Canada's Nuclear Regulator

Environmental Protection Review Report:
Pickering Nuclear Site

January 2024

e-Doc: 6993211 (Word)
e-Doc: 7188661 (PDF)

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

Environmental Protection Review Report: Pickering Nuclear Site

Cat. No. CC172-251/2024E-PDF
ISBN 978-0-660-49878-2

Également publié en français sous le titre : *Rapport d'examen de la protection de l'environnement : Complexe nucléaire de Pickering*

Revision History

The following table identifies the revision history of this document.

Revision number	Change	Summary of changes	Date
000	Initial release	N/A	January 2024
001			

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Executive summary

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

This EPR report was written by CNSC staff as a stand-alone document, describing the scientific and evidence-based findings from CNSC staff's review of Ontario Power Generation's (OPG's) environmental protection measures. The periodic EPR report provides an assessment of documents related to the Pickering Nuclear Site (PN Site), which consists of the Pickering Nuclear Generating Station (PNGS) and the Pickering Waste Management Facility (PWMF).

The PN Site is located on the traditional and treaty territories of the Wendat, Anishinabek Nation, and the territory covered by the Williams Treaties with the Michi Saagiig and Chippewa Nation. Under its current power reactor operating licence, PROL 48.01/2028, OPG is permitted to operate the PNGS units for power production. Under the waste facility operating licence, WFOL-W4-350.00/2028, OPG is also permitted to operate the PWMF.

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

This EPR report includes CNSC staff's assessment of documents submitted by the licensee to CNSC staff from 2016 to 2022 and the results of CNSC staff's compliance activities, including the following:

- the results of OPG's environmental monitoring, as reported in the environmental monitoring program reports
- OPG's 2022 environmental risk assessment for the PN Site
- OPG's preliminary decommissioning plan for the PN Site
- the results of the CNSC's Independent Environmental Monitoring Program
- the results from other environmental monitoring programs and/or health studies (including studies completed by other levels of government) in proximity to the PN Site

Based on their assessment and evaluation of OPG's documentation and data, CNSC staff have found that the potential risks from radiological and hazardous releases to the atmospheric, terrestrial, aquatic and human environments from the PN Site are low to negligible, and that these releases are at levels similar to natural background. Furthermore, human health is not impacted by operations at the PN Site and the health outcomes are indistinguishable from health outcomes found in the general public. CNSC staff have also found that OPG continues to implement and maintain effective environmental protection measures that meet regulatory requirements and adequately protect the environment and the health and safety of persons. CNSC staff will continue to verify OPG's environmental protection programs through ongoing licensing and compliance activities.

CNSC staff's findings from this report may inform recommendations to the Commission in future licensing and regulatory decisions, as well as inform CNSC staff's ongoing and future compliance verification activities. CNSC staff's findings do not represent the Commission's conclusions. The Commission's decision-making will be informed by submissions from CNSC staff, the licensee, Indigenous Nations and communities, and the public, as well as through any interventions made during public hearings on Commission proceedings.

OPG makes many summary documents, including reports containing environmental data, available on OPG's website (external). References used throughout this document are available upon request and requests can be sent to er-ee@cnsc-ccsn.gc.ca.

1.0 Introduction

1.1 Purpose

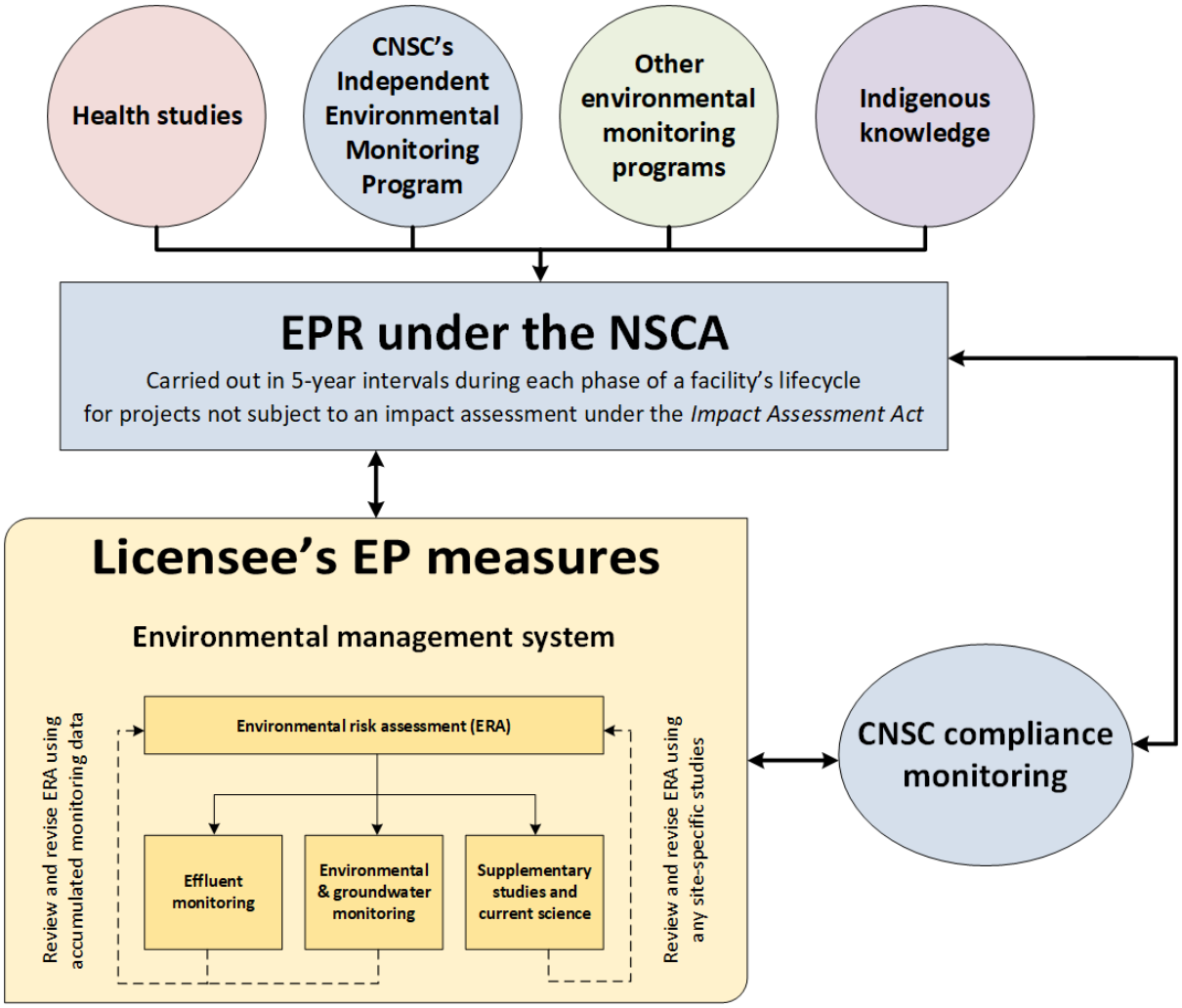
The Canadian Nuclear Safety Commission (CNSC) conducts environmental protection reviews (EPRs) for all nuclear facilities with potential interactions with the environment, in accordance with its mandate under the *Nuclear Safety and Control Act* (NSCA) [1]. CNSC staff assess the environmental and health effects of nuclear facilities and/or activities during every phase of a facility's lifecycle. As shown in figure 1.1, an EPR is a science-based environmental technical assessment conducted by CNSC staff to support the CNSC's mandate for the protection of the environment and human health and safety, as set out in the NSCA. The fulfillment of other aspects of the CNSC's mandate is met through other regulatory oversight activities and is outside the scope of this report. Each EPR report is typically conducted every 5 years and is informed by the licensee's environmental protection (EP) program and documentation submitted by the licensee as per regulatory reporting requirements.

As per the CNSC's Indigenous Knowledge Policy Framework [2], the CNSC recognizes the importance of considering and including Indigenous Knowledge in all aspects of its regulatory processes, including EPRs. CNSC staff are committed to working directly with Indigenous Nations and communities and knowledge holders on integrating their knowledge, values, land use information, and perspectives in the CNSC's EPR reports, where appropriate and when shared with the licensee and the CNSC.

The purpose of this EPR is to report the outcome of CNSC staff's assessment of the Ontario Power Generation Inc. (OPG)'s EP measures and CNSC staff's health science and environmental compliance activities for the Pickering Nuclear Site (PN Site) – operations at both the Pickering Nuclear Generating Station (PNGS) and the Pickering Waste Management Facility (PWMF). This review serves to assess whether OPG's EP measures at the PN Site meet regulatory requirements and adequately protects the environment and health and safety of persons.

While this EPR focuses on the EP measures of the PN Site from 2016-2022, it should be noted that in June 2023, OPG submitted a licence application to extend operations of PNGS Units 5 to 8 from December 31, 2024, to December 31, 2026 [3].

Figure 1.1: Environmental protection review framework



CNSC staff's findings may inform recommendations to the Commission in future licensing and regulatory decision making, as well as inform CNSC staff's ongoing and future compliance verification activities.

CNSC staff's findings do not represent the Commission's conclusions. The Commission is an independent, quasi-judicial administrative tribunal and court of record. The Commission's conclusions and decisions are informed by information submitted by CNSC staff, the licensee, Indigenous Nations and communities, and the public, as well as through any interventions made during public hearings on Commission proceedings.

EPR reports are prepared to thoroughly document CNSC staff's technical assessment relating to a licensee's EP measures and are posted online for information and transparency. Posting EPR reports online, separately from the documents drafted during the licensing process, allows interested Indigenous Nations and communities and members of the public additional time to review information related to EP prior to any licensing hearings or Commission decisions. CNSC

staff may use the EPR reports as reference material when engaging with interested Indigenous Nations and communities, members of the public and interested stakeholders.

This EPR report is informed by documentation and information submitted by OPG, compliance activities completed by CNSC staff from 2016 to 2022, and other sources, such as:

- regulatory oversight activities (section 2.0)
- CNSC staff's review of OPG's preliminary decommissioning plan (PDP) for the PN Site [4] (section 2.2)
- CNSC staff's review of OPG's Results of Environmental Monitoring Programs for Pickering [5, 6, 7, 8, 9]
- CNSC staff's review of OPG's 2022 environmental risk assessment (ERA) for the PN Site [10] (section 3.2)
- results of the CNSC's Independent Environmental Monitoring Program (IEMP), including discussions with Indigenous Nations and communities (section 4.0)
- health studies with relevance to the PN Site (section 5.0)
- data from other environmental monitoring programs (EMPs) in proximity to the PN Site (section 6.0)

This EPR report focuses on topics related to the facility's environmental performance, including atmospheric (emission) and liquid (effluent) releases to the environment, and the potential transfer of constituents of potential concern (COPCs) through key environmental pathways and associated potential exposures and/or effects on valued ecosystem components (VECs), including human and non-human biota. VECs refer to environmental, biophysical or human features that may be impacted by a project. The value of a component relates not only to its role in the ecosystem, but also to the value people place on it (for example, it may have scientific, social, cultural, economic, historical, archaeological or aesthetic importance). The focus of this report is on radiological and hazardous substances associated with licensed activities undertaken at the PN Site, with additional information provided on other topics of Indigenous, public and regulatory interest. CNSC staff also present information on relevant regional environmental and health monitoring, including studies conducted by the CNSC or other governmental organizations.

1.2 Facility overview

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

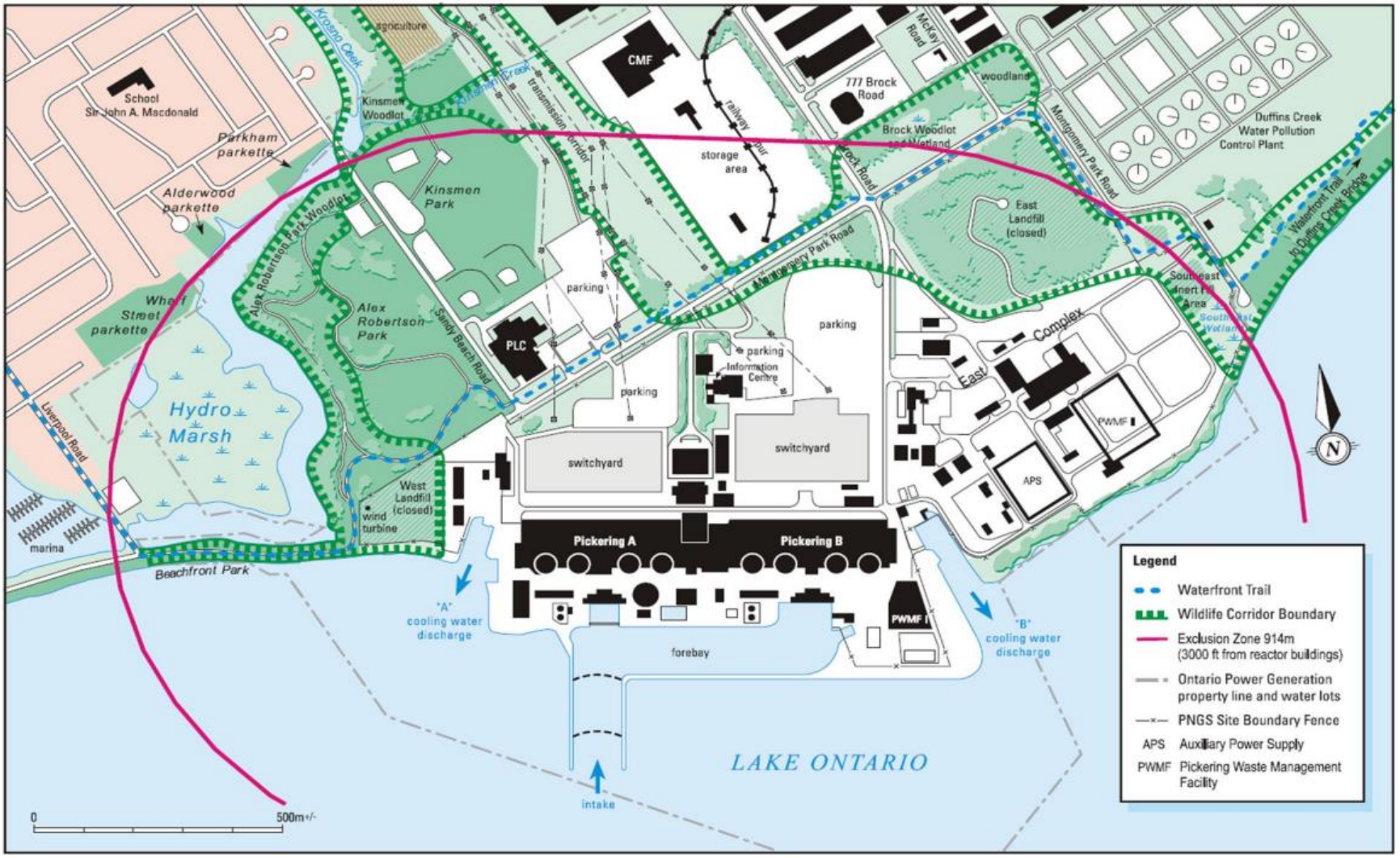
1.2.1 Site description

The PN Site is within the traditional and treaty territories of the Wendat, Anishinabek Nation, and the territory covered by the Williams Treaties with the Michi Saagiig and Chippewa Nation. The facilities are located in the City of Pickering, within the Regional Municipality of Durham, approximately 32 kilometres (kms) east of downtown Toronto, Ontario.

The PN Site is owned and operated by the licensee, OPG. PNGS and the PWMF operate under separate licences issued by the Commission to OPG. This EPR Report includes CNSC staff's assessment of the EP measures at both the PWMF and PNGS.

OPG owns approximately 240 hectares (ha) of land and 100 ha of water property, located either adjacent to or on the PN Site. The majority of these lands are designated as part of the station's exclusion zone, which is the land within or surrounding a nuclear facility on which there can be no permanent habitation. The protected area of the PN Site is fenced and access to the site is restricted and controlled by OPG. The PN Site is surrounded by residential and recreational areas to the north-west, the hydro corridor to the north, industrial areas to the east and north-east and Lake Ontario to the south. The PN Site is located close to other important water bodies, namely Hydro Marsh (owned by OPG), Duffins Creek and Frenchman's Bay (refer to figure 1.2).

Figure 1.2: Aerial view of the Pickering Nuclear Site [10]



1.2.2 Facility operations

The PNGS began operating in 1971, and the PWMF became operational in 1996. Within the PNGS licence, OPG possesses and uses nuclear substances and associated equipment to generate power. Within the PWMF licence, OPG operates the waste management facility and associated activities to manage waste generated from the PNGS.

1.2.2.1 Pickering Nuclear Generating Station

The PNGS consists of 8 CANada Deuterium Uranium (CANDU) pressurized heavy water nuclear reactor units and auxiliary systems that support their operation and the production of electricity. 6 reactor units are in operation (Units 1, 4 and 5–8), and 2 reactor units (Units 2 and 3) have been in safe storage state since 2010. Units 1 to 4 are located on the western side of the nuclear station, formerly licensed as "Pickering A," and Units 5 to 8 are located on the eastern side of the nuclear station, formerly licensed as "Pickering B."

The PN Site comprises a large number of buildings of various sizes with a wide range of functions (see figure 1.2). An overview of the main features are described in table 1.1.

Table 1.1: Definition of the Pickering Nuclear Generating Station's main components

Component	Definition
Reactor buildings	The facility has 8 reactor buildings, each of which contain 1 reactor, 12 steam generators, a ventilation system to control airflow and temperature, a moderator which circulates heavy water and other related equipment. Units 1 and 4 have 390 fuel channels; units 5 to 8 have 380 fuel channels. All airborne emissions from the reactor buildings are controlled and monitored for radioactive contaminants by the stack monitoring system.
Turbine buildings	These 2 buildings each contain steam turbines, electricity generators, steam condensers and feedwater systems.
Irradiated fuel bays (IFBs)	Irradiated fuel bays are used to store and cool used fuel bundles. The IFBs are located in the reactor auxiliary bays at ground level. The used fuel bundles from Pickering B (Units 5–8) are stored in the Pickering B IFB for at least 10 years prior to transferring to dry storage containers (DSCs) and then transported to PWMF for interim storage. Used fuel bundles from Pickering A (Units 1-4) are held in the Pickering A IFB for 4 years and then transferred to the Pickering A auxiliary IFB. Filters and ion exchange columns are used to remove radionuclides from the IFB water.

Forebay, intake channel and discharge channels	The intake channels for Units 1–4 and 5–8 draw condenser cooling water (CCW) from the forebay into each unit. There are 2 CCW pumps per reactor to pump water to the condensers. After the CCW is used in the condensers, the CCW is discharged into Lake Ontario through the drainage channel.
Fish diversion system (FDS):	The FDS is a barrier net surrounding the intake structure, which is seasonally installed for 8 to 9 months of the year (see figure 1.3). The FDS is in place to mitigate impingement of fish at the PN facility.

1.2.2.2 Pickering Waste Management Facility

At the PWMF, OPG processes and stores DSCs containing used nuclear fuel (high–level radioactive waste) generated at the PNGS. OPG also stores the intermediate level radioactive waste generated from retubing the PNGS Units 1–4 in above ground dry storage modules (DSMs) located at the Retube Component Storage Area (RCSA) at the PWMF. The PWMF includes:

- the PWMF Phase I, composed of 1 DSC processing building (hereinafter referred to as the "processing building"), 2 DSC storage buildings (#1 and #2) (hereinafter referred to as "storage buildings"), and 1 RCSA
- the PWMF Phase II, composed of 2 storage buildings (#3 and #4)

Table 1.2 defines the key structural components of the PWMF.

Table 1.2: Definition of the Pickering Waste Management Facility's main components

Component	Definition
Dry storage container	A free-standing reinforced concrete container with an inner steel liner and an outer steel shell that is designed and constructed to safely transfer and store dry used fuel on-site.
Processing building	A secured building where empty dry storage containers are prepared before being sent to the PNGS for used fuel loading, and where loaded dry storage containers are processed before being transferred to storage buildings. Processing activities include welding, painting and testing. The processing building also includes an amenities area with utility rooms, offices, washrooms, a lunch room and other supporting facilities.

Storage building	A single-storey, commercial-type, pre-engineered or precast concrete structure with a concrete slab-on-grade floor that is designed and constructed to safely store dry storage containers.
Dry storage container transporter	A specially designed multi-wheeled vehicle for the transfer of dry storage containers between the PNGS's irradiated fuel bays and the processing building, and from the processing building to storage buildings.
Retube component storage area	A fenced and access controlled area, located south of the PWMF Phase I storage buildings, where 36 dry storage modules containing intermediate-level waste from retubing the PNGS are stored and periodically inspected, monitored and maintained.
Dry storage module	A specifically designed and shielded container loaded with irradiated reactor components that were removed from the PNGS Units 1 to 4 between 1984 and 1992. These components include pressure tubes, end fittings, shield plugs and miscellaneous identified components.

2.0 Regulatory oversight

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

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

2.1 Environmental protection reviews and assessments

To date, 4 federal environmental assessments (EAs) and 3 EPRs (including this one) have been carried out for the PN Site, as indicated in table 2.1. Subsection 2.1.1 provides a description of the EAs conducted under the *Canadian Environmental Assessment Act* (CEAA 1992) [11] predecessor to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) [12]. Subsection 2.1.2 provides information on the EPRs conducted for the PN Site. In 2019, the *Impact Assessment Act of Canada* (IAA) [13] came into force, replacing CEAA 2012. OPG's current activities at the PN Site do not require an impact assessment under the IAA's *Physical Activities Regulations* (external) [14]. The purpose of an assessment under any 1 of these pieces of legislation is to identify the possible impacts of a proposed project or activity and to determine whether those effects can be adequately mitigated to protect the environment and the health and safety of persons.

Table 2.1: Federal environmental assessments for the Pickering Nuclear Site

Project	Regime	EA start date	EA decision date	EA follow-up monitoring program
Pickering NGS-A Return to Service	CEAA 1992	November 24, 1999	October 3, 2001	Yes
PWMF Phase II Expansion Project	CEAA 1992	July 4, 2002	May 28, 2004	Yes
Pickering A Units 2 and 3 Guaranteed Defuelled State	CEAA 1992	February 4, 2008	November 28, 2008	No

Project	Regime	EA start date	EA decision date	EA follow-up monitoring program
Refurbishment and Continued Operation of the Pickering B NGS	CEAA 1992	July 28, 2006	January 26, 2009	Yes*

*The EA follow-up program was not implemented due to this project being cancelled.

2.1.1 Environmental assessments completed under *Canadian Environmental Assessment Act*

2.1.1.1 Pickering Nuclear Generating Station-A return to service

In late 1999, OPG requested approval from the CNSC to return to service Units 1–4. These reactors had been placed in a non-routine guaranteed shutdown state at the end of 1997 to free up resources to improve the safety and productivity of OPG's other nuclear operations. An EA Screening Report was completed under CEAA 1992 [15]. In October 2001, the Commission concluded that the project, taking into account the appropriate mitigation measures, was not likely to cause significant adverse environmental effects [16]. The EA process identified the need for an EA follow-up program for the Pickering A Return to Service project. This follow-up program was tracked through the various iterations of the annual follow up and monitoring reports for PNGS. All items of the program were deemed to be met and the program was officially closed [17].

2.1.1.2 Pickering Waste Management Facility Phase II Environmental Assessment

In 2002, OPG communicated its intent to expand the capacity of the PWMF by constructing and operating 2 additional storage buildings (#3 and #4) at the PWMF Phase II site. The proposed expansion was required to accommodate used fuel from the PNGS to the end of its proposed service life. An EA Screening Report was completed under CEAA 1992 [18]. In May 2004, the Commission concluded that the project, taking into account the appropriate mitigation measures, was not likely to cause significant adverse environmental effects [19]. The EA process identified the need for an EA follow-up program for the PWMF Phase II project. For more details on the follow-up program, see section 2.1.3.1.

2.1.1.3 Refurbishment and Continued Operation of the Pickering B Nuclear Generating Station

In June 2006, OPG communicated its intent to refurbish and continue to operate Units 5 to 8 until 2060. The proposed project involved the refurbishment or replacement of major components in each of the 4 units. An EA Screening Report was completed under CEAA 1992 [20]. In December 2008, the Commission concluded that the project, taking into account the appropriate mitigation measures, was not likely to cause significant adverse environmental effects [21].

The EA process identified the need for an EA follow-up program for the Pickering B Refurbishment and Continued Operation project. However, OPG announced in February 2010

that it would not pursue the refurbishment project. As such, the EA follow-up program was not implemented.

2.1.1.4 Pickering A Units 2 and 3 Guaranteed Defuelled State

Following EA approval and NSCA licensing requirements of the PNGS-A Return to Service in 2000, Units 1 and 4 were returned to service; however, Units 2 and 3 remained in the Guaranteed Shutdown State. In November 2005, OPG advised the CNSC that PNGS-A Units 2 and 3 would not be returned to service, while Units 1 and 4 would continue to operate. OPG indicated that it wished to place Units 2 and 3 into a Guaranteed Defuelled State from which the units could not be returned to service. This involved physical modifications to deactivate these units and isolate them from operating Units 1 and 4 and place Units 2 and 3 in a permanent shutdown state. An EA Screening Report was completed under CEAA 1992 [22]. In November 2008, the Commission concluded that the project, taking into account the appropriate mitigation measures, was not likely to cause significant adverse environmental effects [23]. The EA process did not identify the need for an EA follow-up program for the PNGS-A Guaranteed Defuelled State project.

2.1.2 Current environmental assessment follow-up program

EA follow-up programs are designed to validate the predicted environmental effects and the effectiveness of mitigation measures. The CNSC ensures that EA follow-up programs that are within the CNSC's mandate are incorporated into licensing and compliance activities.

2.1.2.1 Pickering Waste Management Facility Phase II Environmental Assessment Follow-up Program

The EA under the CEAA 1992 identified the need for an EA follow-up program to verify the EA predictions and the effectiveness of mitigation measures for the PWMF Phase II project. CNSC staff's EA Screening Report [18] identified follow-up program elements, including areas of concern, such as stormwater management, visual screening of the PWMF Phase II and public attitudes. CNSC staff will continue to review the monitoring results for the EA follow up program that are included in the PWMF annual compliance report to ensure that objectives are being met [24].

2.1.3 Previous environmental protection review completed under the *Nuclear Safety and Control Act*

2.1.3.1 Pickering Nuclear Generating Station Licence Renewal

In 2018, OPG applied for a 10-year licence to renew its PNGS Operating Licence. An EA under the NSCA was conducted for the licence application [17]. CNSC staff concluded that OPG has and would continue to make adequate provision for the protection of the environment and the health of persons. A public Commission hearing on the licence application was held in April 2018 and the Commission approved OPG's application [25].

2.1.3.2 Pickering Waste Management Facility Licence Renewal

In 2016, OPG applied for a 10-year licence to renew its PWMF Operating Licence. An EA under the NSCA was conducted for the licence application [26]. CNSC staff concluded that OPG has

and would continue to make adequate provision for the protection of the environment and the health of persons. A public Commission hearing on the licence application was held in April 2017 and the Commission approved OPG's application [27].

2.2 Planned end-state

The following section provides high-level information on the currently planned end-state of the PN Site following decommissioning activities. This section is informed by OPG's preliminary decommissioning plan (PDP) for the PN Site. The PDP is important to consider as part of CNSC staff's ongoing oversight for the assessment of environmental and health effects of nuclear facilities and activities.

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

PDPs for nuclear facilities are updated by the licensee at least every 5 years, or considering notable changes relevant to decommissioning. The decommissioning strategy and end-state objectives for the PN Site are documented in the Pickering Nuclear Site Preliminary Decommissioning Plan [4].

OPG's PDP assumes that units 1-4 and units 5-8 will be shut down in 2024 and 2025 respectively, and a deferred decommissioning strategy is planned. However, flexibility is built into the process to cater to the final decision OPG may make with respect to shutdown dates. This PDP is the proposed plan for decommissioning the PNGS and since it also addresses the interfaces of the PNGS with the PWMF, which is also located on the PN Site, it is referred to as the site PDP. The purpose of the PDP is to define the areas to be decommissioned and the sequence of the principal decommissioning work for the PNGS. The PDP also demonstrates that decommissioning is feasible with existing technology, and it provides a basis for estimating the cost of decommissioning. The PDP describes the final end state after dismantling, demolition and site restoration, which notes that the site will be free of industrial and radiological hazards.

In January 2022, OPG submitted the updated PN Site PDP. CNSC staff have reviewed the PDP and provided comments and requests to which OPG is required to respond. An updated PN Site PDP is expected in 2027. It should be noted that in June 2023, OPG submitted an application to extend the commercial operation date of PNGS Units 5 to 8 from December 31, 2024 to December 31, 2026 [3]. This application is currently under review by CNSC staff and will require a Commission hearing for decision.

2.3 Environmental regulatory framework and protection measures

The CNSC has a comprehensive EP regulatory framework which includes the protection of people and the environment and considers both radiological and hazardous substances, as well as physical stressors. Public dose is included in the EP framework. OPG calculated the estimated dose to the public from all activities at a site-wide level. The focus of this section of the EPR report is on the EP regulatory framework and the status of OPG's environmental protection program (EPP) for the PN Site. The results from OPG's EPP are detailed in section 3.0 of this report.

OPG's EPP for the PN Site was designed and implemented in accordance with REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (2017) [28], as well as the CSA Group's environmental protection standards listed below. The implementation status for these documents is shown in table 2.2. The EPP includes derived release limits (DRLs) and public dose modelling.

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

Regulatory document or standard	Status
CSA N288.1-14, *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities* [29]	Implemented
CSA N294-09 (reaffirmed 2014), *Decommissioning of facilities containing nuclear substances* [30]	Implemented
CSA N288.4-10, *Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills* [31]	Implemented
CSA N288.5-11, *Effluent monitoring program at Class I nuclear facilities and uranium mines and mills* [32]	Implemented
CSA N288.6-12, *Environmental risk assessment at Class I Nuclear facilities and uranium mines and mills* [33]	Implemented
CSA N288.7-15, *Groundwater protection programs at Class 1 nuclear facilities and uranium mines and mills* [34]	Implemented
CSA N288.8-17, *Establishing and implementing action levels for releases to the environment from nuclear facilities* [35]	Implemented
CNSC REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures, version 1.1* (2017) [28]	Implemented
CSA N288.0-22, *Environmental management of nuclear facilities: Common requirements of the CSA N288 series of Standards* [36]	Implemented

CNSC staff confirm that OPG has implemented programs that are following the relevant EP regulatory documents and standards or has implementation plans in place.

Licensees are also required to regularly report on the results of their EPPs. Reporting requirements are specified in REGDOC-3.1.1, *Reporting Requirements for Nuclear Power Plants* [37] and REGDOC-3.1.2 *Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills* [38].

OPG is required to submit quarterly safety performance indicator reports, annual reports on environmental protection for the NGS and quarterly reports and annual compliance reports as per REGDOC-3.1.1 and REGDOC-3.1.2 [37, 38]. These reports are reviewed by CNSC staff for compliance and verification, as well as trending. OPG publishes several of these reports on its website, such as web page Reporting > Regulatory reporting - OPG (external) [39].

CNSC staff regularly report on licensee performance to the Commission for activities conducted at the PN Site. For example, CNSC staff's regulatory oversight reports (RORs) are a standard mechanism for updating the Commission, Indigenous Nations and communities, and the public on the operation and regulatory performance of licensed facilities. Previous RORs are available on the CNSC regulatory oversight reports web page [40]. CNSC staff may also report to the Commission on significant events, such as unplanned releases to the environment, through an event initial report.

2.3.1 Environmental protection measures

To meet the CNSC's regulatory requirements under REGDOC-2.9.1 (2017) [28], OPG is responsible for implementing and maintaining EP measures that identify, control and monitor releases of radioactive and hazardous substances from the PN Site, as well as the effects of these substances on human health and the environment. EP measures are an important component of the overall requirement of licensees to make adequate provisions to protect the environment and the health of persons.

This subsection and the following ones under section 2.3 summarize OPG's EPP for the PN Site and the status of each specific EP measure, relative to the requirements or guidance outlined in the latest regulatory document or CSA Group standard.

OPG is required to implement an environmental management system (EMS) that conforms to REGDOC-2.9.1 (2017) [28] and to submit an EPP for the PN Site. OPG's EPP includes the following components to meet the requirements and guidance as outlined in REGDOC-2.9.1 (2017) [28]:

- EMS (subsection 2.3.2)
- environmental risk assessment (ERA) and predictive effects Assessment (PEA) (subsection 2.3.3 and 2.3.4)
- effluent and emissions control and monitoring (section 2.3.5)
    - derived release limits
    - air emissions and liquid effluent monitoring
- environmental monitoring program (EMP) (section 2.3.6)
    - air monitoring
    - fruits and vegetables monitoring
    - animal feed monitoring
    - eggs and poultry monitoring
    - milk monitoring
    - soil and sand monitoring
    - surface water (Water Supply Plant monitoring and lake water)
    - well water
    - groundwater monitoring
    - sediment monitoring

- fish monitoring

Section 3.0 of this EPR report summarizes the results of these programs or measures against relevant regulatory limits and environmental quality objectives or guidelines, and discusses, where applicable, any notable trends.

2.3.2 Environmental management system

An EMS refers to the management of an organization's environmental policies, programs and procedures in a comprehensive, systematic, planned, and documented manner. It includes the organizational structure as well as the planning and resources to develop, implement and maintain an EP policy. The EMS serves as a management tool to integrate all of a licensee's EP measures in a documented, managed and auditable process in order to:

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

OPG has established and implemented a corporate EMS for the PN Site in accordance with REGDOC-2.9.1 (2017) [28] and is also registered and certified under the International Organization for Standardization (ISO) standard 14001:2015 (a standard that helps an organization achieve the intended outcomes of its EMS). CNSC staff review OPG's annual internal audits; management reviews; and environmental goals, targets and objectives to ensure compliance with REGDOC-2.9.1 (2017). While the CNSC does not consider ISO 14001 certification as part of the criteria for meeting the requirements of REGDOC-2.9.1, the results of these third-party audits are reviewed by CNSC staff as part of the compliance program. CNSC staff also review the status of OPG's annual goals, targets and objectives and the implementation of the EMS as part of their review of the annual reports on EP.

The results of these reviews demonstrate that OPG's EMS for the PN Site meets the CNSC requirements as outlined in REGDOC-2.9.1 (2017) [28]. The implementation of the EMS ensures that OPG continues to improve environmental performance at the PN Site.

2.3.3 Environmental risk assessment

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

control measures and EMPs. The results of these programs, in turn, inform and refine future revisions of the ERA.

In April 2022, OPG submitted an updated ERA report for the PN Site, which includes risks associated with both the PNGS and the PWMF, based on effluent and environmental monitoring data for the 5-year period between 2016 and 2020, and also incorporated other years of data as needed [10]. A revised ERA report was submitted in April 2023, taking into consideration CNSC staff comments [41]. The ERA included an ecological risk assessment (EcoRA) and a human health risk assessment (HHRA) for radiological and non-radiological (hazardous) COPCs and physical stressors related to the PN Site and its activities. The purpose of the 2022 ERA was to update the previous ERA that was completed by OPG in 2017 [42] and to reflect current operations and incorporate recent monitoring data into the risk assessment process. The ERA encompasses normal operations at the PN Site during the Continued Operations Phase of the project. OPG's Predictive Effects Assessment (PEA) for Pickering Nuclear Safe Storage [43] represents the predicted risks to human and ecological receptors related to future activities from transitioning the station from the Continued Operation Phase to the Stabilization and Storage with Surveillance Phases and is further discussed under section 2.3.4 of this report. OPG has posted the submitted ERA and PEA on its website.

CNSC staff completed a detailed technical review of the 2022 site-wide ERA and found it to be consistent with the overall methodology of the CSA Group Standard N288.6-12, *Environmental risk assessments at class I nuclear facilities and uranium mines and mills (2012)* [33]. The ERA was performed in a stepwise manner, as follows:

- quantify the releases (of COPCs) to the environment from current (see section 3.1) and future activities
- identify the environmental interactions of the current and expected releases of COPCs, and COPC exposure pathways in the environment
- identify predicted COPC exposure for ecological and human receptors
- identify potential effects to receptors
- determine whether the environment and health and safety of persons is and will continue to be protected

Although OPG's 2022 ERA report for the PN Site provides a complete evaluation of all potential risks to human health and the environment associated with the facility operations, CNSC staff provided comments to OPG with recommendations to validate ERA conclusions and to improve the quality of the ERA. In response to CNSC staff's comments, OPG committed to continue to engage with local Indigenous Nations and communities to develop ongoing and meaningful dialogue, and to engage prior to and during the preparation of the next ERA to incorporate Indigenous Knowledge and perspectives, as available. Future ERAs will include a section in the report that discusses what was heard from the engagement activities and how this feedback has been considered in the assessment. An ERA is required to be reviewed and revised every 5 years, or earlier, should there be significant changes in either the facility or activity, or in the science on which the ERA is based.

The findings of the 2022 review of the ERA are summarized in table 2.3. Adverse effects to ecological and human health due to releases of COPCs to the air and water from the PN site were found to be unlikely.

Table 2.3: Summary of environmental risk assessment findings for the Pickering Nuclear Site [10]

Type	Humans	Aquatic and terrestrial biota
Radiological	No adverse impacts expected from radiological COPCs released from the PN Site. The annual dose to the critical receptor was well below the public dose limit and there were no concerns.	No adverse impacts expected from radiological COPCs released from the PN Site. There were no exceedances of the radiation dose benchmarks for ecological receptors.
Hazardous	No adverse impacts expected from non-radiological COPCs. However, there was a recommendation made in the ERA to refine risk levels for nitrogen oxides as there was some uncertainty around short-term exposure concentrations for the Sport Fisher and other potential critical groups. CNSC staff will follow up on this in the next ERA.	No adverse impacts expected from non-radiological COPCs released from the PN Site. Although there were some exceedances of benchmark values in the water, sediment, and soil for some metals, the risks to ecological receptors were determined to be low.
Physical stressors*	No adverse impacts expected to human health expected from noise at the PN Site. It was determined that the occasional periods of elevated sound levels are not likely associated with PN activities so it is not expected that noise from PN activities is having a direct adverse effect on human receptors near the PN Site	Impingement and entrainment of fish from the operation of the PNGS occur from the use of lake water for condenser cooling water. A FDS is used to mitigate impingement. In 2020, impingement estimates were less than the 2-year threshold specified in the PN *Fisheries Act* Authorization (FAA). Both impingement and entrainment losses are required to be counterbalanced by the 3 offset measures that were approved by Fisheries and Oceans Canada (DFO) in the PN FAA. The approved rate of entrainment during the operations phase is 106 kg age 1 equivalent per year as specified in the FAA. If OPG plans to continue operations past 2026 (which will require a licensing decision), then OPG must conduct an entrainment study as per the FAA, beginning the study no later then summer of 2024 [44]. Results of the entrainment study

		are expected in the next iteration of the ERA. It is unlikely that there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species. No adverse impacts are expected from noise or wildlife collisions associated with the operation of the PN Site.

*Physical stressors for aquatic receptors include entrainment/impingement of aquatic biota and thermal releases to the aquatic environment. Physical stressors for terrestrial receptors include noise, wildlife collisions with vehicles and bird or bat strikes on buildings.

2.3.4 Predictive environmental effects assessment

In May 2017, OPG submitted a PEA, *Predictive Effects Assessment for Pickering Nuclear Safe Storage* [45], to determine whether the potential changes to the baseline conditions resulting from transitioning the station from the Continued Operation Phase to the Stabilization and Storage with Surveillance Phases would pose risks to human and ecological receptors. It was determined in the 2018 PNGS EA under the NSCA that adverse effects associated with the transition from power generation to safe storage are considered unlikely [17]. In June 2022, OPG submitted a PEA Addendum Report, *Predictive Effects Assessment for Pickering Nuclear Safe Storage – Addendum Report* [43]. The 2022 PEA Addendum Report focuses on identifying and documenting changes to previous assumptions made in the 2017 PEA report [45] in order to evaluate whether those changes could have an impact on the previously established bounding conditions. A revised 2022 PEA Addendum Report was submitted in April 2023, taking into consideration CNSC staff comments [46]. As per the revised 2022 PEA Addendum Report, OPG plans to pursue continued operation of PNGS to 2026 and a licence application has been submitted by OPG for the plan to shut down the remaining 6 PN reactor units beginning in December 2024 with Unit 1 and Unit 4, and by December 2026 for Units 5-8.

OPG concluded that no potential adverse effects are predicted from the updated assumptions. The Tier 1 Assessment concludes that the assessment of human health at potential critical group locations, and ecological health in the outfall and at Frenchman's Bay are bounded by the 2017 PEA and no further quantitative assessment is warranted in the 2022 PEA Addendum Report. Dose to human receptors during the Stabilization Phase is bounded by the operational dose presented in the 2022 ERA. The Tier 2 Assessment focuses on an updated assessment of potential ecological risks in the forebay during the Storage with Surveillance Phase as the forebay is considered potential habitat due to assumed removal of the FDS (note that DFO's prior approval to remove the FDS will be required). No adverse effects were predicted.

CNSC staff completed a detailed technical review of the 2022 PEA Addendum Report and found it to be consistent with the overall methodology of the CSA Group Standard N288.6-12, *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills (2012)* [33]. The results of the review indicate that meaningful human health or ecological effects

attributable to the proposed Stabilization and Safe Storage with Surveillance activities are unlikely. CNSC staff will verify predictions made in the 2022 PEA Addendum Report based on operational experience, results of monitoring, supplementary studies or recent developments in scientific knowledge. Any variances will be addressed in future iterations of the ERA report as the project transitions to the Stabilization and Storage with Surveillance phases.

The 2022 PEA Addendum Report conclusions are summarized in table 2.4. Adverse effects associated with the transition from power generation to safe storage are considered unlikely.

OPG initiated engagement with the Williams Treaties First Nations in July 2021 to seek feedback on the list of VECs that would be used in the 2022 ERA. The 2022 ERA serves as an updated baseline on which the PEA is based. For future iterations of the PEA, OPG plans to engage with Indigenous nations and communities early in the process, prior to the drafting of the PEA. The PEA will include a summary of what OPG heard from the Indigenous nations and communities and how this feedback has been considered in the assessment.

The OPG PEA provides insight into potential risks associated with transition to safe storage, but EPR focus is on current environmental risks posed by normal operations at the PN site.

Table 2.4: Summary of predictive environmental risk assessment findings for the Pickering Nuclear site

Type	Humans	Aquatic and terrestrial biota
Radiological	No additional adverse impacts expected from radiological COPCs released from the PN Site during Stabilization or Safe Storage with Surveillance phases. Dose to human receptors during the Stabilization Phase is bounded by the operational dose presented in the ERA.	As a result of the reduced flows into the station and the assumed removal of the FDS during the Storage with Surveillance Phase, the assessment of the forebay as potential habitat is updated in the Tier 2 assessment. The COPCs in the evaluation include tritium, carbon-14, cobalt-60, cesium-134 and cesium-137. The predictive ecological risk assessment concludes that there are no potential adverse effects since all predicted doses to ecological receptors in the forebay during the Storage with Surveillance Phase are below the aquatic benchmark of 9.6 milligray per day (mGy/d) and the terrestrial benchmark of 2.4 mGy/d.
Hazardous	Continued operations assessed within the ERA are bounding and no additional adverse impacts are expected from non-radiological COPCs released from the PN Site during the Stabilization or Safe Storage with Surveillance phases.	Continued operations assessed within the ERA are bounding and no additional adverse impacts are expected from non-radiological COPCs released from the PN Site during the Stabilization or Safe Storage with Surveillance phases.
Physical stressors	Continued operations assessed within the ERA are bounding and no additional adverse impacts are expected to human health from noise at the PN Site during the	Potential entrainment and impingement effects are re-assessed in the Tier 2 assessment due to the current plan for a higher flow rate of 250,500 m^3/day through the PNGS Units 5-8 intake compared with the 2017 PEA assumption of 50,000 m^3/day during the Storage with Surveillance Phase, along with removal of the

Type	Humans	Aquatic and terrestrial biota
	Stabilization or Safe Storage with Surveillance phases.	FDS (if approved by DFO). This flow of 250,500 m^3/day translates to a maximum velocity of 11.5 mm/s. This maximum velocity remains less than the mean swim speed of pertinent local fish species considered in the PEA, which range from 221 mm/s for Northern Pike to 3,612 mm/s for White Sucker; therefore, impingement rates will decrease because of the significant reduction in flow volume into the station. The proposed flow during the Storage with Surveillance Phase when cooling requirements are reduced will be 2.9 m^3/s, which is less than the flow of 5.5 m^3/s identified as the volume of flow where entrainment may be of concern, so entrainment remains negligible [47]. Continued operations assessed within the ERA are bounding and no additional adverse impacts are expected from noise or wildlife collisions associated with the operation of the PN Site.

2.3.5 Effluent and emissions control and monitoring

OPG has controls in place to minimize airborne and waterborne effluents and emissions for radiological and non-radiological COPCs, and to ensure that releases are within regulatory limits and as low as reasonably achievable (ALARA).

OPG has implemented an effluent monitoring program in compliance with REGDOC-2.9.1 (2017) [28] and the relevant standards, including CSA N288.5-11, *Effluent monitoring program at Class I nuclear facilities and uranium mines and mills* [32]. This program contains DRLs and action levels (ALs). The DRLs represent the maximum acceptable level of emitted contaminants from the processes at the PN site and are derived from the dose limit for members of the public (that is, 1 millisievert [mSv] per year). In addition, the PN Site has established ALs that serve as an early warning of potential loss of control of the environmental protection program.

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

2.3.6 Environmental monitoring program

The CNSC requires each licensee to design and implement an EMP that is specific to the monitoring and assessment requirements of the licensed facility and its surrounding environment. The program is required to:

- measure contaminants in the environmental media surrounding the facility or site
- determine the effects, if any, of the facility or site operations on people and the environment
- serve as a secondary support to emission monitoring programs to demonstrate the effectiveness of emission controls

More specifically, the program must gather the necessary environmental data to calculate the public dose and demonstrate compliance with the public dose limit found in the *Radiation Protection Regulations* (external) [48] of 1 mSv per year. The program design must also address the potential environmental interactions identified at the facility or site. Radionuclides are the major focus at the PN Site, though hazardous substances (environmental compliance approval (ECA) are included within monitoring activities associated with liquid discharges and air emissions. OPG's EMP for the PN Site consists of the following components:

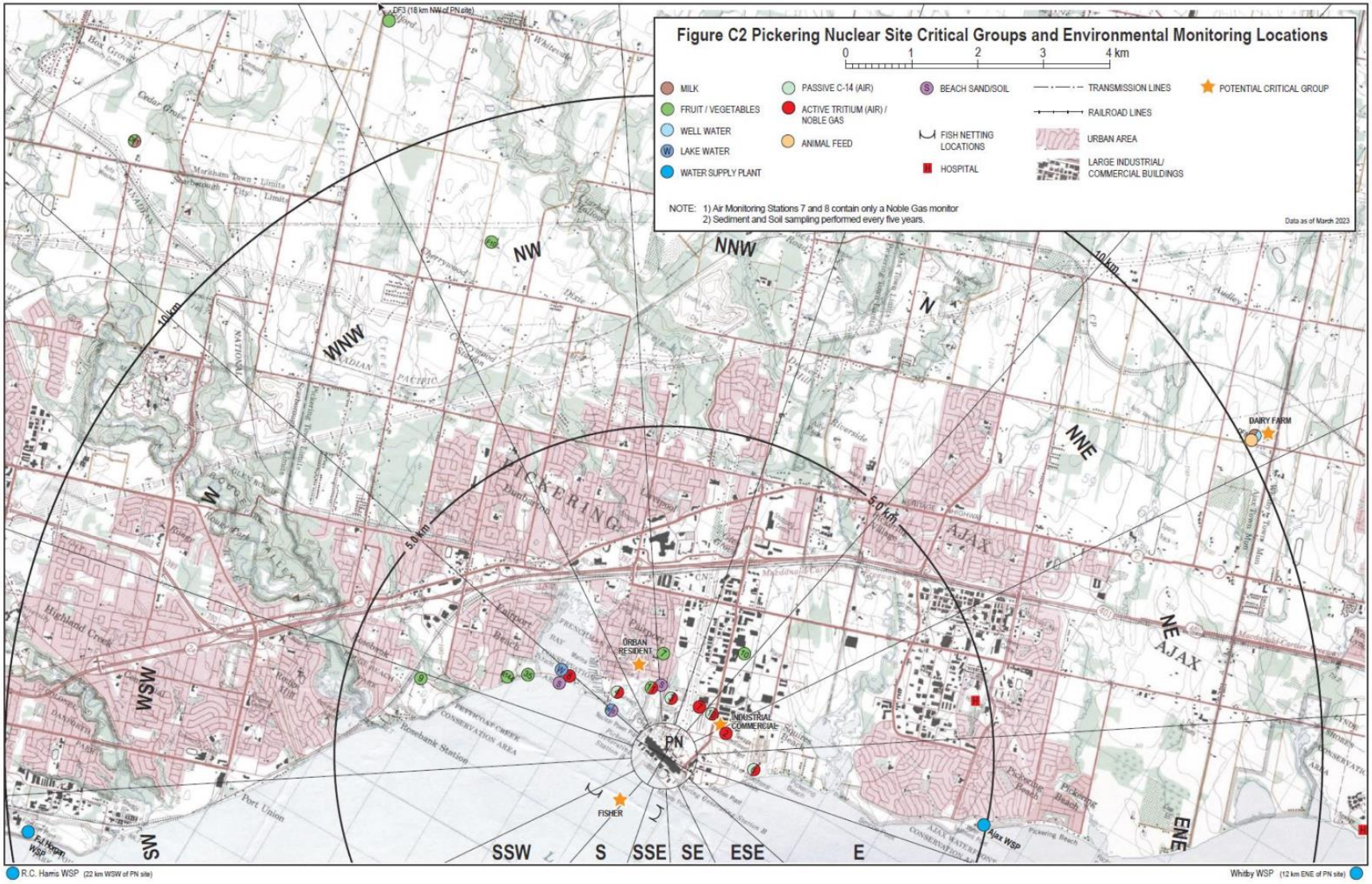
- air monitoring
- fruits and vegetables monitoring
- animal feed monitoring
- eggs and poultry monitoring
- milk monitoring
- soil and sand monitoring
- surface water (Water Supply Plant monitoring and lake water)
- well water
- groundwater monitoring
- sediment monitoring
- fish monitoring

Monitoring frequency and parameters are specified in OPG EMP reports [39]. The sampling locations are shown on the map below figure 2.1.

OPG is required to maintain its EMP to comply with REGDOC-2.9.1 (2017) [28] and relevant standards, including CSA N288.4-10, *Environmental monitoring programs at Class I nuclear facilities and uranium mines and ills* [31].

Based on compliance activities and technical assessments, CNSC staff have found that the PN Site is compliant with REGDOC-2.9.1 (2017) [28] and continues to implement and maintain an effective EMP for the PN Site that adequately protects the environment and the health and safety of persons.

Figure 2.1: Pickering Nuclear Site Environment Monitoring Program sampling locations [39]



2.4 Requirements under other federal or provincial regulations

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

2.4.1 Greenhouse gas emissions

While there is a range of broadly applicable federal environmental regulations (for example, petroleum products storage tanks, environmental emergency regulations), the management of greenhouse gas (GHG) emissions has been identified as a national priority.

Under the federal *Canadian Environmental Protection Act, 1999* (external)(CEPA 1999) [49], nuclear facilities that emit more than the emission reporting threshold (that is, 10,000 tonnes of CO_2 equivalent) on an annual basis must report their GHG emissions to Environment and Climate Change Canada (ECCC). In the case of the PN Site CO_2 releases remained below the reporting threshold from 2018 to2022 [5, 6, 7, 8, 9].

The CNSC maintains a collaborative working relationship with ECCC through a formal memorandum of understanding (MOU) [50], which includes a notification protocol. An exceedance of the GHG emissions reporting threshold would be included under this notification protocol. This ensures that a coordinated regulatory approach is achieved to meet all federal requirements associated with EP, including GHGs.

2.4.2 Ozone depleting substances

In accordance with the *Federal Halocarbon Regulations, 2022* (external) [51], OPG is required to provide a semi-annual halocarbon release report to ECCC on the release of halocarbons of an amount greater than 10 kg but less than 100 kg from any system, container or equipment at the PN Site. In the event of a release that surpasses 100 kg, OPG would be required to report the releases to ECCC within 24 hours and ECCC would inform the CNSC through the notification protocol of the CNSC-ECCC MOU. OPG would then be required to submit a follow-up report to ECCC within 30 days of the release detailing the circumstances leading to the release and the corrective and preventive actions taken to prevent a reoccurrence.

OPG has reports as required the information needed for the PN Site for the assessed period (2018–2022).

2.4.3 Sulphur dioxide emissions

Under CEPA 1999 [49], OPG is also required to estimate the total sulphur dioxide emissions from the PN Site and report to the National Pollutant Release Inventory (NPRI), provided that the reporting thresholds are met. The sulphur dioxide emissions at the PN Site remained below the NPRI reporting threshold for the assessed period (2018–2022). OPG is still reporting its sulphur dioxide releases in its annual environmental monitoring report [5, 6, 7, 8, 9].

2.4.4 Other environmental compliance approvals

Non-radiological liquid effluent is monitored in accordance with the provincial ECA requirements. Non-radiological liquid effluent from the radioactive liquid waste management system must comply with ECA requirements. COPCs not addressed by the ECA are assessed through the ERA to determine whether they merit additional regulatory oversight.

Non-radiological airborne emissions are required to be in compliance with provincial regulation O. Reg. 419/05, which is met by complying with the ECA for Air and Noise. OPG did not report any non-compliances for its ECA. An Emissions Summary and Dispersion Modelling report is used to document and maintain compliance with O.Reg. 419/05.

2.4.5 *Fisheries Act* Authorization

In October 2023, DFO and the CNSC signed a revised MOU outlining areas for cooperation and administration of the *Fisheries Act* [52], which aims to conserve and protect fish and fish habitat across Canada.

The CNSC-DFO MOU focuses on sections 34 and 35 of the *Fisheries Act*, which state that no person shall carry on any work, undertaking or activity that could cause the death of fish and/or harmful alteration, disruption or destruction of fish habitat, unless the Minister of DFO issues a FAA. This authorization, if granted, includes terms and conditions to avoid, mitigate, offset (that is, counterbalance impacts) and monitor the impacts on fish and fish habitat resulting from a specific project.

At PNGS, large volumes of water from Lake Ontario are drawn, through a surface water intake, for cooling purposes. An incidental effect of the taking of lake water for cooling is impingement and entrainment of aquatic organisms. In the 2008, CNSC staff raised fish mortality at PNGS as an unreasonable risk to the environment and issued an order to OPG to reduce impingement by 80% by 2012 [53]. In 2009, in response to an order by the CNSC to reduce impingement by 80% by 2012, OPG installed a FDS consisting of a barrier net surrounding the intake structure of the PNGS (figure 2.2). No reasonable technological solution is available to reduce entrainment significantly, but these losses are counterbalanced by the offset measures approved by DFO in the PNGS FAA.

The PNGS FAA was issued to OPG on January 17, 2018, with administrative amendments approved by DFO on August 25, 2022 [54]. The authorization period runs from January 17, 2018, to December 31, 2028. As required by the PNGS FAA, OPG submits an annual impingement monitoring report to DFO to satisfy conditions of the authorization. These annual reports are reviewed by DFO and the CNSC.

Figure 2.2: Ontario Power Generation's fish diversion system, a mitigation structure to reduce the biomass of fish impingement [10]

2.5 Canadian Nuclear Safety Commission and federal partners consideration of climate change

The CNSC's regulatory framework requires licensees and proponents to consider climate change primarily through requirements related to EAs and safety assessments. These assessments take place throughout the licensing lifecycle as part of the licence application, licence renewal and periodic safety review (PSR) process.

CNSC staff's consideration of climate change during these assessments may include examining whether climate change is considered in the analysis of external hazards and environmental parameters such as meteorological and hydrological parameters used in the design, evaluation and upgrade of a nuclear facility, and whether a licensee has applied the defence-in-depth principle in its design with sufficient safety margin.

Specifically, climate change considerations are included in the following mechanisms in the regulatory framework:

Environmental assessment

Previously under CEAA 2012 and currently under the IAA, proponents must assess the climate change impact on a project itself and thereby the surrounding environment, over the lifetime of the facility. As noted in section 2.1, the PN Site has undergone numerous EAs that have demonstrated that, with mitigation measures implemented, climate change, as well as the anticipated increases in the magnitude and frequency of external hazards due to climate change, would not likely have impact on the project that would lead to residual adverse effect. The most recent EA for the PN Site conducted in 2007 assessed the impact of climate change and is discussed further in this section.

Periodic safety reviews

Licensees for nuclear power plants are required to conduct PSRs to evaluate the design, condition and operation of the facility. Probabilistic Safety Assessment (PSA), as 1 of the safety factors evaluated in the PSR, includes analysis of external hazards, such as flooding, and their impact on a facility. As part of the 5-year cyclical review process, CNSC staff review the PSA and ensure that up-to-date hazard information is included.

In OPG's latest hazard analysis report [55], flood hazards (including probable maximum flood due to a combination of probable maximum precipitation (PMP), 1:100 year lake level and storm surge) were screened out from additional probabilistic safety assessment, indicating that risk due to external flood hazards is low.

Environmental risk assessment

As described further in section 2.3.3, an ERA (updated in a 5-year review cycle) evaluates risk posed by contaminants and physical stressors to the environment under normal operating conditions, taking into consideration recent monitoring data (including meteorological parameters) and new scientific knowledge. The latest ERA update [10] graphically evaluated the monthly variability of temperature and precipitation, as well as the annual prevailing wind distribution, based on latest monitoring data. Thermal plume monitoring results were presented and OPG demonstrated that it is unlikely there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species. CNSC staff will continue to assess

potential thermal impacts to aquatic receptors from site discharges keeping in mind any environmental changes due to climate change.

CNSC and ECCC collaboration

The CNSC and ECCC have an MOU in place that includes collaboration related to climate change. For example, ECCC contributes expertise on projection of climate change and estimates of probable maximum precipitation for various sites, including the PN Site, to CNSC staff. This informs CNSC staff's technical reviews.

ECCC also has the mandate to monitor and provide meteorological data to Canadians, to conduct scientific research regarding the mechanism and effects of climate change, and to develop science based guidance on assessment of climate change for application when projects are subject to federal impact assessments. The Strategic Assessment of Climate Change guidance [56] includes specific guidance on net zero plans, calculation of GHG emissions/intensity and resiliency.

3.0 Status of the environment

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

CNSC staff regularly review the potential effects on environmental components through annual reporting requirements and compliance verification activities, as detailed in other areas of this report. This information is reported to the Commission in the sections on EP in licensing commission member documents and annual RORs. The EMP reports submitted by OPG for the PN Site are made publicly available and can be viewed on OPG's website: Reporting > Regulatory reporting - OPG (external) [39].

3.1 Releases to the environment

Radioactive and hazardous substances that have the potential to cause an adverse effects to ecological or human receptors are identified as COPCs. The ways in which COPCs could find their way to the different receptors considered by the ERA are called "exposure pathways."

Figure 3.1 illustrates a conceptual model of the environment around a nuclear site to show the relationship between releases (airborne emissions or waterborne effluent) and human and ecological receptors. This graphic is meant to provide an overall conceptual model of the releases, exposure pathways and receptors for the PN Site and thus should not be interpreted as a complete depiction of the PN Site and its surrounding environment. The specific releases and COPCs associated with the PN Site are explained in detail in the following subsections.

Figure 3.1: Conceptual model of the environment around the Pickering Nuclear Site

3.1.1 Licensed release limits

OPG uses DRLs and Als, approved by the CNSC, to control radiological effluent and emission releases from the site as discussed in section 2.3.5. A DRL for a given radionuclide is the release rate that would cause an individual of the most highly exposed group to receive a dose equal to the regulatory annual dose limit of 1 mSv.

3.1.2 Airborne emissions

OPG controls and monitors airborne emissions from the PN Site to the environment under its effluent monitoring program. This program is based on CSA N288.5-22, *Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* [32] and includes monitoring of both radiological and hazardous emissions.

PN site radiological air emissions

Radiological emissions to air from PN Site operations include noble gases, tritium and carbon-14. Argon-41 is the predominant noble gas that is measured around the PN Site. Tritium, in the form of tritiated water vapour, is released from the heavy water system. Carbon-14 is produced from PN Site operations.

As part of OPG's effluent monitoring program, releases to the atmosphere are collected and are routinely analyzed for tritium, carbon-14, iodine-131, noble gases and particulates. The results are compared against DRLs developed by OPG and approved by the CNSC to ensure release limits to the environment will not exceed the annual regulatory public dose limit of 1 mSv. As shown in table 3.1, the average radiological emissions from the PN Site remain at a very small fraction of the DRLs.

Table 3.1: Annual airborne releases from the Pickering Nuclear Site compared with applicable derived release limits (2018 – 2022) [5, 6, 7, 8, 9]

Parameter (Bq/yr)	2018	2019	2020	2021	2022	DRLs [57]
Tritium oxide	6.2×10^{14}	5.6×10^{14}	6.5×10^{14}	5.2×10^{14}	4.9×10^{14}	1.02×10^{17}
Noble gas*	1.3×10^{14}	1.3×10^{14}	4.5×10^{13}	1.4×10^{14}	1.0×10^{14}	2.66×10^{16}
Iodine-131	1.2×10^{7}	1.4×10^{7}	1.0×10^{7}	9.7×10^{6}	1.1×10^{7}	2.82×10^{12}
Particulate Gross Beta/Gamma	7.7×10^{6}	5.7×10^{6}	5.8×10^{6}	1.1×10^{7}	1.1×10^{7}	4.28×10^{11}
Carbon-14	3.7×10^{12}	2.6×10^{12}	2.3×10^{12}	2.6×10^{12}	2.4×10^{12}	2.69×10^{15}

* Airborne noble gas emission units are in Bq-MeV

PWMF radiological airborne releases

Releases from the PWMF operation is considered in the site releases. The primary source of radiological emissions from the PWMF is the processing building's active ventilation exhaust. Atmospheric releases from this stack are monitored through the Effluent and Emissions Monitoring Program and analyzed weekly. The main airborne particulate emitted from the PWMF is gross beta-gamma.

The annual airborne particulates from the PWMF for the 2018 to 2022 period are orders of magnitude below the set DRLs, Als and releases from the PNGS. Although no significant radiological emissions are anticipated, OPG continues to sample airborne particulates and report the results to the CNSC. These releases are included in the particulate site releases to air presented in table 3.1.

PN site non-radiological emissions

The main sources of non-radiological emissions at the PN Site are the standby diesel generators onsite. These sources release small quantities of carbon monoxide, nitrogen oxides, sulphur dioxide and hydrocarbons. In addition, hydrazine, morpholine and ammonia are used in the feedwater system to prevent corrosion and are released in small quantities through controlled venting.

Non-radiological air emissions from the PN Site are controlled in accordance with provincial ECA requirements. Dispersion modelling was used to predict the maximum concentrations of COPCs at the property line of the PN Site. OPG did not report any ECA non-compliances to the provincial regulator or the CNSC on during the 2018-2022 period.

PWMF non-radiological emissions

Based on the nature of the activities carried out at the PWMF, non-radiological airborne releases are considered to be negligible from the PWMF.

The 2 operational activities known to generate non-radiological emissions at the processing building:

- dry storage container paint touch-up operations to remove scrapes and scuffs
- dry storage container seal welding operations

Both paint aerosols and welding fumes pass through filters, which remove potentially hazardous particulates, before being exhausted to the active ventilation system. Due to the use of appropriate filtration, OPG is not required to monitor emissions from these activities, which are considered to be negligible.

The PWMF emergency power generator also represents a minor source of nitrogen oxide emissions.

3.1.2.1 Findings

Based on CNSC staff's review of the results of the effluent monitoring program at the PN Site, staff have found that OPG's air emissions to the environment from the PN Site have remained below the CNSC-approved licence limits throughout the reporting period (2018 to 2022). CNSC staff have also found that OPG continues to provide adequate protection of people and the environment from air emissions.

3.1.3 Waterborne effluent

OPG controls and monitors liquid (waterborne) effluent from the PN Site to the environment under its implementation of the effluent monitoring program. This program is based on CSA N288.5-17, *Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* [32] and includes monitoring of radiological and hazardous releases.

The PN Site is located on the north shore of Lake Ontario. The shoreline immediately adjacent to the PN Site has been altered by the construction of the CCW intake channel and the 2 water outfall channels, 1 on each side of the PN Site. The active drainage system collects active (radiological) effluent waste from the drains in the reactor building, reactor auxiliary bay, irradiated fuel bay and PWMF. The active liquid waste is directed to the receiving tanks of the radioactive liquid waste management system. The activity in the liquid waste may include tritium, carbon-14, gross alpha and gross beta-gamma (such as cesium-134, cesium-137, strontium-90, cobalt-60). The radioactive liquid waste management system uses a purification system to purify the waste to reduce radiological and non-radiological contaminants. The waste is sampled and chemically analyzed to ensure it meets radiological and non-radiological limits prior to discharge to Lake Ontario. Radioactivity monitors are on the discharge piping to automatically stop discharge flow if the detected activity is above specified limits.

As part of OPG's EMP, samples of waterborne emissions are collected and routinely analyzed for tritium, carbon-14 and gross beta/gamma. As per table 3.2, the annual radiological waterborne releases from the PN Site remain a very small fraction of the licensed DRLs. From 2018 to 2022 there have been no DRL (regulatory limit) exceedances.

Table 3.2: Annual waterborne releases from the Pickering Nuclear Site compared with applicable release limits (2018 – 2022) [5, 6, 7, 8, 9]

Parameter (Bq/yr)	2018	2019	2020	2021	2022	Licence limits [57]
Tritium oxide	4.2×10^{14}	4.3×10^{14}	4.3×10^{14}	4.8×10^{14}	5.0×10^{14}	7.87×10^{17}
Gross beta/gamma	4.3×10^{10}	7.8×10^{10}	3.2×10^{11}	1.2×10^{11}	2.0×10^{10}	1.87×10^{12}
Carbon-14	1.1×10^{9}	3.5×10^{9}	1.8×10^{9}	4.6×10^{9}	1.4×10^{9}	3.75×10^{13}

PWMF radiological liquid releases

A small quantity of radioactive liquids is potentially generated during dry storage container decontamination in the processing building. Therefore, the active liquid waste tanks in the processing building are sampled for tritium and gross beta-gamma prior to being routed to the PNGS active liquid waste system for monitoring and processing. These waterborne releases are included in the site release numbers.

Although no operational activities for retube component storage have occurred since 1993, water is sampled from the surface drainage system and catch basins at the retube component storage area for gross beta-gamma activity on a quarterly basis. By sampling the water originating from this area, OPG is able to ensure that any radioactive contamination in the surface water runoff is detected.

The waterborne gross beta-gamma levels have typically been below the Minimum Detectable Activity of 1.51×10^{-2} Bq/ml.

PN Site non-Radiological liquid releases

Boiler treatment chemicals including hydrazine and morpholine are used within the feedwater system to prevent corrosion in the boilers and are released to the aquatic environment through the discharge channels.

In addition, sodium hypochlorite is also used to control colonization of the water intake structures by quagga and zebra mussel to ensure safe operations of the reactor units. OPG dechlorinates to limit the residual chlorine input to Lake Ontario.

All effluent except sewage and some stormwater are released into the outfall and into Lake Ontario.

Non-radiological liquid effluent is monitored in accordance with the provincial ECA requirements. Effluent is sampled at the outfall of the PN Site for ammonia, hydrazine, morpholine, acidity/alkalinity, copper and total residual chlorine. OPG reported a few ECA non-compliances to the provincial regulator and the CNSC during the 2018-2022 period. There were no significant impacts to the natural environment as a result of the reported non-compliances.

PWMF non-radiological liquid releases

Typical industrial building consumables, such as adhesives, abrasives, solvents and lubricants, are stored and used at the PWMF in minimal quantities. Non-radiological releases from these consumables are considered negligible and thus are not required to be monitored. Based on the nature of the activities carried out at the PWMF, non-radiological liquid effluents are not expected to be generated from the PWMF under normal operating conditions.

3.1.3.1 Findings

CNSC staff have found that OPG's reported liquid effluent discharged to Lake Ontario from the PN Site remained below the DRLs throughout the 2018–2022 reporting period.

CNSC staff are satisfied that OPG is taking the appropriate measures at the PN Site as mentioned above, to effectively control and reduce concentrations and loadings of hazardous and radiological substances in waterborne effluent.

3.2 Environmental effects assessment

This section presents an overview of the assessment of predicted effects from licensed activities on the environment and the health and safety of persons. CNSC staff reviewed OPG's assessment of current and predicted effects on the environment and health and safety of persons due to licensed activities included in the ERA (see subsection 2.3.3) for the PN Site.

To inform this section of the report, CNSC staff reviewed OPG's ERA [10]. While CNSC staff conducted a review for all environmental components, only a selection of components is presented in detail in the following subsections. The environmental components were selected based on regulatory requirements, facility type, and geographic context; some were also included because they have historically been of interest to the Commission, Indigenous Nations and communitiesand the public.

3.2.1 Atmospheric environment

An assessment of the atmospheric environment requires OPG to characterize both the meteorological conditions and the ambient air quality at the PN Site.

3.2.1.1 Meteorological conditions

Meteorological conditions, such as temperature, wind speed, wind direction, and precipitation are monitored to assess the extent of the atmospheric dispersion of contaminants emitted to the atmosphere and the rates of contaminant deposition, and to determine predominant wind directions, which are used to identify critical receptor locations from the air pathway. Meteorological data were collected from stations within the site, and in local and regional areas.

Temperature and precipitation in the vicinity of the PN Site do not differ substantially from the general climatic conditions found in southern Ontario. Local air temperature data are collected at the PN meteorological station at a height of 10 meters (m) above ground level. Local precipitation data are not available from the PN Site and data were obtained for the period of 1981 to 2010 from the Oshawa Climate Station located approximately 19 km east of the PN Site in Pickering. Climate norms for the Oshawa Climate Station for the period of 1981 to 2010 provide the most recent available precipitation data for the regional study area. The most recent consecutive 5-year period of reliable wind data is 2016 to 2020 from the on-site Pickering meteorological tower at the 10m elevation. The prevailing winds for the 2016 to 2020 period were from the northwest approximately 8.9%
of the time, north-northwest 8.2% of the time, from the southwest 8.3% of the time, and from the north approximately 8.6% of the time. The distribution of winds at the PN site are slightly different from those reported for the region based on wind patterns reported at Pearson International Airport (2016 to 2020), where the wind direction is primarily from the north and the west.

3.2.1.2 Ambient air quality

Radiological

Samples of air are collected to monitor the environment around the PN Site. These samples are analyzed for tritiated water (HTO), C-14, and noble gases (argon-41, xenon-133, xenon-135 and iridium-192) and the results are used in the calculation of public dose. Background samples are also collected for the dose calculations.

There are 6 active tritium-in-air samplers (measuring HTO) around the PN Site which are collected and analyzed monthly. The background concentration of HTO in air is measured at Nanticoke, which is considered to be far from the influence of nuclear stations. The levels of HTO observed in the environment depend on station emissions, wind direction, wind speed, ambient humidity and seasonal variations. Fluctuations from year to year are expected even if site HTO emissions remain similar. There were no statistically significant trends over the past 10 years, and the highest annual average for HTO in air was in 2018 which was 8.9 Bq/m^3. The annual average HTO in air measured at the background location in recent years has been at or below the active sampler detection limit. In 2022, HTO in air measured at Nanticoke was 0.04 Bq/m^3.

Carbon-14 in air is monitored at 4 boundary locations for the PN Site. Samples are analyzed after each quarter. There was a statistically significant downward trend over the past 10 years. Annual average Carbon-14 concentrations have all been under 350 Bq/kg-C. Carbon-14 is naturally occurring

in the environment but is also a by-product of past nuclear weapons testing from the early 1960s. Carbon-14 background concentrations around the world are decreasing as weapons test carbon-14 levels naturally decay over time. The annual average carbon-14 in air concentration observed at the Nanticoke EMP background location in 2022 was 205 Bq/kg-C.

External gamma radiation doses from noble gases and iridium-192 are measured using sodium iodide spectrometers set up around PN Site. There are 8 detectors around the PN Site that monitor the dose rate continuously. Natural background dose has been subtracted from noble gas detector results. The annual boundary average noble gas dose rate is estimated from the monthly data from each detector. Argon-41 is the predominant radionuclide measured in noble gas around the PN Site followed by xenon-133 and xenon-135. A Mann-Kendall trend analysis at the 95% confidence level indicates an increasing trend over the past 10 years for argon-41. Generally, higher argon-41 emissions are largely related to a higher operating time of PNGS Units 1 and 4. There was a decrease in argon-41 emissions observed in 2020 which was associated with a relatively lower operating time of Units 1 and 4. All annual averages have been below 400 nGy/month over the past 10 years.

Physical Stressor

Physical stressors, such as noise, are relevant to both human receptors and ecological receptors. CNSC staff's review of the Annual Acoustic Assessment Reports prepared for the PN Site and the ECA for Air and Noise, issued by the Ontario Ministry of the Environment, Conservation and Parts (MECP), demonstrate that the PN Site operates in compliance within applicable regulatory noise limits and therefore, adverse effects are not expected. There are occasional periods of elevated sound levels, however they are not likely associated with the PN Site activities and therefore it is not expected that noise from the PN Site activities is having a direct adverse effect on human receptors near the PN Site.

Noise levels at the PN Site can potentially cause disturbance to wildlife. The Terrestrial Environment technical supporting document for the EA of the Refurbishment and Continued Operation of the Pickering B NGS [58] concluded that, although some wildlife may be sensitive to high noise levels, most wildlife in the area (onsite and offsite) are likely accustomed to noise levels associated with an urban environment, and have already acclimated to the noise levels in this specific environment as the PN facility has been fully operational for 3 decades. There is currently no specific noise level threshold for wildlife within provincial or federal guidelines.

3.2.1.3 Findings

CNSC staff have evaluated the environmental monitoring data and the ERA and conclude that OPG's reported measurements of radiological contaminants in the atmospheric environment from the PN Site have remained within expected trends. OPG continues to provide adequate protection of people and the environment from atmospheric releases, including noise.

3.2.2 Terrestrial environment

An assessment of potential effects on terrestrial biota at the PN Site and the surrounding area involves characterizing the local habitat and species (including considering federal and provincial species at risk) and assessing the possibility of their exposure to radiological and hazardous substances, as well as physical stressors that may be disruptive to ecological receptors.

3.2.2.1 Soil quality

Soil quality monitoring

Soil quality is important for species that live or breed within the soil. The PN Site and surrounding area is home to a number of terrestrial species, including plants, mammals, birds, soil invertebrates, reptiles and amphibians, which have the potential to be exposed to contaminants through ingestion, inhalation or skin contact.

As part of the updated baseline data for the ERA, surficial soil samples were collected from 8 locations around the PN Site in 2015. The soil sampling program focused on areas of previously identified contamination. The focus was on surface soils (0 to 20 cm) as VECs ingesting soils would only access shallow/surface soils. A shallow root zone is appropriate for herbaceous plants, and soil invertebrates are primarily active in the shallow humus layer. Soil samples were analyzed for polycyclic aromatic hydrocarbons, volatile organic compounds, petroleum hydrocarbons (PHCs) F1 to F4, metals and inorganics, glycol, tritium, gamma emitters (such as, cesium-137, cesium-134, cobalt-60) and carbon-14.

In general, soils onsite that exceed benchmark concentrations are localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, accumulation of COPCs in soil over time is not expected. Although, soil sampling only occurred in areas identified as potential habitat, many of these areas on the PN Site are not likely to be frequented by the selected VECs since they are near the PN Site operations and not in highly vegetated areas. More details on the results of the monitoring program are provided below.

3.2.2.2 Terrestrial habitat and species

Terrestrial habitat within the vicinity of the PN Site includes small independent forested lots, a wetland systems, and cultural vegetation including farmed land, city parks, and manicured (mown) lawn. Major terrestrial habitat features include the wooded areas of Kinsmen Park and Alex Robertson Park, as well as the wetland habitat of Hydro Marsh and Frenchman's Bay. Figure 1.2 in section 1.2 provides an overview of the regional areas of the PN Site and the location of these features.

Frenchman's Bay is a provincially significant wetland and is designated an Environmentally Sensitive Area by the Toronto and Region Conservation Authority. It is a habitat for wetland vegetation, benthic invertebrates, fish, riparian species such as the muskrat, amphibians, and some birds. Frenchman's Bay is Hydro Marsh's link to Lake Ontario and water from the lake enters the system when the water level rises in Lake Ontario.

The current list of species occurring within or in the vicinity of the PN Site referenced in the 2022 ERA included a total of 775 species of flora and fauna at the PNGS, divided into the following groups of wildlife:

- 27 mammals
- 10 reptiles and amphibians
- 242 birds
- 26 butterflies and moths
- 26 dragonflies and damselflies
- 66 fish
- 378 species of vascular plants

Terrestrial biota, such as riparian birds (such as, the Trumpeter Swan, or Common Tern), the riparian mammal (such as, muskrat), and amphibians and reptiles (such as, Northern Leopard Frog and the Midland Painted Turtle), are considered aquatic receptors for the purposes of the exposure assessment. The effects of radiological and non-radiological COPCs on these biotas are considered and further discussed in section 3.2.4 Aquatic Environment.

Terrestrial species at risk

In Ontario, the following legislation applies to species at risk: the provincial *Endangered Species Act* (external) [59] and the federal *Species at Risk Act* (external) (SARA) [60]. To comply with these laws, and as part of 2022 ERA [10], OPG conducted a review of all flora and fauna identified within the PN Site against the Species at Risk in Ontario (SARO) list, the SARA (Schedule 1) list and the Committee on the Status of Endangered Wildlife in Canada list for threatened or endangered species. A number of threatened and endangered species have been identified within the PN Site Study Area and the species that were identified during the 2016 – 2020 time period and considered for the 2022 ERA are presented in table 3.3.

Table 3.3 does not include historical species at risk observations that have not been confirmed in recent years, since routine monitoring has demonstrated that the PN Site is no longer providing habitat for these species. These exclusions include 3 plant species (Slender Bush-Clover, Kentucky Coffee Tree, Red Mulberry; not observed since 2000), and 3 bird species (Common Nighthawk, Bobolink and Bank Swallow; not observed since 2006-2010). Species at risk can be assessed using representative species already selected for the EcoRA.

Thirty-five Barn Swallow (threatened status on both federal and provincial lists) active nests were present in 2020, divided between inside the Protected Area and the south side of the Protected Area. 4 Chimney Swift (threatened status on both federal and provincial lists) were observed over the Protected Area in 2020, and a large flock was also observed over the site. The Red-winged Blackbird was selected as a representative species for all terrestrial insectivores, and conservatively represented Barn Swallow and Chimney Swift for chemical and radiological exposure assessments. Butternut Trees (endangered status on both federal and provincial lists) were last identified on the PN Site in 2020. Red Ash was chosen to represent Butternut in the ERA as it is also a deciduous tree. The Least Bittern and Blanding Turtle are discussed under section 3.2.3 as they are considered aquatic receptors for the purposes of the exposure assessment.

Table 3.3: Species at risk present around the Pickering Nuclear Site 2016 – 2020 [10]

Common name	Provincial status	Federal species at risk status	Most recent year observed	Surrogate species
Amphibians and reptiles				
Blanding's Turtle	Threatened	Endangered	2006	Midland Painted Turtle
Fish				
American Eel	Endangered (federal)	Under review	2020	American Eel
Birds				
Chimney Swift	Threatened	Threatened	2020	Red-winged Blackbird
Barn Swallow	N/A	Threatened	2020	Red-winged Blackbird
Least Bittern	Threatened	Threatened	2020	Common Tern
Plants				
Butternut	Endangered	Endangered	2020	Red Ash

ERA predictions

The most recent assessment of potential effects on terrestrial biota near the PN Site was provided in the 2022 ERA [10]. As discussed in subsection 2.3.3, CNSC staff found that the ERA fully complied with requirements of CSA N288.6-12, *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills* [33] and incorporated recent environmental monitoring data.

OPG selected a total of 12 terrestrial receptors for the assessment based on knowledge of the PN Site and its surrounding environment and relevant field observations. They included the categories of terrestrial plants, invertebrates, birds and mammals. The terrestrial species at risk identified as potentially occurring in the area (namely Barn Swallow, Chimney Swift, and Butternut) are also included as terrestrial receptors represented by the Red-winged Blackbird and Red Ash receptors. The Least Bittern, which is represented by the Common Tern, is further discussed under section 3.2.3 of this report. The selected terrestrial receptors reflect a variety of diets or feeding habits, cover various trophic levels, and are representative of the potential species present in the area.

All the avian receptors assessed are considered migratory, and are likely to reside at the PN Site for half of the year. However, for the exposure assessment, a conservative approach was taken and their occupancy at the PN Site is assumed to be for the whole year.

For soil invertebrates and terrestrial plants, the main exposure pathway is through contact with soil and contaminant uptake from soil via bioaccumulation. The dominant exposure pathways for birds and mammals is through the uptake of contaminants via the ingestion of water, incidental ingestion of soil or sediment, and ingestion of food.

Exposure to radiological substances

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

The overall radiation dose, which included all internal and external doses form all exposure pathways, was significantly below the radiological dose benchmarks recommended in NCSA 288.6-12 [33] (that is, 100 microgray per hour [µGy/h] for terrestrial receptors). This result indicates no potential for adverse effects and no need for further detailed assessment.

Exposure to hazardous substances

The potential hazardous effects on ecological receptors were assessed by comparing the estimated exposure concentration received by each ecological receptor from hazardous COPCs through all applicable pathways (namely exposure to hazardous contaminants in air, soil, lichen, vegetation, water, sediment, benthic invertebrates, phytoplankton, zooplankton and aquatic vegetation) with the recommended benchmark values (that is, toxicity reference values for non-human biota).

Based on updated surficial soil samples collected in 2015, a number of COPCs were assessed against soil quality guidelines. These guideline levels were then compared against exposure levels for terrestrial receptors to calculate a hazard quotient (HQ), which is the ratio of the concentration of the COPCs (in soil for terrestrial receptors) to the most conservative toxicological benchmark. An HQ that is ≤1, meaning the concentration of the COPCs in the sampled soil was less than or equal to the benchmark, indicates there is no potential risk to terrestrial receptors from exposure. The interpretation of HQ results also takes into consideration other factors that may affect the risk. These factors may include the distribution of areas with an HQ>1, the mobility and home range of the affected receptor, and whether the exposure point concentrations can be attributed to PN operations.

Based on the values presented in table 3.4 the maximum concentrations of arsenic, copper, lead, zinc and PHC F4 used in the calculation of the HQ for terrestrial receptors (the earthworm, terrestrial plant, Meadow Vole, Red-winged Blackbird, Red-tailed Hawk, and White-tailed Deer) exceeded the HQ of 1. However, these terrestrial receptors, with the exception of the Meadow Vole, terrestrial plant, and earthworm, are highly mobile and are unlikely to be exposed to the maximum concentration for the entire year. As such, the Upper Confidence Limit of the Mean (UCLM) concentration would be more appropriate for the calculation of the HQ. In this instance, the HQ remains below 1 (with the exception of the Red-wing Blackbird for zinc). The higher HQ for zinc for the Red-winged Blackbird is likely due to transfer of the COPC through feeding on earthworms with higher levels of zinc. However, this assessment is very conservative since the earthworm was used as the sole food source for the Red-winged Blackbird, which results in an overestimate of exposure. Note also that the Red-winged Blackbird was used as a surrogate species for the Barn Swallow (a

SARA species), which is primarily an aerial insectivore and is unlikely to feed on earthworms. As such, the Barn Swallow is not likely to be impacted at an individual level by PN Site operations.

The higher HQ value for copper for the Meadow Vole is driven by the maximum modelled concentrations in terrestrial plants. The maximum copper concentration in the plant is localized to 1 sampling location. Therefore, any effects on the Meadow Vole due to copper intake are limited to 1 area. Although localized effects on individual VECs may occur, the populations on the site as a whole are not expected to be affected.

Copper (maximum), zinc (maximum and UCLM), and PHC F4 (maximum and UCLM) soil exposure concentrations exceeded benchmark values for earthworms. Although localized effects on individual earthworms may occur, the earthworm community on the site as a whole is not expected to be affected.

Terrestrial plants had toxicological benchmark exceedances when maximum and UCLM soil concentrations were considered for copper, zinc, PHC F4s, and arsenic (only maximum). The potential effects on plants due to exposure to these COPCs is expected to be limited to small areas on the PN Site as these exceedances occurred at only 1 of the 8 soil sampling locations. The Butternut tree, identified as a federally and provincially listed endangered species at risk present in the PN Site area, could be affected by these COPCs; however there are no Butternut tree species in areas with elevated concentrations of COPCs; therefore, the Butternut tree is not likely to be impacted by PN Site operations.

HQs for exposure of terrestrial mammals and birds to PHC F4 were not calculated. The Canadian Council of Ministers of the Environment (CCME) has indicated that PHC F4 is not a toxicological concern for mammals and birds [61].

Although site soil data shows localized areas of contamination, OPG has not recommended specific monitoring or remediation at this stage as the contamination will be addressed during decommissioning of the PN site.

Table 3.4: Non-radiological hazard quotients for terrestrial biota [10]

Receptor	Arsenic		Copper		Lead		Zinc		Cyanide		PHC F4	
	Max	**UCLM**	**Max**	**UCLM**	**Max**	**UCLM**	**Max**	**UCLM**	**Max**	**UCLM**	**Max**	**UCLM**
Earthworm	1	0.16	9.1	**1.4**	0.46	0.08	16	**2.6**	0.04	0.03	1.7	**1.1**
Terrestrial plant	2.2	0.37	8.3	**1.3**	0.92	0.17	16	**2.6**	0.04	0.03	1.7	**1.1**
Meadow Vole	0.82	0.14	2.9	0.46	0.01	1.90×10^{-3}	0.86	0.14	7.50×10^{-6}	4.90×10^{-6}	N/A	N/A
Red-winged Blackbird	0.22	0.04	1.3	0.2	1.1	0.2	13	**2.1**	0.02	0.01	N/A	N/A
Red Fox	0.1	0.03	0.19	0.03	1.80×10^{-3}	3.40×10^{-4}	0.29	0.05	2.60×10^{-6}	1.70×10^{-6}	N/A	N/A
Red-tailed Hawk	0.27	0.04	0.76	0.12	1.1	0.21	1.6	0.26	0.09	0.06	N/A	N/A
White-tailed Deer	0.39	0.06	1.4	0.22	4.60×10^{-3}	8.40×10^{-4}	0.41	0.07	3.00×10^{-6}	2.00×10^{-6}	N/A	N/A

Notes: Shaded values indicate a HQ > 1. Bold and shaded values indicate a UCLM HQ>1.
N/A denotes that HQs were not calculated because COPC is not of toxicological concern to receptor.
UCLM is the Upper Confidence Limit of the Mean

Exposure to physical stressors

Noise levels due to the operation of the PN Site may potentially pose a disturbance to wildlife. Please refer to section 3.2.1.2 for a description of noise effects on receptors.

Wildlife collisions with vehicles and bird or bat strikes on buildings have been assessed in prior PN Site EAs and continue to be monitored. The results indicate that mortality rates have remained low and fairly consistent over the years of operation. No federal species at risk were among wildlife collisions recorded from 2016 to 2020.

Based on these observations, no effects at a population level are expected to result from these losses. For these reasons, the effects of noise and wildlife collisions were not carried forward for further assessment.

Terrestrial environment monitoring

As part of the site's EMP, and in addition to monitoring for soil quality (as explained earlier in this section), OPG also collects and analyzes radionuclide concentrations in fruits and vegetables, animal feed, eggs, poultry, and milk around the PN Site. This data, which is reported annually through OPG's annual compliance reports and assessed by CNSC staff, provides a comprehensive understanding of the terrestrial environment surrounding the PN Site. Radionuclide concentrations in samples confirm that they are within expected trends, so human and ecological receptors near the facility are protected.

Findings

Based on CNSC staff's review of the most recent ERA results and terrestrial monitoring data for the PN Site, CNSC staff have found that the terrestrial environment remains protected from radiological and hazardous releases from the facility, as well as from physical stressors such as noise and wildlife interactions with traffic and structures. Although there are some localized areas of soil contamination, the risks to terrestrial receptors is considered low, and the contamination will be addressed by OPG during decommissioning of the PN site.

3.2.3 Aquatic environment

An assessment of potential effects on aquatic biota at the PN Site and the surrounding area involves characterizing the local habitat and species (including considering federal and provincial species at risk) and assessing the possibility of their exposure to radiological and hazardous substances, as well as physical stressors that may be disruptive to ecological receptors.

3.2.3.1 Surface water quality

The PN Site is located on the north shore of Lake Ontario. The shoreline immediately adjacent to the PN Site has been altered by the construction of the CCW intake channel and the 2 water outfall channels, 1 on each side of the PN Site (see figure 1.2). Nearshore lake currents are affected by the existing operation of the PNGS reactor units. Under normal operations, with all 6 units running, typical water withdrawal rates estimated at 190 m^3/s are required to cool down the reactor units. Water withdrawal results in some localized effects, such as fish impingement as well as egg and larvae entrainment at the water intake. The discharge of cooling water also results in a thermal plume

that can potentially affect localized fish populations. These effects are discussed more under the Physical stressors section of this report.

Outfall

All liquid effluent, except domestic sewage (discharged into the Regional Municipality of Durham sewage mains) and some stormwater drainage (discharged directly into Lake Ontario at different locations), is discharged into the CCW discharge duct, the outfall structures or the forebay. The surface water monitoring program for the PN Site provides regular monitoring of COPCs in effluent and surface water in the vicinity of the site.

A surface water monitoring program was conducted in the summer of 2015 as part of the updated baseline environmental program in support of the 2017 ERA, to quantify the concentration of COPCs in the PN discharge channels. Since there have not been significant changes to operations at the PN Site, the 2015 results were considered to be still applicable for the 2022 ERA and this approach was accepted by CNSC staff. The maximum measured concentrations of copper and morpholine exceed their corresponding surface water quality screening levels and were carried forward in the assessment which is further described below under the Exposure to hazardous substances section of this report. For some COPCs (such as barium, calcium, magnesium), lake water concentrations exceeded the selected toxicity-based screening value; however these maximum concentrations only marginally exceeded (between 3% and 7%) the background sample location, so these metals were not carried forward for further quantitative assessment. Based on a 2014 EMP supplementary study, the maximum observed hydrazine concentration (0.25 µg/L) in lake water was below the screening level of 2.6 µg/L; therefore, hydrazine was not carried forward for further quantitative assessment in the 2022 EcoRA.

Stormwater

Stormwater runoff from the PN Site is collected by the stormwater drainage system, consisting of 19 catchments, and is directed through drainage pathways to Lake Ontario. As part of the updated baseline EMP, a stormwater sampling program was conducted in 2015 in order to characterize the current quality of stormwater runoff released to the PN Site outfalls and stormwater runoff released directly to Lake Ontario. The point of discharge concentrations were compared against provincial water quality guidelines. None of the measured radiological and non-radiological contaminants exceeded provincial guidelines. As such, stormwater quality was not assessed further. However, to address the water quality of stormwater discharging directly to Lake Ontario from the PN Site that was not sampled in the previous program, CNSC staff, along with ECCC staff, recommended during their review of the 2017 ERA that OPG develop a stormwater sampling plan and that the results be included in future ERA submissions. OPG indicated in the 2022 ERA that it has postponed further stormwater sampling until the PWMF Phase II expansion is further along (as it will likely result in changes to the stormwater catchments in the East Complex). OPG plans to carry out this recommendation prior to and for inclusion in the next ERA after the expansion. CNSC staff and ECCC will continue to monitor this recommendation.

Frenchman's Bay

As part of the updated baseline environmental program, surface water and sediment data were collected in the summer of 2015 from Frenchman's Bay with the objective of addressing recommendations in the 2014 ERA to reduce uncertainty and provide additional data for the bay. In the north and south ends of Frenchman's Bay, 10 sediment samples and 3 surface water samples were

collected. Water samples were analyzed for alkalinity, ammonia (total and un-ionized), biochemical oxygen demand, chemical oxygen demand, hardness, acidity/alkalinity, conductivity, temperature, total suspended solids, total residual chlorine (in-situ), PHC F1 to F4, morpholine, metals, total organic carbon and radionuclides. The maximum concentrations of total aluminum and iron at Frenchman's Bay exceeded their respective CCME water quality guidelines and the maximum sodium concentration exceeded its toxicity benchmark, so they were retained as COPCs for the EcoRA.

3.2.3.2 Sediment quality

Frenchman's Bay

As part of the updated baseline EMP, sediment data were collected in the summer of 2015 from Frenchman's Bay to address recommendations in the 2014 ERA to collect sediment and water samples in the bay. Frenchman's Bay is a provincially significant wetland and is the closest location to the PN Site that is considered a depositional area. Sediment samples were analyzed for total organic carbon, metals and radionuclides. Although considered low risk, aluminum and bismuth were kept in the EcoRA for consistency with the 2017 ERA assessment. Total organic carbon was also carried forward as it exceeded the Ontario MECP lowest effect level; however, exceedances were expected as Frenchman's Bay is greatly influenced by urban runoff.

3.2.3.3 Aquatic habitat and species

Aquatic habitat

Spawning habitat for several fish species, such as Lake Trout and Round Whitefish, is found along the exposed shoreline of Lake Ontario. Duffins Creek, Frenchman's Bay and Hydro Marsh also provide spawning and rearing habitat for such species as Northern Pike, Smallmouth Bass and Emerald Shiner. The discharge channels of the PN Site also provide spawning habitat for Smallmouth Bass.

More than 90 fish species are known to inhabit Lake Ontario, almost all of which use the nearshore waters for spawning, rearing, feeding and migrations. Table 2.17 in the 2022 ERA lists the resident and migratory fish species observed within the PN Site. Zebra mussels and quagga mussels have colonized the nearshore areas in the vicinity of the PN Site and throughout Lake Ontario and are very abundant, including in the vicinity of the water intake and discharge channels of the PN Site. Benthic organisms such as Diporeia spp., oligochaetes, sphaeriid clams and unionid clams have been negatively affected by this colonization in nearshore areas of the lake.

The main exposure pathway for the aquatic community is through direct contact with water and sediment at the PN Site outfall and/or at Frenchman's Bay.

As indicated in section 3.2.2 Terrestrial environment, some terrestrial species (such as riparian birds and mammals, amphibians and reptiles) were assessed as aquatic species for the purpose of the radiological and non-radiological exposure assessments.

Aquatic species at risk

In Ontario, the following legislation applies to species at risk: the provincial *Endangered Species Act* [59] and the federal SARA [60]. 3 fish species at risk, with a provincial or federal ranking of

threatened, endangered or extinct were recorded at the PN Site (American Eel, Atlantic Salmon and Lake Sturgeon). However, Lake Sturgeon has not been observed since 2005 and is considered no longer present in the area. Atlantic Salmon were observed within the area as recently as 2020; however, Atlantic Salmon found in Lake Ontario are likely individuals from the Lake Ontario Atlantic Salmon Restoration Program and are not considered individuals of the native Lake Ontario Population. American Eel was observed every year in the annual impingement monitoring programs between 2016 and2020 and is therefore considered in the ERA and presented in table 3.3. Impingement monitoring in 2013 identified Silver Shiner and Spotted Gar, which are both provincially ranked as threatened, and under SARA Schedule 1 are ranked as of special concern and threatened, respectively. However, these species are not resident or migratory fish species of Lake Ontario and they are typically associated with creeks and streams rather than large lakes. The presence of these species in impingement samples is considered questionable, and these prior records are deemed to be misidentifications. As such, Silver Shiner and Spotted Gar have not been considered for the ERA.

As indicated in section 3.2.2 Terrestrial environment, some terrestrial species were assessed as aquatic species for the purpose of the radiological and non-radiological exposure assessments. As presented above in table 3.3, the Least Bittern (listed as having Threatened status both federally and provincially), was last observed on the PN Site in 2020 breeding in Hydro Marsh. The Common Tern was selected to represent the Least Bittern as a riparian bird that ingests fish and insects. Although Blanding's Turtle has not been observed since 2006, its presence in Frenchman's Bay has not been ruled out as targeted surveys have not been conducted for turtles. The Midland Painted Turtle can represent Blanding's Turtle in the assessment as a species that may be present in Frenchman's Bay.

ERA predictions

The most recent assessment of potential effects on aquatic biota near the PN Site was provided in the 2022 ERA [42]. As discussed in subsection 2.3.3, the ERA fully complied with the requirements of CSA N288.6-12, *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills* [33] and incorporated recent environmental monitoring data.

OPG selected a total of 18 aquatic receptors for the assessment based on knowledge of the PN Site and its surrounding environment, and relevant field observations. The chosen aquatic receptors include the categories of aquatic invertebrates, aquatic plants, amphibians and reptiles, benthic fish, pelagic fish, riparian birds and riparian mammals. The chosen ecological receptors reflect a variety of diets or feeding habits, cover a variety of trophic levels, and are representative of the potential species present in the area and include species identified as important to Indigenous Nations and communities.

In July 2021, OPG sought input from the Williams Treaties First Nations representatives on VEC selection. A representative of Williams Treaties First Nations suggested 2 VEC options based on prevalence in Lake Ontario – the inclusion of Round Goby instead of Brown Bullhead, and the assessment of zebra mussels instead of benthic invertebrates. During the VEC selection process the risk assessors concluded that assessment of the Brown Bullhead (selected as a native species) will be protective of the Round Goby (not selected, as it is an introduced invasive species), and benthic invertebrates, which are intended to represent both sensitive and resilient aquatic organisms, would be protective of zebra mussels (an invasive species). OPG acknowledges that the ERA was completed from a Western scientific perspective, and that it may not fully address the impact on Indigenous

inherent and treaty rights as they are understood today. OPG is working with the Williams Treaties First Nations to have more detailed and ongoing engagement on future ERAs. CNSC staff will follow up on OPG's commitment to engage with Indigenous communities during, and/or in advance of, the drafting of the next ERA.

Exposure to radiological substances

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

The overall radiation dose, which included all internal and external doses from all exposure pathways, were significantly below the radiological dose benchmarks recommended in NCSA 288.6-12 [33] (that is, 400 µGy/h for aquatic receptors). This result indicates negligible potential for adverse effects and no need for further detailed assessment.

Exposure to hazardous substances

The potential hazardous effects on ecological receptors were assessed by comparing the estimated exposure concentration received by each ecological receptor from hazardous COPCs through all applicable pathways (namely exposure to hazardous contaminants in air, soil, lichen, vegetation, water, sediment, benthic invertebrates, phytoplankton, zooplankton and aquatic vegetation) to the recommended benchmark values (that is, toxicity reference values for non-human biota). Benchmarks were then compared against exposure levels for aquatic and riparian receptors to calculate a HQ, which is the ratio of the concentration of the COPC (in surface water or sediment) to the most conservative toxicological benchmarks. A HQ that is ≤ 1, meaning the concentration of COPCs in surface water or sediment is less than or equal to the benchmark, indicates there is no potential risk to aquatic or riparian receptors from exposure. The interpretation of HQ results also takes into consideration the distribution of areas with a HQ>1, the mobility and home range of the affected receptor, and whether the exposure point concentrations can be attributed to PN operations.

Outfall and discharge channels – surface water

All effluent except sewage and some stormwater is released into the outfall and into Lake Ontario. As part of the ECA requirements, effluent is sampled at the outfall of the PN Site for ammonia, hydrazine, morpholine, pH and total residual chlorine. For each COPC, the maximum concentration of the effluent was screened against federal and provincial water quality guidelines in order to estimate potential impacts on nearshore water due to effluent loading. Hydrazine, morpholine and total residual chlorine from the effluent exceeded the surface water quality guidelines and were further assessed in the risk assessment.

A surface water monitoring program was also conducted in the summer of 2015, as part of the updated baseline EMP, in order to quantify the concentration of COPCs in the discharge channels. Since there have not been any significant changes to operations at the PN Site, the 2015 results were considered to be still applicable for the current assessment and this approach was accepted by CNSC staff.

Maximum and UCLM concentrations of morpholine in lake water measured near the outfall and from the CCW did not exceed their benchmark values for the receptors of interest. The maximum concentrations of hydrazine, copper and total residual chlorine (TRC) (measured from the CCW) at the outfall exceeded the benthic invertebrate benchmark concentration by 1.5 to 7.5 times, thus resulting in a risk (HQ) above 1. However, since benthic invertebrates are generally sessile organisms it is expected that a few individuals near the outfall may be exposed to these maximum measured concentrations, but, the benthic community as a whole is not expected to be affected.

There were some HQ exceedances for the maximum concentration of copper (HQ of 2.3) and maximum (HQ of 4.1) and UCLM (HQ of 1.7) concentrations of TRC for fish. Since fish swim around, exposure to the UCLM concentration is more likely and still likely an over-estimate of the exposures of fish that would be unlikely to spend 100% of their time in the outfall. The exposure concentration for TRC is also based on discharges from the CCW, and it is expected that concentrations would be rapidly diluted in the lake.

The American Eel is an identified species at risk; therefore, the assessment endpoint is the health of the individual. As discussed, the UCLM water concentration for copper was not exceeded. As eels are mobile, the HQ for UCLM water concentration is more appropriate than the maximum exposure concentrations. As such, the American Eel is not likely to be impacted by exposure to copper from PN Site operations. The fish benchmark was also exceeded in the outfall for Max and UCLM concentrations for TRC. However, as stated above, the exposure concentration for TRC is based on CCW discharges at the outfall, and it is expected that concentrations would be diluted in the lake. Since fish swim around a wider area, they are also unlikely to be exposed to UCLM concentrations. The American Eel is thus likely not at risk from PN operations.

Outfall and discharge channels – sediment

Estimated maximum copper concentrations in sediment near the PN Site outfall also slightly exceeded the sediment benchmark for copper (HQ of 1.5), therefore the HQ was above the risk level of 1 for benthic invertebrates. Based on the UCLM measured copper concentrations near the PN Site outfall (HQ of 0.3), the estimated sediment concentration is below the sediment benchmark for copper and, as such, the benthic invertebrate community as a whole is not likely to be impacted by PN Site operations.

Frenchman's Bay – surface water

As part of the updated baseline environmental program, surface water data were collected in the summer of 2015 from Frenchman's Bay with the objective to address recommendations in the 2014 ERA to reduce uncertainty and provide additional data for the southern section of the bay. Since there have not been significant changes to operations at the PN site, the 2015 results were considered to be still applicable for the current assessment and this approach was accepted by CNSC staff. Frenchman's Bay water concentrations were screened against surface water quality guidelines. Maximum and UCLM measured concentrations of hydrazine, morpholine, total residual chlorine and sodium at Frenchman's Bay did not exceed the benchmark for any of the aquatic biota identified at Frenchman's Bay. Maximum concentrations of copper, aluminum and iron exceeded the surface water quality guidelines and were further compared against toxicological benchmarks.

The maximum (HQ of 1.9) and UCLM (HQ of 1.4) measured iron concentration in water at Frenchman's Bay exceeded the benthic invertebrate toxicological benchmark. Although a few benthic invertebrates may be exposed to these maximum measured concentrations of iron, the community as

a whole is not expected to be impacted by PN operations. In addition, the maximum and UCLM measured iron concentrations in sediment at Frenchman's Bay did not exceed the sediment benchmarks for benthic invertebrates.

The maximum measured copper concentration in water at Frenchman's Bay is 2.1 µg/L, which marginally exceeds the aquatic plant benchmark of 2 µg/L. The maximum and UCLM aluminum concentration for the muskrat and Bufflehead; the maximum and UCLM iron concentrations for the Trumpeter Swan, Bufflehead and Ring-billed Gull; and the maximum iron concentration for the Common Tern exceeded the toxicological benchmark for these riparian species for both water and sediment concentrations (see table 3.5). However, as these receptors would not reside at Frenchman's Bay exclusively, these HQs are considered very conservative. Combined with the influence of the urban runoff at Frenchman's Bay, it is unlikely that the populations of these receptors will be impacted by PN Site operations. In addition, PN operations contribute a small proportion of the overall risk to aquatic receptors at Frenchman's Bay. The percent contribution from the PN Site ranges from 0.3% to 22% for most COPCs and the calculated contribution ranges from 17% to 49% for nickel.

The Least Bittern was identified as a species at risk on the PN Site and was represented by the Common Tern. As indicated in table 3.5, maximum iron concentration exceedances for the Common Tern were recorded as an HQ of 1.0. However, based on UCLM concentrations, the HQ for the Common Tern did not exceed the acceptable risk level of 1 (HQ of 0.82). Since the Common Tern is highly mobile, the use of UCLM exposure concentration is more representative than the maximum exposure concentration of the COPC. As such, the Least Bittern is not likely to be impacted by iron exposure in Frenchman's Bay due to PN Site operations.

Frenchman's Bay – sediment

In sediment samples taken from Frenchman's Bay, several metal COPCs exceeded sediment quality guidelines and were further assessed against toxicological benchmarks. It should be noted that many of the COPCs identified in sediment samples from Frenchman's Bay were not related to the PN Site but due to urban stormwater runoff.

The maximum and UCLM measured copper concentrations in sediment in Frenchman's Bay exceeded the sediment toxicological benchmarks for benthic invertebrates (HQ greater than 1) (see table 3.6). Although the results of the ERA to ecological receptors at Frenchman's Bay indicate copper results above the acceptable risk level, exceedances of toxicological benchmarks are not uncharacteristic for an area such as Frenchman's Bay, since it is highly influenced by urban stormwater runoff. The ERA evaluated the contribution to the overall risk and concluded that the PN Site operations contribute only a small portion of the overall risk to aquatic receptors at Frenchman's Bay.

Table 3.5: Non-radiological hazard quotients for aquatic biota and riparian birds and mammals

Receptors	Hydrazine from CCW		Morpholine from CCW		Morpholine from lake water		Copper		Chlorine (TRC) from CCW		Aluminum		Sodium		Iron	
	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM
PN discharge channel																
Fish	0.40	0.03	0.00	0.00	0.01	0.00	2.30	0.73	4.10	**1.70**	N/A	N/A	N/A	N/A	N/A	N/A
Benthic invertebrate	6.20	0.46	0.00	0.00	0.01	0.00	1.50	0.46	7.50	**3.20**	N/A	N/A	N/A	N/A	N/A	N/A
Ring-billed Gull	N/A	N/A	nd	nd	N/A	N/A	0.05	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Frenchman's Bay																
Fish	0.05	0.00	0.00	0.00	0.00	0.00	0.55	0.50	0.47	0.20	0.08	0.06	0.79	0.66	0.43	0.33
Frog (Tadpole)	0.05	0.00	0.00	0.00	0.00	0.00	0.55	0.50	0.47	0.20	0.08	0.06	0.79	0.66	0.43	0.33
Benthic invertebrate	nd	nd	nd	nd	nd	nd	0.35	0.31	0.87	0.37	0.14	0.11	0.13	0.11	1.90	**1.40**
Aquatic plant (Cattail)	nd	nd	nd	nd	nd	nd	1.1	0.95	0.56	0.24	0.59	0.44	0.53	0.44	0.38	0.29
Muskrat	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.12	0.00	0.00	5.20	**3.90**	N/A	N/A	0.31	0.24
Trumpeter Swan	N/A	N/A	N/A	N/A	N/A	N/A	0.01	0.01	N/A	N/A	0.38	0.29	N/A	N/A	5.20	**4.00**
Bufflehead	N/A	N/A	N/A	N/A	N/A	N/A	0.02	0.01	N/A	N/A	4.10	**3.10**	N/A	N/A	17.00	**14.00**
Common Tern	N/A	N/A	N/A	N/A	N/A	N/A	0.00	0.00	N/A	N/A	0.20	0.15	N/A	N/A	1.00	0.82
Ring-billed Gull	N/A	N/A	N/A	N/A	N/A	N/A	0.01	0.01	N/A	N/A	0.66	0.49	N/A	N/A	5.20	**4.00**

Notes: Shaded values indicate a HQ>1. Bold and shaded values indicate a UCLM HQ > 1.
nd denotes that no data were available.
N/A denotes that the parameter is not applicable to the specific area of assessment.
Max and mean HQs for morpholine and total residual chlorine are generally equivalent for most receptors since surface water concentrations were generally measured below the detection limit.
The HQs for fish, frog, benthic invertebrate and aquatic plant are based on toxicological reference values for water concentrations. Sodium is considered non-toxic to birds and mammals.

Table 3.6: Non-radiological hazard quotients for benthic invertebrates from sediment toxicity reference values

Parameter		**Benthic invertebrate**	
		PN discharge channel	**Frenchman's Bay**
Copper	**Max**	**1.5**	**4.6**
	UCLM	0.3	**3.2**
Iron	**Max**	N/A	2.8E-2
	UCLM	N/A	2.0E-2

Notes: Bold and shaded values indicate an HQ >1.
N/A denotes that the parameter is not applicable to the specific area of assessment.

Exposure to physical stressors

Impingement and entrainment

Impingement of fish and entrainment of fish eggs and larvae within the PN facility occurs from the use of lake water for CCW. Fish impingement sampling was conducted at the PN Site from September 2003 to September 2004. Fish egg/larvae entrainment sampling was conducted from mid-March through December 2006.

In 2008, the CNSC issued a directive to the PNGS to reduce fish impingement by 80% by 2012. In 2009, a FDS (see figure 2.2) was installed by OPG around the cooling water intake structure to mitigate impingement. Monitoring conducted annually from 2009 to 2011 indicated that the FDS met and exceeded the impingement reduction target each year. As a result, in 2012, the CNSC accepted the FDS as a permanent solution to reduce fish impingement. OPG installs the FDS from spring to fall and monitoring of fish impinged is conducted weekly throughout the year. OPG provides the CNSC with an annual report on fish impingement results.

An FAA for PN operational activities was issued to OPG by DFO on January 17, 2018, associated with the continual intake of cooling water from Lake Ontario. The DFO Authorization included a 2-year biomass condition, where consultation with DFO is required if the combined biomass across all species and ages is over 3,619 kg/yr in 2 consecutive years. The approved rate of entrainment during the operations phase is 106 kg age 1 equivalent per year. This entrainment estimate is 1.7 % of the 6143 kg age 1 equivalent per year estimated impingement during operations. If OPG seeks to continue operations past 2026 (which would require OPG to bring a licensing application and for the Commission to authorize such a license), then OPG must conduct an entrainment study as per condition 3.2.3 of the PNGS FAA, beginning the study no later then summer of 2024 [44]. CNSC staff expect the results of the entrainment study in the next iteration of the ERA.

Both impingement and entrainment losses are required to be counterbalanced by the 3 offset measures that were approved by DFO in the PN Site FAA. The offset measures consist of a portion of the Big Island Wetland Fish Habitat Bank, a portion of the restored Simcoe Point Wetland, and 2018-2020 stocking contributions of Lake Ontario Atlantic Salmon into Duffins Creek. Offset monitoring field studies are to be conducted and reports are to be submitted to DFO as conditions of the Authorization, demonstrating the offset measures effectively counterbalance the impingement and entrainment residual impacts and risks.

Table 3.7 summarizes the results of the total biomass of all species impinged from 2016 to 2020. The results in 2017 were heavily influenced by a single event starting on November 16 and lasting several days, which was reported to the CNSC and DFO. During the event, a preliminary estimate of 24,000 kg of Alewife was impinged. In the absence of this event, impingement was 1,217 kg, the second lowest on record since assessment commenced in 2010. Impingement estimates provided in 2018-2019 indicate an exceedance of the 2-year threshold, and DFO was notified. Further evaluation by OPG concluded that the exceedances did not appear to be caused by PNGS operations related to spills, waterborne releases, or the station discharge and were likely caused by net performance issues due to algae intrusion events, and lake water temperatures causing cold shock to fish (not caused by PNGS thermal releases). Installation of a pilot air bubble curtain system was also completed in July 2021 to address the increasing abundance of nuisance algae in the nearshore area of Lake Ontario. In 2020, impingement

estimates were less than 3,619 kg, and therefore impingement was below the 2-year threshold. Impingement monitoring data from 2016 to 2020 identified the most commonly impinged fish species (as per total impinged biomass) were Alewife, Gizzard Shad, Round Goby, Carp, Three-Spine Stickleback, Northern Pike, American Eel and Rainbow Smelt.

The loss of Northern Pike has not been reduced overall by the FDS, likely because this species is prevalent in the winter, when the FDS is not in place. OPG has participated with the Toronto and Region Conservation Authority in tagging Northern Pike captured in the Pickering area nearshore, Frenchman's Bay and Duffins Creek Marsh. Over the 2010–2020 period, only 1 tagged individual has been confirmed as impinged since monitoring of tags began in 2010. This result suggests that impinged pike represent a small fraction of the local population.

From 2010 to 2020, American Eel impinged annually ranged from 16 to 112 individuals and 0.5 to 104 kg reported biomass impinged. The American Eel is listed as endangered under Ontario's *Endangered Species Act* [59]. OPG has a permit issued by the Ontario Ministry of Natural Resources and Forestry (OMNRF) that allows it to impinge American Eel. CNSC staff consulted OMNRF regarding the number of American Eel impinged. ONMRF indicated that it was aware of the impingement numbers and was of the opinion that the increased number was a reflection of the success of OMNRF's stocking program.

Table 3.7: Impinged fish biomass from 2016-2020

Year of measurement	2016	2017	2018	2019	2020
Total biomass (kg)	1,035	1,217	5,616	15,115	3,526

Thermal plume

The discharge of warm water during normal operation of the CCW system has the potential to impact fish spawning, egg hatching success and larvae development. A thermal plume exists in the area resulting from current operations of the 6 reactor units where temperatures are typically on average 2°C above ambient lake water temperature. The spatial extent of the thermal plume ranges from 1.5 to 8 km^2. OPG has an ECA discharge temperature limit for different operating conditions. On occasion, thermal releases from the CCW discharge can increase during algae and ice buildup events at the intake. During these events, some CCW pumps are turned off to reduce pressure which causes the temperature of the water being released at the outfall to be higher than the provincial regulatory limit for a short time and for which special ECA limits apply. The regulatory approval allows for a maximum difference of 11°C between cooling water going in and coming out of the plant. OPG has implemented mitigation measures, including the installation of a skirt on the FDS and the installation of an ice barrier at the mouth of the intake channel to reduce thermal impact effects at the discharge point. Installation of a pilot air bubble curtain system was also completed in July 2021 to address the increasing abundance of nuisance algae in the nearshore area of Lake Ontario, which is affecting PNGS operations and causing issues such as single or multi-unit shutdowns.

CNSC staff and ECCC staff evaluated OPG's thermal risk assessment to fish that used 2011–2012 data from thermal dataloggers. The CNSC and ECCC staff verified OPG's comparison of lake water in the thermal plume of the Units 5–8 discharge channel and reference locations against the maximum weekly average temperature and short-term daily maximum criteria relevant to fish spawning, embryo-larval development, and growth of juvenile and adult fish for 15 species of fish to determine the HQ values. As previously indicated, a HQ above 1 is indicative of potential adverse effects from the thermal plume. For fish spawning, embryo-larval development, juvenile and adult life stages, the highest HQs were marginally above 1 in the thermal plume, but were similar in the reference locations. As such, it is unlikely that there are any effects arising from the thermal plume in the lake at any life stages for most fish species.

For Round Whitefish, a species known to be particularly sensitive to water temperature during spawning and larval development, the estimated survival loss at the PN Site compared with the reference stations was all below the survival loss of 10% (the threshold for no-effect on Round Whitefish embryo survival) at all stations, except for 1 station near the thermal discharge point in 2011–2012. This station represents only 1% of suitable spawning habitat and the survival loss threshold was only exceeded once in 2011-2012. CNSC staff and ECCC conclude that the thermal plume is not likely to have an adverse effect on embryo development and survival of Round Whitefish and other fish species. However, OPG committed to conducting 2 additional years of thermal monitoring (2018– 2019 and 2019–-2020) to reassess the uncertainties in the thermal risk assessment [62].

OPG monitored the results over the periods of December 2018 to April 2019 and December 2019 to April 2020, and compared these findings with the 2009– 2012 studies, which were undertaken by OPG and presented in the 2022 ERA. The largest relative survival loss observed was 3.8% in 2018–2019 and 1.5% in 2019–2020, at plume locations closest to the PNGS B discharge channel. These values are well below the CNSC threshold of concern of 10% relative survival loss.

A conservative value of 7 °C was chosen for plume temperature at which there could be a possible indication of acute temperature effects on Round Whitefish embryos. 8 locations had hourly water temperatures exceeding 7 °C between December 15, 2018, and March 31, 2019. The longest consecutive period over 7 °C during this time was 13 hours. 7 locations had hourly temperatures exceeding 7 °C between December 15, 2019, and March 31, 2020, with the longest consecutive period over 7 °C being 26 hours. These short-term exceedances of temperatures above 7 °C are believed to have no adverse effects on the development of the Round Whitefish embryos. Thermal monitoring conducted in the winter of 2018–2019 and 2019–2020 supported the 2018 PN ERA conclusion that there are likely no adverse effects to Round Whitefish embryo survival or on the local or regional Round Whitefish population from the thermal plume at the PN Site.

Aquatic environment monitoring

As part of the site's EMP, OPG regularly collects and analyzes radionuclide concentrations in municipal drinking water, well water, lake water, fish, beach sand and sediment around the PN Site. These data can be found in OPG's annual compliance reports, which are assessed by CNSC staff and provide a comprehensive understanding of the aquatic environment surrounding the facility. Radionuclide concentrations in samples confirm that radionuclide concentrations are

within expected trends, and therefore, human and ecological receptors near the facility are protected.

3.2.3.4 Findings

Based on the review of OPG's ERA and the results of the environmental program for the PN Site, CNSC staff have found that the aquatic environment remains protected from radiological and hazardous releases from the PN Site, as well as from physical stressors. Although there were some exceedances of HQs for aquatic receptors, these exceedances were considered to be low risk as the interpretation of HQ results takes into consideration the distribution of areas with HQ>1, the mobility and home range of the affected receptor, and whether the exposure point concentrations can be attributed to PN operations.

3.2.4 Hydrogeological environment

Assessment of the impacts on the hydrogeological environment consists in identifying potential onsite sources of groundwater contamination, determining the extent of contamination (if any) which could lead to an exposure pathway to human and/or non-human receptors, and determining the significance of any exposure from this pathway. Additionally, this assessment evaluated the effectiveness of current control measures in place in protecting the environment.

Groundwater protection is an element of the overall EP measures at the PN Site. In 2020, as part of OPG's implementation of CSA Standard N288.7-15, *Groundwater protection programs at Class I nuclear facilities and uranium mines and mills* [34], OPG established a groundwater protection program (GWPP) that includes a groundwater monitoring program (GWMP) [63]. The purpose of the GWPP is to minimize or prevent releases to and effects on groundwater, as well as to confirm that adequate measures are in place to control and/or monitor these releases. The GWMP serves to provide timely indication of unusual or unforeseen groundwater conditions that may require corrective action or additional monitoring.

This section summarizes the hydrogeological conditions at the PN Site, as well as the project's effects on groundwater quality and quantity. Although this review encompasses both the PNGS and the PWMF, collectively referred to as the PN Site, it will focus primarily on impacts from the PNGS, given that, under normal operating conditions, the PWMF is not expected to have any impacts on groundwater. CNSC staff's EA screening report for the PWMF Phase II [64] did not predict any measurable changes to groundwater quality or quantity as a result of activities associated with the PWMF. These predictions are continually verified by groundwater monitoring by OPG at potential locations of contamination around the PWMF as part of the GWMP. Results from this monitoring program are reported annually to the CNSC and continue to demonstrate that the impact of the PWMF operations on groundwater is negligible.

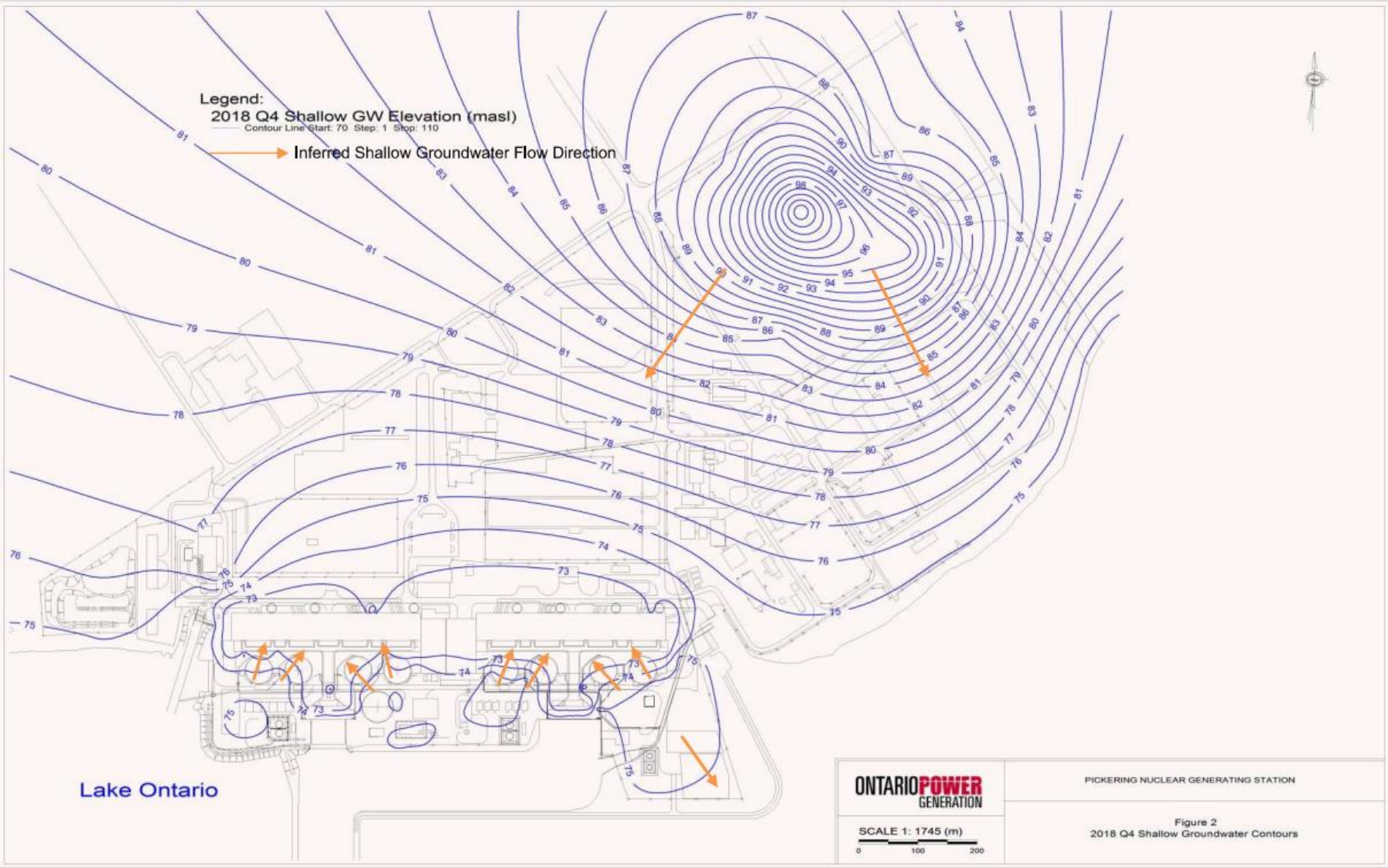
3.2.4.1 Description of existing environment

The PN Site is situated on the north shore of Lake Ontario between the Oak Ridges Moraine to the north and the Lake Ontario shoreline to the south. The Oak Ridges Moraine is situated approximately 20 to 30 km inland from the north shore of Lake Ontario. South of the moraine, the north shore of Lake Ontario is largely underlain by glacial till and glaciolacustrine deposits of clayey silt to silty clay composition. Groundwater flow at the PN Site is divided into 4 main layers consisting of compacted sands and gravels (construction fill), which form the shallow overburden groundwater system; the Upper Till Complex, which acts as an aquitard and

represents the intermediate overburden groundwater system; and the Lower Till Complex, which exhibits interbedded water-bearing layers and is the deep overburden groundwater system. The overburden materials sit atop the Blue Mountain Shale, which is considered an aquitard due to low permeability, and represents the shallow bedrock groundwater system.

Groundwater flows from north to south toward 1 of 3 surface water bodies in the vicinity of the PN Site (as shown in figure 3.2) – Frenchman's Bay to the west, Duffins Creek to the east and Lake Ontario to the south. Both Frenchman's Bay and Duffins Creek flow into Lake Ontario. Groundwater flow in the shallow overburden is downward, whereas flow in the bedrock unit is predominantly upward, which serves to mitigate contaminant migration under the site in this unit. Groundwater flow in the Protected Area (fenced-in area) of the PN facility is complex, influenced not only by the general horizontal gradient toward the lake, but also by infrastructure features that include deep building excavations and associated subdrainage systems. As can be observed by the northward flow of groundwater toward the reactor buildings in figure 3.2, the combined presence of these infrastructure features creates a hydraulic sink, meaning that groundwater within the station's area of influence discharges into the subdrainage systems (that is, travels inwards) rather than toward the shoreline. All effluent collected through drainage systems is analyzed by OPG (and treated if necessary) to ensure it meets radiological and non-radiological limits prior to discharge to Lake Ontario.

Figure 3.2: Groundwater flow regime at the Pickering Nuclear Site [65]



3.2.4.2 Groundwater quantity and quality

As discussed in the ERA [10], the potential for exposure of human and ecological receptors to COPCs through groundwater pathways associated with the PN facility includes discharge into Lake Ontario at the site boundary, as well as deposition of airborne radionuclides through soil. Both pathways are monitored as part of the GWMP, as well as the EMP. Direct exposure is not considered as groundwater is not used as a source of drinking water on the PN Site and is not considered potable. Groundwater is monitored for radiological and non-radiological contaminants before it migrates off-site, ultimately toward Lake Ontario. Collection frequencies range from quarterly to biennially for over 100 locations, most of which are near the reactor buildings. OPG collects the following data from various onsite monitoring wells, drains, sumps and ground tubes:

- groundwater levels in select monitoring wells
- tritium in groundwater adjacent to, and downgradient of, the nuclear generating station and the PWMF
- tritium in perimeter wells to establish concentrations surrounding the site (site boundary wells) and at the Lake Ontario shoreline (shoreline wells)
- tritium in nearby offsite residential wells
- dissolved iron downgradient of the East and West Landfills
- PHCs and benzene/toluene/ethylbenzene/xylenes in the vicinity of generators and the Standby Boiler Building

The monitoring data for groundwater levels confirm that groundwater flow in all 4 flow systems is controlled by flow to Lake Ontario. Water levels in the overburden and shallow bedrock systems have remained consistent with historical values and do not indicate any significant changes. Groundwater levels in the Protected Area are below lake level, representing inward flow caused by the hydraulic influence of the subsurface drains and sumps, which extends into the shallow bedrock system.

Proportions of tritium observed in nearby offsite wells (see table 3.8) over the past 5 years of monitoring remain orders of magnitude below Health Canada's Guidelines for Drinking Water Quality [66] and the Ontario Drinking Water Quality Standard [67] of 7,000 becquerels per litre (Bq/L), confirming that offsite impacts due to atmospheric deposition are negligible.

At the PN Site, tritium concentration trends over time at monitored locations show that, in most cases, concentrations have remained nearly constant or decreased, which indicates stable or improved environmental performance. Elevated concentrations of tritium were previously observed in the vicinity of Units 5–8 and the associated IFB-B between 2013 and 2016. A detailed assessment was carried out to determine the source of these elevated concentrations, and subsequent repairs were completed in 2017–2018. Recent samples taken indicate that tritium in the area has declined substantially. In a few cases, tritium concentrations at certain locations in the Protected Area increased unexpectedly during the 2018–2022 period that is, Unit 1 in 2018–2020 exceeded the generic screening criterion. These unexpected increases were reported to CNSC staff and addressed through detailed assessments as well as corrective actions, where necessary. There was no potential for adverse offsite impacts on humans or the environment, given that groundwater in the Protected Area is contained on-site by the hydraulic sink at the reactor buildings associated with the subsurface drains and sumps—this is demonstrated by

groundwater elevation data, as well as the contaminant fate and transport model developed for the PN Site [68]. This is also confirmed by groundwater monitoring, which over the past 5 years has demonstrated that no exceedances of the screening criterion for the protection of human health and aquatic life (that is, 1×10^8 Bq/L tritium, see [10]) have been observed in perimeter wells at the PN Site (see table 3.8). Although water on-site is not considered potable, monitoring data over the past 5 years also demonstrates that there have been no exceedances of the 7,000 Bq/L drinking water quality standard identified by Health Canada [66] and the province of Ontario [67] in perimeter wells at the PN Site. Tritium concentrations within the perimeter wells are stable and within historical ranges. Shoreline wells exhibit higher proportions of tritium than site boundary wells due to their closer proximity to the reactors.

Proportions of dissolved iron in shoreline wells have been shown to exceed the screening criteria for the protection of aquatic life of 3 mg/L. However, there are several reasons why risks to human or ecological receptors are not expected. Primarily, groundwater at the PN Site is not used as a drinking water source and is not considered potable. Depth to groundwater at the PN Site is at least 2 metres below surface, meaning exposure to offsite terrestrial biota is not anticipated. Finally, elevated proportions of dissolved iron discharging to Lake Ontario would be attenuated through both dilution and precipitation of iron oxide minerals in the oxygenated environment. This was confirmed by lake water sampling carried out under the auspices of the surface water monitoring program [10], which found proportions of dissolved iron below screening guidelines protective of ecological health.

Detectable proportions of PHCs were found in the vicinity of the Units 1–4 and 5–8 standby generators. Monitoring data confirm that these PHCs exhibit limited mobility in the subsurface, and that natural attenuation of residual fuel oil in groundwater is occurring. Concentrations of PHCs are decreasing over time. Proportions of PHCs remain below detection limits and thus within provincial groundwater quality standards (that is, [69]) at any shoreline wells.

Table 3.8: Annual tritium concentrations in groundwater at the Pickering Nuclear Site from 2018 to 2022 [70, 71, 72, 73, 65] and [5, 6, 7, 8, 9]

Parameter	Units	Data measured	Value	2018	2019	2020	2021	2022	Health Canada Drinking Water Guideline/Ontario Drinking Water Quality Standard [66, 67]
Tritium as tritium oxide	Becquerels per litre, Bq/L	Nearby off-site wells	Maximum	20.5	18.5	10.7	15.3	27.9	7,000
			Average	15.7	14.6	9.8	9.9	11.4	
		On-site shoreline wells	Maximum	6,290	5,920	4,440	4,070	4,810	(a)
			Average	2,779	2,291	1,985	1,716	2,241	
		On-site boundary wells	Maximum	1,480	2,220	692	672	895	
			Average	340	431	144	130	175	

[(a)]These wells are used for monitoring purposes only and are not used for drinking water, nor are they considered potable water. No regulatory limit for tritium in on-site groundwater exists. However, a conservative screening level of 1×10^8 Bq/L based on guidance from the U.S. Department of Energy [74] is used in the ERA [10] when considering the potential for off-site impacts on humans or ecological receptors.

3.2.4.3 Findings

Based on a review of the ERA and the results from OPG's GWMP and EMP, CNSC staff conclude that OPG's reported radiological and non-radiological releases of COPCs to groundwater from the site perimeter concentrations have remained low and there are no adverse effects on groundwater quantity or quality from the site. While elevated proportions of tritium are observed in the Protected Area, these are effectively contained due to the hydraulic influence of deep building excavations and associated subdrainage systems. CNSC staff continually review results from the ERA, GWMP and EMP to evaluate whether the conclusion of no adverse effects remains valid.

3.2.5 Human environment

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

OPG's 2022 ERA [10] included a HHRA to assess the risk to humans from both radiological and hazardous substances released from activities at the PN Site. The 6 potential critical groups were:

- C2 Correctional Institution
- local Urban Residents
- local Farms
- local Dairy Farms
- Sport Fishers
- off-site Industrial/Commercial Workers

These groups were used for the exposure assessment for both radiological and non-radiological COPCs. Indigenous peoples were considered in the selection of receptors for the HHRA. OPG initiated engagement with the Williams Treaties First Nations in July 2021 to seek feedback on the list of VECs that would be used in the 2022 ERA. OPG did not receive any specific feedback on the current use of the lands, water or resources for traditional purposes; however, OPG plans to have ongoing discussions with the Williams Treaties First Nations to incorporate relevant information into future ERAs. It was concluded that any influence from PN on the health of Indigenous peoples was likely to be bounded by the assessment for non-Indigenous potential critical groups located much closer to PN who consume foods local to PN as part of their diet. For example, the farm receptors obtain a large fraction of their fruits, vegetables and animal produce locally, with the nearest location at 6 km from PN. While there may be dietary differences such as more wild game in the Indigenous diet, and more farm produce in the farm diet, both groups will have high local fractions, and overall dietary intakes will be similar.

Likewise, Sport Fishers are assumed to obtain their entire fish diet from the PN outfall. It is expected that Indigenous peoples would receive doses that are equal to or lower than those received by these potential critical groups.

3.2.5.1 Exposure to radiological substances

The CNSC's *Radiation Protection Regulations* [48] prescribe radiation dose limits to protect workers, the public, and Indigenous Nations and communities from exposure to radiation from licensed activities. Doses are either monitored by direct measurement or by estimation of the quantities and concentrations of any nuclear substance released as a result of the licensed activities. The annual effective dose limit for a member of the public is 1 mSv per year.

The following exposure pathways were considered to assess doses to human receptors from radiological COPCs:

- inhalation of air and external exposure to air
- ingestion of water and external exposure to water
- incidental ingestion of soil and sediment
- external exposure to soil and sediment
- ingestion of food

The radiological HHRA presents doses reported in the EMP reports from 2016 to 2020, which have been reviewed and accepted by CNSC staff. Radiological dose calculations to human receptors were calculated using environmental monitoring data from the EMP and supplemented with modelling, where necessary. The annual dose during the 5-year period of interest (2016 – 2020) for the critical receptor ranged from 1.2 to 2.1 micro-sieverts (µSv), approximately 0.2% of the regulatory limit of 1 mSv/year (1,000 µSv/year) for the PN site (table 3.9). The primary radionuclide pathways contributing to this total dose were inhalation of tritium and external exposure to noble gases. The critical receptor was the local urban resident (adult). As the critical receptor group presumably receives the highest dose other receptor groups near the PN Site are also protected. Since the dose estimates are a small fraction of the public dose limit and natural background exposure, no discernable health effects are anticipated due to exposure of potential groups to radioactive releases from the PN site.

For PWMF, Sport Fishers are the only potential critical group where gamma radiation fields would likely be measurable. The fields outside the PWMF are due primarily to contributions from direct gamma radiation and secondarily from gamma skyshine. Sport Fishers may receive a maximum dose up to 0.063 µSv/year from exposure to the PWMF (Phase I and Phase II) when the facility is at full storage capacity. The dose to Sport Fishers from existing PN operations is between 0.2 and 0.5 µSv/year, therefore, the total dose from PN operations and the PWMF may be up to 0.57 µSv/year; however, this is still a small fraction of the regulatory public dose limit.

Table 3.9: Summary of dose to limiting critical group from 2016 to 2020 for the Pickering Nuclear Site [10]

Effective Dose to Critical Group (µSv)					
Public dose limit (µSv)	**2016**	**2017**	**2018**	**2019**	**2020**
1,000	1.5	1.8	2.1	1.7	1.2

3.2.5.2 Exposure to hazardous substances

In OPG's HHRA [10] for the PN Site, the exposure of critical receptors to hazardous substances was evaluated. Based on the results of the screening, the human exposure assessment was performed for the inhalation pathway for nitrogen oxides (NOx), and the drinking water and fish ingestion pathway for hydrazine. The following exposure pathways were considered to assess doses to human receptors from Nox and hydrazine COPCs:

- inhalation (Nox) for all 6 human receptor groups
- water ingestion (hydrazine) for Urban Residents, Correctional Institutions and Industrial/Commercial Workers
- fish ingestion (hydrazine) for Sport Fishers and Urban Residents

As there is no complete exposure pathway from onsite groundwater and soil to human receptors, these pathways were not considered in the exposure assessment to human receptors from non-radiological COPCs.

Potential risks to human receptors were characterized quantitatively in terms of hazard quotients for non-carcinogens (nitrogen oxides) and incremental lifetime cancer risks (ILCRs) for potential carcinogens (hydrazine). Consistent with CSA N288.6-12, the acceptable risk levels are less than 0.2 for non-cancer risk (HQ) and less than a cancer risk of 10^{-6} (ILCR).

In addressing the inhalation pathway for nitrogen oxides, the hazard quotient is determined by comparing it with a toxicity reference value, which in this case is a reference air concentration. The ECCC 1-hour and annual Canadian Ambient Air Quality Standards (CAAQS) for nitrogen dioxide (NO_2) were selected as the reference air concentrations for the ERA [75]. Exposure to Nox in air was assessed at the location of all potential critical groups. The estimated short-term hazard quotient for Sport Fishers exceeded the acceptable level of 0.2 based on a modelled 1-hr Nox concentration during normal operations (HQ = 1.4). The modelled concentrations used to quantify short-term inhalation risk represent the highest point of impingement concentrations for nitrogen oxides that could result from the maximum emission rates generated at PNGS. Although the maximum emission rates are conservative, there is evidence that ambient NO_2 can cause short-term adverse health effects. There is uncertainty around the short-term (1-hour) air concentrations that have been applied to estimate risk for Sport Fishers. The maximum point of impingement concentration reported in the Emission Summary and Dispersion Modelling reports represents the highest concentration that may be expected at the property boundary; however, the Sport Fisher's location is approximately 0.5 km offshore, where a greater degree of dispersion from the source may take place. There is also uncertainty around the short-term air concentrations at other potential critical group locations, and therefore risks were not quantified

for the other receptors. Since other potential critical groups are located outside of the boundary used to determine the POI concentration, it is anticipated that the hazard quotient for the other receptors will be lower than that for Sport Fishers. No chronic risk to human receptors is expected to result from concentrations of nitrogen oxides released from the site; however, additional air monitoring was recommended in the ERA to refine the risk estimates and CNSC staff will follow up on this recommendation in the next iteration of the ERA.

The ILCR were estimated for potential carcinogenic substances (hydrazine) through water and/or fish ingestion pathway. The ILCRs were compared to an acceptable cancer risk of less than 1 in 1,000,000 (or 1 in 10^{-6}), as recommended in CSA N288.6-12. Below this risk level, the health impacts are considered to be negligible.

For waterborne non-radiological COPCs, exposure point concentrations for hydrazine were determined based on both measured data from the 2014 supplementary study and from weekly measured concentrations at CCW discharges collected as part of ECA requirements. Risks were modelled for hydrazine for the urban resident, correctional institution resident and industrial/commercial worker through drinking water supplied from the Ajax water supply plant (the closest plant to the PN Site). The risk for hydrazine was assessed to be below the acceptable cancer risk level of 10^{-6} when using lake water samples (collected from the 2014 supplementary study). When performing the same analysis using concentrations of hydrazine collected weekly from the CCW from the PN Units 1-4 and PN Units 5-8 outfall, an incremental lifetime cancer risk for Urban Residents and Correctional Institution Residents using maximum concentrations was above the acceptable cancer risk level of 10^{-6}, but risks were acceptable when using the UCLM concentration at the outfall. The UCLM concentrations are more appropriate for the assessment of the drinking water pathway for hydrazine since receptors would be exposed to an averaged concentration over the course of a year.

Risks from hydrazine for the Sport Fisher through fish ingestion was estimated based on measured hydrazine concentrations in the PN outfalls (from both lake water and CCW outfalls), and an assumed bioaccumulation factor for hydrazine. The exposure concentration from lake water samples was determined using all measured lake water samples collected as part of the 2014 supplementary study. The exposure concentrations based on weekly CCW discharge concentrations used a dilution factor of 4.2 to represent travel between the outfall (PN Units 1-4 and PN Units 5-8) and Sport Fishers. Risks were below the acceptable risk level of 10^{-6} based on lake water hydrazine concentrations. However, for the hydrazine concentrations from the CCW outfall after applying the dilution factor, the risk would be above the acceptable cancer risk level of 10^{-6}. Since fish are mobile, the exposure to the UCLM concentration is more realistic than exposure to the maximum. Using UCLM CCW concentrations of hydrazine from PNGS Units 1–4 and PNGS Units 5–8 outfall resulted in an ILCR 6.7 times greater than the acceptable cancer risk level. However, this is based on conservative exposure assumptions for Sport Fishers, who are assumed to consume 100% of their fish diet from those collected in the vicinity of PNGS. Realistically, a fisher would likely visit and harvest fish from various locations throughout the year, including those unaffected by PN emissions. There was no risk to Urban Residents for hydrazine due to fish consumption, since locally sourced fish represents a negligible (0.2%) proportion of the fish in their diet.

These dose estimates demonstrate that there are no health effects expected due to exposure of human receptor groups to non-radiological releases of COPCs from the PN Site.

Physical stressors

Noise is the only physical stressor associated with the PN Site that is of potential concern to human receptors. As mentioned in section 3.2.2 Terrestrial environment, a noise monitoring program was carried out to determine existing noise levels as part of the updated baseline EMP. The baseline program and the ECA in place for noise emission limits indicate that noise levels in populated urban areas, such as the PN Site, will occasionally exceed the applicable prescribed sound level limit. These elevated sound levels are likely the result of road traffic or human activity in the vicinity of noise monitoring locations. As such, the occasional periods of elevated sound levels are likely not having an adverse effect on human receptors near the PN Site.

3.2.5.3 Findings

Based on assessments conducted for the PN Site, including the review of the 2022 ERA and annual environmental monitoring data, CNSC staff have found that impacts on the human environment from radiological and hazardous substances released from the PN Site are unlikely, and that people living and working near the facility remain protected.

3.2.6 Cumulative effects

Potential cumulative effects are assessed at the EA stage for projects, however a formal cumulative effects assessment is not a requirement within CNSC staff's assessments for EPRs as it is not a requirement under the NSCA or other regulatory documents. Nonetheless, CNSC staff's assessments do consider the accumulation of COPCs within the environment because of the facility or activity through the cyclical nature of ERAs, the monitoring data in annual reports, data from the IEMP, and results from any regional monitoring programs and health studies.

Licensees are required to meet onsite, and near-field monitoring requirements associated with their provincial approvals and the federal regulations, including full life-cycle requirements. These programs focus on single operations with scheduled reports on performance submitted to the regulators. These activities are further supplemented by the CNSC's IEMP activities (see section 4.0), which focus on local areas where Indigenous Nations and communities and members of the public could reasonably be expected to conduct recreational or traditional activities (that is, off-site accessible areas).

3.2.7 Climate change considerations

As indicated in section 2.5, potential impacts of climate change on the PN Site have been evaluated in the previous Eas and hazard analysis. A summary of projected climate change, assessment of potential impact of climate change, as well as regulator review is presented in this section.

3.2.7.1 Relevant potential changes in climate in Ontario

CNSC staff consider the latest scientific information related to climate change to inform our regulatory oversight and technical reviews.

Scientific information that is considered includes the following reports:

- Canada's Changing Climate Report [76] and its supplement [77], forecasts that increases in global mean temperature could result in numerous impacts in Canada, such as

increasing severity of heatwaves, drought and wildfires, changing annual and winter precipitation, as well as increasing frequency and magnitude of daily extreme precipitation events.

- The State of the Great Lakes 2022 Report [78] provides Great Lakes (including Lake Ontario) specific climate trend information. Key findings in this regard are as follows:
  - Long term water temperature trends in Lake Ontario could not be assessed due to uncertainties in the data. However, it is concluded that there was a slight increasing trend of approximately 0.03 ℃ per year in the lower Great Lakes (Lake Erie and Lake Ontario) from 1980 to 2020.
  - Based on the 1950 to 2020 annual and seasonal total precipitation data for Lake Ontario, there is a slight increase of 2.3% per decade in the winter, 3.1% per decade in the summer, 4.5% per decade in the fall, and 2.7% per decade in annual precipitation overall.
  - Based on the 1918 to 2020 lake water level data, Lake Ontario water level has been unchanging.
  - Based on maximum ice cover data, spanning from 1973 to 2020, there has been a decreasing trend of 0.24% per year. However, the 30-year trend (that is, 1990-2020) is showing an increase of 0.04% per year in ice cover for Lake Ontario.
- The State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrologic and Ecological Effects [79] synthesizes the state of climate change impacts in the Great Lakes basin and indicates that, over the last 60 years (1950-2010), the Great Lakes basin has experienced an increase in average annual air temperatures between 0.8-2.0 ℃, with this warming trend projected to continue.

3.2.7.2 Pickering Nuclear Site sensitivities to changes in climate

As per the revised 2022 PEA Addendum Report [46], OPG plans to continue the operation of PNGS Units 5-8 to 2026 and shut down Units 1-4 no later than December 2024. A multi decade process to decommission the PN Site is expected to start from 2024. The report discussed the potential effects of climate change on future physical conditions in Lake Ontario relevant to environmental risk assessment modelling for the PN Site.

In the 2007 EA, the physical structures and systems have been evaluated against climate parameters and assessed for potential sensitivity [80]. The climate change parameters that were considered in the 2007 EA to have a potential interaction with the physical structures and systems are:

- precipitation – annual precipitation is projected to increase (20% increase in annual precipitation across the Great Lakes Basin by 2080s under the highest emission scenario [79], and daily extreme precipitation is also projected to increase over the 21st century).
- frequency and severity of extreme weather events – for example, more frequent extreme rain events are projected.
- Lake Ontario water temperature – water temperatures are expected to increase (0.9 to 6.7 °C increase in surface water temperature by the 2080s [79]) due to warmer air temperatures.
- Lake Ontario water level – lower surface water levels of lakes are expected or projected, especially toward the end of this century (low confidence). However, it must be noted that the level of Lake Ontario is regulated for navigation purposes.

Other climate parameters were considered by OPG [80] to have insignificant interactions with the site physical structures and systems and were found not to affect operations. These parameters include: evaporation, soil moisture, and groundwater.

3.2.7.3 Evaluation of climate related impacts

The climate parameter-physical structures or systems interactions identified as having a possible effect have been further evaluated in the 2007 EA [80] and Hazard Screening Analysis [55] for the PN Site. A summary of these analysis, as well as the review by CNSC staff, are described below.

Cobbled shoreline

The eastern portion of the PN Site does not currently have shoreline protection. The current rate of erosion could increase as a result of an increase in the frequency and/or severity of extreme weather events. However, a large amount of erosion of the cobbled shoreline would have to occur to adversely affect the integrity of the land on which the PWMF structures are built or the water quality.

As a commitment in the PWMF Phase II EA Screening Report [18] OPG monitors shoreline stability and will undertake shoreline stabilization as necessary, thus alleviating any impacts on the public or the environment.

Water systems

The current water systems are designed to provide adequate flow of water to service PNGS. Additionally, the PN Site processes are designed to allow for the fluctuation in CCW temperature that occurs seasonally and annually. The effect of the frequency and/or severity of extreme weather events and increasing Lake Ontario water temperatures may result in more entrained algae events or zebra mussel growth, potentially affecting the intake water flow to the CCW and/or service water system. It is also possible that an increase in lake water temperatures may result in discharge water exceeding the permitted maximum temperature limits more frequently.

As part of adaptive management strategy requirements, OPG has monitoring programs in place to detect potential effects on water systems due to algae impingement, zebra mussels, or changes to lake water temperatures, and contingency measures are implemented if necessary. It should be noted that CCW would not be needed after the PN Site ceases operations.

Stormwater management system

The effect of exceeding the design capacity of the stormwater system because of an increase in the frequency and/or severity of extreme precipitation events may include overflow of the system and some localized soil erosion. However, there will be no adverse effects to any structures or equipment at the PN Site nor any risk to the public or the environment as a result of a stormwater system overflow.

Further, any localized soil erosion from the stormwater system is easily repairable as part of the ongoing maintenance program. If the regional storm event is redefined, OPG will re-evaluate the stormwater management system and make appropriate modifications. As part of the adaptive management strategy requirements for the PN Site, the physical structures and systems that could

be affected by a change in environmental parameters, due to changing climate, are monitored and modifications implemented, if required.

Flood hazard

OPG have conducted analysis of flood hazard due to different mechanisms, including surface runoff resulting from PMP falling directly on the site, streams and rivers, waves, seiche (source of flooding in enclosed or semi-enclosed bodies of water), tsunami, and other causes [81]. The probable maximum flood (PMF) used for flood hazard assessment is based on a combination of PMP, a 1:100 year lake level (75.60 m) and storm surge. It should be noted that the water level in Lake Ontario is regulated between a high still-water level of 75.6 m and a low still-water level of 73.9 m [81]. The PMP is based on OMNRF's technical guidelines [82], and represents a 12-hour precipitation, equivalent to 420 mm of total rainfall, with 51% in the 6th hour, based on Table A.2 and A.4 of Appendix A [82]. This PMF has a very low probability of occurrence or exceedance, with an estimated return period in the range of 1 in 10,000 years to 1 in 1,000,000 years [83]. The hazard screening analysis [81] and probabilistic safety analysis [84] demonstrate that potential flood impact is not significant.

3.2.7.4 Findings

The climate change parameters that may have an interaction with the PN Site's physical structures, systems and components include precipitation, extreme weather events (such as extreme storms), and Lake Ontario water temperature and water level.

CNSC staff have reviewed the climate change impact assessment as reported in previous environmental assessment reports for the PN Site, and compared the climate change parameters used in those reports with the latest projections [76, 78, 79]. In addition, CNSC staff review information relevant to climate change resiliency through the cyclical submissions of hazard analysis reports related to safety analysis, and environmental risk assessments.

CNSC staff concludes that, despite possible changes to the climate in the future, the effect of climate change parameters on physical structure, systems and components, and the associated risk to either the public or the environment, is expected to be negligible.

4.0 Canadian Nuclear Safety Commission Independent Environmental Monitoring Program

The CNSC has implemented its IEMP as an additional verification that Indigenous Nations and communities, the public and the environment around licensed nuclear facilities are protected. It is separate from, but complementary to, the CNSC's ongoing compliance verification program. CNSC staff findings are supported by IEMP sampling, along with the licensee EP data and ERA predictions. The IEMP involves taking samples from publicly accessible areas around the facilities and analyzing the quantity of radiological and hazardous contaminant substances in those samples. CNSC staff collect the samples and send them to the CNSC's laboratory for testing and analysis. The CNSC provides opportunities and funding for Indigenous Nations and communities that have an interest in the CNSC-regulated facilities to participate in IEMP sampling campaigns conducted in their traditional and/or treaty territories.

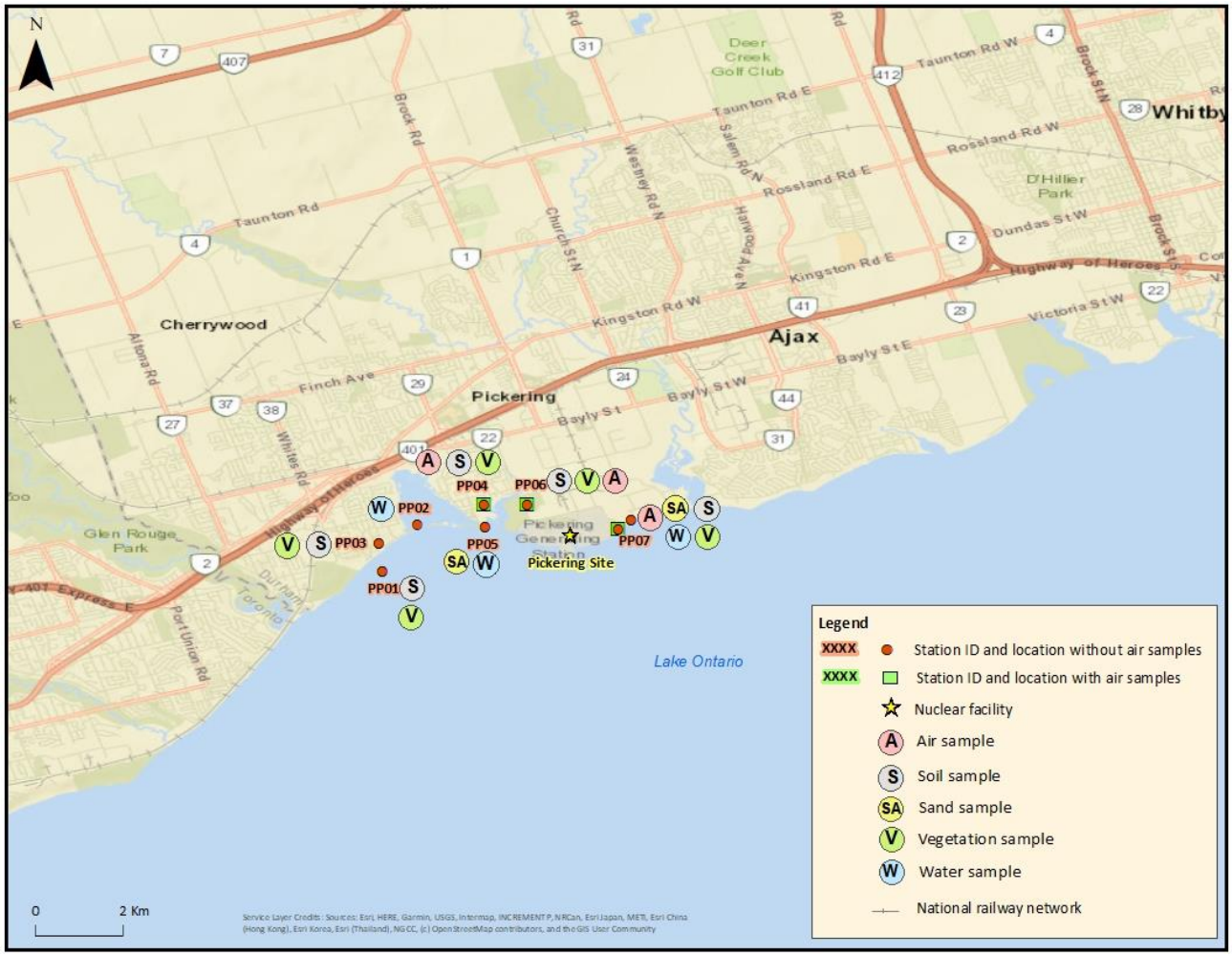
CNSC staff conducted IEMP sampling around the PN Site in 2014, 2015, 2017 and 2021. The sampling plan focused on radiological and hazardous contaminants and considered in OPG's site-wide EMP and the CNSC's regulatory knowledge of the site.

For the most recent sampling campaign in 2021, CNSC staff collected air, water, soil, sand and vegetation samples in publicly accessible areas outside the perimeter of the PN Site. Representatives of Curve Lake First Nation participated in the sampling. For more details, see section 4.2.

Samples collected were analyzed by qualified laboratory specialists in the CNSC's Ottawa laboratory using appropriate protocols. CNSC staff measured radiological and non-radiological substances in the collected samples.

Figure 4.1 provides an overview of the sampling locations for the 2021 IEMP sampling campaign around the PN Site. The IEMP results are published on the CNSC's IEMP web page [85].

Figure 4.1: Overview of the 2021 sampling locations



4.1 Indigenous participation in the Independent Environmental Monitoring Program

It is a priority for the CNSC that IEMP sampling reflects Indigenous traditional land use, values, and knowledge, where possible. In 2021, in advance of the IEMP sampling campaign at PN Site, CNSC staff sent notification emails to all Indigenous Nations and communities near the PN Site, inviting suggestions for species of interest, VECs, or potential sampling locations where traditional practices and activities may take place. The CNSC received a response from Curve Lake First Nation (CLFN), who agreed to participate in the campaign during regular monthly meetings between the CNSC and CLFN. CNSC staff did not receive responses from the other Indigenous Nations and communities contacted.

In July 2021, CLFN joined the sampling team to participate in the sampling for a day. CNSC staff will continue to meet with interested members of Indigenous Nations and communities prior to the IEMP sampling campaigns.

4.1.1 Sampling with the Curve Lake First Nation

Curve Lake First Nation joined the IEMP sampling team to participate in the sampling for a day. 3 Curve Lake First Nation consultation staff accompanied the CNSC IEMP team in the field and observed the collection of air, soil, water, vegetation and sand samples. Curve Lake First Nation's participation in sampling activities promotes a better understanding of sampling methods and locations and improves input into future sampling. In the future, the CNSC looks forward to receiving Curve Lake First Nation's input on species of interest, VECs and potential sampling locations.

4.2 Summary of Results

The levels of radioactive particulates, tritium oxide, gross beta, gross alpha, gamma, pH, total dissolved solids, hydrazine, ammonia, iron, aluminum, zinc and cadmium in all the samples measured during the 2021 IEMP sampling campaign were below available guidelines/screening levels and were similar to the range of results from the 2014, 2015 and 2017 IEMP sampling campaigns at the PN Site. Results for all campaigns are published on the CNSC's IEMP web page [85].

The CNSC's IEMP 2021 results are consistent with the results submitted by OPG, supporting the CNSC's assessment that the licensee's EP program is effective. The results add to the body of evidence that people and the environment in the vicinity of the PN Site are protected and that there are no anticipated health impacts.

5.0 Health studies

The following section draws from the results of regional health studies, and national and international reports and publications to provide further independent verification that the health of people living near or working at the PN Site in southern Ontario is protected. The Durham Region Health Unit works collaboratively with the office of the Medical Officer of Health and other government and non-governmental health service providers to directly monitor the health of people living near the PN Site. In many health studies, disease rates around the facility are compared to similar populations to detect any potential health outcomes that may be of concern.

To complement the CNSC's regulatory oversight, CNSC staff continuously work toward strengthening relationships with the various health units and offices. CNSC staff also keep abreast of any new publications and data related to the health of populations living near, or working at, diverse nuclear facilities. Lastly, CNSC staff, at times, conduct health studies on select populations through their research on the effects of low dose (and low dose-rate) exposures. Select community, Canadian and international publications are discussed below. For additional information on health studies related to nuclear facilities, visit the CNSC's web page on Health Studies [86].

5.1 Population and community health studies and reports

The Municipality of Pickering is located in the southwest of Durham Region. It borders Uxbridge, Whitby, Ajax, Markham (York Region) and the City of Toronto. Pickering is divided into 7 communities, ranging in population size from 9,700 to 16,900 in 2016, when the data were last updated. Population size has changed little, except for the neighbourhood of Brock Ridge Pickering, which is experiencing large growth as a result of development in Seaton. All neighbourhoods are considered urban, with the exception of Pickering North, which is more rural (see all 7 community profiles (external) [87]. Information about this region is captured by the Durham Regional Health Unit and, more broadly, by the statistics reported by Cancer Care Ontario.

5.1.1 Pickering neighbourhood profile

The Pickering neighbourhood profile (external) [87] breaks down demographic information, as well as certain health indicators such as general health, health behaviours (such as smoking and immunization rates, cancer screening), health care use, health conditions and infectious disease rates. The reported statistics were compared with the statistics for Durham Region and were found to be similar overall. Some diseases were more prevalent while others were less prevalent, which is consistent with the natural fluctuation of disease.

Specifically, the Pickering health profile, last updated in June 2022, indicates that the prevalence of asthma in children is 16.9 per 100 (ages 0-14, similar to Durham Region), the prevalence of diabetes is 11.6 per 100 (ages 20+, higher compared with Durham Region), the prevalence of lung disease (including chronic obstructive pulmonary disease [COPD]) is 7.8 per 100 (ages 35+, lower compared with Durham Region), the prevalence of hypertension (high blood pressure) is 23.3 per 100 (ages 20+, higher compared with Durham Region) and the cardiovascular disease hospitalization rate is 8.1 per 1,000 (ages 45-65, similar to Durham Region).

Through the Health Neighbourhoods initiative, the Durham Region Health Department (DRHD) has identified "priority neighbourhoods." These communities have many health challenges, as shown by their rates and rankings on a variety of indicators, and require added focus to build on health and well-being. These priority neighbourhoods are Downtown Ajax, Downtown Whitby, Lakeview (Oshawa), Gibb West (Oshawa), Downtown Oshawa, Central Park (Oshawa) and Beatrice North (Oshawa) [88]. None of the identified priority neighbourhoods are located in the municipality of Pickering.

5.1.2 Durham Region Health Department

The DRHD routinely monitors the health status of Durham Region using health indicators and health data from sources such as hospitals and laboratories, among other record-storing facilities and databases.

The DRHD publishes a health profile through the Health Neighbourhoods initiative (external) [89], which examines information for 50 health neighbourhoods in Durham Region. The profile provides a picture of the health status of Durham Region, and includes demographic, health and health behaviour indicators. As expected, due to Durham Region's diverse population, with a mix of urban and rural communities, Durham Region performs at times better than, and at times poorer than, the province of Ontario as a whole on specific health indicators. For example, Durham Region has a higher prevalence of hypertension (high blood pressure), lung disease (including COPD), asthma in children and diabetes compared with the province of Ontario as a whole. On the other hand, Durham Region is performing better than the province of Ontario overall in terms of lower cardiovascular disease hospitalization and higher reported levels of cancer screening.

The DRHD publishes regional health reports specific to mortality (external) (last updated in June 2017) [90]. In 2012, the average life expectancy in Durham Region was 80.9 years for males, and 84.5 years for females. On average, there were 3,500 deaths per year among Durham Region residents between 2008 and 2012. Ischemic heart disease (heart attacks) were the leading cause of death in Durham Region and Ontario for males and females from 2010 to 2012. Lung cancer was the second leading cause of death among males, and dementia and Alzheimer's disease were the third. These 3 causes accounted for 28% of deaths in Durham Region males. Among females, dementia and Alzheimer's disease were the second leading cause of death and lung cancer was the third. The top 3 causes accounted for 30% of deaths in Durham Region females.

The DRHD also publishes a dashboard with cancer data (external) for Durham Region (last updated November 2022) [91]. Between 2010 and 2018 there were 31,700 newly diagnosed cases of cancer and 10,795 cancer deaths among Durham Region residents. Between 2010 and 2018, there was a decrease in new cases of lung, prostate, colorectal and bladder cancers, and an increase in ovarian cancer cases. For that same time frame, there was a decrease in cancer mortality from lung and colorectal cancer, and an increase in cancer mortality from liver cancer. Between 2010 and 2018, the most common cancers in males were prostate, lung, and colorectal, accounting for almost half of new cancer cases. In females, breast, lung and colorectal cancer made up half of new cancer cases. This is similar to Ontario and Canadian rates ([92], [93]). Cancer incidence rates were similar among Durham Region residents for most cancer sites between 2010 and 2018; however, prostate, thyroid, melanoma and lung cancer rates were higher than overall Ontario rates, while colorectal cancer rates were lower than the provincial rates [92]. Similarly, cancer mortality rates were similar among Durham Region residents for most

cancer sites between 2010 and2018, however, bladder, breast, lung and non-Hodgkin Lymphoma rates were higher than Ontario rates as a whole and colorectal and liver cancer rates were lower than Ontario rates [92].

5.1.3 Cancer Care Ontario

In general, the incidence of cancer is influenced by socio-demographic factors, the availability of early detection and screening, and the prevalence of risk and protective factors. Risk factors for cancer development include unhealthy behaviours (such as physical inactivity, obesity, smoking, alcohol use), previous treatments, genetic predispositions, medical conditions and infectious agents, non-modifiable factors (such as family history, age at first menstrual cycle), and exposure to certain environmental and occupational carcinogens (ultraviolet rays, asbestos, radon, fine particulate matter) [93].

Cancer Care Ontario, through its Ontario Cancer Profiles (external) [94], provides interactive map-based dashboards that display key public health indicators including cancer incidence, mortality, and risk factors. Regional statistics are available by public health unit and Local Health Integration Network (LHIN). The DRHD is included in the dashboard, and PNGS is located in the Central East LHIN.

In 2018, the Central East Region LHIN and the DRHD had incidence and mortality rates for all cancers combined, lung and breast cancer similar to Ontario (considering males and females together and separately). For colorectal cancer, incidence and mortality were similar to those for Ontario, with the exception that colorectal cancer incidence among females in the DRHD was lower than in Ontario as a whole. For prostate cancer, incidence and mortality were similar to Ontario rates, with the exception that prostate cancer incidence was lower in the Central East LHIN compared with Ontario overall.

The following cancer risk factors differ from the Ontario average. In 2015–2016, the Central East LHIN reported higher rates of second-hand smoke exposure. For the 2015–2017, period, the DRHD had higher rates of alcohol consumption.

The Cancer Risk Factors Atlas of Ontario (external) [95] outlines geographic distribution patterns of risk factors related to cancer and other chronic diseases in LHINs. From 2000 to 2014 within the Central East LHIN, alcohol consumption, smoking, and inadequate vegetable and fruit consumption were deemed to be the top 3 priority risk factors. These findings are supported by another report published by Cancer Care Ontario, the Cancer Risk Factors in Ontario report (external) [96].

5.1.4 Findings

The review of health reports is an important aspect of ensuring that the health of people living near nuclear facilities is protected. The regional and community health reports and dashboards indicate that cancer incidence and mortality rates, and the prevalence of health indicators and risk factors related to cancer, are largely consistent with those of the population of Ontario as a whole.

5.2 Current scientific understanding of radiation health effects

The current scientific knowledge about the sources, effects and risks of ionizing radiation is reviewed and published by the international experts that make up the United Nations Scientific Committee on the Effects of Atomic Radiation (external) (UNSCEAR) [97]. This information comes from population studies, animal and cell studies, and clinical investigations. These studies build the foundation of knowledge about the relationship between radiation exposure and health effects, such as cancer. This knowledge, in turn, informs the recommendations of the International Commission on Radiological Protection (external, English only) (ICRP) [98], which focuses on protecting human health.

5.2.1 Canadian studies of radiation health effects

Epidemiological studies involving the PN Site provide insight on populations living near or working at the PN Site. The levels of exposure in local area residents and workers are low, and there is no evidence of adverse health effects resulting from past and present nuclear operations or activities in the region. These findings are consistent with the select important Canadian and international studies of radiation effects on human health in similar populations, described below.

5.2.1.1 Estimating Cancer Risk in Relation to Tritium Exposure from Routine Operation of a Nuclear-Generating Station in Pickering, Ontario.

In 2013, Cancer Care Ontario and the DRHD published a study to determine whether tritium emitted from a nuclear generating station during routine operation is associated with cancer risk in Pickering, Ontario [99]. The study linked residents of Pickering and North Oshawa in 1985 with new cancer cases diagnosed between 1985 and 2005. Cancers investigated for males and females included all sites combined, leukemia, lung, thyroid, childhood cancers and breast (female only). Tritium concentration exposure was assigned to each person based on exact location of residence. The study concluded that tritium estimates were not associated with increased risk of radiation-sensitive cancers in Pickering.

5.2.1.2 Radiation Exposure and Cancer Incidence (1990 to 2008) Around Nuclear Power Plants in Ontario, Canada (RADICON)

In 2013, the CNSC conducted a study on radiation exposure and cancer incidence around Ontario nuclear power plants. The RADICON (external) study determined the radiation doses to members of the public living within 25 km of the Pickering, Darlington and Bruce nuclear power plants and compared cancer cases among these people with cases among the general population of Ontario from 1990 to 2008 [100].

The study mainly found that there was no consistent pattern of cancer and no evidence of childhood leukemia clusters around the 3 Ontario nuclear power plants. Some types of cancer were higher than expected, but others were lower or similar. The study found that variations in all cancers combined and radiosensitive cancers were within the natural variation of cancer in Ontario.

5.2.1.3 Verifying Canadian Nuclear Energy Worker Radiation Risk: A Reanalysis of Cancer Mortality in Canadian Nuclear Energy Workers (1957–1994)

In 2011, the CNSC published a study entitled *Verifying Canadian Nuclear Energy Worker Radiation Risk: A Reanalysis of Cancer Mortality in Canadian Nuclear Energy Workers (1957–1994)* [101]. CNSC staff also published this work in the scientific literature [102]. An analysis of 42,228 Canadian nuclear workers (including workers employed by PNGS) provided no evidence of increased risk of cancer mortality between 1964 and 1994. Canadian workers had lower all-cause and solid cancer mortality compared with the general Canadian population.

5.2.2 International studies of radiation health effects

The epidemiological evidence of radiation-related health effects comes from several main research populations. These populations include the lifespan studies of atomic bomb survivors [103], people involved in the Chernobyl disaster [104], [105], patients treated with radiotherapy for cancer and non-cancer diseases [106], and miners exposed to radon and radon decay products [107], [108].

The largest and most relevant study is the International Nuclear Worker Study (INWORKS), a multinational cohort study that assessed cancer risk from 1943 to 2005 in 308,297 workers from the nuclear industry in France, the United Kingdom and the United States [109], [110], [111], and [112]. This series of studies provides strong evidence of a linear relationship between low dose radiation exposures and cancer. The results were consistent with the current radiation protection framework, whereby the risk is assumed to be proportional to the dose.

The major findings consistent within all these studies are:

1) excess risk of cancer increases as radiation dose increases
2) statistically significant population effects are typically observed at doses above approximately 100 mSv (either acutely or chronically exposed)
3) at doses of 100 mSv (received acutely or chronically), the increased risk of developing cancer is approximately 0.5% above background cancer risk, which in Canada is approximately 50% [113] (resulting in a total risk of 50.5%)

Importantly, the absence of statistically significant data does not indicate the absence of risk. To put these findings into perspective, for nuclear energy workers from the facility, lifetime dose would fall under 100 mSv, given the average dose is less than 1 mSv per year [114]. In comparison, members of the public living near nuclear facilities receive doses less than 0.04 mSv per year, resulting in negligible lifetime doses.

Doses to workers and members of the public from the operation of nuclear facilities are in addition to the average natural background radiation in Canada of 1.8 mSv per year, which varies between 1 and 4 mSv per year [115].

5.2.3 Findings

The existing body of knowledge on various populations is used by CNSC staff to help determine the health and safety of workers and persons living near the PN Site, in the absence of substantial population-specific studies with radiation exposure data.

Experts worldwide study radiation health effects to provide objective scientific evidence, which supports the licensees' environmental and radiation protection programs, ensuring that workers and members of the public are protected. The current international understanding is that low doses of radiation are associated with low risks to health, indiscernible from the natural variation of disease. CNSC staff are confident that those living near, and working at, any nuclear facility in Canada are adequately protected.

5.3 Summary of health studies

Reviewing and conducting health studies and reports are important to help ensure the protection of people living near or working at nuclear facilities. The population and community health studies and reports indicate that cancer incidence and mortality rates, as well as the prevalence of specific health indicators and risk factors related to cancer, are largely consistent between this population and the population of Ontario as a whole.

The current understanding of the risks associated with radiation exposures is supported by the publications by international agencies like UNSCEAR and the ICRP, as well as academics and researchers worldwide. Very low exposures of radiation (like those experienced by Durham Region residents and facility employees) result in very low risks to health, indiscernible from the natural variation of disease.

In conclusion, the health studies and reports presented in this section provide a snapshot of the health of people living near the PN Site. Based on CNSC staff's compliance monitoring of radiation and environmental protection at the facility and available health data, CNSC staff have not observed, and do not expect to observe any adverse health outcomes attributable to the operation of the PN Site.

6.0 Other environmental monitoring programs

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

6.1 Drinking Water Surveillance Program

The Drinking Water Surveillance Program (external) (DWSP) [116] provides water quality information for selected municipal drinking water systems for scientific and research purposes through the monitoring of analytes, including organic, inorganic and radiological parameters (such as, tritium, gross alpha and gross beta). The water supply plants in the DWSP in closest proximity to the PN Site include, in increasing distance; F.J. Horgan (~9 km), R.C. Harris (~23 Km), Toronto Island (~33 Km) and R.L Clarke (~43 Km) see Figure 6.1.

The most recent dataset from the DWSP is for 2020. Radioactivity levels were measured for both Lake Ontario intake waters (raw) and water treated at the drinking water plant (treated water). In 2020, the results show that tritium, gross alpha and gross beta radioactivity levels have all been well below their respective drinking water standard or screening levels. The detailed data are available on the Drinking Water Surveillance Program website (external).

6.2 Ontario Ministry of Labour, Training and Skills Development Ontario Reactor Surveillance Program

The objective of the Ontario Reactor Surveillance Program **(**external) **(**ORSP) [117] is to establish, operate and maintain a radiological surveillance network to assess radiological concentrations around designated major nuclear facilities in the province. The ORSP monitors the air, water and food around nuclear power plants for radioactivity. The purpose of the ORSP is to assure the public living and working in the vicinity of nuclear facilities that their health, safety, welfare and property are not affected by emissions from nuclear facilities.

The ORSP's core surveillance focuses on air and drinking water, with the most recently posted dataset from 2019. For the PN Site, air is monitored at 4 locations within the Toronto/Pickering Surveillance Area (Figure 6.1).

A derived survey criterion was calculated to represent radioactivity levels in specific media (such as water and air) that would result in a dose at or below 0.1 mSv/year, which is an order of magnitude lower than the regulatory public dose limit of 1 mSv. To supplement the core surveillance program associated with air (Table 6.1) and drinking water (Table 6.2), the ORSP also monitors precipitation, surface water, milk and vegetation.

In 2019, the ORSP concluded that the measured concentrations were well below the derived survey criteria that would result in a dose commitment of 0.1 mSv to the public from either inhalation or ingestion

Figure 6.1: Ontario Reactor Surveillance Program map of Toronto/Pickering surveillance area – monitoring sites for air and drinking water

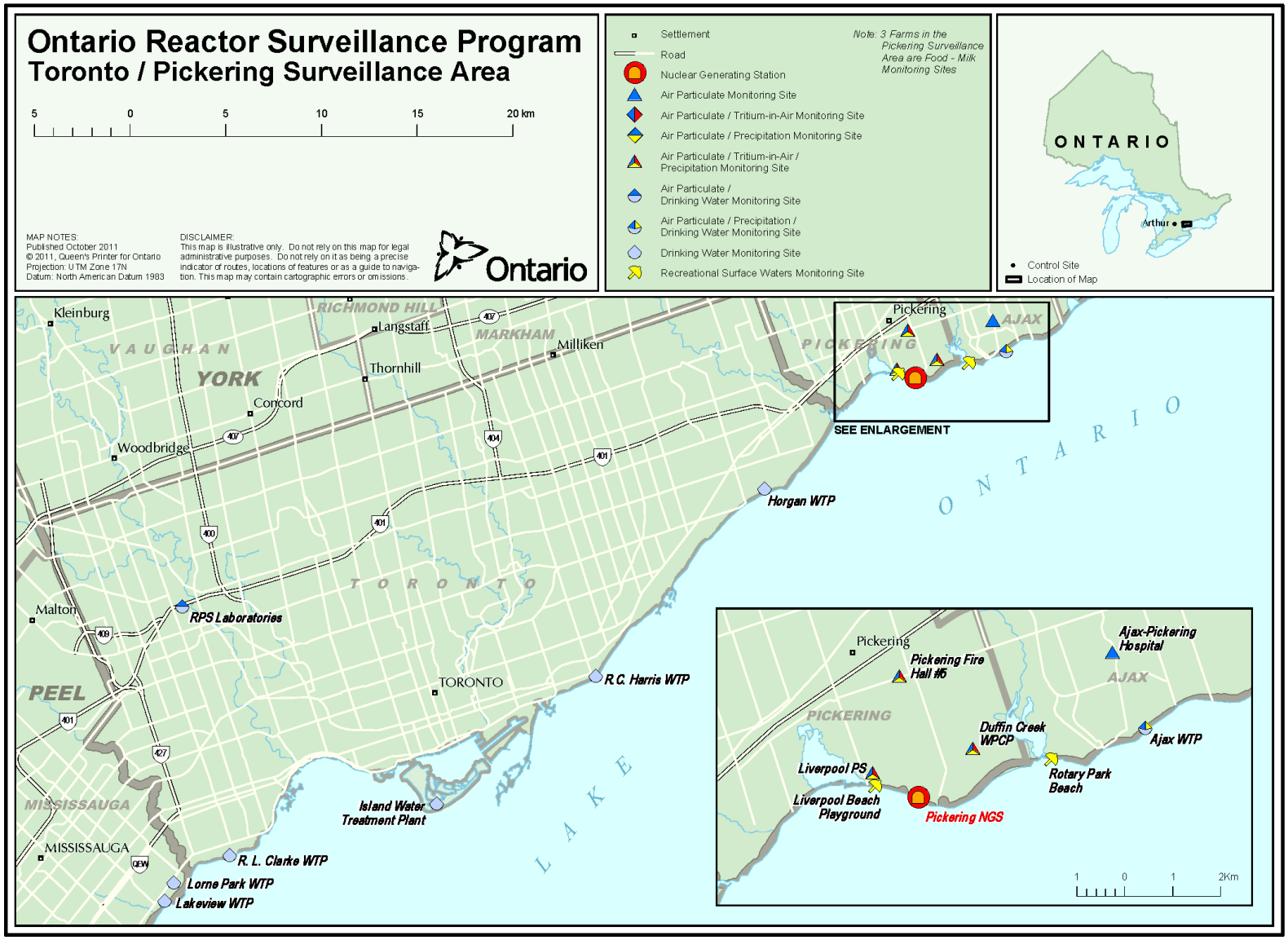


Table 6.1: 2019 Ontario Reactor Surveillance Program results for particulates in air (Be-7 and cesium-137) and tritium oxide

	No. of samples/ analyzed	Be-7 ($\mu Bq/m^3$)	Cs-137 ($\mu Bq/m^3$)	Sample No.	Tritium oxide (Bq/m^3)
Pickering Fire Hall #5	9/1	4100	<80	9	1.70
Liverpool P.S.	9/1	4,100	<80	9	1.66
Duffin Creek WPCP	9/1	4,600	<80	9	4.94
Ajax-Pickering Hospital	9/1	3,400	<80	N/A	N/A

Table 6.2: Summary of 2019 Ontario Reactor Surveillance Program sampling of drinking water results

	No. of samples	Gamma emitters			Tritium Bq/L
		Co–60 (Bq/L)	Cs–134 (Bq/L)	Cs–137 (Bq/L)	
F. J. Horgan WTP	53 (Tritium)	N/A	N/A	N/A	9.1
R. C. Harris WTP	49 (Tritium) 4 (Gamma emitter)	<0.3	<0.3	<0.3	9.5
R. L. Clarke WTP	53 (Tritium) 4 (Gamma emitter)	<0.3	<0.3	<0.3	8.9
Toronto Island WTP	48 (Tritium) 4 (Gamma emitter)	<0.3	<0.3	<0.3	9.5

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

The Canadian Radiological Monitoring Network (CRMN) [118] routinely collects drinking water, precipitation, atmospheric water vapour, air particulate, and external gamma dose for radioactivity analysis at dozens of monitoring locations across the country. The closest CRMN monitoring location to the PN Site is in Toronto. The results at the Toronto station for 2022 are consistent with data from previous years and are well below the public dose limit of 1 mSv per year.

The Fixed Point Surveillance (external) (FPS) system [118] functions as a real-time radiation detection system designed to monitor the public dose from radioactive materials in the air, including atmospheric releases associated with nuclear facilities and activities both nationally and internationally. Monitoring stations continuously measure gamma radioactivity levels from ground-deposited (ground-shine) and airborne contaminants.

Health Canada measures the radiation dose rate as Air KERMA (Kinetic Energy Released in Matter). These measurements are conducted every 15 minutes at 79 sites of its FPS network across the country. Air KERMA is also measured for 3 radioactive noble gases associated with nuclear fission which may escape into the atmosphere during the normal operation of nuclear facilities. These 3 noble gases are Argon-41, Xenon-133 and Xenon-135.

The Health Canada website reports the external absorbed dose from all gamma sources (natural and artificial) as well as the external gamma dose from the 3 monitored noble gases as nanoGray per month. The monthly data is provided on the Health Canada website (external) and the results are below the public dose limit of 1mSv per year.

7.0 Findings

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

7.1 Canadian Nuclear Safety Commission staff's follow-up

The following list summarizes CNSC staff's recommendations regarding the EP measures implemented by OPG for the PN Site. CNSC staff will follow-up on these recommendations during the review of future submissions of EP documents. The following do not change CNSC staff's findings and are included for transparency with Indigenous Nations and communities and the public. CNSC staff expect that OPG will:

- review and sample the appropriate stormwater outfalls in the East Complex after the completion of PWMF Phase II expansion as planned by OPG.

7.2 Canadian Nuclear Safety Commission staff's findings

CNSC staff's findings from this EPR report may inform and support staff recommendations to the Commission in future licensing and regulatory decision making that pertains to the PN Site. These findings are based on CNSC staff's technical assessments associated with OPG's PN Site, such as the submitted ERA documentation and the conduct of compliance verification activities, including the review of annual and quarterly reports and onsite inspections. CNSC staff also reviewed the results from various relevant or comparable health studies, and other EMPs conducted by other levels of government, to substantiate CNSC staff's findings. CNSC staff also conducted IEMP sampling around the PN Site in 2014, 2015, 2017 and 2021.

CNSC staff have found that the potential risks from physical stressors, as well as from radiological and hazardous releases to the atmospheric, aquatic, terrestrial and human environments from the PN Site, are low to negligible. The potential risks to the environment from these releases or stressors are similar to natural background, and the potential risks to humans health are indistinguishable from health outcomes in the general public. Therefore, CNSC staff have found that OPG has and will continue to implement and maintain effective EP measures to adequately protect the environment and the health and safety of persons. CNSC staff will continue to verify and ensure that, through ongoing licensing and compliance activities and reviews, the environment and the health and safety of persons around the PN Site are protected.

8.0 Abbreviations

Units

Bq/L	becquerels per litre
cm	centimetres
ha	hectares
km	kilometres
m	metres
mSv	millisievert
mGy/d	milligray per day
µGy/h	microgray per hour
µSv	micro-sieverts
µg/L	microgram per litre
µSv	microsievert

Acronyms

AL	action level
ALARA	as low as reasonably achievable
CAAQS	Canadian Ambient Air Quality Standards
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of the Environment
CCW	condenser cooling water
CEAA 1992	*Canadian Environmental Assessment Act* (1992)
CEAA 2012	*Canadian Environmental Assessment Act, 2012*
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CLFN	Curve Lake First Nation
CNSC	Canadian Nuclear Safety Commission
COPC	contaminant of potential concern
COPD	chronic obstructive pulmonary disease
DFO	Fisheries and Oceans Canada
DRHD	Durham Region Health Department

DRL	derived releases limit
DSC	dry storage container
DSM	dry storage module
DWSP	Drinking Water Surveillance Program
EA	environmental assessment
ECA	environmental compliance approval
ECCC	Environment and Climate Change Canada
EcoRA	ecological risk assessment
EMP	Environmental monitoring program
EMS	Environmental management system
EP	environmental protection
EPP	environmental protection program
EPR	environmental protection review
ERA	environmental risk assessment
FAA	*Fisheries Act* authorization
FDS	fish diversion system
FPS	fixed point surveillance
GHG	greenhouse gas
GWPP	groundwater protection program
GWMP	groundwater monitoring program
HHRA	human health risk assessment
HQ	hazard quotient
HTO	tritiated water
IAA	*Impact Assessment Act of Canada*
ICRP	International Commission on Radiological Protection
IEMP	Independent Environmental Monitoring Program
IFB	irradiated fuel bays
ILCR	incremental lifetime cancer risk
INWORKS	International Nuclear Worker Study
ISO	International Organization for Standardization
LCH	licence conditions handbook
LHIN	Local Health Integration Network
MECP	Ontario Ministry of the Environment, Conservation and Parks

MOU	memorandum of understanding
NO_2	nitrogen dioxide
NOx	nitrogen oxides
NPRI	National Pollutant Release Inventory
NSCA	*Nuclear Safety and Control Act*
OMNRF	Ontario Ministry of Natural Resources and Forestry
OPG	Ontario Power Generation Inc
ORSP	Ontario Reactor Surveillance Program
PDP	preliminary decommissioning plan
PEA	predicted effects assessment
PHC	petroleum hydrocarbon
PMF	probable maximum flood
PMP	probable maximum precipitation
PN Site	Pickering Nuclear Site
PNGS	Pickering Nuclear Generating Station
PSA	probabilistic safety analysis
PSR	periodic safety review
PWMF	Pickering Waste Management Facility
RADICON	Radiation Exposure and Cancer Incidence Around Nuclear Power Plants
ROR	regulatory oversight report
SARA	*Species at Risk Act*
SARO	species at risk in Ontario
TRC	total residual carbon
UCLM	upper confidence limit of the mean
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VEC	valued ecosystem component

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