Review of the Environmental Risk Assessment for Port Hope Conversion Facility

Fuel Facility Operating Licence FFOL-3631.00/2027

May 15, 2023

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1.0 Introduction

In accordance with its licence requirements, the Port Hope Conversion Facility (PHCF) maintains an environmental risk assessment (ERA) in accordance with the standardized requirements of CSA N286.6-12: *Environment Risk Assessments at Class 1 Nuclear Facilities and Uranium Mines and Mills* (N288.6-12). An ERA is a systematic process used to identify and assess the potential risk posed by contaminants and physical stressors in the environment on biological receptors. There are two parts to an ERA – an assessment of the facility's operations on human receptors through a human health risk assessment (HHRA) and an assessment on non-human environmental receptors through an ecological risk assessment (EcoRA).

PHCF completed its ERA in March 2016, which found there were no undue risks to the environment or to human health as a result of PHCF operations. A summary of the ERA and a redacted version of the ERA are available on the Cameco community website (www.camecofuel.com/library/media-library). Under Clause 11 of N288.6-12 Cameco is required to review the ERA for the PHCF every five years. The current review was undertaken in 2021 and 2022.

1.1 Scope of Review

As per N288.6-12 (R2017) Clause 11.1:

> *A nuclear facility shall review its ERA to verify its applicability, and shall update it as necessary, consistent with the overall iterative process for ERAs.*
>
> *The purpose of the periodic review of the ERA is to identify and assess any risks that might have emerged since the last ERA review. This review can indicate that the potential for risks is substantively the same and therefore that the ERA does not require changes. Conversely, the review can identify new risks or highlight changes in the risk assessment variables that need to be updated to reflect the new risk profile. In either case, the review process and findings shall be thoroughly documented. A full or partial update of the ERA may be completed, as needed, to reflect important changes since the last ERA review.*

The present review of the ERA is to identify:

(a) changes that have occurred in site ecology or surrounding land use;
(b) changes to the physical facility or facility processes that have the potential to change the nature of facility effluent(s) and the resulting risks to receptors;
(c) new environmental monitoring data collected since the last ERA update;
(d) new or previously unrecognized environmental issues that have been revealed by the EMP;
(e) scientific advances that require a change to ERA approaches or parameters; and
(f) changes in regulatory requirements pertinent to the ERA.

In addition, specific comments (CNSC, 2017) from CNSC staff regarding the March 2016 ERA have been considered and addressed in the current review. The purpose of the review is to evaluate the applicability of the final conclusions of the 2016 for the ongoing operations of the PHCF. Under the current operating licence, operations of the PHCF include the Vision in Motion (VIM) project, Cameco's plan to clean up and renew the PHCF. The current review recognizes that during the ongoing execution of the VIM project, the site is under a constant state of improvements, all of which are expected to positively impact the environmental interactions of the site. The purpose of this review was to determine whether there were any potential gaps which would significantly alter the conclusions and require addressing in the interim. As the various aspects of the project were in progress during this review, preliminary assessment of the changes has been included. Once the VIM project is complete, a new ERA will be completed in accordance with N288.6 and submitted to the CNSC for review and acceptance. The Environmental Protection Program will be revised in accordance with the new ERA.

1.2 Available Data and Information Sources

The following facility data and information were used in the current review of the ERA.

1. Environmental monitoring data 2015-2022
2. 2020 Emission Summary Dispersion Model
3. 2022 Emission Summary Dispersion Model
4. Facility Design Change records 2015-2022
5. 2016 Environmental Risk Assessment
6. 2016 Derived Release Limit report
7. Annual Compliance Reports 2015-2022
8. Annual Groundwater and Surface Water Reports 2015-2022
9. Applicable provincial and federal guidelines for environmental protection
10. Literature reviews to support specific disposition of CNSC staff comments

1.3 Report Organization

This report is structured as follows, based on the guidance in N288.6-12 (R2017) Clause 11.1 for review of an ERA:

Section 2 provides a review of site changes (physical facility and facility processes), site ecology, and surrounding land use. It also identified opportunities for enhancing the site characterization.

Section 3 provides a review of the environmental monitoring data collected since the 2016 ERA. An updated screening of contaminants of potential concern (COPC) is provided.

Section 4 provides a review of environmental issues revealed by the 2016 ERA and a review of other issues identified with the methodology of the 2016 ERA.

Section 5 provides a review of scientific advances and changes in regulatory requirements that may impact the ERA approaches or parameters.

Section 6 provides a review of the information presented in Sections 2-5 and the impact of these issues on problem formulation in the ERA.

Section 7 provides an evaluation of the ongoing applicability of the final conclusions of the 2016 ERA.

2.0 Review of Site Characterization

This section provides a description of the review completed to identify changes that have occurred to site ecology or surrounding land use, changes to the physical facility or facility processes that have the potential to change the nature of facility effluents(s) and the resulting risks to receptors as recommended by Clause 11.1 (a) and (b) of N288.6-12. It also provides a description of information requested by CNSC staff to enhance the overall robustness of the site characterization and the conceptual site model.

2.1 Site Ecology and Surrounding Land Use

As described in the 2016 ERA, Cameco owns and/or leases 9.6 acres on which the secured area of the PHCF is situated. Since the 2016 ERA, Cameco permanently terminated its licensed activities on the Centre Pier property, which involved the transfer of stored wastes to the Long-Term Waste Management Facility (LTWMF) in Port Hope, demolition of the Centre Pier buildings and transfer of the demolition debris to the LTWMF and installation of flood-protection. The care and control of the property was transferred to Canadian Nuclear Laboratories (CNL) in July 2019.

In the immediate area of the PHCF, CNL has subsequently isolated access to the Port Hope harbour and is using the Centre Pier as a staging area for its ongoing remediation of the harbour as part of the Port Hope Area Initiative (PHAI).

In the surrounding area, the PHAI has commenced the clean-up of low-level radioactive waste within the MPH, including remediation of the former waterworks properties to the west of the facility, the viaducts northeast of the facility, residential properties to the north of the facility and the Centre Pier east of the facility. PHCF is located in a general employment zoned area of the MPH with floodplain overlay zoning along the east property boundary.

2.2 Changes to the Physical Facility and Facility Processes

In order to assess the changes to the PHCF between 2016 and 2022, a review of the facility design control files, annual reports and management review reports was carried out.

The following changes were made at the facility which had an impact on environmental performance. All these changes moved performance in a positive direction.

- Demolition of buildings on the Centre Pier
- Ongoing removal of obsolete process equipment and contaminated building material from various buildings as part of Vision in Motion (VIM)
- Ongoing relocation of utilities and supporting infrastructure as part of VIM, including relocation of the liquid hydrogen station
- Installation of new storm sewer infrastructure and an oil/grit separator with a new harbour outlet at the southernmost portion of the facility
- Disposal of accumulated waste at the LTWMF or other appropriately permitted facility

- Rehabilitation of targeted sanitary sewer infrastructure to reduce groundwater infiltration
- Soil remediation in targeted areas of the facility
- Construction and commissioning of closed loop cooling water systems for the UF_6 and UO_2 plants
- Rerouting of air emissions in the UO_2 plant to eliminate the UO_2 baghouse

The changes related to VIM and accumulated waste have an impact on the sources of gamma radiation at the facility, which resulted in a change in the critical receptor used for estimating dose to the public in 2019. Sanitary sewer rehabilitation has reduced the infiltration of contaminated groundwater into the sanitary discharge from the facility, which impacts total uranium loadings discharged to the sanitary sewer.

In the fall of 2022, the UO_2 plant commissioned its closed-loop cooling water system and severed the tie-ins to the harbour cooling water supply and cooling water return, eliminating the potential for uranium or other contaminant discharge to the harbour and reducing the overall thermal loading to the Port Hope harbour. The closed-loop cooling system for the UF_6 plant is scheduled to come online in 2023, which will eliminate operations-related discharges to the harbour and the associated chemical and thermal impacts as well as the physical impacts of the cooling water intake.

2.3 Opportunities for Enhancement of Site Characterization

Site characterization information was documented in Section 2 of the 2016 ERA. Additional information is provided to enhance the site characterization as part of this review of the 2016 ERA.

2.3.1 Information Regarding Site Selection

The development of land around the Port Hope harbour took place in the mid-to-late 1800's. The primary use of the land prior to 1932 was for agricultural products production/storage. Other industrial facilities were also located on the land, including a machine shop and a Florida rock phosphate processing plant. In 1932, Eldorado Gold Mines Limited selected the site for a new refining and extraction plant. The southern part of the current site, where the current UO_2 plant is located, includes land that was backfilled in a land reclamation project between 1940 and 1959. The land where the current UF_6 plant is located was a residential area prior to the plant's construction in the 1980's.

The nearest residence is approximately 200 m north of the facility on Alexander Street.

2.3.2 Information Regarding Topography

At the PHCF, the ground surface elevation generally increases northward away from Lake Ontario, rising from about elevation 76 m near the shoreline to an approximate elevation of 87 m near Hayward Street north of the UF_6 plant. The mean lake stage on Lake Ontario, and in the Port Hope harbour, has an approximate elevation of 75 m. South of the site, a breakwater exists along the shoreline and to the east of the site a steel sheet pile wall is present at the edge of the harbour.

2.3.3 Releases to the Environment

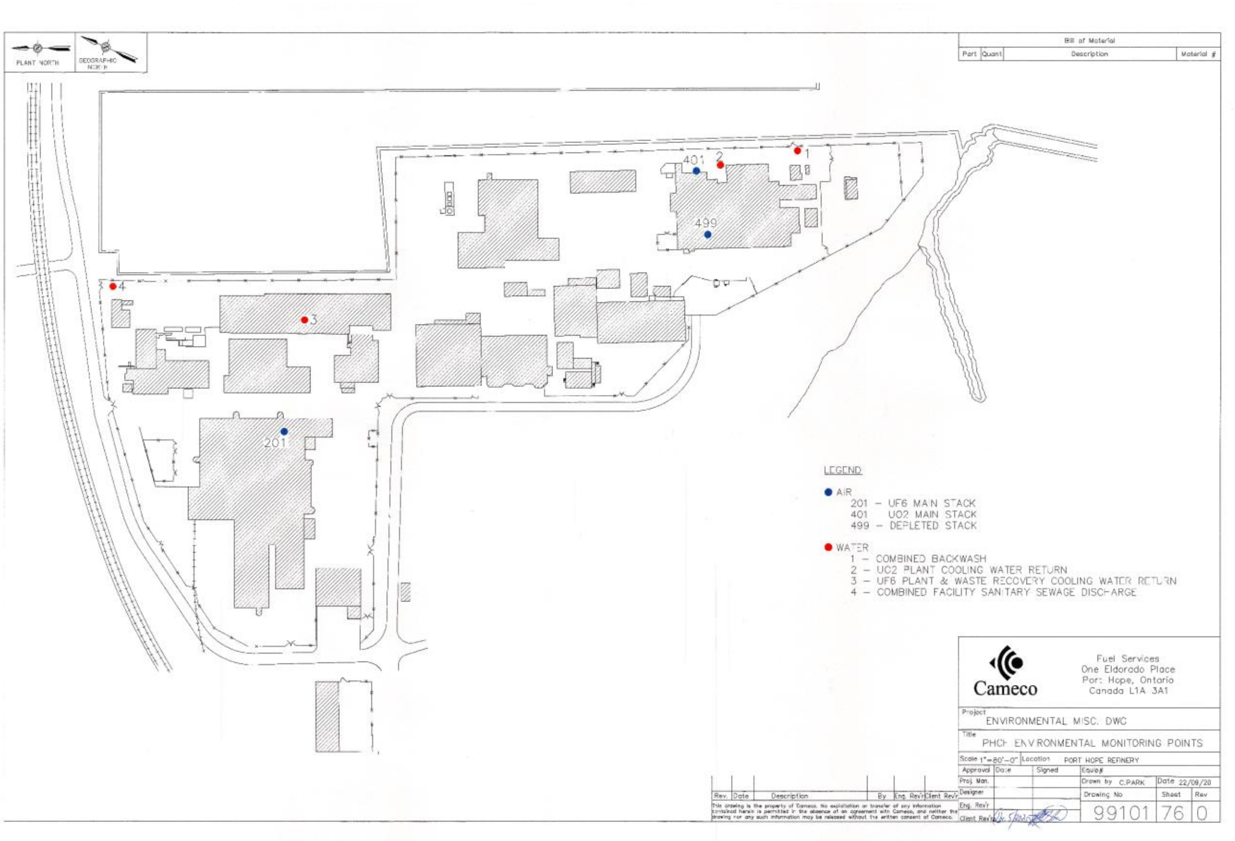
The primary air emissions associated with the PHCF are uranium, fluorides, ammonia and nitrogen oxides. These contaminant emissions are measured using source monitoring and/or estimated using available monitoring data. The main process stacks in the UF_6 plant and UO_2 plant are continuously sampled during operations. In the UF_6 main stack, fluoride and uranium emissions are monitored and in the UO_2 main stack, ammonia and uranium emissions are monitored. All other stacks and discharge points are sampled on an occasional or as requested basis.

The municipal sewage treatment plant processes the sanitary sewer discharges from the PHCF and sewage quality is defined by the municipal sewer-use by-law. The combined sanitary sewer discharge primarily consists of contributions from sanitary facilities, showering facilities, Powerhouse effluent (i.e. boiler blowdown, compressor cooling water, softener regeneration effluent) and condensates, among other items.

At the time of the review, PHCF cooling requirements were met by a closed loop cooling system for the UO_2 plant and the facility's harbour water intake located at the entrance to the Port Hope harbour. With the elimination of the UO_2 plant harbour cooling water return, the facility cooling water works currently includes two discharges. The combined backwash stream, consisting of contributions from the cooling water pumphouse and filter room associated with harbour water mechanical pre-treatment operations, discharges to the approach channel adjacent to building 25. The north cooling water return, consisting of UF_6 plant non-contact harbour and municipal water and a minor harbour water by-pass contribution from building 2, is discharged to the harbour turning basin. The balance of the once-through cooling system is being replaced with a closed loop cooling system in 2023, which will eliminate cooling water works harbour discharges in the near-term.

The environmental emission monitoring points from the PHCF are shown in Figure 1.

Figure 1 Environmental Emission Points from PHCF



Corresponding monitoring for COPCs in the environment was described in section 2.3 of the 2016 ERA.

2.3.4 Meteorological Statistics and Climate Setting

A review of available climatic data was carried out as part of this review. The long-term record of general meteorological conditions in the region and average climatic conditions of the PHCF facility are described by 30-year climate normals (1981-2010) from the closest Environment and Climate Change Canada (ECCC) climate station located in Cobourg (Climate ID 6151689 – Cobourg STP). The long-term averages of observed climate data at Cobourg station are summarized in Table 1.

The annual average daily temperature at Cobourg station is 7.5 degrees Celsius (°C), and monthly average air temperatures are at or below zero from December to March. January is the coldest month with a daily average of -5.6°C, while July is the warmest month with a daily average of 19.9°C. The extreme minimum temperature was -39°C (in January), while the extreme maximum temperature was 36°C (in July). Temperatures below -10°C have occurred in November through April, while temperatures above 30°C occur occasionally in May through August (IEC, 2021a).

Table 1 Cobourg Climate Normals (1981-2020) – Temperature

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-5.6	-4.3	-0.5	5.9	11.7	16.9	19.9	19.4	15.4	9	3.7	-2	7.5
Standard Deviation	3.2	2.1	1.5	1.3	1.6	1.4	1.2	1.3	1.3	1.0	1.2	2.6	1.0
Daily Max (°C)	-1.4	0	3.7	10.3	16.4	21.6	24.6	24.0	19.9	13.1	7.3	1.9	11.8
Daily Min (°C)	-9.7	-8.5	-4.6	1.5	6.9	12.1	15.2	14.9	10.8	4.8	0.1	-5.8	3.1
Extreme Max (°C)	13.0	13.0	20.0	26.0	29.0	31.5	**36.0**	34.0	30.0	24.0	18.0	15.5	
Extreme Min (°C)	**-39.0**	-27.8	-26.0	-12.0	-5.0	-1.0	5.0	1.0	-5.0	-10.0	-16.0	-29.0	
Days with Maximum Temperature													
<= 0 °C	16.9	13.6	7.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.5	49.9
> 0 °C	14.1	14.6	23.8	29.5	31.0	30.0	31.0	31.0	30.0	31.0	28.9	20.5	315.4
> 10 °C	0.3	0.2	3.0	14.0	28.8	30.0	31.0	31.0	29.7	23.4	7.7	0.8	199.9
> 20 °C	0.0	0.0	0.0	0.7	5.7	18.6	28.7	27.9	13.8	1.0	0.0	0.0	96.4
> 30 °C	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.3	0.0	0.0	0.0	0.0	1.1
> 35 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Days with Minimum Temperature													
> 0 °C	2.5	2.1	5.9	18.1	29.3	29.9	31.0	31.0	29.5	25.7	14.4	4.8	224.2
<= 2 °C	30.2	27.6	28.5	17.3	3.7	0.1	0.0	0.1	1.2	9.8	20.4	28.8	167.7
<= 0 °C	28.5	26.1	25.1	11.9	1.7	0.1	0.0	0.0	0.5	5.3	15.6	26.2	141.0
< -2 °C	24.8	22.4	19.0	4.7	0.1	0.0	0.0	0.0	0.1	1.0	8.8	20.3	101.0
< -10 °C	13.5	10.8	4.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	7.2	36.9
< -20 °C	3.3	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	5.2
< - 30 °C	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

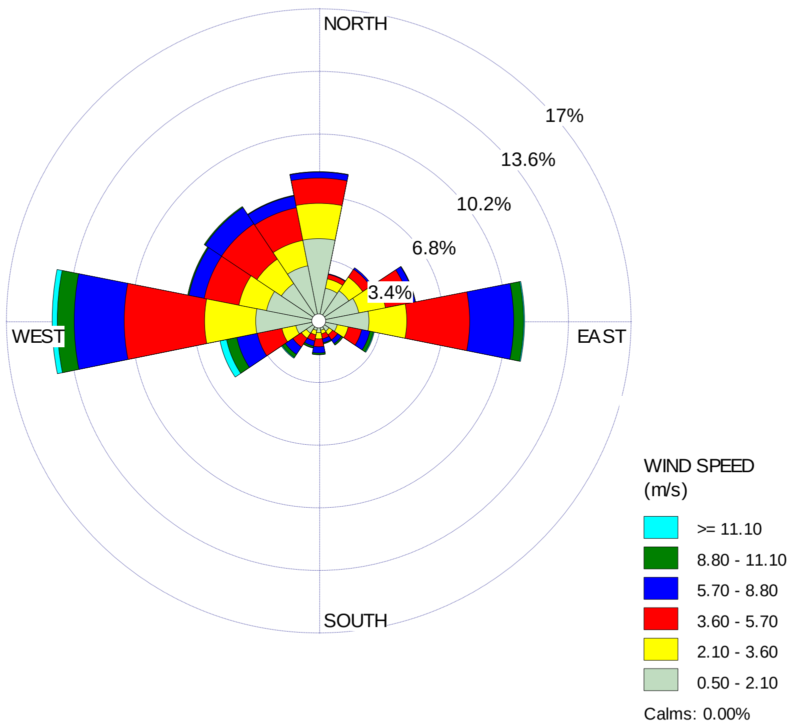
The monthly and annual precipitation observations at Cobourg station are summarized in Table 2. The average annual precipitation amount is 890.4 millimeters (mm), of which 793.9 mm falls as rain (i.e., 89 %). More than half of the total precipitation falls as rain between May and October, while the wettest month is September (average monthly rainfall of 93.2 mm). The greatest extreme daily precipitation also occurs in September at 73.4 mm. From November to April, most precipitation falls as snow, with January typically experiencing the heaviest snowfall (average monthly snowfall of 32.7 cm). The extreme daily snowfall occurs in February, while the extreme snow depth of 44 cm was recorded in January (IEC, 2021a).

Table 2 Cobourg Climate Normals (1981-2010) - Precipitation

Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	34.0	32.9	42.7	74.3	81.2	80.5	64.8	71.7	93.2	76.3	89.2	53.1	793.9
Snowfall (cm)	32.7	21.2	14.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4.0	22.7	96.5
Precipitation (mm)	66.7	54.1	56.8	76.2	81.2	80.5	64.8	71.7	93.2	76.3	93.2	75.8	890.4
Extreme Daily Rainfall (mm)	65.0	31.0	49.5	46.1	53.0	52.5	62.5	70.0	**73.4**	51.0	54.8	40.0	
Extreme Daily Snowfall (cm)	20.0	**35.6**	17.0	17.3	0.0	0.0	0.0	0.0	0.0	0.0	13.2	25.4	
Extreme Snow Depth (cm)	44.0	35.0	22.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	25.0	
Days with Rainfall													
>= 0.2 mm	4.6	4.2	6.5	10.7	10.9	9.8	8.5	10.0	10.0	11.6	11.3	6.6	104.8
>= 5 mm	2.4	2.1	3.2	4.9	5.5	5.2	4.0	4.2	5.5	5.3	5.7	3.6	51.6
>= 10 mm	1.2	1.3	1.4	2.5	2.9	2.9	2.0	2.1	3.2	2.4	3.4	1.9	27.1
>= 25 mm	0.2	0.1	0.2	0.2	0.3	0.6	0.6	0.7	0.7	0.4	0.7	0.2	4.8
Days with Snowfall													
>= 0.2 cm	7.0	4.6	3.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.9	4.6	21.2
>= 5 cm	2.6	1.7	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.8	7.8
>= 10 cm	1.1	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	3.2
>= 25 cm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Days with Precipitation													
>= 0.2 mm	11.2	8.3	9.3	11.2	10.9	9.8	8.5	10.0	10.0	11.6	12.1	10.8	123.6
>= 5 mm	5.0	3.7	4.4	5.1	5.5	5.2	4.0	4.2	5.5	5.3	6.1	5.5	59.5
>= 10 mm	2.4	2.0	2.0	2.6	2.9	2.9	2.0	2.1	3.2	2.4	3.4	2.8	30.7
>= 25 mm	0.2	0.2	0.2	0.2	0.3	0.6	0.6	0.7	0.7	0.4	0.6	0.3	4.9

According to the climatic data files from ECCC, climate normals for wind observations for the period 1981-2010 are not available for Cobourg climate station. However, hourly wind observations are recorded at the nearby automated Cobourg station (Climate ID 6151684) for the period 1994-2010 and have been used to characterize long-term wind patterns at the site. A wind rose showing the annual frequencies of wind speed and wind direction is provided in Figure 2. Winds are predominantly from the west and from the east (14.5 % and 11.2 % of the time, respectively) and annual average wind speed is 3.7 m/s (IEC, 2021a).

Figure 2 Cobourg Historical Weather (1994-2010) – Wind Rose



A further discussion of meteorological data as it pertains to air dispersion modelling is provided in section 3.2.1.

3.0 Review of Environmental Monitoring Data

This section provides a description of the review of the environmental monitoring data collected since the 2016 ERA as recommended by Clause 11.1 (c) of N288.6-12. It also provides a review of modelling information relevant to the determination of contaminants of potential concern (COPC). An updated COPC screening is provided.

3.1 Overview of Available Data

The Environmental Protection Program (EPP) for PHCF describes the effluent and environmental monitoring programs. The data from this program is used in this review of the ERA.

The following discharge data and environmental monitoring data were included in the ERA review.

3.1.1 Air Quality Data

Uranium emissions from the UF_6 main stack is sampled nearly continuously during operations using a TSI sampler, and the sample analyzed in the site laboratory. Fluoride emissions are continuously monitored by three stack monitors on the main stack of the UF_6 plant. The monitors continuously withdraw a sample of gas from the main stack, and then measure the fluoride concentration in the impingement solution.

Uranium and ammonia emissions from the UO_2 main stack is sampled nearly continuously through a filter and impingement train, the sample is analyzed in the site laboratory.

During depleted uranium dioxide production runs NOx emissions are monitored using a continuous emission monitor and ammonia is measured using an impinger system. Third-party stack sampling has also been used during depleted production.

Monitoring data from the process stacks is summarized in the quarterly and annual compliance monitoring and operational performance reports which are available on the Cameco community website (www.camecofuel.com/library/media-library). This data is shown in Table 3. All emissions in the review period 2015 – 2022 were below all regulatory limits. All emissions from the UO_2 plant were below action levels during the review period. In 2022, the uranium action level and the fluoride action level for the UF_6 main stack were exceeded in separate events. Action levels serve as an early warning of a condition that warrants further investigation and do not represent an impact on the public or the environment.

Table 3 Comparison of 2014 Effluent Quality Data with 2015-2022 Data

Constituent	Unit	2016 ERA		2015-2022			
		2014 Average	2014 Maximum	7-year Average	Range of Annual Averages		7-year Maximum
					Min	Max	
UF_6 Main Stack - Uranium	g/h	1.2	6.3	1.9	1.1	2.7	44.7
UF_6 Main Stack – Fluoride	g/h	13	99	21.6	10	30	273
UO_2 Main Stack - Uranium	g/h	1.2	3.9	0.7	0.5	1.2	5.2
UO_2 Main Stack – Ammonia	kg/h	2.2	5.4	2.0	1.4	2.4	7.7

The facility maintains an Emission Summary and Dispersion Modelling Report (ESDM) documents the air emissions sources at the PHCF and maintains the most current listing of all stacks/sources, their specifications and parameters emitted as required by Ontario Regulation 419/05 *Air Pollution – Local Air Quality* (O. Reg. 419/05). The 2016 ERA used air quality data extracted from the 2013 ESDM. The information for ammonia, fluorides, nitrogen oxides, carbon monoxide, uranium, suspended particulate matter, and magnesium was summarized and screened for COPCs in the 2016 ERA. For the external review of the ERA, the 2020 ESDM (IEC, 2021b) and the 2022 ESDM (IEC, 2023) were used in the same screening process as described in section 3.3. All contaminants not considered negligible under s.8 of O. Reg. 419/05 were included in the screening. From this screening, although it was below applicable criteria, uranium was carried forward as a COPC due to the facility operations and observations in environmental endpoints.

3.1.2 Water Quality Data

Waterborne effluents from the PHCF consist of two discharges associated with facility cooling water system operations and a discharge to the municipal sanitary sewer system. The production facility cooling water returns and the combined facility sanitary sewage discharge point are included in this program and are continuously sampled. Monitoring data from the effluent discharges is summarized in the quarterly and annual compliance monitoring and operational performance reports which are available on the Cameco community website (www.camecofuel.com/library/media-library). The data is further summarized in Table 4.

The cooling water system at PHCF is a once-through non-contact system and discharge of uranium through this system is not expected in normal operations. However, the intake and discharges are monitored continuously to confirm that there is no net loading of uranium to the cooling water. During the review period, the harbour was isolated from Lake Ontario using a wave attenuator in preparation for remediation of the harbour by CNL. The initiation of remediation activities in 2021 has coincided with the increase in concentration of COPCs in cooling at both the intake and the outfall.

The combined sanitary sewer discharge is sampled continuously on a time-proportional basis and facility inputs to this discharge include sanitary facilities, showering facilities, Powerhouse effluent (i.e. boiler blowdown, compressor cooling water, softener regeneration effluent) and condensates, among other items. Discharges from municipal facilities upstream of the PHCF also flows through the site system. During the review period, a daily sanitary sewer discharge action level was developed and implemented. This action level has been exceeded numerous times in recent years due to contaminated groundwater infiltration to the underground civil works for the sanitary sewer. Assessment of the discharge to sanitary sewer is included in section 3.2.2.

While included in the routine effluent monitoring program, discharges to the sanitary sewer and cooling water discharges in the context of release of contaminants of concern were not discussed in the 2016 ERA.

The discussion of effluent quality of cooling water in this ERA review is limited because at the time of the writing of this report, PHCF was constructing a closed-loop cooling system for both operating plants, which are anticipated to be put online late 2022/early 2023. Once this transition occurs the cooling water system will be decommissioned and cooling water works harbour discharges will be eliminated.

Table 4 Comparison of 2014 Effluent Quality Data with 2015-2022 Data

Sampling Location	Constituent	Unit	2014 Data		2015-2022			
			2014 Average	2014 Maximum	5-year Average	Range of Annual Averages Min	Range of Annual Averages Max	5-year Maximum
Sanitary Sewer	Uranium	mg/L	0.017	0.25	0.039	0.013	0.044	3.0
North Cooling Water	Uranium	mg/L	0.003	0.007	0.025	0.0025	0.11	0.52
	Fluoride	mg/L	0.13	4.3	0.13	0.07	0.19	0.76
	Ammonia	mg/L	0.13	0.34	0.09	0.02	0.16	0.84
	Nitrate	mg/L	0.80	1.4	0.90	0.78	1.0	2.2
	TSS	mg/L	14	91	15	8.2	20	150
	Arsenic	ug/L	1.2	2.0	7.2	1.1	30	100
	Copper	ug/L	3.5	13	3.5	2.5	4.5	12
	Lead	ug/L	0.5	3.7	0.84	0.33	1.8	8.4
	Nickel	ug/L	2.8	6.0	2.5	1.5	4.0	20
	Zinc	ug/L	2.0	15	2.2	1.5	2.8	25
South Cooling Water	Uranium	mg/L	0.003	0.008	0.02	0.0026	0.078	0.54
	Ammonia	mg/L	0.20	1.1	0.08	0.01	0.18	8.8
	Nitrate	mg/L	0.85	1.4	0.89	0.40	1.1	2.2
	TSS	mg/L	15	98	17	9.6	22	290

3.1.3 Environmental Monitoring Data

The environmental monitoring program is intended to collect data to monitor the impact of the airborne and aqueous discharges into the offsite receiving area in the vicinity of the PHCF by verifying concentrations of contaminants of potential concern in the airborne, terrestrial and aquatic receiving environments. This data is used to determine exposure point concentrations for comparison to screening criteria from available standards to confirm COPCs.

The atmospheric environmental monitoring program is intended to collect data for uranium and fluorides to assess whether airborne emissions from the PHCF may be detected at offsite locations in the vicinity of the facility. Data from the high volume (hi-vol) air samplers and dustfall monitoring were used in the validation of the model in the ESDM (IEC, 2021b).

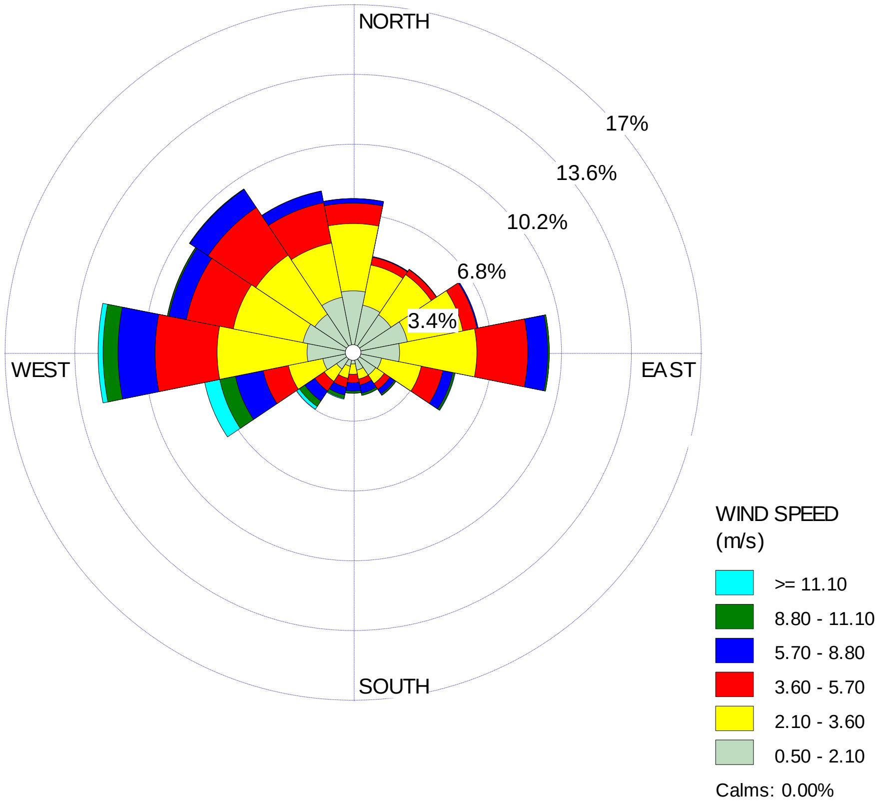
The 2016 ERA assessed groundwater data, soil data, surface water data, sediment data and gamma measurement data. This review of the ERA assessed groundwater data, soil data and surface water data available for the period 2015-2020 (CanNorth, 2021a). Gamma measurement data was not included in the ERA review, as this will be assessed in the 2023 Derived Release Limit report update.

3.2 Updated Modelling

3.2.1 Air Dispersion

As part of the review of the ERA, updated air dispersion modelling was completed for uranium (IEC, 2021a) using emissions data and model setup files from the 2020 Consolidated ESDM Report (IEC, 2021b). The site-specific meteorological data set used in the ESDM Report was prepared from 2013-2017 data at the Cobourg surface by the Ontario Ministry of Environment, Conservation and Parks (MECP) using AERMET. Figure 3 shows the wind rose plot based on the wind direction and wind speed data from the MECP meteorological data set. The predominant wind is from the west (12.4 % of time) and the annual average wind speed is 3.2 m/s. The wind distribution shown in Figure 3 is consistent with the long-term wind pattern at the automated Cobourg ECCC station (Figure 2). Overall, the wind data used in the updated dispersion modelling is representative of long-term climate in the region, and of the current local wind conditions at the site. Therefore, wind data set used in the updated modelling is considered suitable for dispersion modelling at the PHCF site (IEC, 2021a).

Figure 3. PHCF Air Dispersion Modelling (2013-2017)-Wind Rose



As the meteorological data set was prepared by the MECP and is acceptable for determining compliance with Ontario Regulation 419/05 (O.Reg. 419/05), this lends confidence to the meteorological data. The use of this dataset addresses a CNSC staff comment regarding the 2016 ERA (CNSC, 2016). Furthermore, any uncertainty with the data set can be examined through model validation, which is discussed below.

The uranium emission rates from the ESDM Report are replicated in Table 5, along with the source parameters used in the model. The building setup in the existing model files was used to run the building downwash model, BPIP-Prime. The emission rates from the production main stacks were based on stack testing. Emission rates for all other sources are based on stack testing, emission factors, engineering calculations or mass balance that are appropriate for the source in accordance with acceptable methods for assessing compliance with O.Reg. 419/05 standards.

Table 5: Model Source Parameters and Uranium Emission Rates

Source ID	Stack Volumetric Flow Rate (m^3/s)	Stack Gas Exit Temp. (deg C)	Stack Inner Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Source Coordinates UTM (m) [1] Easting, Northing	Maximum Emission Rate
201	37.6	22	1.4	49.4	7.4	717007, 4869232	6.50E-04
202	5.4	22	0.7	20.0	6.0	716954, 4869260	2.02E-08
203	14.0	25	1.1	41.9	3.9	716989, 4869233	1.00E-04
204	14.0	25	1.1	41.9	3.9	716988, 4869227	4.35E-05
205	9.0	25	0.8	41.5	3.5	716986, 4869224	3.89E-05
212	0.1	76	0.2	40.8	2.8	717000, 4869226	2.70E-07
238	3.2	25	0.0	13.7	1.7	717020, 4869206	1.04E-05
248	1.3	25	0.4	21.3	0.0	716973, 4869254	2.12E-05
250a	38.0	29	1.8	39.6	15.6	716981, 4869234	9.20E-06
270	4.7	25	0.0	14.5	1.1	716942, 4869208	9.63E-06
280_281	95.0	25	16.6 x 0.51	25.3	0.0	716991, 4869247	2.70E-05
287	6.8	25	1.5 x 1.0	3.0	N/A	716970, 4869276	9.99E-08
314	4.7	25	0.0	17.3	4.7	717048, 4869232	1.41E-05
350	1.0	100	0.3	17.5	4.9	717044, 4869239	7.26E-05
352	1.0	100	0.5	17.5	4.9	717045, 4869238	7.26E-05
401	5.8	60	0.6	32.1	20.8	717285, 4869039	2.27E-04
402	6.1	35	0.7	14.8	3.5	717268, 4869046	1.84E-05
403	7.1	35	0.7	20.4	9.1	717278, 4869016	4.25E-05
405	2.5	232	0.4	22.5	8.2	717265, 4869040	7.30E-07
406	2.5	232	0.4	22.5	8.2	717272, 4869039	1.14E-06
407	0.6	25	0.2	3.2	0.0	717251, 4869054	8.50E-07
409	0.9	25	0.3	11.3	3.0	717255, 4869033	2.55E-06
410	1.0	100	0.3	29.3	18.0	717283, 4869026	7.00E-05
491	8.5	37	0.8	20.9	6.2	717277, 4868999	9.60E-06
495	23.8	25	1.5	14.3	3.0	717291, 4868993	8.00E-06
496	15.8	25	1.2	14.3	3.0	717285, 4869000	8.00E-06
497	13.8	25	1.2	14.3	3.0	717287, 4868992	1.30E-05
498	3.8	25	0.5	14.3	3.1	717255, 4869018	1.12E-05
607	0.3	25	0.2	11.7	2.1	717147, 4869069	4.25E-07
608	3.8	25	0.5	18.2	8.6	717164, 4869093	1.14E-05
613	4.7	25	0.6	10.7	1.1	717169, 4869077	3.52E-06
614	4.7	25	0.6	10.7	1.1	717164, 4869075	4.63E-06
615	4.7	25	0.6	10.7	1.1	717147, 4869077	4.81E-06
640	4.0	25	0.5	12.7	3.1	717143, 4869085	1.21E-05
851	1.3	25	0.3	10.8	3.0	717029, 4869347	3.96E-06

Notes:
[1] Universal Transverse Mercator (UTM) coordinates are defined in the North American Datum of 1983 (NAD83).

Modelled uranium concentrations at the hi-vol receptors were used for validation of the updated modelling assessment. The updated validation results are provided in **Error! Reference source not found.**6 and are compared to the validation results (i.e., ratio of modelled vs. monitored uranium concentrations) from the 2016 ERA report.

Table 6: Comparison of Modelled vs. Monitored Annual Uranium Concentrations at the Hi-Vol Stations

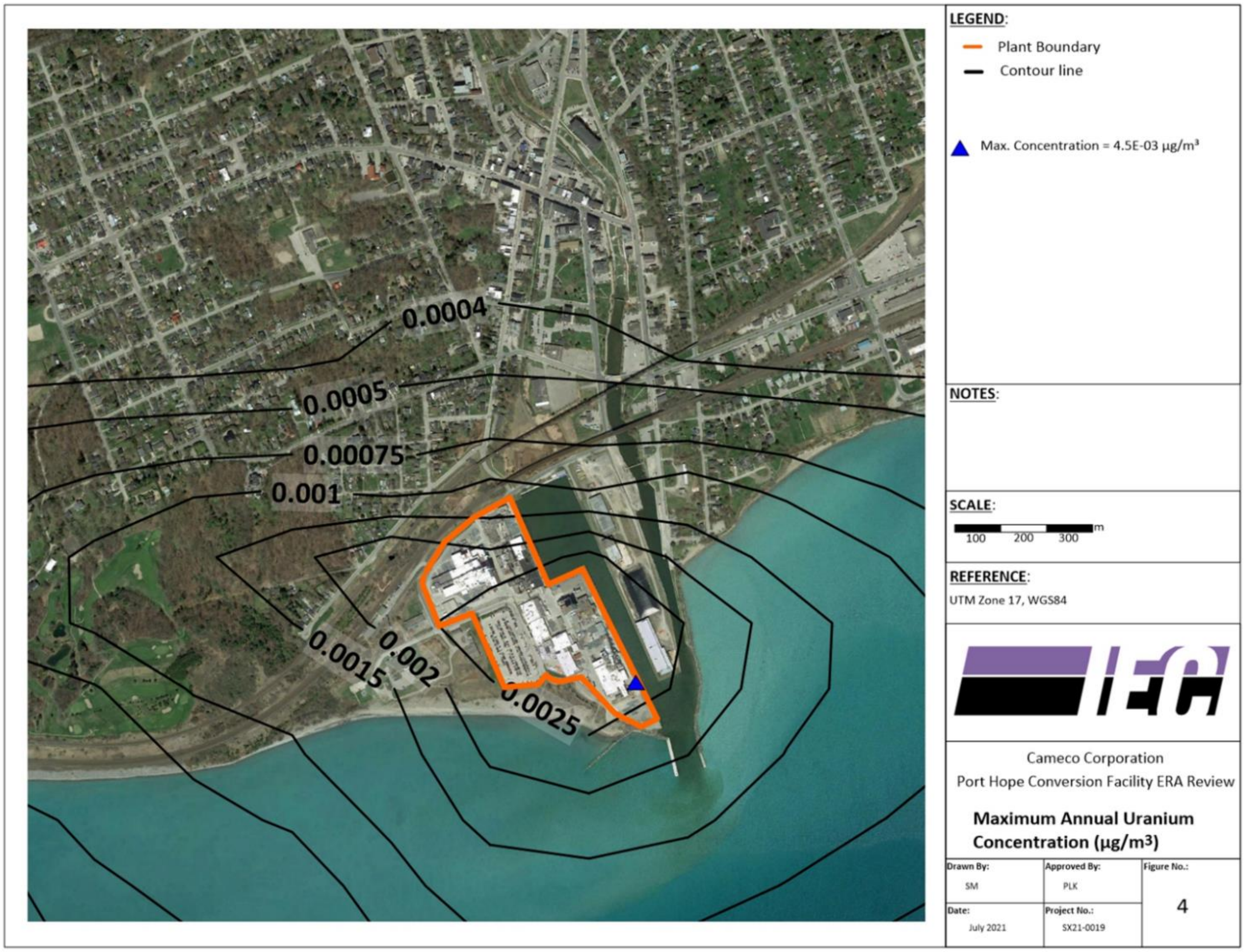
Hi-Vol Station	Annual Uranium Concentration (μg/m^3)			2016 ERA Ratio Model vs. Monitor
	Monitored [1]	Modelled [2]	Ratio Model vs. Monitor	
Marsh Street	0.0029	0.0042	1.4	1.5
Waterworks	0.0016	0.0021	1.3	0.9
Hayward Street	0.0018	0.0017	0.9	0.8
Shuter Street	0.0013	0.0005	0.4	0.5

Notes:
[1] Based on the five-year annual average of hi-vol data (2016-2020). Concentrations at the detection limit (0.0001 μg/m^3) were assumed equal to the detection limit.
[2] Based on the modelled five-year annual average concentration.

As can be seen in **Error! Reference source not found.**6, the results from the updated validation are consistent with the findings in the 2016 ERA report. The ratios of modelled vs. monitored data range from 0.4 at Shuter Street to 1.4 at Marsh Street. The modelled concentrations are within an acceptable factor of two, except for the Shuter Street location which is the furthest hi-vol station from the PHCF facility. A model is considered to perform well if the model results are within a factor of 2 of observed values (U.S.EPA, 2003). Modelled concentrations at Shuter Street station are below measured concentrations. This suggests that model uncertainty may increase with distance from the facility (CanNorth, 2021a).

Figure 4 presents the contour plot for maximum annual uranium concentrations predicted by AERMOD. The predicted concentrations at the risk receptors in the 2021 ERA review are within a similar range to the results presented in the 2016 ERA. The highest annual concentration is predicted to occur at a fenceline receptor on the east side of the facility and has a value of 4.5E-03 μg/m^3 (IEC, 2021a). This prediction is consistent with the 2016 ERA and does not change the conclusion of the 2016 ERA as the air pathway only represents a minor pathway of exposure (CanNorth, 2021a).

Figure 4 Maximum Annual Uranium Concentration



In the ERA review, a deposition velocity was calculated and applied to the model predicted concentrations using monitoring data for the 2016-2020 period, using dustfall jars co-located with hi-vol stations. The highest monthly deposition rate was predicted to be 0.166 mg/m^2/30 days (IEC, 2021a).

Figure 5 presents the contour plot for maximum annual uranium deposition rates predicted by AERMOD. The highest annual deposition rate has a value of 1.38E-05 g/m^2 which is 3 times lower than the maximum deposition rate in the 2016 ERA (4.25E-05 g/m^2). The uranium deposition rates calculated at the eight dustfall monitoring locations are compared to the dustfall data as shown in Table 7. The calculated (i.e., predicted) uranium deposition rates are within a factor of 2 of monitored data, with exception at the Shuter Street dustfall (i.e., Station 9).

Figure 5 Maximum Annual Uranium Deposition Rate (g/m^2)

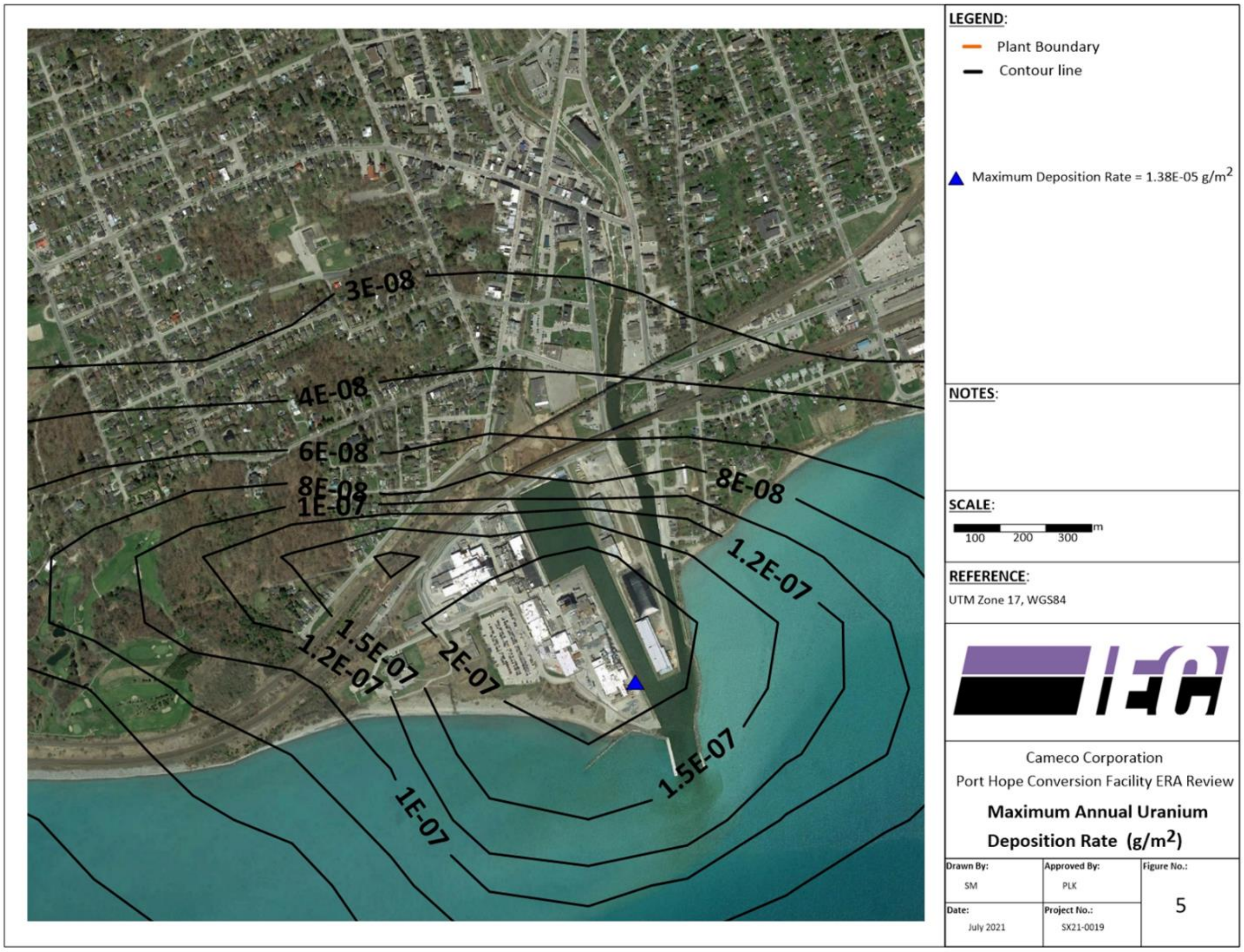


Table 7 :Comparison of Modelled vs. Monitored Uranium Deposition Rates

Station Location	UTM Coordinates		Uranium Deposition Rate (mg/m²/30 days)		
	Easting (m)	Northing (m)	Monitored (2016-2020)	Modelled	Ratio Model vs. Monitor
Station 1	716890	4869025	0.044	0.078	1.8
Station 2	716632	4869081	0.065	0.060	0.9
Station 4	717043	4869312	0.090	0.111	1.2
Station 7	717430	4869455	0.050	0.033	0.7
Station 8	717392	4868884	0.040	0.082	2.0
Station 9	717612	4869638	0.038	0.017	0.4
Station 10	716949	4869293	0.078	0.061	0.8
Station 15	716999	4869157	0.122	0.154	1.3

The results of the updated air dispersion modelling show that predicted uranium concentrations are comparable to the results of modelling completed as part of the 2016 ERA. The summary of monitoring data on uranium deposition from the period 2016-2020 indicates the lower deposition rates in comparison to the PHCF 2014 monitoring data and that is reflected in lower deposition velocity calculated in this assessment.

Overall, the results of the updated air dispersion modelling have shown no significant changes in the air pathway that might affect the conclusions of the ERA and the conclusion from the 2016 ERA that uranium in air is not a concern for off-site receptors remains valid (IEC, 2021a).

3.2.2 Liquid Effluent Release Modelling

Liquid effluent release modelling was completed as part of the 2016 DRL (ARCADIS, 2016c) based on sanitary sewer quality data from 2014. The PHCF monitors the uranium released to the sanitary sewer which is processed at the municipal sewage treatment plant (STP). Following processing in the STP, the treated water is released to Lake Ontario, via a diffuser located east of the PHCF and harbour.

Dispersion calculations were completed to develop a dilution factor that accounts for dispersion between the STP outfall and the harbour using the Cornell Mixing Zone Expert System (CORMIX). Overall, CORMIX modelling results indicate that a dilution of approximately 2090x is achieved between the STP diffuser and the Port Hope Harbour (Arcadis, 2016c). This predicts a contribution of 0.0014 µg U/L from the discharge of the STP at the Port Hope harbour.

The CORMIX model was updated for the STP outfall for work supporting the 2021 Derived Release Limit for CFM (ARCADIS, 2021). As the CORMIX model uses a unit-concentration of effluent (1 ppm) rather than specific concentrations of analytes in effluent, generic dilution factors are developed which apply to any particular analyte (ARCADIS, 2021) and the model may be used for assessment of PHCF contributions to the STP.

The 2021 modelling assessed concentrations from the STP outfall at the public beach in Port Hope (1.5 km west of the STP outfall), the drinking water intake (2.9 km west of the STP outfall) and in concentration at the STP outfall (ARCADIS, 2021). The dilution factors from the CORMIX modelling are 2260 times at the beach, 4219 times at the drinking water intake and no dilution at the STP outfall (ARCADIS, 2021).

Since the PHCF sanitary discharge is released to the STP, it is required to consider the additional volume of waste water treated at the STP. Table 8 illustrates the derivation of the lowest dilution factor (12X) to be used for assessment of impact of uranium discharges to the sanitary sewer.

Table 8 PHCF effluent dilution with municipal sewage

	PHCF Effluent		STP Effluent		Dilution Factor
Year	Concentration (µg/L)	Volume (m^3)	Volume (m^3)	Concentration (µg/L)	
2017	44	138,012	2,163,874	2.8	16
2018	37	131,589	1,857,391	2.6	14
2019	33	161,938	1,912,776	2.8	12
2020	13	140,029	1,665,680	1.1	12

Using the minimum dilution (12X) for the PHCF to STP effluent and the maximum annual PHCF effluent concentration (44 ug/L) a maximum STP effluent concentration was derived. Using the dilution factors from the CORMIX model, predicted concentrations of uranium at the receptor locations can be determined as shown in Table 9.

Table 9 Predicted Concentrations of Uranium from PHCF discharge to sanitary sewer

Receiving Location	PHCF Contribution to STP effluent (µg/L)	Dilution Factor from CORMIX	Predicted Concentration (µg/L)
STP Outfall	3.7	1	3.7
Public Beach	3.7	2260	0.0016
Drinking Water Intake	3.7	4419	0.0008

This is a negligible contribution at all receptor locations and well below the short-term exposure criterion of 33 µgU/L used for development of Exposure-Based Release Limits for Cameco's Ontario facilities (Cameco, 2021).

3.3 Updated COPC Screening

The environmental monitoring data collected since the last ERA in 2016 was reviewed to determine whether additional contaminants of potential concern (COPC) need to be considered. The 2016 ERA used the maximum concentrations in soil, groundwater, surface water and sediments in the screening process. COPC screening followed the methodology set out in the 2016 ERA (ARCADIS, 2016a). Analytes were carried forward for further evaluation in the ERA review if the analyte satisfied one of the following three conditions:

1. The maximum concentration exceeds the corresponding screening criterion; or
2. a) There are measurable concentrations; and

   b) corresponding screening criteria are not available; and

c) toxicity benchmarks are available; or

3. They were identified in other relevant connected environmental media as COPCs (i.e., at levels exceeding screening criteria in those connected media) and are related to current site operations.

3.3.1 Air

Air screening follows the overall screening procedure outlined above using concentrations at the point of impingement (POI), all contaminants not considered negligible under s.8 of O. Reg. 419/05 were included in the screening. The results of air screening are shown in Table 10 (IEC, 2023).

Only uranium was identified as a COPC due to its relevance to current site operations. There is no change to the conclusions of the ERA based on this review.

Table 10 Air – COPC Screening (From 2022 ESDM –IEC (2023)

Contaminant	CAS No.	Aggregate Emission Rate (g/s)	Averaging Period	AERMOD Maximum Ground-level Concentration ($\mu g/m^3$)	Screening Criteria ($\mu g/m^3$)	% of Criteria (%)	Evaluate as COPC?	Comments
Ammonia	7664-41-7	2.34E+00	24	4.28E+01	100	43%	No	Less than screening criterion
Ammonia (without source 499)*	7664-41-7	2.25E+00	24	3.76E+01	100	38%	No	Less than screening criterion
Fluorides (as HF) – Gaseous (Growing Season)	7664-39-3	2.10E-02	24	4.07E-01	0.86	47%	No	Less than screening criterion
Fluorides (as HF) – Gaseous (Growing Season)	7664-39-3	2.10E-02	30-day	1.37E-01	0.34	40%	No	Less than screening criterion
Fluorine	7782-41-4	6.32E-04	24	9.25E-03	0.1	Below De Minimus	No	Less than screening criterion
Nitrogen oxides	10102-44-0	2.41E+00	24	2.81E+01	200	14%	No	Less than screening criterion
Nitrogen oxides	10102-44-0	2.41E+00	1	1.39E+02	400	35%	No	Less than screening criterion
Particulate Matter	N/A	4.74E-01	24	5.23E+00	120	4%	No	Less than screening criterion
Potassium	7440-09-7	9.39E-03	24	1.98E-01	1	< JSL	No	Less than screening criterion
Sulphur dioxide	7446-09-5	2.01E+00	24	2.34E+01	275	9%	No	Less than screening criterion
Sulphur dioxide	7446-09-5	2.01E+00	1	1.15E+02	690	17%	No	Less than screening criterion
Uranium (and Uranium compounds) [4]	7440-61-1	2.12E-03	Annual	4.62E-03	0.03	15%	Yes	Less than screening criterion. Identified as a COPC in other relevant connected media. Directly relevant to site operations.
Uranium (and Uranium compounds)	7440-61-1	2.12E-03	Annual	4.62E-03	0.15	3%	Yes	Less than screening criterion. Identified as a COPC in other relevant connected media. Directly relevant to site operations.
Uranium (and Uranium compounds)	7440-61-1	2.12E-03	24	3.17E-02	1.5	2%	Yes	Less than screening criterion. Identified as a COPC in other relevant connected media. Directly relevant to site operations.

3.3.2 Soil

Table 11 provides a summary of the updated screening for soil. Generally, the concentrations are lower in the recent dataset than the maximum concentrations considered in the 2016 ERA. The updated screening utilized off-site soil concentrations for uranium from 2015 through 2020 and soil borehole data from November 2020. It is noted that the borehole data were collected under a concrete slab and may not be completely appropriate for consideration in the risk assessment. The recent data does not include all constituents considered in the 2016 ERA. The updated screening process removed contaminants that are associated with the Earth's crust such as calcium, magnesium, potassium etc. and also removed contaminants that were not associated with PHCF operations and those for which toxicity information do not exist (CanNorth, 2021a).

A procedural change has occurred in off-site soil sampling since the completion of the 2016 ERA. In 2014, the PHCF soil monitoring program was amended to focus on uranium as the priority contaminant of concern for the PHCF (Cameco 2014); this modification was accepted by the CNSC (2014). Therefore, only uranium concentrations are available in off-site soil from 2015. The number of monitoring locations has also decreased over time.

As identified in **Error! Not a valid bookmark self-reference.**, there were some changes to the COPC identified for the assessment based on consideration of the recent 2020 data. Maximum concentrations of antimony, boron, cadmium, cobalt, nickel, selenium, vanadium, and zinc were below screening criteria in the 2020 dataset and were not identified as COPC in the updated screening. The 2016 ERA did not identify issues for terrestrial ecological receptors for these COPC. Maximum concentrations of silver and TCE were above screening criteria in the 2020 dataset; however, the sample location beneath the floor slab does not represent an operable exposure pathway. Iron, magnesium, and potassium are associated with the Earth's crust and aluminium, barium, copper, lead, manganese, and strontium are not related to PHCF operations, and these constituents were therefore not selected for further consideration. Parameters identified as COPC in the previous dataset without updated information were also carried forward (CanNorth, 2021a).

It is noted that the recent dataset only considers limited data from a focussed site study and does not represent a comprehensive site characterization for soil. Ultimately changes in the screening of soil for human health based on the recent data have no influence on the results of the risk assessment, since none of the identified human receptors were considered to have contact with on-site soil. The only human receptors in the 2016 ERA assumed to contact soil were the nearby resident and the recreational park user. Uranium is measured in off-site soil and the maximum concentration from all depths from 2015 to 2020 was 15 µg/g. This maximum measured concentration is well below the screening criteria of 33 µg/g and therefore, no COPC are identified for soil in the human health assessment (CanNorth, 2021a).

Table 11 Soil: updated screening

Constituent	Units	Screening Criteria MOE Table 3a	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Aluminum	µg/g	NA	36300	No data	**Yes**	No	Not associated with PHCF operations
Antimony	µg/g	40	166	12	**Yes**	No	Below screening criteria
Arsenic	µg/g	18	1790	160	**Yes**	**Yes**	
Barium	µg/g	670	2020	3500	**Yes**	No	Not associated with PHCF operations
Beryllium	µg/g	8	1.6	1.1	No	No	
Bismuth	µg/g	NA	55	No data	No	No	No toxicity data
Boron (total)	µg/g	120	1790	13	**Yes**	No	Below screening criteria
Calcium	µg/g	NA	316000	No data	No	No	Part of Earth's crust
Cadmium	µg/g	1.9	9.8	0.24	**Yes**	No	Below screening criteria
Chromium	µg/g	160	114	0.35	No	No	
Cobalt	µg/g	80	2730	70	**Yes**	No	Below screening criteria
Copper	µg/g	230	8830	730	**Yes**	No	Not associated with PHCF operations
Iron	µg/g	NA	180000	No data	**Yes**	No	Part of Earth's crust
Lead	µg/g	120	30000	4000	**Yes**	No	Not associated with PHCF operations
Magnesium	µg/g	NA	84300	No data	**Yes**	No	Part of Earth's crust
Manganese	µg/g	NA	3600	No data	**Yes**	No	Not associated with PHCF operations
Molybdenum	µg/g	40	15	1	No	No	
Nickel	µg/g	270	5690	51	**Yes**	No	Below screening criteria
Phosphorus	µg/g	NA	44900	No data	No	No	Part of Earth's crust
Potassium	µg/g	NA	45000	No data	**Yes**	No	Part of Earth's crust
Selenium	µg/g	5.5	16	<0.5	**Yes**	No	Below screening criteria
Silicon	µg/g	NA	5800	No data	No	No	Part of Earth's crust
Silver	µg/g	40	40	67	No	No	Above screening criteria; recent data max from BH4 SA2 of floor slab and does not represent an exposure pathway
Sodium	µg/g	NA	10000	No data	No	No	Part of Earth's crust
Strontium	µg/g	NA	3000	No data	**Yes**	No	Not associated with PHCF operations
Thallium	µg/g	3.3	0.94	0.22	No	No	
Titanium	µg/g	NA	2100	No data	No	No	Part of Earth's crust
Uranium	µg/g	33	16800	1900	**Yes**	**Yes**	
Vanadium	µg/g	86	150	55	**Yes**	No	Below screening criteria
Zinc	µg/g	340	5500	97	**Yes**	No	Below screening criteria
Radium-226	Bq/g	NA	32	No data	**Yes**	**Yes**	
Benzene	µg/g	0.32	<0.002	0.022	No	No	
Ethylbenzene	µg/g	9.5	0.012	0.021	No	No	
Toluene	µg/g	68	0.028	0.11	No	No	

Constituent	Units	Screening Criteria MOE Table 3a	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Xylene (total)	µg/g	26	0.212	0.55	No	No	
Bromodichloromethane	µg/g	18	<0.002	<0.04	No	No	
Bromoform	µg/g	0.61	<0.002	<0.04	No	No	
Bromomethane	µg/g	0.05	<0.009	<0.04	No	No	
Carbon tetrachloride	µg/g	0.21	<0.002	<0.04	No	No	
Chlorobenzene	µg/g	2.4	<0.002	<0.04	No	No	
Chloroform	µg/g	0.47	<0.003	0.36	No	No	
Dibromochloromethane	µg/g	13	<0.002	<0.04	No	No	
1,1-Dichloroethane	µg/g	17	<0.002	<0.04	No	No	
1,2-Dichloroethane	µg/g	0.05	<0.002	<0.049	No	No	
1,1-Dichloroethylene	µg/g	0.064	<0.002	<0.04	No	No	
cis-1,2-Dichloroethylene	µg/g	55	0.003	<0.04	No	No	
trans-1,2-Dichloroethylene	µg/g	1.3	<0.004	<0.04	No	No	
1,2-Dichloropropane	µg/g	0.16	<0.002	<0.04	No	No	
cis-1,3-Dichloropropene	µg/g	0.18	<0.002	<0.03	No	No	
trans-1,3- Dichloropropene	µg/g	0.18	<0.002	<0.04	No	No	
Ethylenedibromide	µg/g	0.05	<0.002	0.021	No	No	
Dichloromethane	µg/g	1.6	0.021	<0.049	No	No	
1,1,1,2-Tetrachloroethane	µg/g	0.087	<0.002	<0.04	No	No	
1,1,2,2-Tetrachloroethane	µg/g	0.05	<0.004	<0.04	No	No	
Tetrachloroethylene	µg/g	4.5	<0.002	0.086	No	No	
1,2,4-Trichlorobenzene	µg/g	3.2	0.004	No data	No	No	
1,1,1-Trichloroethane	µg/g	6.1	<0.003	<0.04	No	No	
1,1,2-Trichloroethane	µg/g	0.05	<0.002	<0.04	No	No	
Trichloroethylene	µg/g	0.91	0.188	1	No	No	Above screening criteria; recent data max from BH2 SA1A of floor slab and does not represent an exposure pathway
Vinyl Chloride	µg/g	0.032	<0.003	<0.019	No	No	
1,2-Dichlorobenzene	µg/g	6.8	<0.002	<0.04	No	No	
1,3-Dichlorobenzene	µg/g	9.6	0.005	<0.04	No	No	
1,4-Dichlorobenzene	µg/g	0.2	0.002	<0.04	No	No	
Trichlorofluoromethane	µg/g	4	<0.002	<0.04	No	No	
Dichlorodifluoromethane	µg/g	16	<0.002	<0.04	No	No	

Note: Recent data is based on November 2020 borehole sampling and annual off-site soil sampling for uranium from 2015-2020. Not all parameters considered in the 2016 ERA screening Table 4.2 were included here and constituents are limited to those included in recent data and/or relevant for assessment. The 2016 ERA used data from SENES (2013), as well as data from the 2014 off-site soil monitoring program for uranium.

For the ecological assessment, the secondary screening for soil compared the maximum measured concentrations to the ecological soil components (plants and soil invertebrates, mammals and birds) of the Table 3[1] MOE (2011) criteria for full-depth, non-potable water, coarse textured soil. The updated screening is provided in Table 12. Differences in the screening of soil for the ecological assessment are due to changes in the underlying dataset. Arsenic is no longer above the criteria for mammals and birds, while uranium is no longer above the criteria for plants and soil invertebrates.

Table 12 Soil: updated secondary screening for ecological assessment

Parameter	Units	MOE Table 3		2016 ERA Max Value	Recent Data Max Value	Plants and Soil Invertebrates		Mammals and Birds	
		Plants and Soil Invertebrates	Mammals and Birds			2016 ERA COPC?	Updated COPC?	2016 ERA COPC?	Updated COPC?
Arsenic	µg/g	40	330	1790	160	**Yes**	**Yes**	**Yes**	No
Uranium	µg/g	2000	33	16800	1900	**Yes**	No	**Yes**	**Yes**
Radium-226	Bq/g	NA	NA	32	No data	**Yes**	**Yes**	**Yes**	**Yes**

Note: The 2016 ERA indicated that ecological screening criteria were from MOE Table 2 (for potable groundwater); for ecological screening criteria these are the same as the Table 3 values (for non-potable groundwater), however the reference has been updated to MOE Table 3 (full depth, non-potable water scenario, industrial/commercial land use). Also, the plants and soil invertebrates criteria were switched with the mammals and birds in the 2016 ERA secondary screening for ecological receptors (Table 6.4). The corrected values are presented here.

3.3.3 Groundwater

Table 13 provides a summary of the updated screening for groundwater. Screening criteria for groundwater were from Table 9 of MOE (2011) for non-potable groundwater within 30 m of a water body. The 2016 ERA used groundwater data from the 2014 Annual Groundwater and Surface Water Review Report (Golder 2015), which included data from PHCF's internal groundwater monitoring program for 2014 (ARCADIS, 2016a). The recent data maximum value presented in Table 13 is based on data collected from 2015 through 2020, including both Cameco and contract laboratory analyses as available from Golder (2021). The 2016 ERA considered data for petroleum hydrocarbons (PHCs) from the 2009 Site-Wide Risk Assessment (SWRA; SENES 2009a); more recent data for PHCs in groundwater are not available for consideration in the current comparison. As discussed above these data are not considered to represent current conditions and are not discussed further. Similarly, polychlorinated biphenyls (PCBs) are not reported in the recent monitoring data. Thus the information related to these contaminants are dated and not discussed below.

The updated screening process also removed contaminants that are associated with the Earth's crust such as calcium, magnesium, potassium etc. and also removed contaminants that were not

[1] Indicated as Table 2 in the 2016 ERA text. Table 2 is for potable water and the values in Table 2 and Table 3 (non-potable water) are the same for ecological criteria, but the reference is corrected here for completeness.

associated with PHCF operations and those for which toxicity information do not exist (CanNorth, 2021a).

Table 13 Groundwater: updated screening

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Fluoride	mg/L	NA	75	100	**Yes**	**Yes**	
Ammonia	mg-N/L	NA	150	400	**Yes**	**Yes**	
Calcium	mg/L	NA	12200	23200	**Yes**	No	Part of Earth's crust
Chloride	mg/L	1800	82000	130000	**Yes**	**Yes**	
Magnesium	mg/L	NA	5190	5716	**Yes**	No	Part of Earth's crust
Nitrite	mg-N/L	NA	<0.3	0.32	No	**Yes**	Previously below detection limit and was not considered; recent data max from 2018 at HW-23C (near UO_2 plant)
Nitrate	mg-N/L	NA	115	140	**Yes**	**Yes**	
Potassium	mg/L	NA	1080	1000	**Yes**	No	Part of Earth's crust
Sodium	mg/L	1800	23700	24200	**Yes**	No	Part of Earth's crust
Sulphate	mg/L	NA	1200	1500	**Yes**	**Yes**	
Aluminum	µg/L	NA	220	6710	**Yes**	No	Not associated with PHCF operations
Antimony	µg/L	16000	30	13.1	No	No	Not associated with PHCF operations
Arsenic	µg/L	1500	1150	1690	**Yes**	**Yes**	
Barium	µg/L	23000	6540	7320	No	No	Not associated with PHCF operations
Beryllium	µg/L	53	<0.007	0.3	No	No	
Boron	µg/L	36000	1470	1360	No	No	Not associated with PHCF operations
Bismuth	µg/L	NA	<0.007	2.7	No	**Yes**	Previously below detection limit and was not considered; recent data max from 2019 at MW50-19B (near UF_6 plant)
Cadmium	µg/L	2.1	<0.003	0.003	No	No	Not associated with PHCF operations
Cobalt	µg/L	52	20	17.3	No	No	
Chromium	µg/L	640	20	68.4	No	No	Not associated with PHCF operations
Copper	µg/L	69	290	114	**Yes**	No	Not associated with PHCF operations
Iron	µg/L	NA	36700	32000	**Yes**	No	Part of Earth's crust
Lead	µg/L	20	20	15	No	No	Not associated with PHCF operations
Manganese	µg/L	NA	2600	2810	**Yes**	No	Not associated with PHCF operations
Molybdenum	µg/L	7300	230	572	No	No	
Nickel	µg/L	390	100	54	No	No	Not associated with PHCF operations

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Selenium	µg/L	50	538	608	**Yes**	No	Not associated with PHCF operations
Silicon	µg/L	NA	20400	21400	No	No	
Silver	µg/L	1.2	30	22.6	**Yes**	**Yes**	
Strontium	µg/L	NA	1090000	1300000	**Yes**	No	Not associated with PHCF operations
Thallium	µg/L	400	<0.005	3.2	No	No	
Titanium	µg/L	NA	20	29.7	No	No	Part of Earth's crust
Uranium	µg/L	330	21000	21100	**Yes**	**Yes**	
Vanadium	µg/L	200	20	64	No	No	Not associated with PHCF operations
Zinc	µg/L	890	2220	534	**Yes**	No	Below screening criteria
Radium-226	Bq/L	NA	0.89	12	**Yes**	**Yes**	
Benzene	µg/L	44	277	277	**Yes**	**Yes**	
Ethylbenzene	µg/L	1800	21.3	26	No	No	
Toluene	µg/L	14000	275	286	No	No	
Xylene (Total)	µg/L	3300	192	218	No	No	
Bromodichloromethane	µg/L	67000	2	<0.5	No	No	
Bromoform	µg/L	29000	1	<0.5	No	No	
Bromomethane	µg/L	5.8	<0.5	<0.5	No	No	
Carbon tetrachloride	µg/L	0.35	1.2	<0.2	**Yes**	No	Below screening criteria
Chlorobenzene	µg/L	500	<0.5	1	No	No	
Chloroform	µg/L	240	17	1.3	**Yes**	No	Updated guideline; below screening criteria
Dibromochloromethane	µg/L	65000	0.59	<0.5	No	No	
1,1-Dichloroethane	µg/L	320	31.7	21	No	No	
1,2-Dichloroethane	µg/L	1.6	<0.5	0.9	No	No	
1,1-Dichloroethylene	µg/L	1.6	20.8	7.6	**Yes**	**Yes**	
cis-1,2-Dichloroethene	µg/L	1.6	1020	1080	**Yes**	**Yes**	
trans-1,2- Dichloroethene	µg/L	1.6	28.6	10.8	**Yes**	**Yes**	
1,2-Dichloropropane	µg/L	16	<0.5	<0.5	No	No	
cis-1,3-Dichloropropene	µg/L	5.2	<0.5	<0.5	No	No	
trans-1,3-Dichloropropene	µg/L	5.2	<0.5	<0.5	No	No	
Ethylenedibromide	µg/L	0.25	<1	<0.2	**Yes**	No	Below screening criteria
Dichloromethane	µg/L	1400	2	<0.5	No	No	
1,1,1,2-Tetrachloroethane	µg/L	3.3	<0.5	<0.5	No	No	
1,1,2,2-Tetrachloroethane	µg/L	3.2	0.25	<0.5	No	No	
Tetrachloroethylene (perchloroethylene)	µg/L	1.6	1.4	<0.5	No	No	
1,2,4-Trichlorobenzene	µg/L	180	0.25	0.8	No	No	
1,1,1-Trichloroethane	µg/L	640	15.1	3.9	No	No	
1,1,2-Trichloroethane	µg/L	4.7	<1.2	1.2	No	No	
Trichloroethylene	µg/L	1.5	1800	207	**Yes**	**Yes**	
Vinyl Chloride	µg/L	0.5	613	911	**Yes**	**Yes**	
1,2-Dichlorobenzene	µg/L	4600	<0.5	<0.5	No	No	
1,3-Dichlorobenzene	µg/L	7600	<0.5	0.9	No	No	
1,4-Dichlorobenzene	µg/L	8	0.6	1.4	No	No	

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Trichlorofluoromethane	µg/L	2000	<5	<5	No	No	
Dichlorodifluoromethane	µg/L	3500	2.3	4.1	No	No	

Note: NA – not available. For simplicity, not all constituents considered in the 2016 ERA screening Table 4.1 were included here (i.e., pH, conductivity, hardness and some general chemistry constituents like phosphorus and TDS). Data for PHCs and PCBs from 2009 considered in the 2016 ERA is not included in the comparison, because no recent data are available and data from 2009 are over 10 years old and no longer representative of concentrations at the site. The identification of maximum concentrations considered data from 2018 through 2020 for organic constituents.

As identified in Table 13 , there were some changes to the COPC identified for the assessment based on consideration of the 2015 through 2020 data. Nitrite and bismuth, which have no screening criteria, were previously reported with all data less than the detection limit and were not selected for further consideration. With detected concentrations in the 2015 to 2020 data, nitrite and bismuth were identified for further evaluation in the updated screening. Updated concentrations of zinc, carbon tetrachloride, and ethylene dibromide were below the available screening criteria and were not selected for further evaluation, which is a change from the 2016 ERA. Finally, chloroform has an updated screening criteria and the maximum concentrations are below this value; therefore, chloroform is no longer identified as a COPC. Calcium, magnesium, potassium, sodium, iron, and titanium were not identified for the assessment since these constituents are part of the Earth's crust, while aluminium, antimony, barium, boron, cadmium, chromium, copper, lead, manganese, nickel, selenium, strontium, and vanadium are not associated with PHCF operations (CanNorth, 2021a).

Generally the concentrations considered in the 2016 ERA are similar to the maximum values from more recent data. However, there is one notable difference for radium-226; the 2016 ERA considered a concentration of 0.89 Bq/L (2014) and the maximum concentration in the recent data is 12 Bq/L. Both values are from bedrock well HW-18D (screened from 19.2 m to 21.2 m bgs) and data has ranged at this location from < 0.01 Bq/L (2010) to 12 Bq/L (2017), with an average of 3.4 Bq/L based on detected concentrations. In 2020, radium-226 was reported at a level of 0.02 Bq/L at this location. The variability in concentrations reflect that radium-226 concentrations are not increasing. The use of the maximum concentration in the screening process may be an overestimation of the current radium-226 groundwater concentrations at that location (CanNorth, 2021a).

As part of the annual groundwater and surface water review, WSP (previously Golder) reviews the current years data against that used in the 2016 ERA. The most recent review identified three monitoring wells with data above the maximums in the 2016 ERA (WSP, 2023). Of these, three parameters (calcium, manganese, sodium) are not identified as COPCs in this ERA review. In addition, for the wells screened in bedrock which have consistently elevated concentrations, it has been inferred that these results are representative of naturally occurring conditions, not anthropogenic sources (WSP, 2023).

The 2016 ERA completed a secondary screening for groundwater for both humans and ecological receptors. The secondary screening for humans compared the maximum measured groundwater concentrations to human health components of the MOE (2011) Table 6 for coarse textured shallow soil and potable groundwater. The GW1 component associated with the potable groundwater scenario was used as a surrogate for direct contact. Ultimately changes in the screening of groundwater for human health based on the recent data and changes in approach have no influence on the results of the risk assessment, since none of the identified human receptors were considered to have contact with groundwater.

For the ecological assessment, the secondary screening for groundwater in the 2016 ERA compared the maximum measured concentrations to the GW3 component of the Table 9 MOE (2011) criteria for groundwater within 30 m of a water body. The GW3 component is protective of aquatic biota in surface water bodies potentially affected by groundwater and are also considered protective of terrestrial species such as earthworms. It is important to note that depth to groundwater at the site is generally 3.5 to 4.5 mbgs and becomes shallower at about 1 mbgs towards the southern part of the site. These depths generally do not represent an exposure pathway for humans or terrestrial species such as earthworms. Surface water integrates inputs from groundwater as well as stormwater runoff from the PHCF and represents the potential exposure pathway for humans and aquatic receptors.

The updated screening is provided in Table 14. Differences in the screening of groundwater for the ecological assessment are due to changes in the underlying dataset. Nitrite was previously less than detection limit, but in the more recent data was reported at detected concentrations. With no criteria available for comparison, it is selected for further assessment. The maximum concentration of arsenic in groundwater is higher in the more recent dataset and no longer below the screening criteria; therefore, arsenic is also added to the groundwater COPC list for the ecological assessment (Can North, 2021).

Table 14 Groundwater: updated secondary screening for ecological assessment

Constituent	Units	MOE Table 9 Non-Potable GW3	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Fluoride	mg/L	NA	75	100	**Yes**	**Yes**	No GW3
Ammonia	mg-N/L	NA	150	400	**Yes**	**Yes**	No GW3
Chloride	mg/L	NA	82000	86000	**Yes**	**Yes**	No GW3
Nitrite	mg-N/L	NA	<0.3	0.32	No	**Yes**	No GW3
Nitrate	mg-N/L	NA	115	140	**Yes**	**Yes**	No GW3
Sulphate	mg/L	NA	1200	1500	**Yes**	**Yes**	No GW3
Arsenic	µg/L	1500	1150	1690	No	**Yes**	Above GW3
Bismuth	µg/L	NA	<0.007	2.7	No	**Yes**	No GW3
Silver	µg/L	1.2	30	22.6	**Yes**	**Yes**	Above GW3
Uranium	µg/L	330	21000	21100	**Yes**	**Yes**	No GW3
Radium-226	Bq/L	NA	0.89	12	**Yes**	**Yes**	No GW3
Benzene	µg/L	4600	277	277	No	No	Below GW3
1,1-Dichloroethylene	µg/L	12000	20.8	10.3	No	No	Below GW3
cis-1,2-Dichloroethene	µg/L	140000	1020	1180	No	No	Below GW3
trans-1,2-Dichloroethene	µg/L	220000	28.6	14.1	No	No	Below GW3
Trichloroethylene	µg/L	220000	1800	884	No	No	Below GW3
Vinyl Chloride	µg/L	360000	613	911	No	No	Below GW3

Note: Screening criteria from MOE (2011) Table 9 for non-potable groundwater within 30 m of a water body.

3.3.4 Harbour Water - Inferred from Groundwater and Stormwater

The 2016 ERA completed modelling for water quality in the Port Hope Harbour based on stormwater and groundwater discharges from the PHCF. Groundwater discharge estimates were based on 2014 average pumping rates and annual loadings while stormwater discharge estimates were based on information for 2010 (ARCADIS, 2016a).

The current review compared the previous groundwater mass loading to the harbour that was used in the 2016 ERA with more recent data on mass loadings (2016, 2018, and 2020) to determine if there have been increased loadings to the harbour since the completion of the 2016 ERA (CanNorth, 2021a). The more recent groundwater mass loadings to the harbour (2016, 2018, 2020 and 2022) were presented in WSP (Table 7, 2023) and are reproduced in Table 15. Table 155 shows that, in general, the estimated mass loadings from groundwater to the harbour are similar over the 2014 to 2022 period. Estimated mass loadings of some constituents have decreased (i.e., fluoride, ammonia, nitrate, and uranium) while other constituents have shown variability (i.e., arsenic, radium-226, cis-1,2-DCE, and VC). The most significant difference is noted for radium-226, with a 3x increase from 2014 to 2020 (CanNorth, 2021a), however, it is noted that 2022 represented a reduction to 2016 levels. Fluoride and uranium loadings have decreased by a factor of two over the 2014-2022 period and ammonia and nitrate loadings have decreased by a factor of three over the same period. This decrease in loadings/mass discharge is partially attributable to the sustained operation of pumping wells and the gradual decrease of COPCs in groundwater as a consequence of pump-and-treat operations (WSP, 2023).

Table 15 Comparison of estimated groundwater mass loading to Port Hope Harbour

Constituent	Estimated Mass Discharge to Harbour (kg/yr[a])				
	2014	2016	2018	2020	2022
Arsenic	2.0	1.7	1.3	2.7	2.5
Fluoride	15	9.4	11	11	6.5
Ammonia	95	116	66	42	30
Nitrate	3.8	3.4	2.0	2.3	1.2
Radium-226	657	1216	1812	1829	1345
Uranium	5.1	4.2	3.9	3.2	2.6
cis-1,2-Dichloroethene	0.02	0.02	0.01	0.04	0.03
Trichloroethylene	0.01	0.01	0.01	0.01	0.01
Vinyl Chloride	0.03	0.01	0.01	0.05	0.01

Note: Based on average pumping scenario from Table 7 of Golder (2021) and WSP (2023).
a – As specified in Table 7 of Golder (2021) and WSP (2023).

Table 16 presents the comparison of the stormwater concentrations used in the 2016 ERA for loading estimates to the harbour with the measured concentrations from 2015 to 2020. The stormwater assumptions from the 2016 ERA were based on information for 2010 presented in Golder (2011). Data from stormwater monitoring were available from Cameco's internal monitoring program, which is summarized in annual reports. The table shows that, in general, the concentrations considered for stormwater in the 2016 ERA modelling are similar to concentrations measured from 2015 to 2020 from stormwater discharge outlets, with the average concentration typically less than the assumed concentration for the 2016 ERA (CanNorth, 2021a). The concentrations in 2022 monitoring continue to exhibit this general trend (Cameco, 2023). As the VIM project is further implemented, these trends are expected to continue.

Table 16 Comparison of stormwater concentrations

Year	Stormwater Concentration					
	Uranium	Fluoride	Ammonia	Arsenic	Radium	Zinc
	mg/L	mg/L	mg/L	mg/L	Bq/L	mg/L
2010 (2016 ERA)	0.195	0.69	0.38	0.067	0.09	0.24
2015-2020 Min	0.02	<0.06	No data	0.0002	<0.01	0.04
2015-2020 Avg	0.19	0.22	No data	0.01	0.08	0.28
2015-2020 Max	1.5	0.63	No data	0.11	0.73	0.95
2022 Average	0.05	0.14	0.45	0.003	0.021	0.1
2022 Max	0.15	0.32	2.4	0.01	0.064	0.2

Note: 2016 ERA values based on information presented in Table 3.7 of ARCADIS (2016a). Average calculations assumed values reported as < method detection limit (MDL) were equal to the MDL.

Exposure point concentrations (EPCs) for surface water were primarily based on measured data in the 2016 ERA; the results of the harbour surface water modelling, which incorporated stormwater and groundwater loadings, were only considered in the 2016 ERA for the calculation of incremental concentrations for arsenic, uranium, and radium-226 (Tables 5.10 and 5.11, ARCADIS 2016a). Based on the groundwater mass loading comparison and stormwater concentration comparison, the modelling completed for the 2016 ERA remains valid.

3.3.5 Surface Water

At the time of the 2016 ERA, the surface water sampling program consisted of thirteen sampling locations distributed along the perimeter of the Port Hope harbour turning basin and approach channel with many locations were specifically placed adjacent to harbour proximal monitoring wells exhibiting elevated contaminants of concern in groundwater. As a result of the installation of the phase 1 wave attenuator and associated turbidity curtain(s) by the PHAI, commencing in August 2018, this program was suspended until the remediation of the harbour by Canadian Nuclear Laboratories is complete. It will be reactivated once these activities are complete.

Table 17 provides a summary of the updated screening for surface water. The 2016 ERA considered results from Cameco's quarterly monitoring program in 2014. The 2016 ERA supplemented the 2014 data with data for additional constituents from the 2009 SWRA (SENES 2009a). Recent data are based on quarterly surface water sampling from 2015 to 2018 at shallow and deep locations in the harbour and limited constituents were available. As shown in **Table 1718**, ammonia and fluoride were not selected as COPC for surface water based on a comparison with recent data and updated screening considerations.

Table 1718 Surface water: updated screening

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Ammonia (total)	mg-N/L	1.8[a]	0.5	0.4	**Yes**	No	2016 ERA used incorrect screening criteria
Nitrate	mg-N/L	2.9	<2.2	1.4	No	No	Below screening criteria
Uranium	µg/L	5	7.8	23	**Yes**	**Yes**	Above screening criteria
Radium-226	Bq/L	1	<0.055	<0.055	**Yes**	**Yes**	Radionuclides included
Arsenic	µg/L	5	3.2	8.8	**Yes**	**Yes**	Concern at site and above screening criteria
Fluoride	mg/L	1.94[b]	0.3	1.0	**Yes**	No	Below screening criteria

Note: Recent data is based on quarterly surface water sampling at shallow and deep locations from 2015-2018. Not all parameters considered in the 2016 ERA screening Table 4.3 were included here and constituents are limited to those included in recent data. The 2016 ERA used data for additional constituents from the 2009 SWRA (SENES 2009a); more recent data are not available.

a – The 2016 ERA used a screening value of 0.197 mg-N/L for total ammonia, based on CCME protection of aquatic life guidelines. The footnote to Table 4.3 indicates that a pH of 8.5 and temperature of 15ºC were assumed for the conversion. However, the value of 0.197 mg-N/L corresponds to a pH of 10 and temperature of 15ºC. The value has been corrected to represent a pH of 8.5 and temperature of 15ºC as originally intended.

b – The CCME protection of aquatic life guideline for fluoride is 0.12 mg/L and this value was used in the 2016 ERA. This guideline was developed in 2002. Since that time additional toxicity have become available and McPherson et al. (2014) developed a chronic effects benchmark for fluoride based on an SSD approach. A value of 1.94 mg/L F- was derived for fluoride. Thus, if concentrations of fluoride exceed the CCME value, a secondary step can be implemented to compare the measured concentrations to a value of 1.94 mg/L F-.

Exposure point concentrations (EPCs) for surface water were primarily based on measured data in the 2016 ERA; the results of the harbour surface water modelling, which incorporated stormwater and groundwater loadings, were only considered in the 2016 ERA for the calculation of incremental concentrations for arsenic, uranium, and radium-226 (Tables 5.10 and 5.11, ARCADIS 2016a). Based on the groundwater mass loading comparison and stormwater concentration comparison, the modelling completed for the 2016 ERA remains valid for present day conditions. On completion of the harbour remediation and the VIM project, remodelling will be required for the new site conditions.

3.3.6 Sediments

The CNSC commented on the groundwater and stormwater loading assumptions and asked for a determination of whether the future groundwater contamination and stormwater discharge would re-contaminate the sediments. The 2010 Assessment of Recontamination Potential in the Harbour (SENES, 2010) assessed the potential for future re-contamination of sediments from stormwater and groundwater loadings. Based on the hydro-geochemical model predictions, dredging of sediments will result in improved water and sediment quality even with continued groundwater and stormwater loadings into the Harbour (assuming current loadings). Based on 2010 stormwater quality, dredging the sediment would result in the Harbour water meeting Provincial Water Quality Objectives (PWQOs) and sediment quality meeting Lower Exposure Limits (LELs) for the compounds of potential concern (COPCs). Implementation of VIM remedial work will further improve both surface water and sediment quality and further reduce the discharges to the harbour which will contribute to sediment loading in the future (SENES, 2010). These assumptions will be revalidated in the ERA to be completed after the VIM project.

3.3.7 Comparison of EMP with 2016 ERA Predictions

From looking at the data in the 2016 ERA in comparison with the more recent monitoring data at the PHCF, it appears that concentrations in the various media are declining and therefore the more recent data does not have a significant impact on the screening process for the COPC. In the revised screening, fewer COPCs are identified for evaluation than the 2016 ERA due to improvement in environmental performance and overly conservative assumptions in the 2016 ERA. The more recent monitoring data were compared to the exposure point concentrations (EPCs) used in the 2016 exposure assessment to determine the impact on the conclusions of the 2016 ERA. This comparison found that that most of the recent data remain consistent with the EPCs and the results of the revised screening does not have a significant effect on the conclusion of the 2016 ERA (CanNorth, 2021a).

4.0 Review of Environmental Issues Identified in 2016 ERA

This section provides a review of environmental issues revealed by the 2016 EMP and a review of other issues identified with the methodology of the 2016 ERA and the impact of these issues on problem formulation in the ERA.

4.1 Follow-up to 2016 ERA Results

The 2016 ERA results are summarized in Table 19:

Table 19 2016 ERA Results

Stressor Type	Members of the Public	Aquatic Biota	Terrestrial Biota
Radiological	No adverse effect expected from COPCs associated with PHCF operations.	No adverse effect expected from COPCs associated with PHCF operations.	No adverse effect expected from COPCs associated with PHCF operations.
Non-Radiological	Non-Arsenic exposure is below background, but it is recommended to minimize arsenic risk to the extent that it is practical. The facility has restricted the arsenic levels in chemicals it is using (as of 1989)	No adverse effect expected from COPCs associated with PHCF operations.	Potential for adverse effects from F, PHCs in limited area that is not suitable habitat (i.e., the grass patch along Harbour wall)
Physical*	N/A	No I&E issues identified. Thermal exceedances tend to be limited spatially (i.e., localized near the discharge)	No adverse effect expected from stressors associated with PHCF operations.(i.e., noise)

Notes:
N/A – Not applicable or not assessed.
* - Physical stressors include fish entrainment, fish thermal effects, fish acute stormwater effects and acoustic assessment. For terrestrial receptors, only acoustic assessment is applicable.

4.1.1 Non-radiological Impacts on Members of the Public

In the 2016 ERA, arsenic and uranium were identified for further evaluation in the Tier 2b assessment. Uranium was ultimately determined to not be a concern in a Tier 2c evaluation. As mentioned above in the selection of COPC, comparison of the maximum measured uranium concentration from all depths in off-site soil between 2015 and 2020 (15 µg/g) to the screening criteria of 33 µg/g would not have identified uranium as a COPC for quantitative evaluation in the human health assessment (CanNorth, 2021a). The Tier 2c evaluation for arsenic considered background exposures to assess arsenic exposure on an incremental basis. The evaluation of incremental exposure to arsenic should have been completed initially since cancer risk levels are assessed on an incremental basis. In addition, fish exposures derived using transfer factors were the driver of arsenic risk and exposure and there is high uncertainty in this approach (CanNorth, 2021a). Although the conclusions of the assessment remain unchanged, this was a convoluted approach for the assessment and was unnecessarily complicated. For the HQ calculations, the comparison to background exposure would have demonstrated that there was very little increased exposure associated with the PHCF (CanNorth, 2021a).

Based on this review, conclusions of the 2016 ERA are overly conservative.

4.1.2 Non-Radiological Impacts on Terrestrial Biota

In the 2016 ERA a potential for adverse effects from fluoride and PHCs were identified in a limited area (off-site grass strip along the harbour wall). The 2016 assessment recommends to address the contamination in the grass patch along the Harbour walls in coordination with Cameco's Vision In Motion (VIM) and the Port Hope Area Initiative (PHAI) due to exposure to earthworms.

The ERA review identified that as these grass patch areas are not suitable habitat for the ecological receptors and in this case, the area should not have been considered in the exposure assumptions for the assessment (CanNorth, 2021a). This area is planned for remediation under the PHAI and VIM projects and will be included in a Record of Site Condition completed under Ontario Regulation 153/04 once the remediation is complete.

4.1.3 Physical Stressor Impacts on Aquatic Biota

In the 2016 ERA, physical stressors in the aquatic environment were discussed related to the operation of the harbour cooling water system, including the potential impacts to the aquatic environment due to physical stressors, such as impingement and entrainment, and the potential for thermal effects from the cooling water discharge.

During the ERA review period, the PHCF made a business decision to move from a harbour cooling water system to a closed loop cooling system. At the time of the report, the UO_2 plant was using the closed loop system and activities were in progress to transition the UF_6 plant to closed loop in 2023. This change will eliminate the physical stressors on the aquatic environment.

4.2 Follow-Up to Issues raised in Regulatory Review of the 2016 ERA

CNSC staff raised a number of areas for follow-up with the 2016 ERA which is summarized in this section. There were 25 comments raised in the original ERA submission. For this section they are grouped as:

- Addressed in March 2016 ERA
- Addressed in other sections of the ERA review

4.2.1 Comments Addressed in March 2016 ERA

The following topics were addressed in the March 2016 ERA and accompanying disposition of comments (ARCADIS, 2016b) and are not discussed further in this review.

- Evaluation of uncertainties applicable to both HHRA and EcoRA
- Description of QA/QC activities performed
- Additional information regarding the source(s) of soil data
- Additional information regarding the source(s) of surface water data
- Additional information regarding storage loadings for gamma and neutron dose
- Additional discussion regarding ocular exposure
- Additional information regarding exposure factors, dose coefficients and transfer factors selected and information sources
- Inclusion of sample calculations
- Information regarding physical stressors on the aquatic environment

4.2.2 Comments Addressed other Sections of the ERA Review

The description of meteorological and climate setting for the PHCF was incomplete and additional information was included in sections 2.3.4 and 3.2.1 of the ERA review.

Additional detail of the internal groundwater monitoring data was provided in sections 3.3.3 and 3.3.4 of the ERA review.

Additional information regarding the environmental monitoring program and air quality monitoring was provided in sections 3.2.1 and 3.3.1 of the ERA review.

Additional information regarding groundwater and stormwater loadings was provided in section 3.3.4 of the ERA review.

Information on COPC screening is provided in section 3.3 and conservatism in problem formulation in section 4.3.1.

A discussion of problem formulation and issues with the conservative approach is included in section 6.0.

A discussion of changes to the physical stressors in the aquatic environment is included in section 4.1.3

A discussion on air dispersion modelling is included in section 3.2.1 of the ERA review.

4.3 Review of 2016 ERA Compliance with N288.6-12

As part of the review of the ERA, an independent accounting of the 2016 ERA compliance with N288.6-12 (CanNorth, 2021a) was completed. There were technical deficiencies identified, including in the problem formulation for human and ecological receptors.

4.3.1 Levels of Conservatism in Problem Formulation

The 2016 assessment incorporated Tier 1 and Tier 2 assessments, which builds on the database of environmental and operations data, while also, to the extent possible and where appropriate, maintaining consistency with past assessments. Since it was built on current assessments it was not necessary to use the extremely conservative assumptions that necessitated a Tier 1 and Tier 2 assessment. In addition, the exposure point concentrations and the doses calculated for the HHRA were extremely conservative values of potential exposures (CanNorth, 2021a). Reasonable exposure scenarios is also discussed in the Problem Formulation Update for Exposure Assumptions (Section 6.2). Simplification of the problem statements and the screening assessments can help with communication of this information to interested members of the public.

5.0 Review of Changes to Scientific and Regulatory Information

The review process considered the potential for changes to scientific and regulatory information.

5.1 Scientific Advances

Screening criteria used in risk assessment are selected from appropriate standards and guidelines published by federal and/or provincial government agencies. These standards and guidelines are established on the basis of review of scientific literature and other sources of information regarding health or environmental impacts from exposure to a contaminant. Standards and guidelines are periodically reviewed to incorporate new information. As the 2020 Review of the ERA utilized the current standards and guidelines in the COPC screening, relevant advances in scientific information was included in the review.

Under O. Reg. 419/05, PHCF is required to use AERMOD to demonstrate compliance with the provincial regulatory requirements. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. The model code and supporting documents are regularly updated to incorporate the best available science.

5.2 Regulatory Requirements

There have been no significant changes to environmental legislation applicable to PHCF operations since the 2016 ERA. There were no changes to the site-specific provincial Environmental Compliance Approval (ECA) for air emissions. There were several changes to the site-specific ECA for industrial sewage works to reflect the upgrades to stormwater infrastructure, and transition from harbour water cooling to closed loop cooling that were in progress during the review period.

6.0 Problem Formulation Updates

6.1 Conceptual Site Model

From a human health perspective, the 2016 ERA provided a conceptual site model for off-site members of the public. The off-site members of the public included 11 off-site receptors which encompassed a nearby resident, recreational fisherperson, recreational boater, recreational park user, fenceline walker, and a commercial worker. Reducing the number of receptors which represent the maximum potential exposure should be considered in future ERA to simplify the analysis and (CanNorth, 2021a). Various exposure pathways were also discussed including, direct soil exposure, consumption of backyard produce, consumption of local fish, incidental exposure to surface water, inhalation, and gamma exposure. These are typical receptors and exposure pathways considered within an ERA (CanNorth, 2021a).

The ecological CSM considered a wide range of receptors including fish, benthic invertebrates, aquatic and terrestrial plants, terrestrial invertebrates, aquatic and terrestrial birds, and terrestrial mammals. These are typical ecological receptors and the pathways presented are also typical to an ERA. A number of the receptors were evaluated both on-site and off-site. Off-site amphibians and aquatic mammals should be considered for subsequent ERA (CanNorth, 2021a).

The HHRA and EcoRA both used a tiered approach, where all relevant receptor-COPC combinations were assessed at a Tier 1 screening level. Exceedances identified at the Tier 1 level were carried into a Tier 2 assessment comprising more realistic assumptions. The tiered approach used in the 2016 ERA led to an overly complicated assessment, with no benefit or change to the ultimate conclusions (CanNorth, 2021a).

The current review recognizes that during the ongoing execution of the VIM project, the site is under a constant state of improvements, all of which are expected to positively impact the environmental interactions of the site. At the conclusion of the VIM project, a comprehensive environmental risk assessment will be completed to reflect the changes to the site and operations and evaluate the updated operating conditions in an HHRA and EcoRA. The purpose of this review was to determine whether there were any potential gaps which would significantly alter the conclusions and require addressing in the interim.

There is an opportunity for PHCF to simplify the screening and problem formulation in the new risk assessment to focus on the contaminants and pathways that were identified as being of concern in the previous risk assessments.

6.2 Exposure Assumptions

The 2016 ERA is an update of the 2009 ERA and should represent a detailed quantitative risk assessment (DQRA) where reasonable and not consider the highly conservative implausible estimates of exposure that were used. It is very important at the Problem Formulation Stage to set up the foundation for the risk assessment and to ensure that reasonable exposure scenarios are being evaluated (CanNorth, 2021a).

Areas where less conservatism should be used in the post-VIM ERA include:

- Screening out COPC not associated with site operations
- Screening using representative concentrations for COPC
  - not maximum concentrations
  - appropriate for exposure pathway
  - incremental above background exposure
- Realistic exposure scenarios for receptor age groups
- Assessment of habitat suitability for ecological receptors

6.3 Receptor Selection and Characterization

6.3.1 Aquatic Receptors

The 2016 ERA identified fish, benthic invertebrates, and aquatic vegetation as the major biota groups (Table 6.1, ARCADIS 2016a). Amphibians were considered for inclusion, but not identified in the receptor selection. Additional discussion is provided in the TRV evaluation.

6.3.2 Terrestrial Receptors

The 2016 ERA selected ecological receptors based on SENES (2009a; 2009b) studies. According to ARCADIS (2016a), indicator species were selected based on knowledge of the site and surrounding environment, relevant environmental studies, accessibility of the environmental media, and potential species present in the area. Selected indicator species were representative of aquatic birds (scaup, horned grebe), terrestrial birds (warbler, robin, owl, cormorant, swallow), terrestrial mammals (fox, rabbit, vole, mouse), and terrestrial invertebrates and vegetation. Species representative of aquatic mammals (such as beaver, muskrat) were not identified for the assessment, although they were considered for inclusion (CanNorth, 2021a).

The 2016 ERA also considered species at risk in the selection of indicator species for the assessment. Eight bird species were identified as potentially relevant for the site and of those, the horned grebe was selected for the assessment. Table 6.2 of the 2016 ERA demonstrates that the remaining bird species are represented by other selected ecological receptors. In addition, one plant species was identified as vulnerable and is represented in the assessment by the terrestrial vegetation receptor (ARCADIS 2016a). In terms of the risk assessment, SAR species are evaluated at the individual level (CSA 2012, Clause 7.2.4.3), and this evaluation influences the selection of TRVs, which is discussed in the TRV Section below (CanNorth, 2021a).

6.3.3 Human Receptors

As mentioned above, the 2016 ERA selected off-site members of the public (residents, recreational fisherperson, recreational boater, recreational park user, fenceline walker, and a commercial worker). The assessment also considered combined resident and other user (i.e., worker, fenceline walker, park user, fisherperson, boater) receptors. The consideration of Nuclear Energy Workers

(NEWs) is beyond the scope of the assessment, consistent with CSA N288.6-12 (Table 5.6 of 2016 ERA). Cameco defines all employees, maintenance workers, and contractors who conduct work outside of an office area as NEWs and they are treated accordingly following health and safety protocols (ARCADIS 2016a).

The 2016 ERA considered the presence of First Nations groups in the development of the receptor characteristics for the assessment and determined that no groups were present in the study area (ARCADIS 2016a, Table 5.6). The 2016 ERA established exposure factors for the HHRA based on the values from Health Canada[2] (2012, as recommended by CSA 2012). During the review period, Cameco has expanded its Indigenous engagement with local First Nations and now understands that land around the PHCF is included in the traditional hunting/gathering territory for the Williams Treaties First Nations. Future collaboration with the First Nations is expected to result in relevant dietary consumption information for inclusion in future ERAs.

Eleven human receptors were identified for evaluation in the assessment; this led to an overly complicated evaluation. Representative receptors in each group (residents, recreational fisherperson, recreational boater, recreational park user, fenceline walker, and a commercial worker) who are maximally exposed should have been evaluated to simplify the findings.

6.4 Pathways

The 2016 ERA ultimately did not assess any potential exposures to human receptors from on-site soil or groundwater, such as those that might occur for a sub-surface worker or groundwater sampler. The rationale for not considering exposures to on-site workers, like a sub-surface worker, was that all workers at the PHCF are NEW and therefore not appropriate for consideration in the assessment as per CSA N288.6-12 (2012).

The assessment considered exposure to off-site soil, swimming or falling into the water and consumption of fish from the harbour. These were appropriate pathways to evaluate (CanNorth, 2021a).

6.5 TRVs

The 2016 ERA used the methodologies of the time as well as the toxicity reference values (TRVs). This review examines the TRVs and determines whether any values have been changed since the 2016 ERA and indicates the impact of these changes. For the radiological assessment, the selected dose coefficients and dose limits in the 2016 ERA were based on CSA N288.6-12 (2012).

6.5.1 Aquatic Receptors

From an aquatic environment perspective, individual TRVs for benthic invertebrates, aquatic plants, and fish were used. Cameco is now using a Species Sensitivity Distribution (SSD) approach, which considers the aquatic environment as a holistic community. This approach is used

[2] ARCADIS (2016a) referenced the 2010 version of the Health Canada PQRA guidance and CSA (2012) specifies the 2004 Part I guidance; this was updated in 2012.

by the CCME for the setting of water quality guidelines and is currently the approach used by many in the risk assessment community to evaluate risks in the aquatic environment. Based on the SSD approach, potential effects on aquatic receptors are evaluated on a community basis rather than individual receptor types.

As an example, Figure 6 provides the arsenic SSD with the 2016 ERA TRVs (ARCADIS 2016a, Table 6.29) indicated in relation to the SSD curve. As seen from the curve, more sensitive toxicity data are available for aquatic plants and invertebrates than those considered in the 2016 ERA, although the TRVs considered for fish are more sensitive than values considered in the arsenic SSD. The highest SI value for arsenic calculated in the 2016 ERA for aquatic receptors was 0.02 (ARCADIS 2016a, Table 6.48) using a maximum measured concentration of 2.7 µg/L (ARCADIS 2016a, Table 6.12); with consideration of the maximum measured surface water for arsenic in the 2015-2018 dataset (8.8 µg/L, **Table 1718**) it is unlikely that there would be any changes to the results of the assessment (CanNorth, 2021b).

No amphibians were identified for the assessment. Since there is a lack of toxicity data for amphibians, they are typically assessed as fish. Therefore, consideration of amphibians in the assessment is not expected to change the conclusions of the 2016 ERA. It happens that toxicity data for an amphibian species (*Rana pipiens*) is available for arsenic (Figure 6); the value is similar to the TRV for fish (pelagic) considered in the 2016 ERA. The 2016 ERA calculated a SI of 0.004 for arsenic and fish (pelagic) (ARCADIS 2016a, Table 6.48) using a maximum measured concentration of 2.7 µg/L (ARCADIS 2016a, Table 6.12). With the maximum measured surface water for arsenic in the 2015-2018 dataset (8.8 µg/L, **Table 1718**), the SI for fish (pelagic) would remain well below 1 and therefore, negative effects on amphibians would not be expected (CanNorth, 2021b).

Figure 6 Arsenic species sensitivity distribution

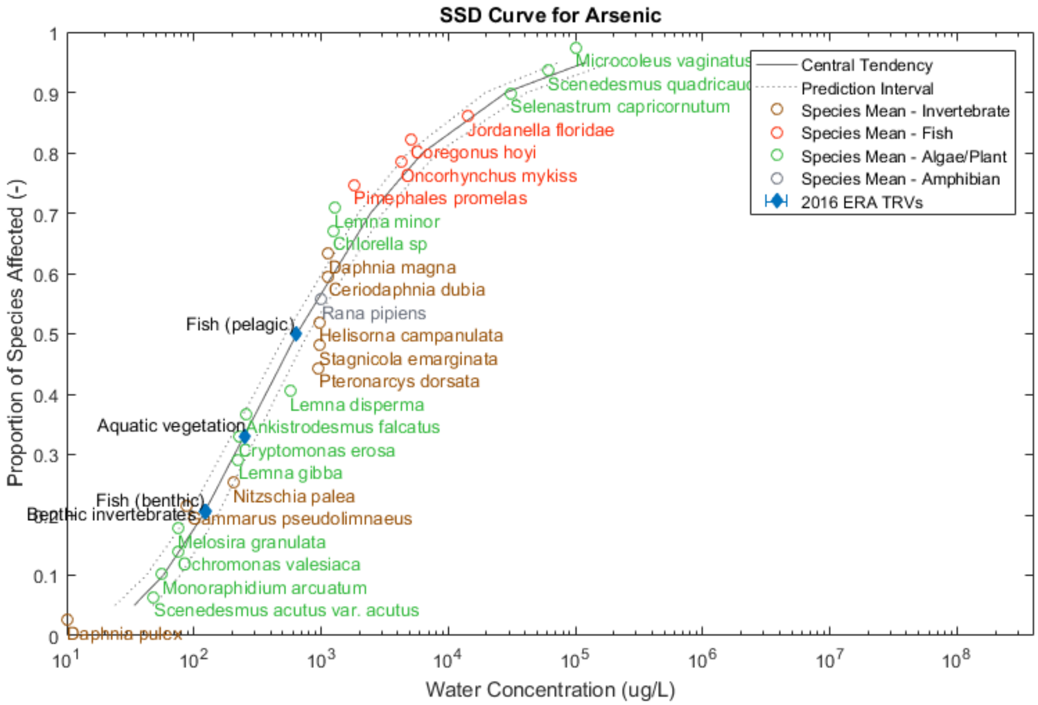
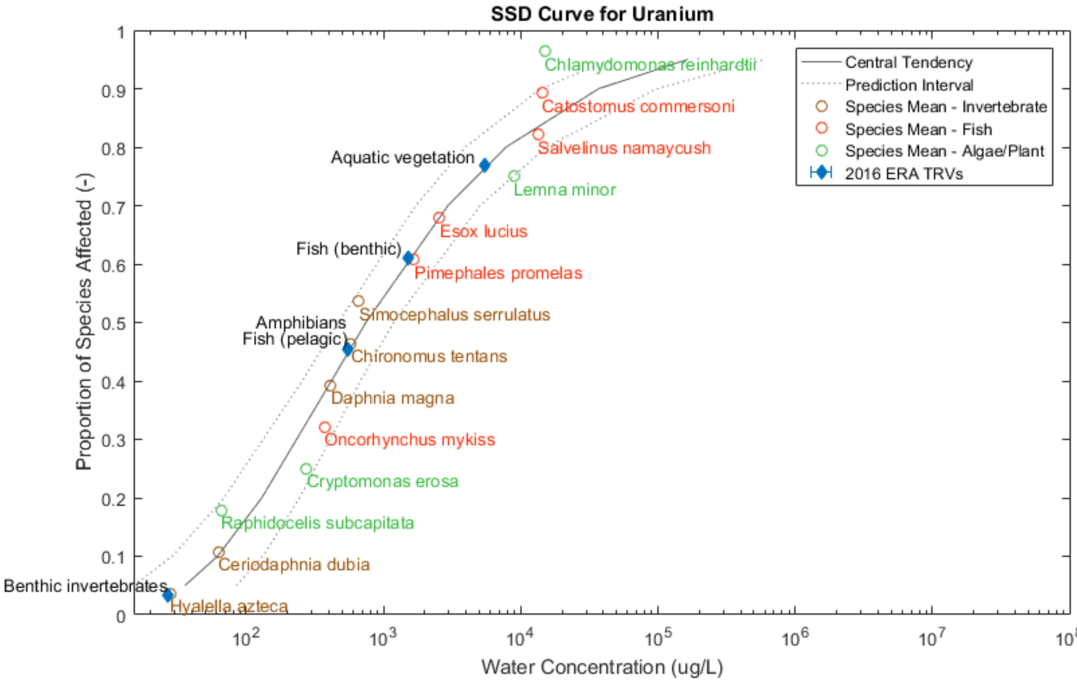


Figure 7 provides the uranium SSD with the 2016 ERA TRVs (ARCADIS 2016a, Table 6.20) indicated in relation to the SSD curve. The use of the SSD approach for uranium incorporates all available toxicity data, provided these data pass quality control and applicability criteria. For uranium specifically, the SSD curve (Figure 6) is based on CCME (2011 Table 11), with additional data from U.S. EPA ECOTOX and a literature review including Goulet et al.(2015). As seen from the curve, a number of the TRVs used in the 2016 ERA are on the curve and thus it is unlikely that the conclusions of the aquatic assessment would change (CanNorth, 2021b).

Figure 7 Uranium species sensitivity distribution



The 2016 ERA did not identify any aquatic receptor SAR in the assessment. Per CSA N288.6-12 (2012, Clause 7.2.4.3), the assessment of SAR influences the selection of TRVs. The use of the SSD curve can assist in the evaluation of potential aquatic SAR species for non-radiological effects. For radiological dose, there are no available dose limits for the assessment of aquatic SAR species. However, from the results presented in the 2016 ERA (ARCADIS 2016a, Table 6.32), the SI values calculated using a dose limit of 9.6 mGy/d are very low (<0.1), which indicates that there is a wide margin of safety for the protection of individual aquatic receptors, including amphibians, fish, and aquatic plants and thus SAR species would not experience adverse effects (CanNorth, 2021a).

6.5.2 Terrestrial Receptors

The TRVs for mammals and birds in the 2016 ERA were primarily obtained from the U.S. EPA ecological soil screening levels (Eco-SSLs) (U.S. EPA 2005) and from Sample et al. (1996). A similar approach was used for more recent ERAs for Cameco in Northern Saskatchewan, with an updated approach for surrogate selection. The approach for the selection of TRVs in the 2016 ERA is considered to be valid (CanNorth, 2021a).

The 2016 ERA considered the horned grebe and lesser scaup as surrogates for other SAR species in the assessment. Per CSA N288.6-12 (2012, Clause 7.2.4.3), the assessment of SAR influences the selection of TRVs. The 2016 ERA appropriately considered NOAEL TRVs (ARCADIS 2016a, Table 6.28) for the assessment of SAR to evaluate protection at an individual level. For radiological dose, a dose threshold value of 1 mGy/d can be used to assess species at risk as IAEA (1992) determined this was the dose rate with no observable effects to biota. The radiological assessment for terrestrial receptors in the 2016 ERA (ARCADIS 2016a, Table 6.30) used a dose limit of 2.4 mGy/d for all terrestrial animals. However, the calculated doses for the horned grebe and lesser scaup (ARCADIS 2016a, Table 6.32) were erroneously compared to a dose limit of 9.6 mGy/d. The horned grebe at the harbour had the highest calculated total dose of 0.098 mGy/d. This dose remains below the dose limit considered for no observable effects to biota (i.e., 1 mGy/d) and therefore the conclusions of the assessment remain unchanged.

6.5.3 Human Receptors

The TRVs specified for the HHRA in the 2016 ERA (ARCADIS 2016a, Table 5.17) are from typical sources, consistent with N288.6-12 (CanNorth, 2021a).

7.0 Conclusion

The 2016 ERA was generally conducted using the framework outlined in N288.6-12 and using the available toxicity information at that time (CanNorth, 2021a). There are a few issues that have been noted:

- Use of extremely conservative measures of exposure (maximum concentrations and 95%tile concentrations) instead of the more reasonable and acceptable exposure of a 95%UCLM.
- Evaluation of a wide range of COPC that were part of the Earth's crust or not associated with PHCF operations.
- Assessment for arsenic risk should have been completed only on incremental exposures to humans
- Complicated problem formulation, screening and tiered approach to the assessment
- Incorrect application of radiation benchmarks in the ecological assessment.

Since the completion of the 2016 ERA, additional monitoring has been completed resulting in decreases in some concentrations of COPCs in monitoring data. In addition, the approach to the evaluation of aquatic receptors has evolved and some toxicity values have changed. The changes in monitoring data and changes in toxicity values and approaches to evaluation of aquatic receptors do not result in changes to the 2016 ERA conclusions.

Physical changes underway at the site as part of ongoing operations and the VIM project will eliminate potential risks identified in the 2016 ERA. This includes the elimination of physical stressors on the aquatic environment through the transition to a closed loop cooling system and remediation of subsurface infrastructure and contamination to improve capture and control of legacy contamination. These changes have improved environmental performance and reduced the overall impact of PHCF operations on the environment. Once completed, these activities are expected to eliminate the potential risks identified in the 2016 ERA.

7.1 Recommendations

This review of the ERA was completed by Cameco subject matter experts with support from third-party experts in the areas of risk assessment and environmental modelling.

Based on this review completed in accordance with Clause 11.1 of N288.6-12, there are no identified risks that have emerged since the last ERA review. In fact, the review identified that several potential risks are becoming less significant. The changes under the VIM project will require a full update of the ERA to establish a new baseline of environmental performance on which to revise the site Environmental Protection Program. It is important that this full update be undertaken once the site remediation and harbour remediation are largely complete and there are no remaining activities such as building demolition or soil excavation which could skew the operational monitoring data required for the ERA update. It is anticipated that this will occur early in the next licence period.

It is recommended that an ERA review be carried out in support of the licence renewal in 2027, with specific consideration to site changes 2023-2025 and the full ERA update be completed within 2 years of the completion of VIM and PHAI remedial activities in the vicinity of the PHCF.

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