are consistent and support each other. The findings for the Port Hope area are consistent with the results of over 40 epidemiological studies conducted elsewhere on populations living around similar facilities or exposed to similar environmental contaminants.

5.3.1.2 An ecological study of cancer incidence in Port Hope, Ontario from 1992–2007

In 2013, the CNSC studied cancer incidence rates in Port Hope for a 16-year period (1992–2007) for continued periodic cancer incidence surveillance of the community [75]. The cancer incidence in the local community for all cancers combined was similar to the Ontario and Canada. No statistically significant differences in childhood cancer, leukemia or other radiosensitive cancer incidences were observed, with the exception of statistically significant elevated lung cancer incidence among women. However, the statistical significance was reduced or disappeared when the comparison was made to populations with similar socio-economic characteristics. These findings are consistent with previous ecological, case-control and cohort studies conducted in Port Hope, and with ERAs and epidemiological studies conducted elsewhere on populations living around similar facilities or exposed to similar environmental contaminants.

5.3.1.3 Findings – Health studies of populations living near nuclear processing facilities

These studies [74, 75] demonstrate that there are no adverse health effects attributable to the nuclear industry in Port Hope.

5.3.2 Health studies of uranium processing workers

In 2020, the average effective dose to a nuclear energy worker at the CFM facility was 0.4 mSv, which is well below the worker annual dose limit for a nuclear energy worker of 50 mSv. Adverse health effects in these workers would not be expected at these dose levels.

The CNSC has conducted a study looking at the health of uranium processing and fuel fabrication workers in Port Hope, which is detailed below. In addition, CNSC continues to undertake research in this area through involvement in an international study and the initiation of a Canadian-wide study of uranium workers including miners, millers and processing workers (including those from CFM), both of which are described further below in section 5.3.2.3.

5.3.2.1 Mortality (1950–1999) and cancer incidence (1969–1999) of workers in the Port Hope cohort study exposed to a unique combination of radium, uranium and gamma-ray doses

In 2013, the CNSC conducted a study looking at cancer incidence and mortality among workers in the Port Hope community exposed to radium, uranium, gamma-ray radiation and, to a lesser extent, radon and radon decay products [66]. The risks of these exposures in a cohort of workers from radium and uranium refinery and processing plants in Port Hope, Ontario, were examined for mortality (1950–1999) and cancer incidence (1969–1999). Overall, the study demonstrated

that workers had lower mortality and cancer incidence compared with the general Canadian population.

5.3.2.2 International Pooled Analysis of Uranium Processing Workers study

The CNSC is also involved in an international collaborative pooled analysis of cohorts of uranium milling, processing, and fabrication workers to address questions concerning low exposure and low exposure rate health effects. There is an emerging consensus that exposures of workers in the uranium milling, processing and fabrication industry are substantially different from those of uranium underground miners, enrichment workers or nuclear reactor workers, and that these workers should be carefully evaluated in separate studies.

The recent UNSCEAR 2016 Report [61] reviewed published epidemiological studies of occupational exposures to uranium. In addition to known effects of exposures to radon decay products and external gamma radiation, it is important to examine long-term health effects of uranium associated with its chemical and radiological toxicity, which depend on the degree of uranium enrichment, the compound solubility, the chemical speciation and the mode of incorporation. Organs most at risk from chemical toxicity of uranium are kidneys, while bones, lungs, liver and brain are mostly affected by irradiation from alpha-emitting particles.

Only a few studies have examined risks of exposures in the uranium processing industry and they have reported contradictory results, necessitating further research in this area. In comparison to the general population, uranium processing workers in some studies had higher mortality rates from lung cancer (likely due to exposure to radon decay products); lymphatic and hematopoietic cancers, particularly non-Hodgkin lymphoma and multiple myeloma; and kidney or bladder cancers. Recent studies have reported increased risks of cardiovascular disease and non-malignant respiratory diseases, but overall mortality was similar to the general population. Only a few studies conducted dose-response analyses of uranium processing workers with individual radiation doses [66, 62, 63, 64].

The International Pooled Analysis of Uranium Processing Workers Study will include 16 cohorts of uranium processing workers, including from the Port Hope radium and uranium processing facility. Findings from this study will be relevant for the radiation protection of current and future uranium milling, processing and fabrication workers. The study is expected to be completed in 2023.

5.3.2.3 Canadian Uranium Workers Study

The Canadian Uranium Workers Study (CANUWS) is a multi-year project initiated by the CNSC in 2017 to assess the health effects of occupational radiation exposure among uranium workers. The project is a partnership between the CNSC, the Government of Saskatchewan and the uranium industry, and involves researchers from the CNSC, Health Canada and the University of Saskatchewan. This retrospective cohort study will assess the information of over 80,000 Canadian uranium mine, mill and processing workers with occupational radiation exposure rates from 1932 to 2017. The study will follow up on workers' mortality (1950 to 2017) and cancer incidence (1969 to 2017).

The main objective of the study is to update information on the radon–lung cancer relationship. Importantly, the study will assess the potential health effects of low cumulative exposures and exposure rates. This is possible due to high-quality exposure measurements and long-term

follow-up of health outcomes of workers employed after radiation protection measures were put in place. The findings of the study will contribute to the verification and, if required, updating of occupational radiation safety standards. This information is relevant for the radiation protection of current and future uranium workers with low cumulative exposures and exposure rates. The study is expected to be completed in 2023.

5.3.2.4 Findings – Health studies of uranium processing workers

The International Pooled Analysis of Uranium Processing Workers study and the Canadian Uranium Workers Study will advance the international understanding of radiation risk and support the international radiation protection framework, especially for radon. The findings will also support the CNSC's mandate to protect the health and safety of workers and to disseminate objective scientific information.

5.4 Findings – Health studies

Reviewing and conducting health studies and reports is an important component of ensuring that the health of people living near or working in nuclear facilities is protected. CNSC staff have considered the most recent international radiation epidemiology reports, our own information and scientific publications, as well as various community, provincial, and national studies and reports for their evaluation of the health of populations living or working near the CFM facility.

The population and community health studies and reports indicate that common causes of death among the surrounding populations include circulatory diseases, cancers, respiratory diseases and dementia. Major health risk factors such as smoking, excess body weight, alcohol consumption and poor diet may account for the occurrence of these diseases.

The health studies and reports presented in this section provide a snapshot of the health of people living near the CFM facility. Based on the assessed exposure and health data, CNSC staff have not observed and do not expect to observe any adverse health outcomes attributable to the CFM facility.

6.0 OTHER ENVIRONMENTAL MONITORING PROGRAMS

Several monitoring programs are carried out by other levels or bodies of government and are reviewed by CNSC staff to confirm that the environment and the health of persons around the facility in question are protected. A summary of the findings of these programs is provided below.

6.1 National Pollutant Release Inventory

ECCC operates the National Pollutant Release Inventory (NPRI) [76], which is Canada's public inventory of pollutant releases, disposals and transfers, tracking over 320 pollutants from over 7,000 facilities across the country. Reporting facilities include factories that manufacture a variety of goods, mines, oil and gas operations, power plants and STPs. Information that is collected includes:

- releases from facilities to air, water or land
- disposals at facilities or other locations
- transfers to other locations for treatment and recycling
- facilities' activities, location and contacts
- pollution prevention plans and activities [77]

CFM does not report to the NPRI because its releases are below the reporting thresholds.

CNSC staff conducted a search of the NPRI database and found that five facilities in the Port Hope area, including Cameco's PHCF and Canadian Nuclear Laboratories' Port Hope Waste Management Facility, report to the NPRI. While reviewing the data, CNSC staff did not identify any trends or unusual results. Radionuclides are not included in the inventory of pollutants in the NPRI database. The CNSC receives radionuclide loadings from the licensees through other means, i.e., annual and quarterly reports. This information has been used in this report, and the complete dataset is available for download on the CNSC's Open Government Portal [78].

6.2 Health Canada's Canadian Radiological Monitoring Network and Fixed Point Surveillance Program

Health Canada's Radiation Protection Bureau manages the Canadian Radiological Monitoring Network (CRMN) [79]. The CRMN routinely collects drinking water, precipitation, atmospheric water vapour, air particulate, and external gamma dose for radioactivity analysis at 26 monitoring locations. The closest CRMN monitoring location to CFM is in Port Hope. The results at the Port Hope station for 2021 are consistent with data from previous years and are well below the public dose limit of 1 mSv per year.

In addition, Health Canada has complemented the CRMN with the Fixed Point Surveillance (FPS) Network [80]. The FPS network functions as a real-time radiation detection system designed to monitor public dose from radioactive materials in the air, including atmospheric emissions associated with nuclear facilities and activities both nationally and internationally. Monitoring stations continuously measure gamma radioactivity levels from ground-deposited (ground-shine) and airborne contaminants.

Health Canada measures the radiation dose rate as Air KERMA (Kinetic Energy Released in unit Mass of Material), reported as nanogray per hour (nGy/h) of absorbed dose. These measurements

are conducted every 15 minutes at 79 sites of its FPS network across the country. Air KERMA is also measured for 3 radioactive noble gases associated with nuclear fission, which may escape into the atmosphere during normal operation of nuclear facilities. These 3 noble gases are argon-41, xenon-133 and xenon-135. CNSC staff converted the absorbed dose rate to an effective dose, reported in mSv per year, which allows for comparison to annual background dose estimates and the regulatory public dose limit.

At the time of writing the report, the October to December 2021 results were not available. The January to September 2021 total external gamma doses reported for the FPS network at the station in Port Hope are similar to the Canadian average for natural background from gamma (the range is 0.007 to 0.027 mSv per year). These results indicate that total external gamma dose at this station is not significantly influenced by activities at CFM. Further evidence of this is provided by the extremely low activity levels reported for the noble gases, as outlined in table 6.1. All of the results are significantly below the public dose limit of 1 mSv per year.

Table 6.1: Annual external gamma doses (mSv/year) for 2021 at the FPS network monitoring stations near CFM [80]

Monitoring stations near CFM	External gamma dose (mSv/year)			
	All gamma sources [a][b]	Monitored noble gases (fission products)		
		Argon-41	Xenon-133	Xenon-135
Port Hope	0.012	*	*	*

* No data is reported when results are below the minimum detectable dose.

[a] Assumptions: Adult located at monitoring station for 24 hours a day, 365 days per year. Air KERMA in nanogray corrected. Total dose: 0.69 Sv for every gray of absorbed dose measured. Argon-41: 0.74; Xenon-133: 0.75; Xenon-135: 0.67.

[b] External gamma dose takes into account data from January 2021 to September 2021.

7.0 FINDINGS

This EPR report focused on items of current Indigenous, public and regulatory interest, including physical stressors and airborne and waterborne releases from ongoing operations at CFM. CNSC staff have found that the potential risks from physical stressors, as well as from radiological and hazardous releases to the atmospheric, terrestrial, aquatic and human environments from CFM, are low to negligible.

7.1 CNSC staff's follow-up

The following bullet point summarizes CNSC staff's comments regarding the EP measures implemented by Cameco for the CFM facility. It is not expected to change CNSC staff's findings and is included for transparency with Indigenous Nations and communities and the public. It is CNSC staff's expectation that Cameco will:

- conduct a thorough identification and description of both federally and provincially listed species potentially present at the CFM site (section 3.2.2). CNSC staff expect that Cameco will include this information in the next ERA revision.

7.2 CNSC staff's findings

CNSC staff's findings from this EPR report may inform and support staff recommendations to the Commission in future licensing and regulatory decision making that pertain to the CFM facility. These findings are based on CNSC staff's reviews of documents associated with CFM, such as the submitted ERA documentation and the conduct of compliance verification activities, including the review of annual and quarterly reports, and onsite inspections. CNSC staff also reviewed the results from various relevant or comparable health studies and other EMP conducted by other levels of government to substantiate their findings. CNSC staff also conducted IEMP sampling around CFM in 2014, 2015, 2017 and 2020.

Based on CNSC staff's assessment of Cameco's documentation, CNSC staff have found that the potential risks from physical stressors, as well as from radiological and hazardous releases to the atmospheric, aquatic, terrestrial and human environments from the CFM facility, are low to negligible. The potential risks to the environment from these releases or stressors are similar to natural background, and the potential risks to humans health are indistiguishable to health outcomes in the general public. Therefore, CNSC staff have found that Cameco has and will continue to implement and maintain effective EP measures to adequately protect the environment and the health of persons. CNSC staff will continue to verify and ensure that, through ongoing licensing and compliance activities and reviews, the environment and the health of persons are protected.

ABBREVIATIONS

kg	kilogram
L	litre
m	meter
mGy	milligray
mSv	millisievert
nGy	nanogray
µGy	microgray
µSv	microsievert

ACRONYMS

AECB	Atomic Energy Control Board
AL	action level
ALARA	as low as reasonably achievable
CANU	Canadian Uranium Workers Study
CCME	Canadian Council of Ministers of the Environment
CEAA 1992	*Canadian Environmental Assessment Act*
CEAA 2012	*Canadian Environmental Assessment Act*, 2012
CFM	Cameco Fuel Manufacturing Inc.
CMD	Commission member document
CNSC	Canadian Nuclear Safety Commission
COPC	contaminant of potential concern
CRMN	Canadian Radiological Monitoring Network
CSA	Canadian Standards Association
DRL	derived releases limit
EA	environmental assessment
EBRL	exposure-based release limit
ECA	environmental compliance approval
ECCC	Environment and Climate Change Canada
EMP	environmental monitoring program
EMS	environmental management system
EP	environmental protection
EPP	environmental protection program

EPR	environmental protection review
ERA	environmental risk assessment
FPS	Fixed Point Surveillance
GHG	greenhouse gas
HHRA	human health risk assessment
HKPR	Haliburton, Kawartha, Pine Ridge
IA	impact assessment
IAA	*Impact Assessment Act*
IEMP	Independent Environmental Monitoring Program
INWORKS	International Nuclear Worker Study
ISO	International Organization for Standardization
LCH	licence conditions handbook
LHIN	Local Health Integration Network
NPRI	National Pollutant Release Inventory
NSCA	*Nuclear Safety and Control Act*
MECP	Ministry of the Environment, Conservation and Parks
PDP	preliminary decommissioning plan
PHCF	Port Hope Conversion Facility
PWQO	Provincial Water Quality Objective
ROR	regulatory oversight report
SAR	species at risk
SEU	slightly enriched uranium
STP	sewage treatment plant
TCE	trichloroethylene
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VC	valued component
VOC	volatile organic compound

REFERENCES

[1] Cameco Corporation, "Cameco Fuel Manufacturing Preliminary Decommissioning Plan," May 2021. e-doc: 6556291.

[2] Cameco Corporation, "2012 Annual Compliance Monitoring & Operational Performance Report," March 2013. e-doc: 4114972.

[3] Cameco Corporation, "2013 Annual Compliance Monitoring & Operational Performance Report," March 2014. e-doc: 4413018.

[4] Cameco Corporation, "2014 Annual Compliance Monitoring & Operational Performance Report, March 2015," e-doc: 4723782.

[5] Cameco Corporation, "2015 Annual Compliance Monitoring & Operational Performance Report," March 2016. e-doc: 4976806.

[6] Cameco Corporation, "2016 Annual Compliance Monitoring & Operational Performance Report," March 2015. e-doc: 52220871.

[7] Cameco Corporation, "2017 Annual Compliance Monitoring & Operational Performance Report," March 2018, e-doc: 5496492.

[8] Cameco Corporation, "2018 Annual Compliance Monitoring & Operational Performance Report," March 2019. e-doc: 5868197.

[9] Cameco Corporation, "2019 Annual Compliance Monitoring & Operational Performance Report," March 2020. e-doc: 6270647.

[10] Cameco Corporation, "2020 Annual Compliance Monitoring & Operational Performance Report," March 2021. e-doc: 6527702.

[11] Cameco Corporation, "2021 Annual Compliance Monitoring & Operational Performance Report," March 2022. e-doc: 6768304.

[12] Cameco Corporation, "Environmental Risk Assessment for the Cameco Fuel Manufacturing Facility," August 2016. e-doc: 5135069.

[13] Cameco Corporation, "Review of the Environmental Risk Assessment for Cameco Fuel Manufacturing," May 2021. e-doc: 6562756.

[14] Cameco, "Cameco Fuel Manufacturing Renewal of Licence FFOL-3641.0/2023 for a 20-year term Revision 1," October 2021. e-doc: 6654789.

[15] Cameco, "Justification for Licence Term and Production Increase for Cameco Fuel Manufacturing," December 2021. e-doc: 6654801.

[16] Cameco Corporation, "Cameco Fuel Services Documents," https://www.camecofuel.com/library/media-library/documents?category=153, 2021.

[17] Government of Canada, "Canadian Environmental Assessment Act (Repealed, 2012, c. 19, s. 66)," 1992. https://laws-lois.justice.gc.ca/eng/acts/c-15.2/index.html

[18] Government of Canada, "Canadian Environmental Assessment Act, 2012 (Repealed, 2019, c. 28 s. 9)," 2012. https://laws-lois.justice.gc.ca/eng/acts/C-15.21/

[19] Government of Canada, "Impact Assessment Act (c. 28, s. 1)," 2019. https://laws-lois.justice.gc.ca/eng/acts/I-2.75/

[20] CNSC, "BMD 95-145 - Apppendix A - Canadian Environmental Assessment Act Screening Report," October 1995. e-doc: 3004958.

[21] Board Meeting Minutes, "Meeting Number 254," October 1995. e-doc: 3004938.

[22] Government of Canada, "Nuclear Safety and Control Act (S.C. 1997, c.9)," amended January 1, 2017. https://laws-lois.justice.gc.ca/eng/acts/n-28.3/page-1.html#h-368751

[23] CNSC, "EA Screening Report, Environmental Assessment of the Proposed SEU (with BDU) CANDU Fuel Production, at Zircatec Precision Industries Inc's Facility in Port Hope, Ontario," March 2008. e-Doc: 3239633.

[24] CNSC, "Information and Recommendations from Canadian Nuclear Safety Commission Staff in the Matter of Proposed SEU (with BDU) CANDU Fuel Production, at Zircatec Precision Industries Inc.'s Port Hope Facility," CMD-08-H2, January 2008. e-Doc: 3475057.

[25] CNSC, "Record of Proceedings, Including Reasons for Decision in the Matter of Zircatec Precision Industries Inc. Environmental Assessment Screening for the Proposed SEU CANDU Fuel Production at Zircatec's Facility in Port Hope, Ontario," January 2008. e-Doc: 3215660.

[26] CNSC, "Quality Assurance Study of Follow-Up Programs," March 2010. e-Doc: 3508293.

[27] CNSC, "CNSC Staff Acceptance of Cameco Fuel Manufacturing Preliminary Decommissioning Plan," September 2021. e-doc: 6619513.

[28] CNSC, "REGDOC-2.9.1, Environmental Protection: Environmental Principles, Assessments and Protection Measures," 2020. http://nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc2-9-1-vol1-2/index.cfm

[29] CSA Group, CSA N288.1-14, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities," Update No.1, 2014.

[30] CSA Group, CSA N288.4-10, "Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills, Update No.2,," May 2015.

[31] CSA Group, CSA N288.5-11, "Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills," May 2010.

[32] CSA Group, CSA N288.6-12, "Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills," June 2012.

[33] CSA Group, CSA N288.7-15, "Groundwater Protection Programs at Class I Nuclear Facilities and Uranium Mines and Mills," June 2015.

[34] CSA Group, CSA N288.8-17, "Establishing and Implementing Action Levels for Releases to the Environment from Nuclear Facilities," February 2017.

[35] CNSC, "REGDOC-3.1.2, Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills, 2018," http://www.nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc3-1-2-v1/index.cfm

[36] CNSC, "Radiation Protection Regulations (SOR/2000-203)," 2000. https://laws-lois.justice.gc.ca/eng/regulations/sor-2000-203/page-1.html

[37] CNSC, "Licence Conditions Handbook - Cameco Fuel Manufacturing FFOL-3641-00/2022," e-doc: 6625396.

[38] CNSC, "Regulatory Oversight Reports," last updated on July 6, 2021. http://nuclearsafety.gc.ca/eng/resources/publications/reports/regulatory-oversight-reports/index.cfm

[39] Cameco Corporation, "Environmental Protection Program for Cameco Fuel Manufacturing, 2021," e-doc: 6633220.

[40] CNSC, "Nuclear Fuel Facility Licence, Cameco Corporation Fuel Manufacturing Facility, FFL-3641.00/2023," March 1, 2022. e-doc :6625390.

[41] Government of Canada, "Canadian Environmental Protection Act, 1999 (c. 33)," 1999. https://laws-lois.justice.gc.ca/eng/acts/c-15.31/

[42] Government of Canada, "Notice with Respect to Reporting of Greenhouse Gases for 2016," https://gazette.gc.ca/rp-pr/p1/2016/2016-12-10/html/notice-avis-eng.html

[43] Ministry of the Environment, Conservation and Parks, "Ontario Regulation 390/18: Greenhouse Gas Emissions: Quantification, Reporting, and Verification, 2021," https://www.ontario.ca/laws/regulation/180390

[44] CNSC, "Memorandum of Understanding between Environment Canada and the Canadian Nuclear Safety Commission," 2003. http://www.nuclearsafety.gc.ca/eng/pdfs/MoU-Agreements/June-2012-MOU-between-CNSC-and-Environment-Canada_e.pdf

[45] Ontario Ministry of the Environment, "Ontario Air Standards for Uranium and Uranium Compounds," 2011.

[46] SENES, "Environmental Review of the Zircatec Port Hope Fuel Fabrication Facility, Project No. 34406-5," 2007.

[47] Cameco, "2020 CFM Surface Water and Groundwater," 2021. e-doc: 6602728.

[48] Ontario Ministry of the Environment, "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act," https://www.ontario.ca/page/soil-ground-water-and-sediment-standards-use-under-part-xv1-environmental-protection-act

[49] Province of Ontario, "Water management: policies, guidelines, provincial water quality objectives - Table of PWQOs and Interim PWQOs.," https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives

[50] Canadian Council of Ministers of the Environment, "Canadian Water Quality Guidelines for the Protection of Aquatic Life," 1999.

[51] "Candian Council of Ministers of the Environment," Candian Soil Quality Guidelines for the Protection of Environmental and Human Health, http://ceqg-rcqe.ccme.ca/en/index.html#void

[52] Cameco, "Incremental Soil Concentration Associated with Proposed Production Increase," March 2022. e-doc: 6759729.

[53] CNSC, "Independent Environmental Monitoring Program (IEMP)," 2021. http://www.nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/port-hope.cfm

[54] CNSC, "Health Studies," May 5, 2021. http://www.nuclearsafety.gc.ca/eng/resources/health/index.cfm

[55] Haliburton, Kawartha, Pine Ridge District Health Unit, "Community Health Summary," Fall 2020.

[56] Haliburton, Kawartha, Pine Ridge District Health Unit, "Health Profile," October 2017.

[57] Cancer Care Ontario, "Ontario Cancer Profiles," https://www.cancercareontario.ca/en/data-research/view-data/cancer-statistics/ontario-cancer-profiles

[58] Statistics Canada, "Casuses of Death and Life Expectancy, 2016, June 2018," https://www150.statcan.gc.ca/n1/daily-quotidien/180628/dq180628b-eng.htm

[59] United Nations Environment Programme, "Radiation: Effects and Sources, 2016," https://wedocs.unep.org/handle/20.500.11822/7790

[60] ICRP, "The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).," 2007.

[61] United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources, Effects and Risks of Ionizing Radiation. UNSCEAR 2016 Report to the General Assembly. Annex D: Biological effects of selected internal emitters – uranium," 2017. http://www.unscear.org/docs/publications/2016/UNSCEAR_2016_Annex-D.pdf

[62] Dupree-Ellis E., Watkins J., Ingle J. N., & Phillips J., "External radiation exposure and mortality in a cohort of uranium processing workers. American Journal Epidemiology, Vol. 152, Issue 1, pp. 91-95," 2000.

[63] Kreuzer M., Dufey F., Laurier D., Nowak D., Marsh J. W., Schnelzer M., Sogl M., & Walsh L., "Mortality from internal and external radiation exposure in a cohort of male German uranium millers, 1946–2008, International Archives of Occupational Environmental Health, Vol. 88, Issue 4, pg. 431-441," 2015.

[64] Silver S. R., Bertke S. J., Hein M. J., Daniels R. D., Fleming D. A., Anderson J. L., Pinney S. M., Hornung R. W., & Tseng C. Y., "Mortality and ionising radiation exposures among workers employed at the Fernald Feed Materials Production Center (1951–1985), Occupational & Environmental Medicine, Vol. 70 Issue 7, pp. 453–463," 2013.

[65] CNSC, "INFO-0812, Setting Radiation Requirements on the Basis of Sound," Science: The Role of Epidemiology, 2011.

[66] Zablotska L. B., Lane R. & Frost S. E., "Mortality (1950-1999) and Cancer Incidence (1969-1999) of Workers in the Port Hope Cohort Study Exposed to a Unique Combination of Radium, Uranium, and Y-Ray Doses," BMJ Open, Vol. 3, Issue 2,, 2013.

http://nuclearsafety.gc.ca/eng/resources/research/technical-papers-and-articles/2013/morality-and-cancer-incidence-of-workers-in-port-hope.cfm

[67] Ashmore J. P., Krewski D., Zielinski J. M., Jiang H., Semenciw R., & Band P. R., "First analysis of mortality and occupational radiation exposure based on the National Dose Registry of Canada," American Journal of Epidemiology, Vol. 148, Issue 6, 1998.

[68] Sont W. N., Zielinski J. M., Ashmore J. P., Jiang H., Krewski D., Fair M. E., Band P. R., & Letourneau E. G., "First analysis of cancer incidence and occupational radiation exposure based on the National Dose Registry of Canada," American Journal of Epidemiology, Vol. 153, Issue 4, pg. 309-318, 2001.

[69] Health Canada, "Canadian Radiological Monitoring Network," 2019. https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/understanding/measurements.html#a2

[70] K. Leuraud, D. B. Richardson, E. Cardis, R. D. Daniels, M. Gillies, J. A. O'Hagan, G. B. Hamra, R. Haylock, D. Laurier, M. Moissonnier, M. K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, "Ionising Radiation and Risk of Death from Leukaemia and Lymphoma in Radiation-Monitored Workers: An International Cohort Study," *The Lancet Haematology*, vol. 2, no. 7, pp. 276-281, 2015.

[71] D. Laurier, D. B. Richardson, E. Cardis, R. D. Daniels, M. Gillies, J. O'Hagan, G. B. Hamra, R. Haylock, K. Leuraud, M. Moissonnier, M. K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, "The International Nuclear Workers Study): A Collaborative Epidemiological Study to Improve Knowledge about Health Effects of Protracted Low-Dose Exposure," *Radiation Protection Dosimetry*, vol. 173, no. 1-3, pp. 21-25, 2017.

[72] Richardson, D. B., Cardis, E., Daniels, R. D., Gillies, M., O'Hagan, J. A., Hamra, G. B., Haylock, R., Laurier, D., Leraud, K., Moissonnier, M., Schubauer-Berigan, M. K., Thierry-Chef, I., and Kesminiene, A, "Risk of Cancer from Occupational Exposure to Ionising Radiation: Retrospective Cohort Study of Workers in France, the United Kingdom, and the United States," *BMJ*, 2015.

[73] D. B. Richardson, E. Cardis, R. D. Daniels, M. Gillies, R. Haylock, K. Leuraud, D. Laurier, M. Moissonnier, M.K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, "Site-specific Solid Cancer Mortality After Exposure to Ionizing Radiation A Cohort Study of Workers," *Epidemiology*, vol. 29, no. 1, pp. 31-40, 2019.

[74] P. Thompson, J. Burtt, M. Ilin, R. Lane, M. Phaneuf and P. Reinhardt, "Use of a Weight of Evidence Approach to Determine the Likelihood of Adverse Effects on Human Health from the Presence of Uranium Facilities in Port Hope, Ontario," Journal of Environmental Protection, Vol. 2, pp. 1149-1161, 2011. doi: 10.4236/jep.2011.29134..

[75] Chen J., Moir D., Lane R., & Patsy Thompson, "An Ecological Study of Cancer Incidence in Port Hope, Ontario from 1992 to 2007," Journal of Radiological Protection, Vol 33. no. 1, 2013. http://nuclearsafety.gc.ca/eng/resources/research/technical-papers-and-articles/2013/2013-ecological-study-cancer-port-hope-1992-2007.cfm

[76] Environment and Climate Change Canada, "National Pollutant Release Inventory," 2021. https://www.canada.ca/en/services/environment/pollution-waste-management/national-pollutant-release-inventory.html

[77] Environment and Climate Change Canada, "National Pollutant Release Inventory - About the National Pollutant Release Inventory, 2021," https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/about-national-pollutant-release-inventory.html

[78] Government of Canada, "Open Government - Radionuclide Release Datasets," 2021. https://open.canada.ca/data/en/dataset/6ed50cd9-0d8c-471b-a5f6-26088298870e

[79] Health Canada, "Canadian Radiological Monitoring Network, 2021," https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/understanding/measurements.html#a2

[80] Health Canada, "Fixed Point Surveillance Network, 2021," https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/understanding/measurements.html#a1