Predictive Effects Assessment for Pickering Nuclear Safe Storage

P-REP-07701-00002 R000

April 2017

Public Information

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April 2017

Predictive Effects Assessment for Pickering Nuclear Safe Storage

Submitted to:
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Project Number: 1522020 (4000)

Report Number: P-REP-07701-00002, R0

REPORT

EcoMetrix INCORPORATED

Golder Associates

LIST OF ACRONYMS AND SYMBOLS

ACRONYMS

AAQC	Ambient Air Quality Criteria
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AIFB	Auxiliary Irradiated Fuel Bay
ALARA	As Low As Reasonably Achievable
BAF	BioAccumulation Factor (L/kg or kg/kg)
BMF	Biomagnification Factor (unitless)
Bq	Becquerel
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of the Environment
CCW	Condenser Cooling Water
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
CWQG	Canadian Water Quality Guidelines
Ci/kg	Curie per kilogram
DC	Dose Coefficient
DFO	Department of Fisheries and Oceans
DRL	Derived Release Limit
DSC	Dry Storage Container
EC/HC	Environment Canada/Health Canada
ECA	Environmental Compliance Approval
EcoRA	Ecological Risk Assessment
EMP	Environmental Monitoring Program
EMS	Environmental Management System
EPA/US EPA	(United States) Environmental Protection Agency
ERA	Environmental Risk Assessment
ES	Executive Summary
ESDM	Emissions Summary and Dispersion Modelling
FDS	Fish Diversion System
GE	General Electric
HEPA	High-Efficiency Particulate Absorber
HHRA	Human Health Risk Assessment
HPECI	High Pressure Emergency Coolant Injection
HQ	Hazard Quotient(s)
HTO	Tritium (tritiated water)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ID	Indentifier (number)
IFB	Irradiated Fuel Bay
ISO	International Organization for Standardization
kg/d dw	Kilograms per day dry weight
kg/d fw	Kilograms per day fresh (total) weight;

kg/h	Kilograms per hour
lbs/h	Pounds per hour
m3/day	cubic meters per day
Mg	Megagram
mGy/d	Milligray per day
mg/L	Milligram per litre
MISA	Municipal Industrial Strategy for Abatement
MOE	Ontario Ministry of Environment
MOECC	Ontario Ministry of Environment and Climate Change (formerly the MOE)
mSv/a	Milliseivert per annum
MWAT	Maximum Weekly Average Temperature
MWe	Megawatt electrical
N/A	Not applicable
NAICS	North American Industry Classification System
NWTP	New Water Treatment Plant
OBT	Organically bound tritium
OPG	Ontario Power Generation
O. Reg.	Ontario Regulation
PCB	Polychlorinated Biphenyls
PEA	Predictive Effects Assessment
PN	Pickering Nuclear
POI	Point of Impingement
PWMF	Pickering Waste Management Facility
PWQO	Provincial Water Quality Objective
RAB	Reactor Auxiliary Bay
REGDOC	Regulatory Document from Canadian Nuclear Safety Commission
RBSW	Reactor Building Service Water
RLWMS	Radioactive Liquid Waste Management System
SENES	Specialists in Energy, Nuclear, and Environmental Sciences Consultants Limited
TAB	Turbine Auxiliary Bay
TWh	Terawatt hours
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UPP	Upgrading Plant Pickering
US EPA	United States Environmental Protection Agency
μSv	Microseivert
VEC	Valued Ecosystem Component

SYMBOLS

Environmental Partitioning Parameters

Cs(fw)	=	concentration in sediment (Bq/kg-fw)
Cw	=	concentration in water (Bq/L)
ρw	=	density of water (1 kg/L)
θ	=	sediment porosity (unitless)
Kd	=	distribution coefficient (L/kg solid)
ρs	=	density of solids (kg/L)

Cs(dw)	=	concentration in sediment (Bq/kg-dw)
fdw	=	dry weight fraction of sediment (unitless)

Ecological Radiological Dose Parameters

Dint	=	internal radiation dose (µGy/d)
Dext	=	external radiation dose (µGy/d)
DCint	=	internal dose coefficient ((µGy/d)/(Bq/kg))
DCext	=	external dose coefficient ((µGy/d)/(Bq/kg))
DCext,w	=	external dose coefficient (in water)
DCext,s	=	external dose coefficient (in soil) ((µGy/d)/(Bq/kg))
DCext,ss	=	external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
Cm	=	media concentration (Bq/L or Bq/kg)
Cf	=	average concentration in food (Bq/kg-fw)
Cw	=	water concentration (Bq/L)
Cs	=	soil/sediment concentration (Bq/kg-fw)
Ct	=	whole body tissue concentration (Bq/kg-fw)
Cx	=	concentration in the ingested item x (Bq/kg-fw)
OFw	=	occupancy factor in water
OFws	=	occupancy factor at water surface
OFs	=	occupancy factor in soil/sediment
OFss	=	occupancy factor at soil/sediment surface
Ix	=	ingestion rate of item x (kg-fw/d)
TF	=	ingestion transfer factor (d/kg)
DWa	=	dry/fresh weight ratio for animal products (kg-dw/kg-fw)
DWp	=	dry/fresh weight ratio for plant/food products (kg-dw/kg-fw plant)
1-DWa	=	water content of the animal (L water /kg-fw)
1-DWp	=	water content of the plant/food (L water /kg-fw plant)
BAF_{a_HTO}	=	aquatic animal BAFs for tritium (L/kg-fw)
BAF_{p_HTO}	=	plant BAF for tritium (L/kg-fw)
k_{af}	=	fraction of food from contaminated sources
k_{aw}	=	fraction of water from contaminated sources (assumed to be 1)
f_{OBT}	=	fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion
f_{w_w}	=	fraction of the animal water intake derived from direct ingestion of water
f_{w_pw}	=	fraction of the animal water intake derived from water in the plant feed
f_{w_dw}	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
$P_{HTOwater\_animal}$	=	transfer of HTO to animals through water ingestion (L/kg-fw)
$P_{HTOfood\_animal}$	=	transfer of HTO to animals through food ingestion
S_a	=	stable carbon content in the aquatic animal/invertebrate/plant (gC/kg-fw)
S_w	=	mass of stable carbon in the dissolved inorganic phase in water (gC/L)
S_a	=	stable carbon content in the animal (gC/kg-fw)
S_p	=	stable carbon content in the food (gC/kg-fw)
BAFaC14	=	Carbon-14 BAF for aquatic animals, invertebrates, and plants (L/kg-fw)
PC14food_animal	=	transfer of Carbon-14 from food to animals

Ecological Non-Radiological Parameters

Cx	=	concentration in the ingested item (x) (mg/kg)
Ding	=	dose from ingestion pathway (mg/kg body weight/d)
Ix	=	ingestion rate of item x (kg/d)
W	=	body weight of consumer (kg-fw)
ΔT	=	change in temperature (ºC)

Executive Summary

Pickering Nuclear Generating Station is located within the Pickering Nuclear Site in the City of Pickering, Ontario on the north shore of Lake Ontario. It is owned and operated by Ontario Power Generation (OPG). In 2016, OPG announced plans to pursue continued operation of the Pickering Nuclear Generating Station to 2024, after which it is anticipated that it will no longer be cost effective to maintain for power generation. For that reason, OPG, which owns and operates the Pickering Nuclear Site, has announced that it will begin planning for the end of commercial operations. Shutdown of the reactor units would be carried out similar to a major unit outage, using existing personnel and procedures. Following shutdown, the activities at Pickering Nuclear Generating Station would involve the four distinct phases outlined below.

1) A 2-3 year ***Stabilization Phase*** per unit to transition each unit, and the station as a whole, from their current operating states to their respective safe storage states. Stabilization activities will include defuelling and dewatering reactor units.

2) A 25-30 year ***Storage with Surveillance Phase*** to allow for natural decay of radioactivity. Activities during this phase include the ongoing operation of the irradiated fuel bays and the continued transfer of spent fuel to Dry Storage Containers. Current planning anticipates that used fuel transfer to Dry Storage Containers will be completed within 10 years of the last unit transitioning to its safe storage state. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue to approximately 2050.

3) A 10 year ***Staged Dismantling and Demolition Phase*** to remove on-site structures and package wastes for long-term management.

4) A 5 year ***Restoration Phase*** to allow lands to be released and repurposed for alternative uses. At the end of this phase, the Pickering Nuclear Generating Station would be released from regulatory control.

To support the licensing process for the continued operations of the reactor units and eventual Stabilization and Storage with Surveillance activities, OPG must demonstrate that its provisions to protect the environment are adequate. To this end, OPG has developed two environmental technical studies to act as reference documents to the licence application.

- An **Environmental Risk Assessment** (EcoMetrix and Golder, 2017) to characterize the baseline environmental and human health conditions in the years leading up to the end of commercial operations.

- A **Predictive Effects Assessment**, which is this report, to identify potential changes to the baseline environmental and human health conditions resulting from the activities associated with the Stabilization and Storage with Surveillance Phases.

The Predictive Effects Assessment applies to the Stabilization Phase and the Storage with Surveillance Phase. The focus of the assessment is on the works and activities from the time of shutdown to the point where the used fuel has been removed from the Pickering Nuclear Generating Station and is housed within the Pickering Waste Management Facility. Environmental effects after this milestone would be expected to be further reduced as few activities will occur on-site until decommissioning is initiated (i.e., during the Staged Dismantling and Demolition

Phase followed by the Restoration Phase). The period assessed in detail (i.e., the first 10 years of the Storage with Surveillance Phase) is considered to bound the remainder of the Storage with Surveillance Phase.

Predictive Effects Assessment Objective and Methodology

The Predictive Effects Assessment was conducted to characterize and illustrate how the environment and the health of persons will continue to be protected during the Stabilization and Storage with Surveillance activities. The specific goals of the Predictive Effects Assessment are to:

- identify changes from the current operational state to the safe storage state and assess which changes result in changed environmental emissions or effects in the Stabilization or Storage with Surveillance Phases;
- evaluate the risk to human and ecological receptors based on the future scenarios;
- identify the specific objectives for environmental monitoring; and
- provide support for the licensing of future Stabilization and Storage with Surveillance activities of the Pickering Nuclear Generating Station.

The overall approach for predicting and assessing effects of the Stabilization and Storage with Surveillance activities is based on CSA N288.6-12 (CSA, 2012). The steps used in this evaluation are:

1) define the existing site conditions and operations. This is primarily conducted through the Pickering Nuclear Environmental Risk Assessment which demonstrates that the current activities and conditions are protective of human health and the environment;

2) define the future activities and conditions;

3) evaluate the future environmental interactions associated with the Stabilization and Storage with Surveillance activities and assess if the current operational conditions are bounding for each interaction identified (Tier 1 assessment):

    a. for those interactions that are bound by current operational conditions no further action is required; and

    b. for those interactions not bound by current operational conditions, emissions from a future bounding scenario are screened against criteria considered protective of human health and the environment; and,

4) conduct a Tier 2 assessment for those interactions where emissions exceed screening values or are considered of public interest. This is primarily a quantitative risk assessment.

Many of the changes to the environment during the Stabilization and Storage with Surveillance activities are anticipated to be less than current operations. The Predictive Effects Assessment was designed to focus on those pathways that may introduce new or modified effects on the environment, as well as focusing on those activity-environment interactions with the potential to cause an adverse environmental effect.

Project Overview

The Stabilization of the remaining six Pickering Nuclear reactor units will be conducted in a stepwise manner transitioning them from their current operating states to their respective safe storage states. Many of the specific details of the Stabilization activities are not finalized; however, assumptions have been made to provide a conservative (i.e., worst case) assessment of effects resulting from the transition and safe storage state.

Activities specific to the Stabilization Phase include:

- shut down of the reactor units, as is typically done with a major unit outage, using existing personnel and procedures;
- removal of all nuclear fuel from the reactor units and transfer to the irradiated fuel bays and auxiliary irradiated fuel bay;
- removal and storage of approximately 3,000 Megagrams (Mg) of heavy water;
- stabilization of all systems no longer required by de-energizing and removing the transient materials (e.g., gasses, liquids, oil, filters, refrigerants, resins etc.) for collection, recycling and/or disposal through approved pathways;
- reduction of condenser cooling water flow as each reactor unit is taken off-line and condenser cooling water pumps are shut down. The station will transition to a reduced flow scenario nearing the end of the Stabilization Phase where all condenser cooling water pumps will be shut down and remaining cooling water demands have been substantially reduced; and
- continued operation of the irradiated fuel bays and auxillary irradiated fuel bay.

Activities during the Storage with Surveillance Phase include:

- continued operation/surveillance of the irradiated fuel bays, including transfer of used fuel from the irradiated fuel bays to Dry Storage Containers for storage on the Pickering Waste Management Facility site. It is anticipated that the irradiated fuel bays will be required for up to 10 years of cooling;
- eventual shut down of the irradiated fuel bays and auxillary irradiated fuel bay, which may include draining, decontamination and sealing; and
- maintenance and monitoring of all buildings in a safe and secure state and potential removal of temporary buildings (i.e., mobile office and storage trailers) from the Pickering Nuclear Generating Station.

Tier 1 Assessment

The Stabilization and Storage with Surveillance activities were evaluated for interactions with environmental pathways and receptors. Interactions not bound by current operational conditions were evaluated and screened against accepted criteria. The findings of the screening found that all emissions containing contaminants of potential concern would be discharged at acceptable levels (i.e., all screened out before further Tier 2 assessment). Radionuclides related to airborne and waterborne emissions were retained for Tier 2 assessment based on public interest. Table ES-1 provides a summary of the interactions and the findings (i.e., screening) from the Tier 1 assessment.

Table ES-1: Stabilization and Storage with Surveillance Bounding Conditions and Tier 1 Findings

Environmental Component	Stabilization Phase	Storage with Surveillance Phase
Atmospheric (Section 4.1)		
Noise	▪ Current operational conditions are bounding.	▪ Current operational conditions are bounding.
Air Quality	▪ Current operational conditions were found to be bounding for radiological and non-radiological emissions, with the following exception. ▪ There may be two heating steam boilers operating during this phase compared to the current one heating steam boiler in current operational conditions. Atmospheric emissions associated with these boilers were assessed and screened out for further evaluation.	▪ Current operational conditions are bounding for radiological and non-radiological emissions, with the following exception. ▪ Future industrial/commercial workers may be present within the Engineering Services Buildings and Pickering Nuclear Information Centre. This potential new receptor is closer to the Pickering Nuclear Generating Station than assessed in the Pickering Nuclear Environmental Risk Assessment. The Tier 1 assessment indicated no potential adverse effects.
Surface Water (Section 4.2)		
Surface Water Flow	▪ The current operational conditions are considered bounding as this is a high flow condition.	▪ During this phase the cooling water flow will be significantly reduced and the Fish diversion System is proposed to be removed. ▪ The effect of this to fish entrainment and impingement are evaluated in the Tier 2 assessment.
Water Quality	▪ The assumptions for the Storage with Surveillance Phase (a low flow condition) are bounding of the Stabilization Phase. ▪ The additional heating steam boiler, and its waterborne emissions, are evaluated in Tier 1 and screened from further assessment. ▪ The current operational conditions are considered bounding for thermal effects.	▪ A conservative flow and waterborne emission scenario was developed to assess potential effects and a surface water model was developed to assist in evaluating receptor concentrations. ▪ Discharges to the forebay were evaluated under this low flow condition and screened out of further evaluation. ▪ Discharges to Lake Ontario from various sources (i.e., water treatment plant, boiler blowdown, radioactive liquid waste management system) were evaluated and the predicted discharge from the discharge outlet meets screening values. ▪ The overall thermal reductions occur over time due to the reduction in thermal releases. ▪ The reduction in thermal plume is evaluated in the Tier 2 assessment

Table ES-1: Stabilization and Storage with Surveillance Bounding Conditions and Tier 1 Findings

Environmental Component	Stabilization Phase	Storage with Surveillance Phase
Other Environmental Interactions		
Sediment Quality and Transport (Section 4.3)	▪ Both the current operational conditions and assumptions for the Storage with Surveillance Phase are bounding of the Stabilization Phase.	▪ Assumptions for the Storage with Surveillance Phase are bounding. ▪ Surface water modelling indicates increased deposition at the intake, forebay and discharge channels and increased erosion immediately southwest of the Pickering Nuclear Generating Station. These effects are considered highly localized and do not require further evaluation. ▪ Waterborne contaminants of potential concern are not considered to contribute to adverse sediment quality and were screened out of further evaluation.
Groundwater (Section 4.4)	▪ Current operational conditions are bounding.	▪ Current operational conditions are bounding.
Soil Quality (Section 4.5)	▪ Current operational conditions are bounding.	▪ Current operational conditions are bounding.

Tier 2 Assessment – Quantitative Risk Assessment

For the Predictive Effects Assessment, a predictive human health and ecological risk assessment (Tier 2) was conducted for radionuclides. No non-radiological contaminants of potential concern exceeded screening values in the Tier 1 assessment.

Human Health Risk Assessment

The human health risk assessment evaluated potential radiological impacts to receptors that include: farm and dairy farm use, urban residents, area industrial/commercial occupants, a potential future industrial/commercial worker at the current Engineering Services Buildings (i.e., a new tenant), and a sport fisher (i.e., a person assumed to be fishing south of the Pickering Nuclear Generating Station). The exposure duration, exposure factors and calculations are the same as those used in the Pickering Nuclear Environmental Risk Assessment. The dose was updated based on conservative assumptions and the modelled surface water and airborne concentrations. All other exposures were considered to be bound by the Pickering Nuclear Environmental Risk Assessment.

The maximum predicted dose was estimated to be 0.002 milliseiverts per annum (mSv/a) to a future industrial/commercial worker at the Engineering Services Buildings). This future industrial/commercial worker was not assessed in the Pickering Nuclear Environmental Risk Assessment. The public dose estimates for the human receptors for the Storage with Surveillance Phase are approximately 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.15% of the dose from Canadian background radiation. 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 Pickering Nuclear during the Storage with Surveillance Phase.

Ecological Risk Assessment

For the ecological risk assessment, exposure points at receptor locations were estimated based on the Tier 1 assessment. The receptor locations of interest were the Pickering Nuclear outfall (nearshore Lake Ontario), forebay, and Frenchman's Bay. Receptors, exposure, dose and risk estimation calculations were based on the work done in the Pickering Nuclear Environmental Risk Assessment.

The outfall and Frenchman's Bay were assessed for dose resulting from exposure to tritium, carbon-14 and Gross beta / gamma (represented by cobalt-60). None of the doses to the receptors assessed exceeded the aquatic benchmark of 9.6 milligray per day (mGy/d) or the terrestrial benchmark of 2.4 mGy/d, and all were less than 1 mGy/d.

As a result of the reduced flows into the station and assumed removal of the Fish Diverson System, the potential forebay habitat was evaluated based on the Storage with Surveillance Phase assumptions. Potential impacts within the forebay were assessed for exposure to tritium, carbon-14 and cobalt-60 for radionuclides. Based on the forebay surface water modelling conducted and the risk evaluation, there were no potential adverse effects identified. All doses to the receptors assessed were below the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.

Thermal effects were also evaluated as part of the Predictive Effects Assessment. In general, the lake near the discharge will be returned to a thermal condition that is more normal for the nearshore zone of Lake Ontario. Whereas the warmed waters in the current operating condition have attracted certain fish species to the discharge (e.g., Smallmouth Bass), and have enhanced aquatic productivity near the discharge, the cooler waters after shutdown will offer thermal habitat more similar to the regional nearshore zone.

Entrainment and impingement effects were evaluated as part of the Predictive Effects Assessment. Entrainment is not considered an issue at a flow of 6.5 m^3/sec or less (US EPA, 2014). The proposed flow during the Storage with Surveillance Phase when the condenser cooling water pumps are no longer used will be 0.58 m^3/sec, which is substantially less than the guidance and current operations. Impingement is not considered an issue if there is an intake water velocity of less than 15 cm/sec (US EPA, 2014). The maximum predicted velocity is less than the US EPA guidance value and below the average swim speed of the local species for the VECs evaluated in the PN ERA.

Conclusions

In this report, the Stabilization and Storage with Surveillance activities were evaluated for potential interactions with the environment. The Tier 1 assessment screened these interactions to assess whether the current operational conditions, which were evaluated in the Pickering Nuclear Environmental Risk Assessment, are bounding. In most cases, the current conditions were considered bounding, with conditions predicted to improve in the future, or the predicted conditions were screened as being acceptable. Radionuclides were considered to be of public interest and therefore, further risk evaluation was conducted in the Tier 2 assessment or these compounds. The final conclusion of the Predictive Effects Assessment is that, based on the assessment described in this report, there are no predicted potential adverse effects from the Stabilization and Storage with Surveillance activities proposed.

Risk Management Recommendations

As noted above, for most interactions evaluated, the current conditions were considered bounding and effects to the environment during future phases are expected to be reduced overall. No interactions were identified that are predicted to pose an unacceptable risk to humans or the environment during the Stabilization and Storage with Surveillance activities proposed. Therefore, no new mitigation is required based on the conclusions of the Predictive Effects Assessment.

During both the Stabilization and Storage with Surveillance Phases, OPG's environmental programs will be maintained, and updated. Many mitigation measures to minimize effects on the environment are incorporated into the existing Pickering Nuclear Generating Station operations. For example, emissions to air are reduced through use of control technologies such as high-efficiency particulate absorber and atmospheric radioiodine carbon filtration in the ventilation exhaust stacks. Emission control measures and discharge limits are specified within specific permits. These permits and in-design mitigation measures will remain in place until such a time that it can be demonstrated, in discussion with the regulator as applicable, that they are no longer required.

Over time, it is expected that overall emissions from the site will be reduced, and thereby the need for monitoring and mitigations and emission controls will be commensurately reduced. As the Pickering Nuclear Generating Station transitions from the end of commercial operations to the safe storage state changes to controls and monitoring will be made in a measured fashion using risk-based analysis and results of the suite of OPG's environmental programs. This will ensure compliance with OPG's overall commitment to take all reasonable measures to protect workers, the public and the environment.

Although there are no specific recommendations for effluent or environmental monitoring based on the outcome of the Predictive Effects Assessment, planning the work to define the safe storage end states of the Pickering Nuclear Generating Station systems is ongoing. The waterborne emissions and cooling water flows in the Storage with Surveillance Phase will be reviewed as final configurations are determined. If the surface water assumptions and the environmental interactions are substantially different than those indicated in this document, a reassessment of the environmental risk would be carried out and mitigation identified as required. The outcome of the review will be documented in the Environmental Risk Assessment.

In summary, as the Pickering Nuclear Generating Station transitions from its current operational condition to its safe storage state, the focus will remain on adapting the environmental programs implemented at the Pickering

Nuclear Generating Station, as needed, to ensure continual protection of human health and the environment, and environmental performance excellence per applicable operating licence, codes and standards.

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FIGURES

APPENDICES

1.0 INTRODUCTION

Pickering Nuclear (PN) Generating Station is located within the PN Site in the City of Pickering, Ontario on the north shore of Lake Ontario (Figure 1-1). It is owned and operated by Ontario Power Generation (OPG).

The PN Site contains the PN Generating Station and the Pickering Waste Management Facility (PWMF). The PN Generating Station has six operating CANadian Deuterium Uranium (CANDU) pressurized heavy water nuclear reactor units (PN U1, U4, U5, U6, U7, and U8); and two reactor units (PN U2 and U3) already in a safe storage state. Each unit was commissioned according to the in-service dates shown in Table 1-1. Units 1 through 4 (PN U1-4) are located on the west side of the nuclear station, formerly licensed as “Pickering A”, and units 5 through 8 (PN U5-8) are located on the east side of the nuclear station, formerly licensed as “Pickering B.” With the six operating reactor units, the PN Generating Station currently has a net electrical power output of 3,100 megawatts (MWe).

Table 1-1: In-Service Dates for PN U1-4 and PN U5-8

Unit #	Net Electrical Output (MWe)	In-Service Date
Pickering Nuclear U1-4		
U1	515	July 29, 1971
U2	0	December 30, 1971 (defuelled as of 2007 and now in safe storage)
U3	0	June 1, 1972 (defuelled as of 2008 and now in safe storage)
U4	515	June 17, 1973
Pickering Nuclear U5-8		
U5	516	May 10, 1983
U6	516	February 1, 1984
U7	516	January 1, 1985
U8	516	February 26, 1986

Since being placed in service, all PN reactor units have operated safely. In 2015, PN produced 21.2 terawatt hours (TWh) of electricity. The production performance was 78.3% of the PN Generating Station’s rated capacity (OPG, 2015c).

The PWMF is also located on the PN Site and is comprised of 2 sites. The PWMF Phase I site is located southeast of PN U8, adjacent to the east side of the station security fence, and contains two used fuel dry storage buildings and a Retube Component Storage area. The PWMF Phase II site is located approximately 500 metres (m) north-east of the power generating facilities in the East Complex, with its own distinct “protected area”. The PWMF Phase II site contains one used fuel dry storage building with additional buildings planned, as required. The Retube Component Storage area was placed in service in 1984 and the most recent development is the used fuel dry storage building #3 with construction completed in 2009.

The specifics of the timing and the sequence of the shutdown of the entire PN Generating Station is being developed. Current planning assumes that all six operating reactor units would operate until 2022; two units would then be shut down, and the remaining four units would operate to 2024. As each of the units cease operation, they will be transitioned into a safe storage state and maintained for a period of approximately 30 years to allow for the natural decay of radioactivity.

Shutdown of the reactor units would be carried out similar to a major unit outage, using existing personnel and procedures. Following shutdown, the activities at PN Generating Station would involve the four distinct phases outlined below.

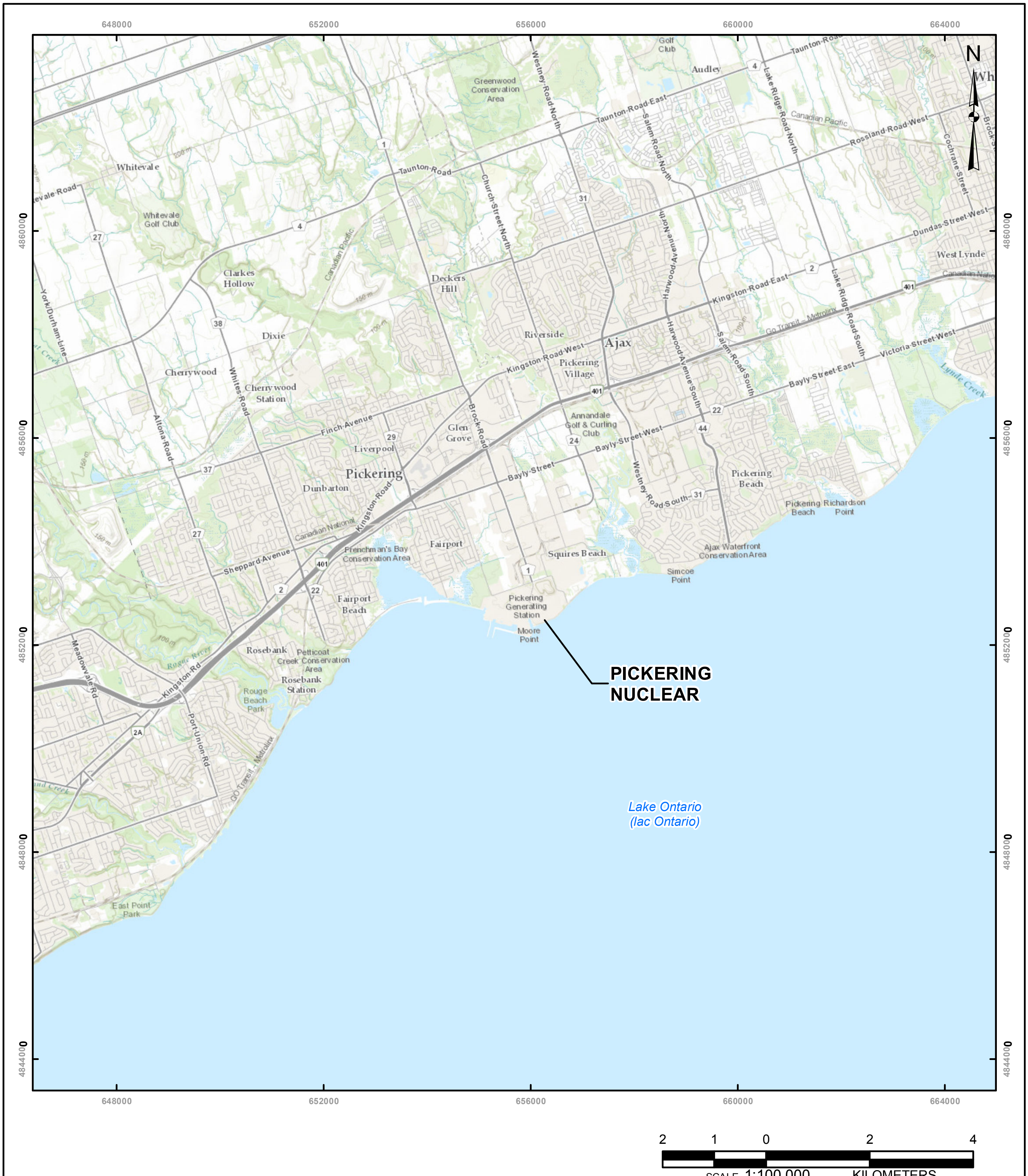
1) A 2-3 year ***Stabilization Phase*** per unit to transition each unit, and the station as a whole, from their current operating states to their respective safe storage states. Stabilization activities will include defuelling and dewatering reactor units.

2) A 25-30 year ***Storage with Surveillance Phase*** to allow for natural decay of radioactivity. Activities during this phase include the ongoing operation of the irradiated fuel bays (IFBs) and the continued transfer of spent fuel to dry storage containers (DSCs). Current planning anticipates that used fuel transfer to DSCs will be completed within 10 years of the last unit transitioning to its safe storage state. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue to approximately 2050.

3) A 10 year ***Staged Dismantling and Demolition Phase*** to remove on-site structures and package wastes for long-term management.

4) A 5 year ***Restoration Phase*** to allow lands to be released and repurposed for alternative uses. At the end of this phase, the PN Generating Station would be released from regulatory control.

The remaining life cycle phases for the PN Generating Station, including proposed timelines, are illustrated in Figure 1-2.



PROJECT

OPG PICKERING SAFE STORAGE
PREDICTIVE EFFECTS ASSESSMENT

TITLE

PICKERING NUCLEAR SITE LOCATION AND VICINITY

Golder Associates
Mississauga, Ontario

PROJECT No. 1522020			SCALE AS SHOWN	REV. 0.0
DESIGN	JR	03 Feb. 2017	FIGURE: 1-1	
GIS	JR	03 Feb. 2017		
CHECK	JDW	03 Feb. 2017		
REVIEW	JDW	03 Feb. 2017		

REFERENCE

Base Data - Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 17

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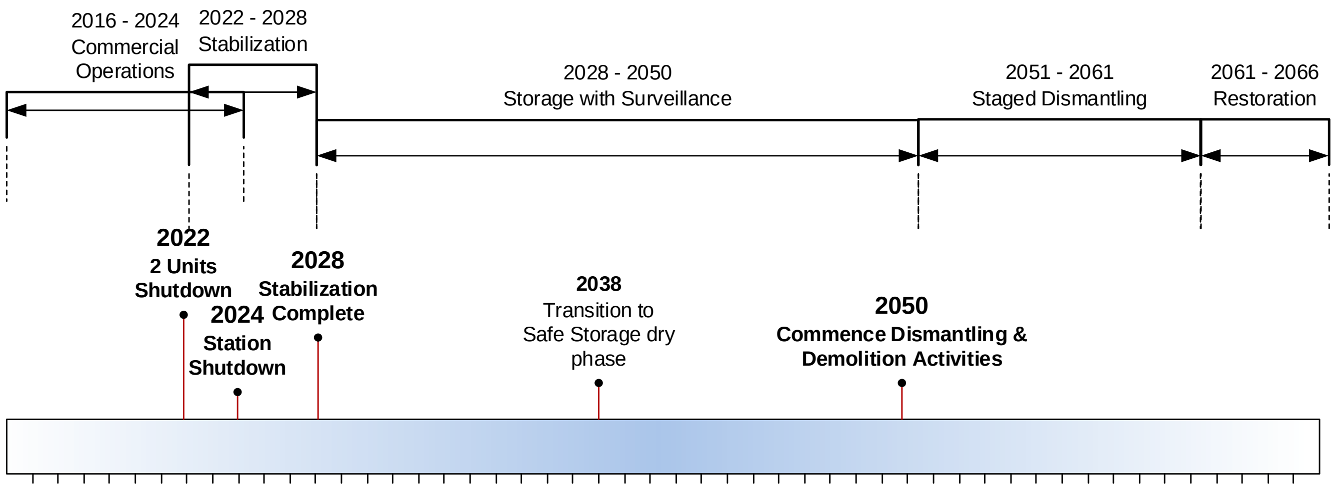


Dates provided are conceptual and for illustration purposes only.

Figure 1-2: Timelines for the Proposed Continued Operation, Shutdown and Safe Storage of the Pickering Nuclear Generating Station

To support the licensing process for the continued operations of the reactor units and eventual Stabilization and Storage with Surveillance activities, OPG must demonstrate that its provisions to protect the environment are adequate. To this end, OPG has developed two environmental technical studies to act as reference documents to the licence application.

- An **Environmental Risk Assessment** (ERA) (EcoMetrix and Golder, 2017) to characterize the baseline environmental and human health conditions in the years leading up to the end of commercial operations.
- A **Predictive Effects Assessment** (PEA), which is this report, to identify potential changes to the baseline environmental and human health conditions resulting from the activities associated with the Stabilization and Storage with Surveillance Phases.

The overall timeframe for the PN Generating Station's remaining life cycle phases is illustrated on Figure 1-2. The PEA includes the Stabilization Phase in its entirety with a focus on the first ten years of the Storage with Surveillance Phase (i.e., up to approximately 2038), which is the point in time when it is assumed all the used fuel will have been transferred from the IFBs to dry storage in the PWMF on the PN Site. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue to approximately 2050.

The Staged Dismantling, and Restoration Phases of the PN Generating Station are not included in the scope of the PEA. However, OPG has a plan in place to eventually decommission the reactor units. This plan (OPG, 2016b) was prepared in accordance with applicable Canadian Nuclear Safety Commission (CNSC) regulatory guidance G-219 (CNSC, 2009). A general assessment of the potential future environmental effects of decommissioning is included in the Preliminary Decommissioning Plan (OPG, 2016b). When appropriate, decommissioning will be subject to the requirements under the *Nuclear Safety and Control Act* (or equivalent legislation in force at that time), and a determination regarding the application of the *Canadian Environmental Assessment Act, 2012* (or equivalent legislation in force at that time) will be made.

1.1 Project Overview

The Stabilization of the remaining six PN reactor units will be conducted in a stepwise manner transitioning them from their current operating states to their respective safe storage states. Many of the specific details of the Stabilization activities are not finalized; however, assumptions have been made to provide a conservative (i.e., worst case) assessment of effects resulting from the transition and safe storage state. To facilitate prediction of effects, the phases for the PEA were defined considering key milestones and the phases illustrated in Figure 1-2.

Activities specific to the Stabilization Phase include:

- shut down of the reactor units, as is typically done with a major unit outage, using existing personnel and procedures;
- removal of all nuclear fuel from the reactor units and transfer to the IFBs and auxiliary irradiated fuel bay (AIFB);
- removal and storage of approximately 3,000 Megagrams (Mg) of heavy water;
- stabilization of all systems no longer required by de-energizing and removing the transient materials (e.g., gasses, liquids, oil, filters, refrigerants, resins, etc.) for collection, recycling and/or disposal through approved pathways;
- reduction of condenser cooling water (CCW) flow as each reactor unit is taken off-line and CCW pumps are shut down. The station will transition to a reduced flow scenario nearing the end of the Stabilization Phase where all CCW pumps will be shut down and remaining cooling water demands have been substantially reduced; and
- continued operation of the IFBs and AIFB.

Activities during the Storage with Surveillance Phase include:

- continued operation/surveillance of the IFBs, including transfer of used fuel from the IFBs to DSCs for storage on the PWMF site. It is anticipated that the irradiated fuel bays will be required for up to 10 years of cooling;
- shut down of the IFB and AIFB, which may include draining and decontamination; and
- maintenance and monitoring of all buildings in a safe and secure state and potential removal of temporary buildings (i.e., mobile office and storage trailers) from the PN Generating Station.

The PEA considers the Stabilization Phase and the Storage with Surveillance Phase. The focus of the assessment is on the works and activities from the time of shutdown to the point where the used fuel has been removed from the PN Generating Station and is housed within the PWMF. Environmental effects after this milestone would be expected to be further reduced as few activities will occur on-site until decommissioning (i.e., the Staged Dismantling and Demolition Phase followed by the Restoration Phase) is initiated. The period assessed in detail (i.e., the first 10 years of the Storage with Surveillance Phase) is considered to bound the remainder of the Storage with Surveillance Phase.

Support systems required for Stabilization and Storage with Surveillance activities, including heating, lighting, security, ventilation and fire protection will be maintained, as required. In addition, environmental management programs and activities in accordance with the requirements specified in the licence(s) by the CNSC, and in accordance with appropriate regulation and standards, will be maintained.

1.2 Regulatory Context

The CNSC is the federal authority responsible for the regulation of nuclear facilities in Canada. Regulatory control of the PN Site is exercised by the CNSC by means of the PN Generating Station operating licence (Power Reactor Operating License 48.03/2018). The *Nuclear Safety and Control Act* mandates the CNSC to regulate the nuclear industry in a manner that prevents unreasonable risk to the environment and makes adequate provision for environmental protection, in conformity with international obligations. This mandate is reflected in the General Nuclear Safety and Control Regulations under the *Nuclear Safety and Control Act*, and in the CNSC Regulatory Policy on Protection of the Environment (CNSC, 2001). This policy indicates that licence applicants will be required to “demonstrate through performance assessments, monitoring, or other evidence, that their provisions to protect the environment are adequate”.

Environmental protection for nuclear facilities and activities is done in accordance with the *Nuclear Safety and Control Act* and the regulations made under it. The CNSC requires the environmental effects of all nuclear facilities or activities be considered and evaluated when licensing decisions are made (CNSC, 2016b). Regulatory Document 2.9.1 (REGDOC-2.9.1) *Environmental Principles, Assessments and Protection Measures* (CNSC, 2016b) provides information to applicants and licensees on protecting the environment and the health of persons. All licence applications must have an environmental assessment, either under the *Nuclear Safety and Control Act* or the *Canadian Environmental Assessment Act, 2012*, and an ERA commensurate with the scale and complexity of the environmental risks associated with the facility or activity. The Stabilization and Storage with Surveillance activities associated with the PN Site are not listed in the *Regulation Designating Physical Activities* (SOR/2012/-147); therefore, an environmental assessment under the *Canadian Environmental Assessment Act, 2012* is not required. An environmental assessment under the *Nuclear Safety and Control Act* will be conducted by CNSC staff to determine if the proposed licensed activities provide adequate protection of the environment and health and safety of people (CNSC, 2016a). The following reports are written to provide information to the CNSC to support their preparation of an environmental assessment under the *Nuclear Safety and Control Act*, as indicated in REGDOC-2.9.1.

An ERA (EcoMetrix and Golder, 2017) for PN has been completed in accordance with Canadian Standards Association (CSA) N288.6-12, *Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills* (CSA, 2012) to characterize the baseline environment and assess the human health and environmental risks from the current operations of PN. CSA N288.6-12 provides guidance for conducting both an ecological risk assessment and a human health risk assessment, for radiological and non-radiological contaminants and physical stressors.

The PEA for the Stabilization and Storage with Surveillance activities has been prepared following the guidance of CSA N288.6-12 (CSA, 2012) to evaluate the potential for adverse effects to human health and the environment from the Stabilization and approximately the first ten years of Storage with Surveillance activities. The PN ERA forms the basis of the PEA and should be consulted for detailed information on current operational conditions on the PN Site.

1.3 PEA Goals, Approach and Scope

The PEA was conducted to characterize and illustrate how the environment and the health of persons will continue to be protected during the Stabilization and Storage with Surveillance activities. The specific goals of the PEA were to:

- identify changes from the current operational state to the safe storage state and assess which changes result in changed environmental emissions or effects in the Stabilization or Storage with Surveillance Phases;
- evaluate the risk to human and ecological receptors based on the future scenarios;
- identify the specific objectives for environmental monitoring; and
- provide support for the licensing of future Stabilization and Storage with Surveillance activities of PN.

To support meeting the above goals, operational scenarios were developed for each phase to represent a range of conditions and emissions that can affect media and concentrations in different ways. Many of the changes to the environment during the Stabilization and Storage with Surveillance activities are anticipated to be beneficial.

Where Stabilization and Storage with Surveillance activities result in environmental emissions that are no greater, and in many cases, substantially less than current operational conditions, the current conditions were considered to represent the bounding environmental emissions. In these cases, detailed evaluation in the PEA was not warranted as effects were evaluated in the PN ERA (EcoMetrix and Golder, 2017). Where Stabilization and Storage with Surveillance activities result in potential environmental emissions or emissions that are greater than the current operational conditions, potential worst case bounding scenarios were characterized. Taken together, these scenarios provide an “upper bounding” case to provide a conservative assessment of potential effects from the Stabilization and Storage with Surveillance activities.

The overall approach for predicting and assessing effects of the Stabilization and Storage with Surveillance activities is based on CSA N288.6-12 (CSA, 2012). The PEA evaluated potential effects of releases from the facility on the human and ecological environment, as well as physical stressors. As indicated in CSA N288.6-12 (CSA, 2012), the PEA does not address acute or high-level exposures resulting from accidents, future potential spills or unplanned emissions.

The PEA report does not include the operations at the PWMF as it operates separately under the Waste Facility Operating Licence issued by the CNSC. The PEA report does, however, discuss the waste operation to the extent there are inter-relationships with the Stabilization and Storage with Surveillance activities.

1.4 Quality Assurance and Quality Control

The PN ERA and PEA made extensive use of environmental monitoring data. These data were derived from chemical and radiochemical analyses of samples collected from effluent streams and environmental media around the PN Generating Station. The environmental data provided by OPG were collected by qualified staff and analyzed by qualified laboratories under the Environmental Monitoring Program (EMP), such as the PN Generating Station chemistry laboratory and the Whitby Health Physics Laboratory. The EMP has its own quality assurance program that encompasses activities such as sample collection, laboratory analysis, laboratory quality control, and external laboratory comparison (OPG, 2007).

Samples collected as part of the updated baseline environmental sampling program were analyzed by Maxxam Analytics and Kinectrics, which are both accredited by the Standards Council of Canada as conforming to the quality assurance requirements of International Organization for Standardization (ISO) Standard 17025.

Throughout the planning and preparation of the PEA, all staff worked under an ISO 9001:2008-certified Quality Management System. All work was internally reviewed and verified. Reviews included verification of data and calculations, as well as review of report content. The review process has been documented through a paper trail of review comments and dispositions, and comments have been dispositioned and addressed as appropriate in report revisions.

Surface water modelling was conducted to support the PEA. The surface water model was calibrated and verified using industry standard practices. A description of the quality assurance program for the modelling, and the uncertainties in the model, is provided in Appendix A.

IMPACT™ version 5.4.0 was used for human health dose calculations. The software has undergone verification and validation in accordance with the requirements of CSA standard N286.7 (CSA, 2009).

1.5 Organization of Report

The main sections of the PEA report, which are generally consistent with the suggested table of contents in CSA N288.6-12 (CSA, 2012), are as follows:

- **Section 2.0:** Predictive Effects Assessment Methodology;
- **Section 3.0:** Stabilization and Storage with Surveillance Activities;
- **Section 4.0:** Interactions and Predictive Screening of Stabilization and Storage with Surveillance Activities and the Environment;
- **Section 5.0:** Conceptual Site Model;
- **Section 6.0:** Predictive Human Health Risk Assessment;
- **Section 7.0:** Predictive Ecological Risk Assessment;
- **Section 8.0:** Environmental Monitoring and Protection Programs;
- **Section 9.0:** Conclusions; and,
- **Section 10.0:** References.

2.0 PREDICTIVE EFFECTS ASSESSMENT METHODOLOGY

The overall approach for predicting and assessing effects of the Stabilization and Storage with Surveillance activities is based on CSA N288.6-12 (CSA, 2012). The CSA N288.6-12 (CSA, 2012) standard does not provide detailed guidance on predictive effects assessment scenarios; therefore, modifications to the ERA approach to complete the PEA are discussed in this section. The PEA approach is presented schematically in Figure 2-1 (modified from Figure 5.1 in CSA N288.6-12).

Many of the changes to the environment during the Stabilization and Storage with Surveillance activities are anticipated to be beneficial. The PEA was designed to focus on those pathways that may introduce new or modified effects on the environment, as well as focusing on those activities-environment interactions with the potential to cause an adverse environmental effect.

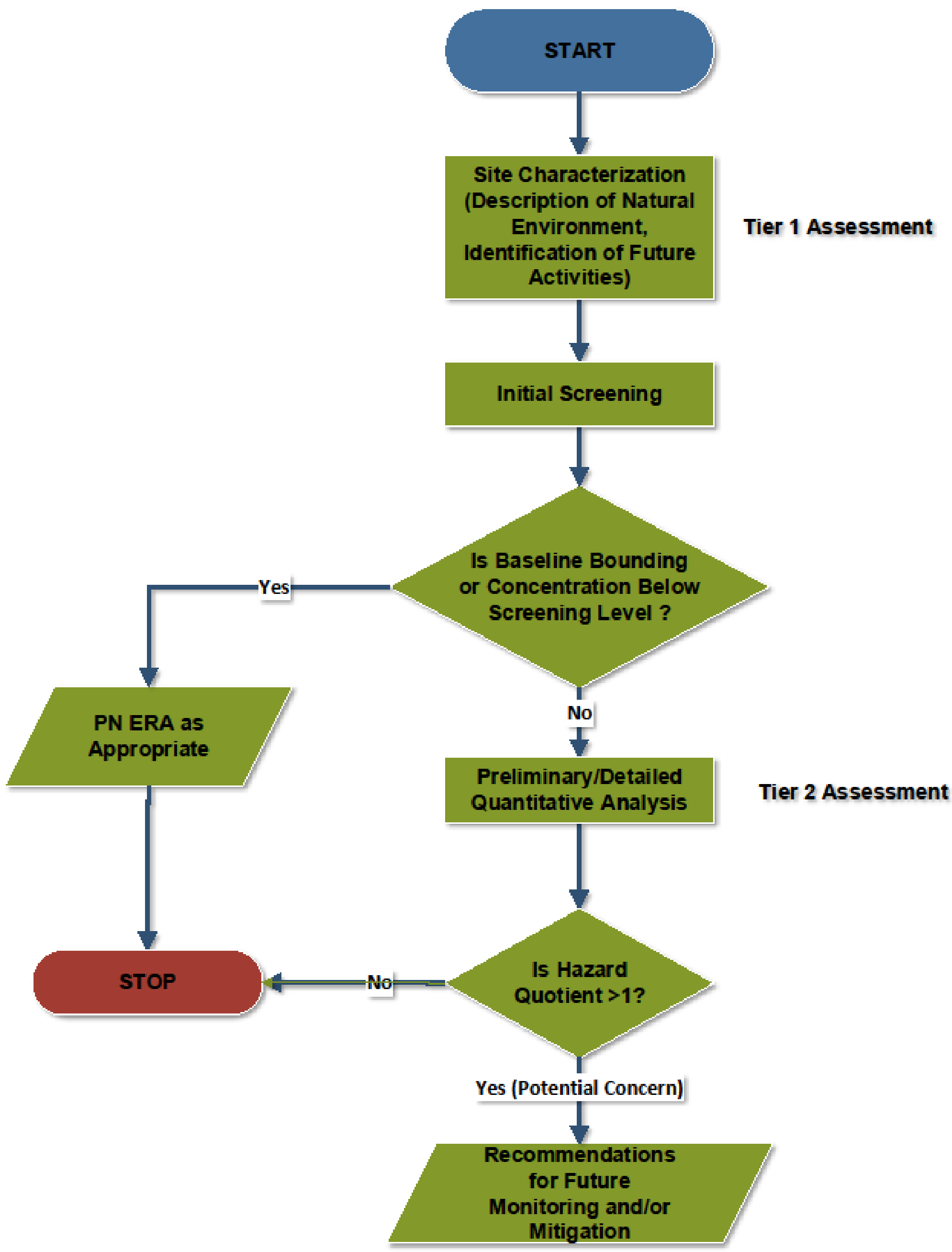


Figure 2-1: Predictive Effects Assessment Methodology Illustration

2.1 Site Characterization

The characterization of the PN Site includes a description of both the existing conditions (i.e., the baseline natural environment and existing PN operations), as well as a description of future Stabilization and Storage with Surveillance activities.

2.1.1 Definition of the Existing Site Conditions and Operations

The existing site conditions (environment baseline) are described in Section 2.3 of the PN ERA (EcoMetrix and Golder, 2017), which is focused on data available from the 2011 to 2015 period. Existing PN facilities and operations are also described in the PN ERA (EcoMetrix and Golder, 2017), including quantitative releases from the facilities/operations in both liquid and gaseous effluents.

The PEA used the PN ERA-defined spatial boundaries with a focus on the ecological and human receptors (Valued Ecosystem Components [VECs]) being assessed, specifically:

- **Human Health:** human receptors within 20 kilometres (km) of the PN Generating Station; and
- **Ecological:** ecological receptors on-site and within the immediate PN Generating Station site boundary (i.e., area encompassing facilities, buildings and infrastructure at the PN Generating Station, and the area within the 914 m exclusion zone shown on Figure 3-2) and the near-field receiving waters.

Where applicable, the baseline conditions identified in the PN ERA are referenced in the identification of potential interactions and bounding scenarios (see Section 4.0) and combined with the estimated predicted changes resulting from the proposed new operating state to evaluate risk (see Section 2.3). Findings of the PN ERA are summarized where applicable within the PEA report; however, the full PN ERA report should be referenced for complete baseline information and perspective.

2.1.2 Definition of Future Stabilization and Storage with Surveillance Activities

The description of future activities during the Stabilization and Storage with Surveillance activities forms the basis for the effects assessment. Each of the major PN systems, structures and facilities are described in terms of how they may change during each of the Stabilization and Storage with Surveillance Phases. For example, some systems and facilities will see decreased activity.

Throughout the PEA, assumptions have been made concerning the future conditions where specific operational details cannot be confirmed at this early stage in the planning. These assumptions are purposely developed to provide a range of conservative estimates of future conditions and emissions. Scenarios are selected from this range of future conditions for the PEA to represent the "bounding conditions" to be used to evaluate the effects from the Stabilization and Storage with Surveillance activities. Most of the bounding conditions identified are associated with the current operational conditions. This is due to expected reductions in emissions released to the environment throughout the Stabilization and Storage with Surveillance Phases.

2.2 Initial Screening (Tier 1 Assessment)

The initial screening, also identified as the Tier 1 assessment in the PEA, includes evaluation of potential interactions of Stabilization and Storage with Surveillance activities with the environment to identify those receptors, exposure pathways, contaminants of potential concern and physical stressors that may warrant further assessment.

Taking into consideration the description of Stabilization and Storage with Surveillance activities as described in Section 3.0, the potential for interaction with each environmental pathway is considered and summarized in Tables 4-1, 4-6, 4-9, 4-10 and 4-11. Each interaction is evaluated as:

- decreasing interaction with the environment compared to current operational conditions (denoted in the summary table with an arrow pointing down '↓');
- increasing interaction with the environment compared to current operational conditions (denoted in the summary table with an arrow pointing up '↑');
- no change or negligible change from current operational conditions (denoted in the summary table with an arrow pointing to the right '→'); or
- not applicable (i.e., the system or structure does not have an interaction with the specified environmental pathway; indicated by a blank cell).

This initial screening is conducted using professional judgement and an understanding of the PN operations and Stabilization and Storage with Surveillance activities. Where an increasing interaction is identified, text is provided to describe and evaluate the interaction and the effect during the Stabilization and Storage with Surveillance Phases. Where interactions are either likely to result in decreased environmental interactions or are considered to be negligible, they are not considered further in the PEA. For these interactions, the effects of the existing PN operations as described in the PN ERA (EcoMetrix and Golder, 2017) are considered to be bounding. There are, however, various interactions considered to result in decreased or similar interactions where some discussion is considered warranted. These are indicated with an asterisk ("*****").

Potential increases in interaction relative to existing conditions are discussed further in the Tier 1 assessment with the objective of determining if a detailed quantitative analysis (i.e., Tier 2 assessment) is required. The potential change to the current conditions is, therefore, further described and evaluated. Multiple interactions may be grouped together into a bounding scenario as the "worst case" as it may relate to specific environmental effects. This evaluation may be qualitative or quantitative and may be for select contaminants of potential concern, physical stressors or receptors, as applicable to the change. The predicted conditions are compared to current operations, and if the predicted conditions are not bound by current operational conditions, they are compared with the accepted screening values for the protection of human health and the environment instead. If the predicted conditions may exceed screening values, the interaction is evaluated further in the Tier 2 assessment, which is described in Section 2.3. Contaminants of potential concern considered of public interest (i.e., radionuclides) are also carried forward to the Tier 2 assessment.

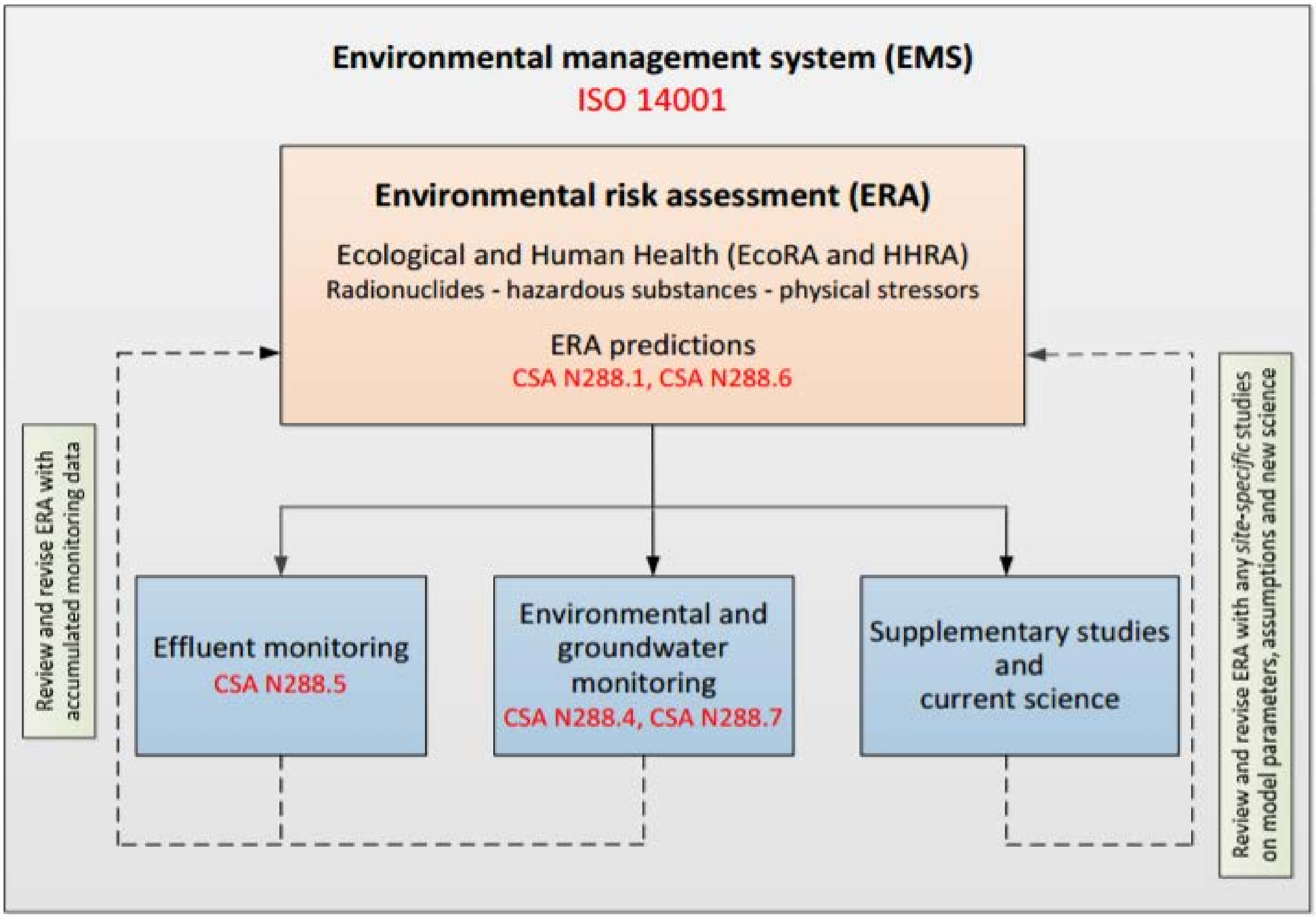
2.3 Preliminary/Detailed Quantitative Analysis (Tier 2 Assessment)

Where a pathway or receptor is not bound by current operational conditions, and the predicted change to a contaminant of potential concern and/or physical stressor cannot be screened using accepted guidelines, then the pathway and/or receptors are described in the Conceptual Site Model (Section 5.0) and evaluated further in the Tier 2 assessment (Sections 6.0 and 7.0).

The Tier 2 assessment includes a human health risk assessment and an ecological risk assessment conducted in accordance with CSA N288.6-12 (CSA, 2012). The Tier 2 assessment is focused only on those elements carried forward from the Tier 1 assessment.

2.4 Monitoring Program Implementation

Based on the findings of the Tier 1 and Tier 2 assessment, OPG may revise the monitoring program or implement risk management to accommodate evolving environmental conditions. This may include modifications to the EMP if the emissions and pathways for environmental effects change as a result of the Stabilization and Storage with Surveillance activities. As outlined in REGDOC-2.9.1, ERA predictions (baseline or predictive) may warrant recommended changes to environmental monitoring programs (i.e., the EMP) and effluent monitoring programs, as per CSA N288.4-10 (CSA, 2010) and CSA N288.5 (CSA, 2011). Figure 2-2 illustrates the interrelationship between ERA and monitoring programs at nuclear facilities.



Source: REGDOC 2.9.1 (CNSC, 2016b)
Note: EcoRA is an Ecological Risk Assessment and HHRA is a Human Health Risk Assessment

Figure 2-2-2: Interrelationships between ERA and Monitoring

If the PEA were to indicate potential adverse effects, then risk management or remedial measures may also be identified and implemented. Adaptations to monitoring activities anticipated as a result of the PEA findings will be recommended in consideration of criteria provided in CSA N288.4-10 (CSA, 2010). The existing monitoring program is described in Section 8.0.

3.0 STABILIZATION AND STORAGE WITH SURVEILLANCE ACTIVITIES

This section provides a description of the Stabilization and Storage with Surveillance activities to provide the basis for the identification of potential interactions with the environment. The baseline environment and existing PN operations are described in Section 2.3 of the PN ERA (EcoMetrix and Golder, 2017).

Project-related works and activities provide the basis for the identification of environmental effects. They are the systems, components and activities that may be expected to affect the environment during the Stabilization and Storage with Surveillance Phases. As noted in Section 1.1, OPG is currently developing plans to determine the specific details of the Stabilization and Storage with Surveillance activities. The risk of change to the PEA findings as a result of changes to the assumptions is minimized by the general use of an "upper bounding" case to provide a conservative assessment of effects. OPG may use options that result in fewer emissions or that otherwise minimize impact to human health and the environment.

The PN Site consists of numerous structures, services and facilities, and Figure 3-1 identifies the major facilities and structures on the PN Site. The PN Site also includes a number of support facilities and the PWMF. PN U1-4 has two operating nuclear reactor units (PN U1 and U4) and two non-operating reactor units (PN U2 and U3). PN U2 and U3 were defuelled in 2008 and have been in a safe storage state since 2010; therefore, they are not included in the Stabilization Phase activities described in the PEA report. PN U5-8 has four operating nuclear reactor units (i.e., PN U5, U6, U7 and U8). The various facilities and structures discussed in this section are shown on Figure 3-2.

The main elements of the Stabilization and Storage with Surveillance Phases include the following.

- Removal of all nuclear fuel from the reactor units and transfer of the fuel to an IFB for approximately up to 10 years of cooling. Continued operation/surveillance of the IFBs and AIFB are required until all irradiated fuel and other components stored in the fuel bays are transferred into DSCs for safe interim storage at the PWMF.
- Draining and storage of approximately 3,000 Mg of heavy water. The heavy water will be stored for the long to medium term as the PN Generating Station inventory will provide supplies to other facilities as required. Periodic transfer of heavy water within the PN Site, as well as off-site, may be undertaken as needed.
- Stabilization of all other systems that are no longer required and can be safely removed from service. Stabilization includes removal of chemicals no longer required (i.e., boiler treatment and reactor control chemicals), as well as removal of transient substances (e.g., gasses, liquids, oil, filters, refrigerants, resins, etc.) for collection, recycling and/or disposal through approved pathways.
- Management of waterborne emissions will continue in compliance with regulatory limits through the radioactive liquid waste management system (RLWMS) or inactive drainage systems.
- Operation and maintenance of the support systems required for the Stabilization and Storage with Surveillance activities within the PN Generating Station include heating, lighting, security, ventilation and fire protection. This will also include operation of an alternative building heating system or source during the winter months to replace the steam heat no longer being produced by the operating units.

- Shut down of the CCW pumps. For the purposes of the PEA, it is assumed that limited amounts of water will continue to be taken in from Lake Ontario to meet the safety and operational needs of the PN Generating Station in the Stabilization and Storage with Surveillance Phases. This consists mainly of IFB cooling.
- Maintenance and monitoring of all buildings in a safe and secure state. Temporary buildings (e.g., mobile office and storage trailers) may be removed from the PN Generating Station site. Demolition is not proposed within the protected area (i.e., the area immediately surrounding the reactor buildings and support services) as part of the Stabilization and Storage with Surveillance activities. Some building may be removed from the areas surrounding the protected area (i.e., the East Complex). Remaining structures, buildings and systems will be monitored and maintained in a safe state. Other PN Generating Station site features (e.g., parking areas) will be maintained as an industrial landscape in a state that will prevent the areas from becoming naturalized.
- Maintenance of environmental monitoring and protection programs and activities in accordance with the requirements specified in the licence(s) by the CNSC and in accordance with appropriate regulation and standards.

The staging of activities for the above systems is summarized in Table 3-1, which is followed by a more fulsome description for each system and/or structure in the following subsections. The intention of these descriptions is to provide sufficient detail about the activities and the changes such that the potential to interact with the environment can be identified, and bounding environmental emissions can be understood. Potential interactions with the environment are discussed in Section 4.0.

The activities noted in Table 3-1 for Storage with Surveillance are focussed on the first 10 years of this Phase. Following that time it is anticipated that fuel will be in dry storage, and located within the PWMF. The residual environmental effects occurring at the PN Generating Station after this milestone are expected to be further reduced as last remaining systems will be drained, dried and prepared for subsequent decommissioning. The few activities that will remain active on-site until decommissioning (i.e., the Staged Dismantling and Demolition Phase followed by the Restoration Phase) will include groundwater management, heavy water storage, building heating and ventilation, security and overall monitoring and maintenance. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue until the Staged Dismantling and Demolition Phase is initiated. Environmental effects during the later period of Storage with Surveillance are considered to be bound by the initial period of the Storage with Surveillance Phase.

Throughout the Stabilization and Storage with Surveillance Phases, all modifications, processes and monitoring activities will be conducted by trained staff working in adherence with applicable procedures and regulations.

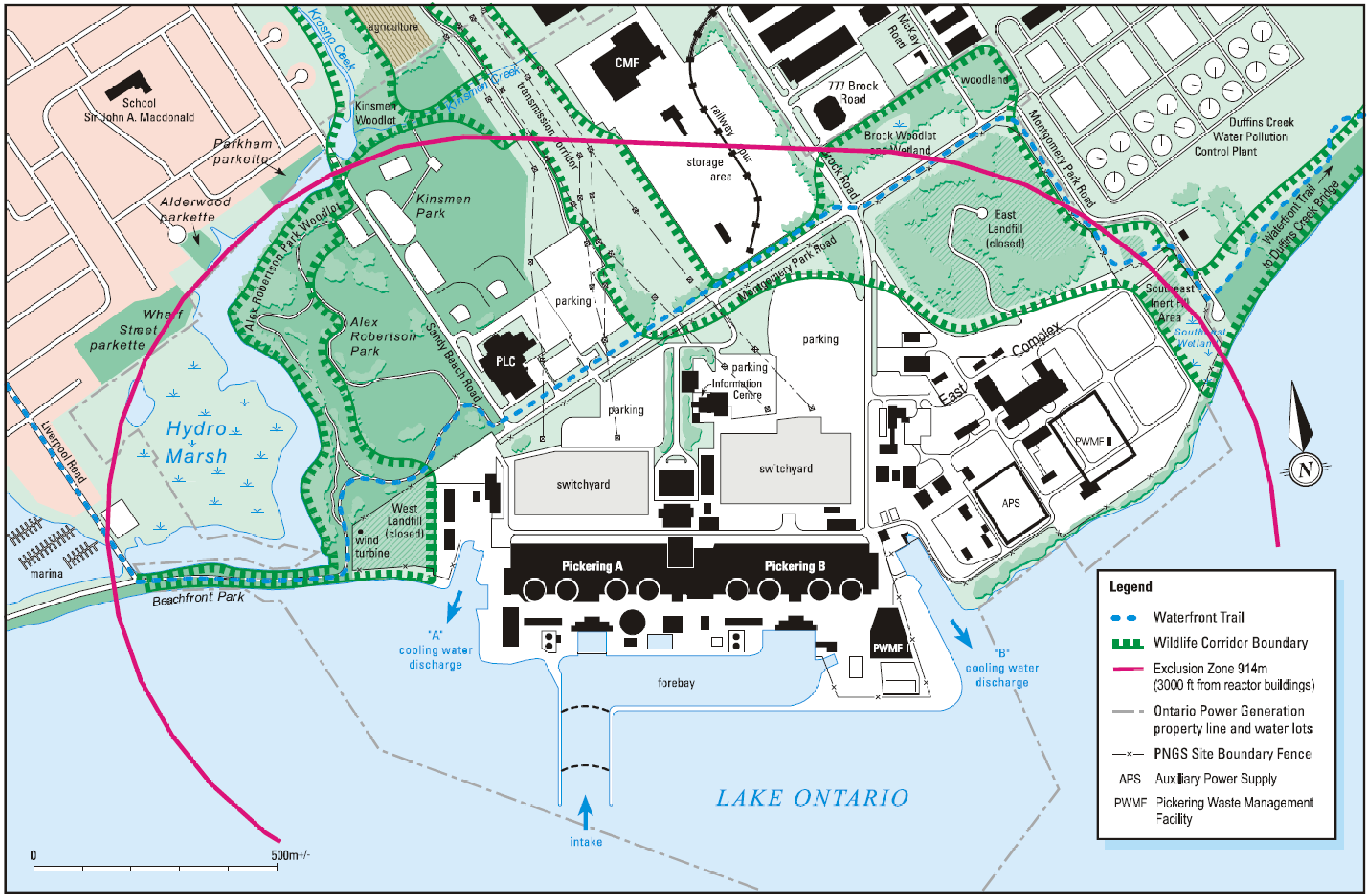
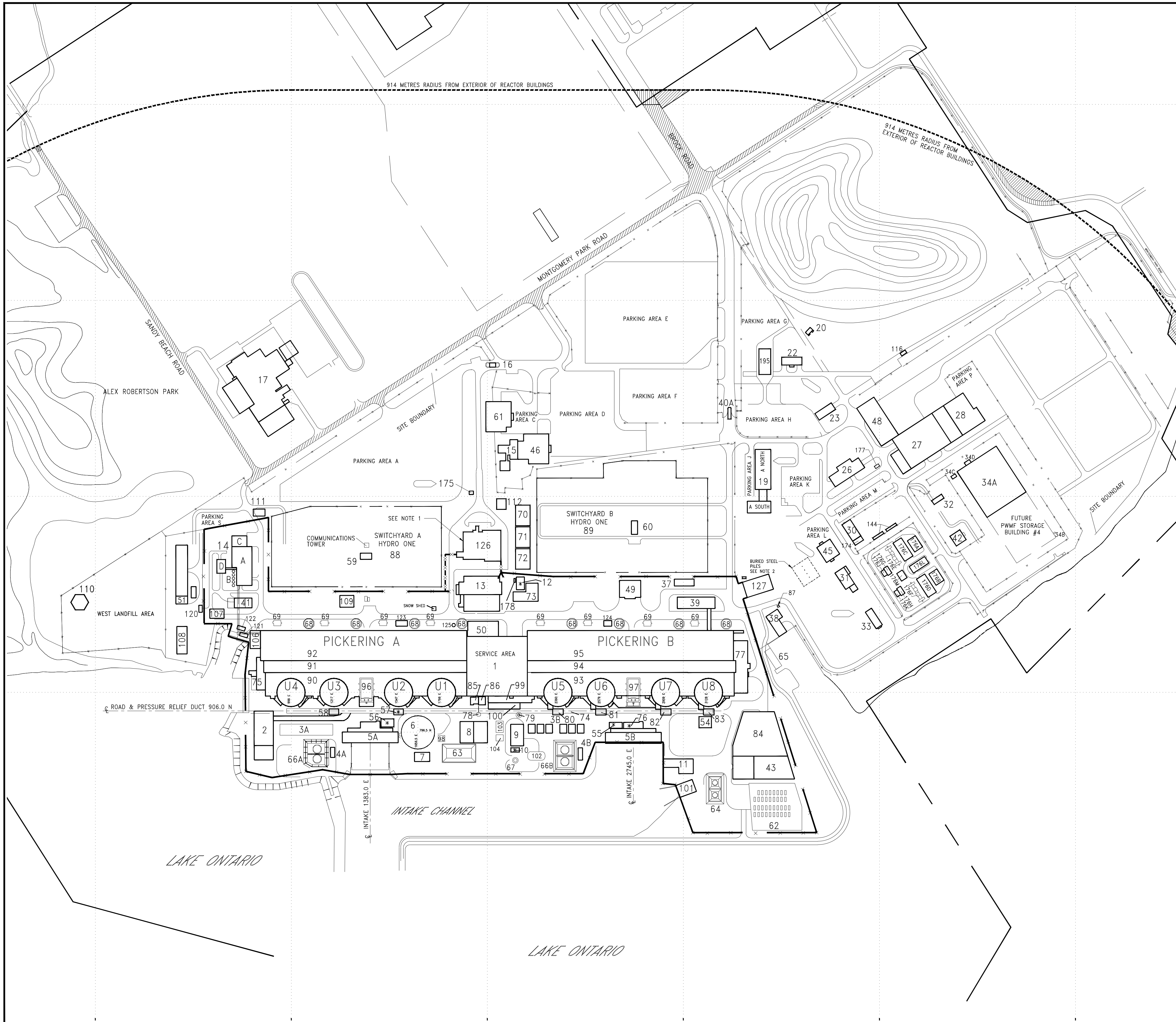


Figure 3-1: Conceptual Plan View of the PN Generating Station



BUILDINGS

U1 to U8 - REACTOR BLDGS.
1. SERVICE AREA / SERVICE WING
2. AUXILIARY IRRADIATED FUEL BLDG.
3A,3B. STANDBY GENERATOR BLDGS.
4A,4B. STANDBY GEN. OIL PUMPHOUSE
5A,5B. SCREENHOUSE
6. VACUUM BUILDING
7. OFF GAS SYSTEM BLDG.
8. WATER TREATMENT BLDG.
9. H.P.E.C.I.S. PUMPHOUSE
10. H.P.E.C.I.S. AUXILIARY SERVICE BLDG.
11. EMERGENCY WATER AND POWER SYSTEM BLDG.
12. QUALITY ASSURANCE VAULT
13. ADMINISTRATION BUILDING
14A. HEAVY WATER UPGRADING PLANT
14B. HEAVY WATER UPGRADING TOWERS
14C. UPP EXPANSION FEED STORAGE AREA
14D. UPP EXPANSION UPP AREA
15. PICKERING ENERGY INFO. CENTRE
34A. PWMF STORAGE BUILDING #3
38 - NEW WATER TREATMENT PLANT
43 - USED FUEL DRY STORAGE BLDG. #1
46 - ENGINEERING SERVICES BLDG.
49 - OIL/CHEMICAL STORAGE BLDG.
54 - STANDBY BOILER BLDG.
62 - DSM AREA
74 - PRESSURE RELIEF DUCT
75 - WEST ANNEX
77 - EAST ANNEX
84 - USED FUEL DRY STORAGE BLDG. #2
85. D_2O UPGRADING TOWER A
86. D_2O UPGRADING TOWER B
88 - SWITCHYARD A
89 - SWITCHYARD B
90 - REACTOR AUXILIARY BAY A
91 - TURBINE AUXILIARY BAY A
92 - TURBINE HALL A
93 - REACTOR AUXILIARY BAY B
94 - TURBINE AUXILIARY BAY B
95 - TURBINE HALL B
101 - TEMPERING WATER/SEDIMENT SUCTION PUMPHOUSE
126 - MAIN SECURITY BLDG.
127 - AUXILIARY SECURITY BLDG.

NOTES:

1. NOT TO SCALE
2. PLEASE SEE ORIGINAL DRAWING FOR A FULL LIST OF BUILDING DESCRIPTIONS

REFERENCES:

BASE PLAN PROVIDED BY ONTARIO POWER GENERATING, ENTITLED "BUILDING DEVELOPMENT SITE PLAN", DRAWING NUMBER NK30-DOA-10200-0001 R31.

PROJECT

OPG PICKERING SAFE STORAGE
PREDICTIVE EFFECTS ASSESSMENT

TITLE

PN LAYOUT

Golder Associates
Mississauga, Ontario, Canada

PROJECT No.		1522020	FILE No. 1522020-0005-CS-0039.dwg	
DESIGN			SCALE AS SHOWN	REV. A
CAD	KD/FC	9/23/2016	FIGURE	
CHECK	CD	9/23/2016		
REVIEW			3-2	

Table 3-1: Summary of the Stabilization and Storage with Surveillance Activities

Pickering Nuclear System, Structure or Activity	Stabilization Phase	Storage with Surveillance Phase
Reactor Building Systems (Section 3.1)	▪ The Reactor Building systems will cease operation for nuclear fission and heat generation. ▪ Fuel will be removed, heavy water systems drained, moderator system flushed, and all other liquids, wastes and potentially hazardous transient materials will be removed. ▪ Building ventilation and stack monitoring will remain operational. ▪ The Reactor Building active drainage sumps will remain operational. ▪ Heavy water will be transferred to storage systems on-site, with periodic transfers off-site as required.	▪ Surveillance will commence to ensure Reactor Building systems are maintained in a safe state. ▪ Operation of ventilation will be reduced and run only as required for occupational safety and building integrity. ▪ Sumps will be isolated from the active drainage system. ▪ Heavy water storage on-site will continue, with periodic transfers off-site as required.
Reactor Auxiliary Bay (RAB), Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB) (Section 3.2)	▪ The RAB systems will remain in operation to accommodate the shutdown of the reactor units, the defuelling, and the removal of other equipment. ▪ Systems no longer required will be taken out of service and left in a safe state, with the equipment remaining in place. ▪ The IFBs and AIFB will remain in normal operation.	▪ Surveillance will commence to ensure RAB is maintained in a safe state. ▪ The IFBs and AIFB will remain in normal operation until all contents can be transferred to dry storage. ▪ Select monitoring equipment will remain operational. ▪ Fuel will be transferred to dry storage containers (DSCs) and transportation to the Pickering Waste Management Facility (PWMF) will continue. ▪ Once no longer required, PN U1-4 IFB, PN U5-8 IFB and AIFB may be drained.
Turbine Hall and Turbine Auxiliary Bay (TAB) (Section 3.3)	▪ Electricity generating equipment (e.g., turbines and generators) associated with each reactor unit will cease operation as units are shut down. ▪ As equipment within the TAB is no longer required, it will be taken out of service and left in a safe state with equipment remaining in	▪ Current steam emissions from PN U1 and U4, and PN U5-8 will no longer exist during surveillance phase. ▪ Surveillance will commence to ensure TAB is maintained in a safe state. ▪ Heating and ventilation will be provided, to the extent required.

Table 3-1: Summary of the Stabilization and Storage with Surveillance Activities

Pickering Nuclear System, Structure or Activity	Stabilization Phase	Storage with Surveillance Phase
	place (some exceptions may be made for equipment that can be resold). ▪ TAB basement sump pumps will remain in operation.	▪ Operation of the TAB basement sumps will continue to maintain the groundwater level below the basement floor.
Service Wing (Section 3.4)	▪ No changes.	▪ Service Wing operation will decrease as PN operations are reduced.
Standby Generators and Emergency Power (Section 3.5)	▪ The generators will continue to be tested and relied on to supply back-up power and water to PN Generating Station systems while fuel remains in the reactor units.	▪ A single back-up power source (e.g., one emergency power generator) will be required.
Building Heating and Ventilation (Section 3.6)	▪ Adequate building heating and ventilation will continue to be supplied. ▪ An alternative heating source/supply (e.g., a boiler in addition to the Auxiliary Boiler) is proposed to supply the powerhouse with adequate heat.	▪ Building heating and ventilation will be supplied to the extent necessary to satisfy occupational safety and maintain system and building integrity. ▪ Less heat (i.e., less heating boiler use) will be required than in the Stabilization Phase.
Condenser Cooling Water (CCW) and Reactor Building Service Water (RBSW) Systems (Section 3.7)	▪ CCW pumps will be taken out of service as reactor units are shut down. ▪ Select CCW pumps may continue to operate following the shutdown of reactor units to facilitate Stabilization activities.	▪ CCW pumps will be fully shut down by the end of the Stabilization Phase and will not function during the Storage with Surveillance Phase. ▪ Cooling water for the IFBs is likely to be provided by the RBSW system.
Electrical Transmission Facilities (Section 3.8)	▪ Main output transformers and generating system transformers associated with each unit will be taken out of service and placed into a safe state following the shutdown of the reactor units. ▪ Select station service transformers and switchyard equipment may remain in operation to supply power to the facility. Any transformers	▪ The output transformers and the transmission yard will be de-energized and disconnected from the PN Generating Station, with the exception of service transformer(s) needed to supply power to the PN site during the Storage with Surveillance Phase.

Table 3-1: Summary of the Stabilization and Storage with Surveillance Activities

Pickering Nuclear System, Structure or Activity	Stabilization Phase	Storage with Surveillance Phase
	no longer required would be placed in a safe storage state.	
Oil and Chemical Storage Building (Section 3.9)	▪ Waste consolidation activities and transportation off-site will increase.	▪ Operations will continue, though waste consolidation and transportation activities will be reduced.
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre (Section 3.10)	▪ No changes.	▪ The Administration, Engineering Services Buildings, and Pickering Nuclear Information Centre will be left in a safe and vacant state when no longer needed. ▪ The Engineering Services Buildings, and Pickering Nuclear Information Centre may be leased to future industrial/commercial workers (i.e., a new tenant). ▪ Security buildings will remain operational.
High Pressure Emergency Coolant Injection (HPECI) Facilities (Section 3.11)	▪ No changes while fuel remains in the reactor units. ▪ Once the reactor units are all defuelled, the HPECI will be drained and all associated equipment placed in an inactive safe state. ▪ HPECI water will be discharged via an approved pathway.	▪ HPECI facilities will no longer be in operation and will be in an inactive safe state.
New Water Treatment Plant (NWTP) (Section 3.12)	▪ Once the demineralized water demand has been substantially reduced, the transition to an alternative supply may be warranted, such as a scaled down mobile water treatment system.	▪ Demineralized water requirements will be minimal and may be met by an alternative means, such as a mobile water treatment system.
Pickering Waste Management Facility (PWMF) (Section 3.13)	▪ No changes, the PWMF will continue to receive, process and store DSCs.	▪ No changes, the PWMF will continue in full operation to receive, process and store DSCs until all the fuel has been removed from the IFBs and they have been decommissioned.
Waste Management (radiological and non-radiological) (Section 3.14)	▪ Radioactive and non-radiological solid and liquid wastes will continue to be generated and managed as they are during normal operations.	▪ There will be a reduction in wastes produced. ▪ Waste will continue to be managed in accordance with accepted procedures and licence requirements.

Table 3-1: Summary of the Stabilization and Storage with Surveillance Activities

Pickering Nuclear System, Structure or Activity	Stabilization Phase	Storage with Surveillance Phase
Site Drainage and Waterborne Emissions (Section 3.15)	▪ Drainage systems, including stormwater runoff, sewage, active and inactive drainage systems will remain operational. ▪ Draining of systems may result in additional flow to the RLWMS (e.g., upgraders), but it will be discharged as in current operations. ▪ Additional materials may be generated for discharge via the inactive drainage; however, approval will be obtained for the disposal options. ▪ The volumes of active and inactive liquid emissions generated will be gradually reduced as operations are terminated. ▪ If no CCW pumps are in service, the waterborne emissions will be conducted as assumed for the Storage with Surveillance Phase.	▪ All types of waterborne emissions will be reduced. ▪ Stormwater volumes will remain the same. ▪ All drainage systems, including stormwater runoff, sewer, and active and inactive drainage systems will remain operational to the extent necessary to meet operational and regulatory requirement. ▪ Inactive drainage will be re-routed to RLWMS, RBSW or the PN U5-8 discharge channel.
Supporting Services and Activities (Section 3.16)		
Forebay, Intake and Discharge	▪ Will remain operational and continue to operate as in the current operations. ▪ The CCW duct may not be used when the CCW pumps cease operations at the end of the Stabilization Phase.	▪ The forebay will continue to be an operating intake, but with substantially reduced flows. ▪ The PN U5-8 discharge channel will be used to discharge cooling water, however, flows (likely via RBSW) will be substantially reduced.
Fish Diversion System (FDS)	▪ The FDS will continue to be installed seasonally as necessary while any number of CCW pumps remain in operation.	▪ The FDS will be removed from service.
Tempering Water Duct	▪ No changes.	▪ No changes.
Auxiliary Boiler	▪ The Auxiliary Boiler may be used as a primary or back-up building heating supply.	▪ The Auxiliary Boiler may continue to be used as a primary or back-up heating supply.

Table 3-1: Summary of the Stabilization and Storage with Surveillance Activities

Pickering Nuclear System, Structure or Activity	Stabilization Phase	Storage with Surveillance Phase
Other Supporting Services	▪ The East and West Annex will see reduced activity over time. ▪ The East Complex may continue to be used as is, with operations reduced over time. ▪ Upgraders will continue to be used to upgrade heavy water. Necessary process steam may be supplied by the building heating boilers.	▪ The East Complex, East and West Annex will no longer be required and will be largely vacant. ▪ The East Complex will be maintained as an industrial landscape to limit naturalization. ▪ Upgraders will no longer be in service.

3.1 Reactor Building Systems

The reactor units will cease operation for nuclear fission and heat generation in the Stabilization Phase, and be defuelled, dewatered and placed into a safe state. All nuclear power and associated operational and safety systems will be shut down in a manner that ensures the safety of the reactors, the workers, the environment, and the public. Following shutdown, Stabilization activities will consist of removal of fuel, draining of heavy water systems, flushing of the moderator system, vacuum drying of the heat transport system, and removal of all other liquids, wastes and potentially hazardous transient materials. The fuel will be removed using the existing fuel handling system. The associated systems such as the fuelling machines, regulating, reactivity moderator and heat transport systems will be placed into an inactive safe state and reactor units will be rendered impossible to re-fuel.

Moderator pumps and normal operating practices will be used to remove the majority of the heavy water inventory from the units down to the low level drained state. Moderator water may be pumped directly to converted helium storage tanks or drums using temporary hoses and connections. Alternatively, the water may be transferred from the Reactor Buildings to the Supply and Inventory System via the heavy water transfer system.

Following the initial drainage, the moderator will be refilled with demineralized water and a flush of this water may be carried out to remove any residual heavy water remaining in the system. The water will be circulated using one or more of the moderator pumps.

Similarly, the heat transport system will be drained of heavy water to the low level drained state using standard operating procedures. Any remaining heavy water held up in the low points of feeders and channels will be removed using vacuum dryer skids. Drying completion will be confirmed when air entering the vacuum dryer skid reaches a predefined dewpoint.

The heavy water may be purified (i.e., filtered to remove radionuclides and other impurities) and upgraded as required and transferred to medium or long-term storage. OPG is developing a heavy water management plan that is considering a range of options including both on-site and/or off-site storage. All heavy water will be stored in qualified vessels and associated transfers of material will be conducted in a manner that ensures the safety of human health and the environment. For the purposes of the PEA, it is assumed that all heavy water is stored on-site during the Stabilization and Storage with Surveillance Phases.

Heavy water recovery dryers will be utilized to minimize atmospheric emissions from the Reactor Buildings while carrying out all draining, flushing and drying activities. Reactor Building atmospheric emissions will be subject to filtration and monitoring throughout. Additionally, Reactor Building active drainage sumps will also remain operational during the Stabilization Phase.

All collected flush water will be sampled, and depending on sample results, the water will either be sent to storage, sent for upgrading, or sent to RLWMS as per normal procedures. As is the case with all active liquid waste streams, RLWMS emissions will be subject to sampling, treatment (as required) and monitoring.

Following defuelling, dewatering and end-stating Reactor Building systems, the Reactor Buildings will be placed into a monitored safe state. During the Storage with Surveillance Phase, the humidity in the Reactor Buildings may be controlled; however, they are not intended to be maintained for occupation. The ventilation for a Reactor Building will be placed in service as required for occupational safety and building integrity. Environmental stack monitoring will remain operational on select streams either on an intermittent or continuous basis as required. The Reactor Building sumps will be isolated from the active drainage system.

3.2 Reactor Auxiliary Bay Systems and Irradiated Fuel Bay Operations

The Reactor Auxiliary Bay (RAB) systems will remain in operation during the Stabilization Phase to accommodate the shutdown of the reactor units, defuelling, and the stabilization of other equipment. When no longer needed these systems will be taken out of service and left in a passive safe state, with the equipment remaining in place.

The IFBs, AIFB and associated systems will remain in operation throughout the Stabilization Phase and for much of the Storage with Surveillance Phase. Operations will include bay monitoring, cooling and purification of IFB water, ventilation and stack monitoring, and climate control.

Fuel stored in the IFBs and AIFB will be stored until cooling requirements are met for dry storage (up to 10 years), when they will be transferred to DSCs. Once all fuel is transferred out of the bays, the IFBs and AIFB may be drained, decontaminated and sealed, as required. All discharges from these operations, including discharges to RLWMS, will occur by approved methods.

Apart from IFB and AIFB operations, equipment in the RABs remaining in service during the Storage with Surveillance Phase will be minimal, as compared to current operations.

3.3 Turbine Hall and Turbine Auxiliary Bay

The operations in the Turbine Hall and Turbine Auxiliary Bay will cease in the Stabilization Phase. As equipment is no longer required, it will be de-energized, drained, and left in an inactive safe state. Limited equipment will remain in service during the Storage with Surveillance Phase, including the inactive drainage sumps located in the basement of the Turbine Auxiliary Bay (TAB). The inactive drains and the associated sumps and pumps will remain operational to continue to manage groundwater that is collected in the sumps. Other water sources to the TAB sumps will be reduced (i.e., equipment drains from conventional systems).

Water drainage systems are described in more detail in Section 3.15.

3.4 Service Wing

The service wing will remain operational throughout the Stabilization Phase. Service wing operations will be scaled back to limited areas and services once in the Storage with Surveillance Phase, such as the RLWMS, select workshops, offices and/or laboratories.

3.5 Standby Generators and Emergency Power

During the Stabilization Phase, the standby generators will continue to provide back-up power to safety systems and will be tested regularly. The standby generators and the emergency power generator will gradually become unnecessary over the course of the Stabilization Phase.

During the Storage with Surveillance Phase, a single back-up power source will be required. Although the current generation sources are oversized for this use, for the purpose of the PEA, it is assumed the emergency power generator (2,500 kW) will remain in service.

Emergency water will continue to be available to the PN Site during the Stabilization Phase and the Emergency Water Supply Pumphouse will cease operations when no longer needed for reactor safety.

3.6 Building Heating and Ventilation

Building heating and ventilation will continue to be required during the Stabilization and Storage with Surveillance Phases. Existing building heating is supplied by steam from the operating reactor units, which will no longer be available following the shutdown of the last unit. The strategy to supply adequate heating to the station has not yet been confirmed. A number of options are under consideration to provide future heating load requirements, which could range from electric heaters to a boiler fueled by fuel oil.

For the purposes of the PEA, the bounding assumption is that the alternative heating source will be provided by fuel-based boilers similar to the existing Auxiliary Boiler (see Sections 4.1.2.2.2 and 4.2.3.2.1.2 for additional details). The heating load in the Stabilization Phase is such that both the existing Auxiliary Boiler, plus an additional heating steam boiler would be required to provide adequate process steam. As the operational footprint is minimized, the demand for heating steam will be commensurately reduced such that the heating load in the Storage with Surveillance Phase could be met by a single heating steam boiler.

3.7 Condenser Cooling Water and Reactor Building Service Water

The CCW will continue operations during the Stabilization Phase; however, the volume of water being pumped may be reduced as units are shut down and service water demands are decreased. At the end of the Stabilization Phase it is expected that all CCW pumps will be shut down.

With the exception of the IFB cooling, the majority of service-water loads will be eliminated in the Storage with Surveillance Phase. As a bounding case, it is assumed that the IFB cooling water will continue to be provided from the Reactor Building Service Water (RBSW) system during the Storage with Surveillance Phase (details provided on bounding assumptions in Section 4.2). The specifics for how the IFBs and AIFB will be cooled may change over time as overall service water requirements decrease.

3.8 Electrical Transmission Facilities

During the Stabilization Phase the main output transformers and generating system transformers associated with each unit will be taken out of service and placed into a safe state following the shutdown of the reactor units. Select station service transformers and switchyard equipment may remain in operation to supply power to the facility. Any transformers no longer required would be placed in a safe storage state.

During the Storage with Surveillance Phase the output transformers and the transmission yard will be de-energized and disconnected from the PN Generating Station, with the exception of service transformer(s) needed to supply power to the PN site.

Unused transformers will be drained of oil in accordance with accepted practices and placed in a safe storage state.

3.9 Oil and Chemical Storage Building

The oil and chemical storage building will see increased activity during the Stabilization Phase as wastes are consolidated and transported off-site. The operations are expected to be greatly reduced in the Storage with Surveillance Phase. The operations in this facility will continue to be conducted in accordance with procedures and good industrial practices.

3.10 Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre

The Administration Building, Engineering Services Buildings, security buildings and Pickering Nuclear Information Centre will be used throughout the Stabilization Phase. The buildings may become vacant during the Storage with Surveillance Phase however, the security buildings will continue to be used during the Storage with Surveillance Phases.

OPG is currently undertaking studies to explore future uses of the PN Site. The intention is to repurpose the PN Generating Station in a way that continues to benefit both OPG and the surrounding communities, while remaining consistent with the decommissioning plans. After consultation with stakeholders and the public, OPG has prepared a Repurposing Pickering Preliminary Assessment Report (OPG, 2016b), which provides a short list of preferred options for further investigation. The final decision for the preferred option is still to be determined; however, there is the potential that on-site buildings outside of the PN operations may be leased for use by future industrial/commercial workers. As part of the PEA it is assumed that the Engineering Services Building and Pickering Information Centre are leased.

3.11 High Pressure Emergency Coolant Injection Facilities

The High Pressure Emergency Coolant Injection (HPECI) facilities will remain in operation (i.e., filled with water and maintained) during the Stabilization Phase until defuelling activities are complete. The system will be drained using approved procedures, compliant with Environmental Compliance Approval (ECA) conditions, and left in a safe state during the Storage with Surveillance Phase.

3.12 New Water Treatment Plant

The existing New Water Treatment Plant (NWTP) may continue to be used for the supply of demineralized water during the Stabilization Phase, though the demand will progressively decrease over time as the units are shut down. Once the demineralized water demand has been substantially reduced, the transition to an alternative supply may be warranted. For the purposes of the PEA, as a bounding condition it is assumed that the Storage with Surveillance demineralized water demand is supplied by a scaled down mobile water treatment system.

3.13 Pickering Waste Management Facility

Used fuel bundles will continue to be stored in an IFB up to 10 years and then transferred to DSCs for interim storage in the PWMF.

The PWMF operations during both the Stabilization and Storage with Surveillance Phases will continue to include receiving, processing and storing DSCs (i.e., fuel contained in reinforced concrete with carbon steel inner and outer liners). The processing at the PWMF includes the drying of the container, the addition of helium gas to detect leaks, final welding of the container lid, and drain port and leak testing. The DSCs are moved to the PWMF via a custom built transporter. The PWMF is licensed independently of the PN operations and therefore an assessment of PWMF operations is outside of the scope of the PEA.

3.14 Waste Management (Radiological and Non-radiological)

There are numerous radioactive and non-radioactive materials handled on-site. In general, the final years of operations will be conducted in a manner that will minimize the amount of waste that remains on-site at the beginning of the Storage with Surveillance Phase. The following summarizes the Stabilization and Storage with Surveillance waste management activities.

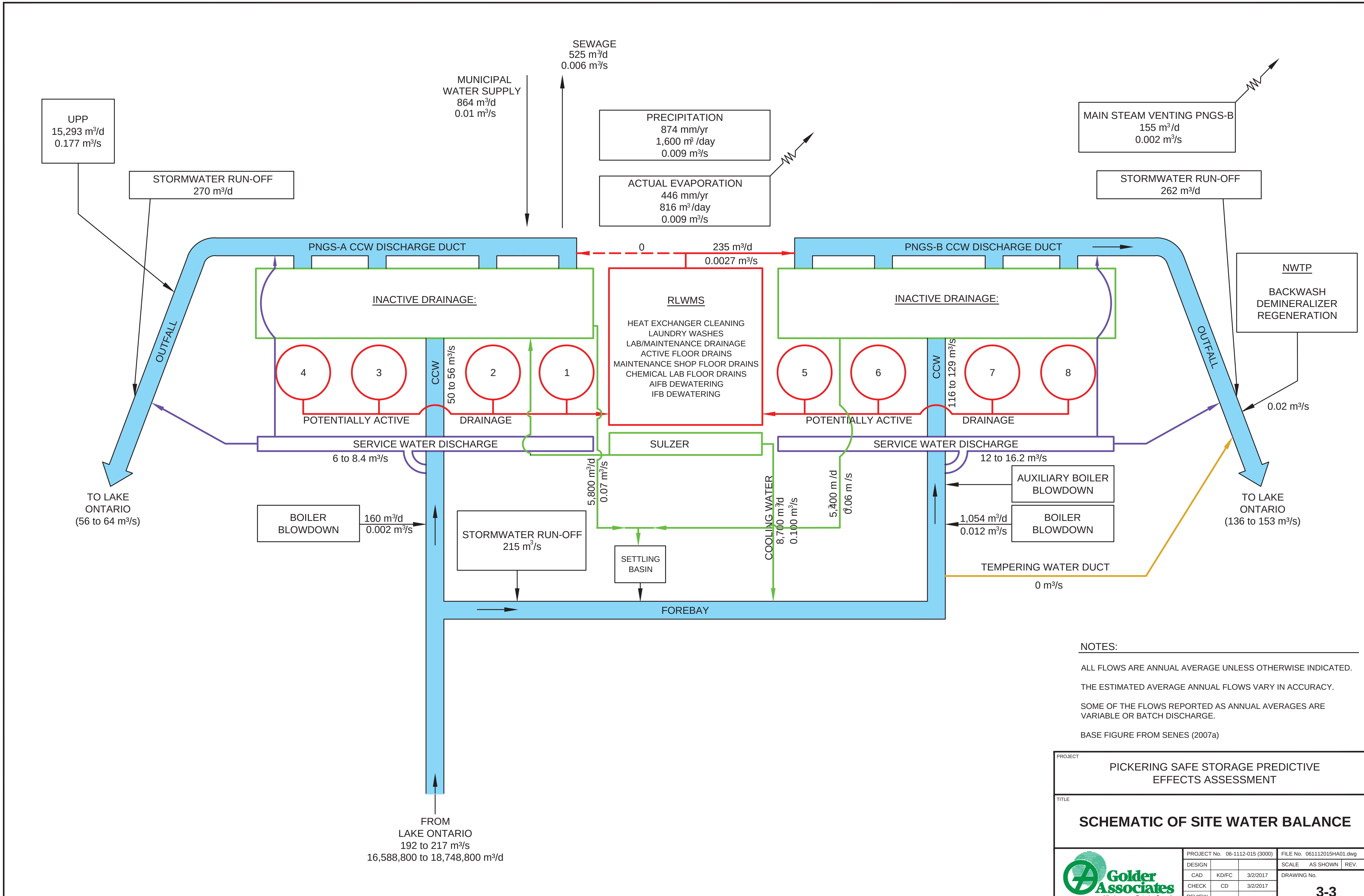
- Radioactive solid and liquid wastes will continue to be generated during the Stabilization Phase in a similar manner as they are generated during normal operations. These wastes will also be generated during the Storage with Surveillance Phase; however, it is expected that the volume of waste generated will be substantially reduced. For example, spent resins may be generated for fuel bay water purification only, with no spent resins generated for reactor operations. These wastes will be stored and disposed of consistent with current operational procedures and in accordance with applicable regulations.
- Other hazardous materials required for the Stabilization Phase and ongoing Storage with Surveillance activities will remain on-site and be managed as in current operations. This may include, but is not limited to, distillate oil (fuel/diesel) for use by generators and/or building heating boiler, sodium hypochlorite for zebra mussel control, and sodium bisulphite for water dechlorination.
- For systems no longer required, liquids remaining will be drained, contained, and removed off-site by a licensed contractor. These liquids may include reactor control chemicals, boiler chemistry chemicals, lubricants, fuels and others.
- Pressurized gas tanks will be removed off-site by a licensed contractor. Nitrogen gas may continue to be used as cover gas for stored heavy water.
- In-service radioactive equipment that contains Polychlorinated Biphenyls (PCBs) will continue to be managed in accordance with the Federal PCB Regulations (SOR/2008-273). Non-radioactive PCB waste will be disposed in accordance with the Federal PCB Regulations and Ontario Regulation 362 (O. Reg. 362) Waste Management - PCBs. Radioactive PCB waste will be stored on-site in a designated PCB storage area to allow secured monitoring and further reduction of radioactivity during the safe storage period, prior to disposal.
- Surveillance of regulated building materials such as asbestos, lead and PCBs will be conducted to ensure they are kept in a safe state. Maintenance of these materials will be conducted as required.

3.15 Site Drainage and Waterborne Emissions

Throughout the Stabilization Phase and extending into the Storage with Surveillance Phase, the drainage operations will generally operate as in the current operations; however, various streams will be modified, reduced and/or integrated. The current water balance is shown in Figure 3-3 and change to the drainage systems are discussed below.

- **Inactive Drainage System –** Inputs to the inactive drainage system will be gradually reduced over the Stabilization Phase as existing sources are taken out of service. The inactive drainage system will remain in-service in the Storage with Surveillance Phase to handle foundation drainage and drains from conventional equipment that will remain in-service. The remaining waste streams may be consolidated for operational and monitoring efficiencies, where possible. Bounding assumptions are discussed in Section 4.2, where applicable. Discharges from the inactive drainage system will continue to be conducted per approved procedures which include compliance with ECA conditions and internal limits to ensure the protection of the environment.

- **Active Drainage System –** The active drainage system will remain operational during the Stabilization and Storage with Surveillance Phases, including the associated RLWMS. During the Stabilization Phase, there may be times when additional sources of water are drained to the RLWMS when systems are emptied, resulting in temporary increases in the generation of active liquid waste. The quality and volume discharged to the environment, however, will be controlled by the RLWMS. Discharge pathways will be reconfigured as required through the Storage with Surveillance Phase and will continue to be monitored in accordance with internal limits to ensure protection of the environment (see Section 4.2.3.2.1.4).
- **Domestic Sewage System –** Domestic sewage will continue to be discharged into the Regional Municipality of Durham sewage mains. Sewage waste will continue to be sampled and analyzed on a regular basis for radioactivity unless it can be demonstrated that this is no longer required. The amount of sewage will decrease with a decreased workforce on-site.
- **Station Stormwater Runoff –** The stormwater collection and runoff will operate as it currently does in the both the Stabilization and Storage with Surveillance Phases. As this is a passive collection system for precipitation it is expected that the flows will remain the same as the current operations. The decreased activity on-site and decreased atmospheric emissions will decrease the potential for contaminants in the stormwater runoff.


SEWAGE
525 m³/d
0.006 m³/s
MUNICIPAL WATER SUPPLY
864 m³/d
0.01 m³/s
UPP
15,293 m³/d
0.177 m³/s
STORMWATER RUN-OFF
270 m³/d
PRECIPITATION
874 mm/yr
1,600 m³ /day
0.009 m³/s
ACTUAL EVAPORATION
446 mm/yr
816 m³/day
0.009 m³/s
MAIN STEAM VENTING PNGS-B
155 m³/d
0.002 m³/s
STORMWATER RUN-OFF
262 m³/d
PNGS-A CCW DISCHARGE DUCT
0
235 m³/d
0.0027 m³/s
PNGS-B CCW DISCHARGE DUCT
NWTP
BACKWASH
DEMINERALIZER
REGENERATION
INACTIVE DRAINAGE:
RLWMS
HEAT EXCHANGER CLEANING
LAUNDRY WASHES
LAB/MAINTENANCE DRAINAGE
ACTIVE FLOOR DRAINS
MAINTENANCE SHOP FLOOR DRAINS
CHEMICAL LAB FLOOR DRAINS
AIFB DEWATERING
IFB DEWATERING
INACTIVE DRAINAGE:
OUTFALL
CCW
50 to 56 m³/s
4
3
2
1
5
6
7
8
CCW
116 to 129 m³/s
OUTFALL
POTENTIALLY ACTIVE
DRAINAGE
POTENTIALLY ACTIVE
DRAINAGE
0.02 m³/s
SERVICE WATER DISCHARGE
6 to 8.4 m³/s
SULZER
SERVICE WATER DISCHARGE
12 to 16.2 m³/s
TO LAKE ONTARIO
(56 to 64 m³/s)
5,800 m³/d
0.07 m³/s
COOLING WATER
8,700 m³/d
0.100 m³/s
5,400 m³/d
0.06 m³/s
AUXILIARY BOILER BLOWDOWN
TO LAKE ONTARIO
(136 to 153 m³/s)
BOILER BLOWDOWN
160 m³/d
0.002 m³/s
STORMWATER RUN-OFF
215 m³/s
SETTLING BASIN
1,054 m³/d
0.012 m³/s
BOILER BLOWDOWN
TEMPERING WATER DUCT
0 m³/s
FOREBAY
FROM LAKE ONTARIO
192 to 217 m³/s
16,588,800 to 18,748,800 m³/d
NOTES:
ALL FLOWS ARE ANNUAL AVERAGE UNLESS OTHERWISE INDICATED.
THE ESTIMATED AVERAGE ANNUAL FLOWS VARY IN ACCURACY.
SOME OF THE FLOWS REPORTED AS ANNUAL AVERAGES ARE VARIABLE OR BATCH DISCHARGE.
BASE FIGURE FROM SENES (2007a)
PROJECT
PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT
TITLE
SCHEMATIC OF SITE WATER BALANCE
Golder Associates
Mississauga, Ontario, Canada
PROJECT No. 06-1112-015 (3000)
FILE No. 061112015HA01.dwg
DESIGN
SCALE AS SHOWN
REV. A
CAD KD/FC 3/2/2017
DRAWING No.
CHECK CD 3/2/2017
REVIEW
3-3

3.16 Supporting Services and Activities

Supporting services are discussed in this section to indicate changes that may be required as part of the Stabilization and Storage with Surveillance Phases. This is not considered a complete list of services and activities, but is focused on those with substantial changes during the Stabilization and Storage with Surveillance Phases.

- **Screenhouses, forebay, intake channel, intake and discharge ducts –** These structures and systems will remain in operation during both the Stabilization and Storage with Surveillance Phases. The CCW duct (i.e. the concrete structure north of the TAB), will not be used during the Storage with Surveillance Phase and cooling water will be discharged via the RBSW to the discharge channel. It is possible that all water intake and discharge will be directed through either PN U1-4 and/or PN U5-8. For the purposes of the PEA discharge via PN U5-8 has been assumed.

  Seasonal chlorination for zebra mussel control is currently conducted and will likely continue during both the Stabilization and Storage with Surveillance Phases. As in the current operating conditions, water intake and discharges will be conducted in accordance with approved processes and dechlorination will occur as required.

- **Fish Diversion System (FDS) –** This system will remain in operation during the Stabilization Phase and is expected not be needed and removed from use during the Storage with Surveillance Phase based on the substantially reduced volumetric flowrate of the raw water intake.
- **Tempering water duct –** The tempering water discharge duct may continue to be used in the Storage with Surveillance Phase, providing a flow path between the forebay and the PN U5-8 outfall.
- **Auxiliary Boiler –** As noted in Section 3.6, the Auxiliary Boiler may be used in the winter months during the Stabilization and Storage with Surveillance Phases for building heating supply. During the Stabilization Phase this may be supplemented with an additional heating steam boiler. This is discussed in Section 4.1 as part of the Building Heating and Ventilation.
- **East and West Annex buildings –** The East and West Annex buildings may be used for storage and operations as needed. They will however, be primarily vacant during the Storage with Surveillance Phase.
- **East Complex –** The East Complex will likely continue to be used as it is currently used during the Stabilization Phase with operations greatly reduced or eliminated for the Storage with Surveillance Phase. Emergency equipment buildings storing Fukishima-related equipment will continue to remain available in the Storage with Surveillance Phase, as required.
- **Heavy water upgrading plant and towers –** The Sulzer and Upgrading Plant Pickering (UPP) will continue to be used, as required, during the Stabilization Phase to upgrade heavy water. Process steam required to operate the upgraders may be provided by the heating steam boilers. Liquid waste produced from upgrading operations will continue to be managed per current operational procedures. These facilities will not be required during the Storage with Surveillance Phase.

Buildings and systems no longer required will be left in a passive safe state. Portable trailers and associated equipment no longer required (i.e., offices or storage trailers) may be removed during the Stabilization Phase or the Storage with Surveillance Phase.

4.0 INTERACTIONS AND PREDICTIVE SCREENING OF STABILIZATION AND STORAGE WITH SURVEILLANCE ACTIVITIES AND THE ENVIRONMENT

This section presents the Tier 1 assessment (i.e., the initial screening), which includes the identification and assessment of potential interactions between the Stabilization and Storage with Surveillance activities and the existing environment. Where a potentially increasing interaction is identified, text is provided to describe and evaluate the interaction and the change during the Stabilization and Storage with Surveillance Phases.

The interactions were evaluated using the methodology outlined in Section 2.0 to determine whether they are bound by existing operational conditions and therefore were adequately assessed in the PN ERA (EcoMetrix and Golder, 2017). Interactions bound by current operations were not considered further in the PEA. Those interactions not readily bound by the current operations were considered in the PEA to identify whether the predicted conditions were indeed bound by current operational conditions or if they exceed accepted screening values for the protection of human health and the environment. If the screening values were predicted to be exceeded, the interaction was evaluated further in the Tier 2 assessment and documented in Sections 5.0 through 7.0. Contaminants of potential concern that are considered to be of public interest (i.e., radionuclides) were also carried forward to the Tier 2 assessment. Where applicable, the findings of the PN ERA were summarized to provide context for the Tier 1 assessment.

In the interaction tables provided below, the arrows indicating a potentially increasing effect (denoted by an arrow pointing up - ↑) are discussed or evaluated in the Tier 1 assessment. As well, some pathways are identified as staying the same or decreasing, but warrant discussion because the screening or bounding condition may not be straightforward. For example, in Table 4-1, the air quality at the Engineering Services Buildings will be improved by the reduction of operations in the Storage with Surveillance Phase; however, during this Phase future industrial/commercial workers may occupy this space and this new receptor will be closer to the PN Generating Station than assessed in the PN ERA; thus, the new pathway is discussed. The items that are identified as staying the same or decreasing, but that warrant discussion are indicated with an asterisk (*) next to the arrow in the tables. For the Supporting Services and Activities row in each interactions tables, only those systems predicted to have an interaction are noted. The full list of supporting systems is discussed in Section 3.16.

For the human and ecological receptors, an evaluation is made regarding how exposure pathways may be modified in ways that have effects on the receptors(s) or their habitat as a result of the Stabilization and Storage with Surveillance activities. The potential changes are discussed in the physical pathway-interaction discussions (e.g., for air quality and surface water quality). Additional detail on receptors is provided in the Conceptual Site Model (Section 5.0) and the PN ERA.

The description of anticipated Stabilization and Storage with Surveillance activities includes reasonable and conservative estimates, as many of the specific details for the Stabilization and Storage with Surveillance activities are being developed. For example, assumed discharges for the RLWMS system procedure are assessed as the full pump-out/Municipal Industrial Strategy for Abatement (MISA) limits for non-radiological parameters. This is an unlikely case (e.g., future emissions are expected to be lower than MISA limits), however, it provides a conservative bounding condition.

4.1 Atmospheric Environment

The initial screening of potential effects of the Stabilization and Storage with Surveillance activities on the atmospheric environment included consideration of both air quality and noise levels. The predicted interactions between the atmospheric environment and Stabilization and Storage with Surveillance activities are summarized in Table 4-1.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Reactor Building Systems	↓	↓	↑	↓*	▪ Noise and non-radiological air quality emissions associated with the Reactor Buildings operations during the Stabilization Phase will decrease over the period of time when the Reactor Buildings cease operations. In particular, the emissions related to the nuclear fission and heat generation process will be removed as units cease operations. ▪ Venting during dewatering and drying may temporarily increase radiological airborne emissions in the Stabilization Phase and is evaluated (Section 4.1.2.2.1). ▪ Noise and air quality emissions associated with the Reactor Building operations during the Storage with Surveillance Phase will decrease further as no nuclear fission will be conducted; therefore no associated Reactor Building operations will be required. ▪ Venting (including venting of stored heavy water) during the Storage with Surveillance Phase is expected to be less than current operational conditions; however, air emissions are discussed and evaluated to allow for an overall dose calculation (Section 4.1.2.2.1). ▪ The isolation and draining of systems during the Stabilization Phase may also require cutting and welding activities, and are expected to be short-lived and similar to the current maintenance activities.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Reactor Auxiliary Bay (RAB) and Irradiated Fuel Bays (IFBs) and Auxiliary Irradiated Fuel Bay (AIFB)	→	↓	→*	↓*	▪ The operations, and therefore noise and vented air emissions (non-radiological and radiological), of the RAB (including IFBs and AIFB) will remain as in the current operational conditions during the Stabilization Phase. They will gradually decrease during the Storage with Surveillance Phase as the IFBs are removed from service. ▪ Radionuclide emissions in the Storage with Surveillance Phase will gradually decrease with time as used fuel is transferred to dry storage containers (DSCs). ▪ The radiological air emissions are discussed and predicted to allow for dose calculations (Section 4.1.2.2.1).
Turbine Hall and Turbine Auxiliary Bay (TAB)	↓	↓	↓	↓	▪ Noise emissions (e.g., steam venting) and air quality emissions (e.g., morpholine and hydrazine in steam venting) associated with the turbine operations during Stabilization activities will decrease to very low levels as units are taken off-line. ▪ Noise and air quality emissions associated with the turbine operations during the Storage with Surveillance Phase will, as with Stabilization, be sustained at very low levels.
Service Wing	→	↓	→	↓	▪ The Service Wing operations will not change appreciably and will have similar emissions in the Stabilization Phase as in the current operations. ▪ The Service Wing will see reduced operation in the Storage with Surveillance Phase, with similarly reduced emissions.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Standby Generators and Emergency Power Generators	↓	↓	↓	↓	▪ Both the Security Building and the Auxiliary Security Building have standby generators that will remain in service. However, in general, the requirement for standby generators will be reduced as reactor units are shut down during the Stabilization Phase and air and noise emissions correspondingly reduced. Testing will continue for standby generators remaining in service, but for fewer generators and therefore at an overall lower frequency. ▪ There will be only one standby or emergency generator required to be maintained and tested during the Storage with Surveillance Phase. From a size and emissions standpoint, current emergency generators bound Storage with Surveillance emergency power requirements.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Building Heating and Ventilation	→	→	↑	→	▪ With the removal of heating steam previously supplied by the PN units, the heating steam requirements will be supplied by the existing Auxiliary Boiler and an additional boiler during the Stabilization Phase. ▪ Noise emissions from the additional boiler will be similar to the current operational condition. This additional boiler is considered a minor source of noise, and during the Stabilization Phase the overall noise will be less than the overall current operational condition and therefore not discussed further. ▪ Air emissions from the additional boiler have the potential to increase effects on air quality through combustion of fuel and the potential use of boiler compounds (Section 4.1.2.2.2). ▪ One of the two boilers would be removed from service in the Storage with Surveillance Phase. The air and noise emissions from the remaining boiler are bound by the current operational conditions.
Condenser Cooling Water (CCW) System/Reactor Building Service Water (RBSW)	↓	↓			▪ CCW or RBSW pumps generate minimal noise during the current operations and will be reduced as the units are shut down in the Stabilization Phase, then further reduced in the Storage with Surveillance Phase. ▪ No potential interaction with air quality.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Electrical Transmission Facilities	↓	↓			▪ The output transformers and the transmission yard will be de-energized and disconnected from the PN Generating Station, with the exception of service transformer(s) needed to supply power to the PN site during the Stabilization and Storage with Surveillance Phases. ▪ Noise from the switchyard (i.e., hum) and breakers for the electrical transmission facilities will be reduced as reactor units are shut down in the Stabilization Phase. ▪ No potential interaction with air quality.
Oil and Chemical Storage Building	↓	↓	→	→	▪ The nominal noise from operations at this facility will be reduced through the course of the Stabilization and Storage with Surveillance activities. ▪ Vented air emissions will remain similar to existing conditions (i.e., minimal) during the Stabilization and Storage with Surveillance activities.
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre	↓	↓	↓	↓*	▪ Traffic and nominal atmospheric emissions (both noise and air) from operations at these buildings will be reduced through the course of the Stabilization Phase. ▪ While there is a potential for a commercial lease of the Engineering Services Buildings and/or Pickering Nuclear Information Centre in the Storage with Surveillance Phase, the atmospheric emissions are expected to be substantially less than the current operational conditions at this receptor. Potential effects for this new receptor are, however, discussed further in Section 4.1.2.2.3.

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
High Pressure Emergency Coolant Injection (HPECI) Facilities					
New Water Treatment Plant (NWTP) and Emergency Water Supply Pumphouse	↓	↓	↓	↓	▪ Noise and air quality emissions from these facilities would be reduced over the course of the Stabilization and Storage with Surveillance activities.
Waste Management	→	↓	→*	↓	▪ During the Stabilization Phase, the transfer of wastes would continue at a similar frequency and using similar methods as during current operations. The transfer of wastes will decrease substantially in the Storage with Surveillance Phase. ▪ The potential for air emissions associated with resin handling may increase temporarily in the Stabilization Phase as systems are drained (Section 4.1.2.2.1). ▪ The overall emissions are expected to be less than current operational conditions in the Storage with Surveillance Phase.
Site Drainage and Waterborne Emissions					

Table 4-1: Summary of Stabilization and Storage with Surveillance Interactions – Atmospheric Environment

PN System, Structure or Activity	Atmospheric Environment				Discussion of Potential Interaction
	Noise		Air Quality		
	Stabilization	Surveillance	Stabilization	Surveillance	
Supporting Services and Activities ▪ East and West Annex Building ▪ Auxiliary Boiler ▪ Heavy Water Upgrading Plant ▪ East Complex	→	→	↓	↓	▪ Overall, operations of supporting systems will be terminated as they are no longer required and emissions reduced, although most do not have potential interactions with noise and air quality. ▪ Emergency signals may still occur to support necessary safety systems during the Stabilization and Storage with Surveillance activities. ▪ Emissions related to heating steam and the Auxiliary Boiler are noted above in Building Heating and Ventilation.

↓ = effects decreasing relative to current operational conditions.
↑ = effects potentially increasing relative to current operational conditions.
→ = no change to effects from or similar to current operational conditions.
* = interaction discussed in Tier 1 (all ↑'s are also discussed in Tier 1).
Blank = no potential interaction.

4.1.1 Noise

4.1.1.1 PN ERA Summary – Noise

Noise emissions from the PN Generating Station originate from various on-site sources as described in the PN ERA (EcoMetrix and Golder, 2017). The Acoustic Assessment Reports prepared for PN and the ECA issued by the Ontario Ministry of the Environment and Climate Change (MOECC) (OPG, 2011 and OPG, 2015a), demonstrate that PN operates in compliance within applicable MOECC noise limits.

Although there are periods of recorded maximum sound levels above the MOECC Class 1 and Class 2 sound-level limits (MOECC, 2013), site observations indicate these are unlikely to be directly associated with PN activities. These elevated sound levels are likely the result of localized events such as road traffic or human activity in the vicinity of the noise monitoring locations. It is common for noise levels in populated urban areas, such as near the PN Generating Station, to occasionally exceed the applicable prescribed sound-level limit. As these occasional periods of elevated sound levels are not likely associated with PN activities, it is not expected that noise from PN activities is having a direct adverse effect on human or ecological receptors near the PN Site.

4.1.1.2 Tier 1 Screening of Interactions – Noise

Stabilization and Storage with Surveillance activities are expected to result in a reduction or removal of most noise sources as the reactor units are shut down and facilities are transitioned to a safe storage state as presented in Section 3.0. For example, noise emissions are expected to decrease as the reactor and turbine operations are stopped and there is less activity overall at the PN Generating Station. As the overall noise is expected to be reduced, the current operations as assessed in the PN ERA (EcoMetrix and Golder, 2017) are determined to be bounding and no further assessment is required.

4.1.2 Air Quality

4.1.2.1 PN ERA Summary – Air Quality

Existing air quality emissions have been quantified in the PN ERA and the ECA, including the Emission Summary and Dispersion Modelling (ESDM) report (OPG, 2015b). Non-radiological emissions from the PN Generating Station are reported as part of ECA reporting to the MOECC, along with the supporting ESDM report that was prepared to support the application for the ECA. All contaminants of potential concern assessed met the screening criteria (Point of Impingement [POI] limits).

Radiological atmospheric emissions of tritium, carbon-14, particulates, noble gases and radioiodine are presented in the annual EMP reports as one of the pathways considered for calculation of exposure of receptors (critical group) to contaminants of potential concern. Radiological dose calculations from 2011 to 2015 for the annual EMP followed the methodology outlined in CSA N288.1-08 (CSA, 2008). The annual dose to the critical group (the urban resident adult) during this 5-year period ranged from 0.9 to 1.2 microseivert (µSv), which is approximately 0.1% of the regulatory public dose limit of 1 milliseivert per annum (mSv/a), and approximately 0.1% of the dose due to Canadian background radiation. The dominant pathways and radionuclides that contribute substantially to the total dose are inhalation of tritium and external exposure to noble gases. Since the critical groups receive the highest dose from PN, the demonstration that they are protected implies that other human receptor groups near PN are also protected (EcoMetrix and Golder, 2017).

4.1.2.2 Tier 1 Screening of Interactions – Air Quality

As summarized in Table 4-1, several Stabilization and Storage with Surveillance activities have the potential to interact with air quality, with most sources of emissions expected to be reduced as the reactor units are shut down. In general, the airborne radioactive emissions will decrease during the Stabilization Phase as units are permanently removed from service and will be further reduced in the Storage with Surveillance Phase. Gaseous emissions from potentially active areas will continue to be monitored for radioactivity until demonstrated that this monitoring is no longer required.

The Stabilization Phase is evaluated to assess whether the emissions from planned activities are bound by current operational conditions. The Storage with Surveillance Phase is assumed to be bound by current operational conditions; however, it is discussed as the radionuclide emissions during this phase are considered of public interest and are included in the Tier 2 assessment.

In general, the non-radiological emissions will gradually decrease during the Stabilization Phase. Changes to the use and operation of the on-site combustion generators, steam generating boilers for electricity production and the heating steam boilers are the only emission sources with the potential to change emissions notably, and are discussed further below. No other substantial changes to non-radiological atmospheric emission sources are anticipated. During the Storage with Surveillance Phase, emissions will be further reduced.

During normal operations, boiler chemicals including hydrazine and morpholine are used within the feedwater system to prevent corrosion in boilers. The heat transport system generates heat to produce steam to drive the turbines, resulting in controlled atmospheric emissions of boiler chemicals through steam venting. During the Stabilization Phase, the use of boiler chemicals will be reduced as units cease production of heat; therefore, current operational conditions are bounding. No boiler chemicals are proposed for use during the Storage with Surveillance Phase; however, minimal use of boiler chemicals for heating steam boilers would also be considered bound by current operational conditions.

Those changes identified in Table 4-1 as having the potential to increase air emissions relative to current operations are discussed below to evaluate whether further assessment is required. In addition to the operational changes discussed, there are two other changes that are considered to warrant discussion. First, OPG has been given notice of changes proposed to Ontario Regulation 419/05 (O. Reg. 419/05) that may come into force during the course of the Stabilization or Storage with Surveillance activities. The implications of this change are discussed, as well as a summary evaluation. Second, OPG may lease some office buildings at PN during the Storage with Surveillance Phase. This decision could cause a future non-OPG industrial/commercial worker to be the closest receptor to the PN facility, and a new receptor closer than assessed in the PN ERA. The potential effect of this change is also discussed.

4.1.2.2.1 Reactor Building Systems, RAB, IFB/AIFB and Waste Management

Several changes to radioactive atmospheric emissions during the Stabilization and Storage with Surveillance Phases are discussed below in relation to the Reactor Building systems, RAB and IFB/AIFB, and Waste Management.

Stabilization

During the Stabilization Phase, similar to current operations and under normal circumstances, handling of resins and other solid and liquid wastes may result in emissions of radionuclides through venting to the atmosphere.

These are currently and will remain monitored release pathways. Under normal circumstances the atmospheric emissions due to material handling are an insignificant portion of the operational emissions and are bound by current operational conditions.

The draining and drying of the heavy water systems is unique to the Stabilization Phase and is evaluated to determine the potential for emissions beyond the current operational conditions. The Stabilization Phase requires draining and flushing of the moderator systems, and draining and vacuum drying of the heat transport systems as described in Section 3.1. Temporary increases in atmospheric emissions may be experienced while carrying out dewatering activities; however, based on PN U2 and U3 experience, these levels are expected to be below operating levels. Heavy water recovery dryers will be in service to minimize atmospheric emissions during all draining, flushing and drying activities. Reactor Building atmospheric emissions will be subject to filtration and ongoing monitoring throughout the Stabilization Phase.

Experience from reactor dewatering of PN U2 and U3 can be used to demonstrate the expected decrease in emissions. PN U2 and U3 were shut down at the end of 1997. In 2008, following a decision not to return these units to service, PN U2 and U3 were defuelled and they are currently in safe storage. From December 2008 through December 2009, the period when draining, flushing and drying occurred, airborne tritium emissions data were collected and were several times less than normal operations for PN U1 and U4, as shown in Figure 4-1. OPG’s expectation is that carbon-14 and other radionuclides would show a similar, and likely further reduced pattern.

The data demonstrates that tritium emissions from PN U2 and U3 during dewatering and drying activities were substantially lower compared to operational units. This suggests that a similar decrease in radioactive emissions (i.e., tritium and other potential radionuclide emissions such as noble gases, particulate, radioiodine and carbon-14) from the current operational conditions can be expected during the draining, flushing and drying process. A substantial decrease in radioactive atmospheric emissions can be expected when this activity is completed for each unit during the Stabilization Phase. In addition to this evaluation, OPG will use lessons learned from PN U2 and U3 to ensure emissions are minimized and managed to the As Low as Reasonably Achievable (ALARA) principle. Based on the monitoring data available to date and the discussion above, this emission source is considered bound by current operational conditions and does not warrant further evaluation in the PEA.

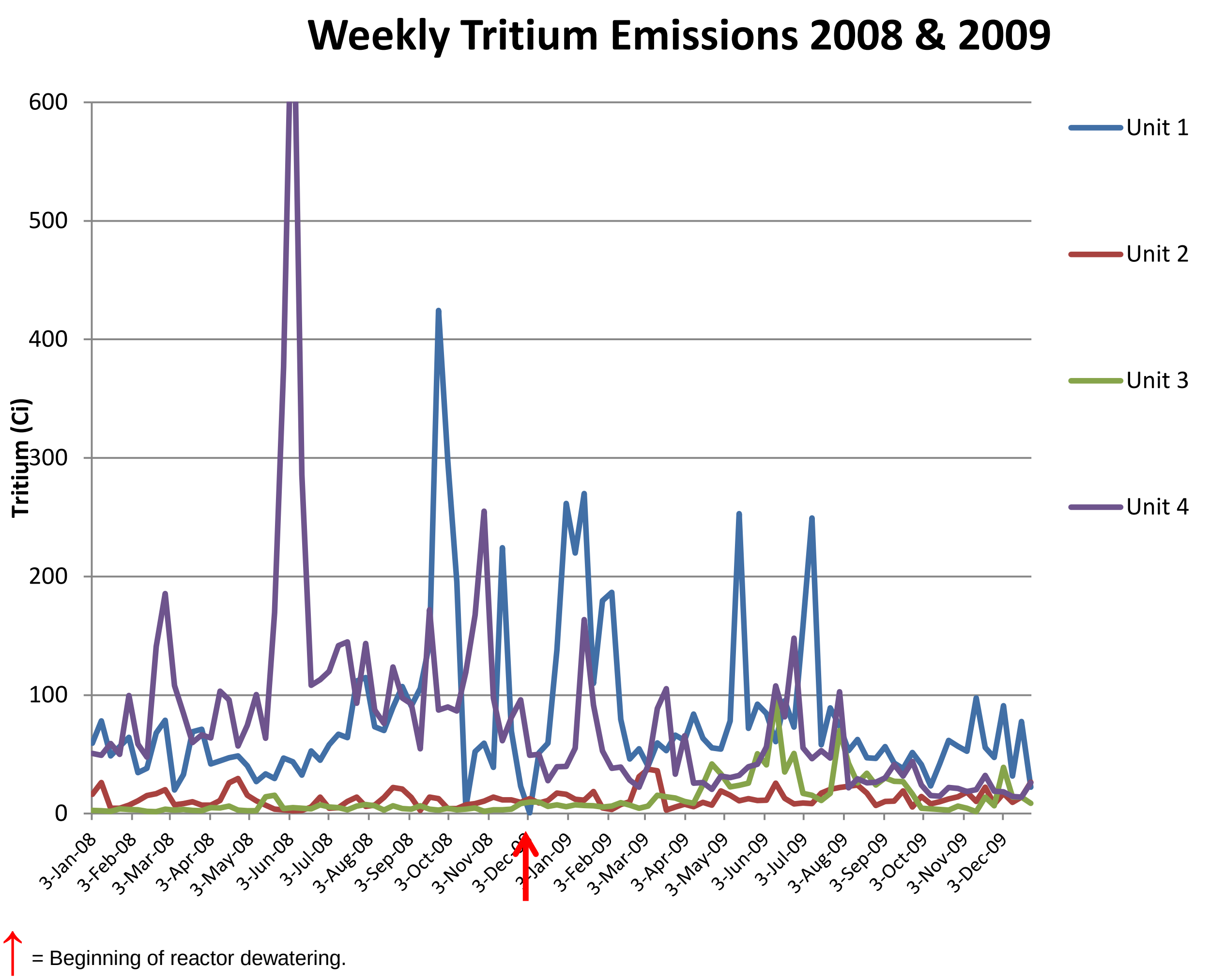


Figure 4-1: Weekly Atmospheric Tritium Emissions from December 2008 through December 2009 for PN U1-4

Storage with Surveillance

Although the operational footprint of the PN Generating Station will be substantially reduced in the Storage with Surveillance Phase, radiological airborne emissions will continued to be released, albeit to a lesser extent as source terms are eliminated as a result of reactor shutdown and stabilization activities. Sources of potential tritium releases include ongoing operation of the IFBs, the continued storage of tritiated heavy water, and the ventilation of buildings that may have some residual tritium. There are no new sources of carbon-14 emissions on the site, however, there may be some residual sources that could result in low-level releases, depending on the ventilation demands during the Storage with Surveillance Phase.

For the current PN operations, radioactive airborne emissions are monitored for tritium, carbon-14, particulates, noble gases and radioiodine. A description of the various sources of these radionuclides from the existing operations is provided in the PN ERA (PN ERA Section 2.2.2.1.4). The Storage with Surveillance Phase is considered generally bound by current operational conditions for radioactive atmospheric emissions; however, low level tritium and carbon-14 emissions are expected due to possible residual sources and therefore release estimates were determined for use in dose calculations (Tier 2 assessment). Airborne particulates, noble gases and radioiodine emissions are not assessed as their sources terms are either minor or will be eliminated as described below.

- Radioactive particulates are formed as products of fission reactions or by neutron absorption in various materials. The release of particulates originates from the fuel bundles or from corrosion of system components. With the removal of the fuel, and with limited maintenance activities anticipated in the Reactor Buildings, major sources and generation of particulates will be virtually removed. Historical measurement of particulates in the PN U2 and U3 Reactor Building indicates that the emissions are largely based on detection limits of the stack monitors. Purification of the IFB water through filters and ion exchange columns will minimize atmospheric emissions. Release to the environment will be further reduced by the use of high-efficiency particulate absorber (HEPA) filters in the ventilation exhaust stacks.
- Radioactive noble gases are a product of fission reactions and can also be released to the heat transport system if a small defect occurs in a fuel element seal. Once the units are defuelled, the primary source term will be eliminated from the Reactor Buildings, but could be a minor source in the IFBs. Noble gas monitoring at the IFBs demonstrates that noble gas emissions are typically at detection limits. Argon-41, a noble gas, can be released in the Reactor Building ventilation due to leaks and purges from the annulus gas system and various cover gas systems during normal operation; however, activation of atmospheric argon is improbable once the units are shut down and these systems are no longer operational.
- Radioiodine is a product of fission reactions that is usually contained within the sealed fuel bundle elements. Gaseous radioiodine may escape into the heat transport system if a small defect occurs in a fuel element seal. Once the units are defuelled, the primary source term will be eliminated from the Reactor Buildings, but radioiodine may continue to be a minor airborne source in the IFBs. Purification of the IFB water through filters and ion exchange columns will minimize atmospheric emissions. Reported atmospheric radioiodine emissions from the IFBs are often a sum of the detection limits. Release to the environment is further reduced by the use of carbon filters in the ventilation exhaust stacks.

Based on removal of various atmospheric emission sources, estimates of tritium and carbon-14 emissions were predicted to decrease during the Storage with Surveillance Phase. The tritium and carbon-14 emission rates were estimated based on remaining sources and on historical data (average emissions) from 2010 to 2015. To ensure the estimates are conservative, for some of the systems described below a percentage of the existing emissions was assigned based on the understanding of the extent to which the station will be operated. The calculation of tritium atmospheric emissions was conducted with the following assumptions.

- Reactor Building emissions are based on PN U3 emissions as this unit has higher emissions than PN U2. It is recognized that tritium levels in the PN U1, U4 and U5-8 moderator systems may be higher when the units are shut down than currently found in PN U3. However, operating experience from the safe storage activities of PN U2 and U3 will be fully utilized in the planning and executing of draining and drying reactor systems in order to ensure future atmospheric emissions are minimized in the Storage with Surveillance Phase. In planning and executing Stabilization activities, emphasis will be placed on removal of residual water from the remaining operating units in order to minimize remaining source terms, thereby minimizing future emissions.

- IFB and AIFB emissions are assumed to be as in the current operational conditions. This is a conservative assumption as levels of radionuclides are expected to gradually decrease.
- PN U1-4 Service Wing, upgraders, East and West Annex, Pickering Incoming/Outgoing Heavy Water Transfer System, Service Wing Chemistry Lab, heavy water storage, Tritium Off-gas Facility/Laundry are all assumed to have emissions at 30% of the current operational conditions. The overall reduction is based on the removal of current sources such as fuelling machine maintenance activities, heavy water processing (ion exchange, upgrading, etc.), and an assumption of an overall reduction in operations across those areas of the facility.
- The Sulzers are not expected to be operational in the Storage with Surveillance Phase. The emissions are assumed to be the same as the current operational condition for Sulzer A.
- PN U5-8 Service Wing is assumed to have emissions at 50% of the current operational conditions as some ongoing decontamination may occur at this area.

The calculation of carbon-14 atmospheric emissions was conducted with the following assumptions:

- Reactor Building emissions are based on PN U3 emissions as this unit has higher emissions than PN U2; and,
- Current practices will continue to be used to capture carbon-14 emissions during the transfer of spent resins from the in-station storage tanks to the flask used for off-site transport.

Based on the assumptions above, it is estimated that there will be an overall tritium emission of 1.77×10^{14} Bq/year during the Storage with Surveillance Phase compared to a current emission of 5.2×10^{14} Bq/year. Similarly, carbon-14 emissions are predicted to be no more than 2.96×10^{10} Bq/year compared to a current emission of 2.0×10^{12} Bq/year. The estimate is provided in more detail in Table 4-2.

The Storage with Surveillance radioactive emissions are predicted to be substantially less than current operations and the assumptions above are considered conservative. The emission sources and pathways are well understood today, and they will continue to be monitored and routinely reported on an ongoing basis until it can be demonstrated that monitoring is no longer required.

As residual radionuclide emissions are considered of public interest, predicted radiological atmospheric emissions from the Storage with Surveillance Phase have been evaluated in the Tier 2 assessment for the purpose of assessing overall dose (see Sections 6.0 and 7.0).

Table 4-2: Predicted Atmospheric Emissions - Storage with Surveillance

Virtual Source	Tritium Yearly Emission (Bq)	Carbon-14 Yearly Emission (Bq)
PN U1-4	8.05×10^{13} (a)	1.48×10^{10} (c)
PN U5-8	9.64×10^{13} (b)	1.48×10^{10} (c)
Total	**1.77×10^{14}**	**2.96×10^{10}**

Notes:

a) Includes atmospheric tritium emissions from the U1-4 Reactor Buildings, IFB, Upgrading Plant Pickering, Service Wing, Sulzer, and West Annex, Heavy Water Storage, and Tritium Off-Gas Facility

b) Includes atmospheric tritium emissions from the U5-8 Reactor Buildings, IFB, Upgrading Plant Pickering, Service Wing, Sulzer, and East Annex, and Service Wing Chemistry Lab

c) Includes atmospheric carbon-14 emissions from the U1-4 and U5-8 Reactor Buildings

4.1.2.2.2 Building Heating and Ventilation

As the powerhouse heating steam will become unavailable once all reactor units have been shut down, an alternate building heating supply will be required during the Stabilization and Storage with Surveillance Phases. Steam will also be required for the upgrading facilities (Sulzer and UPP) during the Stabilization Phase. The bounding scenario for non-radiological emissions during this phase is to assume that an auxiliary boiler powered by fuel oil will provide the alternative heating supply. For the purposes of this assessment, it was assumed that the existing Auxiliary Boiler on-site would be utilized, supplemented by an additional heating steam boiler. These boilers are assumed to be running continually during the heating season. Atmospheric emissions related to combustion products and boiler compounds are evaluated.

In the Storage with Surveillance Phase, it is assumed that the heating demand could be met by the steam from a single boiler: either the existing Auxiliary Boiler or the new additional heating steam boiler used during the Stabilization Phase. The Stabilization Phase is considered to bound the Storage with Surveillance Phase as only one heating steam boiler is needed for the latter phase. Therefore, only the Stabilization Phase is evaluated further below.

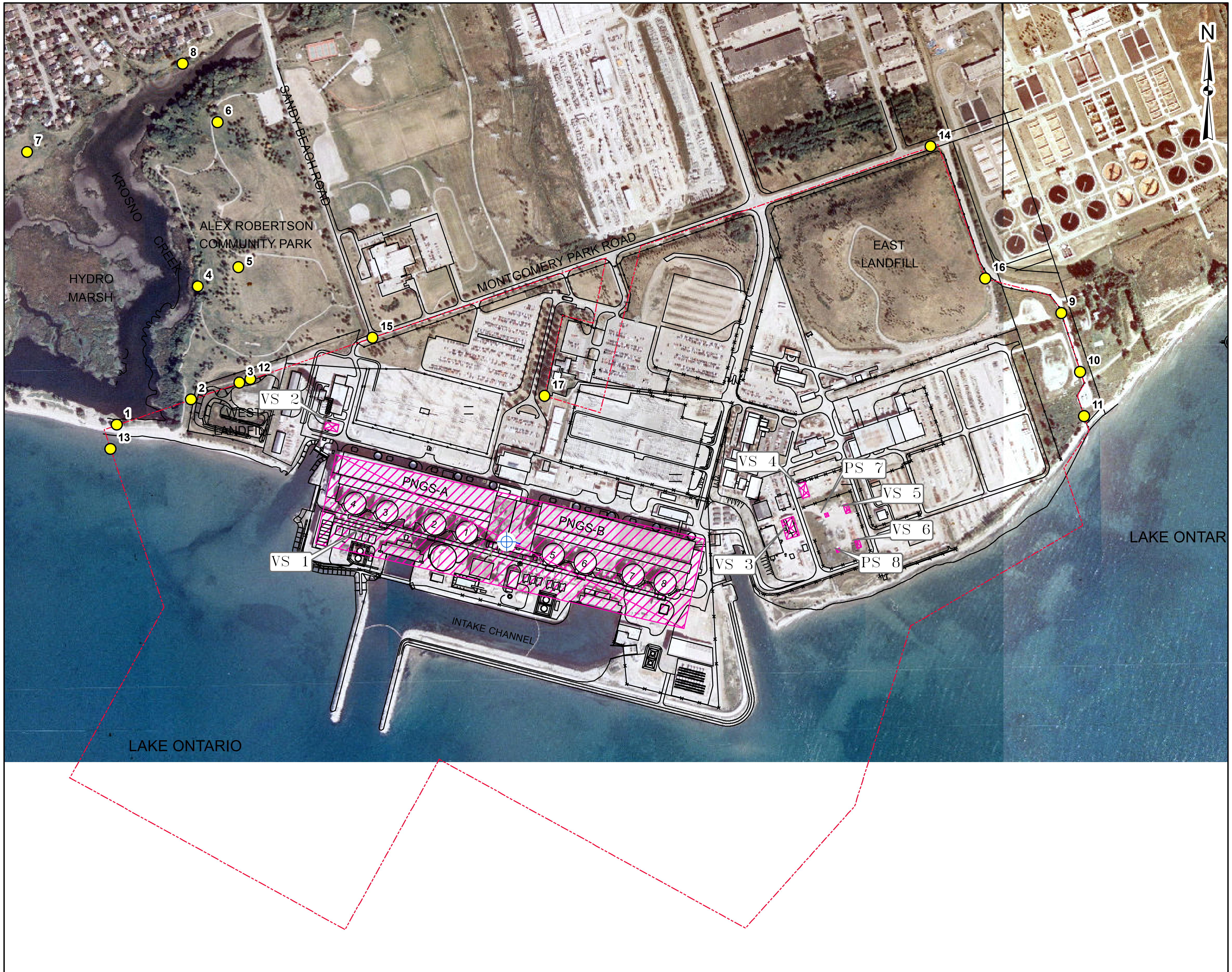
Combustion Products

The existing Auxiliary Boiler has a steam output of approximately 21,340 kilograms per hour (kg/h - 47,000 pounds per hour [lbs/h]), and the additional proposed boiler is assumed to have a capacity of up to 34,050 kg/h (75,000 lbs/h). As a bounding condition it is assumed that both would be supplied by fuel oil. The location of the additional boiler is not known at this time. This is not considered a limitation if the boiler is within the area indicated as the virtual source in Figure 4-2, as sources in this area are included in the ESDM calculations noted below. The contaminants of potential concern for the additional boiler, supplied by fuel oil, include nitrogen oxides, sulphur dioxide, carbon monoxide, and particulate matter.

Table 4-3 identifies the sources of the fuel-related contaminants assessed in the 2015 ESDM report (OPG, 2015b), demonstrating each source's emission rate, as well as each source's contribution to the total facility-wide emission rate for the two maximum emission scenarios. The existing Auxiliary Boiler that is expected to operate during the Stabilization and Storage with Surveillance Phases (listed in Table 4-3 as third Source Description) is shown to be a relatively small contributor to the total facility-wide emission rates of contaminants of potential concern when compared to other sources that were assessed under simultaneous operation in the ESDM report's maximum emission scenarios. The two scenarios considered in the ESDM report are hypothetical and designed to calculate the maximum allowable (i.e., limiting) equipment for an operational scenario.

- Scenario 1 was designed to show the allowable operating equipment to maintain nitrogen oxides within the provincial limit. This scenario considers one standby generator operating on PN U1-4, two standby generators running on PN U5-8, and other base operations.
- Scenario 2 was designed to assess emission of total hydrocarbons, which have no provincial limit, but do have a previously approved limit under the provincial air-permitting program for the PN operations. This scenario considered two standby generators operating on PN U5-8, the Auxiliary Power System generator, and base operations.

The scenarios were specifically designed to allow for the maximum operations within the limits of O. Reg. 419/05, and the PN Generating Station ECA for Air and Noise at the current time. The applicable O. Reg. 419/05 standards are the Schedule 2 *Updated Standards with Half Hour Averaging Periods* (Schedule 2) limits. These limits are considered applicable for the PN Generating Station as Section 19 of O. Reg. 419/05 is expected to apply until 2020. The Schedule 2 limits are based on human health, environmental or nuisance effects (e.g., particulate or odour). Emissions below these limits are not considered to have the potential to cause adverse effects on ambient air quality and therefore the Schedule 2 limits are considered adequate for screening risk. The changes that are expected to apply in 2020 and their effect on the screening is discussed in Section 4.1.2.2.4.



Legend

- Boundary for Dispersion Modelling
- Virtual Source
- Virtual Source Centre
- Receptors

VS - virtual source
PS - point source

Receptor ID	Easting	Northing
1	654703	4852547
2	654854	4852599
3	654953	4852633
4	654868	4852829
5	654951	4852868
6	654908	4853164
7	654521	4853103
8	654837	4853283
9	656626	4852775
10	656664	4852655
11	656672	4852565
12	654975	4852640
13	654690	4852498
14	656360	4853114
15	655224	4852725
16	656471	4852845
17	655574	4852606

REFERENCE

Drawing Source: OPG 2015b

Golder Aerial image from Triathlon Mapping Corporation (TMC)

PROJECT
Pickering Safe Storage Predictive Effects Assessment

TITLE
Emission Summary Dispersion Model Source and Receptor Locations

Golder Associates
Sudbury, Ontario

PROJECT No. 11-1192-0005			SCALE AS SHOWN	REV. 0
DESIGN	RRD	25 Nov. 2009		
GIS	RRD	May 2011		
CHECK	RLP	May 2011		
REVIEW	SFC	May 2011		

FIGURE:4-2

Table 4-3: Summary of Modelled Emission Rates for Fuel Combustion Contaminants of Potential Concern

Source Description	Contaminant	Emission Rate – Scenario 1[(a)] (g/s)	Emission Rate – Scenario 2[(b)] (g/s)	Averaging Period (hours)	Percentage of Overall Modelled Emissions – Scenario 1 (%)	Percentage of Overall Modelled Emissions – Scenario 2 (%)
Six Standby Gas Turbine Generating Sets – PN U1-4	Nitrogen Oxides	1.23×10^{1}	0	½	23%	—
	Carbon Monoxide	4.62×10^{-2}	0	½	<1%	—
	Sulphur Dioxide	7.07×10^{0}	0	½	21%	—
	Particulate Matter	1.68×10^{-1}	0	½	18%	—
Six Standby Gas Turbine Generating Sets – PN U5-8	Nitrogen Oxides	3.77×10^{1}	3.77×10^{1}	½	71%	44%
	Carbon Monoxide	1.41×10^{-1}	1.41×10^{-1}	½	<1%	<1%
	Sulphur Dioxide	2.17×10^{1}	2.17×10^{1}	½	65%	51%
	Particulate Matter	5.15×10^{-1}	5.15×10^{-1}	½	54%	1%
Auxiliary Boiler	Nitrogen Oxides	1.39×10^{0}	1.39×10^{0}	½	3%	2%
	Carbon Monoxide	2.89×10^{-1}	2.89×10^{-1}	½	2%	1%
	Sulphur Dioxide	4.54×10^{0}	4.54×10^{0}	½	14%	11%
	Particulate Matter	1.16×10^{-1}	1.16×10^{-1}	½	12%	<1%
Exhaust Extraction System Work Area Exhaust Battery Room Exhaust Oil Storage Area Exhaust	Nitrogen Oxides	4.60×10^{-2}	4.60×10^{-2}	½	<1%	<1%
	Carbon Monoxide	1.60×10^{-1}	1.60×10^{-1}	½	1%	<1%
	Particulate Matter	1.20×10^{-2}	1.20×10^{-2}	½	1%	<1%
Carpentry Shop Baghouse	Particulate Matter	3.97×10^{-2}	3.97×10^{-2}	½	4%	<1%
Site-wide Bottled Gas Releases	Carbon Monoxide	1.14×10^{-5}	1.14×10^{-5}	½	<1%	<1%

Table 4-3: Summary of Modelled Emission Rates for Fuel Combustion Contaminants of Potential Concern

Source Description	Contaminant	Emission Rate – Scenario 1[(a)] (g/s)	Emission Rate – Scenario 2[(b)] (g/s)	Averaging Period (hours)	Percentage of Overall Modelled Emissions – Scenario 1 (%)	Percentage of Overall Modelled Emissions – Scenario 2 (%)
Mobile Small Combustion Sources	Nitrogen Oxides	1.33×10^{0}	1.33×10^{0}	½	3%	2%
	Carbon Monoxide	1.41×10^{1}	1.41×10^{1}	½	95%	57%
	Sulphur Dioxide	8.34×10^{-2}	8.34×10^{-2}	½	<1%	<1%
	Particulate Matter	9.22×10^{-2}	9.22×10^{-2}	½	10%	<1%
East Complex Garage	Nitrogen Oxides	4.40×10^{-2}	4.40×10^{-2}	½	<1%	<1%
	Carbon Monoxide	1.20×10^{-1}	1.20×10^{-1}	½	<1%	<1%
	Particulate Matter	1.20×10^{-2}	1.20×10^{-2}	½	1%	<1%
Two 57 MW Combustion Turbine Units w/ Associated Generators – Auxiliary Power System	Nitrogen Oxides	0	4.23×10^{1}	½	—	50%
	Carbon Monoxide	0	9.85×10^{0}	½	—	40%
	Sulphur Dioxide	0	1.51×10^{1}	½	—	36%
	Particulate Matter	0	3.96×10^{1}	½	—	98%
Two Auxiliary Diesel Generators	Nitrogen Oxides	0	2.37×10^{0}	½	—	3%
	Carbon Monoxide	0	8.53×10^{-2}	½	—	<1%
	Sulphur Dioxide	0	6.85×10^{-1}	½	—	2%
	Particulate Matter	0	2.36×10^{-2}	½	—	<1%

Notes:

a) Maximum Emission Scenario 1: One Standby Gas Turbine Generating Set – U1-4, two Standby Gas Turbine Generating Sets – U5-8 Side, Base Case sources.

b) Maximum Emission Scenario 2: Two Standby Gas Turbine Generating Sets – U5-8, One 57 MW Combustion Turbine with Associated Generator, Base Case sources.

g/s = grams per second.

Table 4-4 was used to evaluate the Stabilization Phase bounding scenario of the additional heating steam boiler. This table presents the percent increase in the emission rates of combustion-related contaminants of potential concern from the additional heating steam boiler to the emission scenarios assessed in the ESDM report. The additional boiler contribution to the ESDM emission rate values are then added to each scenario's predicted POI concentrations to allow for comparison to Schedule 2 standards. For example, the total carbon monoxide for Scenario 1 (Table 4-4) has calculated emissions of 0.434 grams per second (g/s) based on the assumption of a direct correlation of the rate of emission from the existing Auxiliary Boiler and the proposed additional boiler. This 0.434 g/s is calculated as 3% in addition to the total current emissions. The current facility-wide POI concentration for carbon monoxide of 145 µg/m^3 (from the ESDM report) was then increased by an additional 3% to predict a bounding POI concentration of 149 µg/m^3. This is compared to the Schedule 2 standard of 6,000 µg/m^3**.** As shown below, all future emissions of contaminants of potential concern are predicted to be within limits (i.e., less than Schedule 2 values). Although the POIs are for a half-hour period, they would not be changed as the result of running the boilers for 24 hours and the ESDM based on these POIs are considered protective of human health and the environment.

There are limitations to the prediction shown in Table 4-4. In particular, a direct correlation has been made between an emission rate and final POI concentrations. This is considered to be a reasonable assumption given that most emission sources are modelled as one large virtual source in the ESDM. This prediction assumes the future/additional boiler is at a location similar to the existing boiler or within the limits of the virtual source. The ESDM model has not been re-run for the prediction; however, the prediction is still considered conservative as standby generators and other equipment will be removed from service during the course of the Stabilization Phase. There is additional conservatism in that the ESDM report assumes that all equipment included in the modelled scenarios are operating simultaneously and at full capacity, and the scenarios are hypothetical to show maximum allowable conditions.

As part of the Stabilization and then Storage with Surveillance activities, the ECA will be updated to demonstrate ongoing compliance with O. Reg. 419/05. The modelled emission of the day will confirm the absence of adverse effects prior to the change being made at the PN Generating Station.

For consistency with the benchmarks in the PN ERA, the POI concentrations were also compared to the Ambient Air Quality Criteria (AAQC) (MOE, 2012) and this is shown in Table 4-5. The half-hour (½ hr) POI concentrations were converted to concentrations with averaging times comparable to the relevant AAQCs using the following formula:

$$\frac{1}{2}\ hr\ POI\ Concentration\ (\frac{\mu g}{m^3}) \times (t_0 \div t_1)^n$$

Where,

t_0 = the shorter of, i) the averaging period for which the approved dispersion model was designed to be used for, expressed in hours, and ii) the specified averaging period, expressed in hours,

t_1 = the longer of, i) the averaging period for which the approved dispersion model was designed to be used for, expressed in hours, and ii) the specified averaging period, expressed in hours,

n = 0.28

The AAQCs are developed to be protective of health and the environment. All POI concentrations for nitrogen oxides, carbon monoxide, sulphur dioxide and particulate matter are below their applicable AAQCs and are not likely to have potential effects on human and ecological receptors located at the property line during the Stabilization and Storage with Surveillance Phases.

Boiler Compounds

No chemicals are currently used in the existing Auxiliary Boiler (OPG, 2016a). The specific chemistry control requirements for the additional heating steam boiler are not available at this time. Similar to the existing Auxiliary Boiler, demineralized water could be used or chemicals such as the ones used for the Darlington Nuclear Generating Station heating steam boiler could be added for treatment. It is assumed that boiler water in the future may contain the treatment chemicals: GE water MCA4288 (comprised of sodium sulfite, sodium hydroxide, sodium carbonate, and diethylaminoethanol) and GE water MCM4280 (comprised of sodium hydroxide, sodium molybdate, and sodium tripolyphosphate). These compounds may be emitted as steam, however, the ECA for the Darlington Nuclear Generating Station indicates this emission is considered insignificant (OPG, 2014a). Based on this assessment, which represents PN in a general sense, these potential contaminants of potential concern are not considered further. No chemicals are currently used in the existing stand-by boiler.

Table 4-4: Comparison of Emission Rates of Contaminants of Potential Concern during Stabilization to ESDM Report Emission Scenarios

Emission Scenario	Emission Source(s)	Contaminant Emission Rates (g/s)			
		Nitrogen Oxides	**Carbon Monoxide**	**Sulphur Dioxide**	**Particulate Matter**
Stabilization Assumption	Existing Auxiliary Boiler [Source ID5; 22,700 kg/h (50,000 lb/h)]	1.39×10^{0}	2.89×10^{-1}	4.54×10^{0}	1.16×10^{-1}
	Additional Steam Boiler 34,050 kg/h (75,000 lb/h)	2.09×10^{0}	4.34×10^{-1}	6.81×10^{0}	1.74×10^{-1}
ESDM Max Emission Scenario 1	Total Facility-Wide	5.28×10^{1}	1.49×10^{1}	3.34×10^{1}	9.55×10^{-1}
ESDM Max Emission Scenario 2	Total Facility-Wide	8.52×10^{1}	2.47×10^{1}	4.21×10^{1}	4.04×10^{1}
% addition of new boiler to ESDM Scenario 1		4%	3%	20%	18%
% addition of new boiler to ESDM Scenario 2		2%	2%	16%	0.4%
Emission Scenario and Comparison to Standard		**Modelled/Predicted Contaminant Emission Concentration (μg/m³)**			
		Nitrogen Oxides	**Carbon Monoxide**	**Sulphur Dioxide**	**Particulate Matter**
Current ESDM Emission POI Concentration (Scenario 1)		478	145	333	9.6
Estimated (pro-rated) Scenario 1 POI Concentration		497	149	401	11
Schedule 2 Standard		**500**	**6,000**	**830**	**100**
Current ESDM Emission POI Concentration (Scenario 2)		371	145	265	24
Estimated (pro-rated) Scenario 2 POI Concentration		380	148	308	24
Schedule 2 Standard		**500**	**6,000**	**830**	**100**

ESDM = Emission Summary and Dispersion Modelling; POI = Point of Impingement; g/s = grams per second; kg/h = kilogram per hour; lb/h = pound per hour; μg/m³ = microgram per cubic metre.

Table 4-5: Comparison of Point of Impingement Concentrations to Ambient Air Quality Criteria

Emission Scenario and Comparison to AAQC	Modelled/Predicted Contaminant Emission Concentration ($\mu g/m^3$)							
	Nitrogen Oxides		Carbon Monoxide		Sulphur Dioxide		Particulate Matter (<44 µm)	
Averaging Time	½ hr	24 hr	½ hr	8 hr	½ hr	Annual	½ hr	24 hr
Current ESDM Emission POI Concentration (Scenario 1)	478	162	145	67	333	22	9.6	3.2
Estimated (pro-rated) Scenario 1 POI Concentration	497	168	149	69	401	26	11	3.7
Current ESDM Emission POI Concentration (Scenario 2)	371	125	145	67	265	17	24	8.1
Estimated (pro-rated) Scenario 2 POI Concentration	380	129	148	68	308	20	24	8.1
AAQC	-	200 (health)	-	15,700 (health)	-	55 (health and vegetation)	-	120 (visibility)

AAQC = Ambient Air Quality Criteria; ESDM = Emission Summary and Dispersion Modelling; POI = Point of Impingement; hr = hour; µm = micrometre; $\mu g/m^3$ = microgram per cubic metre.

4.1.2.2.3 Engineering Services Buildings and/or Pickering Nuclear Information Centre

As noted in Section 3.0, there is a potential for OPG to lease the Engineering Services Buildings and Pickering Nuclear Information Centre to non-OPG industrial/commercial businesses during the Storage with Surveillance Phase. As a result, the nearest human receptor(s) present would be a future industrial/commercial worker leasing this space. A repurposing study was conducted by OPG and the results are summarized in a report (OPG, 2016b). The repurposing report divided the OPG-owned lands associated with the PN Site into several zones as shown on Figure 4-3. Of these zones, it was determined that Zones 3, 4 and 5 have a high repurposing potential within the timeframe of this assessment (i.e., within 13 years of the end of PN operations). Reuse of Zones 6, 7 and 8 was not considered practical at this time and are not considered further in the PEA report.

Reuse of the Engineering Services Buildings and Pickering Nuclear Information Centre is within Zone 4 and use or either Zones 3, 4 or 5 represents a potential public access closer than in the current operations. As such, a public use closer to the PN Generating Station than the current operations was considered a bounding condition and is considered in greater detail below.

The potential receptor locations for Zones 3, 4 and 5 were compared to the current ESDM report calculations (OPG, 2015b) to evaluate risk. The ESDM evaluated receptors and sources including Receptor ID 17 (Figure 4-2) which is considered to adequately assess the reuse of the Engineering Services Buildings and Pickering Nuclear Information Centre in the Storage with Surveillance Phase. The ESDM report demonstrated that there were no potential adverse effects at any of the receptor locations and therefore the ESDM calculations are considered protective of the public given the potential repurposing in this area. Similarly, ESDM calculations for Receptor IDs 15 and 17, and to some degree Receptor ID 14, are considered to be protective of re-use in Zones 3 and 5. As noted above, the ESDM report ensures releases are within limits that protect human health and the environment and therefore further assessment is not warranted.

Dose from radioactive atmospheric emissions to the closest potential future industrial/commercial worker (i.e., at the Engineering Services Buildings) is evaluated in Section 6.0 for the Storage with Surveillance Phase to assess overall potential dose to a member of the public.

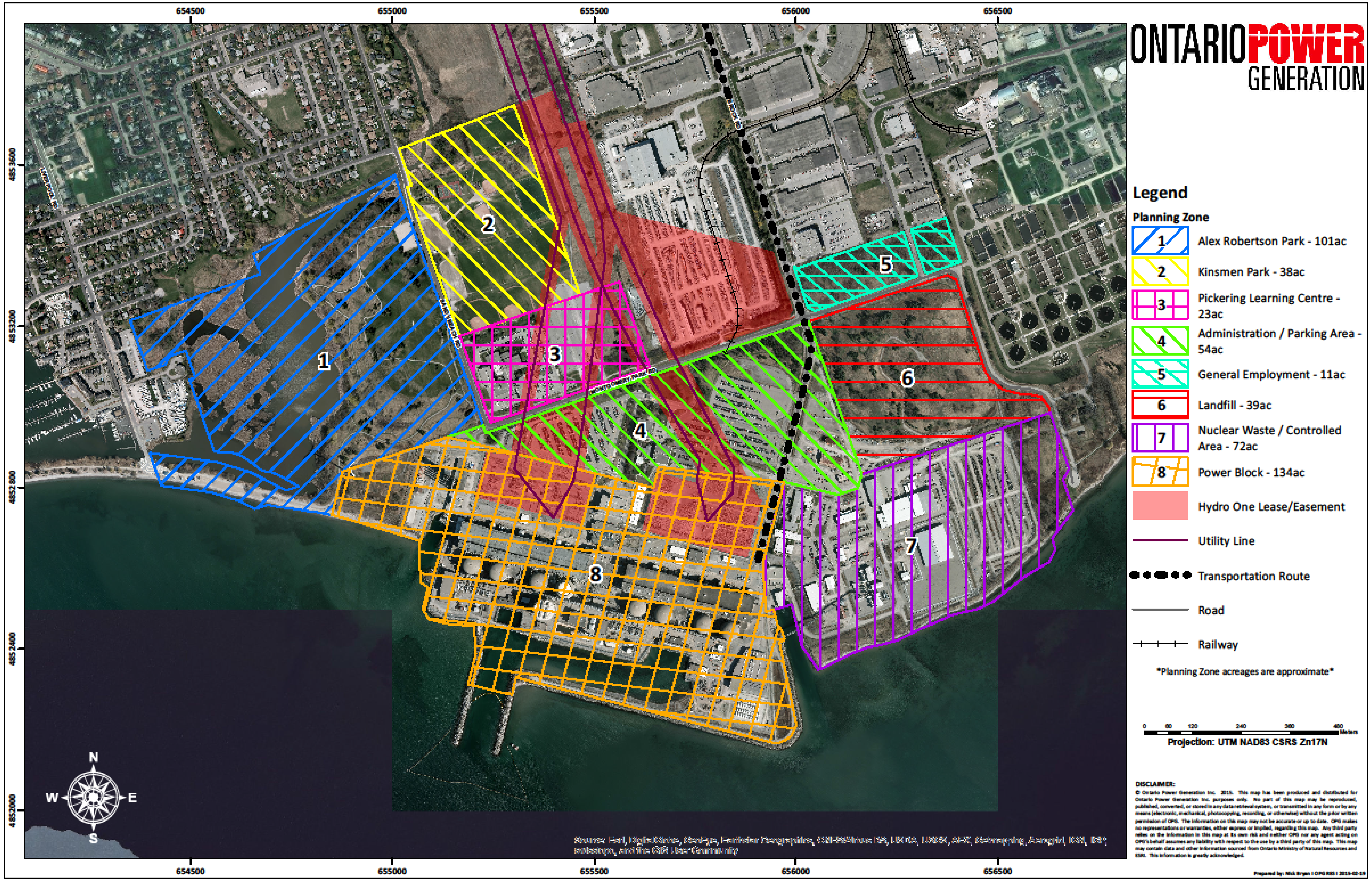


Figure 4-3: Planning Zones Defined for the Pickering Repurposing Land Use Assessment (OPG, 2016b)

4.1.2.2.4 Phase-in of O. Reg. 419/05 Schedule 3 Air Quality Standards

As described in 4.1.2.2.2, the PN Generating Station is required to meet the air quality standards as stated in O. Reg. 419/05. The compliance with a MOECC approved ECA for air and noise for the facility, as part of O. Reg. 419/05 compliance, confirms the protection of human health and the environment. The regulatory requirements for the PN Generating Station are expected to change in 2020. These regulatory changes are discussed qualitatively in this section in the context of the predictions made in Section 4.1.2.2.2.

O. Reg. 419/05 outlines the documentation and dispersion modelling requirements to demonstrate compliance through an ESDM report. Section 19 of O. Reg. 419/05 applies to the use of models and allows for the use of Schedule 2 limits in the facility's ESDM report; however, these limits will only apply to the facility until February 1, 2020, at which time Section 20 of O. Reg. 419/05 will apply and the requirement to use more advanced dispersion models (e.g., American Meteorological Society/Environmental Protection Agency Regulatory Model [AERMOD] or SCREEN3) and Schedule 3 standards will be phased-in for all facilities, regardless of the North American Industry Classification System (NAICS) code for the facility.

This 2020 phase-in date for O. Reg. 419/05 Schedule 3 Air Standards for the Facility is expected to occur before the beginning of the Stabilization Phase. The two main changes in the 2020 update are the use of limits with varying averaging periods (i.e., 1 hour or 24 hour) and the use of a more advanced model. This change is not expected to have a substantive effect on the future prediction of effects from non-radiological atmospheric discharges.

The 24-hour modelling and averaging period are not expected to change compliance to O. Reg. 419/05 as the main sources of fuel consumption are currently intermittent and therefore averaging over 24 hours should result in lower overall POI concentrations. For example, the standby generators are tested for approximately a ½ hour to 1 hour and averaging this use over a 24-hour period will likely result in a lower calculated emission rate. Although the heating boilers are assumed to run 24 hours during the heating months, they are a relatively minor source of overall emissions, as shown in Table 4-3.

The full modelling, calculations and comparison to Schedule 3 will be conducted prior to 2020 to ensure compliance with O. Reg. 419/05 and confirm protection of human health and the environment. Where required, modifications to the ECA will be made once the heating steam requirements are finalized and the detailed design is available. Modelling conducted as part of this change will consider the future scenarios for the purposes of assessing risk and confirming the preliminary assessment in the PEA.

4.1.3 Summary of Tier 1 Screening – Atmospheric Environment

Following evaluation of potential interactions between Stabilization and Storage with Surveillance activities and the atmospheric environment (i.e., air quality and noise levels), a set of bounding conditions was developed. These conditions are summarized as follows.

1) Current operational conditions are bounding for noise emissions during all Stabilization and Storage with Surveillance activities.

2) The current operational conditions are bounding for radiological and non-radiological air emissions with two exceptions.

a) **Auxiliary Boiler Compounds.** For the auxiliary boiler fuel combustion-related compounds, the bounding condition is considered to be when there are two auxiliary boilers operating at PN (i.e., existing Auxiliary Boiler and the additional heating steam boiler) for the generation of upgrader steam and building heat during the winter months of the Stabilization Phase. The addition of a heating steam boiler was considered in the context of existing emissions. Based on a scaling evaluation, emissions for this bounding condition are predicted to be below screening values. Therefore, this emission source is not considered further in the PEA report.

b) **Future Industrial/Commercial Receptor.** Although emissions overall are reduced once in the Storage with Surveillance Phase, OPG noted the potential for industrial/ commercial receptors to be present within the Engineering Services Buildings and Pickering Nuclear Information Centre (i.e., a future industrial/commercial worker leasing this space), which represents a new public receptor located closer to the PN operations than currently assessed in the PN ERA. Exposure to non-radiological contaminants for these receptors were considered within the ESDM report and considered protected by the presence of the ECA and the current bounding conditions. Although radionuclide emissions from the PN Generating Station will be a fraction of the current atmospheric emissions, radionuclides are of public interest, and therefore dose from radioactive atmospheric emissions to the closer potential future industrial/commercial worker is evaluated in the Tier 2 assessment for the Storage with Surveillance Phase.

4.2 Surface Water

The predicted interactions between surface water and the Stabilization and Storage with Surveillance activities are presented in Table 4-6. In this discussion, surface water includes changes in flow and quality. Changes in the physical stressors such as thermal profile, entrainment and impingement are discussed as part of surface water flow and quality, respectively. Stabilization and Storage with Surveillance activities involve substantial reductions in the cooling water flow, as well as changes and redirection of other water emissions at the PN Site. This section describes how these flows are predicted to change and presents the future water balance expected at the PN Site.

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Reactor Building Systems	↓	↓	→	↓	▪ The RBSW needs (and associated thermal load) will decrease as reactor units are taken off-line in the Stabilization Phase. ▪ The Reactor Building systems' waterborne emissions will decrease as reactor units are taken off-line. Radioactive waterborne emissions may temporarily increase during the Stabilization Phase; however, annual average emissions of radionuclides are not anticipated to increase beyond current emissions. The sporadic emissions, controlled by RLWMS, are shown as a "no change" arrow. ▪ Reactor Building sumps are expected to be isolated from the RLWMS and no longer a source of waterborne emissions during the Storage with Surveillance Phase.

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Reactor Auxiliary Bay (RAB) and Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB)	→	→	→*	↓*	▪ The IFBs and AIFB will have a cooling water demand similar to the current operational conditions with requirements reducing over time. The thermal loading will decrease in the Storage with Surveillance Phase as fuel cools and requires less heat removal. ▪ The IFBs and AIFB will continue to have waterborne radiological emissions as in the current operational condition during the Stabilization Phase and initial years of the Storage with Surveillance Phase. These are evaluated further in Storage with Surveillance Phase in Sections 4.2.2.2 and 4.2.3.2. ▪ Once the IFBs and AIFB are emptied of used fuel, the bays may be drained, decontaminated and sealed during the Storage with Surveillance Phase. Overall, radiological waterborne emissions will decline as the bays are removed from service. The final draining and decontamination of the IFBs will be managed through the RLWMS or other approved pathways and waterborne emissions to Lake Ontario are likely to be equal to or less than current operational conditions. ▪ Other Reactor Building support systems in the RAB will be drained, dried and rendered inoperable. The radiological waterborne emissions will be managed through the RLWMS or other approved means (e.g., discharge through an approved ECA).

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Turbine Hall and Turbine Auxiliary Bay (TAB)	↓	↓	↓	↓*	▪ Boiler feedwater chemical emissions (e.g., hydrazine and morpholine) from blowdown and other sources will progressively be reduced as units are shut down and eventually eliminated as a source of waterborne emissions. ▪ TAB sumps will remain in service, discharging to the forebay with reduced sources and volumes during the Stabilization Phase. ▪ As TAB sump sources are eliminated (i.e., heating steam condensate and compressor cooling water), the remaining TAB sump sources (primarily groundwater) are proposed to be redirected and consolidated for discharge to the RLWMS, RBSW or other approved pathways during the Storage with Surveillance Phase. ▪ The groundwater contribution to the overall Storage with Surveillance waterborne emissions is discussed in Section 4.2.3.2.1.4 as the discharge of groundwater to surface water is evaluated with a lower cooling water discharge.
Service Wing	→	↓	→	↓	▪ During the Stabilization Phase, waterborne emissions from the Service Wing will be as in current operations. ▪ In the Storage with Surveillance Phase, waterborne emissions from this area will decrease as activities are reduced (e.g., in the chemical laboratories and maintenance workshop).
Standby Generators and Emergency Power Generators					

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Building Heating and Ventilation	↑	→*	↑	→*	▪ With the addition of another building heating steam boiler, blow down discharges may increase during the Stabilization Phase (Section 4.2.3.2.2). ▪ The heating steam boiler discharges during the Storage with Surveillance Phase will be similar to the current operational conditions for this system. These inputs are considered further in Section 4.2.3.2.1.2 in the context of overall site-wide water balance changes.
Condenser Cooling Water (CCW) and Reactor Building Service Water (RBSW) Systems	↓*	↓*	↓*	↓*	▪ The operation of the CCW pumps will decrease throughout Stabilization with eventually all pumps removed from service at the end of this phase. ▪ As units are shut down during Stabilization, the thermal loading will decrease as cooling loads are eliminated, eventually being removed during the Storage and Surveillance Phase. This interaction is discussed further in Section 4.2.3.2.3. ▪ The CCW system is not expected to be operational during the Storage with Surveillance Phase. Cooling water needs are expected to be provided by the RBSW system. ▪ Chlorination and dechlorination of RBSW will continue as needed. ▪ The CCW or RBSW systems themselves do not directly interact with radiological water quality; however, other systems are affected by the amount of mixing the cooling water provides, as noted where appropriate under other interactions within this table. Therefore, RBSW flows during Storage with Surveillance Phase are considered in Section 4.2.3. This section also includes an evaluation of the Storage with Surveillance Phase as bounding for the Stabilization Phase.

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Electrical Transmission Facilities					
Oil and Chemical Storage Building					
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre					
High Pressure Emergency Coolant Injection (HPECI) Facilities	→		→		▪ The system will be drained using approved procedures, compliant with the ECA conditions and left in a safe state. ▪ The system will not be operational in the Storage with Surveillance Phase; therefore, no interactions are identified.

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
New Water Treatment Plant (NWTP) and Emergency Water Supply Pumphouse	→	↓	→	→*	▪ The NWTP, or an alternative treatment system, will continue operation during the Stabilization Phase. ▪ Since the NWTP is oversized to supply demineralized water for the PN Generating Station, it is likely a new, smaller, water treatment plant will replace the NWTP during the Storage with Surveillance Phase. ▪ Depending on the selected technology, the discharges from the smaller water treatment plant may be a source of non-radiological emissions and is evaluated further during the Storage with Surveillance Phase (Section 4.2.3.2.1.1). Any new water treatment system will be in compliance with regulatory requirements.
Waste Management					

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Site Drainage and Waterborne Emissions (inactive, active, stormwater runoff)	→	→	→	↓*	▪ The RLWMS will continue operation in the Stabilization and Storage with Surveillance Phases with decreasing emissions over time. This system is discussed further in Sections 4.2.3 and 4.2.3.2.1.4 for its potential to affect water quality in consideration of other changes in the PN water balance. ▪ Similar to current operations, dewatering of spent resin storage tanks will continue through the Stabilization Phase with reductions of spent resin tank slurrying in the Storage with Surveillance Phase. These waterborne emissions are part of the RLWMS noted above. ▪ The inactive drainage system will continue operation in the Stabilization Phase. Non-radiological waterborne emissions will be reduced as operations decrease in the Storage with Surveillance Phase. All inactive drainage (with the exception of stormwater runoff) is proposed to be re-routed to the RLWMS, the RBSW or the PN U5-8 discharge channel. ▪ Stormwater runoff to the forebay will remain unchanged. Forebay water quality is evaluated further relative to the decrease in water intake in the Storage and Surveillance Phase (Section 4.2.3.1.2). ▪ Stormwater runoff to the discharge channels will remain unchanged. The PN U1-4 and PN U5-8 discharge channel water quality is evaluated based on the decreased flow in the discharge channels in the Storage with Surveillance Phase (Section 4.2.3.2.1.3).

Table 4-6: Summary of Stabilization and Storage with Surveillance Interactions – Surface Water

PN System, Structure or Activity	Surface Water Flow		Surface Water Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Supporting Services and Activities – Intake channel	↓	↓ *	→ *	↑	▪ The forebay will experience reduced flow throughout the Stabilization Phase, as cooling water loads are reduced. This is not considered a habitat based on the flow and the presence of the fish diversion system (FDS). ▪ The Storage with Surveillance Phase (as bounding for the Stabilization Phase) for forebay water quality is discussed in Section 4.2.3.1.2 ▪ The forebay may become a habitat in the Storage with Surveillance Phase (Figure 5-5) with the reduced flows and removal of the FDS. The potential effects to his habitat are discussed in Section 4.2.3.1.2. Potential entrainment and impingement effects during Storage with Surveillance are discussed in Section 4.2.2.

↓ = effects decreasing relative to current operational conditions.
↑ = effects potentially increasing relative to current operational conditions.
→ = no change to effects from or similar to current operational conditions.
* = interaction discussed in Tier 1 (all ↑'s are also discussed in Tier 1).
Blank = no potential interaction.

4.2.1 PN ERA Summary – Surface Water

The PN Site is situated on the north shore of Lake Ontario. Lake-wide circulation in Lake Ontario is primarily driven by wind and by seasonal temperature effects. As described in Section 2.3.4.1 of the PN ERA (EcoMetrix and Golder, 2017), nearshore lake currents are affected by the existing operation of the PN Generating Station reactor units. Some localized effects are observed near the water intake and water discharge points. Water velocities in the vicinity of intake groynes are directed toward the PN Generating Station and a zone of in-flowing water is evident around the intake.

As described in the PN ERA (EcoMetrix and Golder, 2017), the PN Generating Station currently interacts with surface water quality in the normal course of operations. Potential risks to human receptors from non-radiological contaminants of potential concern were characterized quantitatively in the PN ERA in terms of Hazard Quotients (HQs) for non-carcinogens (morpholine) and Incremental Lifetime Cancer Risks for potential carcinogens (hydrazine). All modelled results were below the benchmarks for both non-carcinogenic and carcinogenic contaminants of potential concern, meaning there is no increased risk expected to human receptors from exposure to non-radiological contaminants of potential concern from PN sources. For the assessment of radiological contaminants of potential concern, radiological dose calculations followed the methodology outlined in CSA N288.1-08 (CSA, 2008). The annual dose to the critical group (the urban resident adult) during the five-year period from 2011 to 2015 ranged from 0.9 to 1.2 µSv., which is approximately 0.1% of the regulatory public dose limit of 1 mSv/a and approximately 0.1% of the dose due to Canadian background radiation. Since the critical groups receive the highest dose from the PN Site, the demonstration that they are protected implies that other receptor groups near PN are also protected (EcoMetrix and Golder, 2017).

The potential for ecological effects from non-radiological contaminants of potential concern was assessed by comparing exposure levels to toxicological benchmarks, and characterized quantitatively in terms of HQs. Maximum measured concentrations of contaminants of potential concern did not exceed their respective benchmarks for the ecological receptors evaluated near the PN outfall, with the exception of measured maximum copper and iron surface water concentrations near the PN outfall that exceeded fish and benthic invertebrate benchmarks. However, mean copper and iron concentrations in water were acceptable. Since fish are mobile, exposure to the mean concentration is more likely.

Although the results of the ecological risk assessment to ecological receptors at Frenchman's Bay indicate results above the acceptable risk level, exceedances of toxicity benchmarks are not uncharacteristic for an area such as Frenchman's Bay that is highly influenced by urban stormwater runoff. The PN ERA evaluated the contribution from PN to the overall risk, and concluded that PN operations contribute a small proportion of the overall risk to aquatic receptors at Frenchman's Bay. The percent contribution from PN ranges from 0.3% to 22% of the total risk for all contaminants of potential concern.

Radiation dose benchmarks of 9.6 milligray per day (mGy/d) and 2.4 mGy/d (UNSCEAR, 2008) were selected for the assessment of the effects from radiological contaminants of potential concern on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-12 standard (CSA, 2012). There were no exceedances of the radiation dose benchmarks for any aquatic or terrestrial (riparian) receptors at the PN outfall or at Frenchman's Bay.

The potential effects of the thermal plume on fish eggs, larvae and fish growth were evaluated in the Aquatic Environment Technical Support Document for the environmental assessment for the refurbishment and continued operation of PN U5-8 (Golder, 2007b). An evaluation was conducted of lake temperatures in the vicinity of the PN U5-8 discharge for fish spawning and embryo-larval development and fish growth (juvenile and adult) against thermal criteria for 15 fish species (Cooper, 2013). For fish spawning and embryo-larval development, the highest HQs were marginally above 1 in the plume, but usually very similar in the reference area. For fish growth, the highest HQs were marginally above 1 in the plume for Lake Trout and White Sucker only, but were less than or equal to reference values for both species. Therefore, it is was considered unlikely that there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species.

OPG (2017) also evaluated the lake water temperature from the thermal plume at PN and reference sites from 2009 to 2012 using a revised impact assessment model to predict hatch date and survival of Round Whitefish embryos. The estimated survival loss at the plume stations compared to the reference stations (Thickson Point and Bonnie Brae) was 0.80% (2009-2010), 1.39% (2010-2011), and 2.51% (2011-2012), all below the survival loss of 10%, the threshold for no-effect on Round Whitefish embryo survival. The average water temperature during the spawning and egg incubation period for all plume stations and each individual station in the three winters studied were below the threshold effect level of 6^{0}C in each year (OPG, 2017). Therefore, the thermal plume from PN was not considered to be having an adverse effect on Round Whitefish embryo survival.

In 2009, in response to an order by the CNSC to reduce impingement by 80%, OPG installed an FDS consisting of a barrier net surrounding the intake structure of the PN Generating Station. Overall, reductions in impinged biomass from 2011 to 2015 are considered to meet or exceed the 80% reduction target requested by the CNSC. No reasonable technological solution is available to reduce entrainment by the 60% requested (OPG, 2012), but these losses are more than offset by operation of the FDS and by OPG support for projects to create Northern Pike spawning and nursery habitat (OPG, 2012), and by OPG participation in the Bring Back the Salmon Program (Lake Ontario Atlantic Salmon Restoration Program, 2011).

4.2.2 Tier 1 Screening of Interactions – Surface Water Flow

4.2.2.1 Stabilization Phase

During the Stabilization Phase, as units are shut down in a staggered or partially staggered sequence, each will be fully defuelled and dewatered and placed into its safe storage state. As a result of these stabilization activities, the PN water balance will change in a step-wise manner from that shown in Figure 3-3 to the water balance shown in Figure 4-4 for the Storage with Surveillance Phase. The most substantial change to the water balance being the gradual shutting down of the CCW pumps.

The current operational conditions, as assessed in the PN ERA (EcoMetrix and Golder, 2017), represent a high PN Generating Station flow condition. During current operational conditions, the CCW flow from the PN U1-4 CCW discharge duct is estimated at approximately 48 m^3/s (4,100,000 cubic meters per day [m^3/day]), and from the PN U5-8 CCW discharge duct is 116 m^3/s (10,000,000 m^3/day). At the end stages of the Stabilization Phase, cooling water intake flow may range from 1,600,000 to 2,100,000 m^3/day (two CCW pumps at PN U5-8 or PN U1-4, respectively), which is considerably less than existing CCW flows (i.e., <15% of existing flows). Therefore, effects during the Stabilization Phase on surface water flow are not assessed separately, but are considered bound by existing operations.

4.2.2.2 Storage with Surveillance Phase

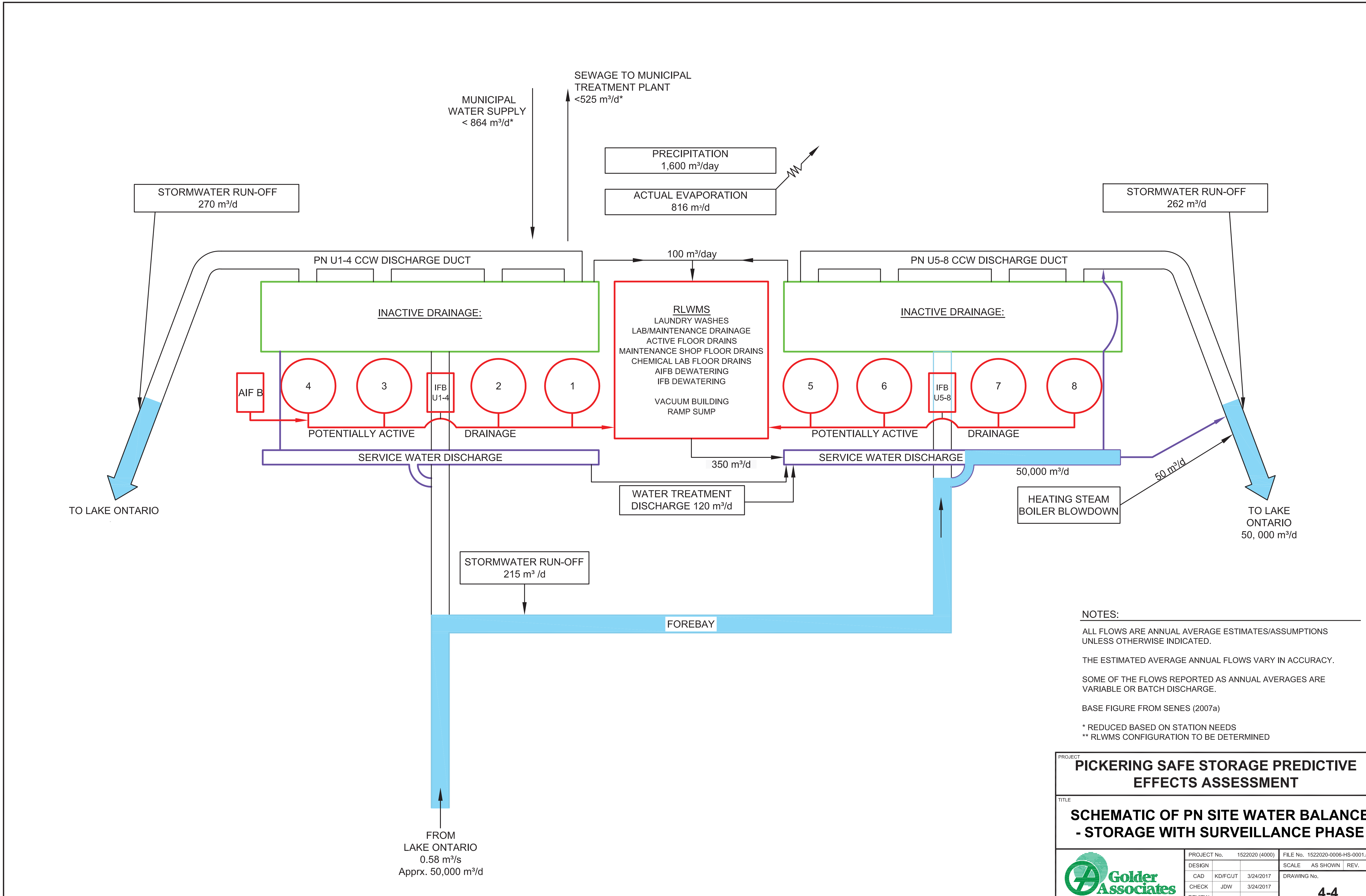
In the Storage with Surveillance Phase, the cooling water flows will be generally limited to the cooling requirements for the IFBs, where IFB cooling water requirements are estimated to be less than 1% of existing cooling water loads. Under these reduced flow conditions, the PN Site will cease to have a substantial influence on the nearshore hydraulic environment. The water balance scenario assessed in the PEA for the Storage with Surveillance Phase is shown schematically in Figure 4-4.

To understand how the nearshore environment will behave without influence of the high CCW flows and to support surface water predictions, a hydrodynamic surface water model (Appendix A) was developed to predict changes to lake currents, sediment transport and water temperature in the current operational condition and the Storage with Surveillance Phase. The following key assumptions were made for the purposes of developing the water balance during the Storage with Surveillance Phase.

- Based on anticipated IFB and AIFB cooling water needs, and intermittent loads such as heating steam coolers and compressor cooling, there is expected to be an intake and discharge flow of approximately 50,000 m^3/day. This value is near the low end of estimated flows and was chosen as a conservative assumption. As cooling water needs decrease due to fuel cooling and as the IFBs are decommissioned, the water management strategy will be updated, as required, to meet regulatory requirements and the protection of the environment.
- For planning purposes, it is assumed that the reduced cooling water flow will be provided through one screenhouse to the PN Generating Station (i.e., via the PN U5-8 screenhouse).
- It is assumed that the piping for the PN Generating Station will be modified so that the only inputs to the forebay are from stormwater runoff. All other water discharges will be re-routed to the RLWMS, the service water duct (RBSW), or directly to the PN U5-8 discharge channel, as appropriate. This re-routing of flows is proposed to allow for operational and monitoring efficiencies.

Details of the modelling and findings are provided in Appendix A. Predicted changes in surface water flow during the Stabilization and Storage with Surveillance Phases are used to assess potential effects to water quality (Section 4.2.3), including thermal, and sediment quality and transport (Section 4.3).

The substantial reduction in CCW flows will remove and/or eliminate the potential for impingement and entrainment. In the assumed condition for the Storage with Surveillance Phase, it is proposed that the FDS may be removed. As some cooling water flow will remain, the effect on entrainment and impingement are evaluated further in the Tier 2 assessment (Section 7.3.4).



SEWAGE TO MUNICIPAL TREATMENT PLANT <525 m³/d*
MUNICIPAL WATER SUPPLY < 864 m³/d*
PRECIPITATION 1,600 m³/day
ACTUAL EVAPORATION 816 m³/d
STORMWATER RUN-OFF 270 m³/d
STORMWATER RUN-OFF 262 m³/d
PN U1-4 CCW DISCHARGE DUCT
100 m³/day
PN U5-8 CCW DISCHARGE DUCT
INACTIVE DRAINAGE:
RLWMS
LAUNDRY WASHES
LAB/MAINTENANCE DRAINAGE
ACTIVE FLOOR DRAINS
MAINTENANCE SHOP FLOOR DRAINS
CHEMICAL LAB FLOOR DRAINS
AIFB DEWATERING
IFB DEWATERING
VACUUM BUILDING RAMP SUMP
INACTIVE DRAINAGE:
AIF B
4
3
IFB U1-4
2
1
5
6
IFB U5-8
7
8
POTENTIALLY ACTIVE
DRAINAGE
POTENTIALLY ACTIVE
DRAINAGE
SERVICE WATER DISCHARGE
350 m³/d
SERVICE WATER DISCHARGE
50,000 m³/d
TO LAKE ONTARIO
WATER TREATMENT DISCHARGE 120 m³/d
HEATING STEAM BOILER BLOWDOWN
50 m³/d
TO LAKE ONTARIO 50, 000 m³/d
STORMWATER RUN-OFF 215 m³ /d
FOREBAY
FROM LAKE ONTARIO 0.58 m³/s Apprx. 50,000 m³/d
NOTES:
ALL FLOWS ARE ANNUAL AVERAGE ESTIMATES/ASSUMPTIONS UNLESS OTHERWISE INDICATED.
THE ESTIMATED AVERAGE ANNUAL FLOWS VARY IN ACCURACY.
SOME OF THE FLOWS REPORTED AS ANNUAL AVERAGES ARE VARIABLE OR BATCH DISCHARGE.
BASE FIGURE FROM SENES (2007a)
* REDUCED BASED ON STATION NEEDS
** RLWMS CONFIGURATION TO BE DETERMINED
PROJECT
PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT
TITLE
SCHEMATIC OF PN SITE WATER BALANCE - STORAGE WITH SURVEILLANCE PHASE
Golder Associates
Mississauga, Ontario, Canada
PROJECT No. 1522020 (4000)
DESIGN
CAD KD/FC/JT 3/24/2017
CHECK JDW 3/24/2017
REVIEW
FILE No. 1522020-0006-HS-0001.dwg
SCALE AS SHOWN
REV. A
DRAWING No.
4-4

4.2.3 Tier 1 Screening of Interactions – Water Quality

4.2.3.1 Forebay Water Quality

4.2.3.1.1 Stabilization Phase

As described in Section 4.2.2, during the Stabilization Phase CCW pumps will be shut down in sequence as each unit is fully defuelled, cooled, drained, dried and placed in a safe storage state. It is assumed that at least two CCW pumps are operational during this phase, and the FDS will remain in place. Therefore, the forebay is not considered potential habitat, and further assessment for water quality is not considered warranted for the Stabilization Phase.

4.2.3.1.2 Storage with Surveillance Phase

As described in Section 4.2.2.2, in the Storage with Surveillance Phase, the cooling water flow will be substantially reduced. During the Storage with Surveillance Phase, with potential removal of the FDS and reduced flows, the forebay may become aquatic habitat. Therefore, this reduced-flow water balance (see Figure 4-4) has been assessed for its potential to affect water quality.

To predict the forebay water quality, a mass balance box model was developed and is discussed in Appendix A. In summary, stormwater runoff enters the forebay via two stormwater outfalls (Drain A and Drain B), adjacent to the U1-4 and U5-8 intake structures on the west and east sides of the forebay respectively. Concentration factors for each of these inputs were developed from the model.

Maximum concentrations in stormwater runoff from sampling conducted in 2015 and 2016 were conservatively used as inputs to the model. Two sampling points were used for each of Drain A (MH106 and MH85) and Drain B (CB70 and MH20). As a first step, the full suite of maximum concentrations in stormwater runoff were screened against criteria (Tables C-1, C-2 in Appendix C) with the parameters shown on Tables A-15 and A-16 (Appendix A). In these two tables the maximum tritium values and detection limit for carbon-14 were modified to allow for a more accurate dose evaluation, as noted in the tables. The values from Tables A-15 and A-16 (Appendix A) were then multiplied by the modelled average concentration factors for both Drain A and Drain B, and summed to obtain the predicted concentrations shown on Table A-17 (Appendix A - with unit conversion as appropriate).

The predicted concentrations in the forebay (Table A-17, Appendix A) were then compared to screening values. The results indicate no predicted concentrations above the criteria. Further evaluation of discharges to the forebay in the Tier 2 assessment is therefore not required. However, considering public interest, assessment of radionuclides is carried forward for evaluation in Tier 2.

4.2.3.2 Lake Water Quality

Changes to water quality in the lake were considered for the Stabilization and Storage with Surveillance Phases. This assessment was required primarily based on the reduced cooling water flows from the PN Generating Station during these phases. As with forebay water quality (Section 4.2.3.1), the Safe Storage with Surveillance Phase provides the bounding assessment scenario for lake water quality and is discussed first.

4.2.3.2.1 Storage with Surveillance Phase

As noted in Section 4.2.2.2, a cooling water flow of 50,000 m^3/day is conservatively assumed for Storage with Surveillance as it is likely the flow required to cool to the IFBs and AIFB. It is also assumed that cooling water discharge is made via PN U5-8 RBSW and that some systems are re-routed to discharge via the RLWMS or the

RBSW (see Figure 4-4). In this section, estimates of future releases are screened using a simple mixing approach and the lake water model.

Estimates of future releases, provided below, are based on the current operational conditions or existing RLWMS discharge limits, as well as the predicted volumes of waterborne emissions. Other potential discharges were considered minimal and not requiring further discussion. A description of each key input is provided, followed by a summary of predicted lake water quality concentrations.

4.2.3.2.1.1 Water Treatment Discharges

Based on the reduced demand for demineralized water in the Storage with Surveillance Phase, a mobile water treatment system may be used in place of the existing water treatment plant. A similar treatment system at Darlington Nuclear Generating Station was assumed to illustrate potential contaminants and flows. Based on experience with the Darlington water treatment system for their auxiliary boiler, sulphates (from backwash) were identified for further assessment (OPG, 2014b). Sulphates in the water treatment system were measured at a concentration of 1,500 milligram per litre (mg/L) as calcium carbonate ($CaCO_3$). This concentration was converted to 1,441.5 mg/L as sulphate (SO_4) based on molecular weight in order to compare the value to sulphate benchmarks. The waterborne emission is assumed to be 120 m^3/day based on scaling of the Darlington water treatment plant use. The screening of this waterborne emission, mixed within the 50,000 m^3/day cooling water, is shown in Table 4-7. Predicted concentrations are below screening levels.

4.2.3.2.1.2 Heating Steam Boiler Blowdown

The heating steam boiler will result in continuous release of boiler blowdown into the PN U5-8 outfall, and will be mixed with the RBSW discharge. While the exact design of the heating steam system is not known at this time, representative chemicals were chosen to illustrate the type of chemicals that may be present in the system. Currently no chemical is added to the existing heating steam boiler; however, based on the chemistry control for the heating steam boiler at the Darlington Nuclear Generating Station, it is assumed that boiler water may contain treatment chemicals such as GE water MCA4288 (comprised of sodium sulfite, sodium hydroxide, sodium carbonate, and diethylaminoethanol) and GE water MCM4280 (comprised of sodium hydroxide, sodium molybdate, and sodium tripolyphosphate).

The boiler blowdown discharge flow rate is assumed to be 50 m^3/day based on a conservative assumption of 10% of the current feed rate. This discharge would occur during the heating season only. The boiler blowdown discharge is likely a separate discharge point, but is expected to rapidly mix with the 50,000 m^3/day cooling water in the discharge channel and Lake Ontario, as shown in the lake water model (Appendix A).

Acute toxicity data are available for these boiler blowdown waters. These have been converted to chronic criteria (i.e. divided by 10) for use as screening concentrations since Provincial Water Quality Objectives (PWQO) and Canadian Water Quality Guidelines (CWQG) do not exist for these parameters. Based on the assessment conducted, MCA4288 and MCM4280 in boiler blowdown will not exceed the estimated chronic toxicity threshold, as shown in Table 4-7.

The Auxiliary Boilers condensate currently discharges into TAB sumps. It is possible that future boiler heating steam condensate will continue to be discharged in this manner. Alternatively, condensate could be recycled and collected recognizing the cost of producing demineralized water. The final configuration for the condensate and blowdown streams will be determined once details of the heating design is confirmed and ECA requirements are established. The current assumption is that the boiler condensate is recirculated and therefore this potential waterborne emission is not evaluated in the Tier 1 assessment. Similarly the waterborne emission would not require assessment provided it meets screening criteria.

4.2.3.2.1.3 Stormwater

There are no changes to the stormwater runoff anticipated as a result of the Stabilization and Storage with Surveillance activities. Stormwater runoff outfalls to the forebay are discussed in Section 4.2.3.1.2. Stormwater runoff catchments to Lake Ontario have been assessed in the PN ERA (EcoMetrix and Golder, 2017). The stormwater runoff that drains into the discharge channels is assumed to be 270 m^3/day and 262 m^3/day for PN U1-4 and PN U5-8, respectively, based on annual precipitation of 872 mm. For PN U5-8, the stormwater runoff was screened assuming a mixture of the stormwater with the 50,000 m^3/day of cooling water. The quality of the stormwater runoff is likely to improve with the reduction of industrial activities; however, the maximum concentrations from 2015/2016 sampling were used as a conservative screening level. All concentrations were found to be below screening values (Appendix C).

With the current assumptions, there would not be a similar flow at the PN U1-4 discharge channel and therefore the lake model was used to obtain a concentration factor in the PN U1-4 discharge channel (Appendix A). The result of combining maximum concentrations with concentration factors for the PNU1-4 discharge channel is provided in Appendix C. These calculations indicate that no additional parameters screen into the Tier 2 assessment.

4.2.3.2.1.4 Radioactive Liquid Waste Management System

This section provides estimates of radionuclides discharges from the RLWMS and their overall discharge from the PN Site via the RBSW. Radionuclides are carried forward for further evaluation in the Tier 2 assessment, as they are considered of public interest.

RLWMS quantity and quality of radioactive liquids are expected to decrease with time as sources terms are reduced or eliminated. The remaining sources during the Storage with Surveillance Phase are likely to include the IFBs, spent resin storage tanks, limited decontamination and PWMF Processing Building flows. Conservatively, the PEA has assumed the average operational RLWMS emissions from 2011 to 2015 to be:

- Tritium – $1.2x10^6$ Bq/L;
- Carbon-14 – 46 Bq/L; and
- Beta/Gamma – 91 Bq/L.

The current average RLWMS release volume is approximately 235 m^3/day. As noted in Section 4.2.2.2, there will be some redirection of water flows in the Storage with Surveillance Phase. The main additional radiological input to RLWMS is considered groundwater from the Vacuum Building ramp sump (12.6 m^3/day at an average 2011 to 2015 tritium concentration of $1.41x10^6$ Bq/L) and groundwater from TAB sumps [approximately 70 m^3/day at an approximate tritium concentration of $5.3x10^5$ Bq/L (CH2M Gore and Storrie, 2000)]. Carbon-14 and beta/gamma are considered negligible in groundwater. These flows may be directed to the RLWMS or alternatively to RBSW (with monitoring), however the RLWMS has been assumed for the purposes of this assessment. Discharge to the RBSW would have the same result in the overall assessment.

An RLWMS daily average flow of 350 m^3/day was conservatively assumed based on the current daily average of RLWMS generated (235 m^3/day), the groundwater inputs (86 m^3/day) and some allowance for other discharges to the TAB sumps or other sumps re-routed to RLWMS. This flow was assumed to be fully mixed with the RBSW cooling water prior to reaching the discharge channel.

The end of pipe RBSW discharges were calculated based on the RLWMS and groundwater streams noted, mixed together with cooling water to produce an assumed final discharge of 50,000 m^3/day. This calculation resulted in estimated end of pipe RBSW concentrations as follows:

- Tritium – 6,834 Bq/L (conservatively rounded to 7,000 Bq/L);
- Carbon-14 – 0.22 Bq/L (conservatively rounded up to 0.3 Bq/L); and
- Beta/Gamma – 0.43 Bq/L (conservatively rounded up to 0.5 Bq/L).

These values were combined with lake water model concentration factors identified in Appendix A (Tables A-7 to A-14) and used to calculate concentrations at various receptors as shown in Table 4-8. These radionuclide concentrations are used in the Tier 2 assessment to calculate dose to receptors.

For non-radiological parameters expected to be released with the RLWMS discharge, calculations were conducted assuming that releases through the RLWMS are at their maximum allowable concentrations or the current maximum MISA limits (O. Reg. 215/95 and summarized in the Table 2.4 of the PN ERA). This is considered a conservative estimate as all water would not be discharged with concentrations at their maximum allowable concentration at all times. Hydrazine and ammonia, although not be planned to be used during the Storage with Surveillance Phase, were retained in the screening as they could be used during the Stabilization Phase. The non-radiological RLWMS limits were designed to ensure non-toxicity for discharges and therefore were considered a suitable set of parameters for evaluation.

4.2.3.2.1.5 Predicted Lake Water Quality

The screening of predicted lake water quality is shown in Table 4-7. All concentrations meet screening levels within the RBSW discharge with the exception of hydrazine, which is discussed below the table. Further mixing for all parameters is provided in the discharge channel itself and Lake Ontario. Predicted radionuclide concentrations at receptors considered in the Tier 2 assessment are provided in Table 4-8.

Table 4-7: Comparison of Expected End of Pipe RBSW Non-radiological Concentrations against Screening Concentrations

Parameter	Units	Assumed System Concentrations	RBSW Point of Discharge Concentrations[d]	MOECC PWQO[e]	CCME CWQG[f]	Other	Carried forward to Tier 2?
RLWMS Discharge							
Iron	mg/L	9[a]	0.063	0.3	0.3	—	No
Copper	mg/L	0.05[b]	0.00035	0.005	0.002	—	No
Zinc	mg/L	1[a]	0.007	0.02	0.03	—	No
Lithium	mg/L	2[b]	0.014	—	—	—	No
Total residual chlorine	mg/L	0.001[b]	0.000007	0.002	—	—	No
Total suspended solids	mg/L	73[a]	0.511	—	6 (for clear flow)	—	No
Total organic carbon	mg/L	0.5[b]	0.0035	—	—	—	No
Oil in water	mg/L	36[a]	0.252	—	—	15 (produces visible sheen)[g]	No
Phosphorus	mg/L	1[b,c]	0.007	0.02		—	No
Dissolved Oxygen	mg/L	6[b]	0.042		6.5 max	—	No
pH	-	7.0-8.5[b]	-	6.5-8.5	6.5-9.0	—	No
Un-ionized ammonia	mg/L	0.2[b]	0.0014	0.02	0.019	—	No
Hydrazine	mg/L	0.3[b]	0.0021	—	—	0.00001[l]	No*
Boiler Blowdown							
MCA4288[h][i]	mg/L	1160	1.16	—	—	200	No
MCM4280[h][j]	mg/L	1160	1.16	—	—	500	No
Water Treatment Plant Discharge							
Sulphate[m]	mg/L	1441.5	3.4596	—	—	128[k]	No

Notes:

a) Municipal Industrial Strategy for Abatement (MISA) daily limit selected as maximum discharge concentration

b) RLWMS pump out limit selected as maximum discharge concentration

c) MISA monthly limit selected as maximum discharge concentration

d) RLWMS Flow = 350 m^3/day. RBSW Flow = 50,000 m^3/day, Boiler Blowdown Flow= 50 m^3/day. Water Treatment Plant Flow= 120 m^3/day.

e) Ontario Ministry of Environment and Climate Change (MOECC) Provincial Water Quality Objectives (PWQOs) (MOE, 1994)

f) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life (CCME, 1999)

g) Quality Criteria for Water. EPA 440/5-86-001 (US EPA, 1986).

h) Boiler blowdown flow of 50 m^3/day mixed with RBSW flow of 50,000 m^3/day

i) Material Data Safety Sheet. OPTIGUARD MCA4288. (converted from acute to chronic). (General Electric, 2016a)

j) Material Data Safety Sheet. OPTIGUARD MCM4280. (converted from acute to chronic) (General Electric, 2016b)

k) British Columbia Ministry of Environment (BC MOE, 2013) Ambient Water Quality Guidelines for Sulphate. Technical Appendix Update.

l) US EPA cited in (EC/HC, 2011) - Drinking water concentration that corresponds to a cancer risk level of 1x-6

m) Water treatment plant discharge of 120 m^3/day mixed with RBSW flow of 50,000 m^3/day

* text provided below on the screening of hydrazine.

mg/L = milligrams per litre

Table 4-8: Predicted Lake Surface Water Concentrations – Tritium, Carbon-14, Gross Beta/Gamma

Receptor Locations	Tritium (Bq/L)	Carbon-14 (Bq/L)	Gross Beta/Gamma (Bq/L)
RBSW Discharge	7.00×10^{3}	0.3×10^{0}	0.5×10^{0}
PN-U1-4 Discharge Channel	2.49×10^{0}	1.07×10^{-4}	1.78×10^{-4}
PN U5-8 Discharge Channel	4.76×10^{2}	2.04×10^{-2}	3.40×10^{-2}
Sport Fisher	8.78×10^{0}	3.76×10^{-4}	6.27×10^{-4}
Squires Beach	5.24×10^{0}	2.24×10^{-4}	3.74×10^{-4}
Liverpool Beach	2.53×10^{0}	1.08×10^{-4}	1.81×10^{-4}
Frenchman's Bay Inlet	2.21×10^{0}	9.47×10^{-5}	1.58×10^{-4}
Frenchman's Bay	1.82×10^{0}	7.81×10^{-5}	1.30×10^{-4}
Ajax Water Supply Plant	0.71×10^{0}	3.03×10^{-5}	5.06×10^{-5}

Bq/L = Becquerel per litre

Hydrazine is predicted to potentially be above the screening value, as shown in Table 4-7. Although a screening level is indicated, this is a derived value and hydrazine does not have a published human health screening level. The United States Environmental Protection Agency (US EPA) derived a hydrazine screening concentration of 1×10^{-5} mg/L based on risk and US EPA guidance (EC/HC, 2011). The predicted concentration at the end of the cooling water pipe for the scenario evaluated may exceed this human health value, but would be below the ecological screening value of 0.0026 mg/L recommended by Environment Canada (EC, 2013). To further screen this value for human receptors, the lake water model concentration factors were used in conjunction with the calculated end of pipe concentration to predict concentrations at the sport fisher and Ajax Water Supply Plant receptor locations, representing the closest and most likely human exposure points. This results in predicted concentrations at these receptors of 2.7×10^{-6} mg/L and 2.1×10^{-7} mg/L, respectively. Both of these are below the human health screening level of 1×10^{-5} mg/L, and therefore are not considered further in the Tier 2 assessment. It is also noted that hydrazine is not expected to be used during the Storage with Surveillance Phase and that this assessment was conducted to ensure the Storage with Surveillance activities would be bounding for the Stabilization Phase. There will be considerably more mixing present during the Stabilization Phase than the scenario assessed and less hydrazine than the current operational condition as hydrazine use is discontinued as reactor units are shut down.

4.2.3.2.2 Stabilization Phase

As systems are taken out of service, existing operational procedures and approved discharge pathways will be used to drain and vent systems no longer required to support station operations. Such activities will be planned and executed to minimize releases containing contaminants of potential concern. It is anticipated that releases that support stabilization activities will be more than off-set by the gradual elimination of previous waterborne emissions that would be associated with the normal operation of the units (boiler blow downs, decontamination activities, heavy water purification, etc.). Additionally, proposed timing of unit shutdowns will allow for a partial staggering of key stabilization activities including defuelling and dewatering sequences for each unit. This will ensure that stabilization activities that result in waterborne emissions can be planned and executed in a steady fashion.

Water flow for the Stabilization Phase is considered bound by the Storage with Surveillance condition for interactions that are increased due to a low flow (i.e., water quality). The Storage with Surveillance condition is considered bounding in this case as both phases are assumed to have similar quantities of waterborne emissions to Lake Ontario with a much higher flow in the Stabilization Phase and therefore lower concentrations discharged to the discharge channel. Although some of the pathways of inputs to cooling water are different (e.g., groundwater is assumed to discharge to the forebay in the Stabilization Phase and to RLWMS in the Storage with Surveillance Phase), this does not affect the overall discharge to Lake Ontario.

During the Stabilization Phase, there may be an additional heating steam boiler, as discussed in Section 4.1.2.2.2. This boiler may result in additional boiler blowdown (and possible condensate) emissions. For this change, the Storage with Surveillance scenario is still considered bounding as it considers one boiler with 50,000 m^3/day of cooling water available for mixing and dispersion (Section 4.2.3.2.1.2) and Stabilization activities would potentially have two boilers, but with a flow available for mixing and dispersion of at least 1,600,000 m^3/day. This considerable increase in flow demonstrates that there is substantially more mixing and dispersion in the Stabilization Phase relative to the additional potential waterborne emissions. The Storage with Surveillance Phase is therefore considered bounding.

4.2.3.2.3 Thermal

As noted above, the water discharge temperature will decrease with the removal of the fission heat source. This change in the temperature was modelled with the surface water model described in Appendix A. The effect of the gradual change in the thermal environment back to normal nearshore lake water temperatures are discussed qualitatively in the Tier 2 assessment (Section 7.3.3).

Stabilization will be conducted in a step-wise fashion (i.e., a unit shut down, with cooling water pumps continuing to operate until residual heat is dissipated). Over the period of the Stabilization Phase, each of the six units will move from full power, through cool down and residual heat dissipation to an eventual cold state. The potential for sudden temperature differentials that would lead to cold shock will be less and less likely as more of the units cease operation. During the Stabilization Phase the areal extent of the thermal plume will shrink, until the plume extent is limited to the existing discharge channel(s). The difference between the lake temperatures and the discharged cooling water will also decrease over time as units are retired. Given the low frequency of such events over the known history of full power operation, conditions with the potential to cause cold shock will be increasingly unlikely.

By the end of the Stabilization Phase, the lake near the discharge will be returned to a thermal condition that is more typical of the nearshore zone of Lake Ontario. The cooler return to ambient lake water temperatures after shutdown will offer thermal conditions more like the regional nearshore zone. The gradual return to normal lake water temperatures and water quality from the reduced influence of the PN discharge may gradually alter the species composition in the vicinity of the PN Generating Station to those found generally in the Frenchman's Bay to Duffin's Creek mouth nearshore. This change in fish species composition may result in the sport fisher receptor moving away from the PN Generating Station area. As a conservative measure, the Tier 2 assessment assumes the sport fisher is still located in the immediate vicinity (500 m) of the PN Generating Station.

4.2.4 Summary of Tier 1 Screening – Surface Water

Following evaluation of potential interactions between the Stabilization and Storage with Surveillance activities and surface water flow, a set of bounding conditions was developed. Based on the discussion above, the following is a summary of the environmental interactions considered and the findings of the Tier 1 assessment:

1) Current operational conditions are bounding for surface water flow and all Stabilization and Storage with Surveillance activities as flows are continually reduced following cessation of operations.

2) With the reduced flows and removal of the FDS, the forebay may become an aquatic habitat in the Storage with Surveillance Phase.

3) Although reduced, some flow will remain during the Storage with Surveillance Phase. This is evaluated further in the Tier 2 assessment for potential effects on entrainment and impingement (Section 7.3.4).

4) For water quality, the Storage with Surveillance condition is bounding. For assessment it was conservatively assumed that the waterborne emissions are as they are in the current operational condition with a reduced flow for mixing and dispersion. Waterborne emissions are, however, expected to be reduced in the Stabilization and Storage with Surveillance Phases.

5) In the assumed Storage with Surveillance Phase scenario, non-radiological contaminants of potential concern concentrations predicted in the forebay and discharge channel meet the screening criteria and do not require further evaluation.

6) In the assumed Storage with Surveillance Phase scenario radionuclide emissions predicted at receptors meet screening criteria, but are evaluated further in the Tier 2 assessment as these are of public concern.

7) Thermal changes for the Stabilization and Storage with Surveillance Phases are predicted to be gradual and localized, but are advanced for further qualitative analysis in the Tier 2 assessment as thermal emissions has been an area of public concern.

8) The gradual return to normal lake water temperatures and water quality from the reduced influence of the PN discharge may gradually alter the species composition in the vicinity of the PN Generating Station. Although the sport fisher may no longer be present in the area of the PN Generating Station, this receptor has been retained in the Tier 2 assessment.

4.3 Sediment Quality and Transport

Nearshore changes in surface water flow during Stabilization and Storage with Surveillance activities are anticipated, relative to existing operations. The potential interactions between these activities and sediment quality and transport are summarized in Table 4-9.

Table 4-9: Summary of Stabilization and Storage with Surveillance Interactions – Sediment Transport and Quality

PN System, Structure or Activity	Sediment Transport		Sediment Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Reactor Building Systems					
Reactor Auxiliary Bay (RAB) and Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB)					
Turbine Hall and Turbine Auxiliary Bay (TAB)					
Service Wing					
Standby Generators and Emergency Power Generators					
Building Heating and Ventilation					
Condenser Cooling Water System / Reactor Building Service Water	→*	→*	→*	→*	▪ Change in the PN water balance may change water quality and subsequently sediment quality during the Stabilization and Storage with Surveillance Phases. The effects of contaminants of potential concern to the sediments in the forebay and Lake Ontario are evaluated in Section 4.3.3. ▪ There will be changes in sediment deposition and erosion, as well as the thermal profile based on the new flow regime. The effect of this is discussed further in Section 4.3.2. ▪ The “no change to effects” symbol is provided based on the uncertainty related to the effects.

Table 4-9: Summary of Stabilization and Storage with Surveillance Interactions – Sediment Transport and Quality

PN System, Structure or Activity	Sediment Transport		Sediment Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	Stabilization	Surveillance	
Electrical Transmission Facilities					
Oil and Chemical Storage Building					
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre					
High Pressure Emergency Coolant Injection (HPECI) Facilities					
New Water Treatment Plant (NWTP) and Emergency Water Supply Pumphouse					
Waste Management					
Site Drainage and Waterborne Emissions					
Supporting Services and Activities - Forebay	→	→*	→	→*	▪ The effects of contaminants of potential concern to the sediments in the forebay is evaluated in Sections 4.3.3. ▪ Sediment deposition is likely to continue to occur in the forebay as cooling water flows are reduced during the Stabilization Phase. The “no change to effects” symbol is provided based on the uncertainty related to the effects. This interaction is discussed further in Section 4.3.2.

Notes:

↓ = effects decreasing relative to current operational conditions.

↑ = effects potentially increasing relative to current operational conditions.

→ = no change to effects from or similar to current operational conditions.

* = interaction discussed in Tier 1 (all ↑'s are also discussed in Tier 1).

Blank = no potential interaction.

4.3.1 PN ERA Summary – Sediment Quality and Transport

As described in the PN ERA (EcoMetrix and Golder, 2017), the PN Generating Station currently interacts with sediment quality and transport in the normal course of operations.

Estimated maximum copper concentrations in sediment near the PN outfall slightly exceeded the benthic invertebrate benchmarks, however, the estimated mean copper concentrations were acceptable. Although a few benthic invertebrates may be exposed to these maximum measured water concentrations and estimated sediment concentrations, the community as a whole is not expected to be affected. Additionally, there is uncertainty surrounding this risk as the sediment in Lake Ontario near the PN Site is transient, and the invertebrate community is mainly epifaunal. For all other contaminants of potential concern, the maximum and mean sediment concentrations near the PN outfall did not exceed their respective benchmarks for the ecological receptors evaluated.

Under current operational conditions, the nearest depositional area for sediment is Frenchman's Bay. Measured concentrations in sediments at Frenchman's Bay have been considered in the PN ERA and the PN Generating Station's contribution to these concentrations was assessed to be minor.

There were no exceedances of the radiation dose benchmarks for any aquatic or terrestrial (riparian) receptors at the PN outfall or at Frenchman's Bay.

4.3.2 Tier 1 Screening of Interactions – Sediment Transport

There will be a substantial reduction in the current speed expected in the discharge and intake channels during the Storage with Surveillance Phase. Given the minimal influence of the PN Generating Station discharge flow in this Phase, sediment transport will largely be driven by natural longshore currents and wave action. Deposition of sediments are anticipated to refill the discharge channels that were scoured out over many years of cooling water discharge during PN Generating Station operation. The forebay structure is likely to become a depositional area in the assumed case where the intake of the cooling water is the PN U5-8 screenhouse. The sediment accumulations may, over time, extend out along the nearshore and connect to the shallow beaches to the west and east of the PN Generating Station, reflecting natural sedimentation patterns along the north shore of Lake Ontario. The surface water modelling indicates that increased depositional areas during the Storage with Surveillance activities should be limited to these areas (Figure A-9, Appendix A).

4.3.3 Tier 1 Screening of Interactions – Sediment Quality

The screening of waterborne emissions in Appendix A indicates there are no contaminants of potential concern that exceed screening values, and therefore changes to water quality from the Stabilization and Storage with Surveillance activities are not expected to affect Lake Ontario sediment quality. The PN water quality is not predicted to result in adverse sediment quality issues.

As described in Section 4.2.3.1.2, the forebay may become aquatic habitat during the Storage with Surveillance Phase. As there are no non-radiological contaminants of potential concern that are considered a risk, based on screening in Section 4.2.3, evaluation of contaminants of potential concern partitioning from water to the sediments was not considered required.

Radiological effects to sediment are evaluated to calculate human and ecological dose in the Tier 2 assessment.

4.3.4 Summary of Tier 1 Screening – Sediment Quality and Transport

Based on the discussion above, the following is a summary of the environmental interactions considered and the findings of the Tier 1 assessment.

1) Changes to sediment quality are not considered to warrant further evaluation as contaminants of potential concern identified in predicted water discharges in water are below screening values. Potential radionuclide effects to sediment are, however, estimated for evaluation in Tier 2.

2) Changes in sediment transport are expected to be localized to the immediate vicinity of the PN Site (i.e., forebay, discharges and nearshore area). Changes in sediment transport in the vicinity of the forebay may create changes in or new nearshore aquatic habitat. This is discussed qualitatively in Tier 2.

4.4 Groundwater

A summary of the potential groundwater interactions with the Stabilization and Storage with Surveillance activities is presented in Table 4-10, with additional detail about each of these items identified as potentially increasing or otherwise requiring discussion provided below.

In general, the groundwater flow regime is not expected to change substantively over the course of the Stabilization and Storage with Surveillance activities evaluated in the PEA. The groundwater in the area of the PN Generating Station is collected primarily by the TAB sumps and Vacuum Building ramp sump and discharged to the forebay (as noted in Section 4.2.3.2.1.4). This will continue in the Storage with Surveillance Phase with groundwater routed to the RLWMS system rather than the forebay.

The groundwater quality will improve over time by natural processes and the removal of the tritium atmospheric contribution to groundwater.

Table 4-10: Summary of Stabilization and Storage with Surveillance Interactions – Groundwater Environment

PN System, Structure or Activity	Groundwater Quality and Quantity		Discussion of Potential Interaction
	Stabilization	Surveillance	
Reactor Building Systems	↓	↓	▪ Reactor Building foundation drains will continue to collect groundwater and route the groundwater to the RLWMS during both the Stabilization and Storage with Surveillance Phases. ▪ Tritium in groundwater in the area of the PN Generating Station will be reduced over time as atmospheric emissions reduce and decay occurs.
Reactor Auxiliary Bay (RAB) and Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB)	→	→	▪ The IFBs may continue to collect groundwater in the inner space as in the current operational condition during both the Stabilization and Storage with Surveillance Phases and will continue to be managed through the RLWMS.
Turbine Hall and Turbine Auxiliary Bay (TAB)	→	↓	▪ The TAB sumps will continue to collect groundwater in the area of the PN Generating Station during both the Stabilization and Storage with Surveillance Phases. The tritium level in the groundwater will decrease over time due to decay. ▪ Groundwater associated with these sumps will be re-routed to the RLWMS or RBSW in the Storage with Surveillance Phase.
Service Wing	→	→	▪ There are foundation drains below the RLWMS tanks that will continue to collect groundwater as the TAB sumps do during both the Stabilization and Storage with Surveillance Phases.
Standby Generators and Emergency Power Generators			
Building Heating and Ventilation			
Condenser Cooling Water System / Reactor Building Service Water			

Table 4-10: Summary of Stabilization and Storage with Surveillance Interactions – Groundwater Environment

PN System, Structure or Activity	Groundwater Quality and Quantity		Discussion of Potential Interaction
	Stabilization	Surveillance	
Electrical Transmission Facilities			
Oil and Chemical Storage Building			
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre			
High Pressure Emergency Coolant Injection (HPECI) Facilities			
New Water Treatment Plant (NWTP) and Emergency Water Supply Pumphouse			
Waste Management			
Site Drainage and Waterborne Emissions	↓	↓	▪ The Vacuum Building ramp sump is currently part of the stormwater runoff system, but will be re-routed to the RLWMS or RBSW system at the end of the Stabilization Phase. This sump will continue to collect, and control, groundwater in the immediate area during both the Stabilization and Storage with Surveillance Phases. The tritium level in the groundwater will decrease over time due to decay.
Supporting Services and Activities			

Notes:

↓ = effects decreasing relative to current operational conditions.

↑ = effects potentially increasing relative to current operational conditions.

→ = no change to effects from or similar to current operational conditions.

* = interaction discussed in Tier 1 (all ↑'s are also discussed in Tier 1).

Blank = no potential interaction.

This section evaluates the potential groundwater changes during the Stabilization and Storage with Surveillance Phases. That is the potential changes in flow or water quality due to changes to the TAB sumps.

4.4.1 PN ERA Summary – Groundwater

The groundwater flow in the protected area is controlled by groundwater collection at the TAB sumps and Vacuum Building ramp sump (i.e., these sumps create a groundwater capture zone). Other groundwater flow surrounding the PN Generating Station is towards Lake Ontario.

Although contaminants of potential concern have been identified in the area of the PN Generating Station, the lack of complete exposure pathways for site groundwater to the public indicates that there is no need for inclusion of these pathways in the PN ERA (EcoMetrix and Golder, 2017). Contaminants of potential concern collected within the sumps are considered in the surface water pathway.

4.4.2 Tier 1 Screening of Interactions – Groundwater

In the Stabilization and Storage with Surveillance Phases, the foundation drains and associated sumps and pumps will continue to remain in operation to keep the TAB basement free of standing water. In addition, the Vacuum Building ramp sump and other foundation drains are assumed to remain operational. During the Storage with Surveillance Phase it is assumed the TAB sump and Vacuum Building ramp sump groundwater will be re-routed to the RLWMS or RBSW, but this will have no effect on groundwater flow.

The groundwater conditions will continue to be monitored over the Stabilization and Storage with Surveillance Phases as part of the Groundwater Protection Program (see Section 8.4).

4.4.3 Summary of Tier 1 Screening – Groundwater

Based on the discussion above, the following is a summary of the environmental interactions considered and the findings of the Tier 1 assessment.

1) The existing capture zone created by the PN groundwater collection sump will continue to capture groundwater containing contaminants of potential concern to allow for monitoring prior to discharge. The current operational conditions are bounding for the groundwater pathway.

2) Tritium in groundwater will decrease in concentration as tritium sources such as atmospheric emissions cease and decay occurs.

Therefore, no further assessment of groundwater is warranted. Groundwater discharge to surface water, via the RLWMS (or RBSW), is discussed in Section 4.2.3.2.1.4.

4.5 Soil Quality

A summary of the potential soil interactions with the Stabilization and Storage with Surveillance activities is presented in Table 4-11. In general, the Stabilization and Storage with Surveillance activities are not expected to result in changes to the site topography or surficial geological conditions of the PN Generating Station. The soil quality will improve over time.

Table 4-11: Summary of Stabilization and Storage with Surveillance Interactions – Soil Quality

	Soil Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	
Reactor Building Systems	↓	↓	▪ Tritium in soil in the area of the PN Site will be reduced over time as atmospheric emissions decrease in both the Stabilization and Storage with Surveillance Phases and natural decay occurs.
Reactor Auxiliary Bay (RAB) and Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB)			
Turbine Hall and Turbine Auxiliary Bay			
Service Wing			
Standby Generators and Emergency Power Generators			
Building Heating and Ventilation			
Condenser Cooling Water System			
Electrical Transmission Facilities			
Oil and Chemical Storage Building			
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre			
High Pressure Emergency Coolant Injection (HPECI) Facilities			

Table 4-11: Summary of Stabilization and Storage with Surveillance Interactions – Soil Quality

	Soil Quality		Discussion of Potential Interaction
	Stabilization	Surveillance	
New Water Treatment Plant (NWTP) and Emergency Water Supply Pumphouse			
Waste Management			
Site Drainage and Waterborne Emissions			
Supporting Services and Activities – East Complex (and other areas outside the Protected Area)		→	▪ Soil quality in the areas outside the protected area are expected to remain in the current condition with potential improvements over time with the reduction of industrial activity.

Notes:

↓ = effects decreasing relative to current operational conditions.

↑ = effects potentially increasing relative to current operational conditions.

→ = no change to effects from or similar to current operational conditions.

* = interaction discussed in Tier 1 (all ↑'s are also discussed in Tier 1).

Blank = no potential interaction.

4.5.1 PN ERA Summary – Soil Quality

As described in the PN ERA (EcoMetrix and Golder, 2017), the PN Generating Station has historically caused isolated areas with chemical and radiological contaminants in soil as part of the normal course of operations.

Non-radiological contaminants of potential concern were not assessed in terms of human health risks for soil since there are no complete human exposure pathways for site soil, and the PN Generating Station is not a source of dust for off-site soil. For the assessment of radiological contaminants of potential concern, radiological dose calculations followed the methodology outlined in CSA N288.1-08 (CSA, 2008). The annual dose to the critical group (the urban resident adult) during the five year period from 2011 to 2015 ranged from 0.9 to 1.2 μSv., approximately 0.1% of the regulatory public dose limit of 1 mSv/a and approximately 0.1% of the dose due to Canadian background radiation. The soil incidental ingestion and external exposure pathways are small contributors to total dose compared to air inhalation and external exposure pathways for the urban resident. Since the critical groups receive the highest dose from the PN Generating Station, the demonstration that they are protected implies that other receptor groups near the PN Site are also protected. (EcoMetrix and Golder, 2017).

The potential for ecological effects from non-radiological contaminants of potential concern was assessed by comparing exposure levels to toxicological benchmarks, and characterized quantitatively in terms of HQs. The PN ERA indicated exceedances of the acceptable risk level to a number of terrestrial receptors resulting from exposure to soil contaminants of potential concern on the PN Site. In general, soils on site that exceed benchmark concentrations are localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, contaminant of potential concern accumulation 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 PN operations and not in highly vegetated areas. Based on the above discussion, risk to terrestrial receptors on the PN Site is expected to be low.

A radiation dose benchmark of 2.4 mGy/d (UNSCEAR, 2008) was selected for the assessment of the effects of radiological contaminants of potential concern on terrestrial biota, as recommended in the CSA N288.6-12 standard (CSA, 2012). There were no exceedances of the radiation dose benchmark for terrestrial biota on the PN Generating Station.

4.5.2 Tier 1 Screening of Interactions – Soil Quality

There are no changes to the soil conditions, or interactions of the Stabilization and Storage with Surveillance activities with the soil, predicted as part of Stabilization and Storage with Surveillance activities. There are no modifications proposed to the site topography or surface cover and no substantial excavations proposed. Based on this evaluation, the current soil quality conditions are considered bounding.

4.5.3 Summary of Tier 1 Screening – Soil Quality

In summary, the Tier 1 screening indicates that there are no substantial changes proposed to the PN soil quality. Some soil conditions (e.g., as impacted by tritium or fuel oil) are expected to improve with time. No further assessment is warranted.

5.0 CONCEPTUAL SITE MODEL

The conceptual model illustrates how receptors are exposed to contaminants of potential concern. It represents the relationship between the source and receptors by identifying the source of contaminants, receptor locations and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

5.1 Human Health Conceptual Model

Problem Formulation includes receptor selection and characterization, identification of contaminants of potential concern, and identification of exposure pathways. The end result is the human health conceptual model.

The receptors selected are consistent with the PN ERA (EcoMetrix and Golder, 2017), with the addition of a future industrial/commercial worker located outside the PN operations, but within the existing PN Site boundary. Contaminants of potential concern in the atmosphere and surface water were identified in Sections 4.1.2.2 and 4.2.3.2 respectively. For contaminants of potential concern identified in the atmospheric environment, groundwater, and soil, the current operational conditions are bounding. Contaminants of potential concern were identified in surface water that will not be bound during the Storage with Surveillance Phase by the current operational conditions. Radiological contaminants of potential concern have been identified in both the lake and in the forebay. Human exposure to contaminants of potential concern in the forebay is negligible; therefore the assessment focuses on exposure to radiological contaminants of potential concern in the lake, specifically tritium, carbon-14, and gross beta.

Not all exposure pathways are considered complete. A complete exposure pathway consists of a contaminant source, release mechanism, transport mechanism within the relevant environmental medium (or media), point of exposure and exposure route to a receptor. For exposure of human receptors to radiological contaminants of potential concern, the relevant exposure pathways include:

- 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; and
- ingestion of food.

The complete exposure pathways for exposure of relevant human receptors to radiological contaminants of potential concern are summarized in Table 5-1.

Table 5-1: Complete Exposure Pathways for Relevant Receptors for Exposure to Radiological Contaminants of Potential Concern

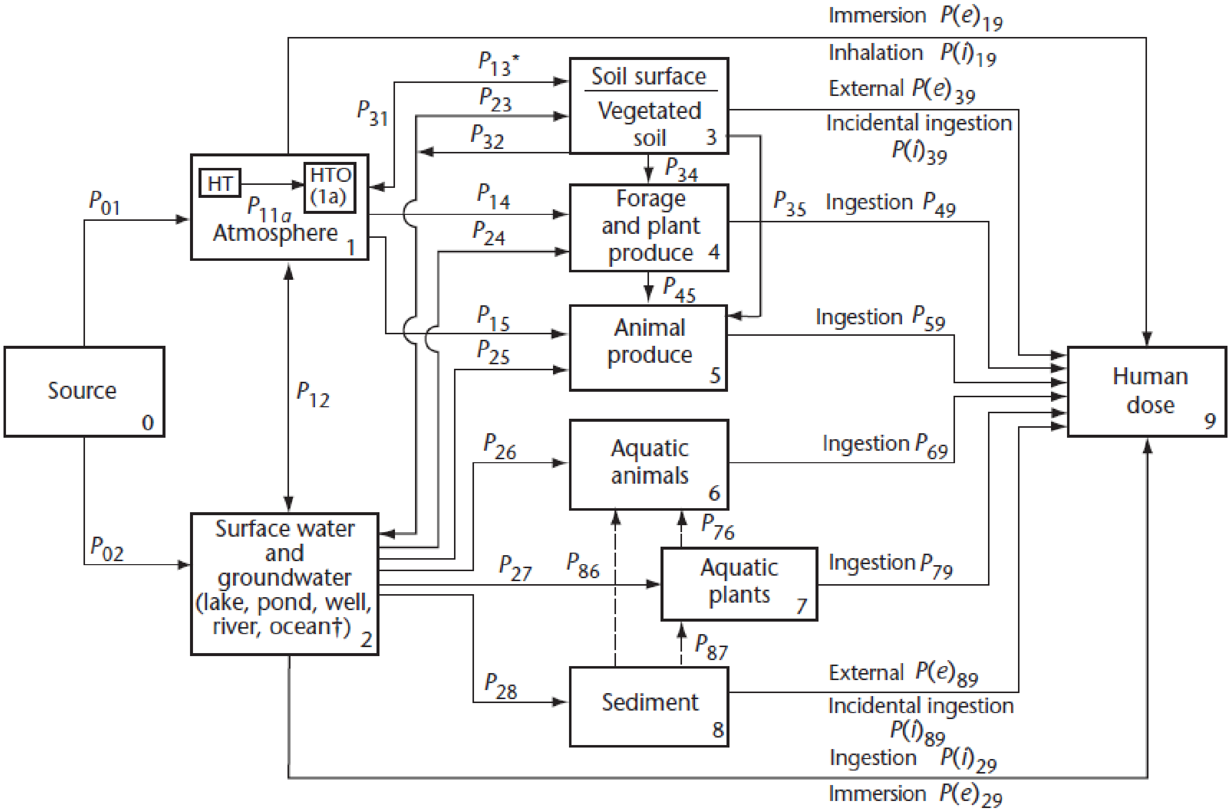
Receptor	Exposure Pathway	Environmental Media
Sport Fisher	Inhalation	Air
	Ingestion	Aquatic animals (fish)
	External	Air
Industrial/Commercial Worker[(a)] (both existing and future)	Inhalation	Air
	Ingestion	Water Soil (incidental) Sediment (incidental) Aquatic animals Terrestrial plants Terrestrial animals
	External	Air Water Soil Sediment
Urban Resident	Inhalation	Air
	Ingestion	Water Soil (incidental) Sediment (incidental) Aquatic animals Terrestrial plants Terrestrial animals
	External	Air Water Soil Sediment
Correctional Institution	Inhalation	Air
	Ingestion	Water Soil (incidental)
	External	Air Water Soil

Table 5-1: Complete Exposure Pathways for Relevant Receptors for Exposure to Radiological Contaminants of Potential Concern

Receptor	Exposure Pathway	Environmental Media
Farm	Inhalation	Air
	Ingestion	Water Soil (incidental) Sediment (incidental) Aquatic animals Terrestrial plants Terrestrial animals
	External	Air Water Soil Sediment
Dairy Farm	Inhalation	Air
	Ingestion	Water Soil (incidental) Sediment (incidental) Terrestrial plants Terrestrial animals
	External	Air Water Soil Sediment

Note:
a) A small fraction of Industrial/Commercial workers are also urban residents; therefore, the ingestion pathway is included to account for when the worker is at home.

A generic conceptual model, taken from CSA N288.1-08 (CSA, 2008) is shown in Figure 5-1, and is applied to human receptors around PN. This represents the exposure pathways from source to receptor. The locations for the human receptors evaluated are shown in Figure 5-2.



*Includes transfer factors P_{13area}, P_{13mass}, and P_{13spw}.

†For ocean water, pathways P_{23}, P_{24}, P_{25}, and $P(i)_{29}$ are not used.

Notes:

(1) *The broken lines represent pathways that are not explicitly considered in the model, or are considered only in special circumstances.*

(2) *Factors include multiple transfers where appropriate.*

Figure 5-1: Generic Conceptual Model for Human Receptors (CSA, 2008)

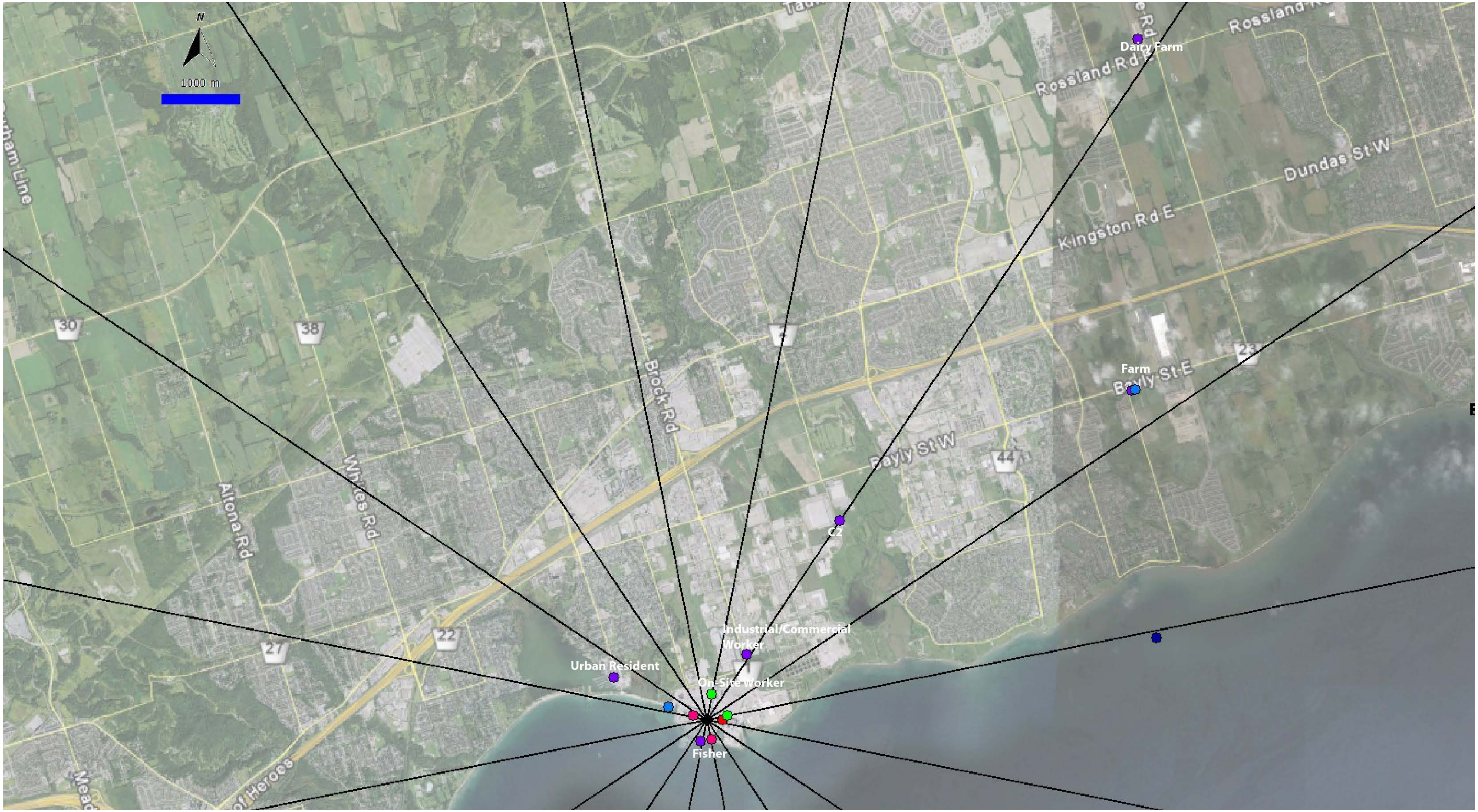


Figure 5-2: Human Receptors for the Predictive Effects Assessment

5.2 Ecological Conceptual Model

The ecological conceptual model involves receptor selection and characterization, assessment and measurement endpoints, identification of contaminants of potential concern, and identification of exposure pathways..

The terrestrial and aquatic receptors considered in the PEA are consistent with the PN ERA (EcoMetrix and Golder, 2017), with the addition of aquatic receptors in the forebay structure. Terrestrial receptors are bound by the current operational conditions, as exposures will change insignificantly.

The forebay structure will act as an artificial embayment, and as such will be more quiescent, warmer and more depositional than the adjacent lake. Hypothetical aquatic receptors, including fish, aquatic plants (macrophytes), invertebrates, and riparian mammals and birds, are assessed at the forebay.

Frenchman's Bay is a provincially significant wetland, is designated an Environmentally Sensitive Area by the Toronto and Region Conservation Authority, and is an Aquatic Biology Core Area. Frenchman's Bay is a habitat for wetland vegetation, mainly cattails, aquatic invertebrates, fish, and wildlife. The wetland is located in the northern section of the bay. Frenchman's Bay is a suitable location to assess riparian and aquatic receptors in the PN ERA and the PEA.

Fish are abundant in the discharge channel, which provides spawning habitat for Smallmouth Bass. There is also very sparse vegetation cover along the discharge channel (Golder, 2007b). Due to the prevalence of fish at the discharge channel, fish are assessed at the outfall.

As discussed in the PN ERA, VECs were selected to represent each major plant and animal group, reflecting the main ecological exposure pathways, feeding habits and habitats at or around the PN Site. Species that were ecologically similar to other species and could be represented by another species were not included in the assessment to reduce redundancy in the exposure calculations. The assessment model used in estimating dose and risk is either specific to the selected VEC species, or is a more generic assessment model that is appropriate to a number of VECs with similar exposure characteristics, as shown in Table 5-2.

Assessment endpoints are attributes of the receptors to be protected in environmental programs (Suter et al., 1993). The purpose of the ecological risk assessment is to evaluate whether these environmental protection goals are being achieved or are likely to be achieved. The assessment endpoint for all receptors in this ecological risk assessment is population abundance. The environmental protection goal is to maintain population abundance for the majority of species, and thereby maintain ecosystem function.

Species at risk have been identified on-site, and are represented by other ecologically similar species. The assessment endpoint for the identified species at risk is the individual, as recommended in Clause 7.2.4.3 of CSA N288.6-12 (CSA, 2012), since effects on even a few individuals of species at risk would not be acceptable. As the focus is on the aquatic environment, the relevant species at risk is the American Eel.

Contaminants of potential concern were identified in Sections 4.1.2.2.1 and 4.2.3.2.1.5. For contaminants of potential concern identified in the atmospheric environment, groundwater, and soil, the current operational conditions are bounding. Contaminants of potential concern were identified in surface water that will not be bound during the Stabilization and Storage with Surveillance activities by the current operational conditions. Radiological contaminants of potential concern have been identified in the lake, and in the forebay. Since terrestrial receptors on the PN Generating Station are minimally exposed to surface water contaminants of potential concern through drinking water, the evaluation of terrestrial receptors (mammals and birds) from the PN ERA is considered appropriate and no new assessment is provided.

Table 5-2 summarizes the relevant exposure pathways for each type of ecological receptor. The conceptual model for the aquatic environment and terrestrial environment is illustrated in Figure 5-3 and Figure 5-4. For completeness, the air exposure pathway is shown, but is not evaluated since it is usually minor compared to the soil or sediment ingestion exposure (CSA, 2012). The area of assessment for ecological receptors is shown in Figure 5-5.

Table 5-2: Complete Exposure Pathways for All Selected VECs

VEC Category	Location	Assessment Model	VEC	Exposure Pathways	Environmental Media
Fish	Outfall Forebay Frenchman's Bay	Bottom Dwelling Fish	Brown Bullhead	Direct Contact	Water Sediment
			Round Whitefish	Direct Contact	Water Sediment
			White Sucker	Direct Contact	Water Sediment
			American Eel	Direct Contact	Water Sediment
		Pelagic Fish	Alewife	Direct Contact	Water
			Smallmouth Bass	Direct Contact	Water
			Lake Trout	Direct Contact	Water
			Walleye	Direct Contact	Water
			Northern Pike	Direct Contact	Water
Aquatic Plants	Frenchman's Bay	Aquatic Plant	Narrow-leaved Cattail	Direct Contact	Water
	Forebay	Aquatic Plant	Macrophytes	Direct Contact	Water
Aquatic Invertebrates	Outfall Forebay Frenchman's Bay	Benthic Invertebrate	Benthic Invertebrates	Direct Contact	Sediment
Amphibians and Reptiles	Frenchman's Bay	Bottom Dwelling Fish	Northern Leopard Frog	Direct Contact	Water Sediment
			Midland Painted Turtle	Direct Contact	Water Sediment
Riparian Birds	Forebay Frenchman's Bay	Trumpeter Swan	Trumpeter Swan	Immersion	Air
				Ingestion	Water Sediment Aquatic Plant
		Ring-Billed Gull	Ring-Billed Gull	Immersion	Air

Table 5-2: Complete Exposure Pathways for All Selected VECs

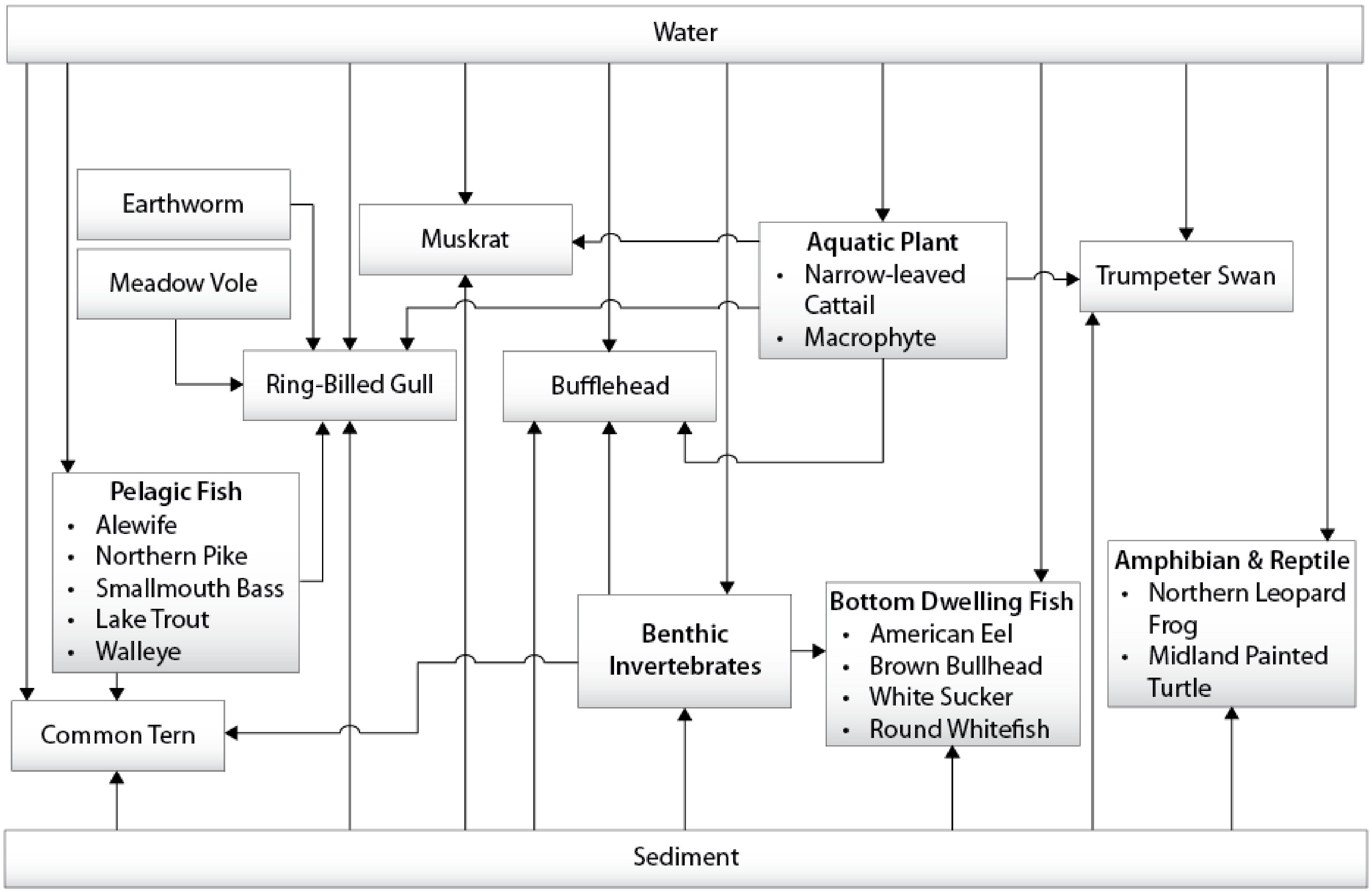
VEC Category	Location	Assessment Model	VEC	Exposure Pathways	Environmental Media
				Ingestion	Water Sediment Aquatic Plant Fish Earthworm Mammals
		Common Tern	Common Tern	Immersion	Air
				Ingestion	Water Sediment Benthic Invertebrate Fish
		Bufflehead	Bufflehead	Immersion	Air
				Ingestion	Water Sediment Benthic Invertebrate Aquatic Plants
Riparian Mammals	Forebay Frenchman's Bay	Muskrat	Muskrat	Immersion	Air
				Ingestion	Water Sediment Aquatic Plant

Table 5-2: Complete Exposure Pathways for All Selected VECs

VEC Category	Location	Assessment Model	VEC	Exposure Pathways	Environmental Media
Terrestrial Plants	Pickering Nuclear Site	Terrestrial Plant	Chokecherry	Immersion	Air
				Direct Contact	Soil
			New England Aster	Immersion	Air
				Direct Contact	Soil
			Eastern Hemlock	Immersion	Air
				Direct Contact	Soil
			Red ash	Immersion	Air
				Direct Contact	Soil
			Sandbar Willow	Immersion	Air
				Direct Contact	Soil
			Pine/Grass	Immersion	Air
				Direct Contact	Soil
Terrestrial Invertebrates	Pickering Nuclear Site	Earthworm	Earthworm	Direct Contact	Soil
Terrestrial Birds	Pickering Nuclear Site	Red-winged Blackbird	Red-winged Blackbird	Immersion	Air
				Ingestion	Insects Soil Water
		Red-tailed Hawk	Red-tailed Hawk	Immersion	Air
				Ingestion	Birds Mammals Soil Water

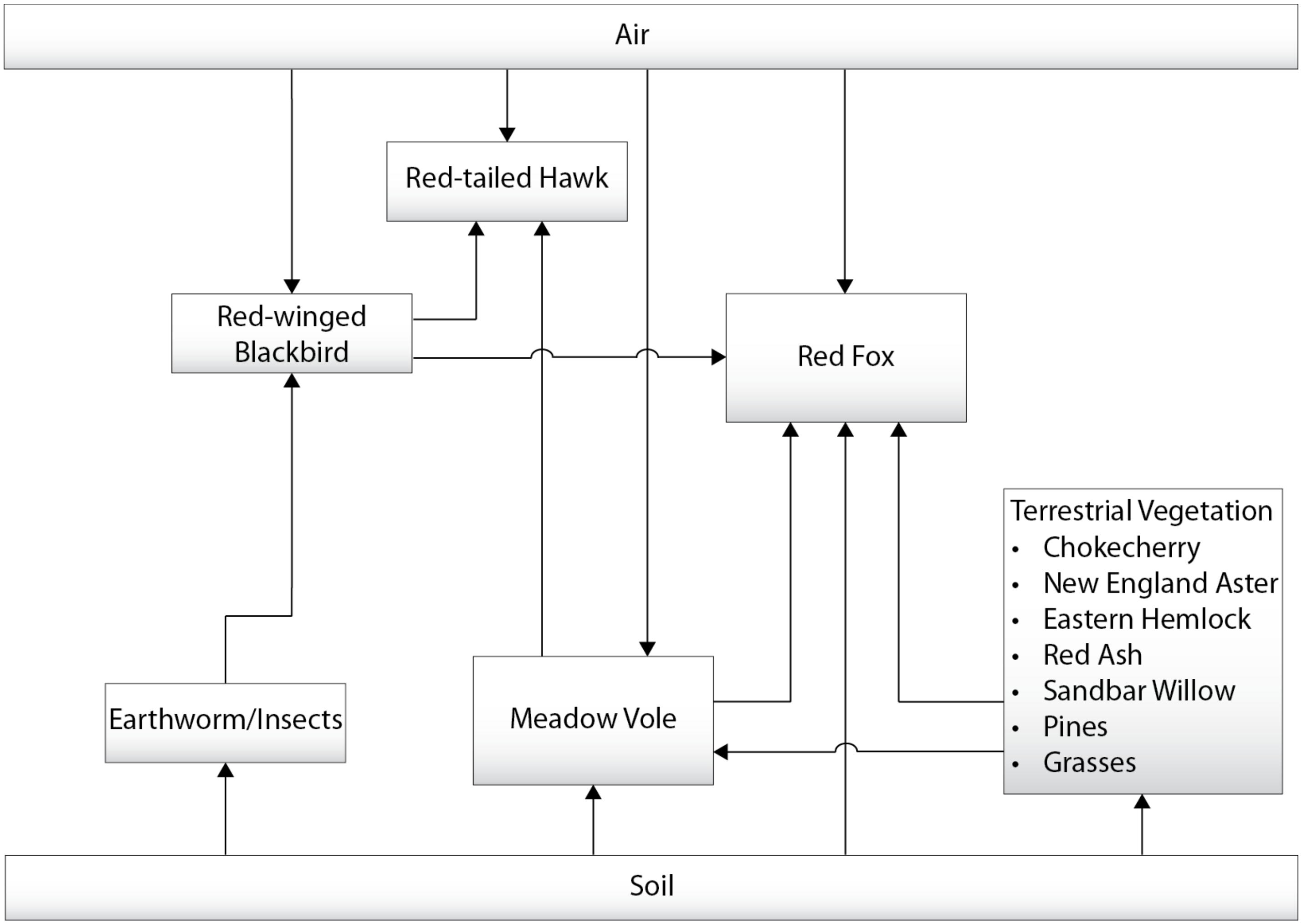
Table 5-2: Complete Exposure Pathways for All Selected VECs

VEC Category	Location	Assessment Model	VEC	Exposure Pathways	Environmental Media
Terrestrial Mammals	Pickering Nuclear Site	Red Fox	Red Fox	Immersion	Air
				Ingestion	Soil Terrestrial Vegetation Mammals Birds Water
		Meadow Vole	Meadow Vole	Immersion	Air
				Ingestion	Soil Terrestrial Vegetation Water



Note:
Riparian birds and mammals (i.e., Muskrat) are exposed to air immersion which is not shown in the figure.

Figure 5-3: Conceptual Model for the Aquatic Environment



* Although not shown on the figure, all terrestrial birds and mammals drink water.

Figure 5-4: Conceptual Model for the Terrestrial Environment

Figure 5-5: Area of Assessment for Predictive Ecological Risk Assessment

6.0 PREDICTIVE HUMAN HEALTH RISK ASSESSMENT

6.1 Exposure Assessment

In the exposure assessment, the exposure of human receptors to radiological or non-radiological contaminants of potential concern is quantified in terms of radiation or chemical dose. The screening conducted in Section 4.0 indicated that no waterborne or airborne non-radiological contaminants of potential concern exceeded screening levels; therefore the exposure assessment focuses only on radiological exposure.

6.1.1 Exposure Locations

The exposure location is the location where the receptor comes into contact with the contaminant of potential concern or stressor. For the exposure assessment, the relevant human receptors are the potential critical groups defined by the EMP, with the addition of a future industrial/commercial receptor at the Engineering Services Buildings, where appropriate. Table 6-1 presents the locations of these receptors. The approximate distance from PN is an average of the distance from PN U1-4 and U5-8.

Table 6-1: Distance and Wind Sector of Potential Critical Groups

Potential Critical Group	Approximate Distance from PN (km)	Wind Sector (Direction TO)
Farm	6.9	Northeast
Dairy Farm	10.25	North-Northeast
Urban Resident	1.35	West-Northwest
Industrial/Commercial	0.95	North-Northeast
Sport Fisher[(a)]	0.5	South
Correctional Institution[(b)]	3.1	North-Northeast
Industrial/Commercial (future)	0.37	North

Notes:

a) The sport fisher receptor is located 500 metres south, offshore of PN Generating Station.

b) The Correctional Institution is the Kennedy Youth House located 3.1 km NE of PN U1-4

6.1.2 Exposure Duration and Frequency

Consistent with the PN ERA, full-time residency was assumed for the correctional institute resident, urban resident, farm resident, and dairy farm resident. For both industrial/commercial workers and the sport fisher, a residency of 23% and 1% was assumed, respectively. A small fraction of residents living near the PN Site also work within 5 km of the PN Generating Station; therefore, they receive a portion of their dose while at home and a portion of their dose while at work. A small fraction of workers in the Industrial/Commercial critical group also live near the PN Site; therefore, they receive a portion of their dose while at work and a portion of their dose while at home. The dose received by these critical groups has been adjusted to account for these lifestyles, consistent with the annual EMP reports.

6.1.3 Exposure and Dose Calculations

Radiological dose calculations follow the equations presented in CSA N288.1-08 (CSA, 2008) which are not reproduced in this report. IMPACT 5.4.0 is used for the dose calculations and is consistent with the method of dose calculation described in CSA N288.1-08 standard.

As no non-radiological contaminants of potential concern were carried forward from the screening assessment, non-radiological exposure and dose calculations were not required.

6.1.4 Exposure Factors

For the radiological dose calculations, the exposure factors (e.g., intake rates, occupancy and shielding factors) are generally those used in CSA N288.1-08 (CSA, 2008). The intake rates for ingestion and inhalation are the mean intake rates provided in CSA N288.1-08 (CSA, 2008) and Hart (Hart, 2008) with the exception of the drinking water intake rate for a 1-year old infant. The drinking water intake rate for the 1-year old infant was adjusted from the default value in CSA N288.1-08 based on guidance in Clause 6.15.3.2 since the PN infant is assumed to drink only cow's milk (and not water and infant formula). Table 6-2 summarizes the exposure factors used in the radiological dose calculations.

Table 6-2: Human Exposure Factors for Radiological Dose Calculations

Exposure Factor	Units[(d)]	Infant 1 year	Child 10 year	Adult
Inhalation rate	m^3/a	1830	5660	5950
Inhalation occupancy factor	N/A	1.0	1.0	1.0
Incidental soil ingestion rates	g dw/d	0.04	0.04	0.01
Incidental ingestion of sediment	g dw/d	0.04	0.04	0.01
Drinking water intake rates[(a)]	L/a	0	262.8	511
Aquatic animal intake rates[(b)]	kg/a	0.58	1.97	4.6
Terrestrial animal intake rates	kg/a	249	234	256.6
Terrestrial plant intake rates	kg/a	120.5	275.1	465.9
Outdoor occupancy factor	N/A	0.2	0.2	0.2
Indoor plume shielding factor (effective dose)	N/A	0.5	0.5	0.5
Indoor plume shielding factor (skin dose and pure beta emitters)	N/A	1.0	1.0	1.0
Indoor groundshine shielding factor (gamma emitters)[(c)]	N/A	0.2	0.2	0.2
Groundshine shielding factor (uneven surface shielding)	N/A	0.5	0.5	0.5
Beach swim occupancy factor	N/A	0	0.014	0.014
Bathing occupancy factor	N/A	0.014	0.014	0.014
Pool swim occupancy factor (Water supply plant fill)	N/A	0	0.028	0.028
Pool swim occupancy factor (Well water fill)	N/A	0	0.014	0.014
Skin area	m^2	0.72	1.46	2.19

Table 6-2: continued

Exposure Factor	Units(d)	Infant 1 year	Child 10 year	Adult
Dilution factor for shoreline sediments	N/A	1.0	1.0	1.0
Shore Width factor (lake)	N/A	0.3	0.3	0.3
Shoreline occupancy factor	N/A	0.02	0.02	0.02
No. days/a soil ingested	d/a	135	135	135
No. days/a sediment ingested	d/a	45	45	45

Notes:

a) The infant water intake rate is the difference between the water intake and milk intake rate given in CSA N288.1-08 factoring in the water content of milk.

b) Excludes shellfish due to fresh water environment at the PN Site. Shellfish are a marine environment food product.

c) For effective and skin dose. For essentially pure beta emitters, this shielding factor is zero.

d) dw used in specification of units indicates dry weight.

N/A = Not applicable

m^3/a – cubic meters per annum; g dw/d – grams dry weight per day; L/a – litres per annum; kg/a – kilograms per annum; m^2 – square meters; d/a – days per annum

6.1.5 Models

A surface water model was developed (Appendix A) to predict changes to lake currents, sediment transport and water temperature in Lake Ontario during the current operational conditions and the Storage with Surveillance Phase. The results of the modelling are used to assess potential effects to human health and the environment. Details of the modelling are provided in Appendix A. The surface water model provides plume concentration factors at selected receptor locations that were used to predict concentration of contaminants of potential concern at these locations. The concentrations of contaminants of potential concern were used as inputs (dictator sources) to the IMPACT™ (IMPACT) model to calculate radiological doses to human receptors identified in Section 6.1.1.

IMPACT version 5.4.0 was used to calculate the radiological doses using predicted atmospheric and waterborne emissions during the Storage with Surveillance Phase. IMPACT 5.4.0 represents the method of dose calculation presented in CSA N288.1-08 (CSA, 2008). The concentration of radionuclides in air was determined from the sector-averaged Gaussian plume atmospheric dispersion model in IMPACT, based on the estimated release rates from PN U1-4 and PN U5-8 during the Storage with Surveillance Phase.

6.1.6 Exposure Point Concentrations and Doses

6.1.6.1 Exposure Point Concentrations

Exposure point concentrations are based on the predicted airborne and waterborne emissions from the PN Generating Station during the Storage with Surveillance Phase. Concentration factors from the surface water model for a number of receptor locations were applied to the predicted waterborne emissions during the Storage with Surveillance Phase to determine the exposure point concentrations for tritium, carbon-14, and gross beta/gamma. Cesium-137 is considered appropriated to represent gross beta/gamma in water based on derived release limit calculations. The concentration factors used to predict exposure point concentrations for subsequent use in the IMPACT model are presented in Appendix A. Concentration factors used represent the scenario where

RBSW and RLWMS streams are released via the PN U5-8 outfall during the Storage with Surveillance Phase (see Section 4.2.3.2.1.4 and Appendix A, Section A.4.3).

The concentration factors are applied to the predicted emissions of tritium, carbon-14, and gross beta/gamma to determine the exposure point concentrations at locations of receptor exposure. For receptors exposed to the beach (e.g., urban resident), the average of the water concentrations from Squires Beach, Liverpool Beach, and Frenchman's Bay Inlet were used. The exposure point concentrations for waterborne radionuclides used as input (dictator sources) to the IMPACT model for dose calculations are presented in Table 6-3.

Table 6-3: Exposure Point Concentrations for Water Contaminants of Potential Concern Used in Dose Calculations

Receptor Locations	Tritium (Bq/L)	Carbon-14 (Bq/L)	Gross Gamma-Beta (Bq/L)
RBSW Discharge	7.00×10^{3}	0.3×10^{0}	0.5×10^{0}
Sport Fisher	8.78×10^{0}	3.76×10^{-4}	6.27×10^{-4}
Squires Beach	5.24×10^{0}	2.24×10^{-4}	3.74×10^{-4}
Liverpool Beach	2.53×10^{0}	1.08×10^{-4}	1.81×10^{-4}
Frenchman's Bay Inlet	2.21×10^{0}	9.47×10^{-5}	1.58×10^{-4}
Average Beach	3.33×10^{0}	1.43×10^{-4}	2.38×10^{-4}
Ajax Water Supply Plant	0.71×10^{0}	3.03×10^{-5}	5.06×10^{-5}

Notes:
a) Gross beta / gamma is represented in IMPACT by cesium-137.
b) "Average Beach" is the average of Squires Beach, Liverpool Beach, and Frenchman's Bay (inlet).

For airborne emissions, predicted releases of tritium and carbon-14 were estimated and the process is discussed in Section 4.1.2.2.1. Atmospheric dispersion was calculated in IMPACT using the Gaussian plume model described in CSA N288.1-08 (CSA, 2008). The PN Generating Station has multiple sources of airborne releases; however, two virtual sources were modelled, one in the midpoint of PN U1-4 and one in the midpoint of PN U5-8. Combining multiple sources into virtual sources is appropriate based on recommendations in CSA N288.1-08 (CSA, 2008). The tritium and carbon-14 predicted release rates during the Storage with Surveillance Phase are presented in Table 4-2.

Meteorological data used in the atmospheric dispersion model were average triple joint frequencies of wind direction, speed and stability class compiled from hourly data collected over the 5-year period 2011 to 2015 from the on-site Pickering meteorological tower at the 10 m elevation.

Table 6-4: Air Concentrations at Human Receptor Locations

Potential Critical Group	Approximate Distance from PN (km)	Wind Sector (Direction TO)	Tritium Concentration (Bq/m^3)	Carbon-14 Concentration (Bq/m^3)
Farm	6.9	Northeast	4.58×10^{-1}	7.71×10^{-5}
Dairy Farm	10.25	North-Northeast	2.83×10^{-1}	4.72×10^{-5}
Urban Resident	1.35	West-Northwest	5.55×10^{0}	9.28×10^{-4}
Industrial/Commercial Worker	0.95	North-Northeast	9.30×10^{0}	1.57×10^{-3}
Sport Fisher	0.5	South	4.12×10^{1}	6.89×10^{-3}
Correctional Institution	3.1	North-Northeast	1.75×10^{0}	2.95×10^{-4}
Future Industrial/Commercial Worker (tenant)	0.37	North	5.03×10^{1}	8.49×10^{-3}

6.1.6.2 Exposure Doses

The resulting dose to all human receptors based on the exposure point concentrations for air and water presented above are summarized in Table 6-5. The results are based on the assumption that all RLWMS and RBSW are directed to PN U5-8. The dose breakdown by pathway is presented for each potential critical group in Appendix B.

Table 6-5 Total Dose to Potential Critical Groups – RBSW to U5-8, RLWMS to U5-8

Potential Critical Group	Adult (µSv/a)	Child (10 yr old) (µSv/a)	Infant (1yr old) (µSv/a)
Farm	0.205	0.177	0.117
Dairy Farm	0.126	0.123	0.126
Urban Resident[(a)]	1.072	1.218	0.834
Industrial/Commercial Worker[(b)]	0.448	N/A	N/A
Sport Fisher	0.206	0.133	0.077
Correctional Institution	0.320	0.376	N/A
Future Industrial/Commercial Worker (tenant) [(c)]	2.132	N/A	N/A

Notes:
a) A small fraction of the urban resident group is also considered to be an industrial/commercial worker.
b) A small fraction of the industrial/commercial worker group is also considered to be an urban resident.
c) A small fraction of the future industrial/commercial worker group (Engineering Services Buildings) is also considered to be an urban resident.
NA = Not applicable

6.1.7 Uncertainties in the Exposure Assessment

Table 6-6 summarizes the major uncertainties in the exposure assessment.

Table 6-6: Summary of Major Uncertainties in the Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
Average concentration factors from the surface water model were used to estimate water concentrations at the sport fisher, beach, and Ajax Water Supply Plant	Based on maximum and minimum lake water conditions, the concentration factors can vary. For example, the concentration factor for the Ajax Water Supply Plant intake can range from $1.9x10^{-12}$ to $1.2x10^{-3}$ with an average of $3.6x10^{-4}$.	Neither (Best Estimate)
Mixed beta-gamma emissions to water are represented by cesium-137	These radionuclides are the radionuclides with the most limiting dose based on derived release limit calculation	Overestimate
CSA N288.1-08 was used for human dose calculations in the PEA.	The 2008 standard was used instead of the 2014 standard in order to remain consistent with OPG's method for human dose calculations and the PN ERA.	Neither
Exposure doses to human scenarios during Storage with Surveillance is based only on modelling from predicted future emissions. During existing operations, exposure doses to human receptors are calculated primarily from environmental monitoring data and supplemented with modelling from emissions when necessary, to provide a realistic dose estimate.	Environmental monitoring data are not available for future emissions.	Overestimate

6.2 Toxicity Assessment

In the toxicity assessment, the selected toxicity reference values and/or benchmark values that will be used in the risk characterization are identified.

The public dose limit (benchmark) for radiation protection is 1 mSv/a, as described in the Radiation Protection Regulations under the *Nuclear Safety and Control Act*. This limit is defined as an incremental dose. It is set at a fraction of natural background exposure to radiation. Public doses arising from licensed facilities are compared to the public dose limit and higher doses are considered unacceptable.

6.3 Risk Characterization

In the risk characterization, the results of the exposure assessment and toxicity assessment are integrated together. The exposure concentration/dose is compared against the toxicity benchmark to estimate the likelihood of risk posed to human receptors.

6.3.1 Risk Estimation and Discussion of Radiation Effects

The total radiological dose is compared to the public dose limit of 1 mSv/a as shown in Table 6-7. The predicted radiological dose to the potential future Industrial/Commercial worker at the Engineering Services Buildings during Storage with Surveillance is 0.002 mSv/a. The dose to this receptor is dominated by the air pathway. The future industrial/commercial worker at the Engineering Services Buildings is a new receptor that may exist in the future that is not in the PN ERA (EcoMetrix and Golder, 2017).

Table 6-7 also compares the dose to the critical groups under existing operations (average 2011-2015) to the predicted dose to the critical groups during the Storage with Surveillance Phase. The main difference between the two scenarios is that dose to human receptors for existing operations is calculated primarily from environmental monitoring data and supplemented with modelling from emissions, when necessary, to provide a realistic dose estimate. The dose to human receptors during Storage with Surveillance is based only on modelling from predicted future emissions. Modelling exclusively from emissions provides a conservative estimate of dose.

During existing operations, the dose to the urban resident is typically around 0.0011 mSv/a, based largely on use of environmental monitoring data. During the Storage with Surveillance Phase, the dose to the urban resident is expected to be marginally higher (approximately 0.0012 mSv/a), based on predictions from emissions. The dose to the urban resident is primarily due to the air inhalation pathway.

The public dose estimates for the human receptors in the Storage with Surveillance Phase is approximately 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.15% of the dose from Canadian background radiation.

Expected facility releases during Storage with Surveillance activities are considered to be adequately controlled, and further optimization of PN operations is not required. Nevertheless, the ALARA principle is applied at the PN Generating Station to reduce emissions as low as reasonably possible.

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 Generating Station during the Storage with Surveillance Phase.

Table 6-7: Comparison of Total Dose to Potential Critical Groups Under Existing Conditions and Storage with Surveillance

Potential Critical Group	Existing Conditions (Average 2011-2015)		Storage with Surveillance	
	Maximum Dose and Limiting Age Group[d] (µSv/a)	% of Public Dose Limit	Modelled Dose and Limiting Age Group (µSv/a)	% of Public Dose Limit
Farm	0.34 (adult)	0.03	0.21 (adult)	0.02
Dairy Farm	0.40 (adult)	0.04	0.13 (adult)	0.01
Urban Resident[(a)]	1.10 (adult)	0.11	1.22 (10 y old)	0.12
Industrial/Commercial Worker[(b)]	0.93 (adult)	0.09	0.45 (adult)	0.05
Sport Fisher	0.30 (10 y old)	0.03	0.21 (adult)	0.02
Correctional Institution	0.86 (10 y old)	0.09	0.38 (10 y old)	0.04
Future Industrial/Commercial Worker (tenant)[(c)]	N/A	N/A	2.13 (adult)	0.21

Notes:

a) A small fraction of the urban resident group is also considered to be an industrial/commercial worker.

b) A small fraction of the industrial/commercial worker group is also considered to be an urban resident.

c) A small fraction of the future industrial/commercial worker group is also considered to be an urban resident.

d) Dose is the average for the critical group from 2011-2015 for the limiting age group as presented in annual EMP reports. For the farm and sport fisher the dose only includes 2011 and 2012 as these are no longer reported in the annual EMP.

6.3.2 Uncertainties in the Risk Characterization

There is inherent uncertainty in the air model in IMPACT that is used by OPG to estimate atmospheric dispersion factors to the critical group locations. Uncertainty in the air predictions arises from the following assumptions made in the air model (Hart, 2008):

- the activity in the plume has a normal distribution in the vertical plane;
- the effects of building-induced turbulence on the effective release height and plume spread have been generalized, while data suggest that effects of building wakes vary substantially depending upon the geometry of the buildings and their orientation with respect to wind direction; and
- a given set of meteorological and release conditions leads to a unique air concentration, where in reality measured concentrations can vary by a factor of 2 under identical conditions.

At distances greater than 1 km, there is a two-fold uncertainty around the predictions of the sector-averaged Gaussian model used in IMPACT (Hart, 2008). At all distances, the Gaussian air model in IMPACT on average, overpredicts air concentrations by approximately a factor of 1.5 (Hart, 2008). Considering the combined uncertainties in the exposure assessments and the target values, it is reasonable that the overall risks presented are conservative estimates.

A probabilistic risk assessment to quantify uncertainty in the risk estimate has not been performed and is not considered necessary since it is not likely to provide a better basis for risk management/decision making. According to CSA N288.6-12 (CSA, 2012), a qualitative or semi-quantitative evaluation of uncertainty is considered sufficient for evaluation of uncertainty.

There are also uncertainties and conservative assumptions made in the development of the dispersion model inputs for the PN Site in the ESDM:

- most sources were modelled as volume sources, which is conservative since this model source type does not take advantage of favourable dispersion characteristics such as plume buoyancy and initial exit velocity of emissions; and
- the dispersion modelling source dimensions selected for a given volume source result in a dispersion modelling source which is smaller than the corresponding real-life source. This results in a conservative dispersion modelling scenario for this source since estimated emissions occur over a smaller area and thus are more concentrated (and therefore less dispersed) at the point of release.

There are uncertainties and conservative assumptions made in the emission estimates and operating conditions for the ESDM as well:

- the highest emission rate that each source is capable of (i.e., maximum usage rates or throughputs) was used to characterize the emissions;
- all sources are assumed to be operating simultaneously at the corresponding maximum emission rate for the averaging period;
- all fuel-fired combustion equipment (i.e., comfort heating and emergency power) emission rates were determined using the highest emission factor, combined with the maximum thermal heat input or engine rating for each piece of equipment; and
- incorporate any other conservative assumptions (e.g. virtual products, 100% volatilization).

Based on the conservative assumptions summarized above the emission rates used for the ESDM are not likely to be an underestimate of the actual emission rates.

A three dimensional, hydrodynamic, surface water model was developed (Appendix A) and was used to predict concentrations for use in dose calculations. The model was also used for a quantitative assessment of temperature effects and a qualitative sediment deposition locations. There are various uncertainties associated with the surface water model; however, all were considered to be acceptable when compared to industry standards and do not significantly affect the outcomes and use of the model. Appendix A details many of the uncertainty issues within the report and the following is a summary of some of these uncertainties.

- The data available for use in developing the model has limits, as is common for any field data, and the limits are discussed in Section A.2.
- The calibration of the model indicates acceptable results however, as with all surface water models there is not perfect reproducibility of actual conditions. A qualitative assessment of the model indicates that the model predicts alongshore current well, but is less accurate for offshore components of flow. Alongshore current is

considered the primary factor affecting thermal and contaminant plumes and therefore this was not considered a significant limitation. A quantitative calibration and verification was conducted and indicates the model generally meets industry standard acceptance criteria with a higher degree of uncertainty for offshore flow (Section A.3).

- The sensitivity of the model predictions with respect to the tracer concentrations (e.g., Concentration Factor) is addressed by providing predictions for extended simulation periods. These simulation periods are expected to encompass all of the expected variations and combinations of current speed, current direction, duration of current event, and water temperature. Tables in Appendix A provide the average, minimum, maximum, and standard deviation for Concentration Factors at each of the receptor locations. Use of the average Concentration Factor was considered suitable for long term predictions. However, it is expected that use of the maximum Concentration Factors would still result in acceptable dose calculations as the doses calculated are orders of magnitude below the acceptable limits.

7.0 PREDICTIVE ECOLOGICAL RISK ASSESSMENT

7.1 Exposure Assessment

7.1.1 Exposure Points

Exposure points at receptor locations are estimated based on concentration factors from the surface water model. The receptor locations of interest are the PN outfall, forebay, and Frenchman's Bay.

7.1.2 Exposure Averaging and Environmental Partitioning

7.1.2.1 Exposure Averaging

Receptors were exposed to maximum concentrations expected during the Storage with Surveillance Phase. Protection of receptors at maximum exposure concentrations ensures that the assessment is bounding if concentrations are lower.

7.1.2.2 Environmental Partitioning

Water:sediment partitioning was estimated as described below in activity units:

$$C_{s(fw)} = \frac{\theta \cdot C_w \cdot \rho_w + (1-\theta) \cdot C_w \cdot K_d \cdot \rho_s}{\theta \cdot \rho_w + (1-\theta) \cdot \rho_s}$$

$$C_{s(dw)} = C_{s(fw)} / f_{dw}$$

$$f_{dw} = \frac{(1-\theta) \cdot \rho_s}{\theta \cdot \rho_w + (1-\theta) \cdot \rho_s}$$

where,

$C_{s(fw)}$	=	concentration in sediment (Bq/kg-fw)
C_w	=	concentration in water (Bq/L)
ρ_w	=	density of water (1 kg/L)
θ	=	sediment porosity (unitless)
K_d	=	distribution coefficient (L/kg solid)
ρ_s	=	density of solids (kg/L)
$C_{s(dw)}$	=	concentration in sediment (Bq/kg-dw)
f_{dw}	=	dry weight fraction of sediment (unitless).

The sediment distribution coefficients (K_d) used in the environmental partitioning calculations to estimate sediment concentrations from water concentrations are listed in Table 7-1. For contaminants of potential concern that do not have a sediment K_d in CSA N288.1-14 (CSA, 2014) or International Atomic Energy Agency (IAEA) (IAEA, 2010), the soil K_d found in IAEA (2010) was used. The soil K_d is multiplied by a factor of 10 to take into account the typically higher water content (water filled porosity) in sediment and greater available particle surface area for adsorption. The sediment porosity and sediment density at the PN Generating Station is assumed to be 0.1 and 1.5 kg/L respectively (for sand) (CSA, 2014). At Frenchman's Bay, since measured moisture content was available for sediment samples collected in 2015, the sediment porosity was 0.6, the average moisture content from all sediment samples.

Table 7-1: Sediment Distribution Coefficients

Contaminant of Potential Concern	Distribution Coefficient (K_d) (L/kg-dw)	Reference
Tritium	0	CSA, 2014
Carbon-14	50	CSA, 2014
Cobalt-60	43,000	CSA, 2014
Cesium-134	9,500	CSA, 2014
Cesium-137	9,500	CSA, 2014

Note: L/kg-dw – litres per kilogram dry weight

7.1.3 Exposure and Dose Calculations

Exposure and dose calculations for each contaminant of potential concern were performed for the ecological receptors and receptor locations outlined in the ecological conceptual model (Section 5.2).

7.1.3.1 Radiological Dose Calculations

The radiation doses for the aquatic biota were estimated using the methods outlined in CSA N288.6-12 (CSA, 2012). The dose for each radionuclide is comprised of an internal dose component, and an external dose component, which is driven by water and sediment. The 0.5 in the equation is for semi-infinite exposure to activity in water, for the time the organism spends at water surface, and a semi-infinite exposure to activity in sediment, for the time the organism spends at sediment surface. The aquatic biota dose was calculated using the following equations:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext} \cdot [(OF_w + 0.5 \cdot OF_{ws} + 0.5 \cdot OF_{ss}) \cdot C_w + (OF_s + 0.5 \cdot OF_{ss}) \cdot C_s]$$

where,

D_{int}	=	internal radiation dose (µGy/d)
D_{ext}	=	external radiation dose (µGy/d)
DC_{int}	=	internal dose conversion factor ((µGy/d)/(Bq/kg))
DC_{ext}	=	external dose coefficient ((µGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg-fw)
C_w	=	water concentration (Bq/L)
C_s	=	sediment concentration (Bq/kg-fw)
OF_w	=	occupancy factor in water (unitless)
OF_{ws}	=	occupancy factor at water surface (unitless)
OF_{ss}	=	occupancy factor at sediment surface (unitless)
OF_s	=	occupancy factor in sediment (unitless)

For riparian biota that have both an on soil (sediment) and a water external dose coefficient, such as the Muskrat and waterbirds, the external dose component was calculated as follows:

$$D_{ext} = DC_{ext,w} \cdot OF_w \cdot C_w + DC_{ext,s} \cdot OF_{ss} \cdot C_s$$

where,

$DC_{ext,w}$	=	external dose coefficient (in water)
$DC_{ext,s}$	=	external dose coefficient (on sediment)
C_w	=	water concentration (Bq/L)
C_s	=	sediment concentration (Bq/kg-fw)
OF_w	=	occupancy factor in water (unitless)
OF_{ss}	=	occupancy factor on sediment surface (unitless)

The radiation dose to terrestrial biota is estimated using a method similar to that for riparian biota, except the external dose component is driven by soil rather than water and sediment. The equations used to estimate radiation dose to terrestrial biota are:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext,s} \cdot OF_s \cdot C_s + DC_{ext,ss} \cdot OF_{ss} \cdot C_s$$

where,

DC_{int}	=	internal dose coefficient ((µGy/d)/(Bq/kg))
$DC_{ext,s}$	=	external dose coefficient (in soil) ((µGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg-fw)
C_s	=	soil concentration (Bq/kg-dw)
OF_s	=	occupancy factor in soil (unitless)
OF_{ss}	=	occupancy factor at soil surface (unitless)

The total radiation dose to biota is the sum of the internal and external dose components for each radionuclide (D_{int} + D_{ext}). External exposures through the air immersion and inhalation pathway are considered to be minor compared to the ingestion pathway, and were considered to warrant assessment. Although CSA N288.6-12 (CSA, 2012) recommends assessing noble gases in air, noble gas emissions are not expected during the Storage with Surveillance Phase; therefore noble gases were not assessed. The dose coefficients and occupancy factors used in the radiological dose estimation are provided in Section 7.1.3.4.

7.1.3.2 Non-Radiological Dose Calculations

As no non-radiological contaminants of potential concern were carried forward from the screening assessment, non-radiological exposure and dose calculations were not required.

7.1.3.3 Tissue Concentration Calculations

The tissue concentrations (C_t) for plants, invertebrates or fish were derived using bioaccumulation factors, as per CSA N288.6-12 (CSA, 2012) as follows:

$$C_t = C_m \cdot BAF$$

where,

C_t	=	whole body tissue concentration (Bq/kg-fw)
C_m	=	media concentration (Bq/L or Bq/kg)
BAF	=	bioaccumulation factor (L/kg or kg/kg)

For birds and mammals, tissue concentrations were estimated using transfer factors, or biomagnification factors (BMFs) and the concentrations in their food, as follows:

$$C_t = \Sigma\, C_x \cdot I_x \cdot TF = C_f \cdot BMF$$

where,

C_x	=	concentration in the ingested item x (Bq/kg-fw)
I_x	=	ingestion rate of item x (kg-fw/d)
TF	=	ingestion transfer factor (d/kg)
C_f	=	average concentration in food (Bq/kg-fw)
BMF	=	biomagnification factor (unitless)

The BMF is equivalent to the total food intake rate multiplied by the transfer factor:

$$BMF = \Sigma\, I_x \cdot TF$$

The bioaccumulation factors, transfer factors and ingestion rates used for the calculation of tissue concentrations in biota are further described in Section 7.1.3.4.

7.1.3.4 Exposure Factors

There are several contaminant of potential concern- and biota-specific exposure factors required for the dose calculations. These parameters include intake rates, body weights, occupancy factors, bioaccumulation factors, transfer factors, and dose coefficients.

7.1.3.4.1 Body Weight and Intake Rates

The body weight and intake rates are required for the calculation of exposure to birds and mammals. The body weights and total feed intake rates were consistent with those in the PN ERA (EcoMetrix and Golder, 2017). The values are summarized in Table 7-2.

Table 7-2: Bird and Mammal Body Weights and Intake Rates

Receptor	Body weight (kg)	Total Feed Intake		Dietary Components	Feed Type Fraction	Feed Intake		% Moisture[a]	Intake of Soil/ Sediment [b] (%)	Total Soil/ Sediment (kg-dw/d)	Water Intake (kg/d)	Inhalation (m^3/d)
		(kg/d dw)	(kg/d fw)			(kg/d dw)	(kg/d fw)					
Trumpeter Swan	11.0	0.347	1.386	Aquatic Plants	1	0.347	1.386	75%	3.3%	$1.14x10^{-2}$	0.294	2.591
Ring-Billed Gull	0.700	0.050	0.193	Aquatic Plant	0.2	0.010	0.040	75%	3.3%	$1.64 x10^{-3}$	0.046	0.311
				Fish	0.6	0.030	0.120	75%				
				Soil Invert	0.1	0.005	0.017	70%				
				Small Mammals	0.1	0.005	0.017	70%				
Common Tern	0.125[c]	0.015	0.060	Fish	0.9	0.014	0.054	75%	2%	$3.01 x10^{-4}$	0.015	0.082
				Benthic Invert	0.1	0.002	0.006	75%				
Bufflehead	0.473[d]	0.045	0.179	Aquatic Plant	0.1	0.004	0.018	75%	10.4%	$4.65 x10^{-3}$	0.036	0.230
				Benthic Invert	0.9	0.040	0.161	75%				
Muskrat	1.18	0.088	0.353	Aquatic Plant	1.0	0.088	0.353	75%	3.3%	$2.91 x10^{-3}$	0.114	0.621
Red-winged Blackbird	0.055[e]	0.009	0.029	Insects (Soil Invert)	1	0.009	0.029	70%	7.3%	$6.39 x10^{-4}$	0.008	0.044
Red-tailed Hawk	1.22	0.066	0.221	Birds	0.27	0.018	0.060	70%	3.3%	$2.19 x10^{-3}$	0.068	0.478
				Small Mammals	0.73	0.048	0.162	70%				
Red Fox	4.54	0.088	0.313	Small Mammals	0.5	0.047	0.157	70%	2.8%	$2.45 x10^{-3}$	0.386	1.831
				Riparian Bird	0.3	0.028	0.094	70%				
				Vegetation	0.2	0.013	0.063	80%				
Meadow Vole	0.034	0.002	0.011	Vegetation	1	0.002	0.011	80%	2.4%	$5.28 x10^{-5}$	0.005	0.036

Notes:
Data is from 2000 ERA (SENES, 2000), unless otherwise indicated.
kg/d dw – kilograms per day dry weight; kg/d fw – kilograms per day fresh (total) weight;
a) (CSA, 2014). b) (Beyer et al., 1994) c) (Cuthbert et al., 2003)
d) (NatureServe, 2013) e) (MOE, 2009)

7.1.3.4.2 Occupancy Factors

The fraction of time the biota resides in the PN Generating Station area, as discussed in Section 7.1.2, is assumed to be one. An occupancy factor is defined as the fraction of time the receptor species spends in or on various media. The occupancy factors, where available, are those in the previous ERA (SENES, 2000) and (SENES, 2001). For new biota, the occupancy factors are based on the experience and judgement of the risk assessor and the known behaviour of the receptor. The occupancy factors used in the radiological dose estimation are given in Table 7-3, and are applied to the equations discussed in Section 7.1.3.1.

Table 7-3: Receptor Occupancy Factors

Aquatic Biota	OF_s	OF_{ss}	OF_w	Terrestrial Biota	OF_s	OF_{ss}
Bottom Dwelling Fish		0.5	0.5	Terrestrial Plant		1
Pelagic Fish			1	Earthworm	1	
Amphibians		0.5	0.5	Red-winged Blackbird		1
Benthic Invertebrates	1			Red-tailed Hawk		1
Aquatic Plants			1	Meadow Vole		1
Riparian Birds		0.5	0.5	Red Fox	0.2	0.8
Muskrat		0.5	0.5			

Notes:
OF_s = occupancy factor in soil/sediment.
OF_{ss} = occupancy factor on soil/sediment surface.
OF_w = occupancy factor in water.

7.1.3.4.3 Bioaccumulation Factors

Bioaccumulation factors relate the contaminants of potential concern in the environmental media to the concentration in the receptor. Since tissue concentrations were not available for the receptors at the PN Generating Station, bioaccumulation factors were used to calculate contaminant of potential concern concentrations in plant, invertebrate and fish tissues. These factors vary throughout the literature. For the exposure assessment, bioaccumulation factors were taken from CSA N288.1-14 (CSA, 2014), IAEA (IAEA, 2010) and literature sources, including those suggested in CSA N288.6-12 (CSA, 2012). The bioaccumulation factors used in the assessment are presented in Table 7-4 and Table 7-7. Bioaccumulation factors for tritium and carbon-14 are calculated using the specific activity model, which is discussed in Section 7.1.3.4.6 and 7.1.3.4.7.

Table 7-4: Bioaccumulation Factors for Fish, Amphibians, Benthic Invertebrates, and Aquatic Plants (L/kg-fw)

Contaminant of Potential Concern	Fish	Amphibian	Benthic Invertebrate	Aquatic Plant
Cobalt-60	5.40×10^{1} [(a)]	5.40×10^{1} [(a)]	1.10×10^{2} [(a)]	7.90×10^{2} [(a)]
Cesium-134	3.50×10^{3} [(a)]	3.50×10^{3} [(a)]	9.90×10^{1} [(a)]	2.20×10^{2} [(a)]
Cesium-137	3.50×10^{3} [(a)]	3.50×10^{3} [(a)]	9.90×10^{1} [(a)]	2.20×10^{2} [(a)]

Note:
a) (CSA, 2014).

7.1.3.4.4 Transfer Factors

Transfer factors represent the fraction of daily contaminant of potential concern intake transferred to the tissue of birds and mammals. Ingestion transfer factors are contaminant of potential concern and biota-specific. Transfer factors from feed to tissue for agricultural livestock are available in CSA N288.1-14 (CSA, 2014). An allometric equation (transfer proportional to a -3/4 power of body weight) (CSA, 2012), was applied to transfer factors available for beef, rabbit and poultry, to estimate the transfer factors for the bird and mammal receptors. The derived transfer factors are presented in Table 7-5. The transfer factors for tritium and carbon-14 were derived using specific activity methods, which are discussed in Sections 7.1.3.4.6 and 7.1.3.4.7.

Table 7-5: Transfer Factors for Riparian Birds and Mammals (d/kg-fw)

Contaminant of Potential Concern	Trumpeter Swan	Ring-Billed Gull	Common Tern	Bufflehead	Muskrat
Cobalt-60	2.70×10^{-1}	2.13×10^{0}	7.76×10^{0}	2.86×10^{0}	4.62×10^{-2}
Cesium-134	7.52×10^{-1}	5.93×10^{0}	2.16×10^{1}	7.96×10^{0}	2.36×10^{0}
Cesium-137	7.52×10^{-1}	5.93×10^{0}	2.16×10^{1}	7.96×10^{0}	2.36×10^{0}

Radionuclide transfer factors were derived from beef and poultry transfer factors from CSA N288.1-14 (CSA, 2014).

7.1.3.4.5 Dose Coefficients

Radiation dose coefficients used for terrestrial and aquatic biota are shown in Table 7-6. These dose coefficients were taken from the International Commission on Radiological Protection (ICRP, 2008) and the ERICA Tool (ERICA Tool, 2011). The surrogate species from these sources were selected to represent the indicator species, considering similarities in body size and likely external exposure media. The dose coefficient values for tritium in both sources (ICRP, 2008 and ERICA Tool, 2011) do not incorporate radiation quality factors for relative biological effectiveness. Therefore, the “low beta” components of the dose coefficients were multiplied by 2 (as per CSA N288.6-12) in order to represent its greater relative effectiveness.

Table 7-6: Dose Coefficients (DCs) of Surrogate Receptors Used for Radiological Exposure Calculations

Radionuclide	Earthworm[a]		Shrub[b,c]		Insect Larvae[b,c]		Vascular Plant[b,c]	
	Internal DC	External DC (in soil)	Internal DC	External DC	Internal DC	External DC	Internal DC	External DC
	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)
Tritium	1.38×10^{-4}	0	1.39×10^{-4}	0	1.39×10^{-4}	5.76×10^{-12}	1.39×10^{-4}	4.32×10^{-8}
Carbon-14	6.80×10^{-4}	0	6.72×10^{-4}	0	6.72×10^{-4}	1.97×10^{-5}	6.48×10^{-4}	2.64×10^{-5}
Cobalt-60	1.80×10^{-3}	3.10×10^{-2}	1.78×10^{-3}	1.08×10^{-2}	1.25×10^{-3}	3.36×10^{-2}	1.25×10^{-3}	3.36×10^{-2}
Cesium-134	2.60×10^{-3}	2.00×10^{-2}	2.40×10^{-3}	6.96×10^{-3}	1.73×10^{-3}	2.21×10^{-2}	1.66×10^{-3}	2.21×10^{-2}
Cesium-137	3.40×10^{-3}	7.30×10^{-3}	3.36×10^{-3}	2.64×10^{-3}	2.35×10^{-3}	8.88×10^{-3}	2.35×10^{-3}	8.88×10^{-3}

Radionuclide	Rat[a,c]			Trout[a]	
	Internal DC	External DC (on soil)	External DC (in soil)	Internal DC	External DC (in water)
	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)	(µGy/d)/(Bq/kg)
Tritium	1.38×10^{-4}	0	0	1.38×10^{-4}	8.50×10^{-12}
Carbon-14	6.80×10^{-4}	0	0	6.80×10^{-4}	4.40×10^{-7}
Cobalt-60	4.00×10^{-3}	1.20×10^{-2}	2.90×10^{-2}	5.10×10^{-3}	3.10×10^{-2}
Cesium-134	4.10×10^{-3}	7.40×10^{-3}	1.90×10^{-2}	4.90×10^{-3}	1.90×10^{-2}
Cesium-137	4.10×10^{-3}	2.70×10^{-3}	6.80×10^{-2}	4.40×10^{-3}	6.80×10^{-3}

Table 7-6: Dose Coefficients of Surrogate Receptors Used for Radiological Exposure Calculations (continued)

Radionuclide	Tadpole[(a)]		Duck[(a,c)]		
	Internal DC	External DC (in water)	Internal DC	External DC (on soil)	External DC (in water)
	(μGy/d)/(Bq/kg)	(μGy/d)/(Bq/kg)	(μGy/d)/(Bq/kg)	(μGy/d)/(Bq/kg)	(μGy/d)/(Bq/kg)
Tritium	1.38×10^{-4}	3.20×10^{-10}	1.38×10^{-4}	0	8.50×10^{-12}
Carbon-14	6.80×10^{-4}	5.50×10^{-6}	6.80×10^{-4}	0	4.30×10^{-7}
Cobalt-60	1.50×10^{-3}	3.40×10^{-2}	5.70×10^{-3}	1.10×10^{-2}	3.00×10^{-2}
Cesium-134	2.30×10^{-3}	2.20×10^{-2}	5.30×10^{-3}	7.00×10^{-3}	1.90×10^{-2}
Cesium-137	3.20×10^{-3}	8.10×10^{-3}	4.50×10^{-3}	2.60×10^{-3}	6.70×10^{-3}

Notes:

a) Earthworm, rat, trout, tadpole and duck does coefficients (DCs) from International Commission on Radiological Protection (ICRP, 2008)

b) Shrub, insect larvae and vascular plant does coefficients (DCs) from ERICA Tool (Brown et al., 2003)

c) Shrub is the surrogate species for all terrestrial plants, insect larvae used for benthic invertebrates, vascular plants for aquatic plants, rat for mammals, and duck for all birds.

7.1.3.4.6 Specific Activity Model for Tritium

For tritium and carbon-14, tissue concentrations were calculated using specific activity models, as recommended in Clause 7.3.4.3.7 of CSA N288.6-12 (CSA, 2012). Aquatic bioaccumulation factors for tritium assume that the specific activity in the aqueous component of the aquatic animal or plant is the same as the specific activity in the water. Bioaccumulation factors are used to calculate tritium concentrations in plant, invertebrate and fish tissues. Therefore the bioaccumulation factor (L/kg-fw) is:

$$BAF_{a\_HTO} = 1\text{-}DW_a$$

or

$$BAF_{p\_HTO} = 1\text{-}DW_p$$

where,

$1\text{-}DW_a$	=	water content of the animal (L water /kg-fw)
$1\text{-}DW_p$	=	water content of the plant (L water /kg-fw plant)

For tritium (tritiated water or HTO), the majority of the tritium taken into the animal is from water ingestion and food consumption. Soil ingestion dose from tritium is negligible. The transfer of tritiated water to animals ($P_{HTOwater\_animal}$, L/kg-fw) through water ingestion was determined using the specific activity model from CSA N288.1-14 (CSA, 2014), and is calculated as follows:

$$P_{HTOwater\_animal} = k_{aw} \cdot f_{w\text{-}w} \cdot (1\text{-}DW_a)$$

where,

k_{aw}	=	fraction of water from contaminated sources (assumed to be 1)
$f_{w\text{-}w}$	=	fraction of the animal water intake derived from direct ingestion of water (0.5 from CSA N288.1-14)
DW_a	=	dry/fresh weight ratio for animal products (kg-dw/kg-fw) (0.3 from CSA N288.1-14)

The transfer of tritiated water to animals through food ingestion ($P_{HTOfood\_animal}$, unitless) was also determined using the specific activity model from CSA N288.1-14 (CSA, 2014), and is calculated as follows:

$$P_{HTOfood\_animal} = k_{af} \cdot ((1\text{-}f_{OBT}) \cdot f_{w\text{-}pw} + 0.5 \cdot f_{w\text{-}dw}) \cdot (1\text{-}DW_a)/(1\text{-}DW_p)$$

where,

k_{af}	=	fraction of food from contaminated sources (assumed to be 1)
$f_{w\text{-}pw}$	=	fraction of the animal water intake derived from water in the plant feed
$f_{w\text{-}dw}$	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
f_{OBT}	=	fraction of total tritium in the animal product in the form of organically bound tritium (OBT) as a result of tritium ingestion
$1\text{-}DW_a$	=	water content of the animal product (L water/kg-fw)
$1\text{-}DW_p$	=	water content of the plant/food (L water/kg-fw plant)

For each receptor, the water content of the total diet (DW_p) was determined based on the weighted average of the water content of the individual food items in the receptor's diet. For example, the Ring-billed Gull's diet consists of 60% fish, 20% aquatic plants, 10% invertebrates, and 10% small mammals. The combined DW_p for the Ring-billed Gull was the weighted average of the dry weight fraction for fish, plants, invertebrates, and small mammals.

A summary of the input parameters is provided in Table 7-8 and a summary of the transfer factors for Tritium (tritiated water) are provided in Table 7-10.

Table 7-7: Summary of BioAccumulation Factors for Tritium and Carbon-14

Receptor	Units	Tritium (tritiated water)	Carbon-14
Fish	L/kg-fw	7.50×10^{-1}	5.70×10^{3}
Aquatic Plant	L/kg-fw	7.50×10^{-1}	5.90×10^{3}
Benthic Invertebrate	L/kg-fw	7.50×10^{-1}	5.20×10^{3}
Amphibian	L/kg-fw	7.50×10^{-1}	5.70×10^{3}

7.1.3.4.7 Specific Activity Model for Carbon-14

Aquatic bioaccumulation factors for carbon-14 assume that the carbon-14 to stable carbon ratio in aquatic animals is equal to the ratio in dissolved inorganic carbon in the water. Therefore the bioaccumulation factor (L/kg-fw) for aquatic animals, invertebrates, and plants is calculated as follows:

$$BAFa_{C14} = S_a/S_w$$

where,

S_a = stable carbon content in the aquatic animal/invertebrate/plant (gC/kg-fw)
S_w = mass of stable carbon in the dissolved inorganic phase in water (gC/L)

S_w is 0.0213 gC/L, consistent with N288.1-14 (CSA, 2014). For fish, the stable carbon content is 122 gC/kg-fw. For freshwater invertebrates, the stable carbon content for marine crustaceans (111 gC/kg-fw) was considered appropriate, and for aquatic plants, the stable carbon content for terrestrial plants (500 gC/kg-dw or 125 gC/kg-fw) was considered appropriate (CSA, 2014).

For carbon-14, food consumption contributes to the majority of the carbon ingested by the animal, compared to inhalation, water and soil ingestion. The transfer of carbon-14 from food to animals was determined using a specific activity model consistent with that presented in CSA N288.1-14 update (CSA, 2014).

$$P_{C14food\_animal} = k_{af} \cdot S_a/S_p$$

where,

S_a = stable carbon content in the animal (gC/kg-fw) (X_{5_C} in N288.1-14 [CSA, 2014])
S_p = stable carbon content in the food (gC/kg-fw) ($X_{4\_C} \cdot DW_p$ in N288.1-14 [CSA, 2014])

The stable carbon content in the animal was obtained from CSA N288.1-14 (CSA, 2014). The beef value was applied for all mammals and the poultry value was applied for all birds. For each receptor, the carbon content of the total diet (S_p) was determined based on the weighted average of the carbon content of the individual food items in the receptor's diet. A summary of the input parameters is provided in Table 7-8 and Table 7-9, and a summary of the transfer factor for carbon-14 is provided in Table 7-10.

Table 7-8: Input Parameters for Specific Activity Calculations for Tritium and Carbon-14

Receptor	f_{w_ww}	f_{w_pw}	f_{w_dw}	f_{OBT}	DW_p (kg-dw/ kg-fw)	S_a (gC/kg-fw)	S_p (gC/kg-fw)
Trumpeter Swan	0.22	0.65	0.121	0.1	0.25	244	125
Ring-Billed Gull	0.22	0.65	0.121	0.1	0.26	244	129.3
Common Tern	0.22	0.65	0.121	0.1	0.25	244	120.9
Bufflehead	0.22	0.65	0.121	0.1	0.25	244	112.4
Muskrat	0.413	0.509	0.071	0.11	0.25	201	124.4

Notes:
f_{w_w}, f_{w_pw}, f_{w_dw}, and f_{OBT} are from Table 16 and 17 in CSA N288.1-14 (CSA, 2014)
S_a are the beef and poultry values from Table 18 in CSA N288.1-14 (CSA, 2014)

Table 7-9: Stable Carbon Content for Food Types

Food Type	Stable Carbon Content (gC/kg-fw)	Reference
aquatic plants	125	(CSA, 2014)
fish	122	(CSA, 2014)
insects/earthworms	111	(CSA, 2014)
small mammals	200	(IAEA, 2010)(Table 67)
benthic invertebrates	111	(CSA, 2014)
birds	240	(IAEA, 2010) (Table 67)
vegetation	95	(Zach and Sheppard, 1992) (adjusted to fw)

Table 7-10: Summary of Transfer Factors for Tritium and Carbon-14

Receptor	$P_{HTOwater\_animal}$ (L/kg-fw)	$P_{HTOfood\_animal}$ (unitless)	$P_{C14food\_animal}$ (unitless)
Trumpeter Swan	0.154	0.60	1.95
Ring-Billed Gull	0.154	0.61	1.89
Common Tern	0.154	0.60	2.02
Bufflehead	0.154	0.60	2.17
Muskrat	0.289	0.46	1.61

7.1.4 Dispersion Models

No dispersion models were used for the predictive ecological exposure assessment.

7.1.5 Exposure Point Concentrations and Doses

7.1.5.1 Exposure Point Concentrations

Exposure point concentrations were estimated from the expected radiological and non-radiological emissions from PN during the Storage with Surveillance Phase. As mentioned, based on the screening in Section 4.2.3, only radiological contaminants of potential concern were carried forward in the exposure assessment for the PN outfall, Frenchman’s Bay, and the PN Forebay.

7.1.5.1.1 PN Outfall and Frenchman’s Bay

Concentration factors from the surface water model for the PN outfall and inside Frenchman’s Bay were applied to the predicted waterborne emissions during the Storage with Surveillance Phase to determine the exposure point concentrations for tritium, carbon-14, and gross beta/gamma. The estimated exposure point concentrations for the PN outfall and Frenchman’s Bay are presented in Table 7-11 for tritium, carbon-14 and Gross beta / gamma (represented by cobalt-60). Concentration factors used represent the scenario where RBSW and RLWMS streams are released via the PN U5-8 outfall during the Storage with Surveillance Phase (see Section 4.2.3). Exposure point concentrations for radionuclides in PN Generating Station soil are presented in Table 7-12 and are those from existing conditions in the PN ERA, as soil concentrations are not expected to change during the Stabilization or Storage with Surveillance Phases.

Table 7-11: Exposure Point Concentrations for Radiological Contaminants of Potential Concern Released to PN U5-8

Location	Media	Units	Tritium	Carbon-14	Gross beta / gamma	Notes
RBSW Outfall	Water	Bq/L	$7.00x10^{3}$	$3.00x10^{-1}$	$5.00x10^{-1}$	Section 4.2.3.2.1.5
PN U5-8 Discharge Channel	Water	Bq/L	$4.76x10^{2}$	$2.04x10^{-2}$	$3.40x10^{-2}$	RBSW discharge with PN U5-8 discharge channel concentration factor applied (Section 4.2.3.2.1.5).
Frenchman's Bay	Water	Bq/L	$1.82x10^{0}$	$7.81x10^{-5}$	$1.30x10^{-4}$	RBSW discharge with Frenchman's Bay concentration factor applied (Section 4.2.3.2.1.5).

Note:
Gross beta / gamma is represented by Cobalt-60 in the model.

Table 7-12: Exposure Point Concentrations for Radiological Contaminants of Potential Concern Released on the PN Generating Station

Location	Media	Contaminant of Potential Concern	Units	Max	Mean	Notes
PN Generating Station	Soil	Tritium	Bq/kg-dw	92.4	31.6	2015 PN Site Soil Sampling (EcoMetrix and Golder, 2017)
		Cobalt-60	Bq/kg-dw	<1.00	<1.00	
		Cesium-134	Bq/kg-dw	<1.00	<1.00	
		Cesium-137	Bq/kg-dw	<1.00	<1.00	
		Carbon-14	Bq/kg-C	557	189	

Note:
Soil concentrations are obtained from the PN ERA (EcoMetrix and Golder, 2017) and are not expected to change during Storage with Surveillance.

7.1.5.1.2 PN Forebay

To predict the forebay water quality, a mass balance box model was developed and is discussed in Appendix A. During Storage with Surveillance activities, water will be drawn into the PN Generating Station via the PN U5-8 intake channel and stormwater runoff will be released into the forebay as discussed in Section 4.2.3.1. The estimated maximum and average exposure point concentrations for the forebay are presented in Table 7-13 for tritium, carbon-14, cobalt-60, cesium-134, and cesium-137 based on the mass balance box model. The PN forebay model separates the forebay into six areas (Figure A-13) and estimates exposure concentrations at each of the six areas. Maximum exposure point concentrations represent concentrations in Box 6 of the box model in the PN forebay (Figure A-13). Average exposure point concentrations represent the average of all boxes in the model.

Table 7-13: Exposure Point Concentrations for Radiological Contaminants of Potential Concern Released to the PN Forebay

Location	Media	Contaminant of Potential Concern	Units	Maximum[(a)]	Average[(b)]	Notes
Forebay – RBSW to PN U5-8 intake	Water	Tritium	Bq/L	$7.51x10^{1}$	$1.89x10^{1}$	See Appendix A, Table A-17 for concentrations in each box of the forebay model.
		Carbon-14	Bq/L	$1.96x10^{-3}$	$5.02x10^{-4}$	
		Cobalt-60	Bq/L	$4.30x10^{-3}$	$1.39x10^{-3}$	
		Cesium-134	Bq/L	$4.30x10^{-3}$	$1.39x10^{-3}$	
		Cesium-137	Bq/L	$4.30x10^{-3}$	$1.39x10^{-3}$	

Notes:

a) Maximum represents the concentration in Box 6 in the forebay model.

b) Average represents the average concentration in all boxes in the forebay model.

7.1.5.2 Exposure Doses

The exposure concentrations (Section 7.1.5.1) along with the exposure factors (Section 7.1.3.4) were applied to the equations in Section 7.1.3.1 to estimate the radiological dose to all biota and non-radiological dose to birds and mammals. The estimated doses are presented in Table 7-14 to Table 7-16.

Table 7-14 Estimated Radiation Dose for Aquatic Biota at the Outfall for Release to PN U5-8 (mGy/d)

Contaminant of Potential Concern	Pelagic Fish	Bottom Dwelling Fish	Benthic Invertebrate	Ring-Billed Gull
Tritium	4.94 $\times 10^{-5}$	4.94 $\times 10^{-5}$	4.95 $\times 10^{-5}$	1.47 $\times 10^{-4}$
Carbon-14	7.91 $\times 10^{-5}$	7.91 $\times 10^{-5}$	7.14 $\times 10^{-5}$	1.12 $\times 10^{-4}$
Cobalt-60	1.04 $\times 10^{-5}$	1.06 $\times 10^{-2}$	4.58 $\times 10^{-2}$	8.08 $\times 10^{-3}$
Total Dose	**1.39 $\times 10^{-4}$**	**1.07 $\times 10^{-2}$**	**4.59 $\times 10^{-2}$**	**8.34 $\times 10^{-3}$**

Table 7-15 Estimated Radiation Dose for Biota at Frenchman's Bay for Release to PN U5-8 (mGy/d)

Contaminant of Potential Concern	Pelagic Fish	Bottom Dwelling Fish	Frog/ Turtle	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Tritium	1.89 x10^{-7}	1.89 x10^{-7}	1.89 x10^{-7}	1.90 x10^{-7}	1.90 x10^{-7}	1.59 x10^{-7}	1.53 x10^{-7}	1.53 x10^{-7}	1.53 x10^{-7}	1.19 x10^{-4}
Carbon-14	3.03 x10^{-7}	3.03 x10^{-7}	3.03 x10^{-7}	2.73 x10^{-7}	2.99 x10^{-7}	5.04 x10^{-7}	6.12 x10^{-7}	6.08 x10^{-7}	6.06 x10^{-7}	2.28 x10^{-5}
Cobalt-60	3.99 x10^{-8}	2.17 x10^{-5}	2.38 x10^{-5}	9.41 x10^{-5}	1.33 x10^{-7}	1.54 x10^{-5}	1.57 x10^{-5}	1.59 x10^{-5}	1.55 x10^{-5}	1.56 x10^{-5}
Total Dose	**5.32 x10^{-7}**	**2.22 x10^{-5}**	**2.43 x10^{-5}**	**9.45 x10^{-5}**	**6.21 x10^{-7}**	**1.61 x10^{-5}**	**1.65 x10^{-5}**	**1.67 x10^{-5}**	**1.63 x10^{-5}**	**1.57 x10^{-4}**

Table 7-16 Estimated Radiation Dose for Biota at the PN Forebay for RBSW to PN U5-8 Intake (mGy/d)

Contaminant of Potential Concern		Pelagic Fish	Bottom Dwelling Fish	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Tritium	Max	7.79 x10^{-6}	7.79 x10^{-6}	7.81 x10^{-6}	7.81 x10^{-6}	6.56 x10^{-6}	6.29 x10^{-6}	6.29 x10^{-6}	6.29 x10^{-6}	1.24 x10^{-4}
	Avg	1.96 x10^{-6}	1.96 x10^{-6}	1.97 x10^{-6}	1.97 x10^{-6}	1.65 x10^{-6}	1.59 x10^{-6}	1.59 x10^{-6}	1.59 x10^{-6}	1.20 x10^{-4}
Carbon-14	Max	7.59 x10^{-6}	7.59 x10^{-6}	6.84 x10^{-6}	7.49 x10^{-6}	1.26 x10^{-5}	1.53 x10^{-5}	1.52 x10^{-5}	1.52 x10^{-5}	3.39 x10^{-5}
	Avg	1.94 x10^{-6}	1.94 x10^{-6}	1.75 x10^{-6}	1.92 x10^{-6}	3.24 x10^{-6}	3.93 x10^{-6}	3.90 x10^{-6}	3.89 x10^{-6}	2.53 x10^{-5}
Cobalt-60	Max	1.32 x10^{-6}	7.18 x10^{-4}	3.11 x10^{-3}	4.39 x10^{-6}	5.09 x10^{-4}	5.19 x10^{-4}	5.25 x10^{-4}	5.12 x10^{-4}	5.14 x10^{-4}
	Avg	4.27 x10-7	2.33 x10-4	1.0 x10-3	1.42 x10-6	1.65 x10^{-4}	1.68 x10^{-4}	1.70 x10^{-4}	1.66 x10^{-4}	1.67 x10^{-4}
Cesium-134	Max	7.39 x10^{-5}	1.71 x10^{-4}	4.52 x10^{-4}	2.59 x10^{-6}	7.72 x10^{-5}	7.87 x10^{-5}	8.32 x10^{-5}	1.67 x10^{-4}	1.32 x10^{-4}
	Avg	2.39 x10^{-5}	5.53 x10^{-5}	1.46 x10^{-4}	8.39 x10^{-7}	2.50 x10^{-5}	2.55 x10^{-5}	2.69 x10^{-5}	5.39 x10^{-5}	4.26 x10^{-5}
Cesium-137	Max	6.63 x10^{-5}	1.01 x10^{-4}	1.82 x10^{-4}	3.21 x10^{-6}	3.14 x10^{-5}	3.26 x10^{-5}	3.65 x10^{-5}	1.07 x10^{-4}	7.74 x10^{-5}
	Avg	2.15 x10^{-5}	3.27 x10^{-5}	5.91 x10^{-5}	1.04 x10^{-6}	1.02 x10^{-5}	1.06 x10^{-5}	1.18 x10^{-5}	3.47 x10^{-5}	2.51 x10^{-5}
Total Dose	**Max**	**1.57 x10^{-4}**	**9.98 x10^{-4}**	**3.76 x10^{-3}**	**2.55 x10^{-5}**	**6.37 x10^{-4}**	**6.52 x10^{-4}**	**6.66 x10^{-4}**	**8.07 x10^{-4}**	**8.81 x10^{-4}**
	Avg	**4.97 x10^{-5}**	**3.23 x10^{-4}**	**1.22 x10^{-3}**	**7.19 x10^{-6}**	**2.05 x10^{-4}**	**2.10 x10^{-4}**	**2.14 x10^{-4}**	**2.60 x10^{-4}**	**3.80 x10^{-4}**

7.1.6 Uncertainties in the Exposure Assessment

The main uncertainties and assumptions associated with the exposure assessment are summarized in Table 7-17.

Table 7-17: Summary of Major Uncertainties in the Ecological Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
Average concentration factors from the surface water model were used to estimate water concentrations at the PN outfall and Frenchman's Bay.	Based on maximum and minimum lake water conditions the concentration factors at Frenchman's Bay can vary from 6.24×10^{-5} to 5.57×10^{-4} with an average of 5.57×10^{-4}.	Neither (value is a best estimate)
K_ds, bioaccumulation factors, intake rates, etc. are from literature when measured information was not available.	Reputable literature sources were used.	Neither (value is best estimate)
Dose coefficients for each receptor were not adjusted for exact VEC body size and dimensions.	Surrogates selected with attention to similar body size and exposure habits.	Neither (value is best estimate)
Sediment K_ds are used to estimate sediment concentration in the forebay and the outfall for the PEA; however, in the PN ERA measured sediment concentration was used for the PN outfall.	Measured sediment concentrations are not available for the future.	Value is best estimate, but may over estimate

7.2 Effects Assessment

7.2.1 Toxicological Benchmarks

As no non-radiological contaminants of potential concern were carried forward from the screening assessment, non-radiological toxicity benchmarks were not applicable.

7.2.2 Radiation Benchmarks

Radiation dose benchmarks of 400 µGy/h (9.6 mGy/d) and 100 µGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the PN assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-12 standard (CSA, 2012). This is a total dose benchmark; therefore, the dose to biota due to each radionuclide of concern is summed to compare against this benchmark.

The aquatic biota dose benchmark of 10 mGy/d was initially developed by the National Council of Radiation Protection (NCRP, 1991) and was recommended by the IAEA (IAEA, 1992) which concluded that limiting the dose rate to individuals in an aquatic population to a maximum of 10 mGy/d would provide adequate protection for the population. Later reviews by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) have supported this recommendation (UNSCEAR, 1996 and UNSCEAR, 2008).

The aquatic biota considered by UNSCEAR are organisms such as fish and aquatic invertebrates that reside in water. Birds and mammals with riparian habitats are considered to be terrestrial biota. Dose calculations in this ERA follow the same convention.

For terrestrial biota, a level of 1 mGy/d has been widely used as an acceptable level based on IAEA and UNSCEAR (IAEA, 1992 and UNSCEAR, 1996). More recently, UNSCEAR (UNSCEAR, 2008) has supported a slightly higher exposure level of 100 µGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms. UNSCEAR (UNSCEAR, 2008) updated its review of radiation effects on natural biota, and noted that the 0.04 mGy/h (1 mGy/d) exposure produced no effect in the most sensitive mammalian study (with dogs), while 0.18 mGy/h produced eventual sterility. Therefore, UNSCEAR chose an intermediate exposure level of 0.1 mGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms. UNSCEAR concluded that lower dose rates to the most highly exposed individuals would be unlikely to have substantial effects on most terrestrial communities.

It is recognized that the selection of reference dose levels is a topic of ongoing debate. For example, the CNSC has recommended dose limit values of 0.6 mGy/d for fish, 3 mGy/d for aquatic plants (algae and macrophytes), 6 mGy/d for benthic invertebrates (aquatic invertebrates and zooplankton in this assessment), and 3 mGy/d for terrestrial animals and plants (Bird et al., 2002 and EC/HC, 2003). The dose limit value for fish was based on a reproductive effects study in Carp in a Chernobyl cooling pond with a history of higher exposures (Makeyeva et al., 1995). A value of 0.6 mGy/d was found to be in the range where both effects and no effects were observed. The aquatic plant benchmark was based on information related to terrestrial plants (conifers), which are considered to be sensitive to the effects of radiation. Reproductive effects in polychaete worms were used to derive the dose limit for benthic invertebrates.

The ICRP (ICRP, 2008) has suggested "derived consideration levels" as a range of dose rates reflecting a range in potential for effect, for each of several taxonomic groups. The ICRP states that the ranges of dose rates they provide are preliminary and need to be revised as more data become available.

Considering the history and discussions surrounding the selection of radiation benchmarks, 400 µGy/h (9.6 mGy/d) and 100 µGy/h (2.4 mGy/d) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively (UNSCEAR, 2008). These benchmarks were recommended in CSA N288.6-12 (CSA, 2012), and are appropriate for this assessment.

7.2.3 Thermal Benchmarks

The thermal plume modelling for the predictive effects assessment estimated the extent of the thermal plume as an increment above ambient temperature (ΔT). Turnpenny and Liney (Turnpenny and Liney, 2006) - cited in CSA N288.6-12) indicate that ΔT criterion of 3°C should be protective of most species in most waters. Considering this value, thermal plumes were conservatively defined by a ΔT of 2°C.

The modelled thermal increments are used in conjunction with nearshore ambient temperatures to estimate absolute temperatures that may be seen within the small thermal plume during the Storage with Surveillance Phase. These estimated values are compared with optimum temperatures and maximum weekly average temperatures (MWAT criteria) for Smallmouth Bass and Emerald Shiners, two warm water species that currently benefit from elevated temperatures in the existing plume. The optimum temperatures and MWAT criteria were evaluated in a previous Environmental Assessment (Tables 10.26 and 10.27 from Golder, 2007b) and were used previously in the PN ERA.

Table 7-18: Thermal Criteria Relevant to Embryo and Larval Development of Selected Fish Species

Fish Species	Life Stage	Optimum Temp (°C)	Upper Lethal Temp (°C)	MWAT Criteria (°C)	Relevant Timeframe
Smallmouth Bass	Embryo	18	37	24.3	mid-Apr-May
	Larvae	21	33	25	mid-Apr-May
Emerald Shiner	Embryo	24	29	27	mid-Apr-May
	Larvae	24	29	27	mid-Apr-May

Note: Maximum Weekly Average Temperature (MWAT) criteria are calculated from the optimum and upper lethal temperatures.
Source: (Golder, 2007b)

Table 7-19: Thermal Criteria Relevant to Growth and Mortality of Selected Fish Species

Fish Species	Life Stage	Optimum Temp (°C)	Upper Lethal Temp (°C)	MWAT Criteria (°C)	Nearshore Timeframe
Smallmouth Bass	Adult	21	36	29, 33	all year
	Juvenile	28.5	35	29	all year
Emerald Shiner	Adult	25	42	30	all year
	Juvenile	23	35	30	all year

Note: MWAT criteria are calculated from the optimum and upper lethal temperatures
Source: (Golder, 2007b)

7.2.4 Uncertainties in the Effects Assessment

Toxicological benchmarks used in the risk assessment were selected from sources recommended in the CSA N288.6-12) standard (CSA, 2012, and other reputable sources). These benchmark values represent the low end of threshold effect levels in literature for each receptor category. Benchmark values for the test species were not adjusted for body weight and were considered directly applicable to the wildlife species. The benchmark values are considered to be conservatively representative of the effect threshold for the contaminant of potential concern for the receptor of interest. There is uncertainty because most species of interest have not been tested to determine their effect thresholds. Nevertheless, it is expected that few species will be much more sensitive than indicated by the selected benchmark values.

Radiation dose benchmarks for biota are a topic of ongoing debate. Uncertainties exist related to some low values that have been suggested based on field studies around Chernobyl. The radiation dose benchmarks chosen follow UNSCEAR (UNSCEAR, 2008) and CSA N288.6-12 (CSA, 2012) in giving more credence to values based on controlled laboratory studies and demonstrated low levels of effect.

Thermal benchmarks represent a variety of species, life stages and endpoints, and vary among literature sources. Selected values are considered appropriate for assessment of thermal effects at the PN Generating Station.

7.3 Risk Characterization

7.3.1 Risk Estimation

A summary of the radiation doses to each receptor by contaminant of potential concern is presented in Table 7-20 through Table 7-23 . Radiation doses to terrestrial receptors have been reproduced in Table 7-23 from the PN ERA.

Table 7-20: Estimated Radiation Dose for Aquatic Biota at the Outfall for Release to PN U5-8 (mGy/d)

Contaminant of Potential Concern	Pelagic Fish	Bottom Dwelling Fish	Benthic Invertebrate	Ring-Billed Gull
Tritium	4.94×10^{-5}	4.94×10^{-5}	4.95×10^{-5}	1.47×10^{-4}
Carbon-14	7.91×10^{-5}	7.91×10^{-5}	7.14×10^{-5}	1.12×10^{-4}
Cobalt-60	1.04×10^{-5}	1.06×10^{-2}	4.58×10^{-2}	8.08×10^{-3}
Total	1.39×10^{-4}	1.07×10^{-2}	4.59×10^{-2}	8.34×10^{-3}

Note: Aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.

Table 7-21 Estimated Radiation Dose for Biota at Frenchman's Bay for RLWMS and RBSW to U5-8 (mGy/d)

Contaminant of Potential Concern	Pelagic Fish	Bottom Dwelling Fish	Frog/ Turtle	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Tritium	1.89×10^{-7}	1.89×10^{-7}	1.89×10^{-7}	1.90×10^{-7}	1.90×10^{-7}	1.59×10^{-7}	1.53×10^{-7}	1.53×10^{-7}	1.53×10^{-7}	1.19×10^{-4}
Carbon-14	3.03×10^{-7}	3.03×10^{-7}	3.03×10^{-7}	2.73×10^{-7}	2.99×10^{-7}	5.04×10^{-7}	6.12×10^{-7}	6.08×10^{-7}	6.06×10^{-7}	2.28×10^{-5}
Cobalt-60	3.99×10^{-8}	2.17×10^{-5}	2.38×10^{-5}	9.41×10^{-5}	1.33×10^{-7}	1.54×10^{-5}	1.57×10^{-5}	1.59×10^{-5}	1.55×10^{-5}	1.56×10^{-5}
Total Dose	5.32×10^{-7}	2.22×10^{-5}	2.43×10^{-5}	9.45×10^{-5}	6.21×10^{-7}	1.61×10^{-5}	1.65×10^{-5}	1.67×10^{-5}	1.63×10^{-5}	1.57×10^{-4}

Note: Aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.

Table 7-22: Estimated Radiation Dose for Biota at the PN Forebay for RBSW to PN U5-8 Intake (mGy/d)

Contaminant of Potential Concern		Pelagic Fish	Bottom Dwelling Fish	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Tritium	Max	7.79×10^{-6}	7.79×10^{-6}	7.81×10^{-6}	7.81×10^{-6}	6.56×10^{-6}	6.29×10^{-6}	6.29×10^{-6}	6.29×10^{-6}	1.24×10^{-4}
	Avg	1.96×10^{-6}	1.96×10^{-6}	1.97×10^{-6}	1.97×10^{-6}	1.65×10^{-6}	1.59×10^{-6}	1.59×10^{-6}	1.59×10^{-6}	1.20×10^{-4}
Carbon-14	Max	7.59×10^{-6}	7.59×10^{-6}	6.84×10^{-6}	7.49×10^{-6}	1.26×10^{-5}	1.53×10^{-5}	1.52×10^{-5}	1.52×10^{-5}	3.39×10^{-5}
	Avg	1.94×10^{-6}	1.94×10^{-6}	1.75×10^{-6}	1.92×10^{-6}	3.24×10^{-6}	3.93×10^{-6}	3.90×10^{-6}	3.89×10^{-6}	2.53×10^{-5}
Cobalt-60	Max	1.32×10^{-6}	7.18×10^{-4}	3.11×10^{-3}	4.39×10^{-6}	5.09 x10-4	5.19×10^{-4}	5.25×10^{-4}	5.12×10^{-4}	5.14×10^{-4}
	Avg	4.27×10^{-7}	2.33×10^{-4}	1.01×10^{-3}	1.42×10^{-6}	1.65×10^{-4}	1.68×10^{-4}	1.70×10^{-4}	1.66×10^{-4}	1.67×10^{-4}
Cesium-134	Max	7.39×10^{-5}	1.71×10^{-4}	4.52×10^{-4}	2.59×10^{-6}	7.72×10^{-5}	7.87×10^{-5}	8.32×10^{-5}	1.67×10^{-4}	1.32×10^{-4}
	Avg	2.39×10^{-5}	5.53×10^{-5}	1.46×10^{-4}	8.39×10^{-7}	2.50×10^{-5}	2.55×10^{-5}	2.69×10^{-5}	5.39×10^{-5}	4.26×10^{-5}
Cesium-137	Max	6.63×10^{-5}	1.01×10^{-4}	1.82×10^{-4}	3.21×10^{-6}	3.14×10^{-5}	3.26×10^{-5}	3.65×10^{-5}	1.07×10^{-4}	7.74×10^{-5}
	Avg	2.15×10^{-5}	3.27×10^{-5}	5.91×10^{-5}	1.04×10^{-6}	1.02×10^{-5}	1.06×10^{-5}	1.18×10^{-5}	3.47×10^{-5}	2.51×10^{-5}
Total Dose	Max	1.57×10^{-4}	9.98×10^{-4}	3.76×10^{-3}	2.55×10^{-5}	6.37×10^{-4}	6.52×10^{-4}	6.66×10^{-4}	8.07×10^{-4}	8.81×10^{-4}
	Avg	4.97×10^{-5}	3.23×10^{-4}	1.22×10^{-3}	7.19×10^{-6}	2.05×10^{-4}	2.10×10^{-4}	2.14×10^{-4}	2.60×10^{-4}	3.80×10^{-4}

Note: Aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.

Table 7-23 Summary of Radiation Dose Estimates to Terrestrial Receptors at the Pickering Nuclear Site from Existing Operations (mGy/d)

Contaminant of Potential Concern	Tritium (tritiated water)		Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Argon-41		Total Dose	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Earthworm	1.92×10^{-3}	6.55×10^{-4}	4.20×10^{-5}	1.43×10^{-5}	3.11×10^{-5}	3.11×10^{-5}	2.00×10^{-5}	2.00×10^{-5}	7.33×10^{-6}	7.33×10^{-6}	—	—	2.02×10^{-3}	7.28×10^{-4}
Terrestrial Plant	6.80×10^{-5}	2.33×10^{-5}	3.56×10^{-5}	1.21×10^{-5}	1.08×10^{-5}	1.08×10^{-5}	2.47×10^{-6}	2.47×10^{-6}	2.67×10^{-6}	2.67×10^{-6}	1.30×10^{-5}	5.35×10^{-6}	1.20×10^{-4}	5.13×10^{-5}
Meadow Vole	3.58×10^{-5}	1.29×10^{-5}	7.61×10^{-5}	2.58×10^{-5}	1.20×10^{-5}	1.20×10^{-5}	7.42×10^{-6}	7.42×10^{-6}	2.72×10^{-6}	2.72×10^{-6}	1.30×10^{-5}	5.35×10^{-6}	1.34×10^{-4}	6.08×10^{-5}
Red-winged Blackbird	1.24×10^{-3}	4.24×10^{-4}	9.24×10^{-5}	3.14×10^{-5}	1.12×10^{-5}	1.11×10^{-5}	7.14×10^{-6}	7.14×10^{-6}	2.77×10^{-6}	2.77×10^{-6}	1.30×10^{-5}	5.35×10^{-6}	1.35×10^{-3}	4.77×10^{-4}
Red Fox	2.19×10^{-5}	8.37×10^{-6}	1.14×10^{-3}	4.92×10^{-4}	1.55×10^{-5}	1.55×10^{-5}	1.50×10^{-5}	1.50×10^{-5}	2.106×10^{-5}	2.10×10^{-5}	1.30×10^{-5}	5.35×10^{-6}	1.22×10^{-3}	5.51×10^{-4}
Red-Tailed Hawk	2.37×10^{-4}	8.15×10^{-5}	9.32×10^{-5}	3.16×10^{-5}	1.11×10^{-5}	1.10×10^{-5}	7.10×10^{-6}	7.10×10^{-6}	2.69×10^{-6}	2.69×10^{-6}	1.30×10^{-5}	5.35×10^{-6}	3.51×10^{-4}	1.34×10^{-4}

Note: **Bold and shaded** values exceed the terrestrial benchmark of 2.4 mGy/d.

Max and mean dose for cobalt-60, cesium-134, and cesium-137 are generally equivalent for most receptors since soil concentrations were generally measured below the detection limit.

7.3.2 Discussion of Radiation Effects

7.3.2.1 PN Outfall

For all scenarios evaluated, there are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota at the outfall location including fish and benthic invertebrates. The 2.4 mGy/d radiation benchmark has also not been exceeded for the Ring-billed Gull.

7.3.2.2 Frenchman's Bay

For all scenarios evaluated, there are no exceedances of the 9.6 mGy/d aquatic radiation benchmark for any aquatic receptors at Frenchman's Bay. There are also no exceedances of the 2.4 mGy/d terrestrial radiation benchmark for riparian birds and mammals at Frenchman's Bay.

7.3.2.3 PN Forebay

For all scenarios evaluated, there are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota at the forebay. The 2.4 mGy/d radiation benchmark has also not been exceeded for riparian birds and mammals at the forebay. The American Eel is identified as a species at risk; therefore the assessment endpoint is the health of the individual. Since the aquatic radiation benchmark is not exceeded for fish, the American Eel is not at risk during the Storage with Surveillance Phase.

7.3.3 Thermal Effects

The thermal plume modelling for the PEA (Appendix A) estimated the maximum extent of the thermal plume, for existing conditions and for the Storage with Surveillance Phase. The thermal plumes for discharge at PN U5-8 is defined by a ΔT of 2°C, consistent with previous thermal plume mapping for the PN Generating Station. The predicted thermal plume during the Storage with Surveillance Phase is confined to the discharge channel and the maximum ΔT is predicted not to exceed 5°C (Appendix A). Round Whitefish, as a point of interest, are not expected to be found within the discharge channel as they prefer deeper environments further offshore.

The lake near the discharge will be returned to a thermal condition that is more normal for the nearshore zone of Lake Ontario. Whereas the warmed waters in the current operating condition have attracted certain species to the discharge, such as Smallmouth Bass, and have enhanced aquatic productivity near the discharge; the cooler waters after shutdown will offer thermal habitat more like the regional nearshore zone.

Warm water species such as Smallmouth Bass and Emerald Shiner currently benefit from elevated temperatures within the existing plumes. Smallmouth Bass spawn primarily within the discharge channels, and their embryo-larval development occurs there. The channels also provide habitat for juveniles and adults. Emerald Shiner prefer nearshore areas with some substrate structure. Their spawning and embryo-larval development occurs primarily around the armoured break wall and intake channel, and may also include portions of the discharge channel. For both species the timeframe assessed for embryo-larval development is April to May. It is acknowledged that Emerald Shiner may continue spawning through August.

Absolute temperatures in the discharge channel for the Storage with Surveillance Phase during an April-June (relevant for embryos and larvae) period and during an August (the warmest month for nearshore waters) period were estimated by adding the modelled ΔT value of 5°C to the long-term nearshore ambient temperatures (Golder, 2007a). These estimated maximum temperatures are shown in Table 7-24.

Table 7-24: Estimated Maximum Temperatures in the Discharge Channels in April-June and August for the Storage with Surveillance Phase

	April	May	June	August
Nearshore Surface Temperature (°C) 1970-1988 (Golder, 2007b)	5.3	7.5	10.1	17.3
Maximum ∆T in the Discharge Channels (°C) (modelled)	5	5	5	5
Estimated Maximum Temperature in Discharge Channels (°C)	10.3	12.5	15.1	22.3

Comparison of the estimated maximum temperatures in the discharge channels to the thermal criteria in Section 7.2.3 indicates that temperatures are not likely to exceed the MWAT criteria for Smallmouth Bass embryos and larvae (24.3 and 25°C) or for Emerald Shiner (27°C). Thus adverse effects on embryo-larval development from the thermal discharge are not expected; however, temperatures are expected to be below optimal for embryo-larval development from April through June. Smallmouth Bass will likely still use the discharge channels, but may spawn later in the season than they do under existing thermal conditions.

Similarly, estimated maximum temperatures in the discharge channels will not exceed MWAT criteria for growth of juveniles and adults, either for Smallmouth Bass (29°C) or Emerald Shiner (30°C). Thus adverse effects on growth from the thermal discharge are not expected; however, temperatures are expected to be below optimal for growth for juvenile bass and adult shiners, even during the warmest month. Smallmouth Bass will likely still use the discharge channels for rearing, because of their elevated temperatures, but growth may be less than under existing thermal conditions.

The forebay, if retained in connection with the lake, will act as an artificial embayment, with much reduced inflow from the lake, and as such it will be warmer than the adjacent lake during the Storage with Surveillance Phase. Productivity in the forebay is expected to be moderately increased from the existing condition. Fish species from the lake will use it as rearing habitat similar to other natural embayments. The forebay will not receive thermal loading from the PN Generating Station, and there will be no concern about adverse effects from waste heat.

7.3.4 Entrainment and Impingement

As described in Section 4.2.2, cooling water flows are expected to continually decrease throughout the Stabilization and Storage with Surveillance Phases. During the Stabilization Phase, the FDS will remain in place seasonally while the CCW pumps are operating. The current operational conditions are considered bounding in this case.

During Storage and Surveillance activities, an alternative bounding condition was evaluated for potential entrainment and impingement effects. This bounding condition considers the reduced cooling water flow (i.e., no CCW pumps and 50,000 m^3/day of cooling water flow provided by RBSW) and the removal of the FDS.

The velocity associated with the reduced flow (assumed to be 50,000 m^3/day or 580 L/sec) was calculated in the surface water modelling (Appendix A) to be a maximum of 7.1 mm/sec with maximum average predicted velocities of 1.7 mm/sec. At these velocities, the effects of entrainment and impingement are expected to be negligible as this is less than the average swim speed of the local species for the VECs evaluated in the PN ERA as shown in

Table 7-25. This table is not an exhaustive list of fish species and therefore general guidance on impingement and entrainment were also referenced.

Generally, impingement is not considered an issue if there is a flow rate less than 0.125 m^3/sec (DFO, 1995) or an intake water velocity of less than 15 cm/sec (US EPA, 2014). While the flow of 50,000 m^3/day (0.57 m^3/sec) is above the Department of Fisheries and Oceans (DFO) guidance value, the flow is over a wide forebay and the velocity will allow fish to escape the water flow. This exceedance of the DFO (1995) flow is therefore not considered fully relevant to the impingement risk. The maximum predicted velocity is less than the US EPA guidance value.

Entrainment is not considered an issue at a flow of 6.5 m^3/sec or less (US EPA, 2014). The proposed flow during the Storage with Surveillance Phase, when the CCW pumps are no longer used, will be 0.58 m^3/sec, which is substantially less than the guidance.

Table 7-25: Fish Swim Speeds for Local Species

Fish Species	Average Swim Speed (cm/s)	Burst Swim Speed (cm/s)
Alewife	Juvenile and adults = 43.0 to 53.0 [(b)]	—
Smallmouth Bass	50.0-118.0 [(d)]	—
Northern Pike	Young-of-year, Juvenile = 19 to 47.4 [(a)]	—
Brown Bullhead	Brown bullhead = n/a	—
Round Whitefish	Juvenile = 40.0 and Adults = 55.0 [(b)]	106.7 [(a,c)]
White Sucker	Young-of-year, Juvenile, Adult = n/a; Sucker species = 121-242 [(b)]	—
Emerald Shiner	Adult = 19.6 - 59.0[(a,e)]	81.4 [(e)]
Lake Trout	Juvenile = 20[(b)]; Trout species juvenile and adults = 19.0 to 74.2 [(b)]	—
Walleye	Adult = 30 to 67 [(b)]	160-260 [(b)]
American Eel	20 [(b)]	—

Notes:
"—" data not available
a) (Jones et al., 1974)
b) (Peake, 2008)
c) Burst speed of Lake Whitefish
d) (Bunt et al., 1999)
e) (Leavy and Bonner, 2009)

In addition, it is expected that OPG will seek regulatory concurrence prior to removing the FDS. This will be conducted when there is more certainty regarding the flow required in the Storage with Surveillance Phase and it is assumed a more robust evaluation will be presented to the appropriate regulator at that time.

7.3.5 Uncertainties in the Risk Characterization

There are uncertainties associated with the components contributing to the overall risk assessment. This includes receptor exposure factors, such as transfer factors, intake rates and bioaccumulation factors, partition coefficients, dose coefficients and averaging assumptions (discussed in Section 7.1.3.4), as well as benchmarks values used to determine risk of potential effects (discussed in Section 7.2).

A probabilistic risk assessment to quantify uncertainty in the risk estimate has not been performed and is not considered necessary since it is not likely to provide a better basis for risk management or decision making. According to CSA N288.6-12 (CSA, 2012), a qualitative or semi-quantitative evaluation of uncertainty is considered sufficient for evaluation of uncertainty.

There is also uncertainty associated with air and surface water modelling conducted to support the assessment. These are discussed in Section 6.3.2.

8.0 ENVIRONMENTAL MONITORING AND PROTECTION PROGRAMS

Throughout the lifecycle phases of the PN Generating Station to date (i.e., design, construction, commissioning and operations), worker and public safety has remained the overriding priority for OPG. Preparation and implementation of the Stabilization and Storage with Surveillance Phases will be no different. The focus will remain on both the safe and reliable operation of the facility, while making the necessary arrangements to ensure that all reasonable measures are taken to protect workers, the public and the environment as the PN Generating Station transitions from the end of commercial operations to the safe storage state.

The CNSC, when considering relicensing, has an obligation through the *Nuclear Safety and Control Act* to consider whether an application will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of people. This is achieved through review of effluent and emissions controls, an Environmental Management System (EMS), assessment and monitoring, provisions for protection of the public, and environmental risk assessment. The CNSC has identified the following environmental protection regulatory documents and CSA standards as relevant to the Licence Condition Handbook, and compliance with these documents will be reviewed as part of relicensing (CNSC, 2016a):

- REGDOC 2.9.1 *Environmental Protection Policies, Programs and Procedures* (CNSC, 2016b);
- CSA N288.1-14 *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities* (CSA, 2008);
- CSA N288.4-10, *Environmental Monitoring Program at Class I nuclear facilities and uranium mines and mills* (CSA, 2010);
- CSA N288.5-11, *Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* (CSA, 2011);
- CSA N288.6-12, *Environmental Risk Assessments at Class I nuclear facilities and uranium mines and mills* (CSA, 2012); and
- CSA N288.7-15, *Groundwater Protection Programs at Class I nuclear facilities and uranium mines and mills* (CSA, 2015).

As outlined within the PEA, work to define the activities necessary to transfer the operating units to the safe storage state has commenced. The planning for the transition will continue in the coming years in order to confirm the necessary Stabilization and Storage with Surveillance activities. The objectives of the Stabilization and Storage with Surveillance Phases will include the protection of workers, members of the public and the environment, from remaining radioactive and non-radiological hazards, without creating new hazards.

As the operational footprint of the PN Generating Station is reduced, all unnecessary station systems and components will be placed into an inactive safe state. These components will be de-energized, drained of gas or fluids and isolated from operational systems, and removed from the design basis for the remaining facility. Systems that remain necessary to support Stabilization or Storage with Surveillance activities may be reclassified and reconfigured, as required, to meet operational demands. The operational requirements for each individual system (or groups of related systems) will be identified and their safe storage end-states determined.

Each of the applicable OPG environmental management programs are outlined in the section following, along with how they may evolve through the Stabilization and Storage with Surveillance Phases. Overall, while most environmental effects are anticipated to be reduced during the Stabilization or Storage with Surveillance Phases, it is anticipated that environmental monitoring programs will be retained as required to confirm reductions in risk over time, consistent with the annual EMP findings.

8.1 Environmental Management System

OPG's Environmental Policy requires that OPG maintain an EMS consistent with the ISO 14001 *Environmental Management System Standard.* The EMS provides the structure and processes to ensure implementation and follow-up on the environmental programs needed to comply with the Environmental Policy. As part of OPG's EMS, environmental performance targets, including reportable spills and environmental compliance are reviewed annually to ensure that opportunities for continuous improvement are identified and implemented. The programs include OPG's approach to ensure compliance with applicable statutory and regulatory requirements.

As the PN Generating Station transitions from end of commercial operations to its safe storage state, OPG's EMS will continue to require the assessment of environmental risks associated with the facility's activities, and to ensure that these activities are conducted such that any adverse impact on the natural environment meets the ALARA principle. Ongoing environmental programs will be revised, commensurate with the facility changes and the guidance of the CSA N288 series of standards relating to environmental management for Class I nuclear facilities. Since the CSA N288 standards apply to the entire lifecycle of the facility, they will continue to apply through the Stabilization Phase, Storage with Surveillance Phase and the eventual decommissioning of the PN Generating Station.

The EMS programs will be reviewed to confirm they address the unique needs of the facility as it transitions from the end of commercial operation. A risk-based approach will be applied in determining appropriate governance (or changes to existing governance) to support the Stabilization and Storage with Surveillance activities of the PN Generating Station. The following provides a summary of the programs and description of how these programs will evolve over time.

8.2 Effluent Monitoring Program

Federal and provincial regulations set the requirements to monitor and report on the characteristics of airborne and waterborne effluents. *CSA N288.5-11 Effluent monitoring programs at Class 1 nuclear facilities and uranium mines and mills* (CSA, 2011), expands on some of the regulatory requirements and addresses design, implementation and management of an effluent monitoring program that meets legal requirements, business practices and incorporates best management practices. Effluent monitoring is a risk-informed activity to quantify or estimate the radiological and hazardous substances being released into the environment. Effluent emissions are currently monitored through existing monitoring programs as outlined in the following Section 8.2.1. The PN Effluent Monitoring Program will continue to satisfy the requirements of CSA N288.5-11. The Effluent Monitoring Program includes airborne and waterborne effluents for radiological and hazardous substances.

The PEA does not identify any new pathways of emissions not already monitored through the existing Effluent Monitoring Program. Modifications to the program over time will focus on remaining monitoring needs during Stabilization and Storage with Surveillance Phases, as appropriate.

8.2.1 Hazardous Substance Emissions

Ontario provincial requirements regarding air and water discharges, and management of non-radiological and hazardous (radioactive) wastes are regulated through the *Environmental Protection Act* and the *Ontario Water*

Resources Act and regulations made under those Acts. The MOECC regulates the discharge of non-radioactive substances through ECAs and, in the case of liquid effluent releases, through regulations promulgated under the MISA. Water taking (i.e., withdrawal from Lake Ontario for condenser cooling) is regulated through a Permit to Take Water. The ECAs will identify the appropriate effluent objectives and discharge limits.

Station non-radiological airborne emissions are required to be in accordance with provincial regulation O. Reg. 419/05, *Air pollution – Local Air Quality*, which is met by complying with the ECA for Air and Noise. An ESDM report is used to document and maintain compliance with the regulation by calculating POI concentrations for contaminant sources based on emission rates and output from the dispersion model. The POI concentrations from the maximum emission scenarios are then compared to MOECC POI limits or Jurisdictional Screening Level limits, to ensure compliance.

Stabilization and Storage with Surveillance activities will result in modification of the sources captured within the ESDM (i.e., inclusion of an additional heating steam boiler), as discussed in Section 4.1.2.2.2. These would be captured, along with updated dispersion modelling and calculated POI concentrations, prior to operation of these modified sources in accordance with regulatory requirements at the time. As discussed in Section 4.1.2.2.4, there are proposed changes to air compliance requirements that are expected to take effect in 2020. These changes include the requirement for updated modelling of atmospheric emissions and standards applied over a longer period of time (i.e., moving from ½ hour to 24 hour standard). OPG will ensure ongoing compliance with applicable statutory and regulatory requirements.

With respect to MISA sampling points, as circumstances at the facility change through the Stabilization and Storage with Surveillance Phases, additional/new sampling points may be established and/or existing points eliminated, provided notification is given to MOECC.

8.2.2 Radiological Emissions

To facilitate the control and limitation of radiological releases to air and water, Derived Release Limits (DRLs) are determined, and approved by the CNSC, following the guidance in CSA N288.1, *Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities*. 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.

To ensure that public dose limits and the ALARA principle continue to be met, monitoring and control of emissions are in place at OPG facilities such that the releases are at a small fraction of each DRL. The framework for monitoring and control of emissions consists of a tiered system of management controls starting with:

- commitment to operate according to ALARA;
- establishing internal investigation levels to keep the radionuclide release levels low and provide an early indication that an action level might be reached; and
- action levels which provide an indication that potential loss of control of some part of the environmental protection program may have occurred.

DRLs are reviewed at least once per licence period, as recommended in the Licence Condition Handbook. As PN moves forward with plans for Stabilization and Storage with Surveillance activities, the DRLs will be reviewed and updated as required to incorporate changes. These changes, discussed in this report, include changes in the locations and characteristics of nearby members of the public, and changes in cooling water flow to Lake Ontario. The DRLs will be updated, if required, with future updates of CSA N288.1.

8.3 Environmental Monitoring Program

OPG has several decades of experience in sampling, monitoring, testing, documenting and reporting on air, water, soil and other media for substances at the PN Site. Today, the EMP is in compliance with CSA N288.4-10 *Environmental Monitoring Programs at Class I nuclear facilities and uranium mines and mills* (CSA, 2010). This standard addresses monitoring of radioactive and non-radioactive contaminants, physical stressors, potential biological effects, and pathways for both human and non-human biota. The monitoring program design is risk informed and based on the results of the PN ERA completed for the facility (see Section 8.5).

The annual EMP report is made available through OPGs public website, and submitted to the CNSC in accordance with its Regulatory Document *REGDOC-3.1.1, Reporting Requirements for Nuclear Power Plants* (CNSC, 2016c). The EMP report summarizes the annual emissions and environmental data collected during the year, their interpretations, and the estimates of radiation doses to the public resulting from the operation of the PN Generating Station.

According to N288.4-10, the need for and adequacy of an EMP shall be reviewed following any update or revision of the ERA for the facility (typically every five years) (CSA, 2010). The review process will include, but is not limited to, the changes to the operation of the station, receptors (e.g., closer industrial/commercial critical group), regulatory requirements and new scientific understanding as it relates to the interaction of the facility and the environment. To this end, it is expected that the scope and complexity of the EMP design will be commensurate with the environmental risk once the PN units are no longer in service.

The PEA and the PN ERA (EcoMetrix and Golder, 2017) do not identify any new effects that would warrant additional monitoring beyond that already captured in the existing EMP.

8.4 Groundwater Protection Program

Groundwater protection programs are implemented to prevent or minimize releases of nuclear or hazardous substances to groundwater; prevent or minimize the effects of physical stressors on groundwater end users; and confirm that adequate measures are in place to stop, contain, control, and monitor any releases and physical stressors that can occur under normal operation (CSA, 2015).

CSA N288.7-15 *Groundwater Protection Programs* provides the requirements and guidance on the elements of Groundwater Protection Programs, as well as detailed guidance on developing and implementing Groundwater Monitoring Programs. A risk-based approach can be defined and used when applying the requirements of the standard.

Since this standard was recently published, a gap analysis is being carried out for the current PN groundwater monitoring program and an implementation plan developed to ensure compliance with the standard. PN currently has a well-established groundwater monitoring program that is expected to be largely compliant with the new standard. Therefore, no extensive changes to the monitoring program are anticipated for implementation of N288.7-15.

Similar to the other N288 series of standards, the need for and adequacy of the groundwater protection program shall be reviewed, typically every 5 years or sooner following substantial modification to the station that can impact the conceptual site model. As part of the implementation of a new stage (or phase) in the lifecycle of the facility, the existing groundwater protection program and groundwater monitoring program will be reviewed, and reassessment of the environmental risks will be undertaken, if required. The assessment conducted as part of the PEA (see Section 4.4.2) has confirmed there are no substantial changes to the groundwater monitoring program recommended at this time.

8.5 Environmental Risk Assessment

CSA N288.6-12 *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills* (CSA, 2012), addresses the design, implementation and management of the ERA, including human health risk assessment and ecological risk assessment. The ERA is a systematic process used to identify, quantify, and characterize the risk posed by contaminants and physical stressors in the environment on biological receptors, including the magnitude and extent of the potential effects associated with a facility. The outcome of the ERA is a series of risk-based recommendations.

The ERA can provide the basis for the scope and complexity of monitoring programs, including effluent, environmental and groundwater monitoring programs as described in N288.5, N288.4 and N288.7 (see Sections 8.2, 8.3 and 8.4, respectively). As a result, any future changes to these programs during the safe storage state will be reflected in the ERA prepared for the PN Site.

An ERA for the PN Site was developed in accordance with N288.6-12 (CSA, 2012) to assess the potential environmental risk posed by the existing PN operations (EcoMetrix and Golder, 2017).

CSA Standard N288.6-12 (CSA, 2012) requires that the ERA be reviewed periodically, recommending a five year cycle, or more frequently if major facility changes are proposed. In addition, REGDOC-3.1.1 *Reporting Requirements for Nuclear Power Plants* (CNSC, 2016c) requires that an updated ERA for the site is submitted to the CNSC within five years of the date of the previous submission or when requested to do so by the CNSC.

According to N288.6-12 (CSA, 2012), the review process should include consideration of the following:

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

The overall iterative nature of the ERA will capture any substantial change in the facility or in an activity that could alter the potential interaction with the environment. In other words, the process requires that the ERA reflect the changes in the effluent, environmental monitoring and groundwater monitoring programs such that the environmental risks are assessed and mitigated.

CSA N288.6-12 also provides provision for use of an ERA in a predictive context (CSA, 2012). A predictive ERA is generally applicable to a new facility or process, and attempts to estimate the effects of a contaminant or stressor on an existing environment prior to release into the environment. An update of the PEA, if required, would be provided to the CNSC in advance of future licensing decisions so that the CNSC is able to complete their environmental assessment obligations under REGDOC 2.9.1 (CNSC, 2016b).

8.6 Future Standards and Regulations

It is anticipated that over time new standards and regulations will be introduced that may affect the execution of activities during the Stabilization and Storage with Surveillance Phase. There are two new CSA N288 series documents currently in progress. It is assumed that these will be implemented when approved and as required by the CNSC.

- CSA N288.8, *Establishing and implementing action levels to control releases to the environment from nuclear facilities*, was recently issued and defines a process to establish Action Levels. The new Action Levels will be designed to identify loss of control from a facilities environmental protection program as well as establish an Action Level that leads to continual improvement. This is similar to the current use of Action Levels at the Pickering Generating Station. As with other applicable new standards, OPG anticipates that a gap analysis will be carried out to assess the actions required for compliance.
- CSA N288.9 (Draft), *Guidance for Design of Fish Impingement and Entrainment Programs at Class I Nuclear facilities*, will provide guidance on the development and implementation of impingement and entrainment sampling programs. OPG is currently in the process of obtaining a fisheries authorization which may also include similar requirements.

As described in Section 4.1.2.2.4, regulatory requirements for compliance of the PN Generating Station with O. Reg. 419/05 are anticipated to change, as demonstrated through the MOECC-approved ECA for air and noise for the facility. The 2020 phase-in date for O. Reg.419/05 Schedule 3 Air Standards for the Facility is expected to occur before the beginning of the Stabilization Phase.

The requirements for application of the above guidance in the Stabilization and Storage with Surveillance Phases will be reviewed as the standards are finalized.

8.7 Summary of Monitoring Programs in Stabilization and Storage with Surveillance

Table 8-1 summarizes the environment programs anticipated to continue through the Stabilization and Storage with Surveillance Phases, and actions that may be required. The recommendations are presented by environment program, correlating to the existing programs described in Sections 8.1 through 8.5. Continued execution of these environmental programs, and associated monitoring, will reduce uncertainty in the predicted future environmental conditions.

Table 8-1: Monitoring Programs through Stabilization and Storage with Surveillance

Environment Program(s)	Program Description	Objective	Monitoring Programs
Effluent Monitoring – Hazardous Substance Emissions	Update the ECA and/or ESDM (air and noise) as required to incorporate: ■ heating steam boiler requirements and other changes once detailed design information is available; ■ phase-in of Schedule 3 Air Quality Standards; and ■ incorporation of land use changes as the result of re-purposing the PN Site, when applicable.	Confirm compliance with MOECC ECA requirements.	N/A
	Update the ECAs (industrial sewage works) with liquid effluents and other changes once detailed design information is available, if required.	Confirm compliance with MOECC ECA/ Municipal Industrial Strategy for Abatement (MISA) requirements.	Monitoring as specified by MOECC.
Effluent Monitoring Program – Radiological Emissions	Update DRLs based on reduced cooling water flows and land use changes as the result of re-purposing the PN Site as identified in future Site Specific Surveys carried out for EMP.	Confirm compliance with CNSC licensing requirements.	Effluent monitoring of radionuclides to continue until it can be demonstrated that monitoring is no longer required.
	Update Action Levels in accordance with CSA Standard N288.8.	Confirm compliance with CNSC licensing requirements.	Effluent monitoring to continue as agreed with CNSC.
Environmental Monitoring Program (EMP)	Update EMP design as determined through outcome of other environmental programs described in this table.	To facilitate estimates of radiation doses to the public and to ■ demonstrate that the doses remain below the regulatory limit; ■ demonstrate the effectiveness of containment and effluent control, independent of effluent monitoring; and ■ provide environmental data for the ERA.	Environmental monitoring requirements will be determine as part of the EMP design and associated pathway analysis.

Table 8-1: Monitoring Programs through Stabilization and Storage with Surveillance

Environment Program(s)	Program Description	Objective	Monitoring Programs
Groundwater Protection Program	Consideration of the Stabilization and Storage with Surveillance activities when implementing CSA N288.7-15 (CSA, 2015) (Groundwater Monitoring Program design review), as applicable.	Confirm that the Groundwater Conceptual Site Model has not changed as a result of the final configuration of the groundwater hydraulic sinks.	Groundwater monitoring requirements will be determined as part of the Groundwater monitoring program design review.
Environmental Risk Assessment	Inclusion of updated information such as: ■ changes that have occurred in site ecology or surrounding land use; ■ new environmental and effluent monitoring data collected since the last ERA update; and ■ new or previously unrecognized environmental issues that have been revealed by the EMP.	Confirm emissions and physical stressors do not pose an unacceptable risk to the environment.	Provision of risk-based recommendations for effluent monitoring and EMP, as required.

9.0 CONCLUSIONS

In this report, the Stabilization and Storage with Surveillance activities were evaluated for potential interactions with the environment. The Tier 1 assessment screened these interactions to assess whether the current operational conditions (assessed in the PN ERA) were bounding. Where this was not considered to be the case, a predicted bounding condition was developed and screened against accepted values for the protection of human health and the environment. In all cases, the current operational conditions were considered bounding or the predicted conditions were screened as being acceptable. For radionuclides, further risk evaluation were conducted in the Tier 2 assessment as these were considered to be of public interest.

The discussion of specific conclusions is followed by a discussion of overall risk, mitigation measures and follow-up items that are considered prudent to reduce uncertainty in the PEA.

9.1 Tier 1 and 2 Assessment Conclusions

The pathways, contaminants of potential concern, and receptors carried forward for Tier 2 assessment are as follows:

- **Aquatic environment –** reduced cooling water flows are proposed for the Storage with Surveillance Phase and this new flow regime was evaluated based on current emission rates or maximum emissions currently approved. The discharged contaminants of potential concern were evaluated against screening levels and all contaminants of potential concern are found to be below these levels with minor exceptions discussed. A surface water model was developed to predict the concentrations at receptors based on a set of Storage with Surveillance assumptions and these predicted radionuclide values are used in the Tier 2 assessment. A surface water model was also developed for the forebay under the low flow regime assumed in the Storage with Surveillance Phase. Comparison of modelled values against screening levels also found all contaminants of potential concern are below the screening levels. Similar to the lake water, radionuclides in the forebay were estimated and evaluated for ecological dose.
- **Human receptors –** the Engineering Services Buildings may be occupied by a future industrial/commercial worker not controlled by OPG in the Storage with Surveillance Phase. This future commercial/industrial worker is closer than was evaluated in the PN ERA. This new receptor was considered in OPG's current ECA and, therefore, is considered protected by this assessment such that there were no predicted adverse environmental effects from non-radiological emissions during the Storage with Surveillance Phase of the Project. Radiological emissions to this new receptor were carried forward for Tier 2 assessment due to public interests.

The Tier 2 assessment consisted of a quantitative risk assessment for human health and ecological receptors. The PEA was conducted in accordance with CSA N288.6-12 (CSA, 2012) and relied upon the PN ERA as a basis. The Tier 2 assessment indicated the following:

- **Ecological – Outfall and Frenchman's Bay** – For the ecological risk assessment, exposure points at receptor locations are estimated based on concentration factors from the surface water model. The receptor locations of interest are the PN outfall, forebay, and Frenchman's Bay. The outfall and Frenchman's Bay were assessed for dose resulting from exposure to tritium, carbon-14 and gross beta/gamma (represented by cobalt-60). None of the doses to the receptors assessed exceeded the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d and all were less than 1 mGy/d.

- **Ecological – Forebay** – The forebay may become habitat during Storage with Surveillance and potential impacts were assessed for exposure for tritium, carbon-14 and cobalt-60 for radionuclides. Based on the forebay surface water modelling conducted and the risk evaluation, there were no potential adverse effects identified. All doses to the receptors assessed were below the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.
- **Ecological – Thermal Effects** – Thermal effects were evaluated as part of the PEA. In general, the lake near the discharge will be returned in a step-wise manner to a thermal condition that is more normal for the nearshore zone of Lake Ontario. Whereas the warmed waters in the current operating condition have attracted certain species to the discharge, such as Smallmouth Bass, and have enhanced aquatic productivity near the discharge; the cooler waters after shutdown will offer thermal habitat more like the regional nearshore zone.
- **Ecological – Entrainment and Impingement** – Entrainment and impingement effects were evaluated as part of the PEA. Entrainment is not considered an issue at a flow of 6.5 m^3/sec or less (US EPA, 2014). The proposed flow during the Storage with Surveillance Phase when the CCW pumps are no longer used will be 0.58 m^3/sec, which is substantially less than the EPA guidance and current operations.
- **Human health** – The human health risk assessment evaluated potential radiological impacts to receptors that include farm and dairy farm use, urban residents, area industrial/commercial occupants, a potential future industrial/commercial worker at the current Engineering Services Buildings, and the sport fisher 500 m south of the PN Generating Station. The maximum predicted dose was estimated to be 0.002 mSv/a for the future industrial/commercial worker at the Engineering Services Buildings. The public dose estimates for the human receptors for the Storage with Surveillance Phase are approximately 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.15% of the dose from Canadian background radiation. 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 PN during the Storage with Surveillance Phase.

The final conclusion of the PEA is that, based on the assessment described in this report, there are no predicted potential adverse effects from the Stabilization and Storage with Surveillance activities proposed.

9.2 Recommendations for the Environmental Monitoring Program

As described in Section 8.0, OPG has a robust environmental management program, which takes into consideration results of the existing EMP and the PN ERA. Federal and provincial regulations, the CSA N288 series of standards, and the site-specific EMS ensure that:

- the risks associated with releases to the environment are continually assessed and mitigated;
- releases are controlled and monitored; and
- the environment is monitored.

OPG is committed to complying with applicable regulatory requirements and implementing these standards on an ongoing basis based on future licensing requirements. No additional monitoring programs are recommended as a result of the PEA.

As noted earlier, OPG is currently defining the Stabilization and Storage with Surveillance configurations to confirm the physical and operational footprint of the facility. Through the normal course of implementation of the N288 standards, the changes in activities associated with the Stabilization and Storage with Surveillance activities will be considered as part of the periodic review and update of the monitoring programs resulting in a continual assessment of effects on human and non-human biota.

9.3 Risk Management Recommendations

No interactions were identified in the PEA that may pose an unacceptable risk to humans or the environment during the Stabilization and Storage with Surveillance activities proposed. As noted above, in this report the Stabilization and Storage with Surveillance activities were evaluated for potential interactions with the environment. Where activities were considered to be suitably different than existing operations, a predicted bounding condition was developed and screened against accepted values for the protection of human health and the environment. In most cases, the current conditions were considered bounding and effects to the environment during future phases are expected to be reduced overall.

All Stabilization and Storage with Surveillance activities will be conducted by trained staff, and applicable procedures and regulations will be adhered to for the work planned in accordance with the applicable operating licence, codes and standards. Exposure to workers will be managed by OPG's Occupational Health and Radiation Protection Programs. The ALARA principle will continue to be applied to keep emissions as low as reasonably possible.

During both the Stabilization and Storage with Surveillance Phases, OPG's environmental programs will be maintained and managed in compliance with OPG's EMS and OPG's Environmental Policy. The policy, and supporting systems, ensure that legal requirements are met and that adverse effects are prevented or mitigated. These programs will be updated to incorporate new information as it becomes available through the Stabilization and Storage with Surveillance Phases.

Many mitigation measures to minimize effects on the environment are incorporated into the existing PN Generating Station operations. For example, contaminants of potential concern in air emissions are reduced through use of control technologies such as HEPA and carbon filters in the ventilation exhaust stacks. Emission control measures and discharge limits are specified within specific permits (see Section 8.2). These permits and in-design mitigation measures will remain in place until such a time that it can be demonstrated, in discussion with the regulator as applicable, that they are no longer required. For example, once cooling water flows are sufficiently reduced, OPG may confirm regulatory approval to remove the FDS, if it can be demonstrated that there would be no unacceptable risk to the aquatic environment. No new mitigation is required based on the conclusions of the PEA.

Over time, it is expected that overall emissions from the site, and therefore monitoring and the need for mitigations and emission controls, will be reduced. These recommended changes to the environmental program will be made in a measured fashion using risk-based analysis and results of the suite of environmental programs outlined in Section 8.0, to ensure that OPG's meets it's overall commitment that all reasonable measures are taken to protect workers, the public and the environment as the PN Generating Station transitions from the end of commercial operations to the safe storage state. Where applicable, OPG will implement lessons learned gained through transitioning PN U2 and U3 into a safe storage state to understand source terms and the emission trends.

Although there are no specific recommendations for effluent or environmental monitoring based on the outcome of the PEA, planning the work to define the safe storage end states of the station systems is ongoing. The waterborne emissions and cooling water flows in the Storage with Surveillance Phase will be reviewed as final configurations are determined. If the surface water assumptions and the environmental interactions are substantially different than those indicated in this document, a reassessment of the environmental risk would be carried out and mitigation identified as required. OPG will review the PEA in the next revision of the ERA (i.e., 5-year review). The outcome of the review will be documented in the ERA.

In summary, as the PN Generating Station transitions from its current operational condition to its safe storage state, the focus will remain on adapting the environmental programs implemented at the station, as needed, to ensure continual protection of human health and the environment, and environmental performance excellence per applicable operating licence, codes and standards.

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APPENDIX A

Surface Water Model Details

Acronyms

Acronym	Definition
ADCP	Acoustic Doppler Current Profiler
BC MOE	British Columbia Ministry of Environment
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of Environment
CCW	Condenser Cooling Water
CWQG	Canadian Water Quality Guideline
ERA	Environmental Risk Assessment
LCV	Lowest Chronic Value
LWC	Lake Water Concentration
MOE	Ontario Ministry of the Environment
NA	Not applicable
NOEC	No Observed Effect Concentration
ODWS	Ontario Drinking Water Standards
OPG	Ontario Power Generation
PEA	Predictive Effects Assessment
PHC	petroleum hydrocarbon
PN	Pickering Nuclear
PWQO	Provincial Water Quality Objective
QA/QC	Quality Assurance/Quality Control
RBSW	Reactor Building Service Water
RLWMS	Radioactive Liquid Waste Management System
RMA	Resource Management Associates
RMSE	Root Mean Squared Error
SD	Standard Deviation
TSS	total suspended solids
US	United States

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A.0 SURFACE WATER MODELLING

To support the Baseline Environmental Risk Assessment (ERA) and the Predictive Effects Assessment (PEA), surface water modelling was conducted using an RMA10 hydrodynamic model for the Pickering Nuclear (PN) Generating Station site. The objectives of the surface water modelling study were to:

- update a Lake Ontario Nearshore current/sediment transportation/thermal model to characterize the existing (2016) nearshore environment and changes based on the configurations identified for the Storage with Surveillance activities with sufficient spatial/temporal resolution to support a PEA, with consideration of end points such as adjacent land uses and disruption/impacts to nearshore ecological function; and
- apply the model to compare the proposed future conditions to existing conditions in terms of changes to water temperature, current patterns, and potential for erosion/deposition of sediment in Lake Ontario.

The study was intended to specifically address the requirements of the PEA as follows:

- provide an understanding of changes to sediment deposition and erosion at receptor locations as a result of the project;
- provide estimates of plume dilution factors at selected locations, and provide contaminants of potential concern concentrations at receptors to identify the portion attributable to the PN Generating Station;
- provide an understanding of the exchange of flows between Lake Ontario, the Intake Channel, and the PN Generating Station to predict contaminant of potential concern dilution and concentrations provided by the intake channel;
- provide an understanding of the exchange of flows between Frenchman's Bay and Lake Ontario to predict contaminant of potential concern dilution and concentrations in Frenchman's Bay; and
- predict the extent of thermal plumes to confirm the existing baseline understanding of thermal effects on aquatic species.

A.1 Model Description

A surface water model was developed based on work conducted for environmental assessments from 2000 to 2007 (Golder, 2007). This is referenced as the PN 2007 model in this report. The PN 2007 model is a three dimensional, finite element, hydrodynamic model suitable for simulating stratified flow conditions. The model was developed using the RMA10 model developed by Professor Ian P. King and Resource Management Associates (RMA) for the United States (US) Army Corps of Engineers. These models have been widely used by various industries, universities and government agencies in North America and around the world.

The model is designed to predict two or three dimensional, free-surface flow problems in open channels, lakes, and estuaries. The model accounts for the wind shear stress, gravitational force, turbulent shear stresses, Coriolis force, lake bottom shear stresses, density variations due to temperature changes, and boundary inflow and outflow momentum. The partial differential hydrodynamic equations are solved numerically using a finite element method that can handle flows in complex geometries or boundary conditions. It also maintains a heat budget for every element, which accounts for heat inputs and losses. This heat budget incorporates net short-wave input, long-wave radiation, long-wave back radiation, evaporation, and conduction with the atmosphere. The model can be used to compute water surface levels, flow velocities, and water temperatures.

The PN 2016 modelling approach involved three dimensional numerical simulation of thermal plumes in the "near-field" surrounding the PN Generating Station. This modelling study used the same model setup and grid as the PN 2007 model with the exception of the modifications outlined below in relation to the years of baseline data used. The model extends from East Point (Scarborough) to the west and Whitby Harbour to the east. The total length of shoreline represented in the model is approximately 25 kilometres (km). The model grid includes the mouth of Frenchman's Bay, but not into Frenchman's Bay. The spatial extent of the near-field model was designed to encompass the area most likely to be affected by thermal outputs from the station as well as key aquatic habitat areas and nearby drinking water intakes. The extents of the model are shown in Figure A-1.

A.1.1 Model Update

The PN 2007 model (Golder, 2007) was developed based on a previous 2002 model and required updating to be used on current computer systems.

Due to limitations in the computational speed of computers in 2002, the original model was configured with a daily time step using daily averaged values for all the input parameters. With improvements in computational speed, the model was modified for an hourly time step to provide more insight into the daily variations in water temperature and current patterns.

The updated model was also expanded to include a conservative tracer that was used to predict the concentration of contaminants at selected locations.

A.1.2 Modifications for Storage with Surveillance Conditions

The PN 2007 model (Golder, 2007) represented typical operational condenser cooling water (CCW) flows (e.g., up to 100 m^3/s for each plant) in a manner that specified current speed and direction in order to maintain the offshore momentum of the cooling water discharges.

However, under Storage with Surveillance conditions, the total flow leaving PN is expected to be approximately 50,000 m^3/d from the Reactor Building Service Water (RBSW) discharge. To model the Storage with Surveillance Phase, the PN U5-8 CCW outfall was replaced with a pipe discharge (representing the RBSW outfall) to the model element immediately outside the CCW duct. To provide an option for the Stabilization and Storage with Surveillance activities, a pipe discharge for the Radioactive Liquid Waste Management System (RLWMS) was modelled at the point of the PN U1-4 CCW duct discharge.

The PN 2016 model provides a simplified approach to sediment transport assessment based on velocities. Since the predictions (e.g. output) from the PN 2007 model were suitable for the approach , no additional modifications to the PN 2007 model were required for the sediment transport assessment.

The modification to the model is illustrated on Figure A-2.

A.2 Data Review and Availability

The data used in the PN 2016 model were constrained by the limitations of the model and available data. The required data included current speed and direction, water level, ambient water temperature, meteorological data, and plant operational data (e.g., cooling water flows and temperature).

The following subsections discuss the availability for each of the data categories. Where possible, information regarding the data accuracy and reliability is provided.

A.2.1 Lake Currents

Measured lake currents have been obtained from Ontario Power Generation's (OPG's) Acoustic Doppler Current Profiler (ADCP CM44) at the PN Generating Station. Data was provided for 2011 and 2015 for consistency with the temperature data provided.

There were several periods of missing data within the data set. While short periods (e.g., less than a day) could be interpolated for modelling, longer gaps could not. As a result, the modelling period was broken into two periods. This is not considered to substantially affect the use of the model based on the verifications conducted.

A review of the data found they were suitable for completing this modelling study. The data review was also a Quality Assurance/Quality Control (QA/QC) process that included:

- alignment of speed and direction fields in the dataset;
- the identification of suspect data points;
- removal of layers typically affected by surface interference (e.g., waves, entrained air bubbles, and ice cover); and
- correction for magnetic declinations.

A.2.2 Water Levels

Golder obtained monthly water level data for Lake Ontario from Environment Canada for the period 1918 to 2015 (Environment Canada, 2016a), and hourly water levels recorded for Toronto (Station 13320) for the period 2005 to 2015 (Environment Canada, 2016b).

Environment Canada states that most of its Great Lakes stations use float-cable-counterweight shaft encoder, but do not provide the model number. To provide an illustration of the accuracy of this equipment, an example is provided: the OTT SE 200 float-cable-counterweight shaft encoder provides water level measurements with an accuracy of +/-0.1% of the measured range (Campbell Scientific, 2006).

A.2.3 Lake Water Temperature

Measured lake water temperatures are required at model boundaries. OPG completed a thermal monitoring program that collected lake water temperature data for three years (2010 to 2012). The data collected by OPG was subsequently used in a CANDU Owners Group study (Cooper, 2013). A review of the data suggests that data collected in 2011 and 2012 by OPG are best suited for this study since they provide the most complete data set collected recently near the site. These datasets were therefore selected for use in this study.

According to Cooper (Cooper, 2013), lake water temperature data were recorded using an RBR*solo* T recorder that is capable of recording temperatures with an accuracy of +/-0.002ºC. The typical temperature stability of the unit is rated at 0.002ºC per year (RBR, 2016).

A.2.4 Meteorological Data

The RMA10 model requires detailed meteorological data to fully implement the effects of atmospheric conditions on the thermal plume. These meteorological data requirements include cloud cover, air temperature (dry bulb), wet bulb temperature, atmospheric pressure, wind speed, wind direction, and incident solar radiation.

Measured weather data were obtained from Environment Canada for Toronto Island Airport for consistency with previous modelling studies. These data were readily available with very few gaps for all parameters, except wet bulb temperature, solar radiation, and cloud cover. To supplement the missing parameters, the cloud cover was estimated based on the type of weather and visibility data. Solar radiation was estimated based in longitude, latitude, date, and time of day using software developed by the University of Washington (Pelletier, 2014). Wet Bulb temperature was estimated based on empirical relationships between the air temperature and dew point.

Temperature data provided by Environment Canada for dew point, dry bulb, and wet bulb are typically available with a 0.1ºC resolution for hourly data. Atmospheric pressure data resolution is approximately 0.01 kPa for hourly data measurements. Wind speed is typically observed at a 0.1 km/h resolution, while wind direction will vary by 10s of degrees (based on a 16-point directional range).

A.2.5 Plant Operational Data

Intake and discharge flows from both PN U1-4 and PN U5-8 were provided by OPG. The data include hourly flow rates, intake temperatures and outflow temperatures, and were available with very few data gaps.

The total CCW flow was derived from the number of operational pumps (maximum 2 pumps per unit) with a pump flow rated at 1,187,090 m^3/d (13.74 m^3/s) for PN U1-4 and 1,250,000 m^3/d (14.47 m^3/s) for PN U5-8.

The total RBSW flow was derived from the power production and calculations provided by OPG. In the existing conditions, the flows are seasonally dependent with flow ranging from approximately 125,000 m^3/d (1.44 m^3/s) in the winter months and approximately 261,000 m^3/d (3.02 m^3/s) in the summer months.

A.3 Calibration and Verification

This section provides details about the selection of the modelling periods, a brief review of the data used, and the results of the model calibration and verification.

A.3.1 Modelling Periods

Simulation periods were selected to represent the existing condition and provide a basis for the assessment scenario. The years 2011 and 2012 were selected since they were the only years where suitable data were available to estimate the water temperature at the model boundaries (e.g., data collected at Thickson Point). The selection of data also evaluated:

- at what capacity PN U1-4 and PN U5-8 were operating;
- whether any recent years were considered “average,” “colder than average,” or “warmer than average” in terms of air temperature; and
- the water level in Lake Ontario relative to the long-term average, although Lake Ontario water levels have been regulated by the St. Lawrence Seaway since 1960.

In this project the following were specifically considered in the selection of modelling periods:

- cooling water data were readily available without any major gaps (e.g., data gaps limited to a few hours at a time);
- meteorological data were obtained from Environment Canada with a few gaps less than 3 hours in length;

- water temperature data at Thickson Point contained bottom data from June 27, 2011 to July 5, 2012 with only a few small gaps. Surface water data were collected from June 27, 2011 to October 5, 2011. Ideally both bottom and surface data would be used to set the model boundary; however, in the absence of a complete data set at the surface, bottom data were used for consistency between modelling periods. Based on this information, the earliest and latest modelling dates are June 27, 2011 and July 5, 2012 respectfully;
- in general, the 2011 data period was warmer and wetter than normal, and the 2012 data period was warmer and drier than normal; and
- current data were available from January 2011 to December 2012, but with substantial gaps. While short gaps (e.g., less than 2 days) could be filled with interpolated data, the larger data gaps were used to define two modelling periods that were at least 3 month long (90 days) as follows;
  - September 4, 2011 to December 24, 2011 (111 days); and
  - March 29, 2012 to July 10, 2012 (103 days).

A.3.2 Model Verification

Since the PN 2007 model was rigorously calibrated in the previous studies, the 2016 model was verified against newer data to ensure that the model was still valid. Model verification consisted of a qualitative assessment as well as a statistical assessment. The qualitative assessment was used to determine whether or not the model accurately predicts the pattern and timing of current and temperature events, while the statistical assessment used several goodness-of-fit methods to test the model accuracy. The following sections outline the results of the model verification.

A.3.3 Qualitative Model Assessment

To ensure the updated 2016 model program (i.e., recompiled version) was comparable to the previous version, the updated version was used to simulate one of the scenarios from the previous study (Golder, 2007). This particular scenario still used the daily time step and was not updated to an hourly time step.

The performance of the model was assessed for the ability of the model to predict alongshore and offshore components of the currents and surface water temperature near the PN site. The data available for verification were limited to the data collected at the ADCP CM44. The model predictions are compared to the measured values for currents (8 m depth) on Figure A-3 and A-4, and for water temperature on Figure A-5.

In general, the model accurately predicts the alongshore component of the currents, including the magnitude and timing of current reversals, for both the 2011 and 2012 modelling periods. In contrast, the model does not predict the offshore component of the current very well in 2011, but reasonably well in 2012; however, the magnitude of the offshore component is typically less than 0.05 m/s in 2011.

The model indicates that alongshore currents are the primary factor affecting the movement of thermal and contaminant plumes as well as alongshore sediment transport. The offshore component of the current is typically smaller in magnitude and frequently changes direction as a result of climatic conditions and shoreline features. As a result, the offshore component is difficult to predict in most open lake situations.

The model provides reasonable predictions of the water temperature with the exception of the timing of upwelling events. In some cases, the model predicts that upwelling events occur 2 days after the measured data. This is likely the result of the limitations of the data used to establishing the water temperature at the model boundaries. Since the model boundary was based on temperature measurements outside the eastern limits of the model grid, errors in establishing the western boundary can be expected. These errors are not expected to substantially affect the use of the model predictions for assessment purposes.

In addition to a visual inspection of the model performance, the goodness-of-fit of the model will be numerically determined based on the methods outlined in the following section.

A.3.4 Model Accuracy and Suitability

The model is considered suitable for use in this study based on the model acceptance criteria and the assessment of accuracy conducted. The following points provide specific details regarding the applicability of the model and the expected accuracy with respect to its subsequent use in this report.

- Sediment erosion and deposition is determined by the absolute magnitude of the current. The model is able to accurately predict the magnitude of the current (average correlation coefficient of 0.9). On average, the model predicts the hourly magnitude of the current with an accuracy of ±0.015 m/s.
- The transport of contaminants (e.g., tracers) is primarily determined by the alongshore component of the current in terms of magnitude and duration of events (e.g., the time the current moves in one direction without reversing). On average, the model predicts the hourly alongshore current with an accuracy of ±0.016 m/s.
- The offshore component of the current is small in magnitude and changes direction frequently (e.g., every few hours). As such, it is difficult for the model to predict, as shown in the poor correlation coefficient. The errors are largely related to differences in the timing of events. These frequent changes in direction contribute to the dispersion of thermal and contaminant plumes. Since the model predicts a similar frequency distribution of the offshore current speed, it is expected that the model can adequately represent the mixing caused by the offshore component.
- On average, the model predicts daily water temperature with an accuracy of ±1.3ºC.

A.3.5 Model Accuracy and Goodness-of-Fit

Table A-1 summarizes the proposed model acceptance criteria for current, water temperature and water level and the findings for the two modelling periods. The predicted currents are from an 8-m depth and water temperature from the bottom at ADCP CM44.

The model predictions meet all the acceptance criteria except for:

- the correlation coefficient for the offshore current component (2011 only). This is not considered to be substantial in affecting the model accuracy since the alongshore current typically has a higher magnitude and is accurately predicted by the model. Accurate representations of the offshore currents are less critical than the alongshore components given the importance of the alongshore currents to sediment and contaminant transport; and
- the Root Mean Squared Error (RMSE) for water temperature in 2011 did not meet the acceptance criteria. This is likely the result of the limitation of the temperature data used to define the model boundary and is expected to have insignificant effects on the assessment of thermal effects.

Based on the results of the qualitative and statistical assessments, it was determined that the model was suitable for use in this study.

Table A-1: Model Acceptance Criteria and Results

Parameter		Test	Acceptance Criteria	Time Basis	Model Accuracy at Results at ADCP CM44	
					2011[(a)]	2012[(b)]
Current	Alongshore Component	Correlation Coefficient	>0.5	Hourly	0.97	0.96
	Offshore Component				0.27	0.68
	Magnitude				0.93	0.87
	Speed & Direction	F-Norm	<0.9		0.69	0.62
Water Temperature		Correlation Coefficient	>0.9	Daily	0.96	0.97
		RMSE	<1.5ºC		1.52ºC	1.05ºC
		Avg% Diff	<±10%		-4.7%	-6.6%
Water Level		Max Difference	± 0.5 m	Hourly	-0.11 m	-0.14 m
		Avg Difference	± 0.1 m		-0.01 m	-0.01 m

Notes:
a) Results for the modelling period September 4 to December 24, 2011.
b) Results for the modelling period March 29 to July 10, 2012.
Shaded cells indicate acceptance criteria not met.

A.4 Scenario Assessments

The following scenarios were used in this study:

1) **Existing Conditions –** This scenario was used in the PN Environmental Risk Assessment (ERA) and is representative of current operational conditions (i.e., 6 nuclear reactor units discharging thermal plumes to the lake on an ongoing basis as per the 2011-2012 data); and

2) **Storage with Surveillance Conditions –** This scenario was used in the PEA. The RBSW flow is considered to be 50,000 m³/d and assumed to be discharged from PN U5-8. The rationale for this assumption is provided in the PEA.

A.4.1 Water Temperature Results

The quartile and maximum extents of the thermal plumes were estimated by comparing the predicted hourly water temperatures with Existing Conditions (2011-12) (Scenario 1), Storage with Surveillance Conditions (Scenario 2), and no discharge conditions.

The estimated areal surface extents of the thermal plumes for the existing conditions are shown on Figure A-6 and Figure A-7. The areal plume extents are areas that contain a plume that is specified as in increase over the ambient temperature (No Discharge Conditions) 75% or 95% of the time. Historically, comparisons between different environmental and operational scenarios have been based on the areal extent of the 2ºC plume (e.g., the area of the lake that is 2ºC or more above ambient temperature). At any given point in time, the thermal plume itself only occupies a portion of the area defined by the extents. For the purposes of this assessment, the maximum extents are defined as the area on the surface that contains the thermal plume 95% of the time (i.e., the thermal plume extends beyond these extents 5% of the time).

The predicted thermal plume for the Storage with Surveillance scenario was small, limited to the discharge channel, and did not exceed 5ºC. The maximum extents of the 2ºC plumes was 0.6 hectares (ha) within the PN U5-8 discharge channel for the Storage with Surveillance scenario.

A.4.2 Near-shore Currents and Erosion Potential

The intent of the simplified approach is to identify areas near PN that are expected to have changes in the potential or frequency of erosional and depositional events as a result of the Stabilization and Storage with Surveillance activities. At a minimum, these areas are expected to include the intake and discharge channels.

The erosion / deposition assessment is based on the following:

- Erosion is controlled by the frequency and magnitude of events with high current speeds. A single, short term (e.g., a few hours) erosion event can remove accumulated sediment from an area if the magnitude is high enough. If the discontinuation of operation caused these events to decrease in magnitude or frequency in a particular area, then sediment accumulation can be expected to begin occurring in that area. Conversely, if the magnitude or frequency increases, then erosion can be expected to increase;
- Deposition occurs in areas where the current speeds are typically too low to either mobilize the existing sediment or carry mobilized sediment further. If the discontinuation of operation causes the frequency of low-speeds current (or quiescent) conditions to increase in an area, then increased accumulation of sediment can be expected in those areas; and

- In most coastal areas where sediment transport occurs, the amount of sediment in a particular area is in a dynamic equilibrium. This means that both erosion and deposition occur at various times, but the total mass of sediment in the area remains fairly constant over extended periods of time assuming that the frequency distribution of current speeds does not change over time.

The sediment in the nearshore areas near the PN site are typically sands ranging in size from 0.1 to 0.5 mm (Golder, 2007). The critical current speeds for transport, deposition, and erosion for a range of particle sizes are provided on Figure A-8. For the sediment at the site, the critical velocities range from 0.02 to 0.2 m/s and this range represents the majority of the current speeds at the site. The existing and Storage with Surveillance current distributions at selected locations are provided in Figure A-8. For this assessment, areas that meet the threshold between sediment erosion and deposition are shown on Figure A-9.

As expected, there is a substantial reduction in the current speed expected in the discharge and intake channels during the Storage with Surveillance conditions. Given the minimal influence of the PN Generating Station discharge flow in this condition, sediment transport will largely be driven by natural longshore currents and wave action. Deposition of sediments are anticipated to refill the discharge channels that were scoured out over many years of cooling water discharge during PN Generating Station operation. The sediment accumulations may, over time extend out along the nearshore and connect to the shallow beaches to the west and east of the PN Generating Station, reflecting natural sedimentation patterns along the north shore of Lake Ontario. At all these locations, the current speed is expected to be below the lower threshold for sediment transport (0.02 m/s) most of the time, and sediment deposition can be expected to occur in these areas during the Storage with Surveillance Phase.

During a review of the modelling results for the existing conditions, a current recirculation area has been present where the discharge from PN U5-8 is drawn toward the Intake. As a result of this recirculation, the alongshore currents have been periodically deflected and a calmer area created inside the recirculation area. The currents speed distribution for a location inside this area is identified as “Off PN” on Figure A-8. There is a slight shift of the distribution to the right under the Storage with Surveillance conditions. This is likely the result of the elimination of the recirculation areas and potential deflection of the alongshore currents. With the increase in natural longshore current speeds, there is potential for increased erosion in this area.

A simplified analysis of the model output was completed to identify the extent of the areas where increased deposition and erosion may occur. While the deposition of sediment occurs at low velocities, it is the periodic high current speeds that remove the newly deposited sediments. As such, this analysis was based on the 95th percentile of the current speed at all the model nodes at mid-depth. Areas of increased depositions were identified as model nodes where the 95th percentile current speed was above 0.2 m/s for the existing conditions and below 0.2 m/s in the Storage with Surveillance conditions.

Areas of increased erosion were identified by either nodes where the 95th percentile current speed increased to above 0.2 m/s for the Storage with Surveillance conditions, or nodes where the 95th percentile current speed increased by more than 0.02 m/s for the Storage with Surveillance conditions if the existing conditions had values greater than 0.2 m/s.

The identified areas of increased erosion and deposition are shown on Figure A-9. Since this is a simplified approach, some smoothing of the identified areas was required.

The following points summarize the key results of this analysis:

- The model confirms that the areas near the discharge and intake channels are expected to have increased deposition of sediments based on the natural longshore wave action and sediment transport. In the areas of increased deposition under the existing conditions, the 95th percentile velocities ranged from 0.2 to 1.03 m/s with an average of 0.41 m/s. In contrast, under the Safe Storage and Surveillance conditions the 95th percentile velocities ranged from <0.001 m/s to 0.19 m/s with an average of 0.05 m/s. The average decrease of the 95th percentile velocities in these areas was approximately 0.36 m/s; and
- Discontinuation of the operation of the condenser cooling water (CCW) system will result in increased erosion potential in the offshore areas between the intake and the PN U5-8 discharge channel as a result of the greater influence of natural east–west lake currents to the south of the armourstone breakwall. In the areas of increased erosion under the existing conditions, the 95th percentile velocities ranged from 0.17 to 0.19 m/s with an average of 0.19 m/s. In contrast, under the Safe Storage and Surveillance conditions the 95th percentile velocities ranged from 0.20 m/s to 0.25 m/s with an average of 0.23 m/s. The average increase of the 95th percentile velocities in these areas was approximately 0.02 m/s.

A.4.3 Discharge Characterization

The model was used to predict the transport and dispersion of a conservative tracer for the Storage with Surveillance scenario as well as the existing conditions. Concentration factors were developed for each receptor location based on a constant discharge concentration of 1 g/m^3 (1 mg/L). This concentration factor can be pro-rated for any parameter based on the parameter's discharge concentration. The conservative tracer is not intended to represent any contaminant in particular but is intended to provide a consistent method to determine concentrations at various receptors. The location of these receptors are shown on Figure A-10.

The concentration factors developed in this study are the inverse of dilution factors that are typically used. To estimate the concentration at a specific location, the concentration factor is multiplied by the effluent concentration. In contrast, the effluent concentration is divided by a dilution factor to estimate the concentration at a receptor. For example, if a particular concentration is 1.0×10^{-3}, the corresponding dilution factor would be 1,000:1.

The average concentration factors are summarized in Table A-2, and the contours of the dilution factors (the inverse of the concentration factor) are shown in Figure A-11 and Figure A-12. Based on the tracer modelling, the following general perspectives are summarized:

- In general, the Safe Storage sources modelled have very little mixing opportunity prior to release to the lake, due to the low exit velocities (~1 m^3/s) in comparison to normal operations; and
- Without the current operational CCW flows, the discharge channel is sheltered from the open lake and has limited mixing with lake water due to the low flow (~1 m^3/s) and sheltered conditions.

To represent storm water flow to the PN U1-4 discharge channel a concentration factor of 2.1×10^{-4} was also obtained for the PN U1-4 discharge channel assuming a 200 m^3/day flow to the channel.

Table A-2: Summary of Predicted Concentration Factors for Lake Ontario

Source	Distance from PN U5-8 Outfall (m)	Reactor Building Service Water (RBSW) to U5-8
Ajax Intake (2)	5,061	1.01×10^{-4}
Liverpool Beach (6)	1,485	3.62×10^{-4}
Squires Beach (7)	2,100	7.48×10^{-4}
Frenchman's Bay Inlet (1)	1,970	3.16×10^{-4}
Off PN Generating Station / Sport Fisherman (5)	515	1.25×10^{-3}
PN U1-4 Discharge Channel (3)	939	3.56×10^{-4}
PN U5-8 Discharge Channel (4)	212	6.80×10^{-2}

Note: Estimated average concentration factors based on constant discharge concentration of 1 g/m³ (1 mg/l).
Distances are approximate from straight lines from CCW discharge and water travel distance will be longer. The distances have been provided for relative comparison purposes only.
(#) – Location reference from Figure A-10.

A.4.4 Sample Calculation – Predicted Lake Surface Water Concentration

For contaminants of potential concern that were retained as contaminants of public interest (e.g., tritium, carbon-14 and gross beta/gamma) the discharge concentrations were combined with modelled concentration factors (Table A-2) to obtain a predicted concentration at Lake Ontario receptor locations. An example is provided to illustrate the calculation

$$Surface\ Water\ Concentration\ \left(\frac{Bq}{L}\right) = Discharge\ concentration\ \left(\frac{Bq}{L}\right) \times RBSW\ concentrationfactor$$

Example: Tritium at Ajax Intake:

$$Surface\ Water\ Concentration\ \left(\frac{Bq}{L}\right) = 7{,}000\ \left(\frac{Bq}{L}\right) \times 0.000101 = 0.71\frac{Bq}{L}$$

The implication and interpretation of the results are provided in the main report.

A.5 Frenchman's Bay Modelling

The inlet to Frenchman's Bay from Lake Ontario is located approximately a kilometre west of PN. Since exchange of water between the bay and the lake could potentially transport discharges from PN Generating Station into the bay, a mass balance model was developed to predict the concentrations of tracers in Frenchman's Bay.

A.5.1 Description of Model

The following points outline the development of the mass balance model for Frenchman's Bay:

- It was assumed that Frenchman's Bay can be represented as one compartment;

- Creek inflows were prorated by drainage area using data for West Highland Creek (Station 02HC0598), which is located approximately 10 km west of Frenchman's Bay and has a drainage area of 39.8 ha;
- Exchange flows between the bay and the lake were based on hourly changes in the Lake Ontario water level (see Section A.2.2). If there was an increase in the water level over an hour, then it was assumed that volume of water that flows into the bay was equal to the change in water level times the surface area of the bay. An outflow occurred when there was a decrease in the hourly water level;
- The tracer concentrations predicted by RMA10 were used to define the tracer concentration at the inlet to the bay; and
- Modelling periods identical to the RMA10 simulations were used.

A.5.2 Results

The results of the Frenchman's Bay modelling are summarized in Table A-3. In general, the average concentrations in the bay are 33% lower than in Lake Ontario at the inlet to the bay.

Table A-3: Summary of Predicted Concentration Factors for Inside Frenchman's Bay

	Reactor Building Service Water (RBSW) to U5-8	Existing Conditions	
Source	**RBSW**	**PN U1-4**	**PN U5-8**
2011			
Minimum	8.72×10^{-5}	3.39×10^{-2}	1.25×10^{-2}
Average	2.29×10^{-4}	6.67×10^{-2}	3.09×10^{-2}
Maximum	4.67×10^{-4}	1.29×10^{-1}	5.59×10^{-2}
SD	7.85×10^{-5}	2.13×10^{-2}	8.85×10^{-3}
2012			
Minimum	6.24×10^{-5}	6.30×10^{-2}	7.89×10^{-3}
Average	2.95×10^{-4}	9.87×10^{-2}	3.80×10^{-2}
Maximum	5.57×10^{-4}	1.55×10^{-1}	8.11×10^{-2}
SD	1.11×10^{-4}	1.78×10^{-2}	1.54×10^{-2}
Combined			
Minimum	6.24×10^{-5}	3.39×10^{-2}	7.89×10^{-3}
Average	2.60×10^{-4}	8.21×10^{-2}	3.43×10^{-2}
Maximum	5.57×10^{-4}	1.55×10^{-1}	8.11×10^{-2}
SD	1.01×10^{-4}	2.54×10^{-2}	1.29×10^{-2}

Note: Estimated concentration factors based on constant discharge concentration of 1 g/m^3 (1 mg/l).

A.6 Forebay Discharge Modelling

Under normal operating conditions, discharges to the PN Generating Station forebay are quickly drawn into the intake along with relatively large volumes of lake water, and subsequently discharged through the CCW duct to the PN U1-4 or PN U5-8 discharge channels. However, under the maintenance flows planned for the Storage with Surveillance are substantially reduced and a mass balance model was developed for the forebay to predict tracer concentrations in the forebay for the Storage with Surveillance conditions. As with other tracer predictions in this study, the results were used to develop concentration factors to be used in the PEA.

A.6.1 Description of Model

The following points outline the development of the mass balance model for the Forebay:

- It was assumed that forebay could be represented as six sequential compartments (boxes) as shown in Figure A-13.
- The forebay was estimated to have a surface area of approximately 6.2 ha (62,000 m^2), a total volume of approximately 412,000 m^3, and an average depth of approximately 6.7 m.
- Water exchanges between the forebay and Lake Ontario were based on hourly changes in the Lake Ontario water level. If there was an increase in the water level over an hour, then it was assumed that volume of water that flows into the forebay was equal to the change in water level times the surface area of the forebay. An outflow occurred when there was a decrease in the hourly water level.
- A total pumping flow of 50,000 m^3/d was assumed to be consistent with the predicted cooling water RBSW flows.
- Exchange flows between individual model compartments were based on water level changes and the volume pumped into PN U5-8.
- Current velocities were estimated for flows between each of the model compartments by dividing the flows by the cross-sectional area.
- The stormwater has been modelled as a daily average of the yearly flow expected. Although the short term loadings may vary the average annual concentrations are expected to be as modelled and are considered appropriate for the purposes of the PEA.
- Contributions of flows to the forebay are assumed to come from one of two drains to the forebay:
  - **Drain A,** located just east of the PN U1-4 intake structure was assumed to discharge into Box 4. With the assumed Storage with Surveillance rerouting of flows, this drain is assumed to discharge storm water at 101 m^3/day; and
  - **Drain B,** located just west of the PN U5-8 intake structure was assumed to discharge into Box 6. This drain discharges stormwater runoff at an assumed to have a constant flow rate if 114 m^3/day.
- Given the small discharge flows to the forebay, the tracer concentrations were increased to 1,000 g/m^3 (1,000 mg/L) in order to provide more illustrative results.
- The forebay mass balance modelling was completed independent of the RMA10 modelling.

A.6.2 Tracer Results

The results of the forebay modelling are summarized in Table A-4 and Table A-5 for Drains A and B, respectively. The model indicates that, in general, the concentration factors can be accurately estimated by dividing the drain flows by the pumping rate.

Table A-4: Predicted Forebay Discharge Concentration Factors for Drain A Discharge

		Predicted Model Box Tracer Concentration Factors (g/m³)					
		1	2	3	4	5	6
50,000 m³/d to PN U5-8	Average	<0.001	<0.001	0.001	2.023	2.025	2.021
	Range			<0.001 to 0.031	1.797 to 2.232	1.939 to 2.117	1.999 to 2.046
	SD			0.004	0.056	0.023	0.008

Note: Estimated concentration factors based on constant discharge concentration of 1,000 g/m³ (1,000 mg/l).

Table A-5: Predicted Forebay Concentration Factors for Drain B Discharge

		Predicted Model Box Tracer Concentration Factors (g/m³)					
		1	2	3	4	5	6
50,000 m³/d to PN U5-8	Average	<0.001	<0.001	<0.001	<0.001	<0.001	2.28
	Range						2.24 to 2.32
	SD						0.009

Note: Estimated concentration factors based on constant discharge concentration of 1,000 g/m³ (1,000 mg/l).

A.6.3 PN Surface Water Intake Characteristics

The forebay model was also used to estimate the current velocities within the forebay under the assumed Storage with Surveillance scenario for comparison to threshold values for fish swimming speeds. The velocity results of the forebay modelling (Table A-6) result in the following observations:

- The maximum velocity of lake water entering the forebay was estimated to be 7.1 mm/s occurring at the interface of the lake and Box 1 with an average maximum velocity of 1.7 mm/s; and
- A slight increase in current speeds exists at the interface between Boxes 4 and 5 compared to its adjacent compartments. This is likely attributed to shallower depths at the interface between Boxes 4 and 5.

Table A-6: Predicted Forebay Velocities

		Current Speed (mm/s)					
		Lake to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6
50,000 m³/d to PN U5-8	Minimum	0.12	0.005	0.08	0.11	0.08	0.02
	Average	**1.1**	**1.1**	**1.0**	**1.2**	**1.7**	**1.0**
	Maximum	7.1	5.9	4.1	4.3	4.8	2.2

A.6.4 Predicted Concentrations

As described in Section 4.3.2.2 of the PEA, only stormwater runoff is assumed to discharge to the forebay during the Storage with Surveillance Phase. The modelled concentration factors were applied to the stormwater runoff concentrations for Drain A and Drain B to account for the dilution in the forebay. Concentration factors were modelled for 6 boxes of the forebay. Modelled concentration factors are provided in Table A-4 and Table A-5 and the drain discharge concentrations and predicted diluted concentrations are shown in Table A-15, Table A-16 and Table A-17, attached.

A.7 References

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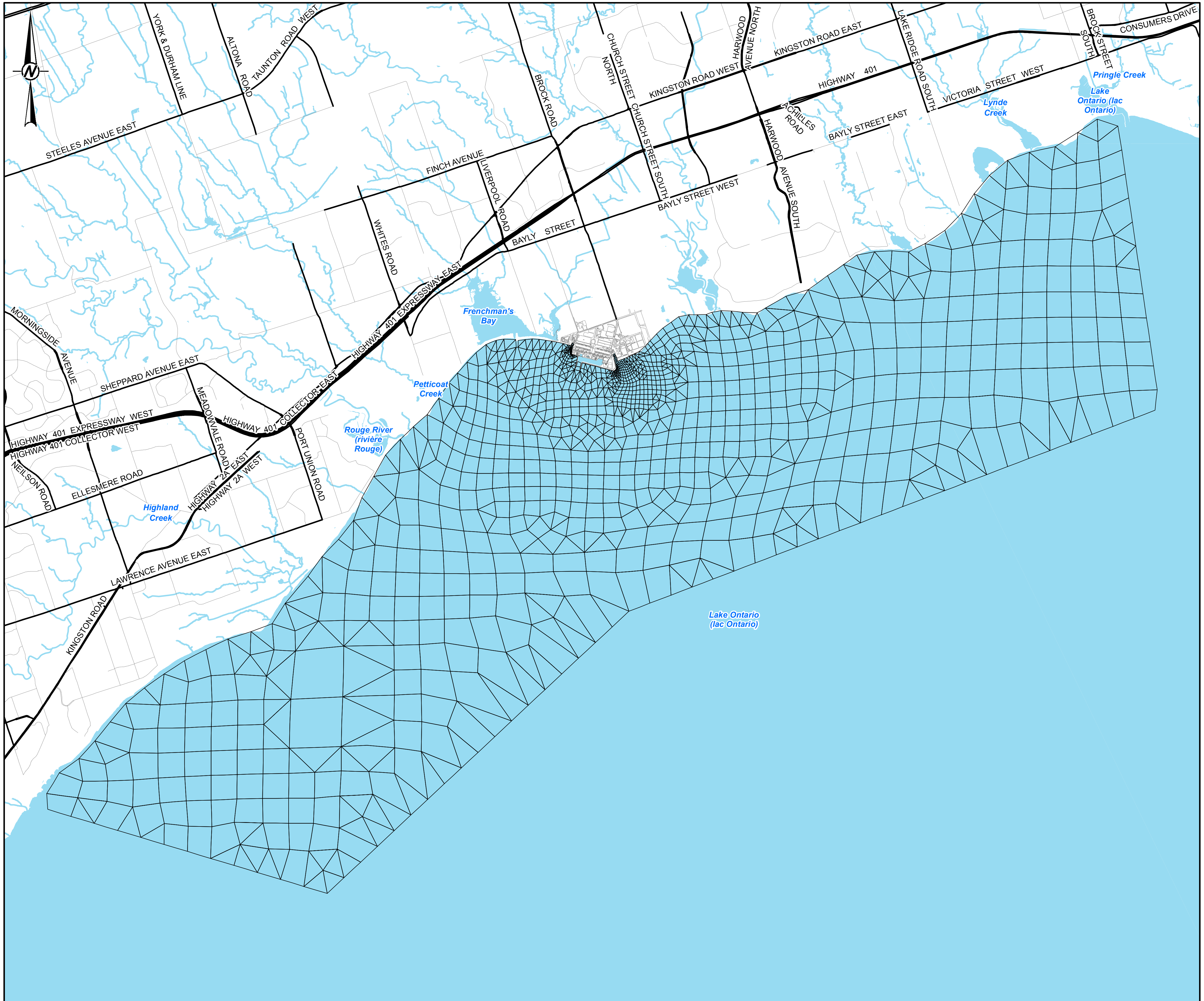

LEGEND

- Site Layout
- Major Road / Highway
- Local Road
- Watercourse
- Waterbody
- Model Grid

0 2 4 6

1:80,000 KILOMETRES

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
RMA10 MODEL GRID EXTENTS AND DETAIL

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	JR
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	**A-1**

LEGEND

- New Discharge for Post-Shutdown Scenarios
- Model Grid

0 200 400 600

1:7,500 KILOMETRES

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

ONTARIO POWER GENERATION INC.

PROJECT

OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE

MODIFICATIONS TO MODEL FOR STORAGE WITH SURVEILLANCE SCENARIO

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	JR
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-2

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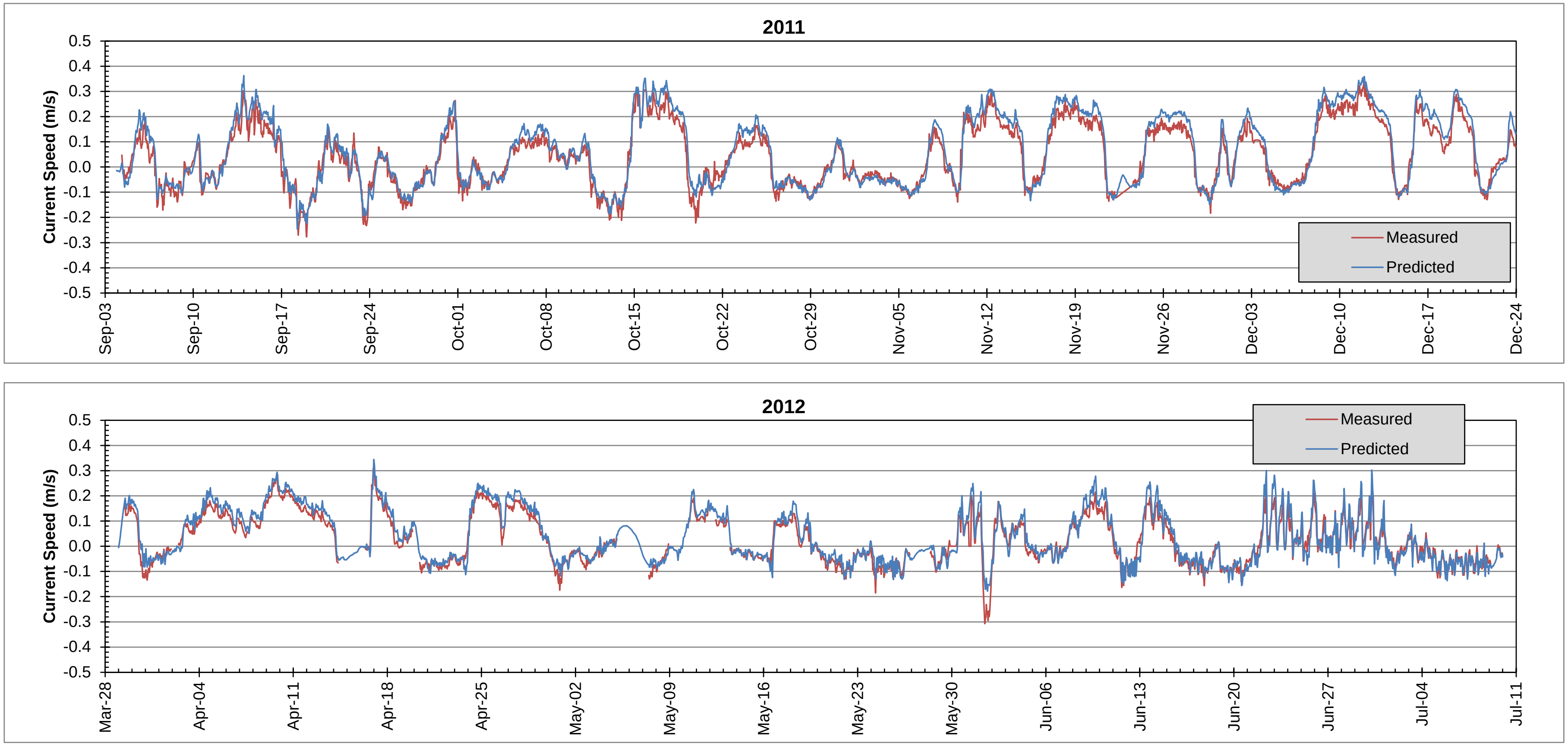

Figure A-3: Comparison of Measured and Predicted Alongshore Currents at ADCP CM44

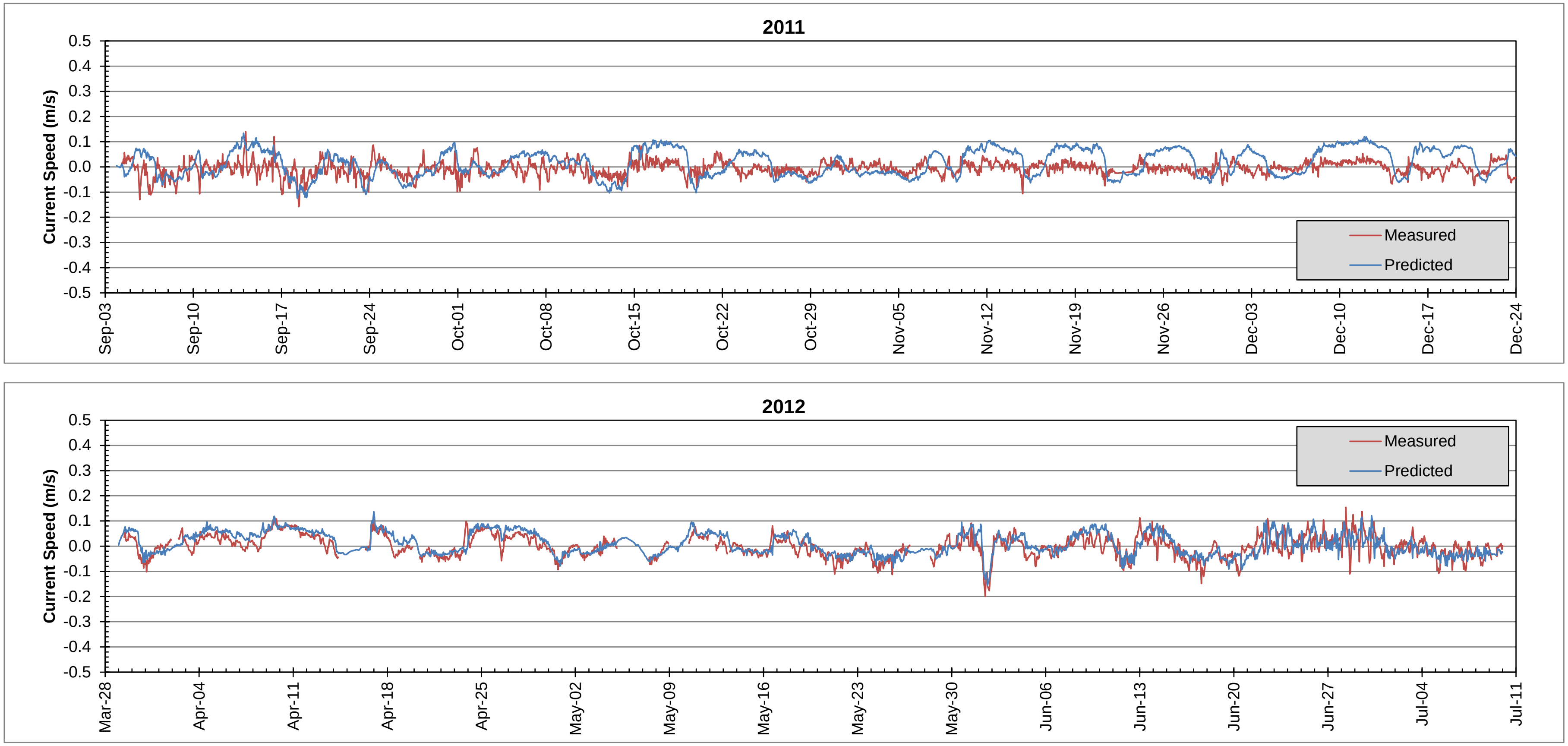

Figure A-4: Comparison of Measured and Predicted Offshore Currents at ADCP CM44

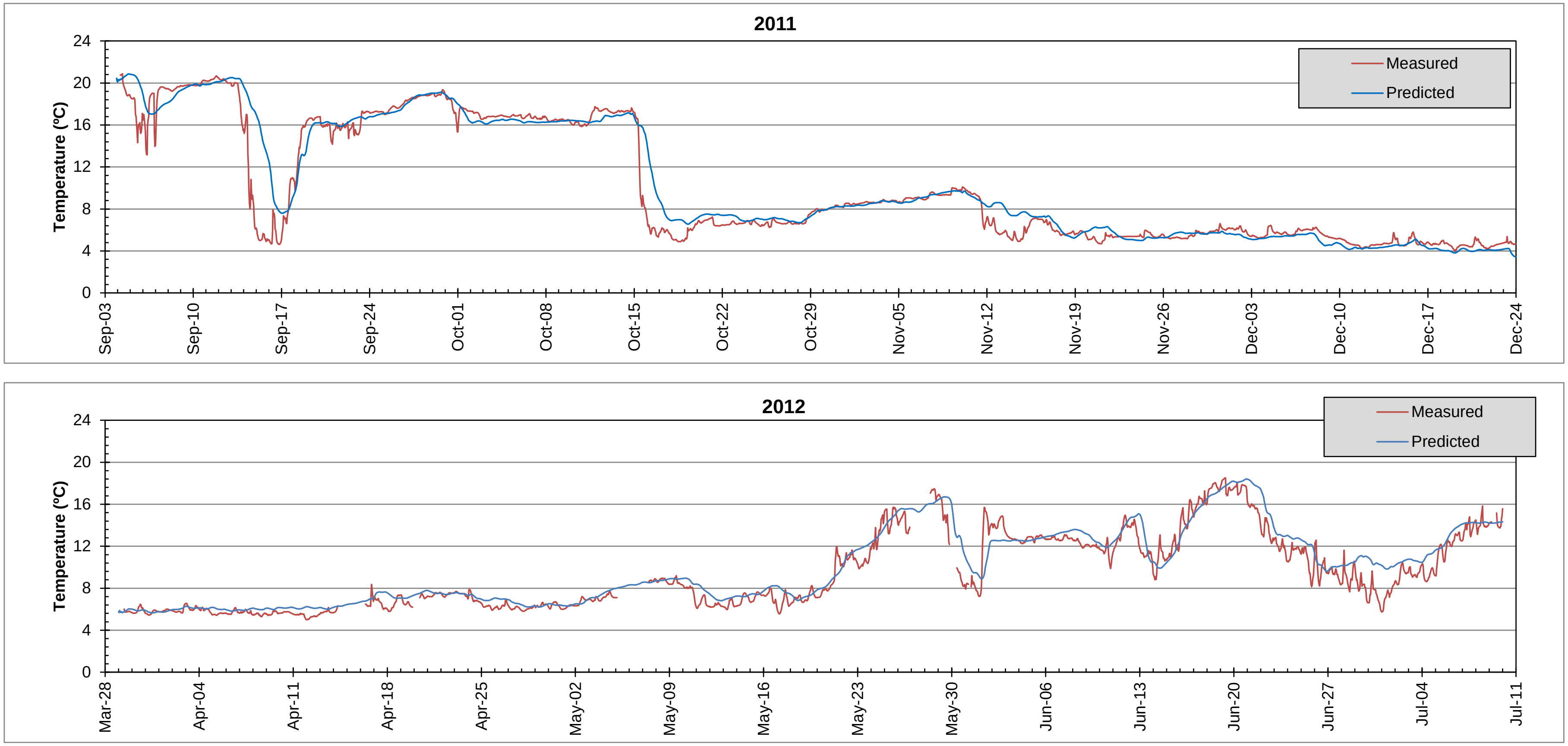

Figure A-5: Comparison of Measured and Predicted Bottom Water Temperatures at ADCP CM44

LEGEND

- Major Road / Highway
- Local Road
- Waterbody
- Site Layout
- Quartile Plume Extent (ºC)
- Model Boundary

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
QUARTILE PLUME EXTENTS FOR EXISTING CONDITIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	KD
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-6

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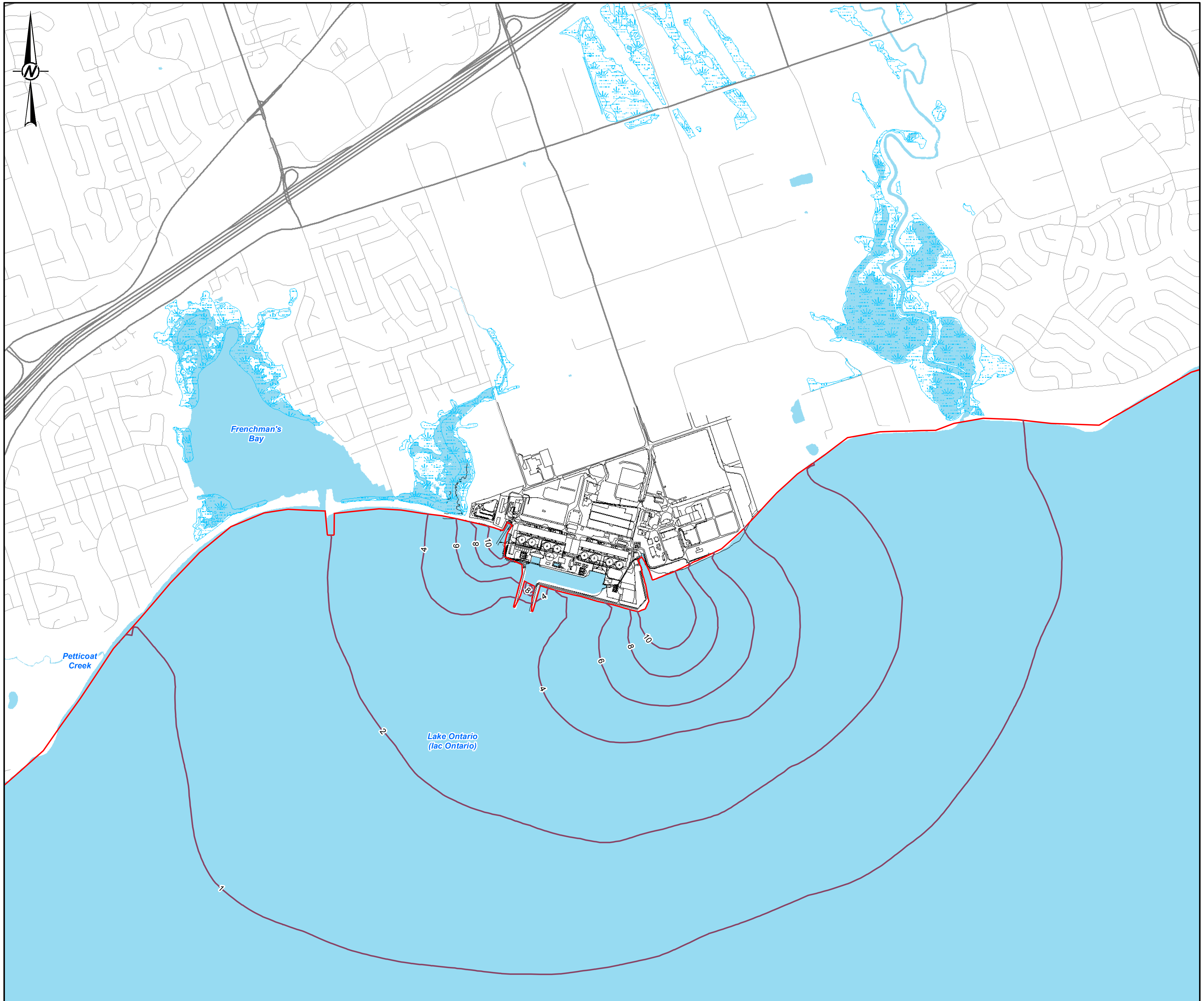


LEGEND

- Major Road / Highway
- Local Road
- Waterbody
- Site Layout
- Maximum Plume Extent (°C)
- Model Boundary

0 500 1,000 1,500

1:25,000 Metres

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

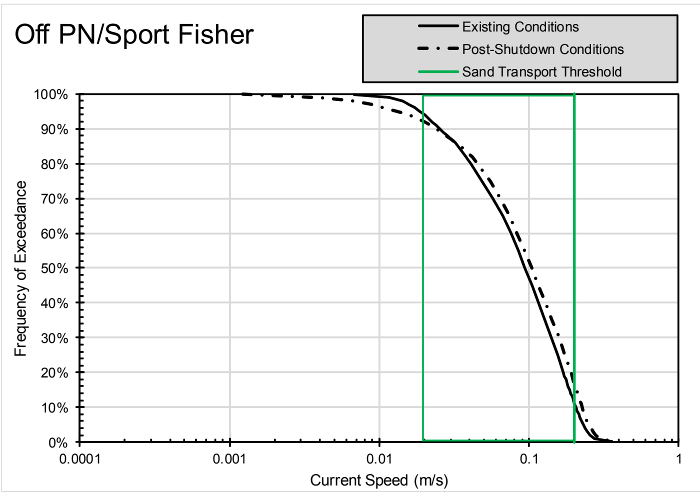
TITLE
MAXIMUM PLUME EXTENTS FOR EXISTING CONDITIONS

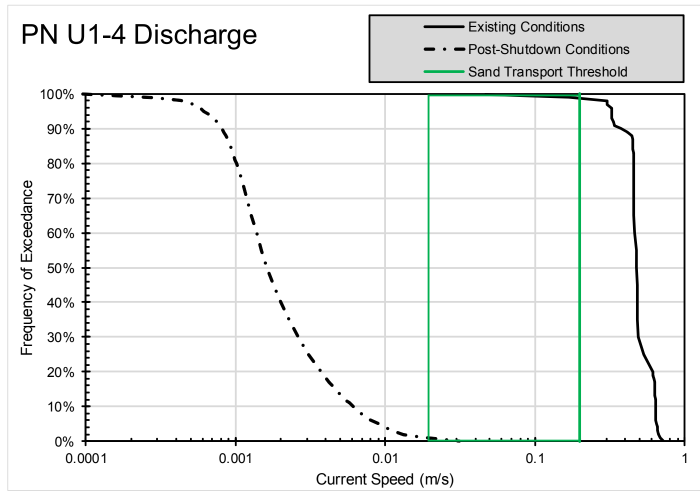
CONSULTANT
Golder Associates

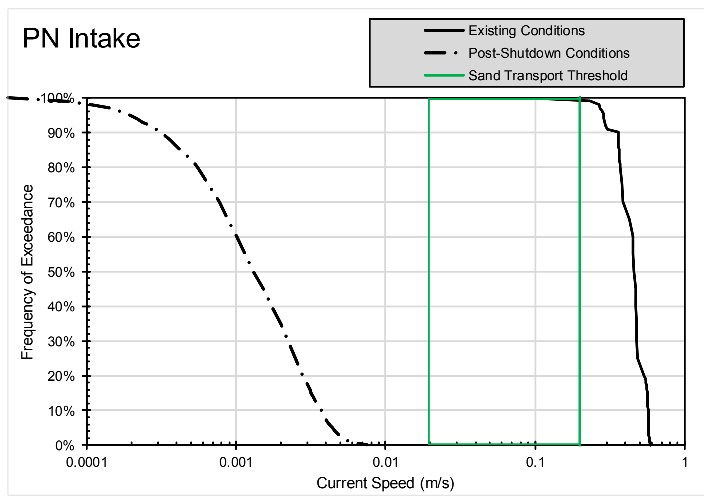
YYYY-MM-DD	2017-03-24
DESIGNED	KD
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm







CLIENT
ONTARIO POWER GENERATION INC.

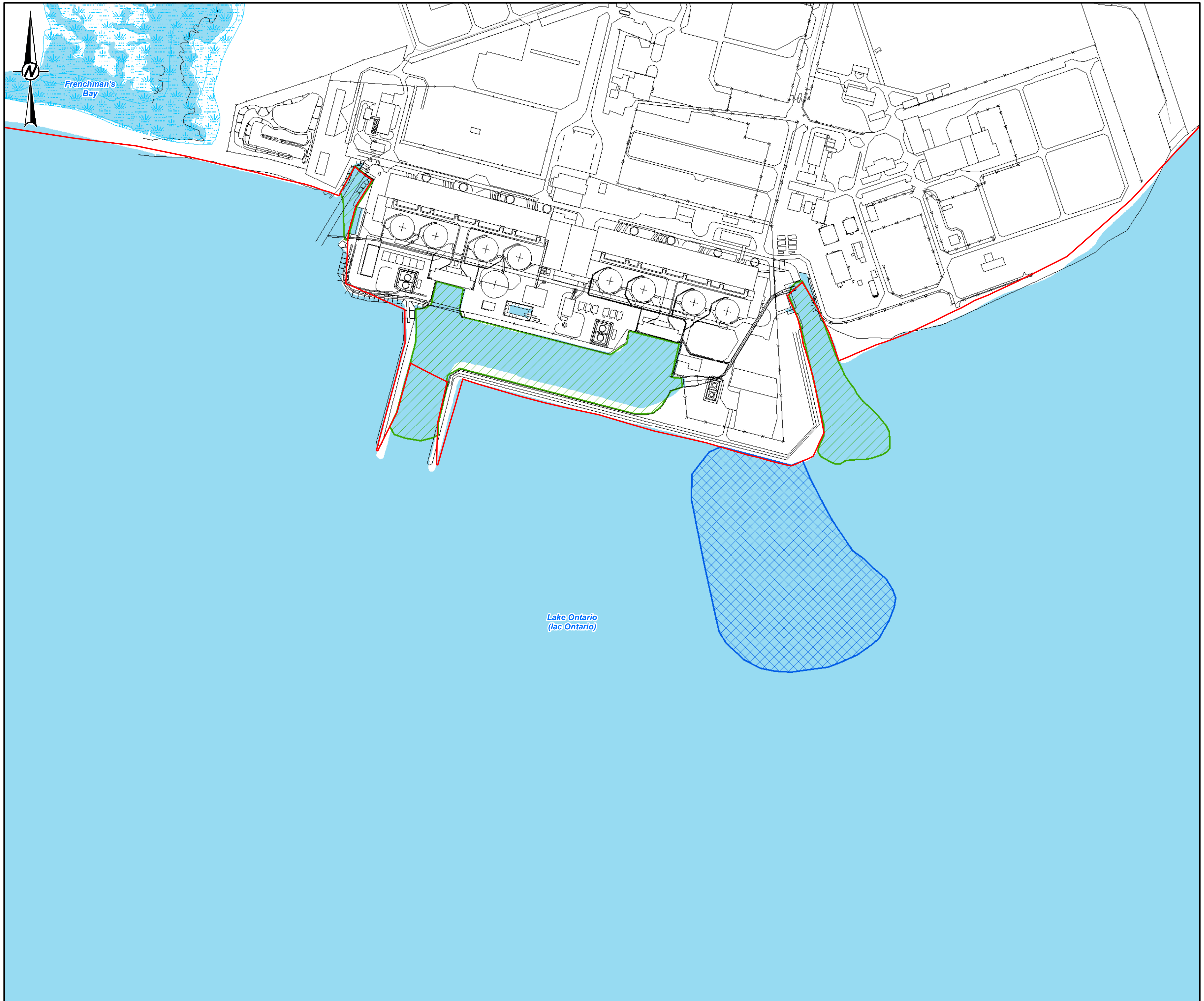
PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
COMPARISON OF EXISTING AND STORAGE WITH SURVEILLANCE CURRENT SPEED DISTRIBUTIONS

CONSULTANT

YYYY-MM-DD	2017-03-24
DESIGNED	JR
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	**A-8**



LEGEND

- Major Road / Highway
- Local Road
- Waterbody
- Site Layout
- Model Boundary

Depositional Effects

- More Deposition
- More Erosion

0 200 400 600
1:7,500 Metres

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

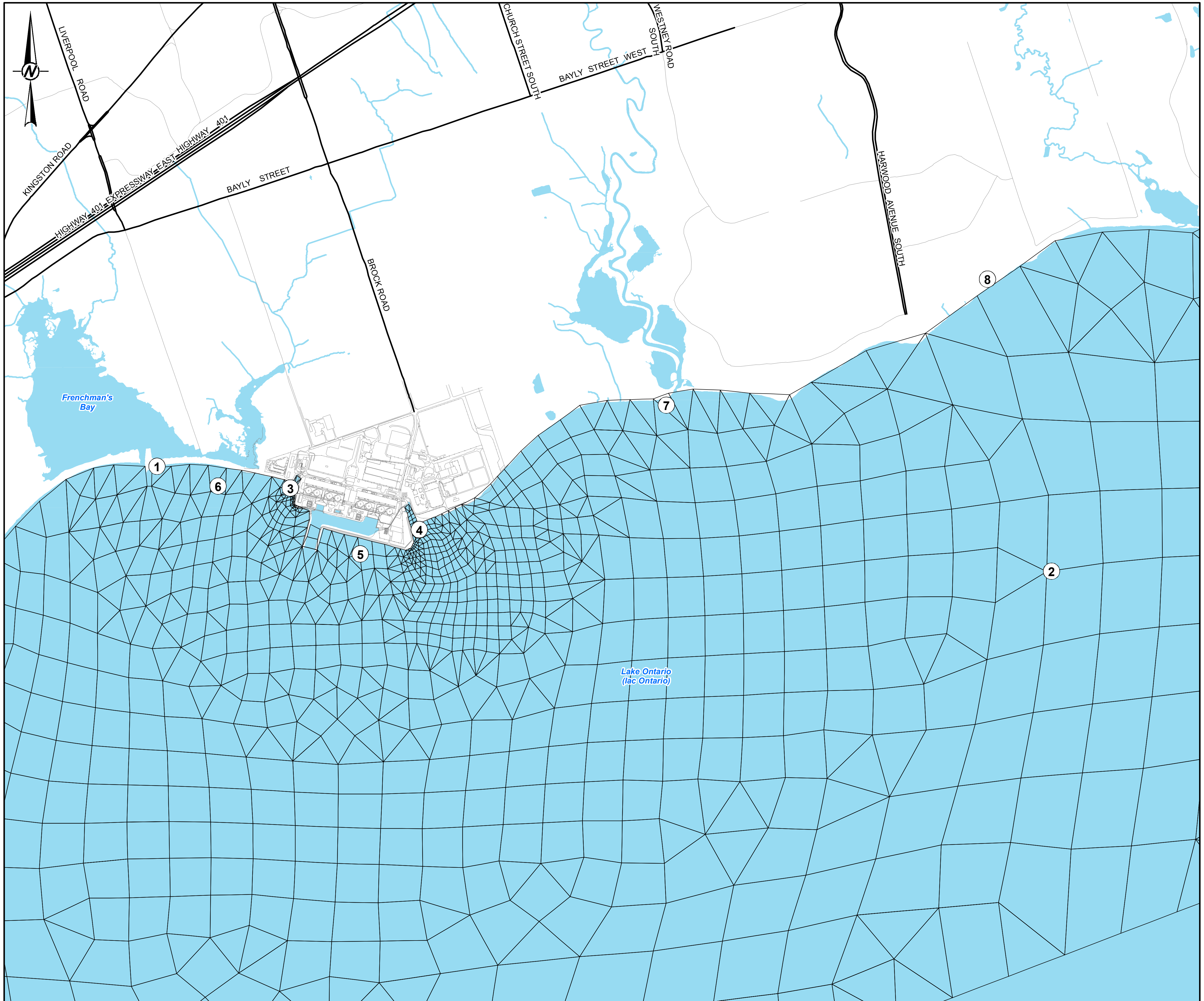
PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
APPROXIMATED AREAS OF INCREASED SEDIMENT EROSION AND DEPOSITION

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	KD
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-9



REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
SPECIFIED RECEPTOR LOCATIONS FOR DILUTION FACTORS

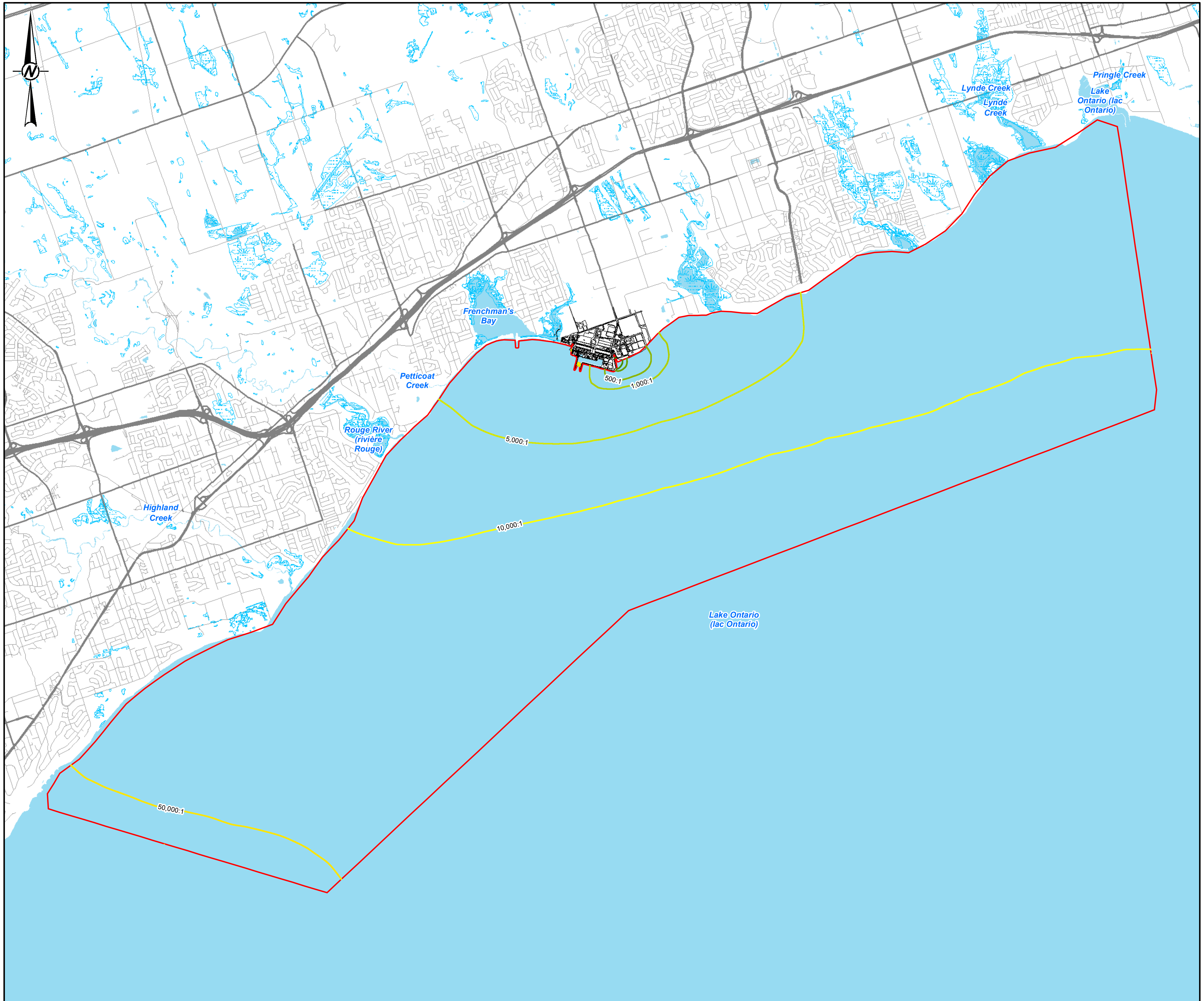
CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	JR
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



LEGEND

- Major Road / Highway
- Local Road
- Waterbody
- Wetland
- Site Layout
- Model Boundary

Contour

- 5:1
- 10:1
- 50:1
- 100:1
- 500:1
- 1,000:1
- 5,000:1
- 10,000:1
- 50,000:1
- 100,000:1
- 500,000:1
- 1,000,000:1
- 5,000,000:1
- 10,000,000:1
- 50,000,000:1

0 2 4 6 Kilometres

1:80,000

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
CONTOUR PLOT OF DILUTION FACTORS FOR STORAGE WITH SURVEILLANCE CONDITIONS – REACTOR BUILDING SERVICE WATER TO U5-8

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	KD
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	**A-11**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

LEGEND

- Major Road / Highway
- Local Road
- Waterbody
- Wetland
- Site Layout
- Model Boundary

Contour

- 5:1
- 10:1
- 50:1
- 100:1
- 500:1
- 1,000:1
- 5,000:1
- 10,000:1
- 50,000:1
- 100,000:1
- 500,000:1
- 1,000,000:1
- 5,000,000:1
- 10,000,000:1
- 50,000,000:1

0 500 1,000 1,500
Metres
1:20,000

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
CONTOUR PLOT OF DILUTION FACTORS FOR STORAGE WITH SURVEILLANCE CONDITIONS – REACTOR BUILDING SERVICE WATER TO U5-8 (INTERMEDIATE AREA)

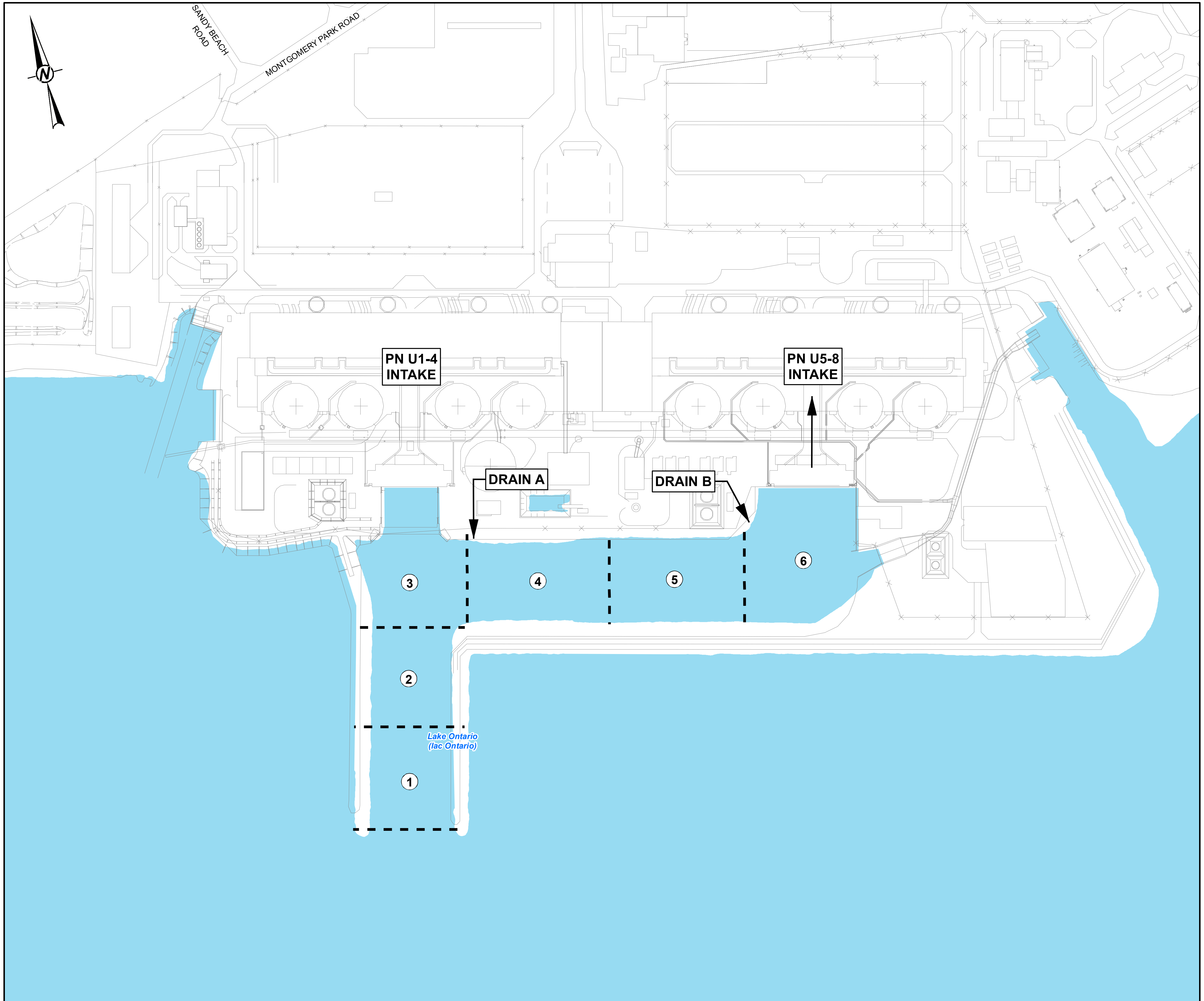
CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	KD
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-12

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0



LEGEND

- Site Layout
- Watercourse
- Waterbody
- Model Box Boundaries
- ① Model Box Numbers

0 100 200 300
1:4,000 KILOMETRES

REFERENCE(S)
BASE DATA - MNR LIO, OBTAINED 2015
BASE FIGURE FROM OPG PICKERING REFURBISHMENT PROJECT. NK30-REP-07701-00007 (GOLDER, 2007).
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
ONTARIO POWER GENERATION INC.

PROJECT
OPG PICKERING SAFE STORAGE PREDICTIVE EFFECTS ASSESSMENT

TITLE
CONFIGURATION OF FOREBAY BOX MODEL

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-24
DESIGNED	JR
PREPARED	JR
REVIEWED	GVA
APPROVED	JDW

PROJECT NO.	CONTROL	REV.	FIGURE
1522020	0005	A	A-13

Table A-7: Predicted Concentration Factors for Ajax Intake

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	1.8×10^{-6}	3.5×10^{-4}	8.0×10^{-4}
Average	7.0×10^{-5}	4.3×10^{-3}	1.5×10^{-2}
Maximum	2.7×10^{-4}	1.6×10^{-2}	5.0×10^{-2}
SD	4.7×10^{-5}	3.1×10^{-3}	9.1×10^{-3}
2012			
Minimum	1.2×10^{-5}	8.3×10^{-4}	1.3×10^{-3}
Average	1.3×10^{-4}	6.8×10^{-3}	2.2×10^{-2}
Maximum	3.3×10^{-4}	1.4×10^{-2}	5.8×10^{-2}
SD	7.0×10^{-5}	3.0×10^{-3}	1.2×10^{-2}
Combined			
Minimum	1.8×10^{-6}	3.5×10^{-4}	8.0×10^{-4}
Average	1.0×10^{-4}	5.5×10^{-3}	1.9×10^{-2}
Maximum	3.3×10^{-4}	1.6×10^{-2}	5.8×10^{-2}
SD	6.7×10^{-5}	3.3×10^{-3}	1.1×10^{-2}

Table A-8: Predicted Concentration Factors for Ajax Shoreline

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	3.4 $\times 10^{-5}$	1.5 $\times 10^{-3}$	7.9 $\times 10^{-3}$
Average	1.4 $\times 10^{-4}$	6.2 $\times 10^{-3}$	2.7 $\times 10^{-2}$
Maximum	4.2 $\times 10^{-4}$	2.5 $\times 10^{-2}$	7.5 $\times 10^{-2}$
SD	7.7 $\times 10^{-5}$	3.6 $\times 10^{-3}$	1.3 $\times 10^{-2}$
2012			
Minimum	6.5 $\times 10^{-5}$	3.2 $\times 10^{-3}$	1.0 $\times 10^{-2}$
Average	2.1 $\times 10^{-4}$	9.3 $\times 10^{-3}$	3.5 $\times 10^{-2}$
Maximum	5.6 $\times 10^{-4}$	2.3 $\times 10^{-2}$	9.9 $\times 10^{-2}$
SD	1.0 $\times 10^{-4}$	3.7 $\times 10^{-3}$	1.5 $\times 10^{-2}$
Combined			
Minimum	3.4 $\times 10^{-5}$	1.5 $\times 10^{-3}$	7.9 $\times 10^{-3}$
Average	1.7 $\times 10^{-4}$	7.7 $\times 10^{-3}$	3.1 $\times 10^{-2}$
Maximum	5.6 $\times 10^{-4}$	2.5 $\times 10^{-2}$	9.9 $\times 10^{-2}$
SD	9.7 $\times 10^{-5}$	4.0 $\times 10^{-3}$	1.5 $\times 10^{-2}$

Table A-9: Predicted Concentration Factors for Liverpool Beach

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	1.9×10^{-12}	3.7×10^{-2}	5.2×10^{-5}
Average	3.2×10^{-4}	1.4×10^{-1}	4.2×10^{-2}
Maximum	1.1×10^{-3}	3.0×10^{-1}	1.3×10^{-1}
SD	3.1×10^{-4}	6.4×10^{-2}	3.7×10^{-2}
2012			
Minimum	3.5×10^{-8}	5.2×10^{-2}	1.7×10^{-4}
Average	4.1×10^{-4}	1.9×10^{-1}	4.9×10^{-2}
Maximum	1.2×10^{-3}	3.0×10^{-1}	1.5×10^{-1}
SD	3.6×10^{-4}	5.5×10^{-2}	4.0×10^{-2}
Combined			
Minimum	1.9×10^{-12}	3.7×10^{-2}	5.2×10^{-5}
Average	3.6×10^{-4}	1.7×10^{-1}	4.5×10^{-2}
Maximum	1.2×10^{-3}	3.0×10^{-1}	1.5×10^{-1}
SD	3.4×10^{-4}	6.4×10^{-2}	3.9×10^{-2}

Table A-10: Predicted Concentration Factors for Squires Beach

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	3.6×10^{-5}	1.5×10^{-3}	8.8×10^{-3}
Average	5.8×10^{-4}	1.1×10^{-2}	9.9×10^{-2}
Maximum	2.1×10^{-3}	4.0×10^{-2}	2.6×10^{-1}
SD	4.4×10^{-4}	7.1×10^{-3}	6.4×10^{-2}
2012			
Minimum	9.5×10^{-5}	3.2×10^{-3}	1.9×10^{-2}
Average	9.3×10^{-4}	1.4×10^{-2}	1.2×10^{-1}
Maximum	2.7×10^{-3}	3.7×10^{-2}	3.2×10^{-1}
SD	5.9×10^{-4}	7.7×10^{-3}	6.4×10^{-2}
Combined			
Minimum	3.6×10^{-5}	1.5×10^{-3}	8.8×10^{-3}
Average	7.5×10^{-4}	1.3×10^{-2}	1.1×10^{-1}
Maximum	2.7×10^{-3}	4.0×10^{-2}	3.2×10^{-1}
SD	5.4×10^{-4}	7.6×10^{-3}	6.5×10^{-2}

Table A-11: Predicted Concentration Factors for Frenchman's Bay Inlet

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	1.2 x10^{-12}	1.2 x10^{-2}	2.4 x10^{-5}
Average	2.8 x10^{-4}	8.1 x10^{-2}	3.9 x10^{-2}
Maximum	9.3 x10^{-4}	2.0 x10^{-1}	1.2 x10^{-1}
SD	2.7 x10^{-4}	4.6 x10^{-2}	3.5 x10^{-2}
2012			
Minimum	2.4 x10^{-8}	2.3 x10^{-2}	1.1 x10^{-4}
Average	3.6 x10^{-4}	1.1 x10^{-1}	4.7 x10^{-2}
Maximum	1.1 x10^{-3}	2.0 x10^{-1}	1.5 x10^{-1}
SD	3.2 x10^{-4}	4.2 x10^{-2}	3.9 x10^{-2}
Combined			
Minimum	1.2 x10^{-12}	1.2 x10^{-2}	2.4 x10^{-5}
Average	3.2 x10^{-4}	9.7 x10^{-2}	4.3 x10^{-2}
Maximum	1.1 x10^{-3}	2.0 x10^{-1}	1.5 x10^{-1}
SD	3.0 x10^{-4}	4.7 x10^{-2}	3.7 x10^{-2}

Table A-12: Predicted Concentration Factors for Off PN Generating Station / Sport Fisher

Source	Radioactive Liquid Waste Management System (RLWMS)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	1.0 $\times 10^{-12}$	8.8 $\times 10^{-3}$	2.6 $\times 10^{-3}$
Average	1.1 $\times 10^{-3}$	4.9 $\times 10^{-2}$	1.6 $\times 10^{-1}$
Maximum	4.4 $\times 10^{-3}$	1.3 $\times 10^{-1}$	5.2 $\times 10^{-1}$
SD	1.2 $\times 10^{-3}$	2.5 $\times 10^{-2}$	1.5 $\times 10^{-1}$
2012			
Minimum	6.9 $\times 10^{-7}$	9.7 $\times 10^{-3}$	3.8 $\times 10^{-3}$
Average	1.4 $\times 10^{-3}$	6.6 $\times 10^{-2}$	2.0 $\times 10^{-1}$
Maximum	5.0 $\times 10^{-3}$	1.4 $\times 10^{-1}$	5.6 $\times 10^{-1}$
SD	1.3 $\times 10^{-3}$	2.8 $\times 10^{-2}$	1.5 $\times 10^{-1}$
Combined			
Minimum	1.0 $\times 10^{-12}$	8.8 $\times 10^{-3}$	2.6 $\times 10^{-3}$
Average	1.3 $\times 10^{-3}$	5.7 $\times 10^{-2}$	1.8 $\times 10^{-1}$
Maximum	5.0 $\times 10^{-3}$	1.4 $\times 10^{-1}$	5.6 $\times 10^{-1}$
SD	1.3 $\times 10^{-3}$	2.8 $\times 10^{-2}$	1.5 $\times 10^{-1}$

Table A-13: Predicted Concentration Factors for PN U1-4 Discharge Channel

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	4.2×10^{-12}	8.8×10^{-1}	5.1×10^{-6}
Average	3.2×10^{-4}	9.2×10^{-1}	4.7×10^{-3}
Maximum	1.1×10^{-3}	9.8×10^{-1}	1.8×10^{-2}
SD	3.1×10^{-4}	3.9×10^{-2}	5.2×10^{-3}
2012			
Minimum	5.2×10^{-8}	8.9×10^{-1}	9.3×10^{-6}
Average	4.0×10^{-4}	9.7×10^{-1}	2.9×10^{-3}
Maximum	1.1×10^{-3}	9.9×10^{-1}	2.1×10^{-2}
SD	3.4×10^{-4}	2.7×10^{-2}	4.5×10^{-3}
Combined			
Minimum	4.2×10^{-12}	8.8×10^{-1}	5.1×10^{-6}
Average	3.6×10^{-4}	9.4×10^{-1}	3.8×10^{-3}
Maximum	1.1×10^{-3}	9.9×10^{-1}	2.1×10^{-2}
SD	3.3×10^{-4}	4.0×10^{-2}	5.0×10^{-3}

Table A-14: Predicted Concentration Factors for PN U5-8 Discharge Channel

Source	Reactor Building Service Water (RBSW)	Existing Conditions	
		PN U1-4	PN U5-8
2011			
Minimum	5.2×10^{-2}	1.0×10^{-12}	9.6×10^{-1}
Average	6.3×10^{-2}	4.3×10^{-5}	1.0×10^{0}
Maximum	9.7×10^{-2}	2.8×10^{-3}	1.0×10^{0}
SD	2.8×10^{-3}	2.4×10^{-4}	4.0×10^{-3}
2012			
Minimum	4.9×10^{-2}	1.0×10^{-12}	7.2×10^{-1}
Average	7.3×10^{-2}	1.7×10^{-4}	1.0×10^{0}
Maximum	1.3×10^{-1}	2.3×10^{-2}	1.0×10^{0}
SD	1.2×10^{-2}	1.4×10^{-3}	2.7×10^{-2}
Combined			
Minimum	4.9×10^{-2}	1.0×10^{-12}	7.2×10^{-1}
Average	6.8×10^{-2}	1.1×10^{-4}	1.0×10^{0}
Maximum	1.3×10^{-1}	2.3×10^{-2}	1.0×10^{0}
SD	9.5×10^{-3}	9.8×10^{-4}	1.9×10^{-2}

Table A-15: Discharge Concentrations – Drain A

Contaminant of Potential Concern	Units	Discharge Concentration(1)	PWQO(4)	Interim PWQO(3)	CCME(5)	Toxicity Benchmark	2015 Mean Background (2)	Selected Benchmark	Reference
Tritium	Bq/L	**9475(11)**	7000	-	-	-	<4.4	7000	(4,8)
Carbon-14	Bq/L	0.26 (12)	-	-	-	-	<0.1	200	(8)
Cesium-134	Bq/L	1	-	-	-	-	<0.1	7	(8)
Cesium-137	Bq/L	1	-	-	-	-	<0.1	10	(8)
Cobalt-60	Bq/L	1	-	-	-	-	<0.1	2	(8)
PHC F1	mg/L	0.025	-	-	0.167	-	<0.025	0.167	(5)
m,p-xylenes	mg/L	**0.007**	-	0.002	-	-	-	0.002	(6)
TSS	mg/L	**60**	-	-	-	-	<1-<10	6	(10)
Aluminum	mg/L	**0.65**	-	-	0.1	-	0.007	0.1	(7)
Arsenic	mg/L	0.001	0.1	-	0.005	-	<0.0010	0.005	(6)
Barium	mg/L	**0.025**	-	-	-	-	0.02	0.02	(2)
Cadmium	mg/L	0.00022	0.0002	0.0005	0.00004 - 0.00037	-	0.0000095	0.00004	(7)
Calcium	mg/L	**38**	-	-	-	-	34	34	(2)
Cobalt	mg/L	0.00058	0.0009	-	-	-	<0.0005	0.0009	(4)
Copper	mg/L	**0.023**	0.005	0.005	0.002	-	<0.0010	0.002	(7)
Iron	mg/L	**1**	0.3	-	0.3	-	<0.1	0.3	(4,7)
Lead	mg/L	**0.0043**	0.025	0.005	0.001-0.007	-	<0.0005	0.001-0.007	(7)
Magnesium	mg/L	**8.8**	-	-	-	-	8.78	8.78	(2)
Mercury	mg/L	0.00002	0.0002	-	0.00003	-	0.00001	0.00003	(7)
Phosphorus	mg/L	**0.14**	0.02	-	-	-	NA	0.02	(4)
Potassium	mg/L	3.8	-	-	-	5.3	1.625	5.3	(9)
Selenium	mg/L	**0.002**	0.1	-	0.001	-	0.00014	0.001	(7)
Sodium	mg/L	16	-	-	-	68	14.5	68	(9)
Strontium	mg/L	0.18	-	-	-	-	0.18	0.18	(2)
Titanium	mg/L	**0.023**	-	-	-	-	<0.005000	0.005	(2)
Zinc	mg/L	**0.19**	0.03	0.02	0.03	-	<0.0050	0.02	(6)

Notes:

Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of Environment; mg/L = milligrams per litre; PHC = petroleum hydrocarbon; PWQO = Provincial Water Quality Objective; TSS = total suspended solids

1) **Bold and shaded** indicates exceedance of selected surface water quality benchmark.
2) Mean background concentration measured in Lake Water (LWC-1).
3) Interim PWQO was set based on readily available information and was not peer reviewed; the CCME (1999) guideline is used in preference.
4) MOE (1994)
5) CCME (2008) aquatic protection value calculated for assumed composition of F1; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6) Interim PWQO (MOE, 1994).
7) CCME (1999) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life
8) Ontario Drinking Water Standards (MOE, 2002)
9) Lowest Chronic Value (LCV) from Suter and Tsao (1996) modified to No Observed Effect Concentration (NOEC)
10) The CCME (1999) TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screening criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.
11) Tritium concentration in stormwater runoff is based on the average of the maximum concentrations from each location. This revision from maximum is made as tritium in stormwater runoff is expected to decrease with the removal of most atmospheric tritium emissions.
12) Maximum value from 2000/2001 and 2006 as 2016 sampling was non-detect but at elevated detection limits.

Table A-16: Discharge Concentrations – Drain B

Contaminant of Potential Concern	Units	Discharge Concentration(1)	PWQO	Interim PWQO(3)	CCME	Toxicity Benchmark	2015 Mean Background (2)	Selected Benchmark	Reference
Tritium	Bq/L	**24550**(11)	7000	-	-	-	<4.4	7000	(4,8)
Carbon-14	Bq/L	0.63 (12)	-	-	-	-	<0.1	200	(8)
Cesium-134	Bq/L	1	-	-	-	-	<0.1	7	(8)
Cesium-137	Bq/L	1	-	-	-	-	<0.1	10	(8)
Cobalt-60	Bq/L	1	-	-	-	-	<0.1	2	(8)
PHC F1	mg/L	**0.19**	-	-	0.167	-	<0.025	0.167	(5)
m,p-xylenes	mg/L	**0.003**	-	0.002	-	-	-	0.002	(6)
TSS	mg/L	**29**	-	-	-	-	<1-<10	6	(10)
Aluminum	mg/L	**0.42**	-	-	0.1	-	0.007	0.1	(7)
Arsenic	mg/L	**0.009**	0.1	-	0.005	-	<0.0010	0.005	(6)
Barium	mg/L	**0.03**	-	-	-	-	0.02	0.02	(2)
Cadmium	mg/L	**0.0004**	0.0002	0.0005	0.00004 - 0.00037	-	0.0000095	0.00004	(7)
Calcium	mg/L	**41**	-	-	-	-	34	34	(2)
Cobalt	mg/L	**0.002**	0.0009	-	-	-	<0.0005	0.0009	(4)
Copper	mg/L	**0.02**	0.005	0.005	0.002	-	<0.0010	0.002	(7)
Iron	mg/L	**0.95**	0.3	-	0.3	-	<0.1	0.3	(4,7)
Lead	mg/L	**0.005**	0.025	0.005	0.001-0.007	-	<0.0005	0.001-0.007	(7)
Magnesium	mg/L	6.5	-	-	-	-	8.78	8.78	(2)
Mercury	mg/L	**0.00003**	0.0002	-	0.00002	-	0.00001	0.00002	(7)
Phosphorus	mg/L	**3.7**	0.02	-	-	-	NA	0.02	(4)
Potassium	mg/L	**31**	-	-	-	5.3	1.625	5.3	(9)
Selenium	mg/L	**0.002**	0.1	-	0.001	-	0.00014	0.001	(7)
Sodium	mg/L	**110**	-	-	-	68	14.5	68	(9)
Strontium	mg/L	**0.57**	-	-	-	-	0.18	0.18	(2)
Titanium	mg/L	**0.02**	-	-	-	-	<0.005000	0.005	(2)
Zinc	mg/L	**0.37**	0.03	0.02	0.03	-	<0.0050	0.02	(6)

Notes:

Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of Environment; mg/L = milligrams per litre; PHC = petroleum hydrocarbon; PWQO = Provincial Water Quality Objective; TSS = total suspended solids

1) **Bold and shaded** indicates exceedance of selected surface water quality benchmark.
2) Mean background concentration measured in Lake Water (LWC-1).
3) Interim PWQO was set based on readily available information and was not peer reviewed; the CCME (1999) guideline is used in preference.
4) MOE (1994)
5) CCME (2008) aquatic protection value calculated for assumed composition of F1; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6) Interim PWQO, as found in MOE (1994).
7) CCME (1999) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life
8) Ontario Drinking Water Standards (MOE, 2002)
9) Lowest Chronic Value (LCV) from Suter and Tsao (1996) modified to No Observed Effect Concentration (NOEC)
10) The CCME (1999) TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screening criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.
11) Tritium concentration in stormwater runoff is based on the average of the maximum concentrations from each location. This revision from maximum is made as tritium in stormwater runoff is expected to decrease with the removal of most atmospheric tritium emissions.
12) Maximum value from 2000/2001 and 2006 as 2016 sampling was non-detect but at elevated detection limits.

Table A-17: Screening of Diluted Forebay Concentrations for Human and Ecological Health Table

Contaminant of Potential Concern	Units	Concentration [1]						PWQO[4]	Interim PWQO[3]	CCME[5]	Toxicity Benchmark	2015 Mean Background[2]	Selected Benchmark	Reference
		Box 1	Box 2	Box 3	Box 4	Box 5	Box 6							
Tritium	Bq/L	3.40×10^{-2}	3.40×10^{-2}	3.85×10^{-2}	1.92×10^{1}	1.92×10^{1}	7.51×10^{1}	7000				<4.4	7000	(4,8)
Carbon-14	Bq/L	8.88×10^{-7}	8.88×10^{-7}	1.01×10^{-6}	5.25×10^{-4}	5.25×10^{-4}	1.96×10^{-3}	-	-	-	-	<0.1	200	(8)
Cesium-134	Bq/L	2.00×10^{-6}	2.00×10^{-6}	2.47×10^{-6}	2.02×10^{-3}	2.03×10^{-3}	4.30×10^{-3}	-	-	-	-	<0.1	7	(8)
Cesium-137	Bq/L	2.00×10^{-6}	2.00×10^{-6}	2.47×10^{-6}	2.02×10^{-3}	2.03×10^{-3}	4.30×10^{-3}	-	-	-	-	<0.1	10	(8)
Cobalt-60	Bq/L	2.00×10^{-6}	2.00×10^{-6}	2.47×10^{-6}	2.02×10^{-3}	2.03×10^{-3}	4.30×10^{-3}	-	-	-	-	<0.1	2	(8)
PHC F1	mg/L	2.15×10^{-7}	2.15×10^{-7}	2.27×10^{-7}	5.08×10^{-5}	5.08×10^{-5}	4.84×10^{-4}	-	-	0.17	-	<0.025	0.17	(5)
m,p-xylenes	mg/L	9.40×10^{-9}	9.40×10^{-9}	1.25×10^{-8}	1.34×10^{-5}	1.34×10^{-5}	1.97×10^{-5}	-	0.002	-	-	-	0.002	(6)
TSS	mg/L	8.90×10^{-5}	8.90×10^{-5}	1.17×10^{-4}	1.21×10^{-1}	1.22×10^{-1}	1.87×10^{-1}	-	-	-	-	<1-<10	6	(10)
Aluminum	mg/L	1.07×10^{-6}	1.07×10^{-6}	1.38×10^{-6}	1.32×10^{-3}	1.32×10^{-3}	2.27×10^{-3}	-	-	0.1	-	0.007	0.1	(7)
Arsenic	mg/L	1.00×10^{-8}	1.00×10^{-8}	1.05×10^{-8}	2.03×10^{-6}	2.03×10^{-6}	2.25×10^{-5}	0.1	-	0.005	-	<0.0010	0.005	(6)
Barium	mg/L	5.60×10^{-8}	5.60×10^{-8}	6.78×10^{-8}	5.06×10^{-5}	5.07×10^{-5}	1.21×10^{-4}	-	-	-	-	0.02	0.02	(2)
Cadmium	mg/L	6.60×10^{-10}	6.60×10^{-10}	7.63×10^{-10}	4.46×10^{-7}	4.46×10^{-7}	1.45×10^{-6}	0.0002	0.0005	0.00004 - 0.00037	-	0.0000095	0.00004	(7)
Calcium	mg/L	7.90×10^{-5}	7.90×10^{-5}	9.69×10^{-5}	7.69×10^{-2}	7.70×10^{-2}	1.70×10^{-1}	-	-	-	-	34	34	(2)
Cobalt	mg/L	2.38×10^{-9}	2.38×10^{-9}	2.65×10^{-9}	1.18×10^{-6}	1.18×10^{-6}	5.28×10^{-6}	0.0009	-	-	-	<0.0005	0.0009	(4)
Copper	mg/L	4.60×10^{-8}	4.60×10^{-8}	5.68×10^{-8}	4.66×10^{-5}	4.66×10^{-5}	9.89×10^{-5}	0.005	0.005	0.002	-	<0.0010	0.002	(7)
Iron	mg/L	1.95×10^{-6}	1.95×10^{-6}	2.42×10^{-6}	2.02×10^{-3}	2.03×10^{-3}	4.19×10^{-3}	0.3	-	0.3	-	<0.1	0.3	(4,7)
Lead	mg/L	9.00×10^{-9}	9.00×10^{-9}	1.10×10^{-8}	8.71×10^{-6}	8.71×10^{-6}	1.94×10^{-5}	0.025	0.005	0.001-0.007	-	<0.0005	0.001-0.007	(7)
Magnesium	mg/L	1.53×10^{-5}	1.53×10^{-5}	1.94×10^{-5}	1.78×10^{-2}	1.78×10^{-2}	3.26×10^{-2}	-	-	-	-	8.78	8.78	(2)
Mercury	mg/L	5.00×10^{-11}	5.00×10^{-11}	5.94×10^{-11}	4.05×10^{-8}	4.05×10^{-8}	1.09×10^{-7}	0.0002	-	0.00003	-	0.00001	0.00003	(7)
Phosphorus	mg/L	3.84×10^{-6}	3.84×10^{-6}	3.91×10^{-6}	2.87×10^{-4}	2.87×10^{-4}	8.72×10^{-3}	0.02	-	-	-	NA	0.02	(4)
Potassium	mg/L	3.48×10^{-5}	3.48×10^{-5}	3.66×10^{-5}	7.72×10^{-3}	7.73×10^{-3}	7.84×10^{-2}	-	-	-	5.3	1.63	5.3	(9)
Selenium	mg/L	4.00×10^{-9}	4.00×10^{-9}	4.94×10^{-9}	4.05×10^{-6}	4.05×10^{-6}	8.60×10^{-6}	0.1	-	0.001	-	0.00013875	0.001	(7)
Sodium	mg/L	1.26×10^{-4}	1.26×10^{-4}	1.34×10^{-4}	3.25×10^{-2}	3.25×10^{-2}	2.83×10^{-1}	-	-	-	68	14.5	68	(9)
Strontium	mg/L	7.50×10^{-7}	7.50×10^{-7}	8.35×10^{-7}	3.65×10^{-4}	3.65×10^{-4}	1.66×10^{-3}	-	-	-	-	0.18	0.18	(2)
Titanium	mg/L	4.30×10^{-8}	4.30×10^{-8}	5.38×10^{-8}	4.66×10^{-5}	4.66×10^{-5}	9.21×10^{-5}	-	-	-	-	<0.005000	0.005	(2)
Zinc	mg/L	5.60×10^{-7}	5.60×10^{-7}	6.49×10^{-7}	3.85×10^{-4}	3.85×10^{-4}	1.23×10^{-3}	0.03	0.02	0.03	-	<0.0050	0.02	(6)

Notes:

Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of Environment; mg/L = milligrams per litre; PHC = petroleum hydrocarbon; PWQO = Provincial Water Quality Objective; TSS = total suspended solids

1) **Bold and shaded** indicates exceedance of selected surface water quality benchmark.
2) Mean background concentration measured in Lake Water (LWC-1).
3) Interim PWQO was set based on readily available information and was not peer reviewed; the CCME (1999) guideline is used in preference.
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5) CCME (2008) aquatic protection value calculated for assumed composition of F1; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6) Interim PWQO, as found in MOE (1994)
7) CCME (1999) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life
8) Ontario Drinking Water Standards (MOE, 2002)
9) Lowest Chronic Value (LCV) from Suter and Tsao (1996) modified to No Observed Effect Concentration (NOEC)
10) The CCME (1999) TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screening criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.

APPENDIX B

Dose Breakdown by Pathway and Radionuclide for Human Receptors

Table B.1: Dose Breakdown by Radionuclide and Pathway for Human Receptors - RLWMS and RBSW to U5-8

Location	HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total (uSv/a)
Farm NE	Adult	C-14	uSv/a	5.508E-06	6.333E-09	1.777E-06	1.332E-10	2.092E-13	3.9E-12	1.305E-09	8.34E-11	0	0.0002875	0.0010147	0.0012727	0.0025823
		Cs-137+	uSv/a	0	0	6.412E-05	5.066E-06	3.001E-09	0.0001961	3.159E-06	0.0016006	0	0.0059148	5.975E-06	8.99E-07	0.0077907
		HTO	uSv/a	0.0817523	0	0.0378454	0.0009132	0	0	0	0	0	2.853E-05	0.0578296	0.0045815	0.1829505
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.225E-05	0.0086447	0.0028653	0.0115222
		Total	uSv/a	0.0817578	6.333E-09	0.0379113	0.0009182	3.001E-09	0.0001961	3.16E-06	0.0016006	0	0.0062431	0.067495	0.0087203	0.2048456
	Child-10y	C-14	uSv/a	7.859E-06	6.333E-09	1.261E-06	1.332E-10	1.154E-12	3.9E-12	7.2E-09	8.34E-11	0	0.0001698	0.0007746	0.0007948	0.0017484
		Cs-137+	uSv/a	0	0	2.537E-05	5.066E-06	9.233E-09	0.0001961	9.72E-06	0.0016006	0	0.0019485	2.429E-06	3.047E-07	0.003788
		HTO	uSv/a	0.0972097	0	0.0243292	0.000761	0	0	0	0	0	1.528E-05	0.0385243	0.0025598	0.1633992
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	7.185E-06	0.0065525	0.0017243	0.008284
		Total	uSv/a	0.0972176	6.333E-09	0.0243558	0.0007661	9.235E-09	0.0001961	9.727E-06	0.0016006	0	0.0021408	0.0458539	0.0050792	0.1772197
	Infant_1y	C-14	uSv/a	5.364E-06	6.333E-09	0	5.46E-12	2.309E-12	3.9E-12	1.44E-08	8.34E-11	0	0.0001	0.0006587	0.0006166	0.0013808
		Cs-137+	uSv/a	0	0	0	2.158E-07	1.108E-08	0.0002554	1.166E-05	0.0020801	0	0.0006884	1.315E-06	1.418E-07	0.0030373
		HTO	uSv/a	0.0666316	0	0	0.0003606	0	0	0	0	0	9.534E-06	0.0364635	0.0022761	0.1057413
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	4.365E-06	0.0057489	0.0014858	0.0072391
		Total	uSv/a	0.066637	6.333E-09	0	0.0003608	1.108E-08	0.0002554	1.168E-05	0.0020801	0	0.0008023	0.0428724	0.0043787	0.1173985
Dairy Farm	Adult	C-14	uSv/a	3.373E-06	3.879E-09	2.618E-07	1.278E-10	0	0	1.305E-09	8.34E-11	0	0	0.0005458	0.0040552	0.0046046
		Cs-137+	uSv/a	0	0	7.972E-06	0.0000049	0	0	3.159E-06	0.0016006	0	0	0	3.75E-08	0.0016166
		HTO	uSv/a	0.0505928	0	0.0188316	0.0006649	0	0	0	0	0	0	0.0165969	0.0228921	0.1095783
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0	0.0026371	0.0078383	0.0104755
		Total	uSv/a	0.0505962	3.879E-09	0.0188398	0.0006698	0	0	3.16E-06	0.0016006	0	0	0.0197798	0.0347857	0.1262751
	Child-10y	C-14	uSv/a	4.813E-06	3.879E-09	1.857E-07	1.278E-10	0	0	7.2E-09	8.34E-11	0	0	0.0004175	0.0040046	0.0044271
		Cs-137+	uSv/a	0	0	3.154E-06	0.0000049	0	0	9.72E-06	0.0016006	0	0	0	1.112E-08	0.0016183
		HTO	uSv/a	0.0601586	0	0.0121061	0.0005541	0	0	0	0	0	0	0.0109842	0.0248778	0.1086808
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0	0.0020028	0.0065366	0.0085394
		Total	uSv/a	0.0601634	3.879E-09	0.0121094	0.000559	0	0	9.727E-06	0.0016006	0	0	0.0134044	0.0354191	0.1232657
	Infant_1y	C-14	uSv/a	3.285E-06	3.879E-09	0	2.276E-13	0	0	1.44E-08	8.34E-11	0	0	0.000312	0.0070467	0.007362
		Cs-137+	uSv/a	0	0	0	0	0	0	1.166E-05	0.0020801	0	0	0	9.936E-09	0.0020918
		HTO	uSv/a	0.0412352	0	0	0.0002087	0	0	0	0	0	0	0.0087905	0.0542506	0.104485
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0	0.0015444	0.0102263	0.0117707
		Total	uSv/a	0.0412385	3.879E-09	0	0.0002087	0	0	1.168E-05	0.0020801	0	0	0.0106469	0.0715236	0.1257094
IND + Res	Adult	C-14	uSv/a	2.988E-05	3.436E-08	2.5E-06	1.416E-11	1.418E-13	2.643E-12	8.039E-11	5.137E-12	0	2.632E-07	5.999E-05	1.657E-08	9.269E-05
		Cs-137+	uSv/a	0	0	9.338E-05	5.045E-07	2.033E-09	0.0001328	1.946E-07	9.859E-05	0	5.415E-06	3.046E-07	6.917E-12	0.0003312
		HTO	uSv/a	0.4430076	0	0.0026915	3.575E-05	0	0	0	0	0	2.612E-08	0.0019518	1.287E-07	0.4476868
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.122E-08	0.0003011	7.053E-08	0.0003012
		Total	uSv/a	0.4430375	3.436E-08	0.0027873	3.626E-05	2.034E-09	0.0001328	1.947E-07	9.859E-05	0	5.716E-06	0.0023132	2.158E-07	0.4484119
C2	Adult	C-14	uSv/a	2.108E-05	2.424E-08	8.891E-06	2.672E-11	0	0	0	0	0	0	0	0	2.999E-05
		Cs-137+	uSv/a	0	0	0.0003322	8.575E-07	0	0	0	0	0	0	0	0	0.000333
		HTO	uSv/a	0.312533	0	0.0072562	4.571E-05	0	0	0	0	0	0	0	0	0.3198349
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	uSv/a	0.3125541	2.424E-08	0.0075972	4.657E-05	0	0	0	0	0	0	0	0	0.3201979
	Child-10y	C-14	uSv/a	3.008E-05	2.424E-08	6.307E-06	2.672E-11	0	0	0	0	0	0	0	0	3.641E-05
		Cs-137+	uSv/a	0	0	0.0001314	8.575E-07	0	0	0	0	0	0	0	0	0.0001323
		HTO	uSv/a	0.371626	0	0.0046647	3.81E-05	0	0	0	0	0	0	0	0	0.3763288
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	uSv/a	0.3716561	2.424E-08	0.0048024	3.895E-05	0	0	0	0	0	0	0	0	0.3764975

Location	HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total (uSv/a)
Sport Fisher	Adult	C-14	uSv/a	4.923E-06	5.66E-09	0	0	0	0	0	0	0	0.0061044	0	0	0.0061093
		Cs-137+	uSv/a	0	0	0	0	0	0	0	0	0	0.12558	0	0	0.12558
		HTO	uSv/a	0.0736047	0	0	0	0	0	0	0	0	0.0006058	0	0	0.0742105
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0.0002601	0	0	0.0002601
		Total	uSv/a	0.0736096	5.66E-09	0	0	0	0	0	0	0	0.1325503	0	0	0.2061599
	Child-10y	C-14	uSv/a	7.024E-06	5.66E-09	0	0	0	0	0	0	0	0.0036059	0	0	0.0036129
		Cs-137+	uSv/a	0	0	0	0	0	0	0	0	0	0.04137	0	0	0.04137
		HTO	uSv/a	0.0875216	0	0	0	0	0	0	0	0	0.0003243	0	0	0.0878459
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	0.0001526	0	0	0.0001526
		Total	uSv/a	0.0875286	5.66E-09	0	0	0	0	0	0	0	0.0454528	0	0	0.1329814
	Infant_1y	C-14	uSv/a	6.917E-06	5.66E-09	0	0	0	0	0	0	0	0.003896	0	0	0.0039029
		Cs-137+	uSv/a	0	0	0	0	0	0	0	0	0	0.0346752	0	0	0.0346752
		HTO	uSv/a	0.0958964	0	0	0	0	0	0	0	0	0.0003851	0	0	0.0962815
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	9.268E-05	0	0	9.268E-05
		Total	uSv/a	0.0599957	5.66E-09	0	0	0	0	0	0	0	0.0170344	0	0	0.0770301
Urban Resident WNW	Adult	C-14	uSv/a	6.625E-05	7.618E-08	7.392E-06	2.299E-10	2.301E-12	4.29E-11	1.305E-09	8.34E-11	0	4.273E-06	0.0009739	2.69E-07	0.0010521
		Cs-137+	uSv/a	0	0	0.0002757	8.19E-06	3.301E-08	0.0021566	3.159E-06	0.0016006	0	8.791E-05	4.944E-06	1.123E-10	0.0041371
		HTO	uSv/a	0.990562	0	0.0165996	0.0005804	0	0	0	0	0	4.241E-07	0.0316849	2.089E-06	1.0394294
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.821E-07	0.0048876	1.145E-06	0.0048889
		Total	uSv/a	0.9906282	7.618E-08	0.0168827	0.0005886	3.301E-08	0.0021566	3.16E-06	0.0016006	0	9.279E-05	0.0375513	3.503E-06	1.0495076
Urban Resident + IND	Adult	C-14	uSv/a	6.794E-05	7.812E-08	7.448E-06	2.214E-10	2.217E-12	4.132E-11	1.257E-09	8.033E-11	0	4.116E-06	0.000938	2.591E-07	0.0010179
		Cs-137+	uSv/a	0	0	0.0002778	7.888E-06	3.179E-08	0.0020773	3.043E-06	0.0015417	0	8.467E-05	4.762E-06	1.082E-10	0.0039971
		HTO	uSv/a	1.0152276	0	0.0162558	0.0005591	0	0	0	0	0	4.085E-07	0.0305189	2.012E-06	1.0625637
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.754E-07	0.0047077	1.103E-06	0.004709
		Total	uSv/a	1.0152955	7.812E-08	0.016541	0.0005669	3.18E-08	0.0020773	3.044E-06	0.0015417	0	8.937E-05	0.0361694	3.374E-06	1.0722876
Urban Resident + Onsite	Adult	C-14	uSv/a	8.612E-05	9.903E-08	7.448E-06	2.214E-10	2.217E-12	4.132E-11	1.257E-09	8.033E-11	0	4.116E-06	0.000938	2.591E-07	0.0010361
		Cs-137+	uSv/a	0	0	0.0002778	7.888E-06	3.179E-08	0.0020773	3.043E-06	0.0015417	0	8.467E-05	4.762E-06	1.082E-10	0.0039971
		HTO	uSv/a	1.2846213	0	0.0162558	0.0005591	0	0	0	0	0	4.085E-07	0.0305189	2.012E-06	1.3319575
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.754E-07	0.0047077	1.103E-06	0.004709
		Total	uSv/a	1.2847074	9.903E-08	0.016541	0.0005669	3.18E-08	0.0020773	3.044E-06	0.0015417	0	8.937E-05	0.0361694	3.374E-06	1.3416996
Urban Resident WNW	Child-10y	C-14	uSv/a	9.453E-05	7.618E-08	5.244E-06	2.299E-10	1.27E-11	4.29E-11	7.2E-09	8.34E-11	0	2.524E-06	0.0007457	2.641E-07	0.0008483
		Cs-137+	uSv/a	0	0	0.0001091	8.19E-06	1.016E-07	0.0021566	9.72E-06	0.0016006	0	2.896E-05	1.996E-06	4.172E-11	0.0039152
		HTO	uSv/a	1.17785	0	0.0106712	0.0004837	0	0	0	0	0	2.27E-07	0.0209999	1.514E-06	1.2100065
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.068E-07	0.0037135	8.007E-07	0.0037144
		Total	uSv/a	1.1779445	7.618E-08	0.0107855	0.0004919	1.016E-07	0.0021566	9.727E-06	0.0016006	0	3.182E-05	0.0254611	2.579E-06	1.2184845
Urban Resident WNW	Infant_1y	C-14	uSv/a	6.452E-05	7.618E-08	0	2.627E-11	2.539E-11	4.29E-11	1.44E-08	8.34E-11	0	1.486E-06	0.0005853	4.831E-07	0.0006519
		Cs-137+	uSv/a	0	0	0	1.094E-06	1.219E-07	0.0028098	1.166E-05	0.0020801	0	1.023E-05	9.797E-07	2.961E-11	0.004914
		HTO	uSv/a	0.80735	0	0	0.0002392	0	0	0	0	0	1.417E-07	0.0181813	2.438E-06	0.8257731
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	6.488E-08	0.0030237	1.067E-06	0.0030249
		Total	uSv/a	0.8074145	7.618E-08	0	0.0002403	1.219E-07	0.0028098	1.168E-05	0.0020801	0	1.192E-05	0.0217913	3.988E-06	0.8343638
Onsite + Res	Adult	C-14	uSv/a	0.0001435	1.65E-07	2.5E-06	1.416E-11	1.418E-13	2.643E-12	8.039E-11	5.137E-12	0	2.632E-07	5.999E-05	1.657E-08	0.0002065
		Cs-137+	uSv/a	0	0	9.338E-05	5.045E-07	2.033E-09	0.0001328	1.946E-07	9.859E-05	0	5.415E-06	3.046E-07	6.917E-12	0.0003312
		HTO	uSv/a	2.1267186	0	0.0026915	3.575E-05	0	0	0	0	0	2.612E-08	0.0019518	1.287E-07	2.1313978
		OBT	uSv/a	0	0	0	0	0	0	0	0	0	1.122E-08	0.0003011	7.053E-08	0.0003012
		Total	uSv/a	2.1268621	1.65E-07	0.0027873	3.626E-05	2.034E-09	0.0001328	1.947E-07	9.859E-05	0	5.716E-06	0.0023132	2.158E-07	2.1322366

APPENDIX C

Groundwater and Stormwater Data and Screening Tables

Table C.1:
Screening of Stormwater COPCs for Human and Ecological Health - Drain A

Station ID		MH106								MH85				Max. Con. At Discharge	PWQO[4]	Interim PWQO[3,6]	CCME Protection of Aquatic Life[7]	Toxicity Benchmark	2015 Mean Background [2]	Selected Benchmark	Reference	Retained For Further Assessment?
Sample Name		MH106	MH106-Dup	MH106	Dup B	MH106	Dup A	MH106	DUP B	MH85	MH85	MH85	MH85									
Sampling Date		20-Aug-15		28-Oct-15		19-Nov-15		11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16									
	Unit																					
Radiological																						
Carbon-14[13]	Bq/L	< 20	< 20	< 20	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20	< 20	--	--	--	--	<0.1	200	(8)	Yes[11]
Cesium-134	Bq/L	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	<0.1	7	(8)	Yes[11]
Cesium-137	Bq/L	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	<0.1	10	(8)	Yes[11]
Cobalt-60	Bq/L	-	-	< 1	< 1	< 1	< 1	<1	<1	-	< 1	< 1	<1	< 1	--	--	--	--	<0.1	2	(8)	Yes[11]
Iodine-131	Bq/L	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	--	6	(8)	No
Manganese-54	Bq/L	< 1	< 1	-	-	-	-	-	-	< 1	-	-	-	< 1	--	--	--	--	--	200	(8)	No
Tritium (Hydrogen-3)	Bq/L	1140	1150	**8560**	**8510**	**14400**	**14400**	1960	1950	4550	1690	1050	1190	**14400**	7000	--	--	--	<4.4	7000	(4,8)	Yes
Zinc-65	Bq/L	< 1	< 1	-	-	-		-	-	< 1	-	-	-	< 1	--	--	--	--	--	40	(8)	No
Petroleum Hydrocarbons (and BTEX)[5]																						
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	<0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	--	100	370	--	--	100	(6)	No
Toluene	µg/L	0.38	0.3	< 0.20	<0.20	< 0.20	<0.20	0.26	0.22	0.23	< 0.20	< 0.20	<0.20	0.38	--	0.8	2	--	--	0.8	(6)	No
Ethylbenzene	µg/L	0.69	0.46	0.39	0.34	< 0.20	<0.20	1.1	1	< 0.20	< 0.20	< 0.20	<0.20	1.1	--	8	90	--	--	8	(6)	No
o-Xylene	µg/L	2.7	2.4	2	2	< 0.20	<0.20	3.8	3.6	< 0.20	< 0.20	< 0.20	<0.20	3.8	--	40	--	--	--	40	(6)	No
m,p-Xylenes	µg/L	**3**	**2.4**	1.7	1.6	< 0.40	<0.40	**6.5**	**6.6**	< 0.40	< 0.40	< 0.40	<0.40	**6.6**	--	2	--	--	--	2	(6)	Yes
Xylenes, Total	µg/L	5.7	4.9	3.8	3.6	< 0.40	<0.40	10	10	< 0.40	< 0.40	< 0.40	<0.40	10	--	--	--	--	--	--	--	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	--	--	167	--	<25	167	(5)	Yes[11]
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	--	--	167	--	<25	167	(5)	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	--	--	42	--	<100	42	(5)	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	--	--	--	--	<200	--	--	--
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	--	--	--	--	<200	--	--	--
Reached Baseline at C50	µg/L	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	N/A	--	--	--	--	--	--	--	--
General																						
Chloride	mg/L	6.9	7.4	3	2.4	8	8.1	3.8	3.2	26	21	27	24	27	--	--	640	--	--	640	(7)	No
Conductivity	mS/cm	0.131	0.131	0.112	0.113	0.189	0.189	0.098	0.1	0.295	0.255	0.322	0.3	0.322	--	--	--	--	0.3135	--	--	--
Hardness, Calcium Carbonate	mg/L	50	53	50	50	81	83	32	32	110	110	130	120	130	--	--	--	--	127.5	--	--	--
pH	pH units	7.75	7.78	7.78	7.73	7.86	7.84	7.65	7.66	8.16	7.95	8.08	8.05	8.16	6.5-8.5	--	6.5-9.0	--	7.9025	6.5 - 8.5	(4)	No
Phosphorous	mg/L	**0.14**	**0.14**	**0.077**	**0.072**	**0.069**	**0.073**	**0.069**	**0.067**	**0.035**	**0.064**	**0.049**	**0.023**	**0.14**	0.02	--	--	--	--	0.02	(4)	Yes
Total Suspended Solids (TSS)	mg/L	**60**	**58**	**46**	**39**	**11**	**15**	**<10**	**<10**	**< 10**	**27**	**15**	**<10**	**60**	--	--	--	--	<1 - <10	6	(2,12)	Yes
Toxicity																						
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	-	0	-	0	-	0	0	0	0	0	--	--	--	--	--	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	-	0	-	0	-	0	0	0	0	0	--	--	--	--	--	--	--	--
Metals																						
Aluminum	µg/L	**650**	**600**	**370**	**360**	**320**	**410**	**110**	84	**110**	**500**	**170**	16	**650**	--	--	100	--	7.075	100	(7)	Yes
Antimony	µg/L	2.6	2.6	1.5	1.5	1.4	1.5	2	2	0.71	< 0.50	< 0.50	<0.50	2.6		20	--	--	<0.5	20	(6)	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	100	--	5	--	<1	5	(7)	Yes[11]
Barium	µg/L	17	16	13	12	18	19	7.5	7.1	23	23	25	21	25	--	--	--	--	22.25	22.25	(2)	Yes[11]
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	<0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	1100	--	--	--	<0.5	1100	(4)	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Boron	µg/L	29	26	12	13	14	15	16	14	23	16	27	15	29	--	200 [3]	1500	--	25.5	1500	(3,7)	No
Cadmium	µg/L	**0.19**	**0.15**	**0.18**	**0.2**	**0.22**	**0.18**	**0.15**	**0.15**	**< 0.10**	**< 0.10**	**< 0.10**	**<0.10**	**0.22**	0.2	0.5	0.04 - 0.37	--	0.0095	0.04	(7)	Yes
Calcium	µg/L	31000	29000	26000	27000	32000	33000	12000	12000	32000	35000	38000	34000	38000	--	--	--	--	34000	34000	(2)	Yes[11]
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	<5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	8.9	--	8.9	--	<5	8.9	(4,7)	No
Cobalt	µg/L	0.58	0.53	< 0.50	<0.50	< 0.50	<0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	0.58	0.9	--	--	--	<0.5	0.9	(4)	Yes[11]
Copper	µg/L	**21**	**17**	**7.2**	**7.1**	**13**	**14**	**9.7**	**9.4**	**23**	**7.4**	**5.4**	**2.6**	**23**	5	5	2	--	<1	2	(7)	Yes
Iron	µg/L	**1000**	**970**	**710**	**700**	**480**	**500**	110	<100	180	**860**	260	<100	**1000**	300		300	--	<100	300	(4,7)	Yes
Lead	µg/L	**4.3**	**4**	**3.7**	**3.9**	**1.6**	**1.7**	**1.2**	**1.1**	0.67	**1.9**	< 0.50	<0.50	**4.3**	25	5	1 - 7	--	<0.5	1	(7)	Yes
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	<5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	--	--	--	--	<5	5	(2)	No
Magnesium	µg/L	1300	1300	1100	1100	1300	1300	440	430	8000	6900	8800	7900	8800	--	--	--	--	8775	8775	(2)	Yes[11]
Manganese	µg/L	51	48	39	40	26	28	10	9.8	11	45	15	3.2	51	1000[9]	--	--	--	<2	1000	(9)	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	0.02	< 0.01	< 0.01	<0.01	0.02	0.2	--	0.026	--	0.01	0.026	(7)	Yes[11]
Molybdenum	µg/L	0.68	0.67	< 0.50	<0.50	0.55	0.58	1	1	1.1	0.85	1.2	1.1	1.2	--	40	73	--	1.3	40	(6)	No
Nickel	µg/L	2.4	2.7	1.6	1.5	1.9	1.7	1.1	1.3	4.5	2.2	2.3	1.2	4.5	25	--	25 - 150	--	1.025	25	(4)	No
Potassium	µg/L	1400	1400	1600	1600	1400	1500	3800	3700	1600	1500	1700	1700	3800	--	--	--	5300	1625	5300	(10)	Yes
Selenium	µg/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2.0**	**<2.0**	**<2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	100	--	1	--	0.13875	1	(7)	Yes
Silicon	µg/L	1800	1700	1200	1100	1600	1900	810	760	330	1100	560	380	1900	--	--	--	--	260	--	--	--
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	<0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.1	--	0.1	--	<0.1	0.1	(4,7)	No
Sodium	µg/L	6600	6300	2800	2900	6700	6800	3400	3400	16000	12000	15000	14000	16000	--	--	--	68000	14500	68000	(10)	Yes[11]
Strontium	µg/L	90	87	61	63	87	89	58	58	180	140	180	170	180	--	--	--	--	180	180	(2)	Yes[11]
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	<0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	--	0.3 [3]	0.8	--	<0.05	0.8	(3,7)	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Titanium	µg/L	**23**	**20**	**15**	**16**	**14**	**21**	<5.0	5	**5.5**	**23**	**9.5**	<5.0	**23**	--	--	--	--	<5	5	(2)	Yes
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	30	--	--	<1	30	(6)	No
Uranium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	0.12	0.14	0.29	0.16	0.55	0.31	0.4	0.5	0.55	--	5 [3]	15	--	0.3675	15	(3,7)	No
Vanadium	µg/L	3.7	3.2	1.8	1.8	1.4	1.9	2.5	2.6	0.86	1.5	0.63	0.72	3.7	--	6	--	--	<0.5	6	(6)	No
Zinc	µg/L	**190**	**190**	**160**	**170**	**130**	**150**	**120**	**120**	**25**	**34**	18	7.9	**190**	30	20	30	--	<5	20	(6)	Yes
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	4	--	4	<1	4	(6)	No

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

1. Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.
2. Mean background concentration measured in Lake Water (LWC-1). Results screened for further evalation if greater than 20% above LWC-1.
3. Interim PWQO was set based on readily available information and was not peer reviewed; the CCME guideline is used in preference.
4. MOE. (1994). Ontario Ministry of the Environment. Water Management: Policies Guidelines Provincial Water Quality Objectives of the Ministry of Environment and Energy (PWQO). Queen's Printer for Ontario. July.
5. CCME (2008) aquatic protection value calculated for assumed composition of F1 and F2; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6. Interim PWQO. (MOE, 1994)
7. CCME. (1999). Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines.
8. Ontario Drinking Water Standards from MOE. (2002). Ontario Ministry of the Environment. Ontario Regulation (O. Reg.) 169/03 Ontario Drinking Water Standards (ODWS)
9. BC MOE, 2001 for hardness of 100 mg/L. - BC MOE. (2001). Ambient Water Quality Guidelines for Manganese- Technical Appendix. British Colombia Ambient Water Quality Guidelines (WGQs). January 2001.
10. LCV from Suter and Tsao (1996) modified to No Observable Effects Concentration - Suter and Tsao. (1996). Suter, G.W. II and C.L. Tsao. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. U.S. Dept. Energy ES/ER/TM-96/R2.
11. Value retained due to public interest or findings in the other Drain.
12. The CCME, 2008 TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screenining criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.

Table C.2:
Screening of Stormwater COPCs for Human and Ecological Health - Drain B

Station ID		CB70				MH20				Max Con. At Discharge	PWQO[4]	Interim PWQO[3,6]	CCME Protection of Aquatic Life[7]	Toxicity Benchmark	2015 Mean Background[2]	Selected Benchmark	Reference	Retained For Further Assessment?
Sample Name		CB70	CB70	CB70	CB70	MH20	MH20	MH20	MH20									
Sampling Date		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16									
	Unit																	
Radiological																		
Carbon-14[13]	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	< 20	--	--	--	--	<0.1	200	(8)	Yes[11]
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	<0.1	7	(8)	Yes[11]
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	<0.1	10	(8)	Yes[11]
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	< 1	--	--	--	--	<0.1	2	(8)	Yes[11]
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	--	--	--	--	--	6	(8)	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	--	--	--	--	--	200	(8)	No
Tritium (Hydrogen-3)	Bq/L	188	6450	**11600**	**13800**	2300	**35300**	**19300**	**13700**	**35300**	7000	--	--	--	<4.4	7000	(4,8)	Yes
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	--	--	--	--	--	40	(8)	No
Petroleum Hydrocarbons (and BTEX)[5]																		
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	--	100	370	--	--	100	(6)	No
Toluene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	0.35	0.35	--	0.8	2	--	--	0.8	(6)	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	1.1	1.1	--	8	90	--	--	8	(6)	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	1.2	1.2	--	40	--	--	--	40	(6)	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	**2.8**	**2.8**	--	2	--	--	--	2	(6)	Yes
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	4.1	4.1	--	--	--	--	--	--	--	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	**190**	<25	< 25	< 25	< 25	<25	**190**	--	--	167	--	<25	167	(5)	Yes
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	**190**	<25	< 25	< 25	< 25	<25	**190**	--	--	167	--	<25	167	(5)	Yes
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	< 100	--	--	42	--	<100	42	(5)	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	--	--	--	--	<200	--	--	--
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	--	--	--	--	<200	--	--	--
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES	N/A	--	--	--	--	--	--	--	--
General																		
Chloride	mg/L	45	23	140	7.3	19	4.2	31	2.2	140	--	--	640	--	--	640	(7)	No
Conductivity	mS/cm	0.267	0.193	1.18	0.079	0.181	0.101	0.301	0.064	1.18	--	--	--	--	0.3135	--	--	--
Hardness, Calcium Carbonate	mg/L	47	48	120	19	52	43	110	29	120	--	--	--	--	127.5	--	--	--
pH	pH units	7.84	7.64	7.27	7.68	7.58	7.64	7.85	7.53	7.85	6.5-8.5	--	6.5-9.0	--	7.9025	6.5 - 8.5	(4)	No
Phosphorous	mg/L	**0.13**	**0.055**	**3.7**	**0.098**	**0.16**	**0.072**	**0.075**	**0.078**	**3.7**	0.02	--	--	--	--	0.02	(4)	Yes
Total Suspended Solids (TSS)	mg/L	**< 10**	**< 10**	**< 10**	**11**	**29**	**17**	**< 10**	**<10**	**29**	--	--	--	--	<1-<10	6	(2, 12)	Yes
Toxicity																		
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	100	--	--	--	--	--	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	100	--	--	--	--	--	--	--	--
Metals																		
Aluminum	µg/L	**190**	**160**	**320**	**240**	**420**	**200**	**290**	**160**	**420**	--		100	--	7.075	100	(7)	Yes
Antimony	µg/L	8.7	2.6	1.6	1.2	2.4	0.88	0.9	0.8	8.7	--	20	--	--	<0.5	20	(6)	No
Arsenic	µg/L	< 1.0	< 1.0	**9**	<1.0	< 1.0	< 1.0	< 1.0	<1.0	**9**	100	--	5	--	<1	5	(7)	Yes
Barium	µg/L	13	10	**31**	4.7	16	7.5	**24**	7	**31**	--	--	--	--	22.25	22.25	(2)	Yes
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	1100	--	--	--	<0.5	1100	(4)	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Boron	µg/L	27	12	49	<10	23	< 10	26	<10	49	--	200[3]	1500	--	25.5	1500	(3,7)	No
Cadmium	µg/L	**0.13**	**< 0.10**	**0.44**	**<0.10**	**0.24**	**0.16**	**< 0.10**	**0.15**	**0.44**	0.2	0.5	0.04 - 0.37	--	0.0095	0.04	(7)	Yes
Calcium	µg/L	17000	15000	**41000**	8400	24000	15000	34000	12000	**41000**	--	--	--	--	34000	34000	(2)	Yes
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	8.9	--	8.9	--	<5	8.9	(4,7)	No
Cobalt	µg/L	< 0.50	< 0.50	**1.8**	<0.50	0.56	< 0.50	< 0.50	<0.50	**1.8**	0.9	--	--	--	<0.5	0.9	(4)	Yes
Copper	µg/L	**20**	**3.8**	**23**	**6.9**	**17**	**8.5**	**7**	**13**	**23**	5	5	2	--	<1	2	(7)	Yes
Iron	µg/L	**400**	280	**950**	**500**	**750**	**380**	**640**	240	**950**	300	--	300	--	<100	300	(4,7)	Yes
Lead	µg/L	**3**	**1.4**	**2.6**	**2.1**	**4.7**	**2.3**	**2.8**	**1.7**	**4.7**	25	5	1 - 7	--	<0.5	1	(7)	Yes
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	--	--	--	--	<5	5	(2)	No
Magnesium	µg/L	1600	1600	6500	440	1700	1100	6200	1200	6500	--	--	--	--	8775	8775	(2)	Yes[11]
Manganese	µg/L	20	26	180	25	37	24	45	18	180	1000[9]	--	--	--	<2	1000	(9)	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	**0.03**	<0.01	< 0.01	< 0.01	< 0.01	<0.01	**0.03**	0.2	--	0.026	--	0.01	0.026	(7)	Yes
Molybdenum	µg/L	0.9	0.91	1.9	<0.50	0.82	< 0.50	1.1	<0.50	1.9	--	40	73	--	1.3	40	(6)	No
Nickel	µg/L	1.4	< 1.0	7.2	1.1	1.7	1.1	1.9	<1.0	7.2	25	--	25 - 150	--	1.025	25	(4)	No
Potassium	µg/L	850	1300	**31000**	600	2900	1600	2400	1500	**31000**	--	--	--	5300	1625	5300	(10)	Yes
Selenium	µg/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	100	--	1	--	0.13875	1	(7)	Yes
Silicon	µg/L	840	690	2000	690	1600	880	1300	720	2000	--	--	--	--	260	--	--	--
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.1	--	0.1	--	<0.1	0.1	(4,7)	No
Sodium	µg/L	36000	20000	**110000**	6400	14000	3200	19000	8300	**110000**	--	--	--	68000	14500	68000	(10)	Yes
Strontium	µg/L	**200**	120	**570**	47	110	41	170	42	**570**	--	--	--	--	180	180	(2)	Yes
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	--	0.3[3]	0.8	--	<0.05	0.8	(3,7)	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	--	--	--	<1	1	(2)	No
Titanium	µg/L	**9.6**	**5.9**	**20**	**12**	**20**	**8.6**	**14**	**14**	**20**	--	--	--	--	<5	5	(2)	Yes
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	30	--	--	<1	30	(6)	No
Uranium	µg/L	0.3	0.33	0.48	0.13	0.25	< 0.10	0.26	<0.10	0.48	--	5[3]	15	--	0.3675	15	(3,7)	No
Vanadium	µg/L	2.5	0.95	2.1	1.6	2.8	1.2	1.5	1.1	2.8	--	6	--	--	<0.5	6	(6)	No
Zinc	µg/L	**100**	**38**	**140**	**55**	**370**	**210**	**110**	**170**	**370**	30	20	30	--	<5	20	(6)	Yes
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	--	4	--	4	<1	4	(6)	No

Notes:

Bq/L = Becquerel per litre; mg/L = milligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

1. Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.
2. Mean background concentration measured in Lake Water (LWC-1). Results screened for further evalation if greater than 20% above LWC-1.
3. Interim PWQO was set based on readily available information and was not peer reviewed; the CCME guideline is used in preference.
4. MOE. (1994). Ontario Ministry of the Environment. Water Management: Policies Guidelines Provincial Water Quality Objectives of the Ministry of Environment and Energy (PWQO). Queen's Printer for Ontario. July.
5. CCME (2008) aquatic protection value calculated for assumed composition of F1 and F2; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6. Interim PWQO. (MOE, 1994)
7. CCME. (1999). Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines.
8. Ontario Drinking Water Standards from MOE. (2002). Ontario Ministry of the Environment. Ontario Regulation (O. Reg.) 169/03 Ontario Drinking Water Standards (ODWS)
9. BC MOE, 2001 for hardness of 100 mg/L. - BC MOE. (2001). Ambient Water Quality Guidelines for Manganese- Technical Appendix. British Colombia Ambient Water Quality Guidelines (WGQs). January 2001.
10. LCV from Suter and Tsao (1996) modified to No Observable Effects Concentration - Suter and Tsao. (1996). Suter, G.W. II and C.L. Tsao. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. U.S. Dept. Energy ES/ER/TM-96/R2.
11. Value retained due to public interest or findings in the other Drain.
12. The CCME, 2008 TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screeninig criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.
13. Stormwater sampling conducted in 2015/2016 does not fully represent potential C-14 effects. Results from 2006 and 2000-2001 were preferentially selected for use in discharge concentrations calculations. C-14 Drain A maximum concentraton= 0259 Bq/L.

Table C.3:
Screening of Stormwater COPCs for Human and Ecological Health - CCW PN U1-4

		Catchment 2				Catchment 1				Max Con. At Discharge	Final Conc. In CCW with 50000 m^3 /day flow	Concentration in Discharge Channel with No Flow	PWQO(4)	Interim PWQO(3,6)	CCME Protection of Aquatic Life(7)	Toxicity Benchmark	2015 Mean Background (2)	Selected Benchmark	Reference
Station ID		MH137				MH149													
Sample Date		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16										
	Unit																		
Radiological																			
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	< 20	0.108	0.0042	--	--	--	--	<0.1	200	(8)
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	0.0054	0.00021	--	--	--	--	<0.1	7	(8)
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	0.0054	0.00021	--	0.00036	--	--	<0.1	10	(8)
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	< 1	0.0054	0.00021	--	--	--	--	<0.1	2	(8)
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	0.0054	0.00021	--	--	--	--	--	6	(8)
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	0.0054	0.00021	--	--	--	--	--	200	(8)
Tritium (Hydrogen-3)	Bq/L	21	588	145	163	327	141	882	235	882	4.7628	0.18522	7000	--	--	--	<4.4	7000	(4,8)
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	0.0054	0.00021	--	--	--	--	--	40	(8)
Petroleum Hydrocarbons (and BTEX)(5)																			
Benzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	0.00108	0.000042	--	100	370	--	--	100	(6)
Toluene	ug/L	0.22	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.22	0.001188	0.0000462	--	0.8	2	--	--	0.8	(6)
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	0.00108	0.000042	--	8	90	--	--	8	(6)
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	0.00108	0.000042	--	40	--	--	--	40	(6)
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	0.00216	0.000084	--	2	--	--	--	2	(6)
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	0.00216	0.000084	--	--	--	--	--	--	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	0.135	0.00525	--	--	167	--	<25	167	(5)
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	0.135	0.00525	--	--	167	--	<25	167	(5)
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	< 100	0.54	0.021	--	--	42	--	<100	42	(5)
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	1.08	0.042	--	--	--	--	<200	--	--
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	1.08	0.042	--	--	--	--	<200	--	--
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES		--	--	--	--	--	--	--	--	--
General																			
Chloride	mg/L	25	25	27	24	**650**	110	**790**	150	**790**	4.266	0.1659	--	--	640	--	--	640	(7)
Conductivity	mS/cm	0.31	0.301	0.323	0.29	2.32	0.521	2.99	0.714	2.99	0.016146	0.0006279	--	--	--	--	0.3135	--	--
Hardness, Calcium Carbonate	mg/L	120	120	130	120	260	93	430	98	430	2.322	0.0903	--	--	--	--	127.5	--	--
pH	pH units	7.97	8.03	8.12	8.01	7.72	7.81	8.11	7.66	8.12	--	--	6.5-8.5	--	6.5-9.0	--	7.9025	6.5 - 8.5	(4)
Phosphorous	mg/L	**0.026**	**0.059**	**0.025**	**0.023**	**0.069**	**0.044**	**0.029**	**0.11**	**0.11**	0.000594	0.0000231	0.02	--		--	--	0.02	(4)
Total Suspended Solids	mg/L	**< 10**	**46**	**< 10**	**<10**	**57**	**17**	**< 10**	**70**	**70**	0.378	0.0147	--	--	--	--	<1-<10	6	(2, 11)
Toxicity																			
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0		0	0	--	--	--	--	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0		0	0	--	--	--	--	--	--	--
Metals																			
Aluminum	ug/L	67	**300**	**110**	19	**680**	**350**	57	**1400**	**1400**	7.56	0.294	--	--	100	--	7.075	100	(7)
Antimony	ug/L	< 0.50	< 0.50	< 0.50	<0.50	1	< 0.50	0.59	0.56	1	0.0054	0.00021	--	20	--	--	<0.5	20	(6)
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.0054	0.00021	100	--	5	--	<1	5	(7)
Barium	ug/L	**26**	**28**	**26**	22	**64**	19	**67**	**31**	**67**	0.3618	0.01407	--	--	--	--	22.25	22.25	(2)
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	0.0027	0.000105	1100	--	--	--	<0.5	1100	(4)
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.2	1.2	0.00648	0.000252	--	--	--	--	<1	1	(2)
Boron	ug/L	26	19	24	15	32	11	19	<10	32	0.1728	0.00672	--	200 (3)	1500	--	25.5	1500	(3, 7)
Cadmium	ug/L	**< 0.10**	**< 0.10**	**< 0.10**	**<0.10**	**< 0.10**	**< 0.10**	**< 0.10**	**<0.10**	**< 0.1**	0.00054	0.000021	0.2	0.5	0.04 - 0.37	--	0.0095	0.04 - 0.37	(7)
Calcium	ug/L	35000	38000	38000	32000	**96000**	29000	**140000**	**48000**	**140000**	756	29.4	--	--	--	--	34000	34000	(2)
Chromium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	0.027	0.00105	8.9	--	8.9	--	<5	8.9	(4,7)
Cobalt	ug/L	< 0.50	< 0.50	< 0.50	<0.50	0.65	< 0.50	< 0.50	**1**	**1**	0.0054	0.00021	0.9	--	--	--	<0.5	0.9	(4)
Copper	ug/L	**3.7**	**5.7**	**3.7**	1.9	**7.3**	**6.5**	**3.7**	**8.6**	**8.6**	0.04644	0.001806	5	5	2	--	<1	2	(7)
Iron	ug/L	110	**570**	200	<100	**1200**	**450**	130	**1800**	**1800**	9.72	0.378	300	--	300	--	<100	300	(4,7)
Lead	ug/L	< 0.50	**1.1**	< 0.50	<0.50	**2.7**	**1.5**	< 0.50	**5.2**	**5.2**	0.02808	0.001092	25	5	1 - 7	--	<0.5	1 - 7	(7)
Lithium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	0.027	0.00105	--	--	--	--	<5	5	(2)
Magnesium	ug/L	8900	8400	8700	8100	**13000**	3500	**20000**	5200	**20000**	108	4.2		--	--	--	8775	8775	(2)
Manganese	ug/L	13	37	9.3	2.8	110	59	16	120	120	0.648	0.0252	1000(9)	--	--	--	<2	1000	(9)
Mercury (filtered)	ug/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	0.000054	0.0000021	0.2	--	0.026	--	0.01	0.026	(7)
Molybdenum	ug/L	1.2	0.96	1.2	1.1	1.3	< 0.50	1.2	0.64	1.3	0.00702	0.000273	--	40	73	--	1.3	40	(6)
Nickel	ug/L	< 1.0	1.3	< 1.0	<1.0	2.5	< 1.0	< 1.0	2.6	2.6	0.01404	0.000546	25	--	25 - 150	--	1.025	25	(4)
Potassium	ug/L	1700	1600	1700	1600	**2200**	1100	**2400**	1900	**2400**	12.96	0.504	--	--	--	--	1625	1625	(2)
Selenium	ug/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	0.0108	0.00042	100	--	1	--	0.13875	1	(7)
Silicon	ug/L	240	810	530	370	2900	1300	2800	3400	3400	18.36	0.714	--	--	--	--	260	--	
Silver	ug/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.00054	0.000021	0.1	--	0.1	--	<0.1	0.1	(4,7)
Sodium	ug/L	15000	14000	16000	14000	**380000**	63000	**430000**	**99000**	**430000**	2322	90.3	--	--	--	68000	14500	68000	(10)
Strontium	ug/L	180	170	190	170	**680**	190	**890**	**300**	**890**	4.806	0.1869	--	--	--	--	180	180	(2)
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.0054	0.00021	--	--	--	--	<1	1	(2)
Thallium	ug/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	0.053	0.053	0.0002862	0.00001113	--	0.3 (3)	0.8	--	<0.05	0.8	(3, 7)
Tin	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.0054	0.00021	--	--	--	--	<1	1	(2)
Titanium	ug/L	< 5.0	**16**	**7.1**	<5.0	**30**	**11**	< 5.0	**49**	**49**	0.2646	0.01029	--	--	--	--	<5	5	(2)
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.0054	0.00021	--	30	--	--	<1	30	(6)
Uranium	ug/L	0.89	0.46	0.62	0.45	0.3	0.33	0.58	0.37	0.89	0.004806	0.0001869	--	5 (3)	15	--	0.3675	15	(3, 7)
Vanadium	ug/L	0.53	1.1	< 0.50	<0.50	2.9	1.2	< 0.50	3.6	3.6	0.01944	0.000756	--	6	--	--	<0.5	6	(6)
Zinc	ug/L	< 5.0	20	12	<5.0	**83**	**43**	**39**	**84**	**84**	0.4536	0.01764	30	20	30	--	<5	20	(6)
Zirconium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.1	1.1	0.00594	0.000231	--	4	--	4	<1	4	(6)

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

1. Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.
2. Mean background concentration measured in Lake Water (LWC-1). Results screened for further evalation if greater than 20% above LWC-1.
3. Interim PWQO was set based on readily available information and was not peer reviewed; the CCME guideline is used in preference.
4. MOE. (1994). Ontario Ministry of the Environment. Water Management: Policies Guidelines Provincial Water Quality Objectives of the Ministry of Environment and Energy (PWQO). Queen's Printer for Ontario. July.
5. CCME (2008) aquatic protection value calculated for assumed composition of F1 and F2; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6. Interim PWQO. (MOE, 1994)
7. CCME. (1999). Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines.
8. Ontario Drinking Water Standards from MOE. (2002). Ontario Ministry of the Environment. Ontario Regulation (O. Reg.) 169/03 Ontario Drinking Water Standards (ODWS)
9. BC MOE, 2001 for hardness of 100 mg/L. - BC MOE. (2001). Ambient Water Quality Guidelines for Manganese- Technical Appendix. British Colombia Ambient Water Quality Guidelines (WGQs). January 2001.
10. LCV from Suter and Tsao (1996) modified to No Observable Effects Concentration - Suter and Tsao. (1996). Suter, G.W. II and C.L. Tsao. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. U.S. Dept. Energy ES/ER/TM-96/R2.
11. The CCME, 2008 TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screenining criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.

Table C.4:
Screening of Stormwater COPCs for Human and Ecological Health - CCW PN U5-8

		Catchment 8					Catchment 6				Max Con. At Discharge	Final Conc. In CCW with 50000 m^3 /day flow	Concentration in Discharge Channel with No Flow	PWQO[4]	Interim PWQO[3,6]	CCME Protection of Aquatic Life [7]	Toxicity Benchmark	2015 Mean Background [2]	Selected Benchmark	Reference
Station ID		M3-3					MH15													
Sample Date		20-Aug-15	19-Nov-15	28-Oct-15	11-Jun-16	Dup of	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16										
	Unit																			
Radiological																				
Carbon-14	Bq/L	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20	< 20	0.1048	0.0072	--	--	--	--	<0.1	200	(8)
Cesium-134	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	0.00524	0.00036	--	--	--	--	<0.1	7	(8)
Cesium-137	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	0.00524	0.00036	--	--	--	--	<0.1	10	(8)
Cobalt-60	Bq/L	-	< 1	< 1	<1	<1	-	< 1	< 1	<1	< 1	0.00524	0.00036	--	--	--	--	<0.1	2	(8)
Iodine-131	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	0.00524	0.00036	--	--	--	--	--	6	(8)
Manganese-54	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	0.00524	0.00036	--	--	--	--	--	200	(8)
Tritium (Hydrogen-3)	Bq/L	974	145	50	78	79	182	1400	1110	1370	1400	7.336	0.504	7000	--	--	--	<4.4	7000	(4,8)
Zinc-65	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	0.00524	0.00036	--	--	--	--	--	40	(8)
Petroleum Hydrocarbons (and BTEX)																				
Benzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	0.001048	0.000072	--	100	370	--	--	100	(6)
Toluene	ug/L	0.31	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.31	0.0016244	0.0001116	--	0.8	2	--	--	0.8	(6)
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	0.001048	0.000072	--	8	90	--	--	8	(6)
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	0.38	<0.20	0.38	0.0019912	0.0001368	--	40	--	--	--	40	(6)
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.46	<0.40	0.46	0.0024104	0.0001656	--	2	--	--	--	2	(6)
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.84	<0.40	0.84	0.0044016	0.0003024	--	--	--	--	--	--	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	0.131	0.009	--	--	167	--	<25	167	(5)
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	0.131	0.009	--	--	167	--	<25	167	(5)
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	0.524	0.036	--	--	42	--	<100	42	(5)
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	1.048	0.072	--	--	--	--	<200	--	--
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	1.048	0.072	--	--	--	--	<200	--	--
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES	YES	N/A	--	--	--	--	--	--	--	--	--
General																				
Chloride	mg/L	**650**	340	120	200	200	47	40	38	14	**650**	3.406	0.234	--	--	640	--	--	640	(7)
Conductivity	mS/cm	2.36	1.4	0.541	0.922	0.944	0.276	0.35	0.305	0.12	2.36	0.0123664	0.0008496	--	--	--	--	0.3135	--	--
Hardness, Calcium Carbonate	mg/L	160	120	69	90	90	49	99	86	30	160	0.8384	0.0576	--	--	--	--	127.5	--	--
pH	pH units	7.91	7.83	7.77	7.91	7.87	7.47	7.85	7.84	7.8	7.91			6.5-8.5	--	6.5-9.0	--	7.9025	6.5 - 8.5	(4)
Phosphorous	mg/L	**0.029**	**0.025**	**0.037**	**0.05**	**0.052**	**0.54**	**0.16**	**0.27**	**0.13**	**0.54**	0.0028296	0.0001944	0.02	--	--	--	--	0.02	(4)
Total Suspended Solids	mg/L	**< 10**	**< 10**	**13**	**47**	**34**	**19**	**16**	**66**	**15**	**66**	0.34584	0.02376	--	--	--	--	<1-<10	6	(2,11)
Toxicity																				
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0	0	0	0	--	--	--	--	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0	0	0	0	--	--	--	--	--	--	--
Metals																				
Aluminum	ug/L	**110**	79	**460**	**390**	**370**	**270**	**210**	**1300**	**440**	**1300**	6.812	0.468	--	--	100	--	7.075	100	(7)
Antimony	ug/L	0.56	0.52	0.51	0.95	0.91	0.64	0.84	< 0.50	0.93	0.95	0.004978	0.000342	--	20	--	--	<0.5	20	(6)
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	1.4	1.5	< 1.0	< 1.0	< 1.0	<1.0	1.5	0.00786	0.00054	100	--	5	--	<1	5	(7)
Barium	ug/L	**37**	21	12	20	20	14	24	25	8.5	**37**	0.19388	0.01332	--	--	--	--	22.25	22.25	(2)
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	0.00262	0.00018	1100	--	--	--	<0.5	1100	(4)
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.00524	0.00036	--	--	--	--	<1	1	(2)
Boron	ug/L	45	14	< 10	13	12	16	17	12	<10	45	0.2358	0.0162	--	200 (3)	1500	--	25.5	1500	(3, 7)
Cadmium	ug/L	**< 0.10**	**< 0.10**	**< 0.10**	**0.2**	**0.23**	**< 0.10**	**< 0.10**	**< 0.10**	**<0.10**	**0.23**	0.0012052	0.0000828	0.2	0.5	0.04 - 0.37	--	0.0095	0.04 - 0.37	(7)
Calcium	ug/L	**52000**	38000	21000	39000	38000	19000	27000	36000	14000	**52000**	272.48	18.72	--	--	--	--	34000	34000	(2)
Chromium	ug/L	< 5.0	< 5.0	< 5.0	5.1	<5.0	< 5.0	< 5.0	< 5.0	<5.0	5.1	0.026724	0.001836	8.9	--	8.9	--	<5	8.9	(4,7)
Cobalt	ug/L	< 0.50	< 0.50	< 0.50	**0.97**	**0.95**	< 0.50	< 0.50	0.88	<0.50	**0.97**	0.0050828	0.0003492	0.9	--	--	--	<0.5	0.9	(4)
Copper	ug/L	**6.2**	**3.6**	**5**	**12**	**11**	**11**	**7.1**	**7.4**	**7.5**	**12**	0.06288	0.00432	5	5	2	--	<1	2	(7)
Iron	ug/L	**370**	130	**550**	**710**	**660**	**340**	280	**1600**	**510**	**1600**	8.384	0.576	300	--	300	--	<100	300	(4,7)
Lead	ug/L	0.66	0.54	**1.8**	**3.1**	**2.9**	**1.3**	0.89	**2.2**	**1.6**	**3.1**	0.016244	0.001116	25	5	1 - 7	--	<0.5	1 - 7	(7)
Lithium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	0.0262	0.0018	--	--	--	--	<5	5	(2)
Magnesium	ug/L	6800	5300	2000	3300	3200	2200	4800	4700	1000	6800	35.632	2.448	--	--	--	--	8775	8775	(2)
Manganese	ug/L	96	20	33	60	60	27	20	63	24	96	0.50304	0.03456	1000(9)	--	--	--	<2	1000	(9)
Mercury (filtered)	ug/L	< 0.01	< 0.01	< 0.01	<0.01	0.01	< 0.01	< 0.01	0.02	<0.01	0.02	0.0001048	0.0000072	0.2	--	0.026	--	0.01	0.026	(7)
Molybdenum	ug/L	1.1	0.66	< 0.50	3.3	3.4	0.54	1.3	0.55	0.71	3.4	0.017816	0.001224	--	40	73	--	1.3	40	(6)
Nickel	ug/L	1.6	1	1.3	4.1	3.6	< 1.0	< 1.0	2.4	<1.0	4.1	0.021484	0.001476	25	--	25 - 150	--	1.025	25	(4)
Potassium	ug/L	1300	960	900	**10000**	**9700**	1200	1500	1200	1200	**10000**	52.4	3.6	--	--	--	--	1625	1625	(2)
Selenium	ug/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	0.01048	0.00072	100	--	1	--	0.13875	1	(7)
Silicon	ug/L	1100	760	1100	2300	2200	1100	1500	3100	1100	3100	16.244	1.116	--	--	--	--	260	--	--
Silver	ug/L	< 0.10	< 0.10	< 0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.000524	0.000036	0.1	--	0.1	--	<0.1	0.1	(4,7)
Sodium	ug/L	**420000**	**220000**	77000	**140000**	**130000**	35000	31000	27000	9900	**420000**	2200.8	151.2	--	--	--	68000	14500	68000	(10)
Strontium	ug/L	**390**	**230**	120	**290**	**280**	**300**	**770**	**670**	86	**770**	4.0348	0.2772	--	--	--	--	180	180	(2)
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.00524	0.00036	--	--	--	--	<1	1	(2)
Thallium	ug/L	< 0.050	< 0.050	< 0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	0.000262	0.000018	--	0.3 (3)	0.8	--	<0.05	0.8	(3, 7)
Tin	ug/L	< 1.0	< 1.0	< 1.0	**6.1**	**6.1**	< 1.0	< 1.0	< 1.0	<1.0	**6.1**	0.031964	0.002196	--	--	--	--	<1	1	(2)
Titanium	ug/L	**6.3**	5.4	**16**	**16**	**16**	**18**	**7.9**	**44**	**23**	**44**	0.23056	0.01584	--	--	--	--	<5	5	(2)
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.00524	0.00036	--	30	--	--	<1	30	(6)
Uranium	ug/L	0.16	0.24	< 0.10	0.21	0.22	< 0.10	0.32	0.17	0.13	0.32	0.0016768	0.0001152	--	5 (3)	15	--	0.3675	15	(3, 7)
Vanadium	ug/L	2.4	0.91	2.1	**8.3**	**8.2**	3.8	1.3	3.6	2.2	**8.3**	0.043492	0.002988	--	6	--	--	<0.5	6	(6)
Zinc	ug/L	**39**	**41**	**40**	**73**	**71**	**160**	**80**	**130**	**91**	**160**	0.8384	0.0576	30	20	30	--	<5	20	(6)
Zirconium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	0.00524	0.00036	--	4	--	4	<1	4	(6)

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

1. Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.
2. Mean background concentration measured in Lake Water (LWC-1). Results screened for further evalation if greater than 20% above LWC-1.
3. Interim PWQO was set based on readily available information and was not peer reviewed; the CCME guideline is used in preference.
4. MOE. (1994). Ontario Ministry of the Environment. Water Management: Policies Guidelines Provincial Water Quality Objectives of the Ministry of Environment and Energy (PWQO). Queen's Printer for Ontario. July.
5. CCME (2008) aquatic protection value calculated for assumed composition of F1 and F2; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
6. Interim PWQO. (MOE, 1994)
7. CCME. (1999). Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines.
8. Ontario Drinking Water Standards from MOE. (2002). Ontario Ministry of the Environment. Ontario Regulation (O. Reg.) 169/03 Ontario Drinking Water Standards (ODWS)
9. BC MOE, 2001 for hardness of 100 mg/L. - BC MOE. (2001). Ambient Water Quality Guidelines for Manganese- Technical Appendix. British Colombia Ambient Water Quality Guidelines (WGQs). January 2001.
10. LCV from Suter and Tsao (1996) modified to No Observable Effects Concentration - Suter and Tsao. (1996). Suter, G.W. II and C.L. Tsao. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. U.S. Dept. Energy ES/ER/TM-96/R2.
11. The CCME, 2008 TSS criteria for clear flow conditions is a maximum increase of 5 mg/L above background. Measured background ranged from <1 - <10 mgL. The screenining criteria was calculated based on 1 mg/L + 5 mg/L = 6 mg/L.

LEGEND

- SWCS SAMPLING LOCATIONS USED IN THIS STUDY
- GROUND SURFACE CONTOUR
- SITE DRAINAGE PATHS
- WATERSHED BOUNDARIES

0 200 400

1:6,000 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

ONTARIO POWER GENERATION INC.

PROJECT

PICKERING, ONTARIO

TITLE

STORM WATER SAMPLING LOCATIONS

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-07-06
DESIGNED	JT
PREPARED	JT
REVIEWED	JDW
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1522020			C-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

APPENDIX D

Dose Sample Calculations

Table D.1: Sample Calculation for Benthic Invertebrate Radiological Dose for Cobalt-60 in Frenchman's Bay

		Cobalt-60		
		Value	**Unit**	**Source**
Environmental Media Concentrations				
Concentration in RBSW Discharge (Co-60)	A	0.5	Bq/L	Tabel 4-7
Concentration Factor (RBSW - Frenchman's Bay)	B	2.60E-04	unitless	Appendix A, Table A-3
Frenchman's Bay Water Concentration (Co-60)	C = A * B	1.30E-04	Bq/L	Calculated
Distribution Coefficient Co-60 (Kd)	D	43000	L/kg dw	Table 7-1
Frenchman's Bay Sediment Concentration (dry weight)	E = C * D	5.599	Bq/kg dw	Calculated
Sediment Porosity	F	0.6	unitless	Section 7.1.2.2
Sediment Density	G	1.5	kg/L	Section 7.1.2.2
Density of Water	H	1	kg/L	Section 7.1.2.2
Dry Weight Fraction of Sediment	I = (1-F)*G/(F*H+(1-F)*G)	0.5	kg dw/ kg fw	Calculation
Sediment Concentration (fresh weight)	J = E * I	2.80	Bq/kg fw	Calculation
Benthic Invertebrate Concentration				
Bioaccumulation Factor - Benthic Invertebrate	K	110	L/kg fw	Table 7-4
Modeled Benthic Invertebrate Tissue Concentration	L = C * K	0.01	Bq/kg fw	Calculated
Benthic Invertebrate Exposure Factors				
Dose Conversion Factor (Internal)	M	1.25E-03	(µGy/d)/(Bq/kg)	Table 7-6
Occupancy Factor, Water	N	0	unitless	Table 7-3
Occupancy Factor, Water Surface	O	0	unitless	Table 7-3
Occupancy Factor, Sediment	P	1	unitless	Table 7-3
Occupancy Factor, Sediment Surface	Q	0	unitless	Table 7-3
Dose Conversion Factor (External)	R	3.36E-02	(µGy/d)/(Bq/kg)	Table 7-6
Benthic Invertebrate Dose (radiological)				
Internal Dose	S = L * M	1.79E-05	µGy/d	Calculated
Contribution of Water to External Dose	T = R * (N + 0.5*O + 0.5*Q) * C	0.00E+00	µGy/d	Calculated
Contribution of Sediment to External Dose	U = R * (P + 0.5*Q) * J	0.09	µGy/d	Calculated
External Dose	V = T + U	0.09	µGy/d	Calculated
Total Radiological Dose	W = S + V	0.09	µGy/d	Calculated
Total Radiological Dose (converted units)	W' = W / 1000	9.41E-05	mGy/d	Calculated

Table D.2: Sample Calculation for Trumpeter Swan Radiological Dose for Cobalt-60 in Forebay

		Cobalt-60		
		Value	**Unit**	**Source**
Environmental Media Concentration				
Co-60 Released to Forebay (Drain A)	A	1.00	Bq/L	Appendix A, Table A-15
Concentration Factor (Box 4)	B	2.02E-03	unitless	Appendix A, Table A-4
Co-60 Released to Forebay (Drain B)	A'	1.00	Bq/L	Appendix A, Table A-16
Concentration Factor (Box 4, Scenario 1)	B'	2.28E-03	unitless	Appendix A, Table A-5
Water Concentration in Box 6 (Co-60)	C = A * B + A' * B'	4.30E-03	Bq/L	Calculated
Distribution Coefficient Co-60 (Kd)	D	43000	L/kg dw	Table 7-1
Sediment Concentration (dry weight)	E = C * D	1.85E+02	Bq/kg dw	Calculated
Sediment Porosity	F	0.6	unitless	Section 7.1.2.2
Sediment Density	G	1.5	kg/L	Section 7.1.2.2
Density of Water	H	1	kg/L	Section 7.1.2.2
Dry Weight Fraction of Sediment	I = (1-F)*G/(F*H+(1-F)*G)	0.5	kg dw/ kg fw	Calculated
Sediment Concentration (fresh weight)	J = E * I	92.494299	Bq/kg fw	Calculated
Aquatic Plant Concentration				
Bioaccumulation Factor (BAF)	K	7.90E+02	L/kg fw	Table 7-4
Tissue Concentration	L = C * K	3.40E+00	Bq/kg fw	Calculated
Trumpeter Swan Exposure Factors				
Water Intake	M	0.294	kg/d	Table 7-2
Sediment Intake	N	1.14E-02	kg dw/d	Table 7-2
Aquatic Plant Intake	O	1.386	kg/d fw	Table 7-2
Occupancy Factor on Sediment Surface	P	0.5	unitless	Table 7-3
Occupancy Factor in Water	Q	0.5	unitless	Table 7-3
Transfer Factor	R	2.70E-01	d/kg fw	Table 7-5
Internal Dose Coefficient	S	5.70E-03	(uGy/d)/(Bq/kg)	Table 7-6
External Dose Coefficient on Sediment	T	1.10E-02	(uGy/d)/(Bq/kg)	Table 7-6
External Dose Coefficient in Water	U	3.00E-02	(uGy/d)/(Bq/kg)	Table 7-6
Trumpeter Swan Dose				
Tissue Concentration	V = R*(M*C+N*E+O*L)	1.84E+00	Bq/kg fw	Calculated
Internal Dose	W = S*V	1.05E-02	uGy/d	Calculated
External Dose	X = (T*P*J)+(U*Q*C)	5.09E-01	uGy/d	Calculated
Total Radiological Dose	Y = W + X	5.19E-01	uGy/d	Calculated
Total Radiological Dose (converted units)	Y' = Y / 1000	5.19E-04	mGy/d	Calculated

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